REM IV

Remedial Planning Activities
at Selected Uncontrolled
Hazardous Waste Sites–Zone II

86250

No 0000015

Environmental Protection Agency
Hazardous Site Control Division
Contract No. 68-01-7251

FIELDWORK DESIGN INVESTIGATION
Volume 2

ARROWHEAD REFINERY SITE
Hermantown, Minnesota

EPA WA 129-5NH8

April 30, 1990

CH2M HILL

Black & Veatch
ICF
PRC
Ecology and Environment

Appendix A
SUMMARY OF FIELDWORK

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Volume 2

Appendix

FIELDWORK DESIGN INVESTIGATION
Volume 2

ARROWHEAD REFINERY SITE
Hermantown, Minnesota

EPA WA 129-5NH8

April 30, 1990

CH2M HILL

TECHNICAL MEMORANDUM NO. 1

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: Don Johnson

DATE: May 26, 1987

RE: Seismic Refraction Survey

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68800.FP

INTRODUCTION

A seismic refraction survey was performed at the Arrowhead Refinery site from May 3 to 6, 1987. Twelve spreads were surveyed along the five traverses shown in Figure TM1-1. The survey was performed by Don Johnson and Jewelle Imada of CH2M HILL, assisted by Jerry McLane of PRC.

The survey was performed to determine depth to bedrock at various locations around the site. The information was required to establish if there are any bedrock topographic features that may influence the movement of groundwater from the site. Bedrock valleys may provide preferential pathways for the movement of groundwater from the site. Bedrock ridges may block or divert groundwater movement. The seismic data supplemented existing bedrock depth information.

SUMMARY OF RESULTS

Bedrock depths were estimated to range from 25 to 60 feet below ground surface, the greatest depths being in the process area and at the southern end of the wastewater ditch. A contour map of the bedrock surface was made using the limited survey data.

The nature of the interpreted bedrock is unknown. It may be extremely hard packed material, a boulder zone above the bedrock surface, or the base of weathered bedrock. In any case, the data indicate changes in depth of the bedrock surface.

High background noise from the highway and air traffic was occasionally a problem. However, waiting for breaks in the traffic and the use of electronic filters on the data minimized the problem. The shotgun shell seismic sources were adequate most of the time, but were sometimes inadequate for the off-end shots on the 300-foot spreads.

Spread 4 was unusable because of unrecogniz-able bedrock arrivals, and Spread 3 was unusable because of unreconcilable differences with the detail spread run in the same area.

PROCEDURES

The seismic refraction method consists of measuring the time required for acoustic compressional waves to travel between an impulse source on or near the surface and a number of receivers at known distances from the source. The energy sources used for this survey were shotgun shells. The arrival time of interest is the time of the first arriving wave at each sensor. The raw data consist of travel times and distances which are processed to determine the subsurface layer thicknesses and velocities.

THEORY OF OPERATION

In general, the first arriving wave can be attributed to either a direct wave or a critically refracted wave (Figure TM1-2). The direct wave travels through the near-surface layer along the shortest path between the source and receiver; the critically refracted wave travels along layer boundaries where the lower layer has an appreciably higher wave velocity than the upper layer. The type of wave that arrives first is determined by the subsurface wave velocity distribution and the source-receiver spacing.

For subsurface materials that can be represented by a sequence of horizontal layers whose wave velocity increases appreciably with depth, the first arrival for small source-receiver spacings will be a direct wave through the uppermost layer. As the source-receiver spacing is increased, the first arrival will become a critically refracted wave from the boundary of the first and second layers, with an observed apparent wave velocity equal to the wave velocity of the second layer. For greater spacings, the first arrival will be a critically refracted wave from deeper layer boundaries and the observed apparent velocity will be that of the deeper, high-velocity layers.

Each spread surveyed at the Arrowhead Refinery site consisted of 12 geophones set in a straight line. Initially, a 30-foot spacing was used to separate the geophones, but after the first day, the two geophones at each end of the spread were separated by 15 feet with all others separated by 30 feet. This modifica-tion allowed for better estimation of near-surface velocities. Additional spreads were run using a 10-foot geophone separation. These spreads provided detailed information where the daily review of data indicated additional information was needed to resolve questionable data.

The seismic source used at the site was a 12-gauge black powder blank. Each shell was inserted into a plastic sleeve and detonated in a shothole about 2 feet beneath ground surface using a Betsie downhole seismic tool. A steel pry bar was used to

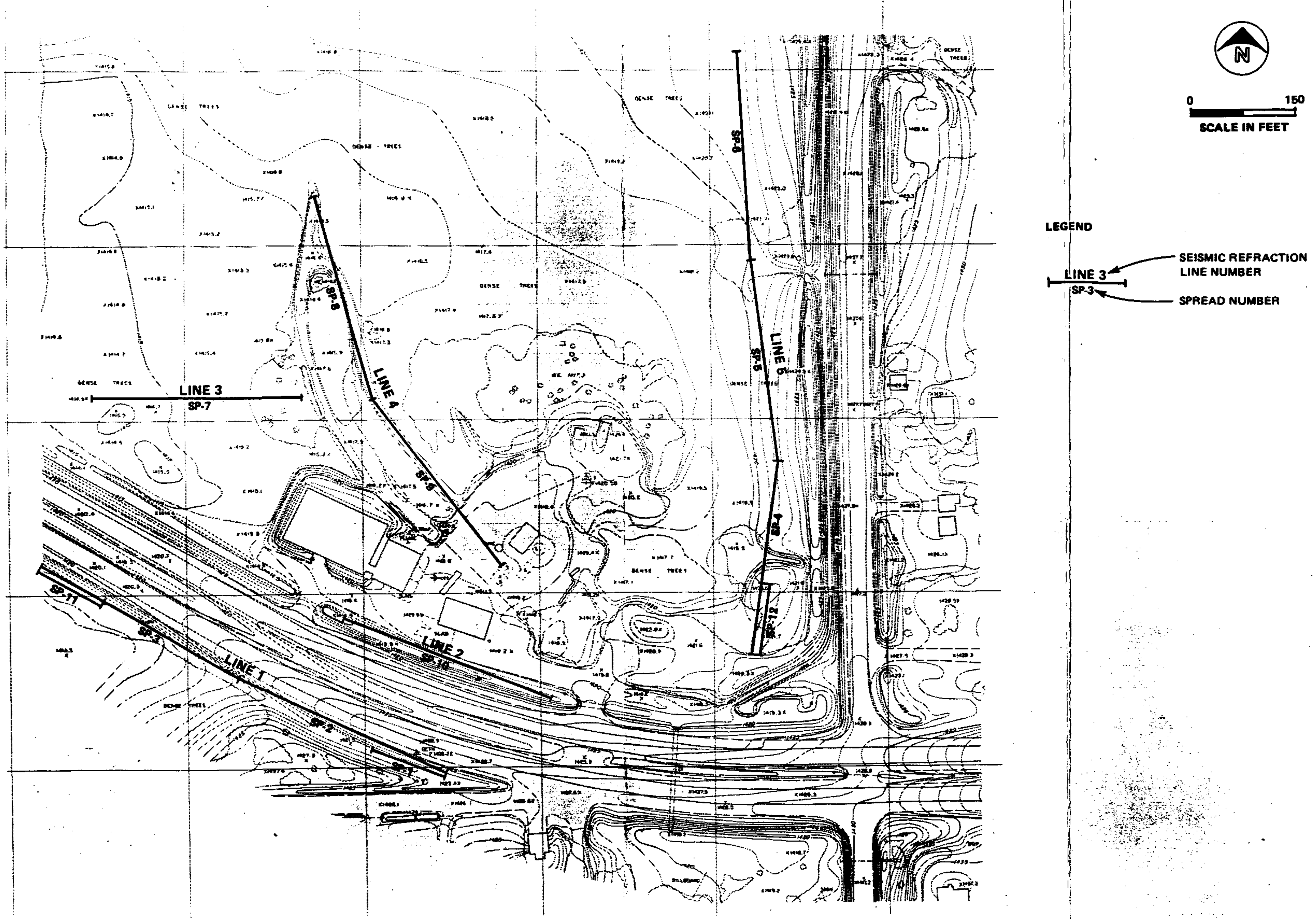


FIGURE TM 1-1
SEISMIC SURVEY
SPREAD LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

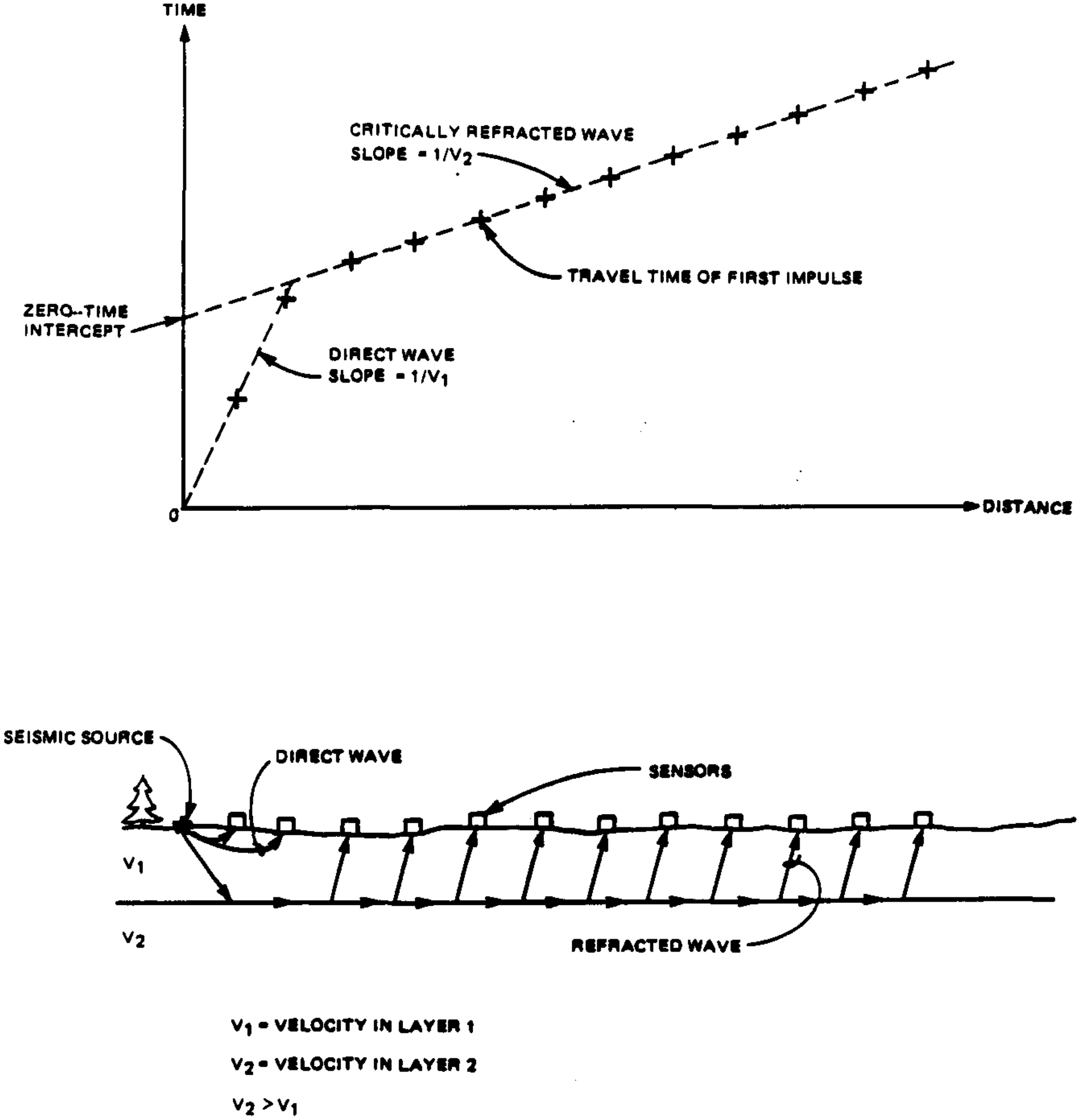


FIGURE TM 1-2
SCHEMATIC SEISMIC
REFRACTION SURVEY
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

make the shotholes. The blanks were detonated by striking the end of the Betsie downhole tool with a hammer. An impact switch taped to the hammer triggered the seismograph simultaneously with the detonation of the charge.

The shots were performed at each end of each spread, one-half to one spread length beyond each end of each spread (this varied depending on access), and in the middle of each spread. The partially redundant data provided by the multiple shots were required to help pick the first arrival times in noisy data. Additionally, the off-end shots allowed the interpreter to pick more accurate zero-time intercepts (see Figure TM1-2), which were needed to interpret the data.

The data from each shot were displayed on the seismograph's CRT screen. The operator could then determine if the record was adequate to pick the arrival times. When necessary, data from additional shots in the same shothole were added to the existing data stored in the seismograph's memory. This procedure is called stacking, and results in the enhancement of the coherent signal and the partial reduction of the random noise. Once the data on the screen were considered acceptable, a permanent paper copy was made (Figure TM1-3).

INTERPRETATION

Once the data were plotted as time-distance plots (Attachment A), the data were used to estimate layer thicknesses and velocities. Two levels of interpretation were performed.

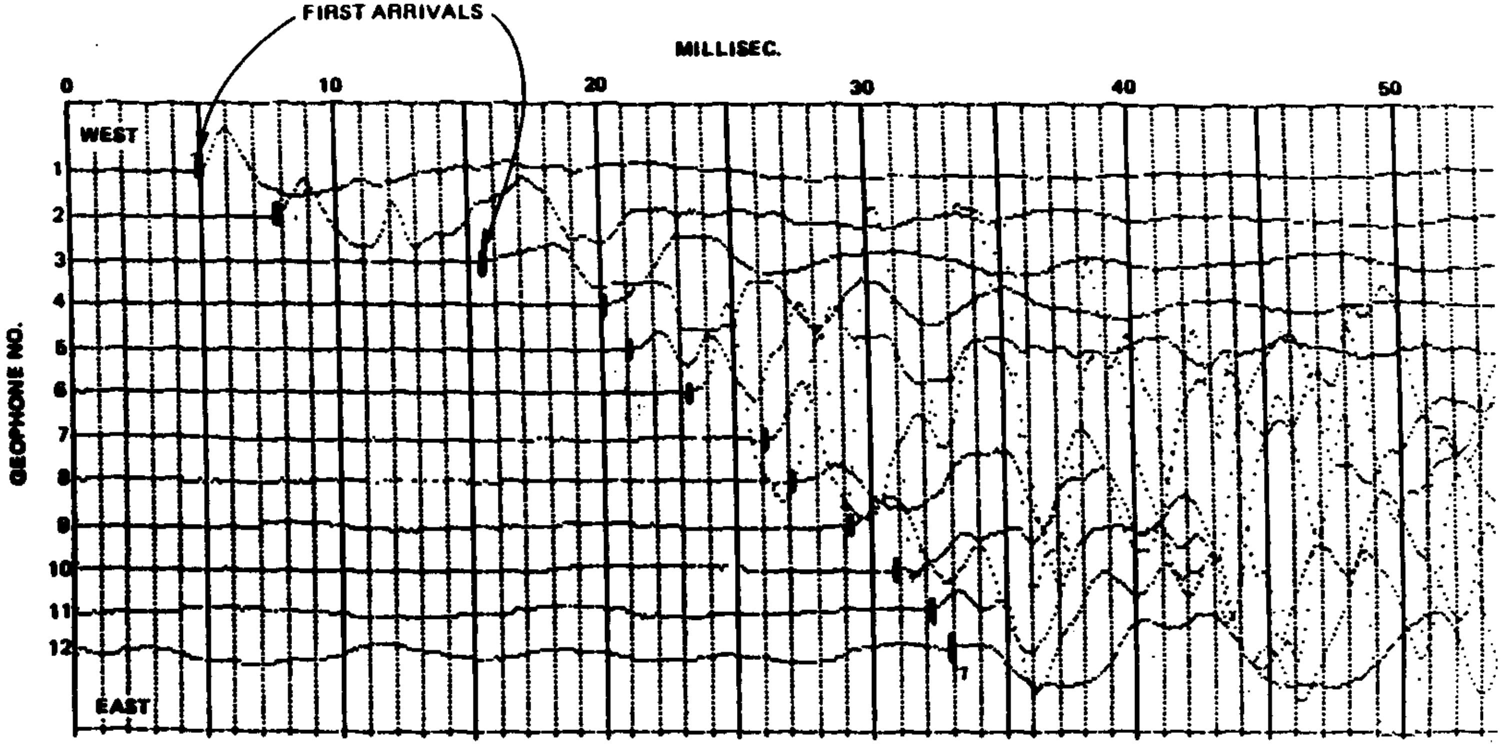
The simpler, less time consuming method, was performed in the field using procedures described by B. B. Redpath in "Technical Report E-73-4, Seismic Refraction Exploration for Engineering Site Investigations." It was used to estimate bedrock depths only at the end of each spread and at the center shot point. The following steps were performed:

- First arrival times were picked and plotted on time-distance plots.

- Layer velocities were estimated by plotting differences in arrival times (Figure TM1-4).

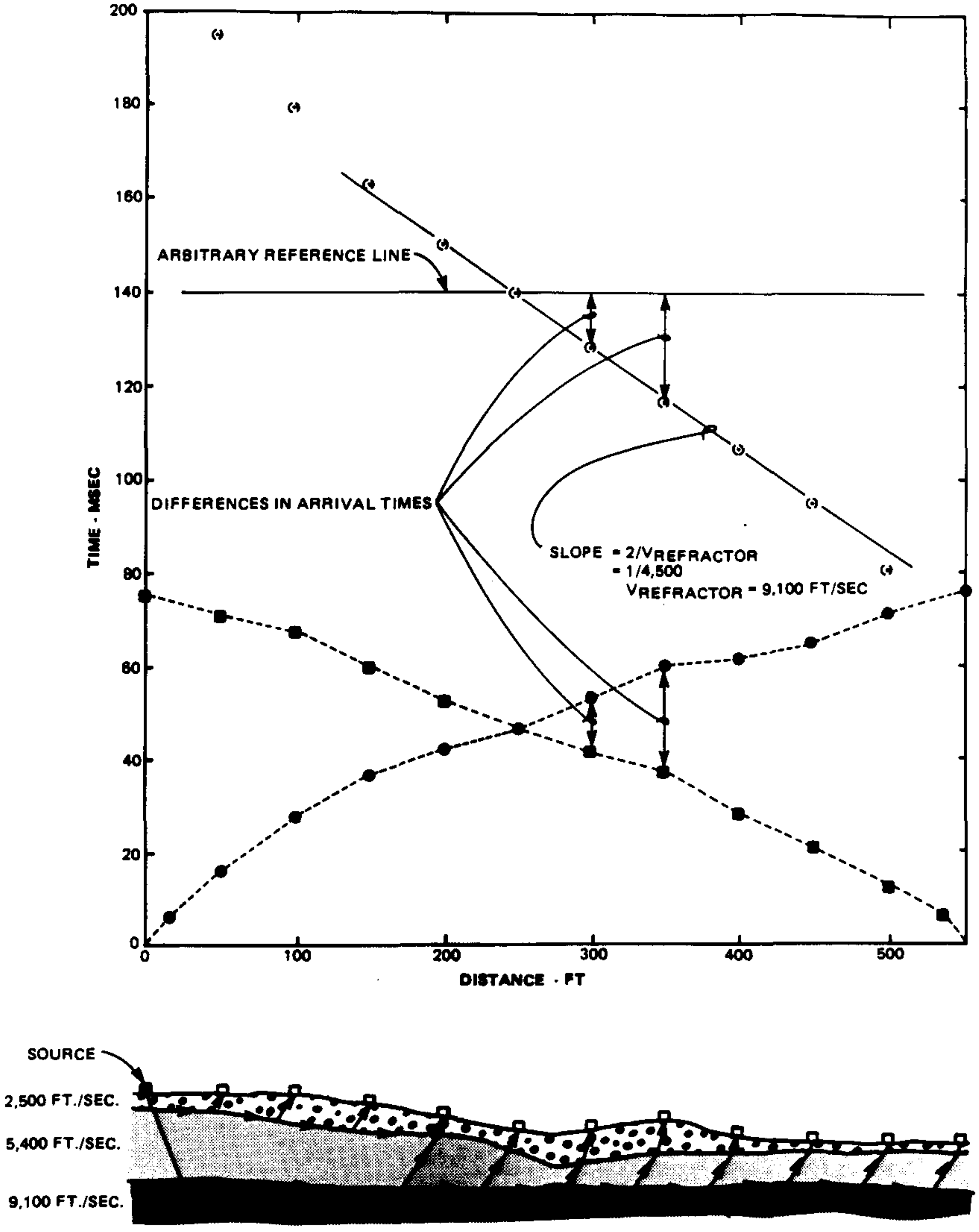
- Layer thicknesses were estimated using either two- or three-layer interpretation equations (Figure TM1-5), assuming horizontal layers. The three-layer interpretation was performed by a com-puter program published by the Bison Corporation.

This method provided quick results on a daily basis and was used to determine if the results were consistent with known subsurface conditions. The estimated velocities also provided a basis for evaluating the velocities calculated in the second method of interpretation.



SPREAD 10
LINE 1
SHOT IS 10' WEST OF GEOPHONE NO. 1
15' BETWEEN GEOPHONES 1-2 AND 11-12
30' BETWEEN ALL OTHERS

FIGURE TM 1-3
TYPICAL SEISMIC RECORD
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



(ADAPTED FROM REDPATH, B.B., 1973)

FIGURE TM 1-4
METHOD OF DETERMINING VELOCITIES
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

$$Z_1 = \frac{T_{i2} V_1}{2 \cos \alpha} \approx \frac{T_{i2} V_1}{2}$$

$$Z_2 = \left[\frac{T_{i3} - T_{i2} \left(\frac{\cos \beta}{\cos \alpha} \right)}{2 \cos \gamma} \right] V_2 \approx \left[\frac{T_{i3} - T_{i2}}{2} \right] V_2$$

WHERE:

T_{i2}, T_{i3} ARE INTERCEPT TIMES

V_1, V_2, V_3 ARE LAYER VELOCITIES

$$\alpha = \sin^{-1} \left(\frac{V_1}{V_2} \right); \ \beta = \sin^{-1} \left(\frac{V_1}{V_3} \right); \ \gamma = \sin^{-1} \left(\frac{V_2}{V_3} \right)$$

$\cos \alpha$, $\cos \beta$ AND $\cos \gamma$ RANGE TYPICALLY BETWEEN 0.8 AND 1.0

FOR THE FIELD INTERPRETATION, THE APPROXIMATE EQUATIONS WERE USED, WHICH ASSUMED ALL COSINE TERMS WERE EQUAL TO 1.0.

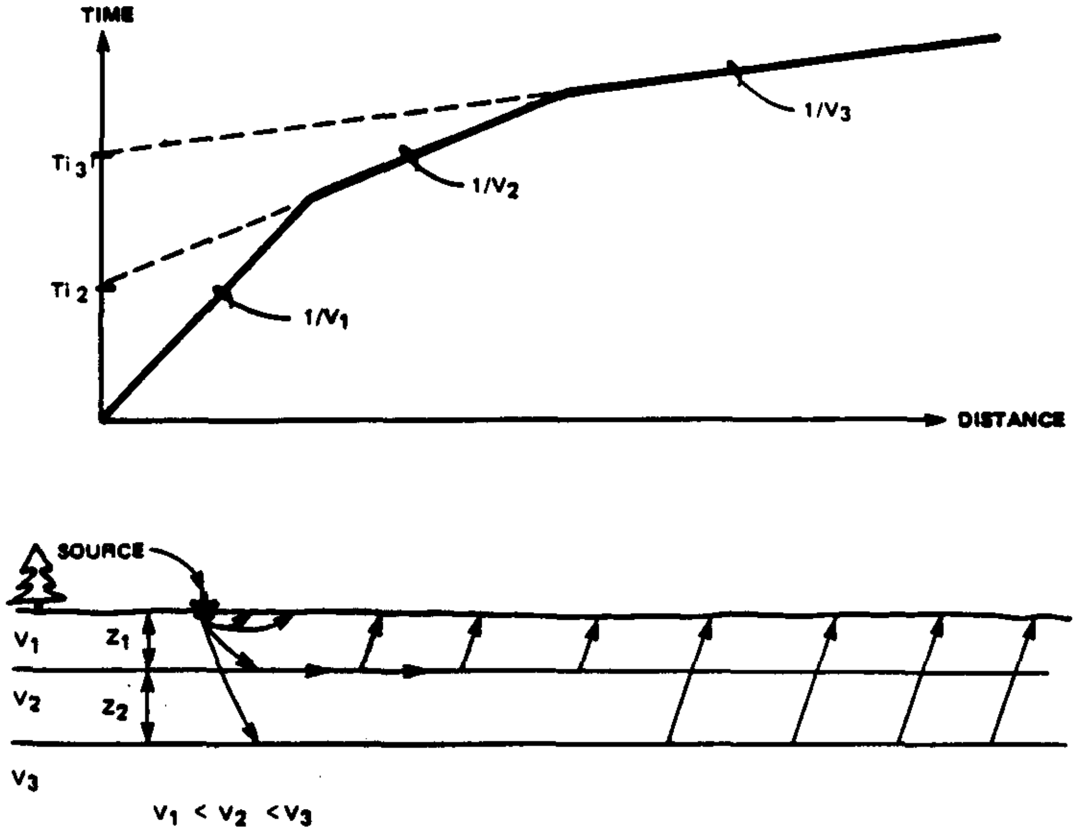


FIGURE TM 1-5
SEISMIC INTERPRETATION EQUATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

The second method of interpretation was performed using a computer method developed for the U.S. Bureau of Mines and published in the USBM Report of Investigations 7595. The program automatically performs weathering and elevation corrections, calculates the depth to a refracting interface, and calculates the time required for an acoustic wave to travel from the shot point to the receiver from the calculated interface. This travel time is then compared to the observed travel time and the interface is adjusted up or down until the calcu-lated travel time best agrees with the observed travel time. As with any computer program, a good deal of discretion must be exercised by the geo-physicist to ensure that the velocities and depths to interfaces make physical and geological sense.

The subsurface model is first approximated using the delay-time method and the model is further refined using the raypath-tracing analysis. The raypath is the actual path of wavefront propagation detected at each geophone. The program uses the raypath technique to test the assumed model, modify the portions of the model that have unacceptable error, and retest the model. The iterative process continues until errors are minimized.

The results of the computer interpretation are studied and if problem areas exist in the interpretation, then the interpreter modifies the input data. The assign-ment of each arrival time to a particular layer often needs to be changed, especially near the breaks in the time-distance curves. Often the first arrival times are adjusted, as the picked times are uncertain in noisy data. When an insufficient number of arrival times are assigned to a particular layer, then the interpreter must declare a velocity for that layer. Several computer runs are required to obtain a reasonable interpretation. This method determines the depths to each layer beneath each geophone and shot point. In this report, only the depths beneath the end and middle shot points were used. The depths calculated at other locations were considered less reliable.

RESULTS

SUMMARY

Three layers were identified from the seismic data based on velocity interpretations. The first layer is the upper layer. The calculated velocities for this layer ranged from 600 to 1,800 feet per second (ft/s). This is typical of unsaturated soils and corresponds to unsaturated fill and undisturbed soil at the site. The second layer is characterized by velocities ranging from 5,000 to 7,500 ft/s, which is typical of saturated, compacted soils. This corresponds to the saturated sediment deposits identified in the boring logs. The seismic data cannot be used to distinguish between soil types. The third layer has estimated velocities between 10,000 and 30,000 ft/s and corresponds to bedrock.

The interpreted bedrock surface is shown in Figure TM1-6. It indicates a bedrock valley with a northwest-southeast axis. The greatest depths to bedrock were found in the process area and near southern end of the wastewater ditch, where bedrock depths greater than 50 feet were estimated.

SEISMIC LINE 1

Seismic Line 1 was run along the south side of U.S. 53. The line consists of spreads 1, 2, 3, and 11. Spread 1 was run using a 10-foot geophone spacing to provide information about the shallow layers and also to make familiarization with the equipment easier. Spreads 2 and 3 were run with 30-foot geophone spacings. Spread 11 was run to provide detailed data after the preliminary interpretation estimated depths to bedrock inconsistent (too shallow) with information from boring MW-10. All data collected along Line 1 were noisy because of the traffic along U.S. 53. To the extent possible, shots were set off only during gaps in traffic. Line 1 was also collected on a Sunday, in hopes that traffic would be at a minimum.

The data from Spread 11 was inconsistent with that from Spread 3 and therefore, Spread 3 was considered unusable. Arrival times for Spread 3 were less than those determined for Spread 11 even though shot points were farther away. This is a physical impossibility, and may be due to an improper seismograph setting. Spread 11 was selected as being correct because the first arrivals were easier to pick, the interpreted depths are more consistent with the minimum depth to bedrock at MW-10.

The interpreted results of Line 1 are shown in Figure TM1-7. Bedrock averages between 25 and 35 feet below the ground surface. There is no interpreted depth beneath the eastern end of Spread 11 because of no observed bedrock refractions from that end of the spread. The bedrock velocity at Spread 11 is based on few points and the computer estimated velocity is probably not reliable. Setting it to a velocity consistent with Spreads 1 and 2 does not significantly affect the interpreted depth.

LINE 2

Line 2 consists of a single spread (Spread 10) run along the north side of U.S. 53.

The interpreted bedrock surface is 35 feet beneath the western end of the line and increases to a depth of up to 55 feet beneath the eastern end (see Figure TM1-7). These depths were calculated using a second layer velocity of 7,200 ft/s. If a lower velocity is used, such as 5,500 ft/s to be more consistent with Line 1, the depth beneath the western end would remain the same and the depth at the eastern end would become about 45 feet.

The geophones and shots were in the edge of the ditch water and higher upper layer velocities were expected. The velocity of sound in water, which would be the minimum expected velocity, is approximately 4,500 ft/s. Observed velocities lower than this cannot be readily explained, but the effect on the interpretation is not more than a couple of feet.

LINE 3

Line 3 is a single spread (Spread 7) that was run east-west. The east end of the line is at MW-2, which penetrated bedrock at a depth of 41 feet. The shot off the east end could not be performed 200 feet off the end as planned, because of the sludge lagoon. It was shot 85 feet off the end instead. The data from that shot, however, could not be used because the first arrival times were inconsistently early, when compared to the other data. The second layer velocity was set at 6,500 ft/s, because the computer calculated ones were unrealistically high (nearly 10,000 ft/s).

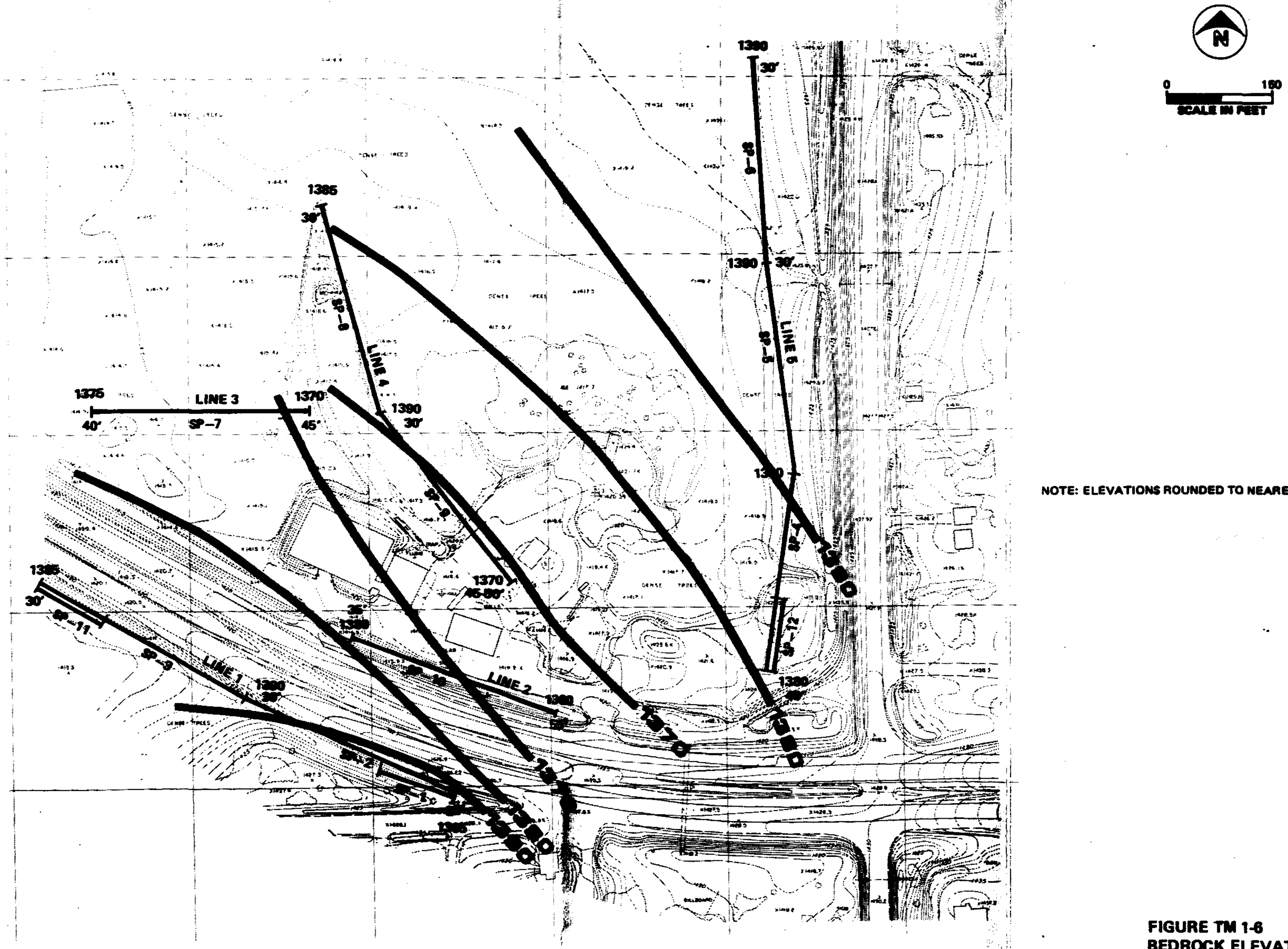
Data from Line 3 was very noisy and hard to use and a higher uncertainty may be associated with this line than with the others. Although it appeared that the geophones and the shots were all in saturated soils (peat bog), there is an apparent upper layer velocity less than that of water. The reason for this is unknown, but the interpreted bedrock depth is not affected by more than a couple of feet. Bedrock is estimated to be 30 to 35 feet below the western end and about 45 feet below the eastern end (Figure TM1-8). (Bedrock was encountered at a 41-foot depth at MW-2, at the eastern end.) The interpreted depth of bedrock at the center of the spread is 30 feet.

LINE 4

Line 4 consists of Spreads 8 and 9 and was run nearly north-south along the track between the wastewater ditch and the sludge lagoon. The southern end of Spread 9 ended up in the process area, where hard ground conditions required moving the end shot to between the second and third geophone.

A reading above background from a photo-ionization detector was noted in the shothole at the south end of Spread 9, in the process area. Clean water was added to the hole before shooting to minimize risk of fire and to drive any from the hole. No incident occurred when the shot was detonated.

The estimated bedrock depths range from about 25 feet at the north end of Spread 8 to between 45 and 60 feet at the south end of Spread 9 (Figure TM1-8). These depths are consistent with boring information. The north end of Spread 9 is at MW-12 which was advanced only 15 feet and did not hit bedrock. MW-5 at the southern end of Spread 9 was advanced 50 feet and did not encounter bedrock.



NOTE: ELEVATIONS ROUNDED TO NEAREST 5 FEET.

FIGURE TM 1-6
BEDROCK ELEVATIONS BASED ON SEISMIC REFRACTION SURVEY RESULTS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

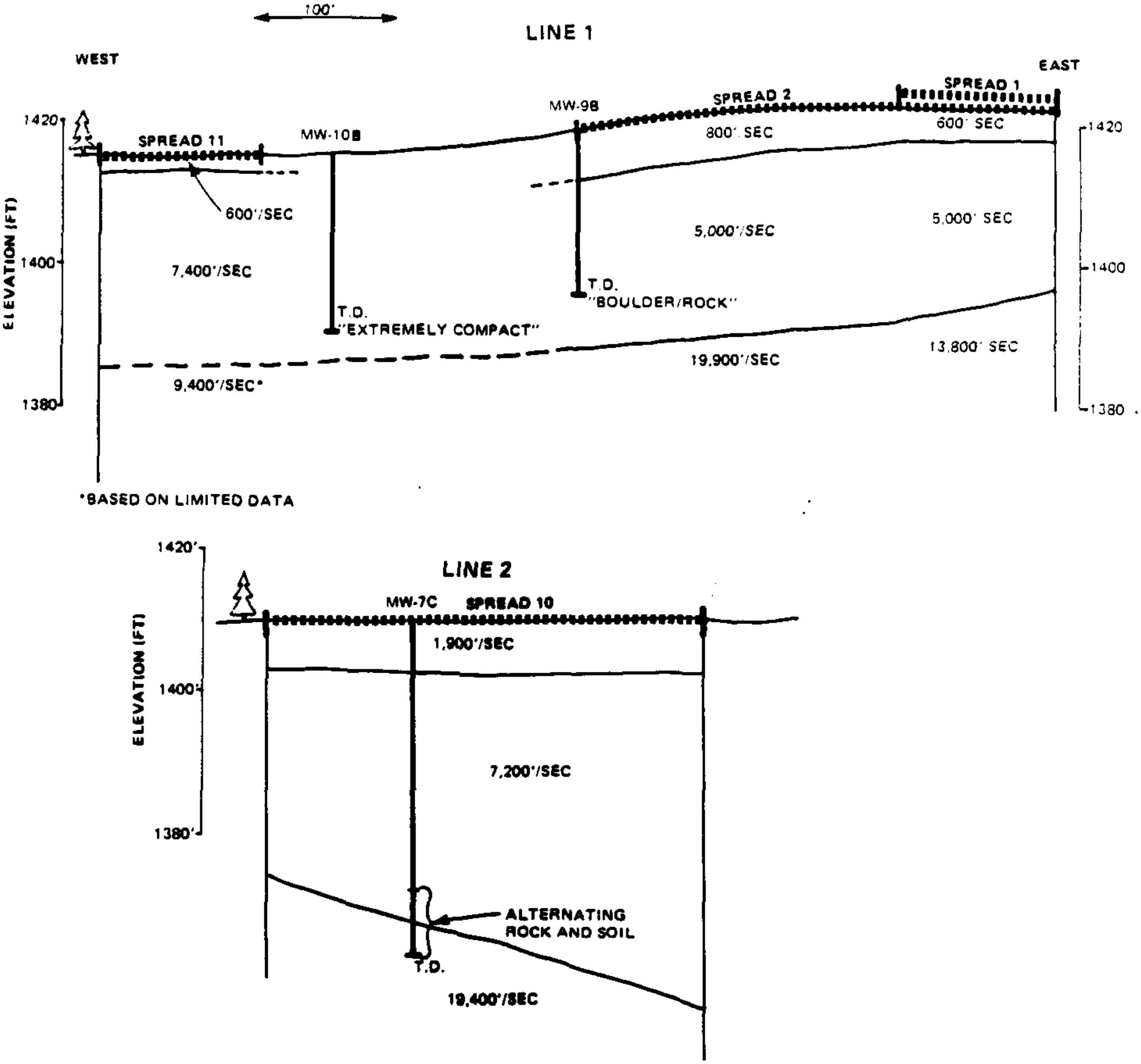
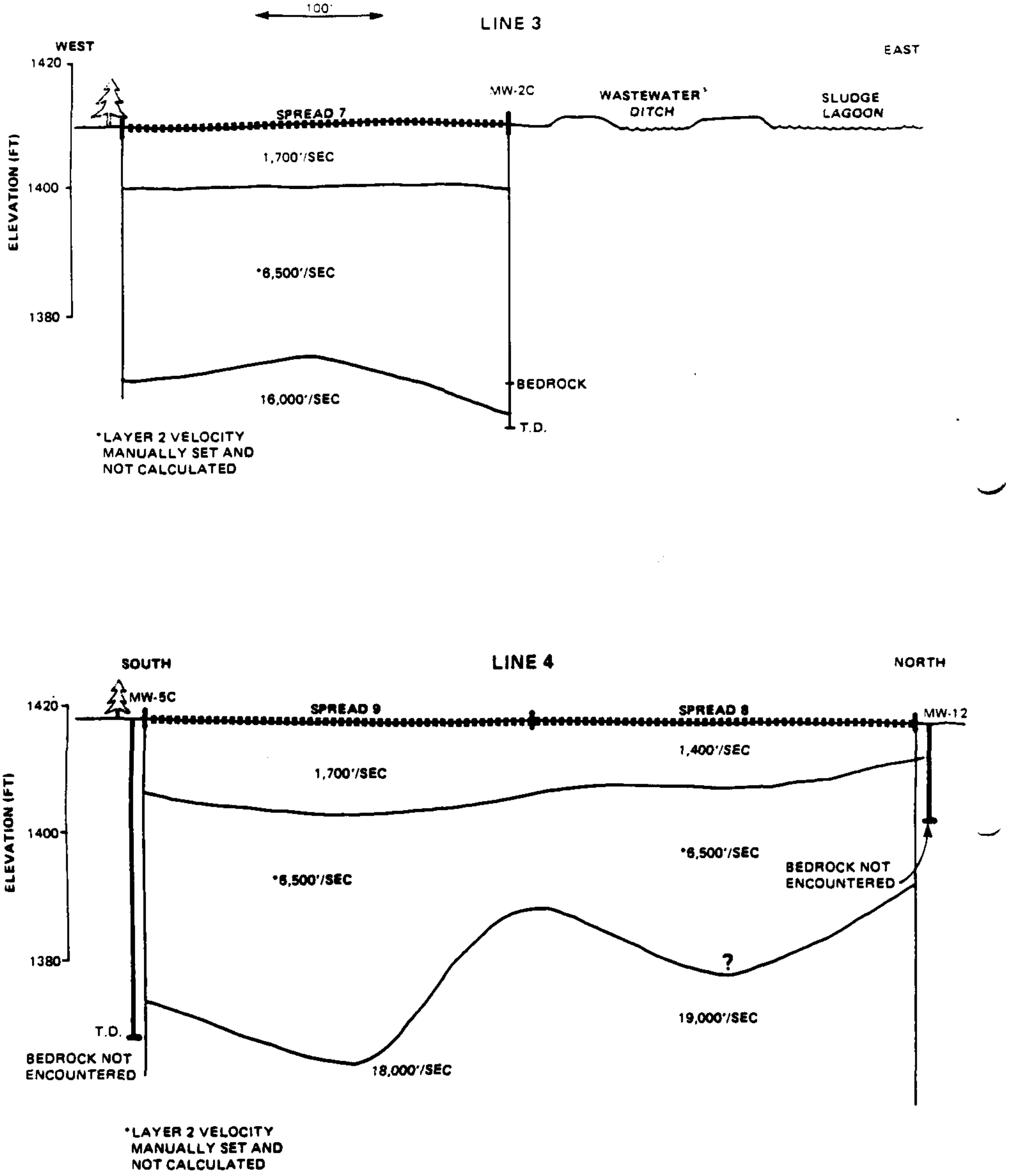


FIGURE TM 1-7
INTERPRETED CROSS SECTIONS
AT LINE 1 AND 2
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



*LAYER 2 VELOCITY MANUALLY SET AND NOT CALCULATED

*LAYER 2 VELOCITY MANUALLY SET AND NOT CALCULATED

FIGURE TM 1-8
INTERPRETED CROSS SECTION AT LINES 3 AND 4
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

The bedrock surface shown in Figure TM1-8 is the surface generated by the seismic interpretation program. It is based on relatively few data points, and for that reason is probably more irregular than in reality. The surface was smoothed for contouring purposes.

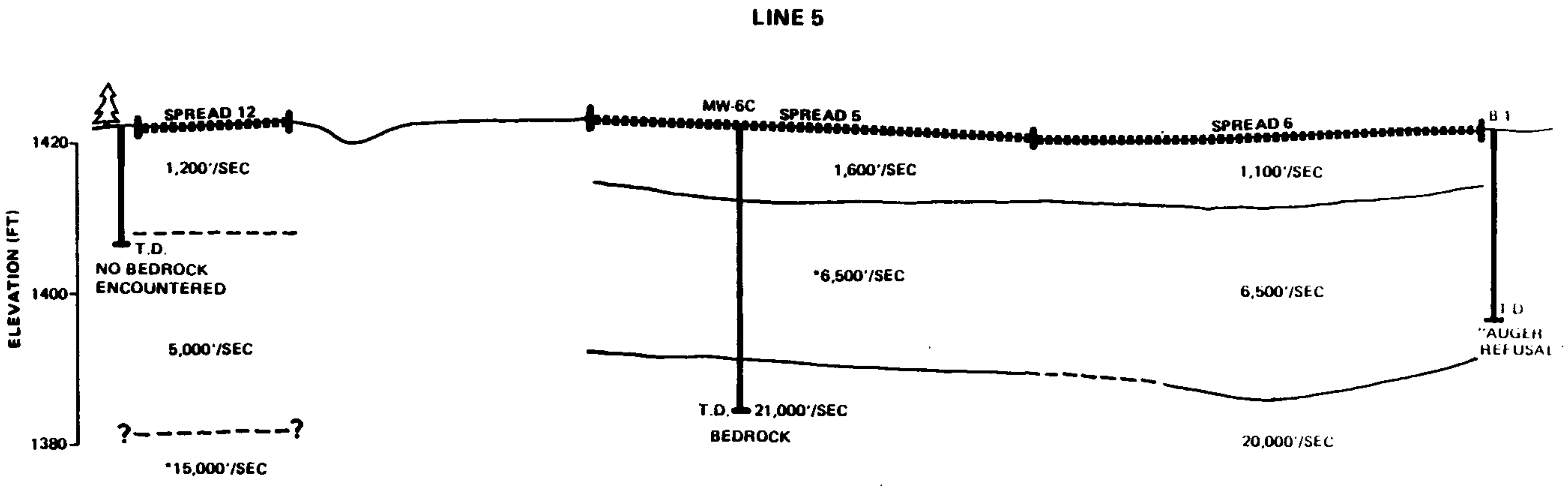
The shot located 200 feet off the south end of Spread 8 was not usable because of high noise and weak signals. The velocity for layer 2 beneath Spread 8 was manually set to 6,500 ft/s because insufficient data points were available for the computer to determine the velocity. Layer 2 velocity beneath Spread 9 was calculated to be 6,200 ft/s, but was manually set to 6,500 ft/s to be consistent with Spread 8.

LINE 5

Spreads 4, 5, and 6 were run north-south to make up Line 5. Spread 12, using 10-foot geophone spacings, was later run at the south end of Spread 4 to provide additional information where the original data were confusing.

Bedrock arrivals were not identified in either Spread 4 or Spread 12. The records were dominated by arrivals from the second layer (5,000 ft/s). Based on Spread 12 data, which is of higher quality than Spread 4 data, bedrock is at least 40 feet deep at the south end of Line 5 (Figure TM1-9). This estimate is based on the assumption that the spread was too short to see bedrock arrivals. If there were bedrock arrivals that were not identified in the data, then the estimated bedrock depth would be less.

Bedrock depths beneath Spreads 5 and 6 are estimated to be between 30 and 35 feet below the surface. The calculated bedrock depth at the southern end of Spread 6 is inconsistent with the results from Spread 5 and the remainder of Spread 6 and was not used. Bedrock velocities are somewhat higher beneath Line 5 than elsewhere in the survey area. At Line 5, the estimated velocities are greater than 20,000 ft/s. Elsewhere they were between 15,000 and 17,000 ft/s. The higher velocities may indicate less weathering or fracturing, or a different rock type.



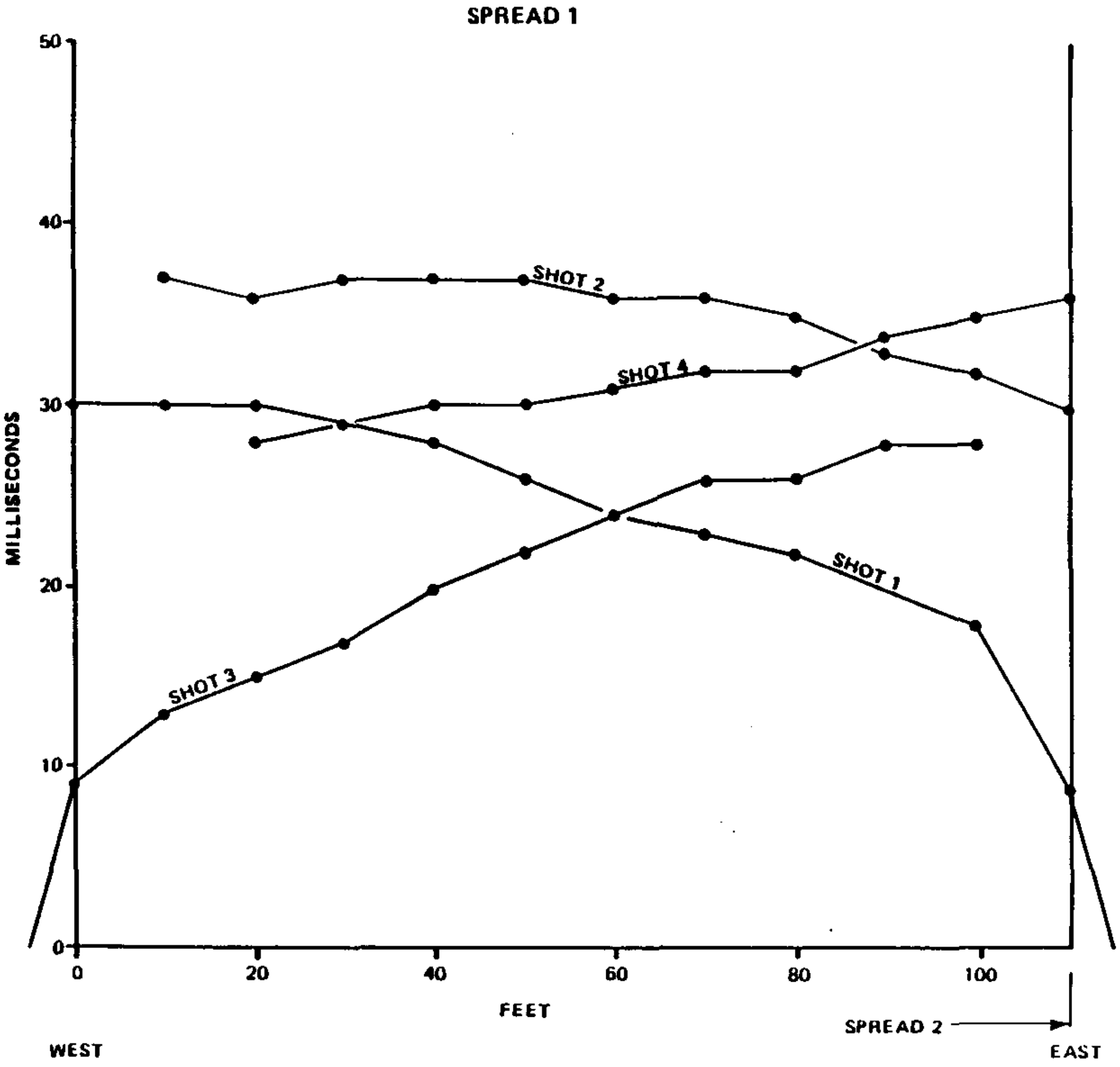
NOTE: SPREAD 12 RESULTS
ARE QUESTIONABLE

*ESTIMATED

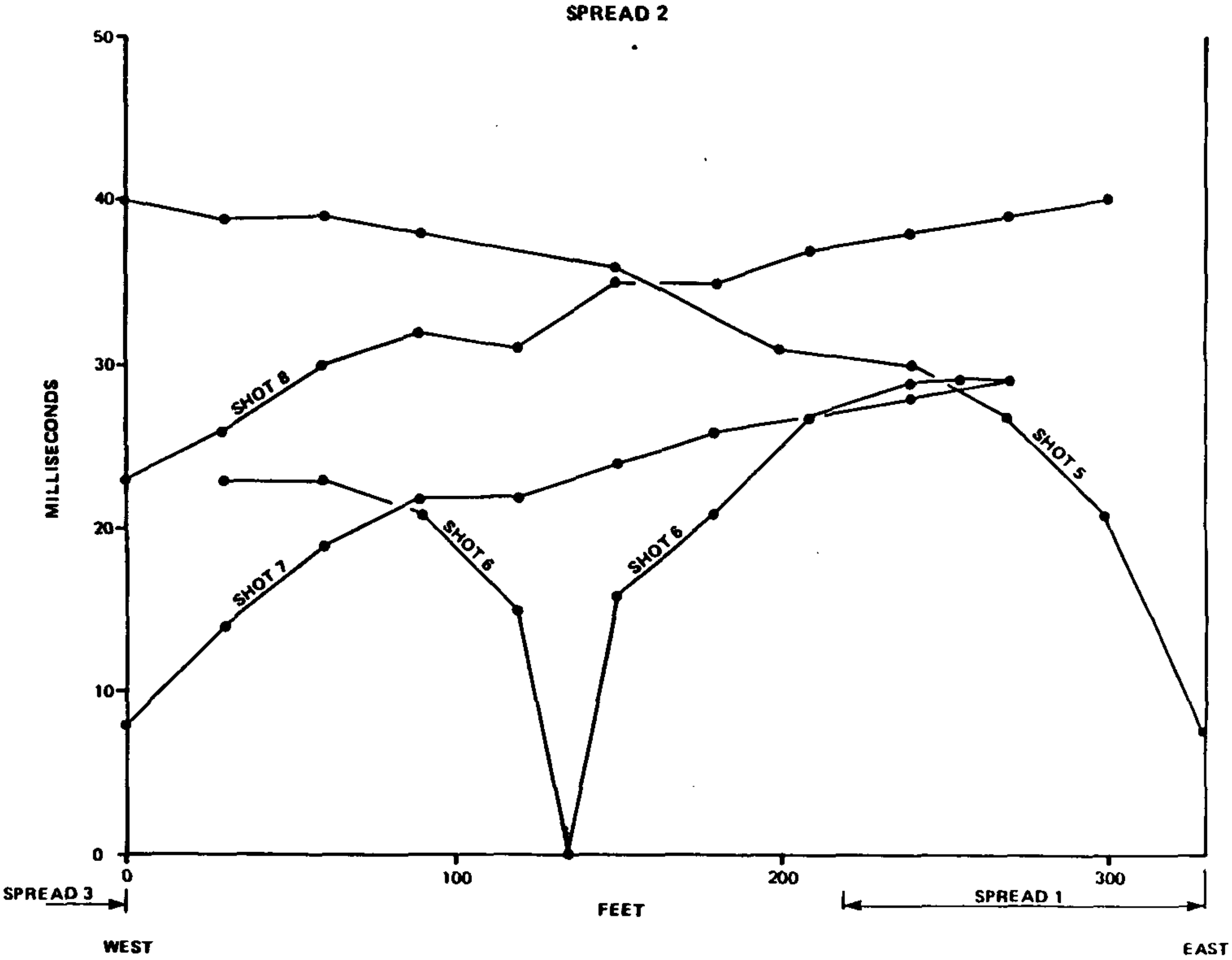
FIGURE TM 1-9
INTERPRETED CROSS SECTION
AT LINE 5
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

TM 1--SEISMIC REFRACTION SURVEY

Attachment A
TIME-DISTANCE PLOTS



TIME - DISTANCE PLOTS
SPREAD 1
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY

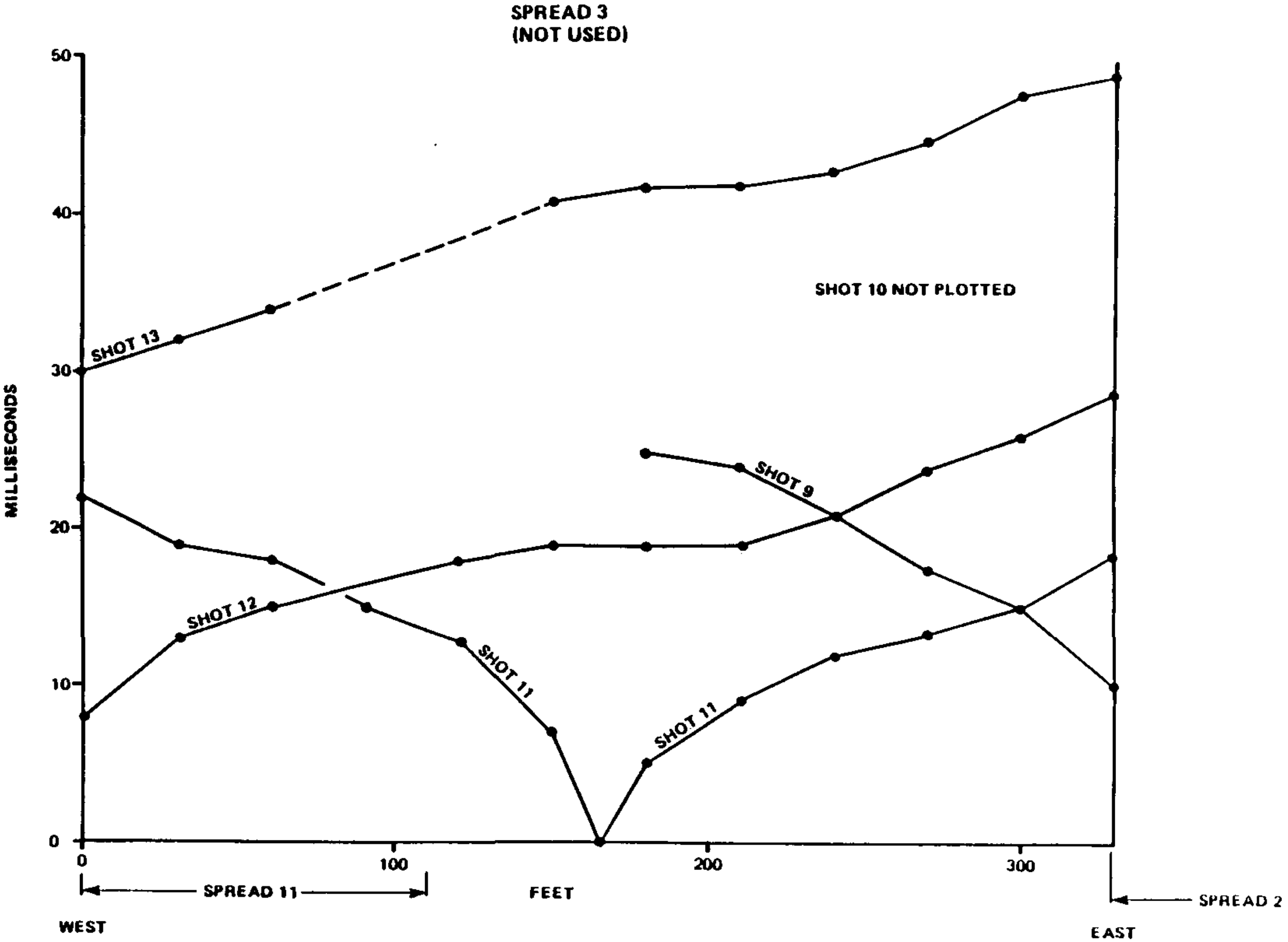


TIME - DISTANCE PLOTS

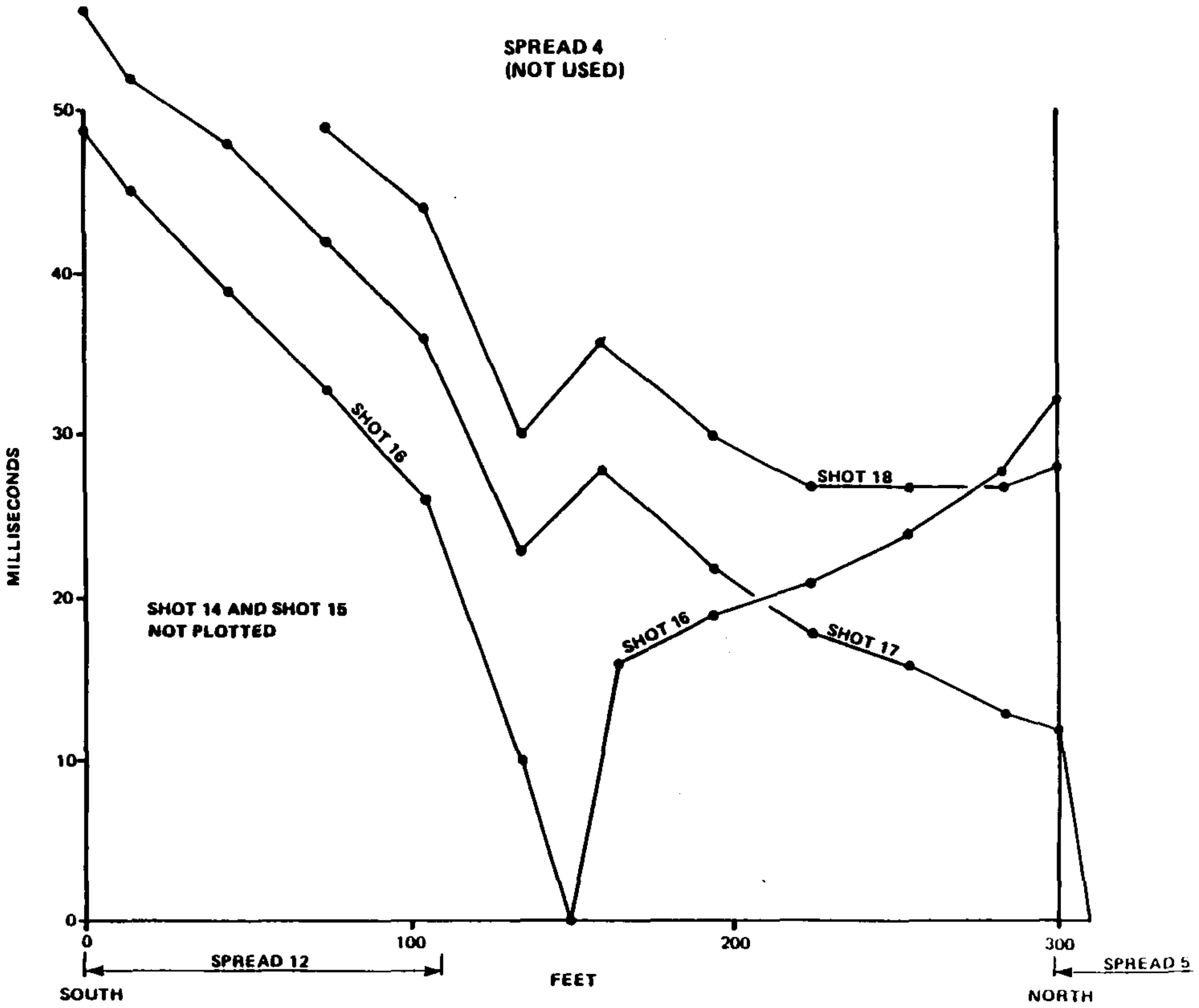
SPREAD 2

ARROWHEAD REFINERY

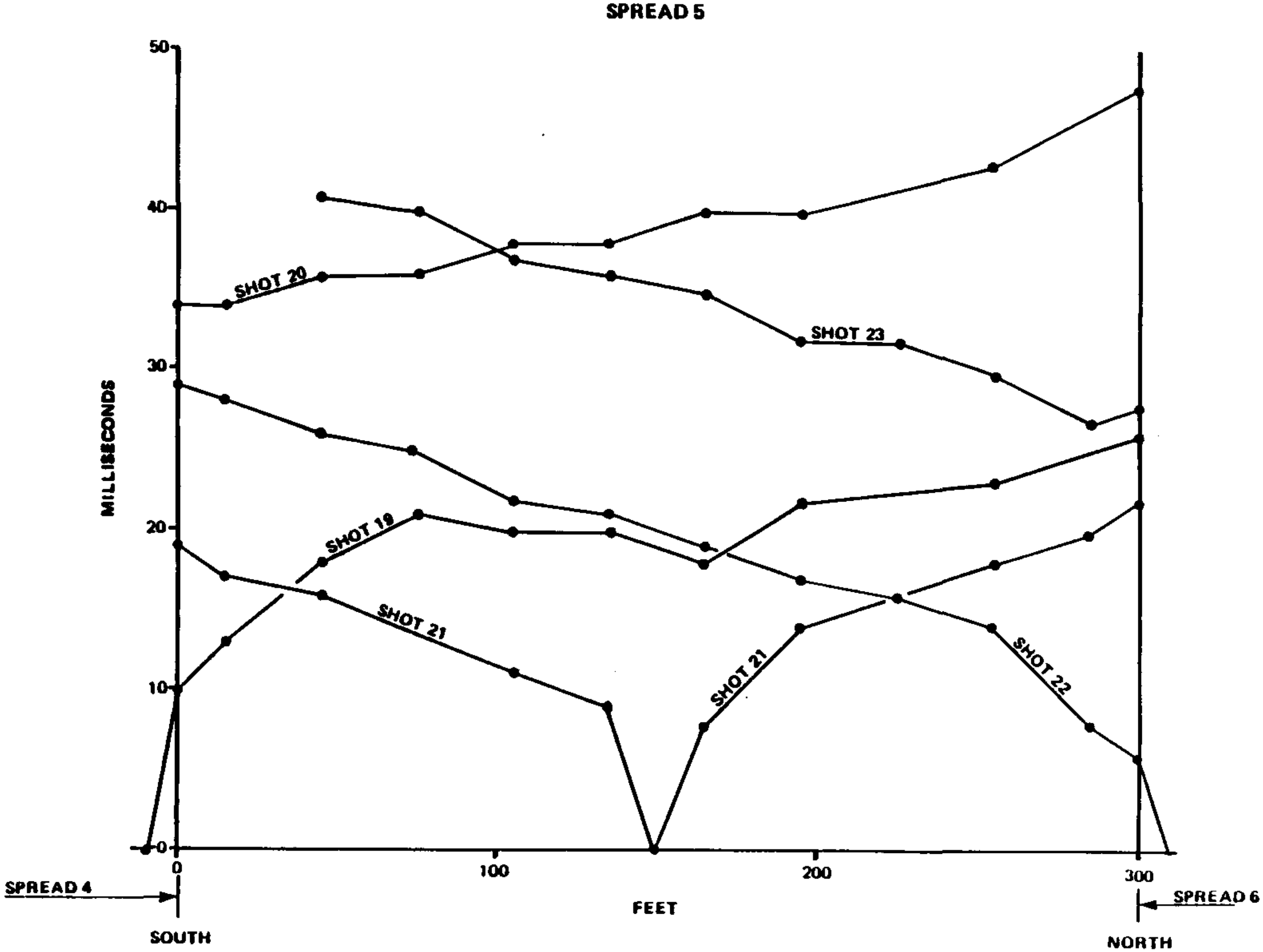
FIELDWORK INVESTIGATION STUD



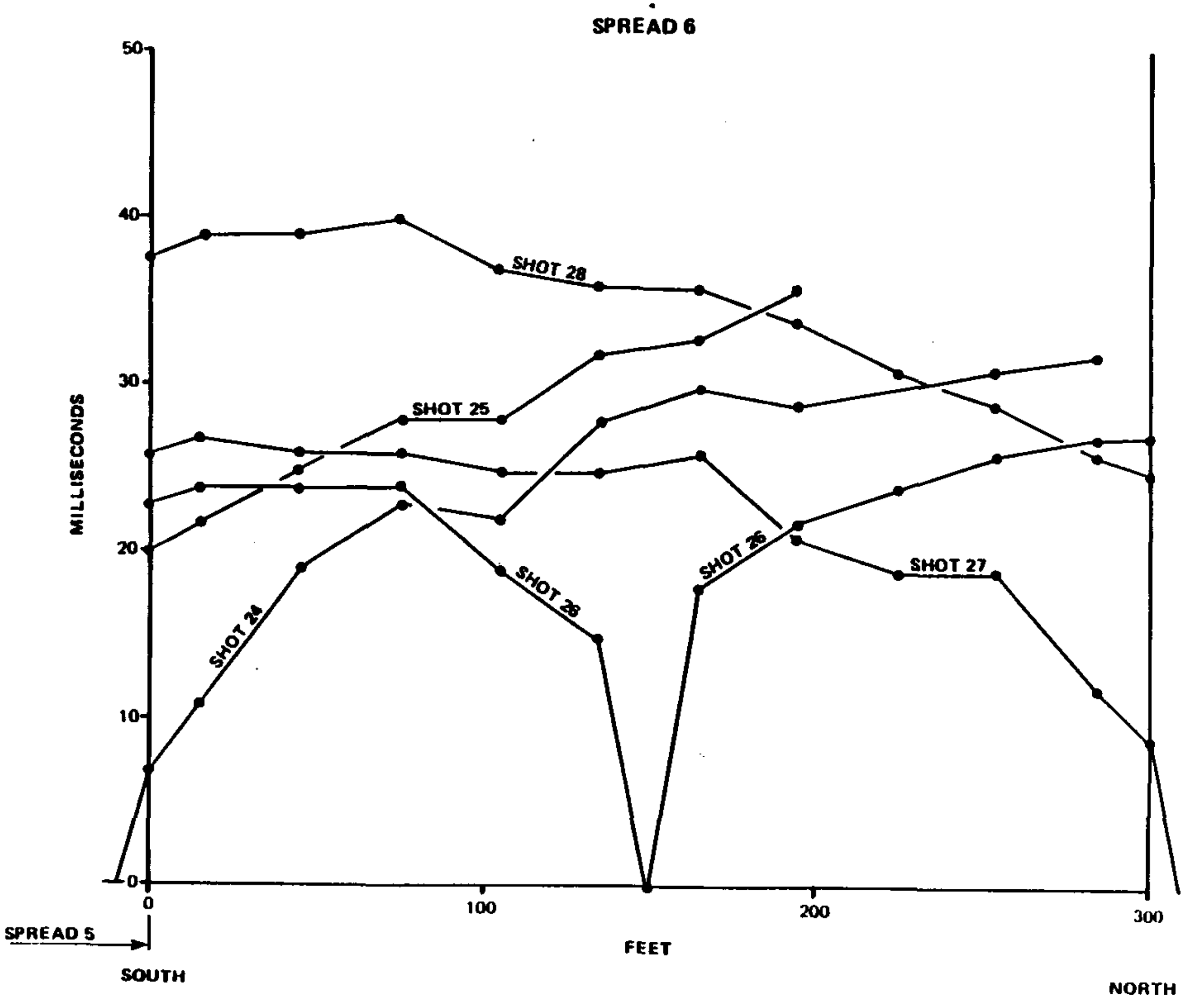
TIME - DISTANCE PLOTS
SPREAD 3
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



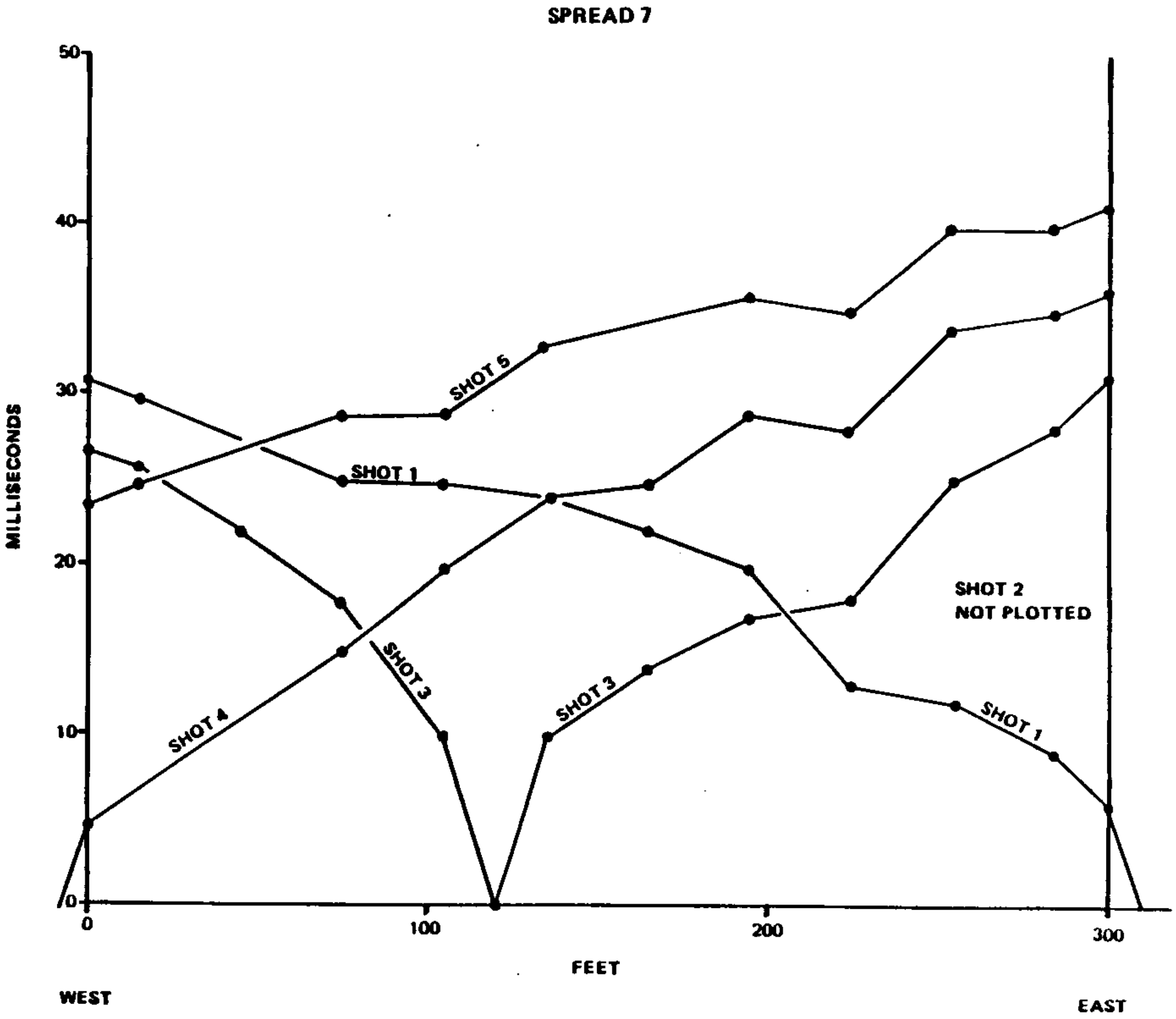
TIME - DISTANCE PLOTS
SPREAD 4
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



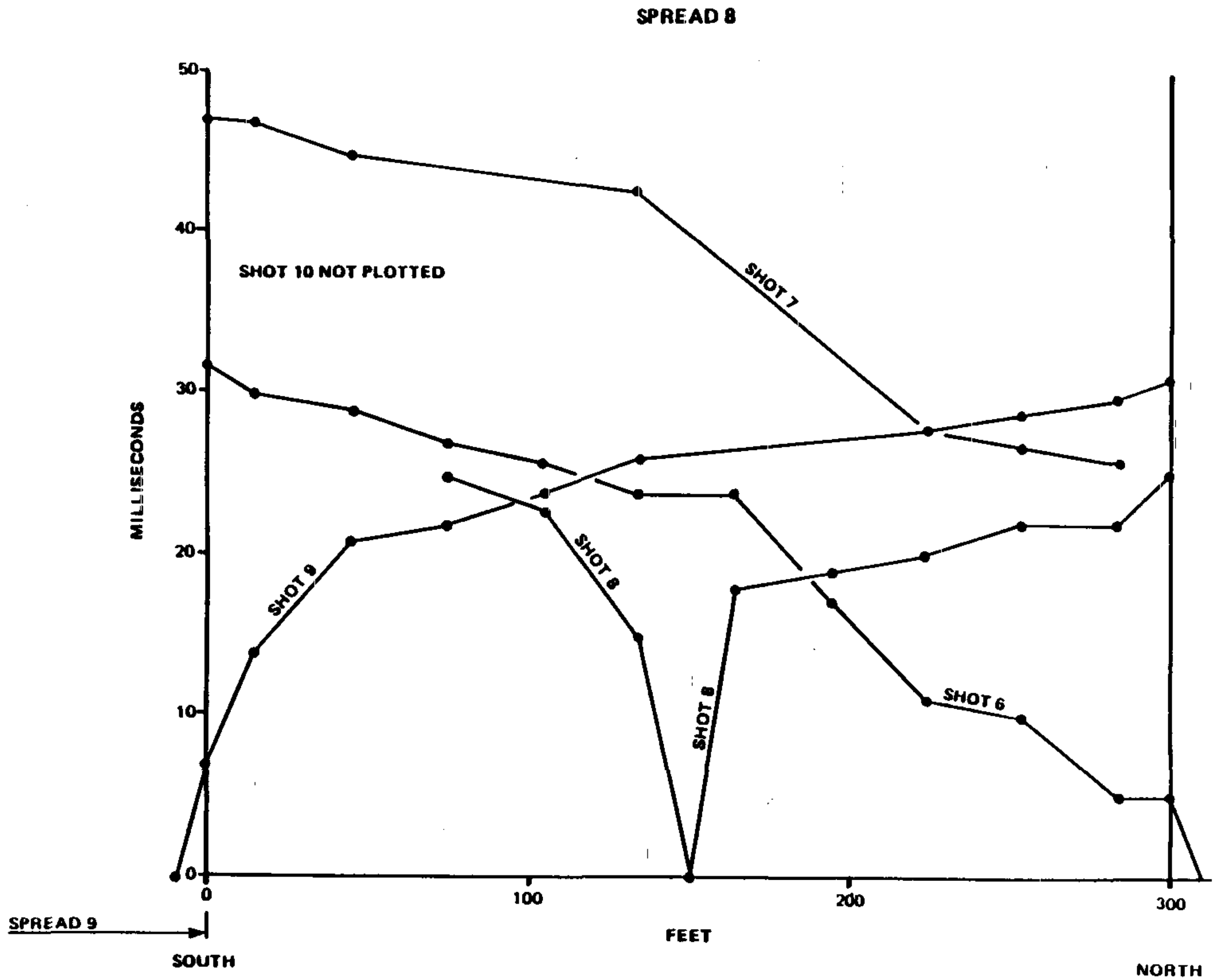
TIME - DISTANCE PLOTS
SPREAD 5
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



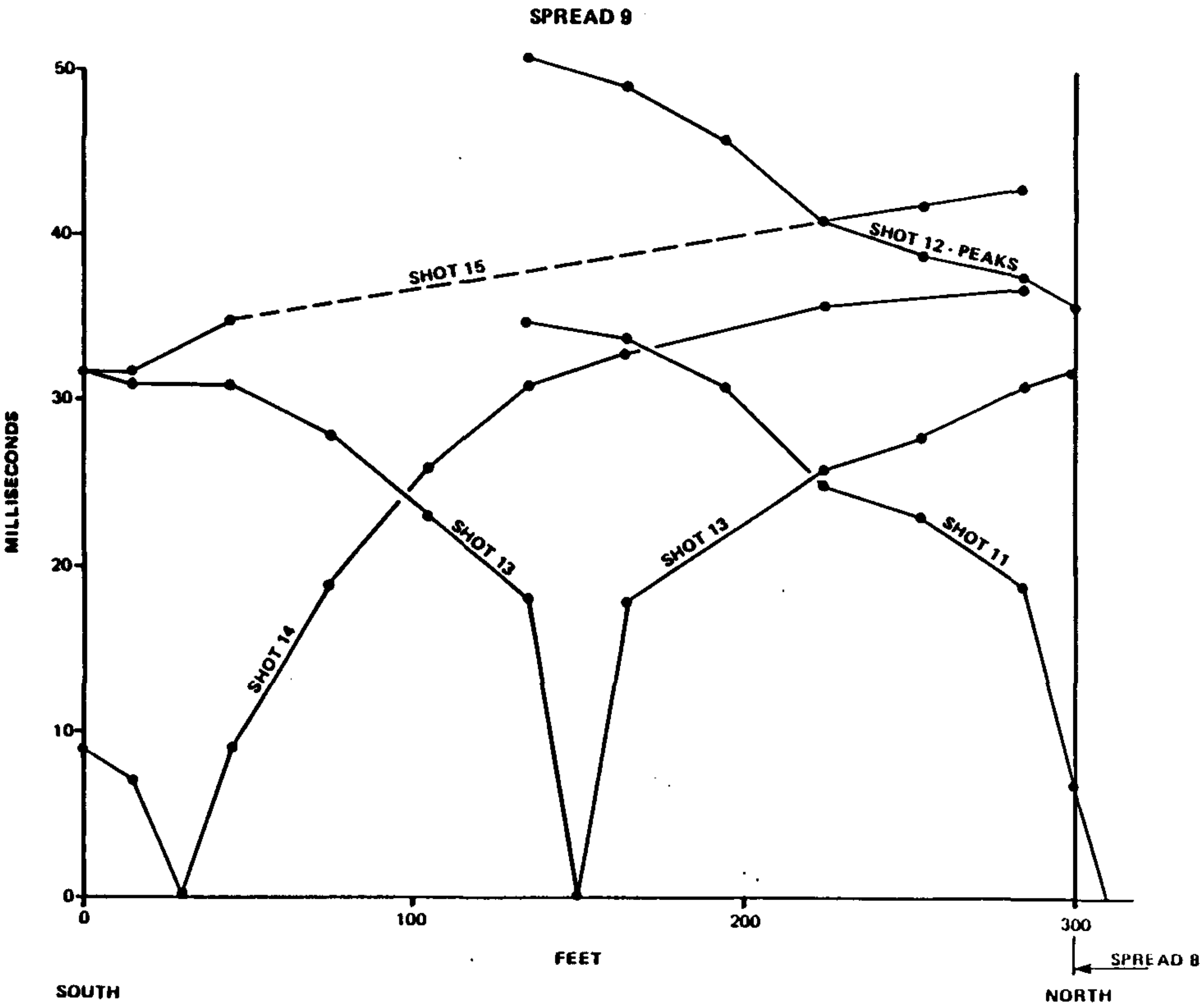
TIME - DISTANCE PLOTS
SPREAD 6
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



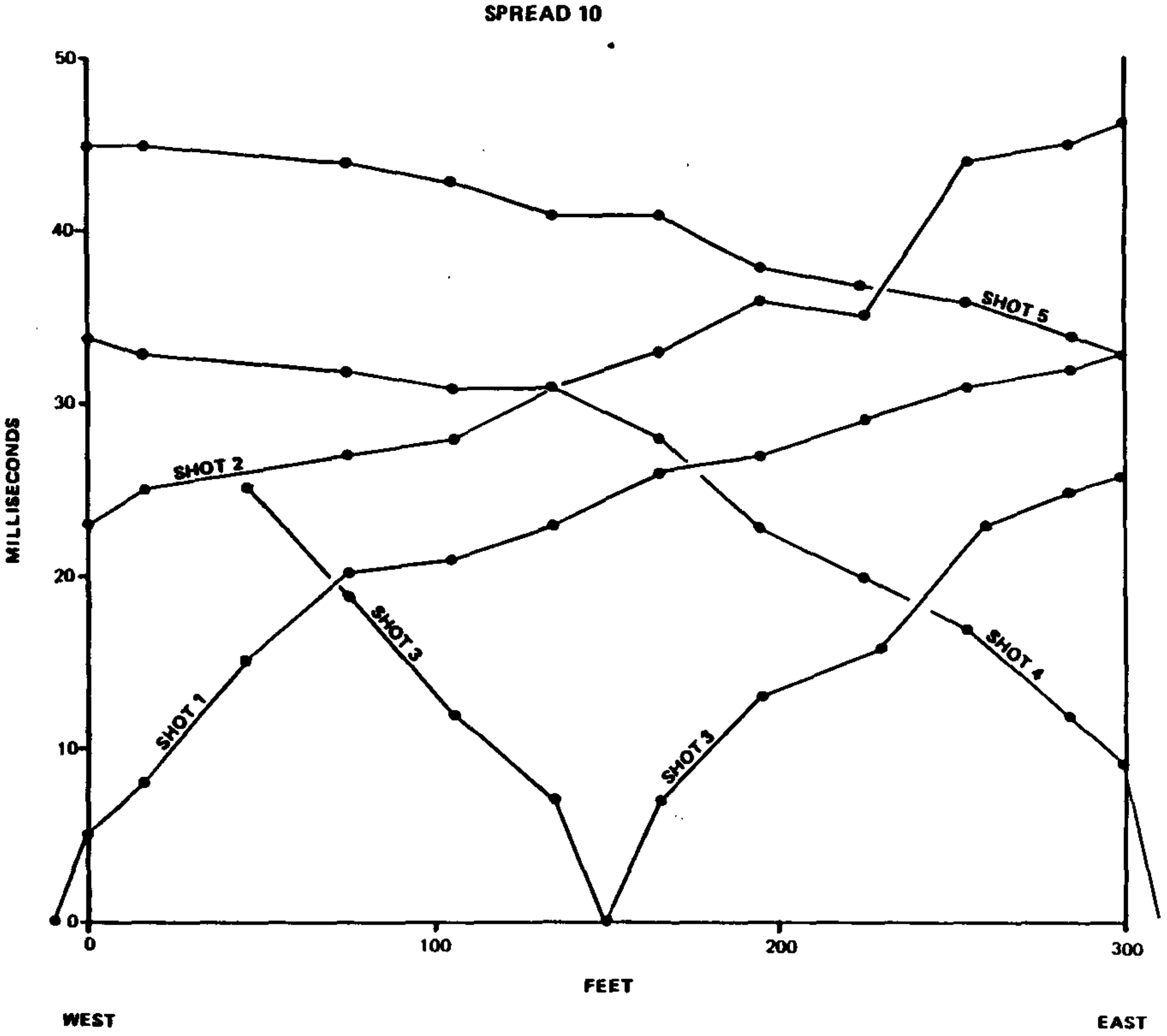
TIME - DISTANCE PLOTS
SPREAD 7
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



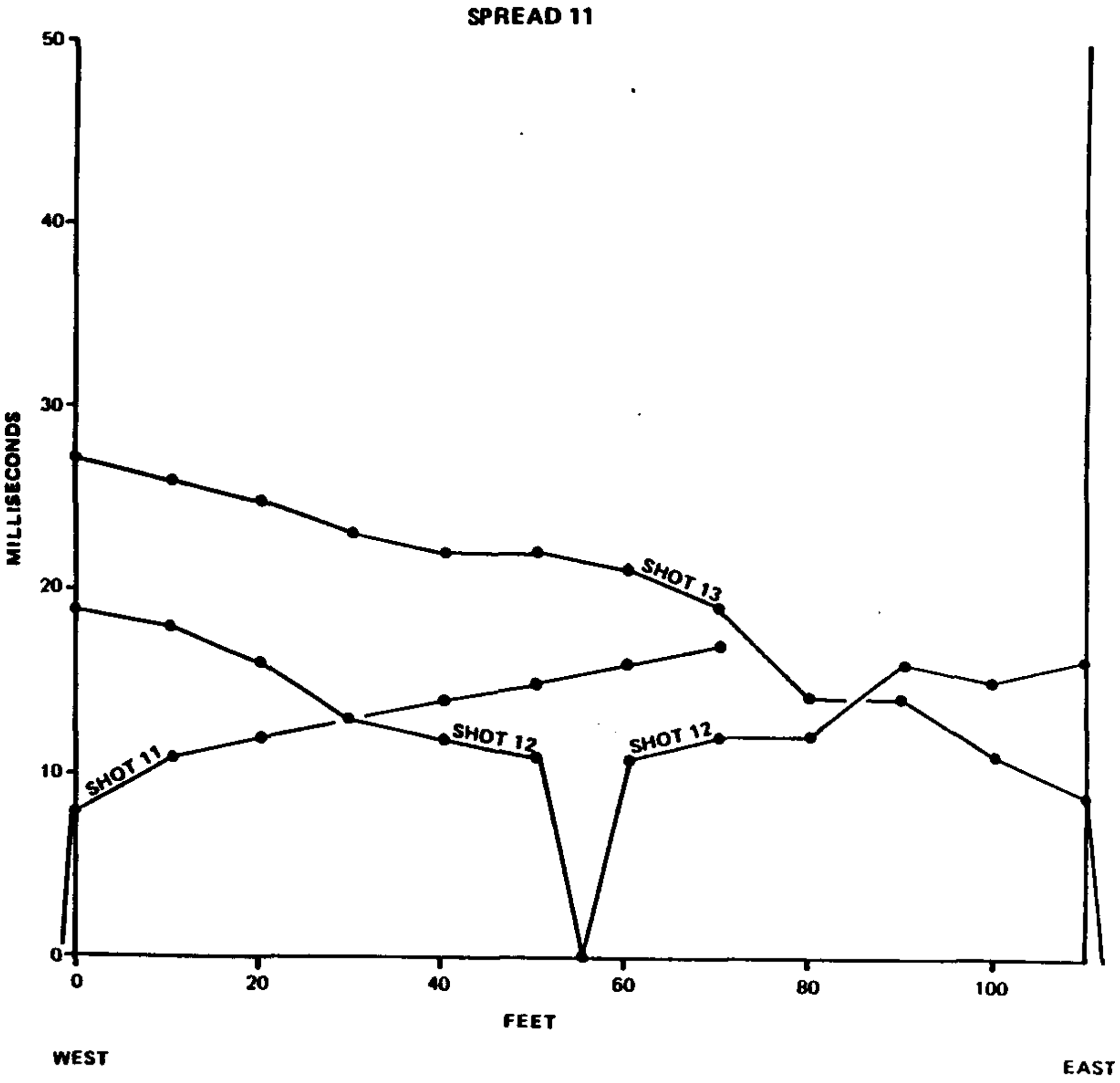
TIME - DISTANCE PLOTS
SPREAD 8
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



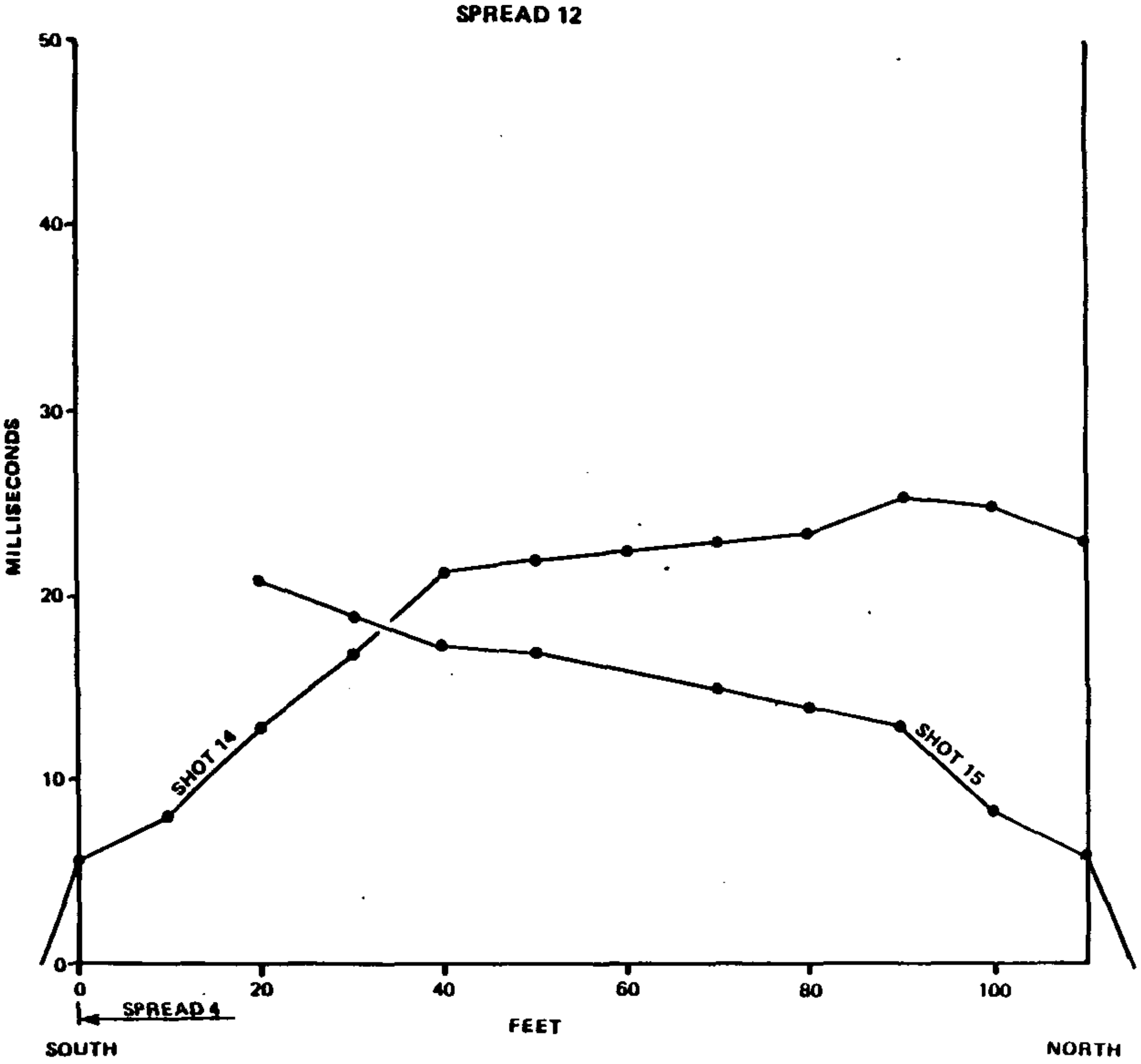
TIME - DISTANCE PLOTS
SPREAD 9
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



TIME - DISTANCE PLOTS
SPREAD 10
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY



TIME - DISTANCE PLOTS
SPREAD 11
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION [illegible]



TIME - DISTANCE PLOTS
SPREAD 12
ARROWHEAD REFINERY
FIELDWORK INVESTIGATION STUDY

TECHNICAL MEMORANDUM NO. 2

TO:	Fred Bartman/U.S. EPA Remedial Project Manager
FROM:	Randy Videkovich/CH2M HILL Project Manager
PREPARED BY:	Roger Huddleston/CH2M HILL Jewelle Imada/CH2M HILL
DATE:	March 2, 1988
RE:	Existing Well Evaluation and In Situ Hydraulic Conductivity Testing
PROJECT:	Arrowhead Refinery Fieldwork Design Investigation W68802.FI

INTRODUCTION

This memorandum summarizes the field activities at the Arrowhead Refinery site from August 16 to 23, 1987; and presents supporting hydraulic conductivity calculations. The objective of this field activity was to evaluate the existing wells to determine their suitability for use in subsequent investigations.

Actual fieldwork consisted of:

- o Collection of water levels from 29 of the 30 existing wells.
- o Redevelopment of appropriate existing wells.
- o In situ hydraulic conductivity measurements (slug tests) on appropriate wells.
- o Construction of two weirs in the EPA ditch for surface water flow measurements.
- o Installation of four staff gauges at various points in the EPA ditch for surface water level measurements.
- o Measuring well depths of 29 of the 30 existing wells.

WATER LEVEL MEASUREMENT

Roger Huddleston and Jewelle Imada of CH2M HILL mobilized equipment to Duluth, Minnesota, on Sunday, August 16. On August 17, they toured the site and measured water levels in 29 monitoring wells and 1 MPCA piezometer (Figure TM2-1). Water levels were measured to obtain a general picture of regional depth to groundwater. Groundwater elevations were not calculated because some wells appeared to have shifted due to frost heave.

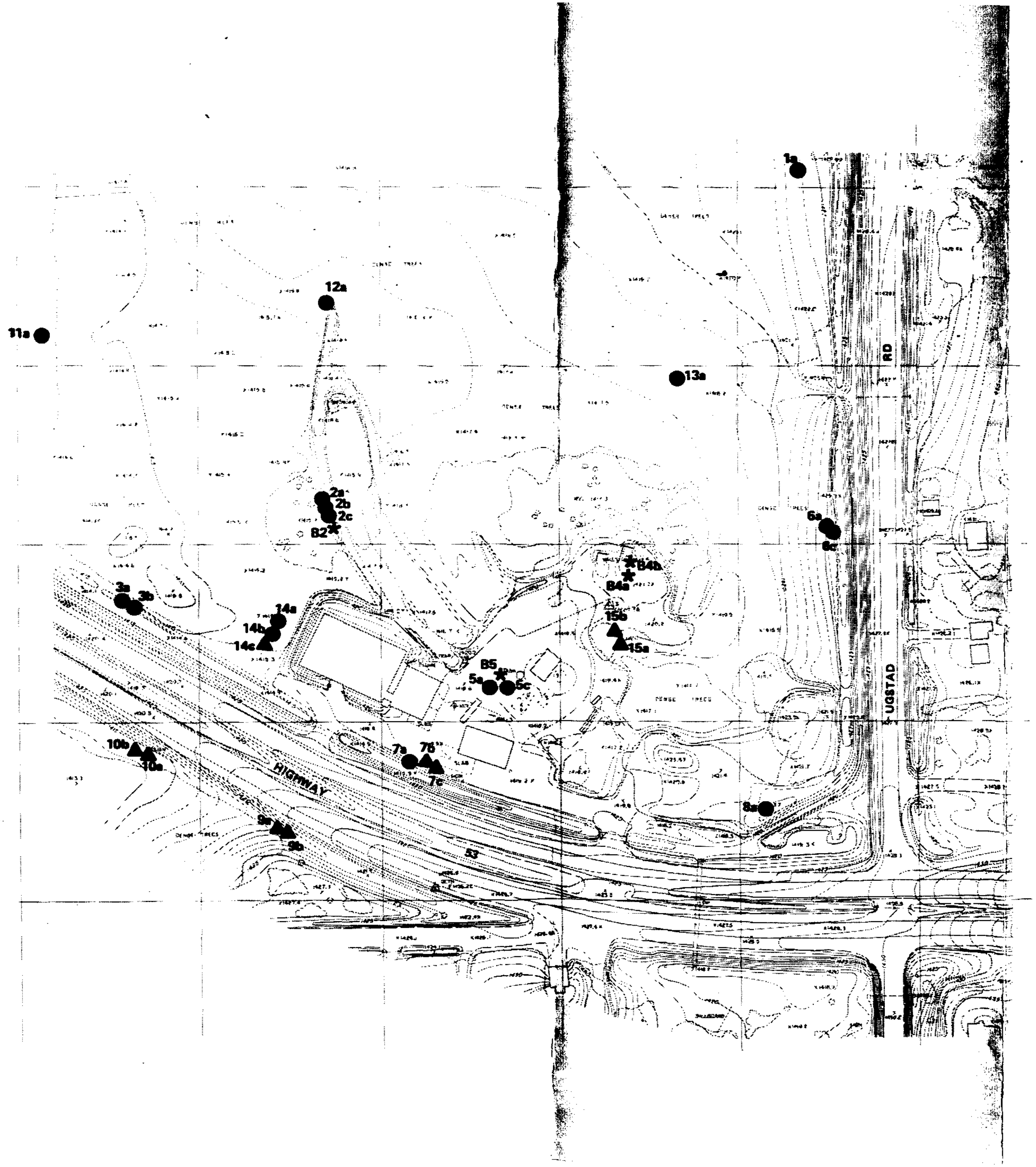
All wells (new and existing) were surveyed on November 22 to 24 following the installation of the additional wells (see Technical Memorandum No. 4). Using the new surveyed elevations, groundwater elevations were plotted and contoured.

WELL REDEVELOPMENT

Initial site investigations indicated that several onsite wells recovered very slowly when they were purged. (Several wells had to be purged at least 1 day before sampling to obtain an adequate volume of water in the well for sampling.) A possible cause for the slow well recovery was that silt had accumulated in the well screens since they were developed. Well redevelopment was proposed to establish a more representative hydraulic connection between the wells and the aquifers that could result in better producing wells.

A review of existing well logs determined that several wells were screened in either a fine silty lacustrine zone or a glacial till zone. It was suspected that wells screened in those zones would recover slowly, and redevelopment would not greatly improve well capacity or hydraulic connection with the aquifer. Two wells, one screened in the till layer (Well 5c), the other screened in the lacustrine zone (Well 8a), were thought to be representative of the respective units and were chosen as test wells for redevelopment.

An in situ hydraulic conductivity (slug) test was performed in each test well prior to development. Each well was then redeveloped, and a second slug test was performed. The results of each test were calculated and the hydraulic conductivity before development was compared to the hydraulic conductivity after development. The hydraulic conductivity in Well 8a before development was calculated to be 3.9×10^{-5} cm/s, while after redevelopment it was 3.4×10^{-5} cm/s, (see Attachment A for supporting plots and calculations). The hydraulic conductivity in Well 5c before development was calculated to 3.4×10^{-4} cm/s, while after redevelopment it was 3.3×10^{-4} cm/s. Because the hydraulic conductivities changed so little following redevelopment, it was determined that redevelopment of wells screened in lacustrine or till units would not significantly affect the wells' capacities or performance and would not be cost-effective. As a result, only wells screened in the peat or coarser granular units were redeveloped and slug tested.



LEGEND

- ★ WELLS FROM PREVIOUS INVESTIGATIONS
- ● PHASE I WELLS
- ▲ PHASE II WELLS

SOURCE: ARROWHEAD REFINERY RI

FIGURE TM-2-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

METHODS

Wells were redeveloped using a Brainard-Kilman hand pump or a PVC bailer. At least 10 well volumes was removed from each well. The development apparatus was decontaminated with a trisodium phosphate wash, a water rinse, and a distilled water rinse between each well.

RESULTS

Twelve wells besides the two test wells were chosen for redevelopment. Wells B2 and B5, installed during the initial FIT investigation, have 1-1/2-inch I.D. PVC risers. The development equipment could not be used on these wells because of the small well diameter. As a result, only 10 wells in addition to the two test wells were redeveloped: Wells MW-1a, MW-2a, MW-3a, MW-7a, MW-7b, MW-9a, MW-10a, MW-12a, MW-14a, and MW-15b. Although geologic interpretation of boring log MW-7a indicates that the well is screened in the lacustrine zone, the formation at Well MW-7a is reportedly coarser than the other lacustrine deposits. Therefore, it was decided that redevelopment of Well MW-7a would probably be beneficial.

The water removed during redevelopment was generally a milky brown color and did not seem to become less turbid after 10 well volumes were removed. Because the wells had already been developed and the water did not appear to clear up, well development was considered complete after 10 well volumes were removed. Additional development (until the water was completely free of sediment) would have required significant additional time and equipment, neither of which was available.

Most wells were redeveloped within 1 day. Well MW-15b, however, recovered much more slowly than would be expected from review of the soil boring log, and only two to three well volumes were removed each day.

HYDRAULIC CONDUCTIVITY MEASUREMENTS

METHODS

In situ hydraulic conductivity tests were conducted using a 5-foot-long, 1-inch-diameter solid PVC slug to displace a column of water. Two tests were performed on each well. First the static water level was measured and the slug was dropped into the well. The level of the falling water column was measured to the nearest 0.01 foot at specific time intervals with an electronic water level indicator. Then the slug was removed and the level of the rising water column was measured. After testing, the slug was decontaminated with a trisodium phosphate wash, water rinse, and distilled water rinse between each well. The water level indicator was decontaminated with distilled water between each well.

A slug test was not performed on Well MW-15b because of its slow recovery, so a baildown test was performed instead. The well was bailed dry, and water levels were measured during the day as the well recovered.

Two rising head slug tests were performed on Well B2. Well B2 is so shallow that the displaced water column did not rise above the top of the slug, and falling head water levels could not be measured.

RESULTS

Results of the in situ hydraulic conductivity tests are summarized in Table TM2-1. Supporting calculations are included in Attachment A. Hydraulic conductivities for wells screened in the peat ranged from 7.5×10^{-5} to 8.8×10^{-3} cm/s, with a logarithmic average hydraulic conductivity of 5.2×10^{-4} cm/s. Hydraulic conductivities for wells screened in the granular zones were slightly lower, ranging from 9.8×10^{-6} to 3.4×10^{-4} cm/s (excluding Well MW-15b). The logarithmic average hydraulic conductivity for wells screened in the granular zones is 1.1×10^{-4} cm/s. Well MW-15b, also screened in the granular zone, had a hydraulic conductivity of approximately 3.5×10^{-6} cm/s, the lowest of any well tested.

WELL DEPTH MEASUREMENTS

The depths of the monitoring wells were measured from September 27 to 29. Casing and riser heights above ground surface and depths to groundwater were also measured (Table TM2-2). The measured well depths were compared to the recorded well depths from the RI report. The objective of this task was to determine which wells have possibly shifted or accumulated silt on the bottom.

Most of the wells measured had less than a 1/2-foot difference between the recorded and measured depths. Well MW-10b was 0.8 foot deeper than recorded so the well was examined for settling during the well elevation survey. Wells MW-12a, MW-2b, and MW-2c had differences in the depth measurements of more than 1 foot, and all had some silt accumulation on the bottom. The depths of all wells was measured once again before purging and groundwater sampling were performed.

Table TM2-1
SUMMARY OF HYDRAULIC CONDUCTIVITIES

Well Number	Units	Hydraulic Conductivity (cm/s)	
		Before	After
Test Wells			
MW-8A	Lacustrine	3.9 x 10^{-5}	3.4 x 10^{-5}[a]
MW-5c	Till	3.4 x 10^{-4}	3.3 x 10^{-4}
Monitoring Wells			
MW-1a	Peat	1.3 x 10^{-4}	1.1 x 10^{-4}
MW-2a	Peat	7.9 x 10^{-5}	7.5 x 10^{-5}
MW-3a	Granular	3.4 x 10^{-4}	2.6 x 110^{-4}
MW-7a	Lacustrine	4.9 x 10^{-4}	4.8 x 10^{-4}
MW-7b	Granular	9.8 x 10^{-6}	1.6 x 10^{-5}
MW-9a	Peat	2.0 x 10^{-4}	1.7 x 10^{-4}
MW-10a	Peat	8.2 x 10^{-3}	8.8 x 10^{-3}
MW-12a	Granular	3.6 x 10^{-4}	3.2 x 10^{-4}
MW-14a	Granular	1.1 x 10^{-4}	1.1 x 10^{-4}
MW-15b	Granular	3.5 x 10^{-6}	--
B2	Peat	1.2 x 10^{-3}	1.2 x 10^{-3}[a]
B5	Peat	9.0 x 10^{-4}	1.3 x 10^{-3}

-- = Falling head test not performed because of time constraints.

[a] Second rising head test.

Table TM2-2
WELL MEASUREMENTS

Well No.	Recorded Well Depth * (Feet below Ground Surface)	Casing Height (Feet above Ground Surface)	Riser Height (Feet above Ground Surface)	Well Depth (Feet below Top of Riser)	Well Depth (Feet below Ground Surface)	Depth to Groundwater (Feet below Top of Riser)
1a	13.33	3.24	3.14	16.69	13.55	5.25
2a	8	2.59	2.54	9.95	7.41	4.94
2b	25	2.94	2.82	26.47	23.65	4.52
2c	38.5	2.55	2.49	39.83	37.34	4.1
B-2b	7.5 **	2.84	2.83	9.67	6.84	4.81
3a	15	3.14	3.1	17.67	14.57	4.41
3b	22.5	2.76	2.71	24.38	21.67	3.76
B-4a	10 **	---	---	---	---	---
B-4b	32 **	---	---	---	---	---
5a	12	2.48	2.42	13.78	11.36	3.68
5c	38.5	2.15	2.1	39.97	37.87	3.57
B-5	7 **	3.47	3.41	10.07	6.66	3.57
6a	14	2.84	2.82	16.38	13.56	7.16
6c	35	2.85	2.77	37.73	34.96	7.89
7a	13.8	3.00	3.1	16.43	13.33	5.59
7b	24.5	2.85	2.7	26.9	24.20	4.86
7c	36	2.69	2.42	38.51	36.09	4.83
8a	14.25	2.90	2.78	17.52	14.74	7.62
9a	14.5	2.55	2.17	16.43	14.26	4.72
9b	22.5	2.59	2.61	24.39	21.78	5.43
10a	12.5	2.80	2.69	14.31	11.62	3.86
10b	22	2.85	2.61	25.37	22.76	3.35
11a	14	3.19	3.14	16.66	13.52	2.73
12a	14	2.93	2.88	15.81	12.93	4.68
13a	14	2.98	2.9	17.3	14.40	3.09
14a	15	2.47	2.34	17.32	14.98	2.69
14b	24	2.76	2.71	26.98	24.27	3.0
14c	31.5	1.78	1.68	33.55	31.87	2.25
15a	14.5	---	---	---	---	---
15b	24.5	---	---	---	---	---

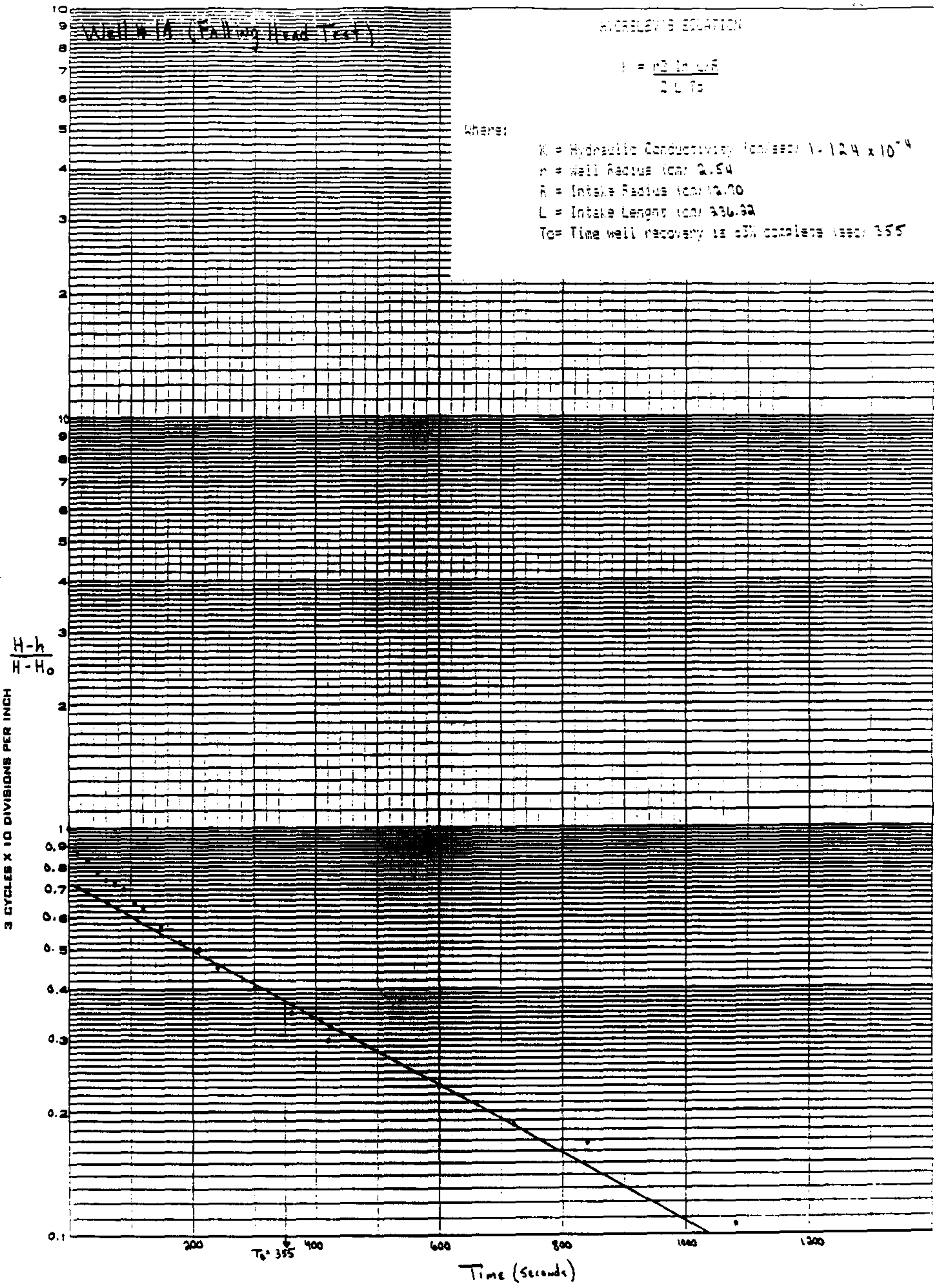
* Well depths taken from well installation logs from the RI.

** Well depths taken from TAT report.

TM 2--EXISTING WELL EVALUATION AND IN SITU HYDRAULIC CONDUCTIVITY TESTS

Attachment A

CALCULATION OF IN SITU HYDRAULIC CONDUCTIVITIES

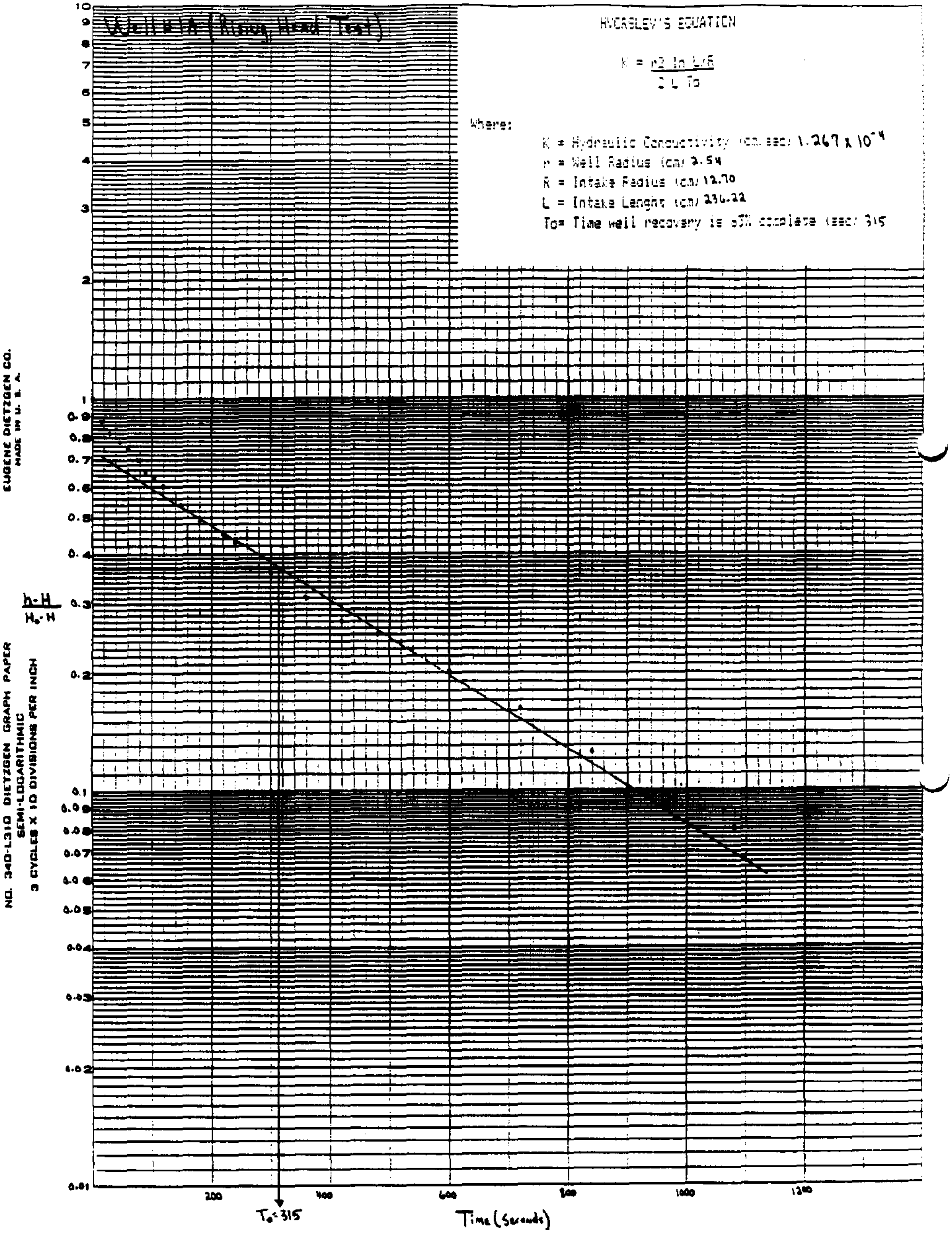


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.124 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 336.32
To= Time well recovery is 63% complete (sec) 355

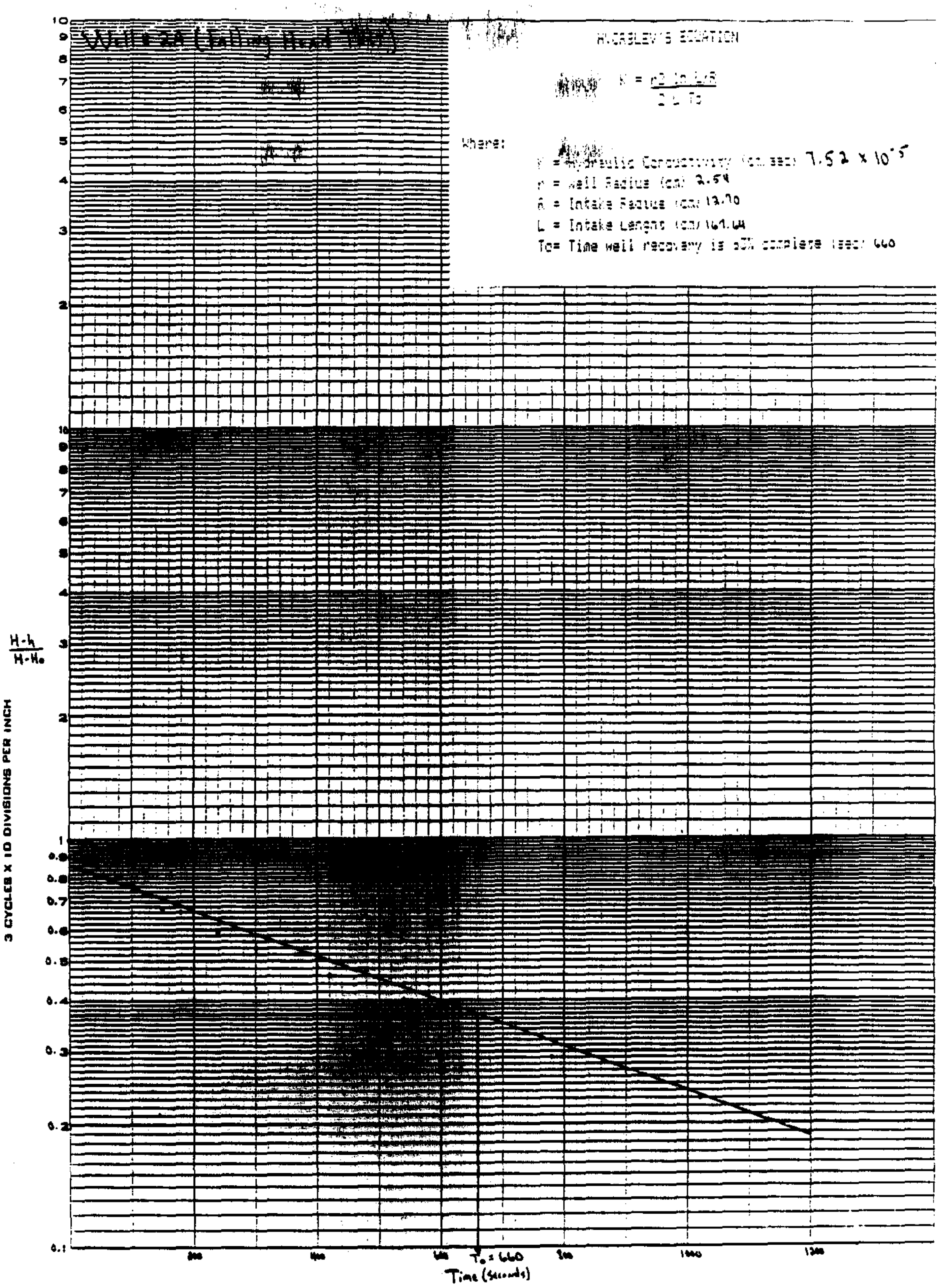


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.267 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 236.22
To= Time well recovery is 63% complete (sec) 315

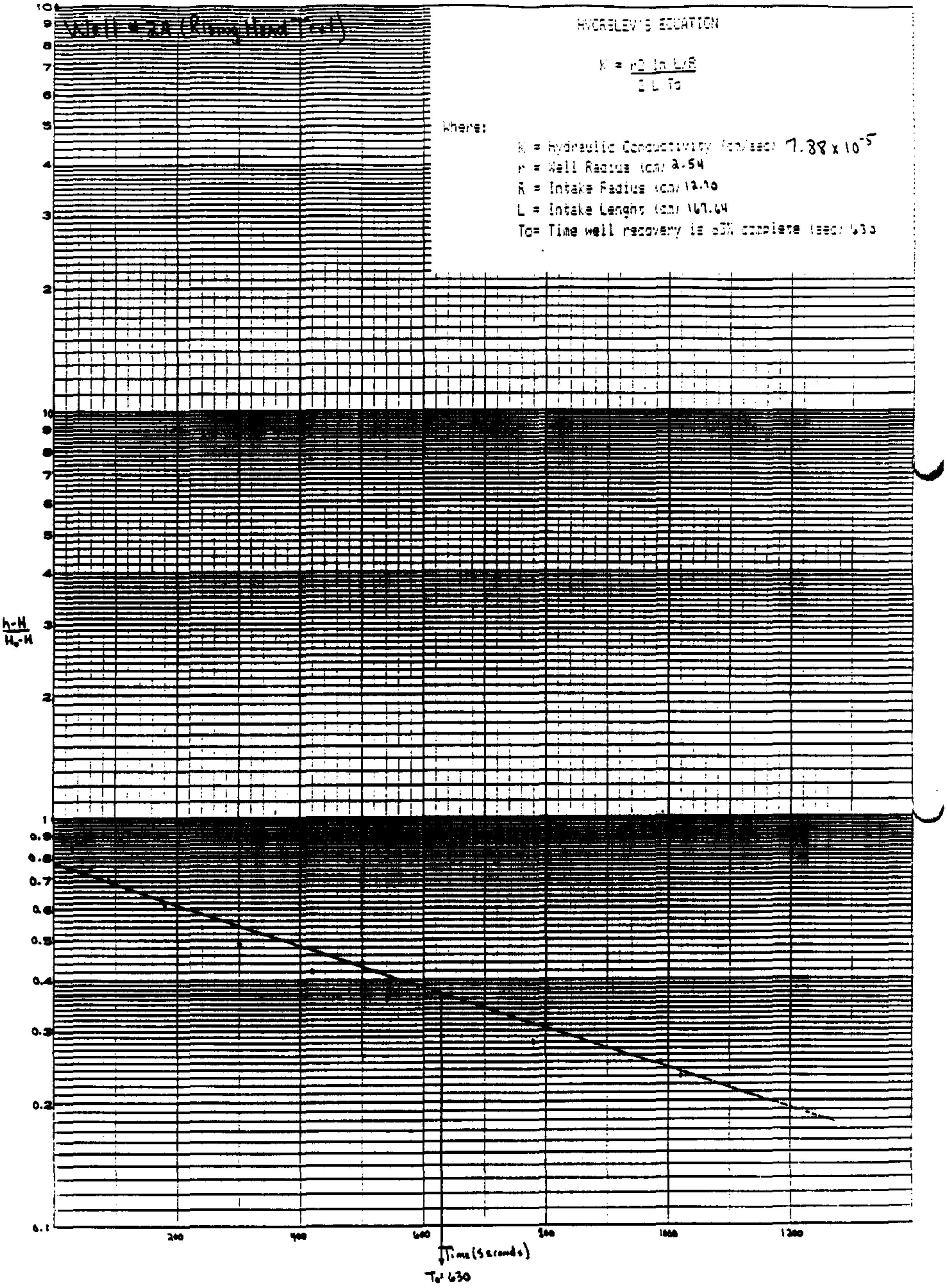


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 7.52 x 10-5
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 13.70
L = Intake Lenght (cm) 161.44
To= Time well recovery is 37% complete (sec) 660



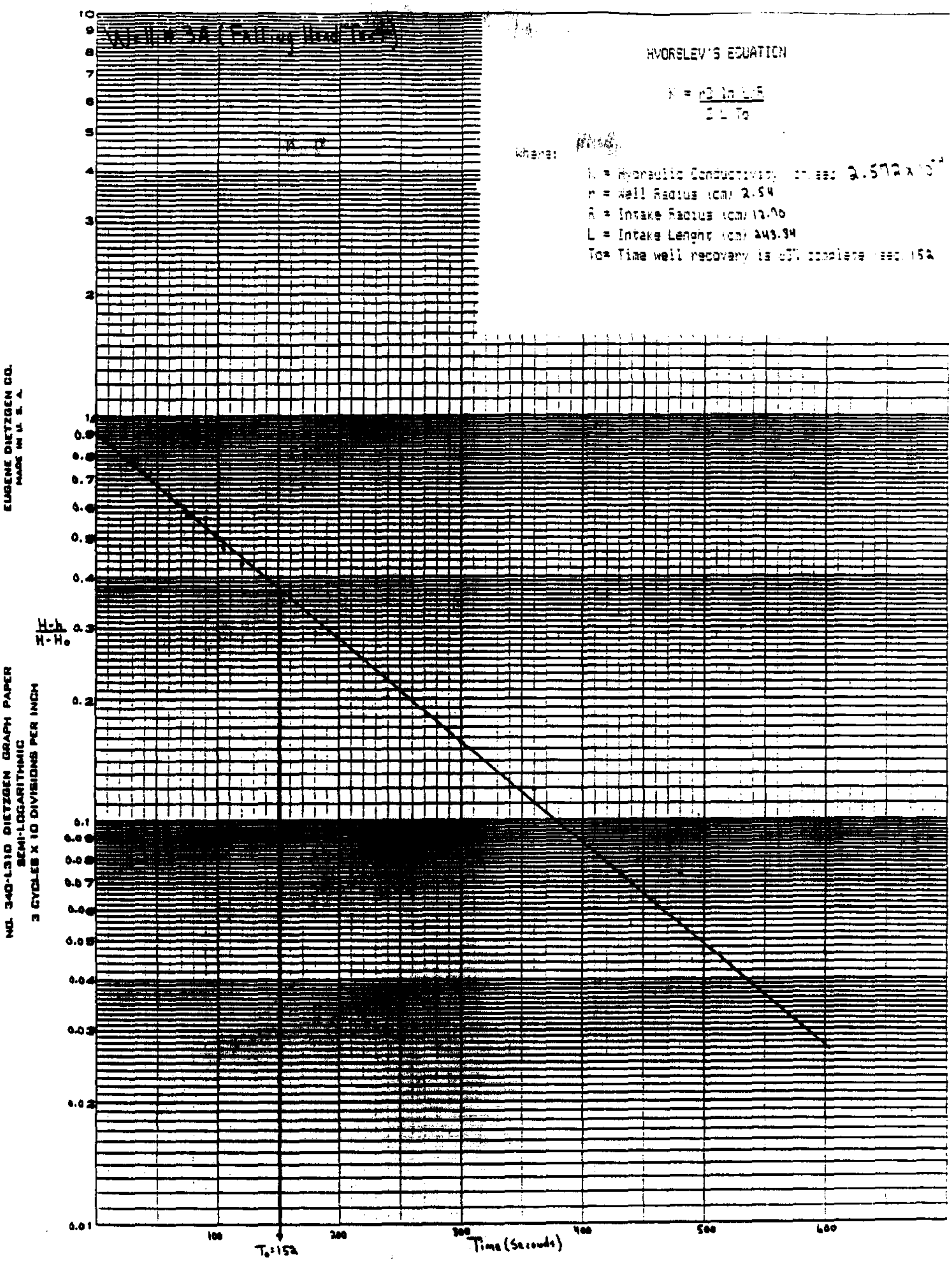
HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_0}$$

Where:

K = Hydraulic Conductivity (cm/sec) 7.88 x 10⁻⁵
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 167.64
To= Time well recovery is 63% complete (sec) 630

Well # 3A (Falling Head Test)



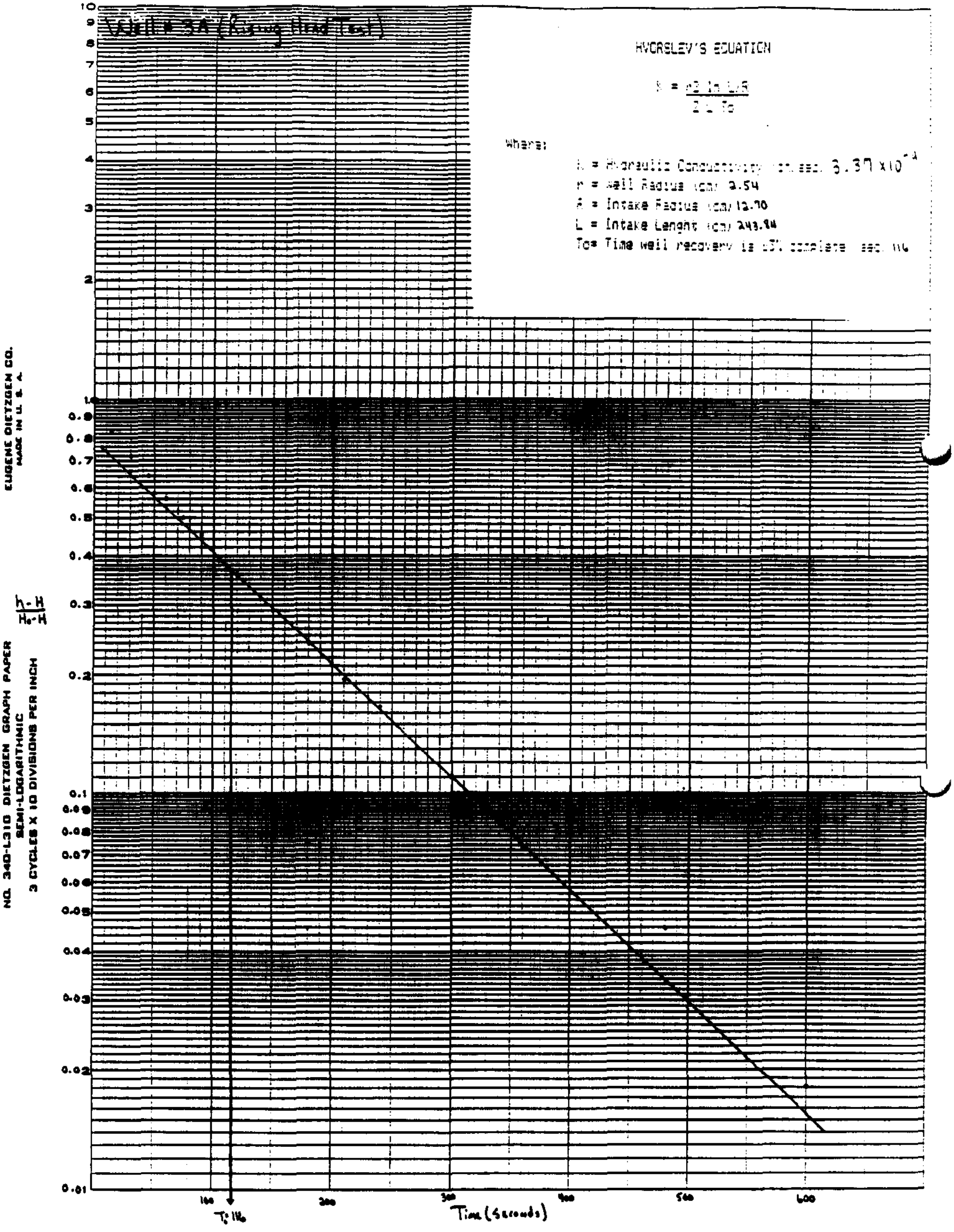
HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 2.572 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 243.84
To= Time well recovery is 37% complete (sec) 152

Well # 3A (Rising Head Test)



HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

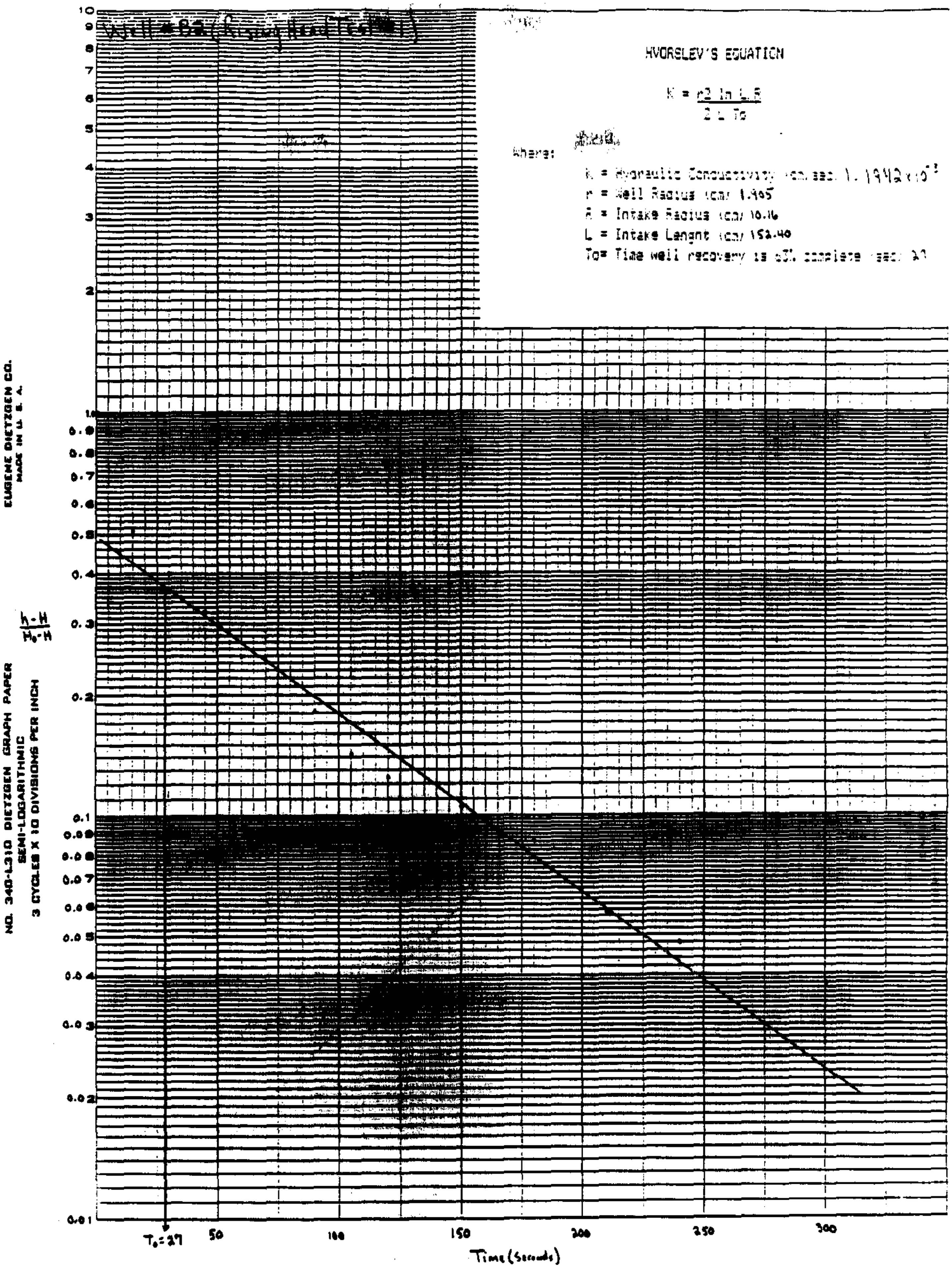
K = Hydraulic Conductivity (cm/sec) 3.37 x10^{-4}

r = Well Radius (cm) 2.54

R = Intake Radius (cm) 12.70

L = Intake Lenght (cm) 243.84

To= Time well recovery is 37% complete (sec) 116



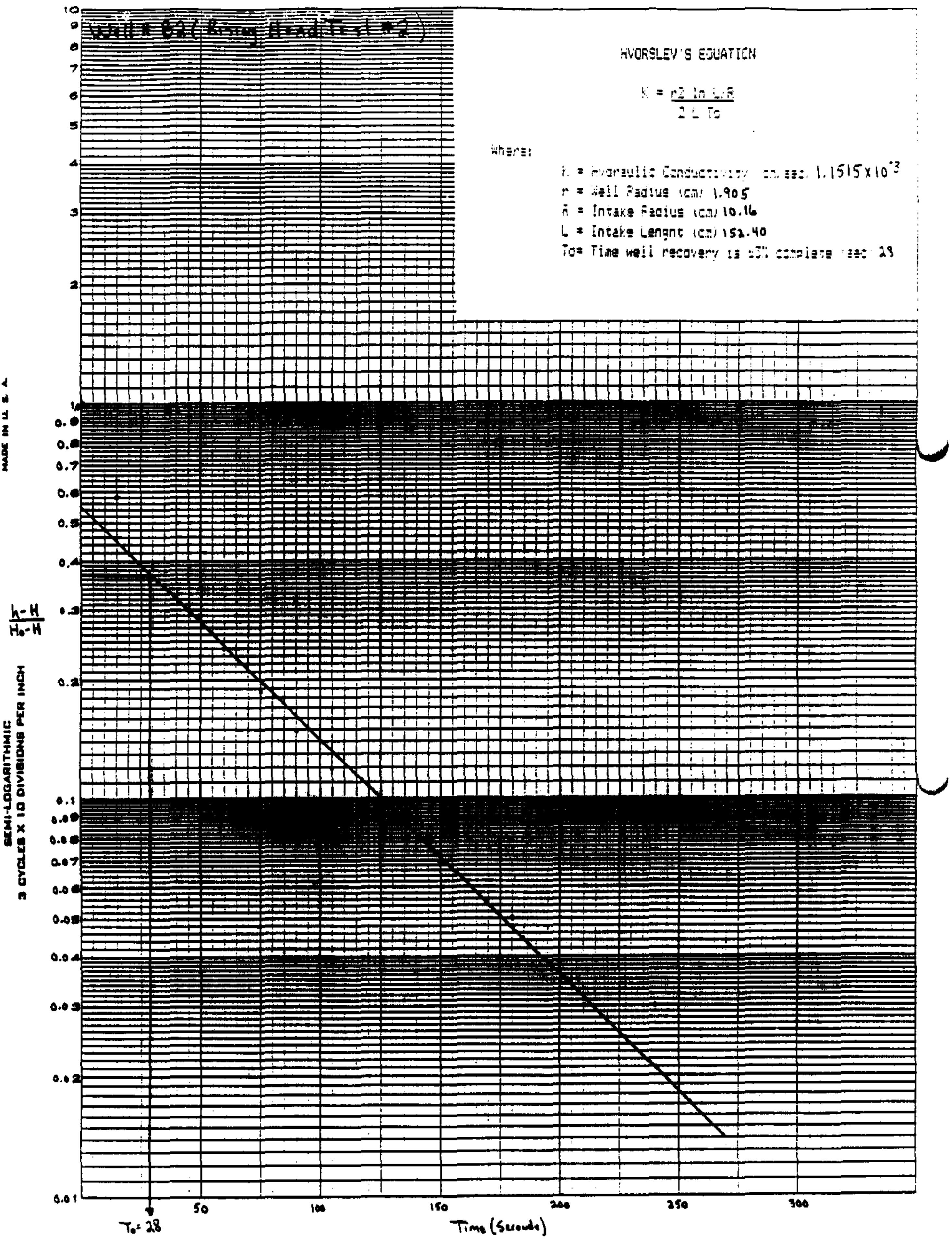
HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.1992×10^{-3}
r = Well Radius (cm) 1.905
R = Intake Radius (cm) 10.16
L = Intake Lengnt (cm) 152.40
To= Time well recovery is 37% complete (sec) 27

Well # 62 (Rising Head Test #2)



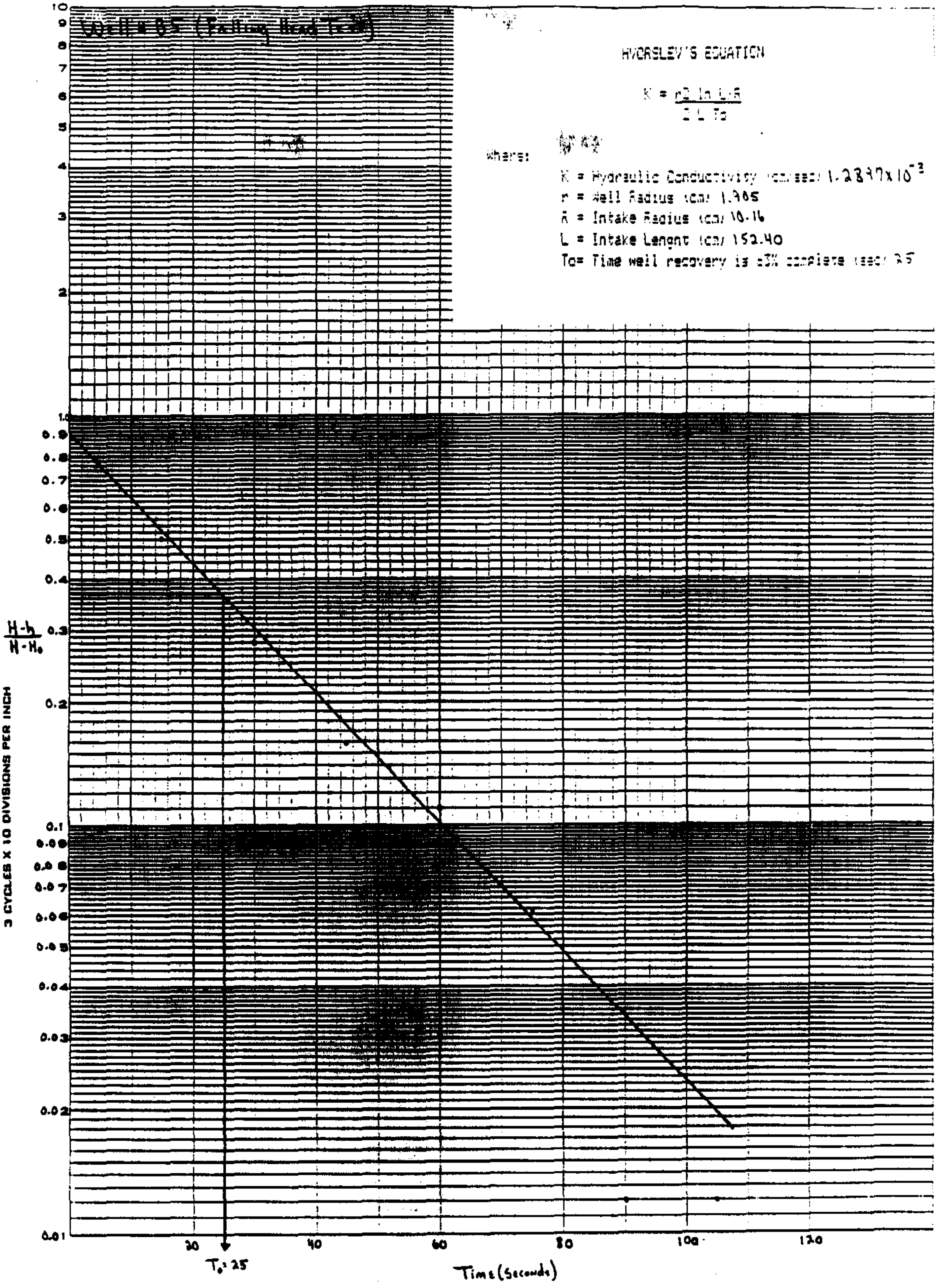
HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_0}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.1515×10^{-3}
r = Well Radius (cm) 1.905
R = Intake Radius (cm) 10.16
L = Intake Lengnt (cm) 152.40
To= Time well recovery is 37% complete (sec) 28

