SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

1984 GEOTECHNICAL EXPLORATION PROGRAM WATANA DAMSITE

APPENDIX B THROUGH G

FINAL REPORT

HARZA-EBASCO
SUSITNA JOINT VENTURE

JULY 1984
DOCUMENT NO. 1736

ALASKA POWER AUTHORITY

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Document No. 1736
Susitna File No. 5.6.1

SUSITNA HYDROELECTRIC PROJECT

1984 GEOTECHNICAL EXPLORATION PROGRAM
WATANA DAMSITE

APPENDIX B THROUGH G

Report by
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
July 1984

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

1984 GEOTECHNICAL EXPLORATION PROGRAM
WATANA DAMSITE

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1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX B - BOREHOLE PERMEABILITY TEST DATA

TABLE B-1

BOREHOLE	TEST INTERVAL (FT.) [1]	TEST INTERVAL (ELEVATIONS)	MATERIAL TESTED	PERMEABILITY TEST PERFORMED	PERMEABILITY, K (CM/Sec)
DH84-1	15.2-19.7	2127.9-2123.4	ROCK	FALLING HEAD	$5x10^{-4}$
	15.7-28.6	2127.4-2114.5	ROCK	FALLING HEAD	$2x10^{-4}$
	22.3-91.0	2120.8-2052.1	ROCK	FALLING HEAD	$7x10^{-5}$
DH84-4	14.7-17.2	2149.7-2147.2	OVERBURDEN	FALLING HEAD	$3x10^{-4}$
	14.7-22.9	2149.7-2141.5	OVERBURDEN	CONSTANT HEAD	$1x10^{-4}$
	14.7-27.0	2149.7-2137.4	OVERBURDEN	CONSTANT HEAD	$1x10^{-4}$
	23.8-31.1	2140.6-2133.3	OVERBURDEN	CONSTANT HEAD	$1x10^{-4}$
	23.8-39.3	2140.6-2125.1	OVERBURDEN	CONSTANT HEAD	$6x10^{-5}$
	63.1-88.5	2101.3-2075.9	OVERBURDEN	CONSTANT HEAD	$3x10^{-5}$
	95.8-137.6	2068.6-2026.8	ROCK	CONSTANT HEAD	$6x10^{-5}$

[1] VERTICAL DEPTH BELOW GROUND SURFACE

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SUSITNA HYDROELECTRIC PROJECT

WATANA DAM & RESERVOIR
FINS AREA
IN-SITU PERMEABILITY
TESTING SUMMARY

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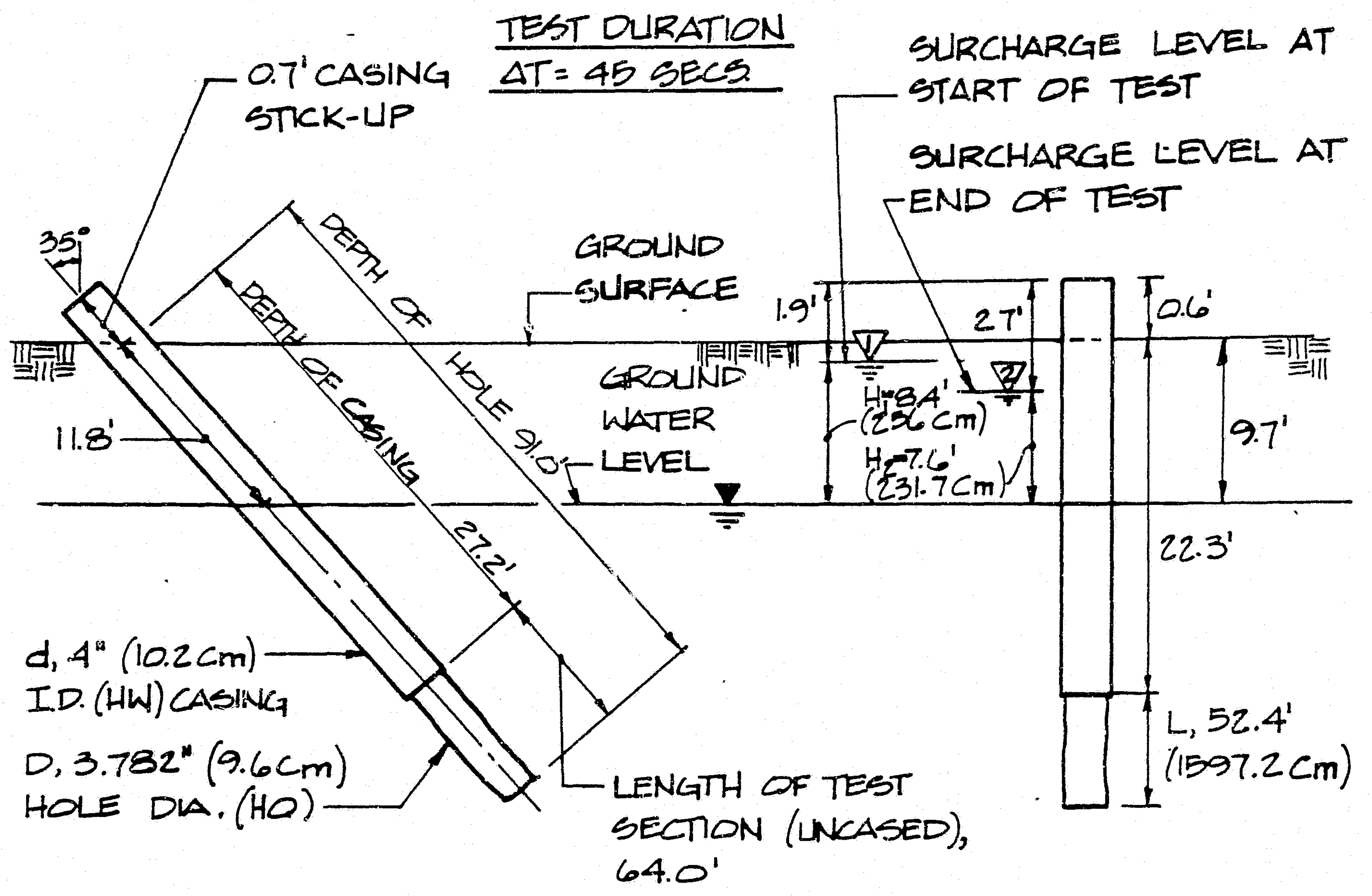
DATE 7/84

CONTRACT NUMBER

TABLE B-1



INCLINED BOREHOLE

VERTICAL PROJECTION

$$K = \frac{d^2 \ln\left[\frac{2mL}{D}\right]}{8L(\Delta T)} \ln\frac{H_1}{H_2}$$

$$K = \frac{(10.2 cm)^2 \ln\left[\frac{(2)(1)(1597.2 cm)}{9.6 cm}\right]}{(8)(1597.2 cm)(45 secs)} \ln\left(\frac{256.0 cm}{231.7 cm}\right)$$

$$K = 1 \times 10^{-4} cm/sec$$

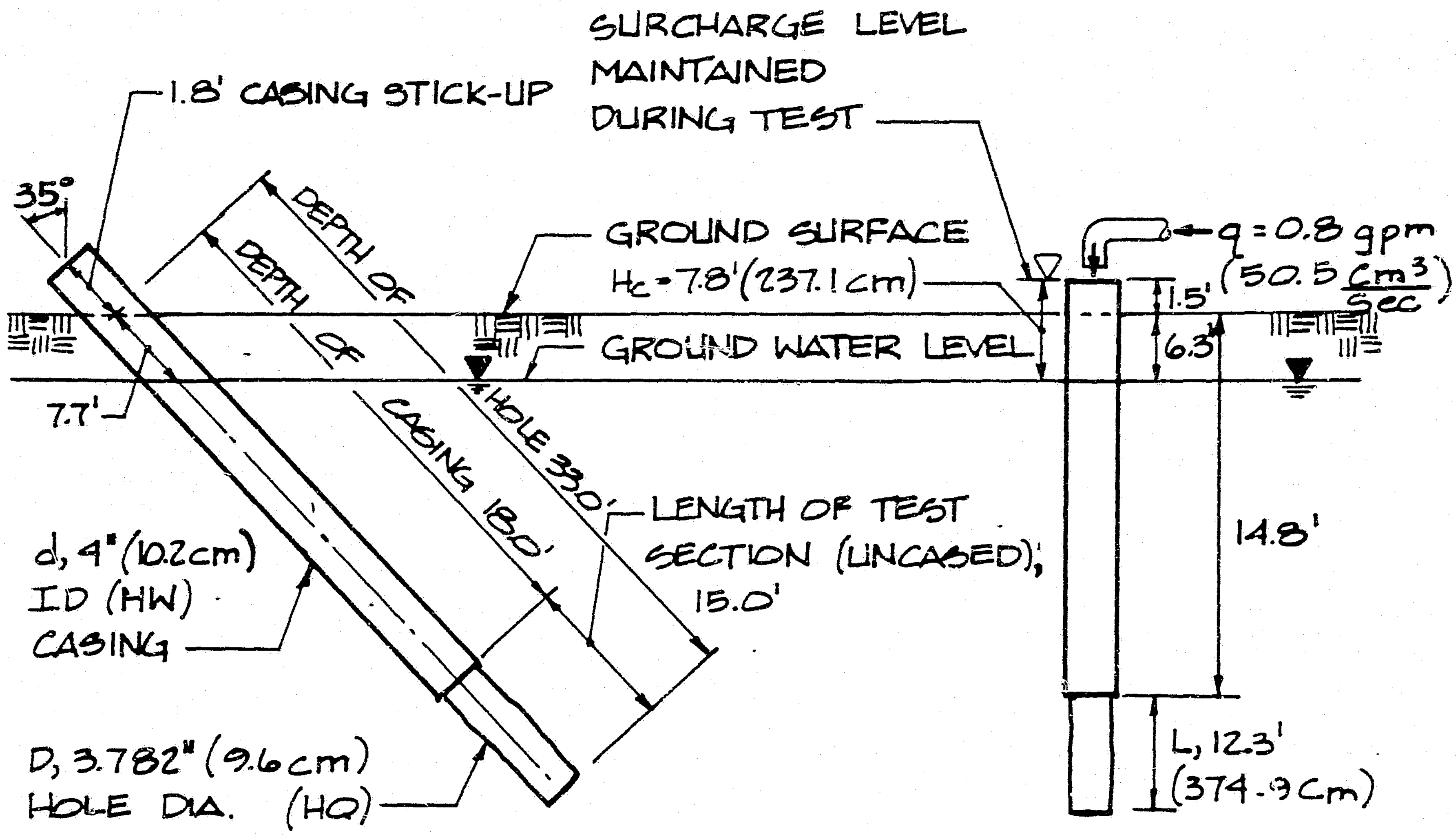
NOTES:

1. FORMULAS USED FOR DETERMINING PERMEABILITY OBTAINED FROM FOUNDATION ENGINEERING HANDBOOK, WINTERKORN AND FANG, VAN NOSTRAND REINHOLD, 1975, p.32, FIG. 1.17.
2. $K_v = K_h$ (ASSUMED)

NOT TO SCALE

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM & RESERVOIR
IN-SITU PERMEABILITY
FALLING HEAD TEST
TYPICAL EVALUATION

ALASKA-EBASCO
ANCHORAGE, ALASKA
JULY 1984
Figure B-1



INCLINED BOREHOLE VERTICAL PROJECTION

$$K = \frac{q \ln\left[\frac{mL}{D} + \sqrt{1+\left(\frac{mL}{D}\right)^2}\right]}{2\pi L H_c}$$

$$K = \frac{(50.5\,cm^3/sec) \ln\left[\frac{(1)(374.9cm)}{9.6cm} + \sqrt{1+\left(\frac{(1)(374.9cm)}{9.6cm}\right)^2}\right]}{(2)(\pi)(374.9cm)(237.1cm)}$$

$$K = 4\times10^{-4}\ cm/sec$$

NOTES:

1. FORMULAS USED FOR DETERMINING PERMEABILITY OBTAINED FROM FOUNDATION ENGINEERING HANDBOOK, WINTERKORN AND FANG, VAN NOSTRAND REINHOLD, p. 32, FIG. 1.17
2. $K_v = K_h$ (ASSUMED)

NOT TO SCALE

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM & RESERVOIR
IN-SITU PERMEABILITY
CONSTANT HEAD TEST
TYPICAL EVALUATION

HARZA-EBASCO SUSITNA JOINT VENTURE | APPROVED
ANCHORAGE, ALASKA | DATE JULY 1984 | Figure B-2

1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX C - HYDRAULIC PRESSURE TEST DATA

APPENDIX C

HYDRAULIC PRESSURE TEST DATA

The basic definition of the hydraulic pressure test, in terms of Lugeons, is a water take of 1 litre/meter/minute at 10 bars pressure.

Lugeon values for the current program were calculated using non-metric units in the following formula:

$$\text{Lugeon Value} = \frac{1820 \times \text{Rate of loss (gpm)}}{\text{Interval tested (ft.)} \times \text{Net pressure (psi)}}$$

Most of the calculations in the accompanying tabulation involved straight forward use of recorded data. There is some manipulation of data, however, particularly when incremental tests were performed. For example, consider a test conducted in interval 189 ft. to 263 ft., and a succeeding test conducted in the interval 159 ft. to 263 ft., the second test having a higher total water take. In this example a note would be recorded in the "Remarks" column of Table C-1 as "159-189", meaning that the water take from the shorter interval has been subtracted from the larger interval to better indicate the water take from 159 ft. to 189 ft.

In some cases, similar to the above example, the water take of the lower test interval exceeded that of the higher interval. In this case, an asterisk (*) appears in the "Remarks" column of Table C-1. This indicates that the differential water take could not be subtracted and for conservative estimating, the entire water take was used to calculate the Lugeon value of just the higher interval.

Friction loss was not calculated in the standard manner, as losses in the HQ wireline rods were considered to be negligible. The pressure restrictions of the piping within the packer was considered in the calculations, however, see Figure C-1. In all tests where water take rates exceeded 5 gpm, all pressure steps were calculated using a net applied pressure reduced by the amount of back pressure generated by the packer restrictions while pumping at relatively higher rates.

TABLE C-1

WATANA EXPLORATION PROGRAM SPRING 1984

SUMMARY OF WATER PRESSURE TESTS

BOREHOLE	INTERVAL	GAGE	PRESSURE/LUGEONS					REMARKS
DH84-1	46-154	PSI	14	25	35	25	15	*
		LU	2.1	1.4	1.4	1.3	1.6	
	154-204.5	PSI	20.0	30.0	40.0	30.0	20.0	*
		LU	2.7	2.1	2.2	2.4	3.0	
	204.5-247.5	PSI	20.0	30.0	40.0	30.0	20.0	204.5-247.5
		LU	1.6	1.0	1.2	1.5	1.4	
	247.5-297.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	2.9	2.5	2.1	2.0	2.3	
	296.5-328.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0	0	0	0	
	327.5-358.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0	0	0	0	
	356.5-408.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	1.2	1.5	1.3	1.3	2.0	
	404.5-458.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0.3	0.2	0	0	
	455-510.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0	0	0	0	
	506-556	PSI	20.0	30.0	40.0	30.0	20.0	*
		LU	1.4	1.5	1.6	1.6	1.7	
	557.5-608.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0	0	0	0	
	604.5-656.2	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0.3	0.1	0.1	0.1	0.2	
	654.5-708.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	2.0	1.8	1.7	1.8	2.1	
	707.5-758.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	1.1	1.3	1.0	1.1	1.4	
	754-805.5	PSI	20.0	30.0	40.0	30.0	20.0	754-805.5
		LU	0.1	0	0	0	0.6	
	805.5-848.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	2.7	2.8	3.5	2.7	2.6	

*See description in notes, p. C-1

TABLE C-1 (cont.)

WATANA EXPLORATION PROGRAM SPRING 1984

SUMMARY OF WATER PRESSURE TESTS

BOREHOLE	INTERVAL	GAGE	PRESSURE/LUGEONS					REMARKS
DH84-2	36-68	PSI	10.0	20.0	30.0	20.0	10.0	
		LU	1.8	2.8	5.5	3.7	2.1	
	62-1125	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	1.8	2.5	2.9	2.5	1.6	
	109-162	PSI	15.0	25.0	35.0	25.0		
		LU	5.3	7.3	6.9	4.7		
	158-212	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	2.9	2.9	3.0	2.5	1.7	
	208-262	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	5.4	5.4	5.5	5.1	4.4	
	259-310	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0.1	0.3	0	0	
	309-359	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0.1	0.1	0.1	0	
	450-500	PSI	20.0	30.0	40.0	30.0	20.0	450-500
		LU	0	0	0	0	0	
	500-548	PSI	20.0	30.0	40.0	30.0	20.0	500-548
		LU	0	0	0	0	0	
	548-598	PSI	20.0	30.0	40.0			548-598
		LU	0.7	0.2	0.1			
	598-765	PSI	20.0	30.0	40.0			
		LU	0.3	0.3	0.4			
DH84-3	33-90	PSI	10.0	15.0	20.0	15.0	20.0	33-90
		LU	8.0	8.7	7.9	7.5	8.5	
	90-132	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	3.6	3.7	3.5	3.3	3.4	
DH84-4	215-268	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0.6	0.3	0.4	0.8	1.6	
	268-318	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0	0	0	0.4	0.6	*
DH84-4A	139-269	PSI	15.0	25.0	35.0	25.0	20.0	139-269
		LU	0.6	0.6	0.6	0.6	0.5	*
	269-399	PSI	15.0	25.0	35.0	25.0	35.0	269-399
		LU	0.6	0.5	0.5	0.5	0.4	*
	399-698	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	0.2	0.2	0.2	0.2	0.2	

*See description in notes, P, C-1

TABLE C-1 (cont.)