Well # 8S (Falling Head Test)

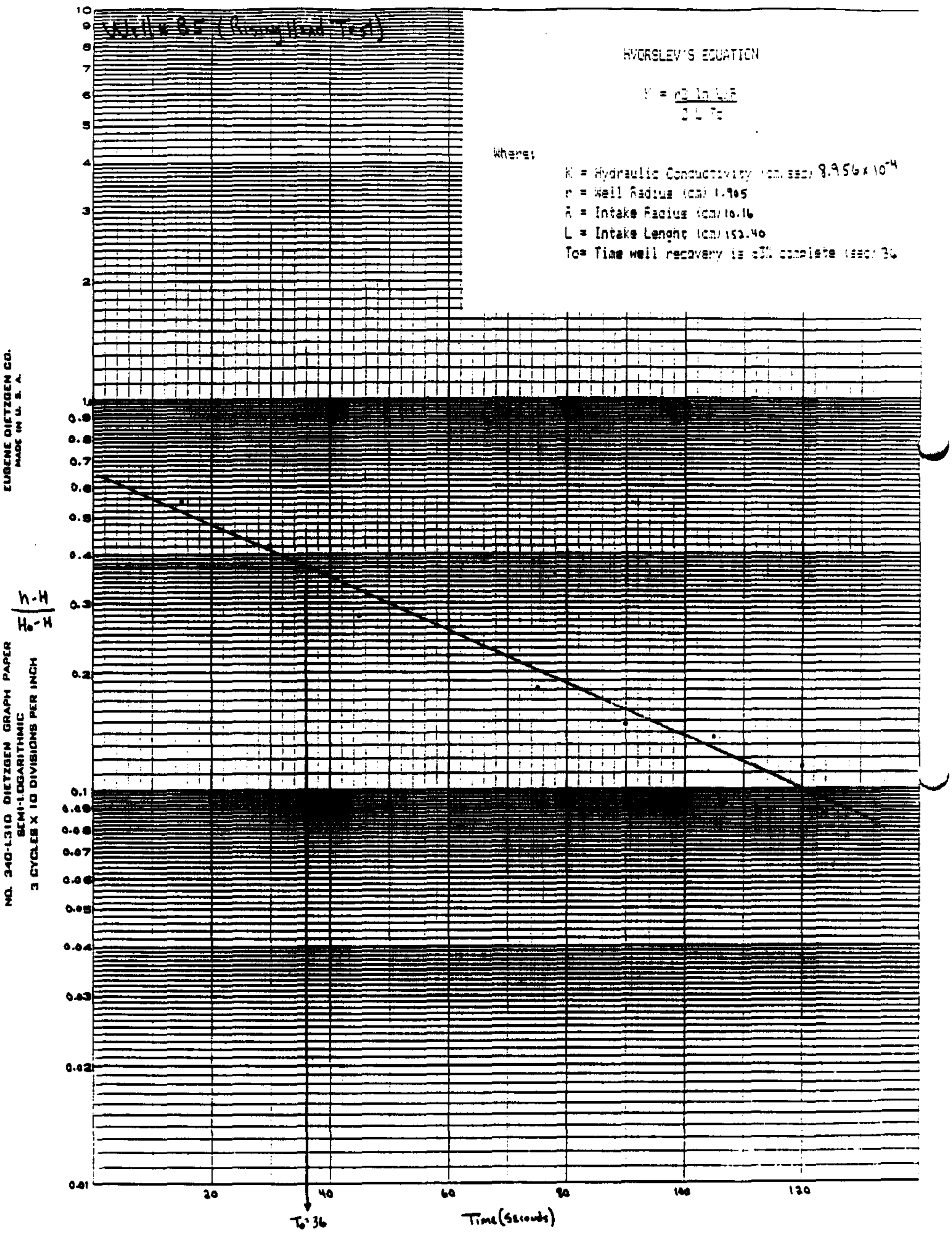


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_0}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.2897×10^{-3}
r = Well Radius (cm) 1.905
R = Intake Radius (cm) 10.16
L = Intake Lenght (cm) 152.40
To= Time well recovery is 63% complete (sec) 25



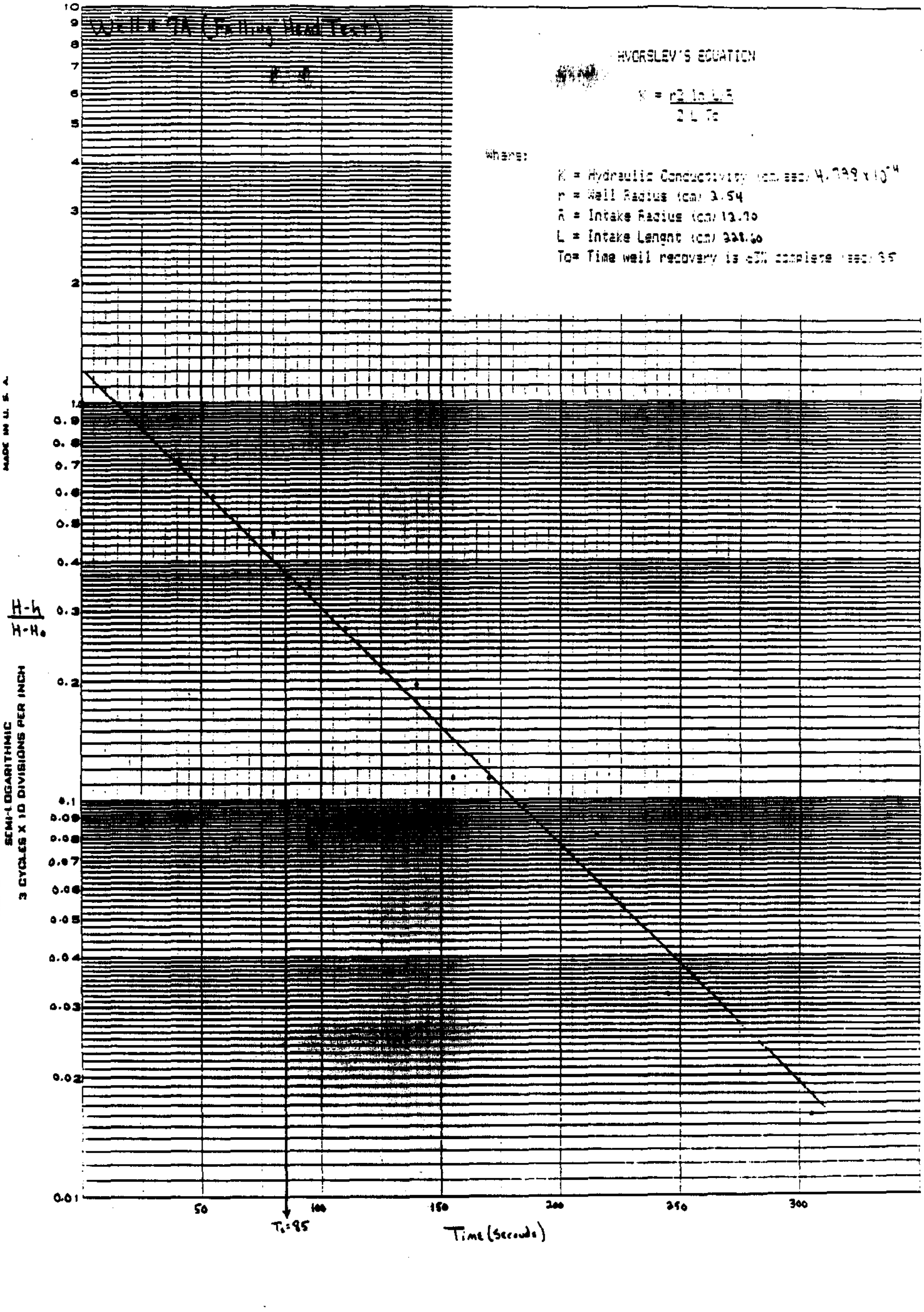
HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 8.956×10^{-4}
r = Well Radius (cm) 1.905
R = Intake Radius (cm) 10.16
L = Intake Lenght (cm) 152.40
To= Time well recovery is 37% complete (sec) 36

Well # 7A (Falling Head Test)

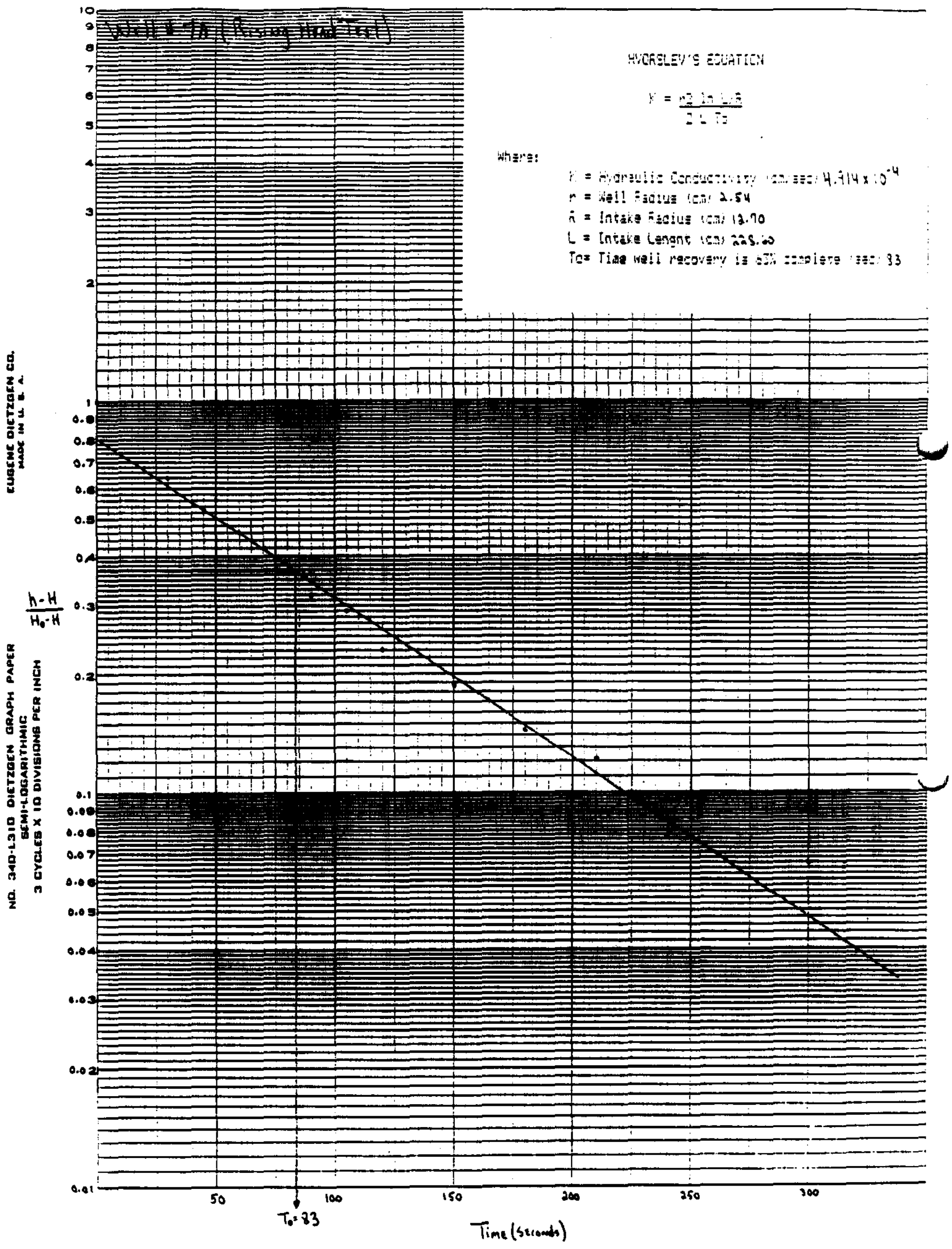


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 4.799×10^{-4}
r = Well Radius (cm) 3.54
R = Intake Radius (cm) 13.70
L = Intake Lenght (cm) 328.60
To= Time well recovery is 37% complete (sec) 95

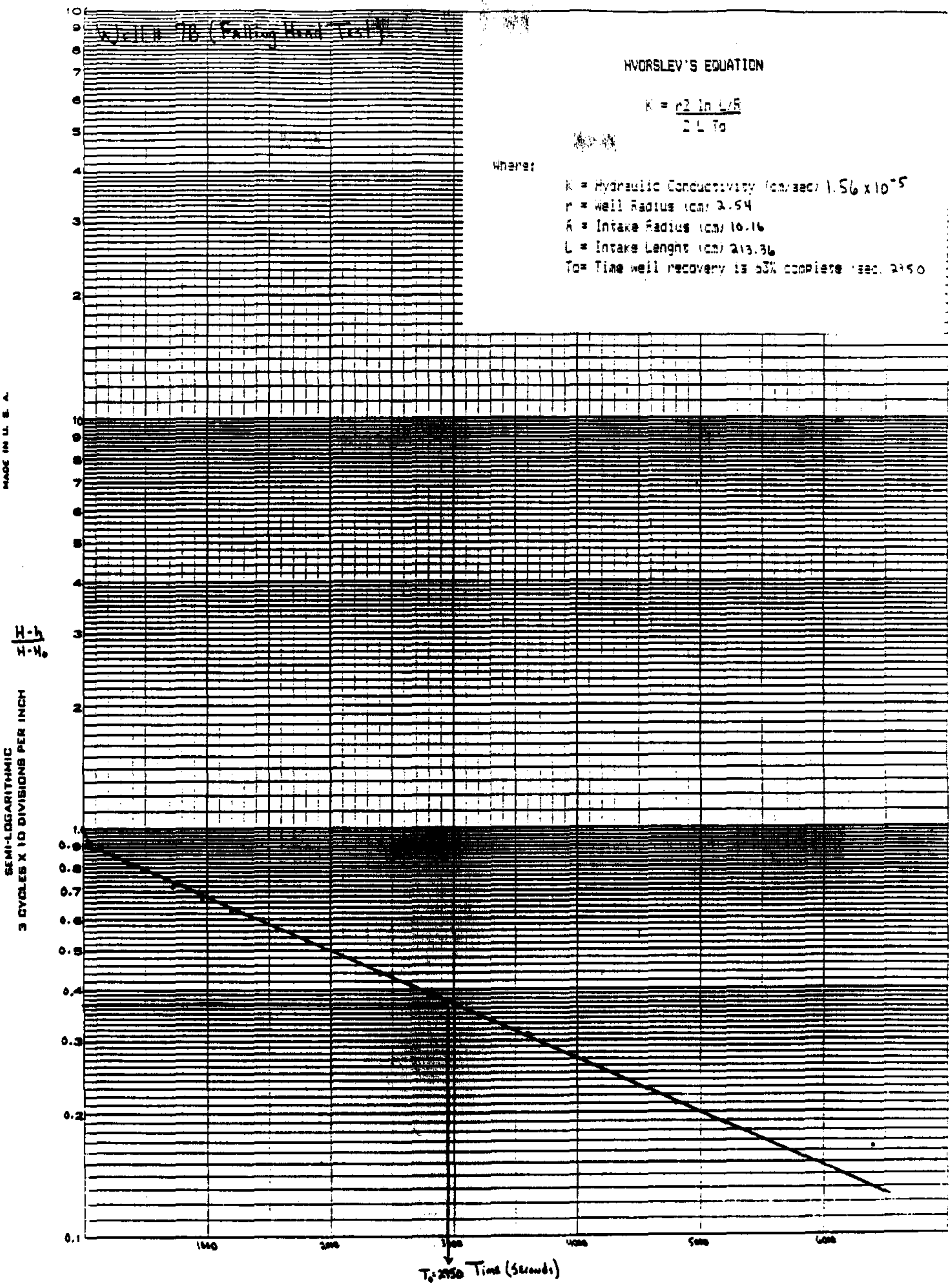


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 4.914 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 228.60
To= Time well recovery is 63% complete (sec) 83



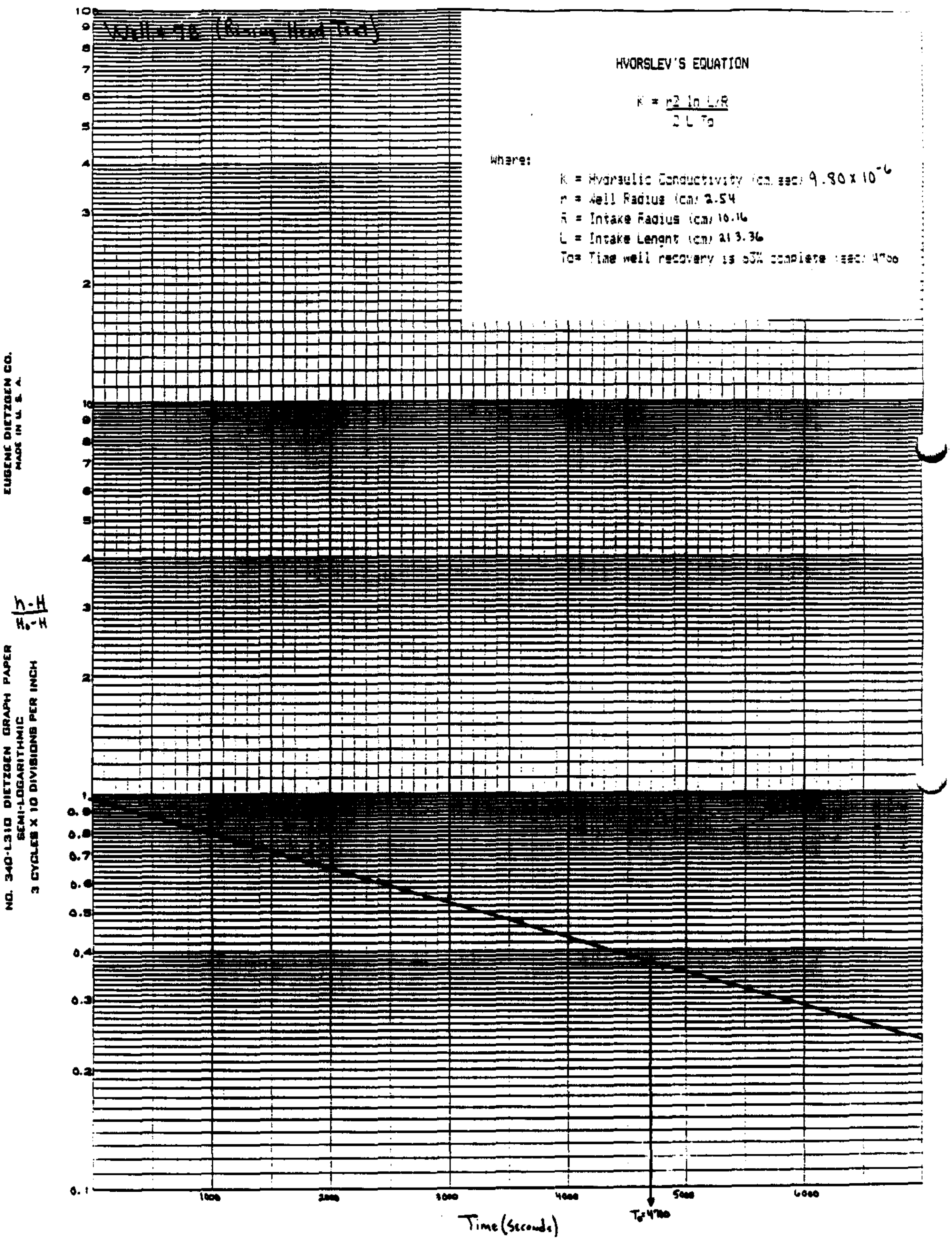
Well # 7B (Falling Head Test)

HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.56×10^{-5}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 16.16
L = Intake Lenght (cm) 213.36
To= Time well recovery is 63% complete (sec) 2950



HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 9.80 x 10^{-6}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 10.16
L = Intake Lenght (cm) 213.36
To= Time well recovery is 63% complete (sec) 4700

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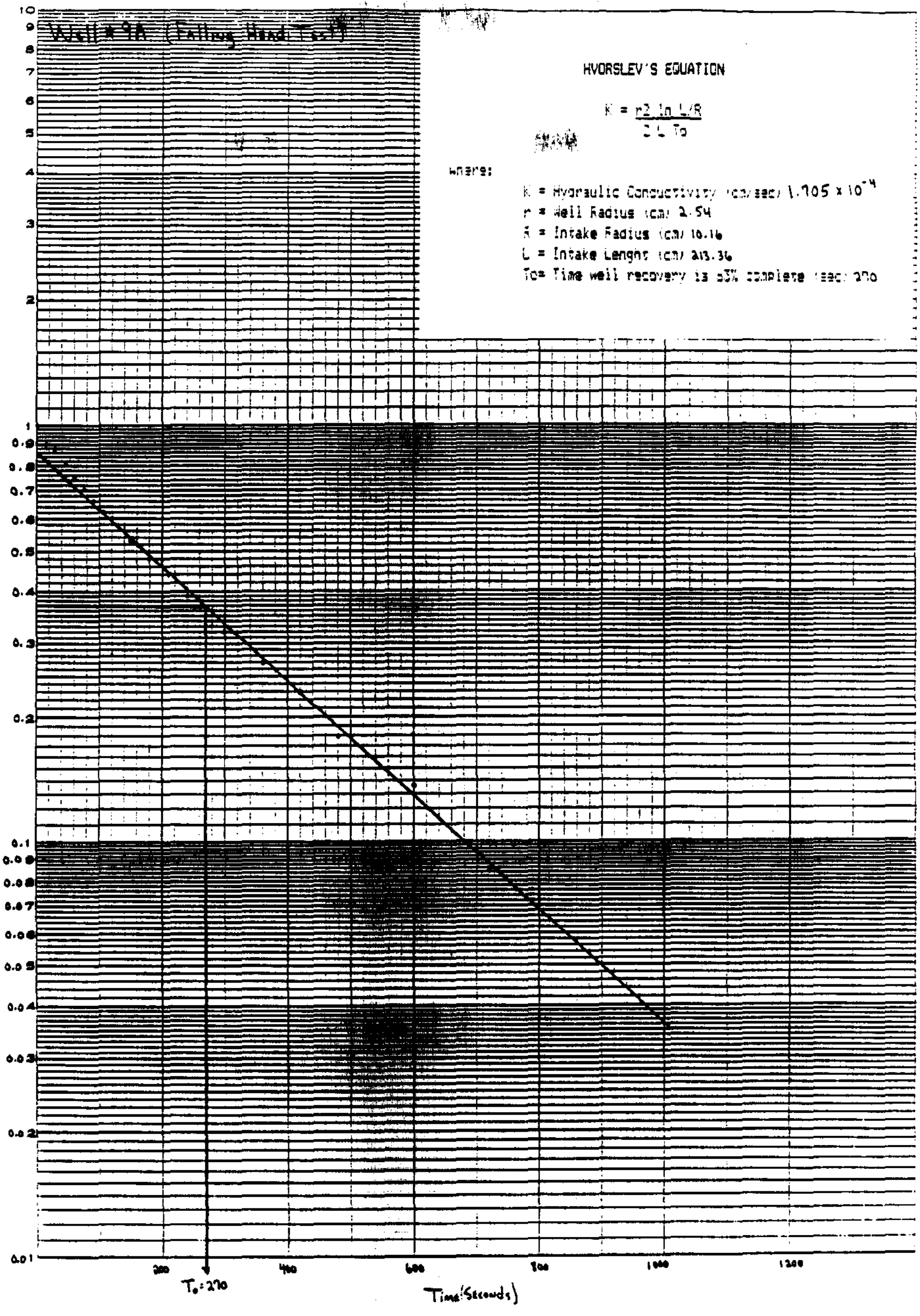
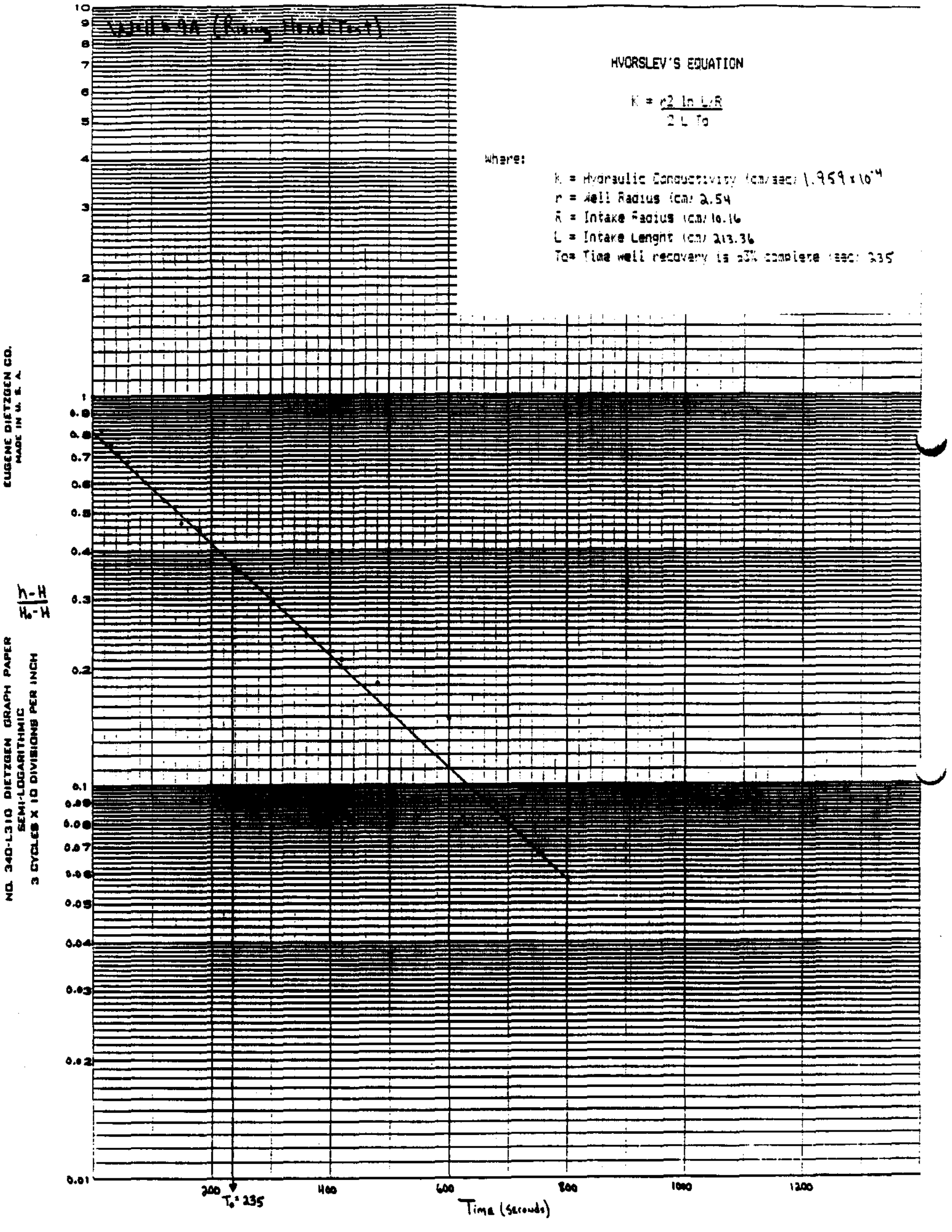


HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

where:

K = Hydraulic Conductivity (cm/sec) 1.705 x 10^{-4}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 10.16
L = Intake Lenght (cm) 213.36
To= Time well recovery is 63% complete (sec) 270



HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.959 x 10^{-4}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 10.16
L = Intake Lenght (cm) 213.36
To= Time well recovery is 37% complete (sec) 235

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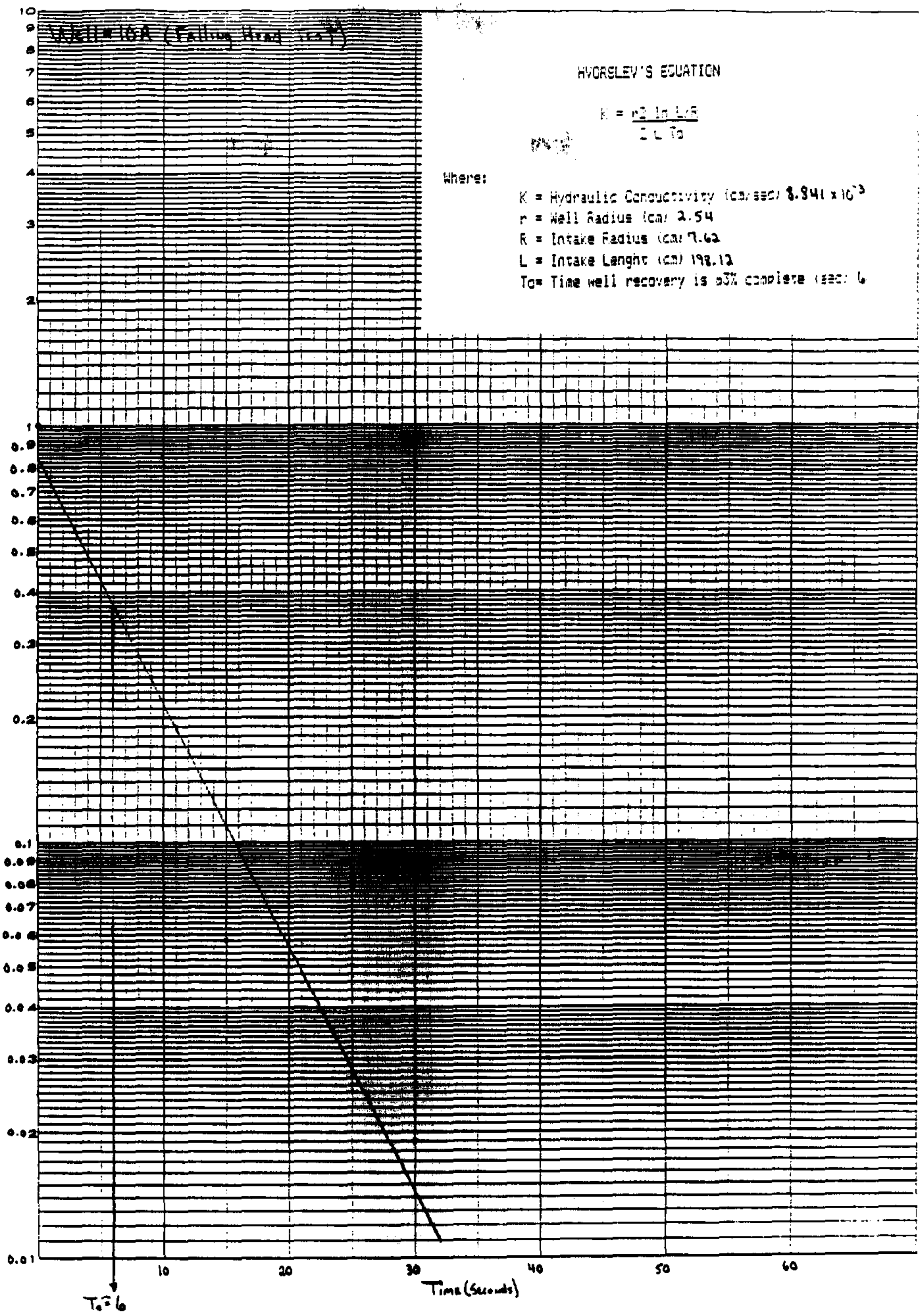
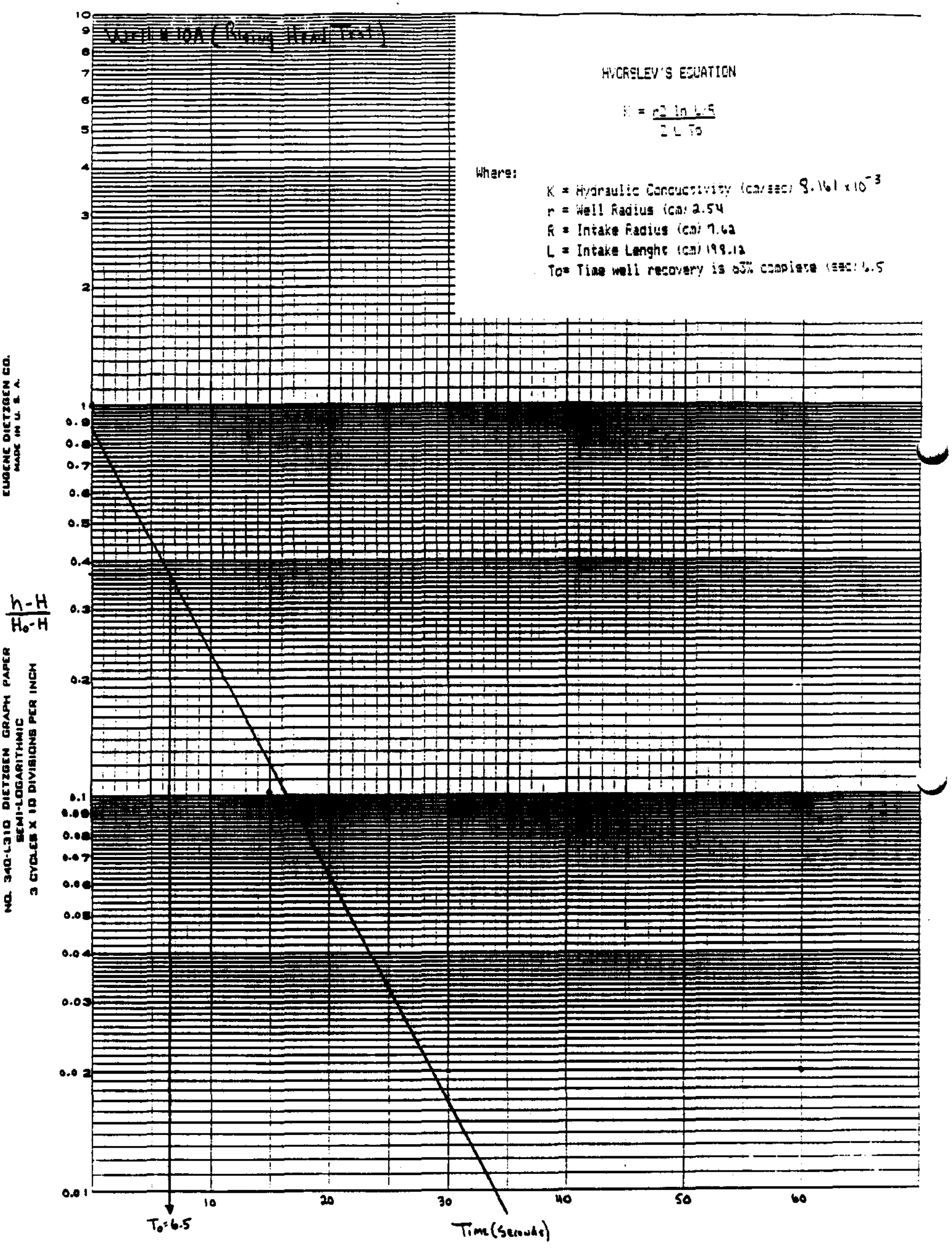


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 8.841 x 10^{-3}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 7.62
L = Intake Lenght (cm) 198.12
To= Time well recovery is 63% complete (sec) 6

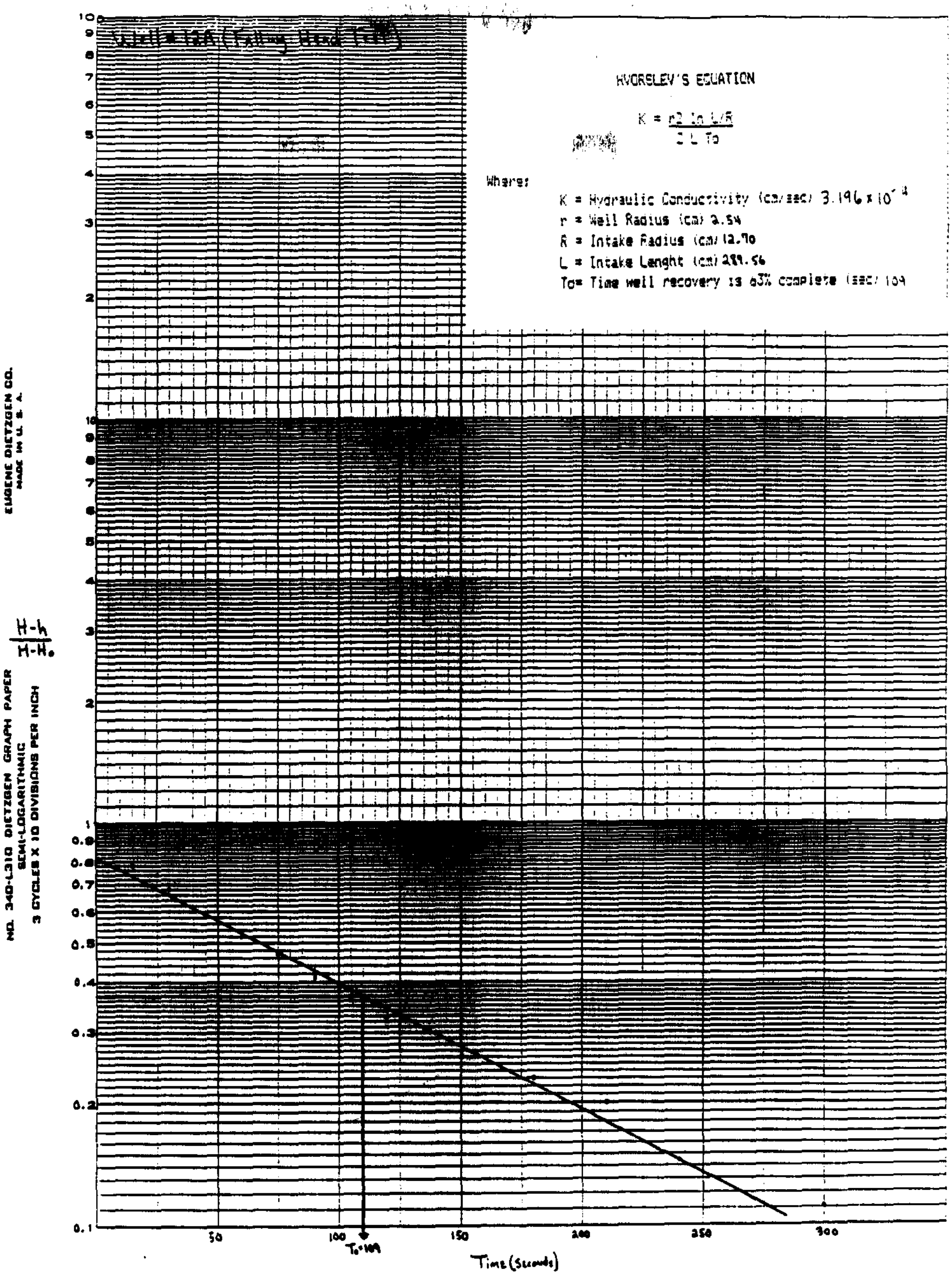


HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 8.161×10^{-3}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 7.62
L = Intake Lenght (cm) 198.12
To= Time well recovery is 63% complete (sec) 6.5



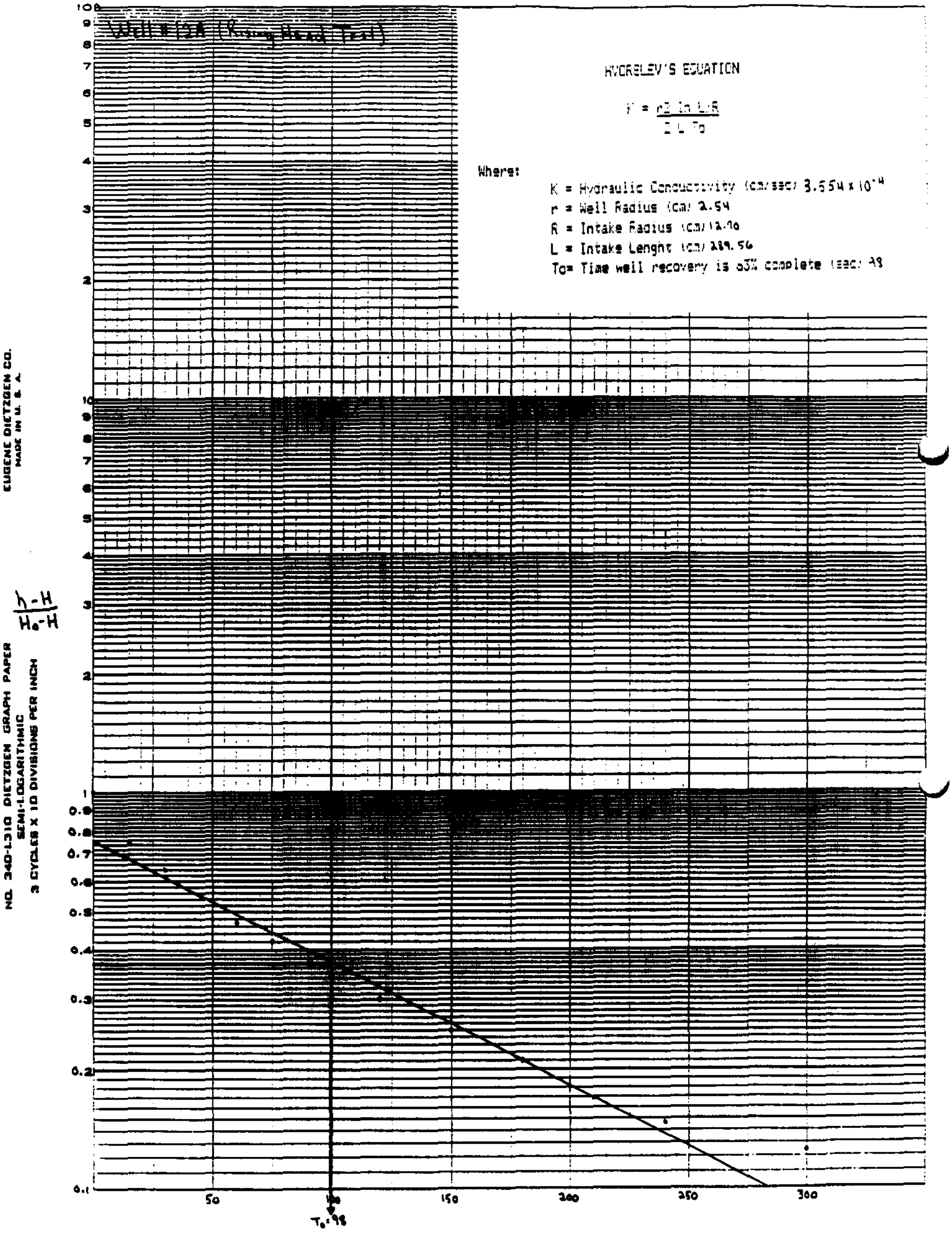
Well # 12A (Falling Head Test)

HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 3.196 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 289.56
To= Time well recovery is 63% complete (sec) 109



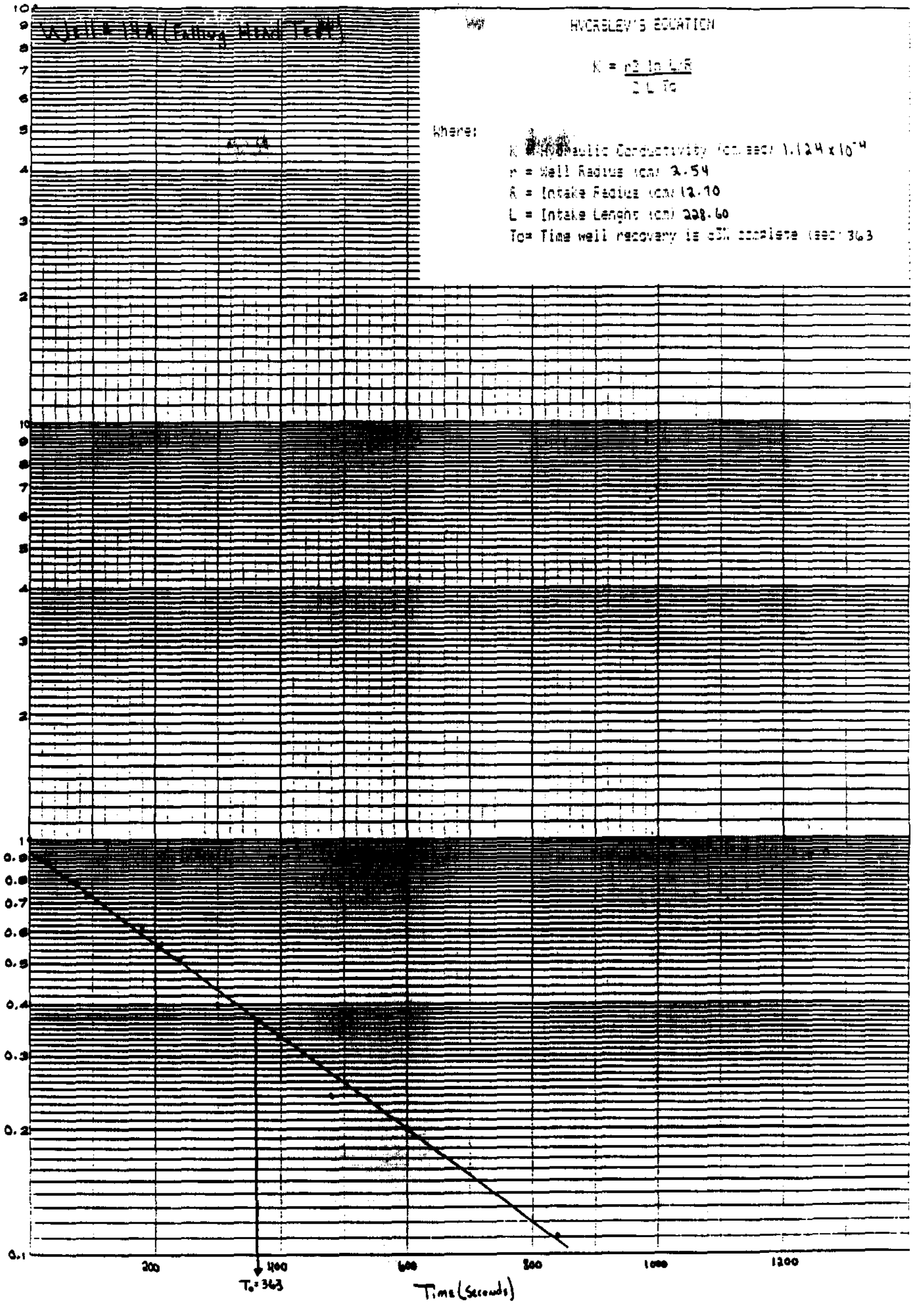
HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 3.554 x 10^{-4}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 289.56
To= Time well recovery is 63% complete (sec) 98

Well # 14A (Falling Head Test)



HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

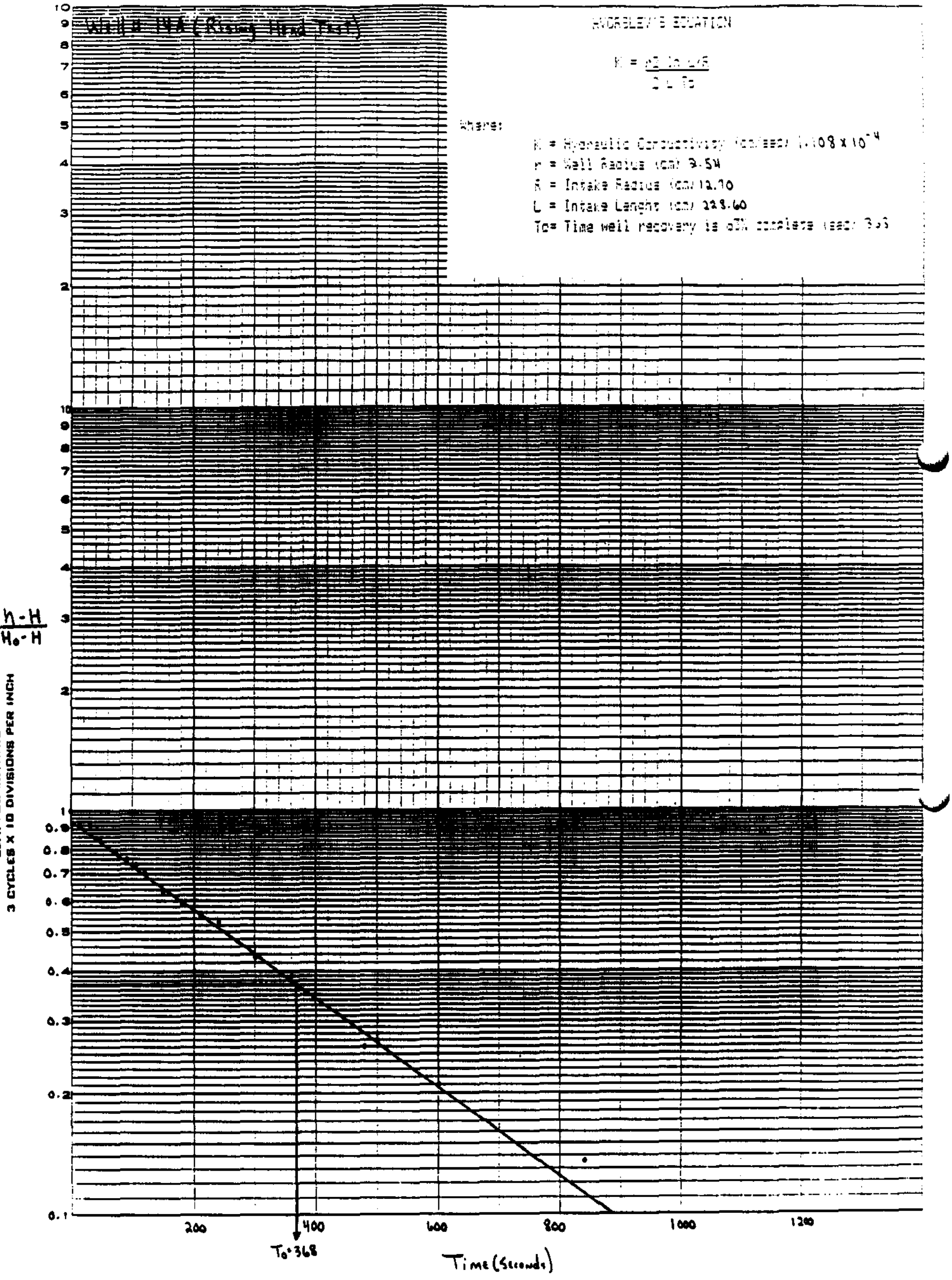
K = Hydraulic Conductivity (cm/sec) 1.124×10^{-4}

r = Well Radius (cm) 2.54

R = Intake Radius (cm) 12.10

L = Intake Lenght (cm) 228.60

To= Time well recovery is 37% complete (sec) 363

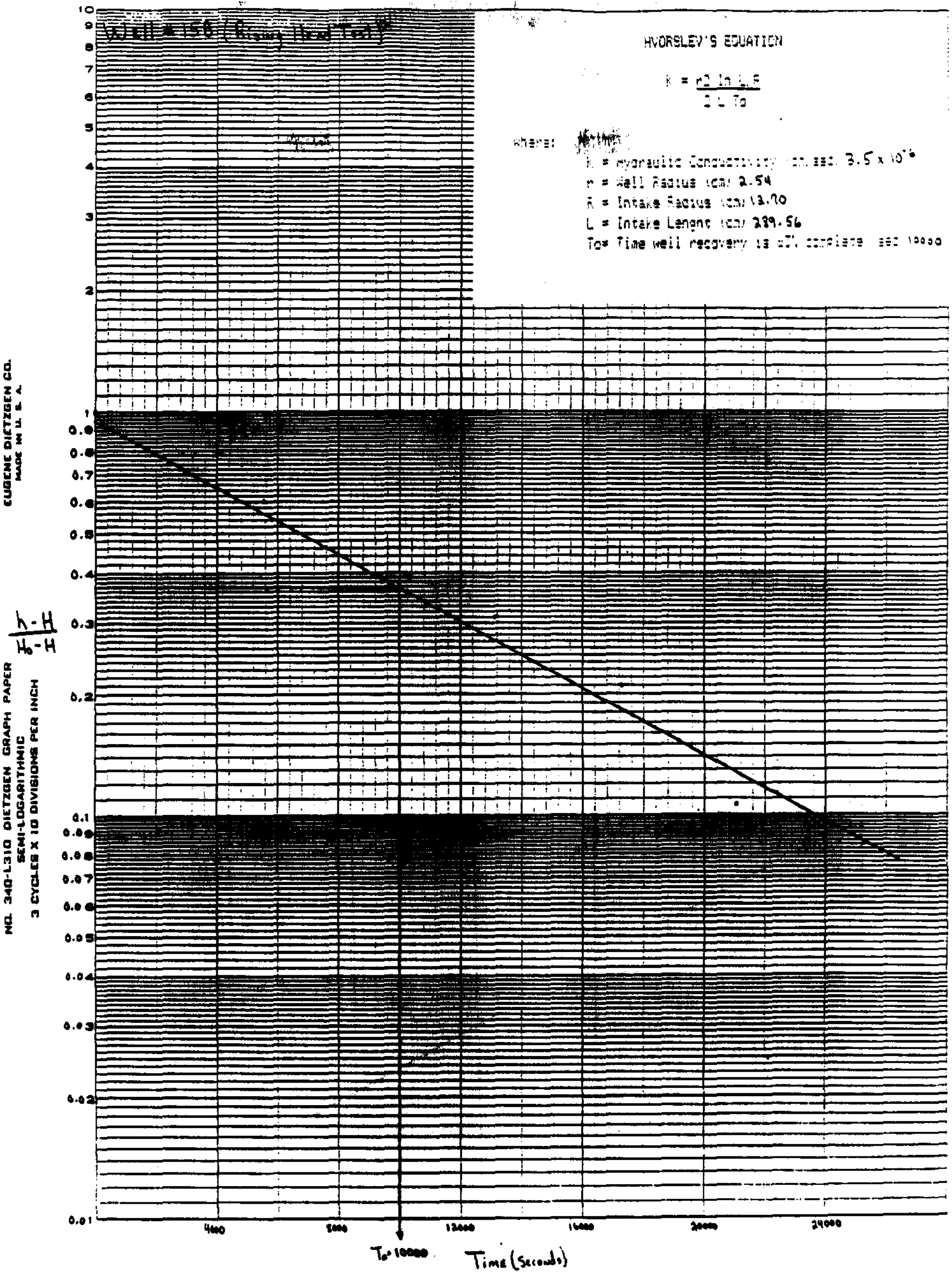


HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_0}$$

Where:

K = Hydraulic Conductivity (cm/sec) 1.108 x 10^{-4}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 228.60
To= Time well recovery is 37% complete (sec) 368



HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

where:

K = Hydraulic Conductivity (cm/sec) 3.5 x 10^{-6}

r = Well Radius (cm) 2.54

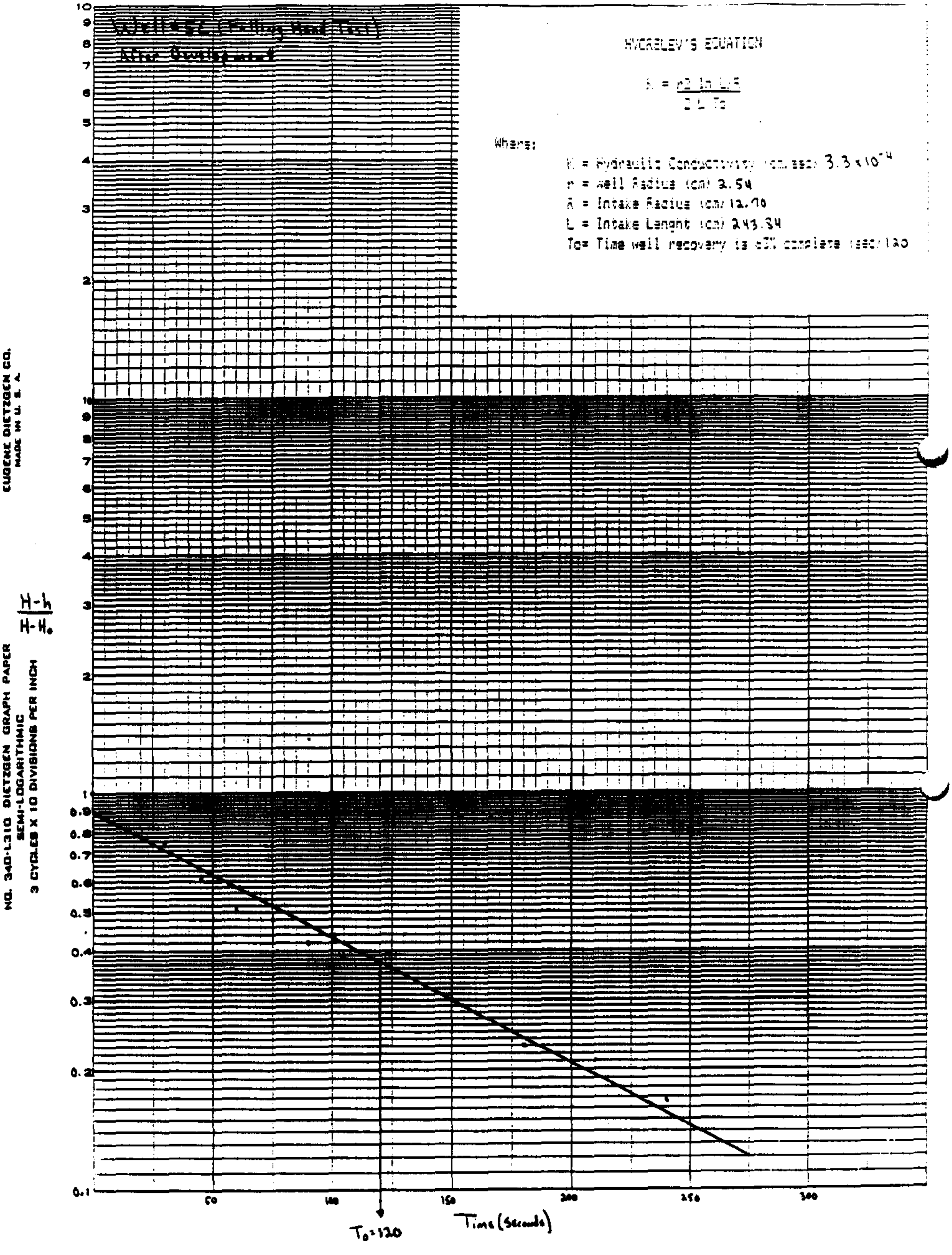
R = Intake Radius (cm) 12.70

L = Intake Lenght (cm) 289.56

To= Time well recovery is 37% complete (sec) 10000

NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



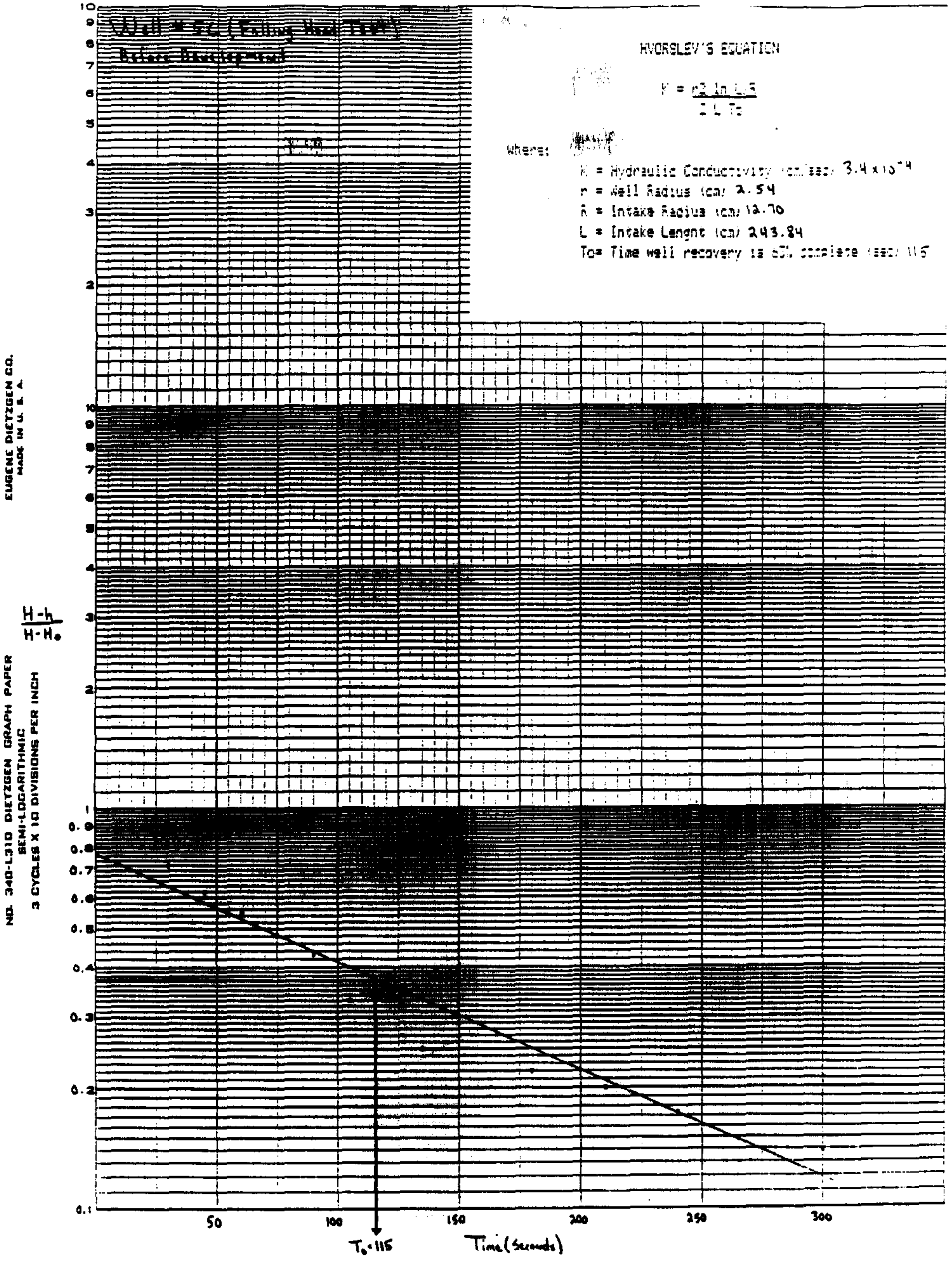
Well #5C (Falling Head Test)
After Development

HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_o}$$

Where:

K = Hydraulic Conductivity (cm/sec) 3.3×10^{-4}
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 243.84
To= Time well recovery is 37% complete (sec) 120

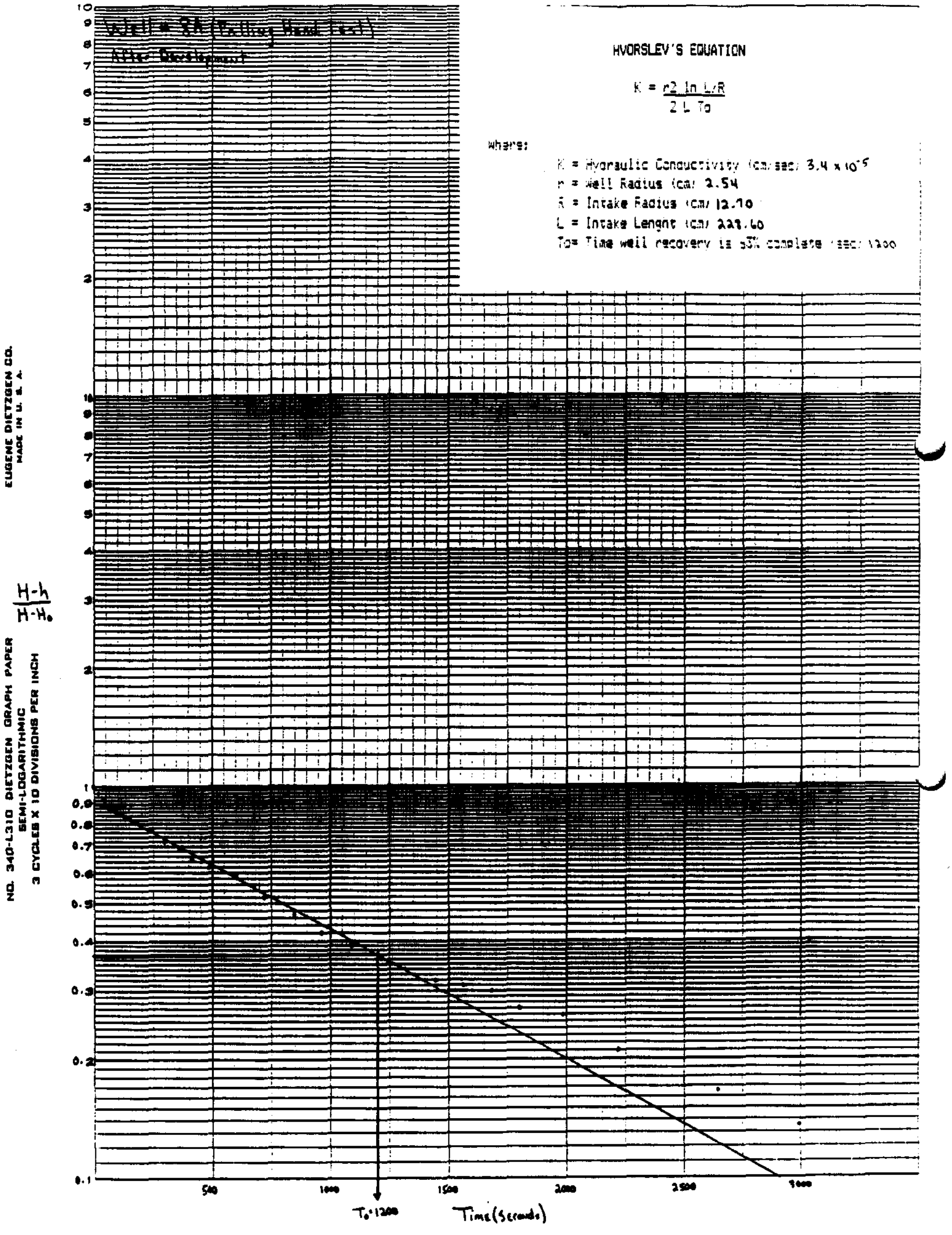


HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

Where:

K = Hydraulic Conductivity (cm/sec) 3.4 x 10⁻⁴
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lengnt (cm) 243.84
To= Time well recovery is 63% complete (sec) 115

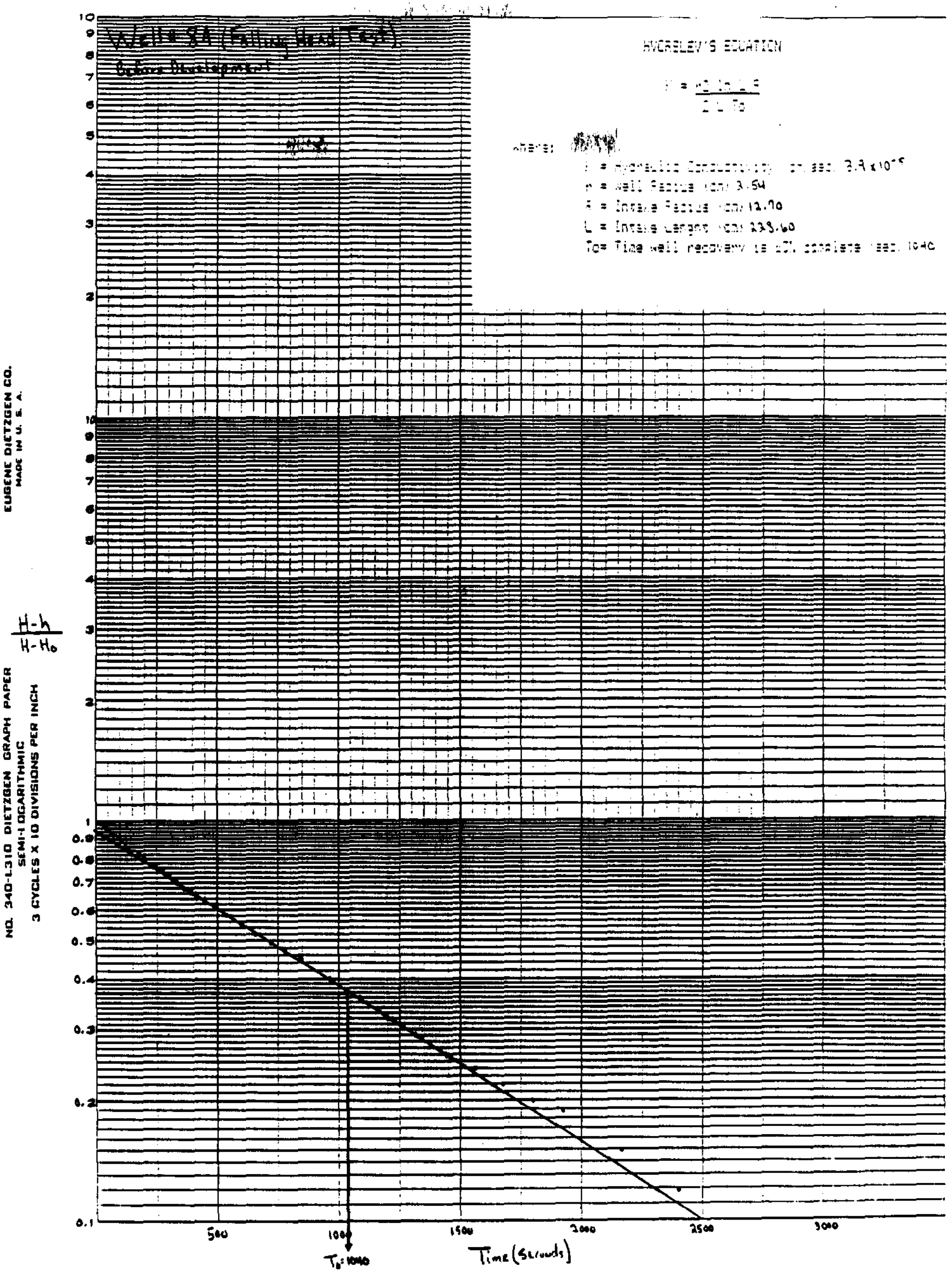


HVORSLEV'S EQUATION

$$K = \frac{r2 \ln L/R}{2 L To}$$

where:

K = Hydraulic Conductivity (cm/sec) 3.4 x 10⁻⁵
r = Well Radius (cm) 2.54
R = Intake Radius (cm) 12.70
L = Intake Lenght (cm) 228.60
To= Time well recovery is 37% complete (sec) 1200



HVORSLEV'S EQUATION

$$K = \frac{r^2 \ln L/R}{2 L T_0}$$

where:

K = Hydraulic Conductivity (cm/sec) 3.9 x 10⁻⁵

r = Well Radius (cm) 3.54

R = Intake Radius (cm) 12.70

L = Intake Length (cm) 233.60

To= Time well recovery is 37% complete (sec) 1040

TECHNICAL MEMORANDUM NO. 3

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: Cynthia Cruciani/CH2M HILL

DATE: March 2, 1988

RE: Monitoring Well and Piezometer Installation

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68802.FI

INTRODUCTION

Monitoring wells and piezometers were installed at the Arrowhead Refinery site between September 14 and October 25, 1987. The piezometers were installed to obtain additional data for:

- Establishing groundwater flow characteristics in the upper granular units (fill and peat)
- Defining groundwater flow characteristics through the deeper sand and gravel zones (i.e., the lower granular unit)
- Establishing groundwater flow characteristics in the bedrock
- Refining hydraulic gradients at the site
- Refining the lateral and vertical extent of groundwater contamination
- Obtaining additional subsurface soil samples to provide information regarding the site stratigraphy

This memorandum describes drilling and well installation procedures and also includes boring logs, well installation information, and well development records.

PERSONNEL

Personnel participating in this task were:

- Jewelle Imada, CH2M HILL
- Cynthia Cruciani, CH2M HILL
- Jim Russell, CH2M HILL
- Bob Weinschrott, CH2M HILL
- Jerry McLane, PRC
- Larry Solhaney, Engineers International
- Greg Weeks, Engineers International

The drilling and installation of wells and piezometers were subcontracted to STS Consultants, Ltd.

LOCATIONS

Well and piezometer locations were selected on the basis of previous site investigations and the results from the seismic refraction survey (see Technical Memorandum No. 1). The locations were staked out before drilling began by Jewelle Imada and Dave Crisman (MPCA). Actual drill locations were adjusted to accommodate drilling access or similar needs.

Existing and new monitoring well and piezometer locations are shown in Figure TM3-1. Thirteen new wells and 7 new piezometers were installed. The wells installed during this field investigation were screened in the bedrock ("e" designation), the lower granular unit ("b"), or the upper granular unit ("s").

DRILLING PROCEDURES

The borings were drilled using a CME-75 rig or a Mobile B-53 drill rig mounted on an all terrain vehicle carrier. The all terrain vehicle was used in low-lying wet areas and where access to boring locations was particularly difficult. This activity included the drilling of five bedrock wells and eight wells and seven piezometers in the overburden. The time used in completing each individual well is listed in Table TM3-1.

BEDROCK DRILLING

Boreholes for wells placed in the bedrock unit were advanced using telescoped casing methods. Hollow-stem auger drilling methods were used to the depth of the lacustrine unit. When the augers were removed, a 6-inch temporary surface casing was emplaced to prevent cross-contamination from upper to lower units. Rotary

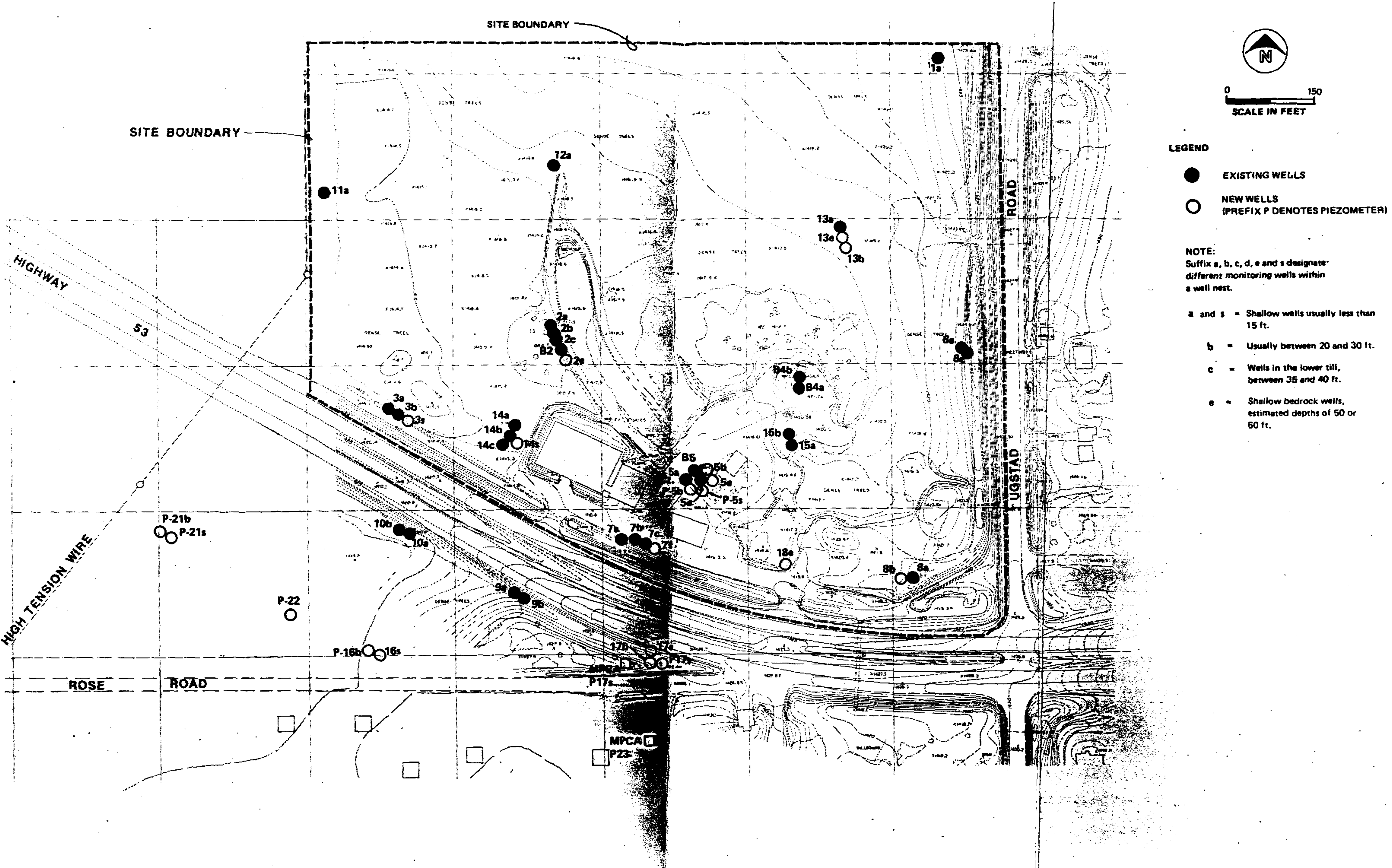


FIGURE TM 3-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM3-1
WELL CONSTRUCTION CHRONOLOGY

Well No.	Screened In Unit	Dates Start	Dates End	Total Days
MW-2e	BR	10-19-87	10-24-87	4.5
MW-3s	US	09-25-87	09-24-87	0.5
MW-5b	LG	10-12-87	10-12-87	1.0
MW-5e	BR	10-07-87	10-10-87	4.0
MW-7s	UG	10-06-87	10-06-87	0.5
MW-8b	LG	09-27-87	09-28-87	1.5
MW-13	LG	10-12-87	10-14-87	3.0
MW-13e	BR	09-29-87	10-09-87	5.0
MW-14s	UG	09-26-87	09-26-87	0.5
MW-16s	UG	09-16-87	09-16-87	0.5
MW-16b	LG	09-15-87	09-15-87	1.0
(Piezometer installed instead: P16b)				
MW-17b	LG	09-23-87	09-23-87	1.0
MW-17e	BR	09-16-87	09-26-87	6.5
MW-18e	BR	09-26-87	09-30-87	4.0
P-5s	UG	10-13-87	10-14-87	2.0
P-5b	LG	10-08-87	10-09-87	1.0
(Additional piezometer not originally planned)				
P-17s	UG	09-24-87	09-24-87	1.0
P-19s	UG	09-26-87	09-26-87	0.5
P-20s	UG			
(P-19s and P-20s not installed, see text)				
P-21s	UG	09-24-87	09-24-87	0.5
P-21b	LG	09-23-87	09-24-87	1.0
P-22s	UG	09-25-87	09-25-98	0.5

Notes:
MW = Monitoring Well (Stainless Steel)
P = Piezometer (PVC Pipe)
BR = Well Screened in Bedrock
UG = Well Screened in Upper Granular Unit(s)
LG = Well Screened in Lower Granular Unit(s)

drilling methods were then used to the top of the bedrock. A second length of narrower, 4-inch casing was seated in rock to provide a conduit for return of bedrock cuttings to the surface. Once the casing was set, the bedrock was cored with an NX core barrel (core diameter of 2.155 inches). The borings were advanced until 10 feet of core was recovered, and the boreholes were reamed to a 4-inch-diameter with a rock bit as required by the Minnesota Department of Health (MDOH) Well Codes.

There was some difficulty in advancing the 4-inch casing to bedrock because of the boulder zone encountered just above the bedrock surface in most locations. Lithology of the boulders included both local and distant bedrock sources, indicating that the zone may be a glacially deposited till unit. The use of the rock bit to drill through 2- to 3-foot boulders did not allow for a wide or straight enough hole to be cased all the way to bedrock. In those cases, the bedrock coring process took longer because of slumping in uncased portions of the hole and in bedrock. Slumping also delayed well placement because the borehole had to be reamed completely to place the well at the desired depth in bedrock.

Soil, drilling mud, and purge water from onsite borings at Well Nests 2 and 5 were screened with an OVA flame-ionization meter and drummed in 55-gallon barrels because of high organic vapor readings.

A 10-foot core was not taken from boring MW-5e because the drillers miscounted the drilling rods and drilled 15 feet into the bedrock with a rock bit.

OVERBURDEN DRILLING

Hollow-stem auger drilling methods were used to advance borings above or to the lacustrine unit for installation of shallow piezometers or monitoring wells. The well screens were placed in upper granular materials. The same general procedure was followed for placing wells screened in the lower granular unit as for those screened in the bedrock, but the 4-inch telescoping casing was not used. Instead, a 6-inch surface casing was used to prevent cross-contamination between the upper and lower granular units. After advancement to the target depth, the wells were installed in the coarse material.

A bentonite drilling mud was used to drill most well holes below the lacustrine unit because of the nature of the coarse material and the silty material within the lower units. The mud facilitated removal of cuttings from the hole better than the use of water alone. The boreholes were thoroughly flushed with clean water to remove drilling mud before the wells were installed.

Health and safety monitoring of downhole and ambient air was conducted during the drilling. HNu photo-ionization meters (calibrated to 68 ppm benzene) and OVA flame-ionization meters (calibrated to 102 ppm methane) were used. Fogging of the UV lamp in the HNu necessitated backup use of the OVA. Elevated concentrations of organic vapors (up to 60 ppm, OVA) were encountered in the breathing zone during the drilling of some onsite wells. When organic vapor readings above level C conditions were encountered, drilling was temporarily halted and the area evacuated until levels dropped back down to safe conditions. A black ooze was brought up from some of the boreholes during the drilling of the shallow zones (approximate range from 0.5 foot to 15 feet at Well Nests 5 and 2).

STRATIGRAPHIC SAMPLING

The deepest well from each well nest was sampled to define the different stratigraphic units. Continuous split-spoon samples were obtained from ground surface to the bottom of the boring. After the split spoons were opened, the samples were logged and screened with an OVA or HNu. A visual description of each sample was recorded on a boring log by the onsite geologist (see Attachment A). A representative sample from each split spoon was then placed into prelabeled jars. At the end of the drilling program, the jars were placed into a 55-gallon drum, labeled, and moved to the central drum storage area.

Soil samples from wells MW-5e and MW-13e were submitted to CLP laboratories for chemical analyses for organic and inorganic compounds and incineration parameters as part of the soil sampling program (see Technical Memorandum No. 6). Laboratory results are discussed in Chapter 4 of this report.

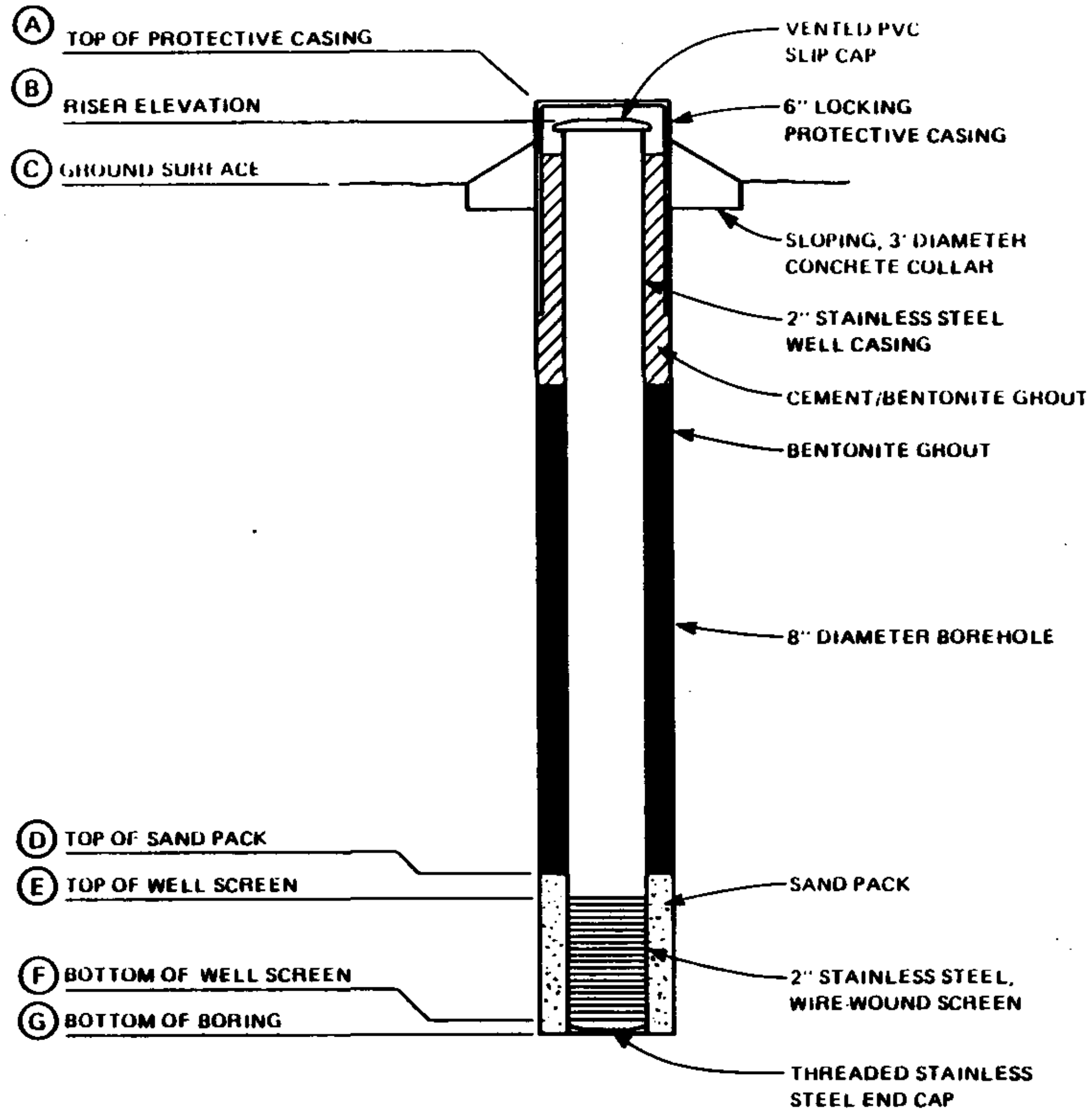
The split spoons and sampling utensils were decontaminated between each sampling interval by rinsing with a trisodium phosphate solution, tap water, methanol, and a final triple rinse of distilled water.

WELL INSTALLATION PROCEDURES

MONITORING WELLS

Well construction diagrams for monitoring wells and piezometers are summarized in Figures TM3-2 and TM3-3; individual well construction diagrams as provided in Attachment B. Monitoring wells consisted of 2-inch-I.D., factory cleaned stainless steel screens and riser pipe. Screens were 0.010-inch, welded, wire-wound, continuous slot type. Teflon O-rings were used at joints to ensure a watertight seal.

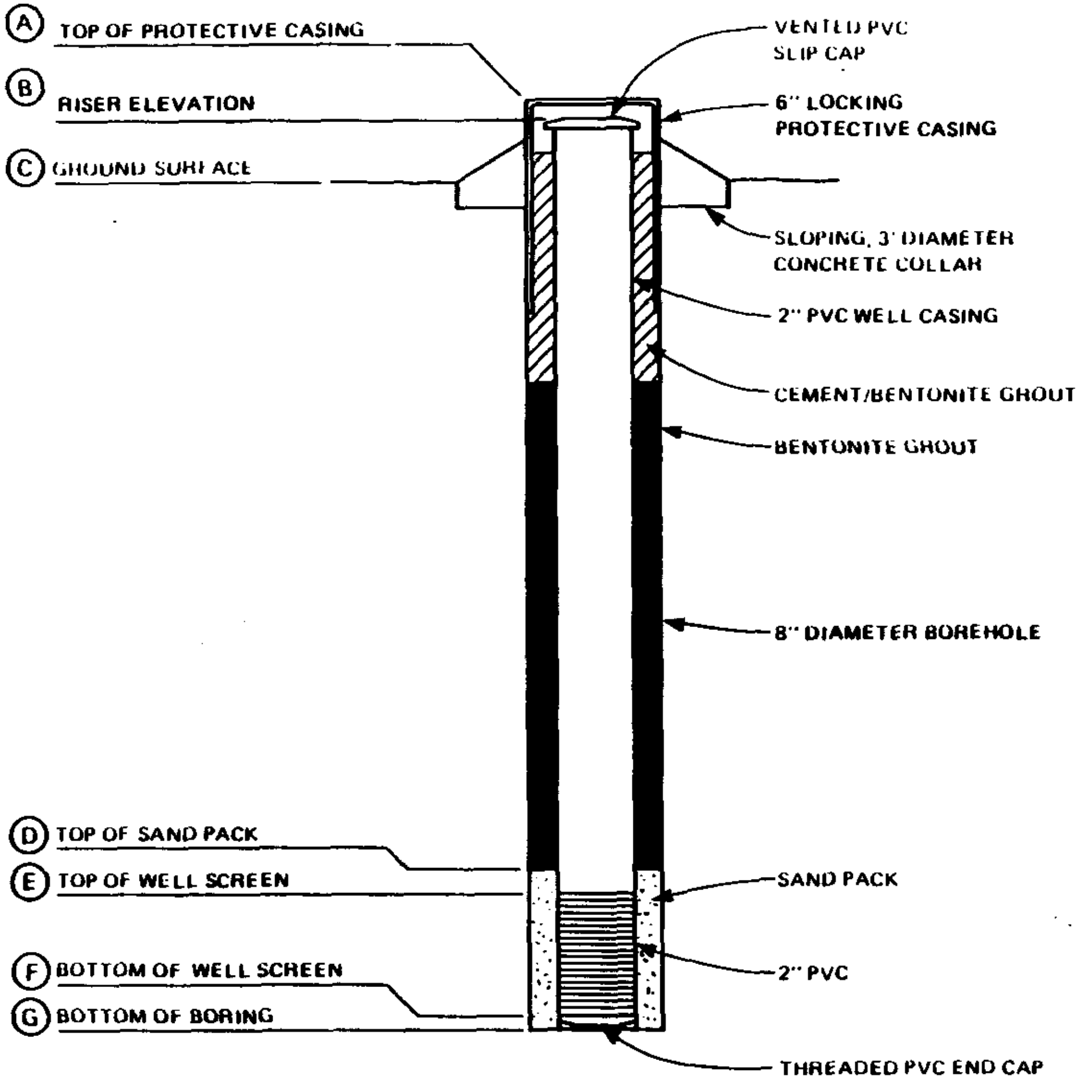
Wells were placed into completed boreholes and the annular spaces around the screens were packed with sand. Sand was placed from approximately 1 foot below the base of the screen to at least 1 foot above the top of the screen. A thick, bentonite slurry seal was used above the sand pack for most of the monitoring wells. Two to 10 feet of slurry was used in most cases (see Attachment B). Bentonite-



ELEVATION (FT. ABOVE M.S.L.)

MW No.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
MW-2E	1420.03	1419.73	1418.03	1375.03	1373.53	1368.53	1367.93
MW-3S	1418.31	1418.30	1416.21	1414.81	1414.51	1409.51	1408.21
MW-5B	1420.58	1420.68	1419.14	1406.14	1403.94	1398.94	1397.64
MW-5E	1420.32	1420.41	1419.08	1371.08	1370.38	1365.38	1363.48
MW-7S	1421.11	1421.07	1419.54	1415.04	1413.24	1408.24	1407.54
MW-8B	1424.58	1424.65	1422.54	1404.84	1404.54	1399.54	1398.84
MW-13E	1420.89	1421.08	1418.83	1373.83	1371.93	1366.93	1366.33
MW-13B	1420.96	1421.05	1418.49	1390.49	1388.99	1383.89	1382.89
MW-14S	1417.77	1417.50	1415.72	1414.72	1414.22	1409.22	1409.22
MW-16S	1423.02	1423.01	1421.31	1414.31	1413.51	1408.51	1405.01
MW-17B	1425.40	1425.26	1423.44	1390.44	1387.54	1382.54	1381.94
MW-17E	1424.69	1424.67	1422.77	1394.77	1371.67	1366.67	1366.67
MW-18E	1421.58	1421.60	1419.79	1360.79	1360.49	1355.49	1353.29

FIGURE TM 3-2
MONITORING WELL
INSTALLATION DETAILS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



ELEVATION (FT. ABOVE M.S.L.)

Piez. No.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ
P-5B	1420.97	1420.82	1419.12	1410.12	1408.12	1403.12	1401.12
P-5S	1420.53	1420.43	1418.71	1414.41	1413.41	1408.41	1407.71
P-16B	1423.15	1423.26	1420.90	1403.90	1400.90	1395.90	1394.40
P-17S	1425.04	1425.00	1423.02	1415.32	1413.02	1408.02	1407.02
P-21B	1416.19	1416.30	1414.00	1389.50	1389.10	1384.10	1383.00
P-21S	1414.16	1414.16	1413.97	1410.47	1409.22	1404.22	1403.97
P-22S	1415.53	1415.58	1413.69	1411.19	1410.19	1405.19	1401.69

FIGURE TM 3-3
PIEZOMETER INSTALLATION DETAILS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

cement grout was then emplaced to the ground surface. The wells were completed with locking protective casings that were grouted in place above the well.

PIEZOMETERS

Piezometers consisted of 1-1/2-inch-diameter, 0.010-inch mill-slotted PVC screen and PVC pipe. Screens were 5 feet in length. Piezometer depths and lengths are designated in piezometer construction diagrams (Attachment B). Piezometer installation was completed in the same manner as for monitoring wells, except that sometimes a bentonite pellet seal was sometimes used instead of bentonite slurry.

The MPCA had requested that a number of piezometers be placed in a wetland area southwest of the site. Piezometer P-20s was planned as the westernmost piezometer in the wetland. However, the MPCA did not obtain access to that location, so the piezometer was not installed.

Piezometer P-19s (south of the southwest corner of the main Gopher Oil building) was also not installed. The piezometer was to be screened in the upper granular unit, but upon drilling the borehole it was found that the upper granular unit does not exist at that location.

A piezometer was installed at boring MW-16b instead of a monitoring well because a lower granular unit was not encountered in which to screen the monitoring well. Piezometer P-16b was placed with the approval of the MPCA and will be used to obtain vertical gradient information.

An additional piezometer was installed at the Well Nest 5 location. Piezometer P-5s was to have been screened in the shallow coarse material. Since it was placed by error below the lacustrine silts in the coarse material, it was relabeled P-5b and Piezometer P-5s was installed in the correct position.

WELL DEVELOPMENT

The new wells and piezometers were developed by Don Johnston (STS Consultants, Ltd) between October 4 and 28. They were developed mainly by removing at least 10 well volumes by pumping with a centrifugal pump or surging with a foot valve attached to a length of PVC pipe. Development continued until the pH and conductivity measurements stabilized. Bedrock Wells 2e, 5e, and 17e stabilized with high pH readings (9.9, 8.4, and 11.2, respectively). The high pH readings may indicate grout contamination. Well development is summarized in Table TM3-2, and the development records are included in Attachment C.

Table TM3-2
WELL DEVELOPMENT SUMMARY

Location	Development Method	Time (hr)	Volume Removed (gal)	Appearance of Discharge Before	Appearance of Discharge After	Comments
MW-2e	Surging	2	22	Turbid	Turbid	
MW-3s	Surging	2	6.5	Opaque	Turbid	
P-5s	Surging	3	20	Opaque	Turbid	Water smelled.
P-5b	Surging	2.5	25	Opaque	Turbid	Water smelled.
MW-5b	Pumping	0.5	86	Turbid	Clear	Pumping rate 14.2 gpm.
MW-5e	Surging and Pumping	3	86	Turbid	Clear	Pumping rate 0.5 gpm.
MW-7s	Pumping	1	55	Turbid	Clear	Good well water clear and clean.
MW-8b	Surging	2	37	Opaque	Clear	
MW-13b	Surging and Pumping	3	66	Opaque	Clear	Pumping rate 0.5 gpm.
MW-13e	Pumping	1.5	102	Turbid	Clear	
MW-14s	Bailing and Surging	2	12	Opaque	Turbid	
MW-16s	Surging	2	20	Opaque	Turbid	
P-16b	Surging	2	30	Opaque	Turbid	
P-17s	Surging and Pumping	1	180	Turbid	Clear	Pumping rate 12 gpm.
MW-17b	Surging and Pumping	2	100	Turbid	Clear	
MW-17e	Surging	2	80	Turbid	Clear	pH 11.2.
MW-18e	Surging	2	10	Turbid	Turbid	Very slow recharge.
P-21s	Surging	2	20	Opaque	Turbid	
P-21b	Surging	2	25	Opaque	Turbid	
P-22s	Surging	2	10	Opaque	Turbid	

TM 3--MONITORING WELL AND PIEZOMETER INSTALLATION

Attachment A
BORING LOGS

CH2M HILL

PROJECT NUMBER	BORING NUMBER
	MW02-E SHEET 1 OF 5

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION South of sludge lagoon

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA 3¼ ID to 10.0' - rock bit (mud rotary to bedrock)

WATER LEVEL AND DATE START 10/19/87 FINISH 10/23/87 LOGGER GERALD A. McLANE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0			1.2'		brown silty sand w/ increasingly less silt towards bottom, some gravel (≈10%) sand is med to coarse grained.	OVA sample >1000ppm
2			0		NO RECOVERY	
4			1.0		0-0.5' brown silt, sand and peat evenly distributed, sand is predom. med grained. 0.5'-1.0' peat	top 0.5' visibly contaminated - 0.4ppm Hnu/300 ppm OVA
6			0.7		0-0.3' peat - visibly contaminated with oil 0.3-0.7' blue grey silty clay, clayey silt	200ppm OVA
8			1.2		0-0.4' blue grey silty clay, clayey silt w/ ≈ 20-30% peat disseminated throughout sample visibly soaked w/ oil 0.4'-1.2' blue grey silty clay, clayey silt.	VISIBLY CONTAMINATED 300-1000ppm OVA
10			1.4		brown sandy silt with some gravel, sand is fine to med grained.	VISIBLY CONTAMINATED 500ppm OVA
12			1.0		brown silty clay ~ clayey silt	1.0ppm to 5.0ppm OVA
14						

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW02-E SHEET 2 OF 5

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION South of sludge lagoon

ELEVATION ____ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (3¼" ID) TO 10.0' - mud rotary to B.R

WATER LEVEL AND DATE ____ START 10/19/87 FINISH 10/23/87 LOGGER GERALD A McLANE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
14			1.7'		same as above	0.6 ppm OVA
16			1.2'		brown clayey silt, 1.0 mm thick red clay layers ≈ 2.0" apart appear throughout sample (VARVES)?	2.0 ppm OVA
18			1.2'		same as above - trace gravel in lower 0.4'	0.2 ppm OVA
20			1.2'		brown clayey silt, 1.0mm thick red clay layers ≈ 2.0" apart appear throughout sample (VARVES)	0.0 ppm OVA
22			1.5'		same as above, except from .5' to 1.0' there is a layer of brown sandy silt w/ trace gravel	0.0 ppm OVA
24			0		NO RECOVERY	Hammer blows indicate that this interval contains significant gravel
26			1.2'	0-0.9'	brown clayey sandy silt with ≈ 15% gravel, sand is fine to med. grained - 0.9'-1.2' brown clayey silt, no sand or gravel	0.0 ppm OVA
28						

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-02E **SHEET** 3 **OF** 5

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY **LOCATION** SOUTH SIDE OF SLUDGE LAGOON

ELEVATION **DRILLING CONTRACTOR** STS

DRILLING METHOD AND EQUIPMENT HSA (3¼" ID) to 10.0' - MUD ROTARY TO BR.

WATER LEVEL AND DATE **START** 10/19/87 **FINISH** 10/23/87 **LOGGER** GERALD A. WELN

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
28			0.3'		brown sandy silt with some (15%) gravel, minor clay in matrix boulder from 28.5' to 29.5' (500 lbs) downpressure for 1.0' before breakthrough	0.0 ppm OVA
30					no sample collection gravel + silts, minor sand - several large boulders (31-32'), (33.75-34.5'), balls of silt, + clayey silt coming up w/ coarse sand + gravel frags	
35					Thick, dense, hard gravel and boulders	
40						

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-02E

SHEET 4 OF 5

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY
LOCATION SOUTH SIDE OF SLUDGE LAGOON
ELEVATION
DRILLING CONTRACTOR STS
DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL SIZE HQ
ORIENTATION VERTICAL
WATER LEVEL AND DATE
START 10/23/87
FINISH 10/23/87
LOGGER GERALD A. MCLANE

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES: R Q D (%)	DISCONTINUITIES: FRACTURES PER FOOT	DISCONTINUITIES: DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
40.5	1st RUN 100% RECOVERY			FIRST RUN STARTS AT 40.7'			
41.0				FRACTURE AT 41.0'		RECOVERY 100% GABBRO — -COARSE GRAINED	
41.5						-DK. GREY -ONLY SLIGHTLY WEATHERD IF AT ALL	
42.0				FRACTURE AT 42.0'		-LITHOLOGY CONSISTANT THROUGHOUT SAMPLE & WILL ONLY BE DEFINED HERE	
42.5							
43.0				FRACTURE AT 43.35		AMPHIBOLE (PROBABLY HORNBLENDE) GREY PLAGICLASE AUGITE	60% 35% 5%
43.5				END OF RUN 43.5			
44.0	2ND RUN 100% RECOVERY						
44.5				FRACTURE AT 44.75'			
45.0							
45.5				FRACTURE AT 45.6'			
46.0							
46.5				FRACTURE AT 46.5			
47.0							

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

PROJECT NUMBER	BORING NUMBER MW-87-02E SHEET 5 OF 5

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY LOCATION SOUTH SIDE OF SLUDGE LAGOON

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT DIAMOND ~~ROCK~~ BIT CORE BARREL ORIENTATION

WATER LEVEL AND DATE START 10/23/87 FINISH 10/23/87 LOGGER GERALD A. MSLA

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	R Q D (%)	FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
47.0 47.5 48.0 48.5	2nd RUN 100% RECOVERY					CONTINUOUS STRING OF CORE FROM LAST FRACTURE AT 46.5 DOWN TO BOTTOM OF CORE AT 48.5	
				BOTTOM OF CORE 48.5			

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-35 SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION WEST OF GOPHER OIL

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER 4 3/8" I.D.

WATER LEVEL AND DATE START 9/25/87 FINISH 9/25/87 LOGGER GERALD A. MSLANS

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0	0-2'		13"	4,3,3,3	top 7" brown clayey sandy silt, trace gravel, sand is med. gr. lower 6" peat with minor sand + silt - smells oily		0.0 ppm Hnu peat smells oily
	2	2-4'		5"	4,4,4,4	clayey peat, peaty clay		0.0 ppm Hnu looks + smells slightly oily
	4	4-6'		17"	6,6,5,5	top 6" blue clay - minor peat + silt lower 11" brown clayey silt, mottled blue - trace very fine gr. sand		same as above
	6	6-8'		15"		top 2" peat - lower 13" - brown sandy silt, silty sand - mottled dark brown		Hnu deflection to 4.5 ppm
	8					END OF BORING		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER W68802-FI
BORING NUMBER P87-05S
SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY
LOCATION HERMANTOWN, MN
ELEVATION
DRILLING CONTRACTOR STS CONSULTING
DRILLING METHOD AND EQUIPMENT 6 5/8 HSA
WATER LEVEL AND DATE
START 10-14-87 FINISH 10-14-87 LOGGER GREGORY C. WEEK

ELEVATION	DEPTH BELOW SURFACE	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0'					FOR SOIL DESCRIPTIONS SEE BORING LOG MW87-05E		
	2.5'							
	5.0'							
	7.5'							
	10.0'							
						6 5/8 HSA FROM 0' TO 11.0' Gregory C. Weeks E.I.T.		
	12.5'							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER W68802-FI
BORING NUMBER P87-05B
SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY
LOCATION HERMANTOWN, MN
ELEVATION
DRILLING CONTRACTOR STS CONSULTING
DRILLING METHOD AND EQUIPMENT 4.25 HSA
WATER LEVEL AND DATE
START 10-09-87
FINISH 10-09-87
LOGGER GREGORY C. WEE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
						FOR SOIL DESCRIPTIONS SEE BORING LOG MW87-05E		
	2.5'							
	5.0'							
	7.5'							
	10.0'							
	12.5'							
	15.0'							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
W68802-FI	P87-05B	SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION HERMANTOWN, MN.

ELEVATION ______ DRILLING CONTRACTOR STS CONSULTING

DRILLING METHOD AND EQUIPMENT 4.25 HSA

WATER LEVEL AND DATE ______ START 10-08-87 FINISH 10-08-87 LOGGER GREGORY C. WEEKS

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
17.5'						
					4.25 HSA FROM 0' TO 18.0' Gregory C. Weeks	
20.0'						

CH2M HILL

PROJECT NUMBER	BORING NUMBER
W68802-FI	MW85-05B SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION HERMANTOWN, MN

ELEVATION ______ DRILLING CONTRACTOR STS CONSULTING

DRILLING METHOD AND EQUIPMENT 6.25 HSA

WATER LEVEL AND DATE ______ START 10-12-87 FINISH 10-13-87 LOGGER GREGORY C. WEEK

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
					FOR SOIL DESCRIPTIONS SEE BORING LOG MW87-05E	
2.5'						
5.0'						
7.5'						
10.0'						
12.5'						
15.0'						

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
W68902-FI	MW87-05B	SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION HERMANTOWN, MN

ELEVATION ______ DRILLING CONTRACTOR STS CONSULTING

DRILLING METHOD AND EQUIPMENT 6.25 HSA

WATER LEVEL AND DATE ______ START 10-12-87 FINISH 10-13-87 LOGGER GREGORY C. WEE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
17.5'						
20.0'						
22.5'					6.25 HSA FROM 0' TO 21' Gregory C. Weeks - E.I.I	

CH2M HILL

PROJECT NUMBER W68802.FI
BORING NUMBER MW-5-E
SHEET 1 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY
LOCATION HERMANTOWN, MINNESOTA
ELEVATION
DRILLING CONTRACTOR STS CONSULTING
DRILLING METHOD AND EQUIPMENT HSA / MUD ROTARY
WATER LEVEL AND DATE
START 10-7-87 FINISH 10-8-87 LOGGER CINDY CRUCIANI

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
					12, 13, 14, 23	VERY BLACK SILTY CLAY, TRACE SAND, GRAVEL, MOIST WITH VISIBLE OIL LIKE MATERIAL	CL ML	12 ppm HNU
	2				9, 12, 14, 28	BROWN FINE TO COARSE SAND, SOME GRAVEL, MOIST. TRACE OF OIL LIKE MATERIAL	SW	
	4				2, 2, 4, 4	DARK BROWN TO GREY SILTY CLAY, TRACE FINE SAND, PLASTIC, MOIST	CL	5 ppm HNU
	6				22, 37, 29, 30	BROWN SILTY FINE TO COARSE SAND, WELL GRADED GRAVEL	GW	15-20 ppm HNU
	8				3, 4, 20, 22	RED BROWN SILTY FINE TO COARSE GRAINED SAND AND GRAVEL	SM/ GW	2.5 ppm HNU
	10				7, 6, 11, 13	BROWN SANDY, SILTY CLAY	CL/ ML	
	12							NO RECOVERY
	14							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER W68802.FI

BORING NUMBER MW-5E

SHEET 2 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY

LOCATION HERMANTOWN, MINNESOTA

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA / MUD ROTARY

WATER LEVEL AND DATE

START 10/7/87 FINISH 10/8/87 LOGGER CINDY CRUCIANI

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14				6,7,3,2	RED BROWN COARSE SAND, TRACE SILT AND GRAVEL WITH COBBLES ~30 mm	SP	
	16				7,6,5,4	RED BROWN COARSE SAND, TRACE SILT AND GRAVEL WITH COBBLES	SP	1.0 ppm HNU
	18					NO RECOVERY POSSIBLY GRAVELS		
	20			1.3'	7,7,8,7	DARK BROWN PLASTIC SILT, SOME CLAY, VERY CONSISTENT THROUGHOUT	ML	0.2 ppm HNU
	22			1.5'	8,10,9,11	BROWN TO GREY VERY PLASTIC SILTY CLAY	CL/ML	
	24				7,9,9,10	LIGHT BROWN TO BROWN SILTY CLAY WITH TRACE GRAVEL	CL/ML	0.3 ppm HNU
	26				12,13,18,19	SAME AS 24'-26' INTERVAL	CL/ML	1 ppm HNU
	28							

CH2M HILL

PROJECT NUMBER W68802 FI

BORING NUMBER MW-5E

SHEET 3 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY

LOCATION HERMANTOWN, MINNESOTA

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA / MUD ROTARY

WATER LEVEL AND DATE

START 10/7/87 FINISH 10/8/87 LOGGER CINDY CRUCIAN

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	28			0.2"	18	COBBLES PEBBLES OF VARIED LITHOLOGY. SOME BROKEN PIECES. BOULDER 29"		SPOON REFUSAL AFTER 6"
	30			0.8'	17,14,27	BROWN CLAYEY SILT, SOME GRAVEL, TRACE SAND, VERY DENSE	ML/CL	1.0 ppm HNU
	32			1.3'	17,15,10,9	BROWN CLAYEY SILT, TRACE SAND, WET, SOFT	CL	9:05 AM STARTED USING 330 lb HAMMER 0.1 ppm HNU
	34			1.1'	10,9,18,20	BROWN SANDY SILT, SOME GRAVEL, PEBBLE TO 5mm, WET, SOFT	ML	0.0 ppm HNU
	36			0.9'	19,25,32,15	SAME AS ABOVE	ML	0.1 ppm HNU HARD RESISTANCE AT 38' (ROCK?)
	38					OVERDRILL NO RECOVERY		
	40				19,30,62	LIGHT BROWN TO BROWN VERY DENSE, DRY TO MOIST SANDY SILT WITH GRAVEL, SOME SAND SEAMS	ML	
	42							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER W 68802. FI

BORING NUMBER MW-5E SHEET 4 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD PROJECT LOCATION HERMANTOWN, MN

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA, MUD ROTARY

WATER LEVEL AND DATE

START 10/7/87 FINISH 10/8/87 LOGGER CINDY CRUCIANI

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	42				37,50	SAME AS ABOVE		1.5 ppm HNU
						FRACTURED ROCK/BOULDER ZONE		BEDROCK 43'
	44							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER W68E02-FI

BORING NUMBER MW87-07S

SHEET OF

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION HERMANTOWN, MN
ELEVATION DRILLING CONTRACTOR STS CONSULTING
DRILLING METHOD AND EQUIPMENT 6.25 HSA / 24" stainless split spoon ɸ 2"
WATER LEVEL AND DATE 4.80' - 10/06/87 START 10/06/87 FINISH 10/06/87 LOGGER [illegible]

ELEVATION	DEPTH BELOW SURFACE	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
		0' TO 2'	1	12"	8-14-17-16 (31)	SANDY TOPSOIL: trace gravel; loose; black-brown. SANDY CLAY: little gravel; trace silt; very stiff; brown. (Fill)	OL CL	0900 - [illegible] OVA = 0ppm 0905 - SAMPLE PULL 0907 - OVA = 0ppm
	2.5	2' TO 4'	2	18"	9-16-16-18 (32)	SANDY CLAY: little gravel; trace silt; very stiff; brown (Fill)	CL	0910 - SAMPLE PULL 0912 - OVA = 0ppm
	5.0	4' TO 6'	3	13"	5-6-4-5 (10)	MED TO COARSE SAND: some clay; little gravel; trace silt; loose; brown.	SC	0915 - SAMPLE PULL 0917 - OVA = 0ppm DOWN HOLE = 0ppm WATER AT 6.0'
	7.5	6' TO 8'	4	12"	8-19-16-19 (35)	SILTY SAND: little gravel; med dense; brown.	SM	0922 - SAMPLE PULL 0925 - OVA = 0ppm
	10.0	8' TO 10'	5	15"	6-9-9-9 (18)	MED TO coarse gravel: some pebbles; little sand; trace silt; med dense; brown. (well graded)	GM	0930 - SAMPLE PULL 0935 - OVA = 0ppm
		10' TO 12'	6	18"	4-3-3-3 (6)	as above SILT: loose;	GM ML	0940 - SAMPLE PULL 0945 - OVA = 0ppm. DOWN HOLE = 0ppm
	12.5					EOB AT 12.0' 6.25 HSA from 0' TO 12.0'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-8B SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION EAST OF OFFICE

ELEVATION ______ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4 3/8 ID) TO 20' - MUD ROTARY TO BOTTOM OF HOLE

WATER LEVEL AND DATE ______ START 9/27/87 FINISH 9/28/87 LOGGER GERALD A MCLA

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
				0.8	8,12,16,16	Brown fine sand with some silt + gravel, dry		0.0 ppm Hnu
	2			0.45	7,9,12,11	Brown sandy silt with trace fine gravel, moist		0.0 ppm Hnu
	4			0.65	11,11,13,11	0.3' Brown sandy silt - damp 0.3 med coarse black sand 0.1 wood		0.0 ppm Hnu
	6			1.35	2,2,3,2	MOIST DARK BROWN PEAT - FIBROUS		7.0' ▼ 0.0 ppm Hnu
	8			0.6'	3,8,2,1	0.2' same as above 0.4' grey clayey silt		0.0 ppm Hnu
	10			1.0'	4,6,4,5	grey clayey silt, trace med. to coarse grained sand, trace fine gravel		0.0 ppm Hnu
	12			.75'	4,6,6,11	grey sandy silt, silty sand - some gravel, trace clay - sand is med. to coarse gr.		0.0 ppm Hnu
	14							

CH2M HILL

PROJECT NUMBER	BORING NUMBER
	MW-87-8B SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION EAST OF OFFICE

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4 3/8 ID TO

WATER LEVEL AND DATE START 9/27/87 FINISH 9/28/87 LOGGER GERALD A. MCLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14			1.2'	4,11,22,26	brown clayey sandy silt some gravel - sand is med. to coarse grained		0.0 ppm Hnu
	16			1.7'	43 20 16 18	top 1.3' brown silty sand + gravel lower 0.4' brown sandy silt - sand is predom med. gr.		0.0 ppm Hnu
	18			0.2'	15 13 12 12	sand + gravel - poorly sorted all size fractions of sand represented		0.0 ppm Hnu
	20			0.4'		same as above		0.0 ppm Hnu
	22			0.1'		gravel - rock fragments minimal recovery.		0.0 ppm Hnu
	24					RESAMPLE 22-24'		
	22			1.7'		top 1.0' sand + gravel - same as above Lower 0.7' grey clayey silt - minor gravel		0.0 ppm Hnu
	24					Bottom of Hole 23.7'		

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-13E SHEET 1 OF 3

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION NORTH OF SLUDGE LAGOON

ELEVATION DRILLING CONTRACTOR

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER TO 30'—MUD ROTARY TO BOTTOM OF HOLE

WATER LEVEL AND DATE START 9/29/87 FINISH 10/9/87 LOGGER GERALD A. McLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
		INTERVAL	TYPE AND NUMBER	RECOVERY				
	1 2	0-2'		0.7'	3,3,2,3	Top 0.3' peat – then 0.4' Blue grey clayey silt with ≈ 15-20% peat interspersed		0.0 ppm Hnu
	3 4	2-4		1.1'	7,6,6,8	Brownish grey silty clay – clayey silt trace coarse gr. sand and fine gravel, trace root hairs		0.0 ppm Hnu
	5 6	4-6		1.8	19,15,12,9	top 0.8' same as above – lower 1.0' brown silty sand, w/ some fine gravel, trace coarse gravel (≈1.0" diam.)		0.0 ppm Hnu 50' ▼
	7 8	6-8		0.8	21,24,23,93	brown silty clay - trace fine gravel + med. to coarse gr. sand trace root hairs		0.0 Hnu
	9 10	8-10		1.8	5,8,11,9	same as above		0.0 ppm Hnu
	11 12	10-12		1.8	4,6,8,8	top 0.9' brown silty clay - trace fine gravel + med to coarse gr. sand trace root hairs lower 0.9' brown clayey silt		0.0 ppm Hnu begin skipping 0.5' interval after each spc
	12.5							
	14.5'			2.0'	5,5,5,11	brown clayey silt – red clay lenses ≈ 1.0mm thick + spaced 1-2" apart appear throughout sample (varves?)		0.0 ppm Hnu
	15.0'							

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-13E SHEET 2 OF 3

SOIL BORING LOG

MW-5L

PROJECT ARROWHEAD REFINERY LOCATION

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER TO 30' - MUD ROTARY TO BOTTOM OF HOLE

WATER LEVEL AND DATE START 9/29/87 FINISH 10/9/87 LOGGER GERALD A. McLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	15 16			2.0'	6,8,10,2	brown clayey silt - red clay lenses ≈ 1.0mm thick + spaced 1-2" apart appear throughout sample (varves?)		0.0 ppm Hnu
	17							
	17.5				13,18,21,53	NO RECOVERY		
	19.5							
	20.0			1.2'	52,24,12,15	brown sandy clayey silt - some gravel - sand + clay in equal proportions - sand is v. fine to fine gr. in upper half - predom. med. gr. in lower half		0.0 ppm Hnu
	22			1.5'	23,25,29,17	brown sandy clayey silt, some gravel (≈10%) - sand is predom. fine grained - some med. gr.		0.0 hnu
	24			1.5'	14 70 130 150	same as above, however matrix contains more clay than above sample		0.0 hnu -- rock fragment stuck in spoon
	26			1.5'	43 67 107 x	top 0.75' brown silt, trace fine sand, minor clay + gravel lower 0.75' brown sandy silt, some gravel, sand is predom med. gr - some clay in matrix	(10%)	0.0 hnu refusal at 27.4
	28			1.6	63 45 99 x	brown silty sand, contains some gravel (15%), minor clay, sand is predom. med gr. - some fine + coarse grained		0.0 ppm Hnu refusal at 29.5
	30							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER
W68802. F1	SHEET 3 OF 3

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION NORTH OF SLUDGE LAGOON

ELEVATION ______ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA / MUD ROTARY

WATER LEVEL AND DATE ______ START 9/29/87 FINISH 10/9/87 LOGGER GERALD A.

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	30			2.0'	47,68,60,41	0-0.8' - BROWN SAND, SOME SILT, MED. TO COARSE GRAINED SAND, TRACE GRAVEL 0.8-1.3' - SILTY SAND, SANDY SILT WITH MED. TO COARSE GRAINED SAND, TRACE GRAVEL 1.3-2.0' BROWN SAND, MORE SILT, SOME GRAVEL (~10%)		0.0 ppm HNU
	32			1.2	43,90,133,x	BROWN SILTY SAND, SOME GRAVEL (~15%), MED. GRAINED SAND		0.0 ppm HNU REFUSAL AT 32.4'
	34			1.0	33, 85, 133, x	BROWN SANDY SILT, ≈ 25% GRAVEL, MED. to COARSE GRAINED SAND		0.0 ppm HNU REFUSAL AT 35.25'
	36			No	SAMPLE TAKEN	BOULDER FROM ≈ 35.25 to 37.75', PROBABLY GABBROIC		
	38			No	SAMPLE TAKEN	COARSE GRAVELS OR VERY WEATHERED AND FRACTURED BEDROCK (GABBROIC)		
	40					BEDROCK - GABBRO/ANORTHOSITE GABBRO CONTAINS A VERY HIGH % OF CALCIC PLAGICLASE (75%), SEVERAL INTERVALS WITHIN CORE ARE TRUE ANORTHOSITES (>90% PLAGICLASE) HIGHLY WEATHERED AND FRACTURED		

REV 11/82 FORM D1586

75
100

PROJECT NUMBER	BORING NUMBER MW-87-13E	SHEET 1 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY LOCATION NORTH OF SLUDGE LAGOON
ELEVATION DRILLING CONTRACTOR STS CONSULTANTS
DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL / SIZE HQ ORIENTATION VERTICAL
WATER LEVEL AND DATE START FINISH LOGGER

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES: R Q D (%)	FRACTURES PER FOOT	DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
42.5	2.65÷2.8×100= 94.64% RECOVERY			TOP OF CORE 42.5'			
42.75						42.5-43.5- Anorthosite- very coarse grained (pegmatitic) ≃ 95% plagiclase 5% amphibole (probably hornblende) this interval is highly fractured and weathered ≈ 20 pieces of rock make up this interval	
43.0							
43.25							
43.5						43.5 - 45.3 Gabbro this section is very rich in plagiclase with the upper 0.3' or so being very close to an anorthosite the lower portion of this interval is a "normal" gabbro plagiclase ≈ 40% Amphibole (Actinolite + Hornblende) 50% Mica-(Biotite or Phlogopite) ≈ 5-7% trace augite very coarse grained somewhat weathered	
43.75							
44.0				FRACTURE AT 44.0			
44.25							
44.5				FRACTURE AT 44.5			
44.75				FRACTURE AT 44.75			
45.0				FRACTURE AT 45.1			
45.25							
				FIRST RUN TO 45.3'			
45.5							

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

PROJECT NUMBER	BORING NUMBER MW-87-13E	SHEET 2 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY LOCATION NORTH OF SLUDGE LAGOON

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL (SIZE HQ) ORIENTATION VERTICAL

WATER LEVEL AND DATE START FINISH LOGGER

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	R Q D (%)	FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
45.25				2nd RUN BEGINS		AT 45.3'	
45.50				FRACTURE AT 45.4' →		GABBRO — COARSE GRAINED	
45.75						PLAGICLASE 75%	
46.0						AMPHIBOLE (LOOKS LIKE ACTINOLITE) 20%	
46.25						2-3% MICA (BIOTITE OR PHLOGOPITE) TRACE AUGITE	
46.50				FRACTURE AT 46.4' →		THIS INTERVAL IS SLIGHTLY	
46.75				FRACTURE 46.7' →		WEATHERED HOWEVER THE LOWER 0.75' OF THIS RUN IS HIGHLY	
47.0				LOWER 0.3' IS CRUMPLED ROCK FRAGS		WEATERED (ROCK BREAKS APART EASILY)	

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-14S

SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY

LOCATION IMMEDIATLY WEST OF GOPHER OIL

ELEVATION

DRILLING CONTRACTOR

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER (4 3/8 ID)

WATER LEVEL AND DATE

START 9/26/87

FINISH 9/26/87

LOGGER GERALD A. McLAN

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0			11"		top 7" dk brown, black, silty sandy clay, sand predom med. gr. lower 4" peat with some grey clay and sand (med gr.)		oily sheen but no Hnu deflection
	2			14"		top 4" peat with minor silt + clay trace sand middle 4" black loamy silt (high % organic matter (peat)) lower 6" grey clayey silt, silty clay with some peat + fine sand		0.0ppm Hnu
	4			22"		brown clayey silt - silty clay - some sand + gravel - sand is med to coarse gr.		0.0ppm Hnu
	6					END OF BORING		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-165

SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION South side of Highway 53

ELEVATION DRILLING CONTRACTOR

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER (4 3/8" ID)

WATER LEVEL AND DATE START 9/16/87 FINISH 9/16/87 LOGGER GERALD A. [illegible]

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
				19"	6,7,11,11	Reddish brown silty clay lower 4" contains gravel (15%)		
	2			12"	6,5,5,8	Reddish clay with some silt, some coarse gr. sand in lower 5"		
	4			19"	5,7,11,12	Reddish brown clay minor gravel interval gets coarser downwards lower 6" silty clayey sand - brown med. gr.		
	6			24"	5,6,10,8	upper 4" reddish brown clay middle 12" brown silty sand, sandy silt (very fine to fine gr sand) lower 8" brown silty sand - coarser gr. than middle interval		
	8			20"	4,7,11,8	Reddish brown sandy silt - sand is very fine to fine gr.		
	10			24"	3,4,5,9	top 10" brown clayey silt w/ 1mm thick red clay lenses middle 6" - fine gr. sand lower 8" sandy silt (sand is fine to med gr.)		
	12			24	7,7,9,11	Reddish brown sandy silt (sand is very fine gr.)		
	14							

REV 11/82 FORM 01586

PROJECT NUMBER

BORING NUMBER MW-87-16S SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION South side of Highway 53

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT Hollow Stem Auger

WATER LEVEL AND DATE START 9/16/87 FINISH 9/16/87 LOGGER Gerald A McLane

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
14			24	2,4,5,9	Reddish brown sandy silt sand is very fine gr.	
16					Bottom of Hole at 16.0	

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-16B SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION S. SIDE OF HWY 53

ELEVATION ______ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4 3/8" ID) TO 26.5'

WATER LEVEL AND DATE ______ START 9/15/87 FINISH 9/15/87 LOGGER GERALD A. MCLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	TYPE AND NUMBER	RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0	0-2		8"	8,10,8,2	Dark brown sandy silt - sand is very fine gr. ≈15%		
	2	2-4		18"	5,8,10,11	Dark reddish brown sand - some gravel some silt, sample is interbedded with clay lenses up to 2" thick		3.5' ▼
	4	4-6		20"	8,11,12,9	Dark brown sandy silt, sand is very fine grained - saturated		INTERVAL 6'-8' NOT SAMPLED
	6 8	8-10		16"	2,5,9,9	Dark brown sandy silt, silty sand, sand is fine gr, somewhat coarser and more abundant than previous sample		
	10 12			18"	6,15,12,12	Brown sandy silt, silty sand, grades into pure silt halfway down + continues to bottom of sample		INTERVAL 10'-12' NOT SAMPLED
	14			23"	8,8,7,8	Dark brown silt, appears to contain organic material - 1mm thick red clay lenses spaced 1 to 2 inches apart appear in lower half of sample (VARVES?) - trace gravel		
	16			23"	7,7,8,8	Dark brown silt, some clayey silt lenses up to 3" thick trace organic matter (root hairs)		
	18							

REV 11/82 FORM 01586

CH2M HILL

PROJECT NUMBER
BORING NUMBER MW-87-16B SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION S. SIDE OF HWY 53
ELEVATION DRILLING CONTRACTOR
DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER (4 3/8" ID)
WATER LEVEL AND DATE START FINISH LOGGER GERALD A McLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	18			22"	2,5,12,20	Dark brown silt, clayey silt lenses up to 3" thick - lower 6" coarse sand and gravel with some silt.		
	20			12"	8,12,2930	Top 6" - sand and gravel with some silt. Brown Lower 6" sandy silt w/ some gravel. Brown		
	22			10"	21,31,38,54	Top 6" coarse sand and gravel Lower 4" sandy silt w/some gravel		
	24			14	7,11,12,29	gravelly silt - brown - some sand (med-coarse gr.).		
	26							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-17E SHEET 1 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION INTERSECTION OF ROSE RD. + HWY 53
ELEVATION DRILLING CONTRACTOR STS
DRILLING METHOD AND EQUIPMENT HSA (4 3/8" ID) to 47.9 ~ MUD ROTARY 3 7/8" DIAM BIT TO
WATER LEVEL AND DATE START 9/16/87 FINISH ? LOGGER GERALD A. MSLAN

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0'-2'		11	4,7,18,18	Brownish red silty sand, minor clay + gravel, trace root hairs, sand is fine to med grained - probably fill?	Dry, Friable 0.0 ppm Hnu
2	2'-4'		18	10,16,16,11	Reddish brown sand + gravel with some silt, sand is med to coarse grained, gravel is up to 1.5" in diam, fill?	Dry Friable 0.0 ppm Hnu
4	4'-6'		18	2,10,14,19	0"-5" reddish brown, fine-med gr. sand, dry 5"-7" reddish brown silty sand (sand is fine gr.) damp. 7"-18" reddish brown sand (coarse to very coarse grained), damp	
6	6'-8'		17	6,8,8,9	Reddish brown sand, trace gravel, no silt - sand is coarse to very coarse grained - minor fine to med gr.	water at 7.0' ▼
8	8'-10'		18	7,8,10,11	same as above - except a 2" thick fine gr. sand seam at 9" to 11" below top of sample	
10	10'-12'		21	7,13,13,12	0-14" Reddish brown sand, trace gravel, no silt, sand is coarse to very coarse grained, minor fine to med gr. 14"-21" sandy gravel, sand is very coarse grained	
12	12'-14'		18	8,5,10,7	Reddish brown sand, trace silt + gravel - sand is coarse to very coarse gr., but not as coarse gr. as above interval (10'-12')	
14						

CH2M HILL

PROJECT NUMBER	BORING NUMBER MW-87-17E	SHEET 2 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION INTERSECTION OF ROSE RD. & HWY 53

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4¼" ID) to 47.9 ~ MUD ROTARY 3 7/8" BIT to —

WATER LEVEL AND DATE START 9/16/87 FINISH LOGGER GERALD A. MCLANE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
14	14-16		17	7,8,7,9	0-10" same as above, gradually fines downwards 10"-17" brownish red sand, some silt (10%) sand is fine to med gr.	
16	16-18		23	5,5,10,10	0-12" brownish red sand with some silt (10%), sand predom. med gr, w/ trace coarse gr., fines downward, 12"-23" sandy silt, silty sand, brown, - sand is fine to v. fine grained	
18	18-20		24	3,5,6,12	0-8" reddish brown sandy silt, sand is fine grained, 8"-23" brownish gray silt, trace clay, no sand 23"-24" - brown sand + gravel (sand is coarse gr.)	
20	20-22		24	3,8,11,11	0-4" reddish brown sand, med gr. 4-24" greyish brown sandy silt grading downwards to silt	
22	22-24		24	7,8,12,10	brownish grey silt, with red clay varves 1mm thick + 1" to 2" apart — sample contains several lenses, up to 3" thick, of silty sand w/ some gravel	
24	24-26		24	12,13,13,11	browinsh grey silt, with varves like above, single fine gr. sand lense 2" thick appears from 11"-13" below top of sample	
26	26-28		24	13,13,13,10	browinsh grey silt - trace clay, red clay varves as in upper two samples	
28						

CH2M HILL

PROJECT NUMBER

BORING NUMBER MW-87-17E

SHEET 3 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY

LOCATION INTERSECTION OF ROSE RD. + HWY

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4 3/8" ID) TO 47.9 — MUD ROTARY 3 7/8" BIT TO —

WATER LEVEL AND DATE

START 9/16/87

FINISH —

LOGGER GERALD A.

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
28			24"	10,11,16,13	0-10" - brownish grey silt, with varves as above 10-24" brownish grey sandy silt with some gravel, sand is predom med. grained, minor fine + coarse gr.	
30			20"	28 25 25 23	0-14" - brown silt w/ several med gr. sand lenses, trace clay 14"-20" brown silt, some gravel	
32			10"	11 15 35 32	sandy gravelly brown silt, sand is med grained gravel up to 1.0" in diameter	
34			15"	6 28 33 31	sandy gravelly brown silt ~ same as above	
36			20"	9 21 57 100	0-8" sandy gravelly brown silt coarsens downwards 8-20" sandy gravelly silt coarser than 0"-8" interval (15% sand, 20% gravel)	
38			20"	54 69 72 X	brown silt, sand + gravel in equal proportions, sand ranges from fine to very coarse grained - encountered boulders at bottom	refusal
40			12"	66 100 X X	silt, sand + gravel, slightly more sand than previous (38'-40') sample, (35% to 40% sand)	refusal
42						

CH2M HILL

PROJECT NUMBER

BORING NUMBER

SHEET 4 OF 4

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION INTERSECTION OF ROSE ROAD + HWY 5

ELEVATION ______ DRILLING CONTRACTOR ______

DRILLING METHOD AND EQUIPMENT HSA 4 3/8" ID TO 47.9 ~ ~~DO~~ MUD ROTARY 3 7/8" BIT TO —

WATER LEVEL AND DATE ______ START 9/16/87 FINISH ______ LOGGER GERALD A. MCLAN

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
42	42-44		10"	66,100,xx	0-4" same as above 4"-6" sandy silt, some gravel, sand is very fine to fine gr.	refusal
44	44-46		10"	129,106,xx	silt, sand and gravel in equal proportions	refusal
46	46-47.5		11"	26,100,x,x	0-6" same as above 6"-11" silty gravelly sand ≈ 50% med. gr. sand, 25% silt, 25% gravel	refusal
48					SWITCH TO ROCK BIT AT 47.5' (MUD ROTARY)	

CH2M HILL

PROJECT NUMBER W68802.FI
BORING NUMBER MW-87-17E
SHEET 1 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY
LOCATION SOUTH SIDE OF LAGOON
ELEVATION
DRILLING CONTRACTOR STS
DRILLING METHOD AND EQUIPMENT DIAMOND BIT — CORE BARRELL
ORIENTATION VERTICAL
WATER LEVEL AND DATE
START
FINISH
LOGGER GERALD A. MEANS

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	R Q D (%)	FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
				BEGINNING OF 1st RUN 49.5			
49.5						GABBRO — DARK GREY COARSE GRAINED	
50.0						ONLY SLIGHTLY WEATHERED	
50.5	RECOVERY 100% FOR RUN 1			FRACTURE 50.4		-PLAGICLASE-GREY COARSE GR.	75%
51.0						-AMPHIBOLE MED GR. BLACK, PROBABLY HORNBLENDE	15-20%
51.5						AUGITE ≈ 5%	
52.0						TRACE BIOTITE OR PHLOGOPITE	
52.5				FRACTURE 52.4			
53.0							
53.5				FRACTURE 53.3			
54.0				FRACTURE 53.8 FRACTURE 54.1			
54.5							
55.0				END OF RUN 1 54.9 RUN 2 FRACTURE 55.1			
55.5							
56.5				FRACTURE 56.5			

58.5

Figure 1
ROCK CORE LOG,
FORM 2113A

PROJECT NUMBER

BORING NUMBER MW-87-17E SHEET 2 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY LOCATION SOUTH OF SLUDGE LAGOON

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL ORIENTATION

WATER LEVEL AND DATE START 9/24/87 FINISH 9/25/87 LOGGER GERALD A. McLANE

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	R Q D (%)	FRACTURES PER FOOT	DISCONTINUITIES DESCRIPTION: DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY: ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS: SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
56.5	97% RECOVERY RUN 2			THIS INTERVAL (56.5-57.0) IS HIGHLY FRACTURED - IT IS BROKEN IN 6 LARGE CHUNKS + NUMEROUS SMALL PIECES ALSO NOTICABLY MORE WEATHERED THAN OTHER INTERVALS			
57.0							
57.5				FRACTURE 57.5			
58.0				FRACTURE 57.83			
58.5				FRACTURE 58.3			
59.0							
				BOTTOM OF CORE + 2ND RUN AT 59.0			

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

PROJECT NUMBER W68802.F1
BORING NUMBER MW-18E
SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY
LOCATION HERMANTOWN, MN
ELEVATION
DRILLING CONTRACTOR STS
DRILLING METHOD AND EQUIPMENT SPLIT SPOON SAMPLER / AUGER
WATER LEVEL AND DATE
START 9/26/87 FINISH 9/28/87 LOGGER L. SALINANEZ

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	2	0-2'		6"	3,2,2,3	BROWN SILTY SAND AND GRAVEL ≈ 1/2" (FILL)		MOIST 0.0 ppm HNU
	4	2-4'		4"	2,1,1,2	SILTY SAND, TRACE OF CLAY		WATER TABLE AT 2.75' BELOW SURFACE
	6	4-6'		18"	4,1,1,2	PEAT WITH PIECES OF WOOD, GRADES TO PEATY CLAY		0.0 ppm HNU SATURATED
	8	6-8'		14"	1,2,4,4	PEAT AND CLAY, SILTY SAND AND CLAY, LAST 2" BROWN GRAVEL WITH SILT		SATURATED GRAVEL UP TO 1/2"
	10	8-10'		6"	6,8,10,7	BROWN SILTY GRAVEL		SATURATED
	12	10-12'		18"	8,10,10,9	SAME AS ABOVE (SOME CLAY IN SPOON)		SATURATED
	14	12-14'		13"	6,8,10,12	BROWN SILTY CLAY WITH GRAVEL		STIFF
	16	14-16'		13"	6,8,5,9	0-3" BROWN SILTLY CLAY 3-10" BLACK SANDY GRAVEL		SAND IS FINE TO COARSE
	19	16-18'				NO SAMPLE		
	20	18-20'		20"	10,10,11,11	0-20" BROWN SILT		0.0 ppm STIFF / IMPERMEABLE
	22	20-22		16"	13,14,15,12	SAME AS ABOVE		
	24	22-24		12"	14,18,15,14	SAME AS ABOVE		
	26	24-26'		10"	14,29,21,15	BROWN SILTY CLAY WITH GRAVEL 3" BAND OF BLACK GRAVEL IN MIDDLE OF SAMPLE		0.0 ppm HNU
	28	26-28'		9"	48,55,50,0	BROWN SILTY SAND WITH GRAVEL ~ 1" IN DIAMETER		0.0 ppm HNU
	30	28-30'			50	NO SAMPLE		SPLIT SPOON ON ROCK

REV 11/82 FORM 01586

CH2M HILL

PROJECT NUMBER W 68802, F1

BORING NUMBER MW-18E

SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY

LOCATION HERMANTOWN, MN

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT SPLIT SPOON SAMPLER / AUGER

WATER LEVEL AND DATE

START 9/26/87

FINISH 9/28/87

LOGGER L. SALHANEY

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	30	30-32'		16"	12, 8, 20, 0	BROWN GRAVELY SILT, GRAVEL up to ½"		0.0 ppm HNu
	32	32-34'		12"	25, 24, 20, 21	BROWN GRAVELY SILT, VERY STIFF		
	34	34-36'		12"	30, 21, 23, 90	BROWN, SANDY, GRAVELY SILT		VERY STIFF 0 ppm HNu
	36	36-38'		0"		NO SAMPLE		
	38	38-40'		16"	85, 100, 125, 250	BROWN SAND AND GRAVEL WITH SILT. HIGHLY COMPACTED (IMPERMEABLE)		VERY STIFF / DRY
	40	40-42'		11"	91, 125	BROWN SAND AND GRAVEL WITH SOME SILT		0 ppm HNu
	42	42-44		6"	150, 150, 150	BROWN MED. TO COARSE SAND, GRAVEL WITH SILT		0 ppm HNu
	44	44-46'		4"	120, 120, 120	SAME AS ABOVE		0 ppm HNu
	46					ROTARY		
	47	47-49		3"	101, 101, 101	SAME AS ABOVE.		
	49					ROTARY		
	49.5	49.5-51.5		4"	99, 99, 99	BROWN SAND AND MED COARSE GRAVEL, CLAY IN LAST 1"		0 ppm HNu
	57.5					ROTARY		
	52	52-54		3"	80, 80	BROWN SAND AND GRAVEL WITH SMALL AMOUNT OF CLAY AND SILT		
	54					ROTARY		
	54.5	54.5-56.5		1"		SILTY SAND AND GRAVEL WITH SOME CLAY		0 ppm HNu BEDROCK @ 56.0'
	56.5	X				ROTARY		
	57							

PROJECT NUMBER

BORING NUMBER MW-87-18E

SHEET 1 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY

LOCATION IMMEDIATELY SOUTH OF TRAILER

ELEVATION

DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL

ORIENTATION

WATER LEVEL AND DATE

START

FINISH /27/87

LOGGER GERALD A. M LAN

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES R Q D (%)	FRACTURES PER FOOT	DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS	GRAPHIC LOG	LITHOLOGY ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	COMMENTS SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
				BEGINNING OF RUN 57.0'			
57						GABBRO— SLIGHTLY WEATHERED IF AT ALL	
57.5				FRACTURE AT 57.65			93.8% Recovery
58				FRACTURE AT 57.9 FRACTURE AT 58.0		PLAGICLASE 75-80% COARSE GRAINED GREY	
58.5	93.			FRACTURE 58.6			
59				FRACTURE 59.1		AMPHIBOLE (HORNBLENDE) FINE-MED GRAINED - BLACK 15%	
59.5							
60				FRACTURE 60.1		AUGITE - BLACK = 5% TRACE BIOTITE OR PHLOGOPITE	
60.5							
61				FRACTURE AT 61.0			
61.5				FRACTURE 61.75			
62				FRACTURE 62.0			
62.5				FRACTURE 62.65			
63.0							
63.5				FRACTURE 63.9'			

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2MHILL

PROJECT NUMBER	BORING NUMBER
	MW-87-19E SHEET 2 OF 2

ROCK CORE LOG

PROJECT ARROWHEAD REFINERY LOCATION

ELEVATION DRILLING CONTRACTOR

DRILLING METHOD AND EQUIPMENT DIAMOND BIT CORE BARREL ORIENTATION VERTICAL

WATER LEVEL AND DATE START FINISH LOGGER GERALD A. MSLANS

DEPTH BELOW SURFACE (FT)	CORE RUN, LENGTH, AND RECOVERY (%)	DISCONTINUITIES			GRAPHIC LOG	LITHOLOGY	COMMENTS
		R Q D (%)	FRACTURES PER FOOT	DESCRIPTION DEPTH, TYPE, ORIENTATION, ROUGHNESS, PLANARITY, INFILLING MATERIAL AND THICKNESS, SURFACE STAINING, AND TIGHTNESS		ROCK TYPE, COLOR, MINERALOGY, TEXTURE, WEATHERING, HARDNESS, AND ROCK MASS CHARACTERISTICS	SIZE AND DEPTH OF CASING, FLUID LOSS, CORING RATE AND SMOOTHNESS, CAVING ROD DROPS, TEST RESULTS, ETC.
64.0							
64.5				FRACTURE 64.8 →			
65.0				FRACTURE AT 65.8 →			
65.5							
66.0				Bottom of core 66.5			
66.5							
67.0							

Figure 1
ROCK CORE LOG,
FORM 2113A

CH2M HILL

TECHNICAL MEMORANDUM NO. 5

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: Don Johnson/CH2M HILL
Project Geophysicist

DATE: March 2, 1988

RE: Borehole Gamma Logging and
Lithologic Correlations

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68802.FL

INTRODUCTION

Gamma logging of 21 selected boreholes was performed at the Arrowhead Refinery site between October 20 and 24, 1987 by Don Johnson, assisted by Jewelle Imada (CH2M HILL) and Greg Weeks (Engineers International). The logging was performed to obtain information that could aid in the interpretation and correlation of lithologic logs. Continuous soil samples had not been collected at all the wells, so gaps exist in the descriptive logs. Descriptions vary between wells because they were logged by different people. The gamma logs provide information to help fill the sampling gaps and to help correlate descriptive logs made by different hydrogeologists.