WATANA EXPLORATION PROGRAM SPRING 1984

SUMMARY OF WATER PRESSURE TESTS

BOREHOLE	INTERVAL	GAGE	PRESSURE/LUGEONS					REMARKS
DH84-5	40-70	PSI	10.0	20.0	30.0	20.0	10.0	40-70
		LU	2.9	2.9	2.8	4.0	3.5	
	70-102	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	17.2	29.6	26.8	22.6	17.2	
	100-150	PSI	15.0	25.0	35.0	25.0	15.0	100-150
		LU	1.6	1.5	0.2	1.3	0.2	
	150-202.5	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	7.0	9.8	14.8	9.0	7.0	
	217-265	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	1.5	1.5	1.5	1.2	0.6	
	177-265	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	5.5	9.8	10.6	5.9	6.6	
DH84-6	28-61	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	0.3	1.0	0.8	1.0	0.8	
	59.5-89.9	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	0	0	0	0	0	
	88.5-143	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	85.7	47.7	53.4	90.2	280	
	138-168	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	11.7	13.0	14.4	13.0	10.4	
DH84-7	37-72.5	PSI	15.0	25.0	15.0			37-72.5
		LU	11.4	10.4	2.6			
	72.5-120	PSI	15.0	25.0	35.0	25.0	15.0	72.5-120
		LU	11.7	20.9	36.4	33.5	31.0	
	120-159	PSI	15.0	25.0	35.0	25.0	15.0	120-159
		LU	1.6	2.2	0.3	1.6	0.8	
	159-189	PSI	15.0	25.0	35.0	25.0		
		LU	3.4	3.2	4.5	2.2		*
	189-263	PSI	15.0	25.0	35.0	25.0	15.0	
		LU	1.6	1.9	1.9	1.4	1.5	
	246.7-257.5	PSI	15.0	25.0	35.0			
		LU	0.4	0	0.5			
DH84-8	18-61	PSI	10.0	15.0	20.0	15.0	10.0	
		LU	47.4	61.8	77.9	80.4	46.6	
	59-100	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	53.3	56.6	25.9	27.2	29.1	

*See description in notes, P. C-1

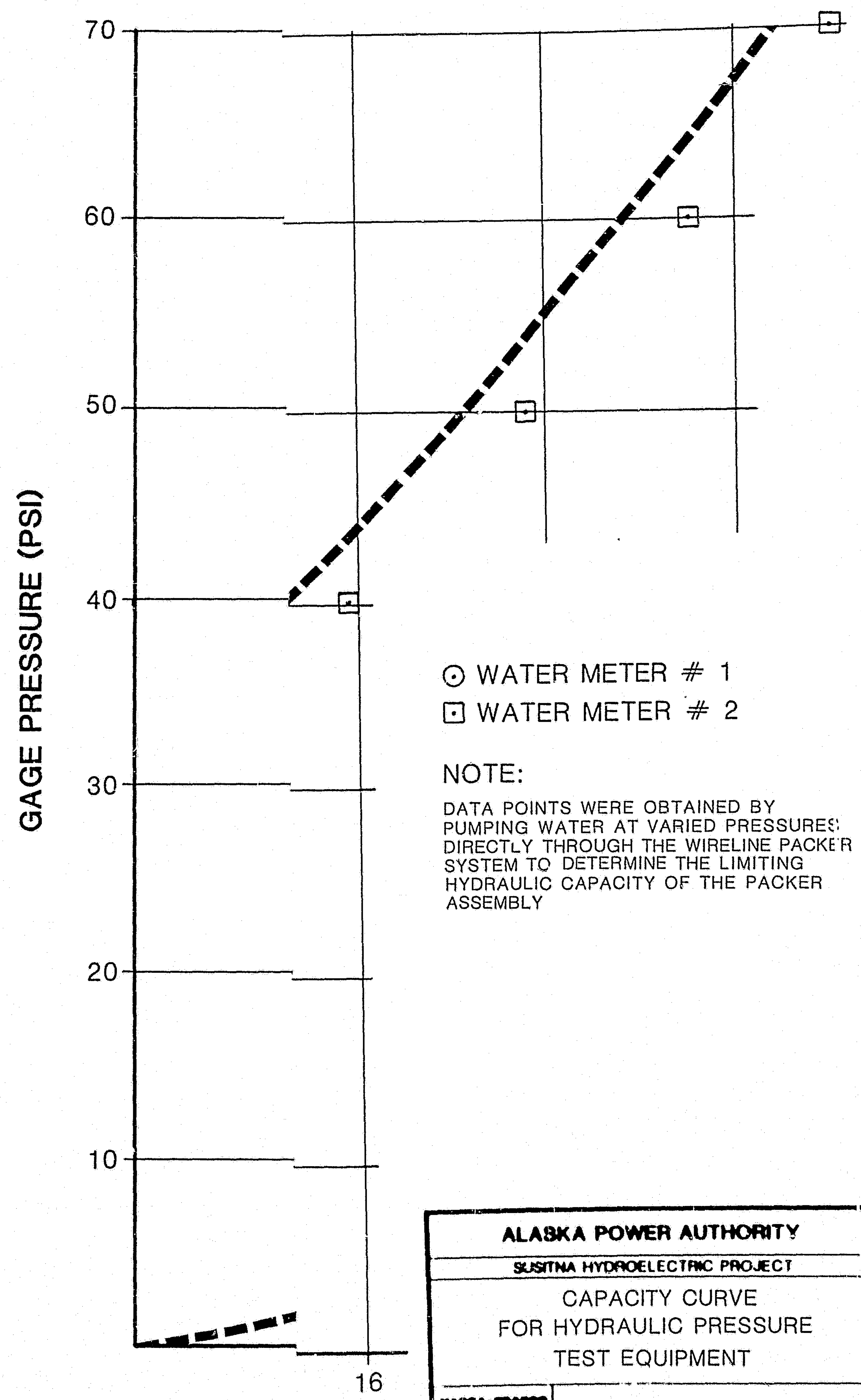
TABLE C-1 (cont.)

WATANA EXPLORATION PROGRAM SPRING 1984

SUMMARY OF WATER PRESSURE TESTS

BOREHOLE	INTERVAL	GAGE PRESSURE/LUGEONS						REMARKS
DH84-9	250-350	PSI	20.0	30.0	40.0	30.0	20.0	250-350
		LU	0.8	0.6	0.5	0.5	0.2	
	350-497.5	PSI	20.0	30.0	40.0	30.0	20.0	
		LU	0.8	0.5	0.4	0.5	0.0	
DH84-10	No Pressure Tests							

*See description in notes, p. C-1



ALASKA POWER AUTHORITY

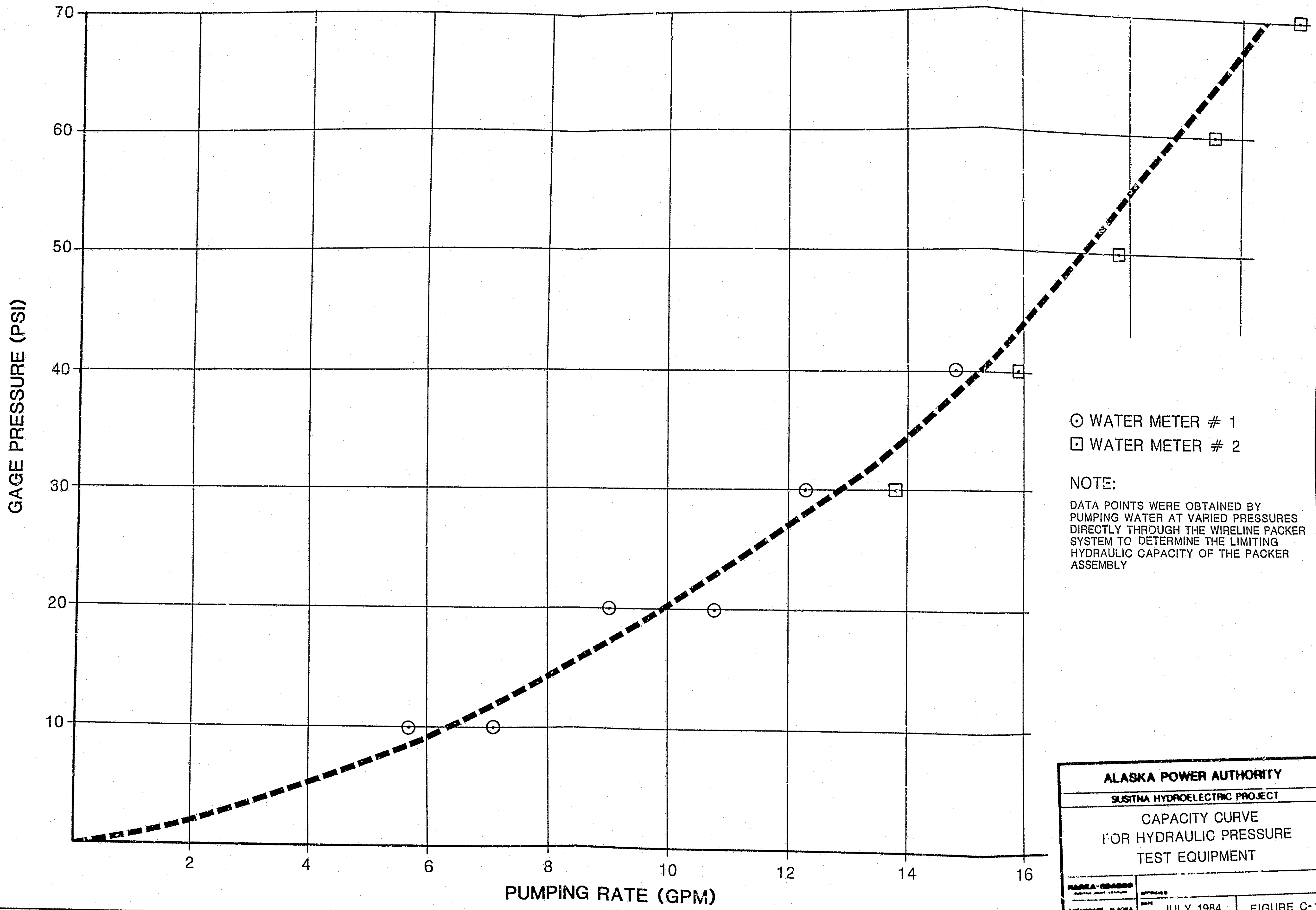
SUSITNA HYDROELECTRIC PROJECT

CAPACITY CURVE
FOR HYDRAULIC PRESSURE
TEST EQUIPMENT

HARZA-EBASCO
SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA

APPROVED
DATE JULY 1984

FIGURE C-1



ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

CAPACITY CURVE FOR HYDRAULIC PRESSURE TEST EQUIPMENT

JULY 1984

FIGURE C-1

1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX D - GEOPHYSICAL LOGS

APPENDIX D

GEOPHYSICAL LOGGING

Description of Equipment

The Watana Site boreholes were logged using a Mount Sopris Model II geophysical borehole logging system. The system consists of components that can be quickly assembled and disassembled in the field by a two man-crew, making it ideal for operations such as Watana that require helicopter transportation. With this system, borehole logs can be obtained to depths of 2700 feet.

The components of the system are the instrument cabinet, winch assembly, boreholes probes, generator, radioactive sources, and support gear (electrical cables, power cord, tripod, etc.). The instrument cabinet mounts on top of the winch assembly, making all operating controls easily accessible to the operator.

The instrument cabinet contains a digital recorder, digital printer and an analog strip-chart recorder. The digital printout and analog recorder provide hard copy that can be used "as is" for log analysis and geologic interpretation. The digital tape recorder provides a back-up means of storing data for later playback, manipulation, and printout using a compatible computer system.

Three borehole proves were used during the 1984 Geotechnical Exploration Program: a combination probe capable of providing readout of resistance, spontaneous potential, and natural gamma activity; a density (gamma-gamma) probe containing a gamma-ray counter to which a Cesium 137 source was attached for each logging run; and a porosity (Neutron) probe containing a thermal neutron counter to which an Americium 241 Beryllium source was attached for each logging run.

The radioactive source for the density (gamma-gamma) probe is a 5 millicure Cesium 137 load contained in a threaded subassembly that screw mounts directly to the lower end of the probe. When not in use, the subassembly is locked in a carbon steel sheathed lead shield that also serves as an NRC approved shipping container. The radioactive source for the porosity (neutron) probe is a 1 curie Americium 241 Beryllium load contained in a threaded subassembly that also screw mounts directly to the lower end of its probe. When not in use, the AmBe subassembly is locked in a 14-inch diameter spherical shield constructed of cold-rolled, low-carbon steel filled with a Boron enriched, water-extended polyester. This shield also serves as an NRC approved shipping container.

Operation and Data Acquisition

Natural Gamma Survey

The natural gamma survey was run first in each borehole for two purposes. The first purpose was to ensure that the borehole was in good condition and open to the full survey depth prior to lowering a probe containing a radioactive source. The second was to obtain a log of the natural gamma radiation of the rock penetrated by the borehole.

Gamma radiation originates in the spontaneous disintegration of atomic nuclei of various radioactive elements. The radiation intensity at any point in the borehole is directly related to the concentration and activity of the radioactive elements disseminated in the material surrounding the borehole. Variations in natural gamma radiation intensities in boreholes frequently can provide a method to correlate lithologies from borehole to borehole and/or can provide diagnostic data on lithologies and anomalies within a single borehole.

Initially, the probe was lowered in the borehole at 25-30 feet per minute, and the instrument response was carefully monitored to determine the most effective scale(s) for recording the gamma log. The borehole was then logged from bottom to top at a speed of 10 feet per minute, with the data being recorded in both analog and digital formats.

Gamma-Gamma (Density) Survey

The density survey was run in each borehole immediately after completion of the natural gamma logging run. The purpose of the density log was to obtain a profile of density variations along the borehole axis.

The density detector is shielded from the Cesium 137 gamma photon source by Mallory-1000 metal. Gamma radiation is absorbed and/or scattered by all materials through which it travels. The amount of radiation absorbed is directly proportional to the electron density of the material penetrated. The electron density is approximately proportional to the bulk density for most materials encountered during borehole geophysical surveys. The number of counts per second recorded by the detector is, therefore, inversely proportional to the bulk density of the material surrounding the density probe. The data from the density log can be used with other borehole logs, to characterize lithologic units, and to detect density changes within individual lithologic units related to weathering, joints, fracture zones, and chemical alteration.

The most effective scale(s) for recording the density log was noted as the density probe was lowered into each borehole at 25-30 feet per minute. The boreholes were then logged from bottom to top at 10 feet per minute, with the data being recorded in analog and digital formats.

Neutron (Porosity) Survey

The porosity survey was run in each borehole (except DH 84-4) immediately after the completion of the density logging. Mechanical difficulties precluded obtaining a porosity log for this borehole. The purpose of the porosity survey was to obtain a profile of porosity variations in the rock along each borehole axis.

The porosity tool contains a neutron-thermal neutron, high energy source separated from a thermal neutron detector. High energy neutrons are introduced into the materials surrounding the borehole and the effect of the environment on the neutrons is measured. The most effective element in moderating neutron speed is hydrogen; therefore, a neutron probe responds most dramatically to the presence of water or hydrocarbons in the rock and soil surrounding a borehole.

There are no naturally occurring concentrations of hydrocarbons in the subsurface of the survey area, hence a decrease in the number of thermal neutrons passing through the probe mounted detector indicates an increase in the amount of water (i.e. porosity) in the subsurface materials adjacent to the probe. The data from the porosity log can be used, along with other geophysical logs, to delineate lithologic units, and to detect porosity variations within individual lithologic units due to joints, weathering, fracture zones, and chemical alteration.

As in the other borehole surveys, the instrument response was monitored during the run down the hole to select the most appropriate logging scale. The Porosity Probe was lowered at 25-30 feet per minute and then logged from bottom to top at 10 feet per minute, with the data being recorded in analog and digital formats.

Radiation Surveys

Prior to and at the conclusion of borehole geophysical surveys that used radioactive sources, the well head and surrounding area were surveyed using a sensitive radiation detection device. Radiation surveys were also performed on the source/shield assemblies before and after each relocation. Both sources were directly tested for any leakage at the completion of each logging operation.

Interpretation

Fractures and Joints

Typically, individual fracture zones in the diorite at the Watana Site are expressed on the density logs of the coreholes as 200 to 500 cps (counts per second) spikes when logged through the HQ drill rods, and 400 to 1000 cps spikes when logged through the PVC casing. Fracture/joint frequency (low density spikes) is variable from hole to hole, but tends to increase toward the surface as might be expected from rocks responding to glacial or erosional unloading. This decrease in fracture frequency with depth is best illustrated on the density log of DH 84-2, with very few fractures/joints indicated below 200 feet.