Figure TM5-1 shows locations of the monitoring wells used for gamma logging. Not all wells were logged. Only the deepest well in each well nest was logged, with two exceptions. At Well Nest 13, both Well MW-13b (35 feet deep) and Well MW-13e (53 feet) were logged. Well MW-13e was subsequently logged when the mistake was discovered. At Well Nest 2, Well MW-2c (39 feet) was logged first because Well MW-2e had not been completed. Well MW-2e (50 feet) was eventually completed in time for it to be logged.

EQUIPMENT AND METHOD

A Mt. Sopris Model 1000-C portable logger with a standard gamma, SP, and single-point resistivity probe was used. The SP and resistivity capabilities were not used.

Before any logging was performed, the location of the sensor in the probe had to be determined. A Coleman lantern mantle, which contains a slight amount of radioactive thorium, was slid along the probe until a maximum signal was obtained. The distance from the sensor to the top of the probe was found to be 3 feet. When setting up the logging unit at each well, the probe was positioned with the top of the probe at the top of the riser. Since the sensor was 3 feet lower, the depth counter was set to 3 feet. The probe was lowered into the well until it rested on the bottom. The actual bottom of the well is 1.7 feet lower than the depth reading because of additional probe length beneath the sensor location.

The gamma log was obtained by engaging the paper drive, lowering the pen, and raising the probe at a rate of 5 to 10 feet per minute. The probe was raised and lowered using a hand-operated winch. The information recorded at each well included location, date, well depth, and scale settings.

After completion of each well log, the probe and affected portion of the cable were decontaminated with a trisodium phosphate wash, a distilled water rinse, a methanol rinse, and another distilled water rinse. Decontamination at the offsite wells consisted of a distilled water rinse only. The logger was hand carried between borings.

RESULTS

GAMMA LOG RESULTS

Four lithologic units are identifiable in the gamma logs (see Attachment A). Peat is characterized by readings around 10 counts per second (cps), silts and sands at 15 to 20 cps, clay at 25 to 30 cps, and bedrock at 5 cps or less. These results are a generalization and exceptions do exist.

The peat identified in the drilling logs exhibited readings of about 10 cps in the gamma logs. The gamma counts in the peat at five wells (Nos. MW-6c, MW-9b, MW-10b, MW-12a, and MW-18e) were at the same level as in the surrounding material (15 to 20 cps). The peat at those locations may have higher silt or sand content than elsewhere. In Well MW-2c, the soil fill above the peat also has a low count rate and cannot be distinguished from the peat in the gamma logs. In Wells MW-5e and MW-18e, the surficial soil has a low count rates but peat was not identified in the lithologic log. The shallow soils with the low gamma counts may be fill (with a lower gamma activity than the native soils), or they may have a high peat content but not high enough to be described as peat.

There is no distinction in the gamma log between the lacustrine or till sediments. There is a small but observable increase in the count rate in some wells that may correspond to the till-lacustrine contact. Wells that exhibit features in their gamma

TABLE TM4-1

ARROWHEAD REFINERY ELEVATION SURVEY
NOV 22-24, 1987

(Elevations in feet above mean sea level)

WELL No.	ELEVATION		
	GROUND	CASING	RISER
12a	1418.53	1421.45	1421.42
13a	1418.50	1421.54	1421.46
13b	1418.49	1420.96	1421.05
13e	1418.83	1420.89	1421.08
14s	1415.72	1417.77	1417.50
14a	1415.59	1418.04	1417.86
14b	1415.66	1418.43	1418.36
14c	1415.69	1417.50	1417.39
15a	1420.73	1423.20	1423.11
15b	1420.54	1422.99	1422.77
MW-16	1421.31	1423.02	1423.01
P-16	1420.90	1423.15	1423.26
17s	1423.02	1425.04	1425.00
17b	1423.44	1425.40	1425.26
17e	1422.77	1424.69	1424.67
P-17s	1426.10	1428.30	1427.63
18e	1419.79	1421.58	1421.60
21s	1413.97	1416.16	1416.16
21b	1414.00	1416.19	1416.30
22s	1413.69	1415.53	1415.58
23s	1430.12	1433.04	1432.33
South Stream Gage	1415.39		
East Stream Gage	1420.32		
Central Stream Gage	1419.25		
West Stream Gage	1419.06		

Note: Stream gage elevations are for the top of the staff.

For the old wells, the new elevations differed from the RI data by generally less than 0.1 foot. Differences were greater than 0.2 foot at the following wells:

Well	New Riser Elevation	Old Riser Elevation	Diff.	Comments
B4a	1,424.22	1,423.27	0.95	Casing and ground elevations match.
B4b	1,424.08	1,423.12	0.96	
MW-7a	1,422.49	1,420.42	2.07	Casing and ground elevations differ by similar amount.
MW-7b	1,421.75	1,420.42	1.33	
MW-7c	1,421.60	1,420.28	1.32	
MW-10a	1,416.63	1,415.66	0.97	Casing elevation differs by a similar amount. Ground elevations match.
MW-15a	1,423.11	1,422.31	0.80	Casing elevations differ by similar amount. Ground elevations differ by about 0.5 feet.
MW-15b	1,422.77	1,421.84	0.93	

CH2M HILL

TECHNICAL MEMORANDUM NO. 4

TO:	Fred Bartman/U.S. EPA Remedial Project Manager
FROM:	Randy Videkovich/CH2M HILL Project Manager
PREPARED BY:	Don Johnson/CH2M HILL
DATE:	November 4, 1987
RE:	Well Elevation Survey
PROJECT:	Arrowhead Refinery Fieldwork Design Investigation W68802.FI

INTRODUCTION

The Well Installation Task included the surveying of all new wells, existing wells, and staff gauges to determine their elevations relative to a common datum. The elevations of both top of casing and ground surface were measured for wells because some wells appeared to have shifted because of frost heave. The new surveyed elevations were used to determine groundwater flow directions and gradients.

FIELD ACTIVITIES

Well elevations were established in a survey performed by Don Johnson and Jewelle Imada from November 22 to 24, 1987. Elevations were tied into the USGS bench mark located on the south side of U.S. Highway 53 near Well Nest 17. The elevation of the bench mark is 1,426.22 feet above mean sea level (msl).

The survey was performed in five loops starting and ending at a known elevation. Closing a loop in such a manner allows any survey errors to be detected. The greatest closure error was 0.06 foot at the first loop. The closure errors at the other loops were 0.03 foot or less. Loop 1 started and ended at the bench mark. Loop 2 started and ended at Well MW-18e to avoid crossing the highway. The elevation at Well MW-18e was confirmed by surveying it twice. Loops 3 and 4 started and ended at Well MW-18e. Loop 5 used the casing elevation of Well MW-5c determined in Loop 4, which was confirmed by existing data.

Elevations at each well were measured at the top of the protective casing, top of the riser, and ground surface. Existing wells were surveyed to determine if frost heave had occurred. Elevations were also obtained for the tops of the stream staff gauges. Table TM 4-1 lists elevations measured during this surveying effort.

TABLE TM4-1

ARROWHEAD REFINERY ELEVATION SURVEY
NOV 22-24, 1987

(Elevations in feet above mean sea level)

WELL		ELEVATION	
No.	GROUND	CASING	RISER
1a	1424.06	1427.29	1427.19
2b	1418.05	1421.03	1420.94
2a	1418.19	1420.74	1420.69
2c	1417.94	1420.50	1420.43
2e			1419.73
3s	1416.21	1418.31	1418.30
3a	1415.64	1418.84	1418.79
3b	1415.70	1418.41	1418.36
B4a	1421.56	1424.33	1424.22
B4b	1421.43	1423.81	1424.08
P-5s	1418.71	1420.53	1420.43
P-5b	1419.12	1420.77	1420.82
5a	1418.64	1421.12	1421.05
5b	1419.14	1420.58	1420.68
5c	1418.95	1421.17	1421.12
5e	1419.08	1420.32	1420.41
B5	1418.94		
6a	1424.95	1427.80	1427.74
6c	1425.06	1427.85	1427.82
7s	1419.54	1421.11	1421.07
7a	1419.44	1422.46	1422.49
7b	1419.03	1421.90	1421.75
7c	1419.19	1421.89	1421.60
8a	1423.36	1426.26	1426.14
8b	1422.54	1424.58	1424.65
9a	1419.01	1421.58	1421.23
9b	1419.25	1421.84	1421.85
10a	1413.93	1416.73	1416.63
10b	1413.96	1416.85	1416.60
11a	1414.89	1418.01	1417.98

WELL DEVELOPMENT RECORD

Job Name Arrowhead Re CHW411 Start Date 10-6
Stickup Above Ground Surface 2.4 feet Job Number 94257
Well # P-87-21B Date of Installation Your Name Don Johnston
Screen Interval to feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 4.50 feet
Sounded Bottom of Well 31.85 feet
Volume of Water in Well 4.5 gallons
Minimum Volume of Water to be Removed for Development 45 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [~~gal~~/min]	Comments
10-6	1	2:30	3:15	45	Bailing	≈5	Dry	7.5 min/ft.	Bailed Dry
10-8	2	10:30	11	30	Bailing	≈5	Dry	.3/min	"

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-6	1	8.2	~90	7	1.5	5 min		Surging & centrifugal
10-6	2	7.8	170	7	5	"		" "
10-8	3	7.3	200	–	10			Surging
								"
			Bailed Dry partly 2 times					
				"				

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8-87				
Static Water Level	4.55				

Sounded Bottom of Well After Development 32.3 feet
Is there any sediment left at the bottom of the well? yes☐ no☑

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Anacortes Refinery Start Date 10-6
Stickup Above Ground Surface 2.3 feet Job Number 9125.1
Well # P87-225 Date of Installation 9-24-87 Your Name Dan Johnston
Screen Interval 8.5 to 3.5 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 3.65 feet
Sounded Bottom of Well 9.0 feet
Volume of Water in Well .9 gallons
Minimum Volume of Water to be Removed for Development 9 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-6	1	2:20	3:15	25	Bailer	≈5	Dry	5 min/ft	Surging
10-8	2	9	9:30	20	Bailing	≈5	Dry		Surging

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [~~°F~~] C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-6	1	7.6	240	7	1	—	Bailer	Surging
10-6	2	7.7	280	|	2	—	|	
10-6	3	7.01	330	↓	3	—	|	
10-8	4	7.2	350	7	~5	—	|	
								Complete
			Bailed	dry another 3 times				

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8-87				
Static Water Level	3.7				

Sounded Bottom of Well After Development 10.8 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name C H2M Hill Arrowhead .... Start Date 10-9-87
Stickup Above Ground Surface 2.05' feet .... Job Number 94257
Well # MW87-18E .... Date of Installation 9-30-87 .... Your Name Don Johnston
Screen Interval 64.3 .... to 54.3 .... feet below ground surface
Internal Diameter of Well Pipe 2" .... Screen Slot #10
Screen Material Stainless Steel type 304. Riser Material Stainless Steel type 304

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 4.0 feet
Sounded Bottom of Well 66.3 feet
Volume of Water In Well 10.2 gallons
Minimum Volume of Water to be Removed for Development 102 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-9	1	11:30	1200	1	—	10	Dry	no recharge	

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-9	1	8.5	70	9	5	—	Surging	Surging with PVC
10-9	2	8.5	80	9	10	—	"	Very Slow recharge

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-21				
Static Water Level	22.05				

Sounded Bottom of Well After Development 66.3 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill [illegible] Start Date 10-6
Stickup Above Ground Surface 2.4 feet Job Number 14259
Well # P-87-215 Date of Installation 9-23-87 Your Name Dan Johnston
Screen Interval 9.25 to 4.75 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 4.75 feet
Sounded Bottom of Well 12.15 feet
Volume of Water in Well 1.9 gallons
Minimum Volume of Water to be Removed for Development 19 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-6	1	2:00	2:25	25	Surging	6	12.5	[illegible]	Surged - Bailed Dry
10-8	2	10	10:30	25	Surging	5	Dry	[illegible]	

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-6	1	6.28	140	—	1 gal	—	Footvalve	clear start.
10-6	2	6.5	220	—	6 gal	—	"	changed to Slight Brown
10-8	3	7.1	710	—	[illegible]	—		[illegible]
					Bailed Dry	another	3 times	

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8-87				
Static Water Level	4.65				

Sounded Bottom of Well After Development 12.15 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name CH2MHill Allegheny Start Date 10-8
Stickup Above Ground Surface 2.0 feet Job Number 94259
Well # MW 17-B Date of Installation 9-23-87 Your Name Don Johnston
Screen Interval 40.9 to 35.9 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material (Johnson) Stainless Steel Riser Material Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 9.1 feet
Sounded Bottom of Well 42.25 feet
Volume of Water in Well 5.5 gallons
Minimum Volume of Water to be Removed for Development 55 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-8	1	3:00	5:00	120	1	100	≈20		Surging with PVC
									+ Foot Valve

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature, [~~°F~~]C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-8	1	10.4	100	10	2	Surging	→	Centrifugal Pump
10-8	2	8.95	80	10	10	"		" "
10-8	3	8.4	100	10	25	"		
10-8	4	8.4	130	10	60	"		
10-8	5	8.4	120	10	90	"		
10-8	6	8.4	130	10	100	"		
								Complete

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8				
Static Water Level	9.4				

Sounded Bottom of Well After Development 42.1 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2MHill Bremerton Start Date 10-8
Stickup Above Ground Surface 2.1 feet Job Number 94259
Well # MW 12 E Date of Installation 9-26-87 Your Name Dan Johnston
Screen Interval 56.1 to 51.1 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material 304 Stainless Steel Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 8.5 feet
Sounded Bottom of Well 58.15 feet
Volume of Water in Well 8.1 gallons
Minimum Volume of Water to be Removed for Development 80 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-8-87	1	1:00	1:37	37min	Surging	8.	Dry		PVC + Foot Valve
10-8-87	2	2	3	1hr	Surging	20	Dry		
10-8	3	4:30	5	30min	″	10	Dry		
10-9	4	4:30	5	30	″	10	″		
10-13	5					10			
10-16	6					10			

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [~~°F~~] C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-8	1	9.6	300	9C	2	Surging		Surging
10-8	2	10.3	130		8.5			
10-8	3	10.4	100		10			Waiting
10-8	4	11.6	2240		15			
10-8	5	12	2490		25			
10-8	6	11.7	2190		35			
10-8	7	11.8	2180		45			Clear
10-9	8	11.2	1900		55			Clear
10-13	—	—	—	—	—			
10-16	—	—	—		≈80 Total			

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-22				
Static Water Level	8.6				

Sounded Bottom of Well After Development 58.2 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrowhead Start Date 10-8-87

Stickup Above Ground Surface 2.0 feet Job Number 94259

Well # MW 87 16b Date of Installation 9-15-87 Your Name Don Johnston

Screen Interval .... to .... feet below ground surface

Internal Diameter of Well Pipe 2" Screen Slot #10 Slot

Screen Material Type 304 Stainless Steel Riser Material Stainless Steel Type 304

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 7.4 feet

Sounded Bottom of Well 14.6 feet

Volume of Water in Well 1.17 gallons

Minimum Volume of Water to be Removed for Development 12 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
Oct 8	1	5:15	6:00	45	[illegible]	2	Dry	—	Surging
10-9	2	4	4:15	15		2	|		
10-13	3	—	—	—		5	|		
10-16	4	—	—	—		8	|		
10-21	5	8	8:10			10			
10-21	6								
10-22	7 completed								

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [~~°F~~] °C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
								merkin Brown
Oct 8	1	8.2	180	10	.5	Surging	Dry	PVC tubing + foot valve
10-9	2	7.1	220	10	4.5	〃	Dry	
10-21	3	9.2	570	—	10		Dry	
10-22	4	7.0	240	10	12		Dry	
10-21	—	—	—	—	—			[illegible]

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development 17.8 feet

Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrowhead Refinery Start Date 10-8
Stickup Above Ground Surface 2.2 feet Job Number 94254
Well # P87-17S Date of Installation 9-24-87 Your Name Don Johnston
Screen Interval 15.0 to 10.0 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material PVC Riser Material PVC 2"

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 8.9 feet
Sounded Bottom of Well 17.2 feet
Volume of Water in Well 1.36 gallons
Minimum Volume of Water to be Removed for Development 13.5 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-8	1	11:10	11:45	35	12	180	13	÷	Clear after 3 min

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [~~F~~]C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-8	1	8.4	880	—	1	Surging		Footvalve
10-8	2	6.46	1160	12°	48	12	Pump	centrifugal
10-8	3	6.6	1150	12°	72	12	"	
10-8	4	6.7	1200	12	168	12	"	
				Pumped	dry 3	more times		

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8-87				
Static Water Level	8.9				

Sounded Bottom of Well After Development 17.2 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrowhead Refinery Start Date 10-9-87
Stickup Above Ground Surface 2.1 feet Job Number 94259
Well # MW87-145 Date of Installation 9-26-87 Your Name Don Johnston
Screen Interval 6.5 to 15 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material 304 Stainless Steel Riser Material Stainless steel, type 304

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 2.2 feet
Sounded Bottom of Well 8.6 feet
Volume of Water in Well 1 gallons
Minimum Volume of Water to be Removed for Development 10 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-9-87	1	3:15	335	20	—	7	Dry	1/2 min	Bailed Dry
10-9-87	2	4:30	445	15	—	3	Dry	—	"
10-13	3								
10-21	4								

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature, ☒C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-9	1	6.8	350	8	.3		Surging	Surging
10-9	2	7.2	460	8	5			
10-9	3	—	—	—	10	—	—	
10-21	4	7.03	420	8	12			

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development — feet
Is there any sediment left at the bottom of the well? yes☐ no☐

WELL DEVELOPMENT RECORD

Job Name CH2M Hill [illegible] Refinery Start Date 10-6-87
Stickup Above Ground Surface 2.6 feet Job Number 9425
Well # P87165 Date of Installation 9-15-87 Your Name Don [illegible]
Screen Interval 25 to 20 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 7.8 feet
Sounded Bottom of Well 27.45 feet
Volume of Water in Well 3.2 gallons
Minimum Volume of Water to be Removed for Development 32 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [~~gal~~ ft/min]	Comments
10-6	1	3:45	4:30	45	Bailing	5	—	—	
10-8	2	930	10	30	Bailing	5	—	.2/min	

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [~~°F~~] C°	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-6	1	6.5	120	7	3	1.6min/ft	Surging	Foot valve PVC
10-6	2	7.41	140	7	5	—	Surging	
10-8	3	7.0	160	7	≈10	—	Surg	
			Bailed Dry [illegible] 3 times					

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-8-87				
Static Water Level	7.65				

Sounded Bottom of Well After Development 27.6 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrow Head Refinery Start Date 10-21

Stickup Above Ground Surface 2.6 feet Job Number 94259

Well # MW 87 13b Date of Installation 10-13-87 Your Name Don Johnson

Screen Interval 34.5 to 29.5 feet below ground surface

Internal Diameter of Well Pipe 2" Screen Slot #10 Slot

Screen Material 304 Stainless Steel Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 2.3 feet

Sounded Bottom of Well 32.1 feet

Volume of Water in Well 4.9 gallons

Minimum Volume of Water to be Removed for Development 4.9 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	900	12:15	3	.5	66	30	.5/min	Cleared

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	11.3	2770	8	5	~~—~~	Surge	Bailed dry
10-21	2	10.3	200	8	15	—		Clearing
10-21	3	8.8	80	9	20	—		
10-21	4	7.45	30	8	66	.5/min	Centrifugal	Clear
	5							Complete
	6							

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development 32.1 feet

Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2MHill [illegible] Start Date 10-21
Stickup Above Ground Surface 2.3 feet Job Number 94259
Well # MW 82-13E Date of Installation 10-9-87 Your Name Ron Johnston
Screen Interval 51.9 to 46.9 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material 304 Stainless Steel Johnson Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 21 feet
Sounded Bottom of Well 54.0 feet
Volume of Water in Well 8.5 gallons
Minimum Volume of Water to be Removed for Development 85 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time 9.36	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	9	10	60	1.7	≈45	30'	1.7	
10-21	2	12	1230	30	5/1.7	≈60	30	1.7	Clear

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	8.8	130	8°	5		[illegible]	Surging PVC [illegible]
10-21	2	8.5	160	8°	15			Bailed
10-21	3	8.1	230	8	20			
10-21	4	8.3	270	8	30			Bailed Dry
10-21	5	8.25	170	8	45			
10-21	6	8	100	8	65	1.7		
10-21	7	8	80	8	80	"		12:19 →
10-21	8	7.8	80	8'	85	"		
10-21	9	7.8	80	8'	102	"	↓	Complete

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development 54.2' feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrowhead Refining Start Date 10-9-87
Stickup Above Ground Surface 1.8 feet Job Number 94259
Well # MW87-75 Date of Installation 10-6-87 Your Name Don Johnston
Screen Interval 11.3 to 6.3 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material 304 Stainless Steel Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 4.70 feet
Sounded Bottom of Well 13.05 feet
Volume of Water in Well 1.7 gallons
Minimum Volume of Water to be Removed for Development 13.6 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-9	1	12:45	1:45	1	1.6	55	≤1.39	1.6 g/min	Good well clear clean

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-9-87	1	7.7	140	13	1			Centrifical pump PVC
10-9	2	7.1	410	13	18			
10-9	3	7.38	570	14°	37			
10-9	4	7.38	570	14°	55			

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development 13.1 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name CH2MHill Arrowhead Refinery Start Date 10-9-87

Stickup Above Ground Surface 2.3 feet Job Number 94259

Well # MW 87-8b Date of Installation 9-28-87 Your Name Ron Johnston

Screen Interval 23 to 18 feet below ground surface

Internal Diameter of Well Pipe 2" Screen Slot #10 Slot

Screen Material 304 Stainless Steel Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 6.3 feet

Sounded Bottom of Well 25.1 feet

Volume of Water in Well 3.1 gallons

Minimum Volume of Water to be Removed for Development 31 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-9	1	10:30	11:30	60	—	6	Dry	.1/10min	
10-9	2	215	2:30	15	—	3	Dry		
10-9	3	330	4:30	15	—	23	Dry	.13/min	Centrifical pump

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [℉]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-9	1	8.25	320	10	3	—	Surging	Murkey - lots of Silts Brown thick
10-9	2	7.6	1100	10	6	—		
10-9	3	7.0	1280	10	9	—	—	
10-9	4	7.2	1820	10	14	—		Murkey Brown
10-9	5	7.3	1820	10	37	—		Clear stable
								Complete

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-12				
Static Water Level	6.4				

Sounded Bottom of Well After Development 25.3 feet

Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill Arrowhead Start Date 10-21-87
Stickup Above Ground Surface 2.0 feet Job Number 94257
Well # MW 5B Date of Installation 10-12-87 Your Name Don Johnston
Screen Interval 20.2 to 15.2 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 slot
Screen Material Type 304 Johnson Stainless Riser Material type 304 stainless steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 3.9 feet
Sounded Bottom of Well 22 feet
Volume of Water in Well 2.95 gallons
Minimum Volume of Water to be Removed for Development 29 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	2:46	3:06	20	14.2	284	—	14.2	pumped clear

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	7.36	570	8°	70	14.2		centrifical pump PVC Foot valve
10-21	2	7.4	560	8°	140	14.2		
10-21	3	7.4	590	8°	170	14.2		
10-21	4	7.4	600	8°	213	14.2		
10-21	5	7.4	600	8°	284	14.2		
								Completed

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-22				
Static Water Level	3.9				

Sounded Bottom of Well After Development 22.2 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☑

WELL DEVELOPMENT RECORD

Job Name C H M Hill Arrowhead Refiny Start Date 10-21-87
Stickup Above Ground Surface 2.2 feet Job Number 94259
Well # MW 5E Date of Installation 10-10-87 Your Name Don Johnston
Screen Interval 53.7 to 48.7 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material type 304 Stainless Steel Riser Material 304 Stainless Steel

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 3.7 feet
Sounded Bottom of Well 55 feet
Volume of Water in Well 8.4 gallons
Minimum Volume of Water to be Removed for Development 84 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	307	6:0A	3hr	.5	~86	≈30'	5/min	Clear

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	9.13	400	8	5	.5	Centrifugal	Surging — Bailed dry
10-21	2	9.25	210	8	10	.5		centrif
10-21	3	10.1	200	8	12	.5	|	
10-21	4	9.0	180	8	17	.5	|	
10-21	5	8.2	140	9°	30	.5	|	
10-21	6	8.1	110	8	≈50	.5	|	
10-21	7	8.1	50	8	62	.5	|	[illegible]
10-21	8	8.5	70	8	65	.5	|	
10-21	9	8.4	60	8	86	.5	↓	
								Complete

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date	10-22				
Static Water Level	3.6				

Sounded Bottom of Well After Development 55.7 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

WELL DEVELOPMENT RECORD

Job Name CH2M Hill [illegible] Refining Start Date 10-9-97
Stickup Above Ground Surface 2.5 feet Job Number 94259
Well # MW 87-3S Date of Installation 9-25-97 Your Name Dan Johnston
Screen Interval 6.7 to 1.7 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10
Screen Material Stainless Steel type 304 Riser Material Stainless Steel type 304

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 4.0 feet
Sounded Bottom of Well 2.9 feet
Volume of Water in Well 1.6 gallons
Minimum Volume of Water to be Removed for Development 6.4 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time min	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-9	1	2:30	3:00	30	—	3	Dry	—	Bailed Dry
10-9	2	3:40	3:45	5	—	.5	Dry		
10-9	3	448	5	15min		2			Bailed Dry
10-21	4	8:15	8:30			1			
10-22	—	—	—						
10-28	—	—							

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [µhmos]	Temperature [~~F~~]C	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-9	1	6.4	560	8	.5	—	Surge	thick Silt, Brown
10-9	2	6.5	630	8	3	—	↓	
10-9	3	6.5	630	8	3.5	—		
10-21	4	6.6	700	8	4.5	—		
10-22	—	—	—		5.5			
10-28	—	—	—	—	6.5			

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development .... feet
Is there any sediment left at the bottom of the well? yes☐ no☐

WELL DEVELOPMENT RECORD

Job Name CH2MHill Arrowhead Refining Start Date 10-21-87
Stickup Above Ground Surface 2.0 feet Job Number 94259
Well # P-875B Date of Installation 10-9-87 Your Name Don Johnston
Screen Interval 16 to 11 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 7.05 feet
Sounded Bottom of Well 12.4 feet
Volume of Water in Well 2.2 gallons
Minimum Volume of Water to be Removed for Development 22 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	3:24	6	2.5	—	25	Dry		

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	7.6	320	10°	1	—	Surging	Surging Bailed Dry
10-21	2	7.4	370	10	5	—		,, ,,
10-21	3	6.7	450	10°	8	—		
10-21	4	6.9	400	10	15	—		
10-21	5	7.7	400	10°	20	—		
10-21	5	7.4	400	10	25	—		
								[illegible]

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development — feet
Is there any sediment left at the bottom of the well? yes ☐ no ☐

WELL DEVELOPMENT RECORD

Job Name CH2M Hill, Allowhead Refining
Start Date 10-28-87
Stickup Above Ground Surface 1.7 feet
Job Number 94257
Well # MW-87-2E
Date of Installation 10-23-87
Your Name Om Johnston
Screen Interval 49.5 to 44.5 feet below ground surface
Internal Diameter of Well Pipe 2"
Screen Slot #10 Slot
Screen Material type 304 Johnson Stainless Stee
Riser Material Stainless Steel type 304

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 21 feet
Sounded Bottom of Well 54.2 feet
Volume of Water in Well 22 gallons
Minimum Volume of Water to be Removed for Development 22 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-28	1	12:30	3	2.5	—	10	Dry	.0163	recharge 2.3hr

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-28	1	10.6	870	8	10			Surging Bailed Dry
10-28	2	9.9	400	8	—			

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

Sounded Bottom of Well After Development — feet

Is there any sediment left at the bottom of the well? yes ☐ no ☐

WELL DEVELOPMENT RECORD

Job Name CH2MHill [illegible] Refining Start Date 10-21-87
Stickup Above Ground Surface 2.0 feet Job Number 44259
Well # P-87 5.5 Date of Installation 10-14-87 Your Name Dan Johnston
Screen Interval 10.3 to 5.3 feet below ground surface
Internal Diameter of Well Pipe 2" Screen Slot #10 Slot
Screen Material PVC Riser Material PVC

INITIAL DATA PRIOR TO DEVELOPMENT

All measurements taken from top of riser pipe.

Water Level 3.8 feet
Sounded Bottom of Well 12.3 feet
Volume of Water in Well 1.4 gallons
Minimum Volume of Water to be Removed for Development 14 gallons

I.D. of riser pipe [inch]	Gallons per foot of depth
2	0.163
3	0.367
4	0.653
5	1.02

PUMPING RECORD

All measurements taken from top of riser pipe.

Date	Run	Start Time	Finish Time	Elapsed Time	Pumping Rate [gal/min]	Volume Removed [gal]	Draw Down [feet]	Recharge Rate [gal/min]	Comments
10-21	1	3:14	16	≃3		-			

STABILIZATION TEST

All measurements taken from top of riser pipe.

Date	Sample Number	ph	Temperature Corrected Conductivity [μhmos]	Temperature [°F]	Total Volume Removed [gal]	Pumping Rate [gal/min]	Method	Comments
10-21	1	9.55	200	12°	1	—	Surging	Bailed Dry
10-21	2	6.4	380	12°	9	—		
10-21	3	7.5	400	12°	15	—		
10-21	4	7.8	400	12	17	—		
10-21	5	7.6	400	12°	19	—		
								complete

WATER LEVEL AFTER DEVELOPMENT

All measurements taken from top of riser pipe.

Date					
Static Water Level					

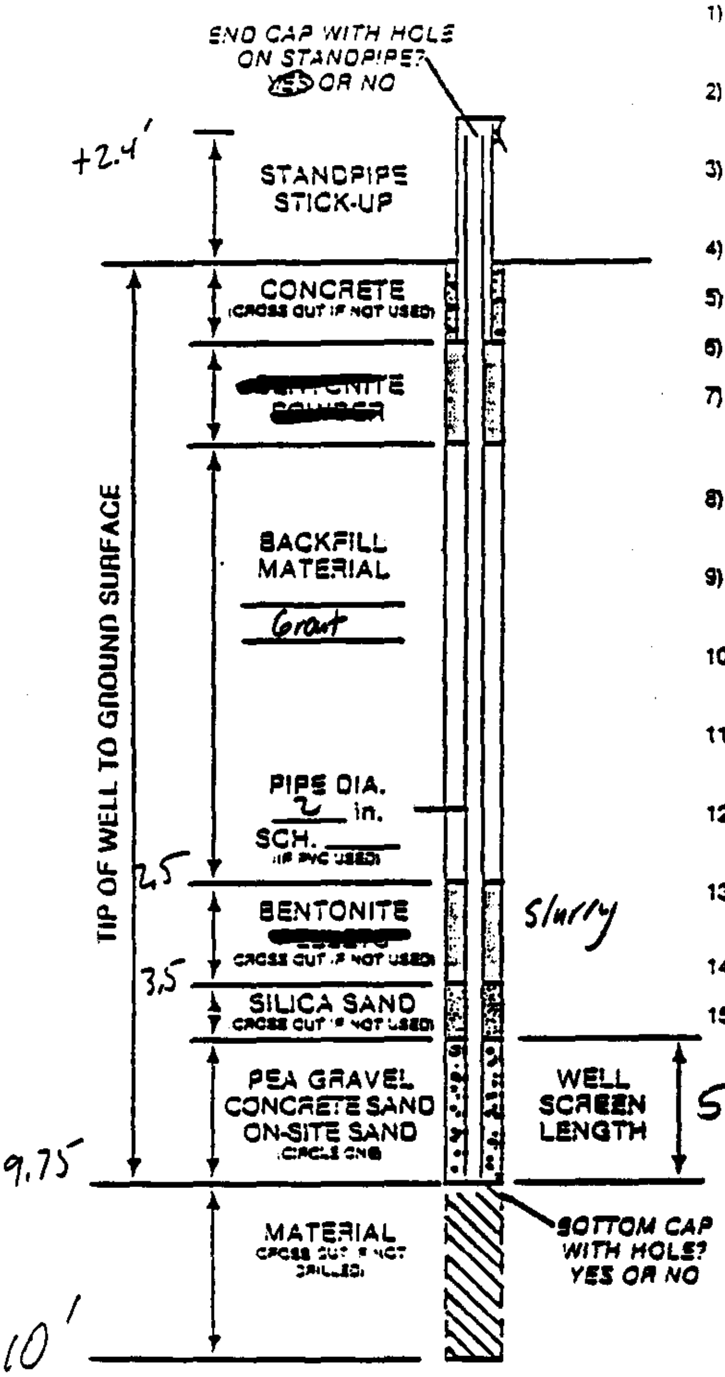
Sounded Bottom of Well After Development 10.3 feet
Is there any sediment left at the bottom of the well? yes ☐ no ☒

TM 3--MONITORING WELL AND PIEZOMETER INSTALLATION

Attachment C
WELL DEVELOPMENT RECORDS

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC], GALVANIZED, STAINLESS, OTHER ______

2) TYPE OF PIPE JOINTS?
[✓ BELLED] COUPLINGS, THREADED, OTHER ______

3) TYPE OF WELL SCREEN
[✓ PVC] GALVANIZED, STAINLESS, OTHER ______

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2hr.

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 20

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
12.15 Ft. or DRY

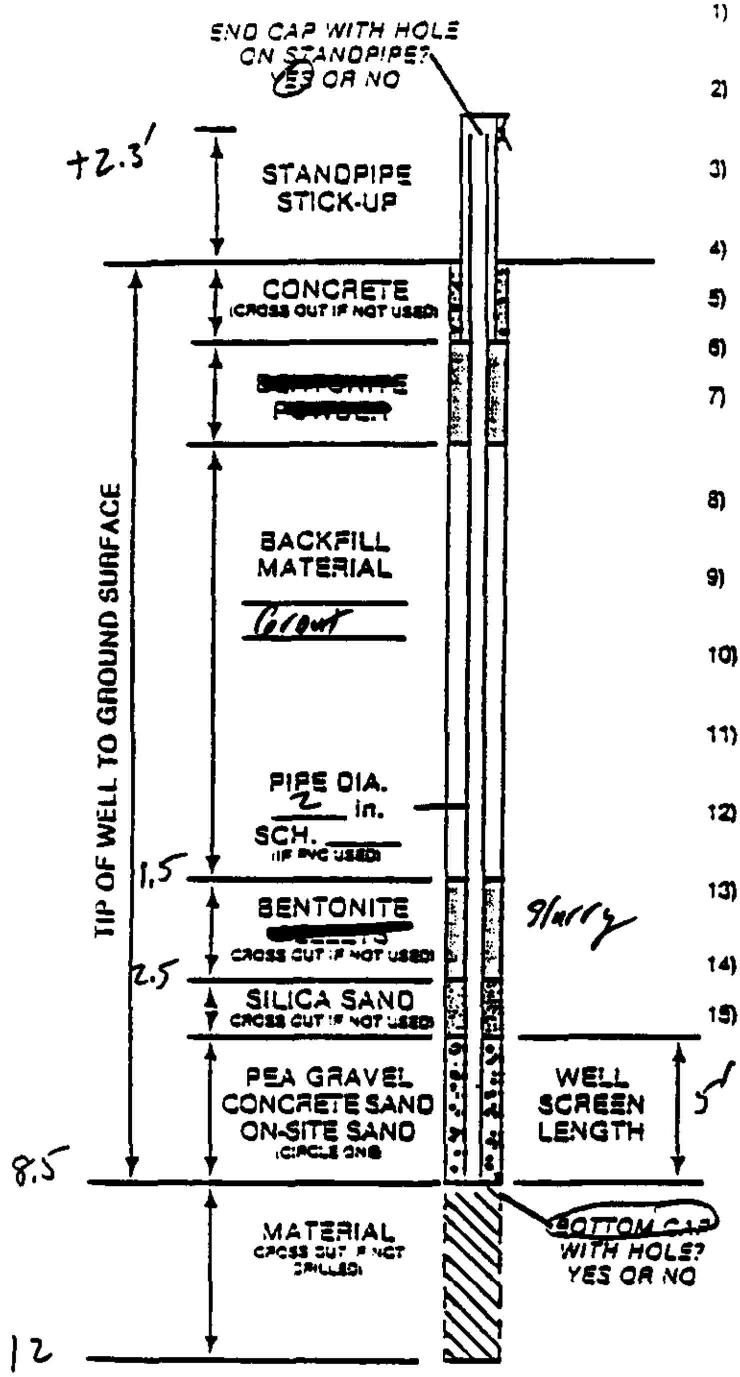
2) OTHER MEASUREMENTS:

DATE 10-8 . 4.65 Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE

Well No. P87 21 S DATE INSTALLED 9-23-87 DRILL RIG B-53
DRILLER Hovland DRILL CREW Boisner
JOB/CLIENT Arrowhead Refining, CH2MHill STS JOB No. 94259
R/V 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC] GALVANIZED. STAINLESS. OTHER ________

2) TYPE OF PIPE JOINTS?
[✓ BELLED] COUPLINGS. THREADED. OTHER ________

3) TYPE OF WELL SCREEN
[✓ PVC] GALVANIZED. STAINLESS. OTHER ________

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? ~~YES~~ OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER. [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING] COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., [✓ 10 gal.], 15 gal., OTHER 10

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
10.8 Ft. or DRY

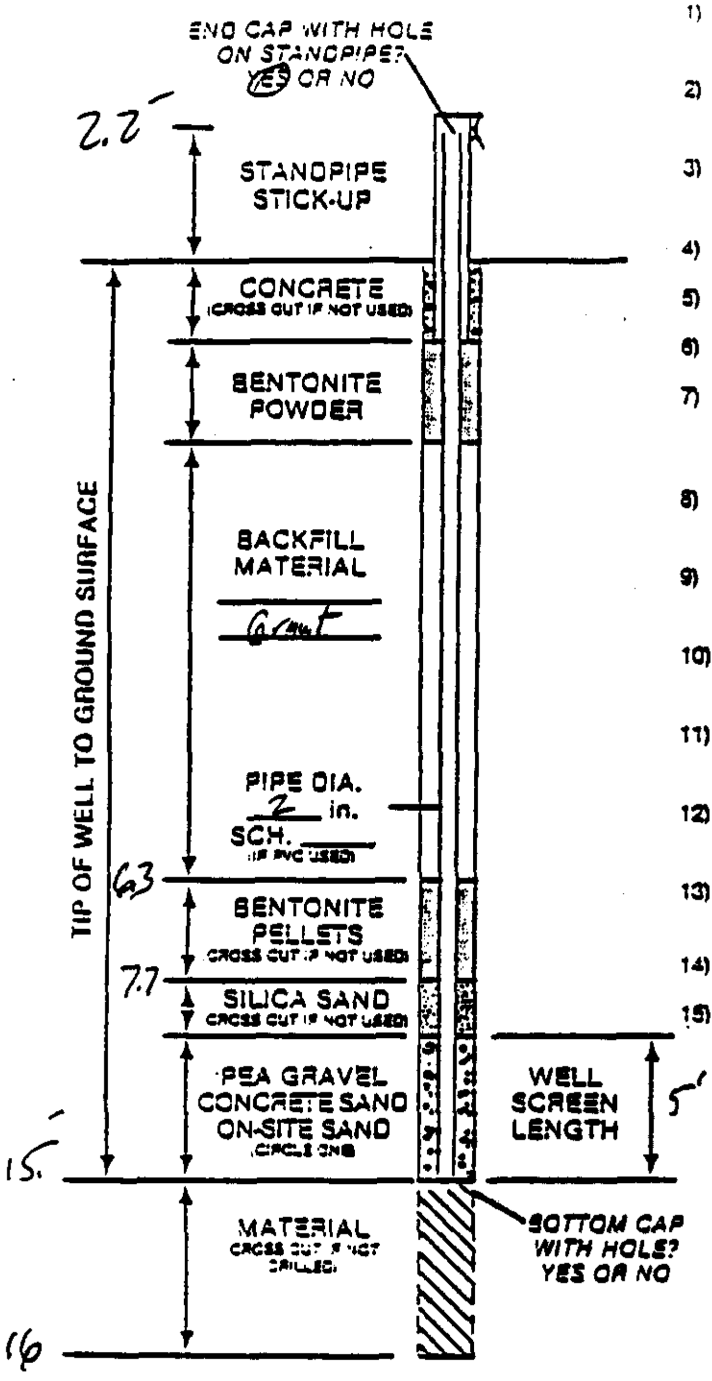
2) OTHER MEASUREMENTS:

DATE 10-8 . 3.7 Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE

Well No. P-87-22S DATE INSTALLED 9-24-87 DRILL RIG B-53
DRILLER O.H. DRILL CREW S.B.
JOB/CLIENT Arrowhead Refinery, CH2MHill STS JOB No. 94254
FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC] GALVANIZED, STAINLESS, OTHER ______

2) TYPE OF PIPE JOINTS?
[✓ BELLED], COUPLINGS, THREADED, OTHER ______

3) TYPE OF WELL SCREEN
[✓ PVC] GALVANIZED, STAINLESS, OTHER ______

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 1hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 180

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
17.2 Ft. or DRY

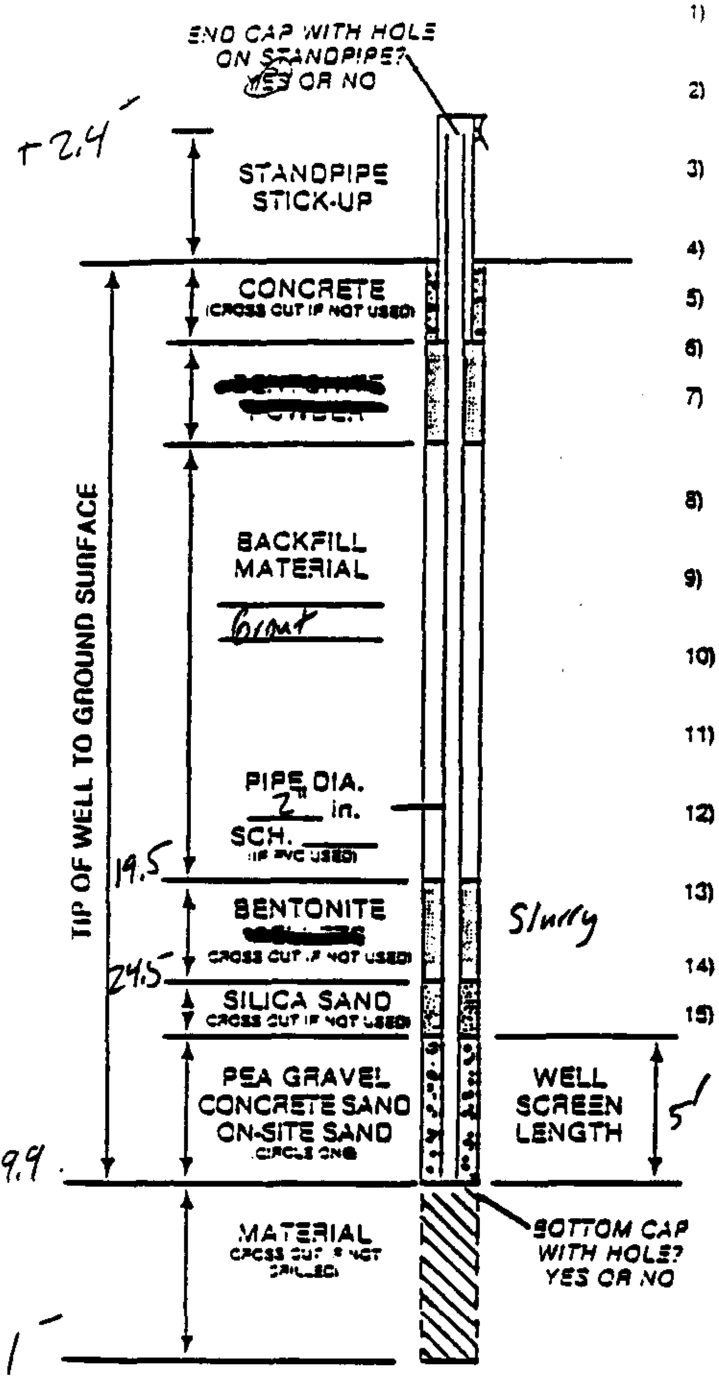
2) OTHER MEASUREMENTS:

DATE 10-8-87, 8.9 Ft. FROM T. ST. PIPE
DATE ______, ______ Ft. FROM T. ST. PIPE
DATE ______, ______ Ft. FROM T. ST. PIPE
DATE ______, ______ Ft. FROM T. ST. PIPE

Well No. P87 17S DATE INSTALLED 9-24-87 DRILL RIG CME75
DRILLER D.Z. DRILL CREW L.S.
JOB/CLIENT Arrowhead Refinery CH, Mill STS JOB No. 94259
[illegible] 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

2) TYPE OF PIPE JOINTS?
[✓ BELLED], COUPLINGS, THREADED, OTHER ________

3) TYPE OF WELL SCREEN
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 525

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
32.3 Ft. or DRY

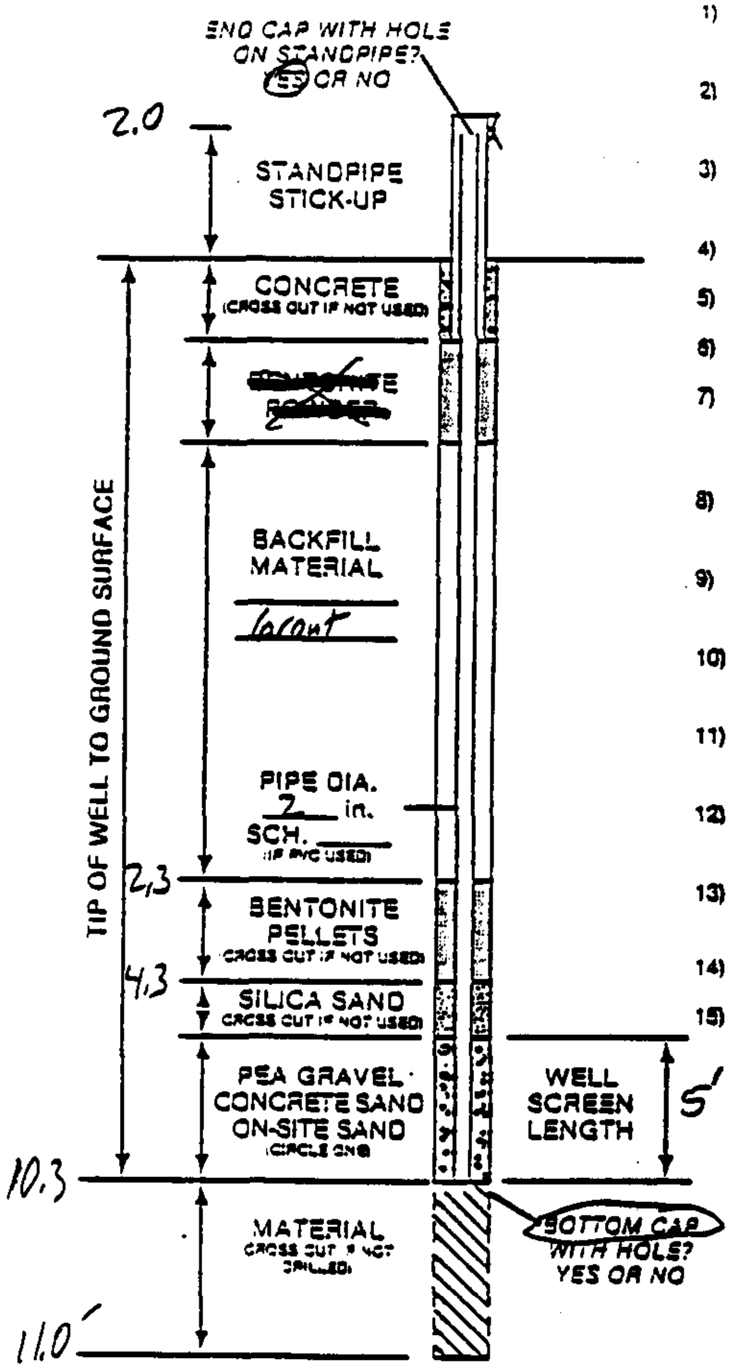
2) OTHER MEASUREMENTS:

DATE 10-8, 4.55 Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE

Well No. P-87-21-B DATE INSTALLED 9-23-87 DRILL RIG B-53
DRILLER D. H. DRILL CREW S.B.
JOB/CLIENT Arrowhead Refining, CH2M Hill STS JOB No. 94254
F/I 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



END CAP WITH HOLE ON STANDPIPE? [✓ YES] OR NO

BACKFILL MATERIAL locant

PIPE DIA. 2 in.

SCH. ____ (IF PVC USED)

WELL SCREEN LENGTH 5'

BOTTOM CAP WITH HOLE? YES OR NO

1) TYPE OF PIPE?
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

2) TYPE OF PIPE JOINTS?
[✓ BELLED], COUPLINGS, THREADED, OTHER ________

3) TYPE OF WELL SCREEN
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER],
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 3 hr

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER ≈ 20

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? [✓ YES] OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
________ Ft. or DRY

2) OTHER MEASUREMENTS:

DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE

Well No. P8705S DATE INSTALLED 10-14-87 DRILL RIG CME 75

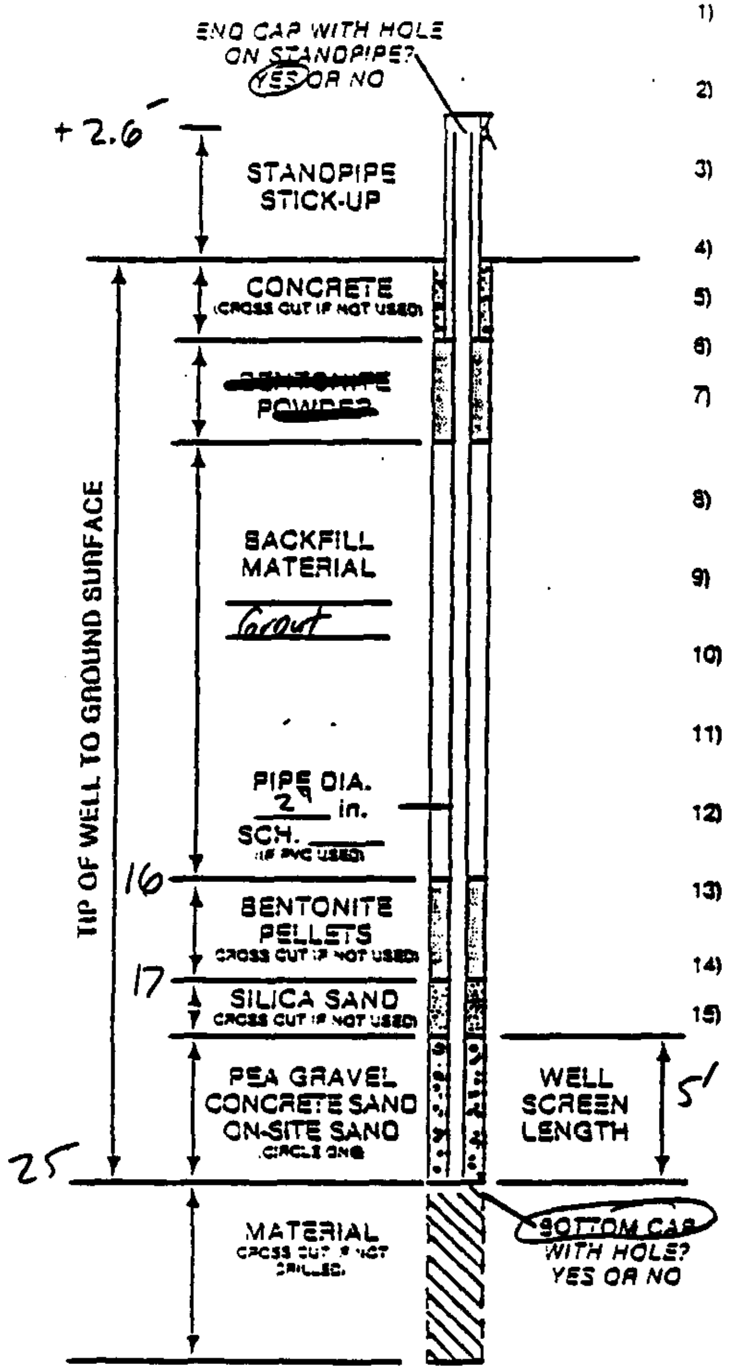
DRILLER DZ DRILL CREW DJ

JOB/CLIENT Arrowhead Refinery STS JOB No. 94254

F/N 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

2) TYPE OF PIPE JOINTS?
[✓ BELLED], COUPLINGS, THREADED, OTHER ________

3) TYPE OF WELL SCREEN
[✓ PVC], GALVANIZED, STAINLESS, OTHER ________

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER ≥30

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
27.6 Ft. or DRY

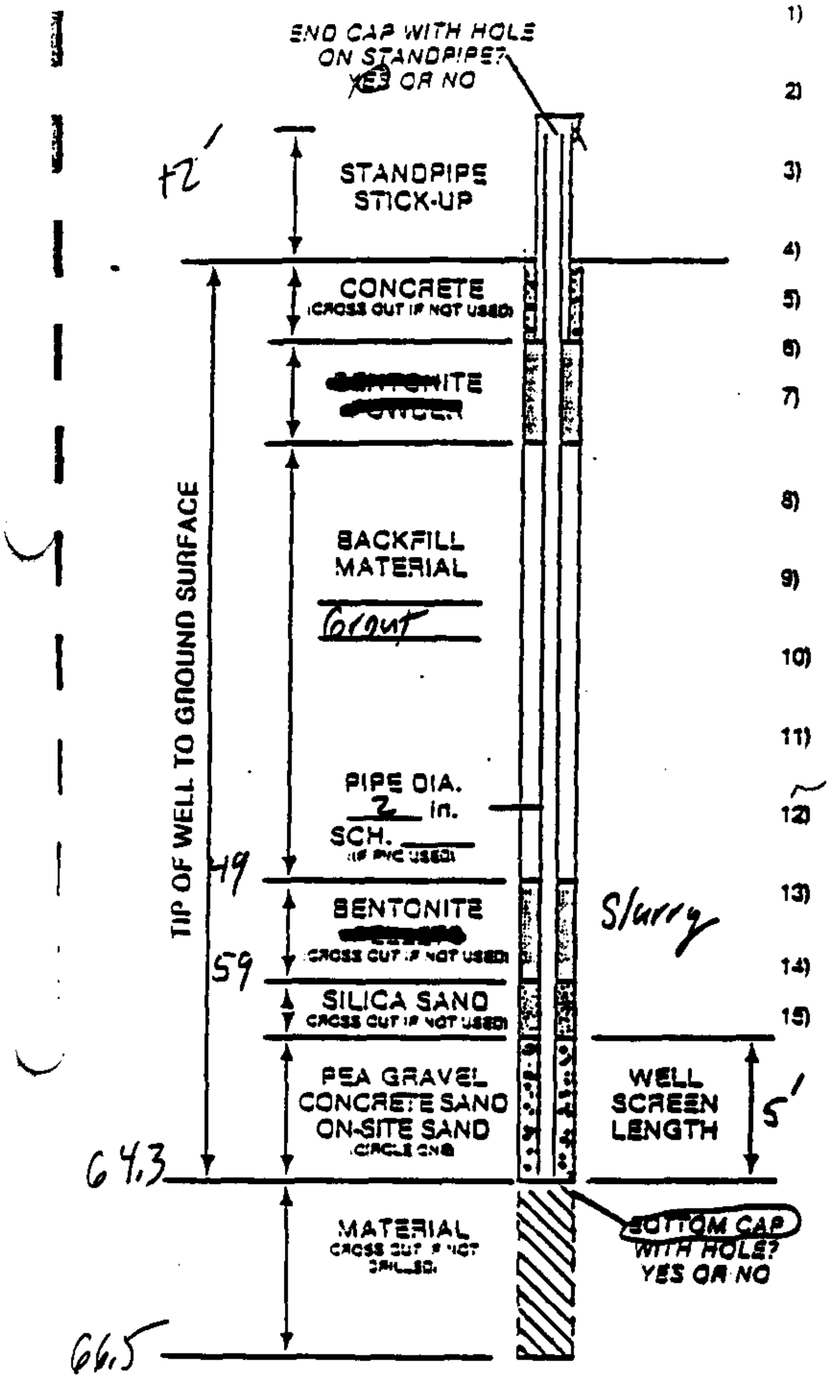
2) OTHER MEASUREMENTS:

DATE 10-8, 7.65 Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE

Well No. P87 16B DATE INSTALLED 9-15-87 DRILL RIG CME 75
DRILLER Hovland DRILL CREW Johnston
JOB/CLIENT Arrowhead Refinery STS JOB No. 94259
FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC. GALVANIZED. [✓ STAINLESS] OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED. COUPLINGS. [✓ THREADED] OTHER ______

3) TYPE OF WELL SCREEN
PVC. GALVANIZED. [✓ STAINLESS] OTHER ______

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER. HOLLOW STEM AUGER,
WATER, REVERT, [✓ BENTONITE] Not in Screen zone

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING] COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER ≚ 2 hr

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 10

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

2) OTHER MEASUREMENTS: Very Slow recharge

DATE 10/21 , 22.05 Ft. FROM T. ST. PIPE

DATE ______ , ______ Ft. FROM T. ST. PIPE

DATE ______ , ______ Ft. FROM T. ST. PIPE

DATE ______ , ______ Ft. FROM T. ST. PIPE

Well No. MW 87 18 E DATE INSTALLED 9-30-87 DRILL RIG CME 75

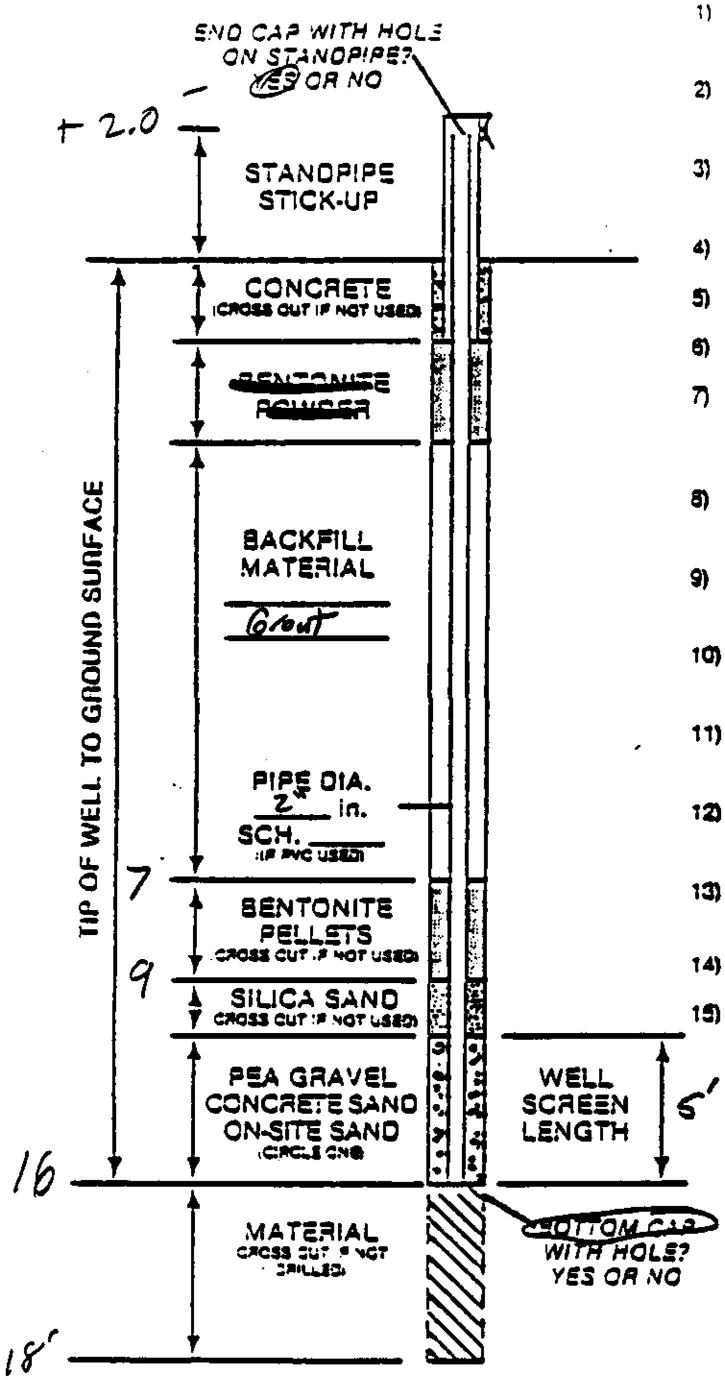
DRILLER D.Z. DRILL CREW L.S.

JOB/CLIENT Arrowhead Refinery, CH2M Hill STS JOB No. 94259

FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
[✓ PVC], GALVANIZED, STAINLESS, OTHER ______

2) TYPE OF PIPE JOINTS?
[✓ BELLED], COUPLINGS, THREADED, OTHER ______

3) TYPE OF WELL SCREEN
[✓ PVC], GALVANIZED, STAINLESS, OTHER ______

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? [✓ YES] OR NO

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER], WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2.5

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 25

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? [✓ YES] OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

2) OTHER MEASUREMENTS:

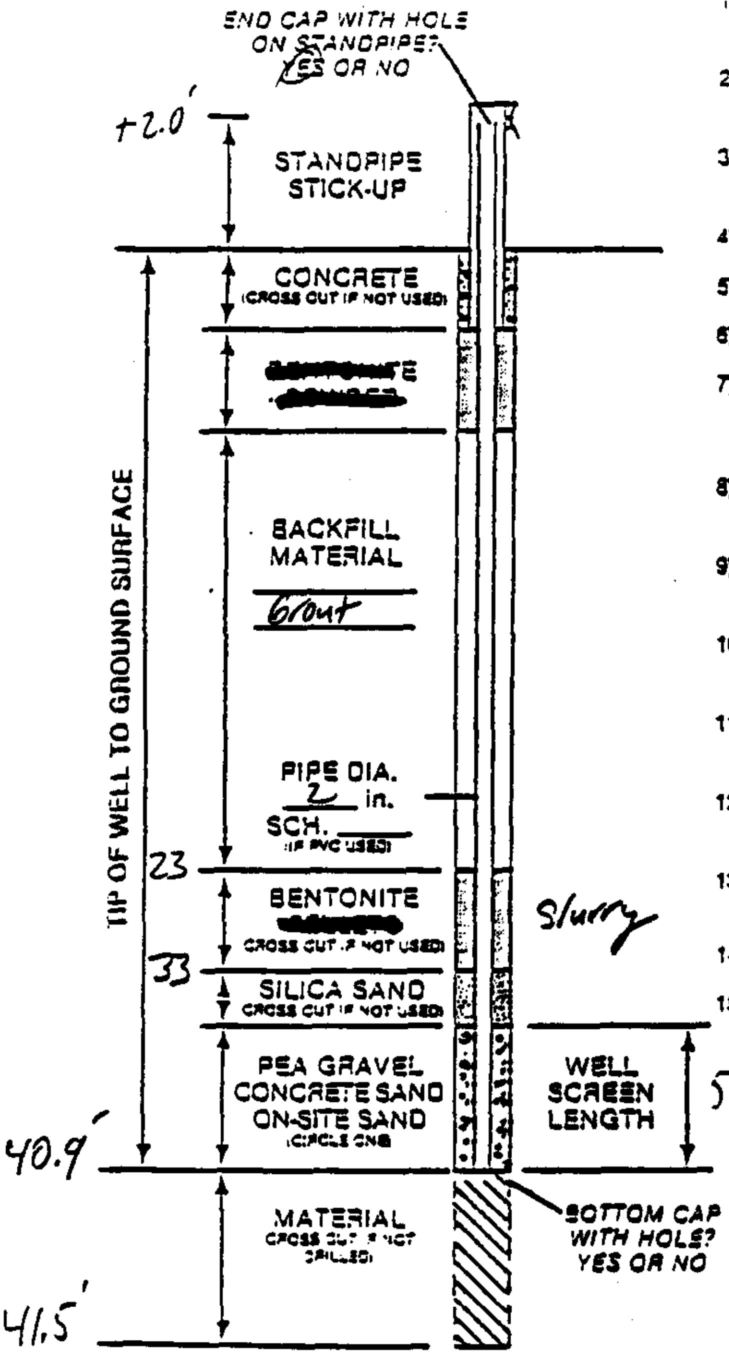
DATE ______ . ______ Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE
DATE ______ . ______ Ft. FROM T. ST. PIPE

050

Well No. P8705[illegible] DATE INSTALLED 10-9-87 DRILL RIG CME 45B
DRILLER D.Z. DRILL CREW L I
JOB/CLIENT Arrowhead Refinery STS JOB No. 94259
FW 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ________

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER],
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 100 gall

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
42.9 Ft. or DRY

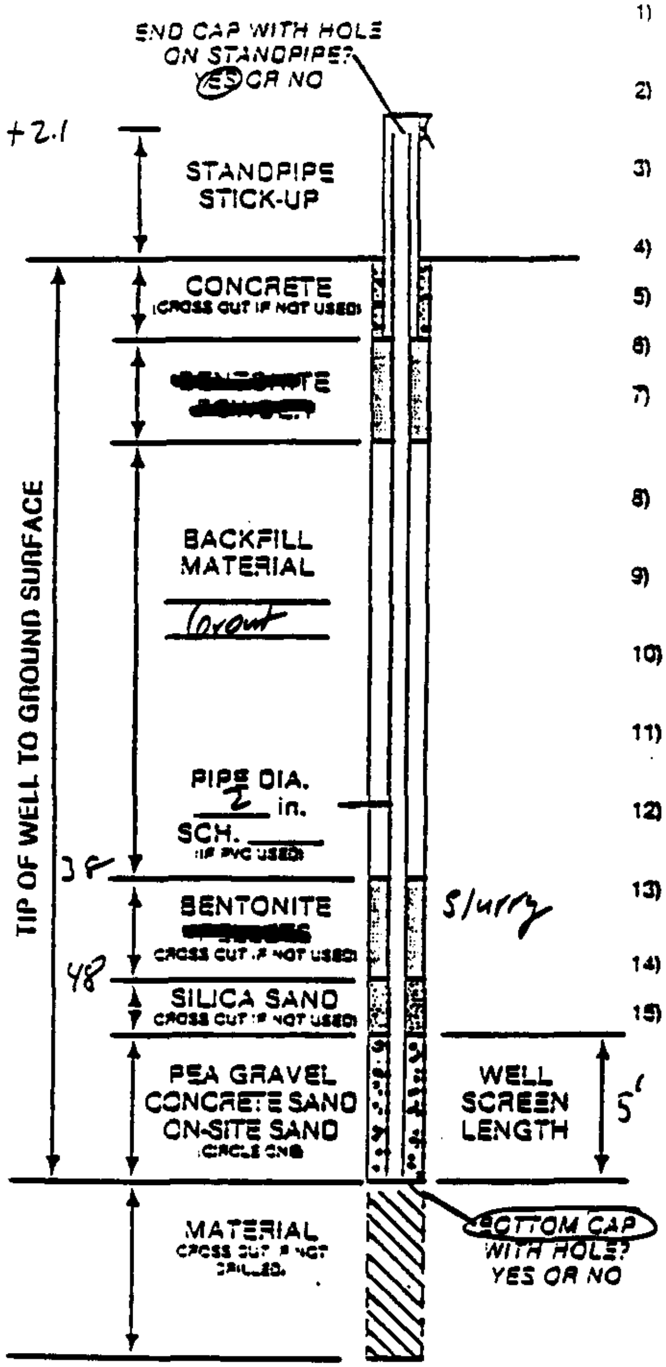
2) OTHER MEASUREMENTS:

DATE 10-8 . 9.4 Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE
DATE ________ . ________ Ft. FROM T. ST. PIPE

Well No. MW-87-17-13 DATE INSTALLED 9-23-87 DRILL RIG CME 75
DRILLER DZ DRILL CREW DJ + LS.
JOB/CLIENT Arrow head Refining STS JOB No. 94254
FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED] OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, HOLLOW STEM AUGER,
WATER, REVERT, [✓ BENTONITE] not in Screen zone

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2hr

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 80

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
582 Ft. or DRY

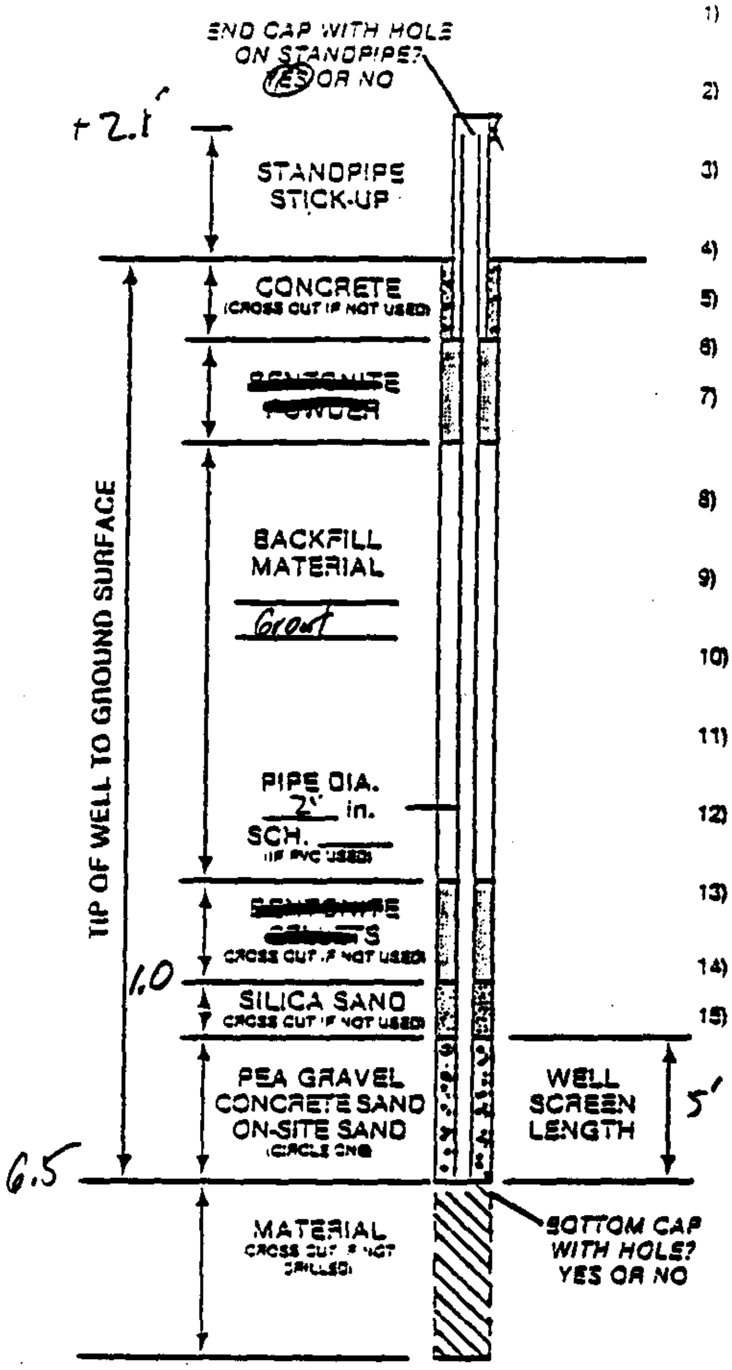
2) OTHER MEASUREMENTS:

DATE 10-22 , 8.6 Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE

Well No. MW87 17E DATE INSTALLED 9-26-87 DRILL RIG CME75
DRILLER DZ DRILL CREW L.S.
JOB/CLIENT Arrowhead Refinery STS JOB No. 94254
FW 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED] OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

4) SCREEN SIZE #10 slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
[✓ BAILING], PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 12

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? ~~YES OR~~ NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

2) OTHER MEASUREMENTS:

DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE

Well No. MW 87 14S DATE INSTALLED 9-26-87 DRILL RIG B-53

DRILLER Hoglund DRILL CREW Brisner

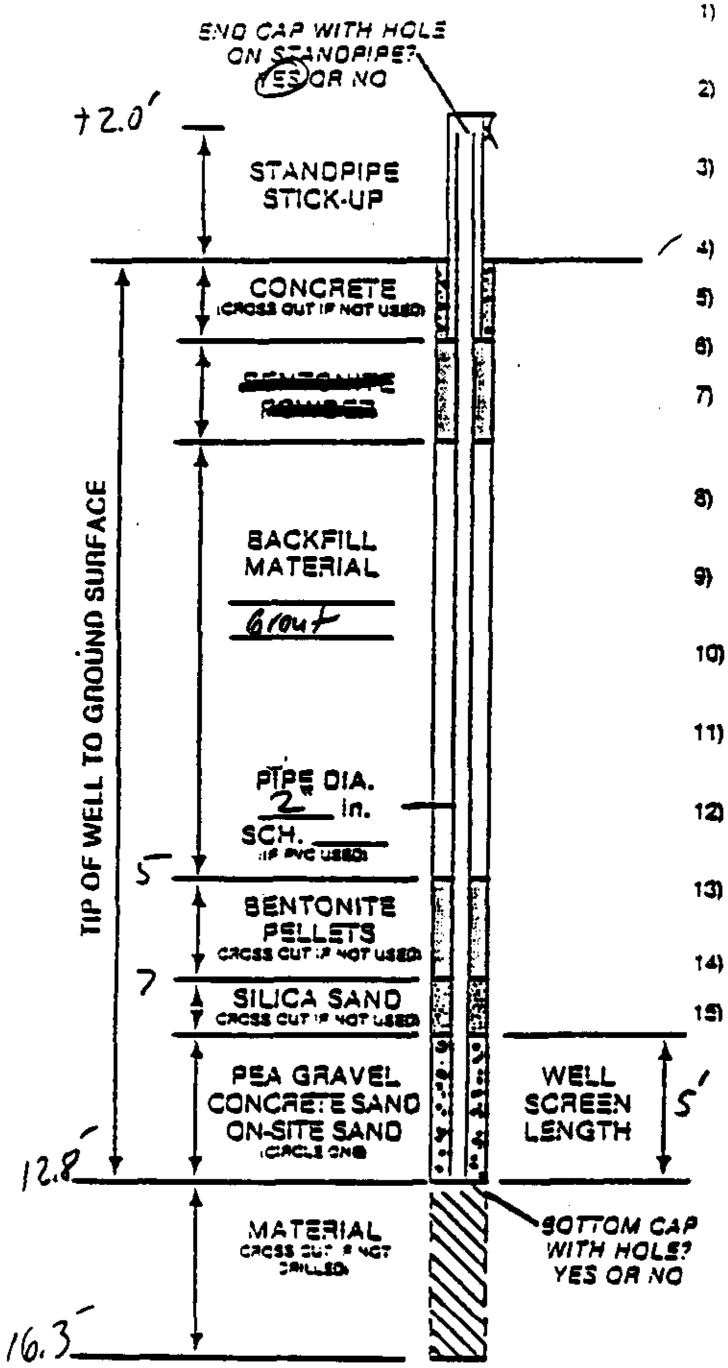
JOB/CLIENT Arrowhead Refining, CH2MHill STS JOB No. 94259

8'

F.W. 1-383

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS], OTHER ______

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER],
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER ≈ 20 gal

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
14.8 Ft. or DRY

2) OTHER MEASUREMENTS:

DATE ______ . ______ Ft. FROM T. ST. PIPE

DATE ______ . ______ Ft. FROM T. ST. PIPE

DATE ______ . ______ Ft. FROM T. ST. PIPE

DATE ______ . ______ Ft. FROM T. ST. PIPE

Well No. MW 8716S DATE INSTALLED 9-15-87 DRILL RIG CME 75

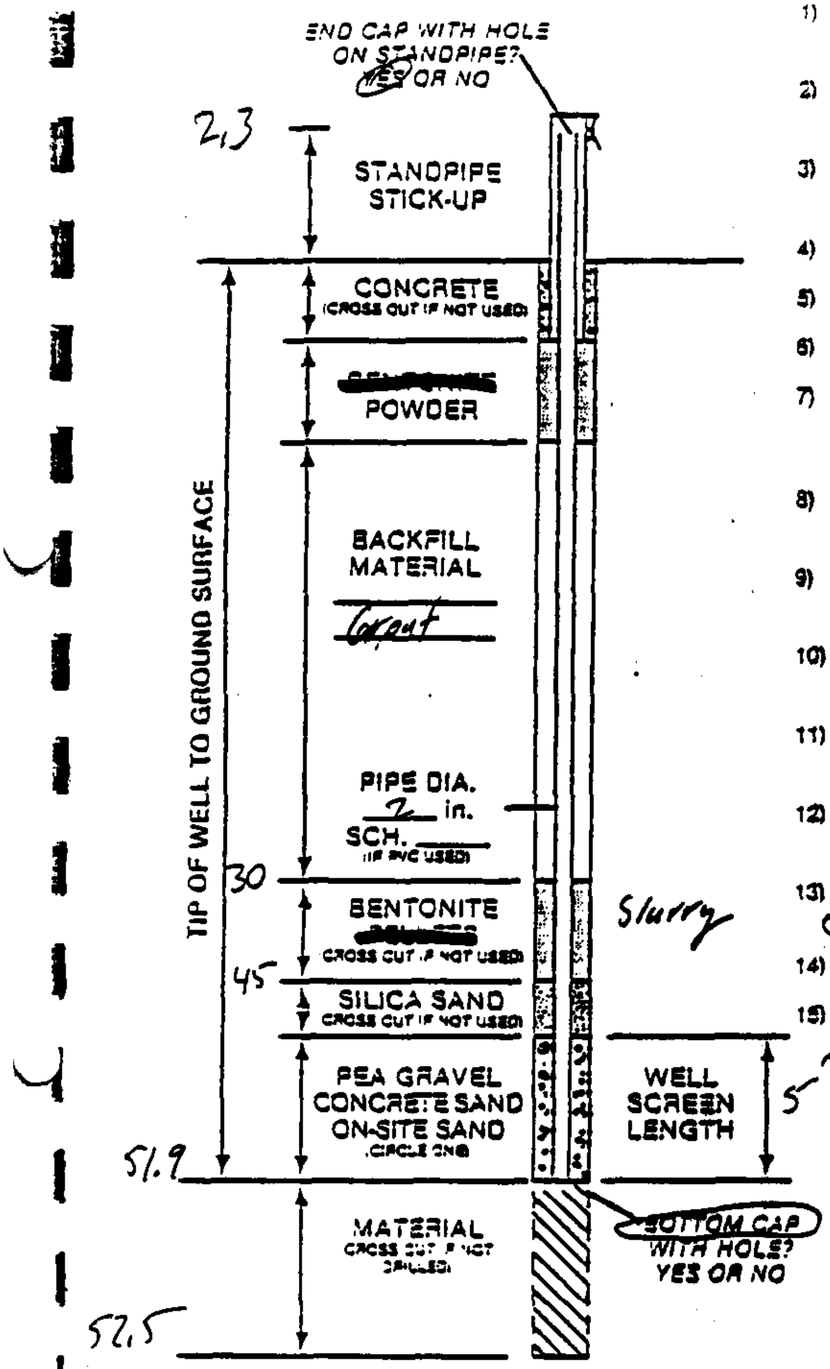
DRILLER Holland DRILL CREW Johnston

JOB/CLIENT Arrowhead Refinery STS JOB No. 94259

FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED] OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED? Yes
SOLID AUGER, HOLLOW STEM AUGER, WATER, REVERT, [✓ BENTONITE]

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
[✓ YES] OR NO

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], SURGING, COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 1,5

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 102

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

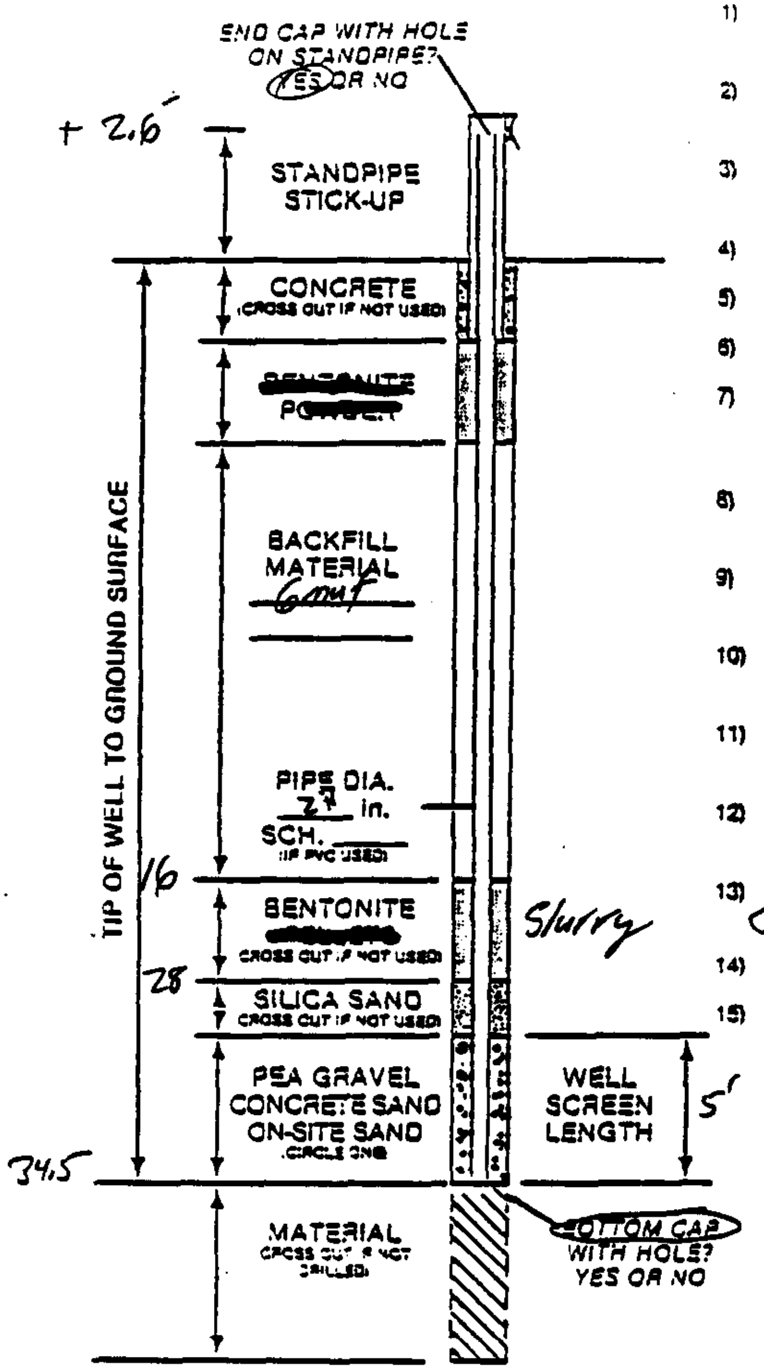
2) OTHER MEASUREMENTS:

DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE

Well No. MW 87 13 E DATE INSTALLED 10-9-87 DRILL RIG B-53
DRILLER Holland DRILL CREW Boisner
JOB/CLIENT Arrowhead CH2M Hill STS JOB No. 94259
FW 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



END CAP WITH HOLE ON STANDPIPE? [✓ YES] OR NO

BOTTOM CAP WITH HOLE? YES OR NO

1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ________

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED? yes
SOLID AUGER, HOLLOW ~~STEM~~ AUGER,
WATER, REVERT, [✓ BENTONITE]

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 3hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 66

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
37.1 Ft. or DRY

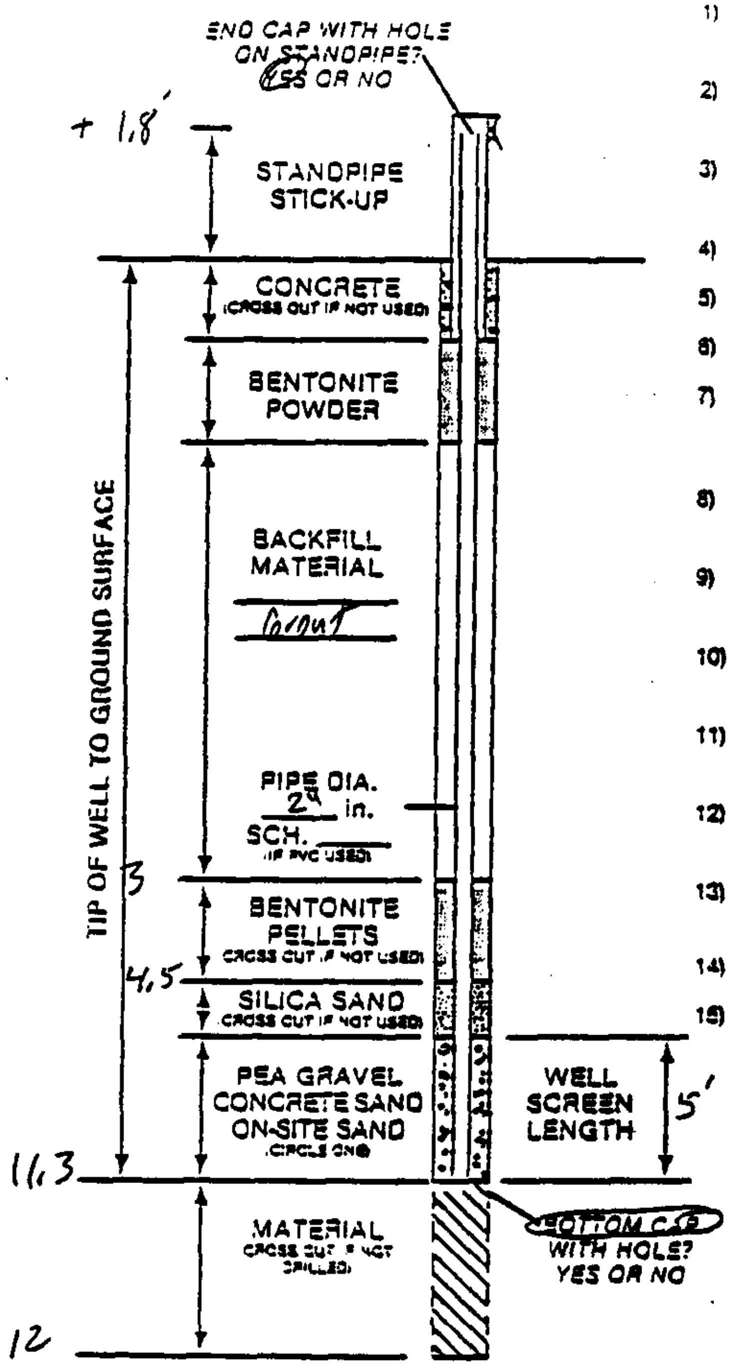
2) OTHER MEASUREMENTS:

DATE ________ , ________ Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE

Well No. MW 8713B DATE INSTALLED 10-13-87 DRILL RIG B-53
DRILLER Houland DRILL CREW Boisner
JOB/CLIENT Arrowhead CH2M Hill STS JOB No. 94259
FW 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS,] OTHER _______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED,] OTHER _______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS,] OTHER _______

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? YES OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, SURGING, COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 1

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 55

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID,] OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR,] TURBID, OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
_______ Ft. or DRY

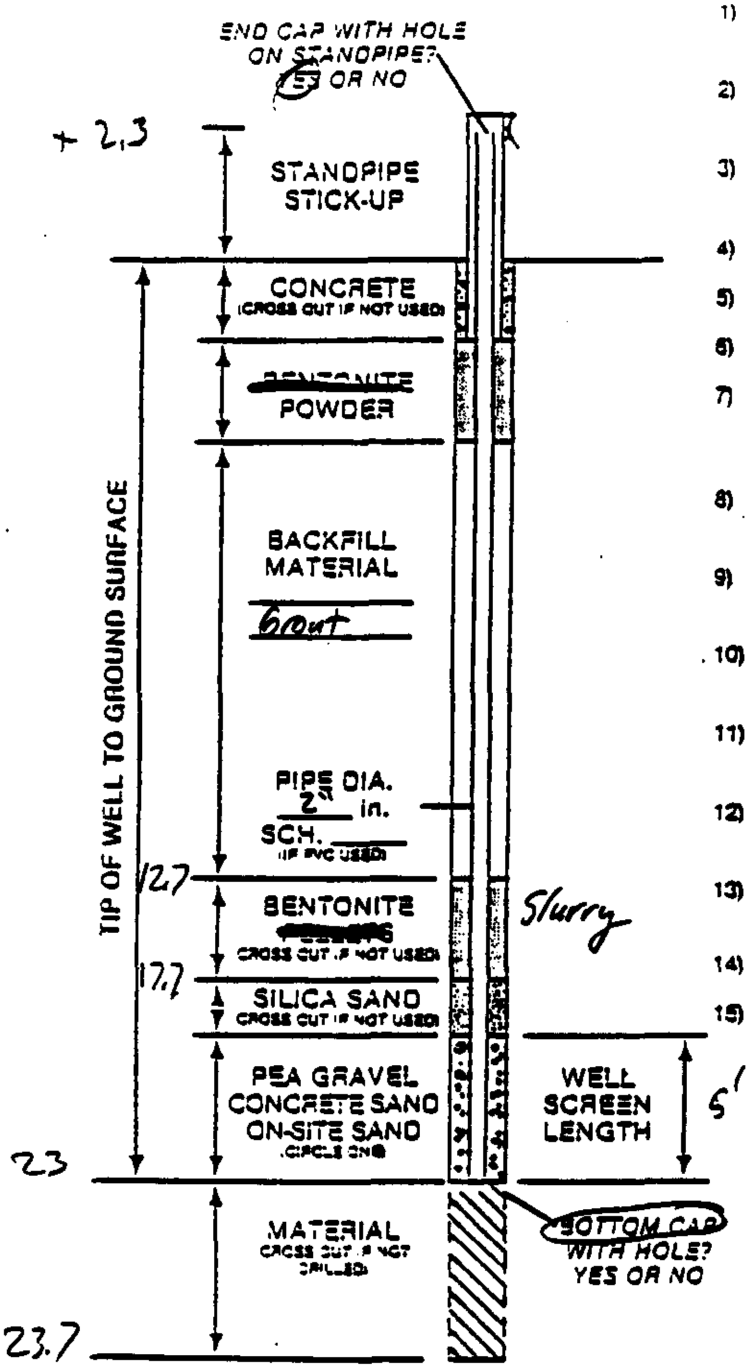
2) OTHER MEASUREMENTS:

DATE _______, _______ Ft. FROM T. ST. PIPE
DATE _______, _______ Ft. FROM T. ST. PIPE
DATE _______, _______ Ft. FROM T. ST. PIPE
DATE _______, _______ Ft. FROM T. ST. PIPE

Well No. MW 87-7S DATE INSTALLED 10-6-87 DRILL RIG CME 75
DRILLER D Z. DRILL CREW TI
JOB/CLIENT Arrowhead Refinery STS JOB No. 94259
FW 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS] OTHER ________

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED] OTHER ________

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ________

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER,]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, SURGING, COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 24hr

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 37

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR] TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR NO

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
25.3 Ft. or DRY

2) OTHER MEASUREMENTS:

DATE 10-22 , 6.6 Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE
DATE ________ , ________ Ft. FROM T. ST. PIPE

Well No. MW/878B DATE INSTALLED 9-28-87 DRILL RIG B-53

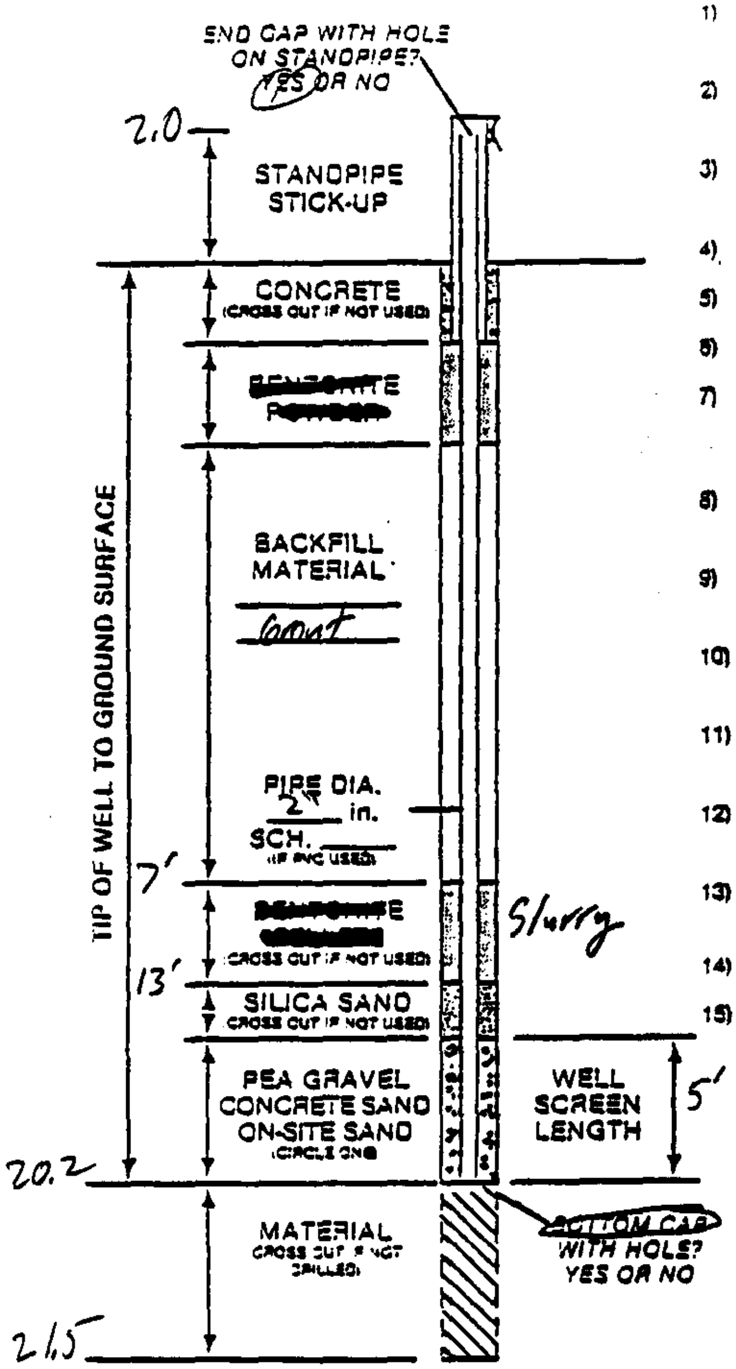
DRILLER OH DRILL CREW SB

JOB/CLIENT Arrowhead Refinery CH2MHill STS JOB No. 94259

F.W. 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ______

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED? NO
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 20 min

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 28

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR [✓ NO]

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

2) OTHER MEASUREMENTS:

DATE 10-22 , 3.9 Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE

58

Well No. MW 8705 B DATE INSTALLED 10-12-87 DRILL RIG CME 75

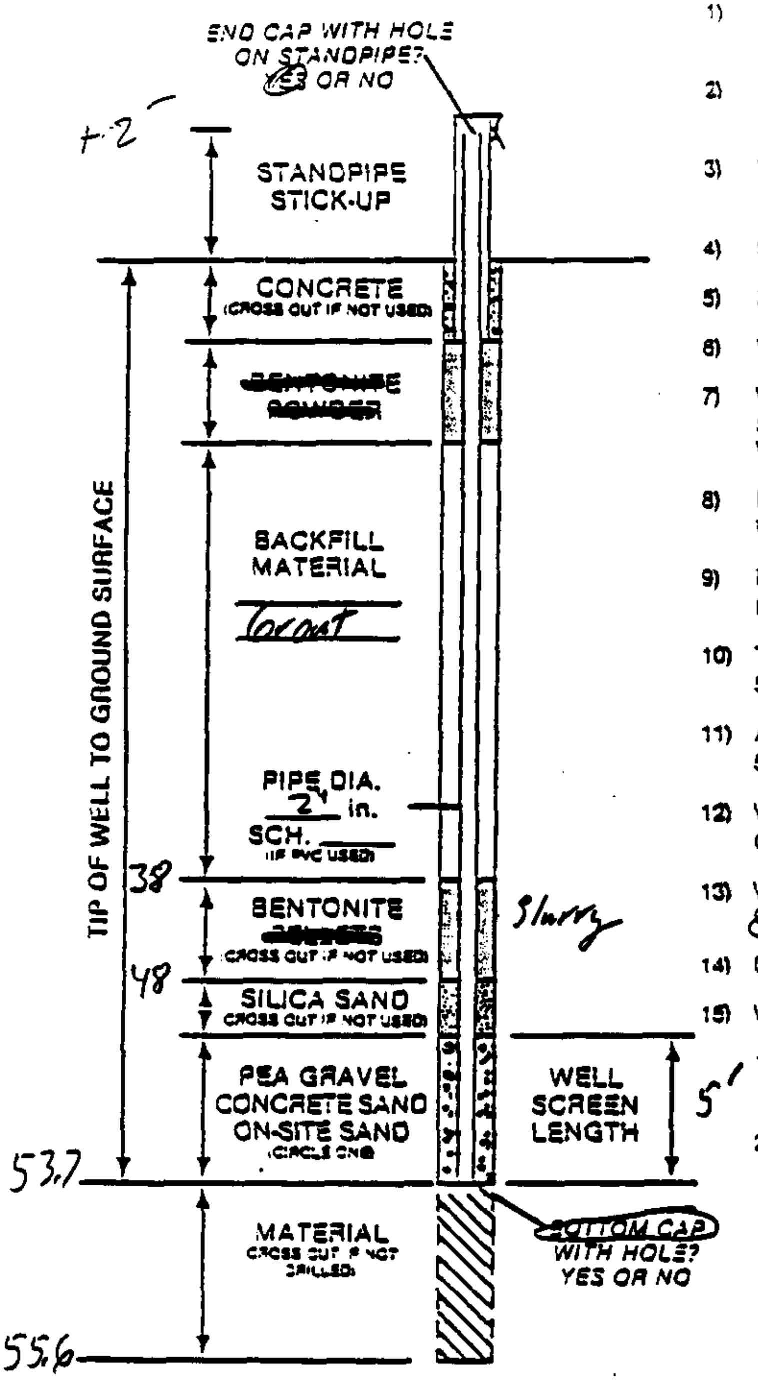
DRILLER DZ DRILL CREW DJ

JOB/CLIENT Arrowhead Refinery, CH2M Hill STS JOB No. 94259

F/I 1983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ______

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS], OTHER ______

4) SCREEN SIZE #10

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, HOLLOW STEM AUGER,
WATER, REVERT, [✓ BENTONITE]

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
[✓ YES] OR NO

9) HOW WAS WELL DEVELOPED?
BAILING, [✓ PUMPING], [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 3 hr.

11) APPROXIMATE WATER VOLUME [✓ REMOVED] OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 86

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER CLARITY AFTER DEVELOPMENT?
[✓ CLEAR], TURBID, OPAQUE

14) DID THE WATER SMELL? YES OR [✓ NO]

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
______ Ft. or DRY

2) OTHER MEASUREMENTS:

DATE 10-22 , 3.6 Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE
DATE ______ , ______ Ft. FROM T. ST. PIPE

Well No. MW 87 05E DATE INSTALLED 10-10-87 DRILL RIG CME75

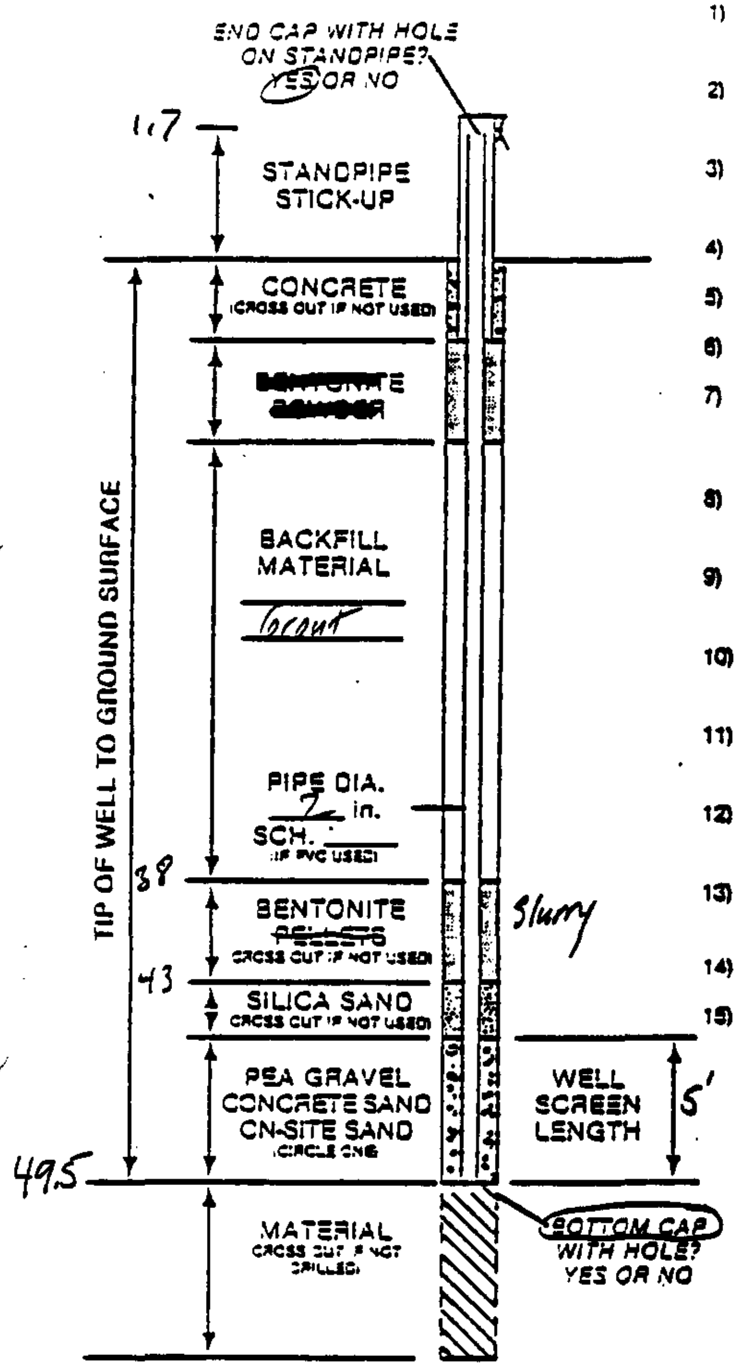
DRILLER DZ DRILL CREW DH

JOB/CLIENT Arrowhead Refinery CH2MHill STS JOB No. 94259

F.J 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED], OTHER ______

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS], OTHER ________

4) SCREEN SIZE #10 Slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, HOLLOW STEM AUGER,
WATER, REVERT, [✓ BENTONITE]

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING], COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2 hr

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., [✓ 10 gal.], 15 gal., OTHER ________

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

13) WATER ~~CLARITY~~ AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? YES OR [✓ NO]

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
—— Ft. or DRY

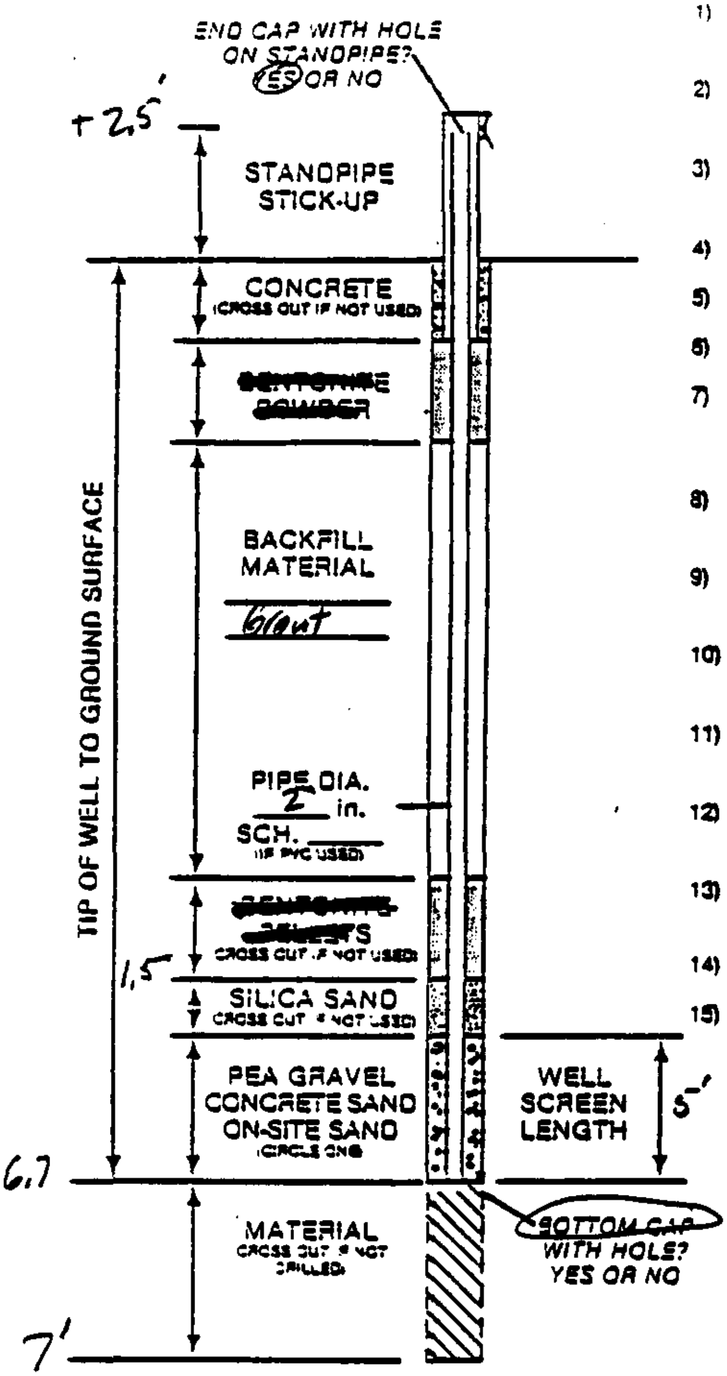
2) OTHER MEASUREMENTS:

DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE

Well No. MW 87-2-E DATE INSTALLED 10-23-87 DRILL RIG 53
DRILLER Harland DRILL CREW Boisner
JOB/CLIENT Arrowhead Refinery CH2M Hill STS JOB No. 94259
FW 1-983

STS Consultants Ltd.

FIELD WELL INSTALLATION DIAGRAM



1) TYPE OF PIPE?
PVC, GALVANIZED, [✓ STAINLESS] OTHER ________

2) TYPE OF PIPE JOINTS?
BELLED, COUPLINGS, [✓ THREADED] OTHER ________

3) TYPE OF WELL SCREEN
PVC, GALVANIZED, [✓ STAINLESS] OTHER ________

4) SCREEN SIZE 10 slot

5) INSTALLED PROTECTOR PIPE W/LOCK? [✓ YES] OR NO

6) WAS SOLVENT USED? YES OR [✓ NO]

7) WAS DRILLING MUD USED?
SOLID AUGER, [✓ HOLLOW STEM AUGER]
WATER, REVERT, BENTONITE

8) DID STANDPIPE COME UP WHEN CASING WAS PULLED?
YES OR [✓ NO]

9) HOW WAS WELL DEVELOPED?
BAILING, PUMPING, [✓ SURGING] COMPRESSED AIR

10) TIME SPENT FOR WELL DEVELOPMENT?
5 min., 15 min., 30 min., OTHER 2hrs

11) APPROXIMATE WATER VOLUME REMOVED OR ADDED?
5 gal., 10 gal., 15 gal., OTHER 6.5

12) WATER CLARITY BEFORE DEVELOPMENT?
CLEAR, TURBID, [✓ OPAQUE]

13) WATER CLARITY AFTER DEVELOPMENT?
CLEAR, [✓ TURBID], OPAQUE

14) DID THE WATER SMELL? ~~YES OR NO~~

15) WATER LEVEL SUMMARY

1) DEPTH FROM T. STANDPIPE AFTER DEVELOPMENT?
— Ft. or DRY

2) OTHER MEASUREMENTS:

DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE
DATE ________, ________ Ft. FROM T. ST. PIPE

Well No. MW-87-3S DATE INSTALLED 9-25-87 DRILL RIG B-53
DRILLER Harland DRILL CREW Boisner
JOB/CLIENT Arrowhead Refining STS JOB No. 94259
FW 1-983

TM 3--MONITORING WELL AND PIEZOMETER INSTALLATION

Attachment B
WELL INSTALLATION INFORMATION

CH2M HILL

PROJECT NUMBER

BORING NUMBER P-87-225

SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION FIELD 1/4 MILE S.W. OF OFFICE

ELEVATION ________ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER (4 3/8" ID)

WATER LEVEL AND DATE ________ START 9/25/87 FINISH 9/25/87 LOGGER GERALD A. MSLAN

	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
DEPTH BELOW SURFACE (FT)	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
0			20"	1,3,3,4	Peat + clay, minor sand + gravel, lower 6" contains more clay than peat	0.0 Hnu damp
2			14"	4,6,5,4	0-8" brownish silty clay with some sand + gravel 8"-6" sandy clay with several clean sand lenses 1.0" thick, trace gravel, sand is med. grained	damp 0.0Hnu ▼ 3.5' Saturated
4			20"	10,15,16,18	0-4" reddish brown silty sandy clay 4"-12" reddish brown silty sand, minor gravel sand is med. to coarse grained 12"-20" red clay with some silt + med. gr. sand	0.0ppm Hnu Saturated
6			24"	19,12,12,11	0-6" brown silty sand with some gravel, sand is med to coarse grained. 6"-24" brownish red clayey silt with trace fine to med gr. sand	0.0ppm Hnu saturated
8			24"	11,11,10,11	0-2" peaty red clay 2"-24" brown clayey silt with trace fine to med. gr. sand	0.0ppm Hnu saturated
10			24"	12,14,16,16	0-6" brown silty clay, clayey silt with trace very fine gr. sand 6"-10" brown silty sand with trace gravel, sand is med to coarse grained 10"-24" brown clayey silt with some med. gr. sand	0.0ppm Hnu saturated
12					end of boring @ 12.0'	

PROJECT NUMBER

BORING NUMBER P-87-21B SHEET 3 OF 3

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION FIELD 1/4 MILE S.W. OF OFFICE

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA ~ 3 1/4" ID FOR SAMPLING ~ 4 3/8" ID FOR PIEZOM. CONSTR.

WATER LEVEL AND DATE START 9/23/87 FINISH 9/24/87 LOGGER GERALD A. MCLANE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
28			12"	13,15,17,19	top 8" - reddish brown sand, trace silt + gravel, sand predom. med. gr., lower 4" brownish grey clay with minor silt, sand + gravel	0.0ppm Hnu saturated
30	30-30.5'		6"	100,X,X,X	brown sand, minor silt + gravel ~ sand is med to coarse grained. hit boulder at 30.5'	refusal at 30.5' saturated
32					Bottom of hole 30.5'	

CH2M HILL

PROJECT NUMBER

BORING NUMBER P-87-21B SHEET 1 OF 3

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION FIELD ¼ MILE S.W. OF OFFICE

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA - 3¼" ID FOR SAMPLING — REAMED w/ 4⅝" ID FOR PIEZOM

WATER LEVEL AND DATE START 9/23/87 FINISH 9/24/87 LOGGER GERALD A McLAN

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0-2'		18"	8,8,9	silty sand, sandy silt with minor gravel, brown — lower 3" is peat	damp 0.0 hnu
2	2-4'		4"	6,4,4,4	peat with trace fine-med. gr. sand	large chunk of wood plugging spoon + preventing full recovery damp 0.0 hnu
4	4-6'		13"	3,4,6,6	top 3" peat middle 4" black organic rich silty clay lower 6" grey clay, trace silt + fine sand trace gravel	0.0 ppm hnu
6	6-8'		12"	WEIGHT OF HAMMER ↓ ↓ X,X,3,6	bluish grey clay — trace silt sample very organic rich (15-20%) organic matter interspersed throughout sample	0.0 ppm Hnu ▼ 7.0 water on spoon
8	8-10'		20"	9,10,11,11	upper 14" - peaty reddish brown clay grading into brown silty clay lower 6" silty sand, brown, sand is predom. med gr.	0.0 ppm Hnu. saturated
10	10-12'		22"	11,8,8,9	brown clayey silt, trace very fine grained sand - no gravel	0.0 ppm Hnu. saturated
12	12-14'		19"	8,10,22,25	top 12" brown clayey silt, silty clay with trace fine sand lower 7" brown - silt, clay, fine to med. grained sand evenly distributed, trace gravel	0.0 ppm Hnu saturated
14						

CH2M HILL

PROJECT NUMBER

BORING NUMBER P-87-21B SHEET 2 OF 3

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION FIELD 1/4 MILE S.W. OF OFFICE

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA ~ 3¼" ID FOR SAMPLING ~ REAMED WITH 4⅜" ID FOR PIEZOM. CONSTR.

WATER LEVEL AND DATE START 9/23/87 FINISH 9/24/87 LOGGER GERALD A. McLANE

DEPTH BELOW SURFACE (FT)	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY (INCHES)	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
14			15"	10 11 27 50	brown sandy silt, some clay + gravel, some wood fragments, sand ranges from fine to coarse but is predom. med gr.	0.0 ppm Hnu saturated
16			17"	12 18 21 23	brown silty sand, sandy silt with gravel (15%-20%), trace clay, sand is med.-coarse grained, trace fine gr.	0.0 ppm Hnu saturated
18			15"	11 16 20 21	brown sandy silt—sand is fine to med. grained—less sand + gravel than previous interval (16'-18'), ≈ 10% gravel	0.0 ppm Hnu saturated
20			2"		2" of basalt fragment stuck in mouth of spoon	saturated
22			12"	13 12 13 16	brown silty sand, some gravel (≈15%), sand is fine to coarse gr. but predom. med gr.	0.0 ppm Hnu saturated
24			12"	8 10 12 15	brown sandy silt, silty sand, some gravel (≈10%) sand predom. fine to med grained, some coarse gr.	0.0 ppm Hnu saturated
26			14"	10 13 13 16	sand + gravel evenly distributed, some silt ≈ 5-10%, sand is med. to very coarse gr., minor fine gr.	0.0 ppm Hnu saturated
28						

CH2M HILL

PROJECT NUMBER	BORING NUMBER	SHEET 1 OF 2
	P-87-195	

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION Just South of Gopher oil

ELEVATION ______ DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HOLLOW STEM AUGER (4¼" ID)

WATER LEVEL AND DATE ______ START 9/26/87 FINISH 9/27/87 LOGGER GERALD A. McLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0			16"	2,3,2,3	grey clayey silt, silty clay-mottled brown, minor sand + peat-sand is med. gr		0.0 ppm Hnu
	2			18"	3,3,4,5	grey silty clay - trace very fine grained sand - some roots		0.0 ppm Hnu
	4			24"	3,3,8,12	top 12" silty clay, clayey silt, brown mottled grey some sand (fine to med. gr.) lower 12" sandy silt, some clay in matrix sand gets coarser downwards - lower 6" of this interval contains some gravel		0.0 ppm Hnu
	6			6"	16,12,19,17	Dark brown clayey silt, silty clay some fine to med. gr sand, minor gravel		0.0 ppm Hnu ▼ water on spoon at 7.0'
	8			12"	16,16,19,21	reddish brown sandy silty clay, some gravel - sand is med. to coarse grained - minor fine gr. sand		0.0 ppm Hnu
	10			6"	11,11,15,18	same as above - minimal recovery		
	12			18"		brownish grey silt, trace fine to med. gr. sand		
	14							

CH2M HILL

PROJECT NUMBER

BORING NUMBER P-87-195 SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY LOCATION Just SOUTH OF ARROWHEAD REFINERY

ELEVATION DRILLING CONTRACTOR STS

DRILLING METHOD AND EQUIPMENT HSA (4 3/8" ID)

WATER LEVEL AND DATE START 9/26/87 FINISH 9/27/87 LOGGER GERALD A McLANE

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14			22"	16 12 12 13	brownish grey clayey silt lower 10" contains minor med. gr. sand + gravel		0.0ppm Hnu
	16			18"	21 23 18 20	top 10" brownish grey silt, minor clay + sand (med. gr.) some gravel lower 8" brown sandy silt with some gravel, sand is fine to med. grained		0.0ppm Hnu
	18			6"	10 32 24 27	grey silt, some gravel, trace clay + med. grained sand		rock frag. in mouth of spoon 0.0ppm. Hnu
	20			15"		brown sandy silt, some clay in matrix, some gravel, sand ranges from medium to very coarse grained.		0.0ppm Hnu
	22			8"	33 114 X X	same as above		
						spoon + auger refusal at 22.5 — hole abandoned because hydraulic oil line blew + spilled oil + in part because target unit was not encountered		

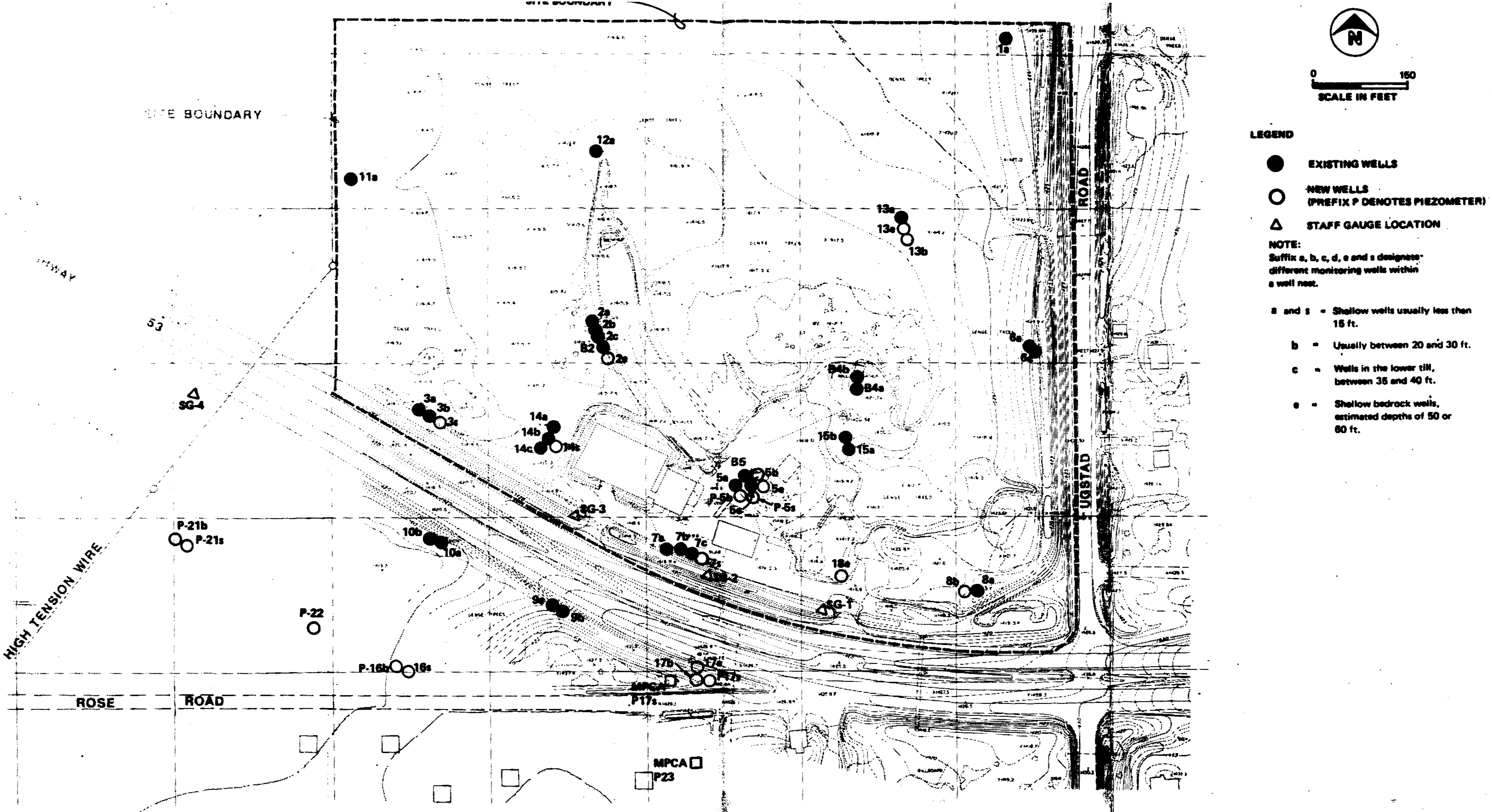


FIGURE TM 5-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

from rock cores. Coring was started at depths based upon previous drilling and the results of the seismic survey.

The till was identified mainly by the descriptive logs and the standard penetration results. It is characterized by high blow counts (more than 40 blows/foot) and poorly sorted sediments generally consisting of grain sizes ranging from clays to fine sand. Blow counts were usually less than 20 blows/foot. The lacustrine sediment also contain sand and gravel lenses up to 7 feet thick.

The lacustrine sediments are generally composed of well sorted, fine grained sediments, ranging from clay to fine sand. Blow counts were usually less than 20 blows/foot. The lacustrine sediments also contain sand and gravel lenses up to 7 feet thick.

Two sand layers were identified within the lacustrine sediments beneath the southern portion of the site (see Figures TM5-2 and TM5-3). The upper sand layer, referred to as Sand Unit A, is observed at Well Nests 5 (Well MW-5e only), 7, 9, 10, 15, 17, and 21, and at Wells MW-1a, MW-12a, and MW-18e. The extent of this sand lens is shown in Figure TM5-4. The sand observed in Wells MW-1a and MW-12a appears to be a separate lens. Sand Unit A occurs at an elevation of 1,410 feet above msl. The lower sand layer, referred to as Sand Unit B, is seen in Well Nests 3, 5, 7, 8, 9, 14, 15, and 17 (only 5 inches), at Well MW-18e, and possibly at Well Nests 10 and 21. This unit occurs at an elevation between 1,400 and 1,405 feet above msl. Sand Unit B is seen in the cross sections in Figures TM5-2 and TM5-3, and its extent is indicated in Figure TM5-5.

Other sands were observed within the lacustrine sediments in some of the wells, but apparently they are not continuous.

Peat was observed in most of the wells. Where it was not, it was probably removed during surface activities, such as road construction. A layer of fill overlies the peat in a number of locations.

logs that may relate to the top of the till are Wells MW-2e, MW-6c, MW-13e, MW-17e, and MW-18e.

A layer interpreted as clay was detected in eight wells (Nos. MW-2c, MW-6c, MW-9b, MW-10b, MW-11a, MW-12a, MW-14c, and MW-15b). The layer is identified by a count rate of 25 to 30 cps, or about twice the level of the other soils. It was observed at an elevation between 1,405 and 1,410 feet above msl in a number of wells, but was not observed in all intervening wells. The clay has apparently not formed a continuous layer beneath the site. A clay layer is interpreted in the gamma log for Well MW-2c, but was not observed in the log for Well MW-2e just a few feet away. Clay was not always identified in the soil log at the location of the high gamma count.

Bedrock was reported in the descriptive logs for Wells MW-2e, MW-5e, MW-13e, MW-17e, and MW-18e. The gamma count rates in Wells MW-2e, MW-17e, and MW-18e drop sharply to less than 5 cps at the reported bedrock contact. The soil log for Well MW-13e identifies the top of bedrock at a depth of about 40 feet below the surface, covered by about 4 feet of weather bedrock (to 36 feet below the surface). The gamma log for Well MW-13e shows a decrease in the gamma count rate (from 15 to 10 cps) at a depth of 35 feet and another slight decrease (to 8 cps) at a depth of 50 feet. It does not have the sharp decrease apparent in the other bedrock wells. The gamma log for Well MW-5e exhibits no decrease at the reported bedrock contact. A 1.5-foot-thick gamma low at a depth of 46 feet below the surface may be due to a boulder or the bedrock. The absence of low gamma counts in the bedrock at Wells MW-5e may have been terminated in a boulder zone rather than in bedrock. No rock cores were obtained to determine the nature of the bedrock reported on the driller's log for Well 5e.

Well 5e was logged twice; once before it had been developed, and once after development. This was done to determine if the drilling mud had any effect on the log. No significant differences were observed.

CORRELATION OF LITHOLOGIC UNITS BETWEEN WELLS

The lithology at each well was interpreted from available information for each well, including the descriptive log, the gamma log, and the standard penetration test results from driving the split spoon. The lithologic units that have been tentatively identified are (from the bottom up) bedrock, till, lacustrine sediments, peat, and fill. Figures TM5-2 and TM5-3 show the lithologic cross sections. Gamma logs and corresponding lithologic logs are included in Attachment A.

Top of bedrock was identified from the geophysical logs and from drilling activities. Auger refusal was used to indicate the top of bedrock in borings drilled during the RI investigation. Boulders in the till may have caused auger refusal above the bedrock. In the drilling performed for this design investigation, top of bedrock was identified

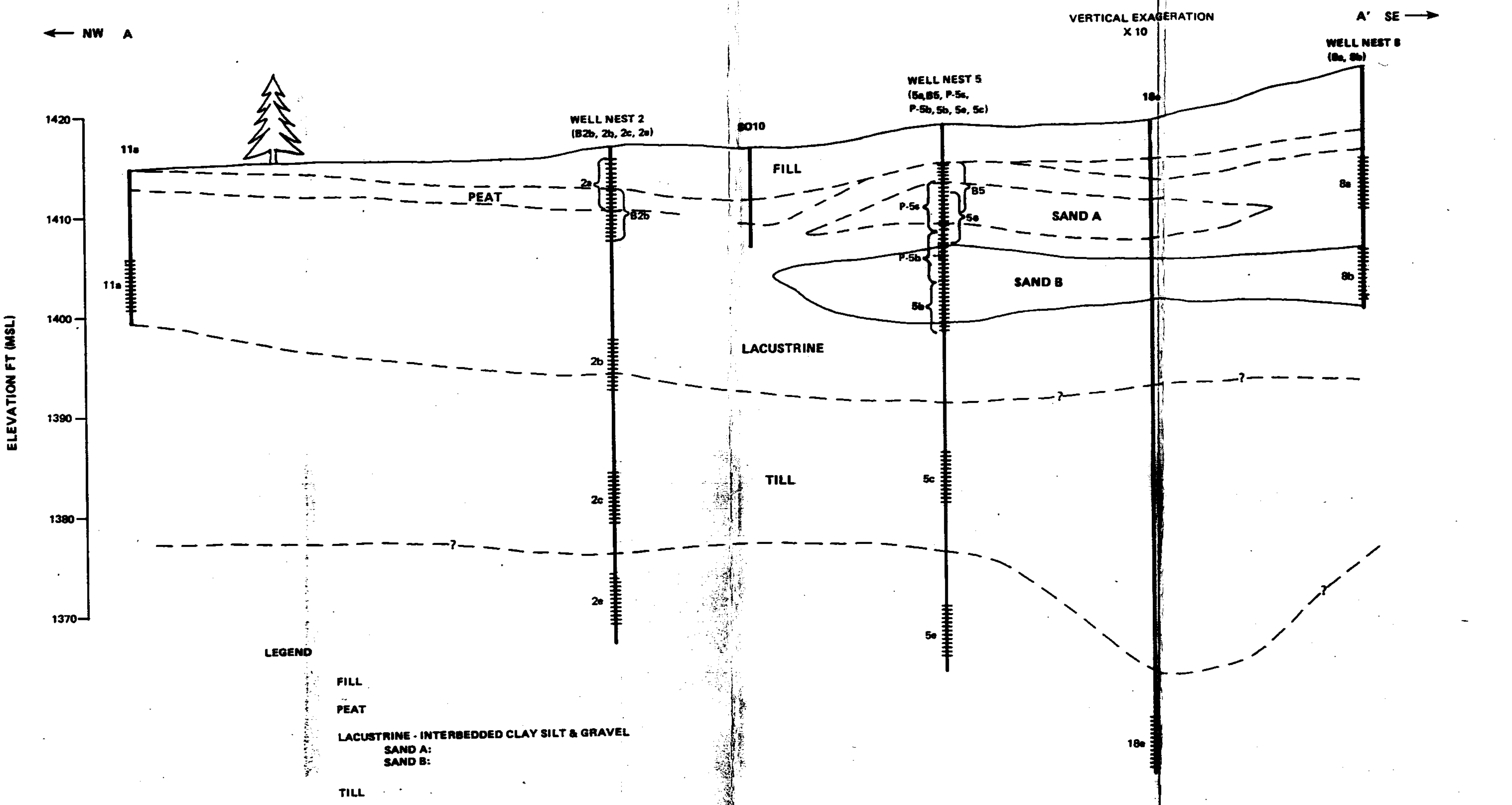


FIGURE TM 5-2
GENERALIZED GEOLOGIC
CROSS SECTION A-A'
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

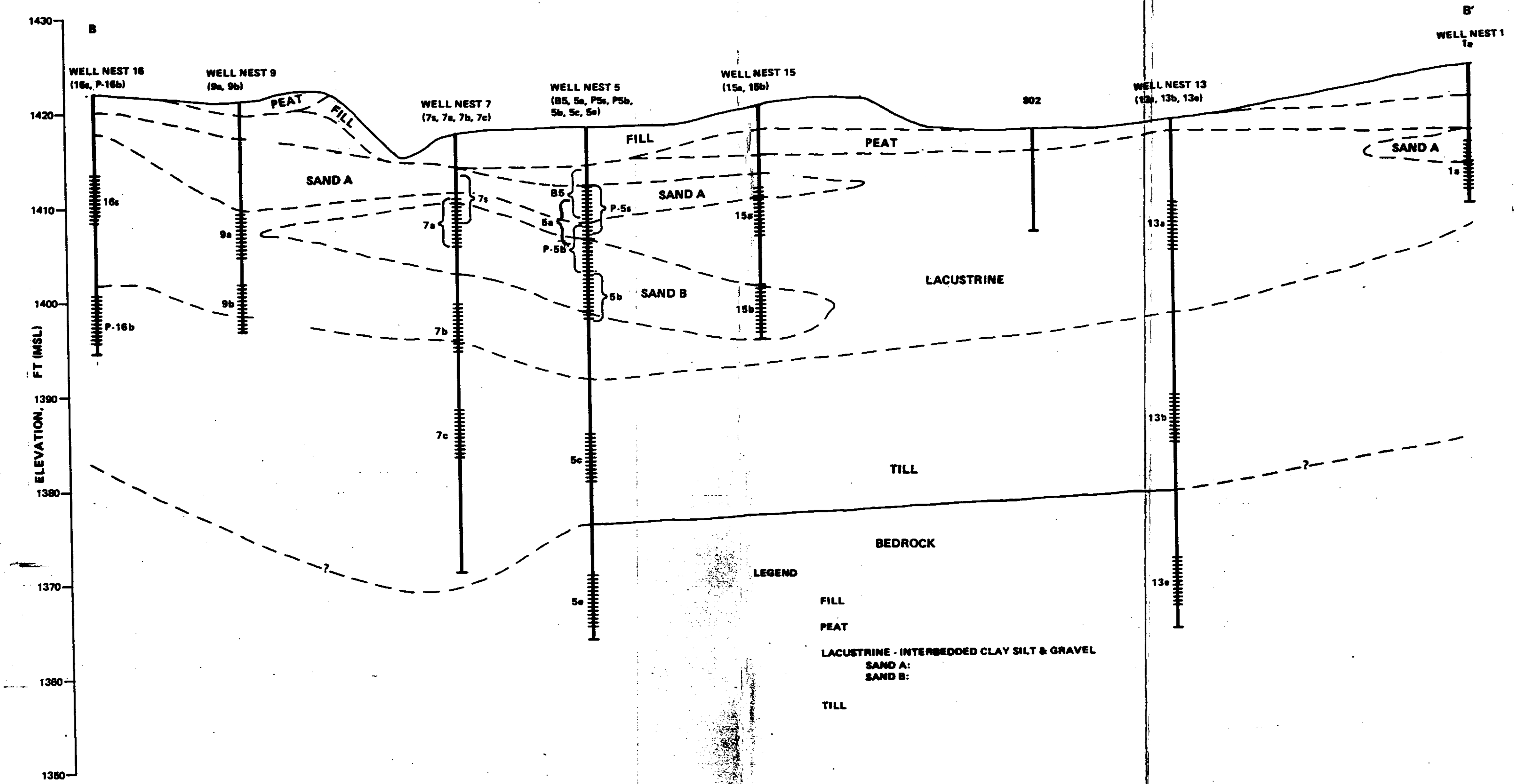


FIGURE TM 5-3
GENERALIZED GEOLOGIC
CROSS SECTION B-B'
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

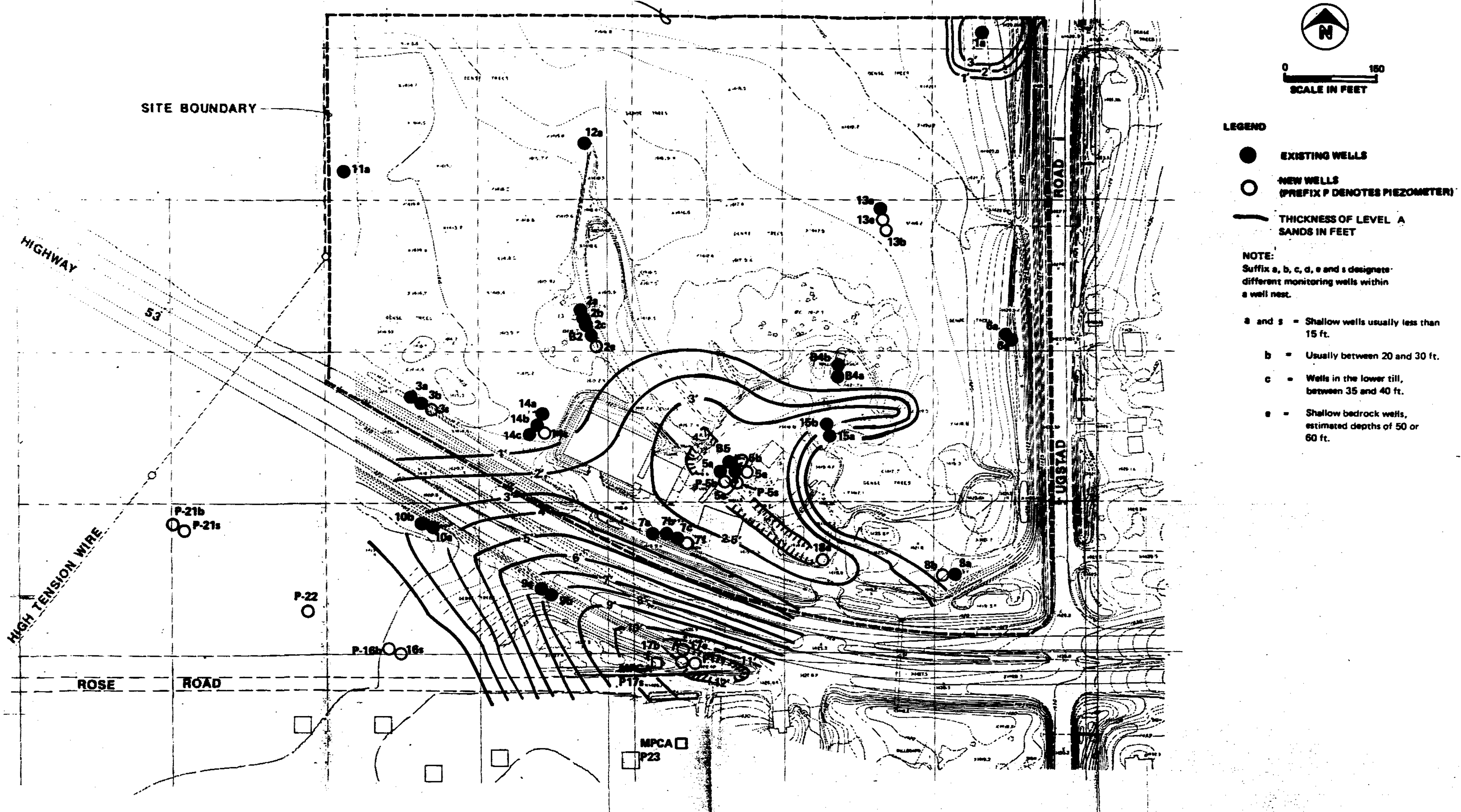


FIGURE TM 5-4
ISOPACH MAP OF
LEVEL A SANDS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

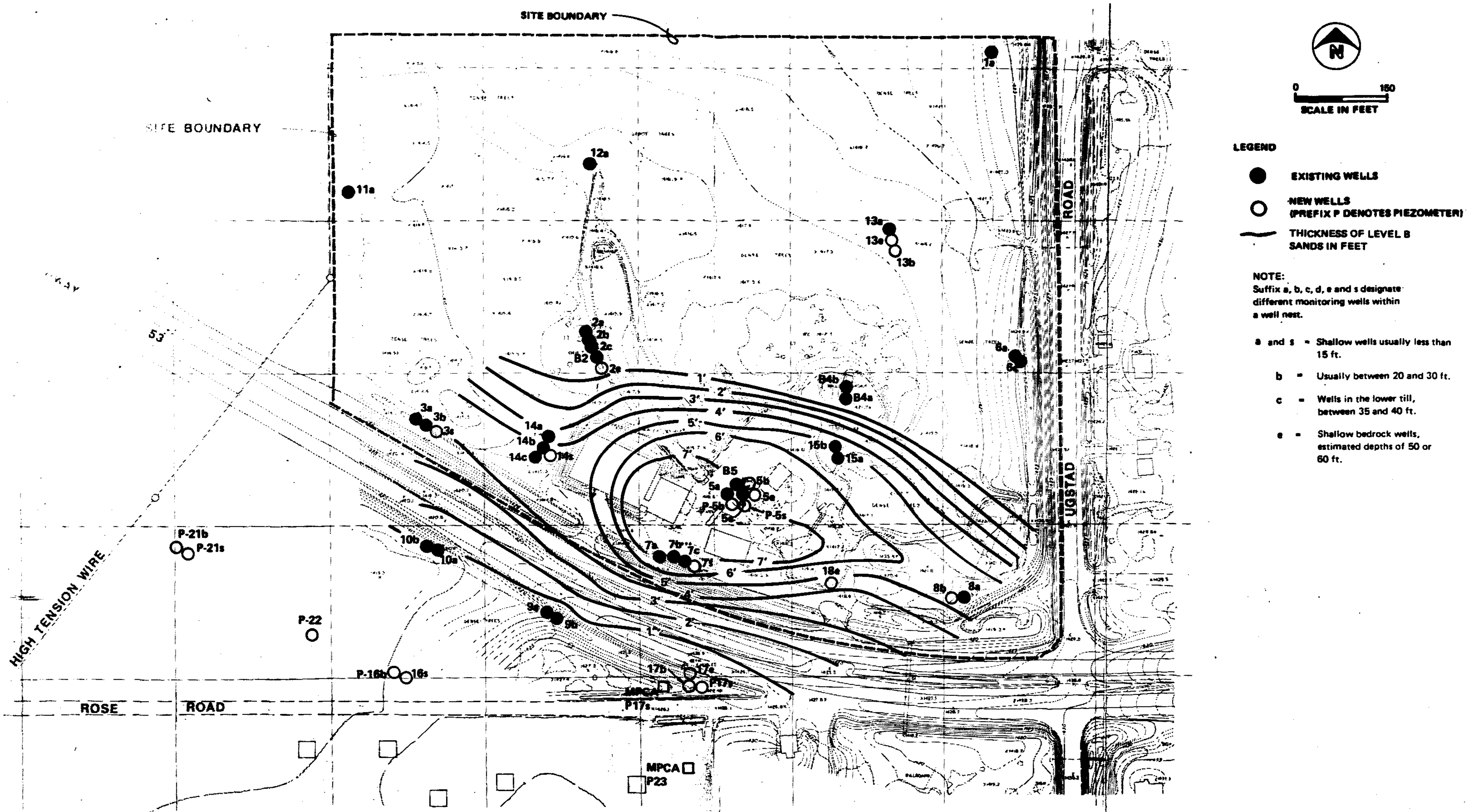
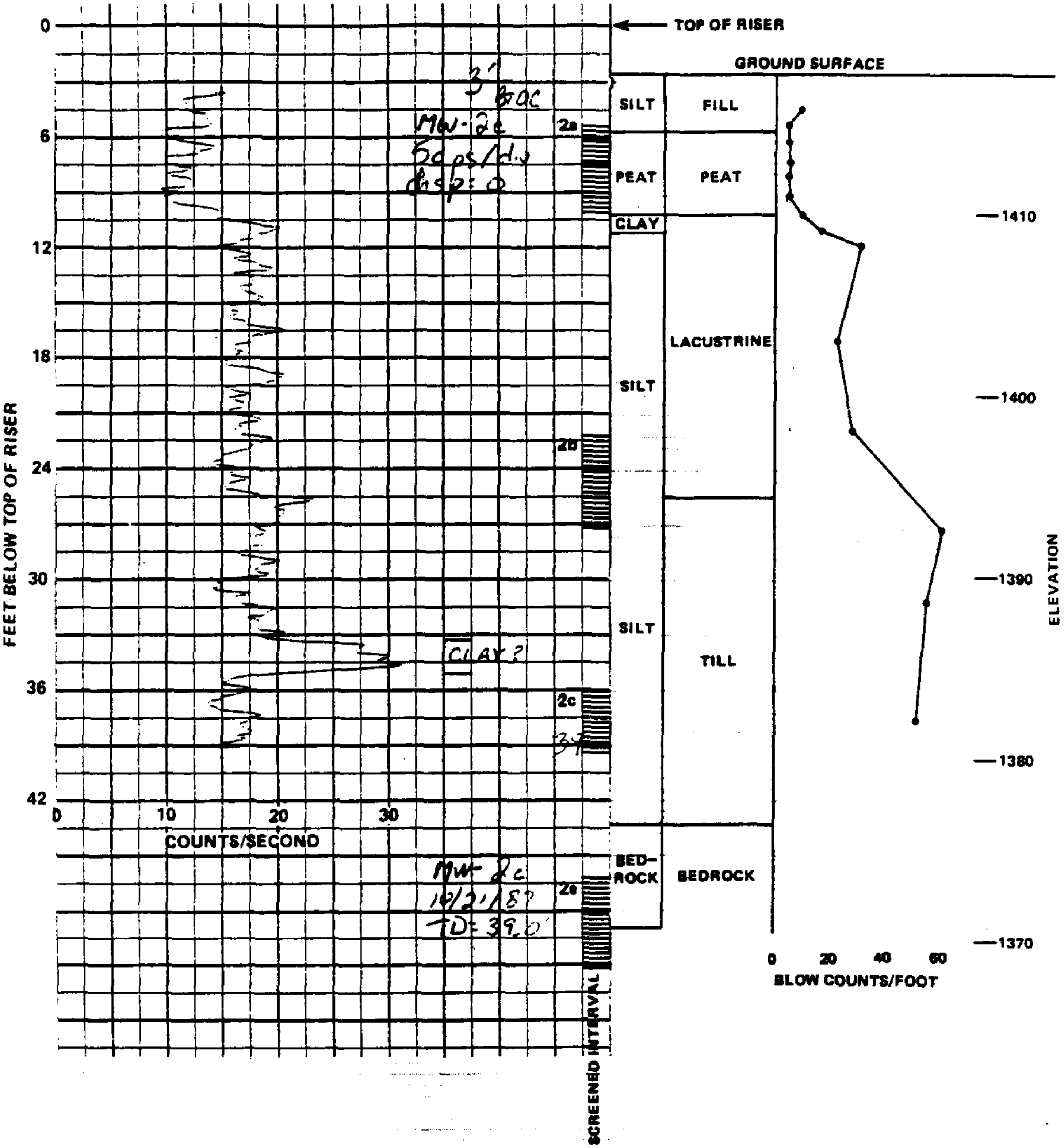


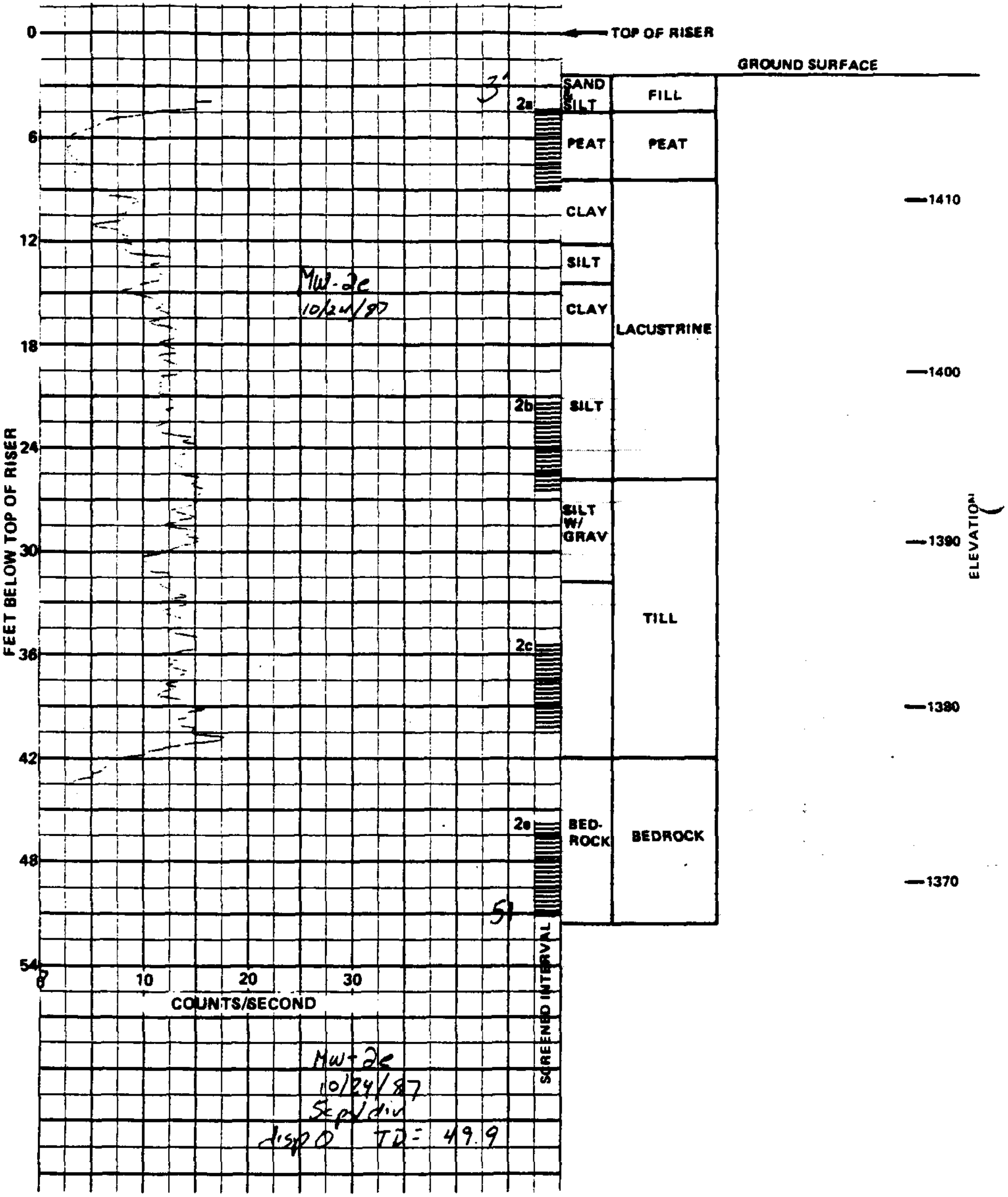
FIGURE TM 5-5
ISOPACH MAP OF
LEVEL B SANDS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

TM 5--BOREHOLE GAMMA LOGGING AND LITHOLOGIC CORRELATIONS

Attachment A
BORING LOGS



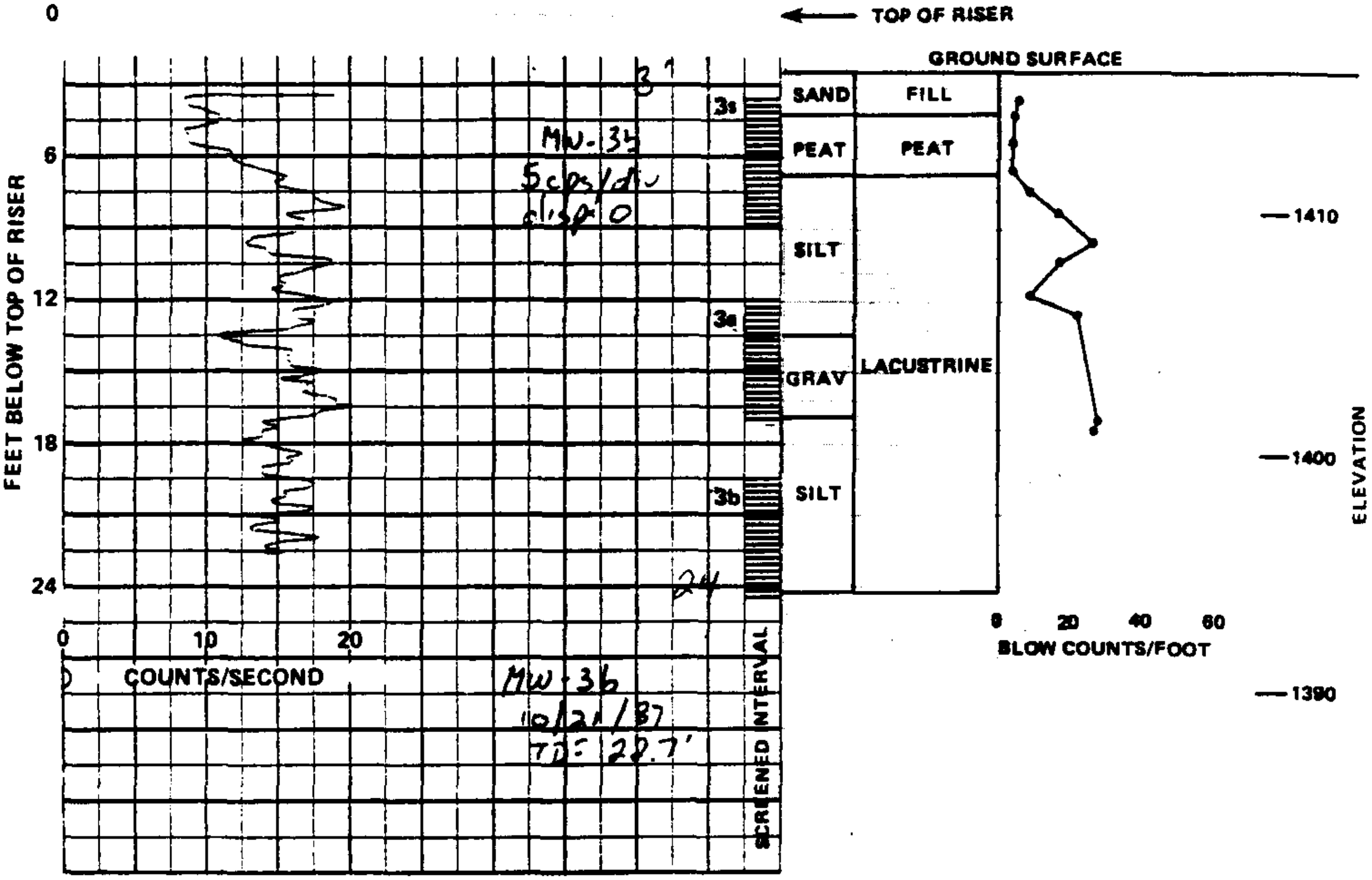
BORING LOGS
WELL 2c
ARROWHEAD REFINERY



MW-2e
10/24/87

MW-2e
10/24/87
5cp/div
disp 0' TD = 49.9

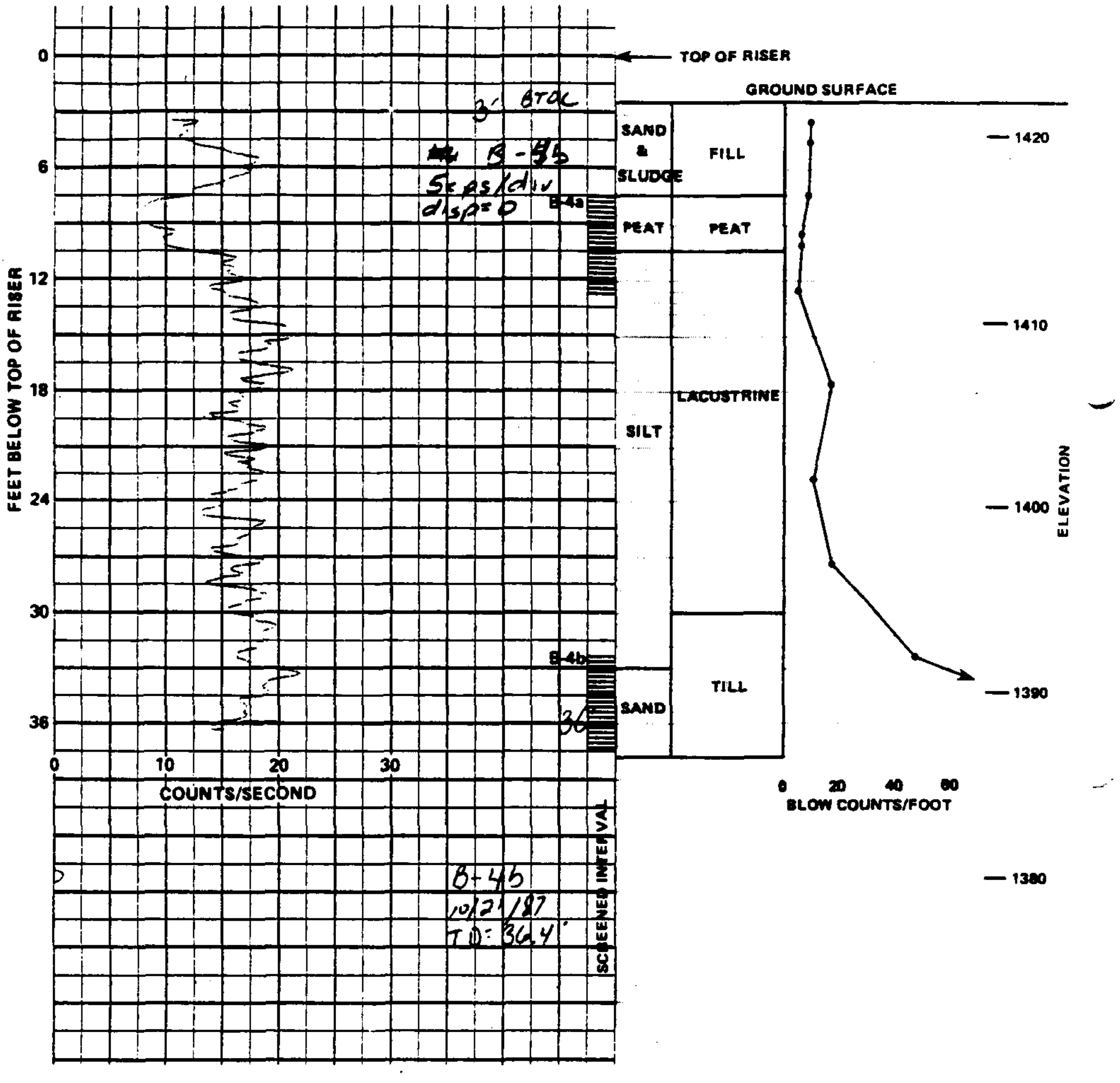
BORING LOGS
WELL 2e
ARROWHEAD REFINERY



MW-3b
5cps/div
disp 0

MW-3b
10/21/87
TD= 28.7'

BORING LOGS
WELL 3b
ARROWHEAD REFINERY



3' BTOC

B-4b

5cps/div

disp=0

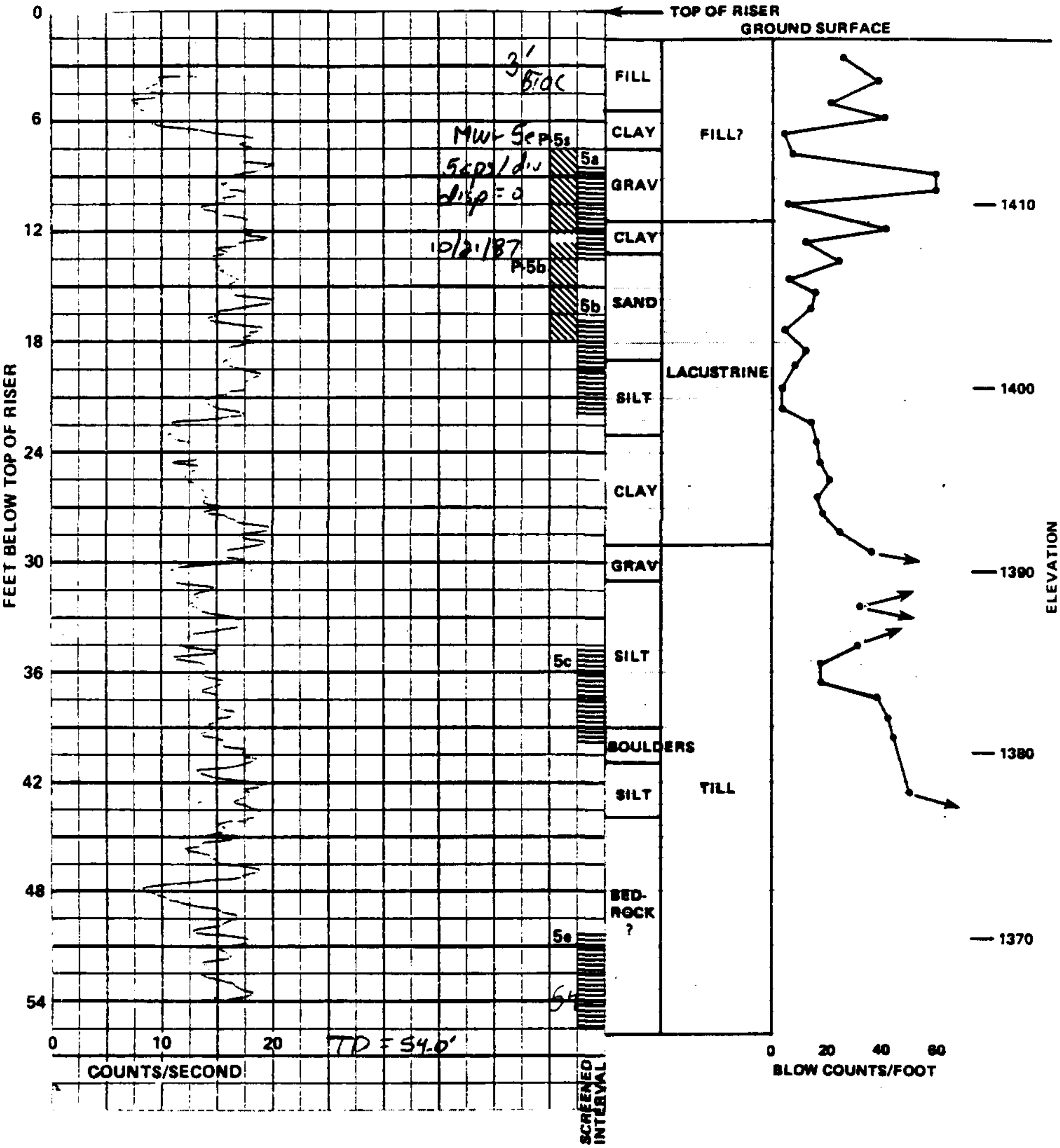
36'

B-4b

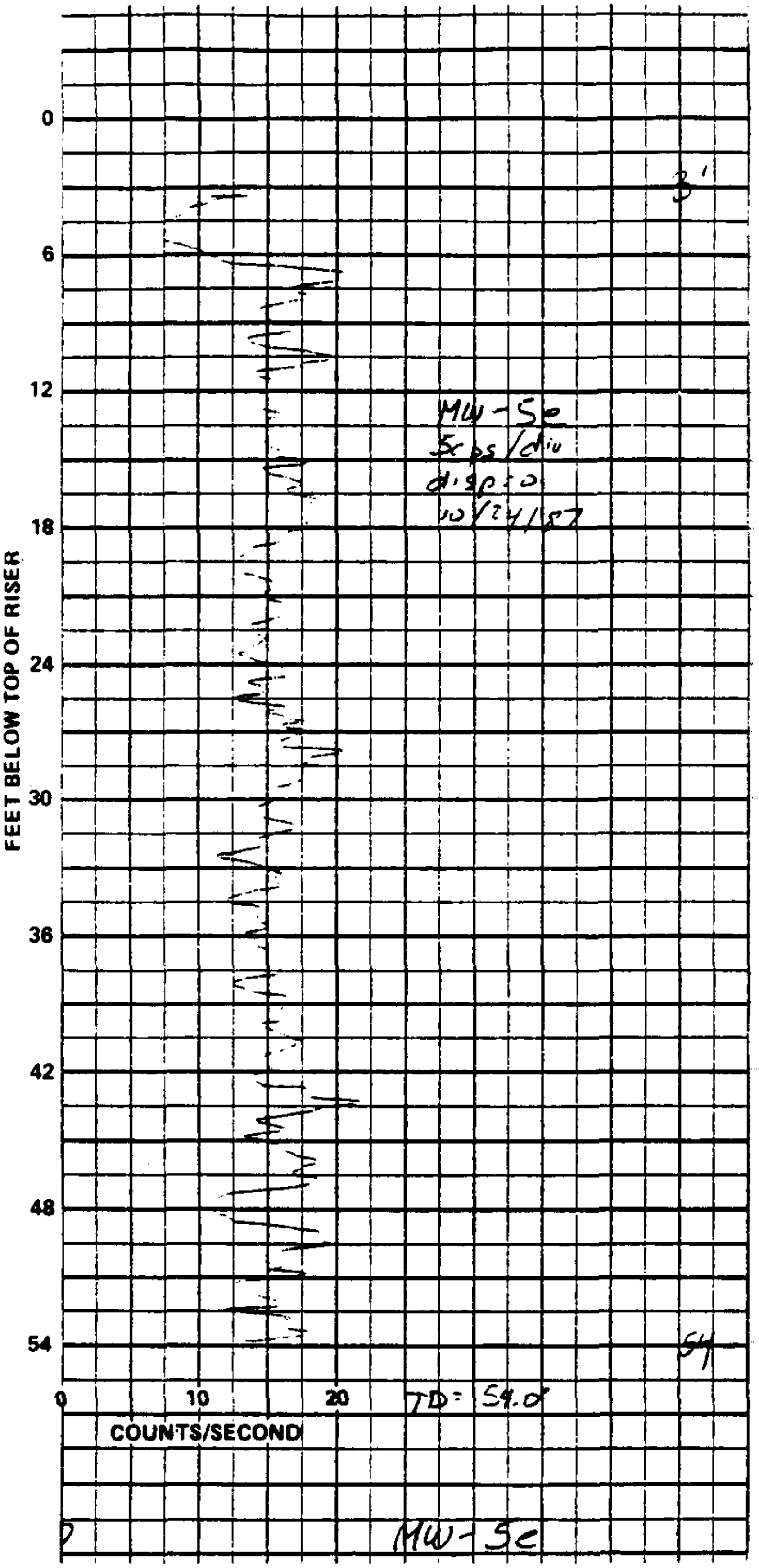
10/21/87

TD: 36.4'

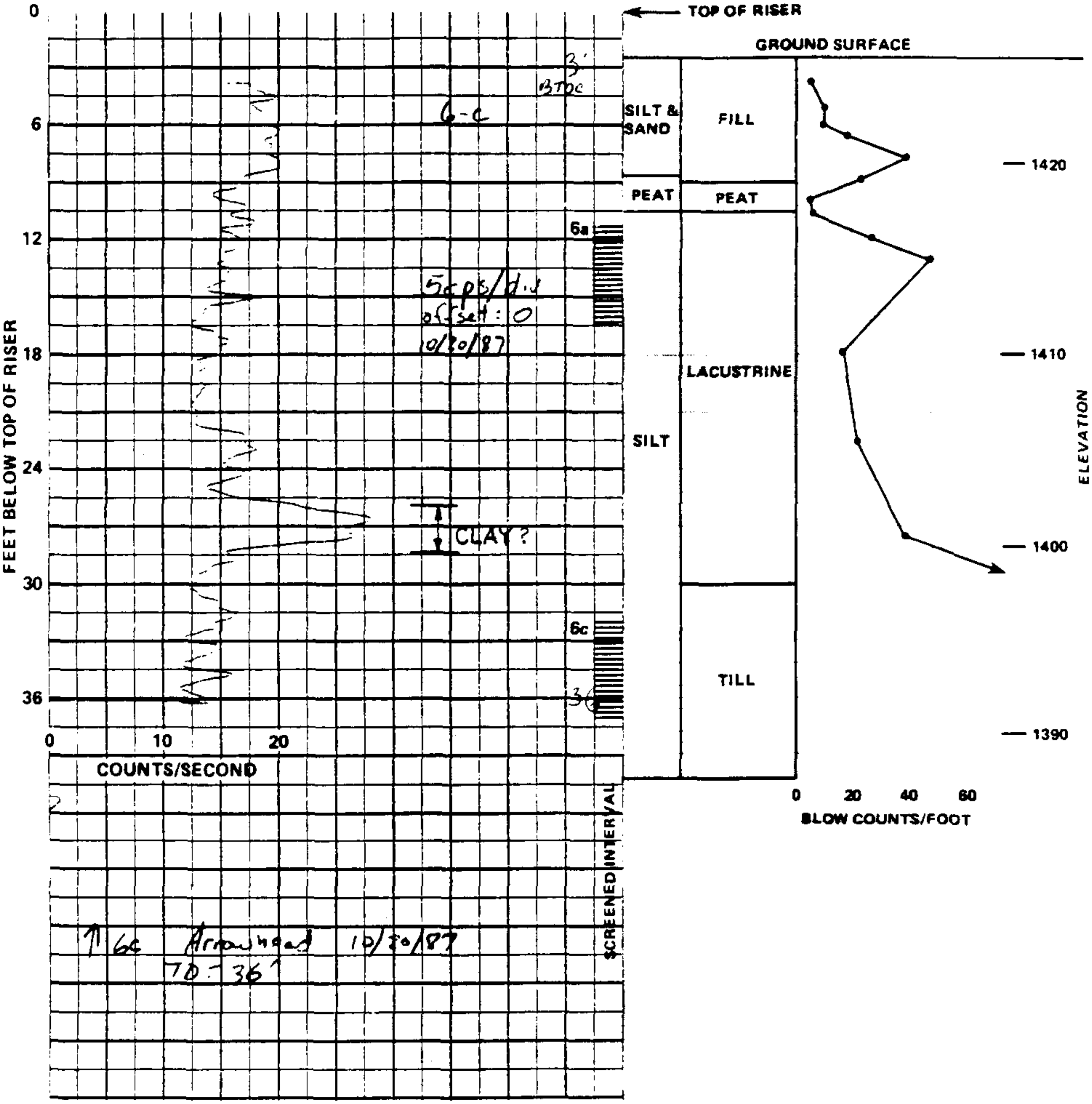
BORING LOGS
WELL B-4b
ARROWHEAD REFINERY



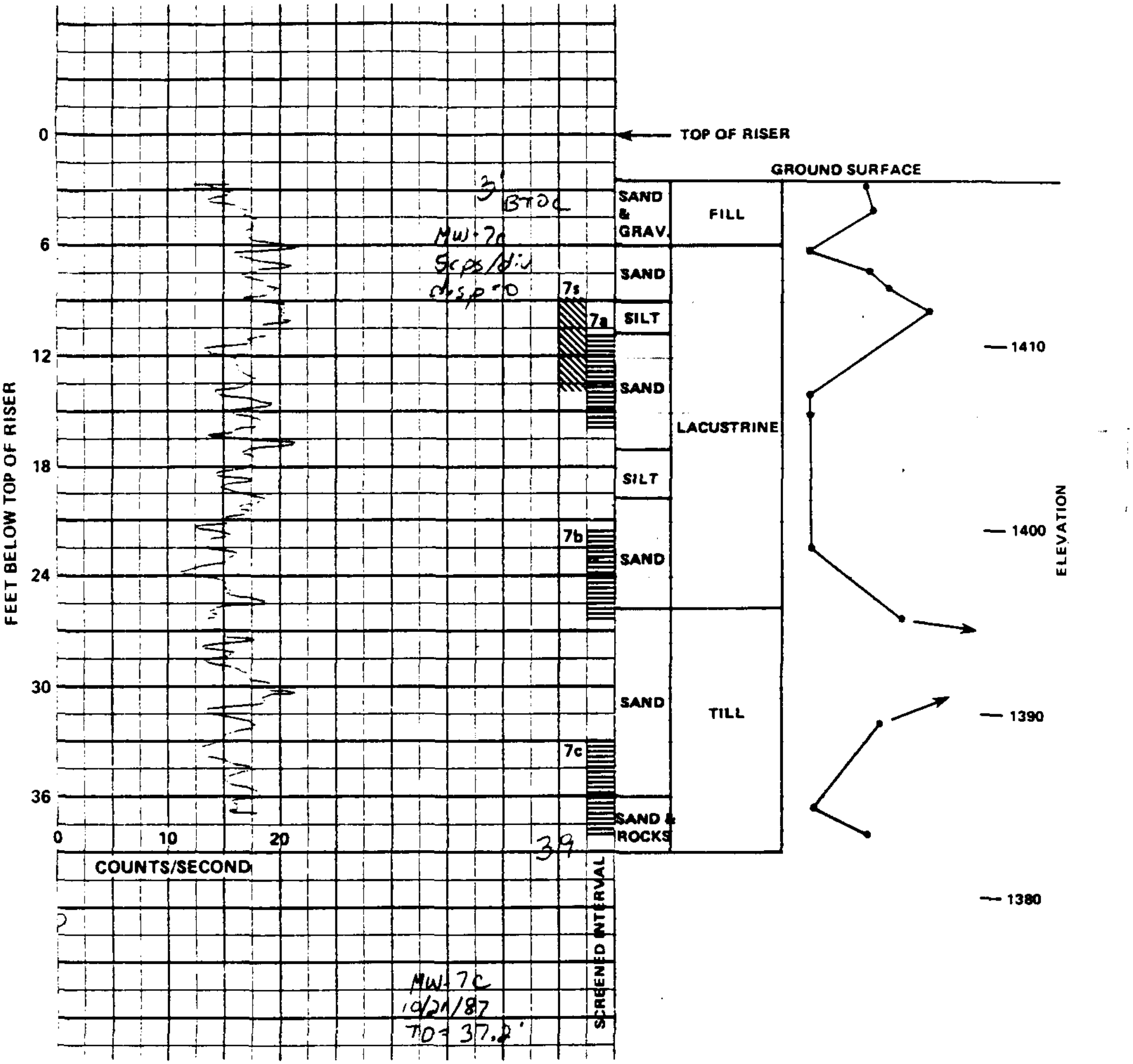
BORING LOGS
WELL 5e
BEFORE DEVELOPMENT
ARROWHEAD REFINERY



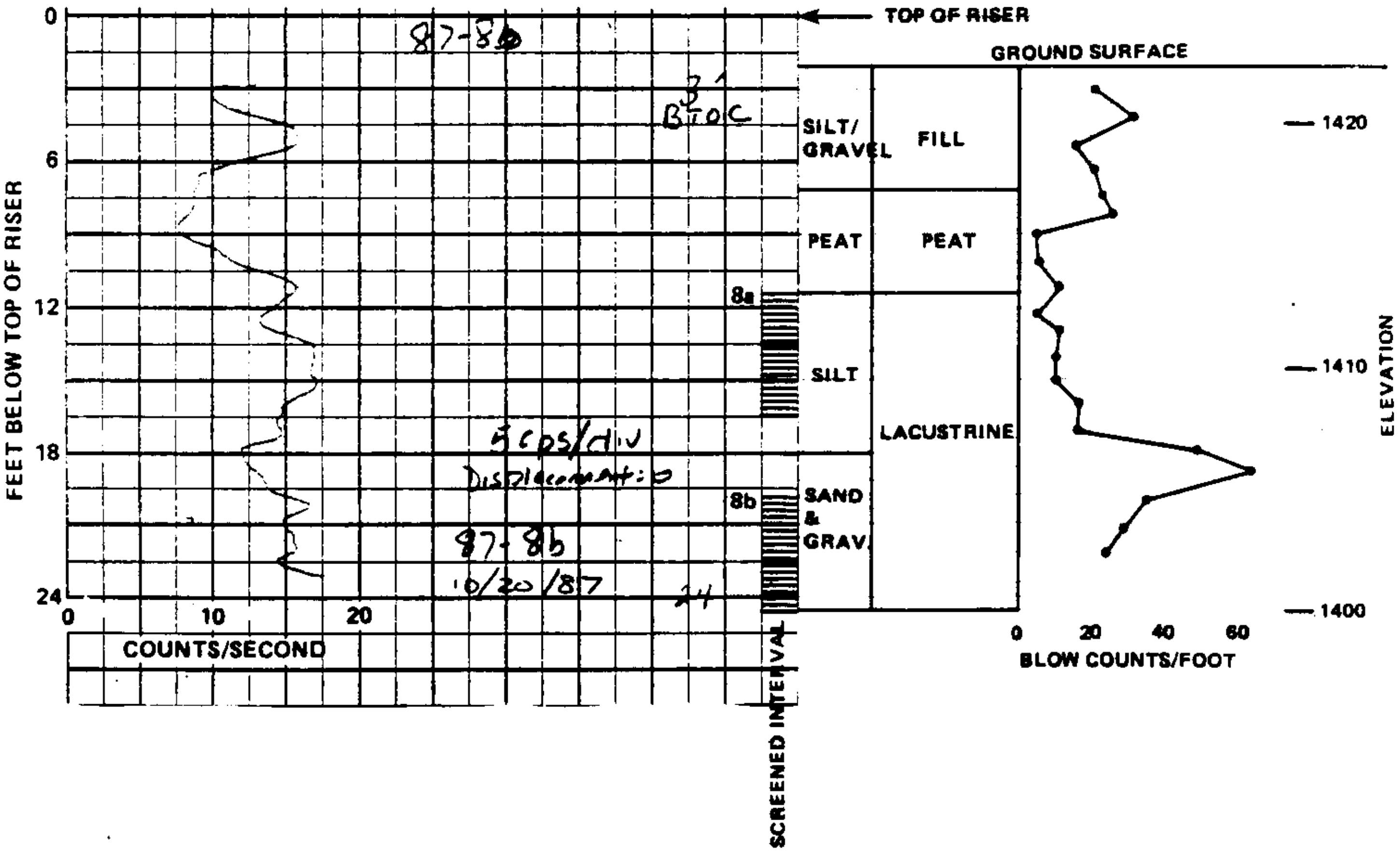
BORING LOGS
WELL 5e
AFTER DEVELOPMENT
ARROWHEAD REFINERY



BORING LOGS
WELL 6c
ARROWHEAD REFINERY



BORING LOGS
WELL 7c
ARROWHEAD REFINERY



87-8b

3' BTOC

5 cps/div

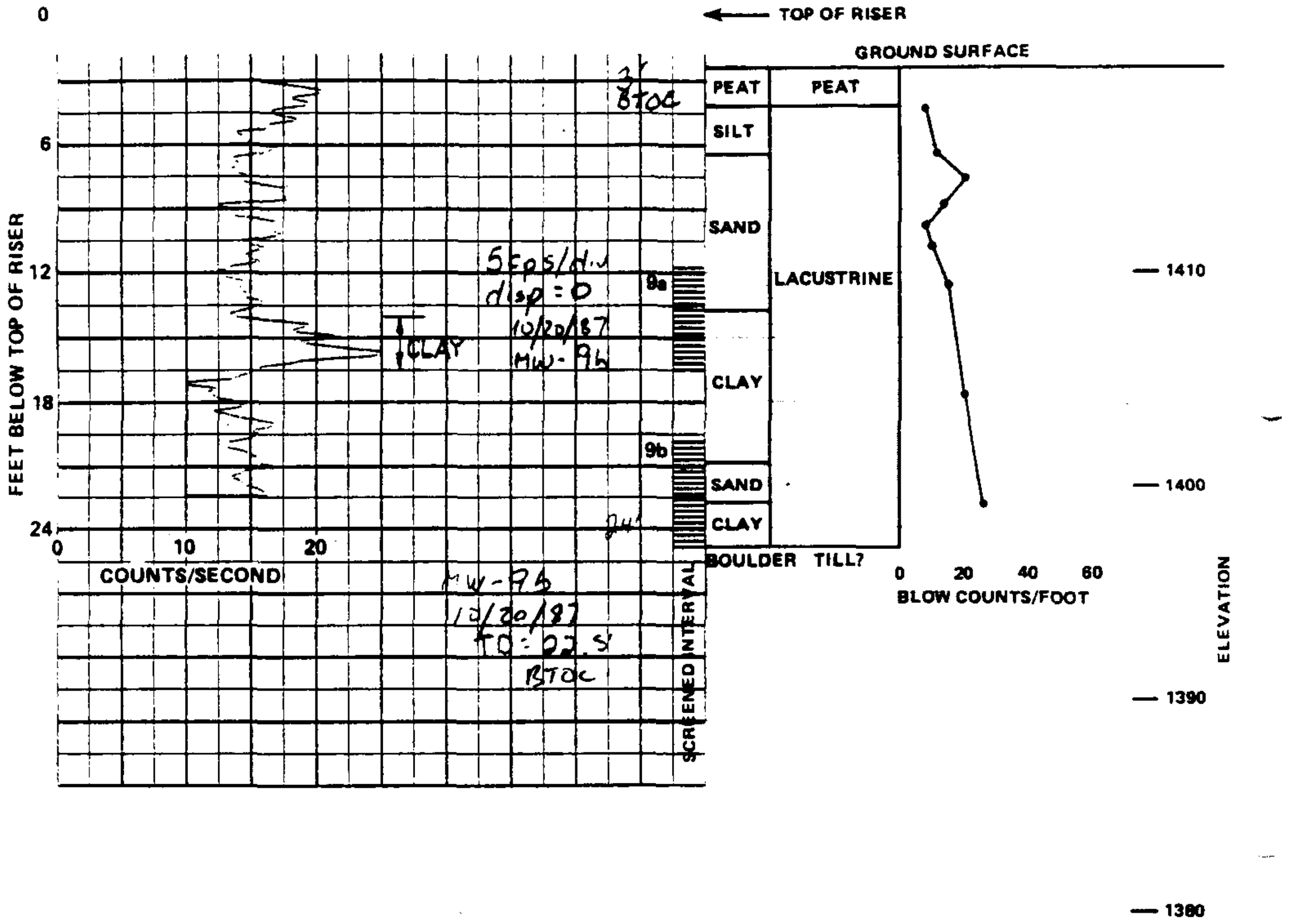
Displacement: 0

87-8b

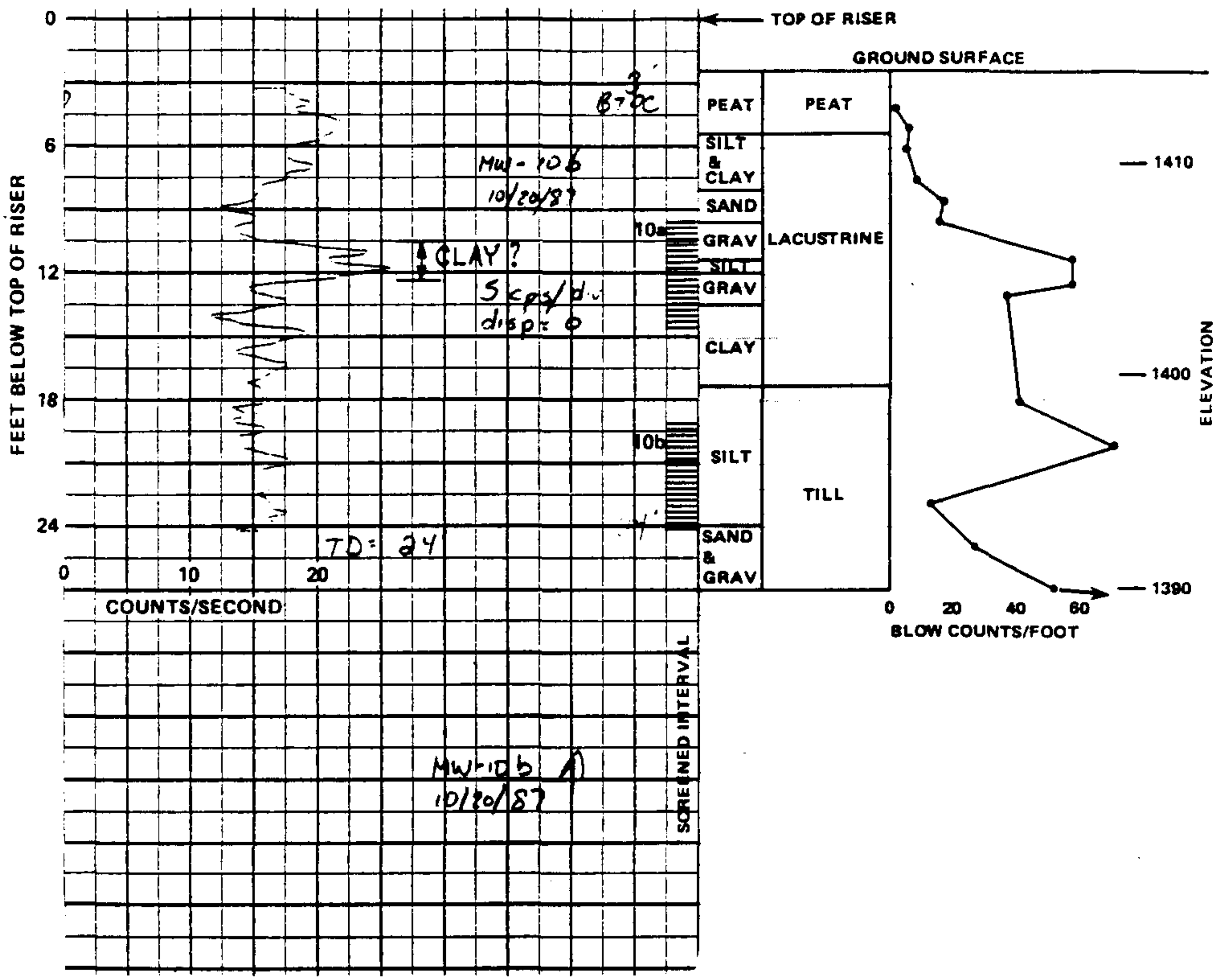
10/20/87

24

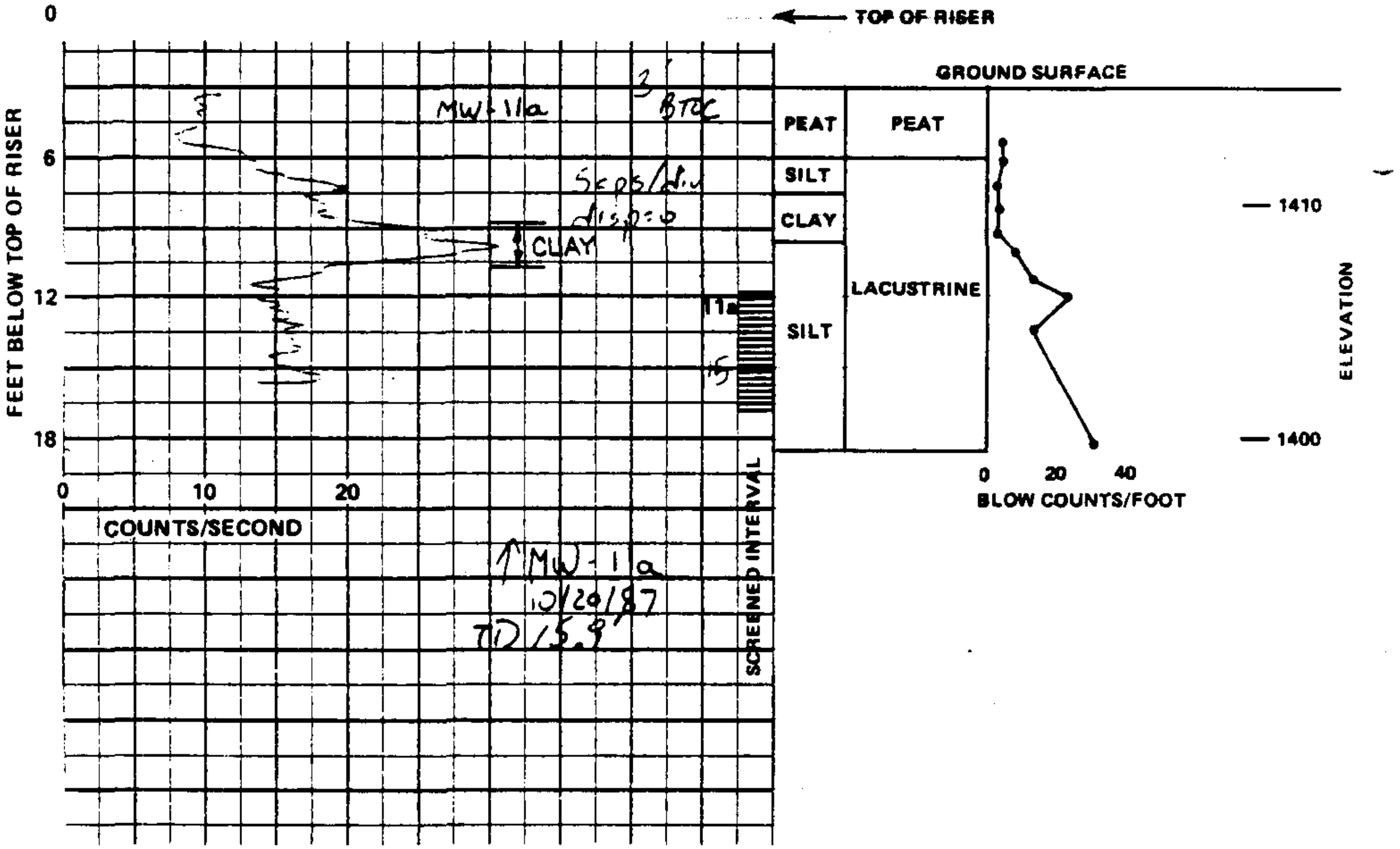
BORING LOGS
WELL 8b
ARROWHEAD REFINERY



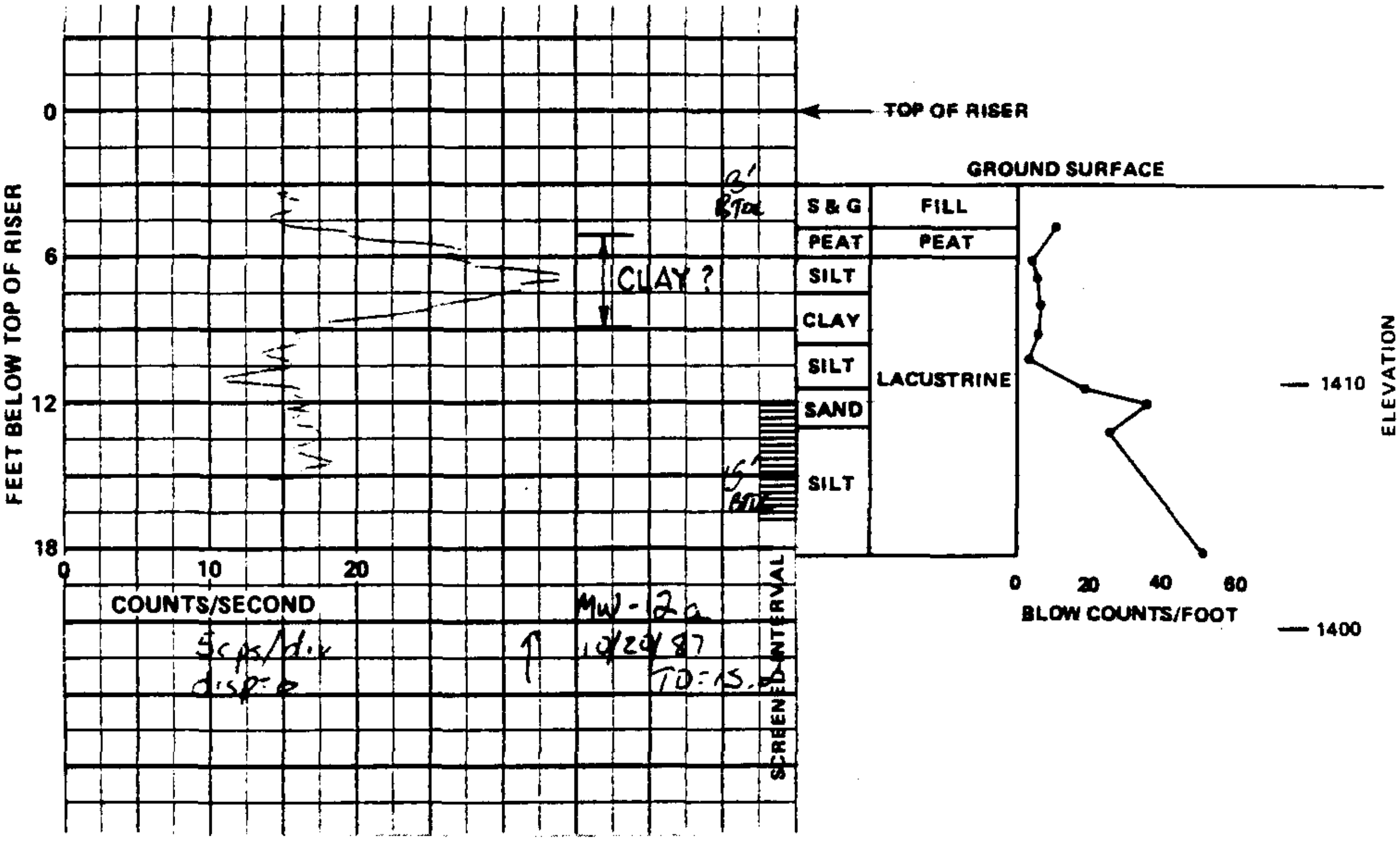
BORING LOGS
WELL 9b
ARROWHEAD REFINERY



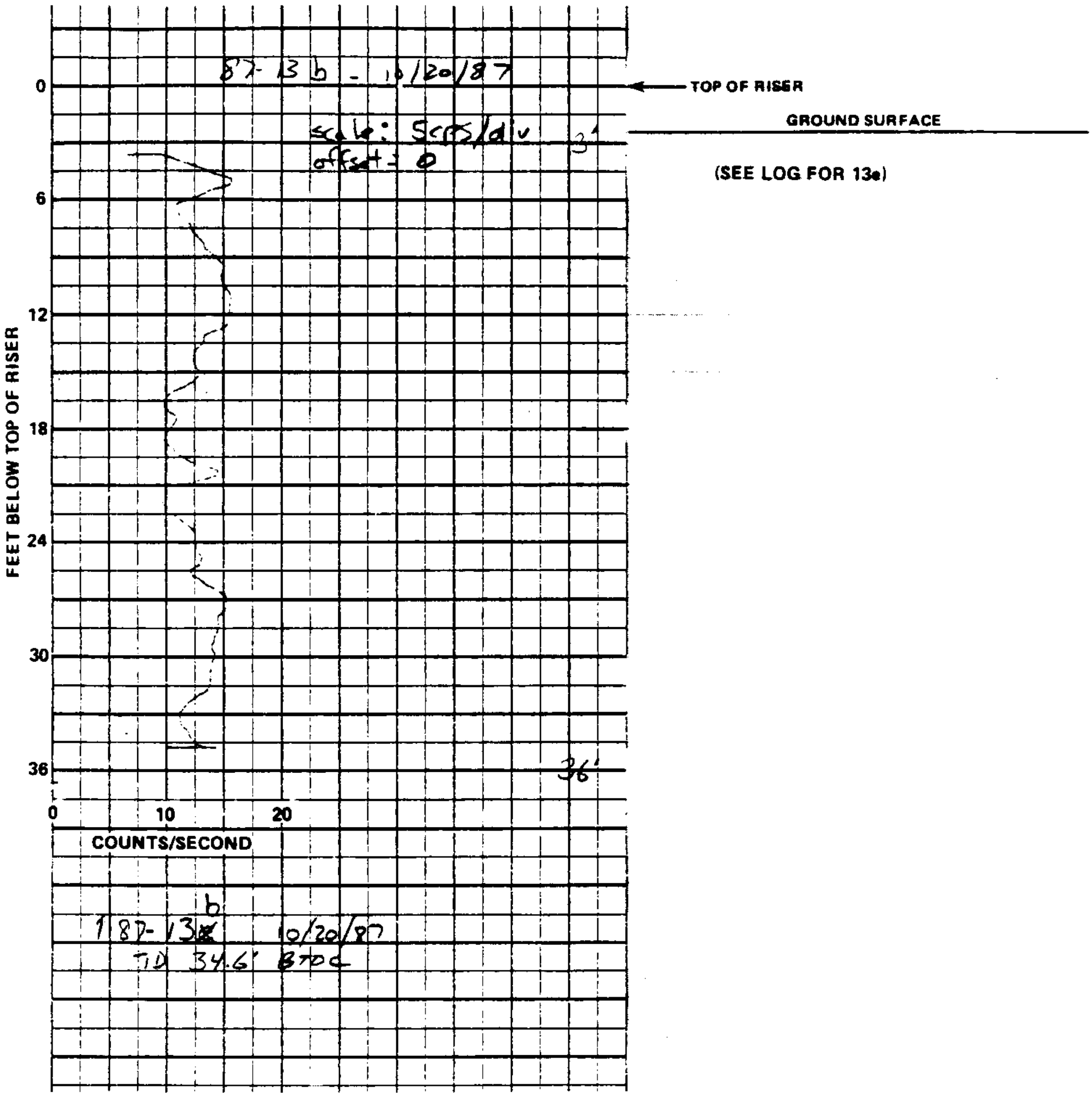
BORING LOGS
WELL 10b
ARROWHEAD REFINERY



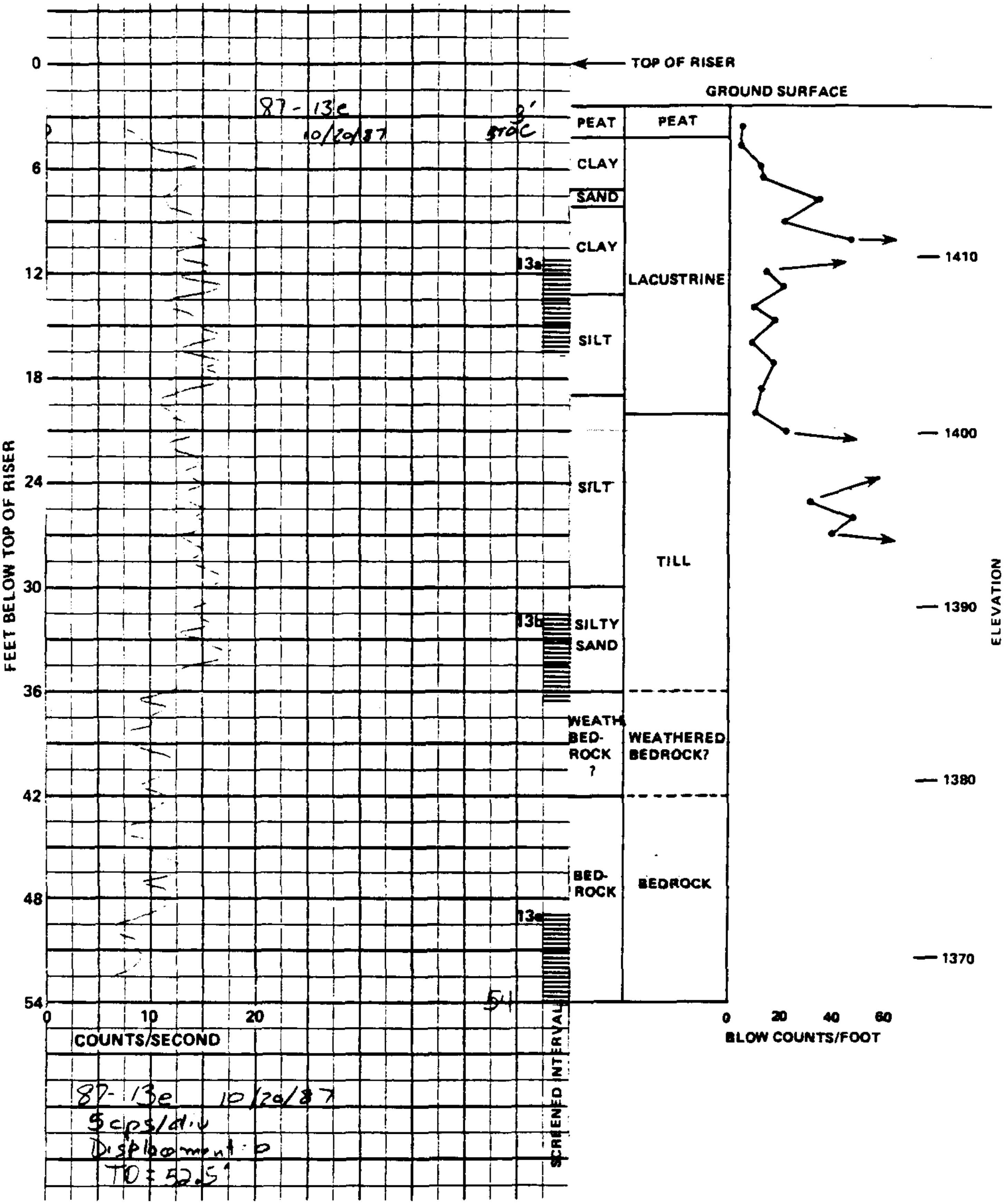
BORING LOGS
WELL 11a
ARROWHEAD REFINERY



BORING LOGS
WELL 12a
ARROWHEAD REFINERY



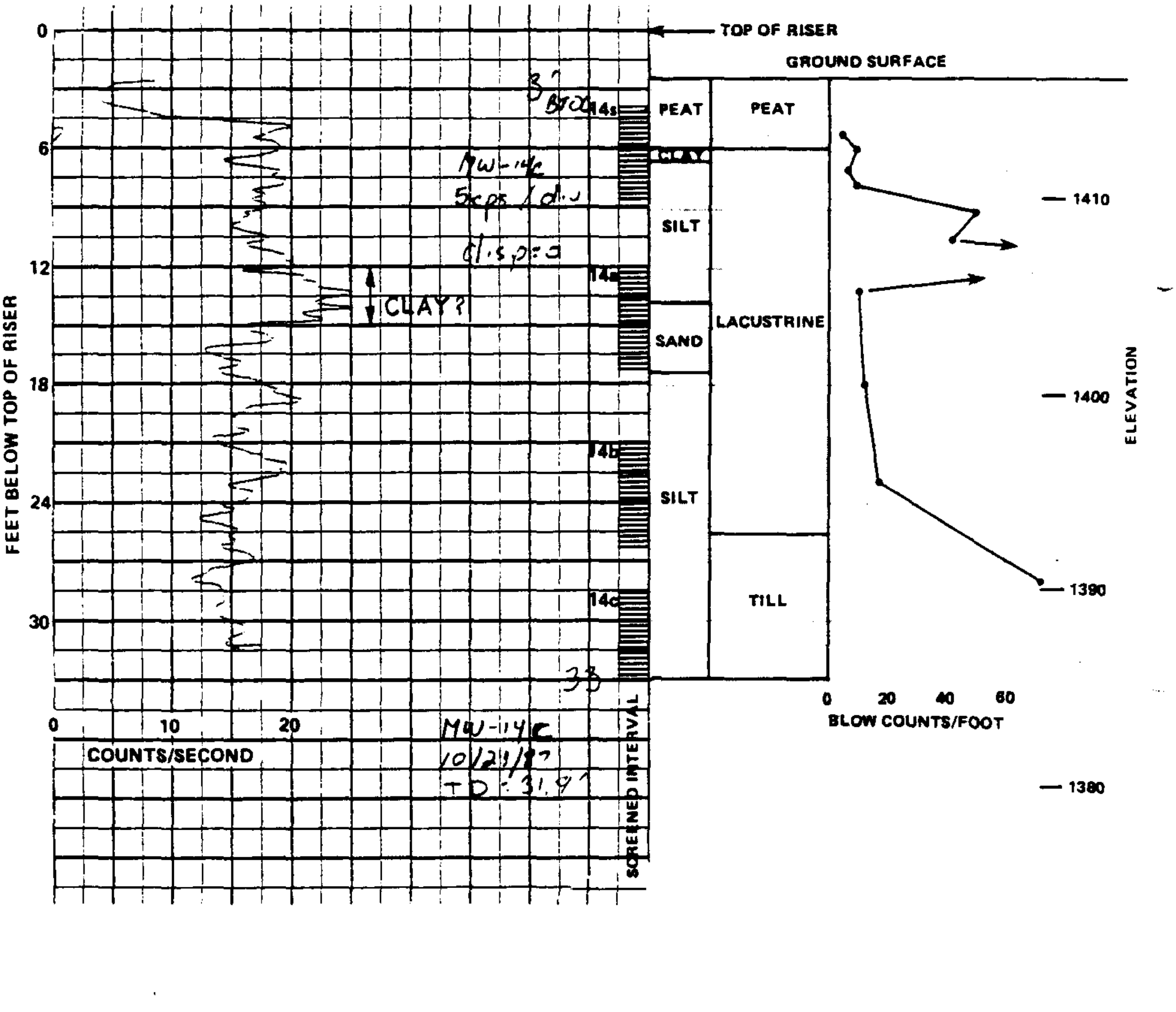
BORING LOGS
WELL 13b
ARROWHEAD REFINERY



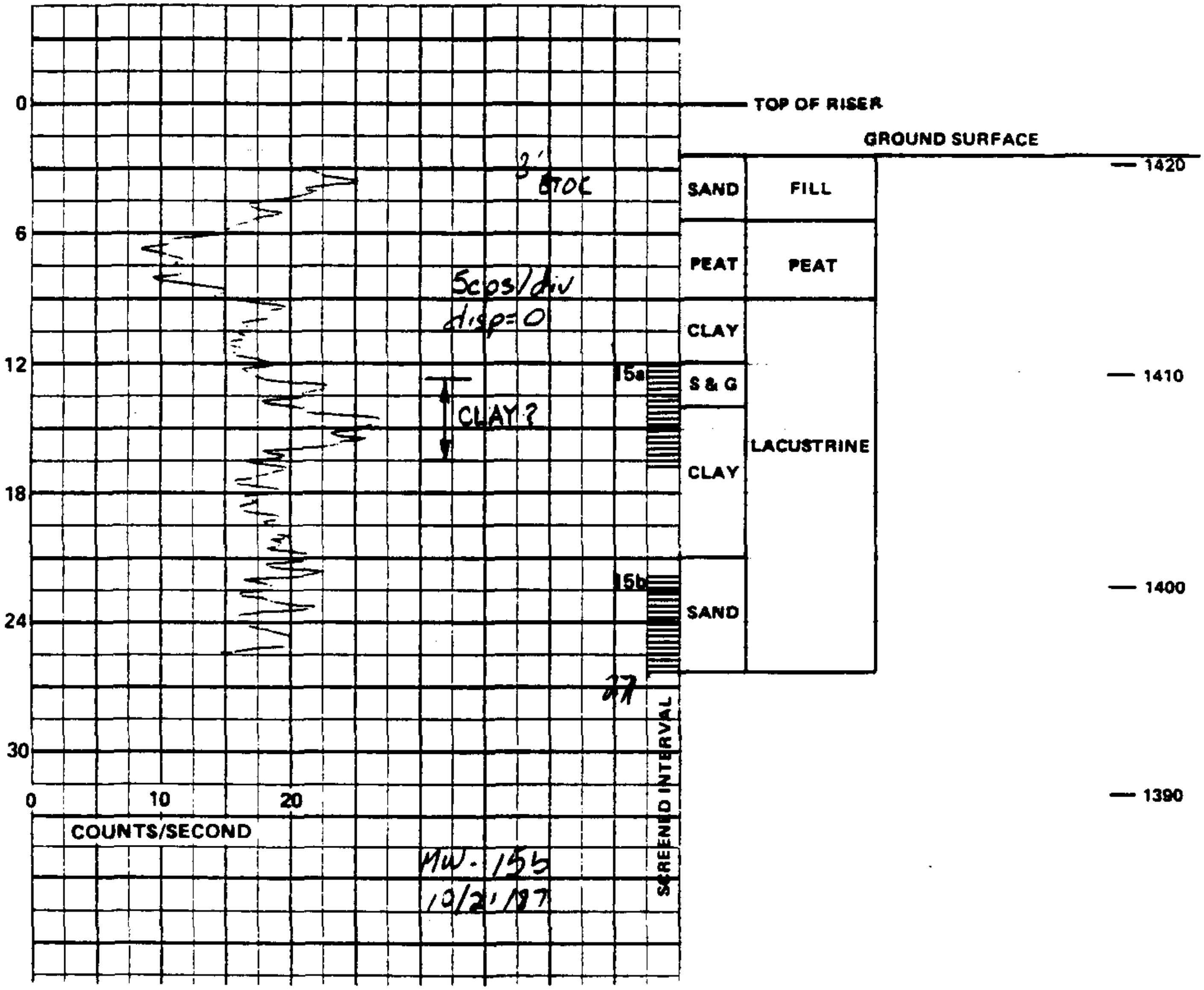
87-13e
10/20/87
3'
BTOC
54

87-13e 10/20/87
5cps/div
Displacement 0
TD = 52.5'

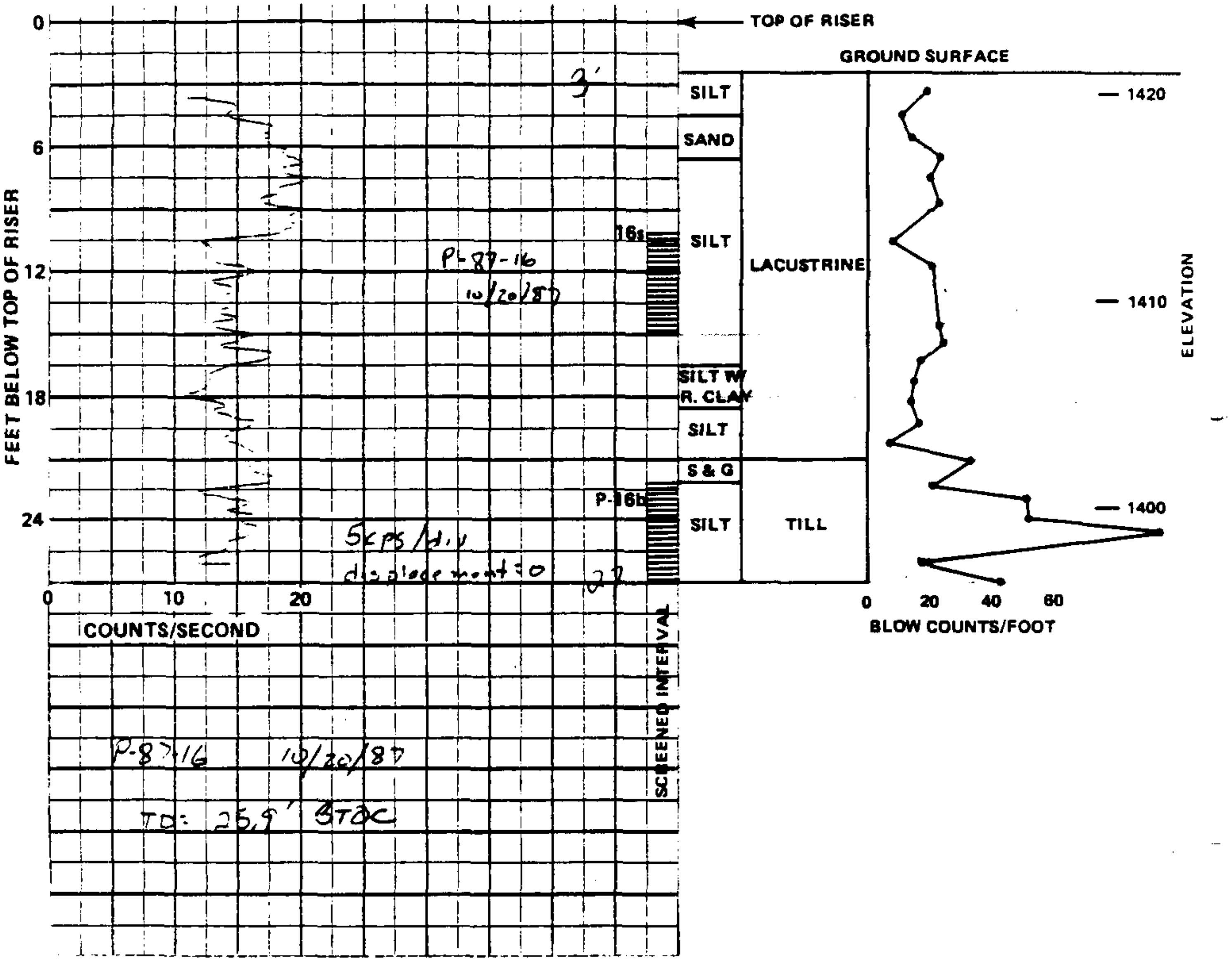
BORING LOGS
WELL 13e
ARROWHEAD REFINERY



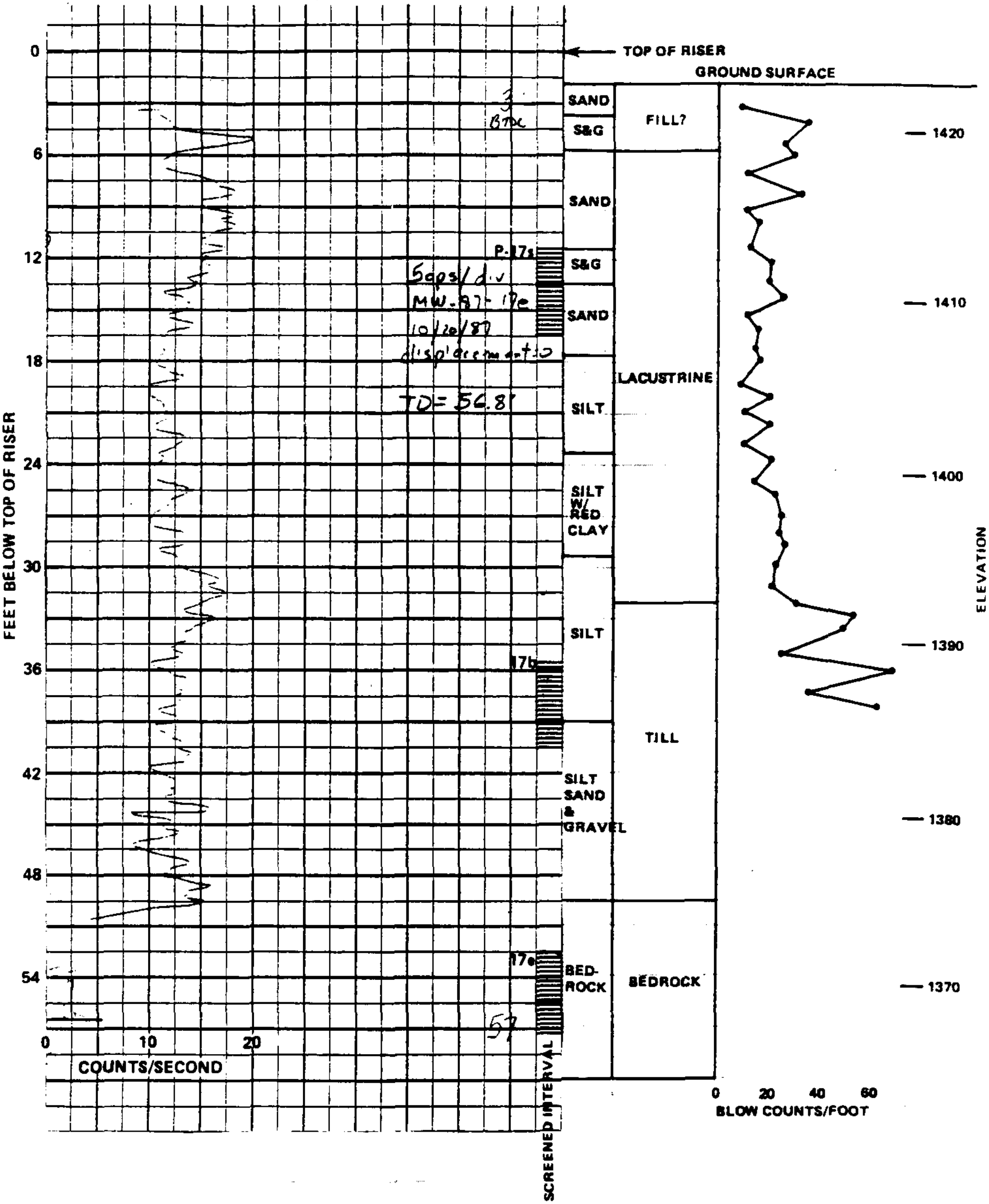
BORING LOGS
WELL 14c
ARROWHEAD REFINERY



BORING LOGS
WELL 15b
ARROWHEAD REFINERY



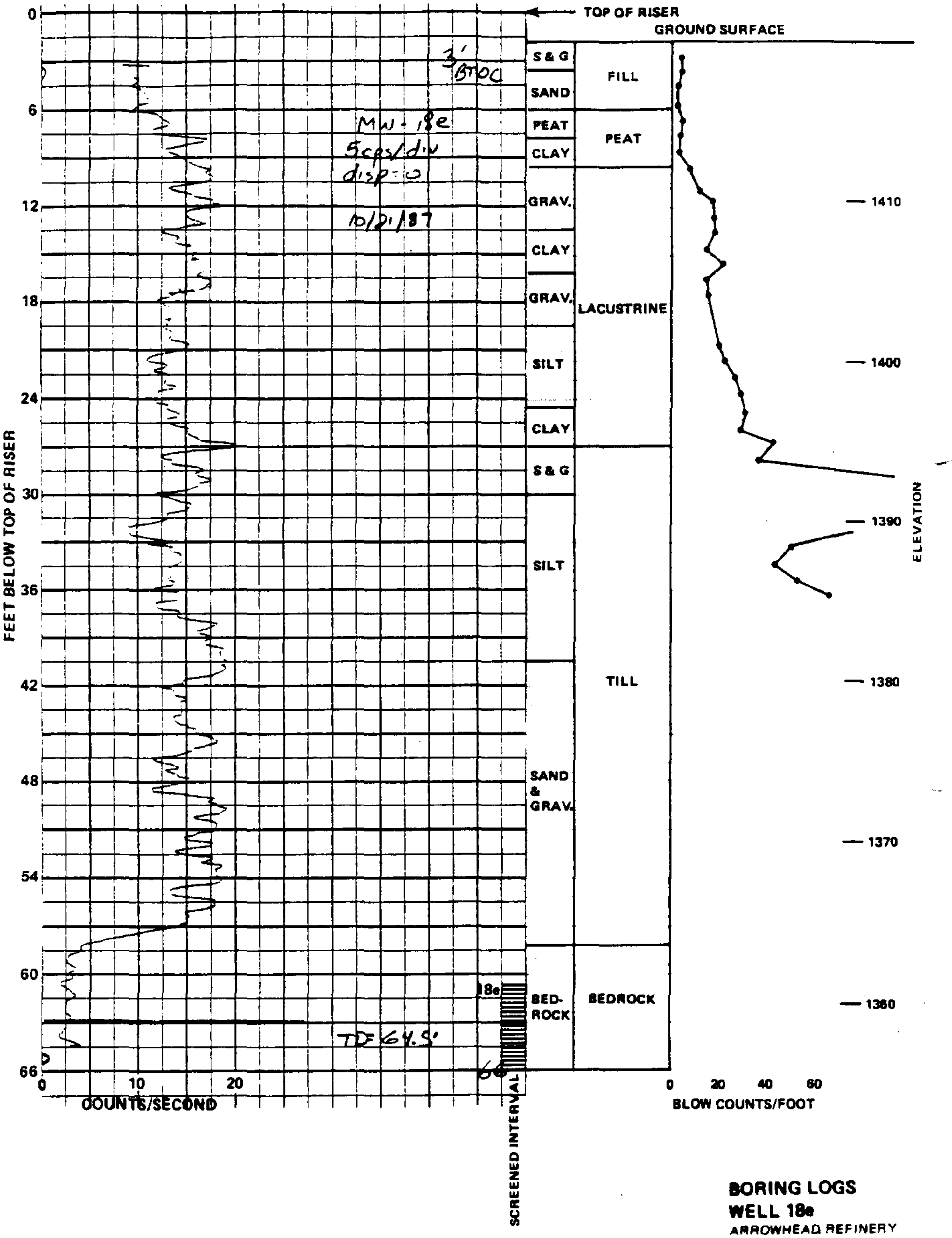
BORING LOGS
WELL P 16
ARROWHEAD REFINERY



5cps/div
MW-87-17e
10/20/87
displacement:0

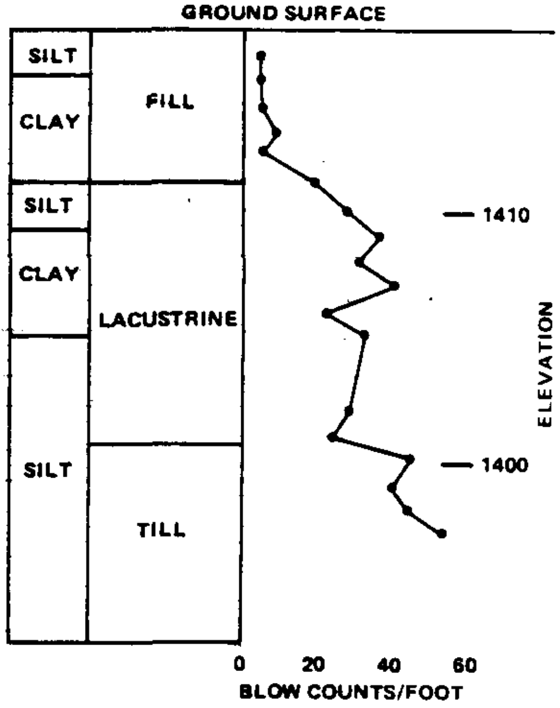
TD=56.8'

BORING LOGS
WELL 17e
ARROWHEAD REFINERY

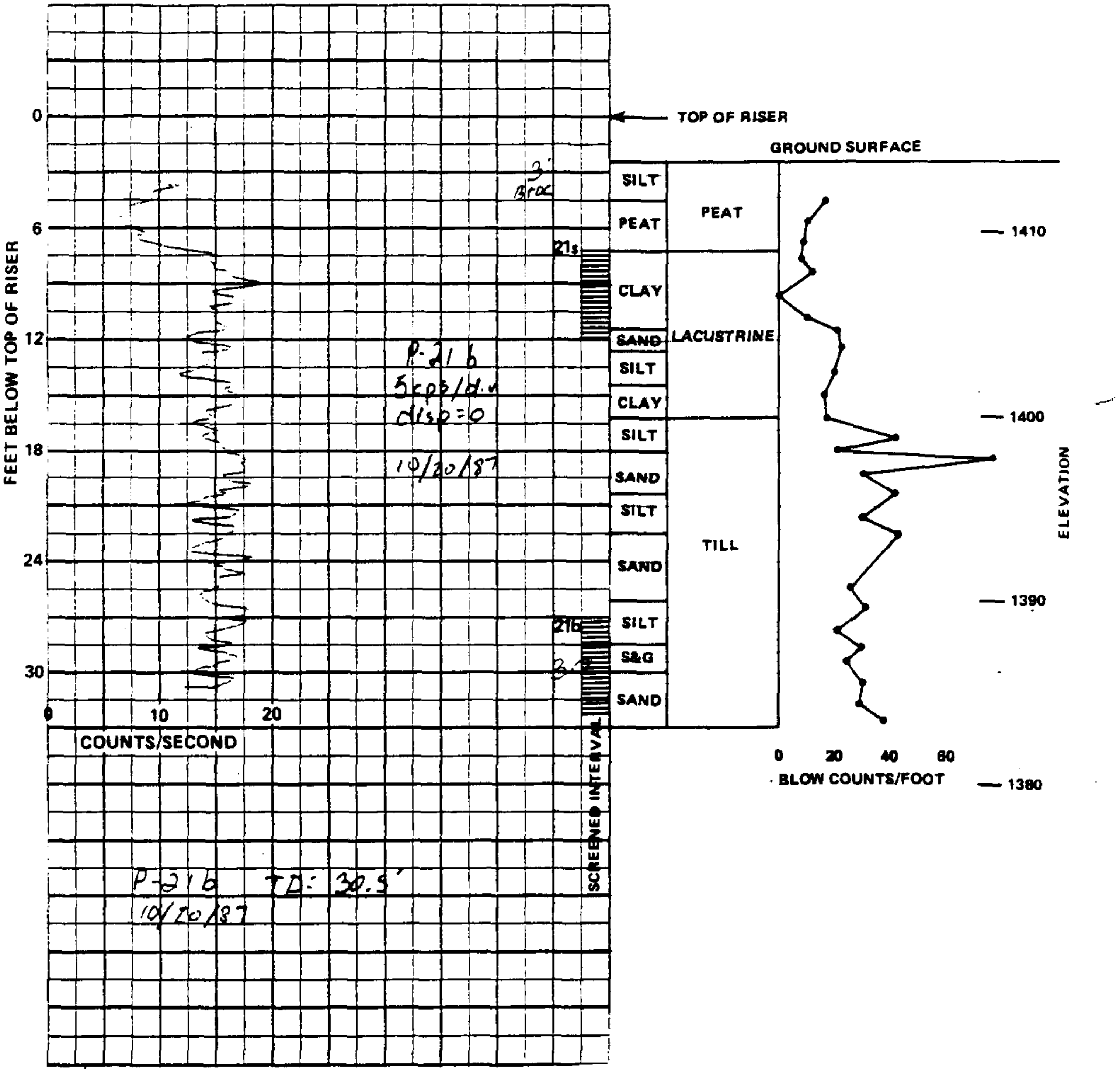


BORING LOGS
WELL 18e
ARROWHEAD REFINERY

NOT LOGGED



BORING LOGS
WELL 19s
ARROWHEAD REFINERY



3'
Broc

P-21b
5cps/div
disp=0

10/20/87

P-21b TD: 30.5'
10/20/87

BORING LOGS
WELL 21b
ARROWHEAD REFINERY

TECHNICAL MEMORANDUM NO. 6

TO: Fred Bartman/U.S. EPA,
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL, Project Manager

PREPARED BY: Jewelle Imada/CH2M HILL

DATE: February 22, 1988

RE: Soil and Sediment Sampling (Step I)

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68802.FS

INTRODUCTION

The soil and sediment sampling investigation was undertaken to determine more exactly the nature and horizontal and vertical extent of contaminated soil and sediment. This memorandum includes descriptions of sampling procedures, field observations and measurements, boring logs, and sample matrix tables for the samples collected.

SURFACE SOIL SAMPLING

Surface soil samples were taken at 11 locations on October 26 and 27, 1987. Surface soil sampling was performed to establish background concentrations in the soil and to refine the lateral extent of soil contamination. The sampling results will be used to evaluate the effects of the wastewater ditch discharge and surface runoff from the sludge lagoon on the level of contaminants found in the surface soil.

PERSONNEL

The sampling team consisted of:

- Randy Videkovich, CH2M HILL
- Jewelle Imada, CH2M HILL
- Alan Esko, Engineers International
- Tom Hahne, PRC

Sample custody was maintained by the sampling team. The CLP paperwork was completed by Cathy Kantowski, Engineers International.

SAMPLING LOCATIONS

The surface soil sampling locations specified in the Work Plan were selected on the basis of previous site investigations. The sampling locations were staked 1 week ahead of sampling. The locations are shown in Figure TM6-1 and briefly described in Table TM6-1. The objectives of sampling for each location are given in the Work Plan.

SAMPLING PROCEDURES

Surface soil samples were collected to a depth of 1 foot using a stainless steel spoon or a sediment corer. The top 1 inch of soil was scraped aside before the sample was collected. Samples to be analyzed for volatile organic compounds (VOCs) were taken first. These samples were usually placed directly into jars using the stainless steel spoon. If the sediment corer was used, the samples were first placed in a stainless steel bowl and then spooned into the jars. Samples for the other analyses were placed in a stainless steel bowl, composited, and then placed in the sample jars. The outside of the sample jars was decontaminated and the paperwork on each sample was completed.

The sampling equipment was decontaminated between samples by scrubbing in a solution of trisodium phosphate and tap water, followed by a methanol rinse and a triple rinse with distilled water. The equipment was laid on a clean plastic sheet to dry and then placed in clean plastic bags for storage or transport to the next location.

Table TM6-1 summarizes the samples taken and field measurements made at each location. Table TM6-2 lists the samples collected and sent for analysis. The surface soil samples were analyzed for TCL inorganic and volatile and semivolatile organic compounds. To facilitate evaluation of thermal treatment methods, selected samples were also sent to be analyzed for carbon, hydrogen, sulfur, oxygen, nitrogen, ash content, heating value, and total organic carbon. Selected samples were also sent in to be analyzed for polynuclear aromatic hydrocarbons (PAHs) at detection levels lower than those for the Contract Laboratory Program's Routine Analytical Analyses.

SEDIMENT SAMPLING

Sediment samples were taken at 11 locations on October 27 and 28. The main objectives of the sediment sampling were to establish background concentrations of the sediments, to refine the lateral extent of sediment contamination, and to define the vertical extent of contamination. The results from this task will be used to refine the estimates of the volume of contaminated sediment to be removed in the remedial action.

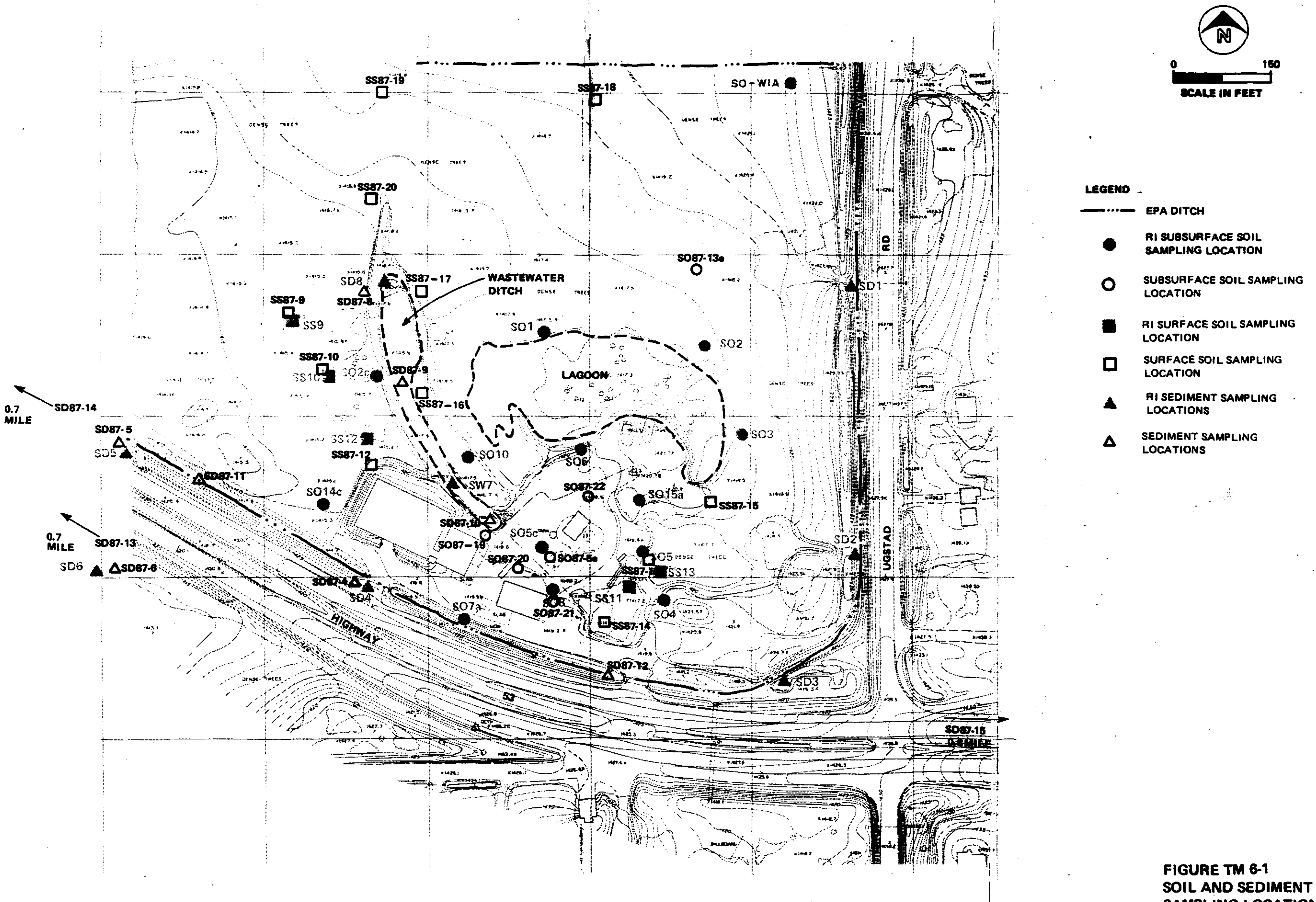


FIGURE TM 6-1
SOIL AND SEDIMENT SAMPLING LOCATIONS (STEP 1)
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM6-1
SUMMARY OF SURFACE SOIL SAMPLING

Sample Number	Location	HNu Deflection[a] (ppm)	Comments and Observations
SS87-9	West of wastewater ditch in area of dead trees, adjacent to SS-9.	None	Fibrous peat.
SS87-10	West of wastewater ditch in area of dead trees, adjacent of SS-10.	None	
SS87-12	West of wastewater ditch in area of dead trees, adjacent to SS-12.	0.4	Water level at ground surface.
SS87-13	Adjacent to SS-13.	1.2 (BKG 0.4)	Water level about 1 foot above ground surface. Sample taken with sediment corer. Oily sheen appeared upon disturbance of soil.
SS87-14	In a low-lying area draining the southeastern portion of the site.	1.6 (BKG 0.8)	Water level above ground surface. Oily sheen and petroleum odor noted.
SS87-15	South of sludge lagoon, topographically downgradient of the lagoon.	0.2	Water level at ground surface.
SS87-16	East of the wastewater ditch, between the wastewater ditch and the sludge lagoon.	0.1	
SS87-17	East of the wastewater ditch, between the wastewater ditch and the sludge lagoon.	0.2	Water level about ½ foot above ground surface. Sample taken with sediment corer. Oily sheen appeared upon disturbance of soil.
SS87-18	In wetland area north of sludge lagoon and wastewater ditch.	0.5	Dark organic soil.
SS87-19	In wetland area north of sludge lagoon and wastewater ditch.	0.5	
SS87-20	In wooded area northwest of wastewater ditch.	0.5	

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[a] HNu readings reported in this table were taken of sample in the stainless steel bowl.

Table TM6-2

SAMPLE MATRIX TABLE FOR SURFACE SOIL SAMPLES

CH2M HILL	CRL	TRAFFIC	COLLECTION		
SAMPLE NUMBER	SAMPLE NUMBER	REPORT NUMBER	DATE	TIME	LABORATORY[a]
SS87-09-01	88HV01S13	EP 344	10/26/87	1614	META TRACE
		MEC 970			ROCKY MOUNTAIN ANALYTICAL
		3330-E21			HITTMAN
SS87-10-01	88HV01S12	EP 343	10/26/87	1606	META TRACE
		MEI 721			ROCKY MOUNTAIN ANALYTICAL
		3330-E20			HITTMAN
		3330-E20			WEYERHAEUSER (TOC ONLY)
SS87-12-01	88HV01S15	EP 350	10/27/87	825	META TRACE
		MEC 976			ROCKY MOUNTAIN ANALYTICAL
		3330-E23			HITTMAN
	88HV01D15	3330-E45	10/27/87	825	HITTMAN (LL PAHS)
SS87-13-01	88HV01S17	EP 352	10/27/87	930	META TRACE
		MEC 978			ROCKY MOUNTAIN ANALYTICAL
		3330-E25			HITTMAN
		3330-E25			WEYERHAEUSER
	88HV01D17	3330-E46	10/27/87	930	HITTMAN (LL PAHS)
SS87-14-01	88HV01S16	EP 351	10/27/87	902	META TRACE
		MEC 977			ROCKY MOUNTAIN ANALYTICAL
		3330-E24			HITTMAN
SS87-15-01	88HV01S18	EP 353	10/27/87	954	META TRACE
		MEC 979			ROCKY MOUNTAIN ANALYTICAL
		3330-E26			HITTMAN
		3330-E26			WEYERHAEUSER
	88HV01D18	3330-E49 & E60	10/27/87	954	WEYERHAEUSER (TOC AND INCINERATOR)
SS87-16-01	88HV01S20	EP 355	10/27/87	1114	META TRACE
		MEM 458			ROCKY MOUNTAIN ANALYTICAL
		3330-E28			HITTMAN
	88HV01D20	3330-E48	10/27/87	1114	HITTMAN (LL PAHS)
SS87-17-01	88HV01S19	EP 354	10/27/87	1050	META TRACE
		MEM 457			ROCKY MOUNTAIN ANALYTICAL
		3330-E27			HITTMAN
		3330-E27			WEYERHAEUSER
	88HV01D19	3330-E47	10/27/87	1050	HITTMAN (LL PAHS)
SS87-18-01	88HV01S11	EP 342	10/26/87	1440	META TRACE
		MEI 792			ROCKY MOUNTAIN ANALYTICAL
		3330-E19			HITTMAN
		3330-E19			WEYERHAEUSER

Table TM6-2

SAMPLE MATRIX TABLE FOR SURFACE SOIL SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION DATE	COLLECTION TIME	LABORATORY[a]
SS87-19-01	88HV01S10	EL 557	10/26/87	1427	META TRACE
		MEI 787			ROCKY MOUNTAIN ANAYTICAL
		3330-E18			HITTMAN
		3330-E18			WEYERHAEUSER
	88HV01D10	EL 558	10/26/87	1427	META TRACE (ORGANICS)
SS87-20-01	88HV01S14	EP 349	10/26/87	1549	META TRACE
		MEC 975			ROCKY MOUNTAIN ANALYTICAL
		3330-E22			HITTMAN
	88HV01D14	3330-E44	10/26/87	1549	HITTMAN (LL PAHS)
FB87-05-01	88HV01S21	EP 356	10/27/87	945	META TRACE
		MEM 459			ROCKY MOUNTAIN ANALYTICAL
		3330-E29			HITTMAN
		3330-E29			WEYERHAEUSER

a = First laboratory listed for organic analysis
Second laboratory listed for inorganic analysis
Third laboratory listed for low level PAHs
Fourth laboratory listed for TOC and incinerator parameters

PERSONNEL

The sampling team consisted of:

- Randy Videkovich, CH2M HILL
- Jewelle Imada, CH2M HILL
- Alan Esko, Engineers International
- Tom Hahne, PRC

Sample custody was maintained by the sampling team. The CLP paperwork was completed by Cathy Kantowski, Engineers International.

SAMPLING LOCATIONS

The sediment samples were taken from three locations in the wastewater ditch, one in the culvert south of Highway 53, and four in the EPA ditch along Highway 53; three samples were taken in roadside locations along Highway 53 about 0.7 mile from the site to serve as background. The sampling locations are shown in Figure TM6-1 and briefly described in Table TM6-3. The objectives of sampling for each location are given in the Work Plan.

SAMPLING PROCEDURES

The sediment samples were collected from two separate depths at each location; 0 to 1 foot, and 1 to 2 feet. Samples from the upper layer were taken using a stainless steel spoon. The lower layer was sampled using a stainless steel spoon or a sediment corer. At each location, the samples to be analyzed for VOCs were taken first. The samples taken with the stainless steel spoon were put directly into the VOC vials. If the sediment corer was used, the sample was first placed in a stainless steel bowl and then spooned into the jars. Samples analyzed for the other parameters were placed in a stainless steel bowl, composited, and placed in the sample jars. The outside of the jars was then decontaminated and the paperwork was completed.

The sampling equipment was decontaminated between samples by scrubbing in a solution of trisodium phospate and tap water, followed by a methanol rinse and a triple rinse with distilled water. The equipment was laid on a clean plastic sheet to dry and then placed in a clean plastic bag for storage or transport to the next sampling location.

Table TM6-3 summarizes the samples taken and field measurements made at each location. Table TM6-4 lists the samples collected and sent for analysis. The sediment samples were analyzed for TCL inorganic and volatile and semivolatile organic compounds. To facilitate evaluation of thermal treatment methods, selected samples were sent to be analyzed for carbon, hydrogen, sulfur, oxygen, nitrogen, ash content,

Table TM6-3
SUMMARY OF SEDIMENT SAMPLING

Sample Number	Location	HNu Deflection[a] (ppm)	Comments and Observations
SD87-4	Western section of the U.S. EPA ditch south of Gopher Oil.	None	Small but noticeable flow through culvert. 0-1 foot sample consisted of brown sandy silt. 1-2 foot sample was peat with brown to black silty sand.
SD87-5	Western section of the U.S. EPA ditch about 15 to 20 feet from the culvert.	None	
SD87-6	Culvert south of Hwy. 53.	None	Some ice on the water. Approximately 6 inches of water. An oily sheen appeared upon disturbance of sediment.
SD87-8	Near discharge point for the wastewater ditch.	1.0 (0-1') 0.2 (1-2')	Samples consist mainly of organic matter. Both samples appear oily with a petroleum odor.
SD87-9	Middle of wastewater ditch. Sample taken in cattail area east of MW2.	4.0 (0-1') 4-5 (1-2')	Both samples were oily with strong petroleum odor. Problems getting lower sample. Lower sample taken by driving corer down about 2 feet, emptying corer and redriving into the same hole to collect the sample.
SD87-10	Approximately 15 feet north of the southern end of wastewater ditch.	40.0 (0-1') 3-5 (1-2')	Samples taken in level C because of strong petroleum odor and oil layer on water surface. Lower sample taken by driving corer down, empty corer, and driving into the same hole to collect samples. Samples very oily, sent in as medium hazard.
SD87-11	Western section of U.S. EPA ditch, 5 feet west of MW3.	None	Approximately 6 inches of water in ditch.
SD87-12	U.S. EPA ditch.	None	Oily sheen appeared upon disturbance of sediments.
SD87-13	Roadside ditch 0.7 mile west of the site, south of Hwy. 53.	None	Water level about 6 inches below ground surface.
SD87-14	Roadside ditch 0.7 mile west of the site, north of Hwy. 53.	None	Water at ground surface.
SD87-15	Roadside ditch 3/4 mile east of the site, south of Hwy. 53.	None	1 to 2 feet of peat. Samples were not saturated.

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[a] HNu readings were taken of headspace in sample jars.

Table TM6-4

SAMPLE MATRIX TABLE FOR SEDIMENT SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION		LABORATORY[a]
			DATE	TIME	
SD87-04-01	88HV01S34	EP 380	10/28/87	1205	A A T S
		MEM 483			ROCKY MOUNTAIN ANAYTICAL
		3330-E53			CH2M HILL
		3330-E53			WEYERHAEUSER
	88HV01D34	3330-E55 & E61	10/28/87	1205	WEYERHAEUSER (TOC & INCINERATOR)
SD87-04-02	88HV01S35	EP 381	10/28/87	1220	A A T S
		MEM 484			ROCKY MOUNTAIN ANAYTICAL
		3330-E50			CH2M HILL
SD87-05-01	88HV01S30	EP 373	10/28/87	1020	ENERGY ENVIR. ENG. INC.
		MEM 476			ROCKY MOUNTAIN ANAYTICAL
		3330-E40			HITTMAN
		3330-E40			WEYERHAEUSER
SD87-05-02	88HV01S31	EP 374	10/28/87	1025	ENERGY ENVIR. ENG. INC.
		MEM 477			ROCKY MOUNTAIN ANAYTICAL
		3330-E41			HITTMAN
SD87-06-01	88HV01S28	EP 363	10/28/87	925	ENERGY ENVIR. ENG. INC.
		MEM 466			ROCKY MOUNTAIN ANAYTICAL
		3330-E36			HITTMAN
	88HV01D28	EP 364	10/28/87	925	ENERGY ENVIR. ENG. INC.
		MEM 467			ROCKY MOUNTAIN ANAYTICAL
		3330-E37			HITTMAN
SD87-06-02	88HV01S29	EP 365	10/28/87	930	ENERGY ENVIR. ENG. INC.
		MEM 468			ROCKY MOUNTAIN ANAYTICAL
		3330-E38			HITTMAN
	88HV01D29	EP 366	10/28/87	930	ENERGY ENVIR. ENG. INC.
		MEM 469			ROCKY MOUNTAIN ANAYTICAL
		3330-E39			HITTMAN
SD87-08-01	88HV01S38	EP 384	10/29/87	1220	A A T S
		MEM 487			ROCKY MOUNTAIN ANAYTICAL
		3330-E56			CH2M HILL
SD87-08-02	88HV01S39	EP 385	10/29/87	1228	A A T S
		MEM 488			ROCKY MOUNTAIN ANAYTICAL
		3330-E54			CH2M HILL
SD87-09-01	88HV01S40	EP 386	10/29/87	1310	A A T S
		MEM 489			ROCKY MOUNTAIN ANAYTICAL
		3330-E57			CH2M HILL
		3330-E57			WEYERHAEUSER
SD87-09-02	88HV01S41	EP 387	10/29/87	1420	A A T S
		MEM 490			ROCKY MOUNTAIN ANAYTICAL
		3330-E55			CH2M HILL
SD87-10-01	88HV02S01	3155-101	10/29/87	1510	NANCO LABS
		3249-101			JTC ENVIRONMENTAL CONSULTING
SD87-10-02	88HV02S02	3155-102	10/29/87	1522	NANCO LABS
		3249-102			JTC ENVIRONMENTAL CONSULTING

Table TM6-4

SAMPLE MATRIX TABLE FOR SEDIMENT SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION		LABORATORY[a]
			DATE	TIME	
SD87-11-01	88HV01S32	EP 378	10/28/87	1130	ENERGY ENVIR. ENG. INC.
		MEM 481			ROCKY MOUNTAIN ANAYTICAL
		3330-E42			HITTMAN
		3330-E42			WEYERHAEUSER
SD87-11-02	88HV01S33	EP 379	10/28/87	1146	ENERGY ENVIR. ENG. INC.
		MEM 482			ROCKY MOUNTAIN ANAYTICAL
		3330-E43			HITTMAN
SD87-12-01	88HV01S36	EP 382	10/28/87	1425	A A T S
		MEM 485			ROCKY MOUNTAIN ANAYTICAL
		3330-E52			CH2M HILL
		3330-E52			WEYERHAEUSER
SD87-12-02	88HV01S37	EP 383	10/28/87	1440	A A T S
		MEM 486			ROCKY MOUNTAIN ANAYTICAL
		3330-E51			CH2M HILL
SD87-13-01	88HV01S26	EP 361	10/27/87	1510	ENERGY ENVIR. ENG. INC.
		MEM 464			ROCKY MOUNTAIN ANAYTICAL
		3330-E34			HITTMAN
		3330-E34			WEYERHAEUSER (TOC ONLY)
SD87-13-02	88HV01S27	EP 362	10/27/87	1515	ENERGY ENVIR. ENG. INC.
		MEM 465			ROCKY MOUNTAIN ANAYTICAL
		3330-E35			HITTMAN
SD87-14-01	88HV01S24	EP 359	10/27/87	1434	META TRACE
		MEM 462			ROCKY MOUNTAIN ANAYTICAL
		3330-E32			HITTMAN
SD87-14-02	88HV01S25	EP 360	10/27/87	1439	META TRACE
		MEM 463			ROCKY MOUNTAIN ANAYTICAL
		3330-E33			HITTMAN
SD87-15-01	88HV01S22	EP 357	10/27/87	1355	META TRACE
		MEM 460			ROCKY MOUNTAIN ANAYTICAL
		3330-E30			HITTMAN
		3330-E30			WEYERHAEUSER (TOC ONLY)
SD87-15-02	88HV01S23	EP 358	10/27/87	1400	META TRACE
		MEM 461			ROCKY MOUNTAIN ANAYTICAL
		3330-E31			HITTMAN
FB87-06-01	88HV01S44	EP 391	10/29/87	825	A A T S
		MEM 493			ROCKY MOUNTAIN ANAYTICAL
		3330-E58			CH2M HILL
		3330-E58			WEYERHAEUSER

a = First laboratory listed for organic analysis
Second laboratory listed for inorganic analysis
Third laboratory listed for low level PAHs
Fourth laboratory listed for TOC and incinerator parameters

A A T S = American Analytical Technical Service Inc.

heating value, and total organic carbon. Selected samples were also sent in to be analyzed for low level PAHs.

SAMPLING PROBLEMS

Problems in the sediment sampling occurred mainly in the collection of the lower samples. The sediment corer used did not have an effective catch so samples were often lost before they could be placed in the stainless steel bowl. The compactibility of the upper sediment and the depth of water in some locations made the depth of the sample difficult to estimate. The presence of a highly contaminated upper sediment layer or the release of an oily sheen to the surface water upon disturbance of the sediment in the wastewater ditch made it difficult to prevent cross-contamination of the lower samples.

SUBSURFACE SOIL SAMPLING

Collection of subsurface soil samples from 12 locations began on October 12. The objective of the sampling effort was to better define the lateral and vertical extent of soil contamination, especially in the process area. The results of this task will be used to refine the volumes of soil to be removed for remediation of the site.

Sampling was suspended on October 20 because of high organic vapor readings measured with an OVA flame-ionization meter or HNu photo-ionization meter during drilling. Six borings were drilled before sampling was suspended. However, complete sets of samples were collected at only four locations (SO87-5B, SO87-13e, SO87-20, and SO87-21). Drilling at Borings SO87-19 and SO87-22 had to be abandoned because of high organic vapor readings measured during drilling.

PERSONNEL

The sampling team consisted of:

- Cindy Cruciani, CH2M HILL
- Jewelle Imada, CH2M HILL
- Jim Russell, CH2M HILL
- Bob Weinschrott, CH2M HILL
- Greg Weeks, Engineers International
- Mehdi Geraminegad, E&E
- Jerry McLane, PRC

Not all personnel were present at the site at the same time. Sample custody was maintained by the sampling team. The CLP paperwork was completed by Cindy Cruciani and Jim Russell. The drilling of the soil borings was subcontracted to STS Consultants, Ltd.

SAMPLING LOCATIONS

Subsurface soil samples were collected at six locations (two of these correspond to monitoring well locations). The locations of the soil borings were based on the RI results. Soil boring locations were staked out by Jewelle Imada and Dave Chrisman (MPCA) before drilling began. Sampling locations are shown in Figure TM6-1 and briefly described in Table TM6-5. The objectives of sampling for each location are given in the Work Plan.

SAMPLING PROCEDURES

Soil borings were drilled using a CME-75 rig or a Mobile B-53 drill rig mounted on an all-terrain vehicle carrier. The borings were advanced using hollow-stem augers. Continuous split-spoon samples were obtained from the ground surface using the standard penetration test method. After the split spoon was opened, the sample was logged and screened with an HNu or an OVA. Samples were placed directly into sample jars using a stainless steel utensil.

The exterior of the jars was decontaminated and the paperwork completed. Split spoons and other sampling equipment were decontaminated between samples with a solution of trisodium phosphate and tap water, followed by a tap water rinse, a methanol rinse, and a triple rinse with distilled water.

Subsurface soil boring logs are provided in Attachment A. Table TM6-5 summarizes the samples taken and field measurements made at each location. Table TM6-6 lists the samples collected and sent for analyses. The subsurface soil samples were analyzed for TCL inorganic and volatile and semivolatile organic compounds. Selected samples were sent in to be analyzed for low level PAHs. The visibly contaminated peat and fill samples were packed for later shipment to a lab as medium hazard samples.

SAMPLING PROBLEMS

The Work Plan had selected 12 locations for the collection of subsurface soil samples. The higher than expected level of contamination of the subsurface soil in the process area precluded completion of the subsurface soil investigation. Health and safety monitoring of air in the breathing zone indicated that level B safety protection was needed instead of level C. Borehole SO87-19 had a reading of more than 80 ppm and borehole SO87-22 had more than 20 ppm, as measured by an OVA. The high readings occurred while drilling through the material at depths of 1 to 6 feet. Breakthrough in level C full face respirator protection occurred as well after only a few minutes of cartridge use. Therefore, borings SO87-19 and SO87-22 were abandoned for health and safety reasons. Because this level of contamination was not expected, subsurface soil sampling was suspended.

Table TM6-5 (Page 1 of 3)
SUMMARY OF SUBSURFACE SOIL SAMPLING

Boring Number	Location Description	Sample Number	Layer Sampled	Analyses[a]	Depth (ft bgs)	HNu$_e$ or OVA Readings[b] Air (ppm)	HNu$_e$ or OVA Readings[b] Sample[b] (ppm)	Number of Spoons to Collect Samples	Comments and Observations
SO87-5b	In process area. Associated with Well MW-5b.	SO-05-01	Fill	Organic Inorganic	0-4	0.3-0.4	5-100 (50 ppm from headspace measurement*)	8	Fill samples varied from wood fragments to silty clay. Samples were black and oily.
		SO-05-02	Peat	Organic Inorganic	5-6	0.4	>1,000* (from headspace measurement)	2	Because of poor peat recovery with split spoon, augers were pulled so peat samples could be collected from the auger blades. Peat samples were soaked with black oil. Vinyl chloride drager tube taken of head-space measured 0.3 ppm.
		SO-05-03	Lacustrine silt	Organic Inorganic TOC LL PAH	7-16	0.4	5-30 (50 ppm from headspace measurement*)	12	
		SO-05-04	Outwash	Organic Inorganic TOC LL PAH	18-20	0.4	1-5 (50 ppm from headspace measurements)	5	
		SO-05-05	Till	Organic Inorganic TOC LL PAH	30-30.5	0.2	0.1-2 (0.2-3.3 ppm from headspace measurement)	7	Switched to mud rotary drilling to collect these samples. Replaced 140 lb hammer with 300 lb hammer at about 33 feet bgs. Note: High HNu readings of 60 ppm in breathing zone measured during grouting with about 20 feet of augers in ground. Site was evacuated and volatiles allowed to dissipate. Grouting resumed once readings dropped to 0.6 ppm after about an hour.
SO87-13c	In wetland area north of the sludge lagoon. Associated with Well MW-13b.	SO-13-01	Peat	Organic Inorganic TOC LL PAH	0-2	0.2	0.2	10	
		SO-13-02	Lacustrine silt	Organic Inorganic TOC LL PAH	5-16.5	0.2	0.2	6	

Table TM6-5 (Page 2 of 3)

Boring Number	Location Description	Sample Number	Layer Sampled	Analyses[a]	Depth (ft bgs)	HNu$_e$ or OVA Readings[b]		Number of Spoons to Collect Samples	Comments and Observations
						Air (ppm)	Sample[b] (ppm)		
		SO-13-03	Lacustrine sands	Organic Inorganic TOC LL PAH	30-34	0.2	0.2	4	
		SO-13-04	Till	Organic Inorganic TOC LL PAH	34-35.5	0.2	0.3-0.4	5	
SO87-19	Between Gopher Oil and the southern extent of the waste-water ditch.	SO-19-01	Fill	Organic Inorganic	0-6	1.7-80*	40-100*	3	Driving spoon from 4-6 feet, OVA readings were measured at 80 ppm in breathing zone. Drillers were evacuated for 15 minutes (OVA reading 2.7 ppm). Went back to borehole to remove split spoon and continue drilling. Drilling stopped because of continued high OVA readings and breakthrough of organic vapor through respirators. Bentonite was placed around augers and in borehole. Augers pulled 2 days later. OVA readings in breathing zone from 40-50 ppm were measured when augers were removed and borehole was grouted.
SO87-20	In process area just north of the auto body shop.	SO-20-01	Fill	Organic Inorganic	0-4	0-0.1	0.5 (400 ppm from headspace measurements*)	2	Fill samples oily. HNu reading suspected to be unreliable because of weather conditions.
		SO-20-03	Lacustrine-silts	Organic Inorganic LL PAH TOC	4-10	0	0 (40 ppm from headspace measurements*)	3	HNu reading suspected to be unreliable because of weather conditions.
SO87-21	About 10 feet east of north-eastern corner of auto body shop.	SO-21-01	Fill	Organic Inorganic	0-4	0.7-1.5*	600->1,000*	2	Fill samples oily.
		SO-21-03	Lacustrine-silts	Organic Inorganic LL PAH TOC	4-10	0.5-2.5*	10->1,000* (0 ppm from head-space measurement with HNu)	3	

Table TM6-5 (Page 3 of 3)

Boring Number	Location Description	Sample Number	Layer Sampled	Analyses[a]	Depth (ft bgs)	HNu$_{e}$ or OVA Readings[b]		Number of Spoons to Collect Samples	Comments and Observations
						Air (ppm)	Sample[b] (ppm)		
SO87-22	In central location of process area.	SO-22-01	Fill	Organic Inorganic	0-4	100-200*	>1,000* (HNu reading = >20 ppm)	2	Drilling shut down because of high OVA readings. Grout pour around augers and down borehole and augers pulled.

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[a] Indicates which analyses the samples were sent in for: TCL organic compounds (volatile and semivolatile) and inorganic constituents, total organic carbon (TOC), low level PAHs.

[b] Both HNu and OVAs were used to monitor drilling. Although the Site Safety Plan called for using the HNu, weather conditions made HNu readings unreliable. OVA readings are designated with an "*."

[c] The HNu or OVA readings in air are measurements taken in the breathing zone.

[d] The HNu or OVA readings of sample refer to measurements taken of sample in split spoons or auger cuttings unless designated as headspace measurements.

Table TM6-6

SAMPLE MATRIX TABLE FOR SUBSURFACE SOIL SAMPLES

CH2M HILL	CRL	TRAFFIC	COLLECTION		
SAMPLE NUMBER	SAMPLE NUMBER	REPORT NUMBER	DATE	TIME	LABORATORY[a]
SO87-05-01	88HV02S03	3155-103	10/12/87	1130	NANCO
		3249-103			JTC ENVIRONMENTAL CONSULTANTS
SO87-05-02	88HV02S04	3155-104	10/12/87	1230	NANCO
		3249-104			JTC ENVIRONMENTAL CONSULTANTS
SO87-05-03	88HV01S05	EP 339	10/12/87	115	META TRACE
		MEI 789			ROCKY MOUNTAIN ANALYTICAL
		3330-E08			HITTMAN
		3330-E08			WEYERHAEUSER
	88HV01R05	3330-E12	10/13/87	115	HITTMAN (LL PAHS)
SO87-05-04	88HV01S04	EP 340	10/12/87	230	META TRACE
		MEI 790			ROCKY MOUNTAIN ANALYTICAL
		3330-E07			HITTMAN
		3330-E07			WEYERHAEUSER
	88HV01R06	3330-E13	10/13/87	230	HITTMAN (LL PAHS)
SO87-05-05	88HV01S06	EP 341	10/13/87	1030	META TRACE
		MEI 791			ROCKY MOUNTAIN ANALYTICAL
		3330-E09			HITTMAN
		3330-E09			WEYERHAEUSER
	88HV01R04	EP 376	10/13/87	1030	META TRACE
		MEM479			ROCKY MOUNTAIN ANALYTICAL
		3330-E11			HITTMAN
		3330-E11			WEYERHAEUSER
SO87-13-01	88HV01S01	EP 345	10/12/87	1000	META TRACE
		MEC 971			ROCKY MOUNTAIN ANALYTICAL
		3330-E01			HITTMAN
		3330-E01			WEYERHAEUSER
	88HV01R01	3330-E03	10/12/87	1000	HITTMAN (LL PAHS)
SO87-13-02	88HV01S02	EP 346	10/12/87	1100	META TRACE
		MEC 972			ROCKY MOUNTAIN ANALYTICAL
		3330-E02			HITTMAN
		3330-E02			WEYERHAEUSER

Table TM6-6

SAMPLE MATRIX TABLE FOR SUBSURFACE SOIL SAMPLES

CH2M HILL	CRL	TRAFFIC	COLLECTION		[a]
SAMPLE NUMBER	SAMPLE NUMBER	REPORT NUMBER	DATE	TIME	LABORATORY
	88HV01R02	EP 375	10/12/87	1100	META TRACE
		MEM 478			ROCKY MOUNTAIN ANALYTICAL
		3330-E04			HITTMAN
		3330-E03			WEYERHAEUSER
S087-13-03	88HV01S03	EP 347	10/12/87	355	META TRACE
		MEC 973			ROCKY MOUNTAIN ANALYTICAL
		3330-E05			HITTMAN
		3330-E05			WEYERHAEUSER
	88HV01R03	3330-E06	10/12/87	355	HITTMAN (LL PAHS)
S087-13-04	88HV01S07	EP 348	10/13/87	1015	META TRACE
		MEC 974			ROCKY MOUNTAIN ANALYTICAL
		3330-E10			HITTMAN
		3330-E10			WEYERHAEUSER
	88HV01R07	3330-E14	10/13/87	1015	HITTMAN (LL PAHS)
S087-19-01	88HV02S05	3155-105	10/16/87	1020	NANCO
		3249-105			JTC ENVIRONMENTAL CONSULTANTS
S087-20-01	88HV02S06	3155-106	10/15/87	904	NANCO
		3249-106			JTC ENVIRONMENTAL CONSULTANTS
S087-20-03	88HV01S08	EP 369	10/15/87	1000	META TRACE
		MEM 472			ROCKY MOUNTAIN ANALYTICAL
		3330-E16			HITTMAN
		3330-E16			WEYERHAEUSER
S087-21-01	88HV01S07	3155-107	10/15/87	1310	NANCO
		3249-107			JTC ENVIRONMENTAL CONSULTANTS
	88HV02D07	3155-108	10/15/87	1350	NANCO
		3249-108			JTC ENVIRONMENTAL CONSULTANTS
S087-21-03	88HV01S09	EP 372	10/15/87	1500	META TRACE
		MEM 475			ROCKY MOUNTAIN ANALYTICAL
		3330-E17			HITTMAN
		3330-E17			WEYERHAEUSER
S087-22-01	88HV02S08	3155-108	10/19/87	1230	NANCO
		3249-108			JTC ENVIRONMENTAL CONSULTANTS

Table TM6-6

SAMPLE MATRIX TABLE FOR SUBSURFACE SOIL SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION DATE	COLLECTION TIME	LABORATORY[a]
FB87-05-01	88HV01B01	EP 377	10/13/87	100	META TRACE
		MEM 480			ROCKY MOUNTAIN ANALYTICAL
FB87-13-01	88HV01B02	3330-E15	10/13/87	130	HITTMAN
		3330-E15			WEYERHAEUSER

a = First laboratory listed for organic analysis
Second laboratory listed for inorganic analysis
Third laboratory listed for low level PAHs
Fourth laboratory listed for TOC

The high level of contamination also caused problems with sending samples to the laboratories for analyses. All the fill and peat samples from the process area were visibly contaminated. Because the original sampling plan specified low-level RAS analyses, the samples had to be stored until a laboratory could be found that would accept the samples.

Selected samples were collected for evaluation of thermal treatment parameters (carbon, hydrogen, sulfur, oxygen, nitrogen, ash content, heating value, and total organic carbon). However, a laboratory could not be found to do the analyses so the samples were collected and stored for later shipment.

Another problem encountered was collecting enough sample from a layer for the specified number of analyses. This called for additional borings to be drilled and sampled. (Seven moves were required at SO87-5b.) To avoid excessive equipment moves, a sampling priority was recommended as follows:

1. TCL volatile organic compounds
2. TCL semivolatile organic compounds
3. Low level PAHs (if sample not visually contaminated)
4. TCL inorganic chemicals
5. TOCs (if sample not from fill or peat)
6. Thermal treatment parameters

It was decided that a maximum of two additional borings could be used for the collection of addition sample volume. The borings were to be limited to a maximum depth of 20 feet.

The four borings sampled after these decisions were made were not affected by the new procedure because of the analyses specified at these locations and the visual contamination of upper samples.

CH2M HILL

TECHNICAL MEMORANDUM NO. 7

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: Jewelle Imada/CH2M HILL

DATE: February 22, 1988

RE: Groundwater and Residential Well Sampling
(Step I)

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68802.FQ

INTRODUCTION

Groundwater samples from new and existing monitoring wells and residential wells were taken during Step I of the Fieldwork Design Investigation. The samples were collected between November 9 and 18, 1987. The results of the investigation will be used to refine the nature and extent of groundwater contamination and to resolve inconsistencies between the RI data sampling rounds and differences with MPCA analytical results. This memorandum includes descriptions of the sampling procedures, any field observations and measurements, and sample matrix tables for the samples collected and sent for analyses.

PERSONNEL

The sampling team consisted of:

- Randy Videkovich, CH2M HILL
- Bryan Laude, CH2M HILL
- Jeff Keiser, CH2M HILL
- Steve Keith, CH2M HILL
- Jewelle Imada, CH2M HILL
- Alan Esko, Engineers International
- Tom Hahne, PRC
- Ken Partymiller, PRC
- Jean Desruisseaux, PRC

Not all personnel were present at the site at the same time. Sample custody was maintained by the sampling team. The CLP paperwork was completed by Cathy Kantowski (Engineers International) and Bobbie Hughes (CH2M HILL).

MONITORING WELL SAMPLING

SAMPLING LOCATIONS

The groundwater samples were collected from 42 new or existing monitoring wells (see Figure TM7-1). Monitoring Well B4a was not sampled because of the high levels of contamination detected previously.

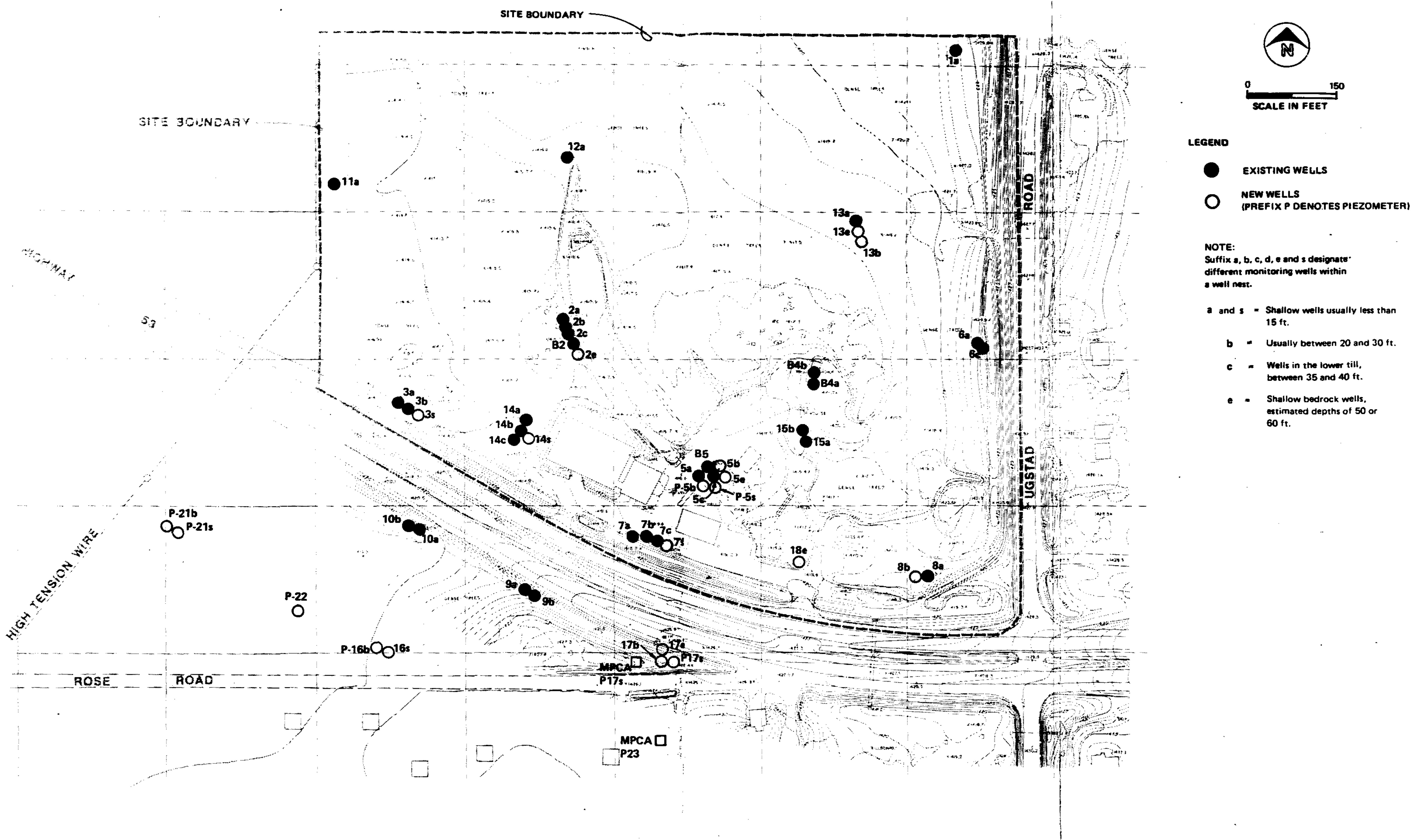
SAMPLING PROCEDURES

Before each well was purged and sampled, a water level measurement and a well depth measurement were taken using an electronic water level indicator (Table TM7-1). The measurements were used to verify well depth and to calculate the volume of water to be purged from the well.

The Sampling Plan specified that the wells be purged of five well volumes immediately before sampling. Slow recharge to many of the wells often made this difficult to do. Wells MW-1a, B4b, MW-5a, MW-5b, MW-7s, MW-9b, MW-13a, MW-14s, MW-14a, and MW-17e were purged dry and allowed to recover before sampling (Table TM7-2). All of the wells were purged of five well volumes of water with stainless steel bailers except Wells B2, MW-2e, MW-B5, MW-7c, MW-14b, and MW-18e. Wells B2 and B5 were purged with a peristaltic pump because the wells were too narrow for the bailer and time constraints made purging with a 1-inch bailer difficult. However, Well B4b was bailed with a 1-inch bailer because of pump problems. Well MW-7c was purged with a peristaltic pump because the bailer could not pass a bend in the casing. Five well volumes could not be purged from Wells MW-2e, MW-14b, and MW-18e because of poor recharge, so they were purged dry, left overnight, purged dry again, and sampled once the wells recovered. The bailers for sampling these wells were suspended in the well during recharge and used for the purging and sampling.

Samples were collected by two teams proceeding from the cleanest wells to the most contaminated. The sample jars were filled in the following order: VOCs with low detection limits (if taken), VOCs, semivolatile organic compounds, metals, cyanide, and SAS parameters (COD, TOC, alkalinity, total suspended solids, and oil and grease). The outside of the sampling jars was then decontaminated and the paperwork started. The samples sent for analyses are listed in Table TM7-3.

Samples to be analyzed for metals were filtered and preserved with HNO_3 to a pH of less than 2. Samples to be analyzed for cyanide were preserved with NaOH to a pH



NOTE:
Suffix a, b, c, d, e and s designate different monitoring wells within a well nest.

a and s = Shallow wells usually less than 15 ft.

b = Usually between 20 and 30 ft.

c = Wells in the lower till, between 35 and 40 ft.

e = Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE TM 7-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM7-1 (Page 1 of 2)
WATER LEVELS AND DEPTH OF WELL

Well Number	Depth to Water Below Top of Riser (ft)	Depth of Well Below Top of Riser (ft)	HNu Readings (ppm)	Comments
MW-1a	5.43*	16.6*	BKG	
MW-2a	5.2	10.47	BKG	
MW-2b	5.3	27.35	BKG	
MW-2c	4.88	40.34	BKG	
B2	5.46	10.26	BKG	
MW-2e	4.12	36.25	BKG	Records indicated well depth greater than 50 feet; remeasured before sampling; depth of well 50.75 ft (below top of riser)
MW-3s	3.93	9.4	BKG	
MW-3a	4.37	17.30	BKG	
MW-3b	3.88	24.13	BKG	
B4a	NM	NM	NM	
MW-B4b	7.70	12.4	BKG	
P5s	3.90	6.98	5	
P5b	4.24	17.68	0.5	
MW-5a	4.44	14.47	NM	
MW-5b	4.04	22.13	2	
MW-5c	4.51	40.88	BKG	
MW-5e	3.80	55.94	BKG	
B5	5.6	10.66	4	
MW-6a	7.81	16.17	BKG	
MW-6c	7.15	37.43	BKG	
MW-7s	4.65	13.04	BKG	
MW-7a	6.09	16.65	BKG	
MW-7b	5.4	27.36	BKG	
MW-7c	5.38	38.82	BKG	
MW-8a	7.83	17.57	BKG	
MW-8b	6.53	24.9	BKG	
MW-9a	5.81*	16.64*	BKG	
MW-9b	6.08	24.6	BKG	
MW-10a	3.94	14.4	BKG	
MW-10b	3.67	25.67	BKG	
MW-11a	2.92	17.3	NM	
MW-12a	4.75	16.22	BKG	
MW-13a	2.94	17.01	BKG	
MW-13b	2.13	32.64	BKG	
MW-13e	2.15	53.6	BKG	
MW-14s	2.65	8.11	BKG	

Table TM7-1 (Page 2 of 2)

Well Number	Depth to Water Below Top of Riser (ft)	Depth of Well Below Top of Riser (ft)	HNu Readings (ppm)	Comments
MW-14a	2.64	16.19	BKG	
MW-14b	3.16	27.04	BKG	
MW-14c	2.2	33.46	BKG	Well may be damaged by soil moving
MW-15a	6.2	16.87	BKG	
MW-15b	5.99	26.74	BKG	
MW-16s	7.68	14.82	BKG	
P16b	8.87	27.55	BKG	
P17s (MPCA)	Dry	9.9	BKG	
P17s	9.17	NM	BKG	
MW-17b	9.35	44.45	BKG	
MW-17e	8.73	58.72	BKG	
MW-18e	NM	NM		Problems with water level indicator; well depth measured before sampling
P21s	4.6	12.02	BKG	
P21b	4.59	32.31	BKG	
P22s	3.69	10.4	BKG	
P23s (MPCA)	NM	NM		

Staff Gauges	Gauge Readings (ft)
SG1	0.32
SG2	0.29
SG3	0.26
SG4	0.46

Note: Staff gauge readings may not reflect normal water levels. City crew opened the hydrant and let water run into the U.S. EPA ditch the same day as when staff gauges were read.

NM = Not measured
BKG = HNu reading background
* = Readings taken from top of the protective casing

GLT932/022.50

Table TM7-2 (Page 1 of 2)
SUMMARY OF GROUNDWATER SAMPLING

			OVA or HNu Readings[a]				
Well Number	Total Water Purged (gal)	Time Between Purging and Sampling (hr)	In Well (ppm)	From Water (ppm)	pH	Conductivity (umhos)	Comment and Observation
MW-1a	8	2	BKG*	BKG*	7.4	250	Bailed dry after 4 gal. Water red and silty.
MW-2a	3	0	10*->1,000*	>1,000*	6.7	675	Elevated OVA readings measured while purging; sample taken in Level C, OVA readings 2 to 3 ppm in breathing zone.
MW-2b	10	0	BKG	BKG	7.8	200	
MW-2c	16	0	2-11*	BKG	7.6	225	
MW-2e	--	7	30	BKG	8.5	250	Bailed dry after 12 gallons. Purged dry 2 days.
B2	2	0	200*-300*	200*-300*	6.8	575	Purged with peristaltic pump.
MW-3s	6	0	BKG	BKG	7.0	625	Turbid; very slow recharging (1 hour to purge 6 gallons).
MW-3a	6	0	BKG	BKG	7.7	225	
MW-3b	10	0	BKG	BKG	8.5	250	Turbid.
B4b	8	0.75	NM	NM	7.6	300	Bailed using 1-inch bailer; after waiting 45 minutes to sample, recharge was only enough to take metals and cyanide samples; VOCs and extractable samples taken next morning.
MW-5a	5	1	BKG	BKG	7.7	500	
MW-5b	10	1	BKG	3*	7.5	625	
MW-5c	17	0	NM	NM	7.8	225	
MW-5e	45	0	BKG	BKG	8.0	250	
B5	5	0	NM	NM	6.6	600	Well had very strong odor, OVA not working.
MW-6a	8	0	BKG	BKG	6.9	425	Some silt at bottom of well.
MW-6c	30	0	BKG	BKG	7.4	350	
MW-7s	9	0.5	BKG	BKG	6.7	725	
MW-7a	10	0	BKG	BKG	6.5	650	Oily sheen observed in purge water. Odor also noted.
MW-7b	10	2	BKG	BKG	7.3	500	Bailed dry after about 6 gallons.
MW-7c	17	16	NM	NM	7.3	275	Could not get bailer down well, possible bend in casing; purged using peristaltic pump.
MW-8a	5	NR	BKG	BKG	7.1	1,746	
MW-8b	15	NR	BKG	BKG	7.1	2,200	
MW-9a	5	0	BKG	BKG	7.9	950	Purged dry after 4 gallons.
MW-9b	8	0.5	1.5*	2*	7.9	800	Purged dry after 5.5 gallons.
MW-10a	5	0	NM	1.5*	8.0	1,150	Turbid.
MW-10b	10	NR	BKG	25*	7.8	1,300	Poor recharge (1 hour to purge 10 gallons).

Table TM7-2 (Page 2 of 2)

Well Number	Total Water Purged (gal)	Time Between Purging and Sampling (hr)	OVA or HNu Readings[a]		pH	Conductivity (umhos)	Comment and Observation
			In Well (ppm)	From Water (ppm)			
MW-11a	7	NR	BKG	BKG	8.1	225	
MW-12a	6	0	BKG	BKG	6.3	195	Turbid, silt on bottom of well.
MW-13a		0.5	BKG	BKG	7.6	250	Purged dry after 5 gallons.
MW-13b	30	0	BKG	BKG	7.6	200	Purged dry after 23 gallons.
MW-13e	50	0	BKG	BKG	7.8	300	Water clear, full recovery.
MW-14s	7	17	BKG	BKG	7.5	375	
MW-14a	7	17	50*	0.5-30*	7.2	550	Purged dry after 5 gallons. Aromatic odor noted.
MW-14b	--	72	600*	>100*	7.3	275	Purged dry after 4 gallons; five well volumes not purged, but purged dry twice and allowed to be recharged for 2 days before sampling.
MW-15c	15	0	2*	80*	8.0	250	Sweet solvent odor noted.
MW-15a	5	0	BKG	BKG	6.7	2,750	
MW-15b	10	NR	BKG	BKG	7.6	525	Purged dry after 4 gallons.
MW-16s	7	NR	BKG	BKG	7.2	400	Note: PVC shavings floating in purge water.
MW-17b	32	0	BKG	BKG	7.6	200	
MW-17e	50	0.5	BKG	BKG	12.6	1,800	Some bentonite observed in purge water.
MW-18e	--	72	BKG	BKG	12.5	1,625	Poor recharge, purged dry 2 days.
FB					7.4	65	

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[a] OVA readings are marked with an "*." Readings in the well were taken by placing probe in the well casing. Readings from the water were measured from the water in the bucket during purging of the well.

NM = Not measured
NR = Not recorded
BKG = HNu or OVA reading background

Table TM-7-3
SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION		LABORATORY[a]
			DATE	TIME	
MW-B2-03	88HV02S01	EP 389 MEK 995	11/17/87	1135	Hazleton Laboratories Ensenco Corporation
MW-3S-01	88HV02S27	EQ 119 MER 617	11/12/87	1525	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water Centec Analytical Services Central Regional Laboratory
MW-3A-03	88HV02S25	EQ 117 MER 615	11/12/87	1425	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water
MW-3B-03	88HV02S26	EQ 118 MER 616	11/12/87	1125	Spectrix Corporation Ensenco Corporation
MW-B4b-03	88HV02S02	EP 390 MEK 996	11/18/87	1550	Hazleton Laboratories Ensenco Corporation
MW-5A-03	88HV02S42	EQ 135 MER 632	11/16/87	1506	Hazleton Laboratories Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-5A-03	88HV02D42		11/16/87	1506	Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-5B-01	88HV02S43	EQ 137 MER 634	11/16/87	1533	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest Centec Analytical Services Central Regional Laboratory
MW-5C-03	88HV02S06	EP 395 MEM 495	11/10/87	1615	Spectrix Corporation Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-5E-01	88HV02S44	EQ 136 MER 633	11/16/87	1505	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest

Table TM-7-3
SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION		LABORATORY[a]
			DATE	TIME	
MW-B5-03	88HV02S46	EQ 139 MER 636	11/17/87	1135	Hazleton Laboratories Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-6A-03	88HV02S12	EQ 215 MER 600	11/11/87	1035	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water Centec Analytical Services Central Regional Laboratory
MW-6C-03	88HV02S13	EQ 103 MER 601	11/11/87	1020	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water Centec Analytical Services Central Regional Laboratory
MW-7A-03	88HV02S03	EP 391 MEK 997	11/10/87	1515	Spectrix Corporation Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-7A-03	88HV02D03	EP 392 MEK 998	11/10/87	1515	Spectrix Corporation Ensenco Corporation
MW-7B-02	88HV02S33	EQ 125 MER 623	11/13/87	1125	Spectrix Corporation Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-7C-02	88HV02S45	EQ 138 MER 635	11/17/87	920	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest
MW-7S-01	88HV02S04	EP 393 MEK 999	11/10/87	1500	Spectrix Corporation Ensenco Corporation Centec Analytical Services (4th) Central Regional Laboratory (5th)
MW-8A-03	88HV02S05	EP 394 MEM 494	11/10/87	1110	Spectrix Corporation Ensenco Corporation
MW-8B-01	88HV02S08	EQ 211 MEM 497	11/10/87	1130	Spectrix Corporation Ensenco Corporation

Table TM-7-3
SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION		LABORATORY[a]
			DATE	TIME	
MW-9A-02	88HV02S22	EQ 115	11/12/87	1040	Spectrix Corporation
		MER 613			Ensenco Corporation
					Spectrix & Calif. Water
MW-9B-02	88HV02S23	EQ 116	11/12/87	1100	Spectrix Corporation
		MER 614			Ensenco Corporation
					Spectrix & Calif. Water
MW-10A-02	88HV02S20	EQ 112	11/12/87	935	Spectrix Corporation
		MER 610			Ensenco Corporation
					Spectrix & Calif. Water
MW-10B-02	88HV02S21	EQ 113	11/12/87	1015	Spectrix Corporation
		MER 611			Ensenco Corporation
					Spectrix & Calif. Water
MW-11A-03	88HV02S16	EQ 104	11/11/87	1130	Spectrix Corporation
		MER 602			Ensenco Corporation
					Spectrix & Calif. Water
MW-12A-03	88HV02S24	EQ 114	11/12/87	900	Spectrix Corporation
		MER 612			Ensenco Corporation
					Spectrix & Calif. Water
MW-12A-03	88HV02D24	MER 604	11/12/87	900	Ensenco Corporation (2nd)
MW-13A-03	88HV02S10	EQ 215	11/11/87	1230	Spectrix Corporation
		MEM 603			Ensenco Corporation
					Spectrix & Calif. Water
MW-13A-03	88HV02D10	EQ 106	11/11/87	1230	Spectrix Corporation
MW-13B-01	88HV02S11	EQ 109	11/11/87	1250	Spectrix Corporation
		MER 607			Ensenco Corporation
					Spectrix & Calif. Water
					Centec Analytical Services
					Central Regional Laboratory
MW-13E-01	88HV02S14	EQ 214	11/11/87	1130	Spectrix Corporation
		MEM 500			Ensenco Corporation
					Spectrix & Calif. Water
					Centec Analytical Services
					Central Regional Laboratory

Table TM-7-3

SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

CH2M HILL	CRL	TRAFFIC	COLLECTION		a
SAMPLE NUMBER	SAMPLE NUMBER	REPORT NUMBER	DATE	TIME	LABORATORY
MW-14A-03	88HV02S28	EQ 121 MER 619	11/13/87	930	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water Centec Analytical Services Central Regional Laboratory
MW-14B-03	88HV02S29	EQ 122 MER 620	11/16/87	1010	Hazleton Laboratories Ensenco Corporation Centec Analytical Services Central Regional Laboratory Spectrix & Calif. Water
MW-14C-02	88HV02S30	EQ 120 MER 618	11/12/87	1435	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water
MW-14S-01	88HV02S31	EQ 123 MER 621	11/13/87	900	Spectrix Corporation Ensenco Corporation Centec Analytical Services Central Regional Laboratory Spectrix & Calif. Water
MW-15A-02	88HV02S37	EQ 128 MER 626	11/16/87	1055	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest Centec Analytical Services Central Regional Laboratory
MW-15A-02	88HV02D37	EQ 132 MER 630	11/16/87	1055	Hazleton Laboratories Ensenco Corporation
MW-15B-02	88HV02S38	EQ 132 MER 630	11/16/87	1450	Hazleton Laboratories Ensenco Corporation Centec Analytical Services Central Regional Laboratory Spectrix & Southwest
MW-16S-01	88HV02S17	EQ 108 MER 606	11/11/87	1522	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water
MW-17B-01	88HV02S18	EQ 110 MER 608	11/11/87	1600	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water

Table TM-7-3
SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC REPORT NUMBER	COLLECTION DATE	TIME	LABORATORY[a]
MW-17E-01	88HV02S19	EQ 111 MER 609	11/12/87	920	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water
MW-18E-01	88HV02S36	EQ 127 MER 625	11/16/87	900	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest
FB-01-01	88HV02S07	EQ 210 MEM496	11/10/87	1510	Spectrix Corporation Ensenco Corporation
FB-02-01	88HV02S15	EQ 213 MEM 499	11/11/87	1015	Spectrix Corporation Ensenco Corporation Spectrix & Calif. Water
BB-03-01	88HV02S35	EQ 134	11/16/87	1015	Spectrix (3rd)
FB-04-01	88HV02S41	EQ 133 MER 631	11/16/87	1410	Hazleton Laboratories Ensenco Corporation Spectrix & Southwest

a = First laboratory listed for organic analysis
Second laboratory listed for inorganic analysis
Third laboratory listed for CODs, TOCs, TSSs and ALKs
Fourth laboratory listed for oil & grease
Fifth laboratory listed for Low Level VOCs and PAHs

of more than 12. The samples taken for COD, TOC, and oil and grease analyses were preserved with H_2SO_4 to a pH of less than 2.

Samples were also collected to measure pH and conductivity in the field (Table TM7-2). Temperature was not measured because of the length of time between sampling and actual measurement at the trailer.

The sampling equipment was cleaned between wells by scrubbing with a solution of trisodium phosphate and tap water, followed by a methanol rinse and a final triple rinse with distilled water. The bailers were laid on a clean plastic sheet to dry and then placed in a clean plastic bag for storage or transport to the next sampling location. The stainless steel wire was initially soaked in a solution of methanol and distilled water, and was rinsed three times with distilled water before use. A new length of wire was used at each sampling location.

Replicates were taken of groundwater samples from Wells MW-13a (organics), MW-12a (inorganics), MW-5a (SAS parameters), MW-15a (organics and inorganics), and MW-7a (organics and inorganics). Field blanks were collected by filling a decontaminated bailer used for sampling with distilled water and transferring the water to the sample containers. Bottle blanks for VOC analyses were taken by pouring HPLC grade water directly into the VOC vials.