There is good correlation between these low density log spikes, low neutron anomalies (higher hydrogen or water content), and the presence of fractured rock seen in the drillcore.

Depth to Bedrock

There are no unique diagnostic indicators for identifying top of bedrock on any of the geophysical logs. Where bedrock surface was shallow, the most charateristic response was a lower neutron shift to the left (higher porosity) and lower density and gamma shifts to the right.

Lithologic Correlation/Lithologic Response

Correlation between boreholes is not always possible in crystalline rock, however, gross lithologic differences usually are discernable as in DH 84-1 where diorite and andesite prophyry are in contact. The andesite at this borehole has a natural gamma response at least twice that of diorite. The high gamma response of andesite is also supported by the high gamma "kick" at the 132-134 ft. interval of DH 84-9 where the borehole passed through an andesite boulder near the base of the glacial till, and at 321 ft. in DH 84-4A where the borehole passed through a fine grained felsic dike.

Clayey sand and dense till observed in the core of DH 84-4A in the 6 to 52 ft. interval correlates well with similar density and gamma responses in the 34-80 ft. interval of DH 84-4 and the 18 to 62 ft. interval of DH 84-10. Similarily, weathered diorite in the 62-120 ft. section of DH 84-10 correlates with weathered diorite in the 72-125 ft. section of DH 84-4A.

Alteration Zones

Hydrothermally altered diorite zones and healed breccia are usually matched on the density log by an anomaly that is lower in amplitude and broader than the low density spikes occurring opposite fractures and joints (compare, for instance, the fracture response from 80 to 84 ft. in DH 84-8 to the altered diorite in DH 84-9 from approximately 308 to 318 ft.).

Weathering

One indicator of the depth of weathering as observed from examination of the core is the depth to which iron oxide staining persists in fracturing and jointing. Another is the condition or degree of kaolinization of feldspars, although other processes can cause kaolinization of feldspar. The point at which hard, strong, fresh diorite is noted in the core equates on the density log to ± 450 cps for those boreholes logged through the HQ drill rod; ± 700 cps when logged through plastic casing; and 800 to 1000 cps when logged in open hole.

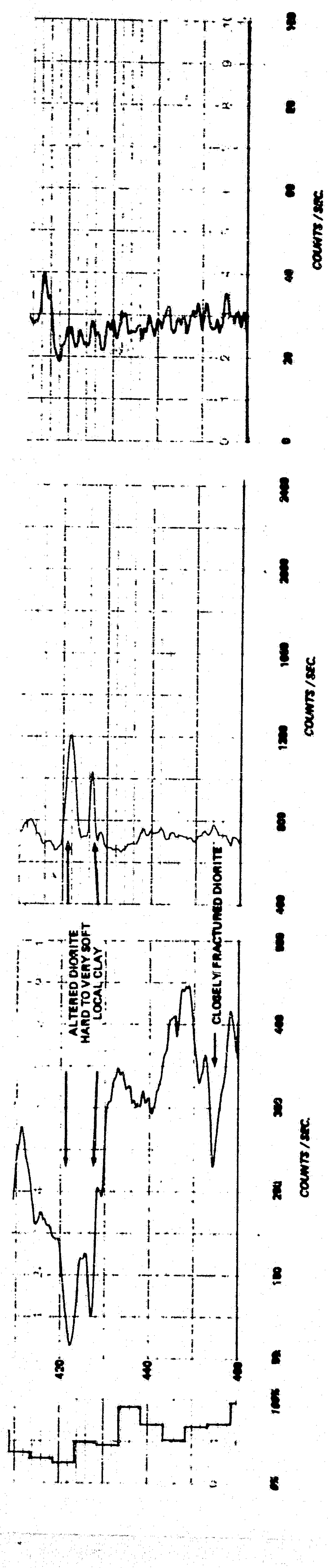
Other Log Responses

Not all geophysical log anomalies are caused by the rock formation being logged. The following log responses in boreholes at Watana need to be noted for more accurate log interpretation:

a. Logging beyond the end of the drill rod or PVC casing (open hole) causes all three curves to shift to the right because of the decrease in signal attenutation such as occurs at 690 ft. in DH 84-4A.

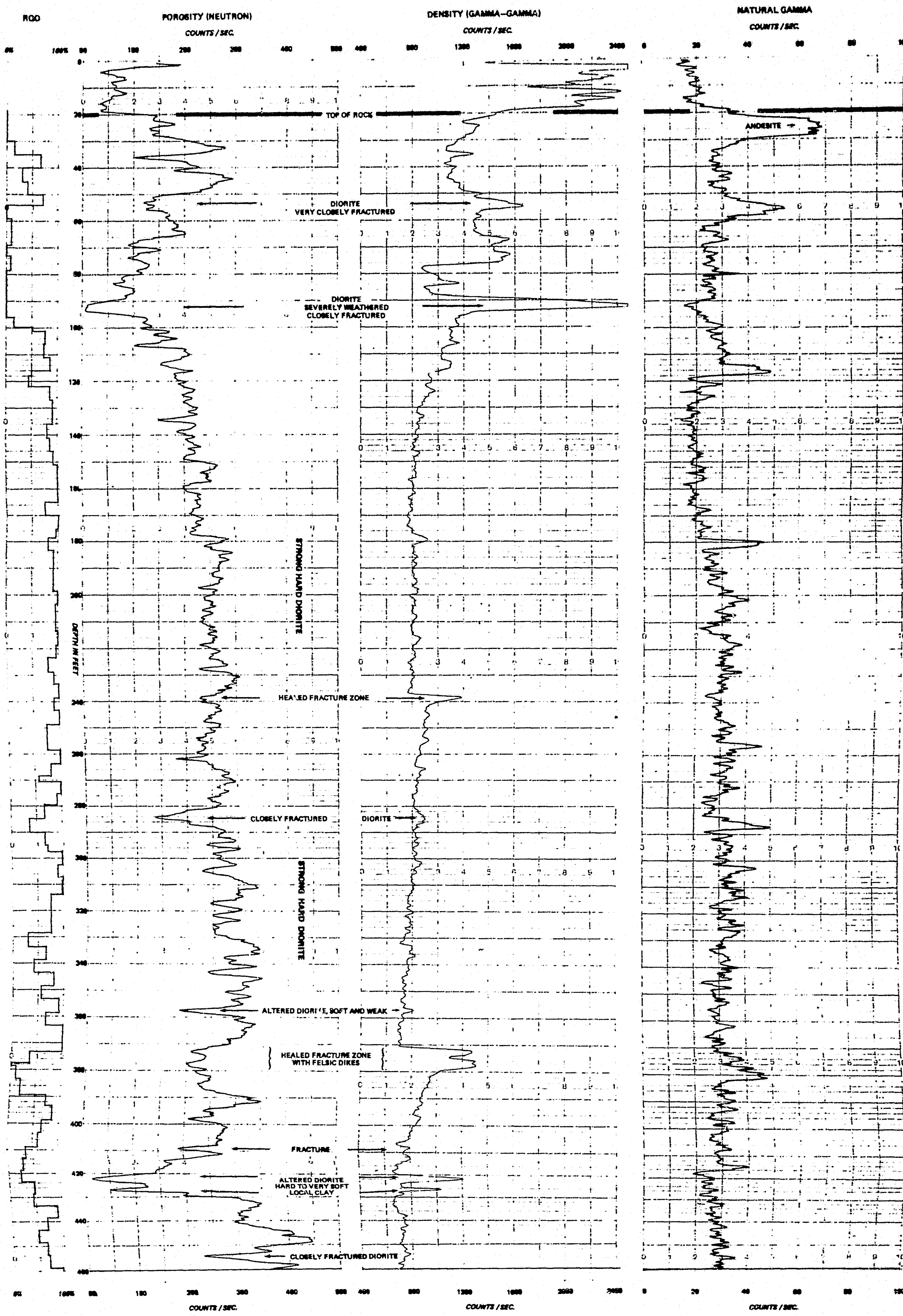
b. Logging up through the water table into the unsaturated zone causes a shift to the right of all three curves because of the decrease in attenuation in air vs. water, such as in DH 84-7 at 79 ft.

c. Different weight (wall thickness) drill rods affects the density response as observed in DH 84-4A at ± 330 ft., 420 ft., 490 ft., 530 ft., and 670 ft., where lighter HCQ drill rods were used. In contrast, the higher density anomaly in the 308-316 ft. section of DH 84-4 is caused by logging through a section of a twisted-off core barrel. Similarily, the low density spike at 663.5 ft. in DH 84-2 is caused by an unscrewed drill rod.



NOTES:
- ***BOREHOLE IS INCLINED 36 DEGREES FROM VERTICAL.***
- ***DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.***
- ***HOLE CEMENTED FROM [illegible] TO [illegible] FT.***
- ***LOGGED 5/17/[illegible].***

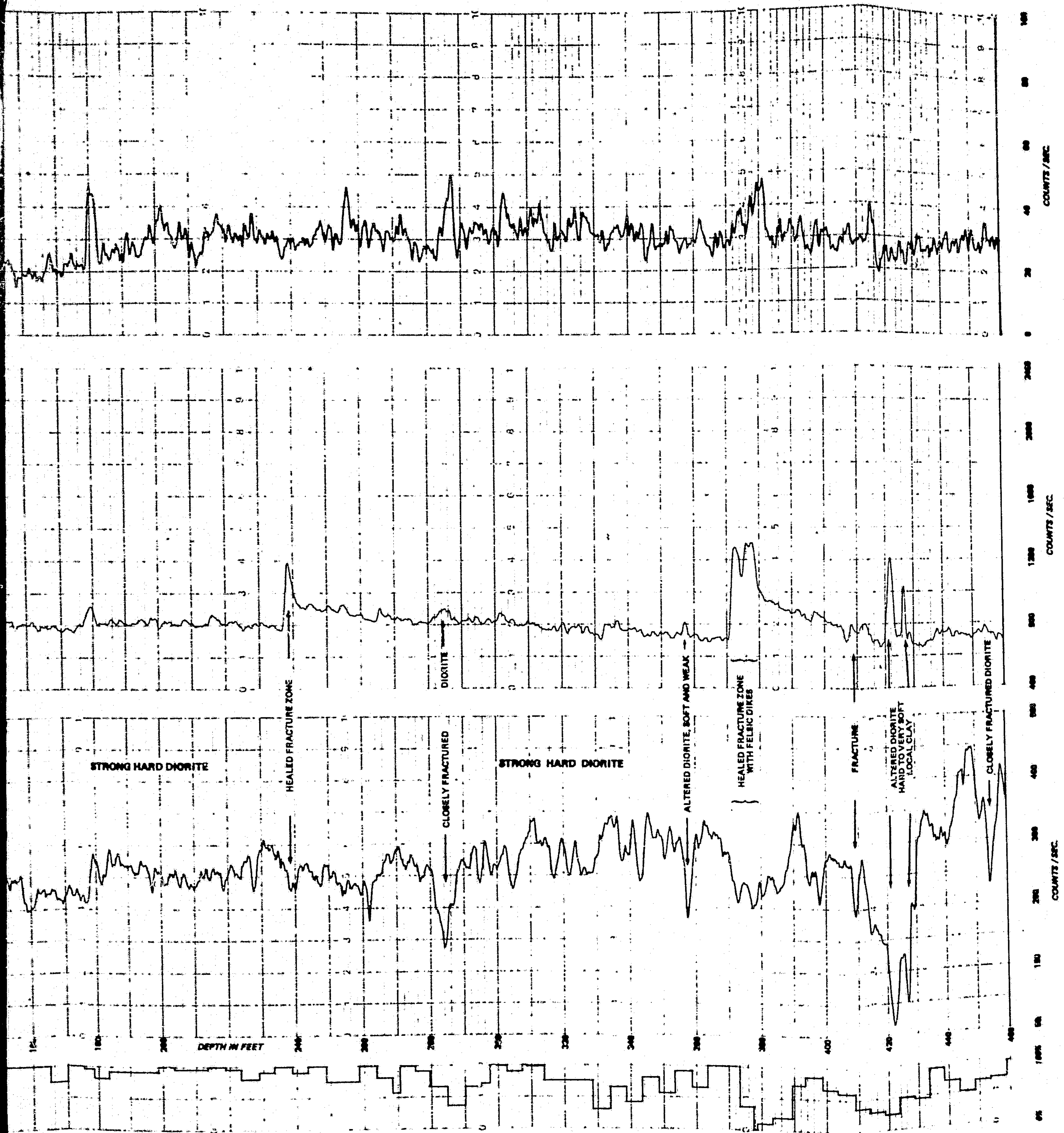
ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-1		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D-1



RQD
POROSITY (NEUTRON)
COUNTS / SEC.
DENSITY (GAMMA–GAMMA)
COUNTS / SEC.
NATURAL GAMMA
COUNTS / SEC.
TOP OF ROCK
ANDESITE
DIORITE
VERY CLOSELY FRACTURED
DIORITE
SEVERELY WEATHERED
CLOSELY FRACTURED
STRONG HARD DIORITE
DEPTH IN FEET
HEALED FRACTURE ZONE
CLOSELY FRACTURED
DIORITE
STRONG HARD DIORITE
ALTERED DIORITE, SOFT AND WEAK
HEALED FRACTURE ZONE
WITH FELSIC DIKES
FRACTURE
ALTERED DIORITE
HARD TO VERY SOFT
LOCAL CLAY
CLOSELY FRACTURED DIORITE

Continued

001736

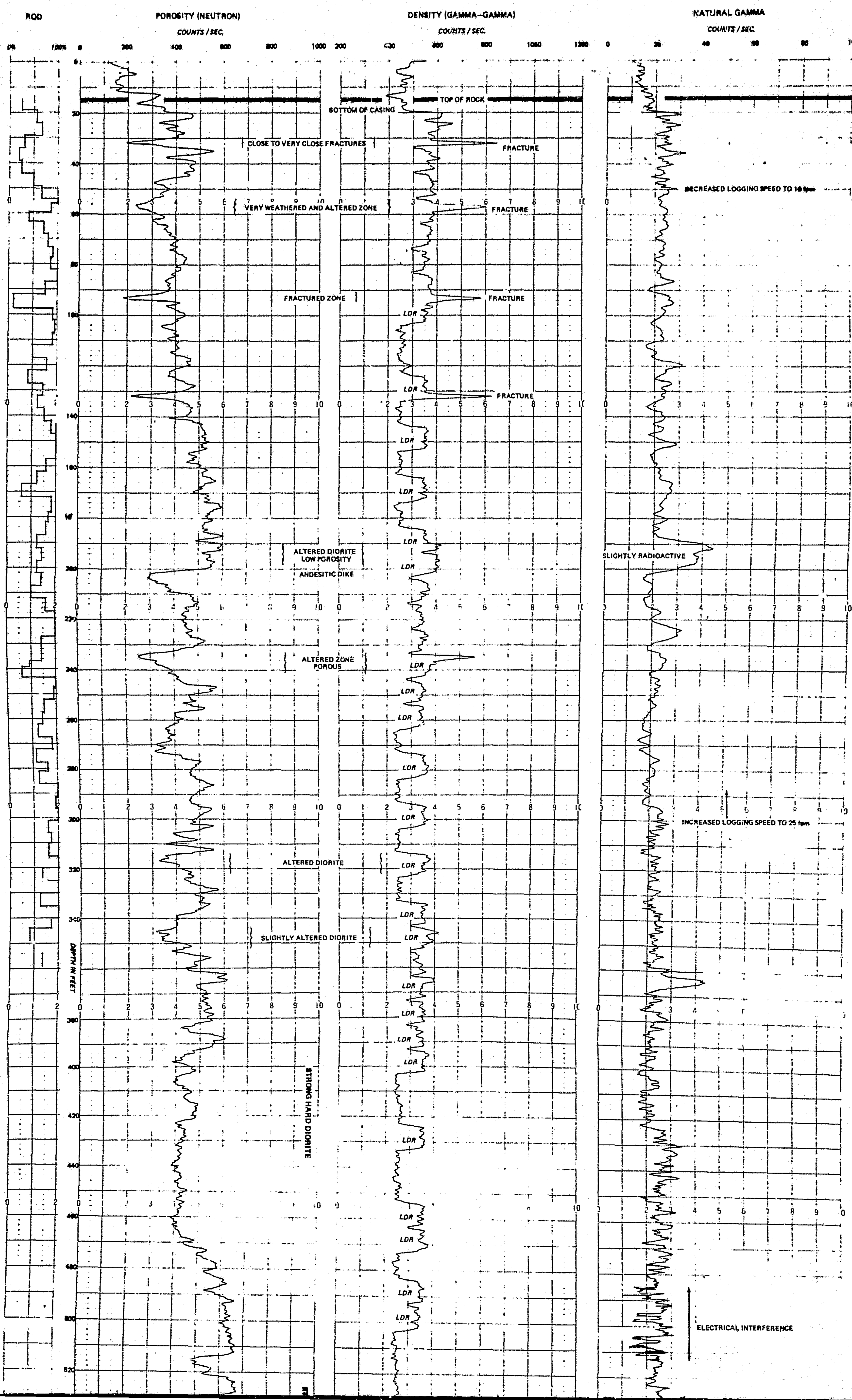


Continued

NOTES:
- BOREHOLE IS INCLINED 35 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- HOLE CEMENTED FROM 486 TO 848.5 FT.
- LOGGED 5/17/84.