RESIDENTIAL WELL SAMPLING

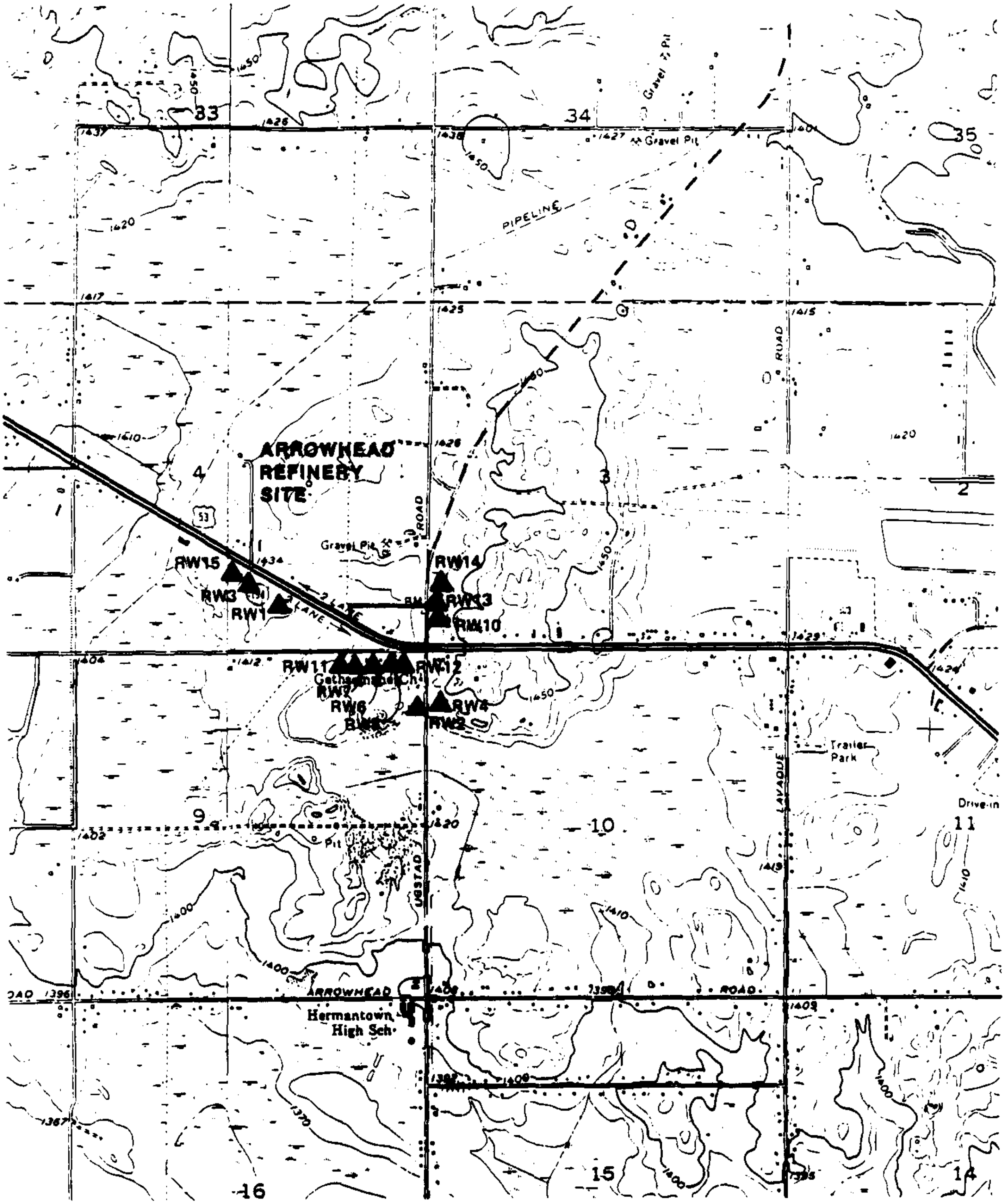
SAMPLING LOCATIONS

Residential well samples were collected at 13 locations selected by the U.S. EPA (Figure TM7-2). After the are initially contacted by U.S. EPA, the residents are contacted again by the sampling team and the approximate time of sampling determined.

SAMPLING PROCEDURES

Samples from residential wells were taken as close to the wells as possible. Groundwater samples were taken from faucets or from the residential wells (see Table TM7-4), preferably upstream of any filters, water softeners, or other online water treatment systems. The wells were allowed to run for at least 10 minutes before sampling. Samples were collected directly into the sample jars.

Samples were collected by two teams. The sample jars were filled in the following order: VOCs with low detection limits, VOCs, semivolatile organic compounds, metals, cyanide, and mercury. The samples sent for analyses are listed in Table TM7-5.



LEGEND

▲ RESIDENTIAL WELL LOCATION

FIGURE TM 7-2
RESIDENTIAL WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM7-4
SUMMARY OF RESIDENTIAL WELL SAMPLING

Residential Well Number	Owner	pH	Conductivity (umhos)	Location Sample Taken
RW001	[redacted] Trunk	7.5	350	From well
RW002	[redacted] Ugstad	7.6	250	Outside faucet
RW003	[redacted] Miller Trunk	7.4	475	Outside faucet
RW004	[redacted] Ugstad	7.4	250	Outside faucet
RW006	[redacted] Road	7.8	550	Outside faucet
RW007	[redacted] Road	7.9	200	Outside faucet
RW008	[redacted] Road	7.0	650	Outside faucet
RW010	[redacted] Ugstad	6.7	575	Outside faucet
RW011	[redacted] Rose Road	7.7	300	Outside faucet
RW012	[redacted] Rose Road	6.9	675	Outside faucet
RW013	[redacted] Ugstad	6.9	700	Inside faucet
RW014	[redacted] Ugstad	7.5	150	From well
RW015	[redacted] Miller Trunk	7.1	350	Outside faucet

Table TM-7-5
SAMPLE MATRIX TABLE FOR RESIDENTIAL WELL SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC NUMBER	COLLECTION DATE	COLLECTION TIME	LABORATORY a
RW-01-03	88HV02S56	EQ 144	11/18/87	1034	Southwest Laboratory of OK Inc.
		MER 641			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-02-03	88HV02S58	EQ 153	11/18/87	1450	Southwest Laboratory of OK Inc.
		MER 650			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-03-03	88HV02S59	EQ 150	11/18/87	1430	Southwest Laboratory of OK Inc.
		MER 647			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-04-03	88HV02S51	EQ 151	11/18/87	932	Southwest Laboratory of OK Inc.
		MER 6428			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-06-03	88HV02S53	EQ 149	11/18/87	930	Southwest Laboratory of OK Inc.
		MER 646			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-07-03	88HV02S55	EQ 143	11/18/87	1010	Southwest Laboratory of OK Inc.
		MER 640			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-08-03	88HV02S50	EQ 142	11/18/87	845	Southwest Laboratory of OK Inc.
		MER 639			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-10-03	88HV02S47	EQ 140	11/17/87	1355	Southwest Laboratory of OK Inc.
		MER 637			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-11-03	88HV02S54	EQ 141	11/18/87	950	Southwest Laboratory of OK Inc.
		MER 638			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-12-03	88HV02S49	EQ 145	11/18/87	820	Southwest Laboratory of OK Inc.
		MER 642			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.
RW-13-03	88HV02S52	EQ 152	11/18/87	910	Southwest Laboratory of OK Inc.
		MER 649			Associated Laboratories Inc.
					Southwest Laboratory of OK Inc.

Table TM-7-5
SAMPLE MATRIX TABLE FOR RESIDENTIAL WELL SAMPLES

CH2M HILL SAMPLE NUMBER	CRL SAMPLE NUMBER	TRAFFIC NUMBER	COLLECTION DATE	COLLECTION TIME	LABORATORY[a]
RW-14-03	88HV02S57	EQ 146 MER 643	11/18/87	1320	Southwest Laboratory of OK Inc. Associated Laboratories Inc. Southwest Laboratory of OK Inc.
RW-15-03	88HV02S60	EQ 148 MER 645	11/18/87	1632	Southwest Laboratory of OK Inc. Associated Laboratories Inc. Southwest Laboratory of OK Inc.
FB-05-01	88HV02S48	EQ 147 MER 644	11/18/87	835	Southwest Laboratory of OK Inc. Associated Laboratories Inc. Southwest Laboratory of OK Inc.

a = First laboratory listed for organic analysis
Second laboratory listed for inorganic analysis
Third laboratory listed for Low Level PAHs and VOCs

Samples analyzed for metals were filtered and preserved with HNO_3 to a pH of less than 2. Samples to be analyzed for cyanide were preserved with NaOH to a pH of more than 12. Samples to be tested for mercury were preserved with 20 ml of a 25 percent HNO_3 and 2.5 percent $K_2Cr_2O_7$ solution.

Samples were also collected to measure pH and conductivity in the field (see Table TM7-4). Temperature was not measured because the length of time between the sampling and actual measurement at the trailer.

Field blanks were collected by pouring distilled water directly into the sample containers.

GLT932/024.51

CH2M HILL

TECHNICAL MEMORANDUM NO. 8

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: Daniel J. Plomb/CH2M HILL

DATE: March 2, 1988

RE: Variable Head Testing

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
W68802.FI

INTRODUCTION

Aquifer tests were conducted at the Arrowhead Refinery site between December 14 and 17, 1987. In situ hydraulic conductivities of soil near groundwater monitoring wells and piezometers were measured using variable head (slug) tests. Testing included wells and piezometers installed for the Fieldwork Design Investigation and selected wells from earlier phases. The locations of the wells and piezometers tested are shown in Figure TM8-1. This memorandum describes test methods, data evaluation procedures, test results, and data limitations.

VARIABLE HEAD TESTING

Variable head (slug) tests are single well tests performed to estimate hydraulic conductivity in the vicinity of a well screen by the addition or removal of a known volume of water. The rate at which the water level in the well recovers is measured and used to estimate hydraulic conductivity.

The tests conducted at the Arrowhead Refinery site were "rising" head tests. A known volume of water was displaced from the well to lower the water level. Data were collected while water levels rose during well recovery. Tests were performed by Dan Plomb, Jewelle Imada, and Jeff Keiser of CH2M HILL.

Two methods were used to remove water from wells. The preferred method, using a nitrogen slug, consisted of displacing water from the well with nitrogen gas. The method is preferred because contact between potentially contaminated well water and test equipment and personnel is minimized. The method also reduces the possibility of cross-contamination of well water when test equipment is moved between several different wells. Use of the nitrogen slug method is limited to wells in which a sufficient volume of water can be displaced from the riser piping without lowering the water level below the top of the well screen. Because nitrogen gas would leak through the screen, it is not physically possible to use this method when the water level goes below the top of the screen. The alternative method, using a PVC slug to displace well water, was used when the screened interval was close to or straddled the water table, or when the location of the well prevented the use of the nitrogen slug method. This method was used at monitoring Wells MW-8b and Piezometers P-21s, P-21b, and P-22s.

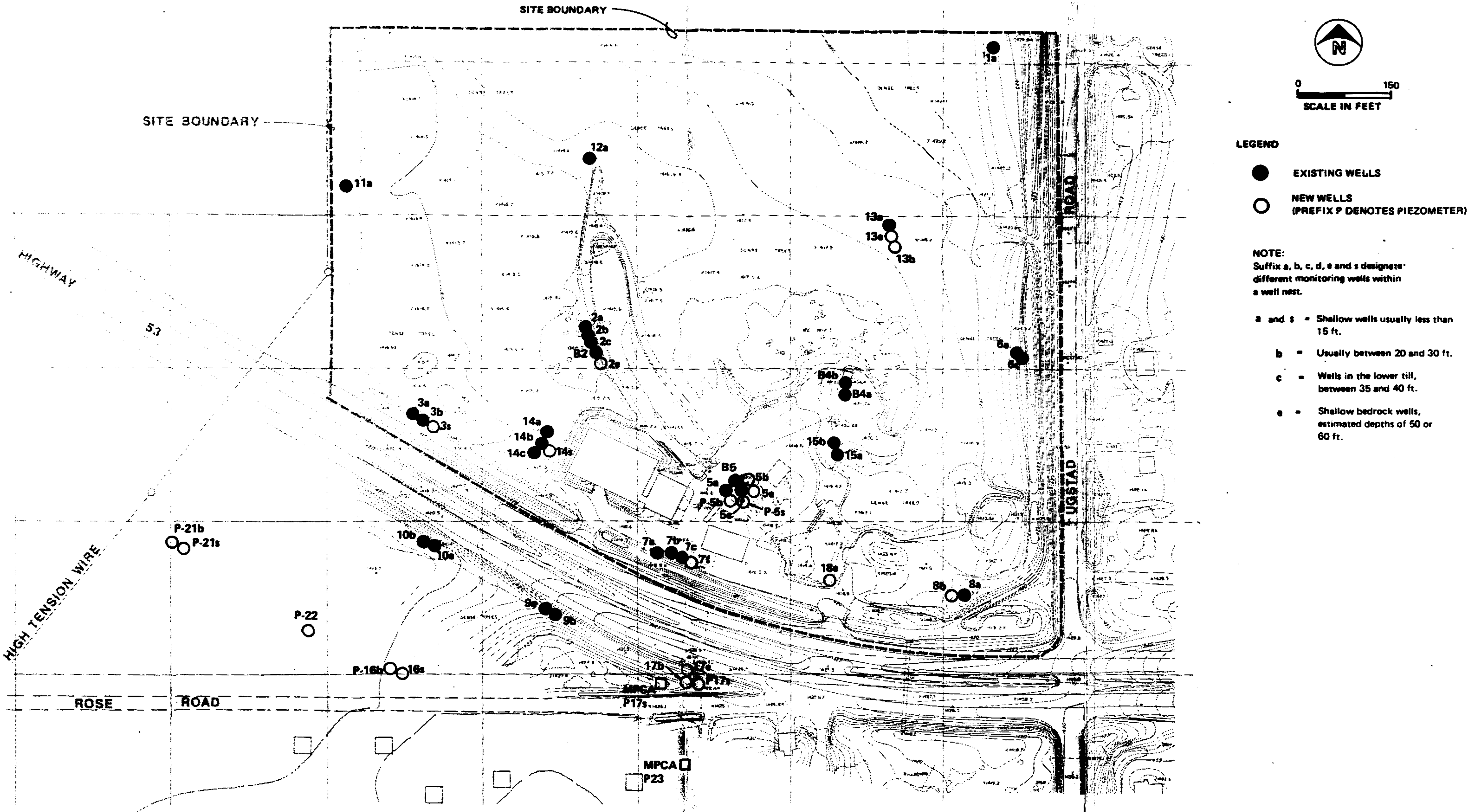
The tests performed were evaluated using Hvorslev's method (Cedergren, pp. 66-76; originally presented in U.S. Department of the Army, Corps of Engineers, 1951). The following sections describe the test and data reduction methods used at the Arrowhead Refinery site.

NITROGEN SLUG METHOD

The test assembly used to displace well water using nitrogen gas is shown in Figure TM8-2. A well head assembly was attached to the top of the riser pipe. A gastight seal between the assembly and riser pipe was obtained with an expandable rubber fitting at the base of the assembly. The well head assembly contains gastight ports for connecting two pressure transducers, a fitting for attaching a pressure regulator, and a vent valve.

The pressure transducers are connected to a data logger. Transducer No. 1 measures total head, which is the sum of the elevation head and pressure head above the transducer. Transducer No. 2 measures the pressure head resulting from the nitrogen gas. In addition to recording head values at discrete time intervals for later analysis, the data logger is programmed to calculate hydraulic conductivity directly in the field using simplifying assumptions regarding aquifer geometry. Therefore, a quick field check on the validity of the data is possible prior to disassembling the equipment.

After the initial water level is noted (prior to pressurizing the system) a column of nitrogen is then placed in the riser pipe. Because the units of the data logger readout are measured in feet of water, the equivalent water height due to the nitrogen pressure head is read directly from transducer No. 2. The amount of pressure head placed in the well is such that water will be displaced at least 3 to 5 feet, but not below the top of the screen. Pressure is controlled by regulators in the nitrogen supply line. The pressure head forces water from the riser casing into the surrounding soil. As the water level in the well decreases under a constant pressure head, the total head (transducer No. 1) decreases. Eventually, total head will return to the initial head value (initial water level), except that now the total head above transducer No. 1 includes the pressure component from the nitrogen gas. At this point the test is started by opening the vent valve to remove the pressure head by depressurizing the system and by starting the data logger. In effect, this is equivalent



LEGEND

● EXISTING WELLS

○ NEW WELLS (PREFIX P DENOTES PIEZOMETER)

NOTE:
Suffix a, b, c, d, e and s designate different monitoring wells within a well nest.

a and s = Shallow wells usually less than 15 ft.

b = Usually between 20 and 30 ft.

c = Wells in the lower till, between 35 and 40 ft.

e = Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE TM 8-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATIONS

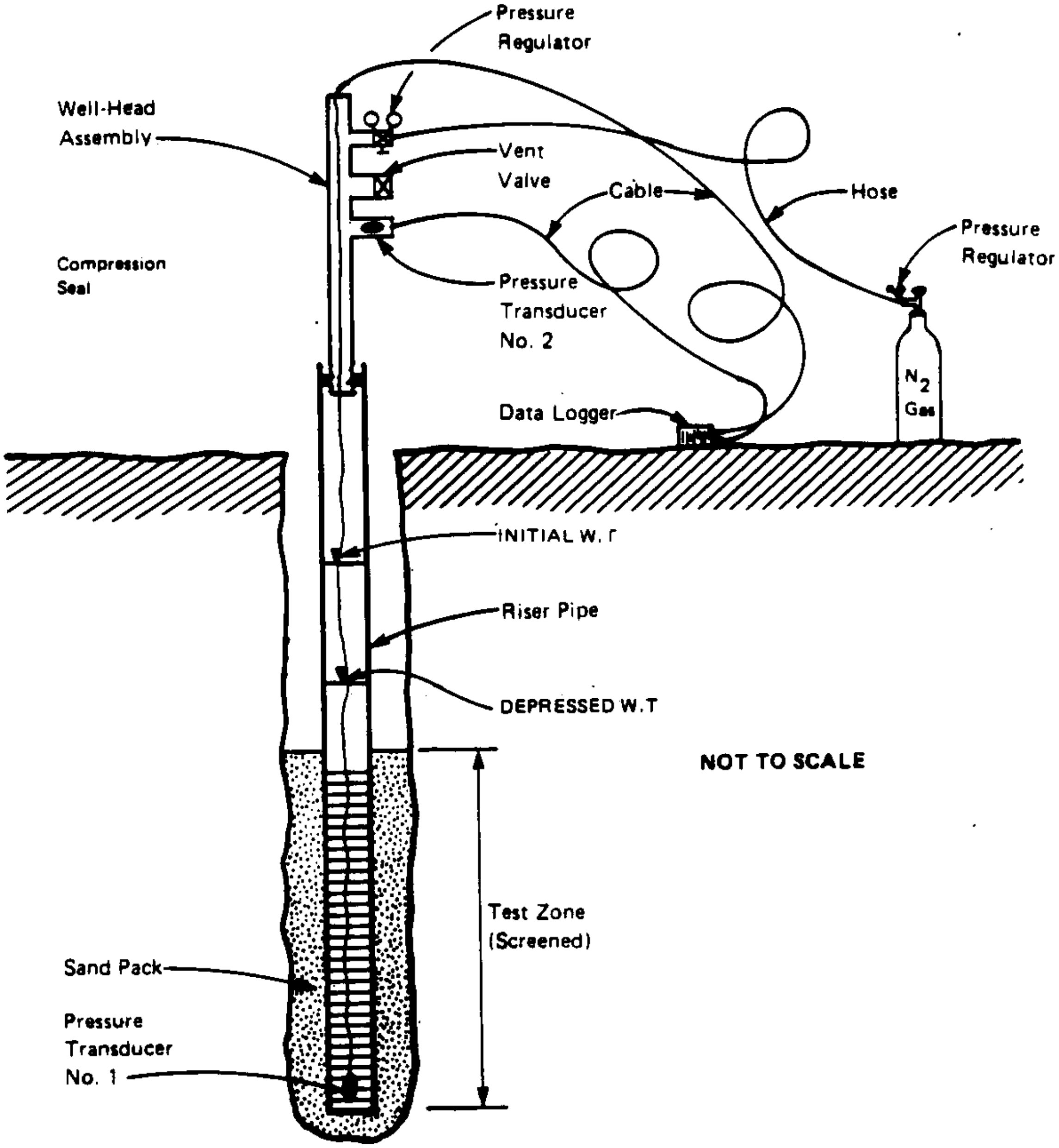


FIGURE TM 8-2
SCHEMATIC DIAGRAM OF SLUG TEST
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

to instantaneously removing a column of water equal to the volume of water displaced by the gas. Water levels are then recorded with time as they recover.

PVC SLUG METHOD

In theory, the PVC slug method is identical to the nitrogen slug method, except that a PVC slug rather than nitrogen gas is inserted in the well to displace the water. The solid PVC slug is inserted into the well, and the water level is allowed to equilibrate. Once the water level has equilibrated, the slug is quickly removed and water level recovery is measured manually over time. This procedure was used only at one well and three piezometers, all of which exhibited slow recovery.

DATA EVALUATION

A complete discussion of the method and definition of terms is presented by Cedergren. Hydraulic conductivities for each test were calculated using a spreadsheet developed by Jonathan Freese, CH2M HILL, for use on Symphony. The equation used to calculate hydraulic conductivity is:

$$K = \frac{r^2 \ln (L/R)}{2 L T_o}$$

where:

K = hydraulic conductivity
r = well radius
R = borehole radius
L = screen length
T_o = basic time lag, determined graphically as the time at which relative recovery is equal to 0.37, or the $\ln((H-h)/(H-H_o)) = -1$ in which H_o is the initial water level.

RESULTS

Test results are summarized in Table TM8-1 and data plots are included in Attachment A. Testing at MW-3s produced erratic data without due explanation, while elsewhere data appeared relatively sound as seen by the low standard deviations. Hydraulic conductivities observed during this phase of testing ranged from 3.53×10^{-2} to 4.01×10^{-5} cm/s. Raw data and data reduction notes are stored in the Arrowhead Refinery site files at CH2M HILL, Milwaukee office.

Table TM8-1
SUMMARY OF SLUG TEST RESULTS

Well Number	Hydraulic Conductivity (cm/s)		
	Test 1	Test 2	Logarithmic Average
MW-3s		DATA NOT VALID	
MW-5a	3.09×10^{-4}	3.65×10^{-4}	3.36×10^{-4}
MW-5b	3.53×10^{-2}	3.52×10^{-2}	3.53×10^{-2}
MW-5e	7.45×10^{-5}	8.35×10^{-5}	7.89×10^{-5}
MW-5s	2.18×10^{-4}	5.97×10^{-5}	1.14×10^{-4}
P-5b	3.16×10^{-4}	3.09×10^{-4}	3.12×10^{-4}
MW-7a	5.50×10^{-4}	3.98×10^{-4}	4.68×10^{-4}
MW-7b	1.69×10^{-4}	5.01×10^{-4}	2.91×10^{-4}
MW-7s	5.99×10^{-4}	7.29×10^{-4}	6.61×10^{-4}
MW-8b	1.36×10^{-4}	1.19×10^{-4}	1.27×10^{-4}
MW-14a	1.07×10^{-4}	1.39×10^{-4}	1.22×10^{-4}
MW-14s	3.55×10^{-4}	2.62×10^{-4}	3.05×10^{-4}
MW-16s	3.17×10^{-5}	5.08×10^{-5}	4.01×10^{-5}
MW-16b	9.54×10^{-4}	8.50×10^{-4}	9.01×10^{-4}
MW-17s	1.68×10^{-2}	1.88×10^{-2}	1.77×10^{-2}
MW-17b	1.78×10^{-4}	2.31×10^{-3}	2.03×10^{-4}
P-21s	6.83×10^{-5}	9.79×10^{-5}	8.18×10^{-5}
P-21b	8.92×10^{-5}	1.11×10^{-4}	9.97×10^{-5}
P-22s	2.89×10^{-4}	3.03×10^{-4}	2.96×10^{-4}

DATA LIMITATIONS

The following assumptions are inherent in the theoretical development of Hvorslev's method for analyzing slug test data:

- Drawdown of the water table around the well is negligible
- Flow in the unsaturated zone can be ignored
- Well losses are negligible
- The aquifer is homogeneous and isotropic

The first three assumptions are probably satisfied at the Arrowhead Refinery site, but the shallow aquifer is neither homogeneous nor isotropic. The data, however, do provide averages of the hydraulic conductivities for the aquifer material near the tested well or piezometer. By comparing the values of hydraulic conductivity obtained, the vertical and horizontal variability of the aquifer is demonstrated.

REFERENCES

Cedergren, Harry R. *Seepage, Drainage and Flow Nets.* New York: John Wiley & Sons, Inc. 1977.

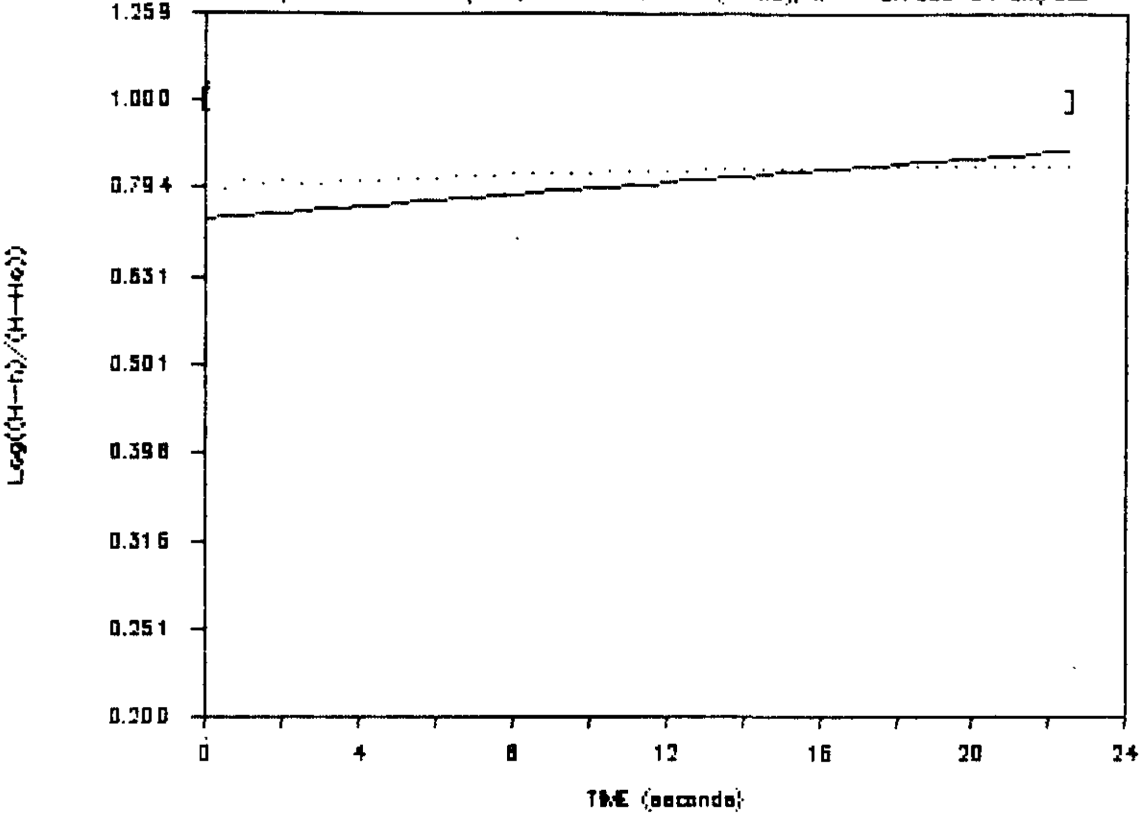
U.S. Department of the Army, Corps of Engineers. *Time Lag and Soil Permeability in Ground-Water Observations.* Bulletin No. 36. Waterways Experiment Station. Vicksburg, Mississippi. 1951. (Written by M. Jull Hvorslev.)

TM 8--VARIABLE HEAD TESTING

Attachment A
DATA PLOTS

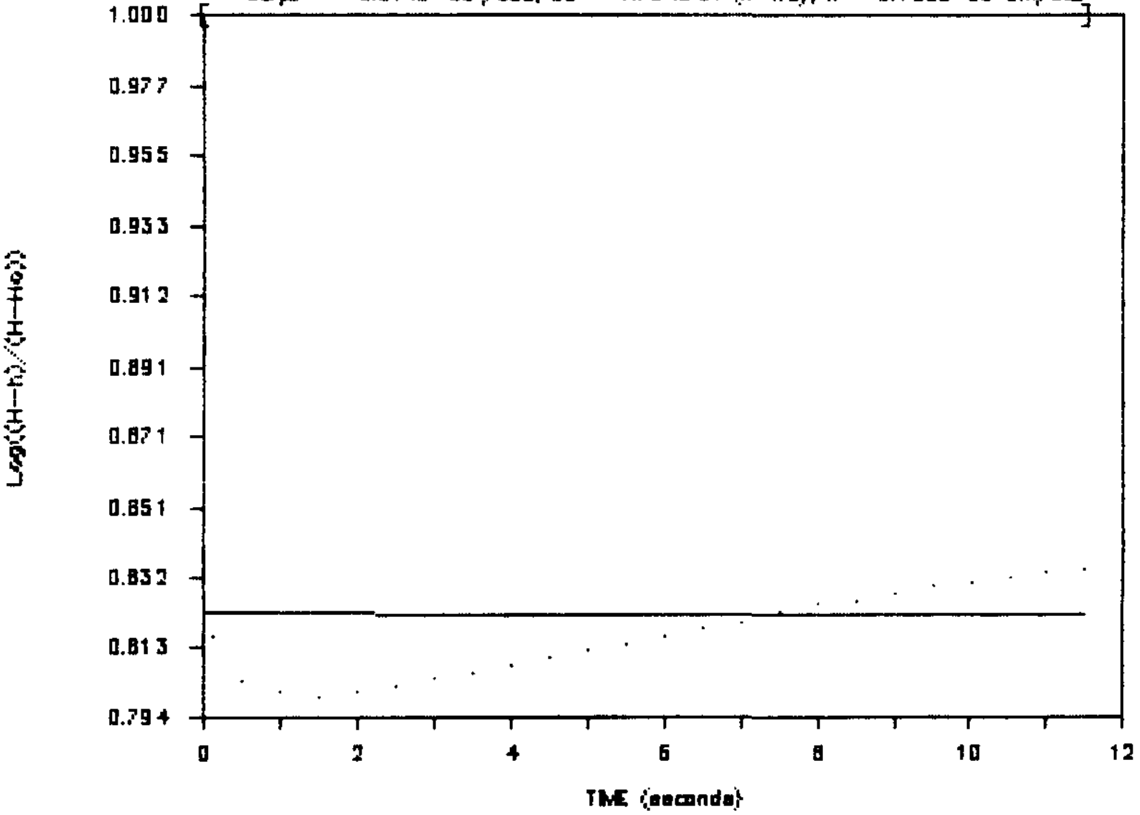
Aquifer Slug Test #2 (Rising Head) at MW-87-3S; 47 data points

Slope = 3.516E-03 /sec; SD = 8.48 % of (H-Ho); K = -6.723E-04 cm/sec



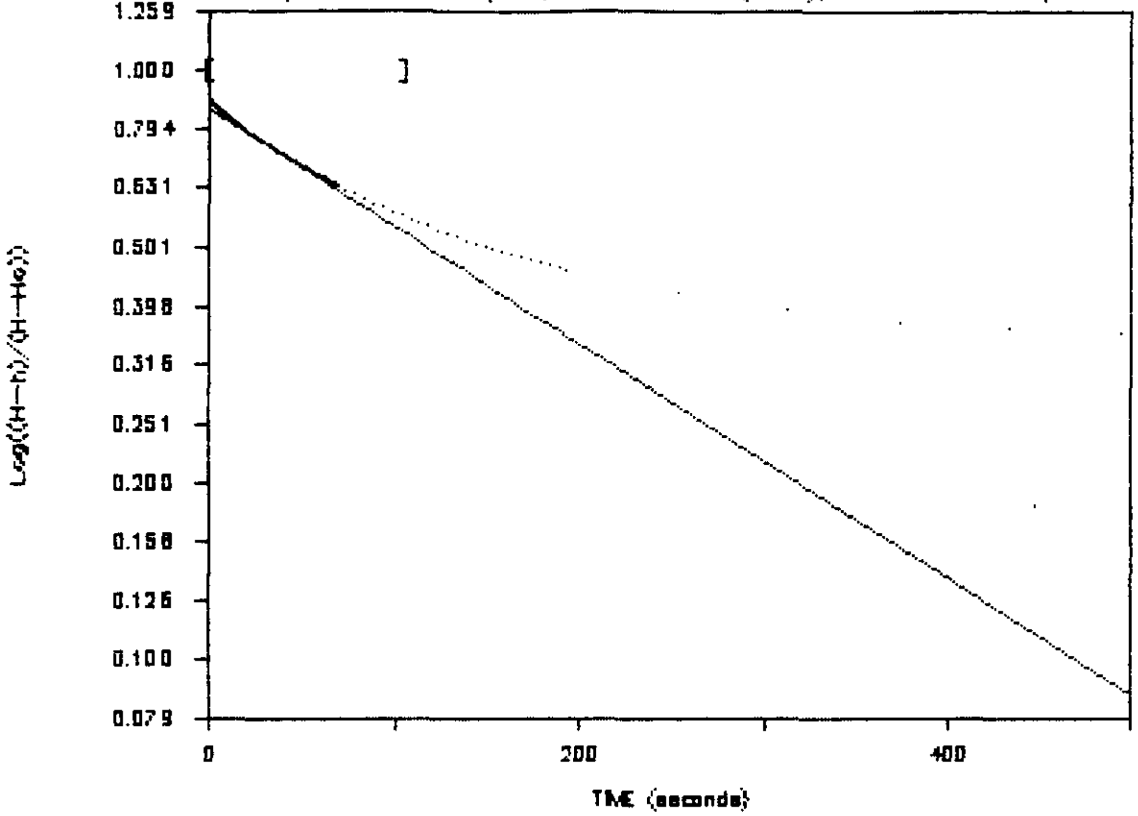
Aquifer Slug Test #3 (Rising Head) at MW-87-3s; 25 data points

Slope = -2.314E-05 /sec; SD = 1.75 % of (H-Ho); K = 3.798E-06 cm/sec



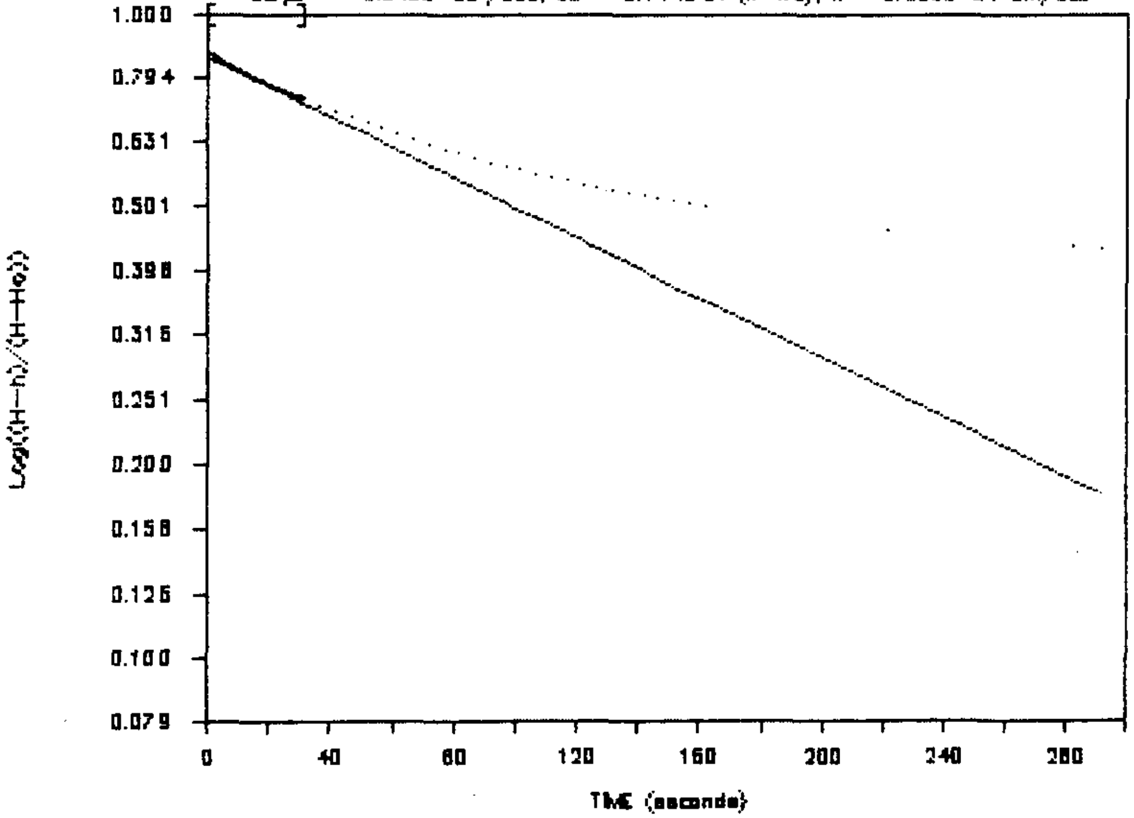
Aquifer Slug Test #1 (Rising Head) at MW-5A ; 170 data points

Slope = −1.997E−03 /sec; SD = 0.93 % of (H−Ho); K = 3.087E−04 cm/sec



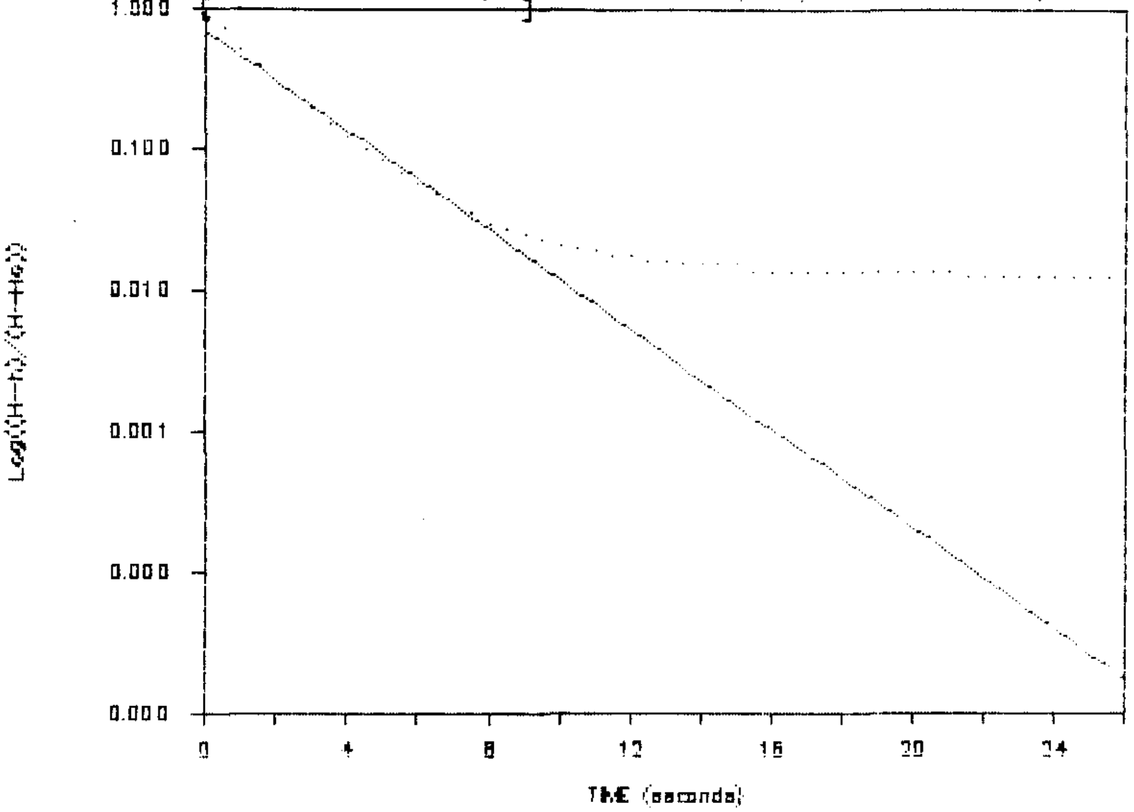
Aquifer Slug Test #2 (Rising Head) at MW-5A ; 94 data points

Slope = −2.342E−03 /sec; SD = 0.14 % of (H−Ho); K = 3.653E−04 cm/sec



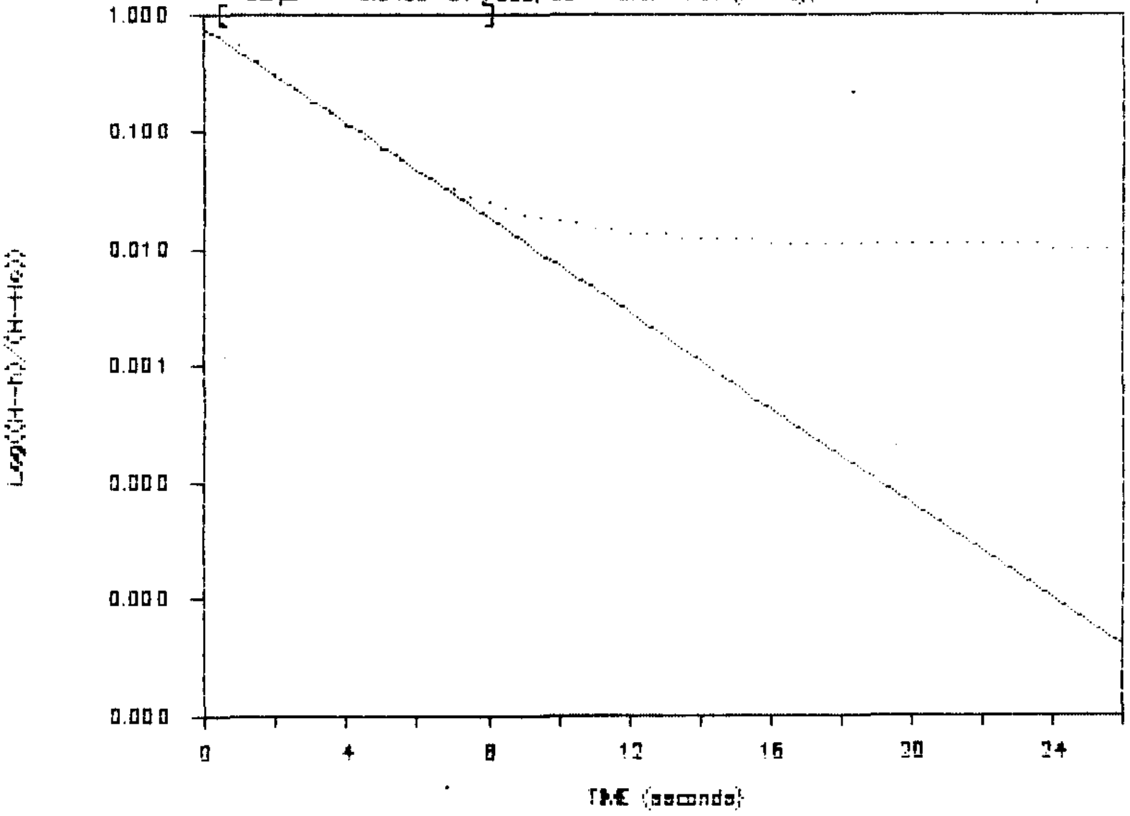
Aquifer Slug Test #3 (Rising Head) at MW-5b; 54 data points

Slope = -1.774E-01 /sec; SD = 5.83 % of (H-Ho); K = 3.535E-02 cm/sec



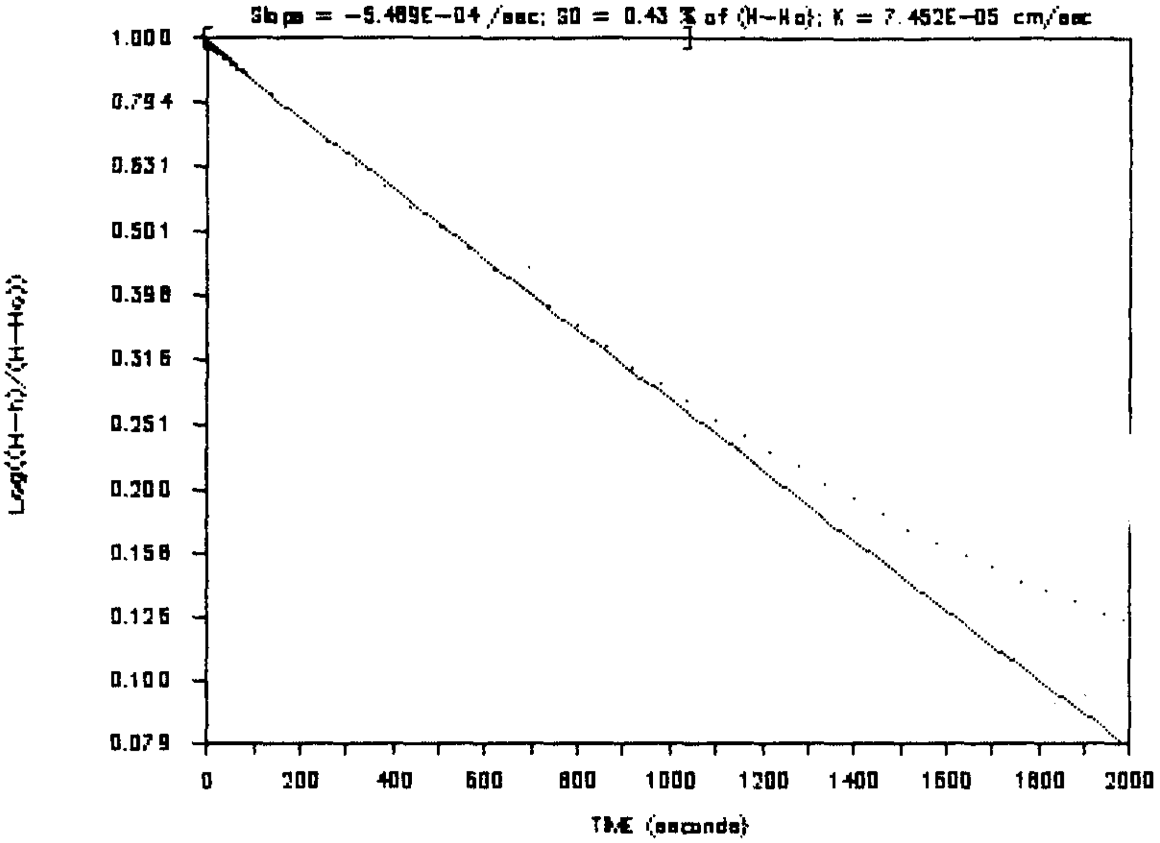
Aquifer Slug Test #2 (Rising Head) at MW-5b; 54 data points

Slope = -2.046E-01 /sec; SD = 5.57 % of (H-Ho); K = 3.515E-02 cm/sec



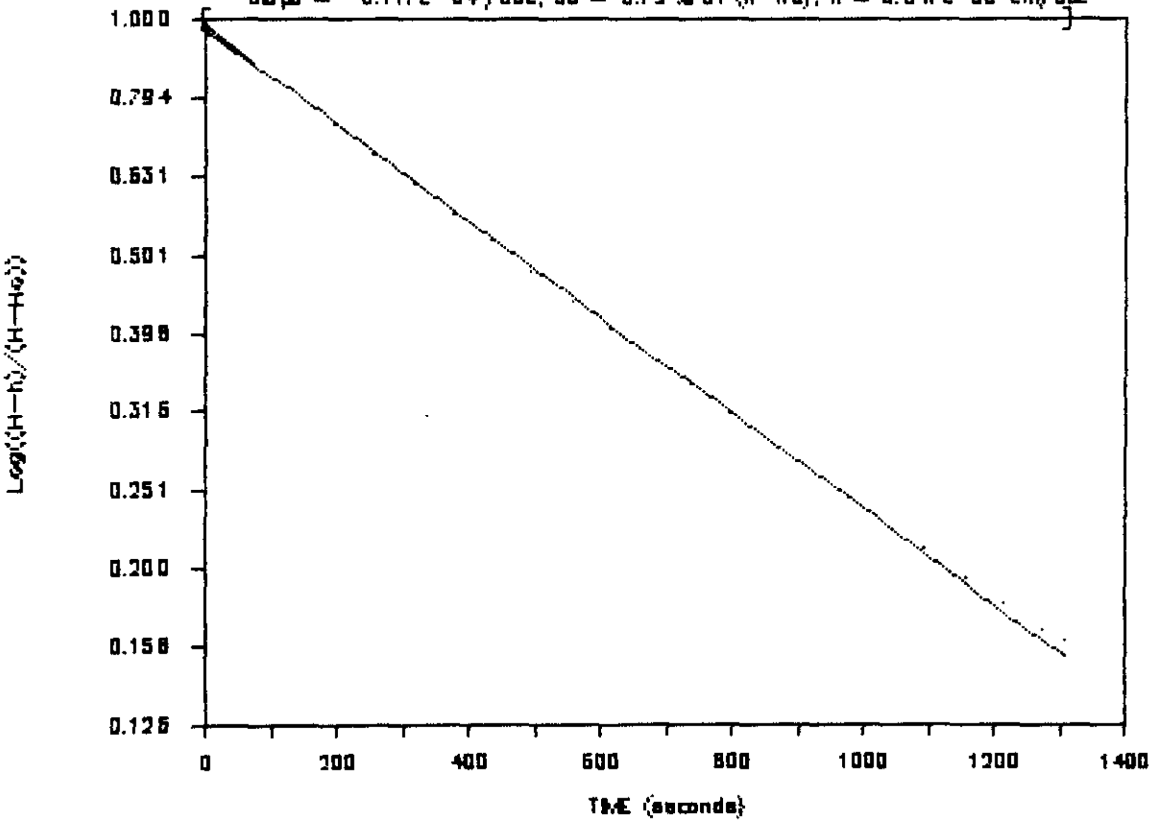
Aquifer Slug Test #1 (Rising Head) at MW-5e; 75 data points

Slope = -5.489E-04 /sec; SD = 0.43 % of (H-Ho); K = 7.452E-05 cm/sec



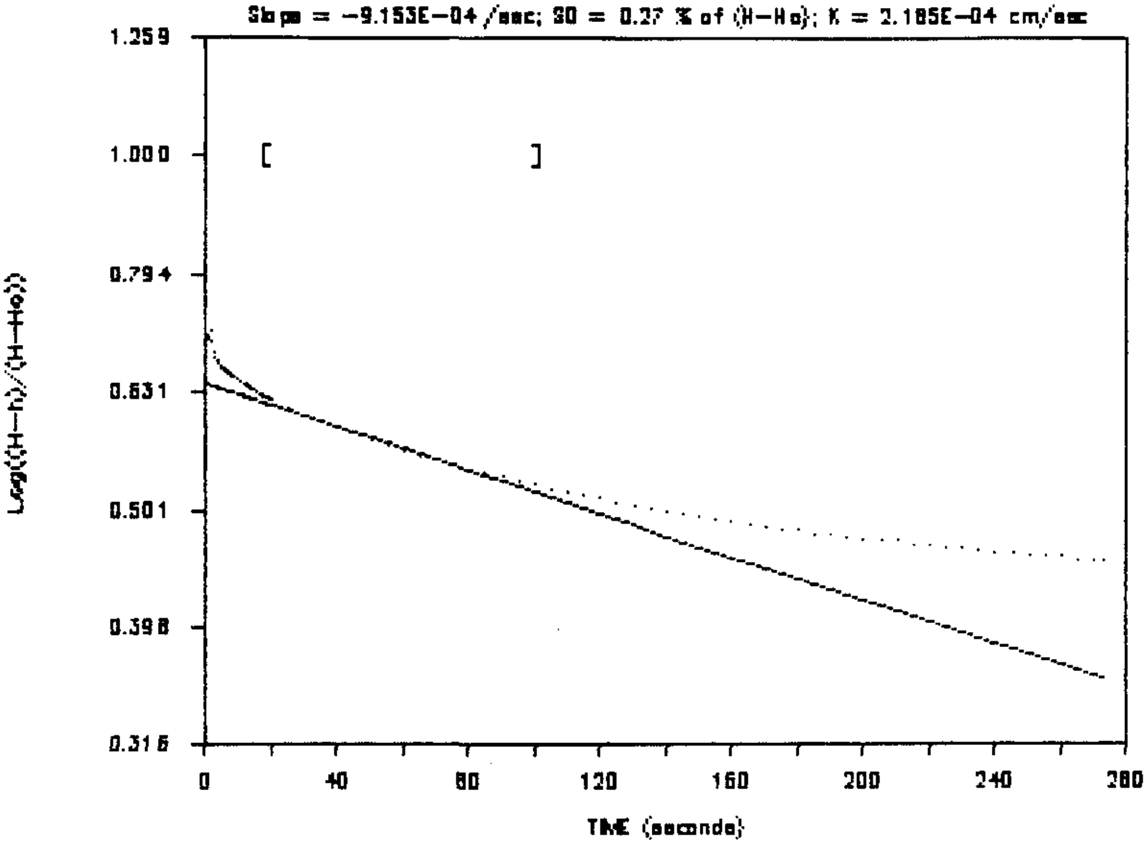
Aquifer Slug Test #2 (Rising Head) at MW-5e; 133 data points

Slope = -6.117E-04 /sec; SD = 0.79 % of (H-Ho); K = 8.347E-05 cm/sec



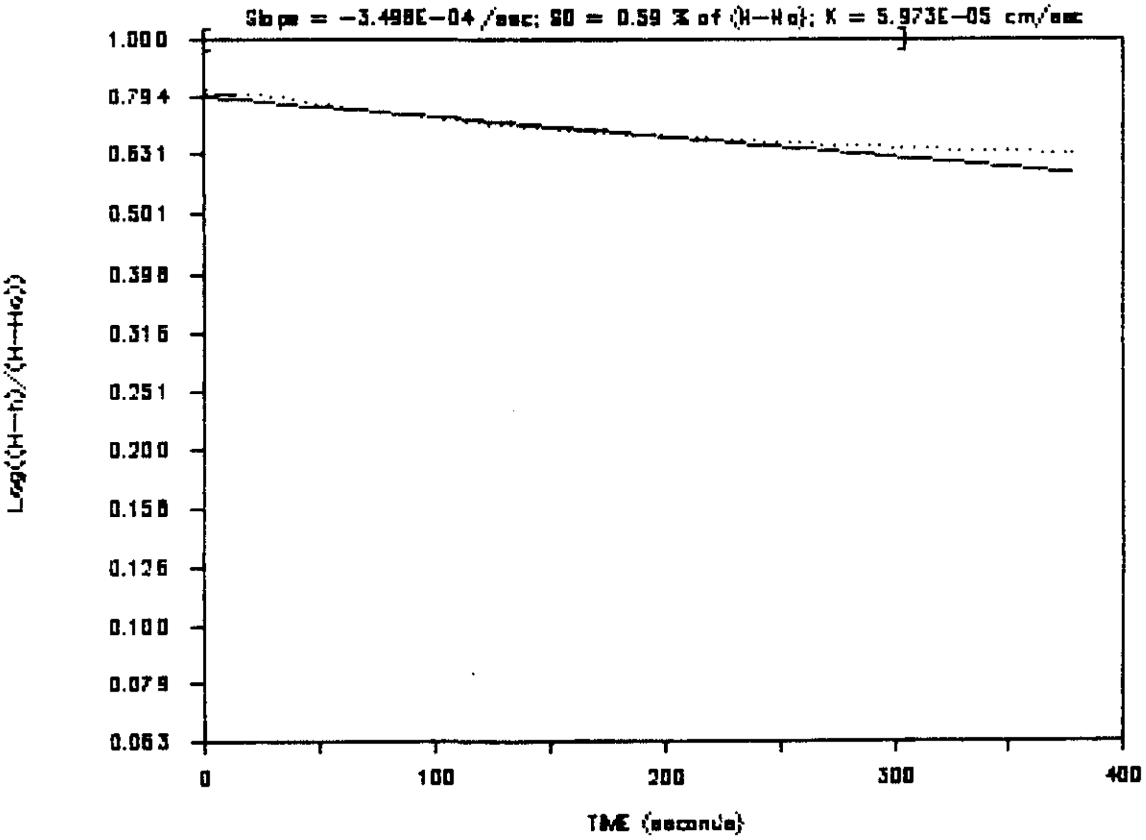
Aquifer Slug Test #1 (Rising Head) at MW-87-5s1; 93 data points

Slope = -9.153E-04 /sec; SD = 0.27 % of (H-Ho); K = 2.185E-04 cm/sec



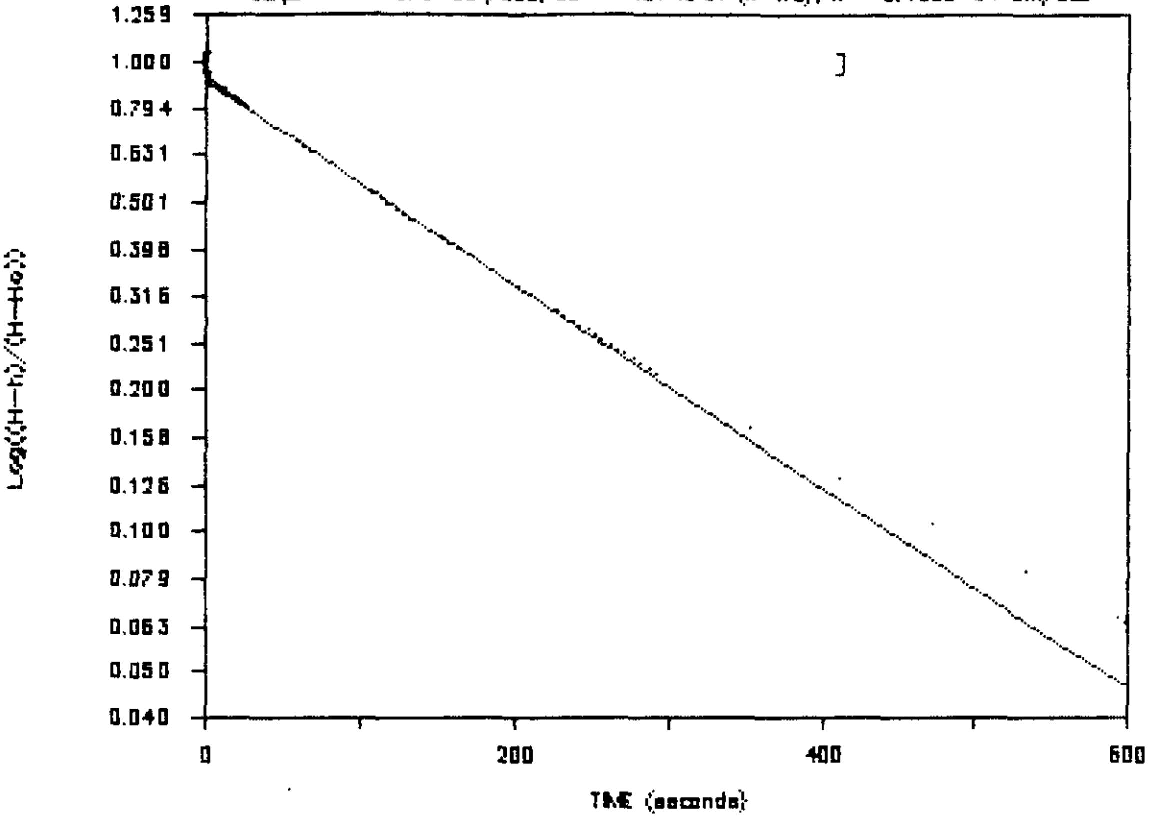
Aquifer Slug Test #2 (Rising Head) at MW-87-5s1; 103 data points

Slope = -3.498E-04 /sec; SD = 0.59 % of (H-Ho); K = 5.973E-05 cm/sec



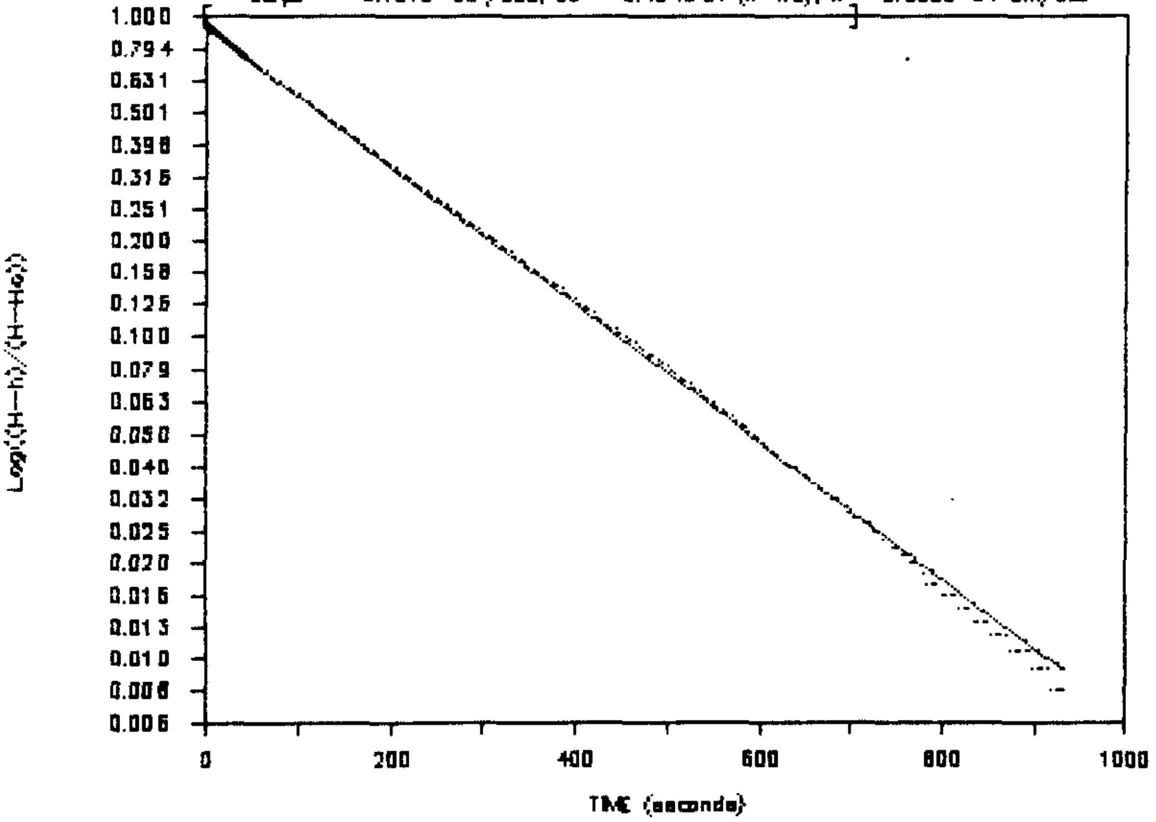
Aquifer Slug Test #1 (Rising Head) at MW-p-5b ; 115 data points

Slope = -2.157E-03 /sec; SD = 1.01 % of (H-Ho); K = 3.165E-04 cm/sec



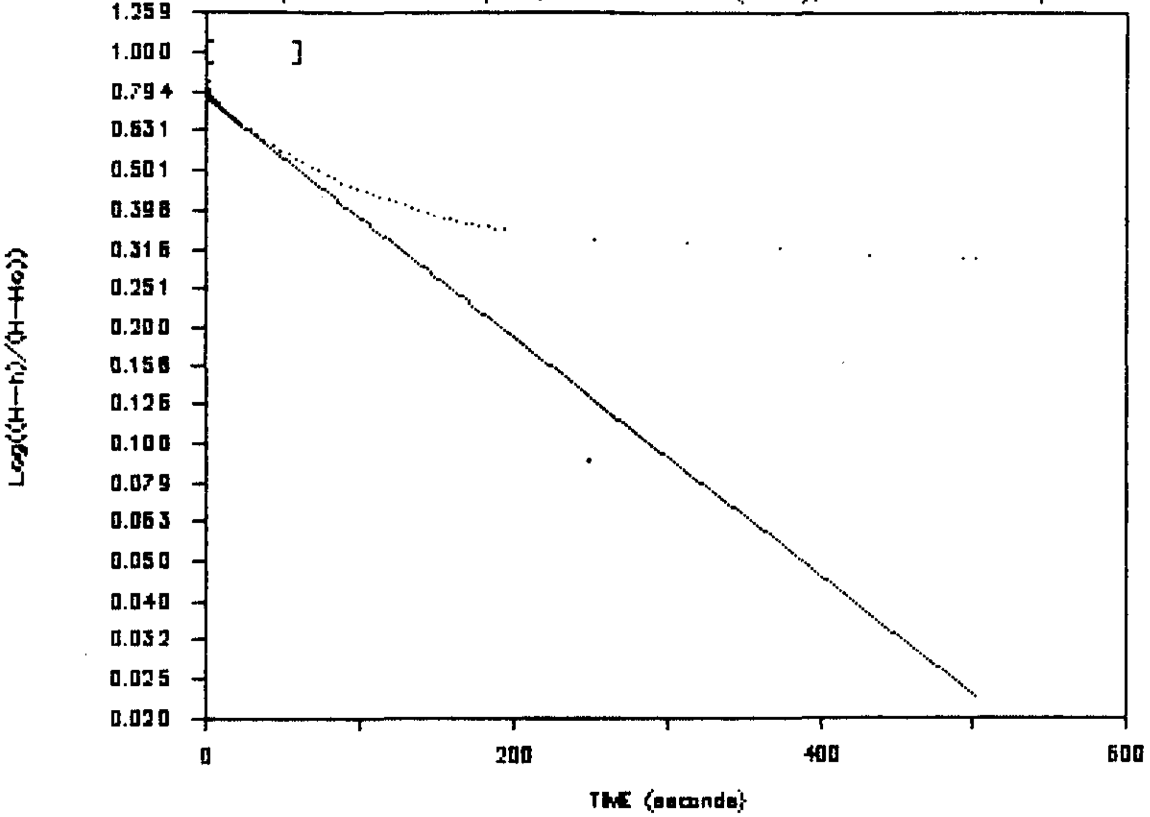
Aquifer Slug Test #2 (Rising Head) at MW-p-5b ; 295 data points

Slope = -2.151E-03 /sec; SD = 0.43 % of (H-Ho); K = 3.085E-04 cm/sec



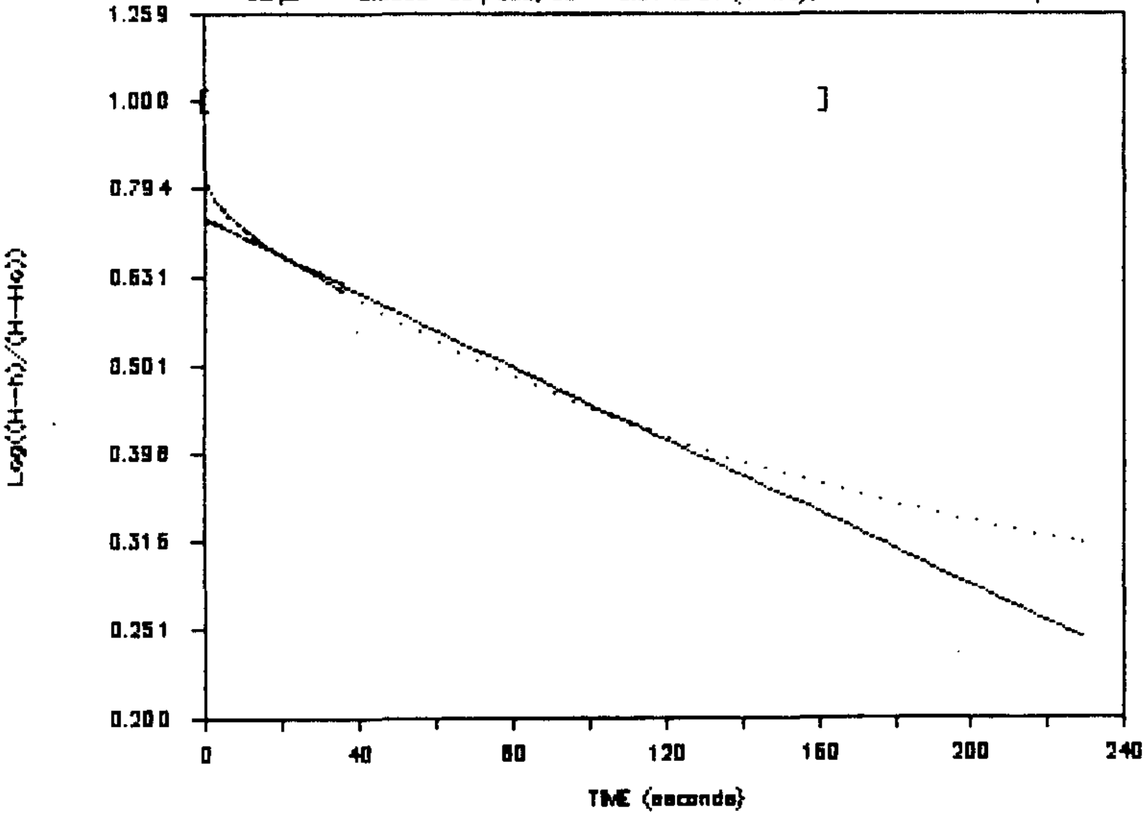
Aquifer Slug Test #1 (Rising Head) at MW— 7A ; 88 data points

Slope = −3.050E−03 /sec; S0 = 0.80 % of (H−Ho); K = 5.502E−04 cm/sec



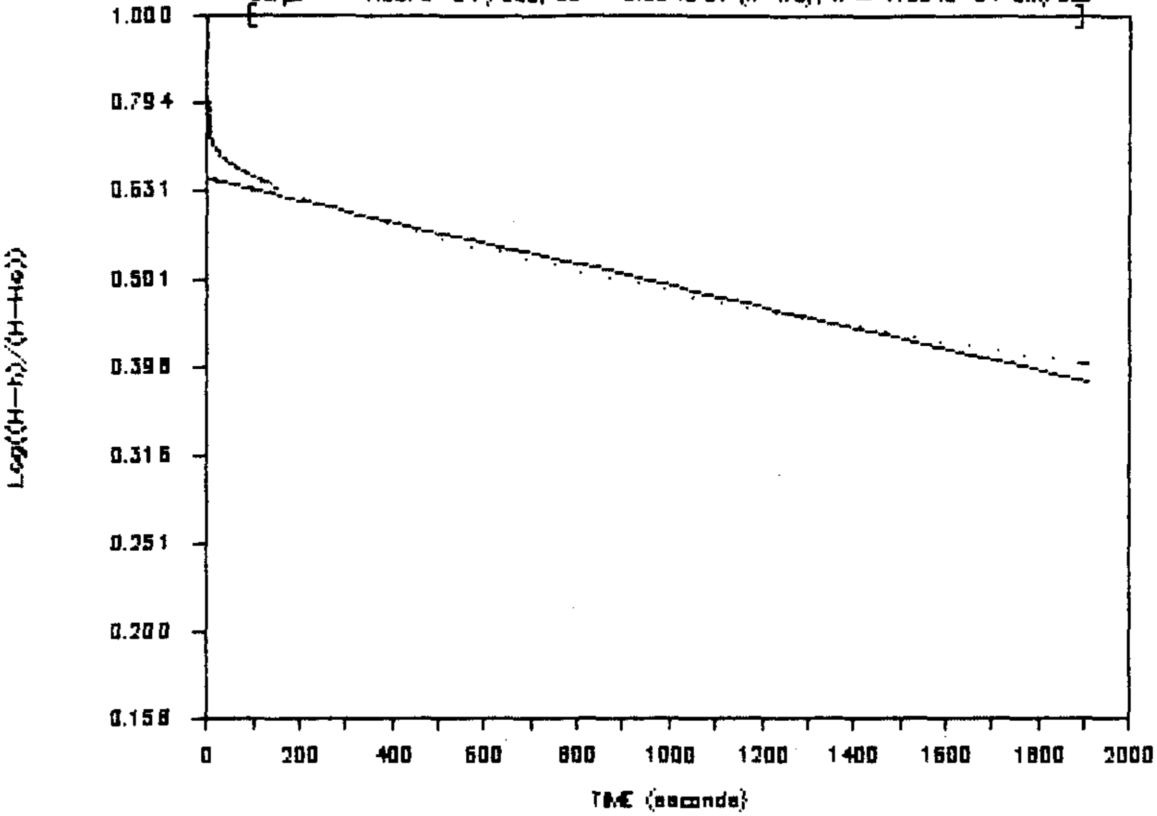
Aquifer Slug Test #2 (Rising Head) at MW— 7A ; 113 data points

Slope = −2.082E−03 /sec; S0 = 2.91 % of (H−Ho); K = 3.985E−04 cm/sec



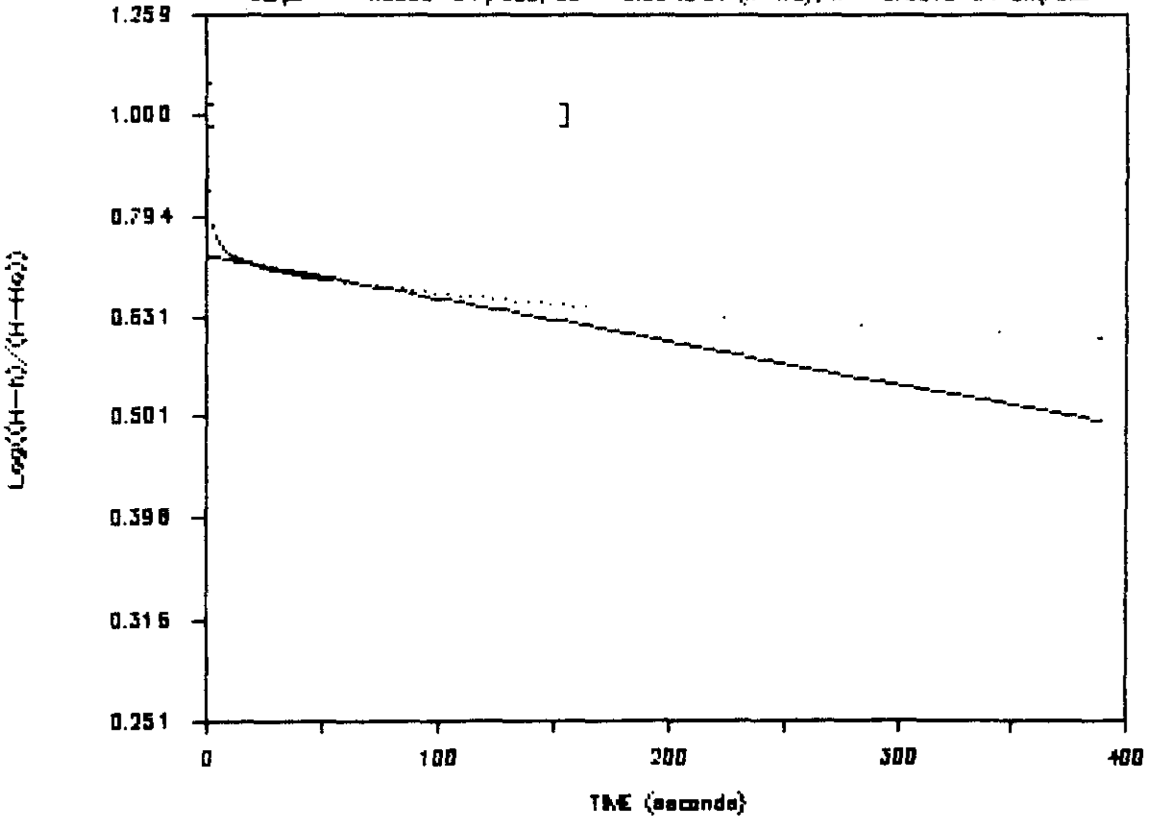
Aquifer Slug Test #1 (Rising Head) at MW-7b; 108 data points

Slope = -1.207E-04 /sec; SD = 0.83 % of (H-Ho); K = 1.694E-04 cm/sec

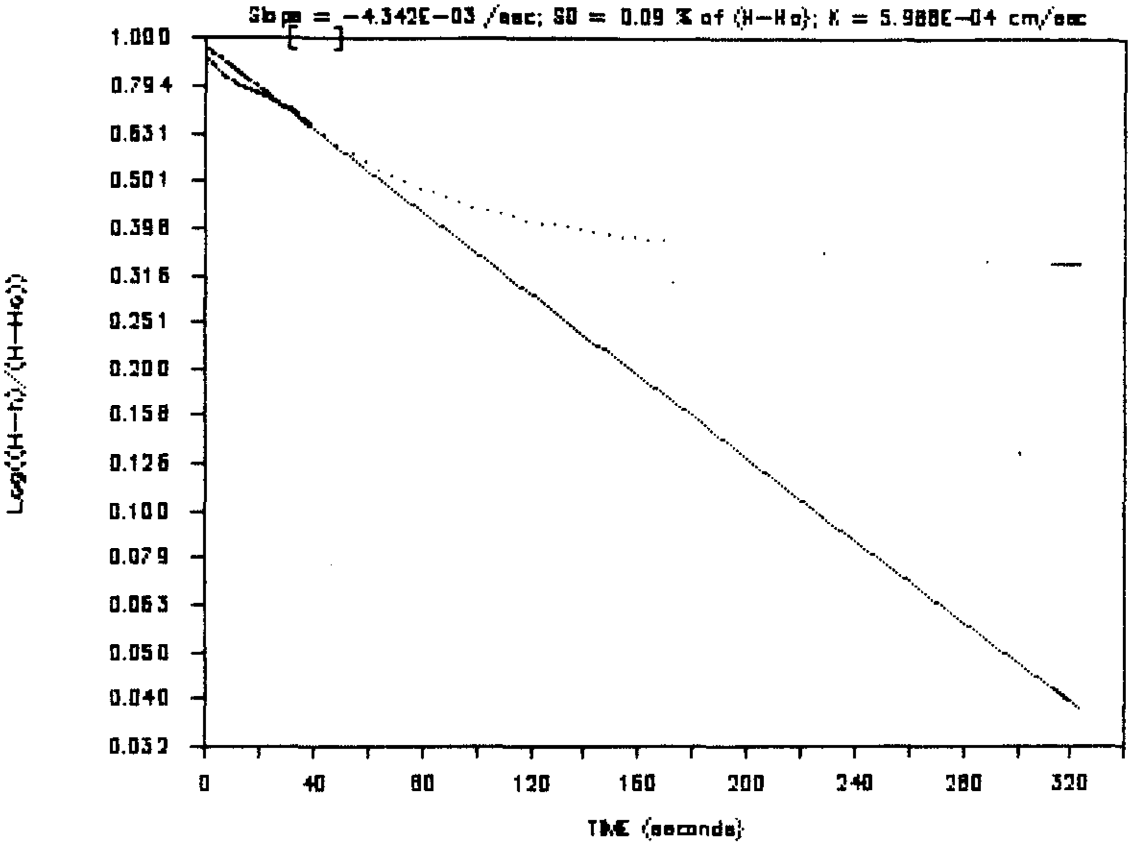


Aquifer Slug Test #2 (Rising Head) at MW-7b; 138 data points

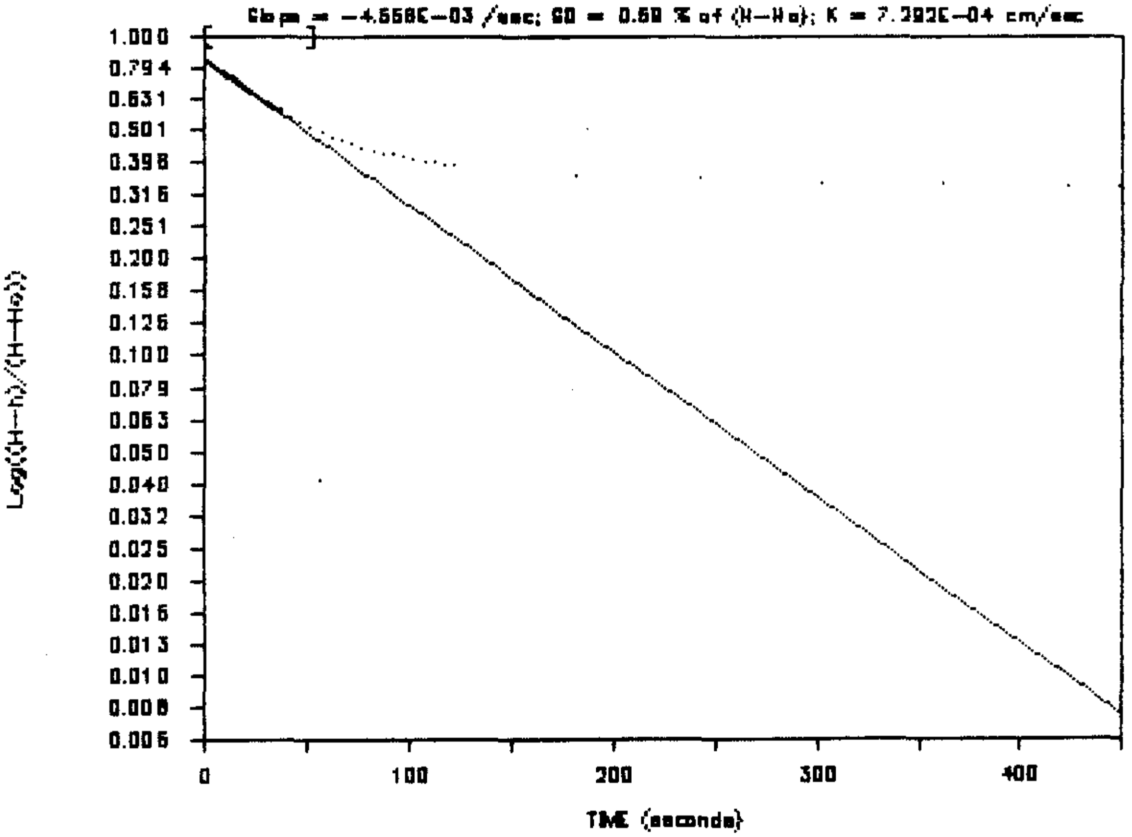
Slope = -4.280E-04 /sec; SD = 0.89 % of (H-Ho); K = 5.051E-04 cm/sec

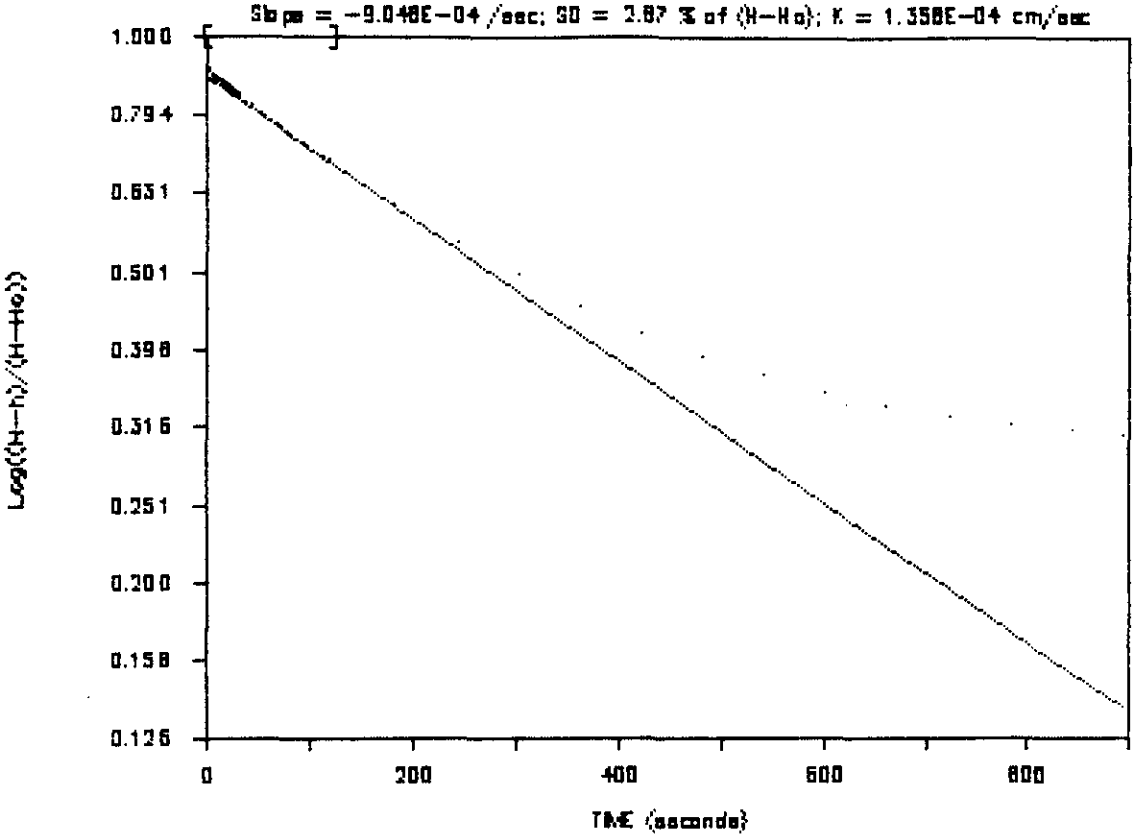


Aquifer Slug Test #1 (Rising Head) at MW-87-7S; 128 data points



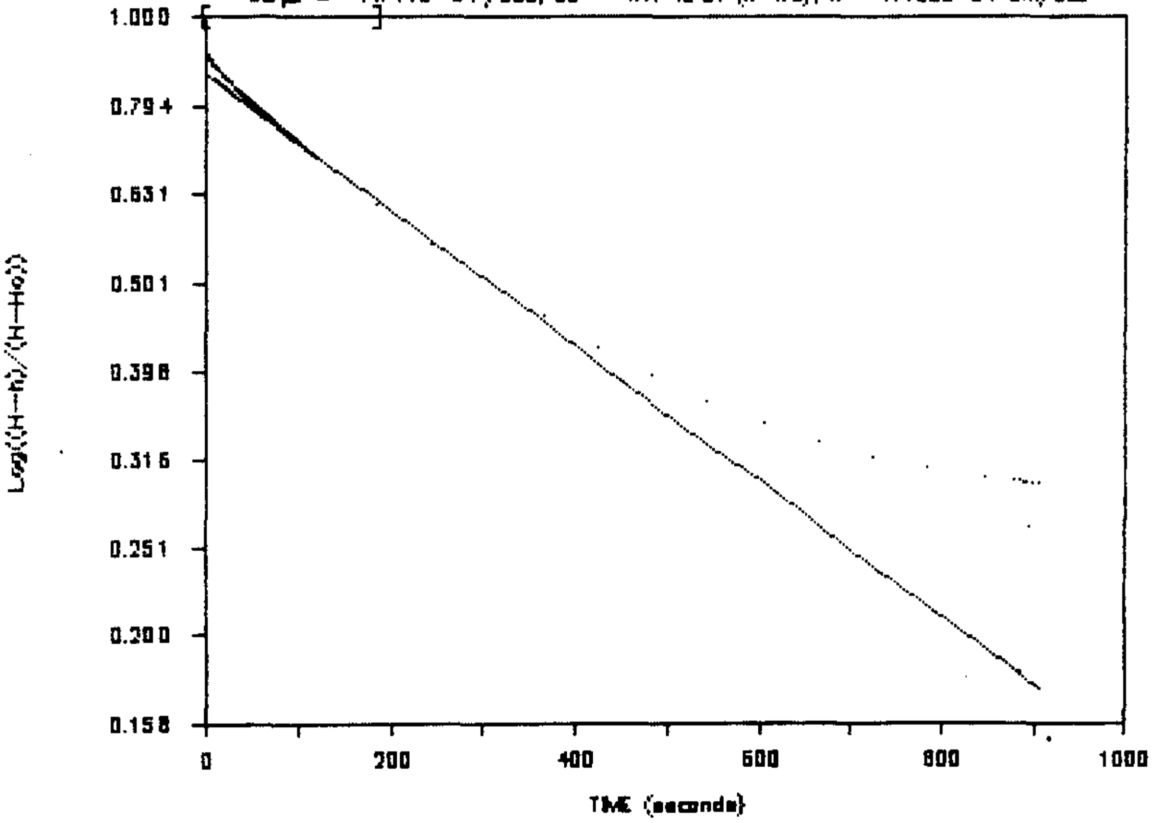
Aquifer Slug Test #2 (Rising Head) at MW-87-7S; 99 data points





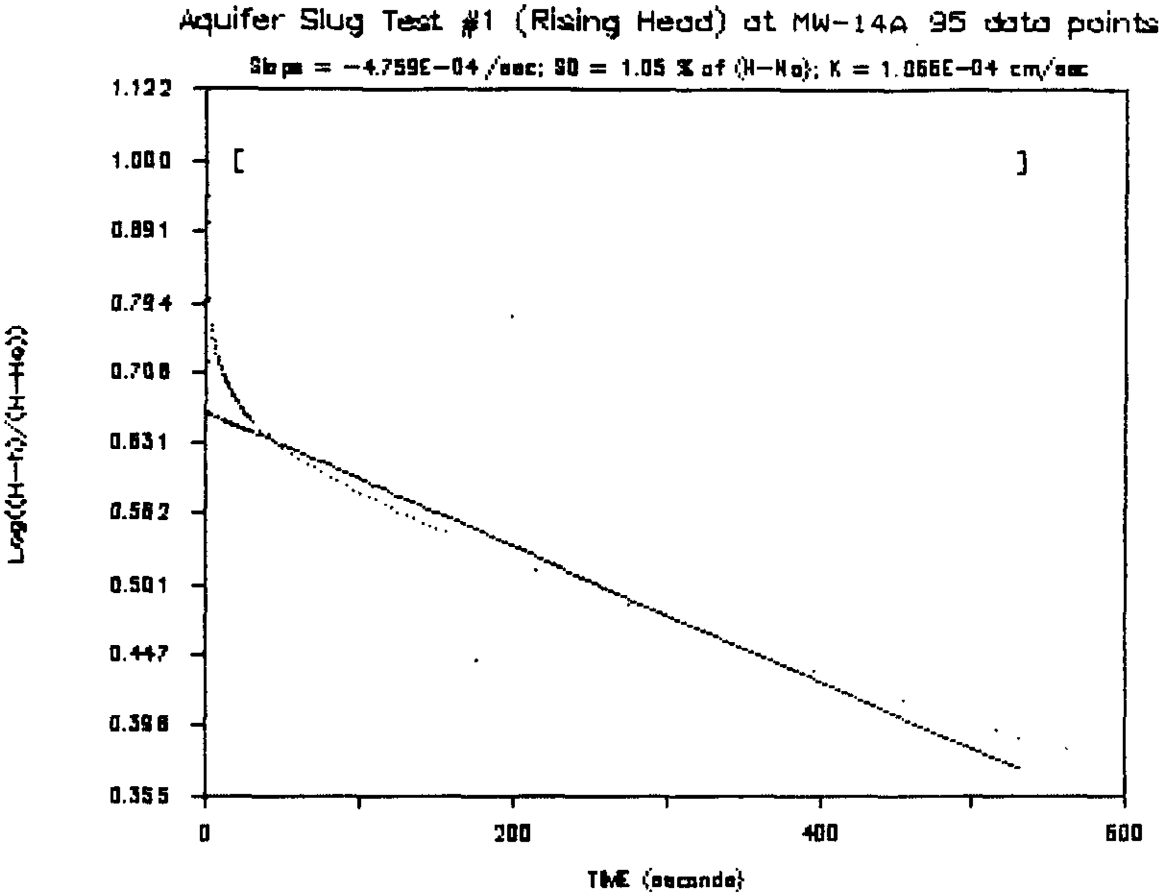
Aquifer Slug Test #1 (Rising Head) at MW-87-8b; 97 data points

Slope = -9.048E-04 /sec; SD = 2.87 % of (H-Ho); K = 1.358E-04 cm/sec

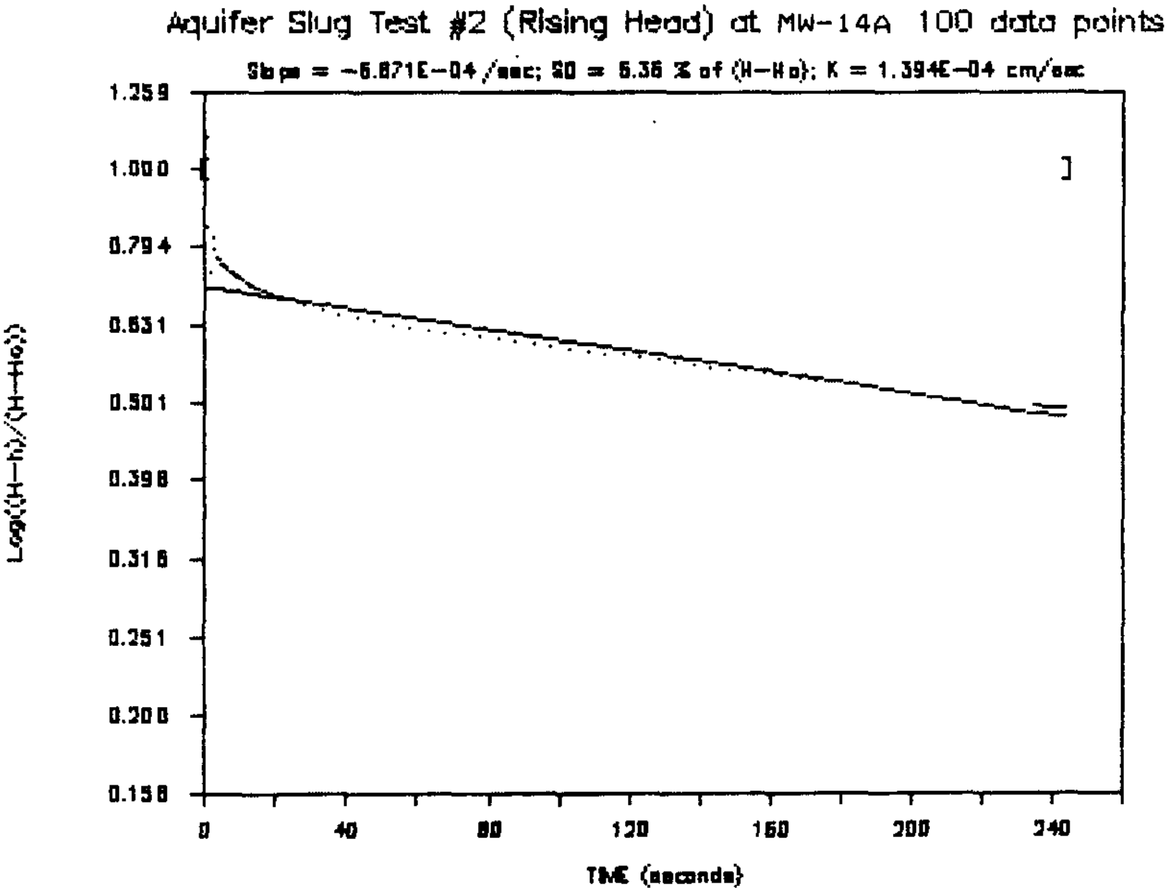


Aquifer Slug Test #2 (Rising Head) at MW-87-8b; 259 data points

Slope = -7.711E-04 /sec; SD = 4.17 % of (H-Ho); K = 1.193E-04 cm/sec


Aquifer Slug Test #1 (Rising Head) at MW-14A 95 data points

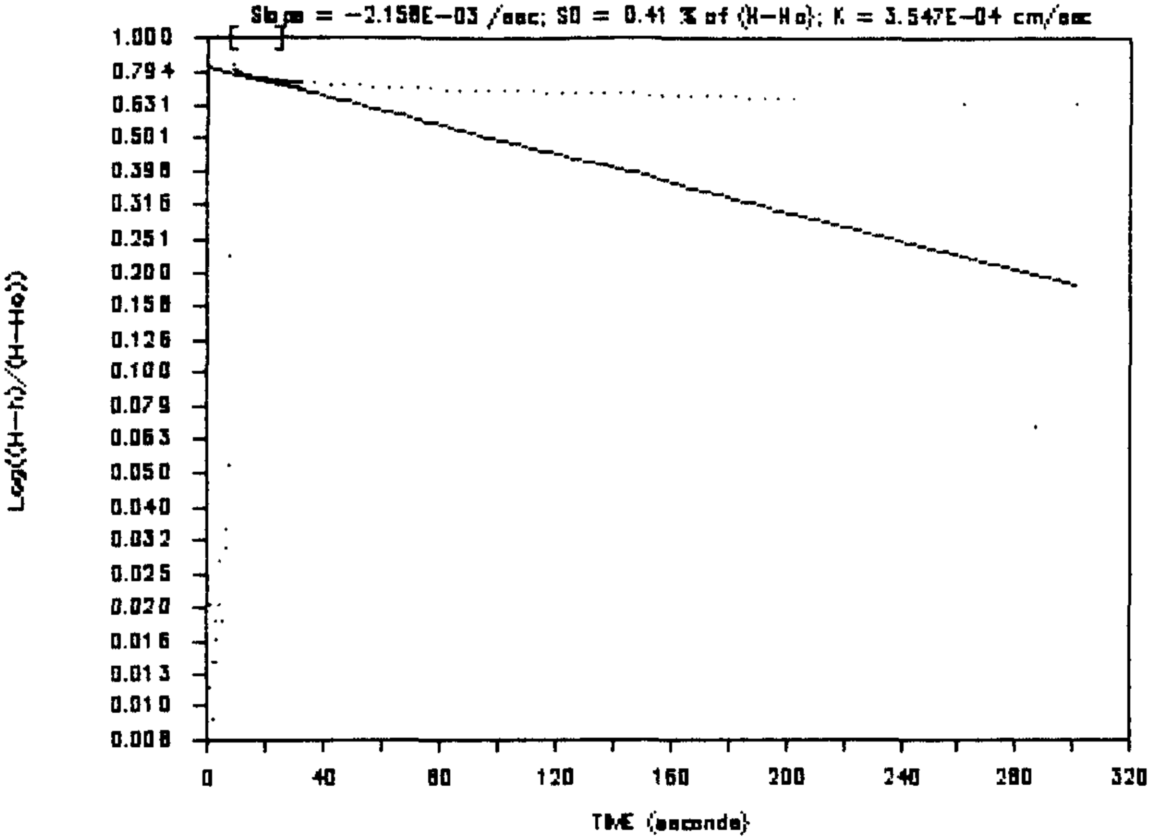
Slope = -4.759E-04 /sec; SD = 1.05 % of (H-Ho); K = 1.066E-04 cm/sec


Aquifer Slug Test #2 (Rising Head) at MW-14A 100 data points

Slope = -6.871E-04 /sec; SD = 6.36 % of (H-Ho); K = 1.394E-04 cm/sec

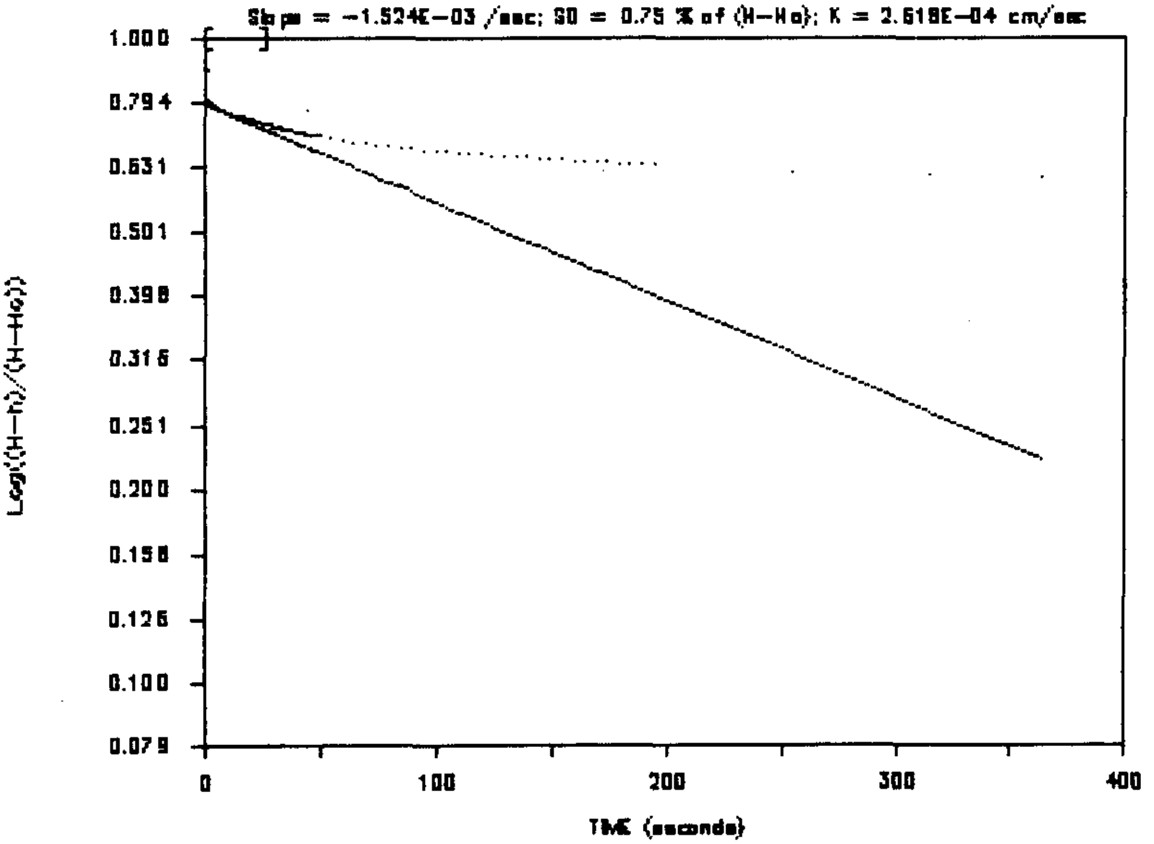
Aquifer Slug Test #1 (Rising Head) at MW-87-14S; 102 data points

Slope = -2.158E-03 /sec; SD = 0.41 % of (H-Ho); K = 3.547E-04 cm/sec



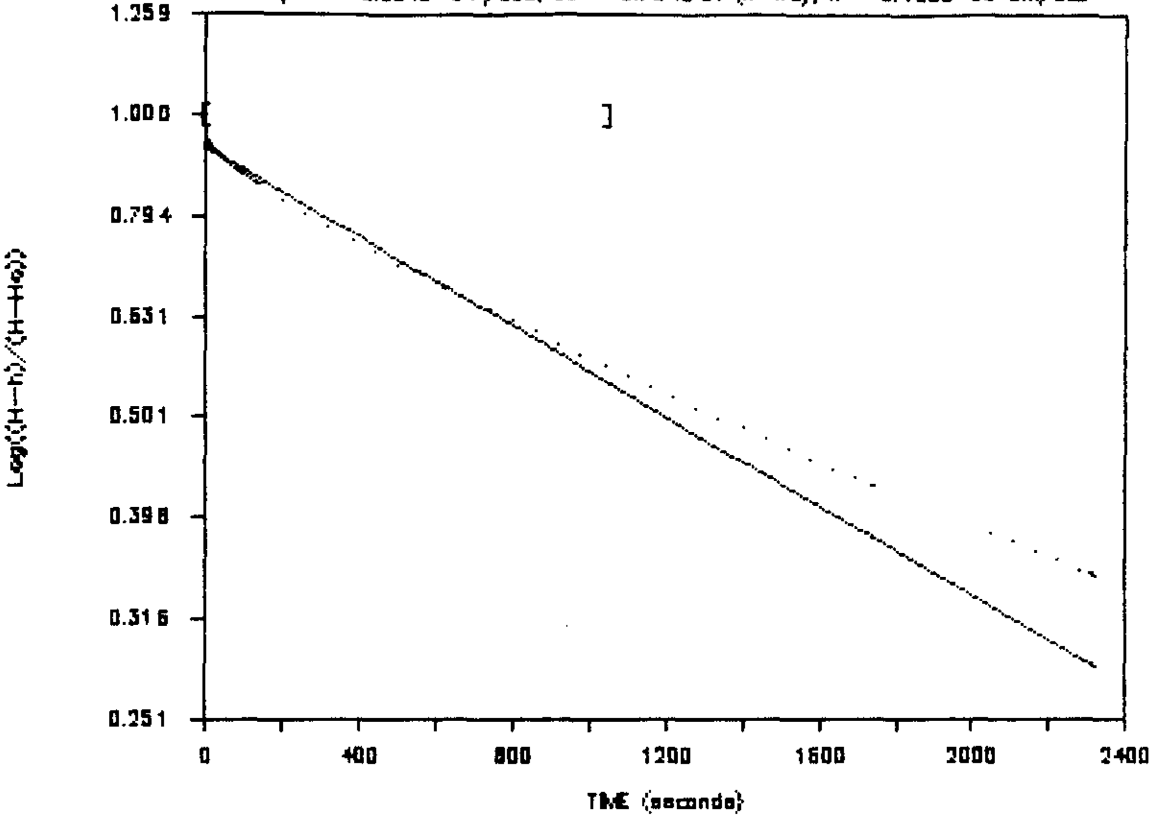
Aquifer Slug Test #2 (Rising Head) at MW-87-14S; 132 data points

Slope = -1.524E-03 /sec; SD = 0.75 % of (H-Ho); K = 2.618E-04 cm/sec



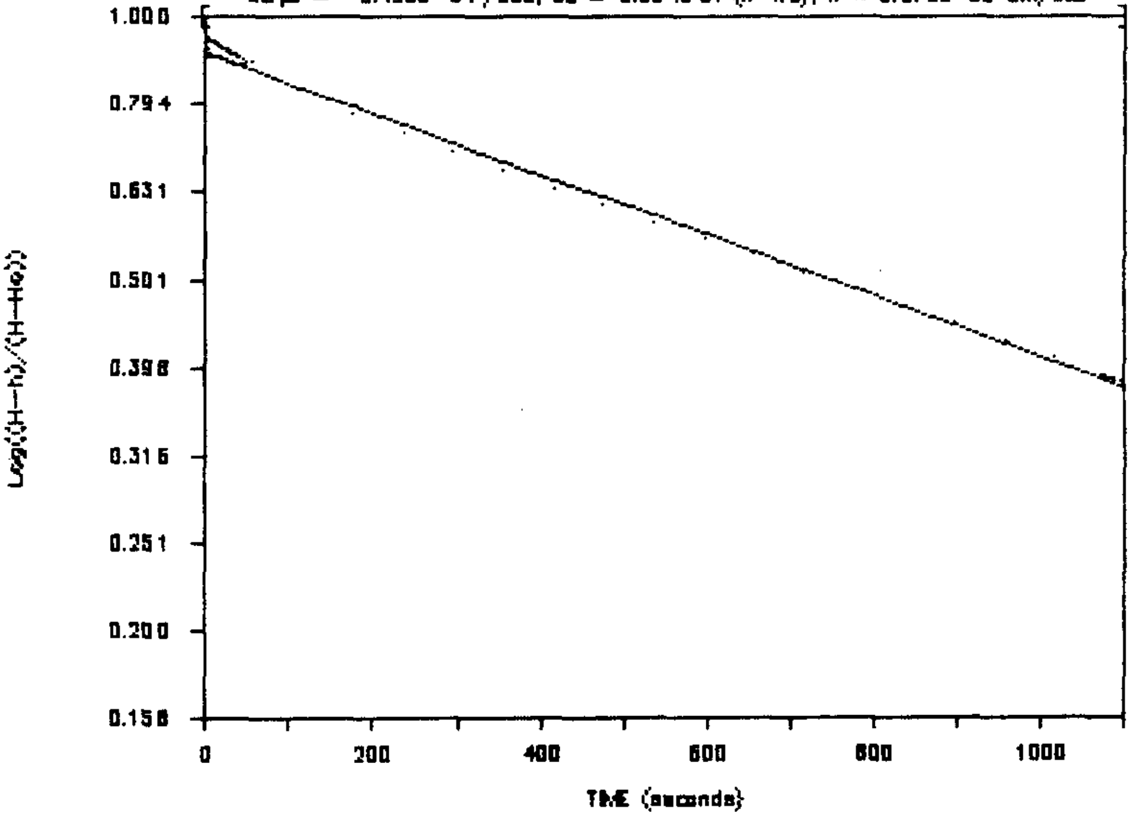
Aquifer Slug Test #1 (Rising Head) at MW-87-16S; 156 data points

Slope = -2.224E-04 /sec; SD = 0.76 % of (H-Ho); K = 3.168E-05 cm/sec



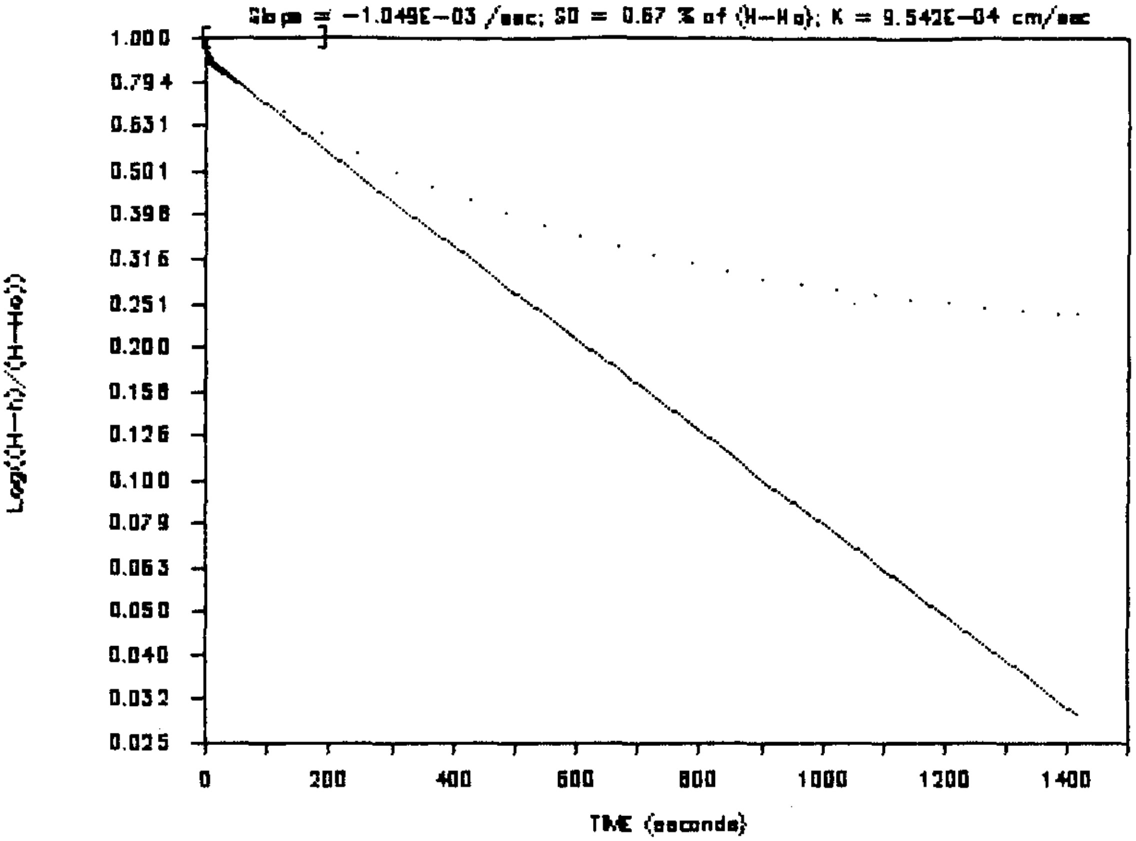
Aquifer Slug Test #2 (Rising Head) at MW-87-16S; 137 data points

Slope = -3.493E-04 /sec; SD = 6.08 % of (H-Ho); K = 5.075E-05 cm/sec



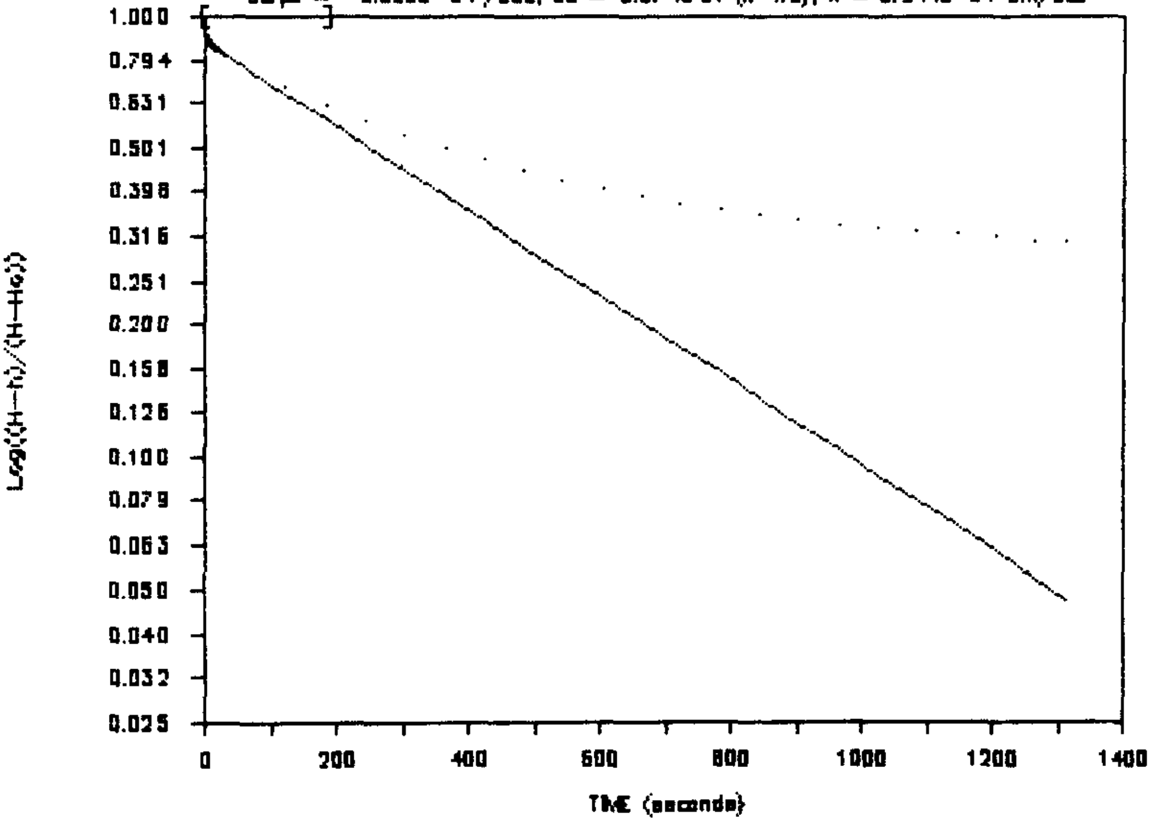
Aquifer Slug Test #1 (Rising Head) at MW-87-16B; 101 data points

Slope = -1.049E-03 /sec; SD = 0.67 % of (H-Ho); K = 9.542E-04 cm/sec

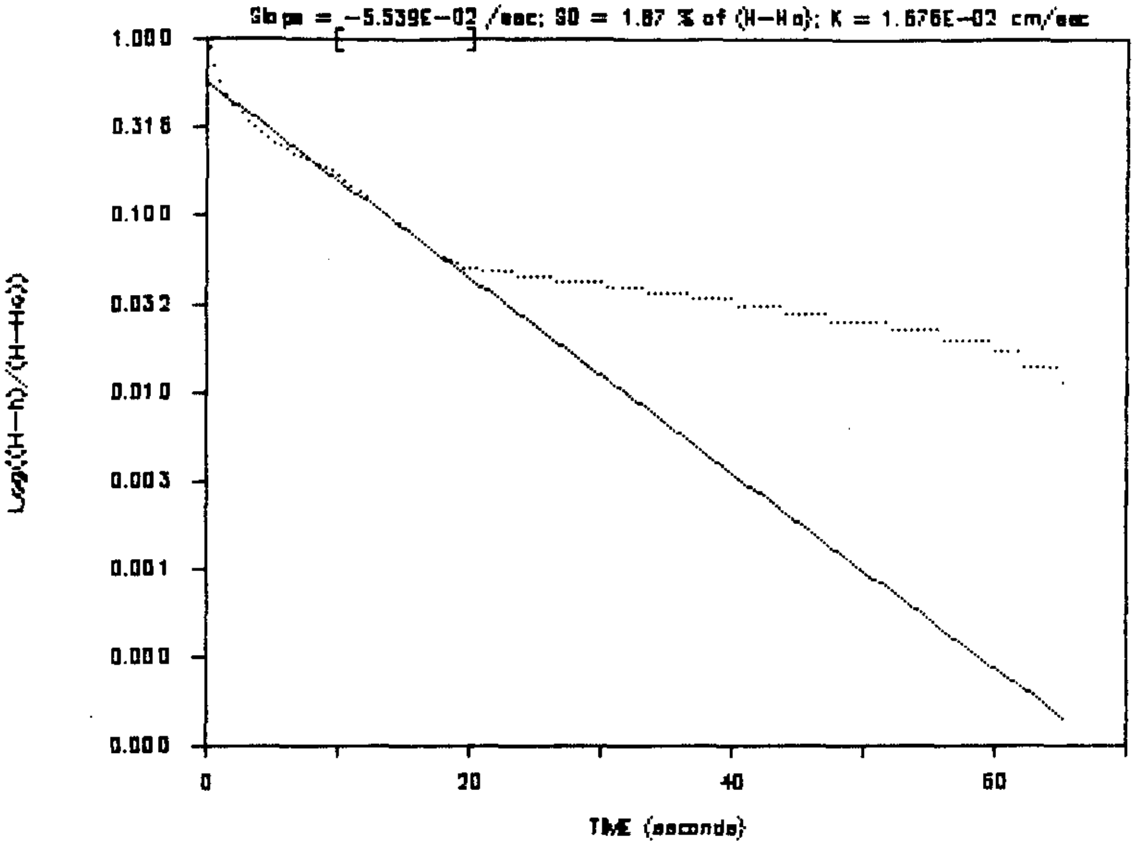


Aquifer Slug Test #2 (Rising Head) at MW-87-16B; 93 data points

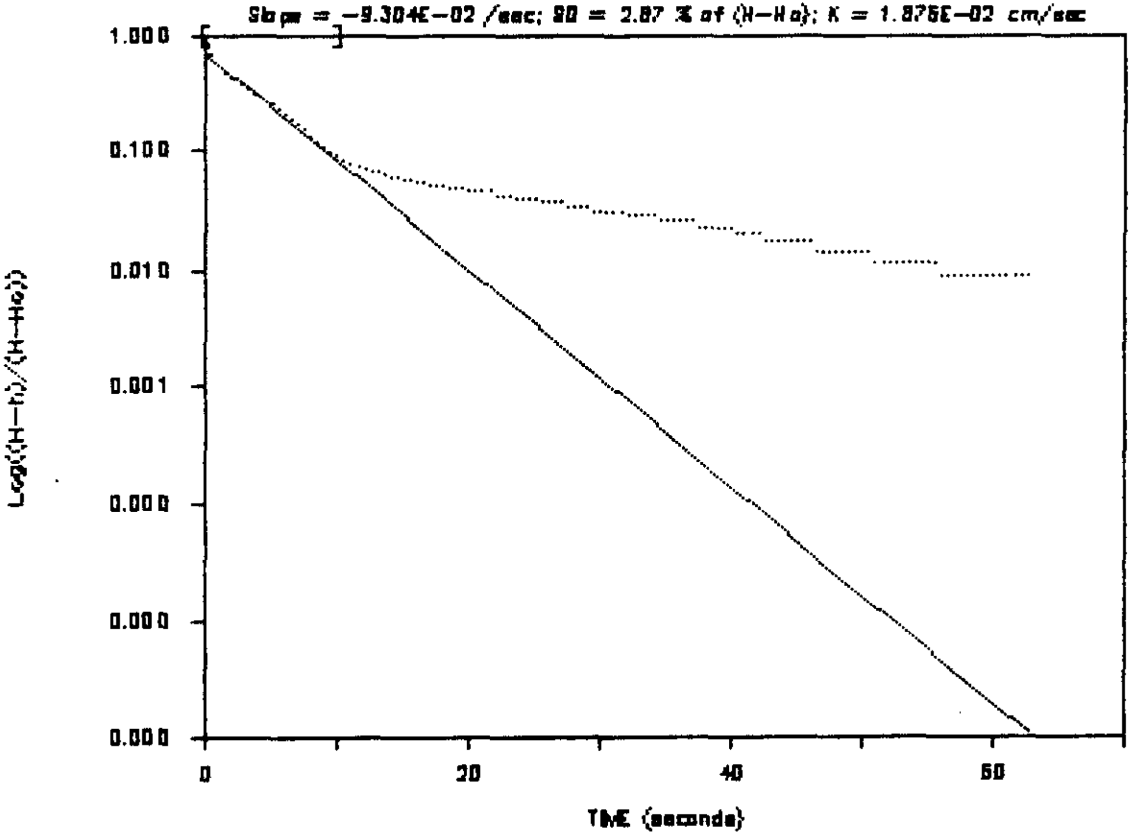
Slope = -9.626E-04 /sec; SD = 0.87 % of (H-Ho); K = 8.944E-04 cm/sec

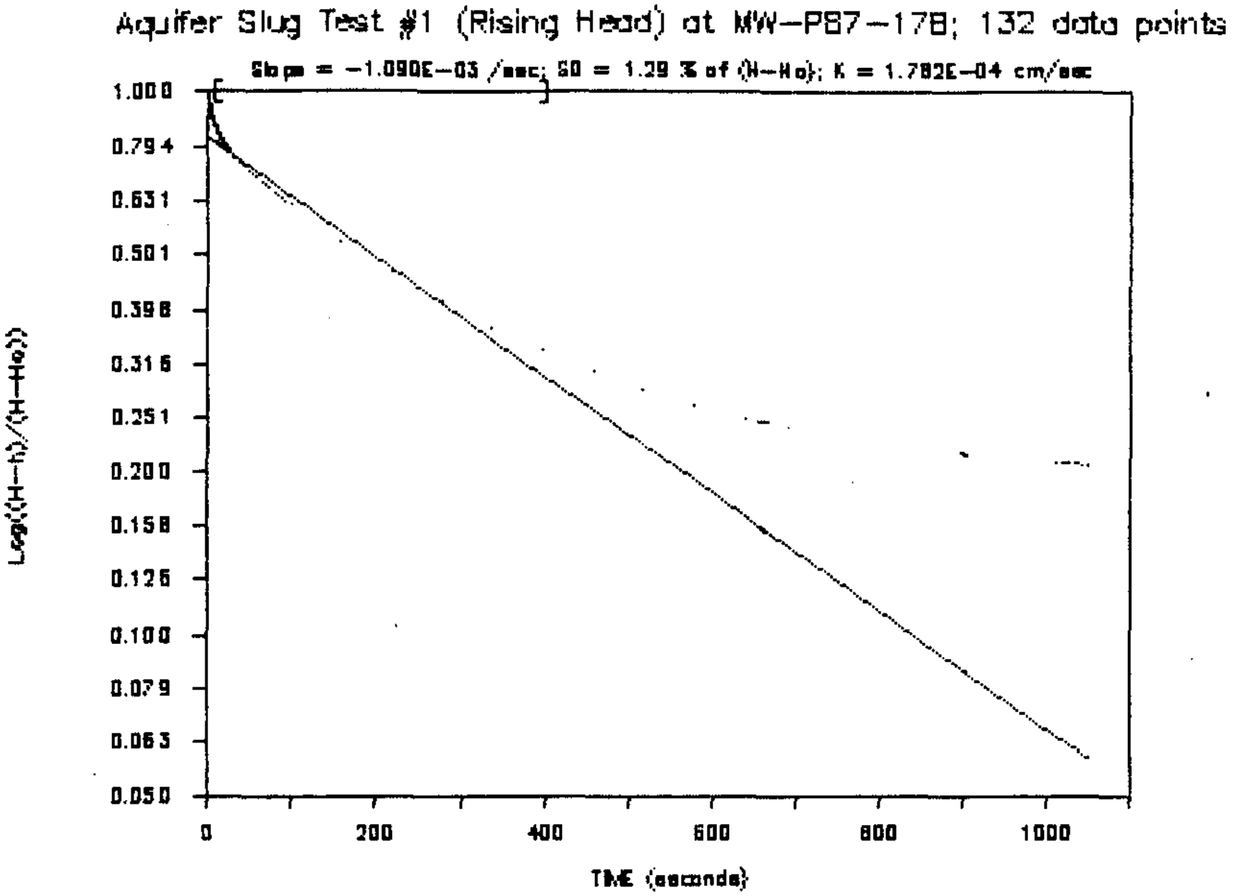


Aquifer Slug Test #1 (Rising Head) at MW-P87-17S; 132 data points



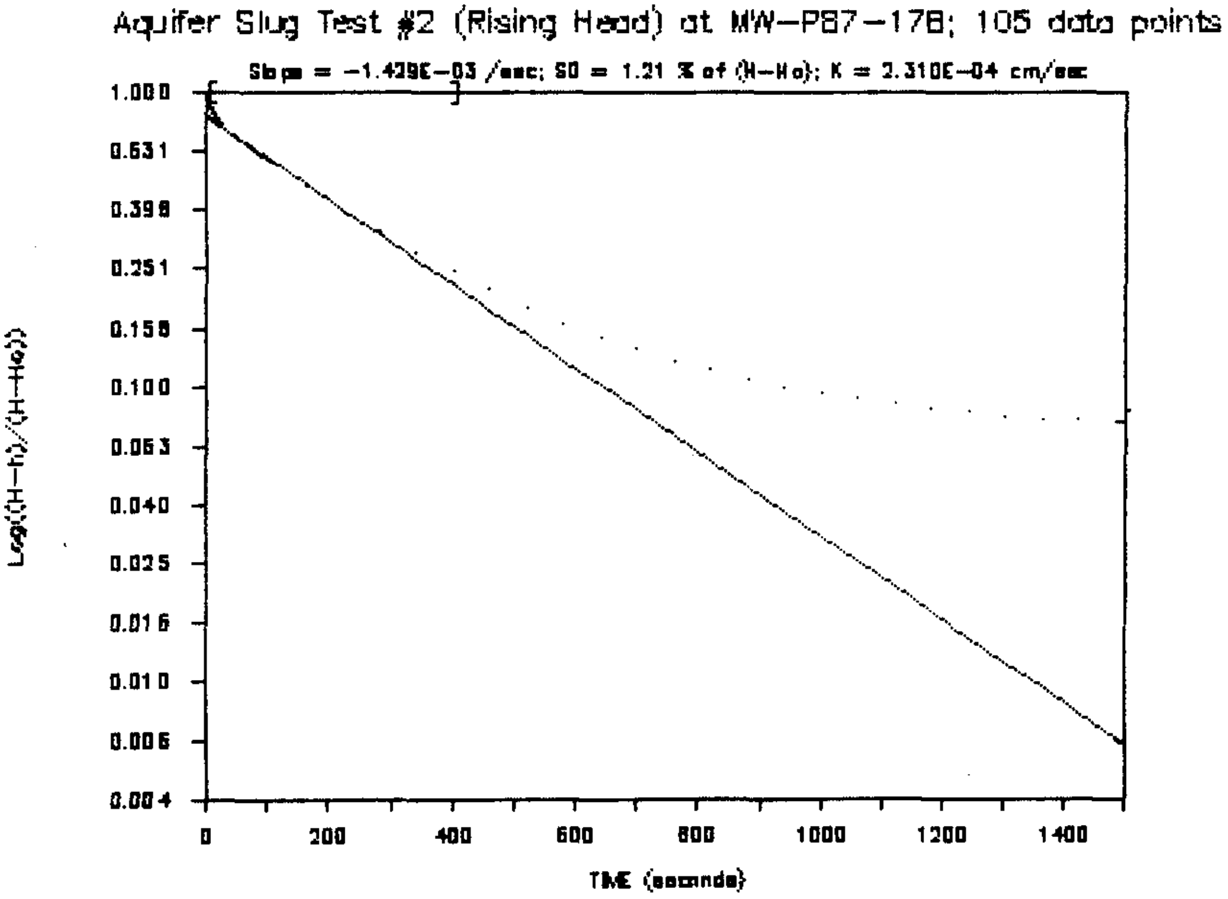
Aquifer Slug Test #2 (Rising Head) at MW-P87-17S; 127 data points





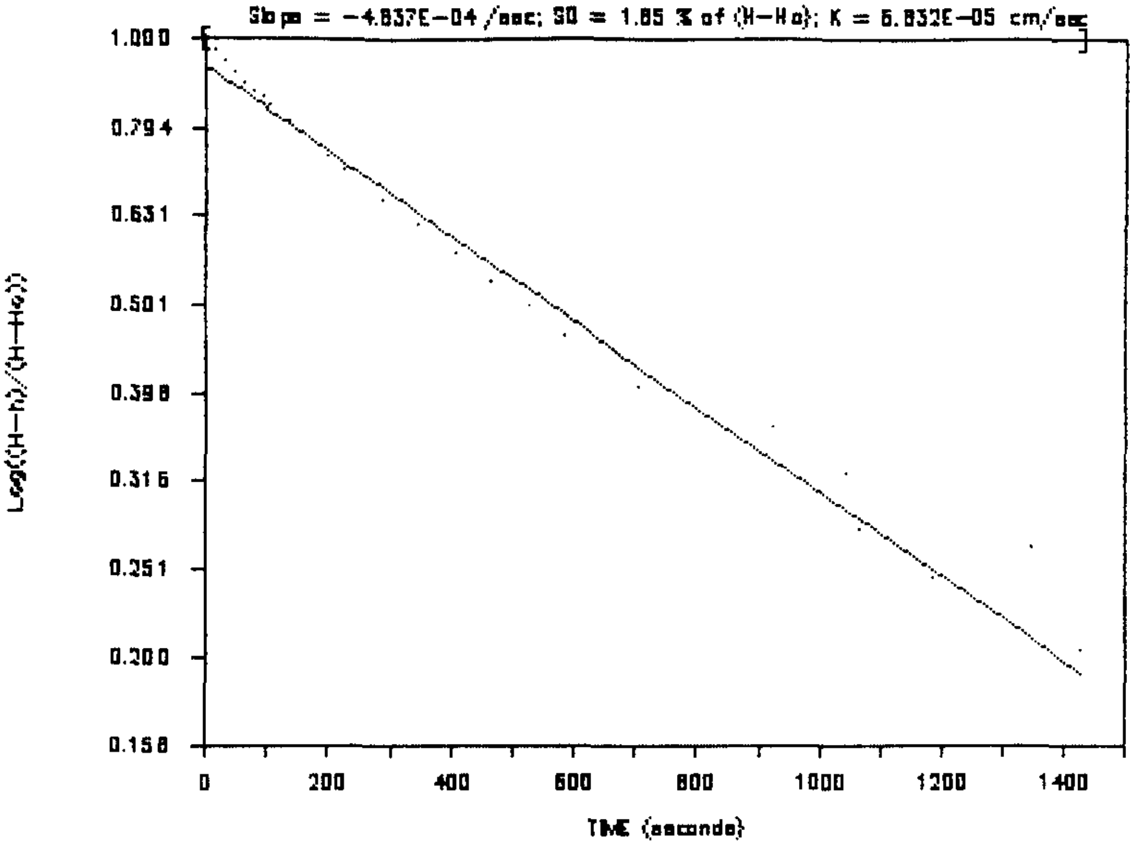
Aquifer Slug Test #1 (Rising Head) at MW—P87—178; 132 data points

Slope = −1.090E−03 /sec; SD = 1.29 % of (H−Ho); K = 1.782E−04 cm/sec



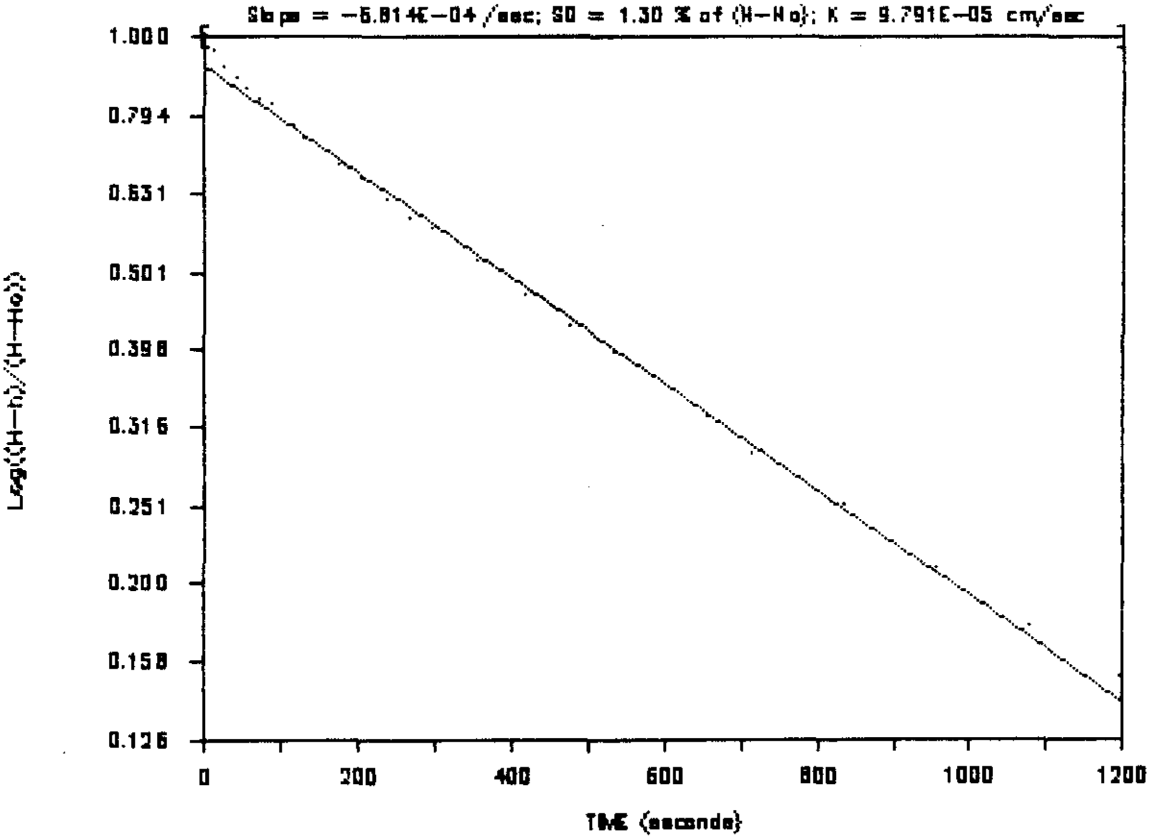
Aquifer Slug Test #2 (Rising Head) at MW—P87—178; 105 data points

Slope = −1.439E−03 /sec; SD = 1.21 % of (H−Ho); K = 2.310E−04 cm/sec



Aquifer Slug Test #1 (Falling Head) at MW-p21sf; 25 data points

Slope = -4.837E-04 /sec; SD = 1.85 % of (H-Ho); K = 6.832E-05 cm/sec

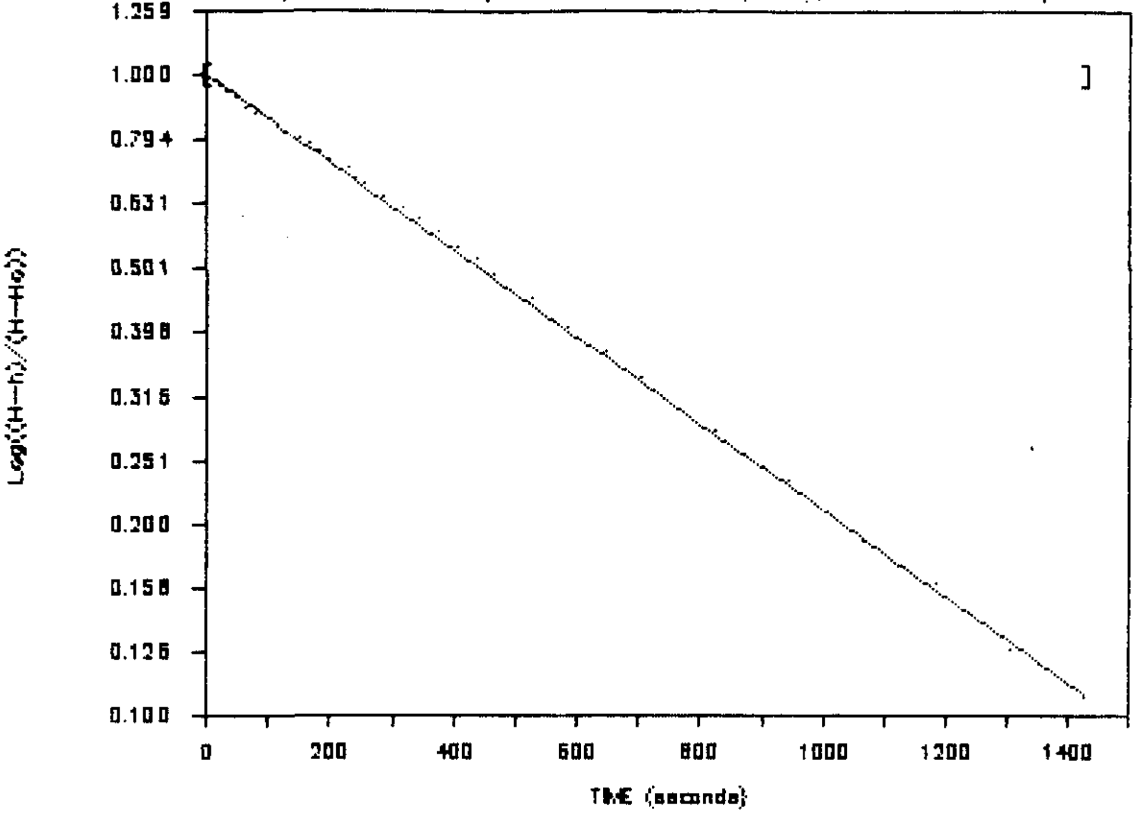


Aquifer Slug Test #1 (Rising Head) at MW-p21sr; 27 data points

Slope = -6.814E-04 /sec; SD = 1.30 % of (H-Ho); K = 9.791E-05 cm/sec

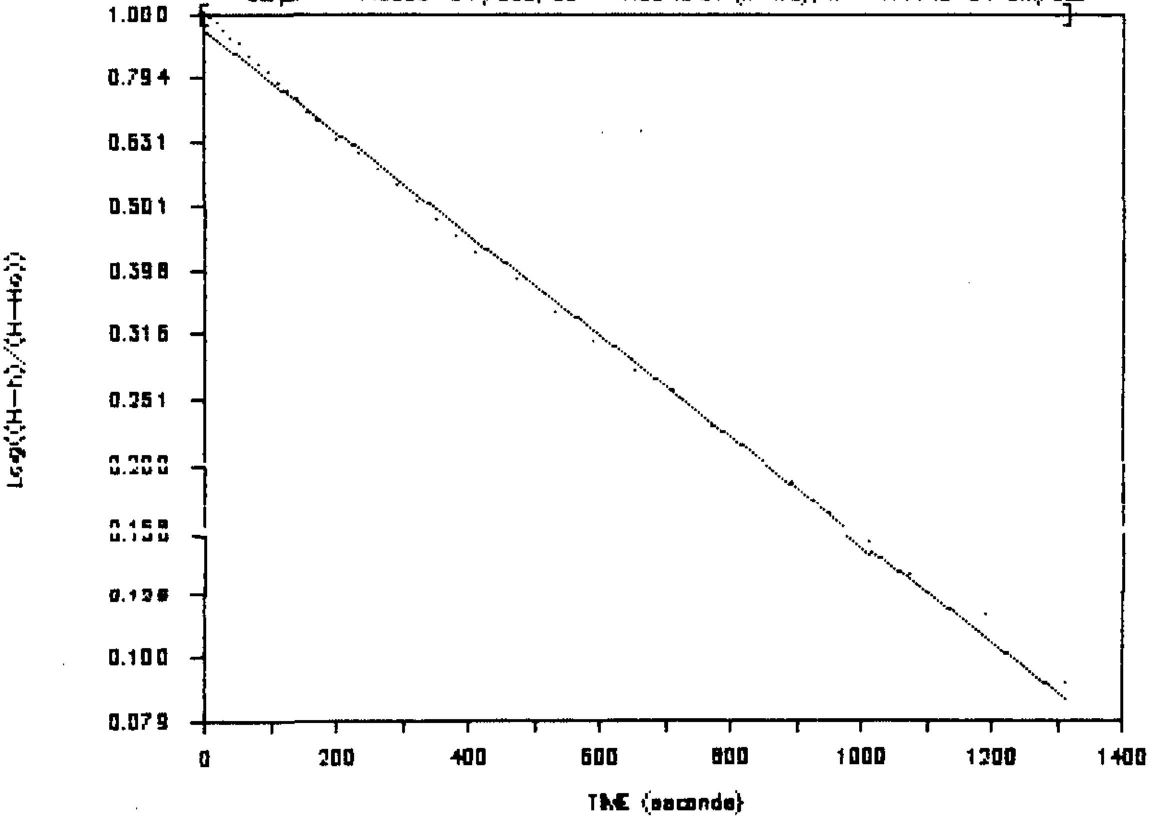
Aquifer Slug Test #1 (Falling Head) at MW-p21bf; 34 data points

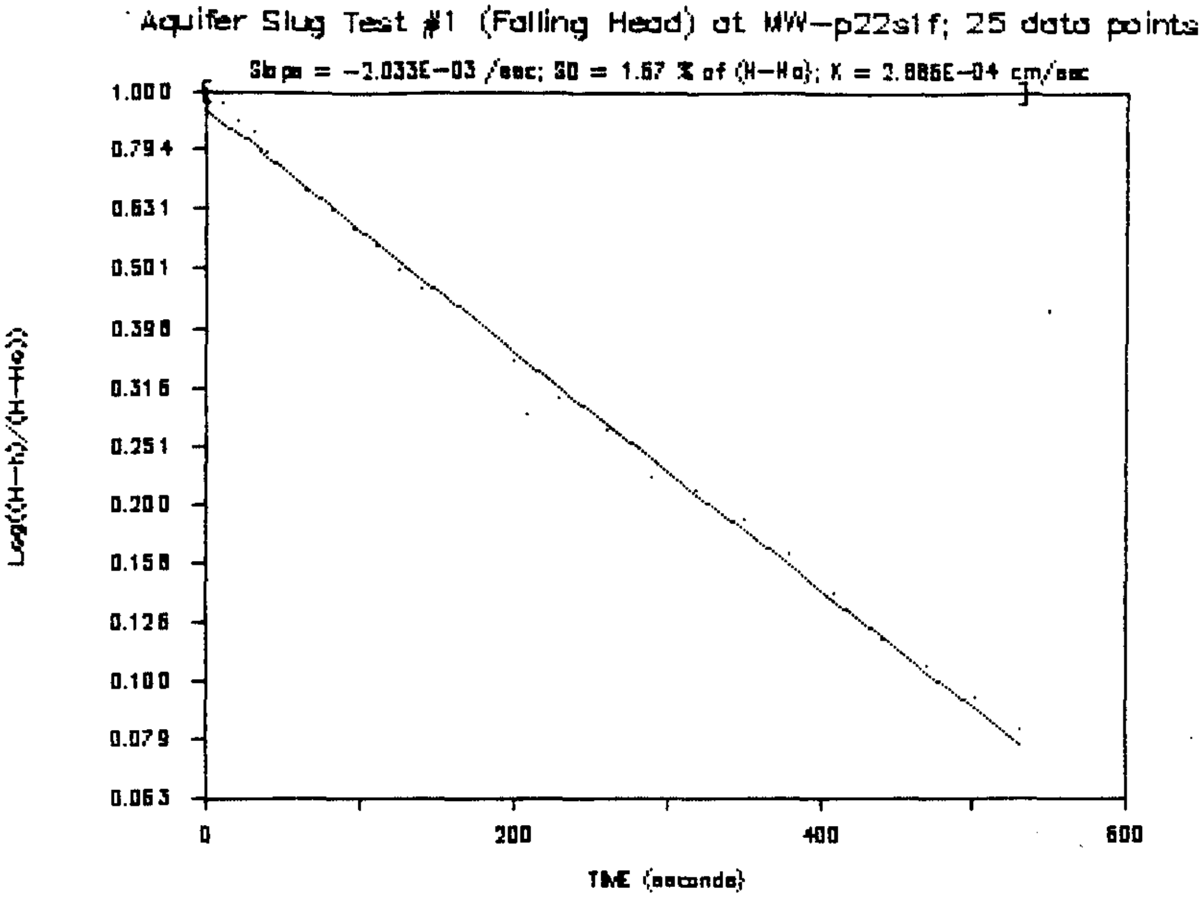
Slope = -6.792E-04 /sec; SD = 0.66 % of (H-Ho); K = 8.921E-05 cm/sec



Aquifer Slug Test #1 (Rising Head) at MW-p21br; 35 data points

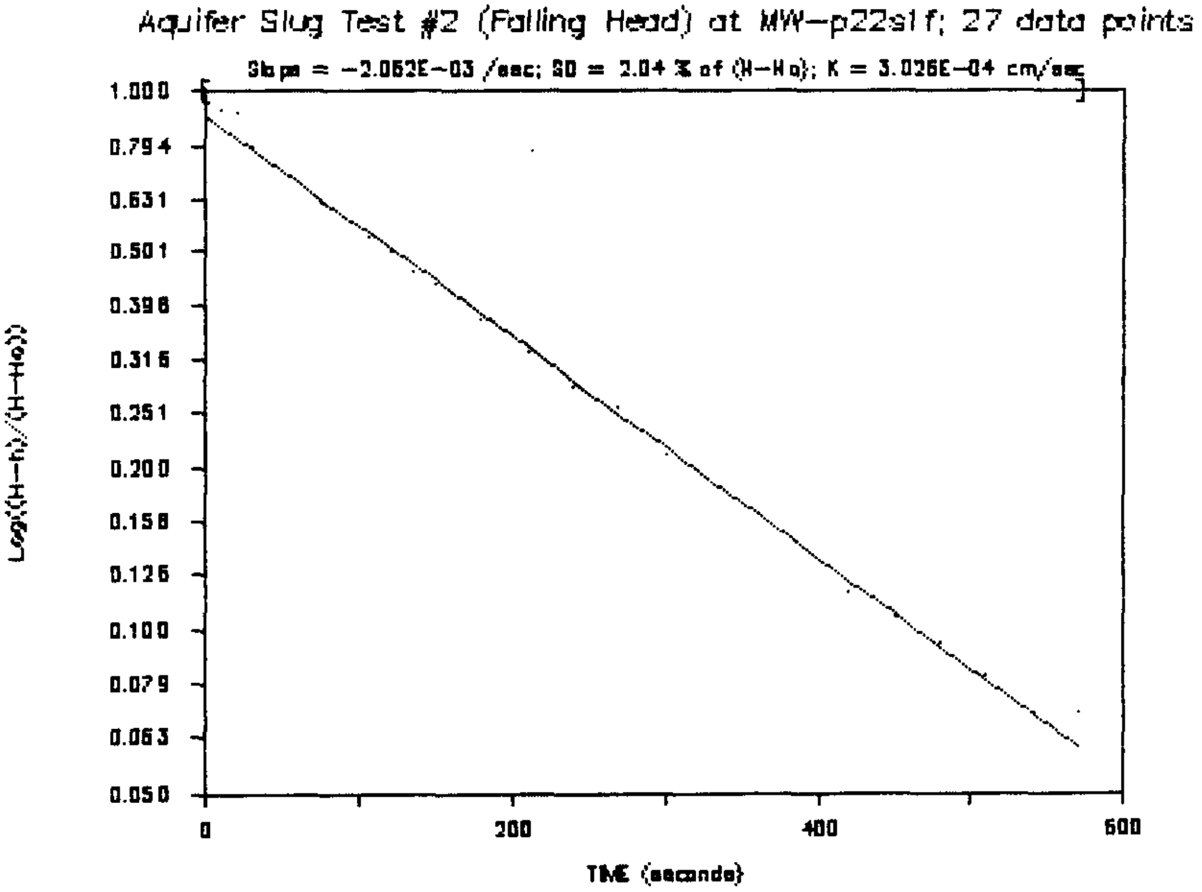
Slope = -7.952E-04 /sec; SD = 1.58 % of (H-Ho); K = 1.114E-04 cm/sec





Aquifer Slug Test #1 (Falling Head) at MW-p22s1f; 25 data points

Slope = -2.033E-03 /sec; SD = 1.67 % of (H-Ho); K = 2.886E-04 cm/sec



Aquifer Slug Test #2 (Falling Head) at MW-p22s1f; 27 data points

Slope = -2.062E-03 /sec; SD = 2.04 % of (H-Ho); K = 3.026E-04 cm/sec

CH2M HILL

TECHNICAL MEMORANDUM NO. 9

TO: Fred Bartman/U.S. EPA

FROM: Randy Videkovich/CH2M HILL

PREPARED BY: Barbara Grundl/CH2M HILL

DATE: May 16, 1988

RE: Pump Test Issue in Process Area

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
GLO68802.R8

The Record of Decision (ROD) issued on September 30, 1986, specified the groundwater remedial response including:

- A system of parallel drains to remove contaminated groundwater from the fill and peat
- A line of 12 wells along the southern boundary of the site to prevent contaminated groundwater from the deeper sediment to leave the site
- Four additional wells in the process area where contaminated soil is excavated

The ROD also required that additional design investigations be conducted to refine the groundwater remedy. Pump tests were recommended by the U.S. EPA and the MPCA to better define the parameters influencing the design of the groundwater extraction system. The pump tests were to be performed in the process area to characterize flow in and yield from the deeper layers. This information would be used to optimize the extraction well system proposed for this area. The data would be in addition to the hydraulic conductivities obtained from in situ slug testing from August 16 to 23, 1987. In January 1988, CH2M HILL suggested that pump testing be postponed until additional characterization of the chemical quality of the soil, sediment, and groundwater was available. Potential negative impacts of pump testing efforts could then be assessed and the usefulness and feasibility could be determined. The agencies agreed to this approach.

From October 26 to November 18, 1987, additional chemical data were collected for soil, sediment, and groundwater as part of Step I of the Fieldwork Design Investigation. The results of the surface/subsurface soil, sediment, and groundwater sampling in the process area near Well Nest 5 showed that most of the chemical constituents were present in the groundwater and were VOCs. The most prevalent VOCs were vinyl chloride (1,100 µg/l), trans-1,2-dichloroethene (270 µg/l), 1,1,1 trichloroethane (340 μg/l), toluene (340 μg/l), ethylbenzene (391 μg/l), and total xylenes (240 μg/l). They were found in samples from wells screened in the fill and peat layers close to the surface. Results from samples collected from deeper intervals were below CLP contract required detection limits for the same compounds. Thus, contaminants found in the groundwater are limited to the fill and peat layers.

Obtaining information through a pump test about the flow characteristics of the morainal deposit (about 1,382 to 1,410 feet above mean sea level) could cause a negative impact on the quality of the groundwater. The VOCs (solvents and benzene, toluene, and xylenes) have not migrated vertically beyond the fill and peat layer, but pump testing would provide a pathway for the contaminants to migrate vertically to deeper layers. Therefore, pump testing should not be performed in this water bearing unit.

An evaluation of groundwater extraction wells performed during the Feasibility Study (FS) indicated that the production capabilities of the fill and peat are not significant enough to justify the installation of an extraction well in this water bearing unit. The extraction method proposed in the FS for the removal of contaminated groundwater from the shallow units was a system of parallel drains. Thus, it is recommended that no pump testing in the process area be performed.

GLT932/028.51

CH2M HILL

TECHNICAL MEMORANDUM NO. 10

TO:	Fred Bartman/U.S. EPA Remedial Project Manager
FROM:	Randy Videkovich/CH2M HILL Project Manager
PREPARED BY:	John Gannon/CH2M HILL
DATE:	May 11, 1988
RE:	Groundwater Sampling (Step II)
PROJECT:	Arrowhead Refinery Fieldwork Design Investigation GLO68802.FQ

INTRODUCTION

Groundwater samples were collected during Step II of the Fieldwork Design Investigation between May 2 and 10, 1988. This memorandum describes the sampling procedures, field observations and measurements, and sample matrix tables for the samples collected.

PERSONNEL

The sampling team consisted of:

- Jewelle Imada, CH2M HILL
- Jeff Keiser, CH2M HILL
- John Gannon, CH2M HILL
- Joanne Holzheimer, EWA
- Kim Paulisch, EWA
- Alan Esko, Engineers International
- Cathy Kantowski, Engineers International

Not all personnel were present at the site for the entire sampling effort. The sampling team maintained sample custody. The CLP paperwork was completed by Cathy Kantowski.

SAMPLING LOCATIONS

Samples were collected from 40 monitoring wells (Figure TM10-1). Monitoring wells B4a and B5 were not sampled because of consistently high levels of contamination detected in earlier sampling rounds. A groundwater sample was not collected from MW-18e because of visible bentonite contamination.

SAMPLING PROCEDURES

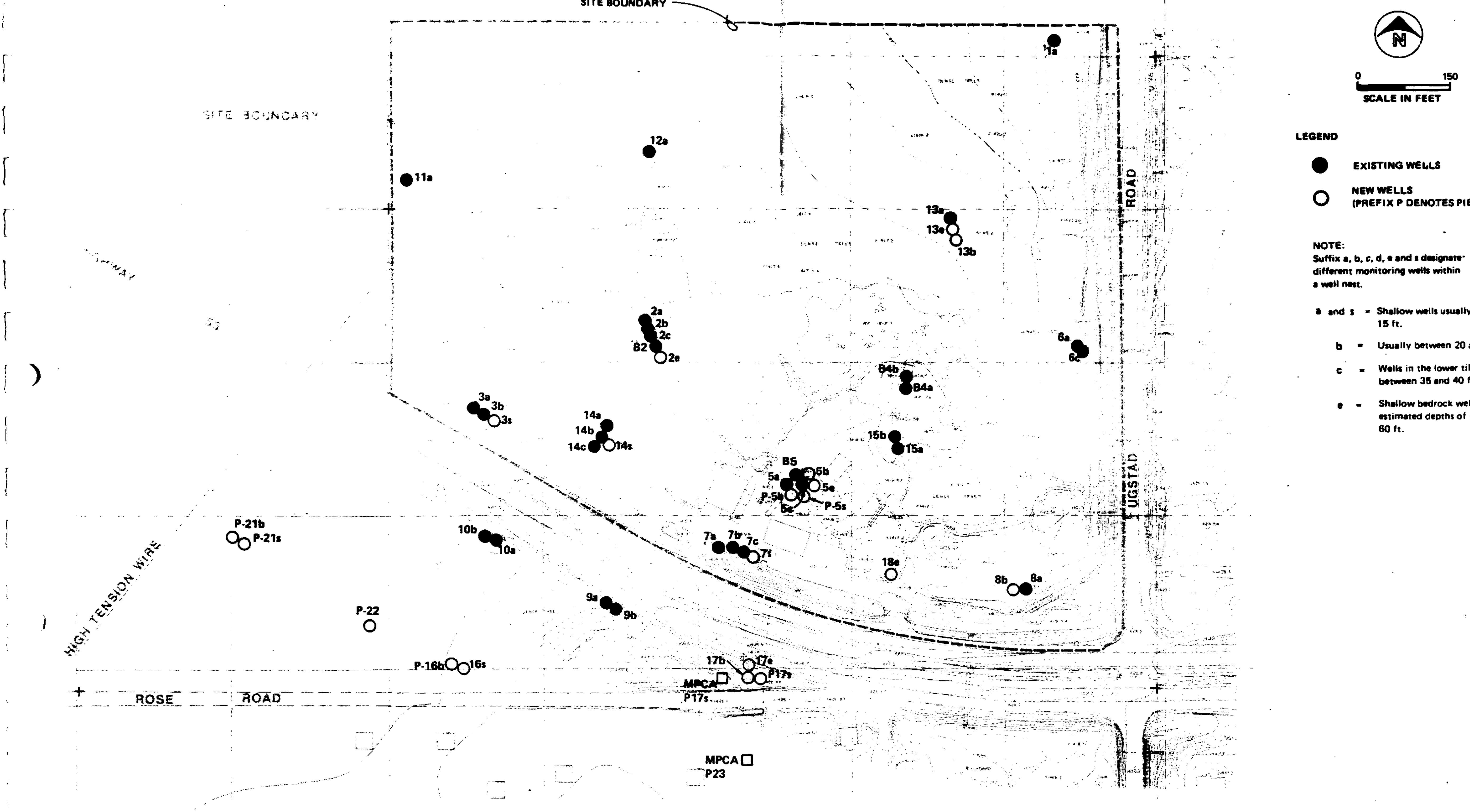
Water levels and well depths were measured before the wells were purged to calculate the purge volume for the well. Water levels were measured on April 28 before the sampling began. The water level readings were approximately the same as those taken during the Step I sampling, so the purge volumes remained the same (Table TM10-1).

The Sampling Plan required that the wells be purged of five well volumes immediately before sampling. Slow recharge of many of the wells often made purging difficult. Wells MW-3s and MW-7b were purged dry before five well volumes had been collected and were allowed to recover to complete purging and sampling. All of the wells were purged of five well volumes except Wells MW-2e, B4b, MW-14b, and MW-15b, which were purged dry twice and sampled upon recovery because of poor recharge. Groundwater samples collected for the analysis of volatile organic compounds (VOCs) were always collected as soon as there was enough water in the wells to do so.

Samples were collected by two teams, beginning with the cleanest wells. The sample bottles were filled in the following order: VOCs with low detection limits (if taken), VOCs, polynuclear aromatic hydrocarbons (PAHs) with low detection limits (if taken), semivolatile organic compounds, unfiltered metals, cyanide, and filtered metals. Whenever possible, only one 40-ml vial was filled for VOC analyses per bailer of water. The excess water was used to fill the remaining bottles. The outsides of the bottles were then decontaminated. Attachment A is a sample matrix table.

All metal samples were preserved with HNO_3 to a pH of less than 2. Samples to be analyzed for cyanide were preserved with NaOH to a pH of more than 12. Samples were also collected to measure pH, conductivity, and temperature of each sample location in the field (Table TM10-1).

The sampling equipment was cleaned between wells by scrubbing with a solution of trisodium phosphate and tap water, followed by a methanol rinse and a final triple rinse with distilled water. The bailers were placed in clean plastic bags for storage or transport between sampling locations. The stainless steel wire was soaked in a solution of methanol and distilled water and was triple rinsed with distilled water.



LEGEND

● EXISTING WELLS

○ NEW WELLS
(PREFIX P DENOTES PIEZOMETER)

NOTE:
Suffix a, b, c, d, e and s designate different monitoring wells within a well nest.

a and s = Shallow wells usually less than 15 ft.

b = Usually between 20 and 30 ft.

c = Wells in the lower till, between 35 and 40 ft.

e = Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE TM10-1
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM10-1 (Page 1 of 2)
SUMMARY OF GROUNDWATER SAMPLING

Well Number	Total Water Purged (gal)	Time Between Purging and Sampling (hr)	HNu Readings (ppm)[a]		pH	Conductivity (µmhos/cm)	Temperature (degrees C)	Comment and Observation
			In Well	From Water				
MW-1a	8	0	BKG	BKG	7.64	450	11	Water red and silty.
MW-2a	3	0	BKG	BKG	6.47	970	11	Water had a strong petroleum odor.
MW-2b	12	0	3-5	2	8.38	275	9.5	
MW-2c	16	0	BKG	BKG	8.47	350	11	Water is cloudy.
MW-2e	16*	2	3-6	2	8.54	325	13	Purged dry after 12 gallons. Purged dry twice prior to sampling.
B2b	2	0	BKG	BKG	6.44	925	10	
MW-3s	6	0.5	BKG	BKG	6.52	950	10	Purged dry after 6 gallons.
MW-3a	6	0	8	BKG	7.61	400	8	Water very turbid.
MW-3b	10	0	8-9	1	7.46	325	10	Water is clear. Good recharge.
B4b	4.5*	4	1	2	8.14	520	13	Used 1-inch bailer to purge the well. Purged dry after 3 gallons. Purged dry twice prior to sampling.
MW-5a	5	0	1	1	8.03	200	10	
MW-5b	10	0	1	BKG	7.78	1,025	14	
MW-5c	17	0	30	NM	8.34	375	11	
MW-5e	45	0	BKG	BKG	8.50	400	12	Water is clear.
MW-6a	8	0	BKG	BKG	7.12	700	11	Water is red and silty.
MW-6c	30	0	BKG	BKG	7.73	1,000	11	Water is clear.
MW-7s	9	0	BKG	1-2	7.75	1,000	9	
MW-7a	10	0	8-10	BKG	7.51	1,170	9	
MW-7b	18	0.5	1-2	BKG	8.06	800	12	Used 1-inch bailer, bend in casing. Bend above water level. Purged dry after 8 gallons.
MW-7c	17	0	20	BKG	8.49	425	11	Used a 1-inch bailer, bend in casing. Bend above water level.
MW-8a	5	0	BKG	BKG	7.25	1,380	12	Slow recharge.
MW-8b	15	0	BKG	BKG	NM	NM	NM	
MW-9a	5	0	4	BKG	7.57	1,060	9	Water slightly turbid.
MW-9b	8	0	BKG	BKG	7.03	1,100	10	
MW-10a	5	0	BKG	BKG	6.78	1,350	9	
MW-10b	10	0	BKG	BKG	7.20	1,580	11	
MW-11a	7	0	5-8	2-3	6.40	300	8	Water very turbid.
MW-12a	6	0	BKG	8 pm	7.13	300	8	Water slightly turbid.
MW-13a	15	0	BKG	BKG	8.18	340	11	
MW-13b	30	0	BKG	BKG	7.95	375	11	Water is clear.

Table TM10-1 (Page 2 of 2)

Well Number	Total Water Purged (gal)	Time Between Purging and Sampling (hr)	HNu Readings (ppm)[a]		pH	Conductivity (µmhos/cm)	Temperature (degrees C)	Comment and Observation
			In Well	From Water				
MW-13e	50	0	BKG	BKG	7.80	300	10	Water is clear. Good recharge.
MW-14s	7	0	BKG	5-6	7.16	600	12	
MW-14a	7	0	BKG	8-10	7.07	760	9	Water turbid. Bend in casing made purging difficult.
MW-14b	NR*	5	BKG	BKG	8.32	410	13	Purged dry twice prior to sampling.
MW-14c	15	0	BKG	BKG	8.83	370	11	
MW-15a	NR	0	BKG	BKG	7.47	2,400	12	Purged water is slightly turbid.
MW-15b	8*	2	BKG	BKG	8.47	725	12	Purged dry after 4 gallons. Purged dry twice prior to sampling.
MW-16s	7	0	BKG	BKG	6.73	560	9	Water is red and silty.
MW-17b	32	0	BKG	BKG	8.53	350	12	
MW-17e	50	0	BKG	BKG	12.07	1,260	13	Some bentonite observed in purged water.

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[a] Readings in the well were taken by placing the probe in the well casing. Readings from the water were measured from the water in the bucket during purging.

NM = Not measured.
NR = Not recorded.
BKG = HNu reading background.
* = Total water purged was less than the required five well locations.

The sections of stainless steel cable were also placed in clean plastic bags for storage or transport between sampling locations.

Replicates, triplicates, and matrix spikes were taken of certain groundwater samples (Attachment A). Field blanks were collected by filling a decontaminated bailer used for sampling with HPLC-grade water and transferring the water to sample containers. Bottle blanks for low level VOC analyses were taken by pouring HPLC-grade water directly into the VOC vials.

GLT932/030.51

TM10--GROUNDWATER SAMPLING
(STEP II)

Attachment A
SAMPLE MATRIX TABLE FOR GROUNDWATER SAMPLES

SAMPLE MATRIX FOR GROUNDWATER
SAMPLES (STEP II)
(PAGE 1 OF 5)

ANALYSIS DURING SAMPLING

Well Number	CRL Sample Number	Collection		Routine HSL VOCs				Routine HSL BNAs				HSL Inorganics (1)				Low Level VOCs					Low Level PAHs				
				OTR Number			Laboratory	OTR Number			Laboratory	ITR Number			Laboratory	SAS Number				Laboratory	SAS Number				Laboratory
		Date	Time	Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	Trip	MS		Sample	Rep	Trip	MS	
1A-04	88MW03S14	5/2/88	1130	EW503			S Cubed	EW503			S Cubed	MER926			RMAL										
	88MW03S51											MER927			RMAL										
2A-04	88MW03S13	5/10/88	1255	EW540			PEI	EW540		EW540	PEI	MER996		MER996	RMAL	3784E-93			3784E-93	S Cubed	3784E-96			3784E-96	Data Chem
	88MW03S33											MER997		MER997	RMAL										
	88MW03S20																	3784E-94		S Cubed					
	88MW03S21																	3784E-95		S Cubed					
2B-04	88MW03S10	5/10/88	0920	EW549			PEI	EW549		EW549	PEI	MEW312			RMAL	3784E-80				S Cubed	3784E-81				Data Chem
	88MW03D10				EW550		PEI						MEW314		RMAL										
	88MW03S29											MEW313			RMAL										
	88MW03S30												MEW315		RMAL										
	88MW03S18																	3784E-82		S Cubed			3784E-84		Data Chem
	88MW03S19																	3784E-83		S Cubed			3784E-85		Data Chem
	88MW03S10		1550											MEW312	RMAL										
	88MW03D10								EW556		PEI														
	88MW03S29													MEW313	RMAL										
2C-04	88MW03S43	5/4/88	1322	EW541			S Cubed	EW541			S Cubed	MER990			RMAL	3784E-54				S Cubed	3784E-55			3784E-55	Data Chem
	88MW03D43								EW542		S Cubed						3784E-56			S Cubed					
	88MW03S70											MER999			RMAL										
2D-04	88MW03S12	5/10/88	1100	EW553			PEI	EW553			PEI	MEW318			RMAL	3784E-89				S Cubed	3784E-90				Data Chem
	88MW03D12				EW554		PEI		EW554		PEI		MEW320		RMAL		3784E-91			S Cubed		3784E-92			Data Chem
	88MW03S31											MEW319			RMAL										
	88MW03S32												MEW321		RMAL										
2E-02	88MW03S04	5/5/88	1435	EW545			S Cubed	EW545			S Cubed	MEW304			RMAL	3784E-70				S Cubed	3784E-71				Data Chem
	88MW03S39											MEW305			RMAL										
3A-04	88MW03S25	5/3/88	1021	EW518			S Cubed	EW518			S Cubed	MER956			RMAL										
	88MW03S84											MER957			RMAL										
	88MW03S17																				3784E-19				Data Chem
	88MW03D17																					3784E-20			
3B-02	88MW03S24	5/3/88	0940	EW514			S Cubed	EW514			S Cubed	MER946			RMAL										
	88MW03D24												MER948		RMAL										
	88MW03S02											MER947			RMAL										
	88MW03S03												MER949		RMAL										
3S-02	88MW03S31	5/3/88	1232	EW520			S Cubed	EW520			S Cubed	MER960			RMAL						3784E-21				Data Chem
	88MW03S65											MER961			RMAL										
	88MW03R06																						3784E-22		Data Chem
	88MW03R07																						3784E-23		Data Chem

SAMPLE MATRIX FOR GROUNDWATER SAMPLES (STEP II)
(PAGE 2 OF 5)

ANALYSIS DURING SAMPLING

Well Number	CRL Sample Number	Collection		Routine HSL VOCs				Routine HSL BNAs				HSL Inorganics (1)				Low Level VOCs					Low Level PAHs				
				OTR Number			Laboratory	OTR Number			Laboratory	ITR Number			Laboratory	SAS Number				Laboratory	SAS Number				Laboratory
		Date	Time	Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	Trip	MS		Sample	Rep	Trip	MS	
B4b-04	8GWV03S11	5/10/88	1540	EW551			PEI	EW551			PEI	MEW316			RMAL	3784E-97				S Cubed	3784E-100				Data Chem
	8GWV03D11				EW552		PEI																		
	8GWV03S34											MEW317			RMAL										
	8GWV03S14																	3784E-98		S Cubed					
	8GWV03S15																	3784E-99		S Cubed					
5A-04	8GWV03S08	5/10/88	0933	EW548		EW548	PEI	EW548		EW548	PEI	MEW310		MEW310	RMAL	3784E-72				S Cubed	3784E-73				Data Chem
	8GWV03S22											MEW311		MEW311	RMAL										
5C-03	8GWV03S01	5/5/88	1017	EW543			S Cubed	EW543		EW543	S Cubed	MEW300			RMAL	3784E-59				S Cubed					
	8GWV03S35											MEW301			RMAL										
	8GWV03S05																				3784E-60				Data Chem
5B-02	8GWV03S09	5/10/88	1116	EW547		EW547	PEI	EW547			PEI	MEW308		MEW308	RMAL	3784E-74				S Cubed	3784E-75				Data Chem
	8GWV03S23											MEW309		MEW309	RMAL										
	8GWV03S16																	3784E-76		S Cubed			3784E-78		Data Chem
	8GWV03S17																	3784E-77		S Cubed			3784E-79		Data Chem
5E-02	8GWV03S02	5/3/88	1110	EW544			S Cubed	EW544			S Cubed	MEW302			RMAL	3784E-63				S Cubed	3784E-64				Data Chem
	8GWV03D02																					3784E-67			
	8GWV03S37											MEW303			RMAL										
	8GWV03S06																	3784E-65		S Cubed					
	8GWV03S07																	3784E-66		S Cubed					
6A-04	8GWV03S13	5/2/88	1400	EW504			S Cubed	EW504			S Cubed	MER928			RMAL										
	8GWV03S52											MER929			RMAL										
6C-04	8GWV03S16	5/2/88	1420	EW505			S Cubed	EW505			S Cubed	MER930			RMAL										
	8GWV03S53											MER931			RMAL										
7A-04	8GWV03S36	5/4/88	1135	EW534			S Cubed	EW534			S Cubed	MER984			RMAL										
	8GWV03D36				EW535		S Cubed						MER986		RMAL										
	8GWV03S71											MER985			RMAL										
	8GWV03S72												MER987		RMAL										
7B-03	8GWV03S03	5/3/88	1134	EW537			S Cubed	EW537			S Cubed	MER990			RMAL	3784E-68				S Cubed	3784E-69			3784E-69	Data Chem
	8GWV03S38											MER991			RMAL										
7C-03	8GWV03S37	5/4/88	1507	EW539			S Cubed	EW539			S Cubed	MER994			RMAL	3784E-50				S Cubed					
	8GWV03S73											MER995			RMAL										
	8GWV03S48																				3784E-51				Data Chem
	8GWV03S49																						3784E-52		Data Chem
	8GWV03S50																						3784E-53		Data Chem
7S-02	8GWV03S35	5/4/88	1000	EW533			S Cubed	EW533			S Cubed	MER982			RMAL	3784E-45				S Cubed					

SAMPLE MATRIX FOR GROUNDWATER
SAMPLES (STEP II)
(PAGE 3 OF 5)

ANALYSIS DURING SAMPLING

Well Number	CRL Sample Number	Collection		Routine HSL VOCs				Routine HSL BNAs				HSL Inorganics (1)				Low Level VOCs					Low Level PAHs				
		Date	Time	DTR Number Sample	Rep	MS	Laboratory	DTR Number Sample	Rep	MS	Laboratory	ITR Number Sample	Rep	MS	Laboratory	SAS Number Sample	Rep	Trip	MS	Laboratory	SAS Number Sample	Rep	Trip	MS	Laboratory
	88HV03S70											NER903			RNAL										
	88HV03S47																				37B4E-46				Data Chem
8A-04	88HV03S21	5/2/88	1715	EW510			S Cubed	EW510			S Cubed	NER938			RNAL										
	88HV03S58											NER939			RNAL										
8B-02	88HV03S19	5/2/88	1637	EW509			S Cubed	EW509			S Cubed	NER936			RNAL										
	88HV03S56											NER937			RNAL										
9A-03	88HV03S39	5/4/88	0822	EW528			S Cubed	EW528			S Cubed	NER972			RNAL										
	88HV03S73											NER973			RNAL										
9B-03	88HV03S33	5/3/88	1620	EW529			S Cubed	EW529			S Cubed	NER974			RNAL										
	88HV03S67											NER975			RNAL										
10A-03	88HV03S28	5/3/88	0925	EW515		EW515	S Cubed	EW515			S Cubed	NER950			RNAL										
	88HV03S62											NER951			RNAL										
10B-03	88HV03S30	5/3/88	1007	EW517			S Cubed	EW517			S Cubed	NER954			RNAL										
	88HV03S64											NER955			RNAL										
11A-04	88HV03S22	5/3/88	0809	EW512			S Cubed	EW512			S Cubed	NER942			RNAL										
	88HV03S80											NER943			RNAL										
12A-04	88HV03S23	5/3/88	0849	EW513			S Cubed	EW513			S Cubed	NER944			RNAL										
	88HV03S81											NER945			RNAL										
13A-04	88HV03S17	5/2/88	1510	EW506			S Cubed	EW506			S Cubed	NER932			RNAL										
	88HV03S54											NER933			RNAL										
13B-02	88HV03S20	5/2/88	1645	EW511			S Cubed	EW511			S Cubed	NER940			RNAL										
	88HV03S57											NER941			RNAL										
13E-02	88HV03S18	5/2/88	1537	EW507			S Cubed	EW507			S Cubed	NER934			RNAL										
	88HV03D18				EW508		S Cubed																		
	88HV03S35											NER935			RNAL										
14A-04	88HV03S27	5/3/88	1605	EW526			S Cubed	EW526			S Cubed	NER970			RNAL	37B4E-32			37B4E-32	S Cubed	37B4E-33				Data Chem
	88HV03D27				EW527		S Cubed				S Cubed														
	88HV03S61											NER971			RNAL										
14B-04	88HV03S38	5/4/88	1615	EW525		EW525	S Cubed	EW525			S Cubed	NER968			RNAL	37B4E-57				S Cubed	37B4E-58				Data Chem
	88HV03S74											NER969			RNAL										
	88HV03S39																								

SAMPLE MATRIX FOR GROUNDWATER
SAMPLES (STEP II)
(PAGE 4 OF 5)

ANALYSIS DURING SAMPLING

Well Number	CRL Sample Number	Collection		Routine HSL VOCs				Routine HSL BNAs				HSL Inorganics (1)				Low Level VOCs					Low Level PAHs				
				OTR Number			Laboratory	OTR Number			Laboratory	ITR Number			Laboratory	SAS Number				Laboratory	SAS Number				Laboratory
		Date	Time	Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	Trip	MS		Sample	Rep	Trip	MS	
14C-03	88NV03S34	5/4/88	0900	EW523			S Cubed	EW523			S Cubed	MER966			RMAL	3784E-37				S Cubed	3784E-38				Data Chem
	88NV03D34								EW524		S Cubed						3784E-39			S Cubed					
	88NV03S69											MER967			RMAL										
	88NV03R08																					3784E-40			Data Chem
	88NV03R09																					3784E-41			Data Chem
14S-02	88NV03S26	5/3/88	1515	EW522			S Cubed	EW522			S Cubed	MER964			RMAL	3784E-28				S Cubed	3784E-29				Data Chem
	88NV03S60											MER965			RMAL										
	88NV03R04																	3784E-30		S Cubed					
	88NV03R05																	3784E-31		S Cubed					
15A-03	88NV03S41	5/4/88	1130	EW536			S Cubed	EW536			S Cubed	MER988			RMAL	3784E-47			3784E-47	S Cubed	3784E-48			3784E-48	Data Chem
	88NV03S77											MER989			RMAL										
15B-03	88NV03S42	5/4/88	1410	EW538			S Cubed	EW538			S Cubed	MER992			RMAL	3784E-49				S Cubed	3784E-56			3784E-56	Data Chem
	88NV03S79											MER993			RMAL										
16S-02	88NV03S29	5/3/88	0815	EW516			S Cubed	EW516			S Cubed	MER952			RMAL										
	88NV03S63											MER953			RMAL										
	88NV03S44															3784E-24				S Cubed					
	88NV03D44																3784E-25			S Cubed					
17B-02	88NV03S40	5/4/88	0955	EW532			S Cubed	EW532			S Cubed	MER980			RMAL	3784E-42				S Cubed	3784E-43				Data Chem
	88NV03D40																					3784E-44			
	88NV03S76											MER981			RMAL										
17E-02	88NV03S32	5/3/88	1315	EW521			S Cubed	EW521			S Cubed	MER962			RMAL										
	88NV03S66											MER963			RMAL										
	88NV03S45															3784E-26				S Cubed	3784E-27				Data Chem
Field Blanks																									
FB07200	88NV03R02	5/3/88	1210	EW519			S Cubed	EW519			S Cubed	MER958			RMAL	3784E-17				S Cubed	3784E-18				Data Chem
	88NV03S59											MER959			RMAL										
FB07300	88NV03R03	5/4/88	0754	EW530			S Cubed	EW530			S Cubed	MER976			RMAL	3784E-34				S Cubed	3784E-35				Data Chem
	88NV03S68											MER977			RMAL										
FB07400	88NV03S46	5/4/88	0754													3784E-36				S Cubed					
FB07500	88NV03R01	5/5/88	1058	EW546			S Cubed	EW546			S Cubed	MEN306			RMAL	3784E-61				S Cubed	3784E-62				Data Chem
	88NV03S36											MEN307			RMAL										
FB07600	88NV03R12	5/10/88	1000	EW555			PEI	EW555			PEI	MER322			RMAL										

SAMPLE MATRIX FOR GROUNDWATER
SAMPLES (STEP II)
(PAGE 5 OF 5)

ANALYSIS DURING SAMPLING

Well Number	CRL Sample Number	Collection		Routine HSL VOCs				Routine HSL BNAs				HSL Inorganics (1)				Low Level VOCs					Low Level PAHs				
				QTR Number			Laboratory	QTR Number			Laboratory	ITR Number			Laboratory	SAS Number				Laboratory	SAS Number				Laboratory
		Date	Time	Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	Trip	MS		Sample	Rep	Trip	MS	
	88MW03S24											MER323			RMAL										
	88MW03R02															3784E-86				S Cubed	3784E-87				Data Chem
FB87700	88MW03R03	5/10/88	1015													3784E-88				S Cubed					

(1) Inorganics includes unfiltered and filtered metals, and cyanide.
ITR numbers for the unfiltererd metals are listed first, followed by the
ITR's for the filtered metals and the cyanide.

CH2M HILL

TECHNICAL MEMORANDUM NO. 11

TO: Fred Bartman/U.S. EPA
Remedial Project Manager

FROM: Randy Videkovich/CH2M HILL
Project Manager

PREPARED BY: John Gannon/CH2M HILL

DATE: May 24, 1988

RE: Subsurface Soil Sampling
(Step II)

PROJECT: Arrowhead Refinery
Fieldwork Design Investigation
GLO68802.FS

INTRODUCTION

Subsurface soil samples were collected from 10 locations at the Arrowhead Refinery site between May 16 and 19, 1988. The objective of sampling was to define the lateral and vertical extent of soil contamination south of the sludge lagoon in and around the process area. The results of this task will be used to refine the volume of contaminated soil to be removed for remediation of the site.

SAMPLING LOCATIONS

The soil borings were completed in and around the process area, which was identified by previous investigations as containing the most contaminated soil. Boring locations were initially staked out by Jewelle Imada (CH2M HILL) and Dave Chrisman (MPCA). Sampling locations are shown in Figure TM11-1.

The subsurface soil samples for analytical analyses were collected at three depths. Samples analyzed for incineration parameters were collected from the visibly contaminated soil. RAS samples were taken of the first visibly noncontaminated soil and again 5 feet lower.

PERSONNEL

The sampling team consisted of:

- Roger Huddleston/CH2M HILL, Level B, C, and D Site Safety Supervisor
- John Gannon/CH2M HILL
- Greg Weeks/Engineers International
- Cathy Kantowski/Engineers International

The sampling team maintained sample custody. Drilling was subcontracted to Exploration Technology Incorporated.

FIELD METHODS

Soil borings were advanced using an all-terrain Diedrich D.50 drill rig. The borings were advanced using 4.25-inch I.D. hollow-stem augers. Continuous subsurface soil samples were obtained with 3-inch O.D. split spoons advanced using a 140-pound hammer. When the drill rod on the hammer broke at boring SO87-14, a 300-pound hammer was used to complete that boring and borings SO87-06 and SO87-17. After each split spoon was opened, each sample was screened with an OVA or an HNu and the soil was logged. Samples were placed directly into sample jars using a stainless steel spatula.

Subsurface soil boring logs are provided in Attachment A. Table TM11-1 is a summary of the subsurface soil sampling. Table TM11-2 lists the samples collected and sent to a CLP laboratory for analysis. The subsurface soil samples were analyzed for TCL inorganic chemicals and volatile and semivolatile organic compounds. Selected samples were also analyzed for low level PAHs, incineration parameters, and total organic carbon.

HEALTH AND SAFETY

During previous investigations at the Arrowhead Refinery site, drilling activities were terminated in the process area when monitoring of ambient air indicated Level B protection was required to continue the borings. As a result, Level B safety protection was used during this field effort at all of the soil borings except SO87-23. Soil boring SO87-23 was south of the process area and was advanced in Level D safety protection. Continuous monitoring during drilling at this boring indicated higher levels of safety protection were unnecessary.

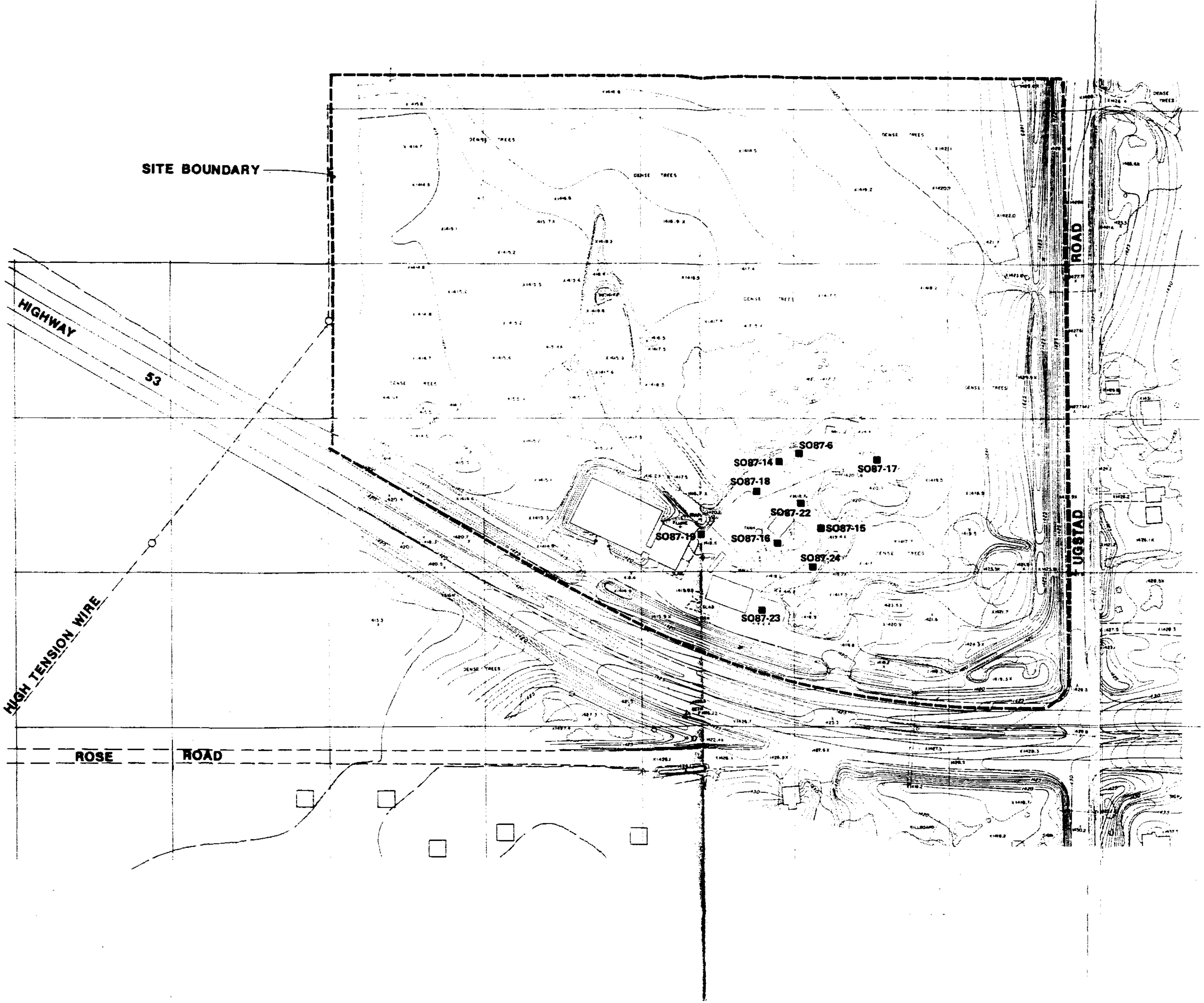


FIGURE TM11-1
SUBSURFACE SOIL SAMPLING LOCATIONS (STEP II)
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Appendix B
ANALYTICAL DATA AND QUALITY ASSURANCE/ QUALITY CONTROL EVALUATION OF LABORATORY DATA

Table TM11-1 (Page 1 of 2)
SUMMARY OF SUBSURFACE SOIL SAMPLING

Boring No.	Sample No.	Layer Sampled	Analyses[a]	Depth (ft bgs)	OVA Readings		Comments and Observations
					Air (ppm)	Sample (ppm)	
SO87-06	01	Fill	Inc.	2-4	Background	50-150	Sample was black and oily.
	02	Silty Sand	Complete	12-14	Background	1.0	
	03	Silty Sand	Organic, Inorganic, L.L. PAH	18-20	Background	Background	
SO87-14	01	Peat	Inc., TOC	2.5-4.5	Background	40	Sample was black and oily.
	02	Sand/Silt Silty Sand	Organic, Inorganic	6.5-8.0	Background	2	
	03		Organic, Inorganic	12-14	Background	Background	
SO87-15	01	Silt/Peat	Inc., TOC	0-2	20-40	150	
	02	Peat/Clay	Complete	8-10	Background	5	
	03	Sand/Gravel	Organic, Inorganic, L.L. PAH	14-16	2-3	1.0	
SO87-16	01	Fill	Inc., TOC	0-2	Background	10	
	02	Sand/Gravel	Organic, Inorganic, L.L. PAH	15-17	Background	2-3	
	03	Sand/Silt	Organic, Inorganic, L.L. PAH	21-23	Background	2	
SO87-17	01	Peat	Inc., TOC	4-6	Background	1-5	
	02	Silt	Organic, Inorganic, L.L. PAH	8-10	Background	Background	
	03	Sand	Organic, Inorganic, L.L. PAH	14-16	Background	Background	
SO87-18	01	Fill	Inc., TOC	2-4	Background	>100	Sample taken adjacent to original borehole.
	02	Silt	Organic, Inorganic, L.L. PAH	6-8	Background	5	
	03	Silt/Gravel	Organic, Inorganic, L.L. PAH	12-14	Background	Background	

Table TM11-1 (Page 2 of 2)

Boring No.	Sample No.	Layer Sampled	Analyses[a]	Depth (ft bgs)	OVA Readings Air (ppm)	OVA Readings Sample (ppm)	Comments and Observations
SO87-19	01	Fill	Inc., TOC	0-2	Background	10-20	
	02	Sand/Gravel	Organic, Inorganic, L.L. PAH	10-12	3-4	10-20	
	03	Sand	Organic, Inorganic, L.L. PAH	14-16	Background	Background	
SO87-22	01	Fill/Peat	Inc., TOC	2-4	Background	50	Bullet cartridge found in sample.
	02	Peat/Clay	Organic, Inorganic, L.L. PAH	6-8	2-3	20	
	03	Silt	Organic, Inorganic, L.L. PAH	12-14	Background	1	
SO87-23	01	Fill	Inc., TOC	1-3	Background	Background	
	02	Fill	Organic, Inorganic, L.L. PAH	3-5	0.2	10	
	03	Sand	Organic, Inorganic	9-11	Background	6	
SO87-24	01	Fill	Inc., TOC	0-2	Background	4	
	02	Peat/Clay	Organic, Inorganic, L.L. PAH	4-6	10-20	400	
	03	Silt	Organic, Inorganic	10-12	Background	1-2	

L.L. PAH = Low level polyaromatic hydrocarbons.

Inc. = Incineration parameters. Incineration parameters include ash content, heating value, carbon, oxygen, hydrogen, sulfur, nitrogen, and percent moisture.

TOC = Total Organic Carbon.

Complete = Incineration parameters, TOC, organic, inorganic, and L.L. PAH.

SAMPLE MATRIX FOR SLUDGE SAMPLING

ANALYSIS DURING SAMPLING

Sample Location	Sample Number	CRL Sample Number	Collection		VOCs				BNAs				Metals(1)				Incinerator Parameters (2)				Viscosity(3)			Comments
			Date	Time	OTR Numbers			Laboratory	OTR Numbers			Laboratory	ITR Numbers			Laboratory	SAS Numbers			Laboratory	SAS Numbers		Laboratory	
					Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS		Sample	Rep	MS(4)		Sample	Rep		
CR87-101	01	88HV03S01	4/27/88	0825	ES595			S Cubed	ES595			S Cubed	MER907			JTC	3784E-01			Versar	3784E-01		Versar	Liquid Oily Sludge
	03	88HV03S02	4/27/88	0835	ES597			S Cubed	ES597			S Cubed	MER909			JTC	3784E-02			Versar				Peat
CR87-102	01	88HV03S03	4/27/88	0920	ES598		ES598	S Cubed	ES598		ES598	S Cubed	MER910		MER910	JTC	3784E-03		3784E-03	Versar	3784E-03		Versar	Liquid Oily Sludge
	03	88HV03S04	4/27/88	0930									MER912		MER912	JTC								Peat
		88HV03S05			ES600		ES600	S Cubed	ES600		ES600	S Cubed					3784E-04		3784E-04	Versar				
CR87-103	01	88HV03S05	4/27/88	1105									MER913			JTC								Liquid Oily Sludge
		88HV03S04			ES601			S Cubed	ES601			S Cubed					3784E-05			Versar	3784E-05		Versar	
	02	88HV03S06	4/27/88	1109	ES602		ES602	S Cubed	ES602		ES602	S Cubed	MER914		MER914	JTC	3784E-06		3784E-06	Versar				Crusty Sludge/Filter Cake
		88HV03D06				ES501		S Cubed		ES501		S Cubed		MER924		JTC		3784E-07A		Versar				
	03	88HV03S07	4/27/88	1114	ES603			S Cubed	ES603			S Cubed	MER915			JTC	3784E-07B			Versar				Peat
		88HV03D07				ES611		S Cubed		ES611		S Cubed		MER923		JTC		3784E-08		Versar				
CR87-104	01	88HV03S08	4/27/88	1133	ES604			S Cubed	ES604			S Cubed	MER916			JTC	3784E-09			Versar	3784E-09		Versar	Liquid Oily Sludge
		88HV03D08				ES610		S Cubed		ES610		S Cubed		MER922		JTC		3784E-10		Versar		3784E-10	Versar	
	02	88HV03S10	4/27/88	1136	ES605			S Cubed	ES605			S Cubed	MER917			JTC	3784E-12			Versar				Crusty Sludge/Filter Cake
	03	88HV03S09	4/27/88	1143	ES606			S Cubed	ES606			S Cubed	MER918			JTC	3784E-11			Versar				Peat
CR87-105	01	88HV03S11	4/27/88	1455	ES607			S Cubed	ES607			S Cubed	MER919			JTC	3784E-14			Versar	3784E-14		Versar	Liquid Oily Sludge
	02	88HV03S12	4/27/88	1450	ES608			S Cubed	ES608			S Cubed	MER920			JTC	3784E-15			Versar				Crusty Sludge/Filter Cake
	03	88HV03S13	4/27/88	1502	ES609			S Cubed	ES609			S Cubed	MER921			JTC	3784E-16			Versar				Peat

Field Blank

FB87-100		88HV03R01	4/27/88	1515	ES502			S Cubed	ES502			S Cubed	MER925			JTC	3784E-13			Versar				

(1) HSL inorganics excludes cyanides, sulfides, pH, and specific conductance
(2) Incinerator Parameters includes sulfur, chlorine, moisture content
ash content, heating value (BTu)
(4) No MS and field blank for moisture, ash, and BTu

TM12--SLUDGE SAMPLING

Attachment A
SAMPLE MATRIX FOR SLUDGE SAMPLES

PERSONNEL PROTECTION HEALTH AND SAFETY

The level of protection established in the project Site Safety Plan was followed. Level C protection was adhered to inside the perimeter of the lagoon until HNu monitoring indicated that downgrading to Level D protection would be appropriate. Level B protection was worn when boring into the lagoon, during sampling, and until all sampling equipment had been removed from the lagoon.

SAMPLE CONTAINER AND PERSONNEL GEAR DECONTAMINATION

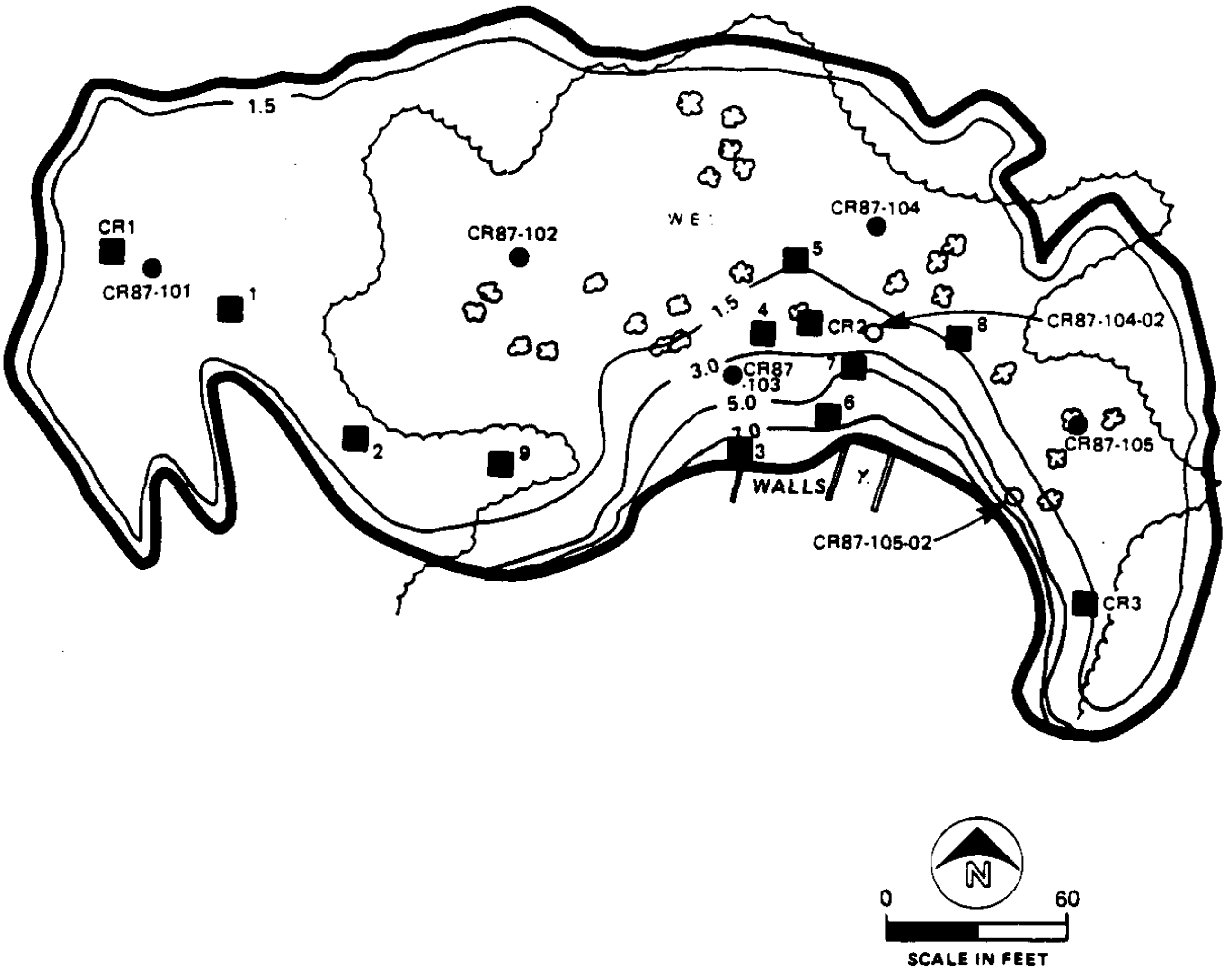
The sample jars were protected from contamination during sampling by enveloping them in latex during sampling operations. After sampling, the latex was removed and the exteriors of the sealed bottles were decontaminated with methanol and distilled water.

Personal gear was washed in a tub half filled with a solution of trisodium phosphate (1 pound per 10 gallons of clean water) and then rinsed in a tub of clean water. All wash and rinse water was disposed of in the sludge lagoon.

SAMPLING EQUIPMENT DECONTAMINATION

Sampling equipment that was to be reused was washed with reagent grade methanol to remove tar deposits after the first sample had been taken. The methanol was first absorbed in a cloth and wiped on the tar areas with no success. Next, a brush was used but with similar results. Thereafter, the trowels were decontaminated as well as possible before reuse.

GLT932/035.51



LEGEND

▬ LAGOON BOUNDARY

—1.5— APPROXIMATE SLUDGE THICKNESS (FEET)

■ RI SLUDGE SAMPLING LOCATIONS

● FDI SLUDGE SAMPLING LOCATIONS

○ FDI SLUDGE SAMPLING LOCATIONS FOR CRUSTY SLUDGE/FILTER CAKE ONLY

〰 TREE LINE

FIGURE TM 12-1
SLUDGE SAMPLING LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table TM12-1
IN-FIELD SAMPLE PARAMETERS

Sample Number	Stratum	Thickness (ft)	Density (lb/ft^3)	pH
CR87-101-01	Sludge	0.7	NR	<0.5
CR87-101-03	Peat	ND	71	<0.5
CR87-102-01	Sludge	1.3	1.3	0.5
CR87-102-03	Peat	ND	90	<0.5
CR87-103-01	Sludge	0.5	NR	<0.5
CR87-103-02	Filter Cake	1.1	90	0.5
CR87-103-03	Peat	ND	90	<0.5
CR87-104-01	Sludge	1.1	NR	<0.5
CR87-104-02	Filter Cake	0.4	77	0.5
CR87-104-03	Peat	ND	86	0.5
CR87-105-01	Sludge	1.2	NR	<0.5
CR87-105-02	filter Cake	0.5	86	0.5
CR87-105-03	Peat	ND	94	<0.5

ND = Thickness of the peat was not determined
NR = Density of the sludge was not required.

TECHNICAL MEMORANDUM NO. 12

TO:	Fred Bartman/U.S. EPA Remedial Project Manager
FROM:	Randy Videkovich/CH2M HILL Project Manager
PREPARED BY:	Jeffrey J. Lamont/CH2M HILL
DATE:	May 24, 1988
RE:	Sludge Sampling
PROJECT:	Arrowhead Refinery Material Handling/Thermal Treatment Design Investigation GLO68803.F3

INTRODUCTION

Sludge samples were taken from the sludge lagoon to refine the nature and extent of contamination and to define the range and variability of the handling and thermal treatment properties of the materials in the lagoon.

Sludge samples were collected on April 27, 1988, from five locations in the sludge lagoon and submitted to the U.S. EPA CLP for analysis. All samples were analyzed for TCL VOCs, metals, semivolatile organic compounds, moisture content, ash content, chlorine content, sulfur content, and Btu value. The oily sludge was also analyzed for viscosity, and the filter cake and peat were analyzed for density in the field. All samples were analyzed for pH in the field using litmus paper. Attachment A is a sample matrix table.

PERSONNEL

The sample team consisted of:

- Jewelle Imada/CH2M HILL
- Jeffrey Lamont/CH2M HILL
- Roger Huddleston/CH2M HILL
- Gregg Weeks/Engineers International

Sample custody and equipment decontamination was maintained by the sampling team. CLP paperwork was maintained by Cathy Kantowski (Engineers International).

SAMPLING LOCATIONS

Samples were obtained from five locations (Figure TM12-1), with the actual number of samples being dependent upon the conditions encountered at each location. Samples of filter cake, liquid sludge, and peat were collected at each location if they were present. To gain access to the sampling locations wooden pallets were laid out end to end from the perimeter of the lagoon. Table TM12-1 summarizes sample parameters measured in the field.

SLUDGE SAMPLING PROCEDURES AND OBSERVATIONS

Samples were taken from the filter cake layer using a stainless steel trowel. Only the solid or semisolid portion of the top layer was collected. Filter cake was available only near the perimeter of the sludge lagoon at sampling locations CR87-103, CR87-104, and CR87-105. The filter cake layer was 0.4 to 1.1 feet thick, and the filter cake itself had a fine texture and was generally hard and dry. All three samples were field tested for pH, which was 0.5. The samples were also field tested for density using the Corps of Engineers Surface Soil Sampler (ASTM D 2937).

Samples of the liquid oily sludge were taken using a stainless steel trowel. This stratum was encountered at all five sampling locations and was 0.5 to 1.3 feet thick. The pH was less than 0.5 with the exception of CR87-102, which was 0.5. The viscosity of this stratum varied slightly, but in general was quite viscous. Water was observed in pockets throughout the liquid sludge and as a discrete layer immediately above the sludge at locations CR87-102 and CR87-104 and also immediately below the sludge at locations CR87-101, CR87-103, and CR87-104. The water content of the sludge varied considerably between sampling locations. As much water as possible was decanted from the samples before they were placed in sample jars.

Samples were taken from the peat layer using a stainless steel trowel. Peat was encountered at all sampling locations. Depending on the viscosity of the overlying sludge, either a spade was used to remove the sludge or a plastic pail with the bottom cut out was placed tightly against the peat and the excess sludge was removed to allow sampling of the peat. All five peat samples were field tested for pH, which was less than 0.5 for all samples except CR87-104, which was 0.5. These samples were also field tested for density. In all cases, the peat layer was saturated with the oily sludge. Some of the peat samples appeared more or less fibrous than others, and sample CR87-103 had a grainy texture.

Replicate and matrix spike samples were collected by filling a complete set of sample containers immediately after filling the first set with the same sampling equipment. Blanks were made by filling sample containers with clean sand.

CH2M HILL

PROJECT NUMBER	BORING NUMBER	SHEET
620.68802.FS	SB87-24	1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ________ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50

WATER LEVEL AND DATE 3.0' START 5/17/88 FINISH 5/17/88 930 LOGGER Jim Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
900	0 1'	0-2'	S.S SB24 -01	8"	13-19-25 -23 (44)	Poorly Sorted Sandy Gravel, brown, moist, loose, gravel 1-2" maximum diameter, some silt (Fill)	(GP)	Start @ 900 OVA ≈ 4 ppm Sample, Air ≈ Bkg Visibly contaminated
	2' 3'	2-4'	S.S.	7"	3-4-5-9 (9)	Peat, brown, loose, some wood chunks 1-2", wet (black layer)	(Pt)	OVA ≈ 500 ppm Visually contaminated W.T. ≈ 3.0'
907	4' 5'	4-6'	S.S. SB24 -02	18"	1-2-4-5 (9)	0-16" Peat, brown, wet 16-18" Silty Clay, grey, wet, stiff	(Pt) (CL-ML)	OVA ≈ 400 ppm Sample, Air ≈ 10-30 ppm Visually contaminated in Peat only
	6' 7'	6-8'	S.S.	12"	9-12-13-11 (25)	Clayey Silt, grey with some brown streaks, wet, stiff	(ML CL)	OVA ≈ 3-4 ppm Visually non-contaminated
	8' 9'	8-10'	S.S.	12"	10-11-12-11 (23)	Silty Clay, brown, wet, stiff	(CL-ML)	OVA ≈ 6 ppm Visually non-contaminated
928	10' 11'	10-12'	S.S. SB24 -03	18"	3-12-17-19 (29)	Clayey Silt, Brown, wet, stiff	(ML CL)	OVA ≈ 1-3 ppm Sample, Air ≈ Bkg Visually non-contaminated
	12'					EOB 12'		

CH2M HILL

PROJECT NUMBER 660.68802.FS
BORING NUMBER 5087-23
SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE
LOCATION HERMANTOWN, MINNESOTA
ELEVATION
DRILLING CONTRACTOR ETI
DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50
WATER LEVEL AND DATE ≈3.5'
START 5/17/88
FINISH 5/17/88 745
LOGGER J.M. Hanna

	ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
			INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
		0 1'							Start @ 705 Skipped 0-1' because of concrete
713		2' 3'	1-3'	S.S. 5023-01	6"	8-5-3-4 (8)	Poorly Sorted Clayey Sand, brown, black layer near surface, moist, loose, some roots (Fill)	(SP)	OVA ≈ Bkg for both Sample and Air Some Contamination visible
717		4' 5'	3-5'	S.S. 5023-02	12"	7-6-7-6 (13)	Poorly Sorted Clayey Sand, Brown, moist, loose, some roots, trace of gravel (Fill)	(SP)	OVA ≈ 10 ppm Sample, Air ≈ 0.2 ppm WT ≈ 3.5' Visibly not contaminated
		6' 7'	5-7'	S.S.	10"	3-5-11-18 (16)	Poorly Sorted Silty Sand, brown, wet, dense, trace clay, trace gravel Fill	(SP)	Not Visibly contaminated OVA ≈ 5-10 ppm
		8' 9'	7-9'	S.S.	18"	14-16-42-32 (58)	Sandy Silt, brown, wet, trace clay and gravel, very stiff	(ML)	Not Visibly contaminated OVA ≈ 5-10 ppm
740		10' 11	9-11	S.S. 5023-03	18"	7-10-16-19 (26)	Poorly Sorted Silty Sand, Greyish-brown, wet, trace clay	(SP)	Not Visibly Contaminated OVA ≈ 6 ppm Sample, Air ≈ Bkg
							EOB 11'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER 6LO.68802.FS
BORING NUMBER S087-22
SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA
ELEVATION ______ DRILLING CONTRACTOR ETI
DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D50
WATER LEVEL AND DATE 1.5' START 5/18/88 FINISH 5/18/88 (11:30) LOGGER J. M. Grannis

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0 1'	0-2'				No Split Spoon sample Taken		Start @ 1045 W.T ≈ 1.5'
1047	2' 3'	2-4'	S.S. S022-01	6"	5-4-5-4 (9)	0-2" Poorly Sorted Gravel, black, moist, loose (Fill) 2-6" Peat, black, wet	(GP) (Pt)	OVA ≈ 50 ppm Sample, Air ≈ BKG Visibly contaminated bullet cartridge was found in sample
	4' 5'	4-6'	S.S.	8"	2-3-3-2 (6)	Peat, black to brown, wet, wood pieces 3" in size	(Pt)	OVA ≈ 40 ppm Visibly contaminated
1056	6' 7'	6-8'	S022-02 S.S.	12"	3-3-7-4	0-6" Peat, black to brown, wet 6-12" Lean Clay, Grey, wet, soft	(Pt) (CL)	OVA ≈ 200ppm Sample, Air ≈ 2-3 ppm Visibly contaminated in Peat only; not in clay
	8' 9'	8-10'	S.S.	10"	24-18-11-7 (29)	Sandy Silt, brown, wet, stiff	(ML)	OVA ≈ 2-3 ppm Visibly non-contaminated
	10' 11'	10-12'	S.S.	13"	7-12-14-22 (31)	Sandy Silt, brown, wet, stiff, trace clay, some gravel (subangular, maximum diameter 3/4")	(ML)	OVA ≈ 2-3 ppm Visibly non-contaminated
1122	12' 13'	12-14'	S.S. S022-03	24"	11-27-42-41 (69)	Sandy Silt, brown, wet, very stiff, some gravel, gravel is subangular - rounded (maximum diameter 1-2")	(ML)	OVA ≈ 1 ppm Sample, Air ≈ BKG Visibly non-contaminated
	14'					EOB 14'		

CH2M HILL

PROJECT NUMBER G10.68802.FS

BORING NUMBER 5087-19 SHEET 1 OF 2

SOIL BORING LOG

PROJECT Arrowhead Refinery Site LOCATION Hermantown, Minnesota

ELEVATION DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT SA (6" O.D.), Diedrich D.50

WATER LEVEL AND DATE W.T. ≈ 1.5' START 5/16/88 FINISH 5/16/88 1528 LOGGER J.M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
1401	0 1' 2'	0-2'	S.S. 5019-01	12"	12-23-30-28 (53)	Silty Sand with Gravel, (Pebbles 1" in diameter, rounded) brown to black, dense, moist (Fill)	(SP)	Start @ 1400 OVA ≈ 10-20 ppm Sample Air ≈ BKG W.T. ≈ 1.5' Visually contaminated
	3' 4'	2-4'	S.S.	10"	12-24-27-23 (51)	Silty sand with Gravel, (Pebbles 1-1.5" in diameter, rounded), brown-black, wet (Fill)	(SP)	OVA ≈ 20 ppm Visually contaminated
	5' 6'	4-6'	S.S.	6"	4-12-88-60 (100)	Silty Sand with Gravel, brown to black, wet, dense (Fill)	(SP)	OVA ≈ 10-20 ppm Visually contaminated
	7' 8'	6-8'	S.S.	10"	4-8-16-20 (24)	Sandy Silt, brown, wet, Sand is medium grained, trace gravel (Outwash)	(ML)	OVA reading ≈ 1.5 ppm Visually contaminated
	9' 10'	8-10'	S.S.	8"	12-17-22-18 (39)	Poorly Sorted Gravel with Sand, brown, wet, loose, trace silt, gravel (1-3" in diameter)	(GP)	OVA ≈ 5 ppm Visually contaminated
1447	11' 12'	10-12'	S.S. 5019-02	8"	12-26-21-20 (47)	Poorly Sorted Silty Sand with Gravel, brown, wet, dense, gravel ½"-2" in diameter. (Outwash)	(SP)	OVA ≈ 10-20 ppm Sample, Air ≈ 3-4 ppm Visually non-contaminated
	13' 14'	12-14'	S.S.	24"	18-27-20-22 (47)	Poorly Sorted Gravel with sand, brown, wet, dense, gravel 1-2" in diameter (Appears to be [illegible])	(GP)	OVA ≈ BKG Visually non-contaminated

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER GLO 68802.FS

BORING NUMBER 5087-19

SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE

LOCATION HERMANTOWN, MINNESOTA

ELEVATION

DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50

WATER LEVEL AND DATE ≃ 15'

START 5/16/88

FINISH 5/16/88

LOGGER Jim [illegible]

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
1528	14' 15' 16'	14-16'	S.S. 5019-03	16"	18-25-26-27 (51)	well Sorted Silty Sand, greyish-brown, wet, dense, sand is fine grained	(SW)	OVA ≅ Bkg For Both Sample and Air Visually non-contaminated

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER GLO.68402.FS

BORING NUMBER S087-18

SHEET 1 OF 1

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE

LOCATION HERMANTOWN, MINNESOTA

ELEVATION

DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D50

WATER LEVEL AND DATE 1'

START 5/18/88

FINISH 5/18/88

LOGGER J.M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0 1'	0-2'				No Split Spoon Taken		start @ 1415 W.T. ≃ 1'
1503	2' 3'	2-4'	S.S. S018-01	8"	4-2-3-2 (5)	Poorly Sorted Silty Gravel, black, some sand, wet, loose (Fill)	(GP)	OVA ≃>100 ppm Sample Air ≈ Bkg Visibly Contaminated Split spoon from 1' north of original boring
	4' 5'	4-6'	S.S.	6"	4-2-5-2 (7)	0-2" Peat, brown 2-6" Poorly Sorted Silty Sand, brown, wet, loose, some peat	(Pt) (SP)	OVA ≃ 5 ppm Visibly contaminated
1425	6' 7'	6-8'	S.S. S018-02	14"	7-10-9-18 (19)	Sandy Silt, grey, wet, soft	(ML)	OVA ≃ 5 ppm Sample Air ≈ Bkg Visibly non-contaminated
	8' 9'	8-10'	S.S.	18"	7-12-13-15 (25)	Clayey Silt, grey, wet, stiff	ML CL	OVA ≃ 2-3 ppm Visibly non-contaminated
	10' 11'	10-12'	S.S.	14"	15-25-20-19 (45)	0-4" Clayey Silt, grey, wet, stiff 4-14" Poorly Sorted Silty Gravel, brown, wet, loose	(ML) (GP)	OVA ≃ 2-3 ppm Visibly non-contaminated
1452	12' 13'	12-14'	S.S. S018-03	24"	13-15-25-36 (40)	Interlayered Silt (20%) and Poorly Sorted gravels 80%, brown wet, gravel is subangular, silt is stiff	ML GP	OVA ≃ Bkg For Sample and Air Visibly non-Contaminated
	14'					EOB 14'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER GLO. 68802. FS

BORING NUMBER S087-17

SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN MINNESOTA

ELEVATION

DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50, 300 lb Hammer

WATER LEVEL AND DATE 1.5'

START 5/19/88

FINISH 5/19/88 (1520)

LOGGER J. M. Cannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY. PARTICLE SIZE DISTRIBUTION. COLOR. MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY. SOIL STRUCTURE. MINERALOGY. USCS GROUP SYMBOL		DEPTH OF CASING. DRILLING RATE. DRILLING FLUID LOSS. TESTS AND INSTRUMENTATION
	0 1'	0-2'	S.S	8"	2-3-13-15 (16)	Clayey Silt, brown and black, moist, soft, some gravel (maximum diameter 1") (FILL)	ML	Start @ 1435 OVA ≈ 1-5 ppm Sample Visibly contaminated W.T. ≈ 1.5'
	2' 3'	2-4'	S.S.	2"	2-1-2-1 (3)	Clayey Silt, brown, wet, soft (FILL)	ML	OVA ≈ 1 ppm Visibly contaminated
1440	4' 5'	4-6'	S.S. SO-17-01	8"	2-3-1-2 (4)	Peat, brown to black, wet, some wood chunks	(Pt)	OVA ≈ 1 ppm-5 ppm Sample, Air ≈ BKG Visibly contaminated
	6' 7'	6-8'	S.S	8"	2-8-8-7 (16)	Poorly sorted Silty Sand, brown, wet, soft	(SP)	OVA ≈ 1 ppm Visibly contaminated
1454	8' 9'	8-10'	S.S. SO-17-02	14"	25-38-50 (88)	Sandy Silt, brown, wet, very stiff	(ML)	OVA ≈ BKG For both Sample and Air Visibly non-contaminated
	10' 11'	10-12'	S.S.	24"	35-45-55-20 (100)	Sandy Silt, brown, wet, soft, some gravel (maximum diameter 1-1.5"), Green coating on split spoon (arsenic?)	(ML)	OVA ≈ 3 ppm Visibly non-contaminated
	12' 13'	12-14'	S.S.	8"	16-13-25-19 (38)	Sandy Silt, brown, wet, soft, Some gravel (maximum diameter 1-2")	(ML)	OVA ≈ 2-3 ppm Visibly non-contaminated
	14'							

REV-11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
620.68802 FS	5087-17	SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA, Diedrich D50, 300 lb Hammer

WATER LEVEL AND DATE 15' START 5/19/88 FINISH 5/19/88 (1530) LOGGER ______

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14'		S.S		19-22-	<u>Poorly Sorted Silty Sand</u>,		CVA = BKG
1519	15'	14-16'	50-17-03	7"	52-37 (74)	brown, some pea sized gravel	(SP)	For both the Sample and the air
						(OUTWASH)		
	16'					EOB 16'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER 620.68802.FS

BORING NUMBER S087-16

SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50

WATER LEVEL AND DATE 2' START 5/17/88 FINISH 5/17/88 (1500) LOGGER J.M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
1314	0 1'	0-2'	S.S. S016-01	8"	21-27-10-12 (37)	Poorly Sorted Gravel, black, moist, trace silt, loose (Fill)	(GP)	Start @ 1300 OVA ≈ 10 ppm Sample, Air ≈ Bkg. Visibly contaminated
	2' 3'	2-4'	S.S.	2"	12-11-6-5 (17)	Poorly Sorted Gravel, black, wet, loose, oily liquid in spoon (Fill)	(GP)	OVA ≈ Not working Hnu ≈ 6 ppm W.T. ≈ 2' Visibly contaminated
	4' 5'	4-6'	S.S.	10"	0-2-3-5 (5)	Poorly Sorted Gravel with sand, black, loose, oily liquid in sample, trace silt (Fill)	(GP)	Hnu ≈ 40 ppm Visibly contaminated
	6' 7'	6-8'	S.S.	6"	2-3-6-12 (9)	Peat, brown-black, loose, oily liquid in sample	(Pt)	Hnu ≈ 50-100 ppm Visibly contaminated
	8' 9'	8-10'	S.S.	8"	5-9-29-51 (38)	Silt, brown-black, soft, wet, oily liquid in split spoon (crack in end of split spoon)	(ML)	Hnu ≈ 100 ppm Visibly Contaminated
	10' 11'	10-12'			100---	(Possibly Gravel ?) No Recovery		Driller say it is augering like gravel
	12' 13'	12-14'			100---	No Recovery		
	14'							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
GL0.68802.FS	5087-16	SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D50

WATER LEVEL AND DATE ______ START 5/17/88 FINISH 5/17/88 LOGGER J. M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14'							Problem with gravel, augering 14-15'
1428	15' 16' 17'	15-17'	S.S 5016 -02	19"	7-17-18-18 (35)	Poorly Sorted Sand with Gravel, brown to grey, wet, loose, gravel 0.5-1" in diameter (Outwash)	(SP)	Hnu ≈ 2-3 ppm Sample, Air ≈ Bkg Visibly non-Contaminated
	18' 19'	17-19'	S.S.	20"	21-20-17-12 (37)	Poorly Sorted Sand, brown, wet, loose, sand grains are rounded (Outwash)	(SP)	Hnu ≈ 2-3 ppm Visibly non-Contaminated
	20' 21	19-21'	S.S	16"	21-18-15-15 (33)	Poorly Sorted Sand, brown, wet, loose	(SP)	Hnu ≈ 6 ppm Visibly non-Contaminated
1508	22' 23'	21-23'	S.S. 5016 -03	16"	14-17-14-13 (31)	0-12" Poorly Sorted Sand, brown, wet, loose 12-16" Silt, brown, wet, soft	(SP) (ML)	Hnu ≈ 2 ppm Sample, Air ≈ Bkg Visibly non-contaminated
						EOB 23'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
660.68802.FS	5087-15	SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA
ELEVATION ______ DRILLING CONTRACTOR ETI
DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Dietrich D.50
WATER LEVEL AND DATE W.T ≈ 1.0' START 5/18/88 FINISH 5/18/88 (850) LOGGER J. M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
730	0 1' 2'	0-2'	S.S. 5015-01	8"	15-7-15-13 (22)	0-6" Silt with gravel, brown-black, (Fill) 6-8" Peat, black, moist	(ML) (Pt)	Start @ 730 OVA ≈ 150 ppm Sample Air ≈ 20-40 ppm Visibly contaminated W.T. ≈ 1'
	3' 4'	2-4'	S.S.	10"	13-24-32-19 (56)	Peat, black, wet, wood chunks 2-3" in size (roots?)	(Pt)	OVA ≈ 200 ppm Visibly contaminated
	5' 6'	4-6'	S.S.	12"	6-3-4-5 (7)	Peat, black, wet, some wood chunks (1")	(Pt)	OVA ≈ 100 ppm Visibly contaminated
	7' 8'	6-8'			2-4-5-3 (9)	No recovery		
756	9' 10'	8-10'	S.S. 5015-02	18"	9-15-20-28 (35)	0-8" Peat, brown, wet 8-18" Silty Clay, lt. Brown, wet, stiff	(Pt) ML-CL	OVA ≈ 5ppm Sample Air ≈ BKG Visibly non contaminated
	11' 12'	10-12'	S.S.	10"	5-25-36-32 (61)	Poorly sorted Gravel with Sand, brown, wet, dense, gravel ½-1" in size, rounded	(GP)	OVA ≈ 4 ppm Visibly non-contaminated
	13' 14	12-14'	S.S.	4"	10-17-23-24 (40)	Poorly Sorted Silty Gravel, brown, wet, loose	(GP)	OVA ≈ 1ppm Visibly non-contaminated

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER GLO.68802.ES

BORING NUMBER 5087-15 SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50

WATER LEVEL AND DATE ______ START 5/18/88 FINISH 5/18/88 LOGGER J. M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
850	14' 15'	14-16'	S.S. 5015-03	18"	7-9-9-9 (18)	Poorly Sorted Sand with Gravel, grey-brown, wet, loose, gravel subangular-rounded	SP	OVA ≅ 1 ppm Sample, Air = 2-3 ppm Visibly non-contaminated
	16'					EOB 16'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER	BORING NUMBER	SHEET 1 OF 1
6LO. 68802. FS	5087-14	

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D50,

WATER LEVEL AND DATE 1.5' START 5/19/88 FINISH 5/19/88 8:50 LOGGER J.M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0 1' 2'	0-2.5'				No Split spoon taken		Start @ 715 W.T. ≈ 1.5' Split spoon refusal 0-2.5'
721	3' 4'	2.5'-4.5'	S.S. SO14-01	6"	2-4-3-5 (7)	Peat, black, wet, wood chunks 1-2" in size, black fluid in sample	(PT)	OVA ≈ 40 ppm Sample, Air ≈ BKG Visibly contaminated
	5' 6'	4.5'-6.5'	S.S.	6"	2-3-4-7 (7)	Peat, brown, wet, some roots and wood chunks, black liquid in sample	(PT)	OVA ≈ 1-2 ppm Visibly Contaminated
740	7' 8'	6.5'-8'	S.S. SO14-02	10"	10-15-21-27 (36)	Sandy Silt, grey, wet, stiff, some gravel, gravel angular. (1" maximum diameter)	(ML)	OVA ≈ 2 ppm Sample, Air ≈ BKG chuck angled down only 8' Visibly non-contaminated
	9'	8-10'	S.S.	12"	3-5-7-12 (12)	Silt, brown, wet, soft, some gravel (subangular to rounded)	(ML)	OVA ≈ 2 ppm Visibly non-contaminated
	10' 11'	10-12'	S.S.	18"	1-8-10-14 (18)	Well Sorted Silty Sand, brown, wet, loose, sand is medium grained and subangular to rounded	(SW)	OVA ≈ BKG Switched to 300 lb Hammer Visibly non-contaminated
843	12' 13'	12-14'	S.S. SO14-03	12"	15-9-7-7 (16)	Poorly Sorted Silty sand with Gravel, brown, wet, loose, Gravel is rounded (maximum diameter 1") (Outwash)	(SP)	OVA ≈ BKG For both Sample and Air Visibly non-contaminated
	14'					EOB 14'		

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER 610.68802.FS | BORING NUMBER SO87-06 | SHEET 1 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA

ELEVATION ______ DRILLING CONTRACTOR ETI

DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D.50, 140 lb Hammer

WATER LEVEL AND DATE 2.0' START 5/19/88 FINISH 5/19/88 (1130) LOGGER J.M. Gannon

ELEVATION	DEPTH BELOW SURFACE	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL	SYMBOLIC LOG	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	0 1'	0-2'	S.S.	7"	7-4-3-4 (7)	Poorly Sorted Silty Sand with Gravel, brown, dry, loose (FILL)	(SP)	Start @ 1002 OVA ≈ 2-3 ppm Sample Air ≈ BKG VISIBLY CONTAMINATED
1005	2' 3'	2-4'	S.S SO16-01	12"	1-3-4-7 (7)	Clayey Silt, black, moist, soft, some gravel, (black thick liquid in sample) (FILL)	ML CL	OVA ≈ 50-150 ppm Sample, Air ≈ BKG Visibly contaminated
	4' 5'	4-6'	S.S.	6"	3-4-12-10 (16)	Silty Poorly Sorted Gravel, brown-black, wet, loose, Gravel is rounded (maximum diameter 1"), some sand (Fill)	(GP)	OVA ≈ 3-4 ppm Slightly contaminated
	6' 7'	6-8'	S.S.	14"	2-10-3-4 (13)	Peat, brown, wet, some woody pieces	(PL)	OVA ≈ 3-4 ppm Slightly contaminated
	8' 9'	8-16'	S.S.		5-14-15-4 (29)	No Recovery (Possibly Gravel?)		Drillers said the rig felt like we were augering through gravel.
	10' 11'	10-12'	S.S.		6-7-25-34 (32)	No Recovery (Possibly Gravel?)		
1047	12' 13'	12-14'	S.S. SO6-02	18"	5-9-15-17 (24)	Poorly Sorted Silty Sand, Brown, wet, dense, some gravel	(SP)	OVA ≈ 1 ppm Sample Air ≈ BKG Visibly non-Contaminated
	14'							

REV 11/82 FORM D1586

CH2M HILL

PROJECT NUMBER GLO.68802.FS
BORING NUMBER 5087-06
SHEET 2 OF 2

SOIL BORING LOG

PROJECT ARROWHEAD REFINERY SITE LOCATION HERMANTOWN, MINNESOTA
ELEVATION ______ DRILLING CONTRACTOR ETI
DRILLING METHOD AND EQUIPMENT HSA (6" O.D.), Diedrich D 50
WATER LEVEL AND DATE ______ START 5/19/88 FINISH 5/19/88 1130 LOGGER J.M. Fanney

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	14' 15'	14-16'	S.S.	14"	5-6-7-8 (13)	Poorly Sorted Silty Sand with Gravel, brown, wet, gravel subangular (1" maximum diameter)	(SP)	OVA ≈ 6 ppm
	16' 17'	16-18'	S.S.	8"	5-9-9-10 (18)	Poorly Sorted Silty Sand with Gravel, brown, wet, loose, one cobble 2.5" in diameter, gravel is rounded	(SP)	OVA ≈ Bkg
1105	18' 19' 20'	18-20'	S.S. S06-03	24"	13-13-14-11 (27)	Poorly Sorted Silty Sand with Gravel, brown, wet, dense, gravel rounded (maximum diameter 1")	(SP)	OVA ≈ Bkg For both sample and air
						EOB 20'		

REV 11/82 FORM D1586

TM11--SUBSURFACE SOIL SAMPLING
(STEP II)

Attachment A
BORING LOGS

Table TM11-2 (Page 3 of 3)

CH2M HILL Sample No.	CRL Sample No.	SAS Sample No.	Traffic Report No.	Collection		Laboratory
				Date	Time	
SO87-22-03	88HK04S03	--	EW580	5/18/88	11:22	Gulf South
	88HK04S03	--	MEW345			Chem Tech
	88HK04S03	3784E 133	--			Data Chem
SO87-23-01	88HK05S07	3784E 108	--	5/17/88	7:13	Weyerhauser
	88HK05D07	3784E 109	--			Weyerhauser
	88HK05S07	3784E 107	--			Weyerhauser
SO87-23-02	88HK04S93	--	EW560	5/17/88	7:17	Gulf South
	88HK04D93	--	EW561			Gulf South
	88HK04S93	--	MEW326			Chem Tech
	88HK04S93	3784E 106	--			Data Chem
SO87-23-03	88HK04S94	--	EW562	5/17/88	7:40	Gulf South
	88HK04S94	--	MEW327			Chem Tech
SO87-24-01	88HK05S08	3784E 111	--	5/17/88	9:00	Weyerhauser
	88HK05S08	3784E 110	--			Weyerhauser
SO87-24-02	88HK04S95	--	EW563	5/17/88	9:07	Gulf South
	88HK04S95	--	MEW328			Chem Tech
	88HK04S95	3784E 112	--			Data Chem
SO87-24-03	88HK04S96	--	EW564	5/17/88	9:28	Gulf South
	88HK04S96	--	MEW329			Chem Tech
FB87-800	88HK04R07	--	EW567	5/17/88	16:30	Gulf South
	88HK04R07	--	MEW332			Chem Tech
	88HK04R07	3784E 118	--			Data Chem
	88HK05R07	3784E 120	--			Weyerhauser
	88HK05R07	3784E 119	--			Weyerhauser
FB87-900	88HK04R06	--	EW583	5/19/88	13:25	Gulf South
	88HK04R06	--	MEW348			Chem Tech
	88HK04R06	3784E 148	--			Data Chem
	88HK05R06	3784E 150	--			Weyerhauser
	88HK05R06	3784E 149	--			Weyerhauser

Ambient air around the drilling rig was monitored at each location with an OVA or an HNu. The site safety coordinator remained dressed in Level B equipment at an upwind location and continuously monitored the air with an HNu during drilling. The site safety coordinator maintained continuous visual contact with the sampling crew and was in periodic radio contact with the trailer.

A decontamination line was set up between the process area and the trailer. The line included a boot wash (trisodium phosphate solution), a boot rinse (tap water), a glove wash (trisodium phosphate solution), and a glove rinse (tap water). A 55-gallon drum was used for disposal of safety protective clothing. The decontamination line was used whenever a member of the sampling team left the process area.

The outsides of filled sample jars were decontaminated using distilled water. Split spoons and other sampling equipment were decontaminated between samples using a solution of trisodium phosphate and water, followed by a water rinse, a methonal rinse, and a double rinse with distilled water.

SAMPLING PROBLEMS

Because of poor split-spoon sample recovery in the peat at SO87-18, two additional borings were advanced to 2 feet below ground adjacent to the original boring. It was also necessary to collect two additional split-spoon samples from the 2- to 4-foot interval to obtain enough sample to submit for laboratory analysis.

Sample recovery was also poor in the sand and gravel units at borings SO87-06 and SO87-16. These two borings had several intervals of no recovery in the split spoons, which probably caused the borings to be deeper than necessary and made it difficult to determine the precise depth of the visually contaminated soil.

GLT932/031.51

Table TM11-2 (Page 1 of 3)
SAMPLE MATRIX TABLE FOR SUBSURFACE SOIL SAMPLES

CH2M HILL	CRL	SAS	Traffic	Collection		
Sample No.	Sample No.	Sample No.	Report No.	Date	Time	Laboratory
SO87-06-01	88HK05S10	3784E 143	--	5/19/88	10:05	Weyerhauser
	88HK05S15	3784E 142	--			Weyerhauser
SO87-06-02	88HK04S89	--	EW576	5/19/88	10:47	Gulf South
	88HK04D80	--	EW577			Gulf South
	88HK04S89	--	MEW341			Chem Tech
	88HK04D89	--	MEW342			Chem Tech
	88HK04S89	3784E 144	--			Data Chem
	88HK05S16	3784E 145	--			Weyerhauser
	88HK05S16	3784E 146	--			Weyerhauser
SO87-06-03	88HK04S90	--	EW578	5/19/88	11:05	Gulf South
	88HK04S90	--	MEW343			Chem Tech
	88HK04S90	3784E 147	--			Data Chem
SO87-14-01	88HK05S14	3784E 139	--	5/19/88	7:21	Weyerhauser
	88HK05S14	3784E 138	--			Weyerhauser
SO87-14-02	88HK04S87	--	EW581	5/19/88	7:40	Gulf South
	88HK04S87	--	MEW346			Chem Tech
	88HK04S87	3784E 140	--			Data Chem
SO87-14-03	88HK04S88	--	EW582	5/19/88	8:43	Gulf South
	88HK04S88	--	MEW347			Chem Tech
	88HK04S88	3784E 141	--			Data Chem
SO87-15-01	88HK05S10	3784E 122	--	5/18/88	7:30	Weyerhauser
	88HK05S10	3784E 121	--			Weyerhauser
SO87-15-02	88HK04S99	--	EW571	5/18/88	7:56	Gulf South
	88HK04S99	--	MEW336			Chem Tech
	88HK04S99	3784E 124	--			Data Chem
SO87-15-03	88HK04S01	--	EW573	5/18/88	8:50	Gulf South
	88HK04S01	--	MEW338			Chem Tech
	88HK04S01	3784E 128	--			Data Chem
SO87-16-01	88HK05S09	3784E 114	--	5/17/88	13:14	Weyerhauser
	88HK05D09	3784E 115	--			Weyerhauser
	88HK05S09	3784E 113	--			Weyerhauser
SO87-16-02	88HK04S97	--	EW565	5/17/88	14:28	Gulf South
	88HK04S97	--	MEW330			Chem Tech
	88HK04S97	3784E 116	--			Data Chem
SO87-16-03	88HK04S98	--	EW566	5/17/88	15:08	Gulf South
	88HK04S98	--	MEW331			Chem Tech
	88HK04S98	3784E 117	--			Data Chem

Table TM11-2 (Page 2 of 3)

CH2M HILL Sample No.	CRL Sample No.	SAS Sample No.	Traffic Report No.	Collection		Laboratory
				Date	Time	
SO87-17-01	88HK05S17	3784E 152	--	5/19/88	14:40	Weyerhauser
	88HK05S17	3784E 151	--			Weyerhauser
SO87-17-02	88HK04S91	--	EW568	5/19/88	14:54	Gulf South
	88HK04D91	--	EW569			Gulf South
	88HK04S91	--	MEW333			Chem Tech
	88HK04D91	--	MEW334			Chem Tech
	88HK04S91	3784E 154	--			Data Chem
SO87-17-03	88HK04S92	--	EW570	5/19/88	15:19	Gulf South
	88HK04S92	--	MEW335			Chem Tech
	88HK04S92	3784D 154	--			Data Chem
SO87-18-01	88HK05S12	3784E 136	--	5/19/88	15:03	Weyerhauser
	88HK05D12	3784E 123	--			Weyerhauser
	88HK05S12	3784E 135	--			Weyerhauser
SO87-18-02	88HK04D04	--	EW572	5/18/88	14:25	Gulf South
	88HK04S04	--	EW574			Gulf South
	88HK04S04	--	MEW339			Chem Tech
	88HK04D04	--	MEW337			Chem Tech
	88HK04D04	3784E 127	--			Data Chem
	88HK04S04	3784E 134	--			Data Chem
	88HK05S04	3784E 126	--			Weyerhauser
	88HK05S13	3784E 125	--			Weyerhauser
SO87-18-3	88HK04S05	--	EW575	5/18/88	14:52	Gulf South
	88HK04S05	--	MEW340			Chem Tech
	88HK04D05	3784E 129	--			Data Chem
	88HK04S05	3784E 137	--			Data Chem
SO87-19-01	88HK05S06	3784E 101	--	5/16/88	14:01	Weyerhauser
	88HK05D06	3784E 102	--			Weyerhauser
	88HK05S06	3784E 104	--			Weyerhauser
SO87-19-02	88HK04S85	--	EW557	5/16/88	14:47	Gulf South
	88HK04D86	--	EW558			Gulf South
	88HK04S85	--	MEW324			Chem Tech
	88HK04S85	3784E 103	--			Data Chem
SO87-19-03	88HK04S86	--	EW559	5/16/88	15:28	Gulf South
	88HK04S87	--	MEW325			Chem Tech
	88HK04S86	3784E 105	--			Data Chem
SO87-22-01	88HK05S11	3784E 131	--	5/18/88	10:47	Weyerhauser
	88HK05S11	3784E 130	--			Weyerhauser
SO87-22-02	88HK04S02	--	EW579	5/18/88	10:56	Gulf South
	88HK04S02	--	MEW344			Chem Tech
	88HK04S02	3784E 132	--			Data Chem

Appendix B
ANALYTICAL DATA AND QUALITY ASSURANCE/QUALITY CONTROL EVALUATION OF LABORATORY DATA

INTRODUCTION

All analytical data gathered during the FDI must be evaluated for precision and accuracy. This appendix presents the analytical data collected during the design investigation at the Arrowhead Refinery site and the quality assurance/quality control (QA/QC) evaluation of those data. The purpose of data validation is to characterize the weaknesses of questionable data (possibly limiting its use) and to determine which data are unusable.

The QA/QC procedures stated in the Quality Assurance Project Plan (QAPP) for this project (CH2M HILL, 1987), include both field sampling and laboratory analysis. Data review is performed by U.S. EPA's Region V Central Regional Laboratory (CRL) according to the *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* (U.S. EPA, 1985), *Standard Operating Procedure for Contract Compliance Screening (CCS) of Routine Analytical Services Analyses of Inorganics Data* (U.S. EPA, 1987), and the *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses* (U.S. EPA, 1988). These reviews, plus additional observations by CH2M HILL, are incorporated into the final data validation written for each set of data before to its use. QA/QC, data review procedures, and results of the data validation for the Arrowhead Refinery site are summarized below.

FIELD AND LABORATORY QA/QC

The analyses discussed below are done to characterize the quality of a data set. They consist of analyzing blank, duplicate, and spike samples to evaluate data precision, accuracy and contamination. The results of the QA/QC analyses are discussed along with the raw analytical data and are used for data review and validation.

BLANKS

A blank is a clean sample equivalent that is processed and analyzed as a sample to determine the existence and magnitude of potential contamination introduced during sampling or analysis. In the field, HPLC-grade water is used for aqueous blanks, and a clean sand for soil blanks. Field or bottle blanks are treated the same as samples from the field through laboratory analysis and reporting. Laboratory preparation blanks (reagent blanks) are prepared from contaminant-free water in the laboratory and processed along with the samples through each sample preparation and analysis step. Field blanks identify contamination from decontamination, sampling, bottle transport, and laboratory procedures. Bottle blanks identify contamination from bottles and bottles transport. Laboratory blanks identify only laboratory contamination.

QUANTIFICATION LIMITS

A quantification limit is the minimum amount of a chemical that can be consistently detected and quantified. An individual laboratory's detection limits may be lower than the Contract Required Quantification Limits (CRQL) established for the Contract Laboratory Program (CLP). In a case such as this, data lower than the CRQL are reported; these data are considered estimated because the accuracy of quantification below these levels is uncertain. Contamination or other analytical problems (such as low sample recoveries) may cause the actual quantification limit to be higher than that reported by the laboratory. When that occurs, it is noted in the laboratory validation writeup. Tables A and B present the target compounds or elements analyzed for by the CLP laboratories and the CRQLs.

SPIKE RECOVERIES

Spike sample analyses are done to determine the effect of the sample matrix on extraction, digestion, and measurement procedures. Spike recoveries are also used to determine the accuracy of the analyses, which is a measure of the agreement between an experimental determination and the true value of the parameter being measured. In general, a known amount of compound is added to a sample, the sample is analyzed, and the amount of spiked compound recovered by analysis is compared to the amount added.

A "surrogate spike" in organic analysis is a compound not expected to be present in environmental samples, but with properties similar to those of the target compounds. It is added to all samples before extraction and other sample preparation. Percent recovery (%R) is calculated by:

$$\%R = SSR/SA \text{ x } 100\%$$

where:

SSR = quantity measured in spiked sample
SA = quantity of spike added

A "matrix spike" consists of target compounds added to a sample just before analysis. It is analogous to the "method spike" done for high concentration inorganic analysis. Both analyses are performed to evaluate matrix effects on the analytical methodology and data accuracy.

Percent recovery for a matrix spike is calculated by:

$$\%R = \frac{SSR\text{-}SR}{SA} \text{ x } 100\%$$

where:

SR = quantity measured in unspiked sample

The "method spike" for high concentration inorganics and the "spike sample analysis" for low and medium inorganic concentrations are the same. The spike is added before any reagents are added to the sample. Percent recovery is calculated as for a matrix or method spike.

A recovery above the control limits may indicate a high bias in the data, while a recovery below the control limits may indicate a low bias and detection limits higher than those specified by the contract.

DUPLICATES

Both field and laboratory duplicate samples are analyzed to determine data precision, a measure of the reproducibility of field sampling and analysis. The results are reported as relative percent difference (RPD) and calculated by:

$$RPD = \frac{D1 - D2}{(D1 + D2)/2} x\ 100\%$$

where:

D1 = concentration of first duplicate
D2 = concentration of second duplicate

SERIAL DILUTIONS

For inorganic inductively coupled plasma (ICP) analysis, a serial dilution analysis is done for each set of samples of similar matrix type and concentration. For an analyte concentration at least a factor of 10 above CRQL, the measured concentrations of the undiluted sample and of the sample after a five-fold dilution should agree within 10 percent. If the difference is greater than 10 percent, the results for that compound are considered estimated because of matrix interference.

INSTRUMENT QC

Other instrument-specific tests include initial and continuing calibration, decafluorotriphenylphosphine (DFTPP) and bromofluorobenzene (BFB) tuning for the GC/MS, and determining the linearity of standard calibration curves by determining the coefficient of correlation (r).

DATA REVIEW AND VALIDATION

CRL DATA REVIEW

The U.S. EPA Sample Management Office receives data packages from the laboratories in the CLP and distributes them to the Laboratory Sciences Services Section (LSSS) of the Region V CRL. The LSSS reviews all data packages resulting from regional sampling efforts. The following items are reviewed (as stated in U.S. EPA guidelines):

- Sample holding times at the CLP laboratory
- GC/MS tuning and performance (organics)
- Instrument calibration
- Blanks

- Interference check sample analysis (inorganics)
- Surrogate recoveries (organics)
- Matrix and analytical spike analysis
- Duplicate sample analysis
- Compound identification (organics)
- Overall assessment of data

DATA VALIDATION

After CH2M HILL receives the CRL-reviewed data packages, the reviewer's comments are summarized in the final data validation before data interpretation by project staff. Any data noted in the review that should be qualified are flagged with the appropriate symbol (Table C). Results for field blanks and field duplicates are reviewed (these may or may not have been considered by the LSSS) and the data further qualified if necessary. Finally, the data set as a whole is examined for consistency, anomalous results, and whether the data are reasonable for the samples involved. Table C lists the data qualifiers used in this project and explanations of their use. Data flagged with a qualifier may be used to varying degrees or may be completely unusable, depending on the type of problem and significance of the data point.

Data review packages are identified by sample case numbers and traffic report numbers for routine analytical services (RAS) and by SAS numbers for special analytical services (e.g., fast turnaround times or high-hazard samples). For RAS samples a case number is assigned to a group of samples collected at one time, and individual samples are assigned unique traffic report numbers to identify them from time of sampling through reporting of the analytical data. For SAS samples, the first four numbers define a group of samples and the final letters/numbers identify individual samples (e.g., SAS 3136-EO1, SAS 3136-EO2).

GROUNDWATER SAMPLE RESULTS AND QUALITY CONTROL REVIEW (STEP I)

INORGANIC CONSTITUENTS

Residential Wells

Thirteen residential well samples and one field blank were submitted to Associated Laboratories for analysis of metals and cyanide (Case 8510, ITR Nos. MER637-MER650). All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-4 and are qualified as follows:

- Spike recovery for mercury (130 percent) is beyond control limits and all positive results are flagged as estimated (J) and may be biased high.

- The field blank contained barium (36 µg/l), calcium (608 µg/l), copper (11 µg/l), iron (59 µg/l), lead (0.62 µg/l), magnesium (49 µg/l), sodium (1,180 µg/l), and zinc (15 µg/l). Laboratory blanks contained iron (7.2 to 48 µg/l), lead (0.9 µg/l), magnesium (39 µg/l), manganese (2.5 µg/l), sodium (38 to 45 µg/l), and zinc (5.4 µg/l). Samples associated with these blanks which contain these contaminants with concentrations less than five times the blank concentration are considered unusable and are flagged "B."

Monitoring Wells

Fourteen groundwater samples and one field blank were analyzed by Rocky Mountain Analytical Laboratory (RMAL) for metals and cyanide (Case 8510, ITR Nos. MER620, MER625- MER636, MEK995-MEK996). All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-5 and are qualified as follows:

- o Spike sample recovery for lead (74.5 percent) indicates a low bias and all lead data are considered as estimated (J).
- o Aluminum (31.6 µg/l), barium (34.3 µg/l), calcium (409 to 1,860 µg/l), lead (1.2 µg/l), magnesium (605 µg/l), manganese (11.6 µg/l), potassium (126 µg/l) and sodium (4,250 µg/l) were identified in the field blanks from this sampling period. These blanks also apply to Case 8413 (see below). Samples associated with the field blanks which contain these contaminants with concentrations less than five times the blank concentration are considered unusable and flagged "B."

Thirty-one groundwater samples and two field blanks were analyzed by RMAL for metals and cyanide (Case 8413, ITR Nos. MEK997-MEK999, MEM494-MEM497, MEM499, MEM500, MER600-MER619, MER621-MER624) by low concentration procedures. The results for these samples are presented in Table B-5. This case consisted of two sample digestion groups (SDG) with separate QA/QC analyses and separate data reviews. The data are qualified as follows:

- o The spike sample recovery for selenium (0 percent) is below the control limits for the 20 samples associated with SDG No. MEK997 (ITR Nos. MEK997-MEK999, MEM494-MEM500, and MEM600-MEM611). All non-detected selenium results for these samples are considered unusable and flagged "R."
- o The percent difference after serial dilution for potassium and sodium are beyond the control limits for the 20 samples associated with SDG No. MEK997. All sodium and potassium results are considered estimated and flagged "J."
- o The field blanks discussed with Case 8510 (above) also apply to these samples.

Twenty-two groundwater samples, including two field blanks and one field duplicate, were analyzed for COD, TSS, TOC and alkalinity by Centec Analytical Services, Inc. (SAS Nos. 3449 E19-E34, E68, E69, E97, E98, E100-E105, E147-E162, E183, and E184). Results are presented in Table B-6. The data are qualified as follows:

- o COD was measured in both field blanks (7.7 to 8.5 mg/l). Any sample with COD less than 20 mg/l is considered unusable and flagged "B."

ORGANIC COMPOUNDS

Residential Wells

Thirteen residential well samples and one field blank were submitted to S-Cubed Laboratory for organics analysis (Case 8510, OTR Nos. EQ140-EQ153). All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-7 and are qualified as follows:

- The holding time limit was exceeded for sample EQ144 and all positive results for this sample are flagged as estimated (J).
- Method blanks contained the common laboratory contaminants methylene chloride (4.4 to 5.2 µg/l), acetone (16 to 20 µg/l), diethylphthalate (1.7 µg/l), and bis(2-ethylhexyl)phthalate (2 µg/l). Samples associated with these blanks which contain these contaminants with concentrations less than 10 times the blank values are considered unusable and flagged "B."
- The field blank contained tetrachloroethene (1.2 µg/l) and the common laboratory contaminants methylene chloride (1.7 µg/l), toluene (3 µg/l) and bis(2-ethylhexyl)phthalate (2.9 µg/l). Samples associated with this blank which contain these contaminants with concentrations less than 5 times the blank concentration for tetrachloroethene or less than 10 times the blank concentrations of the other detected common laboratory contaminants are considered unusable and flagged "B."

Monitoring Wells

Fourteen water samples and two field blanks were submitted to Hazleton Laboratories for analysis of organic compounds (Case 8510, OTR Nos. EP389, EP390, EQ122, EQ127-EQ139). Sample EQ134 was analyzed for VOCs only while all other samples were analyzed for VOCs and semivolatile organic compounds (SVOCs). All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-8 and are qualified as follows:

- Chloroform (0.7 to 2 µg/l) and the common laboratory contaminants methylene chloride (2 to 6 µg/l), acetone (5 to 20 µg/l), and toluene (0.4 to 2 µg/l) were identified in method, field, and bottle blanks. Samples associated with these blanks which contain these contaminants with concentrations less than 5 times the chloroform or 10 times the other detected common laboratory contaminant concentrations in the blanks are considered unusable and flagged "B."

- Due to calibration outliers, the results for acetone (EQ122, EQ127-EQ130, EQ132, EQ133, EQ135-EQ138, EP390), benzene (EQ139), and methylene chloride (all samples) are considered estimated (J).

Thirty groundwater samples and two blanks were submitted to Spectrix Laboratory for analysis of organic compounds (Case 8413, OTR Nos. EP391-EP395, EQ103, EQ104, EQ106-EQ121, EQ123-EQ126, EQ210, EQ211, EQ213-EQ215). In addition, five samples were reextracted for semivolatile organic compounds only. All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-8 and are qualified as follows:

- Holding times for the five reextracted samples (EP391, EQ113, EQ115, EQ117, EQ213) were exceeded. Results for these samples are flagged as estimated (J).
- The common laboratory contaminants methylene chloride (µg/l) and bis(2-ethylhexyl)phthalate (2 to 23 µg/l) were identified in the method and field blanks. Samples associated with these blanks which contain these contaminants with concentrations less than 10 times the blank concentrations are considered unusable and are flagged "B."
- Due to calibration outliers, results for acetone in samples EQ109 and EQ110 and 2-butanone in sample EQ111 are considered estimated and flagged "J."

Low Detection Limit VOCs

Sixty-nine groundwater samples from residential and monitoring wells, including several sets of field triplicates and two field blanks, were analyzed for low concentration VOCs by Spectrix Laboratory (SAS Nos. 3449 E01-E18, E70-E81, E83, E106-E118, E125-E146, E177-E179). A summary of the results is presented in Table B-9. The data are qualified as follows:

- Chloroform (0.05 µg/l) and benzene (0.12 µg/l) were measured in the field blanks. Any sample concentration less than five times the blank concentrations for these compounds are considered unusable and flagged "B."
- Surrogate spike recoveries were below control limits for samples E07 (52 percent) and E08 (54 percent). No VOCs were detected in these samples; however, the data may have a low bias and the detection limits may be higher than reported.

Low Detection Limit PAHs

Sixty-nine groundwater samples from residential and monitoring wells, including several sets of field triplicates and two field blanks, were analyzed by SWOK for low concentration PAHs (SAS Nos. 3449 E37-E67, E82, E84-E96, E99, E120-E125, E163-E176, E180-E182). All data should be considered estimated because of analytical difficulties, except those unusable data where blank contamination was likely. Results are presented in Table B-10. A summary of the QA/QC results and data qualification follows:

- Naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene were measured in the two field blanks, at concentrations from 0.4 to 0.6 ng/l. Any concentrations less than five times field blank concentrations for these compounds in all samples are considered unusable and flagged "B."

- The laboratory blank summary form was not included in the data package from the laboratory, although it was stated that no blank concentrations exceeded 5.0 ng/l (5.0 ng/l is the CRQL for this SAS). Pending further information from the laboratory or CRL, any data less than 25 ng/l should be considered suspect. (No PAH concentrations above 25 ng/l were measured in any of these samples.)

- Fifty-six out of the sixty-nine samples had surrogate spike recoveries below the control limits. The data set as a whole may be biased low, and any usable data should be considered estimated (J).

- Matrix spike recoveries and duplicate results indicate matrix interference for most of the compounds. There were also at least 20 tentatively identified organic compounds in each sample, with many of them matching library spectra of the target compounds. This suggests analytical problems due to interference and supports qualifying the entire set of usable data as estimated.

SOIL AND SEDIMENT SAMPLE RESULTS AND QUALITY CONTROL REVIEW (STEP I)

INORGANIC CONSTITUENTS

High Concentration Soil and Sediment

Nine soil samples, separated into solid and aqueous phases, were analyzed by JTC Environmental Consultants for high concentration metals (SAS Nos. 3249 I01-I09). The results for these samples are presented in Table B-11 and are qualified as follows:

- The aqueous phase analysis spike recovery for lead (81 percent) is below the control limits and all lead results for aqueous samples are considered estimated and flagged "J."

- The aqueous phase method spike recoveries are beyond control limits for cadmium (127 percent) and cobalt (69 percent). Results for these contaminants in aqueous samples are flagged as estimated (J).

- The solid phase spike recoveries for iron (75 percent) and silicon (77 percent) are below the control limits. Results for these contaminants are considered estimated and flagged "J."

- The solid phase method spike recovery for antimony (60 percent) is below the control limit and all results for antimony are flagged as estimated (J).

Subsurface Soil

Eleven subsurface soil samples and one field blank were analyzed by RMAL for low concentration metals (Case 8195, ITR Nos. MEM472, MEM475, MEM478-MEM480, MEI789-MEI791, MEG971-ME6974). Samples MEM472 and MEM475 are included in QC Report No. 87354, and MEM478-MEM480, MEI789-MEI791, and MEG971-MEG974 are included in QC Report No. 87320. The results for these samples are presented in Table B-12 and are qualified as follows:

- o Spike sample recoveries for antimony (51 percent), arsenic (145 percent) and selenium (0 percent) are beyond the control limits for QC Report No. 87354. There were no positive results for these constituents. No flags are necessary for antimony or arsenic, and the non-detected selenium results are considered unusable and flagged "R."
- o The spike recovery for lead (52 percent) is below control limits for samples in QC Report No. 87320. All lead data may be biased low and are considered estimated (J).

Sediment

Twenty-two sediment samples and one field blank were analyzed by RMAL for low concentration metals (Case 8350, ITR Nos. MEM460-MEM469, MEM476, MEM477, MEM481-MEM490, MEM493). The results for these samples are presented in Table B-13 and are qualified as follows:

- o The matrix spike recovery for antimony (55 percent) was below control limits and may indicate a low bias. Results are considered estimated and flagged "J."
- o For lead, the spike recovery (459 percent) and duplicate RPD (70.8 percent) are beyond the control limits so that the data are considered unusable (R).
- o The percent difference after serial dilution for aluminum (15 percent), calcium (262 percent), and manganese (69 percent) indicate interference and the data for these sample constituents are flagged as estimated (J).
- o Duplicate results for copper (41.1 RPD) are beyond the control limits, and these data are considered estimated (J).
- o Analysis spike results were beyond the control limits for thallium (all samples), selenium (MEM466-MEM469, MEM477, MEM483-MEM484, MEM486, MEM488-MEM489), arsenic (MEM464-MEM465, MEM476-MEM477, MEM482, MEM490, MEM493), and lead (MEM493). Usable results for these samples are considered estimated (J).
- o Method of standard addition correlation coefficients for arsenic in samples MEM466-MEM469, MEM485 and MEM486 were less than 0.995. These data are considered estimated (J).

Surface Soil

Eleven surface soil samples and one field blank were analyzed by RMAL for low concentration metals and cyanide (Case 8195 ITR Nos. MEG970, MEG975-MEG979, MEI721, MEI787, MEI792, MEM457-MEM459). The results for these samples are presented in Table B-14 and are qualified as follows:

- Matrix spike recovery for lead (131.9 percent) is above the control limits. All lead results may be biased high and are considered estimated (J).

- Matrix spike recovery for cyanide (17 percent) is below the control limits and all cyanide data are considered estimated (J). Detection limits may be higher than those listed and the data may be biased low.

- Duplicate analysis results for copper are beyond the control limits and all copper results are considered estimated (J).

- The percent difference after serial dilution for calcium (10.3 percent) indicates matrix interference and all calcium data are considered estimated (J).

- High percent moisture resulted in elevated detection limits (above CRQL) for cadmium (MEG970, MEG976, MEI721, and MEM457) and lead (MEG970, MEG976-MEG979, MEI721, and MEM461). Data are reported as less than listed laboratory detection limits (e.g., §49.1 mg/l).

INCINERATION PARAMETERS IN SOIL AND SEDIMENT

Fourteen surface soil and sediment samples and two field blanks were submitted to Weyerhaeuser for analysis of TOC, heating value, ash content, moisture content, and percent content of carbon, nitrogen, oxygen, and sulfur (SAS Nos. 3330 E18, E19, E25-E27, E29, E30, E34, E40, E42, E49, E52, E53, E55, E57, E58, E60-E62). The results for these samples are presented in Tables B-15 and B-16 and are qualified as follows:

- Total organic carbon data are estimated (J) because of low spike recoveries (78 and 84 percent).

- Duplicate sample differences for heating value analyses exceeded 50 Btu/lb. Although the RPD was only 8 percent, these values are considered estimated (J) according to the analytical method.

ORGANIC COMPOUNDS

Soil and Sediment

Ten sediment samples were submitted to Energy and Environmental Engineering, Inc. for analysis of organic compounds, including pesticides (Case 8350, OTR Nos. EP361-EP366, EP373, EP374, EP378, EP379). All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-17 and are qualified as follows:

- All pesticide extraction holding times were exceeded, so all pesticide results are considered estimated and flagged "J."

- Compound degradation during chromatographic analysis, especially noted for DDT, affected samples EP365, EP366, EP373, EP378, and EP379. In samples where DDD/DDE results are positive but DDT was not detected, DDT results are considered unusable (R).

- All endrin and endrin ketone/aldehyde results are flagged as preliminary (P) pending further information from the laboratory.

- One or more VOC surrogate spike recoveries were beyond control limits for samples EP363, EP363RE, EP365, EP365RE, EP378, EP378RE, EP379, and EP379RE. All positive results for these samples are flagged as estimated (J).

- Low recovery for the surrogate spike and one or more SVOC internal standard outliers were identified for samples EP378, EP379, EP379RE, EP361, EP374, EP374RE, EP362, and EP362RE. All positive SVOC results for samples EP361, EP378 and EP379, are estimated (J) and all positive results for sample EP362 are estimated (J) for pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, and benzo(k)fluoranthene.

- The common laboratory contaminants methylene chloride (14 to 21 μg/kg), acetone (15 to 22 μg/kg), toluene (3 to 4 μg/kg) and 2-butanone (19 to 28 μg/kg) were identified in the VOC method blanks. Samples with concentrations of these contaminants less than 10 times the blank concentration are considered unusable and flagged "B."

- Due to calibration outliers the following results are considered estimated (J): acetone, 2-butanone, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene (all samples); pyrene, chrysene, and benzo(k)fluoranthene (EP362-EP364, EP366).

Eight sediment samples and one field blank were analyzed by American Analytical Technicals for organic compounds, including pesticides (Case 8350, OTR Nos. EP380-EP387, EP391). All samples were analyzed by low concentration procedures, except EP386 and EP387 which were analyzed as medium-level samples. The results for these samples are presented in Table B-17 and are qualified as follows:

- Sample EP387 was not associated with any VOC method blank in the laboratory data package. The data for this sample are flagged as preliminary (P) until further information is received.

- The field blank was contaminated with 2-butanone (21 μg/kg) and toluene (8 μg/kg). All positive sample results with concentrations of these contaminants less than 10 times the blank concentrations are considered unusable and flagged "B."

- The method blanks contained chloroform (0.6 to 0.8 μg/kg) and the common laboratory contaminants methylene chloride (8 μg/kg) and toluene (0.3 μg/kg). Samples with chloroform concentrations less than 5 times the blank concentration or with methylene chloride or toluene concentrations less than 10 times the blank are considered unusable and flagged "B."

- Samples EP381, EP384, and EP385 each had two surrogate recoveries above the control limits in the SVOC fraction. All SVOC data for these samples are considered estimated (J).

Four sediment samples, twelve surface soil samples, eleven subsurface soil samples, and two blanks were analyzed by MetaTrace, Inc. for low concentration VOCs and SVOCs (Case 8195, OTR Nos. EL557, EL558, EP339-EP360, EP369, EP372, EP375-EP377). Results are presented in Tables B-17, B-18, and B-19 and are qualified as follows:

- Holding times were exceeded for all VOC samples except EP341, EP342, EP347, EP369, and EP377. Those data are considered estimated and flagged "J."

- Holding times were exceeded for SVOC samples EP348, EP369, EP372, EP376, and EP377. The data for these samples are considered estimated and flagged "J."

- VOC method blanks contained the common laboratory contaminants methylene chloride (2 to 5 µg/kg), acetone (26 to 43 µg/kg), and toluene (6 µg/kg). Samples associated with these blanks which contain these contaminants with concentrations less than 10 times the blank concentration are unusable and flagged "B."

- The surface and subsurface soil field blanks contained methylene chloride (3 to 10 µg/kg), acetone (13 µg/kg), dibutylphthalate (120 to 3000 µg/kg), bis(2-ethylhexyl)phthalate (81 to 470 µg/kg) and di-n-octylphthalate (170 µg/kg). Associated sample results with concentrations for these compounds less than 10 times those in the field blanks are considered unusable and flagged "B."

- VOC calibration outliers were identified for methylene chloride (EL557, EL558, EP342-EP344, EP349-EP354) and acetone (EL557, EL558, EP339, EP348, EP369, EP375, EP376). Methylene chloride and acetone results for these samples have been flagged as estimated (J).

- SVOC calibration outliers were identified for bis(2-ethylhexyl)phthalate (EP341, EP348, EP369, EP372), indeno(1,2,3-cd)pyrene (EP341, EP348, EP356-EP358, EP354, EP360), and benzoic acid (EP341, EP348, EP356-EP358, EP354, EP360, EP369, EP372). The results for these compounds are considered estimated (J).

- Two or more SVOC surrogate recoveries were below control limits but greater than 10 percent for samples EP340, EP339, and EP352. The results for these samples are considered estimated (J).

- Samples EP343, EP347, EP350, and EP354 had at least two surrogate recoveries below 10 percent. The positive results for these samples are considered estimated (J) while the negative results are considered unusable (R).

Medium Concentration Soil

Nine soil samples, including one field duplicate, were analyzed for medium concentration organic compounds by Nanco Laboratory (SAS Nos. 3155 I01-I09). Results are presented in Table B-20 and qualified as follows:

- Methylene chloride was measured in the method blank at 0.7 µg/kg. Any methylene chloride data less than 10 times the blank concentrations are considered unusable and flagged "B."

- Due to calibration outliers, methylene chloride, 1,2-dichloroethane, acetone, 2-chlorophenol, 2-methylnaphthalene, pyrene, and dieldrin in all samples and phenanthrene in samples I01-I08 should be considered estimated and are flagged "J."

Low Detection Limit PAHs

Forty-eight soil samples, including several sets of field duplicates and two field blanks, were analyzed for low concentration PAHs by Hittman Ebasco Associates, Inc. (SAS Nos. 3330 E01-E48). The results are presented in Tables B-21 to B-23. Due to several analytical or QA/QC difficulties, some of the data should be considered unusable; the rest should be considered estimated. Data qualifications are summarized as follows:

- Indeno(1,2,3-cd)pyrene (75 to 130 µg/kg), dibenzo(a,h)anthracene (110 µg/kg), and benzo(g,h,i)perylene (70 to 120 µg/kg) were measured in laboratory blanks. Sample concentrations less than five times blank concentrations for these compounds in associated samples are considered unusable and flagged "B."

- The surrogate spike compounds specified by the SAS were not used in samples E01 through E15, and the surrogate compounds that were used did not include any PAH compounds. Also, surrogate spikes in samples E16 through E48 were added at 30 times the concentration specified by the SAS. Since there are no useful surrogate recovery data for any of the samples, all usable data should be considered estimated (J).

- Data are reported for samples E20, E23, E25, E28, E33, and E46, both undiluted and after diluting by a factor of 10 or 20. Only diluted results are reported for E21, E24, E26 and E45. No reason was given in the data review of laboratory case narrative for the dilutions. Pending an explanation from the laboratory, the undiluted data should be used where both undiluted and diluted sample data are reported. Compounds measured in samples after dilution that were not detected before dilution include: pyrene, chrysene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene in sample E20DL; fluoranthene and pyrene in sample E23DL; phenanthrene, anthracene, and benzo(g,h,i)perylene in sample E25DL; phenanthrene, fluoranthene, pyrene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, perylene, and indeno(1,2,3-cd)pyrene in sample E28DL; and chrysene in E46DL. These data are all considered unusable (R) for the diluted samples as listed.

- Sample E36 was re-analyzed and reported as E36RE, although no reason was given by the laboratory for the re-analysis. Pending an explanation from the laboratory, data from E36 should be used rather than E36RE.

- o Benzo(a)pyrene and perylene were not separated by the laboratory chromatographic analysis, and often the same concentration was reported separately for both in one sample. These data are probably from a single peak and should be reported as benzo(a)pyrene plus perylene.

- o Data for sample E11 were not listed on the laboratory form. It is not known whether any PAHs were detected in this sample. (Further information from the laboratory was requested but has not yet been received.)

- o Poor reproducibility in field duplicates and matrix spike duplicates were apparent for most of the target PAHs. Several calibration outliers were also reported, involving most of the undiluted and all of the diluted samples. These results support the qualification of all usable data as estimated.

GROUNDWATER SAMPLE RESULTS AND QUALITY CONTROL REVIEW (STEP II)

INORGANIC CONSTITUENTS

Eight groundwater samples from monitoring wells and one field blank were submitted to Rocky Mountain Analytical Laboratory for metals analyses (Case 9571, MER996, MEW308, MEW310, MEW312, MEW314, MEW316, MEW318, MEW320, MEW322). All samples were analyzed by low concentration procedures. The data is presented in Table B-24 and qualified as follows:

- o Calcium (94.4 μg/l) potassium (129.0 μg/l), zinc (6.7 μg/l) and lead (4.7 μg/l) were identified in the preparation blanks. Aluminum (80.4 μg/l) calcium (642 μg/l), lead (3.7 μg/l), magnesium (135 μg/l), potassium (125 μg/l) and zinc (11.1 μg/l) were found in the field blank. Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are considered unusable and flagged "B."

- o Spike sample recoveries for antimony (72.4 percent) beryllium (71.2 percent), chromium (74.0 percent), silver (50.0 percent) and selenium (27 percent) indicate a low bias. All antimony, beryllium, chromium and silver data are considered estimated (J). All the nondetected results for selenium are considered unusable and flagged "R."

- o Duplicate results for cadmium (200 RPD) and silver (23.2 RPD) are beyond the control limits and these data are considered estimated (J).

- o Due to interference effects, the results for arsenic (MER996, MEW310, MEW316, MEW318, MEW 320) and thallium (MER996, MEW308, MEW310, MEW316, MEW318), MEW320) are considered estimated (J).

Nineteen groundwater samples from monitoring wells and one field blank were submitted to Rocky Mountain Analytical Laboratory for metals analysis and nineteen filtered groundwater samples and one filtered field blank for metals and cyanide analyses (Case 9542, MER926-962, MER964, MER965, MER971). All samples were analyzed by low concentration procedures. The results are presented in Tables B-24 and B-25 and qualified as follows:

Unfiltered samples (MER 926-962, even numbered, MER 964)

- Antimony (42.8 µg/l) was reported in the initial calibration blank and potassium (57.2 µg/l) was reported in the preparation blank. Aluminum (86.3 µg/l), barium (2.0 µg/l), calcium (499 µg/l), iron (73.4 µg/l), and potassium (48.5 µg/l) were found in the field blank. Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are considered unusable and flagged "B."

- Spike sample recoveries for antimony (39.2 percent), selenium (0 percent) and silver (37.2 percent) indicate a low bias. All antimony, and silver results are considered estimated (J). All the nondetected results for selenium are considered unusable and flagged "R."

- Duplicate results for zinc (22.5 RPD) are beyond the control limits and the data are considered estimated (J).

- The percent difference after serial dilution for barium are beyond the control limits and all barium results are considered estimated (J).

- Due to interference effects, the results for arsenic (MER939), lead (MER944) and thallium (MER926-942, even numbered, MER946-956, even numbered and MER960-964, even numbered) are considered estimated (J).

Filtered samples (MER926-962, odd numbered, MER965, MER971)

- Antimony (45.7 µg/l) and potassium (16.8 µg/l) were identified in the initial calibration blanks. Aluminum (103 µg/l), calcium (570 µg/l), iron (83.0 µg/l) and zinc (6.3 µg/l) were found in the field blank. Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are considered unusable and flagged "B."

- Spike sample recovery for silver (41.8 percent) indicates a low bias and all silver data is considered estimated (J).

- Duplicate results for lead (200 RPD) and vanadium (200 RPD) one beyond the control limits and these data are considered estimated (J).

- Due to interference effects, the results for lead (MER941, MER957), selenium (MER927, MER929, MER937, MER939, MER941, MER951, MER953, MER959, MER961, MER965, MER971) and thallium (MER927-933, odd numbered, MER937-943, odd numbered, MER951-

957, odd numbered, MER961, MER965, MER971) are considered estimated (J).

Eight filtered groundwater samples from monitoring wells and one field blank were submitted to Rocky Mountain Analytical Laboratory for metals and cyanide analyses (Case 9571, MER997, MEW309, MEW311, MEW313, MEW315, MEW317, MEW319, MEW321, MEW323). All samples were analyzed by low concentration procedures. The results are presented in Table B-25 and qualified as follows:

- o Zinc (12.6 μg/l) and lead (4.4 μg/l) were reported in the preparation blanks. Antimony (55.1 μg/l) was found in the initial calibration blank. The field blank was found to have aluminum (182 μg/l), barium (35.1 μg/l), calcium (878 μg/l), iron (108 μg/l), magnesium (146 μg/l), and zinc (7.2 μg/l). Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are considered unusable and flagged "B."

- o Spike sample recoveries for silver (51.8 percent) and lead (63.5 percent) indicate a low bias and all silver and lead data are considered estimated (J).

- o Duplicate results for lead (25.4 RPD) are beyond the control limits, and these data are considered estimated (J).

Seventeen groundwater samples from monitoring wells and two field blanks were submitted to Rocky Mountain Analytical Laboratory for metals analysis and seventeen filtered groundwater samples and two filtered field blanks for metals and cyanide analysis (Case 9542, MEW300-307, MER963, MER966-970, MER972-977, MER980-995, MER998, MER99). All samples were analyzed by low concentration procedures. The results are presented in Tables B-24 and B-25 and qualified as follows:

Unfiltered samples (MEW300-307, even numbered, MER966-970, even numbered, MER972-977, even numbered, MER980-955, even numbered, MER998).

- o Calcium (137 μg/l), copper (9.5 μg/l), and zinc (12.1 μg/l), were identified in the preparation blanks. Aluminum (67.5 μg/l), calcium (567 μg/l), copper (7.2 μg/l), lead (5.6 μg/l), magnesium (129 μg/l), potassium (55.5 μg/l), sodium (2180 μg/l), and zinc (5.6 μg/l) were reported in the field blanks. Field blanks from Case 9542 above also apply to some samples in this group. Samples associated with these blanks which contain these contaminants at concentration less than five times the blank concentration are considered unusable and flagged "B."

- o Surrogate spike recoveries were outside the control limits for aluminum, selenium, and iron. Aluminum and iron results are considered estimated (J), and selenium results are considered estimated (J) for positive results and unusable for nondetected results (R).

- o Due to interference effects, results for lead (MER988), selenium (MER966, MER968, MER988, MER304, MER306), and thallium

(MER966-974 even numbered, MER980-995, even numbered, and MEW300-307, even numbered) are considered estimated.

Filtered samples (MEW300-307, odd numbered, MER963, MER966-970, odd numbered, MER972-977, odd numbered, MEW980-955 odd numbered, and MER995).

- o Calcium (156 µg/l), copper (11.3 µg/l), magnesium (120 µg/l), and zinc were found in the preparation blanks. Aluminum (49.8 µg/l), barium (31 µg/l), calcium (905 µg/l), copper (8.6 µg/l), lead (7.6 µg/l), magnesium (17.1 µg/l), and zinc (15.2 µg/l) were reported in the field blanks. Field blanks from Case 9542 above also apply to some samples in this group. Samples associated with these blanks which contain the contaminants at concentration less than five times the blank concentrations are considered unusable and flagged "B."
- o Spike sample recovery was outside control limits for silver (49.6 percent), lead (74 percent), and selenium (126 percent). Results for these compounds are considered estimated (J).
- o Method duplicates were outside the control limits for zinc and results for this compound are considered estimated (J).
- o Due to interference effects, results for thallium (MER963, MER967, MER969, MER973, MER975, MER980-995, odd numbered, MER999, MEW300-307, odd numbered), arsenic (MER967, MER969, MER975, MER981, MER983, MER987, MER989, MER993, MER995) and lead (MER977, MER995), are considered estimated.
- o Due to low correlation coefficients, results for lead (MER989) and selenium (MER973, MER975, MER981, MER983, MER989, MER993, MER995, and MER987) are considered estimated (J).

ORGANIC COMPOUNDS

Ten groundwater samples from monitoring wells and one field blank were submitted to PEI Associates, Inc., for analysis of organic compounds (Case 9571, OTR Nos. EW547-556, EW540). EW550 and EW552 were analyzed for VOCs only and EW556 for semi-volatile organic compounds only (SVOCs). All other samples were analyzed for VOCs and SVOCs. All samples were analyzed by low concentration procedures. EW548 was diluted and reanalyzed. The results for these samples are presented in Table B-26 and qualified as follows:

- o 2-butanone was reported in EW550 and EW555 and a laboratory blank but the spectrum was actually 1,2-dichloroethane-d4.
- o 2-methylnaphthalene was reported in EW554 but due to poor spectral matching and poor retention time matching, EW554 was considered unusable and flagged "R" for this compound.
- o 2-hexanone (9 µg/l) and the common laboratory contaminant, acetone (6 to 10 µg/l) were identified in the laboratory blanks. The common

laboratory contaminants, methylene chloride (5 to 13 µg/l) and di-n-butyl phthalate (4 µg/l) were found in the laboratory and field blanks and also chloroform (30 µg/l) was found in the field blanks. Samples associated with these blanks which contain these concentrations at concentrations less than five times the 2-hexanone or chloroform or 10 times the common laboratory contaminant blank concentrations are considered unusable and flagged "B."

- Due to calibration outliers, the results for 2-butanone (all samples) are considered unusable and flagged "R" and for bis(2-ethylhexyl) phthalate (all samples) are considered estimated (J).
- Due to interference effects, the results for 1,2-dichloroethene (EW548) and vinyl chloride (EW548) are considered estimated (J).
- The holding time for VOC analyses for sample EW540 was exceeded by two days. All aromatic compounds in this sample are considered estimated and flagged "J."

Thirty-nine monitoring well groundwater samples and three field blanks were submitted to S-Cubed Laboratory for analyses of organic compounds (Case 9542, OTR Nos. EW503-EW530, EW532-EW539, EW541-EW547). Samples EW535, EW508, EW527 where analyzed for VOCs only. EW542 and EW524 were analyzed for semivolatile organic compounds (SVOCs) only. All other samples were analyzed for VOCs and SVOCs. Sample EW534 was diluted and reanalyzed. All samples were analyzed by low concentration procedures. The results for these samples are presented in Table B-26 and are qualified as follows:

- The common laboratory contaminants methylene chloride (3-8 µg/l) was found in the field and laboratory blanks. Chloroform (32 µg/l) was found in the field blanks. Common laboratory contaminants, acetone (9-22 µg/l) and di-n-butyl phthalate (8 µg/l) were found in the laboratory blanks. Samples associated with these blanks which contain these contaminants at concentrations less than five times the chloroform or ten times the other detected common laboratory contaminants are considered unusable and flagged "B."
- Due to calibration outliers, the results for 2-butanone (EW534, EW535, EW537, EW539, EW541, EW544) are considered unusable (R) for nondetected results and estimated (J) for detected results. Also due to calibration outliers, the results for acetone are considered estimated (J).
- Surrogate spike recoveries were below control limits for more than one SVOC surrogate for EW534 (9 percent, 9 percent) and EW534RE (8 percent, 9 percent). The data are biased low and all SVOC results for these samples are flagged estimated (J) for detected compounds and unusable (R) for undetected compounds. Detection limits may be higher than reported.
- Matrix spike recovery for sample EW515 was very low (0 percent) for 4-Nitrophenol. Results for the unspiked sample were considered estimated (J) by the CRL Reviewer although no SVOCs were detected.

- The holding times for re-extraction for EW534RE was exceeded. All positive results are considered estimated (J).

Low Detection Limit VOCs

Twenty-three groundwater samples from monitoring wells including three sets of duplicates and two sets of triplicates, three field blanks, and one bottle blank were submitted to S-Cubed Laboratory for low concentration VOCs analysis (SAS Nos 3784-E17, E24-E26, E28, E30-E32, E34, E36, E37, E39, E42, E45, E47, E49, E50, E54, E56, E57, E59, E61, E63, E65, E66, E68, E70). A summary of the results is presented in Table B-27. The data are qualified as follows:

- Chloroform (0.004 to 24.3 µg/l), trichloroethene (0.007 to 0.11 µg/l) and tetrachloroethene (0.011 to 0.49 µg/l) were identified in the laboratory, field and bottle blanks. Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are considered unusable and flagged "B."

- Due to calibration outliers, the results for tetrachloroethene (all samples) were considered estimated (J) for positive results and unusable (R) for nondetected results.

- Matrix spike recoveries for Sample E31 were high for vinyl chloride (230, 248 percent) and carbon tetrachloride (149, 190 percent). Results for the unspiked sample were considered estimated (J) by the CRL reviewer, although no carbon tetrachloride was detected.

Fifteen monitoring well groundwater samples including one set of duplicates and four sets of triplicates, one field blank, and one bottle blank were submitted to S-Cubed Laboratory for low concentration VOCs analysis (SAS Nos. 3784-E72, E74, E76, E77, E80, E82, E83, E86, E88, E89, E91, E93-E95, E97-E99). A summary of the results is presented in Table B-27. The data are qualified as follows:

- Chloroform (0.008 to 23.1 µg/l), trichloroethene (0.008 to 0.133 µg/l) and tetrachloroethene (0.017 to 0.317 µg/l) were found in the laboratory, field and bottle blanks. Samples associated with these blanks which contain these contaminants at concentrations less than five times the blank concentrations are flagged "B" and considered unusable.

- Matrix spike recoveries for Sample E93 were out of control limits for vinyl chloride (142-147 percent), and benzene (6-44 percent). Positives in the unspiked sample were considered estimated (J) by the CRL Reviewer.

Low Detection Limit PAHs

Thirty-seven monitoring well groundwater samples including several sets of duplicates and triplicates, and four field blanks were submitted to Datachem Laboratories for low concentration PAH analysis (Case SAS3784, E18-E23, E27, E29, E33, E35, E38, E40-E41, E43, E44, E46, E48, E51-E53, E55-E56, E58, E60, E62, E64, E67, E69, E71, E73, E75, E78, E79, E81, E84, E85, E87, E90, E92, E96, E100). The results are presented in Table B-28. Due to severe analytical or QA/QC difficulties, all nondetected data should be considered unusable (R) and the positive results should be considered estimated (J) except unusable data (B) due to blank contamination. Samples E-46, E90, E92, E96, and E100 were diluted and reanalyzed as quantitative values were out of the range of the standard curve.

Data qualifications are summarized as follows:

- o Naphthalene (1 to 3 ng/l), acenaphthene (0.4 ng/l), fluoranthene (0.2 to 2 ng/l), pyrene (0.1 to 1 ng/l), indeno (1,2,3-cd) pyrene (5 ng/l), phenanthrene (1 ng/l), 1-methylnaphthalene (4 ng/l), and 2-methylnaphthalene (1 ng/l) were measured in the laboratory blanks. Naphthalene (3 to 9 ng/l), phenanthrene (0.7 to 1 µg/l), 1-methylnaphthalene (2 to 6 ng/l) were also found in the field blanks. Sample concentration of these contaminants which are less than five times blank concentrations for these compounds in associated samples are considered unusable and flagged "B."

- o Results for surrogate spike and matrix spike analyses were out of control limits for most of the data. Results support the qualification of all usable data as estimated (J).

- o Holding times from collection to extraction for all samples was exceeded by one day but should not affect the data quality.

- o Poor reproducibility in field duplicates and matrix spike duplicates was apparent for most of the target PAHs. Several calibration outliers were also reported, involving most of the undiluted and the diluted samples. These results support the qualification of all usable data as estimated. All nondetected results are probably unusable (R) with elevated detection limits.

SUBSURFACE SOIL AND SLUDGE SAMPLES RESULTS AND QUALITY CONTROL REVIEW (STEP II)

INORGANIC CONSTITUENTS

Subsurface Soil

Twenty-three subsurface soil samples and two field blanks were submitted to Chemtech Consulting Group for metals and cyanide analysis (Case 9692, MEW324-348). All samples were analyzed by low concentration procedures. The results are presented in Table B-29 and qualified as follows:

- o Spike sample recoveries were out of control limits for antimony, copper, manganese, and thallium. Copper, manganese and thallium data are considered estimated (J) and antimony data are considered unusable (R).

- o The percent difference after serial dilution for vanadium are beyond the control limits and all vanadium results are considered estimated (J).

Sludge

Sixteen sludge samples and one field blank were submitted to JTC Environmental Consultants for metals analysis (Case SAS3249, ITR Nos. MER907, MER909, MER910, MER912-925). All were analyzed by high concentration procedures. All samples were found to be 100 percent solid phase. The results are presented in Table B-30 and qualified as follows:

- Spike sample recoveries for antimony, copper, manganese, nickel, and silver were out of control limits. All antimony, copper and manganese results are considered estimated (J) and all nickel and silver data are considered estimated (J) for positive results and unusable (R) for non-detected results.
- Duplicate results for barium (40 RPD), iron (57 RPD), lead (39 RPD) and silicon (45 RPD) are beyond the control limits usually set for soil samples although no controls have been specified for these SAS analyses and these data are considered estimated (J).
- Laboratory control samples were out of the 80-120 percent control limits generally specified for aqueous samples for beryllium, copper, nickel and sodium and these data are considered estimated (J). No control limits were specified for these SAS analyses.
- Correlation coefficients for selenium (MER923) and sodium (MER910) were out of control, and the selenium and sodium results are considered estimated (J) for these samples.

INCINERATION PARAMETERS IN SOIL AND SLUDGE

Subsurface Soils

Fourteen subsurface soil samples and two field blanks were submitted to Weyerhaeuser Laboratory for incineration parameter analysis including moisture content, ash content, total moisture, percent volatile matter, percent fixed carbon, heating value, and percent carbon, hydrogen, nitrogen, oxygen and sulfur content (Case SAS3784-E101, E102, E107, E110, E113, E119, E121, E123, E125, E130, E135, E138, E142, E145, E149, E151).

Fourteen subsurface soil samples and two field blanks were also submitted to the Weyerhaeuser Laboratory for TOC analyses (Case SAS3784-E104, E108, E109, E111, E114, E115, E120, E122, E126, E131, E136, E139, E143, E146, E150, E152) for TOC analyses. The laboratory was unable to analyze sample E143 for TOC using the method specified as the sample was too oily. The results are presented in Table B-31 and qualified as follows:

- Method duplicates for percent carbon and hydrogen content were out of control limits (>10 percent RPD per SAS protocol) and samples for these analyses are considered estimated (J).

Sludge

Fifteen sludge samples and one field blank were submitted to Versar Laboratory for incineration parameter analysis including moisture content, ash content, percent sulfur and chlorine content, and heating value (SAS3784-E01-E16). Six samples were also analyzed for viscosity. The results are presented in Table B-32 and qualified as follows:

- o Field duplicate sample differences for heating value analyses for E09 and E10 exceed 59,000 Btu/lb (155 percent RPD) and the results for this parameter are considered estimated (J).

ORGANIC COMPOUNDS

Subsurface Soil

Twenty-four subsurface soil samples and two field blanks were submitted to Gulf-South Research Institute for analysis of organic compounds (Case 9629, EW557, EW559-EW583). EW569 was analyzed for VOCs only and EW572 and EW562 were analyzed for SVOCs only. All samples were analyzed by low concentrations procedures. The results are presented in Table B-33 and qualified as follows:

- o The common laboratory contaminants, methylene chloride (4 µg/kg to 91 µg/kg) and acetone (4 µg/kg to 31 µg/kg) were found in the laboratory and field blanks. In addition, toluene (15 µg/kg), also a common laboratory contaminant was found in one field blank. Samples associated with these blanks which contain these contaminants at concentrations less than 10 times the blank concentrations were considered unusable and flagged "B."

- o Due to calibration outliers, the results for 2-Butanone (all samples) were flagged "R," unusable if not detected and "J," estimated for positive results. Also due to calibration outliers, the results for acetone and 4-methyl-2-pentanone (EW567, EW560, EW562-564, EW573-575, EW571, EW579, EW580) are considered estimated (J).

Sludge

Sixteen sludge samples and one field blank were submitted to to S-Cubed Laboratory for analyses of organic compounds including VOCs, SVOCs, and pesticides/PCBs (Case SAS31551, Set 36, OTR Nos. ES595, ES597, ES598, ES600-611), EW501, EW502). All samples were analyzed by high concentrations procedures. The results for these analyses are presented in Table B-34 and qualified as follows:

- o Methylene chloride (0.011 mg/l) was reported in the laboratory blank. No data was affected as all concentrations in the samples were greater than 10 times the methylene chloride concentration in the blanks.

- o Due to calibration outliers, the results for methylene chloride (all samples), acetone (all samples), tetrachloroethene (EW562, ES604, ES598, ES607, EW601), and 2-butanone (all samples) are considered estimated (J), 4-Methyl-2-Pentanone results (ES597, ES610, ES602) are considered unusable (R). Also due to calibration outliers, the results for 4,4'-DDD (all samples) and 4,4'-DDT (all samples) are considered estimated (J) and the results for Endosulfan-I (all samples) and Endosulfan-2 (all samples) are considered unusable (R).

- Surrogate spike recoveries were outside of required control limits for VOCs in ES597, and ES607. Positive VOC results were considered estimated (J) for these two samples.

Low Detection Limit PAHs

Twenty subsurface soil samples and two field blanks were submitted to Data Chem Laboratories for low concentration PAH analysis (Case SAS3784, E103, E105, E106, E112, E116-118, E124, E127-E129, E132-E134, E137, E140, E141, E144, E147, E148, E153, and E154). No positives were detected in the samples. No qualification of the data was necessary. Table B-35 presents the compounds which were analyzed for but not detected.

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GLT932/037.51

Table B-1
TARGET ANALYTE LIST AND CONTRACT REQUIRED QUANTIFICATION LIMITS

Inorganic Target Analyte	Quantification Limit Low Concentration Analysis[a] (µg/l)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5,000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	5
Magnesium	5,000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5,000
Selenium	5
Silver	10
Sodium	5,000
Thallium	10
Vanadium	50
Zinc	20
Cyanide	10

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[a] The quantification limits for samples may be considerably higher depending on the sample matrix. Those for soil are approximately 200 times higher than values listed, in mg/kg units.