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-1		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D-1

DH84-2



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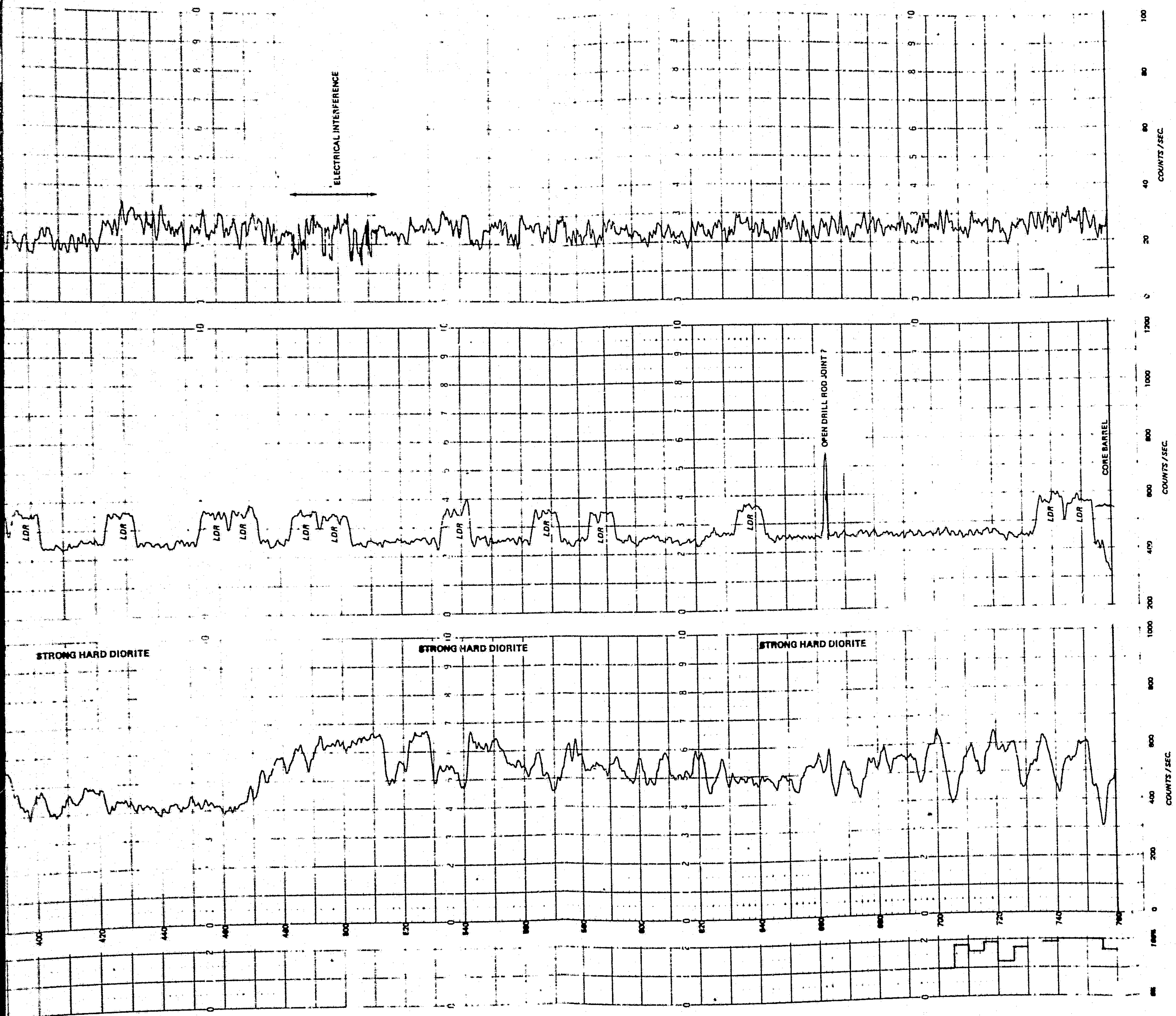


NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LDR INDICATES LIGHT DRILL ROD.
- LOGGED 5/29 – 30/84.

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

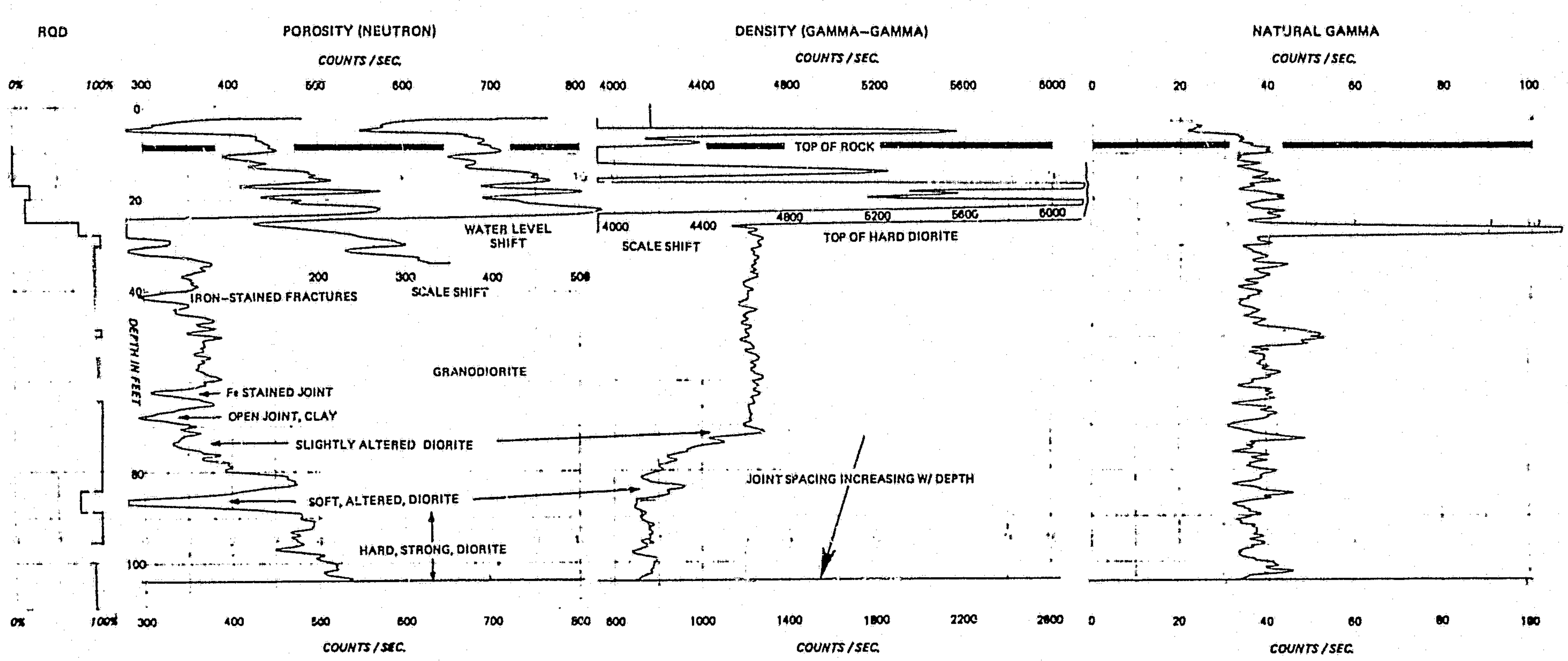
BOREHOLE GEOPHYSICAL LOGS

DH84-2

HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D – 2

Continued

DH84-3



NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/15/84.

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

BOREHOLE GEOPHYSICAL LOGS

DH84-3

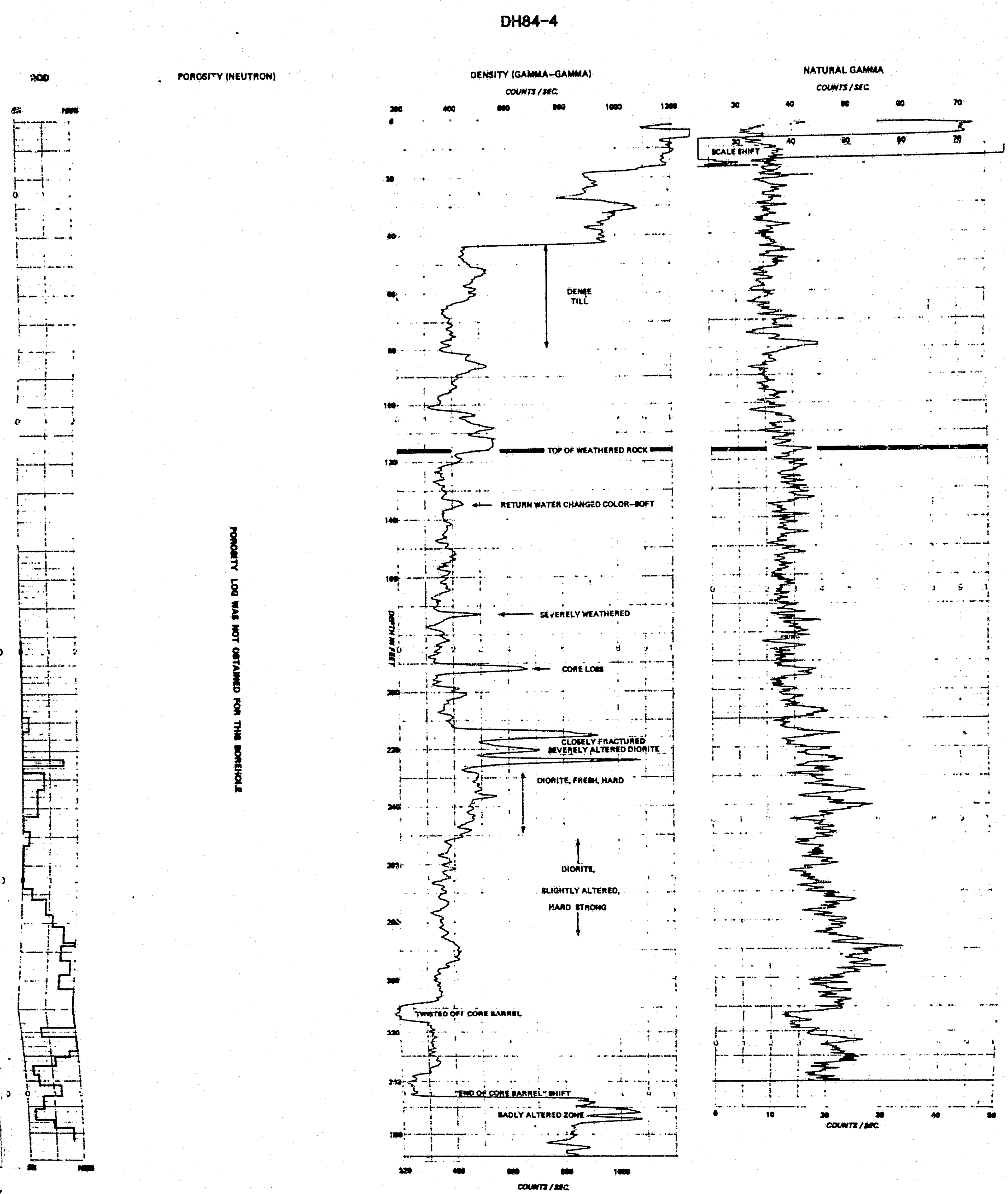
HARZA-EBASCO SUSITNA JOINT VENTURE

ANCHORAGE, ALASKA

APPROVED

JULY, 1984

DRAWING NO.



Continued

NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 8/1984.