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Table B-2 (Page 1 of 4)
TARGET COMPOUND LIST AND
CONTRACT REQUIRED QUANTIFICATION LIMITS

		Quantification Limits Low Concentration Analysis[a,b]	
	CAS Number	Water (µg/l)	Soil/Sediment[c] (µg/kg)
Volatile			
1. Chloromethane	74-87-3	10	10
2. Bromomethane	74-83-9	10	10
3. Vinyl Chloride	75-01-4	10	10
4. Chloroethane	75-00-3	10	10
5. Methylene Chloride	75-09-2	5	5
6. Acetone	67-64-1	10	10
7. Carbon Disulfide	75-15-0	5	5
8. 1,1-Dichloroethene	75-34-4	5	5
9. 1,1-Dichloroethane	75-33-3	5	5
10. 1,2-Dichloroethene (total)	540-59-0	5	5
11. Chloroform	67-77-3	5	5
12. 1,2-Dichloroethane	107-06-2	5	5
13. 2-Butanone	78-93-2	10	10
14. 1,1,1-Trichloroethane	71-55-6	5	5
15. Carbon Tetrachloride	56-23-5	5	5
16. Vinyl Acetate	108-05-4	10	10
17. Bromodichloromethane	75-27-4	5	5
18. 1,1,2,2-Tetrachloroethane	79-34-5	5	5
19. 1,2-Dichloropropane	78-87-5	5	5
20. Cis-1,3-Dichloropropene	10061-02-5	5	5
21. Trichloroethene	79-01-6	5	5
22. Dibromochloromethane	124-48-1	5	5
23. 1,1,2-Trichloroethane	79-00-5	5	5
24. Benzene	71-43-2	5	5
25. Trans-1,3-Dichloropropene	10061-01-6	5	5
26. Bromoform	75-25-2	5	5
27. 2-Hexanone	591-78-6	10	10
28. 4-Methyl-2-pentanone	108-10-1	10	10
39. Tetrachloroethene	127-18-4	5	5
30. Toluene	108-88-3	5	5
31. Chlorobenzene	108-90-7	5	5
32. EthylBenzene	100-41-4	5	5
33. Styrene	100-42-5	5	5
34. Xylenes (total)	133-02-7	5	5
35. Phenol	108-95-2	10	330

Note: Specific quantification limits are highly matrix dependent. The quantification limits listed herein are provided for guidance and may not always be achievable.

[a] Quantification limits listed for soil/sediment are based on wet weight. The quantification limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

[b] Highconcentration Contract Required Quantification Limits (CRQLs) vary, depending on sample dilution.

[c] Medium soil/sediment CRQLs for volatile TCL compounds are 100 times the individual low soil/sediment CRQL; for semivolatile TCL compounds they are 60 times the individual low soil/sediment CRQL.

Table B-2 (Page 2 of 4)

			Quantification Limits Low Concentration Analysis[a]	
Semivolatile (Continued)		CAS Number	Water (ug/l)	Soil/Sediment[b] (ug/kg)
36	bis(2-Chloroethyl)ether	111-44-4	10	330
37.	2-Chlorophenol	95-57-8	10	330
38.	1,3-Dichlorobenzene	541-73-1	10	330
39.	1,4-Dichlorobenzene	106-46-7	10	330
40.	Benzyl Alcohol	100-51-6	10	330
41.	1,2-Dichlorobenzene	95-50-1	10	330
42.	2-Methylphenol	95-48-7	10	330
43.	bis(2-Chloroisopropyl)ether	39638-32-9	10	330
44.	4-Methylphenol	106-44-5	10	330
45.	N-Nitroso-Dipropylamine	621-64-7	10	330
46.	Hexachloroethane	67-72-1	10	330
47.	Nitrobenzene	98-95-3	10	330
48.	Isophorone	78-59-1	10	330
49.	2-Nitrophenol	88-75-5	10	330
50.	2,4-Dimethylphenol	105-67-9	10	330
51.	Benzoic Acid	65-85-0	50	1,600
52.	bis(2-Chloroethoxy)methane	111-91-1	10	330
53.	2,4-Dichlorophenol	120-83-2	10	330
54.	1,2,4-Trichlorobenzene	120-82-1	10	330
55.	Naphthalene	91-20-3	10	330
56.	4-Chloroaniline	106-47-8	10	330
57.	Hexachlorobutadiene	87-68-3	10	330
58.	4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	10	330
59.	2-Metsdhylnaphthalene	91-57-6	10	330
60.	Hexachlorocyclopentadiene	77-47-4	10	330
61.	2,4,6-Trichlorophenol	88-06-2	10	330
62.	2,4,5-Trichlorophenol	95-95-4	50	1,600
63.	2-Chloroanaphthalene	91-58-7	10	330
64.	2-Nitroaniline	88-74-4	50	1,600
65.	Dimethyl Phthalate	131-11-3	10	330
66.	Acenaphthylene	208-96-8	10	330
67.	2,6-Dinitrotoluene	606-20-2	10	330
68.	3-Nitroaniline	99-09-2	50	1,600
69.	Acenaphthene	83-32-9	10	330
70.	2,4-Dinitrophenol	51-28-5	50	1,600

Note: Specific quantification limits are highly matrix dependent. The quantification limits listed herein are provided for guidance and may not always be achievable.

[a] Quantification limits listed for soil/sediment are based on wet weight. The quantification limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

[b] Highconcentration Contract Required Quantification Limits (CRQLs) vary, depending on sample dilution.

[c] Medium soil/sediment CRQLs for volatile TCL compounds are 100 times the individual low soil/sediment CRQL; for semivolatile TCL compounds they are 60 times the individual low soil/sediment CRQL.

Table B-2 (Page 3 of 4)

		Quantification Limits Low Concentration Analysis[a]	
Semivolatile (Continued)	CAS Number	Water (ug/l)	Soil/Sediment[b] (ug/kg)
71. 4-Nitrophenol	100-02-7	50	1,600
72. Dibenzofuran	132-64-9	10	330
73. 2,4-Dinitrotoluene	121-14-2	10	330
74. Diethylphthalate	84-66-2	10	330
75. 4-Chlorophenyl Phenyl ether	7005-72-3	10	330
76. Fluorene	86-73-7	10	330
77. 4-Nitroaniline	100-01-6	50	1,600
78. 4,6-Dinitro-2-methylphenol	534-52-1	50	1,600
79. N-nitrosodiphenylamine	86-30-6	10	330
80. 4-Bromophenyl Phenyl ether	101-55-3	10	330
81. Hexachlorobenzene	118-74-1	10	330
82. Pentachlorophenol	87-86-5	50	1,600
83. Phenanthrene	85-01-8	10	330
84. Anthracene	120-12-7	10	330
85. Di-n-butylphthalate	84-74-2	10	330
86. Fluoranthene	206-44-0	10	330
87. Pyrene	129-00-0	10	330
88. Butyl Benzyl Phthalate	85-68-7	10	330
89. 3,3'-Dichlorobenzidine	91-94-1	20	660
90. Benzo[a]anthracene	56-55-3	10	330
91. Chrysene	218-01-9	10	330
92. bis(2-ethylhexyl)phthalate	117-81-7	10	330
93. Di-n-octyl Phthalate	117-84-0	10	330
94. Benzo[b]fluoranthene	205-99-2	10	330
95. Benzo[k]fluoranthene	207-08-9	10	330
96. Benzo[a]pyrene	50-32-8	10	330
97. Indeno[1,2,3-cd]pyrene	193-39-5	10	330
98. Dibenz[a,h]anthracene	53-70-3	10	330
99. Benzo[g,h,i]perylene	191-24-2	10	330
100. alpha-BHC	319-84-6	0.05	8.0
101. beta-HBC	319-85-7	0.05	8.0
102. delta-BHC	319-86-8	0.05	8.0
103. gamma-BHC (Lindane)	58-89-9	0.05	8.0
104. Heptachlor	76-44-8	0.05	8.0
105. Aldrin	309-00-2	0.05	8.0

Note: Specific quantification limits are highly matrix dependent. The quantification limits listed herein are provided for guidance and may not always be achievable.

[a] Quantification limits listed for soil/sediment are based on wet weight. The quantification limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

[b] Highconcentration Contract Required Quantification Limits (CRQLs) vary, depending on sample dilution.

[c] Medium soil/sediment CRQLs for volatile TCL compounds are 100 times the individual low soil/sediment CRQL; for semivolatile TCL compounds they are 60 times the individual low soil/sediment CRQL.

Table B-2 (Page 4 of 4)

		Quantification Limits Low Concentration Analysis[a]	
Pesticides/PCBs	CAS Number	Water (ug/l)	Soil/Sediment[b] (ug/kg)
106. Heptachlor Epoxide	1024-57-3	0.05	8.0
107. Endosufan I	959-98-8	0.05	8.0
108. Dieldrin	60-57-1	0.10	16.0
109. 4,4'-DDE	72-55-9	0.10	16.0
110. Endrin	72-20-8	0.10	16.0
111. Endosulfan II	33213-65-9	0.10	16.0
112. 4,4'-DDD	72-54-8	0.10	16.0
113. Endosulfan sulfate	1031-07-8	0.10	16.0
114. 4,4'-DDT	50-29-3	0.10	16.0
115. Endrin Ketone	53494-70-5	0.10	16.0
116. Methoxychlor	72-43-5	0.5	80.0
117. Alpha-chlordane	5103-71-9	0.05	80.0
118. gamma-chlordane	5103-74-2	0.05	80.0
119. Toxaphene	8001-35-2	1.0	160.0
120. PCB Arochlor-1016	12774-11-2	0.5	80.0
121. PCB Arochlor-1221	11104-28-2	0.5	80.0
122. PCB Arochlor-1232	11141-16-5	0.5	80.0
123. PCB Arochlor-1242	53469-21-9	0.5	80.0
124. PCB Arochlor-1248	12672-29-6	0.5	80.0
125. PCB Arochlor-1254	11097-69-1	1.0	160.0
126. PCB Arochlor-1260	11096-82-5	1.0	160.0

Note: Specific quantification limits are highly matrix dependent. The quantification limits listed herein are provided for guidance and may not always be achievable.

[a] Quantification limits listed for soil/sediment are based on wet weight. The quantification limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

[b] Highconcentration Contract Required Quantification Limits (CRQLs) vary, depending on sample dilution.

[c] Medium soil/sediment CRQLs for volatile TCL compounds are 100 times the individual low soil/sediment CRQL; for semivolatile TCL compounds they are 60 times the individual low soil/sediment CRQL.

Table B-3
DATA QUALIFIERS

Symbol (Data Flag)	Definition and Explanation
B	Blank Contamination Chemical contaminants were also found in laboratory or field blank. Data were not flagged if sample concentration exceeds blank concentration by at least a factor of 10 for common laboratory contaminants (methylene chloride, acetone, toluene, and phthalate esters), or a factor of 5 for other contaminants. Data not meeting this criterion are flagged and are considered unusable. Data are not corrected by subtracting the blank value.
J	Estimated Value Concentration was above the analytical detection limit but less than CRQL. Or, One or more associated QA/QC parameters were beyond control limits.
R	Unusable Data
N	Compound Identification Not Confirmed Mass spectrum did not confirm compound ID, but CRL reviewer judges compound identification to be accurate.

Notes: All data qualified as estimated are usable at user's discretion.

TABLE B-4
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
RESIDENTIAL WELLS (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	RW-01-03	RW-02-03	RW03-03	RW-04-03	RW-06-03	RW-07-03	RW-08-03	RW-10-03	RW-11-03	RW-12-03
CRL SAMPLE NUMBER:	88HV02556	88HV02558	88HV02559	88HV02551	88HV02553	88HV02555	88HV02550	88HV02547	88HV02554	88HV02549
SMO CASE NUMBER:	8510	8510	8510	8510	8510	8510	8510	8510	8510	8510
ITR NUMBER:	MER 641	MER 650	MER 647	MER 648	MER 646	MER 640	MER 639	MER 637	MER 638	MER 642
LABORTORY:	ALI	ALI	ALI	ALI	ALI	ALI	ALI	ALI	ALI	ALI
DATE SAMPLED:	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87	11/18/87
(ug/l)										
Aluminum	---	---	---	---	---	---	---	---	---	---
Selenuim	---	---	---	1.5 J	---	2.1 J	---	---	1.3 J	---
Arsenic	2.1 J	---	1.9 J	1.5 J	---	---	---	---	---	---
Barium	49 B	39 B	62 B	32 B	26 B	55 B	58 B	50 B	49 B	52 B
Beryllium	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	0.72	---	---	1.2	---	---	0.35 J
Calcium	45100	33500	75100	33200	587 B	20200	80500	96200	39900	66700
Chromium	---	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---
Copper	---	17 B	11 B	20 B	19 B	---	31 B	20 B	11 B	37 B
Iron	66 B	92 B	63 B	172 B	34 B	250 B	167 B	284 B	67 B	113 B
Lead	---	---	0.73 B	2.1 B	0.9 B	---	---	---	1.6 B	1.0 B
Magnesium	24000	12400	31600	12500	117 B	13800	29200	26300	23300	32600
Manganese	282	---	23 B	---	---	10 B	---	36	---	---
Mercury	---	0.80 J	---	0.40 J	---	---	---	---	---	---
Nickel	---	---	---	---	---	---	---	---	---	---
Potassium	---	---	---	---	---	---	---	---	---	---
Selenium	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---
Sodium	8760	6420	9520	6800	157000	13200	39200	13700	14300 J	29700
Thallium	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---	---	---	---	---
Zinc	252	64	24 B	48 B	17 B	14 B	41 B	55	217	46 B
Cyanide	---	2.6 J	---	---	2.6 J	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination

TABLE B-4
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
RESIDENTIAL WELLS (STEP I)
INORGANIC DATA

SAMPLE LOCATION:	RW-13-03	RW-14-03	RW-15-03	FIELD BLANK
CRL SAMPLE NUMBER:	88HV02552	88HV02557	88HV02560	88HV02546
SMO CASE NUMBER:	8510	8510	8510	8510
ITR NUMBER:	MER 649	MER 643	MER 645	MER 644
LABORTORY:	ALI	ALI	ALI	ALI
DATE SAMPLED:	11/18/87	11/18/87	11/18/87	11/18/87
(ug/l)				
Aluminum	---	---	---	---
Selenuim	---	---	---	---
Arsenic	---	---	---	---
Barium	65 B	38 B	53 B	36 J
Beryllium	---	---	---	---
Cadmium	---	---	---	---
Calcium	11200	21200	47300	608 J
Chromium	---	---	---	---
Cobalt	---	---	---	---
Copper	14 B	---	70	11
Iron	156 B	58 B	80 B	59 B
Lead	---	---	---	0.62 B
Magnesium	34600	9570	14100	49 B
Manganese	7.1 B	6.3 B	---	---
Mercury	---	---	---	---
Nickel	---	---	---	---
Potassium	---	---	---	---
Selenium	---	---	---	---
Silver	---	---	---	---
Sodium	14100	4190 B	8850	1180
Thallium	---	---	---	---
Vanadium	---	---	---	---
Zinc	206	32 B	47 B	15 B
Cyanide	---	---	---	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination

TABLE B-5
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	MW-01A-03	MW-02A-03	MW-02B-03	MW-02C-03	MW-02E-01	MW-B2-03	MW-03A-03	MW-03B-03	MW-03S-01	MW-84b-03	MW-05A-03	MW-05A-03	MW-05B-01
CRL SAMPLE NUMBER:	88HV02S09	88HV02S39	88HV02S34	88HV02S32	88HV02S40	88HV02S01	88HV02S25	88HV02S26	88HV02S27	88HV02S02	88HV02S42	88HV02D42	88HV02S43
SMO CASE NUMBER:	8413	8510	8413	8413	8510	8510	8413	8413	8413	8510	8510	8510	8510
ITR NUMBER:	MEM 605	MER 628	MER 624	MER 622	MER 629	MEK 995	MER 615	MER 616	MER 617	MEK 996	MER 632	MER 632	MER 634
LABORATORY	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	11/11/87	11/16/87	11/13/87	11/13/87	11/16/87	11/17/87	11/12/87	11/12/87	11/12/87	11/17/87	11/16/87	11/16/87	11/16/87
(ug/l)													
Aluminum	70.1 B	32.8 B	37.8 B	21.4 B	---	24.1 B	29.2 B	26.9 B	27.9 B	---	---	NA	---
Antimony	---	---	---	---	---	---	---	---	---	---	---	NA	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	NA	---
Barium	19 B	197 J	68.8 B	55.7 B	38.8 B	112 B	24.4 B	13.7 B	234	54.4 B	93.3 B	NA	60 B
Beryllium	---	---	---	---	---	---	---	---	---	---	---	NA	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	NA	---
Calcium	48900	89800	24500	27500	29300	81800	27300	23200	72200	41400	82100	NA	98500
Chromium	---	---	---	---	---	---	---	---	---	---	---	NA	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	NA	---
Copper	---	---	---	---	---	13.5 J	---	---	---	11.3 J	---	NA	---
Iron	89.1 J	5790	50.7 J	35.9 J	---	12600	47 J	46.9 J	1090	---	62.7 J	NA	78 J
Lead	1.2 B	---	---	---	---	1.8 B	---	1.1 B	---	---	---	NA	---
Magnesium	14600	31400	11200	11500	9250	28600	13200	11700	27100	20400	29600	NA	39800
Manganese	5.1 B	1010	45.6 B	37.9 B	6.4 B	1080	34.6 B	29.9 B	4750	149	127	NA	64
Mercury	---	---	---	---	---	---	---	---	---	---	---	NA	---
Nickel	---	---	---	---	---	---	---	---	---	7.4 J	---	NA	---
Potassium	614 B	2100 J	888 J	911 J	1680 J	1620 J	1200 J	899 J	3380 J	1460 J	1260 J	NA	1590 J
Selenium	--- R	---	---	---	---	---	---	---	---	---	---	NA	---
Silver	---	---	5.5 J	5 J	---	---	5.1 J	5.9 J	6.5 J	---	---	NA	---
Sodium	7930 B	20000 B	6910 B	6390 B	11200 B	19400 B	10900 B	9380 B	33900	10800 B	7460 B	NA	7500 B
Thallium	---	---	---	---	---	---	---	---	---	---	---	NA	---
Vanadium	5 J	3.6 J	---	---	---	4.8 J	---	---	---	---	---	NA	---
Zinc	---	67.4	74.9	40.9	---	49.7	---	---	57.1	16.8 J	16 J	NA	15.6 J
Sas No. 3330E													
Oil & Grease (mg/l):	---	---	9.2	NA	NA	NA	NA	NA	---	NA	5.5	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated concentration
R - Laboratory data not usable

TABLE B-5
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	MW-05C-03	MW-05E-01	MW-B5-03	MW-06A-03	MW-06C-03	MW-07A-03	MW-07A-03	MW-07B-02	MW-07C-02	MW-07S-01	MW-08A-03	MW-08B-01
CRL SAMPLE NUMBER:	88HV02S06	88HV02S44	88HV02S46	88HV02S12	88HV02S13	88HV02S03	88HV02D03	88HV02S33	88HV02S45	88HV02S84	88HV02S05	88HV02S08
SMO CASE NUMBER	8413	8510	8510	8413	8413	8413	8413	8413	8510	8413	8413	8413
ITR NUMBER:	MEM 495	MER 633	MER 636	MER 600	MER 601	MEK 997	MEK 998	MER 623	MER 635	MEK 999	MEM 494	MEM497
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	11/10/87	11/16/87	11/17/87	11/11/87	11/11/87	11/10/87	11/10/87	11/13/87	11/17/87	11/10/87	11/10/87	11/10/87
(ug/l)												
Aluminum	---	---	---	---	---	---	---	59.5 B	40.1 B	27.4 B	---	---
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	---
Barium	20.4 B	43.8 B	124 B	40.2 B	26.7 B	108 B	107 B	109 B	51.8 B	73.8 B	358	310
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	23600	24800	56600	80700	42500	118000	114000	74900	33000	76000	243000	226000
Chromium	---	---	5.7 J	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	---	---	---	---	---	---	---	---	11.6 J	---	---	---
Iron	---	---	51900	---	---	196	176	64.1 J	38.9 J	40.3 J	242	722
Lead	---	---	1.6 B	1.2 B	---	1.2 B	1 B	3.3 B	1.5 B	2.1 B	1.3 B	1.6 B
Magnesium	14300	13300	18900	24200	13700	46200	43700	28300	12700	29700	86800	101000
Manganese	104	39.4 B	3520	5.3 B	21.5 B	4250	3540	494	24 B	743	609	1860
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	---	---	---	---	---	---	---	---
Potassium	851 J	1260 J	3980 J	1010 J	867 J	1420 J	1510 J	1560 J	1400 J	1450 J	1970 J	3080 J
Selenium	--- R	---	---	--- R	--- R	--- R	--- R	1.2 J	---	--- R	--- R	--- R
Silver	---	---	---	---	---	---	---	5.3 J	---	---	---	---
Sodium	12300 B	16900 B	14100 B	7880 B	5720 B	16300 B	16100 B	13900 B	11500 B	12400 B	14400 B	30300 J
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	2.1 J	2.2 J	3.5 J	2.9 J	2.1 J	4.3 J	3.4 J	2.2 J	---	2.8 J	8.9 J	---
Zinc	89.8	---	46.8	38.5	---	207	167	38.7	26	40.1	90.7	1000
SAS NO. 3330E Oil & Grease (mg/l):	---	NA	18.6	---	---	---	NA	---	NA	---	NA	NA

"---" - Not detected
B - Blank contamination
NA - Not Analyzed
J - Estimated Concentration
R - Laboratory data not usable

TABLE B-5
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
INORGANIC DATA

SAMPLE LOCATION:	MW-09A-02	MW-09B-02	MW-10A-02	MW-10B-02	MW-11A-03	MW-12A-03	MW-12A-03	MW-13A-03	MW-13B-01	MW-13E-01	MW-14A-03	MW-14B-03
CRL SAMPLE NUMBER:	88HV02S22	88HV02S23	88HV02S20	88HV02S21	88HV02S16	88HV02S24	88HV02D24	88HV02S10	88HV02S11	88HV02S14	88HV02S28	88HV02S148
SMO SAMPLE NUMBER:	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8510
ITR NUMBER:	MER 613	MER 613	MER 610	MER 611	MER 602	MER 612	MER 604	MEM 603	MER 607	MEM 500	MER 619	MER 620
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	11/12/87	11/12/87	11/12/87	11/12/87	11/11/87	11/12/87	11/11/87	11/11/87	11/11/87	11/11/87	11/13/87	11/16/87
(ug/l)												
Aluminum	---	---	25 B	---	---	---	47.2 B	31.7 B	---	---	---	---
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	---
Barium	39.2 B	72 B	110 B	108 B	12.4 B	15.1 B	19 B	21.2 B	25.4 B	7 B	128 B	120 B
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	108000	92400	117000	11800	28800	23700	25600	28400	30800	34100	75900	35300
Chromium	---	---	---	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	10 J	---	---	---	---	10.4 J	---	---	---	---	---	---
Iron	31.1 J	---	32.3 J	703	---	61.7 J	128	36.7 J	---	---	---	70.7 J
Lead	1.7 B	1.8 B	1.1 B	7.7	4.2 B	---	1.5 B	1.8 B	---	1.6 B	---	---
Magnesium	33900	32000	70000	102000	10600	8920	9750	11000	10500	12700	31800	16700
Manganese	538	662	766	424	17 B	25.7 B	33.4 B	37 B	24.7 B	56.8 B	597	162
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	8 J	---	---	---	---	---	---	---	---	---
Potassium	931 J	3090 J	2140 J	2680 J	657 J	723 J	887 J	657 J	993 J	734 J	1950 J	1590 J
Selenium	---	---	--- R	--- R	--- R	---	---	--- R	--- R	--- R	---	---
Silver	---	6 J	---	---	---	---	5.9 J	---	---	---	5 J	---
Sodium	25500	21200 B	28800 J	28800 J	5080 B	7950 B	5210 B	8190 B	9420 B	9490 B	11300 B	14600 B
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	2.6 J	3 J	3.6 J	---	---	---	2.6 J	3.3 J	2.4 J	2.2 J	---
Zinc	---	---	---	---	---	---	---	---	---	---	4640	28
Sas No. 3330E												
Oil & Grease (mg/l):	NA	NA	NA	NA	NA	NA	NA	NA	---	---	5.8	---

"---" - Not detected
B - Blank contamination
NA - Not Analyzed
J - Estimated concentration
R - Laboratory data not usable

TABLE B-5
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	MW-14C-02	MW-14S-01	MW-15A-02	MW-15A-02	MW-15B-02	MW-16S-01	MW-17B-01	MW-17E-01	MW-18E-01	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV02S30	88HV02S31	88HV02S37	88HV02D37	88HV02S38	88HV02S17	88HV02S18	88HV02S19	88HV02S36	88HV02S07	88HV02S15	88HV02S41
SMO CASE NUMBER:	8413	8413	8510	8510	8510	8413	8413	8413	8510	8413	8413	8510
ITR NUMBER:	MER 618	MER 621	MER 626	MER 630	MER 627	MER 606	MER 608	MER 609	MER 625	MEM 496	MEM 499	MER 631
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED: (ug/l)	11/12/87	11/13/87	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87	11/11/87	11/16/87	11/10/87	11/11/87	11/16/87
Aluminum	26.9 B	28.2 B	---	---	---	38.5 B	21.3 B	160 J	---	---	31 6 J	---
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	---
Barium	19.5 B	64.1 B	93 B	78.9 B	56.4 B	45.8 B	18.1 B	98.6 B	276	---	---	34.3 J
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	25700	49800	507000	493000	77500	62200	22000	114000	86600	409 J	479 J	1860 J
Chromium	---	---	---	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	---	---	---	---	---	---	---	---	13.4 J	---	---	---
Iron	35.9 J	40.9 J	1940	1630	58.8 J	58 J	---	---	---	---	---	---
Lead	---	1.1 B	---	---	---	---	---	1 B	2.1 B	1.2 J	---	---
Magnesium	12900	13800	175000	170000	25200	16600	14100	---	266	---	---	605 J
Manganese	39.5	295	2970	3060	122	246	35.2 B	---	---	---	---	11.6 J
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	---	7.3 J	---	---	---	---	---	---
Potassium	1040 J	1910 J	2230 J	2290 J	1860 J	1160 J	843 J	20400 J	130000	---	---	126 J
Selenium	---	---	---	---	---	--- R	--- R	---	---	--- R	--- R	---
Silver	5.2 J	5.5 J	---	---	---	---	---	---	---	---	---	---
Sodium	12000 B	15200 B	13900 B	14600 B	8370 B	7790 B	8030 B	87200 J	125000	---	4250 J	---
Thallium	---	---	10 4	---	---	---	---	---	---	---	---	---
Vanadium	---	9 J	2 9 J	2.5 J	2.2 J	4.4 J	---	6.1 J	3.4 J	---	---	---
Zinc	---	15.9 J	29 9	27	---	---	---	---	15.6 J	---	---	---
Sas No.3330E Oil & Grease (mg/l):	NA	8.9	---	NA	---	NA	NA	NA	NA	---	NA	---

"---" - Not detected
B - Blank contamination
NA - Not Analyzed
J - Estimated concentration
R - Laboratory data not usable

TABLE B-6
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
CONVENTIONAL PARAMETERS

SAMPLE LOCATION:	MW-1A-03	MW-2A-03	MW-2B-03	MW-3S-01	MW-5A-03	MW-5A-03	MW-5B-02	85-03	MW-5C-03	MW-6A-03	MW-6C-03	MW-7A-03
CRL NUMBER:	88HV02S09	88HV02S39	88HV02S34	88HV02S27	88HV02S42	88MV02D42	88HV02S43	88HV02S46	88HV02S06	88HV02S13	88HV02S13	88HV02S03
TR NUMBER:	E27/E28	E149/E150	E104/E105	E68/E69	E155/E156	E157/E158	E161/162	E183/E184	E23/E24	E31/E32	E29/E30	E19/E20
LABORATORY:	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC
SAS NUMBER:	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E
DATE SAMPLED:	11/11/87	11/16/87	11/13/87	11/12/87	11/16/87	11/16/87	11/16/87	11/17/87	11/10/87	11/11/87	11/11/87	11/18/87
(mg/l)												
TOTAL SUSPENDED SOLIDS	383	391	290	NA	88	94	51	97	156	940	60	183
ALKALINITY	180	444	181	NA	225	227	256	213	117	254	133	423
COD	14	210	30	74	6.5	---	9.5	231	6.8	---	---	40
TOC	1.3	26	1.7	12	1.4	2.2	2	---	---	2	---	13

"---" - Not detected
NA - Not analyzed

TABLE B-6
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
CONVENTIONAL PARAMETERS

SAMPLE LOCATION:	MW-7B-02	MW-7S-01	MW-13E-01	MW-14A-03	MW-14B-03	MW-14S-01	MW-15A-02	MW-15B-02	FIELD BLANK	FIELD BLANK
CRL NUMBER:	88HV02S33	88HV02S04	88HV02S14	88HV02S28	88HV02S29	88HV02S31	88HV02S37	88HV02S38	88HV02S07	88HV02S41
TR NUMBER:	E102/E103	E21/E22	E33/E34	E100/E101	E147/E148	E97/E98	E151/E152	E159/E160	E25/E26	E153/E154
LABORATORY:	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC	CENTEC
SAS NUMBER:	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E	3449E
DATE SAMPLED:	11/13/87	11/10/87	11/11/87	11/13/87	11/16/87	11/13/87	11/16/87	11/16/87	11/10/87	11/16/87
(mg/l)										
TOTAL SUSPENDED SOLIDS	13	3110	10	8	3	8	295	9	2	---
ALKALINITY	213	218	138	335	184	187	776	194	---	---
COD	11	19	---	15	12	15	270	9.3	8.5	7.70
TOC	2.4	3.2	---	5.6	4.2	---	21	1.4	---	---

"---" - Not detected
NA - Not analyzed

TABLE 8-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	MW-05C-03	MW-05E-01	MW-08S-03	MW-06A-03	MW-06C-03	MW-07A-03	MW-07A-03	MW-07B-02	MW-07C-02	MW-07S-01	MW-08A-03	MW-08B-01
CRL SAMPLE NUMBER:	88HV02S06	88HV02S44	88HV02S46	88HV02S12	88HV02S13	88HV02S03	88HV02D03	88HV02S33	88HV02S45	88HV02S04	88HV02S05	88HV02S08
SMO CASE NUMBER:	8413	8510	8510	8413	8413	8413	8413	8413	8510	8413	8413	8413
OTR NUMBER:	EP 395	EQ 136	EQ 139	EQ 215	EQ 103	EP 391	EP 392	EQ 125	EQ 138	EP 393	EP 394	EQ 211
LABORATORY:	SPECT	HAZLE	HAZLE	SPECT	SPECT	SPECT	SPECT	SPECT	HAZLE	SPECT	SPECT	SPECT
DATE SAMPLED:	11/10/87	11/16/87	11/17/87	11/11/87	11/11/87	11/10/87	11/10/87	11/13/87	11/17/87	11/10/87	11/10/87	11/10/87
(UG/l)			(DILUTED 20X)			(VOC DILUTED 20 X)	(VOC DILUTED 50 X)					
VOLATILES ORGANICS:												
Acetone	---	21 B	710	---	---	1100 J	1500	---	14 B	---	---	---
Benzene	---	---	100 J	---	---	3500 J	4600 J	---	---	---	---	---
Methylene Chloride	---	7 J	100 J	---	---	---	---	---	4 B	---	---	---
Vinyl Chloride	---	---	1100	---	---	---	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	2 B	17 B	---	---	---	---	---	3 B	---	---	---
1,1-Dichlorethane	---	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	39 J	---	---	220 J	230 J	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	49 J	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	240	---	---	2000 J	2500	---	---	---	---	---
Toluene	---	2 B	340	---	---	800 J	1300 J	---	1 B	---	---	---
Trans-1,2-Dichlorethene	---	3 J	270	---	---	---	---	---	---	---	---	---
1,1,1-Trichlorethane	---	---	34 J	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANICS:												
Bis(2-Ethylhexyl)Phthalate	3 B	---	---	6 B	6 B	12 B	60 B	1 B	---	3 B	3 B	7 B
2,4-Dimethylphenol	---	---	99	---	---	---	---	---	---	---	---	---
2-methylphenol	---	---	61	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	13 J	---	---	71 J	73	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	---	---
2-methylnaphthalene	---	---	---	---	---	7 J	6 J	---	---	---	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated concentration

TABLE B-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	MW-09A-02	MW-09B-02	MW-10A-02	MW-10B-02	MW-11A-03	MW-12A-03	MW-13A-03	MW-13A-03	MW-13B-01	MW-13E-01	MW-14A-03	MW-14B-03
CRL SAMPLE NUMBER:	88HV02S22	88HV02S23	88HV02S20	88HV02S21	88HV02S16	88HV02S24	88HV02S10	88HV02D10	88HV02S11	88HV02S14	88HV02S28	88HV02S14B
SMO CASE NUMBER:	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8810
OTR NUMBER:	EQ 115	EQ 116	EQ 112	EQ 113	EQ 104	EQ 114	EQ 105	EQ 106	EQ 109	EQ 214	EQ 121	EQ 122
LABORATORY:	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	HAZLE
DATE SAMPLED:	11/12/87	11/12/87	11/12/87	11/12/87	11/11/87	11/12/87	11/11/87	11/11/87	11/11/87	11/11/87	11/13/87	11/16/87
(ug/l)												
VOLATILES ORGANICS:												
Acetone	---	---	---	---	---	---	---	---	8 J	---	---	28 B
Benzene	---	---	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	---	7 B	---	---	---	---	3 B	---	5 B	---	4 B	5 B
Vinyl Chloride	---	---	---	---	---	---	---	---	---	---	44	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---	---	---	---	2 B
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	---	---	---	---	---	---	---	---
Toluene	---	---	---	---	---	---	---	---	---	---	---	1 B
Trans-1,2-Dichloroethene	---	---	---	---	---	---	---	---	---	---	45	2 J
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANICS:												
Bis(2-Ethylhexyl)Phthalate	3 B	---	12 B	10 B	10 B	---	840	3200	10 B	3 B	2 B	---
Diethylphthalate	2 J	---	---	---	---	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated concentration

TABLE 8-7
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
RESIDENTIAL WELLS (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	RW-01-03	RW-02-03	RW-03-03	RW-04-03	RW-06-03	RW-07-03	RW-08-03	RW-10-03	RW-11-03	RW-12-03	RW-13-03	RW-14-03	RW-15-03	FIELD BLANK
CRL SAMPLE NUMBER:	88HV02S56	88HV02S58	88HV02S59	88HV02S51	88HV02S53	88HV02S55	88HV02S50	88HV02S47	88HV02S54	88HV02S49	88HV02S52	88VH02S57	88HV02S60	88HV02S48
SAS NUMBER:	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E	3339E
OTR NUMBER:	EQ144	EQ153	EQ150	EQ151	EQ149	EQ143	EQ142	EQ140	EQ141	EQ145	EQ152	EQ146	EQ148	EQ147
LABORTORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*	*11/18/87*
VOLATILE ORGANIC COMPOUNDS (ug/l)														
Methylene Chloride	1.6 B	1.4 B	1.9 B	1.6 B	2.0 B	1.8 B	2.0 B	2.2 B	1.8 B	1.6 B	2.6 B	2.4 B	1.5 B	1.7 B
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	1.3 J	---
Tetrachlorethene	---	---	---	---	---	---	---	---	---	---	---	---	81	1.2 J
Toluene	1.9 B	1.8 B	2.0 B	2.7 B	1.8 B	2.2 B	2.7 B	1.6 B	2.2 B	1.7 B	1.8 B	1.7 B	2.8 B	3.0
SEMIVOLATILE ORGANIC COMPOUND (ug/l)														
Diethylphthalate	---	2.9 B	---	---	---	---	1.0 B	2.4 B	6.4 B	---	---	1.6 B	---	---
Bis(2-ethylhexyl)phthalate	---	---	---	---	---	1.9 B	1.6 B	---	---	---	---	---	111 B	2.9 B

"---" - Not detected
B - Blank contamination
J - Estimated Concentration

TABLE B-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	MW-01A-03	MW-02A-03	MW-02B-03	MW-02C-03	MW-02E-01	MW-082-03	MW-03A-03	MW-03B-01	MW-03S-01	MW-04B-03	MW-05A-03	MW-05B-01
CRL SAMPLE NUMBER:	88HV02S09	88HV02S39	88HV02S34	88HV02S32	88HV02S40	88HV02S01	88HV02S25	88HV02S26	88HV02S27	88HV02S02	88HV02S42	88HV02S43
SMO CASE NUMBER:	8413	8510	8413	8413	8510	8510	8413	8413	8413	8510	8510	8510
OTR NUMBER:	EQ 107	EQ 130	EQ 126	EQ 124	EQ 131	EP 389	EQ 117	EQ 118	EQ 114	EP 390	EQ 135	EQ 137
LABORATORY:	SPECT	HAZLE	SPEC	SPEC	HAZLE	HAZLE	SPEC	SPEC	SPEC 110	HAZLE	HAZLE	HAZLE
DATE SAMPLED:	11/11/87	11/16/87	11/13/87	11/13/87	11/16/87	11/17/87	11/12/87	11/12/87	11/12/87	11/17/87	11/16/87	11/16/87
(ug/l)												
VOLATILES ORGANICS:												
Acetone	---	---	---	---	2 B	---	---	---	---	17 B	10 B	11 B
Benzene	---	15	---	---	---	1 J	---	---	---	---	---	---
Methylene Chloride	---	3 B	3 B	---	2 B	2 B	5 B	---	---	4 B	5 B	6 B
Vinyl Chloride	---	3 J	---	---	---	---	---	---	---	2 J	3 J	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	0.9 B	0.7 B	---	---	---	3 B	2 B	2 B
1,1-Dichlorethane	---	2 B	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	6	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	2 J	---	---	---	4 J	---	---	---	---	---	2 J
Toluene	3 J	3 B	3 J	---	1 B	2 B	---	---	---	3 B	2 B	3 B
Trans-1,2-Dichlorethene	---	---	---	---	---	---	---	---	---	---	23	4 J
1,1,1-Trichlorethane	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	10	---
SEMIVOLATILE ORGANICS:												
Bis(2-Ethylhexyl)Phthalate	4 B	---	---	2 B	---	10 J	---	---	19 B	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	3 J	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated value

TABLE B-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	MW-05C-03	MW-05E-01	MW-085-03	MW-06A-03	MW-06C-03	MW-07A-03	MW-07A-03	MW-07B-02	MW-07C-02	MW-07S-01	MW-08A-03	MW-08B-01
CRL SAMPLE NUMBER:	88HV02S06	88HV02S44	88HV02S46	88HV02S12	88HV02S13	88HV02S03	88HV02D03	88HV02S33	88HV02S45	88HV02S04	88HV02S05	88HV02S08
SMO CASE NUMBER:	8413	8510	8510	8413	8413	8413	8413	8413	8510	8413	8413	8413
OTR NUMBER:	EP 395	EQ 136	EQ 139	EQ 215	EQ 103	EP 391	EP 392	EQ 125	EQ 138	EP 393	EP 394	EQ 211
LABORATORY:	SPECT	HAZLE	HAZLE	SPECT	SPECT	SPECT	SPECT	SPECT	HAZLE	SPECT	SPECT	SPECT
DATE SAMPLED:	11/10/87	11/16/87	11/17/87	11/11/87	11/11/87	11/10/87	11/10/87	11/13/87	11/17/87	11/10/87	11/10/87	11/10/87
(UG/l)			(DILUTED 20X)			(VOC DILUTED 20 X)	(VOC DILUTED 50 X)					
VOLATILES ORGANICS:												
Acetone	---	21 B	710	---	---	1100 J	1500	---	14 B	---	---	---
Benzene	---	---	100 J	---	---	3500 J	4600 J	---	---	---	---	---
Methylene Chloride	---	7 J	100 J	---	---	---	---	---	4 B	---	---	---
Vinyl Chloride	---	---	1100	---	---	---	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	2 B	17 B	---	---	---	---	---	3 B	---	---	---
1,1-Dichlorethane	---	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	39 J	---	---	220 J	230 J	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	49 J	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	240	---	---	2000 J	2500	---	---	---	---	---
Toluene	---	2 B	340	---	---	800 J	1300 J	---	1 B	---	---	---
Trans-1,2-Dichlorethene	---	3 J	270	---	---	---	---	---	---	---	---	---
1,1,1-Trichlorethane	---	---	34 J	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANICS:												
Bis(2-Ethylhexyl)Phthalate	3 B	---	---	6 B	6 B	12 B	60 B	1 B	---	3 B	3 B	7 B
2,4-Dimethylphenol	---	---	99	---	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	61	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	13 J	---	---	71 J	73	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	7 J	8 J	---	---	---	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated concentration

TABLE B-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
ORGANIC DATA

SAMPLE LOCATION:	MW-09A-02	MW-09B-02	MW-10A-02	MW-10B-02	MW-11A-03	MW-12A-03	MW-13A-03	MW-13A-03	MW-13B-01	MW-13E-01	MW-14A-03	MW-14B-03
CRL SAMPLE NUMBER:	88HV02S22	88HV02S23	88HV02S20	88HV02S21	88HV02S16	88HV02S24	88HV02S10	88HV02D10	88HV02S11	88HV02S14	88HV02S26	88HV02S14B
SMO CASE NUMBER:	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8413	8510
OTR NUMBER:	EQ 115	EQ 116	EQ 112	EQ 113	EQ 104	EQ 114	EQ 105	EQ 106	EQ 109	EQ 214	EQ 121	EQ 122
LABORATORY:	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	SPECT	HAZLE
DATE SAMPLED:	11/12/87	11/12/87	11/12/87	11/12/87	11/11/87	11/12/87	11/11/87	11/11/87	11/11/87	11/11/87	11/13/87	11/16/87
(ug/l)												
VOLATILES ORGANICS:												
Acetone	---	---	---	---	---	---	---	---	8 J	---	---	28 B
Benzene	---	---	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	---	7 B	---	---	---	---	3 B	---	5 B	---	4 B	5 B
Vinyl Chloride	---	---	---	---	---	---	---	---	---	---	44	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---	---	---	---	3 B
1,1-Dichlorethane	---	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	---	---	---	---	---	---	---	---
Toluene	---	---	---	---	---	---	---	---	---	---	---	1 B
Trans-1,2-Dichlorethene	---	---	---	---	---	---	---	---	---	---	45	2 J
1,1,1-Trichlorethane	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANICS:												
Bis(2-Ethylhexyl)Phthalate	3 B	---	12 B	18 B	10 B	---	840	3200	10 B	3 B	2 B	---
Diethylphthalate	2 J	---	---	---	---	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
NA - Not analyzed
J - Estimated concentration

TABLE 8-8
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	MW-14C-02	MW-14S-01	MW-15A-02	MW-15A-02	MW-15B-02	MW-16S-01	MW-17B-01	MW-17E-01	MW-18E-01	FIELD BLANK	FIELD BLANK	FIELD BLANK	BOTTLE BLANK
CRL SAMPLE NUMBER:	88HV02S30	88HV02S31	88HV02S37	88HV02R37	88HV02S38	88HV02S17	88HV02S16	88HV02S19	88HV02S36	88HV02S07	88HV02S15	88HV02S41	88HV02S35
SMO CASE NUMBER:	8413	8413	8510	8510	8510	8413	8413	8413	8510	8413	8413	8510	8510
OTR NUMBER:	EQ 120	EQ 123	EQ 128	EQ 132	EQ129	EQ 108	EQ 110	EQ 111	EQ 127	EQ 210	EQ 213	EQ 133	EQ 134
LABORATORY:	SPECT	SPECT	HAZLE	HAZLE	HAZLE	SPECT	SPECT	SPECT	HAZLE	SPECT	SPECT	HAZLE	HAZLE
DATE SAMPLED:	11/12/87	11/13/87	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87	11/11/87	11/16/87	11/10/87	11/11/87	11/16/87	11/16/87
(ug/l)													
VOLATILES ORGANICS:													
Acetone	---	---	---	7 B	---	---	13 J	---	32 B	---	---	6 B	9 B
Benzene	---	---	---	---	---	4 J	---	---	---	---	---	---	---
Methylene Chloride	---	10 B	3 B	6 B	2 B	3 B	5 B	13 B	34 B	3 B	---	6 B	3 B
Vinyl Chloride	---	6 J	---	---	---	---	---	---	---	---	---	---	---
Chloroethane	---	---	---	1 J	---	---	---	---	---	---	---	---	---
Chloroform	---	---	---	2 B	---	---	---	---	4 B	---	---	2 B	1 B
1,1-Dichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	---	---	---	---	---
4-Methyl-2-Pentanone	---	---	---	---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	---	---	---	---	---	---	---	---	---
Toluene	---	---	1 B	1 B	1 B	---	---	---	3 B	---	---	2 B	1 B
Trans-1,2-Dichlorethene	---	39	---	---	---	---	---	---	---	---	---	---	---
1,1,1-Trichlorethane	---	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---	---
2-Butanone	---	---	---	---	---	---	---	200 J	---	---	---	---	---
SEMIVOLATILE ORGANICS:													
Bis(2-Ethylhexyl)Phthalate	27 B	6 B	---	---	---	5 B	---	660	---	2 B	23 B	---	NA
2,4-Dimethylphenol	---	---	---	---	---	---	---	---	---	---	---	---	NA
2-Methylphenol	---	---	---	---	---	---	---	---	---	---	---	---	NA
Naphthalene	---	---	---	---	---	---	---	---	---	---	---	---	NA
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	---	---	

"---" - Not detected
B - Blank contamination
NA - Not Analyzed
J - Estimated concentration

TABLE 8-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION: CRL SAMPLE NUMBER: SAS NUMBER: LABORATORY: DATE SAMPLED: (ug/l)	MW-1A-03 88HV02S09 3449-E01 SPECTRIX 11/11/87	MW-2A-03 88HV02S39 3449-E129 SPECTRIX 11/16/87	MW-2A-03 88HV02D39 3449-E130 SPECTRIX 11/16/87	MW-2A-03 88HV02T39 3449-E131 SPECTRIX 11/16/87	MW-2B-03 88HV02S34 3449-E116 SPECTRIX 11/13/87	MW-2B-03 88HV02T34 3449-E117 SPECTRIX 11/13/87	MW-2B-03 88HV02D34 3449-E118 SPECTRIX 11/13/87	MW-2C-03 88HV02S32 3449-E110 SPECTRIX 11/13/87
Vinyl Chloride	---	1.0	2.0	5.2	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	6.7	7.0	8.2	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE 8-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION: CRL SAMPLE NUMBER: SAS NUMBER: LABORATORY: DATE SAMPLED: (ug/l)	MW-2C-03 88HV02T32 3449-E111 SPECTRIX 11/13/87	MW-2C-03 88HC02D32 3449-E112 SPECTRIX 11/13/87	MW-02E-01 88HV02S40 3449-E140 SPECTRIX 11/16/87	MW-3A-03 88HV02S25 3449-E80 SPECTRIX 11/12/87	MW-3S-01 88HV02S27 3449-E81 SPECTRIX 11/12/87	MW-5B-01 88HV0243 3449-E144 SPECTRIX 11/16/87	MW-5B-01 88HV02T43 3449-E145 SPECTRIX 11/16/87	MW-5B-01 88HV02D43 3449-E146 SPECTRIX 11/16/87
Vinyl Chloride	---	---	---	---	---	---	0.30	---
Chloroform	0.15 B	0.11 B	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	0.10 B	---

"---" - Not detected
B - Blank contamination

TABLE 8-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-5E-01	MW-5E-01	MW-5E-01	MW-6A-03	MW-6A-03	MW-6A-03	MW-6C-03	MW-7B-02
CRL SAMPLE NUMBER:	88HV02S44	88HV02T44	88HV02D44	88HV02S12	88HV02T12	88HV02D12	88HV02S13	88HV02S33
SAS NUMBER:	3449-E141	3449-E142	3449-E143	3449-E05	3449-E06	3449-E07	3449-E04	3449-E113
LABORATORY:	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX
DATE SAMPLED:	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87	11/11/87	11/11/87	11/13/87
(ug/l)								
Vinyl Chloride	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	0.11 B	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION: CRL SAMPLE NUMBER: SAS NUMBER: LABORATORY: DATE SAMPLED: (ug/l)	MW-7B-02 88HV02T33 3449-E114 SPECTRIX 11/13/87	MW-7B-02 88HV02D33 3449-E115 SPECTRIX 11/13/87	MW-7C-02 88HV02S45 3449-E177 SPECTRIX 11/17/87	MW-7C-02 88HV02D45 3449-E178 SPECTRIX 11/17/87	MW-7C-02 88HV02T45 3449-E179 SPECTRIX 11/17/87	MW-9A-02 88HV02S22 3449-E74 SPECTRIX 11/12/87	MW-9A-02 88HV02T22 3449-E75 SPECTRIX 11/12/87	MW-9A-02 88HV02D22 3449-E76 SPECTRIX 11/12/87
Vinyl Chloride	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-9B-02	MW-9B-02	MW-9B-02	MW-10A-02	MW-10B-02	MW-11A-03	MW-12A-03	MW-13A-03
CRL SAMPLE NUMBER:	88HW02S23	88HW02T23	88HW02D23	88HW02S20	88HW02S21	88HW02S16	88HW02S24	88HW02S10
SAS NUMBER:	3449-E77	3449-E78	3449-E79	3449-E71	3449-E72	3449-E83	3449-E73	3449-E11
LABORATORY:	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX
DATE SAMPLED:	11/12/87	11/12/87	11/12/87	11/12/87	11/12/87	11/11/87	11/12/87	11/11/87
(ug/l)								
Vinyl Chloride	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-13A-03	MW-13A-03	MW-13B-01	MW-13B-01	MW-13B-01	MW-13E-01	MW-13E-01	MW-13E-01
CRL SAMPLE NUMBER:	88HV02T10	88HV02D10	88VH02S11	88HV02D11	88HV02T11	88HV02S14	88HV02T14	88HV02D14
SAS NUMBER:	3449-E12	3449-E13	3449-E16	3449-E18	3449-E17	3449-E08	3449-E09	3449-E10
LABORATORY:	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX
DATE SAMPLED:	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87
(ug/l)								
Vinyl Chloride	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	0.08 B	0.10 B
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION: CRL SAMPLE NUMBER: SAS NUMBER: LABORATORY: DATE SAMPLED: (ug/l)	MW-14A-03 88HV02S28 3449-E107 SPECTRIX 11/13/87	MW-14A-03 88HV02T28 3449-E108 SPECTRIX 11/13/87	MW-14A-03 88HV02D28 3449-E109 SPECTRIX 11/13/87	MW-14B-03 88HV02S29 3449-E126 SPECTRIX 11/16/87	MW-14B-03 88HV02T29 3449-E127 SPECTRIX 11/16/87	MW-14B-03 88HV02D29 3449-E128 SPECTRIX 11/16/87	MW-14C-02 88HV02S30 3449-E83 SPECTRIX 11/12/87	MW-14S-01 88HV02S31 3449-E106 SPECTRIX 11/13/87
Vinyl Chloride	27	---	24	---	0.83	---	---	1.2
Chloroform	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-15A-02	MW-15A-02	MW-15A-02	MW-15B-02	MW-15B-02	MW-15B-02	MW-16S-01	MW-17B-01
CRL SAMPLE NUMBER:	88HW02S37	88HW02T37	88HW02D37	88HW02S38	88HW02T38	88HW02D38	88HW02S17	88HW02S16
SAS NUMBER:	3449-E132	3449-E133	3449-E134	3449-E137	3449-E138	3449-E139	3449-E18	3449-E14
LABORATORY:	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX
DATE SAMPLED:	11/16/87	11/16/87	11/16/87	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87
(ug/l)								
Vinyl Chloride	---	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	0.64	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---
Trichloroethylene	---	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	0.09 B	---	---

"---" - Not detected
B - Blank contamination

TABLE B-9
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-17E-01	MW-18E-01	FIELD BLANK	FIELD BLANK	BTL BLANK
CRL SAMPLE NUMBER:	88HV02S19	88HV02S36	88HV02S15	88HV02S41	88HV02S35
SAS NUMBER:	3449-E70	3449-E125	3449-E02	3449-E135	3449-E136
LABORATORY:	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX	SPECTRIX
DATE SAMPLED:	11/11/87	11/16/87	11/11/87	11/16/87	11/16/87
(ug/l)					
Vinyl Chloride	---	---	---	---	---
Chloroform	0.40	0.7	0.05	0.07 B	---
1,2-Dichloroethane	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---
Trichloroethylene	---	---	---	---	---
Benzene	---	---	0.12	0.7 B	---

"---" - Not detected
B - Blank contamination

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-1A-03	MW-2A-03	MW-2A-03	MW-2A-03	MW-2B-03	MW-2B-03	MW-2B-03	MW-2C-03	MW-2C-03	MW-2C-03	MW-2E-01
CRL SAMPLE NUMBER:	88HV02S09	88HV02S39	88HV02D39	88HV02T39	88HV02S34	88HV02D34	88HV02T34	88HV02S32	88HV02T32	88HV02D32	88HV02S40
SAS NUMBER:	3449-E39	3449-E123	3449-E124	3449-E125	3449-E94	3449-E95(RE)	3449-E96(RE)	3449-E88	3449-E89	3449-E90	3449-E163(RE)
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/11/87	11/16/87	11/16/87	11/16/87	11/13/87	11/13/87	11/13/87	11/13/87	11/13/87	11/13/87	11/16/87
(ng/l)											
Naphthalene	---	---	---	---	---	0.3 B	---	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	0.5 B	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---	---
1-Methylanaphthalene	---	---	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	0.2 J	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-3A-03	MW-3S-01	MW-5B-01	MW-5B-01	MW-5B-01	MW-5E-01	MW-5E-01	MW-5E-01	MW-6A-03	MW-6A-03
CRL SAMPLE NUMBER:	88HW02S25	88HW02S27	88HW02S43	88HW20T43	88HW02D43	88HW02S44	88HW02T44	88HW02D44	88HW02S12	88HW02T12
SAS NUMBER:	3449-E60	3449-E61	3449-E167	3449-E168	3449-E169	3449-E164	3449-E165	3449-E166	3449-E41(RE)	3449-E42
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/12/87	11/13/87	11/16/87	11/16/87	11/16/87	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87
(ng/l)										
Naphthalene	---	---	---	---	---	0.7 B	---	---	0.3 B	---
2-Methylnaphthalene	---	0.9 B	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---
1-Methylnaphthalene	---	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---
Phenanthrene	0.4 J	2.1 J	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---	---
Fluoranthene	0.3 J	2.0 J	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-6A-03	MW-6C-03	MW-7B-02	MW-7B-02	MW-7B-02	MW-7C-02	MW-7C-02	MW-7C-02	MW-9A-02
CRL SAMPLE NUMBER:	88HV02D12	88HV02S13	88HV02S33	88HV02T33	88HV02D33	88HV02S45	88HV02T45	88HV02D45	88HV02S22
SAS NUMBER:	3449-E43	3449-E40(RE)	3449-E91	3449-E92(RE)	3449-E93	3449-E180	3449-E181	3449-E182	3449-E62
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/11/87	11/11/87	11/13/87	11/13/87	11/13/87	11/17/87	11/17/87	11/17/87	11/12/87
(ng/l)									
Naphthalene	---	0.2 B	---	---	---	0.3 B	0.3 B	---	---
2-Methylnaphthalene	---	---	---	---	---	0.2 B	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---
1-Methylanaphthalene	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-9A-02	MW-9A-02	MW-9B-02	MW-9B-02	MW-9B-02	MW-10A-02	MW-10B-02	MW-11A-03	MW-12A-03
CRL SAMPLE NUMBER:	88HV02T22	88HV02D22	88HV02S23	88HV02T23	88HV02D23	88HV02S20	88HV02S21	88HV02S16	898VH02S24
SAS NUMBER:	3449-E63	3449-E64	3449-E65	3449-E66	3449-E67	3449-E57	3449-E58	3449-E39	3449-E59
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/12/87	11/12/87	11/12/87	11/12/87	11/12/87	11/12/87	11/12/87	11/11/87	11/12/87
(ng/l)									
Naphthalene	0.6 B	---	---	0.6 B	---	---	---	0.3 B	---
2-methylnaphthalene	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---
1-methylanaphthalene	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	0.2 J	---
Anthracene	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-13A-03	MW-13A-03	MW-13A-03	MW-13B-01	MW-13B-01	MW-13B-01	MW-13E-01	MW-13E-01	MW-13E-01
CRL SAMPLE NUMBER:	88HV02S10	88HV02T10	88HV02D10	88HV02S11	88HV02T11	88HV02D11	88VH02S14	88VH02T14	88HV02D14
SAS NUMBER:	3449-E47	3449-E48	3449-E49	3449-E51	3449-E52	3449-E53	3449-E44	3449-E45	3449-E46
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87	11/11/87
(ng/l)									
Naphthalene	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---
1-Methylanaphthalene	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-14A-03	MW-14A-03	MW-14A-03	MW-14B-03	MW-14B-03	MW-14B-03	MW-14C-02	MW-14S-01	MW-15A-02
CRL SAMPLE NUMBER:	88HV02S20	88HV02T28	88HV02D28	88HV02S14	88HV02T29	88HV02D29	88HV02S30	88HV02S31	88HV02S37
SAS NUMBER:	3449-E85	3449-E86	3449-E87	3449-E120	3449-E131	3449-E122	3449-E82	3449-E84	3449-E170
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/13/87	11/13/87	11/13/87	11/16/87	11/16/87	11/16/87	11/12/87	11/13/87	11/16/87
(ng/l)									
Naphthalene	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---
1-Methylanaphthalene	---	---	---	---	---	---	---	---	---
Perylene	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	0.5 J	0.3 J	---	---
Anthracene	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE B-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP I)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-15A-02	MW-15A-02	MW-15B-02	MW-15B-02	MW-15B-02	MW-16S-01	MW-17B-01	MW-17E-01	MW-18E-01
CRL SAMPLE NUMBER:	88HW02T37	88HW02D37	88HW02S38	88HW02T38	88HW02D38	88HW02S17	88HW02S18	88HW02S19	88HW02S36
SAS NUMBER:	3449-E171(RE)	3449-E172	3449-E174	3449-E175	3449-E176	3449-E86	3449-E55	3449-E56	3449-E99(RE)
LABORATORY:	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK	SWOK
DATE SAMPLED:	11/16/87	11/16/87	11/16/87	11/16/87	11/16/87	11/11/87	11/11/87	11/11/87	11/16/87
(ng/l)									
Naphthalene	---	---	---	---	---	---	2.4 B	---	0.7 B
2-Methylnaphthalene	---	---	---	0.3 B	---	---	13.2 J	---	0.3 B
Acenaphthylene	---	---	---	---	---	---	---	---	---
1-Methylanaphthalene	---	---	---	0.1 B	---	---	7.4 J	0.9 B	---
Perylene	---	---	---	---	---	---	---	---	---
Acenaphthalene	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	1.1 J	1.3 J	---
Phenanthrene	0.6 J	---	---	---	---	---	2.6 J	---	0.3 J
Anthracene	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	0.4 J	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	0.1 J
Benzo(a) Anthracene	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---
Benzo(b) Fluoranthene	---	---	---	---	---	---	---	---	---
Benzo(a) Pyrene + Perylene	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd) Pyrene	---	---	---	---	---	---	---	---	---
Dibenz(a,h) Anthracene	---	---	---	---	---	---	---	---	---
Benzo(g,h,i) Perylene	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

TABLE 8-10
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP 1)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV02S15	88HV02S41
SAS NUMBER:	3449-E38	3449-E173
LABORATORY:	SWOK	SWOK
DATE SAMPLED:	11/16/87	11/11/87
(ng/l)		
Naphthalene	0.5 JN	0.5 JN
2-methylnaphthalene	0.6 J	0.4 JN
Acenaphthylene	---	---
1-methylnaphthalene	0.4 J	---
Perylene	---	---
Acenaphthalene	---	---
Fluorene	---	---
Phenanthrene	---	---
Anthracene	---	---
Fluoranthene	---	---
Pyrene	---	---
Benzo(a) Anthracene	---	---
Chrysene	---	---
Benzo(b) Fluoranthene	---	---
Benzo(a) Pyrene + Perylene	---	---
Indeno(1,2,3-cd) Pyrene	---	---
Dibenz(a,h) Anthracene	---	---
Benzo(g,h,i) Perylene	---	---

"---" - Not detected
B - blank contamination
J - Estimated concentration
N - Compound identification not confirmed

[redacted]

TABLE B-11
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
HIGH CONCENTRATION SOIL AND SEDIMENT (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	SD87-10-01	SD87-10-01	S087-10-02	S087-10-02	S087-05-01	S087-05-02	S087-19-01	S087-20-01	S087-21-01	S087-21-01	S087-22-01
MATRIX:	SOIL	WATER	SOIL	WATER	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
DEPTH:					(0 - 4')	(5 - 6')	(0 - 6')	(0 - 4')	(0 - 4')	(0 - 4')	(0 - 4')
SAMPLE NUMBER:	88HV02S01	88HV02S01	88HV02S02	88HV02S02	88HV02S03	88HV02S04	88HV02S05	88HV02S06	88HV02S07	88HV02S07	88HV02S08
SAS NUMBER:	3249-101	3249-101	3249-102	3249-102	3249-103	3249-104	3249-105	3249-106	3249-107	3249-108	3249-109
LABORATORY:	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC
DATE SAMPLED:	10/29/87	10/29/87	10/29/87	10/29/87	10/12/87	10/12/87	10/16/87	10/15/87	10/15/87	10/15/87	10/19/87
(mg/kg/dry weight)											
Aluminum	9020	595	3050	459	47000	4290	46200	42800	39100	43600	49600
Antimony	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---
Barium	144	---	---	---	615	---	367	765	319	321	822
Beryllium	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---
Calcium	5440	988	4290	---	16800	5600	20100	14200	17200	15100	22400
Chromium	57	---	---	---	46	---	62	55	60	60	60
Cobalt	---	---	---	---	---	---	---	---	---	---	---
Copper	---	---	---	---	57	---	75	70	74	---	52
Iron	16500 J	1030	4590 J	---	41600 J	4630 J	47000 J	39700 J	49000 J	35500 J	50300 J
Lead	845	---	184	---	1360	82	69	3770	256	177	2280
magnesium	1770	---	---	---	10500	1560	12600	7930	10200	9110	11300
manganese	142	---	76	---	548	134	612	547	690	419	649
mercury	---	---	---	---	---	---	---	---	---	---	---
molybdenum	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	62	---	82	---	46	73	56
Selenuim	---	---	---	---	---	---	---	---	---	---	---
Silicon	35100 J	1290	10900 J	---	253000 J	17700	205000 J	211000 J	200000 J	202000 J	242000 J
Silver	---	---	---	---	---	---	---	---	---	---	---
Sodium	---	---	---	---	10300	---	9910	9690	5330	7780	7800
Thallium	---	---	---	---	---	---	---	---	---	---	---
Titanium	993	---	---	---	6250	---	7420	4430	6620	4860	7810
Vanadium	---	---	---	---	---	---	---	---	---	---	---
Zinc	799	---	168	---	215	---	54	853	94	78	193
%solids	86.5	---	83.1	---	100	100	93.2	100	100	91.3	100

"---" - Not detected
J - Estimated concentration

TABLE B-12
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP I)
INORGANIC DATA

SAMPLE LOC:	S087-05-03	S087-05-04	S087-05-05	S0-05-05	S087-13-01	S087-13-02	S087-13-02	S087-13-03	S087-13-04	S087-20-03	S087-21-03	FIELD BLANK
DEPTH:	(10-16')	(18-20')	(30-39.5')	(30-39.5')	(0-5')	(5-12.5')	(5-12.5')	(30-32')	(33-35.5')	(4-10')	(4-10')	
CRL SAMPLE NUMBER:	88HV01S05	88HV01S04	88HV01S06	88HV01004	88HV01S01	88HV01S02	88HV01R02	88HV01S03	88HV01S07	88HV01S08	88HV01S09	88HV01B01
SMO CASE NUMBER:	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195
ITR NUMBER:	MEI 789	MEI 790	MEI 791	MEM479	MEG 971	MEG 972	MEM 476	MEG 973	MEG 974	MEM 472	MEM 475	MEM 480
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	10/12/87	10/12/87	10/13/87	10/13/87	10/12/87	10/12/87	10/12/87	10/12/87	10/13/87	10/16/87	10/16/87	10/13/87
(mg/kg dry weight)												
Aluminum	10100	9590	7580	8490	12800	10600	11700	6860	8060	9460	8820	77 J
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	6 J	7.6 J	8.9 J	---	---	7.2 J	---	9.6 J	---	---	---
Barium	46 J	22 J	24 J	30 J	88 J	38 J	48 J	30 J	20 J	83 J	40 J	---
Beryllium	---	---	---	---	---	---	---	---	---	0.95 J	0.8 J	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	12300	12900	10600	13900	8390	18100	20700	12600	12700	6660	15600	130 J
Chromium	19	18	17	19	32	17	18	17	21	16	13	---
Cobalt	10 J	9.8 J	9.1 J	8.9 J	---	7.5 J	6.2 J	23 J	7.1 J	8.4 J	5 J	---
Copper	56	45	38	37	47	39	42	62	31	71	44	---
Iron	22800	24800	16500	19000	18300	19100	19700	17500	18800	16000	14500	90 J
Lead	41 J	7.1 J	8.7 J	3.3 J	8.6 J	4.2 J	7 J	---	---	6.2 J	3.2 J	---
Magnesium	7130	6990	5190	6150	4820 J	6450	8010	7600	6060	5090	6370	---
Manganese	352	537	233	292	177	322	367	255	248	240	284	4.9 J
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	26 J	24 J	22 J	22 J	16 J	19 J	24 J	54	30 J	22 J	23 J	---
Potassium	561 J	407 J	460 J	686 J	507 J	642 J	814	406 J	516 J	457 J	518 J	88 J
Selenium	---	---	---	---	---	---	---	---	---	--- R	--- R	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	---	---	650 J	---	---	---	---	---	---	663 J	801 J	---
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	46 J	39 J	37 J	42 J	66	48 J	46 J	22 J	40 J	36 J	34 J	---
Zinc	61 J	54 J	33 J	64 J	73 J	36 J	42 J	392 J	37 J	44	40	2.7 J
Cyanide	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
% Solids	84	86	86	89	81	85	83	89	84	88	88	100

"---" - Not detected
J - Estimated concentration
NR - Analysis not required

TABLE B-13

ARROWHEAD - FIELD WORK DESIGN INVESTIGATION

SEDIMENT (STEP 1)

INORGANIC DATA

SAMPLE LOCATION:	SD87-04-01	SD87-04-02	SD87-05-01	SD87-05-02	SD87-06-01	SD87-06-01	SD87-06-02	SD87-06-02	SD87-08-01	SD87-08-02	SD87-09-01	SD87-09-02
SMO CASE NUMBER:	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350
CRL SAMPLE NUMBER:	88HV01S34	88HV01S35	88HV01S30	88HV01S31	88HV01S28	88HV01D28	88HV01S29	88HV01D29	88HV01S38	88HV01S39	88HV01S40	88HV01S41
ITR NUMBER:	MEM 483	MEM 484	MEM 476	MEM 477	MEM 466	MEM 467	MEM 468	MEM 469	MEM 487	MEM 488	MEM 489	MEM 490
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/29/87	10/29/87	10/29/87	10/29/87
(mg/kg dry weight)												
Aluminum	8820 J	8540 J	6730 J	10700 J	4530 J	9560 J	6160 J	7980 J	5620 J	7660 J	10900 J	4860 J
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	9.9 J	8.8 J	---	---	12 J	5 J	7.2 J	7.2 J	---	18.8	53	---
Barium	55.2 J	53.2 J	68.2 J	142 J	33.2 J	36 J	37.1 J	51.6 J	117 J	90.3 J	268	173 J
Beryllium	0.61 J	0.54 J	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	4400 J	4180 J	7010 J	12600 J	4160 J	6610 J	5000 J	6450 J	5220 J	7030 J	16700 J	17000 J
Chromium	14.8	14.1	---	22.3	10.5 J	16.3	10.8	14.3	17.6	13	91.4	---
Cobalt	10.3 J	10.7 J	---	---	---	15.8 J	8.7 J	10.3 J	---	8.1 J	---	---
Copper	43.5 J	50.3 J	54.7 J	71.3 J	42.8 J	65 J	35.9 J	41.8 J	59.3 J	50.7 J	118 J	---
Iron	15000	15100	17900	17300	11300	19700	11100	12500	18700	17300	77700	76100
Lead	--- R	22.4 R	85.8 R	97.6 R	48.9 R	33.1 R	16.8 R	17.7 R	--- R	--- R	--- R	--- R
Magnesium	4690 J	4520 J	2920 J	4270 J	2670 J	7860	3940 J	4880 J	2500 J	4430 J	2850 J	2260 J
Manganese	1170 J	955 J	1450 J	560 J	930 J	671 J	212 J	272 J	153 J	196 J	445 J	410 J
Mercury	0.56	---	---	---	---	---	---	---	---	---	---	---
Nickel	22.2 J	22.6 J	---	23.6 J	13.2 J	36.4 J	17.8 J	21.9 J	---	17.4 J	52.4	---
Potassium	314 J	289 J	---	387 J	233 J	308 J	205 J	241 J	---	287 J	---	---
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	722 J	506 J	---	---	---	---	820 J	---	---	---	---	---
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	26.5 J	25.5 J	21 J	32 J	15.2 J	30.1 J	23.1 J	31.3 J	23.8 J	29.3 J	36.5 J	14.1 J
Zinc	267	237	178	376	128	135	66.3	70.3	453	219	5890	2170
Cyanide	---	---	---	---	---	---	---	---	---	---	---	---
% Solids	70.9	79.1	20.4	25.3	33.3	49.8	64.9	61.1	30.2	53.7	16.6	16.9

"----" - Not detected
B - Blank contamination
J - Estimated concentration
NA - not analyzed
R - Laboratory data not usable

TABLE B-13
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SEDIMENT (STEP 1)
INORGANIC DATA

SAMPLE LOCATION:	SD87-11-01	SD87-11-02	SD87-12-01	SD87-12-02	SD87-13-01	SD87-13-02	SD87-14-01	SD87-14-02	SD87-15-01	SD87-15-02	FIELD BLANK
SMO CASE NUMBER:	8350	8350	8350	8350	8350	8350	8195	8195	8195	8195	8350
CRL SAMPLE NUMBER:	88HV01S32	88HV01S33	88HV01S36	88HV01S37	88HV01S26	88HV01S27	88HV01S24	88HV01S25	88HV01S22	88HV01S23	88HV01S44
ITR NUMBER:	MEM 481	MEM 482	MEM 485	MEM 486	MEM 464	MEM 465	MEM 462	MEM 463	MEM 460	MEM 461	MEM 493
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	10/28/87	10/28/87	10/28/87	10/28/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/29/87
(mg/kg dry weight)											
Aluminum	13400 J	6160 J	7530 J	7300 J	6790 J	7570 J	22500	12100	17600	17800	50.4 J
Antimony	---	---	---	---	---	---	---	---	---	---	---
Arsenic	18.9	---	9.6 J	11.1 J	---	---	12.6	7.1 J	15.9	21.1	---
Barium	95.7 J	48.3 J	114 J	50.8 J	54.1 J	61.8 J	112 J	61.9 J	87.2 J	106	0.75 J
Beryllium	---	---	---	0.42 J	---	---	---	---	0.81 J	0.59 J	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---
Calcium	6950 J	9890 J	5050 J	6390 J	6240 J	7250 J	16400 J	8400 J	3070 J	6460 J	69.1 J
Chromium	23.6	12.3 J	16	13.2	19.9	19.2	36	18.7	37.7	28.1	---
Cobalt	12.3 J	---	15.4 J	10 J	---	---	---	7.2 J	11.6 J	7.5 J	---
Copper	76.8 J	35.3 J	55.3 J	60.6 J	62.7 J	34.7 J	104 J	60.4 J	48 J	62.5 J	---
Iron	19100	10600	30300	15900	7430	7970	30800	17600	30700	21300	83.5 J
Lead	85.5 R	9.2 R	60.1 R	15.3 R	15.6 R	15.9 R	31.1 J	16.9 J	10.3 J	<8.3	1.4 J
Magnesium	4750 J	2960 J	4680 J	4970 J	2220 J	2370 J	7500	4380 J	4260 J	4470	---
Manganese	1350 J	715 J	3170 J	700 J	80.5 J	102 J	294	183	370	272	4.7 J
Mercury	---	---	---	---	---	---	---	---	---	---	---
Nickel	27.1 J	---	25 J	21.8 J	13.9 J	11.5 J	38.3 J	25 J	26.7 J	27	---
Potassium	424 J	---	339 J	347 J	176 J	169 J	826 J	430 J	305 J	532 J	31.5 J
Selenium	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---
Sodium	---	---	---	616 J	---	---	---	---	969 J	1210 J	---
Thallium	---	---	---	---	---	---	---	---	---	---	---
Vanadium	41.4 J	23 J	30.4 J	25.8 J	24.9 J	24 J	78	41.4 J	76.8	49.7 J	---
Zinc	199	45.1	1350	188	39.7	38.7	102	51.5	40.6	79	---
Cyanide	---	---	---	---	---	---	1.7 J	---	---	---	---
% Solids	43.3	29.3	39.6	79.1	39.1	40.3	29.3	43.8	81.9	67.3	99.9

"----" - Not detected
B - Blank contamination
J - Estimated concentration
NA - not analyzed
R - Laboratory data not usable

TABLE B-14
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SURFACE SOIL (STEP 1)
INORGANIC DATA

SAMPLE LOC:	SS87-09-01	SS87-10-01	SS87-12-01	SS87-13-01	SS87-14-01	SS87-15-01	SS87-16-01	SS87-17-01	SS87-18-01	SS87-19-01	SS87-20-01	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S13	88HV01S12	88HV01S15	88HV01S17	88HV01S16	88HV01S18	88HV01S20	88HV01S19	88HV01S11	88HV01D10	88HV01S14	88HV01S21
SMO CASE NUMBER:	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195
ITR NUMBER:	MEG970	ME1721	MEG976	MEG978	MEG977	MEG979	MEM458	MEM457	ME1792	ME1787	MEG975	MEM459
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	10/26/87	10/26/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/26/87	10/26/87	10/26/87	10/27/87
(mg/kg dry weight)												
Aluminum	5650	5540	4700	8330	7860	4890	11600	4610	4680	10100	18200	67 J
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	15.5	6.7 J	--- J	8 J	---	12.5	10	---	---
Barium	84.3 J	112 J	120 J	339	44.2 J	62.2 J	38.5 J	95.9 J	259	70.7 J	114 J	---.
Beryllium	---	---	---	0.91 J	0.4 J	---	---	---	---	---	---	---
Cadmium	<8.4	<8.8	<8.8	5.4	---	<6.8	---	<8.8	---	---	---	---
Calcium	16600 J	16000 J	23200 J	5380 J	4510	33600 J	8190 J	18300 J	28300 J	4610 J	16100 J	69.9 J
Chromium	---	---	---	19.7	19	---	15.3	---	---	23.4	24.3	---
Cobalt	---	---	---	8 J	7.7 J	---	8.3 J	---	---	10.9 J	---	---
Copper	164 J	---	---	167 J	53.5 J	---	63.4 J	---	---	25.9 J	51.2 J	1.9 J
Iron	11700	15200	5720	41200	22800	8560	22000	12800	18900	20700	21900	91.5 J
Lead	<47 J	<49.6	<49.1	<11.6	<7.2	41.9 J	19.2 J	85.7 J	89.4 J	26.4	23 J	---
Magnesium	2910 J	2610 J	2650	3230 J	5390	3620	5710	2120 J	3680 J	3880 J	4190 J	---
Manganese	245	391	336	167	194	477	296	734	7200	728	338	4.1 J
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	24.5 J	22.7 J	---	23.4 J	---	---	22.2 J	25.5	---
Potassium	---	---	---	279 J	320 J	---	424 J	---	873 J	363 J	451 J	23.9 J
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---		---	---	---	---	---	---	---	---	---
Sodium	---	---		---	764 J	---	1450 J	---	---	---	---	---
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	---	32.5 J	40.2 J	---	39.2 J	---	14.8 J	54.8	48.8 J	0.44 J
Zinc	480	801	260	462	55.3	---	89.2	---	136	44.8	58.8	---
Cynanide	---	---	---	---	---	---	---	---	---	---	---	---
% solids	11.9	11.3	11.4	48.4	77.5	14.8	46.4	11.2	20.8	67.8	24.3	100

"---" - Not detected
J - Estimated concentration

TABLE B-15
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SURFACE SOIL (STEP 1)
INCINERATION PARAMETERS

SAMPLE LOCATION:	SS87-10-01	SS87-13-01	SS87-15-01	SS87-15-01	SS87-17-01	SS87-18-01	SS87-19-01	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S12	88HV01S17	88HV01S18	88HV01D18	88HV01S19	88HV01S11	88HV01S10	88HV01S21
SAS NUMBER:	3330E	3330E	3330E	3330E	3330E	3330E	3330E	3330E
SAMPLE NUMBER:	---/E20	E25/E25	E26/E26	E60/E49	E27/E27	E19/E19	E18/E18	E29/E29
LABORATORY:	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER
DATE SAMPLED	10/26/87	10/27/87	10/27/87	10/27/87	10/27/87	10/26/87	10/26/87	10/27/87
INCINERATOR PARAMETERS:								
Moisture Content (%)	NA	40.2	86.3	86.4	88.5	84.2	29.1	<0.1
Ash Content (%)	NA	85.6	22.6	21.6	19.3	21.4	88.7	100.0
Heating Value (Btu/lb)	NA	1847.0 J	7022.0 J	7107.0 J	7753.0 J	7345.0 J	889.0 J	68.0 J
Carbon Content (%)	NA	9.5	42.9	43.7	44.7	43.3	5.5	<0.1
Hydrogen Content (%)	NA	1.3	4.3	4.2	5.0	4.5	0.8	<0.1
Nitrogen Content (%)	NA	0.2	1.6	1.6	2.8	2.1	0.3	<0.1
Oxygen Content (%)	NA	3.2	28.2	28.5	27.2	28.5	4.7	<0.1
Sulfur Content (%)	NA	0.2	0.5	0.5	1.0	0.3	<0.1	<0.1
TOC (mg/g)	410 J	81.0 J	490.0 J	390.0 J	430.0 J	160.0 J	78.0 J	<1.0 J

J - Estimated concentration
NA - Not analyzed

TABLE B-16
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP 1)
INCINERATION PARAMETERS

SAMPLE LOCATION:	SD87-04-01	SD87-04-01	SD87-05-02	SD87-09-01	SD87-11-01	SD87-12-01	SD87-13-01	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S34	88HV01D34	88HV01S39	88HV01S40	88HV01S32	88HV01S37	88HV01S26	88HV01S44
SMO SAS NUMBER:	8350	8350	8350	8350	8350	8350	8350	8350
ITR NUMBER:	MEM 483	MEM 483	MEM 483	MEM 489	MEM 481	MEM 485	MEM 464	MEM 493
SAS NUMBER:	3330-E53	3330-E55	3330-E40	3330-E57&E61	3330-E42	3330-E52	3330-E34	3330-E58
LABORATORY:	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER
DATE SAMPLED:	10/28/87	10/28/87	10/29/87	10/29/87	10/28/87	10/28/87	10/27/87	10/29/87
Moisture Content (%)	30.0	25.9	78.5	85.3	57.9	43.8	NA	<0.1
Ash Content (%)	97.5	97.3	70.1	29.4	86.2	95.4	NA	100.0
Heating Value (Btu/lb)	123.0 J	152.0 J	3055.0 J	7717.8 J	1141.0 J	384.0 J	NA	57.0
Carbon Content (%)	0.7	0.8	17.1	40.4	6.9	1.7	NA	<0.1
Hydrogen Content (%)	0.2	0.3	2.2	5.0	1.0	0.3	NA	<0.1
Nitrogen Content (%)	<0.1	<0.1	0.8	1.3	0.4	<0.1	NA	<0.1
Oxygen Content (%)	1.6	1.6	9.6	16.2	5.4	2.6	NA	<0.1
Sulfur Content (%)	<0.1	<0.1	0.3	7.7	0.1	<0.1	NA	<0.1
TOC (mg/g)	6.0 J	8.0 J	130.0 J	350.0 J	50.0 J	15.0 J	120 J	<1.0

J - Estimated concentration
NA - Not analyzed
"---" - Not detected
B - Blank contamination
R = Laboratory data not usable

TABLE B-17
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	SD87-04-01	SD87-04-02	SD87-05-01	SD87-05-02	SD87-06-01	SD87-06-01	SD87-06-01	SD87-06-02	SD87-06-02	SD87-06-02	SD87-08-01
CRL SAMPLE NUMBER:	88HV01S34	88HV01S35	88HV01S30	88HV01S31	88HV01S28	88HV01S28	88HV01D28	88HV01S29	88HV01S29	88HV01D29	88HV01S38
SMO CASE NUMBER:	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350
OTR NUMBER:	EP 380	EP 381	EP 373	EP 374	EP 363	EP 363RE	EP 364	EP 365	EP 365RE	EP366	EP384
LABORATORY:	AATS	AATS	E31	E31	E31	E31	E31	E31	E31	E31	AATS
DATE SAMPLED:	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/29/87
VOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)											
Vinyl Chloride	---	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	7 B	10 B	76 B	47 B	43 B	49 B	27 B	22 B	22 B	24 B	260
Acetone	11 J	13	250 J	83 B	39 B	68 B	80 B	270	140 B	60 B	620
Total 1,2-Dichloroethenes	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	---	9 J	---	---	---	---	---	---	---	---
2-Butanone	12 B	11 B	110 B	58 B	17 B	76 B	73 B	93 B	51 B	36 B	150 B
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	38 J
Benzene	---	---	---	---	---	---	---	---	---	---	---
Toluene	79 B	30 B	90	13 B	8 B	8 B	6 B	14 B	14 B	8 B	850
Ethylbenzene		---	---	---	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)											
Phenol	---	---	170 J	110 J	68 J	NA	56 J	---	NA	77 J	---
Diethylphthalate	---	86 J	---	---	---	NA	---	---	NA	---	---
Fluorene	---	---	---	---	---	NA	---	---	NA	62 J	---
N-Nitrosodiphenylamine	---	---	---	---	---	NA	---	---	NA	---	2800 J
Phenanthrene	---	---	350	350	---	NA	---	320 J	NA	350 J	---
Anthracene	---	---	---	---	---	NA	---	59 J	NA	66 J	---
Di-n-Butylphthalate	---	---	---	---	---	NA	---	---	NA	---	---
Fluoranthene	---	---	510	510	54 J	NA	48 J	610	NA	390 J	---
Pyrene	---	---	510 J	340 J	58 J	NA	39 J	350	NA	420 J	---
Butylbenzylphthalate	---	---	---	---	---	NA	---	---	NA	---	---
Benzo(a)Anthracene	---	---	300 J	230 J	---	NA	---	220 J	NA	200 J	---
bis(2-Ethylhexyl)Phthalate	---	110 J	---	290 J	---	NA	---	120 J	NA	---	---
Chrysene	---	---	280 J	250 J	---	NA	---	250 J	NA	210 J	800 J
Benzo(b)Fluoranthene	---	---	240 J	---	---	NA	---	110 J	NA	160 J	---
Benzo(k)Fluoranthene	---	---	240 J	---	---	NA	---	110 J	NA	160 J	---
Benzo(a)Pyrene	---	---	---	160 J	---	NA	---	210 J	NA	180 J	---
Indenol(1,2,3-cd)Pyrene	---	---	---	---	---	NA	---	120 J	NA	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	NA	---	120 J	NA	---	---

"---" - Not Detected
B - Blank Contamination
NA - Not analyzed
J - Estimated concentration

TABLE B-17
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	SD87-08-02	SD87-09-01	SD87-09-02	SD87-11-01	SD87-11-01	SD87-11-02	SD87-11-02	SD87-12-01	SD87-12-02	SD87-13-01	SD87-13-02	SD87-14-01
CRL SAMPLE NUMBER:	88HV01S39	88HV01S40	88HV01S41	88HV01S32	88HV01S32	88HV01S33	88HV01S33	88HV01S36	88HV01S37	88HV01S26	88HV01S27	88HV01S24
SMO CASE NUMBER:	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350	8350	8195
OTR NUMBER:	EP385	EP386	EP387	EP378	EP378RE	EP379	EP379RE	EP382	EP383	EP361	EP362	EP359
LABORATORY:	AATS	AATS	AATS	E31	E31	E31	E31	AATS	AATS	E31	E31	META
DATE SAMPLED:	10/29/87	10/29/87	10/29/87 P. VOCS	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/27/87	10/27/87	10/27/87
VOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)												
Vinyl Chloride	---	800	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	10	370	350	24 B	4 B	38 B	71 B	---	---	63 B	50 B	30 B
Acetone	200	2500	1800	72 B	---	130 B	180 J	97	240	27 B	55 B	70 B
Total 1,2-Dichloroethenes	---	560	---	---	---	---	---	---	---	---	---	---
Chloroform	---	28 B	---	---	---	---	---	---	---	---	---	---
2-Butanone	140 B	1100	530	29 B	53 B	130 B	110 B	24 B	110 B	---	43 B	---
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---
Benzene	---	---	51 J	---	---	---	--	---	---	---	---	---
Toluene	220	810	270	13 B	8 B	640 J	210 J	130	510	10 B	10 B	---
Ethylbenzene	4 J	500	330	---	---	---	---	---	---	---	---	---
Total Xylenes	8	2800	970	---	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)												
Phenol	---	---	---	---	NA	---	NA	---	---	---	82 J	---
Diethylphthalate	---	30000 J	---	---	NA	---	NA	140 J	160 J	---	---	---
Fluorene	---	---	---	---	NA	---	NA	---	---	---	89 J	---
N-Nitrosodiphenylamine	750 J	---	---	---	NA	---	NA	---	---	---	---	---
Phenanthrene	---	---	---	370 J	NA	470 J	NA	240 J	340 J	510 J	840	510 J
Anthracene	---	---	---	64 J	NA	85 J	NA	---	---	91 J	180 J	---
Di-n-Butylphthalate	---	---	---	---	NA	---	NA	---	---	---	---	8100
Fluoranthene	---	---	---	480 J	NA	---	NA	260 J	340 J	810 J	920	---
Pyrene	---	---	---	530 J	NA	450 J	NA	240 J	340 J	540 J	1200 J	640
Butylbenzylphthalate	---	---	---	---	NA	---	NA	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	220 J	NA	250 J	NA	210 J	170 J	310 J	450 J	320 J
bis(2-Ethylhexyl)Phthalate	---	---	---	---	NA	93 J	NA	180 J	230 J	180 J	---	1400
Chrysene	---	---	---	250 J	NA	300 J	NA	170 J	190 J	320 J	470 J	410 J
Benzo(b)Fluoranthene	---	---	---	---	NA	210 J	NA	---	140 J	120 J	350 J	290 J
Benzo(k)Fluoranthene	---	---	---	---	NA	210 J	NA	---	170 J	120 J	360 J	290 J
Benzo(a)Pyrene	---	---	---	190 J	NA	280 J	NA	---	100 J	310 J	---	370 J
Indenol(1,2,3-cd)Pyrene	---	---	---	---	NA	140 J	NA	160 J	---	140 J	---	200 J
Benzo(g,h,i)Perylene	---	---	---	---	NA	120 J	NA	150 J	---	---	---	---

"---" - Not Detected
B - Blank Contamination
NA - Not analyzed
J - Estimated concentration

TABLE B-17
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP I)
ORGANIC DATA

SAMPLE LOCATION:	SD87-14-02	SD87-15-01	SD-87-15-02	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S25	88HV01S22	88HV01S23	88HV01S44
SMO CASE NUMBER:	8195	8195	8195	8350
OTR NUMBER:	EP360	EP357	EP358	EP 391
LABORATORY:	META	META	META	AATS
DATE SAMPLED:	*10/27/87*	*10/27/87*	*10/27/87*	*10/31/87*
VOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)				
Vinyl Chloride	---	---	---	---
Methylene Chloride	23 B	79 B	76 B	---
Acetone	35 B	62 B	---	---
Total 1,2-Dichloroethenes	---	---	---	---
Chloroform	---	---	---	---
2-Butanone	---	---	---	21
1,1,1-Trichloroethane	---	---	---	---
Benzene	---	---	---	---
Toluene	---	---	7 J	8
Ethylbenzene	---	---	---	---
Total Xylenes	---	---	---	---
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)				
Phenol	---	---	---	---
Diethylphthalate	---	---	---	---
Fluorene	---	---	---	---
N-Nitrosodiphenylamine	---	---	---	---
Phenanthrene	470	40 J	730	---
Anthracene	---	---	57 J	---
Di-n-Butylphthalate	3700	5100	5100	---
Fluoranthene	---	---	---	---
Pyrene	630	57 J	850	---
Butylbenzylphthalate	---	47 J	---	---
Benzo(a)Anthracene	290 J	---	300 J	---
bis(2-Ethylhexyl)Phthalate	450 J	530	760	---
Chrysene	370 J	---	411 J	---
Benzo(b)Fluoranthene	290 J	---	220 J	---
Benzo(k)Fluoranthene	290 J	---	270 J	---
Benzo(a)Pyrene	340 J	---	370 J	---
Indeno(1,2,3-cd)Pyrene	88 J	---	200 J	---
Benzo(g,h,i)Perylene	---	---	---	---

"---" - Not Detected
B - Blank Contamination
NA - Not analyzed
J - Estimated concentration

TABLE B-18
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SURFACE SOIL (STEP I)
ORGANIC DATA

SAMPLE LOC:	SS87-09-01	SS87-10-01	SS87-12-01	SS87-13-01	SS87-14-01	SS87-15-01	SS87-16-01	SS87-17-01	SS87-18-01	SS87-19-01	SS87-19-01	SS87-20-01	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S13	88HV01S12	88HV01S15	88HV01S17	88HV01S16	88HV01S18	88HV01S20	88HV01S19	88HV01S11	88HV01S10	88HV01D10	88HV01S14	88HV01S21
SMO CASE NUMBER:	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195
OTR NUMBER:	EP 344	EP 343	EP 350	EP 352	EP 351	EP 353	EP 355	EP 354	EP 342	EL 557	EL 558	EP 349	EP 356
LABORATORY:	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace
DATE SAMPLED:	10/26/87	10/26/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/26/87	10/26/87	10/26/87	10/26/87	10/27/87
VOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)													
Methylene Chloride	---	250 J	---	580 J	100 J	180 J	77 J	470 J	---	210 J	220 J	---	10 B
Acetone	---	---	---	550 J	---	---	190 B	1600 J	---	160 J	110 J	320 J	13 B
Benzene	---	---	---	---	52 J	---	---	---	---	---	---	---	---
Toluene	53 B	28 B	390 J	---	38 B	---	---	---	90	160 J	74 J	840 J	2 J
Total Xylenes	---	---	---	---	75 J	---	---	---	---	---	---	---	---
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)													
Hexachloroethane	---	--- R	--- R	---	---	---	---	300 J	---	---	---	---	---
Benzoic Acid	---	--- R	--- R	---	---	---	---	--- R	370 J	---	170 J	---	---
Naphthalene	---	--- R	--- R	---	2700	---	---	--- R	---	---	---	---	---
2-Methylnaphthalene	---	--- R	--- R	350 J	9000	---	---	--- R	---	---	---	---	---
2-Chloronaphthalene	---	--- R	--- R	990 J	---	---	---	--- R	---	---	---	---	---
Fluorene	---	--- R	--- R	450 J	---	---	---	--- R	---	---	---	---	---
4,6-Dinitro-2-Methylphenol	---	--- R	--- R	3000 J	---	---	---	--- R	---	---	---	---	---
Phenanthrene	---	--- R	--- R	630 J	2400	---	---	--- R	---	---	---	---	---
Di-n-Butylphthalate	2600 B	--- R	--- R	2800 B	3600 B	14000 B	5000 B	2600 B	1200 B	520 B	500 B	4000 B	3000
Fluoranthene	---	--- R	--- R	---	---	19000	---	--- R	2100	600	748	2100	---
Pyrene	---	--- R	--- R	580 J	730	---	---	--- R	---	---	---	210 J	---
Butylbenzylphthalate	---	--- R	--- R	---	---	---	---	--- R	---	---	---	140 J	---
bis(2-Ethylhexyl)Phthalate	3800 B	--- R	--- R	---	1600 B	8000	1300 B	1900 B	13000	640 B	830 B	430 B	470
Chrysene	---	--- R	--- R	---	340 J	---	---	--- R	---	---	---	---	---
Di-n-Octyl Phthalate	---	--- R	--- R	---	---	---	---	--- R	---	---	---	---	170 J
Benzo(k)Fluoranthene	---	--- R	--- R	---	---	520	---	--- R	---	---	---	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable

TABLE B-19
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP 1)
ORGANIC DATA

SAMPLE LOC:	S087-05-03	S087-05-04	S087-05-05	S087-05-05	S087-13-01	S087-13-02	S087-13-02	S087-13-03	S087-13-04	S087-20-03	S087-21-03	FIELD BLANK
DEPTH:	(10-16')	(18-20')	(30-39.5')	(30-39.5')	(0-5')	(5-12.5')	(5-12.5')	(30-32')	(33-38.5')	(4-10')	(4-10')	
CRL SAMPLE NUMBER:	88HV01S05	88HV01S04	88HV01S06	88HV01D04	88HV01S01	88HV01S02	88HV01R02	88HV01S03	88HV01S07	88HV01S08	88HV01S09	88HV01B01
SMO SAMPLE NUMBER:	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195	8195
OTR NUMBER:	EP 339	EP 340	EP 341	EP 376	EP 345	EP 346	EP 375	EP 347	EP 348	EP 369	EP 372	EP 377
LABORATORY:	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace	Meta Trace
DATE SAMPLED:	10/12/87	10/12/87	10/13/87	10/13/87	10/12/87	10/12/87	10/12/87	10/12/87	10/13/87	10/16/87	10/16/87	10/13/87
VOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)												
Methylene Chloride	37 J	87 J	71	41 J	80 J	15 B	24 B	10 B	27 B	16 B	56 J	3 B
Acetone	160 B	33 J	33	120 B	160 B	250 B	130 B	27	68 B	133 B	230 B	---
Total 1,2-Dichloroethene	---	5 J	13	---	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	11 J	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	40	---	---	---	---	---	---	---	---	---
Toluene	5 J	---	8	15 J	---	8 J	4 J	---	4 J	---	---	---
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)												
Isophorone	---	---	---	---	---	---	---	--- R	---	---	1800 J	---
Benzoic Acid	---	---	---	---	---	---	---	--- R	---	120 J	---	---
Naphthalene	---	---	---	---	---	---	---	--- R	---	---	170 J	---
2-Methylnaphthalene	---	---	---	---	---	---	---	--- R	---	---	350 J	---
Phenanthrene	---	---	---	---	---	---	---	--- R	---	98 J	110 J	---
Di-n-Butylphthalate	---	---	180 B	340 B	360 B	720 B	120 B	--- R	91 B	6100 J	4700 J	120 J
Fluoranthene	---	---	---	---	970	---	---	--- R	---	860 J	---	---
Pyrene	---	---	---	---	---	---	---	--- R	---	850 J	160 J	---
bis(2-Ethylhexyl)Phthalate	---	410 B	760 B	---	1100	680 B	500 B	590 B	340 B	2200 J	150 B	81 J
Chrysene	---	---	---	---	66	---	---	--- R	---	140 J	100 J	---
Di-n-Octyl Phthalate	---	---	---	---	---	---	---	--- R	---	1000 J	---	---
Benzo(k)Fluoranthene	---	---	---	---	310 J	---	---	--- R	---	3100 J	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration

TABLE B-20
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
HIGH CONCENTRATION SEDIMENT AND SURFACE SOIL (STEP 1)
ORGANIC DATA

SAMPLE LOCATION:	SD87-10-01	SD87-10-02	SD87-05-01	SD87-05-02	SD87-19-01	SD87-20-01	SD87-21-01	SD87-21-01	SD87-22-01
DEPTH:			(0 - 4')	(5 - 6')	(0 - 6')	(0 - 4')	(0 - 4')	(0 - 4')	(0 - 4')
SAMPLE NUMBER:	88HV02S01	88HV02S02	88HV02S03	88HV02S04	88HV02S05	88HV02S06	88HV02S07	88HV02D07	88HV02S08
SAS NUMBER:	31551-101	31551-102	31551-103	31551-104	31551-105	31551-106	31551-107	31551-108	31551-109
LABORTORY:	NANCO	NANCO	NANCO	NANCO	NANCO	NANCO	NANCO	NANCO	NANCO
DATE SAMPLED:	10/29/87	10/29/87	10/12/87	10/12/87	10/16/87	10/15/87	10/15/87	10/15/87	10/19/87
VOLATILE ORGANIC COMPOUNDS (mg/kg dry weight)									
methylene chloride	19 J	24 J	19 J	21 J	20 J	22 J	18 J	21 J	3.6 B
1,2,-Dicloroethane	---	---	---	310 J	---	---	---	---	87 J
Trichlorethene	---	---	---	58	---	---	---	---	---
Toluene	---	---	---	10.1	---	---	---	---	---
Total Xylenes	---	---	---	24	---	---	---	---	76
SEMIVOLATILE ORGANIC COMPOUNDS (ug/kg dry weight)									
2-Chlorophenol	---	---	---	---	---	---	---	---	81 J
1,1-Dichlorobenzene	---	---	---	---	---	---	---	---	45
N-Nitroso-Di-N-Propylamine	---	---	---	---	---	---	---	---	40 J
1,2,4-Trichlorobenzene	---	---	---	---	---	---	---	---	42 J
2-methylnapthalene	17 J	---	---	---	---	---	---	---	---
Acenaphtene	---	---	---	---	---	---	---	---	44
1,2,4-Dinitrotoluene	---	---	---	---	---	---	---	---	57
Phenanthrene	---	---	---	---	---	---	---	---	30 J
Anthracene	---	---	---	---	---	---	---	---	13 J
Fluoranthene	---	---	---	---	---	---	---	---	18 J
Pyrene	---	---	---	---	---	---	---	---	17 J
Dieldrin	---	---	---	---	---	---	---	---	86 J

"---" - Not detected
J - Estimated concentration

TABLE B-21
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SURFACE SOIL (STEP 1)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	SS87-09-01	SS87-10-01	SS87-10-01	SS87-12-01	SS87-12-01	SS87-12-01	SS87-13-01	SS87-13-01	SS87-13-01	SS87-13-01	SS87-14-01
CRL SAMPLE NUMBER:	88HV01S13	88HV01S12	88HV01D12	88HV01S15	88HV01D15	88HV01D15	88HV01S17	88HV01S17	88HV01D17	88HV01D17	88HV01S16
SAS NUMBER:	3330-E21 DL	3330-E20	3330-E20 DL	3330-E23	3330-E23 DL	3330-E23 DL	3330-E25	3330-E25 DL	3330-E46	3330-E46 DL	3330-E24 DL
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/26/87	10/26/87	10/26/87	10/27/87	10/27/87	10/27/87	10/27/88	10/27/87	10/27/87	10/27/87	10/27/88
DILUTION FACTOR:	20	1	10	1	10	20	2	20	2	20	20
(ug/kg dry weight)											
Naphthalene	---	---	---	---	---	---	260 NJ	---	280 NJ	---	2100
2-methylnaphthalene	---	---	---	---	---	---	360 JN	260 JN	430 NJ	250 NJ	8000
Acenaphthylene	---	---	---	---	---	---	24 NJ	---	43 NJ	92 NJ	---
Acenaphthene	---	---	---	---	---	---	26 NJ	---	920 NJ	---	830 NJ
Fluorene	---	---	---	---	---	---	56 NJ	480 JN	25 NJ	---	1100 NJ
Phenanthrene	---	300	---	380	---	---	---	440 R	24000 J	630 NJ	2400
Anthracene	---	---	---	---	960 R	---	---	150 R	21000 NJ	---	---
Fluoranthene	4200 NJ	---	---	---	920 R	790 JN	190 NJ	1100 JN	4800 NJ	1200 J	1200 J
Pyrene	1700 J	---	790 R	---	---	---	600 NJ	950 JN	490 NJ	910 JN	980 NJ
Benzo(a)Anthracene	---	---	---	---	---	---	1400 NJ	---	---	---	560 NJ
Chrysene	870 JN	---	440 R	---	---	---	4300 NJ	2000 JN	---	1000 R	730 NJ
Benzo(b)Fluoranthene	---	2000 JN	1100 NJ	---	---	---	---	---	---	---	---
Benzo(a)Pyrene + Perylene	740 NJ	9000 J	---	420 J	480 NJ	2300 NJ	1600 NJ	---	5800 NJ	410 NJ	---
Indeno(1,2,3-cd)Pyrene	---	6200 NJ	1000 J	---	---	---	2700 NJ	340 NJ	13000 NJ	---	150 NJ
Dibenz(a,h)Anthracene	---	---	1400 R	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	1400 R	---	---	---	---	560 R	17000 NJ	580 JN	300 NJ
1-methylnapthalene	---	---	1200 NJ	---	---	---	420 NJ	280 JN	480 JN	300 NJ	5100

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - laboratory data not usable

TABLE 8-21
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SURFACE SOIL (STEP 1)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	SS87-15-01	SS87-16-01	S87-16-01	SS87-16-01	SS87-17-01	SS87-17-01	SS87-18-01	SS87-19-01	SS87-20-01	SS87-20-01	FIELD BLANK
CRL SAMPLE NUMBER:	88HV01S18	88HV01S20	88HV01S20	88HV01D20	88HV01S19	88HV01D19	88HV01S11	88HV01S10	88HV01S14	88HV01D14	88HV01D20
SAS NUMBER:	3330-E26 DL	3330-E28	3330-E28 DL	3330-E48	3330-E27	3330-E47	3330-E19	3330-E18	3330-E22	3330-E44	3330-E29
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87	10/26/87	10/26/87	10/26/87	10/26/87	10/27/87
DILUTION FACTOR:	20	1	10	1	1	1	1	1	1	1	1
(ug/kg dry weight)											
Naphthalene	---	---	---	---	---	---	---	---	---	---	---
2-methylnaphthalene	---	---	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	530 R	---	---	---	---	---	200	150	---
Anthracene	---	---	---	---	---	---	---	---	---	---	---
Fluoranthene	6200 NJ	---	860 R	---	---	---	---	---	---	---	---
Pyrene	---	---	660 R	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---	---	---	---	---	---	---	---
Chrysene	---	---	490 R	---	360 NJ	---	320 NJ	---	---	---	---
Benzo(b)Fluoranthene	---	---	680 R	---	330 NJ	---	---	---	---	---	---
Benzo(a)Pyrene + Perylene	---	---	370 R	---	810 NJ	920 NJ	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene	---	---	230 R	---	300 NJ	---	---	---	---	---	---
Dibenz(a,h)Anthracene	---	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---	---	---	---
1-methylnapthalene	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - laboratory data not usable

TABLE B-22
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP I)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	S087-05-03	S087-05-03	S087-05-04	S087-05-04	S087-05-05	S087-05-05	S087-13-01	S087-13-01	S087-13-02	S087-13-02	S087-13-03
DEPTH:	(10 - 16')	(10 - 16')	(18 - 20')	(18 - 20')	(30 - 39.5)	(30 - 39.5)	(0 - 5')	(0 - 5')	(5 - 12.5)	(5 - 12.5)	(30 - 32')
CRL SAMPLE NUMBER:	88HV01S05	88HV01R05	88HV01S04	88HV01R06	88HV01S06	88HV01R04	88HV01S01	88HV01R01	88HV01S02	88HV01R02	88HV01R03
SAS NUMBER:	3330-E08	3330-E12	3330-E07	3330-E13	3330-E09	3330-E11	3330-E01	3330-E03	3330-E02	3330-E04	3330-E06
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/12/87	10/12/87	10/12/87	10/12/87	10/13/87	10/13/87	10/12/87	10/12/87	10/12/87	10/12/87	10/12/87
DILUTION FACTOR:	1	1	1	1	1	1	1	1	1	1	1
(ug/kg dry weight)											
Naphthalene	45 J	140	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	86 J	270 J	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---	---
Pryene	---	---	---	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---	---	---	---	---	---	---	---
Chyrsene	---	---	---	---	---	---	---	---	---	---	---
Benzo(b)Fluoranthene	---	---	---	---	---	---	---	---	160 J	---	---
Benzo(a)Pyrene + Perylene	79 J	99 J	---	---	---	---	770 JN	---	---	---	---
Indeno(1.2.3-cd)Pyrene	---	---	---	---	---	---	---	---	---	---	---
Dibenz(a,h)Anthracene	---	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---	---	---	---
1-methylnapthalene	41 JN	130 J	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - Laboratory data not usable

TABLE B-22
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP I)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	S087-13-03	S087-13-04	S087-13-04	S087-20-03	S087-21-03	FIELD BLANK
DEPTH:	(30 - 32')	(33 - 33.5')	(33 - 33.5')	(4 - 10')	(4 - 10')	
CRL SAMPLE NUMBER:	88HV01503	88HV01507	88HV01807	88HV01508	88HV01509	88HV01802
SAS NUMBER:	3330-E05	3330-E10	3330-E14	3330-E16	3330-E17	3330-E15
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/13/87	10/13/87	10/13/87	10/16/87	10/16/87	10/13/87
DILUTION FACTOR:	1	1	1	1	1	1
(ug/kg dry weight)						
Naphthalene	---	---	---	---	400	---
2-methylnaphthalene	---	---	---	---	830	---
Acenaphthylene	---	---	---	---	---	---
Acenaphthene	---	---	---	---	76 JN	---
Fluorene	---	---	---	---	140	---
Phenanthrene	---	---	---	140	260	---
Fluoranthene	---	---	---	160	180	---
Pryene	---	---	---	130	240	---
Benzo(a)Anthracene	---	---	---	---	---	---
Chyrsene	---	---	---	77 J	---	---
Benzo(b)Fluoranthene	---	---	---	89 J	---	---
Benzo(a)Pyrene + Perylene	---	---	---	88 NJ	120 JN	---
Indeno(1,2,3-cd)Pyrene	---	---	---	64 R	70 R	---
Dibenz(a,h)Anthracene	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	78 R	190 R	---
1-methylnapthalene	---	---	16 J	---	940 R	---

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - Laboratory data not usable

TABLE 8-23
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP 1)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	SD87-05-01	SD87-05-02	SD87-06-01	SD87-06-01	SD87-06-01	SD87-06-02	SD87-06-02	SD87-11-01	SD87-11-02	SD87-13-01	SD87-13-02
CRL SAMPLE NUMBER:	88HV01S30	88HV01S31	88HV01S28	88HV01S28	88HV01D28	88HV01S29	88HV01D29	88HV01S32	88HV01S33	88HV01S26	88HV01S27
SAS NUMBER:	3330-E40	3330-E41	3330-E36	3330-E36(RE)	3330-E37	3330-E38	3330-E39	3330-E42	3330-E43	3330-E34	3330-E35
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/28/87	10/28/87	10/27/88	10/27/88	10/28/87	10/28/87	10/28/87	10/28/87	10/28/87	10/27/87	10/27/88
DILUTION FACTOR	1	1	1	1	1	1	1	1	1	1	1
(ug/kg dry weight)											
Naphthalene	---	---	---	---	---	---	---	---	---	---	---
2-methylnaphthalene	---	20 NJ	---	---	---	---	---	31 J	10 JN	---	---
Acenaphthylene	---	17 NJ	---	---	---	---	---	12 J	---	---	---
Acenaphthane	---	76 NJ	---	---	---	---	---	78 J	30 J	---	---
Fluorene	---	92 NJ	---	---	---		52 J	150	62 J	---	---
Phenanthrene	450	670	---	---	150	380	480	1200	470	880	650
Anthracene	120	---	---	---	---	91 J	81 J	190	74 J	.150	130
Fluoranthene	470	1200	94 J	99 J	180	440	340	2000	760	840	500
Pyrene	240 J	790 J	---	---	69 J	240 J	180 J	1100 J	360 J	1000 J	700 J
Benzo(a)Anthrcene	280 NJ	480	---	---	92 J	250	130	840	290 NJ	490	360
Chrysene	350	530	67 J	76 J	110	290	190	600	280	640	490
Benzo(b)Fluoranthene	---	720 NJ	100	87 NJ	160	350	210	1000	400 NJ	750	520
Benzo(a)Pyrene + Perylene	220 NJ	410 NJ	59 NJ	---	90 JN	220 NJ	93 JN	520 NJ	210 NJ	500 NJ	330 NJ
Indeno(1,2,3-cd)pyrene	200	420 NJ	---	---	66 NJ	160	100	440	140 NJ	280	200
Dibenz(a,h)Anthracene	---	---	---	---	---	72 NJ	---	100 NJ	41 NJ	93 NJ	84 NJ
Bezo(g,h,i)perylene	200	390	99 J	---	79 J	160	80 J	500	150	280	200
1-methylnapthalene	---	34 JN	---	---	---	---	---	37 J	16 JN	---	---

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - Laboratory data not usable

TABLE 8-23
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SEDIMENT (STEP I)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	SD87-14-01	SD87-14-02	SD87-14-02	SD87-15-01	SD87-15-02
CRL SAMPLE NUMBER:	88HV01S24	88HV01S25	88HV01S25	88HV01S22	88HV02S23
SAS NUMBER:	3330-E32	3330-E33	3330-E33 DL	3330-E30	3330-E31
LABORATORY:	HITTMAN	HITTMAN	HITTMAN	HITTMAN	HITTMAN
DATE SAMPLED:	10/27/87	10/27/87	10/27/87	10/27/87	10/27/87
DILUTION FACTOR	1	1	10	1	1
(ug/kg dry weight)					
Naphthalene	---	---	---	---	---
2-methylnaphthalene	---	---	---	---	---
Acenaphthylene	---	---	---	---	---
Acenaphthane	---	---	---	---	67 J
Fluorene	150	---	---	---	88 J
Phenanthrene	1400	560	---	99 J	950
Anthracene	250	---	---	---	250
Fluoranthene	1100	540	---	160	630
Pyrene	1500 J	580 J	---	110 J	850 J
Benzo(a)Anthrcene	660	360	---	69 J	490
Chrysene	820	490	---	61 J	600
Benzo(b)Fluoranthene	1000	650	---	94 J	690
Benzo(a)Pyrene + Perylene	710 NJ	390 NJ	---	61 NJ	450 NJ
Indeno(1,2,3-cd)pyrene	360	280	---	---	260
Dibenz(a,h)Anthracene	200	---	---	---	92 J
Bezo(g,h,i)perylene	400	310	---	---	290
1-Methylnapthalene	---	---	---	---	--

"---" - Not detected
J - Estimated concentration
N - Compound identification not confirmed
R - Laboratory data not usable

TABLE B-24
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (UNFILTERED)

SAMPLE LOCATION:	MW-01A-04	MW-02A-04	MW-02B-04	MW-02B-04	MW-02C-04	MW-02E-02	MW-B2-04	MW-B2-04	MW-03A-04	MW-03B-02	MW-03B-02	MW-03S-02
CRL SAMPLE NUMBER:	88HV03S14	88HV03S13	88HV03S10	88HV03D10	88HV03S43	88HV03S04	88HV03S12	88HV03D12	88HV03S25	88HV03S24	88HV03D24	88HV03S31
SMO CASE NUMBER:	9542	9571	9571	9571	9542	9542	9571	9571	9542	9542	9542	9542
ITR NUMBER:	MER 926	MER 996	MEW 312	MEW 314	MER 998	MEW 304	MEW 318	MEW 320	MER 956	MER 946	MER 948	MER 960
LABORATORY	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/02/88	05/10/88	05/10/88	05/10/88	05/04/88	05/05/88	05/10/88	05/10/88	05/03/88	05/03/88	05/03/88	05/03/88
(ug/l)												
Aluminum	13700	2380	129000	121000	46200	3190 J	192 B	108 B	108000	2220	2730	16600
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	6.3 J	---	6.5 J	7.5 J	---	---	---	---	85.4	---	---	6.2 J
Barium	89.4 J	200 J	408	429	140 J	38.1 J	80.2 J	83.3 J	454 J	23.7 J	25.5 J	349 J
Beryllium	---	---	2.8 J	2.9 J	1.4 J	---	---	---	3.2 J	---	---	---
Cadmium	---	---	7.1 J	6.5 J	---	---	---	---	---	---	---	5.5
Calcium	65900	100000	220000	249000	72800	35900	114000	117000	178000	26500	27400	86200
Chromium	26.1	7.6 J	186 J	169 J	73.1	145	---	---	120	11.3	9.8 J	53.2
Cobalt	13.7 J	6.3 J	53.6	52.2	34.0 J	---	---	---	55.4	---	---	27 J
Copper	68.7	31.0	410	411	181	26.6 B	---	---	340	9.3 J	10.7 J	106
Iron	16800 J	9670	138000	120000	47800	4400	13400	13800	124000 J	2550 J	2710 J	45100 J
Lead	3.1 J	2.4 B	19.0 B	24.8	9.2	9.0 B	4.6 B	6.2 B	15.0	---	---	9.1
Magnesium	23000	34800	75700	81400	36300	10600	32200	32000	72200	13400	13800	31600
Manganese	444 J	1360	2350	2500	862	95.7	1820	1940	3070 J	61.3 J	69.7 J	5670 J
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	31.1 J	---	180	172	137	80.1	---	---	154	8.2 J	---	49.7
Potassium	2220 J	1640 J	7600	7330	3280 J	1530 J	1570 J	1580 J	7580	1110 J	1170 J	4730 J
Selenium	--- R	--- R	--- R	--- R	---	---	--- R	--- R	--- R	--- R	--- R	--- R
Silver	---	---	12.1 J	8.2 J	5.9 J	---	---	---	11.7 J	---	---	4.1 J
Sodium	5890	18900	20800	20000	14200	10800	19500	19500	26500	7030	7180	73200
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	37.1 J	18.2 J	336	299	71.6	6.2 J	---	---	279	7.2 J	6.7 J	66.9
Zinc	48.9 J	36.7 B	265	242	160	25.8 B	14.1 B	18.6 B	251	5.3 J	7.8 J	67.0

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-24
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (UNFILTERED)

SAMPLE LOCATION:	MW-08A-04	MW-08B-02	MW-09A-03	MW-09B-03	MW-10A-03	MW-10B-03	MW-11A-04	MW-12A-04	MW-13A-04	MW-13B-02	MW-13E-02	MW-14A-04
CRL SAMPLE NUMBER:	88HV03S21	88HV03S19	88HV03S39	88HV03S33	88HV03S28	88HV03S30	88HV03S22	88HV03S23	88HV03S17	88HV03S20	88HV03S18	88HV03S27
SMO CASE NUMBER	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542
ITR NUMBER:	MER 938	MER 936	MER 972	MER 974	MER 950	MER 954	MER 942	MER 944	MER 932	MER 940	MER 934	MER970
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED: (ug/l)	05/02/88	05/02/88	05/04/88	05/03/88	05/03/88	05/03/88	05/03/88	05/03/88	05/02/88	05/02/88	05/02/88	05/03/88
Aluminum	5580	2490	16700	8400	26100	3630	101000	12300	167000	298 B	204 B	12800
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	3.5 J	---	---	---	10.0	2.7 J	76.4	6.3 J	115	---	---	---
Barium	344 J	358 J	114 J	118 J	252 J	127 J	384 J	70.4 J	619 J	25.2 J	7.5 B	155 J
Beryllium	---	---	---	1.0 J	---	---	3.0 J	---	5.3	---	---	---
Cadmium	---	5.9	---	---	6.2	6.9	---	---	9.8	---	---	---
Calcium	210000	245000	113000	117000	144000	126000	174000	38200	317000	36200	35400	96100
Chromium	37.5	11.6	50.0	18.6	47.1	14.1	106	22.1	141	38.7	20.9	259
Cobalt	6.6 J	---	7.5 J	---	19.1 J	---	54.5	6.9 J	98.2	---	---	12.1 J
Copper	31.4	15.4 J	57.1	40.8 B	137	12.3 J	370	68.0	668	---	---	79.4
Iron	14800 J	4280 J	17600	6650	38400 J	4490 J	112000 J	13900 J	164000 J	567 J	241 B	17500
Lead	3.4 J	---	4 7 J	3 1 J	5.8	---	17	2 4 J	38.6	---	---	4.9 J
Magnesium	76000	81800	35700	42900	88000	110000	68800	15500	113000	13000	13300	42200
Manganese	1320 J	773 J	715	1150	1520 J	408 J	2140 J	221 J	4340 J	45.1 J	59.7 J	975
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	21.8 J	10.6 J	38 9 J	15.7 J	52.5	8.2 J	145	21 2 J	242	20.9 J	13.3 J	152
Potassium	2240 J	30600	2060 J	3130 J	3950 J	3050 J	6790	1830 J	9150	998 J	802 J	3250 J
Selenium	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Silver	---	---	4.0 J	---	4.9 J	---	9 7 J	---	15.5 J	---	---	4.3 J
Sodium	10700	69300	46800	21900	27100	30000	13200	6600	20000	6270	6740	12900
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	35.8 J	10.2 J	40.3 J	19 7 J	75.2	10.6 J	263	28.7 J	333	---	---	34.0 J
Zinc	29.9	9.4 J	39.9 B	21.3 B	75.9	6.7 J	253	30.8	410	8.6 J	2.8 J	47.4 B

"---" - Not detected
J - Estimated Concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-24
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (UNFILTERED)

SAMPLE LOCATION:	MW-84b-04	MW-05A-04	MW-05B-02	MW-05C-03	MW-05E-02	MW-06A-04	MW-06C-04	MW-07A-04	MW-07A-04	MW-07B-03	MW-07C-03	MW-7S-02
CRL SAMPLE NUMBER:	88HV03S11	88HV03S08	88HV03S09	88HV03S01	88HV03S02	88HV03S15	88HV03S16	88HV03S36	88HV03D36	88HV03S03	88HV03S37	88HV03S35
SMO CASE NUMBER	9571	9571	9571	9542	9542	9542	9542	9542	9542	9542	9542	9542
ITR NUMBER:	MEW 316	MEW 310	MEW 308	MEW 300	MEW 302	MER 928	MER 930	MER 984	MER 986	MER 990	MER 994	MER 982
LABORATORY:	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*	*RMAL*
DATE SAMPLED:	05/10/88	05/10/88	05/10/88	05/05/88	05/05/88	05/02/88	05/02/88	05/04/88	05/04/88	05/05/88	05/04/88	05/04/88
(ug/l)												
Aluminum	1170	2540	38500	1750 J	1050 J	79500	---	22700	101000	28200	60.8 B	39100
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	9.9 J	---	---	37.6	---	3.9 J	4.6 J	---	---	2.5 J
Barium	44.9 J	94.8 J	189 J	29.0 J	22.5 J	388 J	51.7 J	239	587	184 J	21.3 J	429
Beryllium	---	---	1.2 J	---	---	2.4 J	---	---	3.3 J	1.9 J	---	1.9 J
Cadmium	---	---	---	---	---	9.3	---	---	9.8	5.5	---	---
Calcium	52600	104000	172000	28300	27800	161000	44500	134000	214000	111000	39500	113000
Chromium	78.0 J	---	56.3 J	---	116	95.3	---	66.9	134	92.1	---	112
Cobalt	---	---	30.6 J	---	---	47.2 J	---	13.6 J	56.7	15.2 J	---	22.0 J
Copper	6.8 J	20.1 J	437	11.7 B	12.0 B	284	10.4 J	128	508	113	---	271
Iron	1620	3300	54400	1990	1540 J	95600 J	---	26300	123000	32500	229 J	49700
Lead	13.8 B	13.2 B	45.0	4.0 B	8.4 B	10.0	---	9.1	28.6	6.1 B	---	10.1
Magnesium	26200	39300	70900	17100	15600	63000	14500	56200	88500	43100	15300	53800
Manganese	234	330	944	129	75.9	1790 J	16.1 J	7430	7990	922	58.2	2030
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	55.3	---	82.0	---	64.6	118	---	52.1	156	78.9	---	73.1
Potassium	1740 J	1690 J	4780 J	1030 J	1080 J	6680	921 J	2890 J	7050	3720 J	1160 J	3260 J
Selenium	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Silver	---	---	4.2 J	---	---	8.7 J	---	4.2 J	13.3	4.5 J	---	8.9 J
Sodium	12200	8940	11600	14200	17500	14600	5220	32600	51300	18700	11600	12700
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	109	---	---	198	---	55.0	266	72.1	---	83.3
Zinc	28.2 B	21.6 B	147	16.8 B	20.5 B	194	7.6 J	53.7 B	248	73.7	7.3 B	93.8

"---" - Not detected
J - Estimated Concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-25
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (FILTERED)

SAMPLE LOCATION:	MW-01A-04	MW-02A-04	MW-02B-04	MW-02B-04	MW-02C-04	MW-02E-02	MW-B2-04	MW-B2-04	MW-03A-04	MW-03B-02	MW-03B-02	MW-03S-02
CRL SAMPLE NUMBER:	88HV03S51	88HV03S33	88HV03S29	88HV03S30	88HV03S78	88HV03S39	88HV03S31	88HV03S32	88HV03S84	88HV03S82	88HV03S83	88HV03S65
SMO CASE NUMBER:	9542	9571	9571	9571	9542	9542	9571	9571	9542	9542	9542	9542
ITR NUMBER:	MER 927	MER 997	MEW 313	MEW 315	MER 999	MEW 305	MEW 319	MEW 321	MER 957	MER 947	MER 949	MER 961
LABORATORY	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/02/88	05/10/88	05/10/88	05/10/88	05/04/88	05/05/88	05/10/88	05/10/88	05/03/88	05/03/88	05/03/88	05/03/88
(ug/l)												
Aluminum	58.6 B	44.4 B	---	666 B	---	---	37.5 B	---	55.2 B	74.4 B	80.3 B	1740
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	---
Barium	50.7 J	183 J	36.5 B	84.7 B	37.4 B	63.5 B	109 B	99.1 B	39.7 J	16.7 J	17.3 J	308
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	7.3
Calcium	50000	96100	27200	28400	30800	32100	99400	98900	33500	24600	24800	77600
Chromium	---	---	---	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	11.5 J
Copper	---	---	---	---	6.3 B	11.0 B	---	---	8.9 J	---	---	24.2 J
Iron	91.0 B	7160	70.4 B	576	---	---	12500	12600	69.0 B	79.1 B	147 B	17300
Lead	---	4.8 B	---	---	---	4.0 B	3.4 B	---	---	---	7.1 J	3.0 J
Magnesium	14900	33700	12300	12600	13400	9140	29000	28900	15400	12800	12800	26100
Manganese	---	1210	32.3	45.2	46.5	12.7 J	1720	1710	398	21.2	26.5	5120
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	---	---	---	---	---	---	---	---
Potassium	606 J	1550 J	967 J	909 J	963 J	1120 J	1300 J	1380 J	1290 J	894 J	879 J	2620 J
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	5500	19900	7260	7050	6500	8790	16300	18800	17300	7640	8060	70000
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---	---	---	---	---	---	8.5 J
Zinc	21.2 B	56.4 B	14.9 B	26.5 B	8.1 B	10.0 B	39.8 B	33.8 B	13.5 B	11.3 B	27.5 B	123
Cyanide	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-24
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (UNFILTERED)

SAMPLE LOCATION:	MW-14C-03	MW-14C-03	MW-14S-02	MW-15A-03	MW-15B-02	MW-16S-02	MW-17B-02	MW-17E-02	FIELD BLANK	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S38	88HV03S34	88HV03S26	88HV03S41	88HV03S42	88HV03S29	88HV03S40	88HV03S32	88HV03R02	88HV03R03	88HV03R01	88HV03R12
SMO CASE NUMBER	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9571
ITR NUMBER:	MER 968	MER 966	MER 964	MER 988	MER 992	MER 952	MER 980	MER 962	MER 958	MER 976	MEW 306	MEW 322
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88	05/03/88	05/04/88	05/03/88	05/03/88	05/04/88	05/05/88	05/10/88
(ug/l)												
Aluminum	1120 J	733 J	7780	7590 J	43.3 B	410000	3780 J	123 B	86.3 J	67.5 J	44.3 J	80.4 J
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	2.4 J	2.4 J	3.2 J	3.8 J	---	105	---	---	---	---	---	---
Barium	49.7 J	24.0 J	138 J	196 J	93.2 J	965 J	38.0 J	86.3 J	2.0 J	---	---	---
Beryllium	---	---	---	1.0 J	---	9.8	---	---	---	---	---	---
Cadmium	---	---	---	8.3	---	19.3	---	---	---	---	---	---
Calcium	37300	28500	76000	502000	65000	607000	27900	82700	499 J	567 B	341 B	642 J
Chromium	8.8 J	---	26.3	23.5	---	1310	32.3	101	---	---	---	---
Cobalt	---	---	7.6 J	7.4 J	---	206	---	---	---	---	---	---
Copper	13.5 B	12.3 B	53.5	89.9	8.7 B	1270	21.2 B	---	---	7.2 B	---	---
Iron	1530 J	1020 J	12400 J	15000	57.6 J	369000 J	4370	540 J	73.4 J	---	---	---
Lead	18.2	2.4 J	3.2 J	---	---	20.7	2.5 J	---	---	---	5.6	3.7 B
Magnesium	17600	14400	22700	175000	18600	179000	17100	1650 J	---	129 J	116 J	135 J
Manganese	227	54.5	749 J	3490	73.0	7610 J	121	11.1 J	---	---	---	---
Mercury	---	---	---	---	---	0.3	---	---	---	---	---	---
Nickel	---	---	25.8 J	23.3 J	9.3 J	1030	21.8 J	52 B	---	---	---	---
Potassium	1660 J	1230 J	2580 J	2960 J	3290 J	14200	1430 J	15400	48.5 B	40.9 J	55.5 J	125 B
Selenium	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Silver	---	---	---	5.4 J	---	31.9 J	---	---	---	---	---	---
Sodium	15200	12300	15500	17100	14900	47000	8950 B	40600	---	2180 J	---	---
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	62.4	22.3 J	---	964	10.5 J	6.6 J	---	---	---	---
Zinc	13.0 B	11.1 B	30.3	38.9 B	11.8 B	738	13.0 B	4.3 J	---	5.0 B	5.6 B	11.1 B

"---" - Not detected
J - *Estimated Concentration*
B - Blank Contamination
R - Laboratory data not usable

TABLE B-28
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-03S-02	MW-03S-02	MW-84b-04	MW-05A-04	MW-05B-02	MW-05B-02	MW-05B-02	MW-05C-03	MW-05E-02	MW-05E-02	MW-07B-03	MW-07C-03
CRL SAMPLE NUMBER:	88HV03R06	88HV03R07	88HV03S11	88HV03S08	88HV03S09	88HV03S16	88HV03S17	88HV03S05	88HV03S02	88HV03D02	88HV03S03	88HV03S48
SAS NUMBER:	3784-E22	3784-E23	3784-E100DL	3784-E73	3784-E75	3784-E78	3784-E79	3784-E60	3784-E64	3784-E67	3784-E69	3784-E51
LABORATORY:	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC
DATE SAMPLED:	05/03/88	05/03/88	05/10/88	05/10/88	05/10/88	05/10/88	05/10/88	05/05/88	05/05/88	05/05/88	05/05/88	05/04/88
(ng/l)												
Naphthalene	--- R	--- R	10 B	20 B	58 J	46 J	58 J	28 B	4 B	5 B	3 B	--- R
2-methylnaphthalene	--- R	--- R	--- R	--- R	58 J	33 J	41 J	32 J	4 B	4 B	--- R	--- R
Acenaphthylene	--- R	--- R	--- R	1 J	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
1-methylnaphthalene	--- R	16 B	110 J	65 J	190 J	81 J	93 J	100 J	14 B	17 B	7 B	--- R
Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Acenaphthene	--- R	--- R	26 J	--- R	2 B	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Fluorene	--- R	--- R	44 J	--- R	--- R	--- R	--- R	3 J	--- R	--- R	--- R	--- R
Phenanthrene	--- R	--- R	--- R	4 B	5 B	5 B	4 B	3 B	3 B	4 B	--- R	--- R
Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	3 J	--- R
Fluoranthene	--- R	--- R	--- R	2 B	--- R	1 B	--- R	3 B	2 B	4 B	--- R	--- R
Pyrene	--- R	--- R	--- R	2 B	--- R	4 B	3 B	2 B	2 B	4 B	--- R	0.8 B
Benzo(a) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Chrysene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(b) Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(a) Pyrene + Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Indeno(1.2.3-cd) Pyrene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Dibenzo(a,h) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(g,h,i) Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R

"---" - Not detected
B - blank contamination
J - Estimated concentration
R - Laboratory data not usable
DL - Diluted

TABLE B-28
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-02A-04	MW-02A-04	MW-02B-04	MW-02B-04	MW-02B-04	MW-02C-04	MW-02E-02	MW-B2-04	MW-B2-04	MW-D3A-04	MW-03A-04	MW-03S-02
CRL SAMPLE NUMBER:	88HV03S13	88HV03S13	88HV03S10	88HV03S18	88HV03S19	88HV03S43	88HV03S04	88HV03S12	88HV03D12	88HV03S17	88HV03D17	88HV03S31
SAS NUMBER:	3784-E96	3784-E96DL	3784-E81	3784-E84	3784-E85	3784-E55	3784-E71	3784-E90DL	S784-E92DL	3784-E19	3784-E20	3784-E21
LABORATORY:	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC
DATE SAMPLED:	05/10/88	05/10/88	05/10/88	05/10/88	05/10/88	05/04/88	05/05/88	05/10/88	05/10/88	05/03/88	05/03/88	05/03/88
(ng/l)												
Naphthalene	280 J	130 J	--- R	--- R	--- R	--- R	4 B	110 J	120 J	--- R	--- R	--- R
2-methylnaphthalene	38 J	22 J	--- R	--- R	4 B	2 B	8 J	--- R	33 J	--- R	--- R	--- R
Acenaphthylene	67 J	--- R	--- R	--- R	--- R	--- R	--- R	120 J	110 J	--- R	--- R	--- R
1-methylnaphthalene	570 J	330 J	--- R	3 B	10 B	--- R	19 B	350 J	370 J	--- R	--- R	18 B
Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Acenaphthene	--- R	--- R	--- R	--- R	--- R	--- R	2 B	--- R	--- R	--- R	--- R	--- R
Fluorene	36 J	33 J	--- R	--- R	--- R	--- R	3 J	32 J	36 J	--- R	--- R	--- R
Phenanthrene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	3 J	--- R	--- R	--- R	--- R	--- R
Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Pyrene	0.1 B	--- R	--- R	--- R	1 B	2 B	1 B	--- R	--- R	1 B	--- R	--- R
Benzo(a) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Chrysene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(b) Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(a) Pyrene + Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Indeno(1,2,3-cd) Pyrene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Dibenzo(a,h) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(g,h,i) Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R

"---" - Not detected
B - blank contamination
J - Estimated concentration
R - Laboratory data not usable
DL - Diluted

TABLE B-27
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT VOCs

SAMPLE LOCATION:	BTL BLANK	BTL BLANK
CRL SAMPLE NUMBER:	88HV03S46	88HV03R03
SAS NUMBER:	3784-E36	3784-E88
LABORATORY:	S-CUBED	S-CUBED
DATE SAMPLED:	05/04/88	05/10/88
(ug/l)		
Vinyl Chloride	---	---
Chloroform	11.2	21.8
1,2-Dichloroethane	---	---
Carbon Tetrachloride	---	---
Trichloroethene	0.054 J	0.063 J
Benzene	---	---
Tetrachloroethene	0.2 J	0.281

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable

TABLE B-27

ARROWHEAD - FIELDWORK DESIGN INVESTIGATION

GROUNDWATER (STEP II)

LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-14C-03	MW-14S-02	MW-14S-02	MW-14S-02	MW-15A-03	MW-15B-03	MW-16S-02	MW-16S-02	MW-17B-02	MW-17E-02	FIELD BLANK	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03D34	88HV03S26	88HV03R04	88HV03R05	88HV03S41	88HV03S42	88HV03S44	88HV03D44	88HV03S40	88HV03S45	88HV03R02	88HV03R03	88HV03R01	88HV03R02
SAS NUMBER:	3784-E39	3784-E28	3784-E30	3784-E31	3784-E47	3784-E49	3784-E24	3784-E25	3784-E42	3784-E26	3784-E17	3784-E34	3784-E61	3784-E86
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED:	*05/04/88*	*05/03/88*	*05/03/88*	*05/03/88*	*05/04/88*	*05/04/88*	*05/03/88*	*05/03/88*	*05/04/88*	*05/03/88*	*05/03/88*	*05/04/88*	*05/05/88*	*05/10/88*
(ug/l)														
Vinyl Chloride	---	0.545	0.026	0.042 J	---	---	---	---	---	---	---	---	---	---
Chloroform	---	0.023 B	---	0.116 B	---	---	0.264 B	0.21 B	0.052 B	0.122 B	29.6	24.3	14.5	23.1
1,2-Dichloroethane	---	---	---	0.012 J	0.088	0.123	---	---	---	---	---	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	0.012 B	0.244 B	0.137	0.131 B	0.013 B	0.017 B	0.013 B	0.008 B	0.015 B	0.011 B	0.11 J	0.061 J	0.023 B	0.133 J
Benzene	---	---	---	---	---	---	---	---	---	0.016 J	---	---	---	---
Tetrachloroethene	0.088 B	0.092 B	0.068 B	0.098 B	--- R	0.155 B	0.096 B	0.102 B	0.125 B	0.076 B	0.49 J	0.111 J	0.34 J	0.317

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable

TABLE B-27
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT VOCs

SAMPLE LOCATION:	MW-05A-04	MW-05B-02	MW-05B-02	MW-05B-02	MW-05C-03	MW-05E-02	MW-05E-02	MW-05E-02	MW-07B-03	MW-07C-03	MW-07S-02	MW-14A-04	MW-14B-04	MW-14C-03
CRL SAMPLE NUMBER:	88HV03S08	88HV03S09	88HV03S16	88HV03S17	88HV03S01	88HV03S02	88HV03S06	88HV03S07	88HV03S03	88HV03S37	88HV03S35	88HV03S27	88HV03S38	88HV03S34
SAS NUMBER:	3784-E72	3784-E74	3784-E76	3784-E77	3784-E59	3784-E63	3784-E65	3784-E66	3784-E68	3784-E50	3784-E45	3784-E32	3784-E57	3784-E37
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED:	05/10/88	05/10/88	05/10/88	05/10/88	05/05/88	05/05/88	05/05/88	05/05/88	05/05/88	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88
(ug/l)														
Vinyl Chloride	270	1.57	4.21	4.58	0.191	---	---	---	0.009 J	---	---	0.645	---	---
Chloroform	---	---	0.014 B	0.015 B	---	0.025 B	0.026 B	0.045 B	0.018 B	0.021 B	---	---	---	0.115
1,2-Dichloroethane	---	---	0.017 J	0.012 J	---	---	---	---	---	---	12	---	---	---
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	230 B	0.047 B	0.116 B	0.083 B	0.182	0.006 B	0.08 B	0.008 B	0.006 B	0.024 B	---	0.038	0.015 B	0.021 B
Benzene	---	---	---	0.04	---	---	---	---	---	---	---	0.022	---	---
Tetrachloroethene	---	0.072 B	0.075 B	0.064 B	0.064 B	0.063 B	0.126 B	--- R	0.056 B	0.082 B	--- R	0.056 B	0.119 B	0.055 B

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable

TABLE B-27
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT VOCS

SAMPLE LOCATION:	MW-02A-04	MW-02A-04	MW-02A-04	MW-02B-04	MW-02B-04	MW-02B-04	MW-02C-04	MW-02C-04	MW-02E-02	MW-B2-04	MW-B2-04	MW-B4b-04	MW-B4b-04	MW-B4b-04
CRL SAMPLE NUMBER:	88HV03S13	88HV03S20	88HV03S21	88HV03S10	88HV03S18	88HV03S19	88HV03S43	88HV03D43	88HV03S04	88HV03S12	88HV03D12	88HV03S11	88HV03S14	88HV03S15
SAS NUMBER:	3784-E93	3784-E94	3784-E95	3784-E80	3784-E82	3784-E83	3784-E54	3784-E56	3784-E70	3784-E89	3784-E91	3784-E97	3784-E98	3784-E99
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED: (ug/l)	05/10/88	05/10/88	05/10/88	05/10/88	05/10/88¹	05/10/88	05/04/88	05/04/88	05/05/88	05/10/88	05/10/88	05/10/88	05/10/88	05/10/88
Vinyl Chloride	0.875 J	0.789	1.37	---	---	---	---	---	---	0.651	0.494	0.035	0.024	0.015 J
Chloroform	-	---	---	0.014 B	0.062 B	---	---	---	0.047 B	---	---	0.013 B	0.021 B	0.02 B
1,2-Dichloroethane	0.468	---	0.425	---	---	---	---	---	---	0.114	0.112	0.042	0.04	0.04
Carbon Tetrachloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	0.015 B	0.021 B	0.05 B	0.016 B	0.013 B	0.008 B	---	0.008 B	0.009 B	0.076 B	0.082 B	0.067 B	0.104 B	0.109 B
Benzene	4.71 J	---	5.74	---	---	---	---	---	---	---	0.653	---	---	---
Tetrachloroethene	---	---	0.205 B	0.072 B	0.066 B	0.052 B	0.174 B	0.234 B	0.083 B	---	---	0.092 B	0.115 B	0.092 B

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable

TABLE 8-26
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	MW-16S-02	MW-17B-02	MW-17E-02	FIELD BLANK	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S29	88HV03S40	88HV03S32	88HV03R02	88HV03R03	88HV03R01	88HV04R12
SMO CASE NUMBER:	9542	9542	9542	9542	9542	9542	9571
OTR NUMBER:	EW 516	EW 532	EW 521	EW 519	EW 530	EW 546	EW 555
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	PEI
DATE SAMPLED:	05/03/88	05/04/88	05/03/88	05/03/88	05/04/88	05/05/88	05/10/88
(ug/l)							
VOLATILES ORGANICS:							
Acetone	---	---	---	---	---	---	---
Benzene	---	---	---	---	---	---	---
2-Butanone	---	---	---	---	---	---	--- R
Chloroform	---	---	---	32	32	32	30
1,2-Dichloroethane	---	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---	---
Total Xylenes	---	---	---	---	---	---	---
Toluene	---	---	2 J	---	---	---	---
Trans-1,2-Dichloroethene	---	---	---	---	---	---	---
Vinyl Chloride	---	---	---	---	---	---	---
1,1 Dichloroethene	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---
Methylene Chloride	---	---	---	---	3 B	---	5 B
SEMIVOLATILE ORGANICS:							
4-methylphenol	---	---	---	---	---	---	---
Benzoic Acid	---	---	---	---	---	---	---
2-methylnaphthalene	---	---	---		---	---	---
Bis(2-Ethylhexyl)Phthalate	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	---	---	---	---
2-methylphenol	---	---	---	---	---	---	---
Naphthalene	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	4 B

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable
DL - Diluted

TABLE B-26
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	MW-13A-04	MW-13B-02	MW-13E-02	MW-13E-02	MW-14A-04	MW-14A-04	MW-14B-04	MW-14C-03	MW-14C-03	MW-14S-02	MW-15A-03	MW-15B-03
CRL SAMPLE NUMBER:	88HV03S17	88HV03S20	88HV03S18	88HV03D18	88HV03S27	88HV03D27	88HV03S38	88HV03S34	88HV03D34	88HV03S26	88HV03S41	88HV03S42
SMO CASE NUMBER:	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542
OTR NUMBER:	EW 506	EW 511	EW 507	EW 508	EW 526	EW 527	EW 525	EW 523	EW 524	EW 522	EW 536	EW 538
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED:	05/02/88	05/02/88	05/02/88	05/02/88	05/03/88	05/03/88	05/04/88	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88
(ug/l)												
VOLATILES ORGANICS:												
Acetone	---	---	---	---	---	---	---	---	NA	---	---	---
Benzene	---	---	---	---	---	---	---	---	NA	---	---	---
2-Butanone	---	---	---	---	---	---	---	---	NA	---	---	---
Chloroform	---	---	---	---	---	---	---	---	NA	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---	NA	---	---	---
Ethylbenzene	---	---	---	---	---	---	---	---	NA	---	---	---
Total Xylenes	---	---	---	---	---	---	---	---	NA	---	---	---
Toluene	1 J	2 J	1 J	---	---	---	---	---	NA	---	---	2 J
Trans-1,2-Dichloroethene	---	---	---	---	35	38	---	---	NA	21	---	---
Vinyl Chloride	---	---	---	---	---	---	---	---	NA	---	---	---
1,1 Dichloroethene	---	---	---	---	---	---	---	---	NA	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	NA	---	---	---
Methylene Chloride	---	---	---	---	---	---	---	9 B	NA	---	2 B	2 B
SEMIVOLATILE ORGANICS												
4-Methylphenol	---	---	---	NA	---	NA	---	---	---	5 J	---	---
Benzoic Acid	---	---	---	NA	---	NA	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	NA	---	NA	---	---	---	---	---	---
Bis(2-Ethylhexyl)Phthalate	---	---	---	NA	---	NA	---	---	---	---	---	---
2,4-Dimethylphenol	---	---	---	NA	---	NA	---	---	---	---	---	---
2-Methylphenol	---	---	---	NA	---	NA	---	---	---	---	---	---
Naphthalene	---	---	---	NA	---	NA	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	NA	---	NA	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
J - *Estimated concentration*
NA - Not analyzed
R - Laboratory data not usable
DL - Diluted

TABLE B-26
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	MW-07A-04	MW-07B-03	MW-07C-03	MW-07S-02	MW-8A-04	MW-08B-02	MW-09A-03	MW-09B-03	MW-10A-03	MW-10B-03	MW-11A-04	MW-12A-04
CRL SAMPLE NUMBER:	88HV03036	88HV03503	88HV03S37	88HV03S35	88HV03S21	88HV03S19	88HV03S39	88HV03S33	88HV03S28	88HV03S30	88HV03S22	88HV03S23
SMO CASE NUMBER:	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542
OTR NUMBER:	EW 535	EW 537	EW 539	EW 533	EW 510	EW 509	EW 528	EW 529	EW 515	EW 517	EW 512	EW 513
LABORATORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED:	05/04/88	05/05/88	05/04/88	05/04/88	05/02/88	05/02/88	05/04/88	05/03/88	05/03/88	05/03/88	05/03/88	05/03/88
(ug/l)												
VOLATILES ORGANICS:												
Acetone	2700	---	31 B	---	---	---	56 B	---	---	---	---	---
Benzene	3800	---	---	---	---	---	---	---	---	---	---	---
2-Butanone	--- R	--- R	--- R	---	---	---	---	---	---	22	---	---
Chloroform	---	---	---	---	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	9	---	---	---	---	---	---	---	---
Ethylbenzene	870	---	---	---	---	---	---	---	---	---	---	---
Total Xylenes	6000	---	---	---	---	---	---	---	---	---	---	---
Toluene	5100	---	---	---	---	---	---	---	---	1 J	---	2 J
Trans-1,2-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
Vinyl Chloride	---	---	---	---	---	---	---	---	---	---	---	---
1,1 Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---	---
Methylene Chloride	59 J	3 B	3 B	2 B	---	---	7 B	---	---	---	---	---
SEMIVOLATILE ORGANICS:												
4-Methylphenol	NA	---	---	---	---	---	---	---	---	---	---	---
Benzoic Acid	NA	---	---	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	NA	---	---	---	---	---	---	---	---	---	---	---
Bis(2-Ethylhexyl)Phthalate	NA	---	---	---	---	5 J	---	---	---	---	---	---
2,4-Dimethylphenol	NA	---	---	---	---	---	---	---	---	---	---	---
2-Methylphenol	NA	---	---	---	---	---	---	---	---	---	---	---
Naphthalene	NA	---	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	NA	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable
DL - Diluted