ALASKA POWER AU

SUSITNA HYDROELECTR

BOREHOLE GEOPHYS

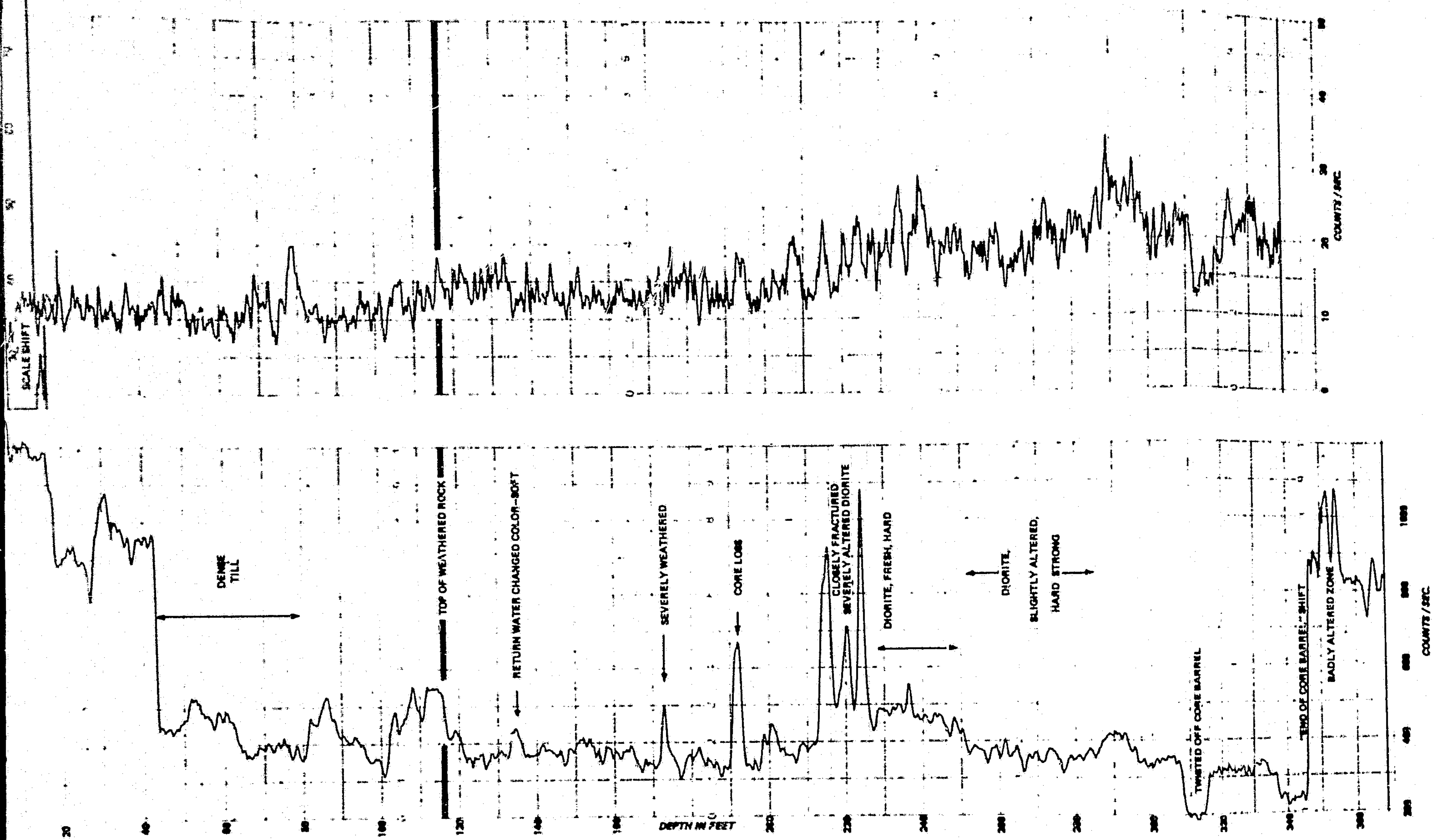
DH84-4

HARZA-EBASCO SUSITNA JOINT VENTURE

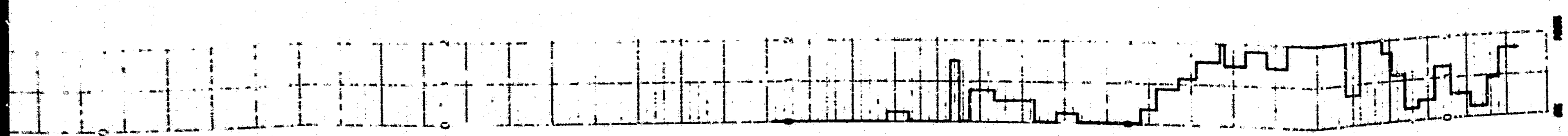
ANCHORAGE, ALASKA

APPROVED

DATE JULY, 1984



POROSITY LOG WAS NOT OBTAINED FOR THIS BOREHOLE

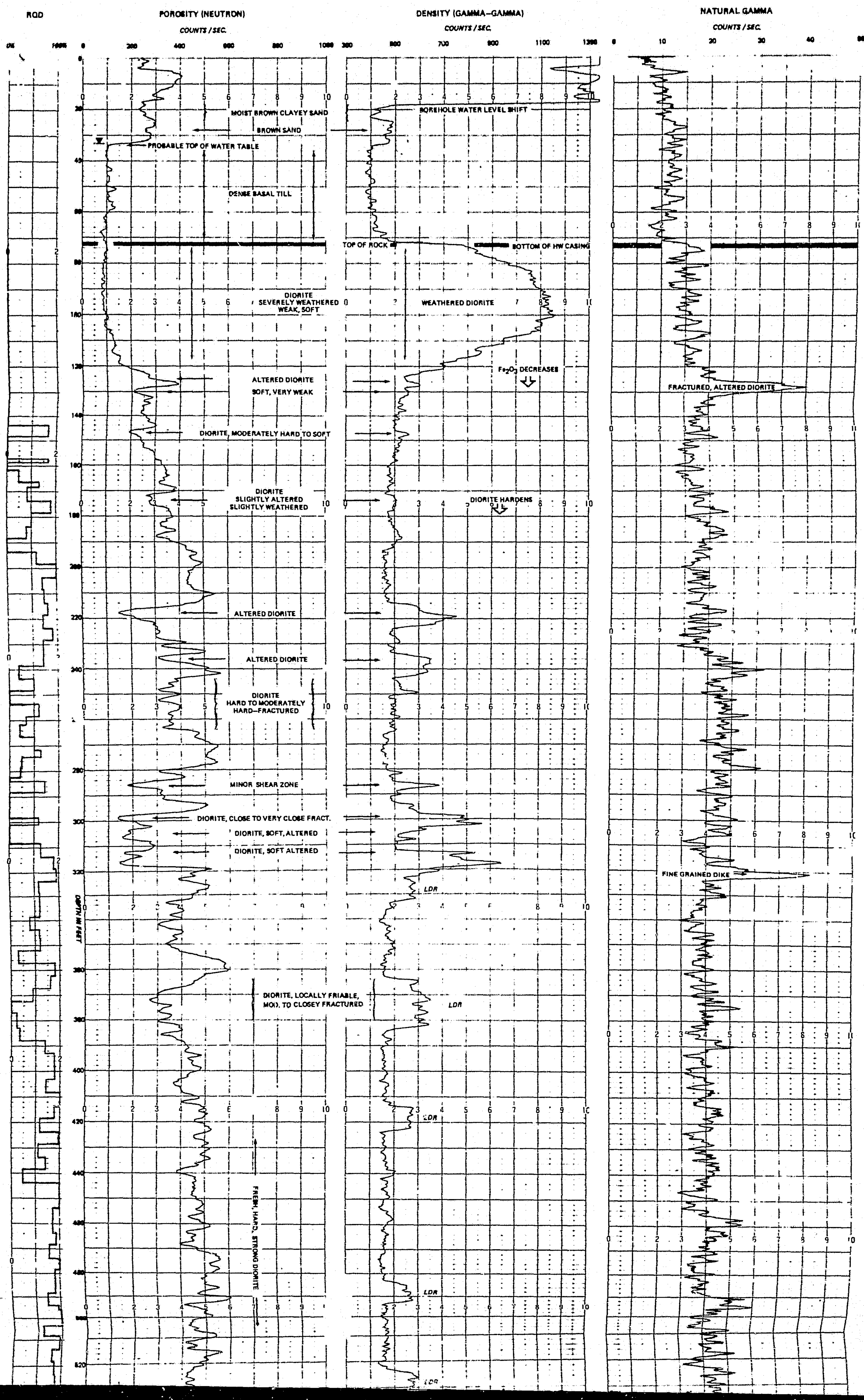


NOTES:
- BOREHOLE IS INCLINED 36 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/16/84.

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-4		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D-4

Continued

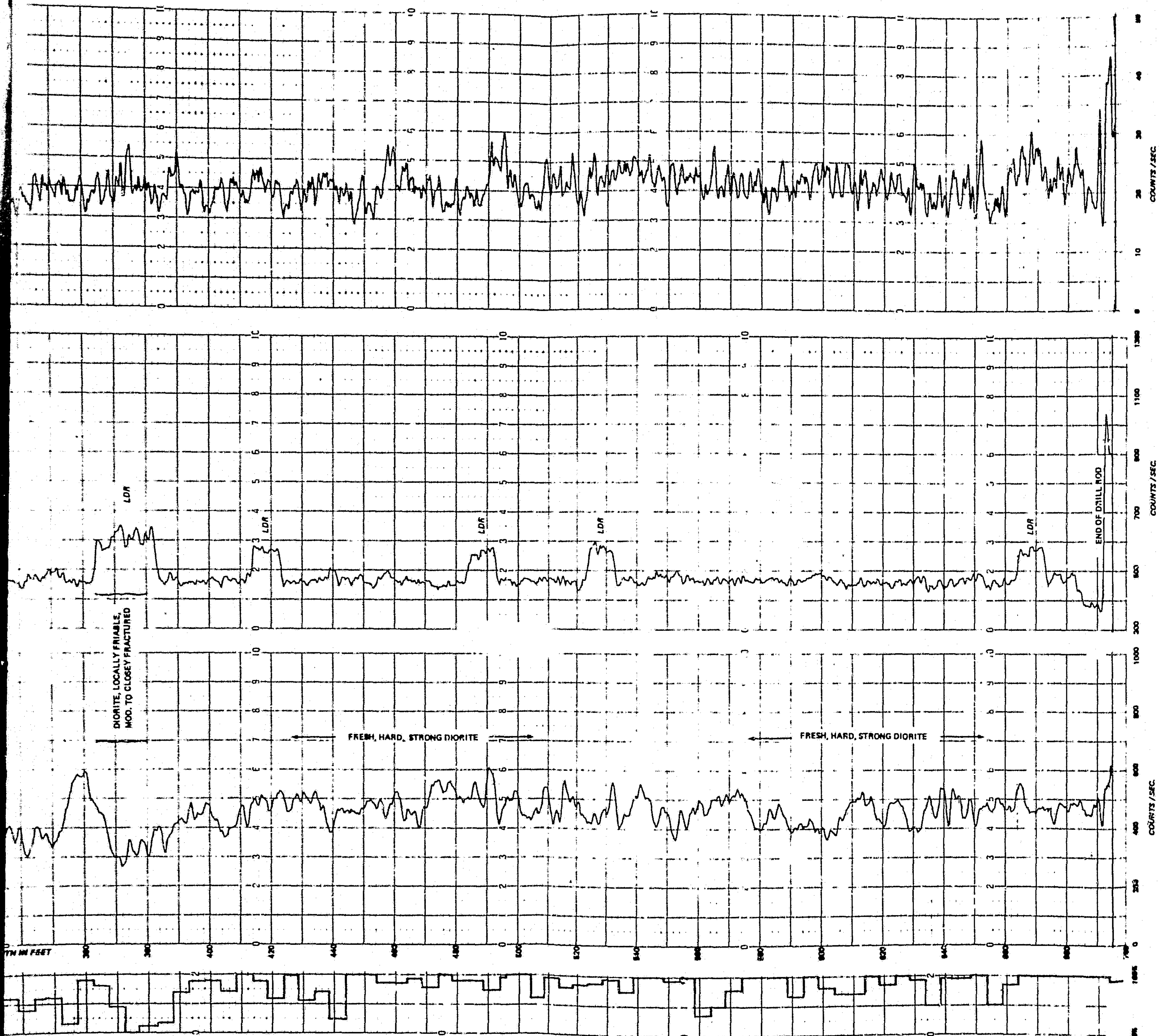
DH84-4A



Continued

11

12

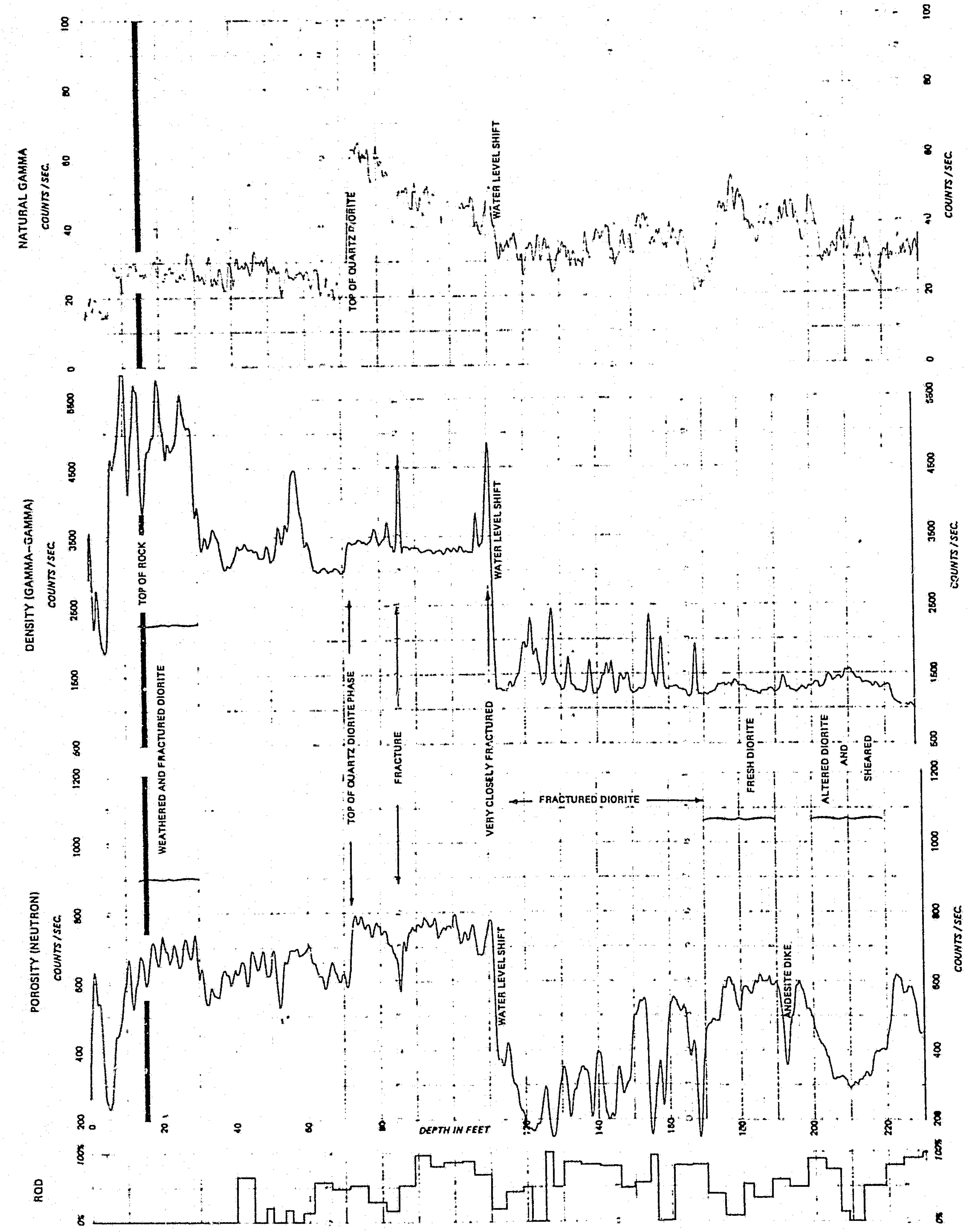


NOTES:
- *BOREHOLE IS INCLINED 35 DEGREES FROM VERTICAL.*
- *DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.*
- *LDR INDICATES LIGHT DRILL ROD*
- *LOGGED 5/21/84.*

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-4A		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D – 4A

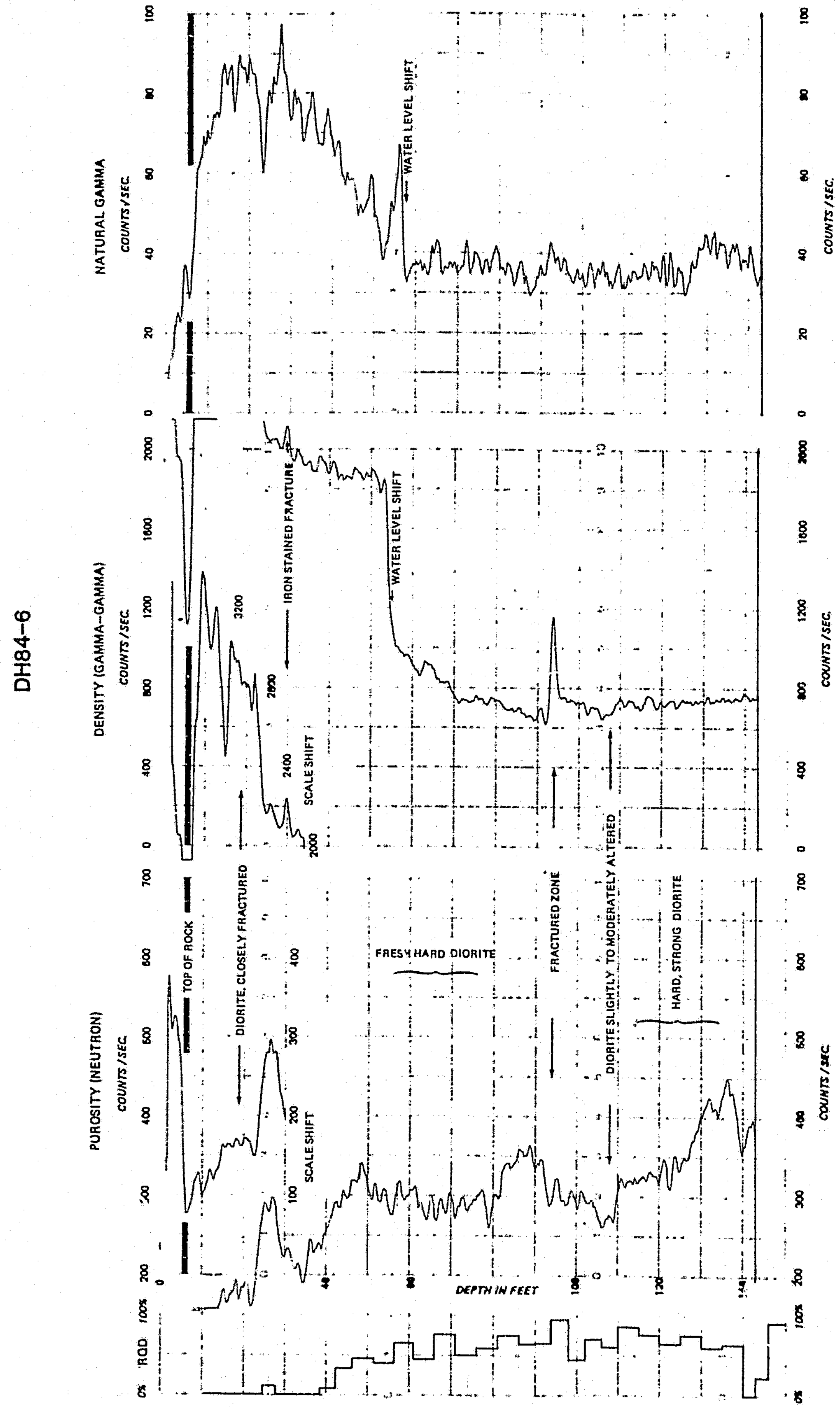
Continued

DH84-5



NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/18/84.

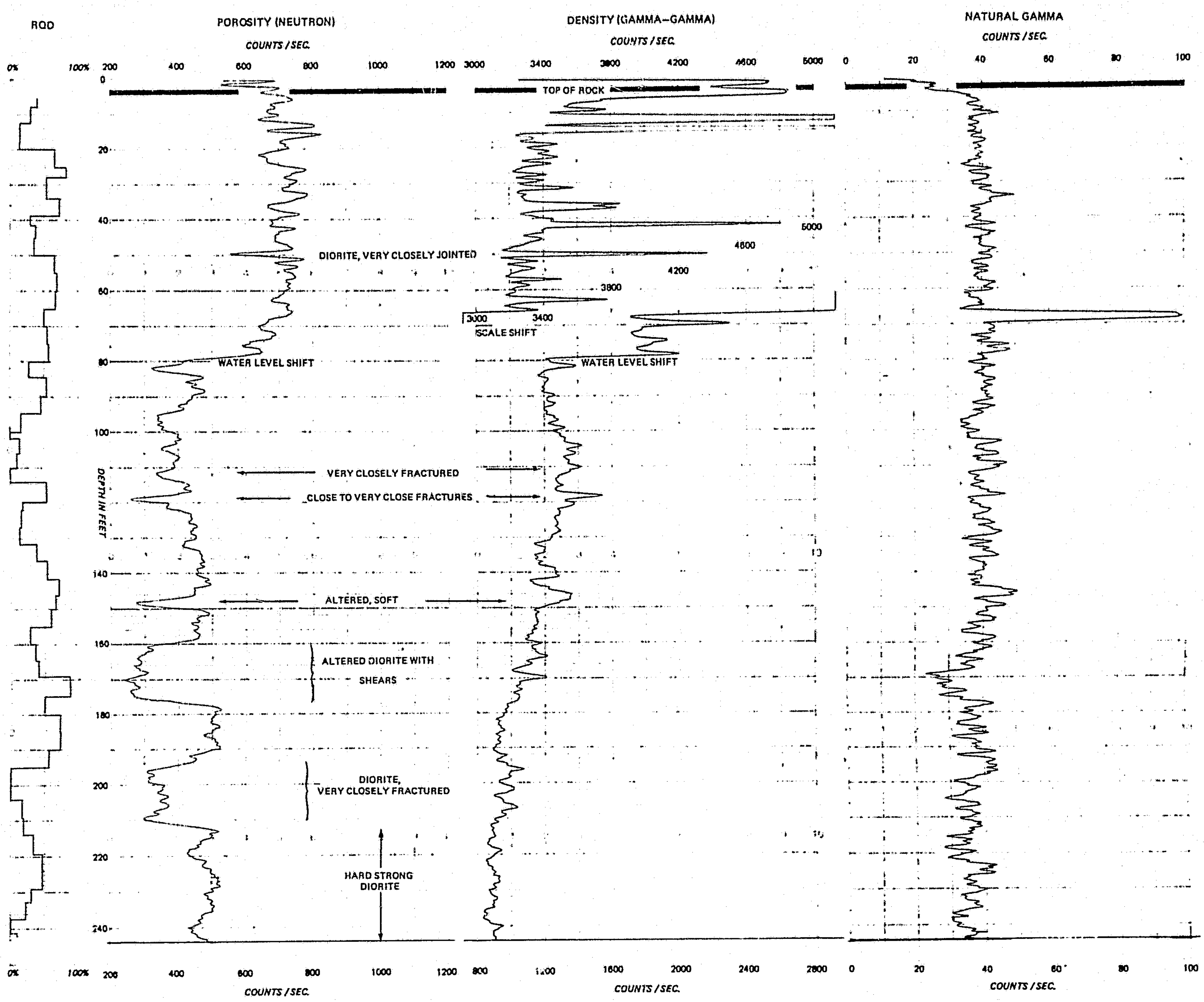
ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-5		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO D-5



NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/15/84.

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-6		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO. D-6

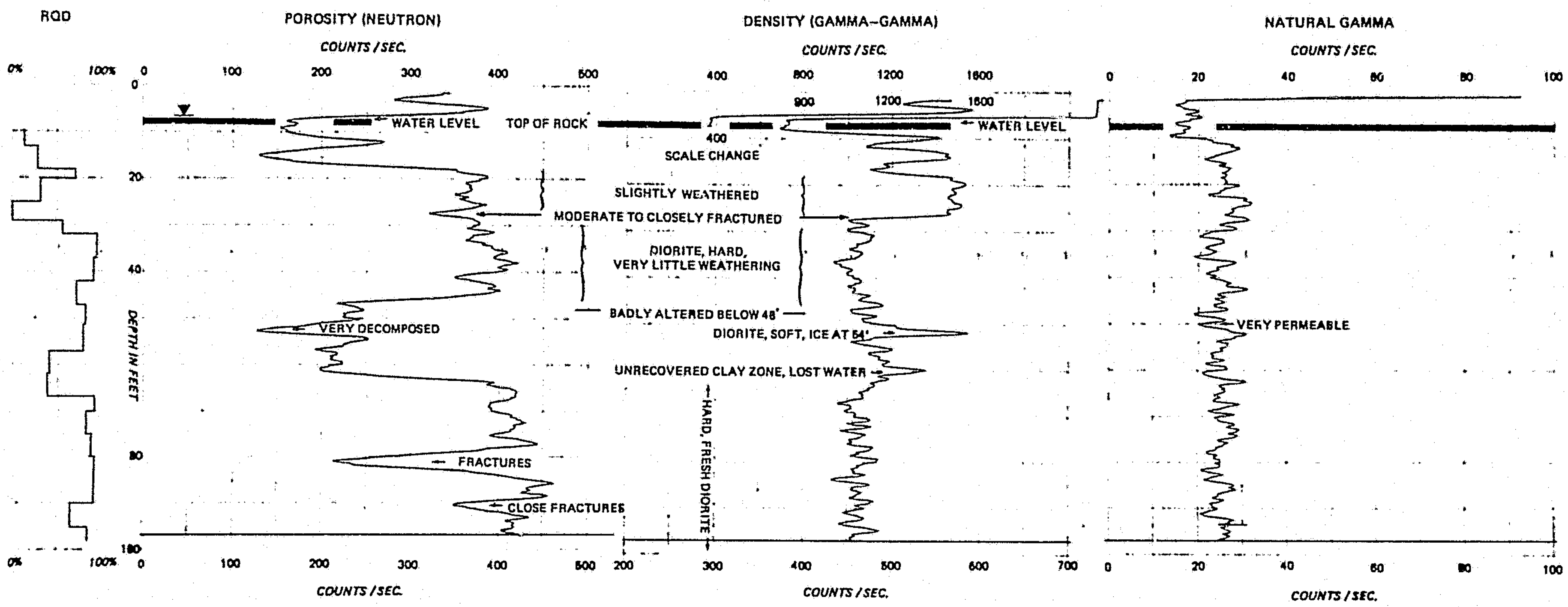
DH84-7



NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/18/84.

ALASKA POWER AUTHORITY SUSITNA HYDROELECTRIC PROJECT	
BOREHOLE GEOPHYSICAL LOGS DH84-7	
HARZA-EBASCO SUSITNA JOINT VENTURE ANCHORAGE, ALASKA	APPROVED DATE JULY, 1984 DRAWING NO D-7

DH84-8



NOTES:
- BOREHOLE IS INCLINED 30 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/13/84.

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

BOREHOLE GEOPHYSICAL LOGS
DH84-8

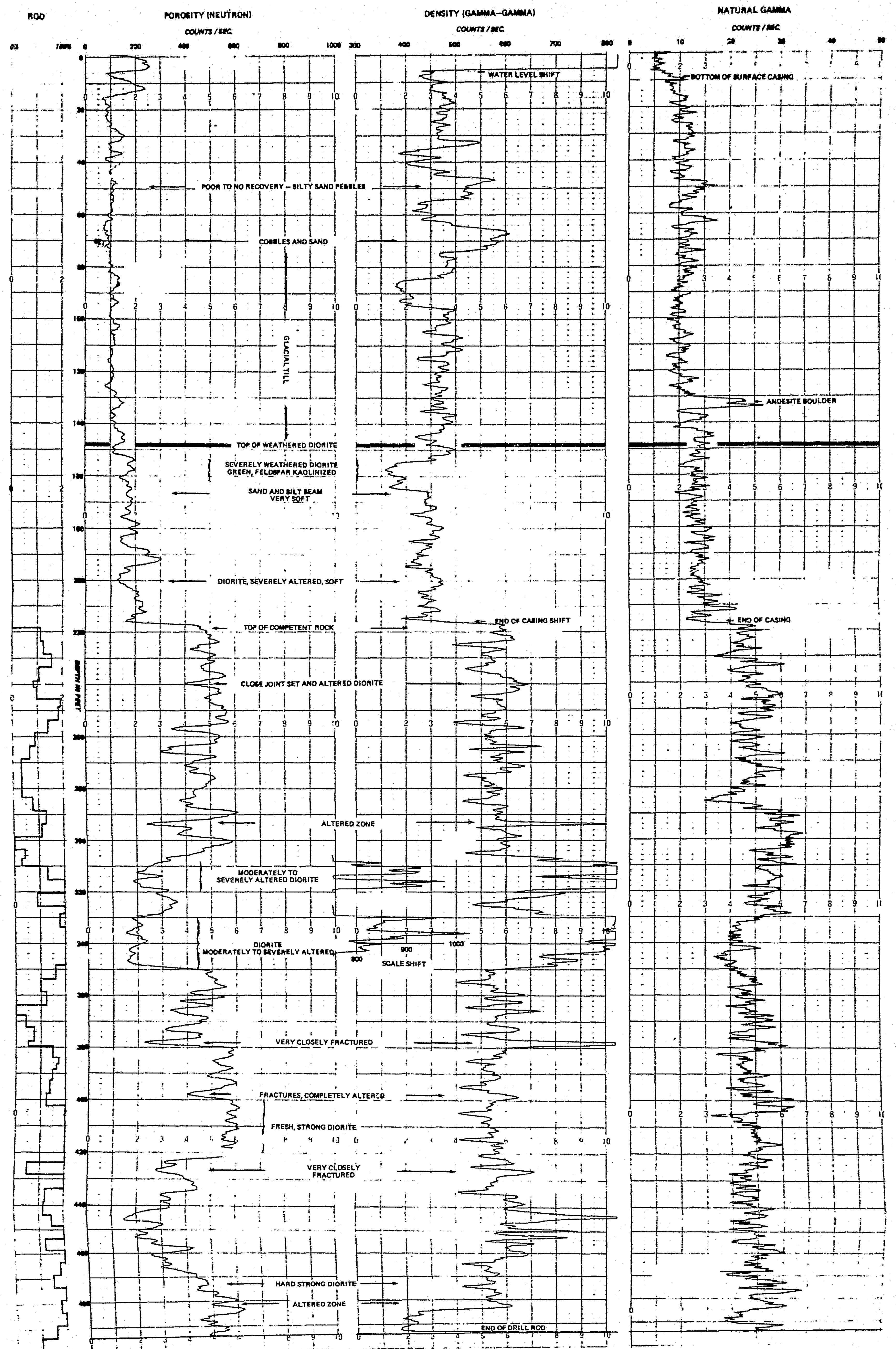
HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA

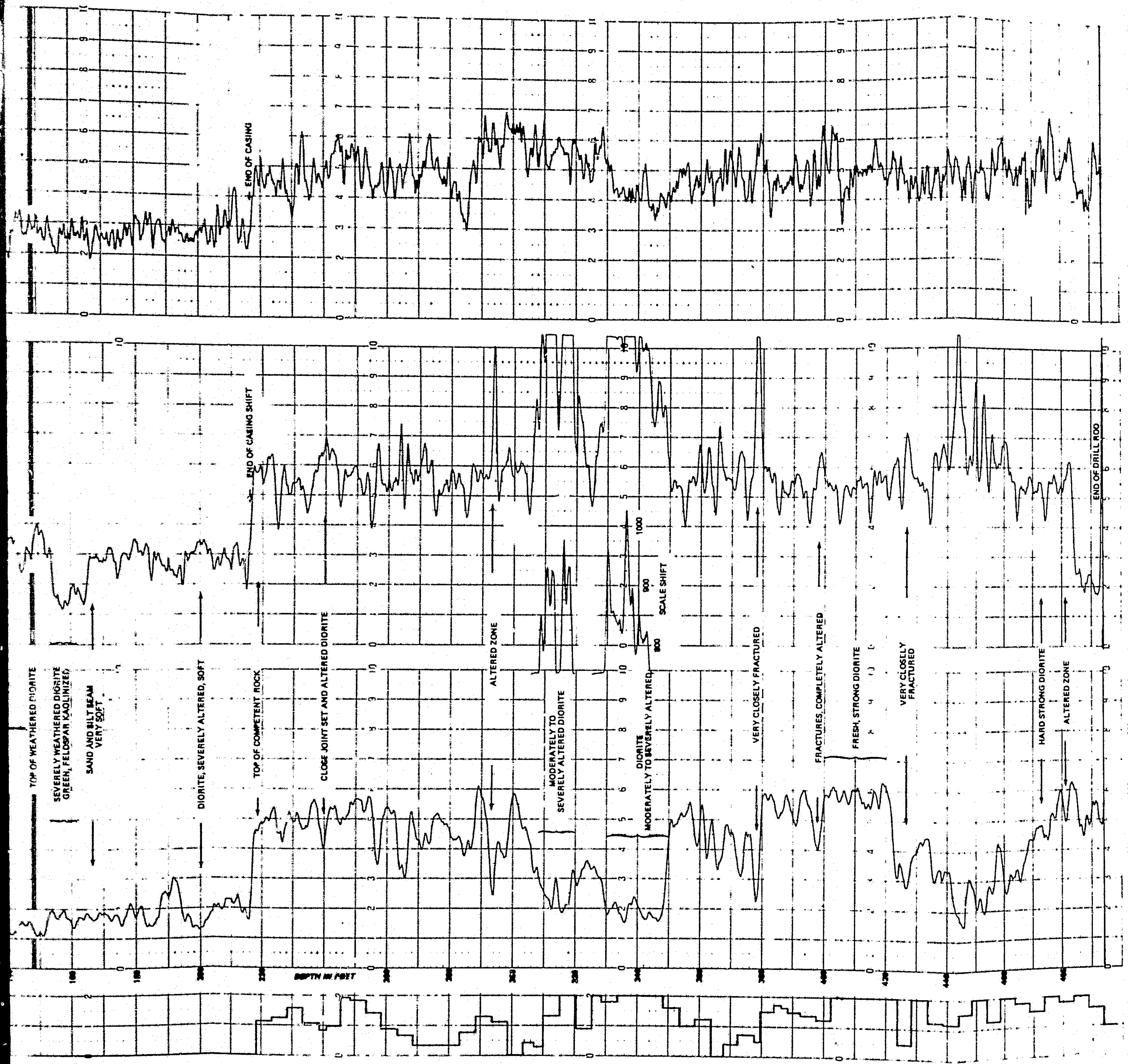
APPROVED

DATE JULY, 1984

DRAWING NO D-8

DH84-9


ROD
POROSITY (NEUTRON)
COUNTS / SEC.
DENSITY (GAMMA–GAMMA)
COUNTS / SEC.
NATURAL GAMMA
COUNTS / SEC.
DEPTH IN FEET
WATER LEVEL SHIFT
BOTTOM OF SURFACE CASING
POOR TO NO RECOVERY – SILTY SAND PEBBLES
COBBLES AND SAND
GLACIAL TILL
ANDESITE BOULDER
TOP OF WEATHERED DIORITE
SEVERELY WEATHERED DIORITE GREEN, FELDSPAR KAOLINIZED
SAND AND SILT SEAM VERY SOFT
DIORITE, SEVERELY ALTERED, SOFT
END OF CASING SHIFT
END OF CASING
TOP OF COMPETENT ROCK
CLOSE JOINT SET AND ALTERED DIORITE
ALTERED ZONE
MODERATELY TO SEVERELY ALTERED DIORITE
DIORITE MODERATELY TO SEVERELY ALTERED
SCALE SHIFT
VERY CLOSELY FRACTURED
FRACTURES, COMPLETELY ALTERED
FRESH, STRONG DIORITE
VERY CLOSELY FRACTURED
HARD STRONG DIORITE
ALTERED ZONE
END OF DRILL ROD
Continued

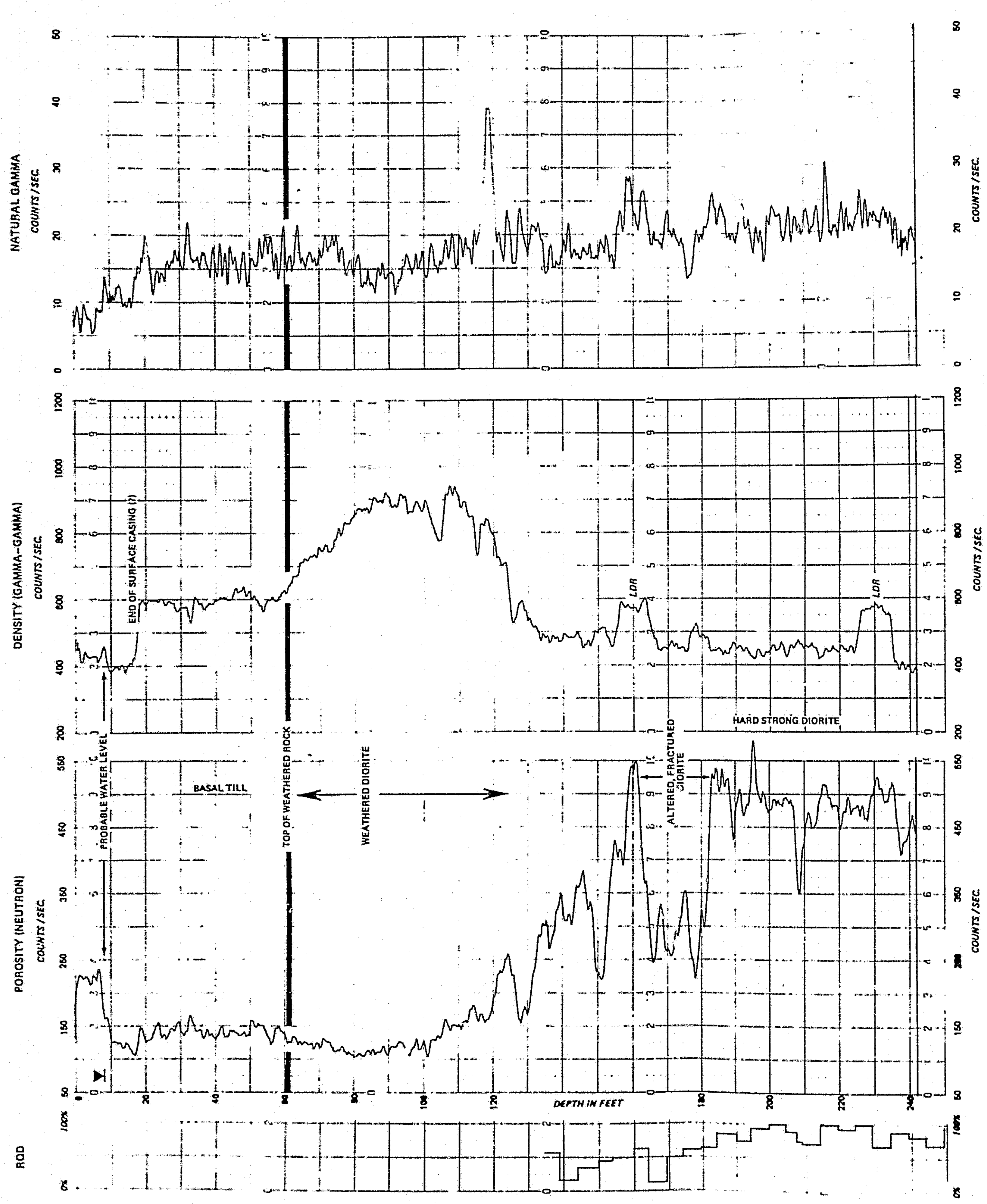


NOTES:
- BOREHOLE IS INCLINED 35 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LOGGED 5/22/84.