TABLE B-26
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	MW-03S-02	MW-B4D-04	MW-B4D-04	MW-05A-04	MW-05A-04	MW-05B-02	MW-05C-03	MW-5E-02	MW-06A-04	MW-06C-04	MW-07A-04	MW-07A-04
CRL SAMPLE NUMBER:	88HV03S31	88HV03S11	88HV03D11	88HV03S08	88HV03S08	88HV03S09	88HV03S01	88HV03S02	88HV03S15	88HV03S16	88HV03S36	88HV03S36
SMO CASE NUMBER:	9542	9571	9571	9571	9571	9571	9542	9542	9542	9542	9542	9542
OTR NUMBER:	EW 520	EW 551	EW 552	EW 548	EW 548DL	EW 547	EW 543	EW 544	EW 504	EW 505	EW 534	EW 534RE
LABORATORY:	S-CUBED	PEI	PEI	PEI	PEI	PEI	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED:	05/03/88	05/10/88	05/10/88	5/10/88	05/10/88	05/10/88	05/05/88	05/05/88	05/02/88	05/02/88	05/04/88	05/04/88
(ug/l)												
VOLATILES ORGANICS:												
Acetone	---	---	---	---	---	7 B	---	---	---	---	4300	NA
Benzene	---	---	---	---	---	---	---	---	---	---	3700	NA
2-Butanone	---	--- R	--- R	--- R	--- R	--- R	---	--- R	---	---	--- R	NA
Chloroform	---	---	---	---	---	---	---	---	---	---	---	NA
1,2-Dichloroethane	---	---	---	---	---	---	---	---	---	---	---	NA
Ethylbenzene	---	---	---	1 J	---	---	---	---	---	---	840	NA
Total Xylenes	---	---	---	3 J	---	---	---	---	---	---	6000	NA
Toluene	---	---	---	3 J	---	---	---	---	3 J	1 J	4900	NA
Trans-1,2-Dichloroethene	---	---	---	1800 J	2000	120	---	---	---	---	---	NA
Vinyl Chloride	---	---	---	490 J	620	16	---	---	---	---	---	NA
1,1 Dichloroethene	---	---	---	8	---	---	---	---	---	---	---	NA
Trichloroethene	---	---	---	150	170	---	---	---	---	---	---	NA
Methylene Chloride	---	7 B	5 B	110 B	500	6 B	---	8 B	---	---	340	NA
SEMIVOLATILE ORGANICS												
4-methylphenol	16	---	NA	---	NA	---	---	---	---	---	30 J	27 J
Benzoic Acid	---	---	NA	---	NA	---	---	---	---	---	52 J	53 J
2-methylnaphthalene	---	---	NA	---	NA	---	---	---	---	---	26 J	28 J
Bis(2-Ethylhexyl)Phthalate	---	31 J	NA	---	NA	---	---	---	---	---	--- R	--- R
2,4-Dimethylphenol	---	---	NA	---	NA	---	---	---	---	---	10 J	11 J
2-methylphenol	---	---	NA	---	NA	---	---	---	---	---	12 J	21 J
Naphthalene	---	---	NA	---	NA	---	---	---	---	---	160 J	180 J
Di-n-Butylphthalate	---	5 B	NA	7 B	NA	3 B	---	---	---	---	--- R	--- R

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable
DL - Diluted

TABLE 8-26
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	MW-01A-04	MW-02A-04	MW-02B-04	MW-02B-04	MW-02B-04	MW-02C-04	MW-2C-04	MW-02E-02	MW-B2-04	MW-B2-04	MW-03A-04	MW-03B-02
CRL SAMPLE NUMBER:	88HV03S14	88HV03S13	88HV03S10	88HV03D10	88HV03D10	88HV03S43	88HV03D43	88HV03S04	88HV03S12	88HV03D12	88HV03S25	88HV03S24
SMO CASE NUMBER:	9542	9571	9571	9571	9571	9542	9542	9542	9571	9571	9542	9542
OTR NUMBER:	EW 503	EW 540	EW 549	EW 550	EW 556	EW 541	EW 542	EW 545	EW 553	EW 554	EW 516	EW 514
LABORATORY:	S-CUBED	PEI	PEI	PEI	PEI	S-CUBED	S-CUBED	S-CUBED	PEI	PEI	S-CUBED	S-CUBED
DATE SAMPLED:	05/02/88	05/10/88	05/10/88	5/10/88	05/10/88	05/04/88	05/04/88	05/05/88	05/10/88	05/10/88	05/03/88	05/03/88
(ug/l)												
VOLATILES ORGANICS												
Acetone	---	6 B	---	---	NA	---	NA	---	---	---	---	---
Benzene	---	7 J	---	---	NA	---	NA	---	---	---	---	---
2-Butanone	---	--- R	--- R	--- R	NA	--- R	NA	---	--- R	--- R	---	---
Chloroform	---	---	---	---	NA	---	NA	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	NA	---	NA	---	---	---	---	---
Ethylbenzene	---	7 J	---	---	NA	---	NA	---	---	---	---	---
Total Xylenes	---	9 J	---	---	NA	---	NA	---	---	---	---	---
Toluene	---	---	---	---	NA	---	NA	---	---	---	---	---
Trans-1 2-Dichloroethene	---	---	---	---	NA	---	NA	---	---	---	---	---
Vinyl Chloride	---	3 J	---	---	NA	---	NA	---	---	---	---	---
1 1 Dichloroethene	---	---	---	---	NA	---	NA	---	---	---	---	---
Trichloroethene	---	---	---	---	NA	---	NA	---	---	---	---	---
Methylene Chloride	---	---	10 B	7 B	NA	7 B	NA	---	10 B	8 B	---	---
SEMIVOLATILE ORGANICS												
4-Methylphenol	---	---	---	NA	---	---	---	---	---	---	---	---
Benzoic Acid	---	---	---	NA	---	---	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	NA	---	---	---	---	---	--- R	---	---
Bis(2-Ethylhexyl)Phthalate	---	---	---	NA	---	---	---	---	---	---	---	---
2,4-Dimethylphenol	---	7 J	---	NA	---	---	---	---	---	---	---	---
2-Methylphenol	---	---	---	NA	---	---	---	---	---	---	---	---
Naphthalene	---	2 J	---	NA	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	---	4 B	5 B	NA	---	---	---	---	5 B	5 B	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable
DL - Diluted

TABLE 8-25
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (FILTERED)

SAMPLE LOCATION:	MW-14B-04	MW-14C-03	MW-14S-02	MW-15A-03	MW-15B-03	MW-16S-02	MW-17B-02	MW-17E-02	FIELD BLANK	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S74	88HV03S69	88HV03S60	88HV03S77	88HV03S79	88HV03S63	88HV03S76	88HV03S66	88HV03S59	88HV03S68	88HV03S36	88HV03S24
SMO CASE NUMBER:	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9571
ITR NUMBER:	MER 969	MER 967	MER 965	MER 989	MER 993	MER 953	MER 981	MER 963	MER 959	MER 977	MEW 307	MEW 323
LABORATORY	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88	05/03/88	05/04/88	05/03/88	05/03/88	05/04/88	05/05/88	05/10/88
(ug/l)												
Aluminum	---	---	---	60.5 B	1230	84.7 B	37.3 B	---	103 J	47.2 J	49.8 J	182 J
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	2.6 J	---	---	---	---	---
Barium	72.5 B	41.4 B	99.1 J	86.0 B	55.4 B	94.7 J	54.4 B	88.3 J	---	31.0 J	19.3 J	35.1 J
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	34100	27000	66500	493000	79300	64100	23200	74800	570 J	905 J	624 B	878 J
Chromium	---	---	---	---	15.6	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	10.9 B	8.3 B	7.1 J	11.6 B	10.4 B	10.4 J	11.3 B	11.3 B	---	8.6 B	6.7 B	---
Iron	---	---	130 B	1000	1640	100 B	---	---	63.0 J	---	---	108
Lead	---	---	2.4 J	11.2 J	---	---	2.8 B	---	---	---	7.6 J	---
Magnesium	16400	13600	19800	172000	23200	17000	15200	1050 J	---	171 B	145 B	146 J
Manganese	178	41.1	530	3280	153	262	49.6	---	---	---	---	---
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	8.5 J	39.5 J	---	---	---	---	---	---
Potassium	1520 J	1030 J	1700 J	2060 J	2940 J	882 J	938 J	14500	---	---	---	---
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	13700	12100	15000	16400	12000	10400	8120	38500	---	---	---	---
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	7.2 J	---	---	---	---	---	---	---	---	---
Zinc	10.4 B	11.2 B	23.8 B	24.2 B	8.2 B	30.0 B	10.4 B	9.4 B	6.3 J	15.2 B	11.7 B	7.2 B
Cyanide	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE 8-25
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
INORGANIC DATA (FILTERED)

SAMPLE LOCATION:	MW-08A-04	MW-08B-02	MW-09A-03	MW-09B-03	MW-10A-03	MW-10B-03	MW-11A-04	MW-12A-04	MW-13A-04	MW-13B-02	MW-13E-02	MW-14A-04
CRL SAMPLE NUMBER:	88HV03558	88HV03556	88HV03575	88HV03567	88HV03562	88HV03564	88HV03580	88HV03581	88HV03554	88HV03557	88HV03555	88HV03561
SMO CASE NUMBER:	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542	9542
ITR NUMBER:	MER 939	MER 937	MER 973	MER 975	MER 951	MER 955	MER 943	MER 945	MER 933	MER 941	MER 935	MER 971
LABORATORY	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/02/88	05/02/88	05/04/88	05/03/88	05/03/88	05/03/88	05/03/88	05/03/88	05/02/88	05/02/88	05/02/88	05/03/88
(ug/l)												
Aluminum	---	---	---	87.7 B	152 B	---	---	109 B	269 B	---	---	53.1 B
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	2.8 J	---	---	---	---	4.1 J	---	---	---	---	---	---
Barium	331	326	66.6 B	119 J	147 J	126 J	62.6 J	58.7 J	93.1 J	43.7 J	35 0 J	129 J
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	5.3	---	---	---	---	---	---
Calcium	197000	221000	93700	114000	118000	124000	28300	26500	30700	39300	34000	78600
Chromium	---	---	---	---	---	---	---	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	6.1 J	---	8 3 B	9.8 B	7.1 J	6.0 J	9.3 J	7 5 J	12.3 J	---	---	---
Iron	3840	102 B	---	122 B	312 B	174 B	175 B	143 B	360 B	---	---	65.9 B
Lead	---	---	2 9 J	4.3 J	---	---	2.0 J	---	---	---	---	---
Magnesium	69300	73600	29200	43400	71100	107000	10600	10200	12200	13900	12700	34200
Manganese	996	502	524	990	770	430	26.9	34 2	47.3	46.3	46 6	576
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	---	---	---	---	---	---	---	---	---	---	---	---
Potassium	1780 J	30300	898 J	2610 J	1920 J	2850 J	556 J	664 J	578 J	1500 J	682 J	1700 J
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	11400	69400	41700	20400	23800	30100	5330	5950	6170	7870	5520	13300
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---	---	---	---	---	---	---
Zinc	35.1	14.0 B	27.5 B	19.0 B	29.1 B	6.5 B	12.7 B	14.7 B	18.1 B	9.4 B	9.0 B	35.6
Cyanide	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-25
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
GROUND WATER (STEP II)
INORGANIC DATA (FILTERED)

SAMPLE LOCATION:	MW-B4b-04	MW-05A-04	MW-05B-02	MW-05C-03	MW-05E-02	MW-06A-04	MW-06C-04	MW-07A-04	MW-07A-04	MW-07B-03	MW-07C-03	MW-07S-02
CRL SAMPLE NUMBER:	88HV03S34	88HV03S22	88HV03S23	88HV03S35	88HV03S37	88HV03S52	88HV03S53	88HV03S71	88HV03S72	88HV03S38	88HV03S73	88HV03S70
SMO CASE NUMBER	9571	9571	9571	9542	9542	9542	9542	9542	9542	9542	9542	9542
ITR NUMBER:	MEW 317	MEW 311	MEW 309	MEW 301	MEW 303	MER 929	MER 931	MER 985	MER 987	MER 991	MER 995	MER 983
LABORATORY:	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL	RMAL
DATE SAMPLED:	05/10/88	05/10/88	05/10/88	05/05/88	05/05/88	05/02/88	05/02/88	05/04/88	05/04/88	05/05/88	05/04/88	05/04/88
(ug/l)												
Aluminum	---	---	69.9 B	---	---	---	175 B	38.3 B	42.4 B	38.3 B	---	---
Antimony	---	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---	---
Barium	40.2 B	113 B	61 7 B	46.8 B	40 7 B	118 J	30 7 J	170 B	134 B	108 J	28.6 B	110 B
Beryllium	---	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---	---
Calcium	44600	98800	123000	25500	26100	79100	45600	117000	[illegible]	78400	37400	99800
Chromium	---	---	---	---	---	---	6 4 J	---	---	---	---	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---	---
Copper	---	---	---	8.6 B	9 8 B	11.9 J	---	9 6 B	12.3 B	11.4 B	7.9 B	11.0 B
Iron	---	---	130 B	---	---	---	264 B	1410	1280	67 3 J	---	---
Lead	---	8 5 B	8 0 B	---	4 3 B	3 1 J	2 4 J	---	---	---	---	2.4 J
Magnesium	21900	35900	46900	16000	15100	23700	14800	48500	45900	30000	15300	43200
Manganese	144	269	71 B	91.9	49 5	---	24 9	6860	6230	266	48.6	1230
Mercury	---	---	---	---	---	---	---	---	---	---	---	---
Nickel	8.3 J	---	---	---	---	---	---	---	---	---	---	---
Potassium	1400 J	1180 J	1500 J	860 J	888 J	770 J	985 J	1390 J	1370 J	1290 J	1120 J	1100 J
Selenium	---	---	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---	---	---
Sodium	9250	8470	8680	13100	16600	7040	5500	32700	33800	12400	10200	11400
Thallium	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---	---	---	---	---	---	---
Zinc	10.7 B	17.8 B	32.2 B	9.9 B	10.4 B	31.9	8.8 B	36.8 B	39 6 B	33.9 B	6.8 B	39.5 B
Cyanide	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
J - Estimated Concentration
B - Blank Contamination
R - Laboratory data not usable

TABLE B-28
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-07C-03	MW-07C-03	MW-07S-02	MW-14A-04	MW-14B-04	MW-14C-03	MW-14C-03	MW-14C-03	MW-14S-02	MW-15A-03	MW-15B-03	MW-17B-02
CRL SAMPLE NUMBER:	88HV03S49	88HV03S50	88HV03S47	88HV03S27	88HV03S38	88HV03S34	88HV03R08	88HV03R09	88HV03S26	88HV03S41	88HV03S42	88HV03S40
SAS NUMBER:	3784-E52	3784-E53	3784-E46DL	3784-E33	3784-E58	3784-E38	3784-E40	3784-E41	3784-E29	3784-E48	3784-E56	3784-E43
LABORATORY:	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC
DATE SAMPLED:	05/04/88	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88	05/04/88	05/04/88	05/03/88	05/04/88	05/04/88	05/04/88
(ng/l)												
Naphthalene	--- R	--- R	350 J	--- R	3 B	6 B	5 B	3 B	--- R	--- R	--- R	3 B
2-methylnaphthalene	--- R	--- R	--- R	--- R	--- R	2 B	--- R	--- R	2 B	--- R	--- R	--- R
Acenaphthylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
1-methylnaphthalene	--- R	--- R	200 J	--- R	--- R	6 B	2 B	3 B	--- R	--- R	--- R	--- R
Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Acenaphthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Fluorene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Phenanthrene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	2 B	--- R	--- R	--- R
Pyrene	1 B	--- R	--- R	1 B	--- R	1 B	--- R	--- R	1 B	--- R	--- R	--- R
Benzo(a) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Chrysene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(b) Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(a) Pyrene + Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Indeno(1,2,3-cd) Pyrene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Dibenzo(a,h) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(g,h,i) Perylene	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable
DL - Diluted

TABLE B-28
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
GROUNDWATER (STEP II)
LOW DETECTION LIMIT PAH

SAMPLE LOCATION:	MW-17D-02	MW-17E-02	FIELD BLANK	FIELD BLANK	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03040	88HV03545	88HV03R02	88HV03R03	88HV03R01	88HV03R02
SAS NUMBER:	3784-E44	3784-E27	3784-E18	3784-E35	3784-E62	3784-E07
LABORATORY:	DATAC	DATAC	DATAC	DATAC	DATAC	DATAC
DATE SAMPLED:	05/04/88	05/03/88	05/03/88	05/04/88	05/05/88	05/10/88
(ng/l)						
Naphthalene	--- R	--- R	3 B	9 B	3 B	--- R
2-methylnaphthalene	0.9 B	4 B	--- R	--- R	--- R	--- R
Acenaphthylene	--- R	--- R	--- R	--- R	--- R	--- R
1-methylnaphthalene	--- R	14 B	--- R	--- R	2 B	6 B
Perylene	--- R	--- R	--- R	--- R	--- R	--- R
Acenaphthene	--- R	--- R	--- R	--- R	--- R	--- R
Fluorene	--- R	--- R	--- R	--- R	--- R	--- R
Phenanthrene	--- R	6 J	0.7 B	1 B	--- R	--- R
Anthracene	--- R	--- R	--- R	--- R	--- R	--- R
Fluoranthene	--- R	2 B	--- R	--- R	--- R	--- R
Pyrene	--- R	2 B	--- R	--- R	--- R	--- R
Benzo(a) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R
Chrysene	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(b) Fluoranthene	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(a) Pyrene + Perylene	--- R	--- R	--- R	--- R	--- R	--- R
Indeno(1,2,3-cd) Pyrene	--- R	--- R	--- R	--- R	--- R	--- R
Dibenzo(a,h) Anthracene	--- R	--- R	--- R	--- R	--- R	--- R
Benzo(g,h,i) Perylene	--- R	--- R	--- R	--- R	--- R	--- R

"---" - Not detected
B - Blank contamination
J - Estimated concentration
R - Laboratory data not usable
DL - Diluted

TABLE B-29
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
INORGANIC DATA

SAMPLE LOCATION:	S087-06-02	S087-06-02	S087-06-03	S087-14-02	S087-14-03	S087-15-02	S087-15-03	S087-16-02	S087-16-03	S087-17-02
DEPTH:	(12-14')	(12-14')	(18-20')	(6.5-8')	(12-14')	(8-10')	(14-16')	(15-17')	(21-23')	(8-10')
CRL SAMPLE NUMBER:	88HK04589	88HK04D89	88HK04590	88HK04587	88HK04588	88HK04599	88HK04501	88HK04597	88HK04598	88HK04591
SMO CASE NUMBER:	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629
ITR NUMBER:	MEW 341	MEW 342	MEW 343	MEW 346	MEW 347	MEW 336	MEW 338	MEW 330	MEW 331	MEW 333
LABORATORY:	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH
DATE SAMPLED:	05/19/88	05/19/88	05/19/88	05/19/88	05/19/88	05/18/88	05/18/88	05/17/88	05/17/88	05/19/88
(mg/kg dry weight)										
Aluminum	9240	10900	8610	10100	7160	14400	9650	5230	5880	12300
Antimony	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Arsenic	1.7 J	1.8 J	1.4 J	1.3 J	1.3 J	1.7 J	1.0 J	1.7 J	4.4	2.1 J
Barium	32 J	72	21 J	61	27 J	95	17 J	24 J	16 J	69
Beryllium	1.9	2.1	1.7	2.0	1.3	1.8	1.2	0.5 J	0.5 J	2.0
Cadmium	7.8	8.7	7.0	6.9	5.6	8.9	6.6	4.3	4.6	10
Calcium	13700	19600	12910	7700	10100	18700	9220	7500	8210	8670
Chromium	19	21	17	21	15	29	16	7.0	8.5	25
Cobalt	9.3 J	13	10 J	13	9.2 J	11 J	13	8.7 J	9.4 J	14
Copper	47 J	54 J	53 J	47 J	45 J	47 J	54 J	61 J	70 J	93 J
Iron	21100	23800	21800	18300	17600	23700	19100	11500	14000	28000
Lead	5.4	26	4.0	5.5	9.2	25	3.5	11	6.9	34
Magnesium	5810	9140	6110	6000	5670	10700	8110	5050	6130	6710
Manganese	270 J	358 J	274 J	180 J	224 J	268 J	242 J	191 J	235 J	387 J
Mercury	---	---	---	---	---	---	---	---	---	---
Nickel	24	33	33	28	24	36	40	20	21	32
Potassium	784 J	853 J	477 J	524 J	562 J	624 J	330 J	677 J	381 J	1800
Selenium	---	---	1.1 J	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---	---	---
Sodium	1410	1540	1370	1330	1280	1450	1750	460 J	445 J	1380
Thallium	---	---	---	---	---	---	---	---	---	---
Vanadium	52 J	58 J	50 J	46 J	43 J	58 J	30 J	15 J	18 J	60 J
Zinc	44	75	58	60	59	78	63	39	47	62
Cyanide	---	---	---	---	---	---	---	---	---	---
% Solids	90	90	86	89	80	85	89	83	84	88

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-29
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
INORGANIC DATA

SAMPLE LOCATION:	S087-17-02	S087-17-03	S087-18-02	S087-18-02	S087-18-03	S087-19-02	S087-19-03	S087-22-02	S087-22-03	S087-23-02
DEPTH:	(8-10')	(14-16')	(6-8')	(6-8')	(12-14')	(10-12')	(14-16')	(6-8')	(12-14')	(3-5')
CRL SAMPLE NUMBER:	88HK04D91	88HK04S92	88HK04S04	88HK04D04	88HK04S05	88HK04S85	88HK04S86	88HK04S02	88HK04S03	88HK04S93
SMO CASE NUMBER:	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629
ITR NUMBER:	MEW 334	MEW 335	MEW 339	MEW 337	MEW 340	MEW 324	MEW 325	MEW 344	MEW 345	MEW 326
LABORATORY:	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH
DATE SAMPLED:	05/19/88	05/19/88	05/18/88	05/18/88	05/18/88	05/16/88	05/16/88	05/18/88	05/18/88	05/17/88
(mg/kg dry weight)										
Aluminum	11500	10300	11400	9760	12800	13900	7990	16100	7520	13800
Antimony	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Arsenic	1.5 J	2.0 J	2.3 J	3.8	---	1.6 J	1.0 J	1.7 J	1.1 J	---
Barium	55	41 J	68	66	51	63	28 J	210	33 J	76
Beryllium	2.3	1.9	1.9	1.5	2	2.0	1.5	1.2 J	1.6	1.6
Cadmium	7.1	7.0	8.2	5.4	9.4	12	6.5	8.6	6.6	6.0
Calcium	8160	13200	12600	18700	17600	16000	16800	10200	11300	5540
Chromium	22	19	27	26	23	25	16	36	14	19
Cobalt	12	12	11 J	10 J	12	16	9.7 J	7.2 J	7.7 J	11 J
Copper	64 J	50 J	46 J	33 J	58 J	92 J	43 J	174 J	36 J	63 J
Iron	21400	19500	23300	14500	24300	31900	19100	14900	17400	17100
Lead	15	15	13	15	3.0	33	4.2	16	9.1	7.2
Magnesium	5890	7080	7410	10600	7900	8450	6030	4830	5240	5110
Manganese	400 J	276 J	207 J	155 J	333 J	396 J	290 J	173 J	324 J	154 J
Mercury	---	---	---	---	0.60	---	---	---	---	---
Nickel	27	25	32	40	34	36	33	38	20	26
Potassium	602 J	595 J	358 J	292 J	545 J	1170	609 J	437 J	582 J	692 J
Selenium	---	---	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	1.7 J	---	1.9 J	---	---
Sodium	1330	1510	1410	1350	1640	1580	1260	1300 J	1230	280 J
Thallium	---	---	---	---	---	---	---	---	---	---
Vanadium	47 J	46 J	65 J	56 J	58 J	96 J	43 J	48 J	38 J	70 J
Zinc	84	46	66	111	57	76	49	104	37	67
Cyanide	---	---	---	---	---	---	---	---	---	---
% Solids	89	86	80	76	91	89	90	59	89	80

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

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TABLE B-29
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
INORGANIC DATA

SAMPLE LOCATION:	SO87-23-03	SO87-24-02	SO87-24-03	FIELD BLANK	FIELD BLANK
DEPTH:	(9-11')	(4-6')	(10-12')		
CRL SAMPLE NUMBER:	88HK04S94	88HK0S95	88HK04S96	88HK04R07	88HK04R06
SMO CASE NUMBER:	9629	9629	9629	9629	9629
ITR NUMBER:	MEW 327	MEW 328	MEW 329	MEW 332	MEW 348
LABORATORY:	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH	CHEMTECH
DATE SAMPLED:	05/17/88	05/17/88	05/17/88	05/17/88	05/19/88
(mg/kg dry weight)					
Aluminum	7410	11500	5860	---	57
Antimony	--- R	--- R	--- R	--- R	--- R
Arsenic	2.3 J	12	1.1 J	---	---
Barium	44 J	112 J	48 J	---	3.1 J
Beryllium	1.0 J	---	0.7 J	---	---
Cadmium	5.9	---	4.3	---	---
Calcium	6340	18900	5290	---	786 J
Chromium	16	20	13	---	---
Cobalt	9.5 J	---	11 J	---	---
Copper	55 J	76 J	34 J	2.7 J	3.7 J
Iron	15800	11200	12200	72	115
Lead	9.7	28	2.5	0.96 J	6.5
Magnesium	4250	3270 J	5140	---	188 J
Manganese	293 J	450 J	261 J	2.2 J	7.3 J
Mercury	---	---	---	---	---
Nickel	20	---	28	---	---
Potassium	648 J	2720 J	210 J	---	116 J
Selenium	---	---	---	---	---
Silver	1.2 J	---	---	---	---
Sodium	397 J	845 J	470 J	---	669 J
Thallium	---	---	---	---	---
Vanadium	35 J	28 J	25 J	---	---
Zinc	44	92	42	3.6 J	2.2 J
Cyanide	---	---	---	---	---
% Solids	84	23	79	100	100

"---" - Not detected
J - Estimated concentration
B - Blank Contamination
R - Laboratory data not usable

TABLE 8-30
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SLUDGE (STEP II)
INORGANIC DATA

SAMPLE LOCATION:	CR87-101-01	CR87-101-03	CR87-102-01	CR87-102-03	CR87-103-01	CR87-103-02	CR87-103-02	CR87-103-03	CR87-103-03	CR87-104-01	CR87-104-01
CRL SAMPLE NUMBER:	88HV03S01	88HV03S02	88HV03S03	88HV03S04	88HV03S05	88HV03S06	88HV03D06	88HV03S07	88HV03D07	88HV03S08	88HV03D08
ITR NUMBER:	MER 907	MER 909	MER 910	MER 912	MER 913	MER 914	MER 924	MER 915	MER 923	MER 916	MER 922
LABORATORY	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC	JTC
DATE SAMPLED:	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	SLUDGE	PEAT	SLUDGE	PEAT	SLUDGE	FILTER CAKE	FILTER CAKE	PEAT	PEAT	SLUDGE	SLUDGE
(mg/kg)											
Aluminum	1850.0	2260.0	1450.0	2020.0	5890.0	14700.0	20500.0	10200.0	22600.0	1910.0	2060.0
Antimony	---	---	---	---	---	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---	---	---	---	---	---
Barium	1280.0 J	1640.0 J	1830.0 J	1560 0 J	995.0 J	1280.0 J	772.0 J	1330.0 J	384.0 J	2020.0 J	2100.0 J
Beryllium	---	---	---	---	---	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---	---	---	---	---	---
Calcium	2480.0	4020.0	1800.0	2960.0	4320.0	8770.0	5190.0	7710.0	3140.0	2940.0	2510 0
Chromium	---	---	---	32.0	---	---	---	41.0	---	30.0	---
Cobalt	---	---	---	---	---	---	---	---	---	---	---
Copper	---	59.0 J	---	43 0 J	61.0 J	115.0 J	53.0 J	127.0 J	---	---	---
Iron	697.0 J	1110.0 J	542.0 J	954.0 J	1730.0 J	2450.0 J	4730.0 J	3260.0 J	6600.0 J	560.0 J	743.0 J
Lead	12400.0 J	17500.0 J	13100.0 J	14400.0 J	10700.0 J	15300.0 J	8630.0 J	19200.0 J	5650.0 J	19200.0 J	16600.0 J
Magnesium	1250.0	1500.0	1350.0	1360.0	2270.0	3510.0	5340.0	3920.0	6720.0	1480.0	1030.0
Manganese	---	---	---	---	---	---	---	---	44.0 J	---	---
Mercury	---	---	---	---	---	---	---	---	---	---	---
Nickel	--- R	--- R	--- R	42.0 J	40.0 J	65.0 J	--- R	--- R	--- R	--- R	--- R
Selenium	---	---	---	---	---	---	---	---	---	---	---
Silicon	5460.0 J	7760.0 J	5360.0 J	5800.0 J	22400.0 J	81300.0 J	109000.0 J	28800.0 J	72100.0 J	7810.0 J	[illegible] J
Silver	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Sodium	---	---	7690.0 J	---	---	---	---	---	---	---	---
Thallium	---	---	---	---	---	---	---	---	---	---	---
Titanium	---	---	---	---	---	860.0	1140.0	---	846.0	---	
Vanadium	---	---	---	---	---	---	---	---	---	---	---
Zinc	512.0	1590.0	599.0	1300.0	1500.0	377.0	620.0	4300.0	1200.0	405.0	559.0

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-30
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SLUDGE (STEP II)
INORGANIC DATA

SAMPLE LOCATION:	CR87-104-02	CR87-104-03	CR87-105-01	CR87-105-02	CR87-105-03	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S10	88HV03S09	88HV03S11	88HV03S12	88HV03S13	88HV03R01
ITR NUMBER:	MER 917	MER 918	MER 919	MER 920	MER 921	MER 925
LABORATORY	JTC	JTC	JTC	JTC	JTC	JTC
DATE SAMPLED:	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	FILTER CAKE	PEAT	SLUDGE	FILTER CAKE	PEAT	
(mg/kg)						
Aluminum	6100.0	7940.0	2750.0	9880.0	1690.0	879.0
Antimony	---	---	---	---	---	---
Arsenic	---	---	---	---	---	---
Barium	478.0 J	1230.0 J	5700.0 J	1330.0 J	3570.0 J	---
Beryllium	---	---	---	---	---	---
Cadmium	---	---	---	---	---	---
Calcium	1960.0	3850.0	4470.0	5280.0	1430.0	---
Chromium	---	41.0	41.0	---	---	---
Cobalt	---	---	---	---	---	---
Copper	---	58.0 J	139.0 J	46.0 J	---	---
Iron	2720.0 J	2740.0 J	1480.0 J	3560.0 J	471.0 J	---
Lead	11400.0 J	11300.0 J	23500.0 J	20100.0 J	15800.0 J	---
Magnesium	1670.0	3430.0	1360.0	2950.0	1360.0	---
Manganese	---	---	---	---	---	---
Mercury	---	---	---	---	---	---
Nickel	75.0 J	47.0 J	--- R	56.0 J	--- R	--- R
Selenium	---	---	---	---	---	---
Silicon	43900.0 J	21800.0 J	7790.0 J	58700.0 J	6330.0 J	458000.0 J
Silver	--- R	--- R	--- R	--- R	--- R	--- R
Sodium	---	4670.0 J	---	---	5510.0 J	---
Thallium	---	---	---	---	---	---
Titanium	784.0	---	---	802.0	---	---
Vanadium	---	---	---	---	---	---
Zinc	169.0	2630.0	1840.0	674.0	305.0	---

"---" - Not detected
J - Estimated concentration
B - Blank contamination
R - Laboratory data not usable

TABLE B-31
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
INCINERATION PARAMETERS

SAMPLE LOCATION:	S087-06-01	S087-06-02	S087-14-01	S087-15-01	S087-16-01	S087-16-01	S087-17-01	S087-18-01	S087-18-01	S087-18-02	S087-19-01	S087-19-01	S087-22-01
CRL SAMPLE NUMBER:	88HK05S15	88HK05S16	88HK05S14	88HK05S10	88HK05S09		88HK05S17	88HK05S12	88HK05D12	88HK05S13	88HK05S06	88HK05D06	88HK05S11
SAS NUMBER:	3784-E142	3784-E145	3784-E138	3784-E121	3784-E113		3784-E151	3784-E135	3784-E123	3784-E125	3784-E101	3784-E102	3784-E130
LABORATORY:	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER	WEYER
DATE SAMPLED:	05/19/88	05/19/88	05/19/88	05/18/88	05/17/88	05/17/88	05/19/88	05/19/88	05/19/88	05/18/88	05/16/88	05/16/88	05/18/88
Moisture Content (%) as Rec'd	3.0	8.7	35.4	13.6	5.4	NA	19.3	38.1	24.6	12.7	8.1	7.5	22.9
Moisture Content (%) Air Dried	10.5	---	1.5	1.8	1.4	NA	4.3	2.0	---	1.1	1.4	---	2.4
Total Moisture (%) as Rec'd	13.2	9.2	36.4	15.2	6.8	NA	22.8	39.3	25.1	13.7	9.4	8.3	24.8
Ash Content (%)	51.5	98.1	87.1	86.5	85.1	NA	86.2	79.0	90.6	97.4	90.9	97.5	78.5
Volatile Matter (%)	46.2	2.8	13.1	12.8	17	NA	12.7	23.8	6.0	3.2	9.5	3.3	23.1
Fixed Carbon (%)	2.3	---	---	---	---	NA	3.3	---	3.4	---	---	---	---
Heating Value (BTU/lb)	7565	---	1320	1475	1791	NA	842	2092	866	---	767	84	2233
Carbon Content (%)	36.6 J	---	8.4 J	7.7 J	10.9 J	NA	5.9 J	13.6 J	6.1 J	---	4.5 J	1.0 J	12.5 J
Hydrogen Content (%)	6.1 J	---	---	---	1.4 J	NA	---	---	---	---	---	---	---
Nitrogen Content (%)	---	---	---	---	---	NA	---	---	---	---	---	---	---
Oxygen Content (%)	3.8	1.9	4.4	5.8	2.5	NA	6.4	7.4	3.4	2.6	4.7	2.5	9.0
Sulfur Content (%)	2.1	---	---	---	---	NA	1.5	---	---	---	---	---	2.1

SAMPLE LOCATION:	S087-06-01	S087-06-02	S087-14-01	S087-15-01	S087-16-01	S087-16-01	S087-17-01	S087-18-01	S087-18-01	S087-18-02	S087-19-01	S087-19-01	S087-22-01
CRL SAMPLE NUMBER:	88HK05S15	88HK05S16	88HK05S14	88HK05S10	88HK05S09	88HK05D09	88HK05S17	88HK05S12		88HK05S04	88HK05S06		88HK05S11
SAS NUMBER:	3784-E143	3784-E146	3784-E139	3784-E122	3784-E114	3784-E115	3784-E152	3784-E136		3784-E126	3784-E104		3784-E131
TOC (mg/g)	*	0.7	64.1	38.8	33.4	19.3	34.3	60.6	NA	12.4	8.9	NA	59.1

"---" - Not detected
NA - Not analyzed
J - Estimated concentration
* - Sample could not be analyzed by laboratory

TABLE B-31
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
INCINERATION PARAMETERS

SAMPLE LOCATION:	S087-23-01	S087-23-01	S087-24-01	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HK05S07		88HK05S08	88HK05R07	88HK05R06
SAS NUMBER:	3784-E107		3784-E110	3784-E119	3784-E149
LABORATORY:	WEYER	WEYER	WEYER	WEYER	WEYER
DATE SAMPLED:	05/17/88	05/17/88	05/17/88	05/17/88	05/19/88
Moisture Content (%) as Rec'd	13.1	NA	4.4	---	---
Moisture Content (%) Air Dried	1.9	NA	1.1	---	---
Total Moisture (%) as Rec'd	14.8	NA	5.5	---	---
Ash Content (%)	92.1	NA	89.1	100.1	100.1
Volatile Matter (%)	7.6	NA	11.4	---	---
Fixed Carbon (%)	---	NA	---	---	---
Heating Value (BTU/lb)	336	NA	1728	---	---
Carbon Content (%)	3.3 J	NA	9.3 J	---	---
Hydrogen Content (%)	---	NA	1.1 J	---	---
Nitrogen Content (%)	---	NA	---	---	---
Oxygen Content (%)	4.6	NA	---	---	---
Sulfur Content (%)	---	NA	---	---	---

SAMPLE LOCATION:	S087-23-01	S087-23-01	S087-24-01	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HK05S07	88HK05D07	88HK05S08	88HK05R07	88HK05R06
SAS NUMBER:	3784-E108	3784-E109	3784-E111	3784-E120	3784-E150
TOC (mg/g)	3.7	11.8	14.0	0.4	0.4

"---" - Not detected
NA - Not analyzed
J - Estimated concentration
* - Sample could not be analyzed by laboratory

TABLE B-32
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SLUDGE (STEP II)
INCINERATION PARAMETERS

SAMPLE LOCATION:	CR87-101-01	CR87-101-03	CR87-102-01	CR87-102-03	CR87-103-01	CR87-103-02	CR87-103-02	CR87-103-03	CR87-104-01	CR87-104-01
CRL SAMPLE NUMBER:	88HV03S01	88HV03S02	88HV03S03	88HV03S05	88HV03S04	88HVD3S06	88HVD3D06	88HV03S07	88HV03S08	88HV03D08
SAS NUMBER:	3784-E01	3784-E02	3784-E03	3784-E04	3784-E05	3784-E06	3784-E08	3784-E07	3784-E09	3784-E10
LABORATORY	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR
DATE SAMPLED:	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	SLUDGE	PEAT	SLUDGE	PEAT	SLUDGE	FILTER CAKE	FILTER CAKE	PEAT	SLUDGE	SLUDGE
Sulfur Content (%)	2.10	3.20	1.71	2.47	4.38	2.9	3.67	8.83	2.38	2.29
Chlorine Content (%)	0.13	0.14	---	0.12	---	---	---	---	---	---
Moisture Content (%)	35.7	26.4	39.5	28.6	10.8	14.6	21.9	6.25	29.3	27
Ash Content (%)	6.14	15.9	5.89	6.08	9.5	34.1	42.5	22.4	7.15	7.53
Heating Value (BTU/lb)	8120	8740	7920	7850	9220	7160	6300	7900	8600 J	68460 J
Viscosity	semi-solid @ 82 degrees C	NA	160,000 @ 40 degrees C 61,200 @ 50 degrees C 36,000 @ 60 degrees C 23,400 @ 70 degrees C 6,610 @ 82 degrees C	NA	semi-solid @ 82 degrees C	NA	NA	NA	74,000 @ 40 degrees C 47,100 @ 50 degrees C 32,200 @ 60 degrees C 26,200 @ 70 degrees C 7,960 @ 80 degrees C	semi-solid @ 80 degrees C

"---" - Not detected
NA - Not analyzed
J - Estimated concentration

TABLE 8-32
ARROWHEAD - FIELD WORK DESIGN INVESTIGATION
SLUDGE (STEP II)
INCINERATION PARAMETERS

SAMPLE LOCATION:	CR87-104-02	CR87-104-03	CR87-105-01	CR87-105-02	CR87-105-03	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S10	88HV03S09	88HV03S11	88HV03S12	88HV03S13	88HV03R01
SAS NUMBER:	3784-E12	3784-E11	3784-E14	3784-E15	3784-E16	3784-E13
LABORATORY	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR	VERSAR
DATE SAMPLED:	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	FILTER CAKE	PEAT	SLUDGE	FILTER CAKE	PEAT	
Sulfur Content (%)	4.17	5.75	1.33	2.77	4.19	---
Chlorine Content (%)	---	---	---	---	0.14	---
Moisture Content (%)	12.8	14.1	39.8	20.0	24.8	---
Ash Content (%)	15.2	9.39	6.79	32.7	9.13	99.9
Heating Value (BTU/lb)	8360	10800	6890	9600	7290	102
Viscosity	NA	NA	semi-solid @ 80 degrees C	NA	NA	solid @ 60 degrees C

"---" - Not detected
NA - Not analyzed
J - Estimated concentration

TABLE B-33
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	S087-06-02	S087-06-02	S087-06-03	S087-14-02	S087-14-03	S087-15-02	S087-15-03	S087-16-02	S087-16-03	S087-17-02	S087-17-02
DEPTH:	(12-14')	(12-14')	(18-20')	(6.5-8.0')	(12-14')	(8-10')	(14-16')	(15-17')	(21-23')	(8-10')	(8-10')
CRL SAMPLE NUMBER:	88HK04S89	88HK04D89	88HK04S90	88HK04S87	88HK04S88	88HK04S99	88HK04S01	88HK04S97	88HK04S98	88HK04S91	88HK04D91
SMO CASE NUMBER:	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629
DTR NUMBER:	EW 576	EW 577	EW 578	EW 581	EW 582	EW 571	EW 573	EW 565	EW 566	EW 568	EW 569
LABORATORY:	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI
DATE SAMPLED:	05/19/88	05/19/88	05/19/88	05/19/88	05/19/88	05/18/88	05/18/88	05/17/88	05/17/88	05/19/88	05/19/88
% MOISTURE:	10	17	16	10	17	16	17	13	15	11	11
(UG/KG)											
VOLATILE ORGANIC COMPOUNDS											
Methylene Chloride	27 B	27 B	39 B	22 B	65 B	270 B	110 B	23 B	25 B	66 B	61 B
Acetone	62 B	44 B	21 B	25 B	20 B	81 B	37 B	40 B	24 B	53 B	52 B
Carbon Disulfide	---	---	---	---	---	---	---	3 J	---	---	---
Total 1,2-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---	---	---	---	---	---
Toluene	48 B	10 B	34 B	25 B	110 B	44 B	99 B	17 B	11 B	120 B	41 B
4-Methyl-2-Pentanone	4 J	---	---	---	---	---	---	7 J	---	---	---
Ethylbenzene	6 J	---	---	---	---	9 J	---	---	---	---	---
Xylene	29	---	---	---	---	32	---	9	---	13	9
2-Butanone	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
SEMIVOLATILE ORGANIC COMPOUNDS											
Phenol	---	170 J	---	---	---	390 J	120 J	---	---	---	NA
Naphthalene	---	140 J	---	---	---	---	---	---	---	---	NA
2-Methylnaphthalene	---	270 J	---	---	---	---	---	---	---	---	NA
Phenanthrene	---	---	---	---	---	---	---	---	---	---	NA
Di-n-Butylphthalate	330 J	190 J	250 J	130 J	150 J	---	---	---	---	250 J	NA
Fluoranthene	---	---	---	---	---	---	---	---	---	---	NA
bis(2-Ethylhexyl)Phthalate	---	---	---	---	130 J	---	110 J	140 J	92 J	120 J	NA
Chrysene	---	---	---	---	---	---	---	---	---	---	NA
Di-n-Octyl Phthalate	---	---	---	---	---	---	---	---	---	---	NA

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable

TABLE B-33
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	S087-17-03	S087-18-02	S087-18-02	S087-18-03	S087-19-02	S087-19-03	S087-22-02	S087-22-03	S087-23-02	S087-23-02	S087-23-03
DEPTH:	(14-16')	(6-8')	(6-8')	(12-14')	(10-12')	(14-16')	(6-8')	(12-14')	(3-5')	(3-5')	(9-11')
CRL SAMPLE NUMBER:	88HK04S92	88HK04D04	88HK04S04	88HK04S05	88HK04S85	88HK04S86	88HK04S02	88HK04S03	88HK04S93	88HK04D93	88HK04S94
SMO CASE NUMBER:	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629	9629
OTR NUMBER:	EW 570	EW 572	EW 574	EW 575	EW 557	EW 559	EW 579	EW 580	EW 560	EW 561	EW 562
LABORATORY:	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI	GSRI
DATE SAMPLED:	05/19/88	05/18/88	05/18/88	05/18/88	05/16/88	05/16/88	05/18/88	05/18/88	05/17/88	05/17/88	05/17/88
% MOISTURE:	10	18	39	10	13	9	72	11	13	11	18
(UG/KG)											
VOLATILE ORGANIC COMPOUNDS											
Methylene Chloride	36 B	NA	160 B	67 B	51 B	32 B	800 B	54 B	290 B	NA	80 B
Acetone	92 B	NA	71 B	96 B	70 B	48 B	210 B	51 B	100 B	NA	23 B
Carbon Disulfide	---	NA	---	---	---	---	---	---	---	NA	---
Total 1,2-Dichloroethene	---	NA	---	---	---	---	---	---	---	NA	---
1,1,1-Trichloroethane	---	NA	---	---	---	---	---	---	---	NA	---
Trichloroethene	---	NA	---	---	---	---	---	---	---	NA	---
Toluene	67 B	NA	240	110 B	40 B	16 B	75 B	70 B	53 B	NA	11 B
4-Methyl-2-Pentanone	15 J	NA	---	---	---	---	---	---	---	NA	---
Ethylbenzene	6 J	NA	---	---	6 J	---	20 J	---	---	NA	---
Xylene	26	NA	7 J	---	50	---	110	---	---	NA	---
2-Butanone	--- R	NA	--- R	--- R	--- R	--- R	--- R	--- R	--- R	NA	--- R
SEMIVOLATILE ORGANIC COMPOUNDS											
Phenol	---	---	---	---	---	---	---	---	---	---	---
Naphthalene	---	---	---	---	---	---	1400	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	---	2800	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---	---	---
Di-n-Butylphthalate	78 J	820	---	200 J	---	---	670 J	---	---	390	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---	---
bis(2-Ethylhexyl)Phthalate	200 J	---	---	---	200 J	99 J	---	---	190 J	87 J	95 J
Chrysene	---	---	---	---	---	---	---	---	---	---	---
Di-n-Octyl Phthalate	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable

TABLE B-33
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	S087-24-02	S087-24-03	FIELD BLANK	FIELD BLANK
DEPTH:	(4-6')	(10-12')		
CRL SAMPLE NUMBER:	88HK04595	88HK04596	88HK04R07	88HK04R06
SMO CASE NUMBER:	9629	9629	9629	9629
OTR NUMBER:	EW 563	EW 564	EW 567	EW 583
LABORATORY:	CSRI	CSRI	CSRI	CSRI
DATE SAMPLED:	05/17/88	05/17/88	05/17/88	05/19/88
% MOISTURE:	27	16	2	1
(UG/KG)				
VOLATILE ORGANIC COMPOUNDS				
Methylene Chloride	140 B	180 B	91 B	29 B
Acetone	140 B	82 B	24 B	31 B
Carbon Disulfide	---	---	---	---
Total 1,2-Dichloroethene	---	---	---	---
1,1,1-Trichloroethane	---	---	---	---
Trichloroethene	---	---	---	---
Toluene	48 B	5 B	---	15
4-methyl-2-Pentanone	---	---	---	---
Ethylbenzene	---	---	---	---
Xylene	---	---	---	---
2-Butanone	48 J	--- R	--- R	--- R
SEMIVOLATILE ORGANIC COMPOUNDS				
Phenol	---	---	---	---
Naphthalene	---	---	---	---
2-methylnaphthalene	---	---	---	---
Phenanthrene	---	---	---	---
Di-n-Butylphthalate	---	6 J	---	---
Fluoranthene	---	---	---	---
bis(2-Ethylhexyl)Phthalate	240 J	80 J	---	---
Chrysene	---	---	---	---
Di-n-Octyl Phthalate	---	---	---	---

"---" - Not detected
B - Blank contamination
J - Estimated concentration
NA - Not analyzed
R - Laboratory data not usable

TABLE B-34
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SLUDGE (STEP (1)
ORGANIC DATA

SAMPLE LOCATION:	CR87-101-01	CR87-101-03	CR87-102-01	CR87-102-03	CR87-103-01	CR87-103-02	CR87-103-02	CR87-103-03	CR87-103-03	CR87-104-01	CR87-104-01	CR87-104-02	CR87-104-03
CRL SAMPLE NUMBER:	88HV03S01	88HV03S02	88HV03S03	88HV03S05	88HV03S04	88HV03S06	88HV03D06	88HV03S07	88HV03D07	88HV03S08	88HV03D08	88HV03S10	88HV03S09
SAS NUMBER:	31551	31551	31551	31551	31551	31551	31551	31551	31551	31551	31551	31551	31551
OTR NUMBER:	ES595	ES597	ES598	ES600	ES601	ES602	EW501	ES603	ES611	ES604	ES610	ES605	ES606
LABORTORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	SLUDGE	PEAT	SLUDGE	SLUDGE	SLUDGE	FILTER CAKE	FILTER CAKE	PEAT	PEAT	SLUDGE	SLUDGE	FILTER CAKE	PEAT
(mg/kg)													
VOLATILE ORGANIC COMPOUNDS													
DILUTION FACTOR:	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PH:	2.7	2.5	2.6	2.7	2.8	2.9	3.5	2.4	2.3	2.6	2.2	2.7	2.6
methylene Chloride	4.7 J	12 J	---	---	---	5 J	---	---	---	4 J	4.7 J	---	6.3 J
1,1,1-Trichloroethane	16	15 J	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	9	9.1 J	---	---	1.1 J	---	---	---	---	---	---	---	---
Toluene	33	43 J	---	2.9	3.3	---	---	4.1	---	3.9	0.56 J	---	---
Acetone	---	13 J	7.6 J	---	---	---	---	15 J	15 J	---	10 J	---	---
2-Butanone	---	43 J	---	---	---	---	16 J	---	---	---	---	---	---
Tetrachloroethene	---	---	---	---	---	---	---	---	---	---	---	---	---
4-methyl-2-Pentanone	---	--- R	---	---	---	--- R	---	---	---	---	--- R	---	---
SEMIVOLATILE ORGANIC COMPOUND													
DILUTION FACTOR:	10	20	10	10	10	20	20	20	20	10	10	10	20
2-methylnaphthalene	38 J	43 J	24 J	96 J	---	---	---	60 J	42 J	30 J	22 J	---	130 J
Bis(2-ethylhexyl)phthalate	38 J	51 J	34 J	37 J	---	---	---	---	---	31 J	43 J	---	---
Phenanthrene	20 J	---	---	26 J	---	---	---	---	---	---	---	---	---
Phenol	---	---	21 J	---	---	88 J	---	---	56 J	---	---	---	120 J
Naphthalene	---	---	---	44 J	---	---	---	---	---	---	---	---	60 J
Dimethyl Phthalate	---	---	---	---	---	---	42 J	---	---	---	---	---	---
Di-n-Butylphthalate	---	---	---	---	---	---	---	---	---	---	23 J	---	---
PESTICIDE/PCBs													
DILUTION FACTOR:	10	20	10	10	10	20	20	20	20	10	10	10	20
4,4' - DDD	---	---	---	---	---	---	---	---	---	---	38 J	---	---
4,4' - DDT	---	---	---	---	---	---	---	---	---	---	96 J	---	---
Endosulfan-1	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R
Endosulfan-2	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R	--- R

"---" - Not detected
J - Estimated Concentration
R - Laboratory data not usable

TABLE B-34
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SLUDGE (STEP II)
ORGANIC DATA

SAMPLE LOCATION:	CR87-105-01	CR87-105-02	CR87-105-03	FIELD BLANK
CRL SAMPLE NUMBER:	88HV03S11	88HV03S12	88HV03S13	88HV03R01
SAS NUMBER:	31551	31551	31551	31551
OTR NUMBER:	ES607	ES608	ES609	EW502
LABORTORY:	S-CUBED	S-CUBED	S-CUBED	S-CUBED
DATE SAMPLED	04/27/88	04/27/88	04/27/88	04/27/88
COMMENTS:	SLUDGE	FILTER CAKE	PEAT	
mg/kg)				
VOLATILE ORGANIC COMPOUNDS				
DILUTION FACTOR:	1.0	1.0	1.0	1.0
PH:	2.3	2.5	2.6	6.4
Methylene Chloride	7 J	---	---	---
1,1,1-Trichloroethane	16 J	---	---	---
Trichloroethene	15 J	---	---	---
Toluene	66 J	2.9	---	---
Acetone	---	15 J	---	---
2-Butanone	---	---	---	---
Tetrachloroethene	2.3 J	---	---	---
4-Methyl-2-Pentanone	---	---	---	---
SEMIVOLATILE ORGANIC COMPOUND				
DILUTION FACTOR:	20	10	20	1.0
2-Methylnaphthalene	50 J	---	---	---
Bis(2-ethylhexyl)phthalate	---	34 J	55 J	---
Phenanthrene	---	---	---	---
Phenol	110 J	25 J	---	---
Naphthalene	---	---	---	---
Dimethyl Phthalate	---	---	---	---
Di-N-Butylphthalate	---	---	---	---
PESTICIDE/PCBs				
DILUTION FACTOR:	20	10	20	1.0
4,4' - DDD	---	---	---	---
4,4' - DDT	---	---	---	---
Endosulfan-1	--- R	--- R	--- R	--- R
Endosulfan-2	--- R	--- R	--- R	--- R

"---" - Not detected
J - Estimated Concentration
R - Laboratory data not usable

TABLE B-35
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	S087-06-02	S087-06-03	S087-14-02	S087-14-03	S087-15-02	S087-15-03	S087-16-02	S087-16-03	S087-17-02	S087-17-03	S087-18-02	S087-18-02	S087-18-03	S087-18-03
CRL SAMPLE NUMBER:	88HK04S89	88HK04S90	88HK04S87	88HK04S88	88HK04S99	88HK04S01	88HK04S97	88HK04S98	88HK04S91	88HK04S92	88HK04D04	88HK04S04	88HK04D05	88HK04S05
SAS NUMBER:	3784-E144	3784-E147	3784-E140	3784-E141	3784-E124	3784-E128	3784-E116	3784-E117	3784-E153	3784-E154	3784-E127	3784-E134	3784-E129	3784-E137
LABORATORY:	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM
DATE SAMPLED:	05/19/88	05/19/88	05/19/88	05/19/88	05/18/88	05/18/88	05/17/88	05/17/88	05/19/88	05/19/88	05/18/88	05/18/88	05/18/88	05/18/88
% MOISTURE:	10	16	14	14	15	15	11	13	13	12	58	19	10	10
(ug/kg)														
Naphthalene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2-Methylnaphthalene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chrysene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Benzo(b)Fluoranthene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Benzo(a)Pyrene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1-methylnapthalene	---	---	---	---	---	---	---	---	---	---	---	---	---	---

"---" - Not detected

TABLE B-35
ARROWHEAD - FIELDWORK DESIGN INVESTIGATION
SUBSURFACE SOIL (STEP II)
LOW DETECTION LIMIT PAHS

SAMPLE LOCATION:	S087-19-02	S087-19-03	S087-22-02	S087-22-03	S087-23-02	S087-24-02	FIELD BLANK	FIELD BLANK
CRL SAMPLE NUMBER:	88HK04S85	88HK04S86	88HK04S02	88HK04S03	88HK04S93	88HK04S95	88HK04R07	88HK04R06
SAS NUMBER:	3784-E103	3784-E105	3784-E132	3784-E133	3784-E106	3784-E112	3784-E118	3784-E148
LABORATORY:	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM	DATACHEM
DATE SAMPLED:	05/16/88	05/16/88	05/18/88	05/18/88	05/17/88	05/17/88	05/17/88	05/19/88
% MOISTURE:	42	11	26	13	19	61	0	0
(ug/kg)								
Naphthalene	---	---	---	---	---	---	---	---
2-methylnaphthalene	---	---	---	---	---	---	---	---
Acenaphthylene	---	---	---	---	---	---	---	---
Acenaphthene	---	---	---	---	---	---	---	---
Fluorene	---	---	---	---	---	---	---	---
Phenanthrene	---	---	---	---	---	---	---	---
Fluoranthene	---	---	---	---	---	---	---	---
Pyrene	---	---	---	---	---	---	---	---
Benzo(a)Anthracene	---	---	---	---		---	---	---
Chyrsene	---	---	---	---		---	---	---
Benzo(b)Fluoranthene	---	---	---	---	---	---	---	---
Benzo(a)Pyrene	---	---	---	---	---	---	---	---
Indeno(1,2,3-cd)Pyrene	---	---	---	---	---	---	---	---
Anthracene	---	---	---	---	---	---	---	---
Benzo(g,h,i)Perylene	---	---	---	---	---	---	---	---
1-methylnapthalene	---	---	---	---	---	---	---	---

"---" - Not detected

Appendix C
HYDROGEOLOGIC INVESTIGATION

Appendix C
HYDROGEOLOGIC INVESTIGATION

This appendix discusses the hydrogeology of the Arrowhead Refinery site by incorporating data from the Fieldwork Design Investigation (FDI) with the RI data. The hydrogeologic investigation included reviewing existing data, performing new fieldwork, and interpreting field data. The interpretation of the site geology and hydrogeology in the RI has been revised to reflect the additional information collected during the FDI.

RI RESULTS AND OBSERVATIONS

GEOLOGY

Based on the results of the RI, the geology at the Arrowhead Refinery site was divided into five layers: fill, peat, outwash, morainal till, and bedrock. The fill material averages 4 feet in thickness. The underlying peat layer, which is zero to 4 feet thick, is underlain by a glacial outwash layer consisting of interbedded clay, silt, and sand and gravel layers 10 to 25 feet thick. Below the outwash is a 20- to 25-foot thick morainal till layer. The morainal till layer grades vertically from silty sand or sandy silt to a sand with some gravel, a trace of silt, and weathered fragments of gabbro. The morainal till overlies a heavily fractured gabbroic bedrock.

HYDROGEOLOGY

The water table underlying the site is shallow, generally zero to 4 feet below ground surface, and occurs within the peat or overlying fill deposit. Groundwater flow, as determined by groundwater level data, is generally to the southwest with gradients ranging from 0.0007 to 0.01 ft/ft. Upward vertical gradients suggested that the site may be a groundwater discharge area during part of the year.

OBJECTIVES

The specific objectives of the hydrogeologic investigation were to define or further investigate:

- The existence of a low permeability layer underlying the peat. Review of the boring logs from the RI indicated that a continuous layer of silty clay from 1 to 15 feet thick may exist beneath the peat.
- The groundwater flow characteristics and the aquifer properties in the different stratigraphic units.
- The existence of high permeability layers in addition to the sand and gravel units encountered during the RI fieldwork. High permeability units may influence groundwater flow, and therefore the contaminant transport, beneath the site.

- The composition, fracturing, and depth of bedrock. Little was known about the bedrock because it was encountered in only two borings during the RI.

- The effect of the EPA drainage ditch on groundwater flow at the site. Water level information collected during the RI indicated that the ditch may be a discharge area. If so, the ditch could affect contaminant transport.

- The vertical gradients at the site. There are upward vertical gradients in some parts of the site during certain times of the year. This indicates that at those times the site is a discharge area. The upward gradients may affect the migration of contaminants.

SUMMARY OF FDI ACTIVITIES

Fieldwork activities conducted between May and December 1987 consisted of:

- Seismic refraction surveys to delineate the bedrock surface
- Drilling and installation of 13 monitoring wells and 7 piezometers
- Drilling and sampling of four additional soil borings in the process area
- Borehole geophysical logging to aid in the interpretation and correlation of boring logs
- Measurements of water level
- In situ hydraulic conductivity testing
- Construction of two weirs and installation of four staff gauges in the U.S. EPA ditch
- Surveying of elevations of new and existing wells, piezometers, and staff gauges

The procedures, field observations, and results of these field activities are described in the Technical Memorandums in Appendix A.

RESULTS OF FDI ACTIVITIES

SITE GEOLOGY

Subsurface geologic data were obtained from borings conducted at 23 locations during the RI and 21 locations during the FDI. Data from soil borings conducted from previous EPA investigations (in 1980) were also used. Monitoring well and soil boring numbers and date drilled are included in Table C-1. The locations of the

Table C-1
SOIL BORING AND MONITORING WELL INSTALLATION SUMMARY

WELLS:

Pre-RI Wells: (installed by U.S. EPA in 1980)

B2b
B4a
B4b
B5

Phase I RI: (installed December 1984)

1a
2a
2b
2c
3a
3b
5a
5c
6a
6c
7a
8a
11a
12a
13a
14a
14b

Phase II RI: (installed June 1985)

7b
7c
10a
9a
9b
10b
14c
15a
15b

FDI Wells: (installed September-October 1987)

2e
3s
P5s
P5b
5b
5e
7s
8b
13e
13b
14s
P16s
16b
P17s
17b
17e
18e
P21s
P21b
P22s

SOIL BORINGS:

Phase II RI: (installed May-June 1985)

S01
S02
S03
S04
S05
S06
S08
S10

Step I FDI: (installed September-November 1987)

SO87-19
SO87-20
SO87-21
SO87-22
19s

Step II FDI: (installed May 1988)

SO87-06
SO87-14
SO87-15
SO87-16
SO87-17
SO87-18
SO87-19
SO87-22
SO87-23
SO87-24

borings, monitoring wells, and geologic cross sections are shown in Figure C-1. Figures C-2 through C-7 are typical generalized geologic cross sections.

Based on RI data and the FDI geologic and hydrogeologic information, the subsurface geology at the site has been redefined into four units: fill, peat and clay, morainal deposits, and bedrock. This interpretation, which is somewhat different from that in the RI, is discussed in greater detail below.

Fill

According to the FDI data, the nature and distribution of the fill was consistent with the results of the RI. The fill material consists of loose to dense dark brown or black sand, silty sand, or sandy silt and is gravelly in some areas. The thickness of the fill ranges from zero to 7 feet. Fill occurs primarily in the south central portion of the site just north of Highway 53 at the Gopher Oil building and the auto body shop, and in the process area and along the wastewater ditch. Fill was also encountered in borings immediately adjacent to the EPA ditch along Highway 53 and Ugstad Road and south of Highway 53. In most places, the fill overlies peat.

Fill in the process area was sandier and contained more gravel compared to other areas of the site. The fill was probably used to stabilize building locations and roadways in the process area, and to construct the berm that forms the southern boundary of the sludge lagoon. Finer-grained fill material composed primarily of silt appears to be associated with the construction of the wastewater ditch and the EPA ditch.

Peat and Clay

Peat. The nature and distribution of peat at the site were also consistent with the results of the RI. The peat is soft to medium stiff, black to brown, and fibrous and contains wood chips. It ranges in thickness from zero to 7.5 feet and occurs at the surface in the western portion of the site and just north of the lagoon (Figures C-2, C-4, and C-5). In other areas of the site where peat is present, it occurs below the fill or sludge.

The peat is continuous across the site except in the southern portion. In soil borings S08, S087-20, S087-21, and S087-23 (near the auto body shop), Well Nest 7, and abandoned piezometer 19s (along the driveway for Gopher Oil and the auto body shop), peat was not encountered during drilling. Peat in these areas was probably removed when the area was filled or when the buildings were constructed. The peat layer is also continuous off site south of Highway 53, except at well locations 16 and 17 where peat was probably removed during highway construction.

Clay

Clay. Underlying the peat in most borings is a medium stiff to stiff, gray, blue gray, green, or yellow brown clay to silty clay that is zero to 5 feet thick. Compared to silty clays in the till unit, it is softer (as indicated by blow counts), has a higher clay content, and usually contains little to no sand and no gravel. It is often mottled or a different color than the silty clays of the till, which are usually brown.

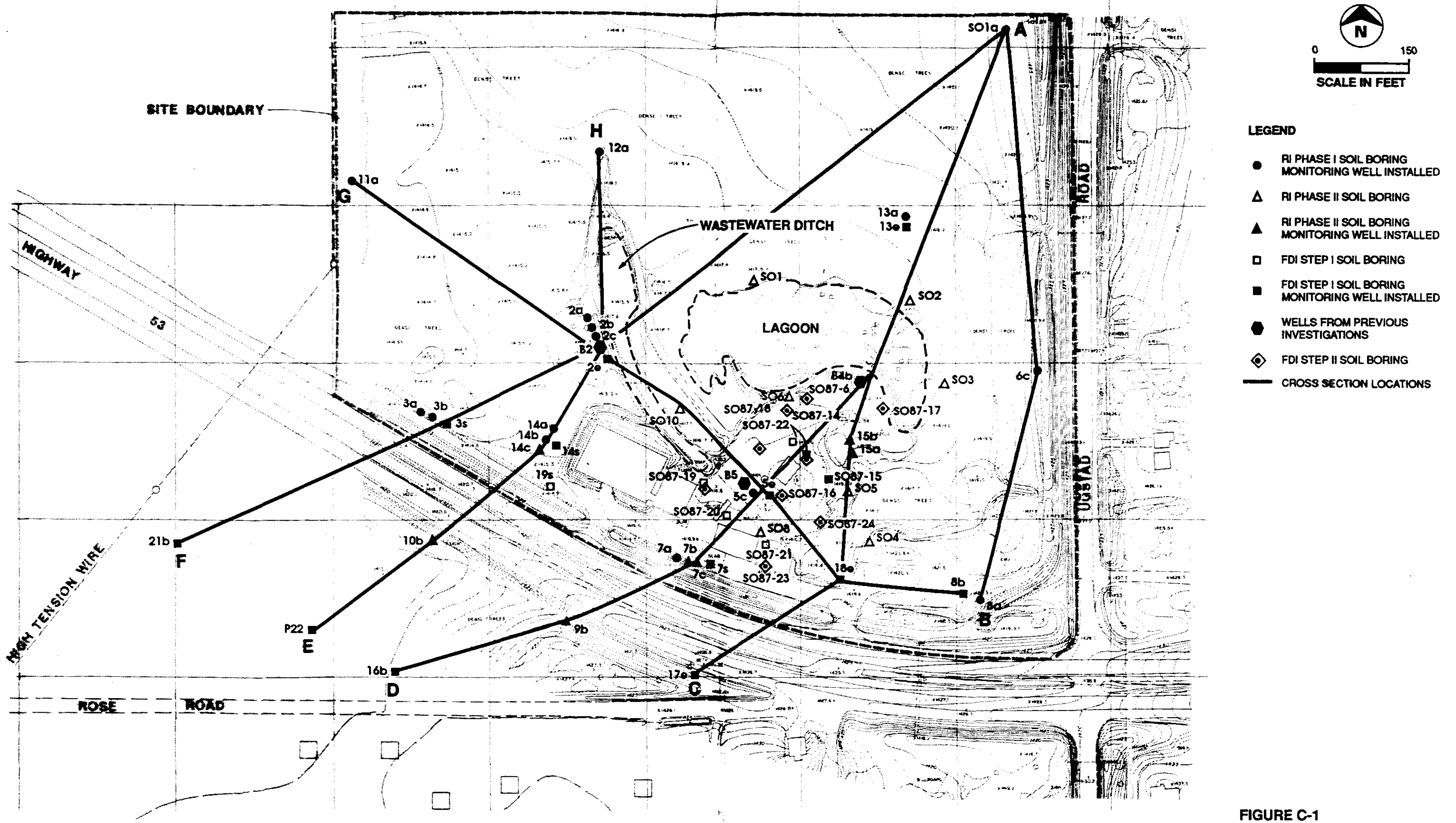
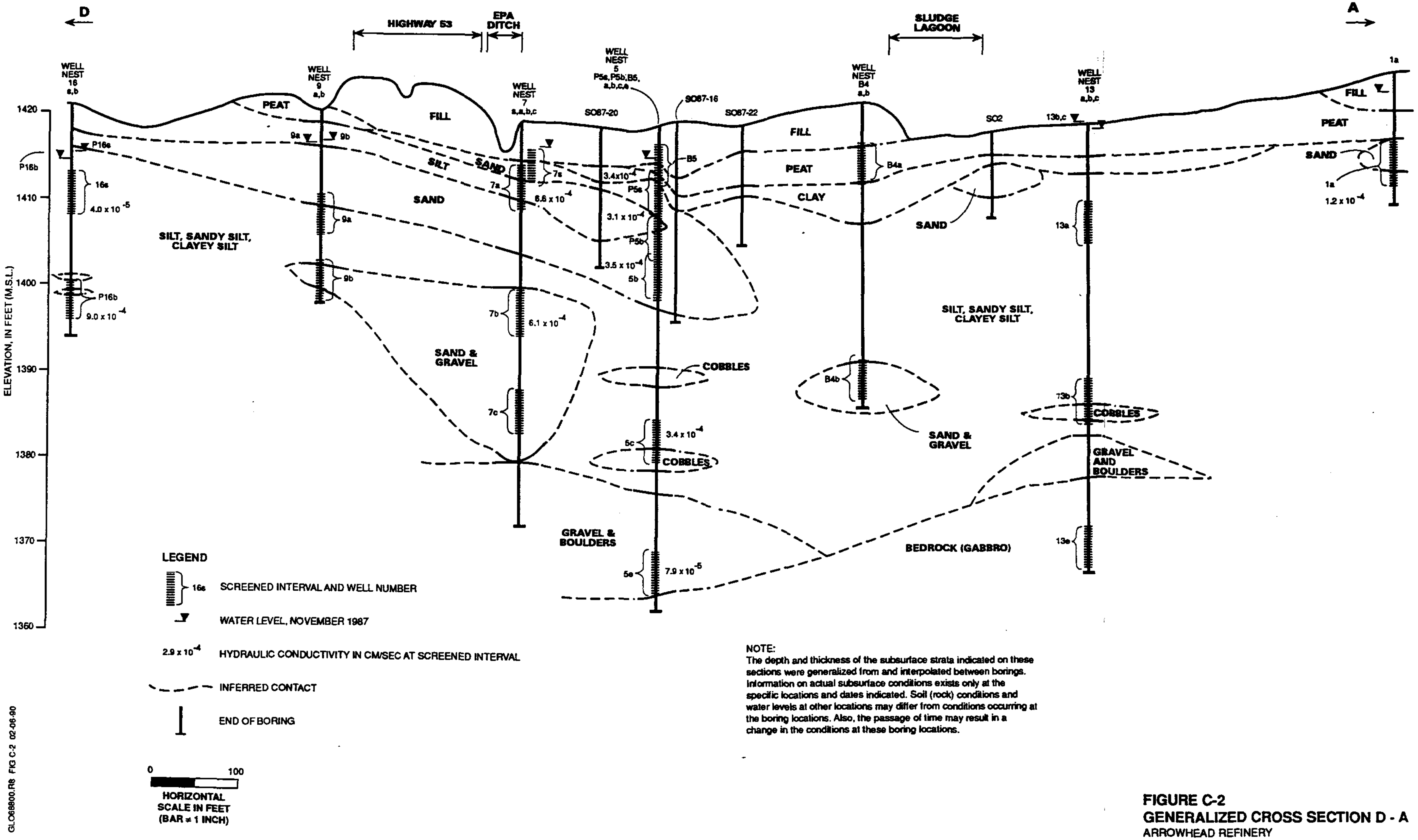


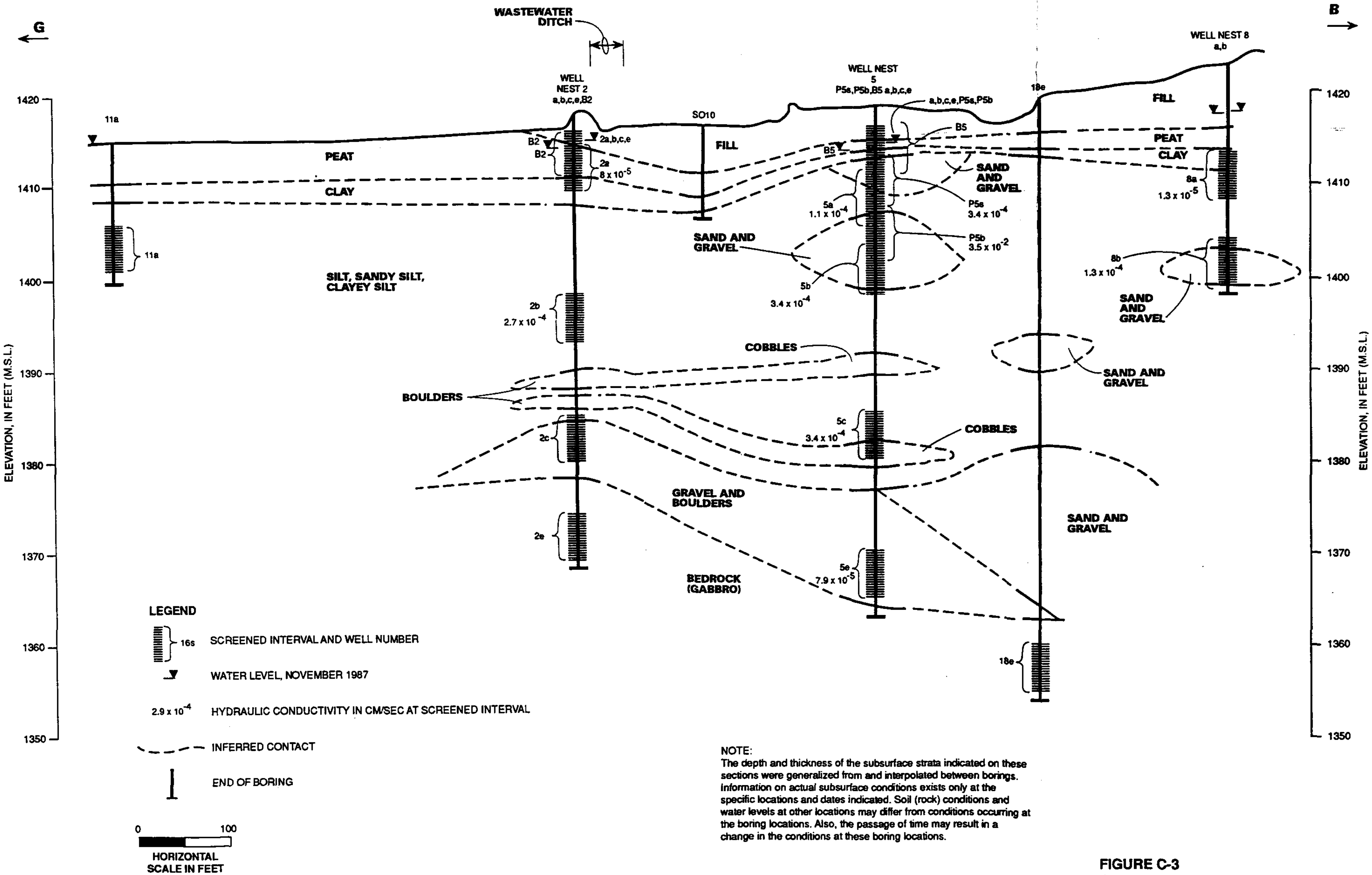
FIGURE C-1
LOCATION OF
CROSS SECTIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

GLO8800.R8 FIG C-2 02-06-90

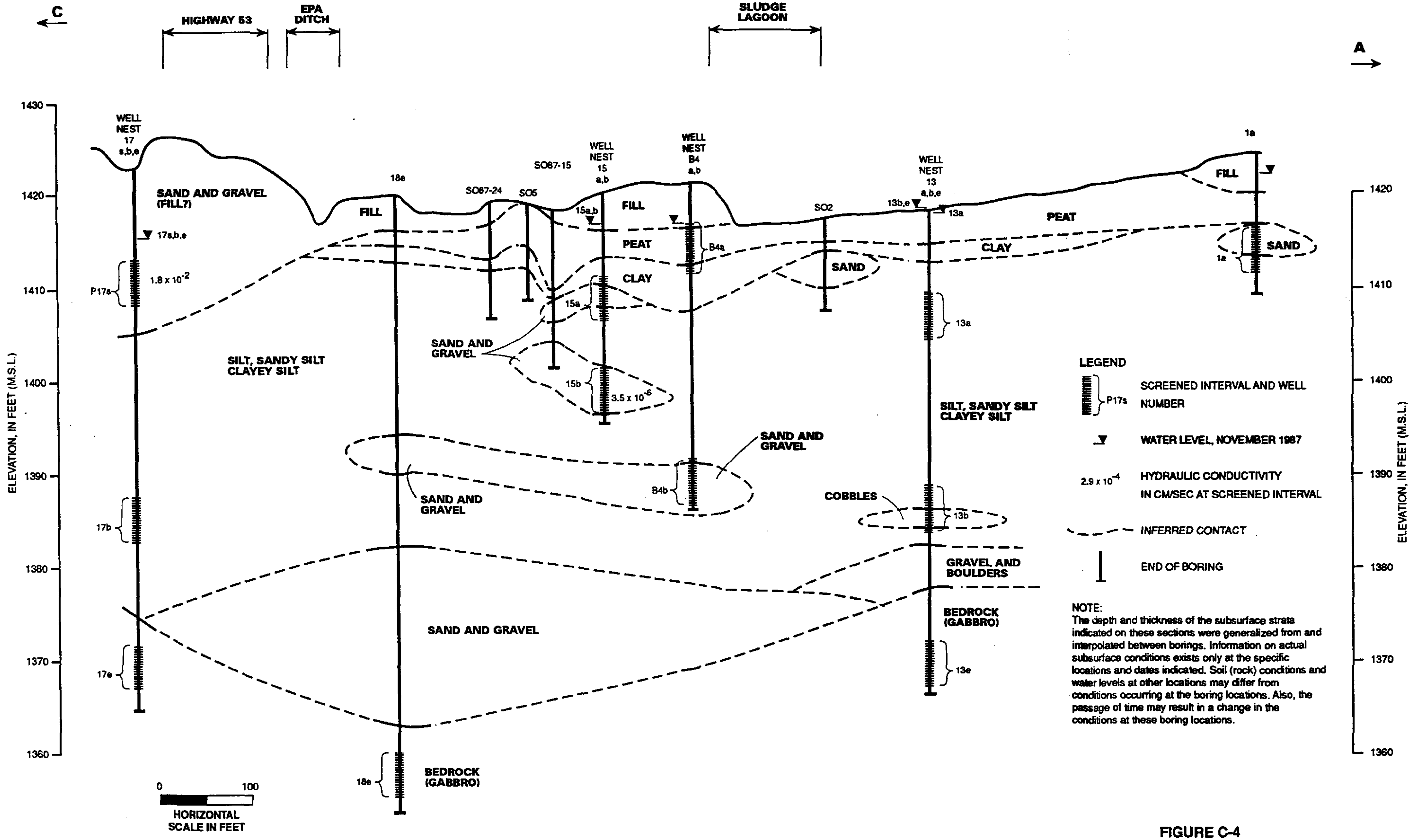
FIGURE C-2
GENERALIZED CROSS SECTION D - A
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

FIGURE C-3
GENERALIZED CROSS SECTION G - B
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

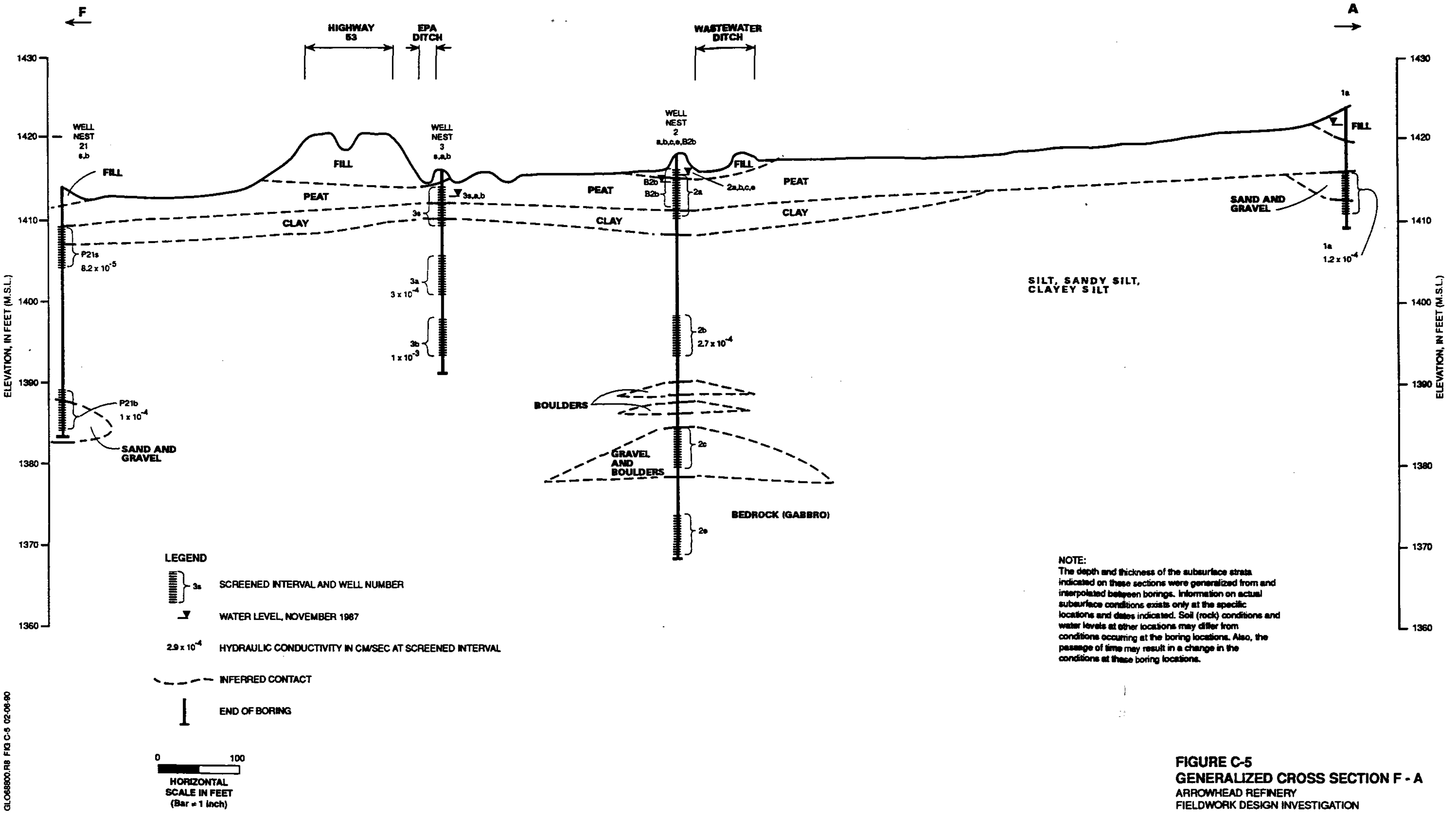
GLO68800.R8 FIG C-3 02-12-90



NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

FIGURE C-4
GENERALIZED CROSS SECTION C - A
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

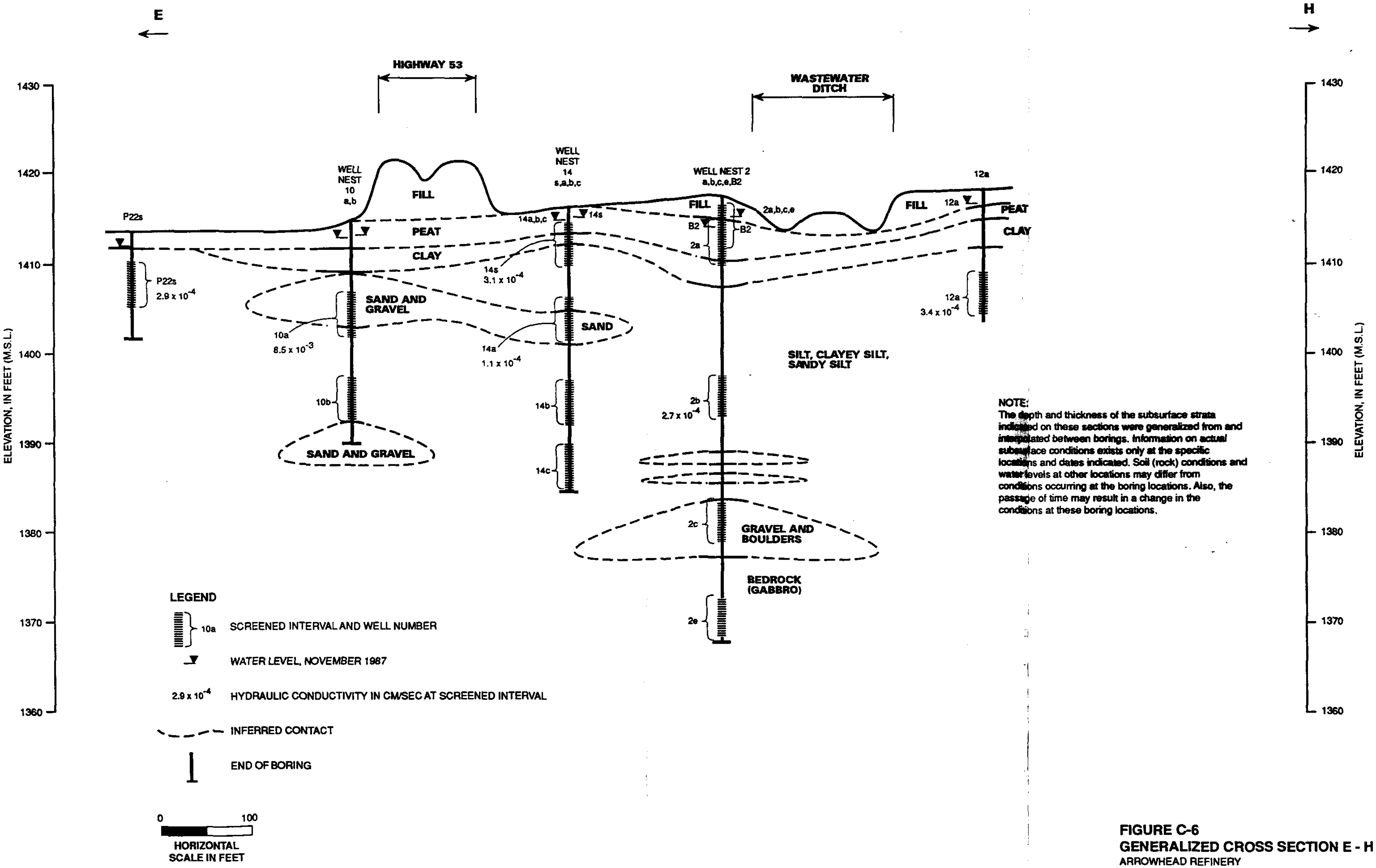
GLO68800.R8 FIG C-4 4-24-90



NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

FIGURE C-5
GENERALIZED CROSS SECTION F - A
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

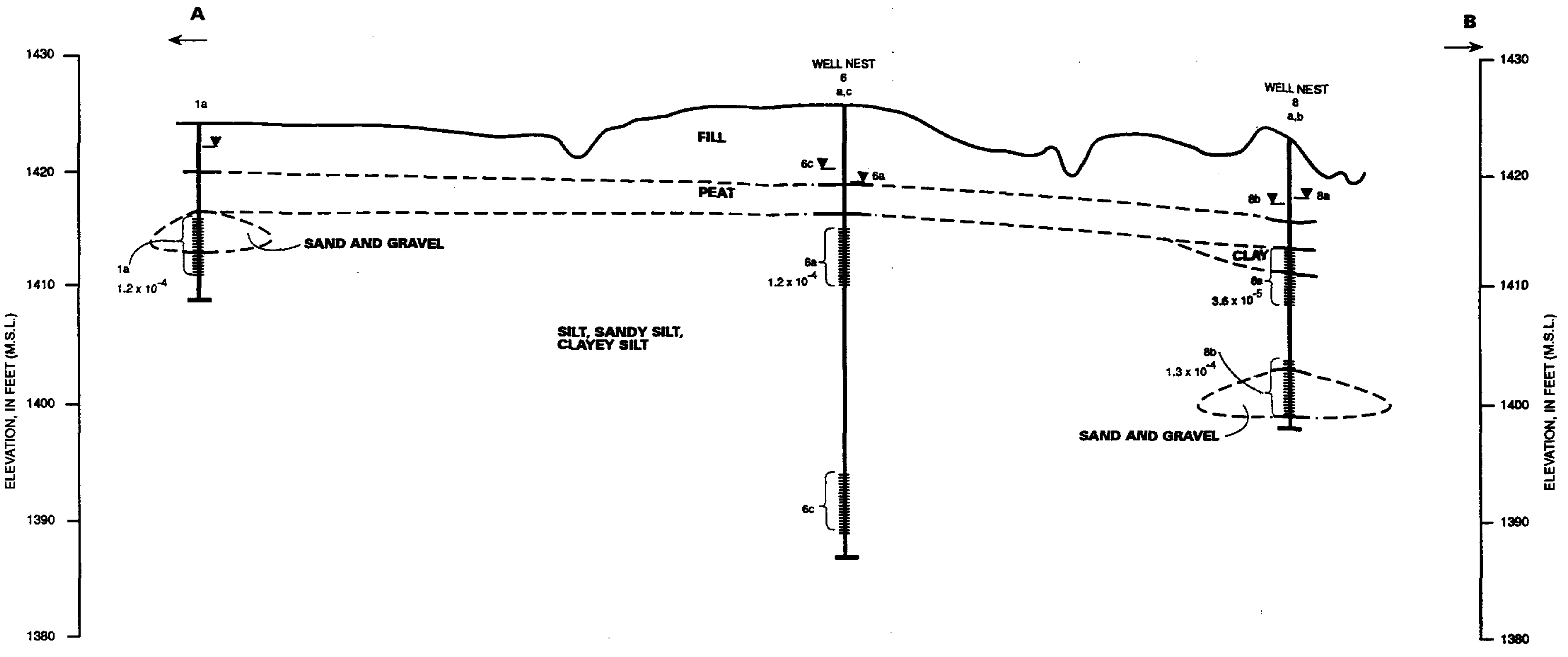
GLO68800.R8 FIG C-5 02-06-90



NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

GLO68800.R8 FIG C-6 02-12-90

FIGURE C-6
GENERALIZED CROSS SECTION E - H
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



LEGEND

1a	SCREENED INTERVAL AND WELL NUMBER
▼	WATER LEVEL, NOVEMBER 1987
2.9 x 10^{-4}	HYDRAULIC CONDUCTIVITY IN CM/SEC AT SCREENED INTERVAL
- - -	INFERRED CONTACT
⊥	END OF BORING

0 100

HORIZONTAL SCALE IN FEET

NOTE:
The depth and thickness of the subsurface strata indicated on these sections were generalized from and interpolated between borings. Information on actual subsurface conditions exists only at the specific locations and dates indicated. Soil (rock) conditions and water levels at other locations may differ from conditions occurring at the boring locations. Also, the passage of time may result in a change in the conditions at these boring locations.

GLO6800.R8 FIG C-7 02-06-90

FIGURE C-7
GENERALIZED CROSS SECTION A - B
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

The clay unit appears to be continuous beneath most of the site (Figures C-2 through C-6) and was encountered beneath the peat in most of the soil borings except near the autobody shop and Gopher Oil. The clay layer was absent in borings near the auto body shop (SO87-20, SO87-21, SO87-23, and Well Nest 7) and Gopher Oil (SO87-19 and abandoned piezometer 19s). The clay unit in this area, like the peat may have also been removed during construction of the buildings and roadways. The clay was also absent in borings (SO1a and Well Nests 6 and 18) which are adjacent to the EPA ditch along U.S. 53 and Ugstad Road.

Morainal Deposit

Below the peat and clay units is a morainal deposit consisting of mixed glacial outwash and till that is made up primarily of very stiff, brown silt, sandy silt, or clayey silt. The deposit sometimes grades to silty sand or silty clay, but the primary constituent of the deposit is silt. Within the morainal deposit are dense to very dense lenses of sand and gravel, 3 to 20 feet thick. Boulder and cobble zones 1 to 8 feet thick commonly occur in the bottom 15 feet of the deposit (Figures C-2 through C-6). The morainal deposit is 30 to 53 feet thick beneath the site.

The amount of coarser materials generally increases with depth in the morainal deposit, as seen in Figures C-2 and C-4, primarily because of the cobble and boulder zones. Also, the sand content of the deposit increases to the south and the clay content increases to the north beneath the site.

In the RI, the deposits below the peat-clay layer and above the bedrock were divided into glacial outwash and glacial morainal units. The existence of a glacial outwash unit was based on the presence of the sand and gravel layers within siltier materials. However, the FDI results show that the sands and gravels are neither as prevalent nor as extensive as concluded in the RI. The sands and gravels do not appear to occur in layers, but rather in discontinuous lenses within the silts. An exception to the discontinuity of the sands and gravels are the two lenses shown in geologic cross section D-A (Figure C-2) which appear to be continuous from monitoring well location 9 northeast to soil boring SO87-16. However, the lenses are continuous only to the northeast and do not appear to be continuous in a southeast/northwest direction because they are not present at boring locations 2, 6, 13, 14, or 16 (Figure C-3).

The existence of a glacial morainal deposit was assumed in the RI because of the boulder and cobble zones found in the deeper borings. Because of the similarity in the composition and hydraulic properties of the "outwash" and "morainal till," the two are now treated as one unit and referred to as the morainal till. Based on the boring logs, it appears that the unit is typical of ice contact deposits, which rapidly change in composition both laterally and vertically.

Bedrock

Bedrock was encountered during the RI in of only two borings (2c and 6c), so a seismic survey was conducted as an initial investigation of the bedrock. The data from the survey were used to establish the possible existence of any bedrock topographic features that could influence the movement of groundwater beneath the site. The results of the geophysical survey indicate that depth to bedrock ranges from

25 to 60 feet below the ground surface. An apparent bedrock valley extends from the vicinity of monitoring well 18e to the northwest across the site. The existence of a bedrock valley is confirmed by the depths to bedrock in the process area and at the southern end of the wastewater ditch (see Technical Memorandum No. 1 in Appendix A). Depths to bedrock are greatest in those portions of the site.

The nature of the bedrock could not be determined from the results of the seismic survey. The bedrock surface generated from the seismic data could represent extremely hard packed material, a boulder zone above the bedrock surface, or the base of the weathered bedrock.

Five bedrock wells were drilled to verify the results of the seismic survey. A 10-foot core of bedrock was taken from each of the boreholes except 5e. During drilling at that location, it was difficult to determine whether bedrock, weathered bedrock, or a boulder zone had been reached. According to well development and recovery data and the gamma log from 5e, it appears that a boulder zone rather than bedrock had been reached when the boring was terminated.

The depths to bedrock in borings confirmed the existence of a bedrock low in the southern portion of the site at monitoring well location 18e (Figure C-3), where bedrock was encountered at an elevation of 1,364 feet above msl. In borings 2e, 6c, 7c, 13e, and 17e, bedrock was encountered at elevations of 1,375 to 1,380 feet above msl. Although the true depth to bedrock could not be determined at well location 5, it was estimated to be 50 feet or more below the surface at an elevation of approximately 1,365 feet (Figure C-2).

The bedrock samples retrieved from cores consisted of fractured, coarse to very coarse grained hornblende gabbro with small amounts of augite and biotite. Most of the bedrock core was very competent (recovery rates between 90 and 100 percent) with evidence of slight weathering. Multiple fractures (6 to 12 per 10-foot core) were also noted.

SITE HYDROGEOLOGY

INTRODUCTION

Fifty-two groundwater monitoring wells and seven piezometers have been installed at the Arrowhead Refinery site. Thirteen of the monitoring wells and all seven piezometers were installed during the FDI. All other monitoring wells were installed before or during Phases I and II of the RI. The well numbers and dates installed are summarized in Table C-1. Well construction information is summarized in Table C-2. Water levels collected from the wells since June 1986 are provided in Attachment A. Most of the water level data were collected by the MPCA or CH2M HILL.

Well locations are shown in Figure C-8 and the screened intervals of each well are shown in the geologic cross sections included in Figures C-2 through C-7. Water levels obtained from the wells in November 1987 are also shown on the geologic cross sections.

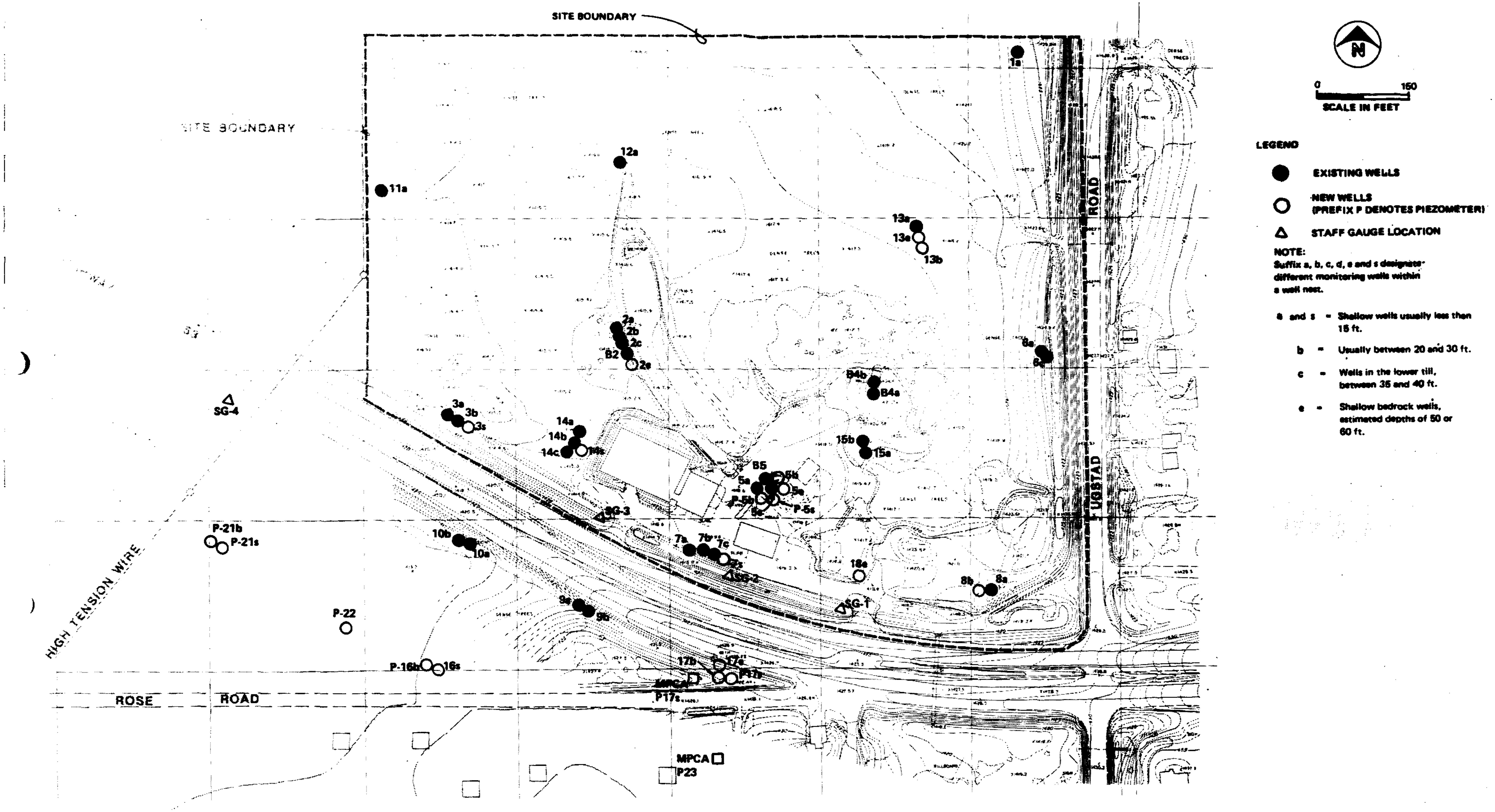


FIGURE C-8
WELL LOCATIONS
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Table C-2

MONITORING WELL CONSTRUCTION INFORMATION

Well No.	Screen Bottom Elev.	Surf. Elev.	Riser Elev.	Casing Elev.
1a	1410.73	1424.06	1427.19	1427.29
2a	1410.19	1418.19	1420.69	1420.74
2b	1395.05	1418.05	1420.94	1421.03
2c	1379.44	1417.94	1420.43	1420.50
B-2b*	1407.48	1418.28	1419.98	1421.00
2e	1368.53	1418.03	1419.73	1420.03
3s	1409.51	1416.21	1418.3	1418.31
3a	1400.64	1415.64	1418.79	1418.84
3b	1393.20	1415.70	1418.36	1418.41
B-4a	1411.06	1421.56	1424.22	1424.33
B-4b	1386.33	1421.43	1424.08	1423.81
P5s	1408.41	1418.71	1420.43	1420.53
P5b	1403.12	1419.12	1420.82	1420.77
5a	1406.64	1418.64	1421.05	1421.12
5b	1398.94	1419.14	1420.68	1420.58
5c	1380.45	1418.95	1421.12	1421.17
5e	1365.38	1419.08	1420.41	1420.32
B-5	1408.34	1418.94	1421.36	1422.42
6a	1410.95	1424.95	1427.74	1427.80
6c	1390.06	1425.06	1427.82	1427.85
7s	1408.24	1419.54	1421.07	1421.11
7a	1405.64	1419.44	1422.49	1422.46
7b	1394.53	1419.03	1421.75	1421.90
7c	1383.19	1419.19	1421.60	1421.89
8a	1409.11	1423.36	1426.14	1426.26
8b	1399.54	1422.54	1424.65	1424.58
9a	1404.51	1419.01	1421.23	1421.58
9b	1396.75	1419.25	1421.85	1421.84
10a	1401.43	1413.93	1416.63	1416.73
10b	1391.96	1413.96	1416.60	1416.85
11a	1400.89	1414.89	1417.98	1418.01
12a	1404.53	1418.53	1421.42	1421.45
13a	1404.50	1418.50	1421.46	1421.54
13b	1383.99	1418.49	1421.05	1420.96
13e	1366.93	1418.83	1421.08	1420.89

Table C-2

MONITORING WELL CONSTRUCTION INFORMATION

Well No.	Screen Bottom Elev.	Surf. Elev.	Riser Elev.	Casing Elev.
P14s	1409.22	1415.72	1417.50	1417.77
14a	1400.59	1415.59	1417.86	1418.04
14b	1391.66	1415.66	1418.36	1418.43
14c	1384.19	1415.69	1417.39	1417.50
15a	1406.23	1420.73	1423.11	1423.20
15b	1396.04	1420.54	1422.77	1422.99
16s	1408.51	1421.31	1423.01	1423.02
P16b	1395.9	1420.9	1423.26	1423.45
P17s-MPCA	1411.1	1426.1	1427.63	1428.3
P17s	1408.02	1423.02	1425	1425.04
17b	1382.54	1423.44	1425.26	1425.4
17e	1366.67	1422.77	1424.67	1424.69
18e	1355.49	1419.79	1421.6	1421.58
P21s	1404.33	1413.97	1416.16	1416.16
P21b	1384.1	1414	1416.3	1416.19
P22s	1405.19	1413.69	1415.58	1415.53
P23s		1430.12	1432.33	1433.04
STAFF GAGE				
SG-1			1420.32	
SG-2			1419.25	
SG-3			1419.06	
SG-4			1415.39	

• MEASUREMENT TAKEN FROM THE TOP OF RISER

Table C-4
SUMMARY OF HORIZONTAL GROUNDWATER GRADIENTS

Unit	Month	Gradient
Fill-Peat-Clay	November 1987	0.0052
Morainal Deposit	April 1987	
	NE quarter of	0.011
	NW quarter of	0.0044
	S half of site	0.0064
	Average	0.0073
	July 1987	
	NE quarter of	0.011
	NW quarter of	0.0051
	S half of site	0.0055
	Average	0.0071
	September 1987	
	NE quarter of	0.011
	NW quarter of	0.0044
	S half of site	0.0048
	Average	0.0066
	November 1987	
	NE quarter of	0.0089
	NW quarter of	0.0053
	S half of site	0.0042
	Average	0.0061
Bedrock	November 1987	0.0059

Table C-5
SUMMARY OF VERTICAL GROUNDWATER GRADIENTS
(June 1987 to March 1988)

Well Pair	Mean Vertical Gradient[a]	Range of Vertical Gradients[a]	Upward Gradients/ Total
2a-b	-0.02	-0.053 to -0.0018	16/16
3a-b	-0.011	-0.044 to 0.16	11/12
B5-5a	-0.44	-0.62 to 0.082	7/8
14s-a	-0.049	--	1/1
21s-b	-0.0099	-0.012 to -0.0075	2/2
2b-c	0.02	0.00073 to 0.083	0/16
3s-a	-0.044	-0.12 to -0.0011	3/3
B4a-b	0.0092	--	0/1
5a-b	-0.016	-0.036 to -0.0039	3/3
5b-c	0.0049	0.00054 to 0.012	0/3
6a-c	-0.021	-0.049 to 0.047	14/17
7s-a	0.0096	0.0077 to 0.012	0/2
7a-b	-0.0089	-0.12 to 0.097	10/16
7b-c	-0.013	-0.090 to 0.025	8/17
8a-b	0.051	0.020 to 0.094	0/4
9a-b	0.0049	-0.045 to 0.026	3/16
10a-b	-0.016	-0.036 to 0.082	10/12
13a-b	-0.02	--	1/1
14a-b	-0.0024	-0.0056 to 0.0022	10/12
14b-c	0.014	-0.0054 to 0.14	2/12
15a-b	-0.0052	-0.11 to 0.089	7/17
16s-b	0.018	0.004 to 0.075	1/4
2c-e	-0.0034	-0.0064 to -0.00091	4/4
5c-e	0.0051	-0.004 to 0.019	1/3
13b-13e	0.001	--	1/1
17b-e	0.012	-0.0088 to 0.013	3/4

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[a] Negative vertical gradients indicate upward gradients.

Slug tests were performed during the RI and FDI to evaluate hydraulic conductivity. The range, mean, and log average of the conductivities for each unit are listed in Table C-3. The log average, calculated by averaging the log of each hydraulic conductivity (rather than averaging the actual conductivity values) and taking the inverse log of the average, is considered to be more representative of actual hydraulic conductivity within each unit than the mean hydraulic conductivity value. Vertical and horizontal groundwater gradients were calculated from the water levels and water table maps (see Tables C-4 and C-5).

Using the calculated hydraulic conductivities and horizontal gradients and an estimated effective porosity, groundwater velocities were calculated for the fill-peat-clay and morainal deposit. The calculations, average velocities, and maximum and minimum velocity for each unit are included in Table C-6.

The hydrogeology of each major stratigraphic unit including the fill-peat-clay unit, the morainal deposit, and bedrock is discussed below. Because only one well is screened in the fill, the hydrogeology of the fill is discussed with that of the peat-clay unit.

FILL-PEAT-CLAY UNIT

Figure C-9 is a water table map of the fill-peat-clay unit for November 1987. Eight wells are screened in the unit. Because so few wells are screened in the unit and the unit appears to be hydraulically connected to the underlying morainal deposit (discussed in the following section), a water table map of the fill-peat-clay was contoured for 1 month only. Water levels and the wells used to construct the map are summarized in Table C-7.

Water levels are zero to 4 feet below ground surface, and in most parts of the site, the water table occurs in the fill-peat-clay unit. Based on the water levels in six of the eight wells, flow in the unit is toward the west-southwest. The horizontal groundwater gradient in the fill-peat-clay unit for November 1987 was 0.0052 ft/ft.

The highest and lowest hydraulic conductivities calculated for the fill-peat-clay unit were 1.8 x 10^{-2} cm/s and 7.7 x 10^{-5} cm/s (Table C-3). The highest hydraulic conductivity in this unit was measured for the fill found at P17s. The fill consists of sand and gravel probably used in the construction of the highway (see Figure C-4).

Using the values for hydraulic conductivities, an estimated effective porosity of 0.55 and a horizontal groundwater gradient of 0.0052 ft/ft, maximum and minimum groundwater velocities of 0.001 cm/s (1.7 ft/day) and 2.7 x 10^{-6} cm/s (0.007 ft/day) were calculated for the unit. Using the log average hydraulic conductivity for the fill-peat-clay of 4.3 x 10^{-4} cm/s and the same horizontal groundwater gradient and porosity, an average groundwater flow velocity of 1.5 x 10^{-5} cm/s (0.04 ft/day) in the unit was calculated.

To assess the potential for downward vertical flow and contaminant migration from the fill-peat-clay to the lower morainal layer, vertical gradients were evaluated from the water level data (see Table C-5). The water level data from six well nests (2a-b, 3s-a, B4a-b, B5-5a, 14s-a, and 21s-b) were used to represent the flow from the fill-peat-clay to the deeper morainal deposit. The calculated gradients were mainly upward from the morainal layer to the fill-peat-clay layer indicating that the

Table C-3
HORIZONTAL HYDRAULIC CONDUCTIVITY

Unit	Well No.	Hydraulic Cond. (cm/s)	
Fill-Peat-Clay	2a	7.7×10^{-5}	Not tested: B2, 3s, B4a, B5
	P14s	3.1×10^{-4}	Range: 1.8×10^{-2} to 7.7×10^{-5}
	P 17s	1.8×10^{-2}	Mean: 4.6×10^{-3}
	P21s	8.2×10^{-5}	Log Average: 4.3×10^{-4}
Glacial Till (Silt, clayey silt, sandy silt)	2b	2.7×10^{-4}	Not tested: 6c, 10b, 11a, 13a, 14b, 14c
	3a	3.0×10^{-4}	Range: 1.0×10^{-3} to 3.7×10^{-5}
	3b	1.0×10^{-3}	Mean: 3.2×10^{-4}
	6a	1.2×10^{-4}	Log Average: 2.1×10^{-4}
	8a	3.7×10^{-5}	
	9a	2.0×10^{-4}	
	12a	3.4×10^{-4}	
	14a	1.2×10^{-4}	
	P16s	4.0×10^{-5}	
	P16b	9.0×10^{-4}	
	17b	2.0×10^{-4}	
	P22s	3.0×10^{-4}	
Glacial Till (Sand and gravel lenses, cobble and boulder zones)	1a	1.2×10^{-4}	Not tested: 2c, B4b P5s, 7c, 9b, 13b, 15a
	5a	3.4×10^{-4}	Range: 3.5×10^{-2} to 3.5×10^{-6}
	5b	3.5×10^{-2}	Mean: 4.2×10^{-3}
	P5b	3.1×10^{-4}	Log Average: 5.6×10^{-4}
	5c	3.4×10^{-4}	
	7s	6.6×10^{-4}	
	7a	4.9×10^{-4}	
	7b	2.9×10^{-4}	
	8b	1.3×10^{-4}	
	10a	8.5×10^{-3}	
	15b[a]	3.5×10^{-6}	
	P21b	1.0×10^{-4}	

Note: Log Average for all wells screened in till: 3.3×10^{-4}.

[a] Hydraulic conductivity results suspect, value not included in averages.

Table C-6
GROUNDWATER VELOCITIES

Effective Porosity[a] (n)	Horizontal Gradient (i)	Hydraulic Conductivity (K)	Groundwater Velocity[c]	
Fill-Peat-Clay				
0.15	5.2×10^{-3} ft/ft	1.8×10^{-2} cm/s	0.001 cm/s (1.7 ft/day)	(highest)
0.15	5.2×10^{-3} ft/ft	7.7×10^{-5} cm/s	2.7×10^{-6} cm/s (0.007 ft/day)	(lowest)
0.15	5.2×10^{-3} ft/ft	4.3×10^{-4} cm/s[b]	1.5×10^{-5} cm/s (0.04 ft/day)	(average)
Morainal Deposit				
0.25 (sand)	6.8×10^{-3} ft/ft	3.5×10^{-2} cm/s	9.5×10^{-4} cm/s (2.7 ft/day)	(highest)
0.10 (silt)	6.8×10^{-3} ft/ft	3.7×10^{-5} cm/s	2.5×10^{-6} cm/s (0.007 ft/day)	(lowest)
0.20 (avg.)	6.8×10^{-3} ft/ft	3.3×10^{-4} cm/s[b]	1.1×10^{-5} cm/s (0.03 ft/day)	(average)

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[a] Assumed values for effective porosity.
[b] Log average hydraulic conductivity.
[c] Calculated from equation: velocity = (K x i)/n, from Freeze and Cherry (1979).

Table C-7
WELL NUMBERS AND WATER LEVELS USED IN CONSTRUCTION OF WATER TABLE MAPS

Unit	Well Number	Water Level* 04/14/87	Water Level* 07/07/87	Water Level* 09/21/87	Water Level* 11/09/87
Fill-Peat-Clay	2a	---	---	---	1,415.49
	3s	---	---	---	1,414.37
	B5	---	---	---	1,415.76
	14s	---	---	---	1,414.85
	17s	---	---	---	1,415.83
	P21s	---	---	---	1,411.56
Morainal Deposit	1a	1,422.43	1,421.62	1,422.06	1,421.87
	2c	1,416.15	1,415.56 (2b)	1,415.85 (2b)	1,415.64 (2b)
	3b	1,415.16	1,414.12	1,414.60	1,414.48
	B4b	1,418.06	---	---	1,416.38
	5c	1,417.51	1,416.70	1,416.94	1,416.64 (5b)
	6a	1,420.83	1,419.48	1,419.99	1,419.93
	7a	1,417.04	1,416.45	1,416.72	1,416.35
	8a	1,418.91	1,417.75	1,418.53	1,418.31
	9a	1,417.21	1,416.29	1,416.55	1,415.42
	10b	1,413.65	1,412.10	1,413.30	1,412.93
	11a	1,416.08	1,414.37	1,415.16	1,415.06
	12a	1,416.91	1,415.84	1,416.69	1,416.67
	13a	1,419.18	1,417.62	1,418.54	1,418.52
	14a	1,415.83	1,414.92	1,415.48	1,415.22
	15a	1,417.52	1,416.83	1,416.93	1,416.91
	P16b	---	---	1,415.33	1,414.39
	P17s	---	1,416.60	1,416.27	1,415.92 (17b)
	P21b	---	---	---	1,411.71
	P22	---	---	---	1,411.39
Bedrock	2e	---	---	---	1,415.61
	13e	---	---	---	1,418.93
	17e	---	---	---	1,415.94
	18e	---	---	---	---

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*Water levels measured relative to mean sea level (msl).
--- No water level measured that month.

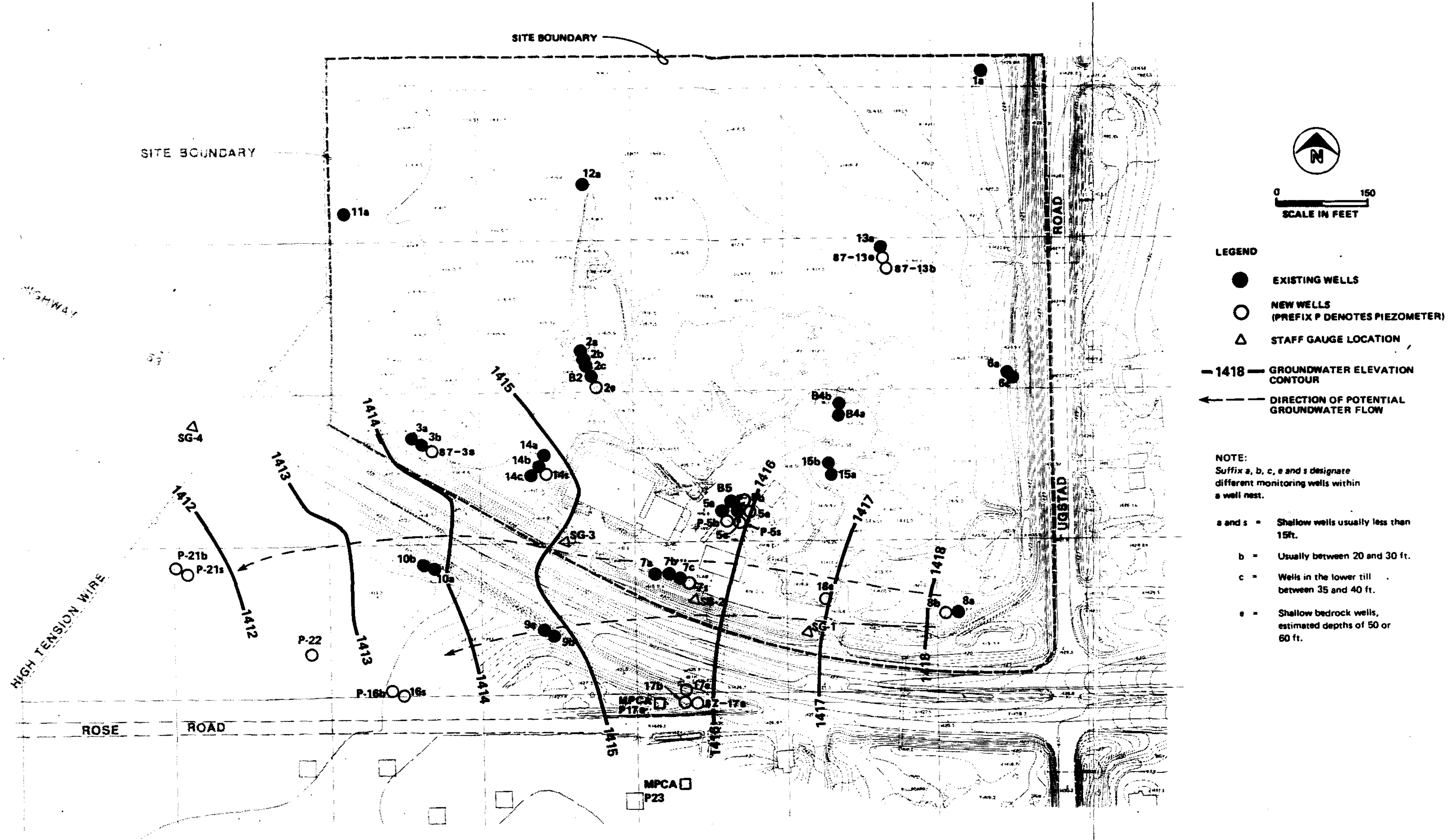


FIGURE C-9
GROUNDWATER ELEVATIONS IN FILL/PEAT/CLAY NOVEMBER 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

Arrowhead site is a groundwater discharge area. Although the data are limited, the upward vertical gradients do not appear to be a related to any seasonal fluctuations in the water levels. In well pair 2a-b for example, water levels were measured monthly from November 1986 through December 1987 (except April 1987) and all of the calculated gradients were upward. The mean gradients of all six well pairs ranged from -0.02 to -0.4 ft/ft (negative vertical gradients indicate upward gradients).

MORAINAL DEPOSIT

The configuration of the water table elevations in the glacial till unit for April, July, September, and November 1987 are summarized in Figures C-10 through C-13. The water levels used for mapping (Table C-7) were from wells screened nearest the surface and completely within the morainal deposit at each location.

In general, minimal seasonal variation can be seen in the water table maps for the morainal deposit. Groundwater elevations range from about 1,412 to 1,422 feet above msl for each month. The highest water levels of the 4 months were recorded in April and the lowest in November, however, the differences in the water levels in individual wells from month to month were less than 1 foot. Groundwater flow is from the northeast to the southwest. The groundwater gradients are slightly steeper in the northeast quarter of the site compared to the northwest quarter and the southern half. A groundwater discharge area is indicated by converging flow lines on the water table elevations and contours in the wetland area southwest of the site between Highway 53 and Rose Road.

The water table surface is flattened somewhat in the process area and near the auto body repair shop, particularly on the April and September maps. In that area, the fill is thicker and sandier than in the rest of the site. Therefore, there could be a higher rate of infiltration and recharge in those areas compared to the rest of the site. Higher recharge rates could cause the flattening of the water table.

The configuration of the water table in the southern half of the site in November 1987 differs somewhat from the other maps. The November contours indicate that the EPA drainage ditch is a groundwater recharge area. At the time the water levels and staff gauge measurements were taken, a fire hydrant adjacent to the drainage ditch near Well Nest 7 had been opened and more water than usual was in the ditch, probably causing the drainage ditch to act as a recharge area for the month of November only.

The horizontal gradients in the morainal deposit are fairly consistent throughout the site and from month to month. The steepest gradient was measured in the northeast corner of the site in April (0.011 ft/ft) and the shallowest in the southern half of the site in November (0.0042 ft/ft; see Table C-4).

The log average hydraulic conductivity calculated for wells screened in the silty portions of the morainal deposit is 2.1×10^{-4} cm/s. The log average conductivity of the sand and gravel units within the deposit is 5.6×10^{-4} cm/s, and the log average conductivity of the deposit as a whole is 3.3×10^{-4} cm/s. The highest and lowest hydraulic conductivities calculated for the morainal deposit were 3.5×10^{-2} cm/s and 3.7×10^{-5} cm/s. Using these values, estimated porosities (from Freeze and Cherry 1979) of 0.25 (for sand) and 0.10 (for silt) and a horizontal groundwater gradient of

0.0068 ft/ft, maximum and minimum groundwater velocities of 9.5×10^{-4} cm/s (2.7 ft/day) and 2.5×10^{-6} cm/s (0.007 ft/day) were calculated for the unit. Using the log average hydraulic conductivity for the morainal deposit of 3.3×10^{-4} cm/s, the same horizontal groundwater gradient, and an average porosity of 0.30, an average groundwater flow velocity of 1.1×10^{-5} cm/s (0.03 ft/day) in the unit was calculated.

The mean vertical groundwater gradients (Table C-5) are variable in the morainal deposit, indicating upward flow in the unit in some areas and downward flow in others. However in most cases, the vertical gradients are small. Average gradients ranged from -0.02 to 0.5 ft/ft. The variations in water levels in the well nests appear to be attributable to localized variations in stratigraphy.

Flow in the morainal deposit is similar to flow in the fill-peat-clay unit. Flow directions and horizontal groundwater gradients are nearly identical. Differences in the water table maps between the morainal deposit and the fill-peat-clay appear to be caused by the lack of water level measurements in the latter from the northern half of the site. A lack of wells screened in the fill-peat-clay in that portion of the site limits the extent to which the water table can be contoured in that unit. Based on the similarity of flow and water levels (see Table C-7), it appears that the fill-peat-clay unit and the morainal deposit are hydraulically connected.

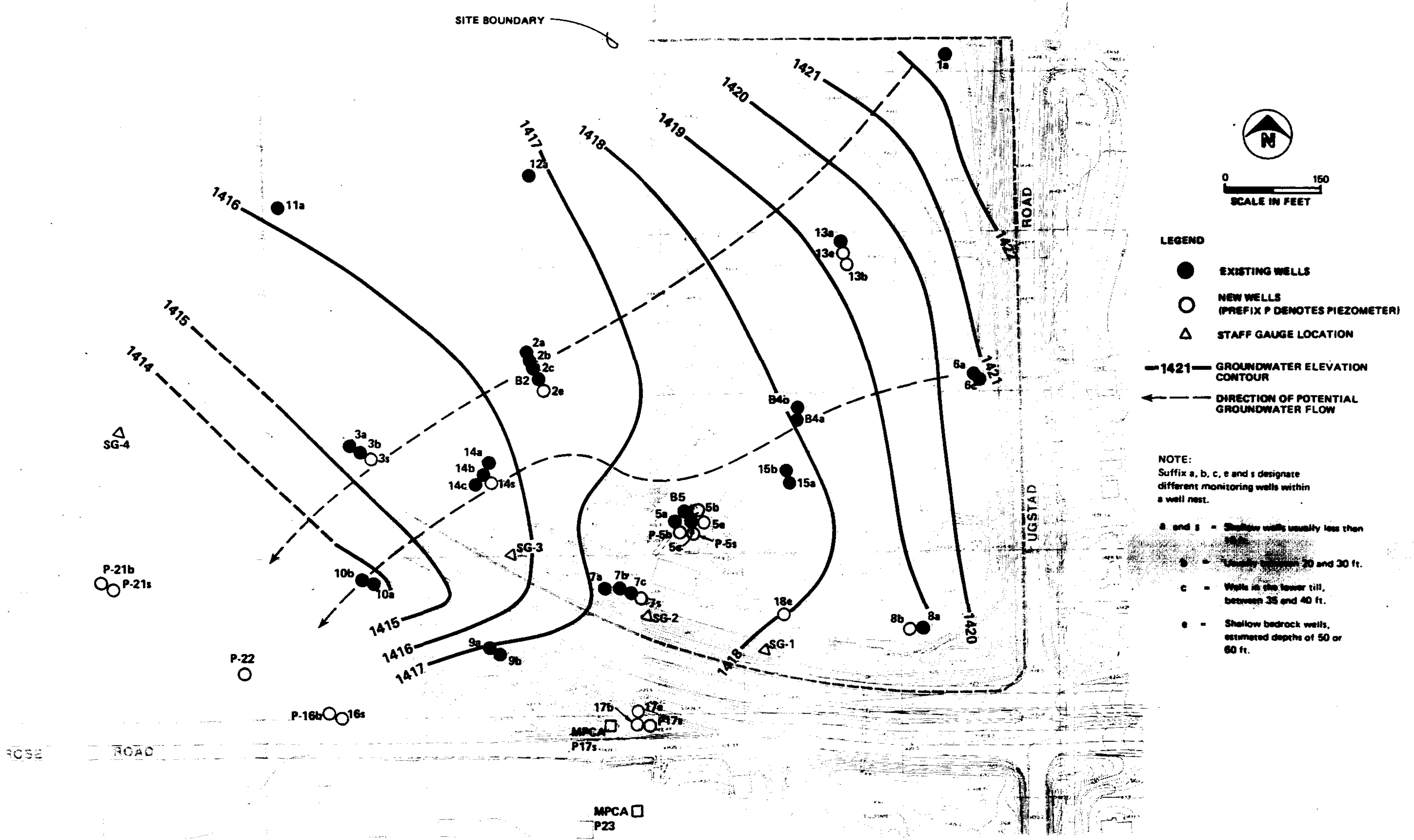
BEDROCK UNIT

Water levels were obtained from three bedrock wells in November 1987. The water table configuration is shown in Figure C-14 and the water levels and well numbers are listed in Table C-7. Groundwater flow in the bedrock unit is toward the southwest and the horizontal groundwater gradient is calculated to be 0.006 ft/ft. Again, flow in the bedrock is in the same direction, horizontal gradients are similar to the morainal deposit and the fill-peat-clay unit, and vertical gradients (Table C-5) from the fill-peat-clay and morainal deposit to the bedrock are very small. This indicates the bedrock unit is hydraulically connected with the morainal deposit.

Slug tests to evaluate hydraulic conductivity were not conducted in wells screened in the bedrock. Therefore, no groundwater velocity in the unit was calculated.

The vertical gradients from the morainal unit to the bedrock was calculated for the three bedrock wells. The vertical gradients were very small, ranging from -0.02 to -0.004 ft/ft. The vertical gradients were all upward indicating that groundwater is flowing from the bedrock to the morainal unit.

GLT932/041.51



NOTE:
Suffix a, b, c, e and s designate different monitoring wells within a well nest.

a and s = Shallow wells usually less than [illegible]

b = Usually between 20 and 30 ft.

c = Wells in the lower till, between 35 and 40 ft.

e = Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE C-10
GROUNDWATER ELEVATIONS IN MORAINAL DEPOSIT, APRIL 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

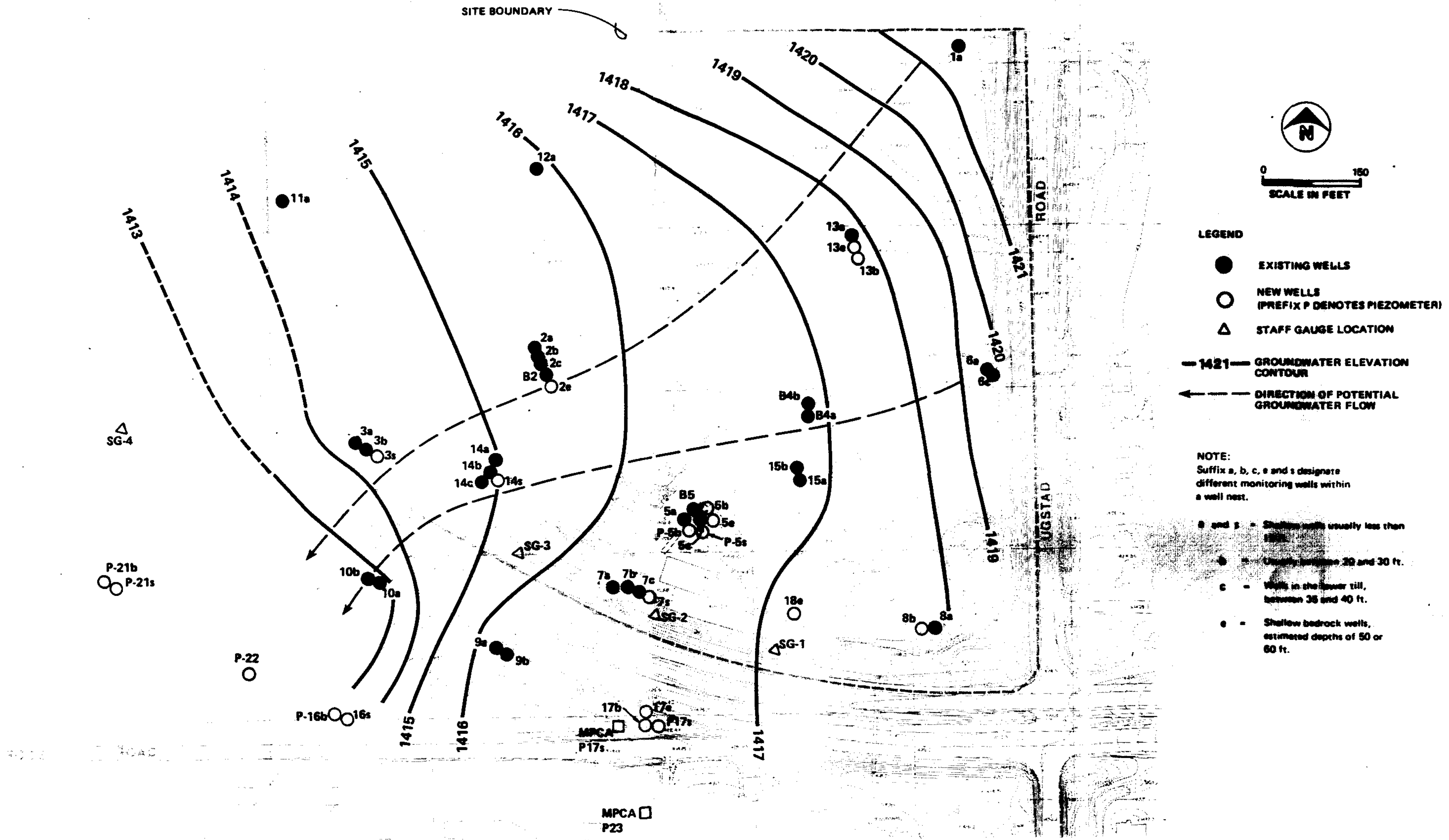


FIGURE C-11
GROUNDWATER ELEVATIONS IN MORAINAL DEPOSIT, JULY 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

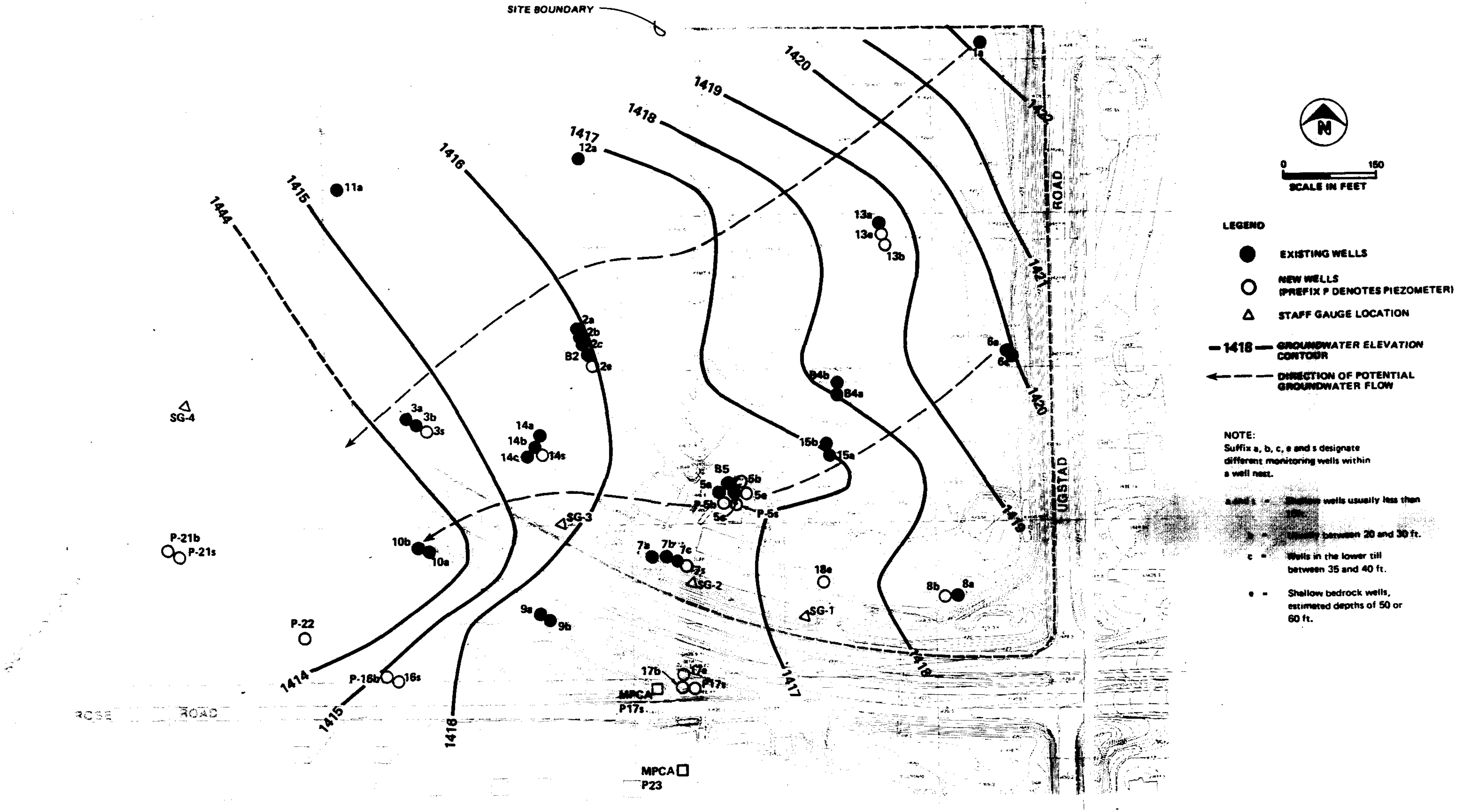
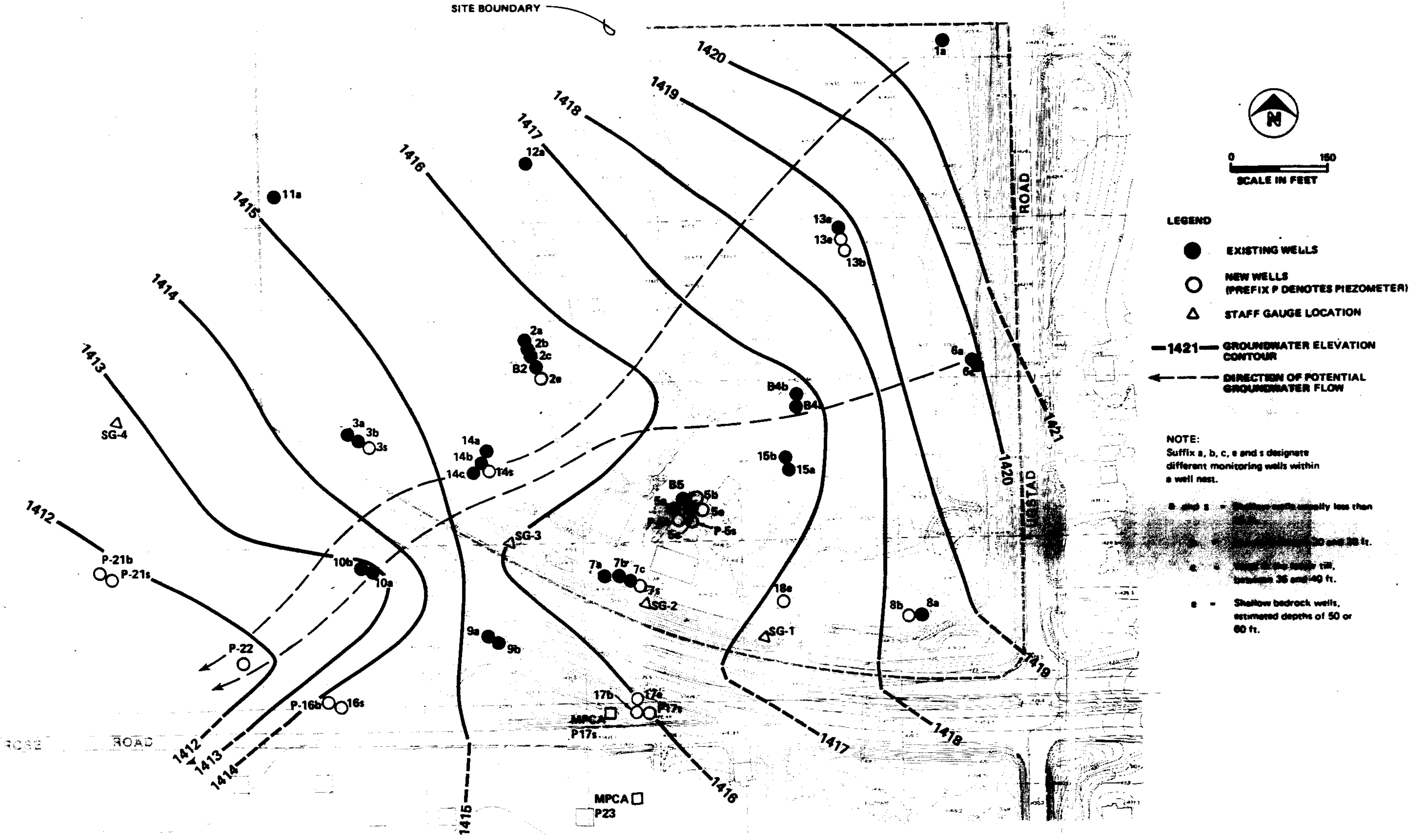


FIGURE C-12
GROUNDWATER ELEVATIONS IN MORAINAL DEPOSIT, SEPTEMBER 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



NOTE:
Suffix a, b, c, e and s designate different monitoring wells within a well nest.

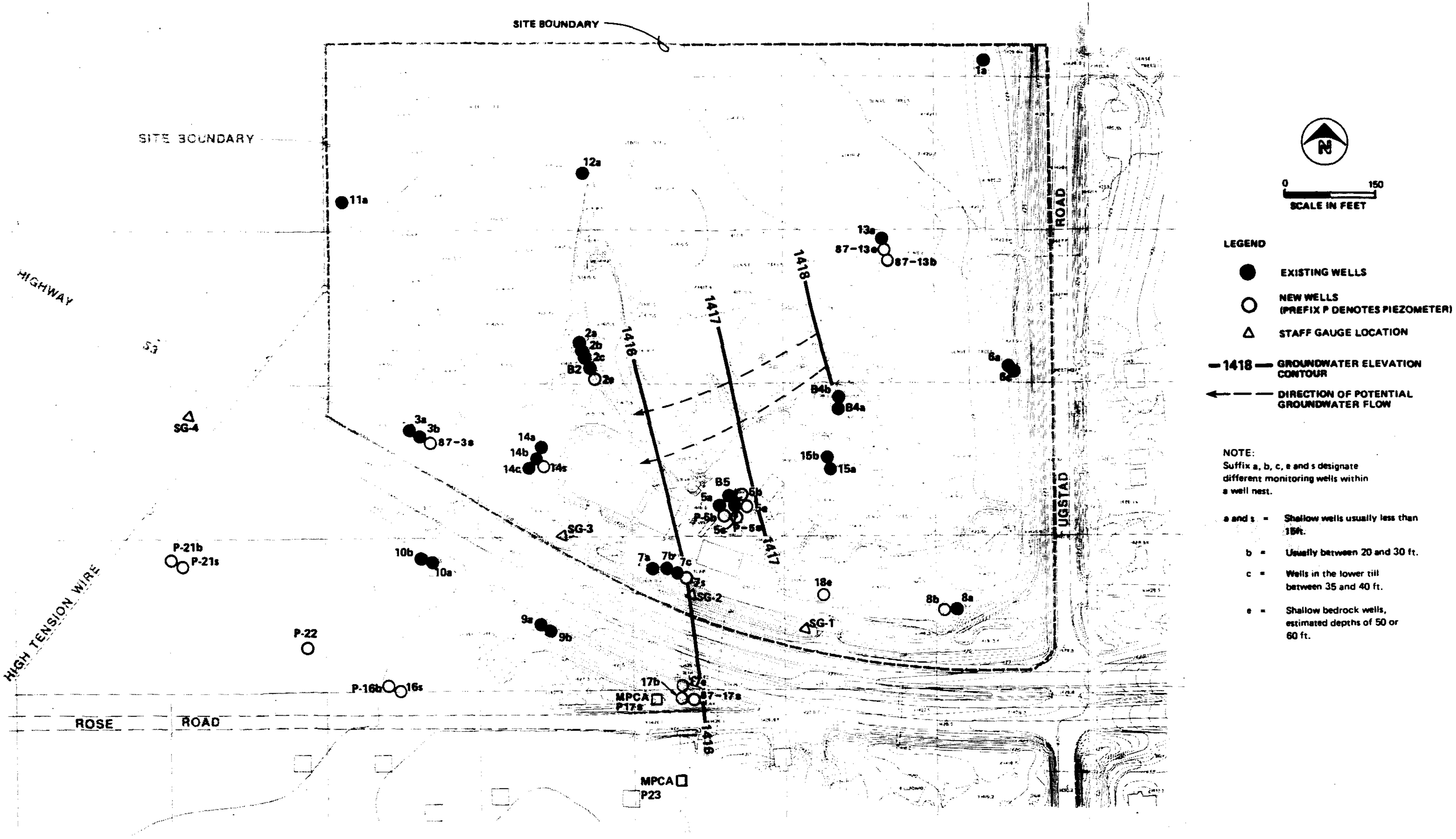
a and s - Shallow wells usually less than [illegible]

[illegible] 30 and 38 ft.

c - [illegible] till, between 36 and 40 ft.

e - Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE C-13
GROUNDWATER ELEVATIONS IN MORAINAL DEPOSIT, NOV. 9, 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION



NOTE:
Suffix a, b, c, e and s designate different monitoring wells within a well nest.

a and s = Shallow wells usually less than 15ft.

b = Usually between 20 and 30 ft.

c = Wells in the lower till between 35 and 40 ft.

e = Shallow bedrock wells, estimated depths of 50 or 60 ft.

FIGURE C-14
GROUNDWATER ELEVATIONS IN BEDROCK, NOVEMBER 1987
ARROWHEAD REFINERY
FIELDWORK DESIGN INVESTIGATION

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