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
BOREHOLE GEOPHYSICAL LOGS DH84-9		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY, 1984	DRAWING NO D-9

Continued

DH84-10



NOTES:
- BOREHOLE IS INCLINED 35 DEGREES FROM VERTICAL.
- DEPTHS SHOWN ARE DISTANCE BELOW GROUND SURFACE ALONG BOREHOLE AXIS.
- LDR INDICATES LIGHT DRILL ROD.
- LOGGED 5/26/84.

ALASKA POWER AUTHORITY	
SUSITNA HYDROELECTRIC PROJECT	
BOREHOLE GEOPHYSICAL LOGS DH84-10	
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED
ANCHORAGE, ALASKA	DATE JULY, 1984 — DRAWING NO D - 10

1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX E - LABORATORY TEST DATA/SOILS

Table E-1

SAMPLE NO.	SAMPLE TYPE	DEPTH (FEET)	UNIFIED SOIL CLASSIFICATION SYSTEM	PARTICLE SIZE ANALYSIS: SIEVE ANALYSIS (%) COBBLE +3"	GRAVEL 3" to #4	SAND #4 to #200	SILT/CLAY -#200	HYDROMETER TEST	ATTERBERG LIMITS L.L.	P.L.	P.I.	MOISTURE CONTENT W_c(%)	REMARKS
DH 84-4													
3	SOIL	19.4 - 20.2	CL	–	–	48.5	51.5	–	30	19.8	11.2	–	WASHED
4	SOIL	62.4 - 64.5	CL-ML	–	–	37.5	62.5	–	21	17	4	19.5	WASHED
DH 84-4A													
2	SOIL	23.0 - 23.8	SC	–	–	53.5	46.5	–	26.4	24	2.4	13.8	WASHED
1	SOIL	50.5 - 51.35	SW-SM	–	–	94.0	6.0	–	–	–	–	8.2	
5	SOIL	58.5 - 60.4	SW-SM	–	6.0	87.5	6.5	–	–	–	–	13.7	
6	* ROCK	78.5 - 79.5	SW-SM	–	–	93.0	7.0	–	–	–	–	16.3	
7	* ROCK	100.9 - 101.7	SW	–	–	95.5	4.5	–	–	–	–	11.9	
DH 84-9													
9	SOIL	53.0 - 54.5	SW	–	7.0	90.0	3.0	–	–	–	–	8.8	
8	* ROCK	82.2 - 83.2	SP	–	3.0	93.0	4.0	–	–	–	–	12.4	
DH 84-10													
15	SOIL	17.0 - 17.5	SC	–	3.0	55.0	42.0	–	25	17	8	15.0	WASHED
10	SOIL	35.7 - 36.7	SW-SM	–	–	92.0	8.0	–	–	–	–	9.5	
11	SOIL	42.2 - 43.2	SW	–	5.5	90.5	4.0	–	–	–	–	10.4	
12	SOIL	52.9 - 54.0	SW	–	8.0	89.0	3.0	–	–	–	–	13.2	
13	* ROCK	66.4 - 67.4	SP-SM	–	–	94.0	6.0	–	–	–	–	14.0	
14	* ROCK	81.2 - 82.3	SP-SM	–	–	91.5	8.5	–	–	–	–	13.1	

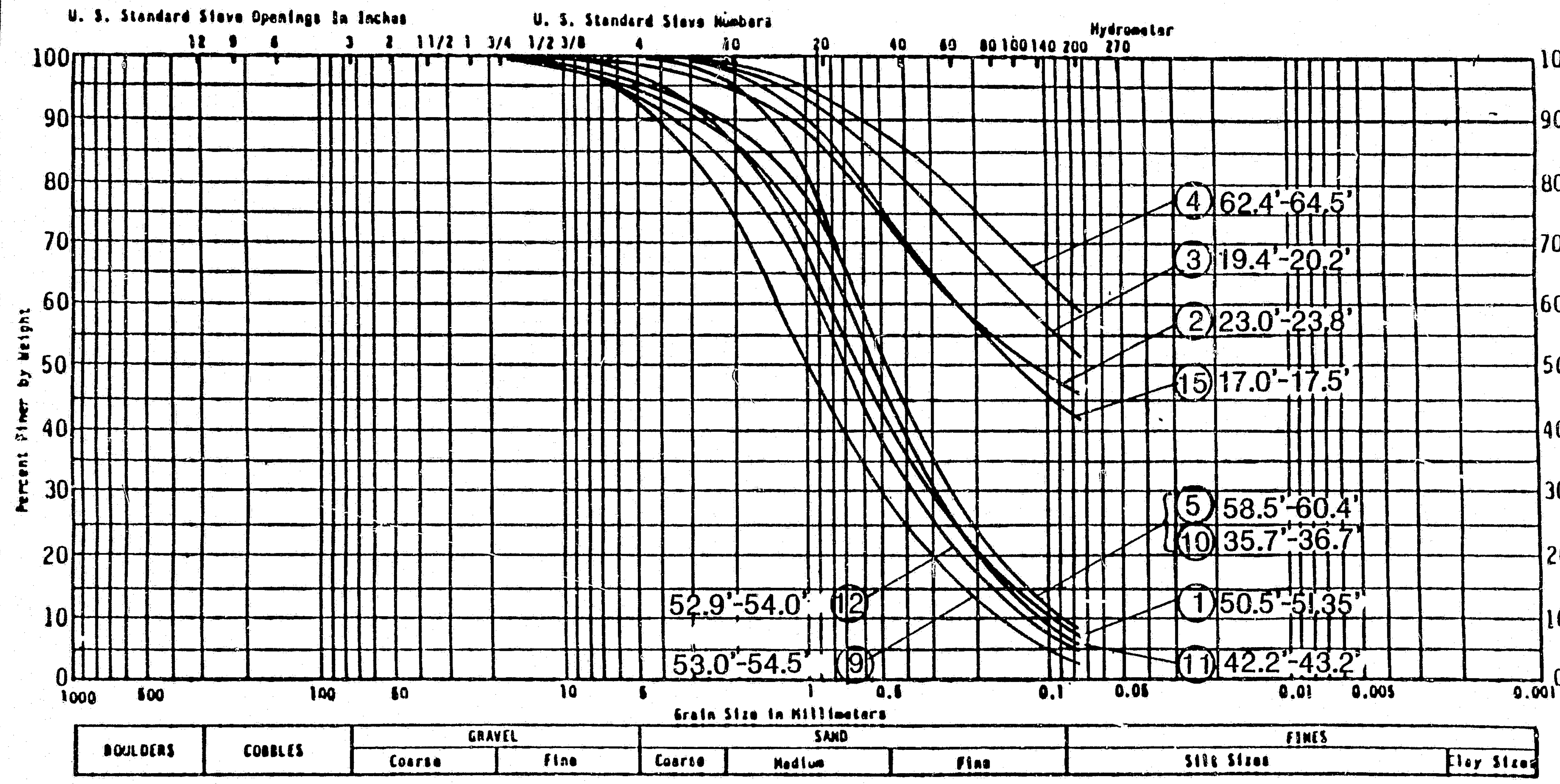
* DECOMPOSED BEDROCK

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM & RESERVOIR
LAB TEST SUMMARY
BOREHOLES DH84-4, 4A, 9, 10

HARZA-EBASCO
ANCHORAGE, ALASKA
DATE 7/84
E-1

Appendix F
Appendix G

GRADATION SIZE ANALYSIS



LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CLASSIFICATION (USC)
	DH84-4,4A	1,2,3,4,5	VARIES	GLACIAL OVERBURDEN IN THE
	DH84-9,10	9,10,11,12,15	VARIES	FINS AREA

VISUAL MANUAL CLASSIFICATION

MEDIUM TO FINE WELL GRADED SAND; SILTY/CLAYEY SAND, SILT, AND CLAY OF LOW PLASTICITY

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM & RESERVOIR

GRADATION ANALYSIS

FINS AREA

BOREHOLES DH84-4,4A,9,10

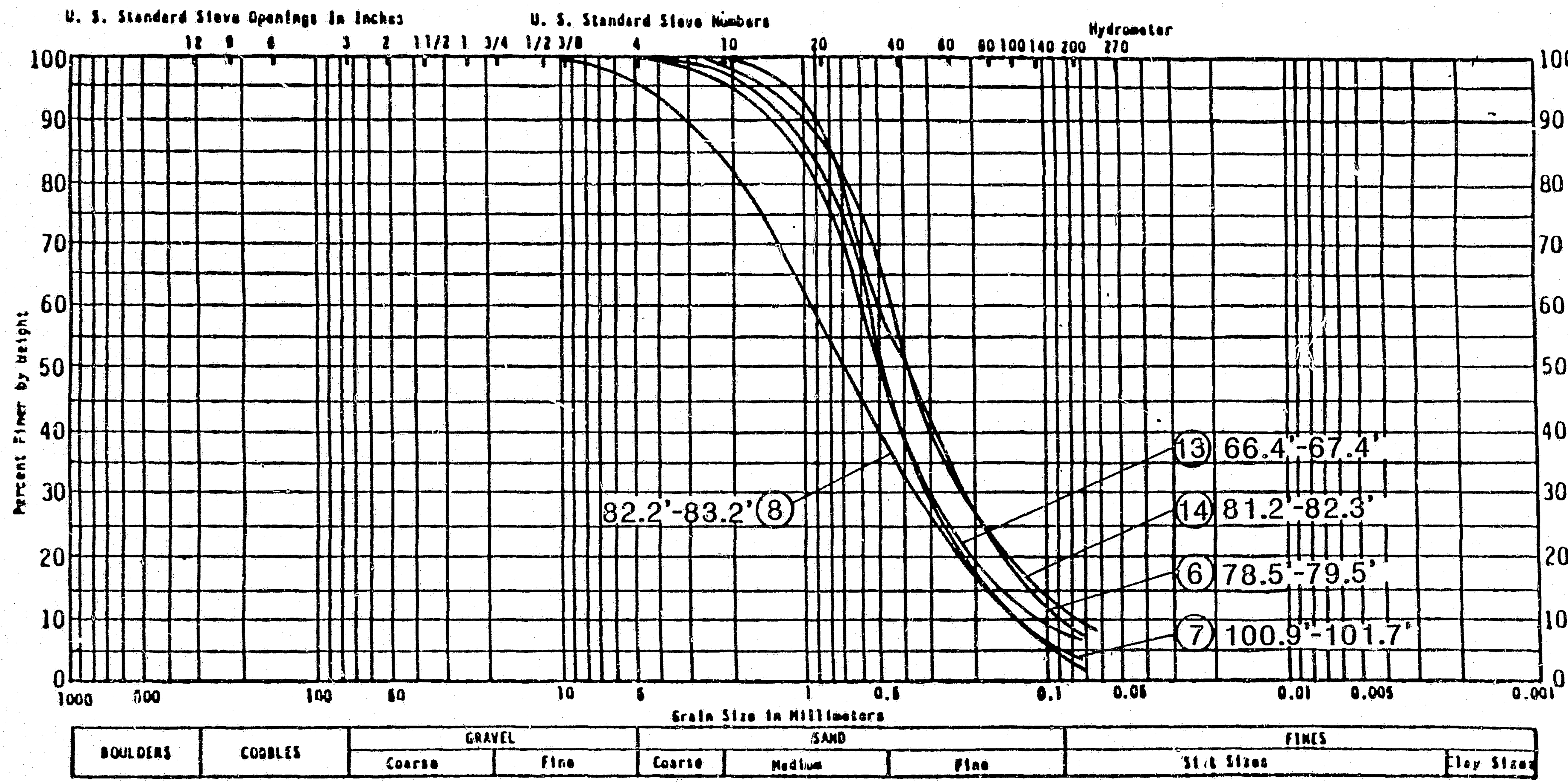
APPROVED

7/84 | Figure E-1

7/19/84

Appendix G Appendix F

GRADATION SIZE ANALYSIS



LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CLASSIFICATION (USC)
	DH84-4A	6,7	VARIES	DEEPLY WEATHERED DIORITE
	DH84-9,10	8,13,14	VARIES	IN THE FINS AREA

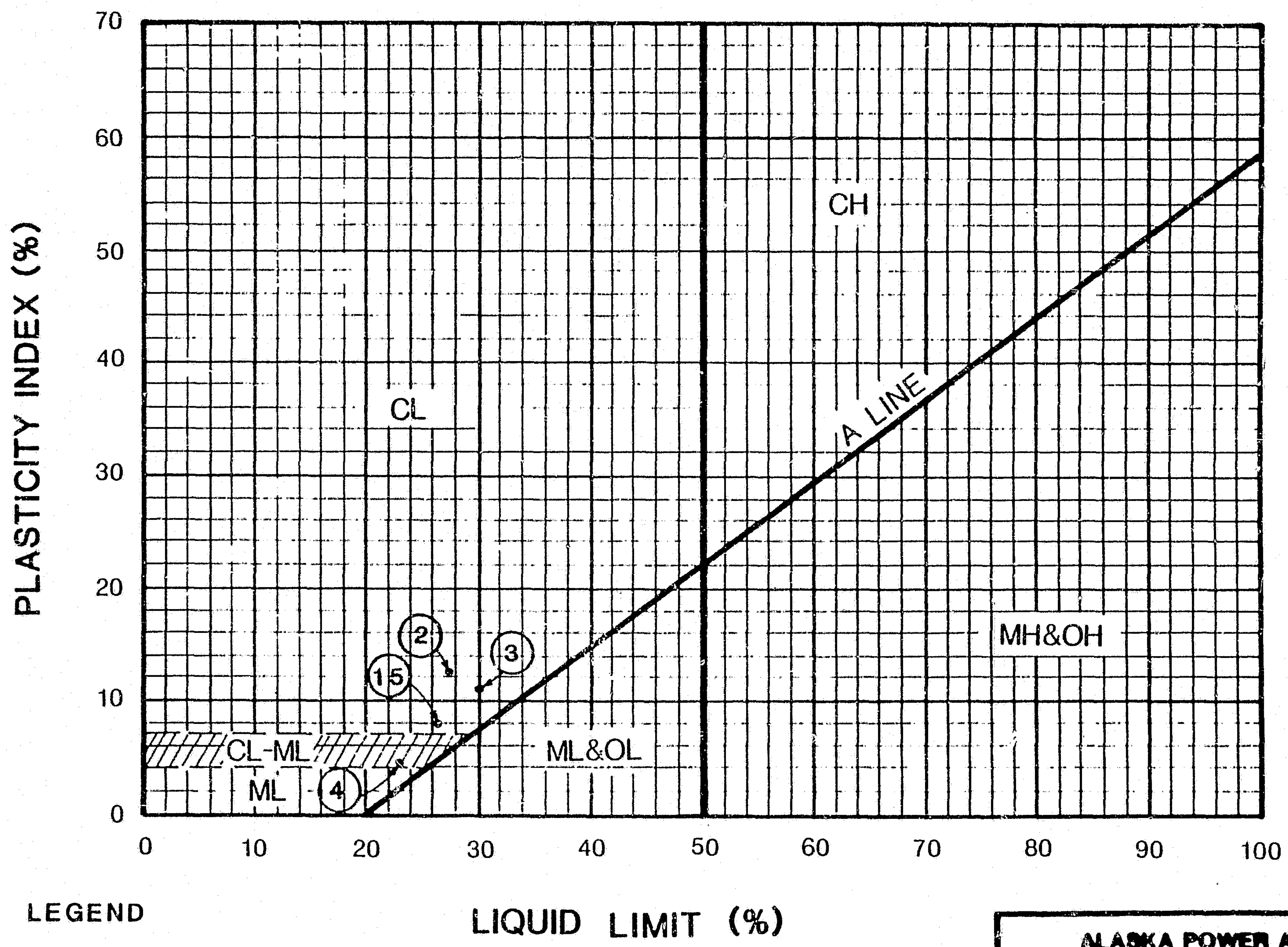
VISUAL MANUAL CLASSIFICATION

MEDIUM TO FINE POORLY TO WELL GRADED SAND AND SILTY SAND (DECOMPOSED ROCK)

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM & RESERVOIR
GRADATION ANALYSIS
FINS AREA
BOREHOLES DH84-4A,9,10

7/84 | Figure E-2

7/19/84



LEGEND

- (2) DH84-4A 23.0'-23.8'
- (3) DH84-4 19.4'-20.2'
- (4) DH84-4 62.4'-64.5'
- (15) DH84-10 17.0'-17.5'

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

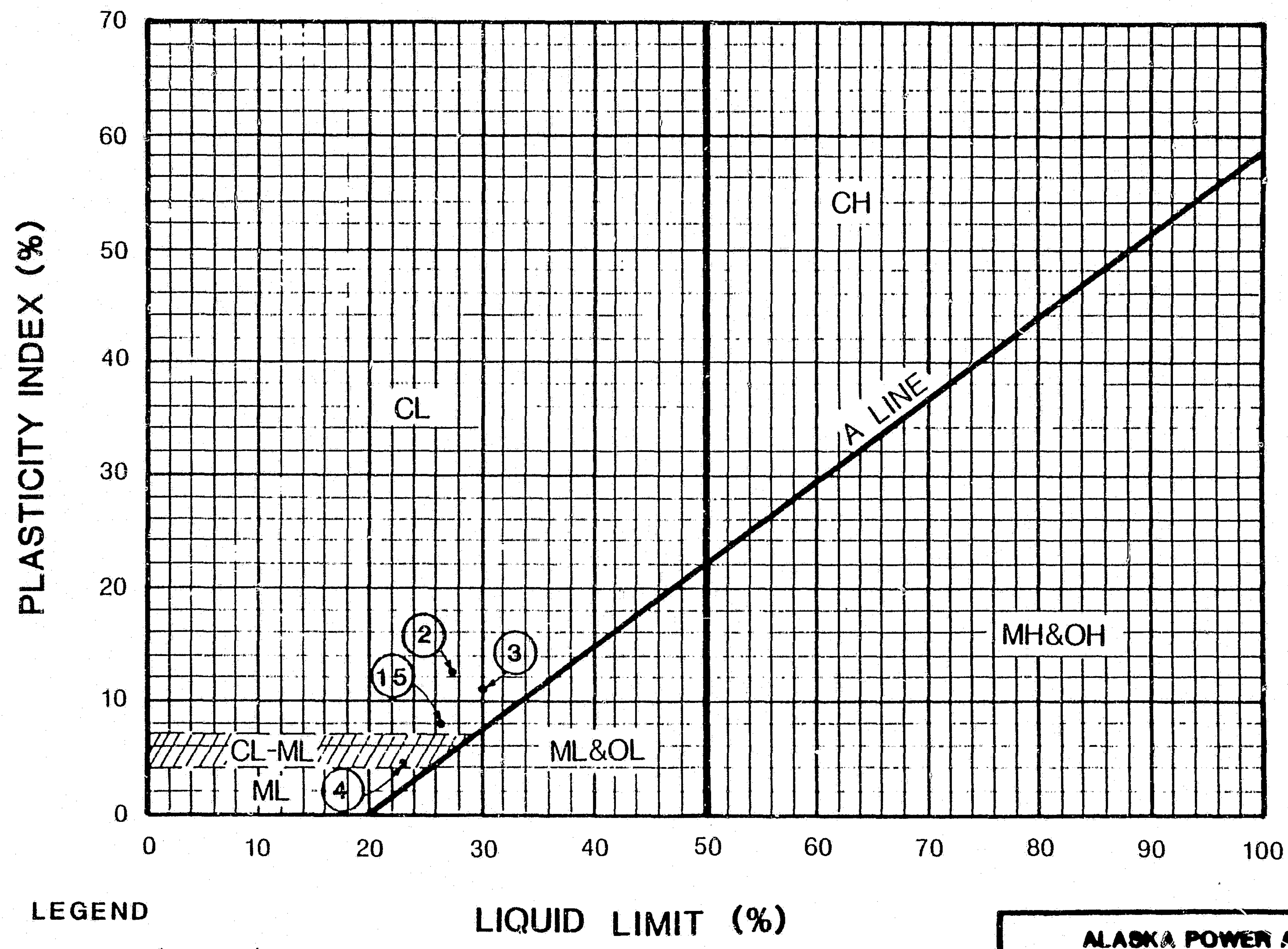
PLASTICITY CHART
FINS AREA

BOREHOLES DH84-4, 4A, 10

HARZA-EBASCO

JULY 1984

FIGURE E-3



LEGEND

- (2) DH84-4A 23 0'-23.8'
- (3) DH84-4 19.4'-20.2'
- (4) DH84-4 62.4'-64.5'
- (15) DH84-10 17.0'-17.5'

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

PLASTICITY CHART
FINS AREA

BOREHOLES DH84-4, 4A, 10

JULY 1984

FIGURE E-3

1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX F - OBSERVATION DEVICES/GROUNDWATER

APPENDIX F

OBSERVATION DEVICES/GROUNDWATER

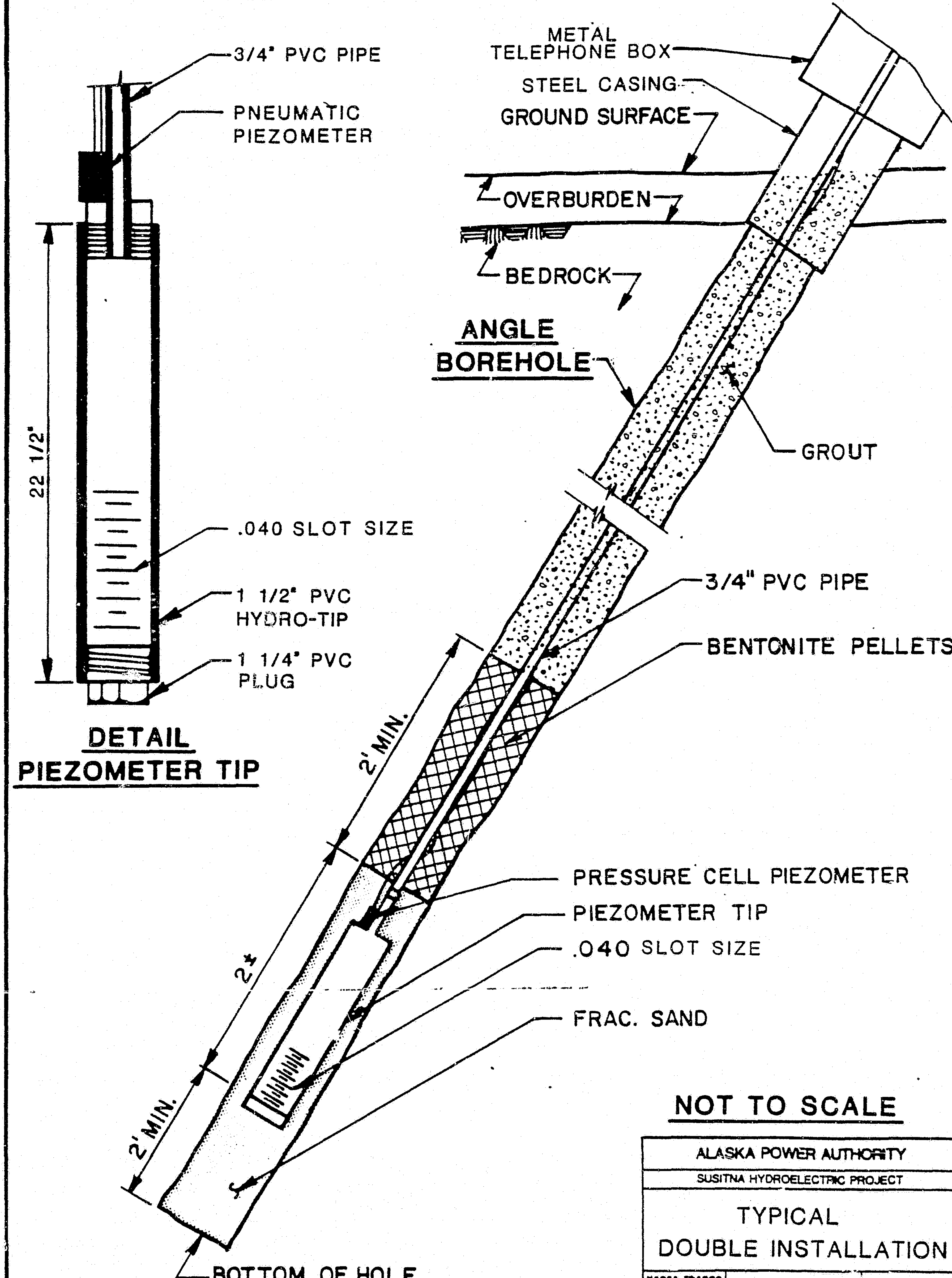
NOTES

1. Typical instrumentation details for the installed piezometers are shown in Exhibits F-1 and F-2. In addition to the details shown, some boreholes were instrumented with 2"ID PVC standpipe with a 5 or 10 foot long slotted section. The larger diameter standpipe enabled geophysical logging to be done later in the program.

2. In several boreholes, a redundant type piezometer system was installed to enable year-round groundwater monitoring. The pneumatic piezometers are not susceptible to freezing during the winter months, which eliminates the need for an anti-freeze mixture in the standpipe piezometers.

3. Shortly after installation all boreholes were purged with nitrogen for the purpose of monitoring groundwater recharge and sampling the groundwater.

Appendix G



ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

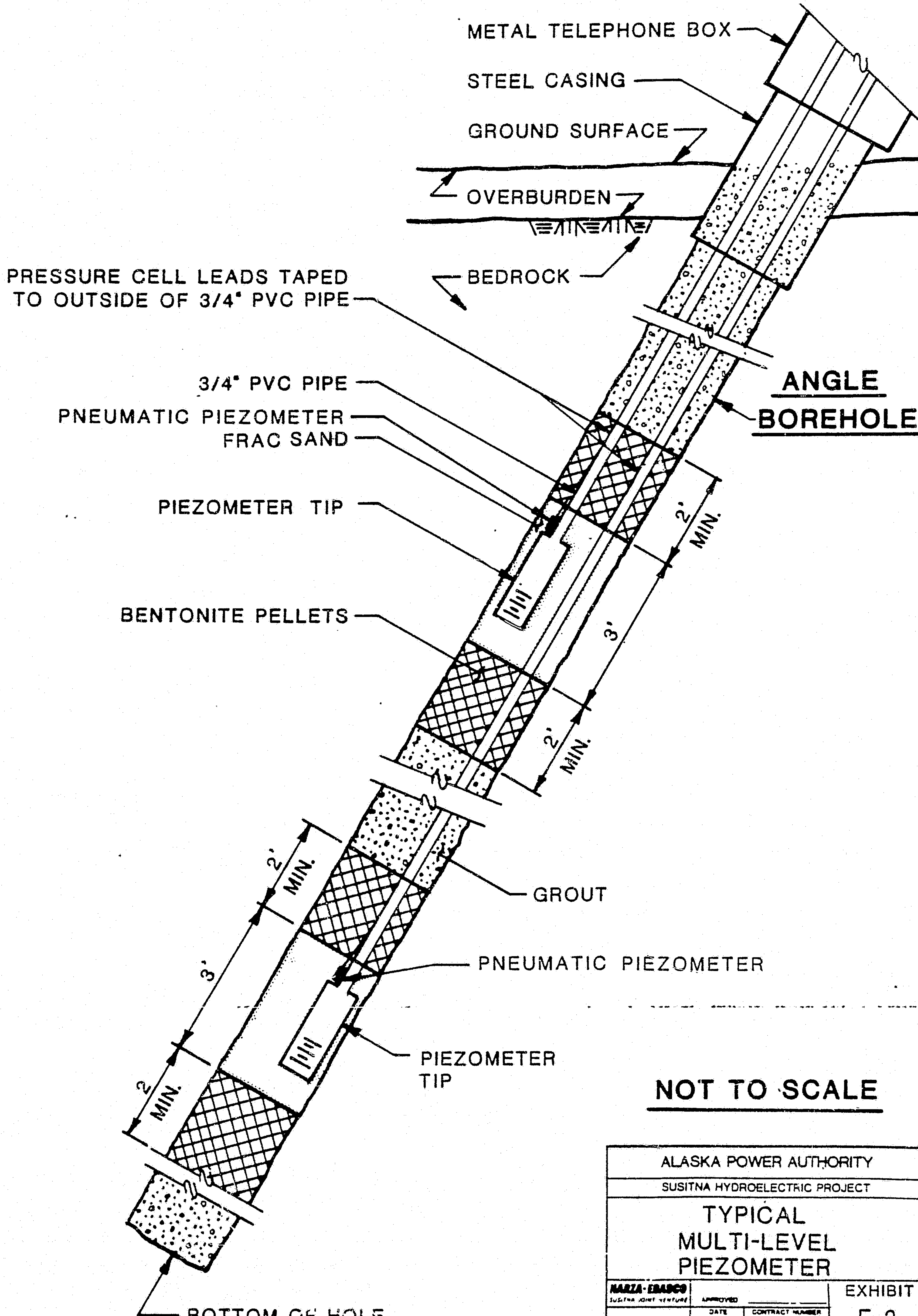
TYPICAL
DOUBLE INSTALLATION

HARZA-EBASCO
SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA

APPROVED
DATE
CONTRACT NUMBER

EXHIBIT
F-1

Appendix G



ALASKA POWER AUTHORITY

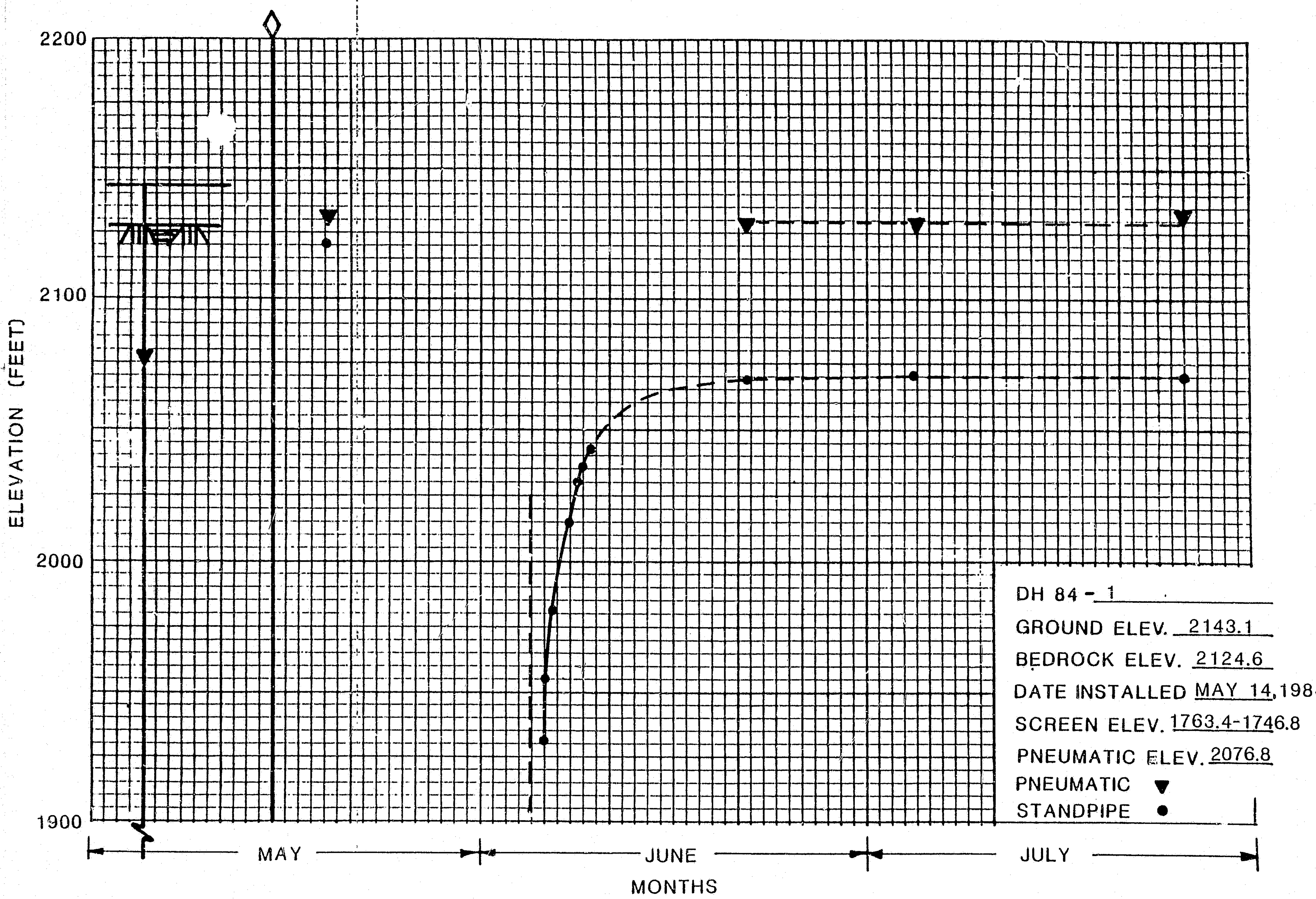
SUSITNA HYDROELECTRIC PROJECT

TYPICAL MULTI-LEVEL PIEZOMETER

HARZA-EBASCO SUSITNA JOINT VENTURE, ANCHORAGE, ALASKA

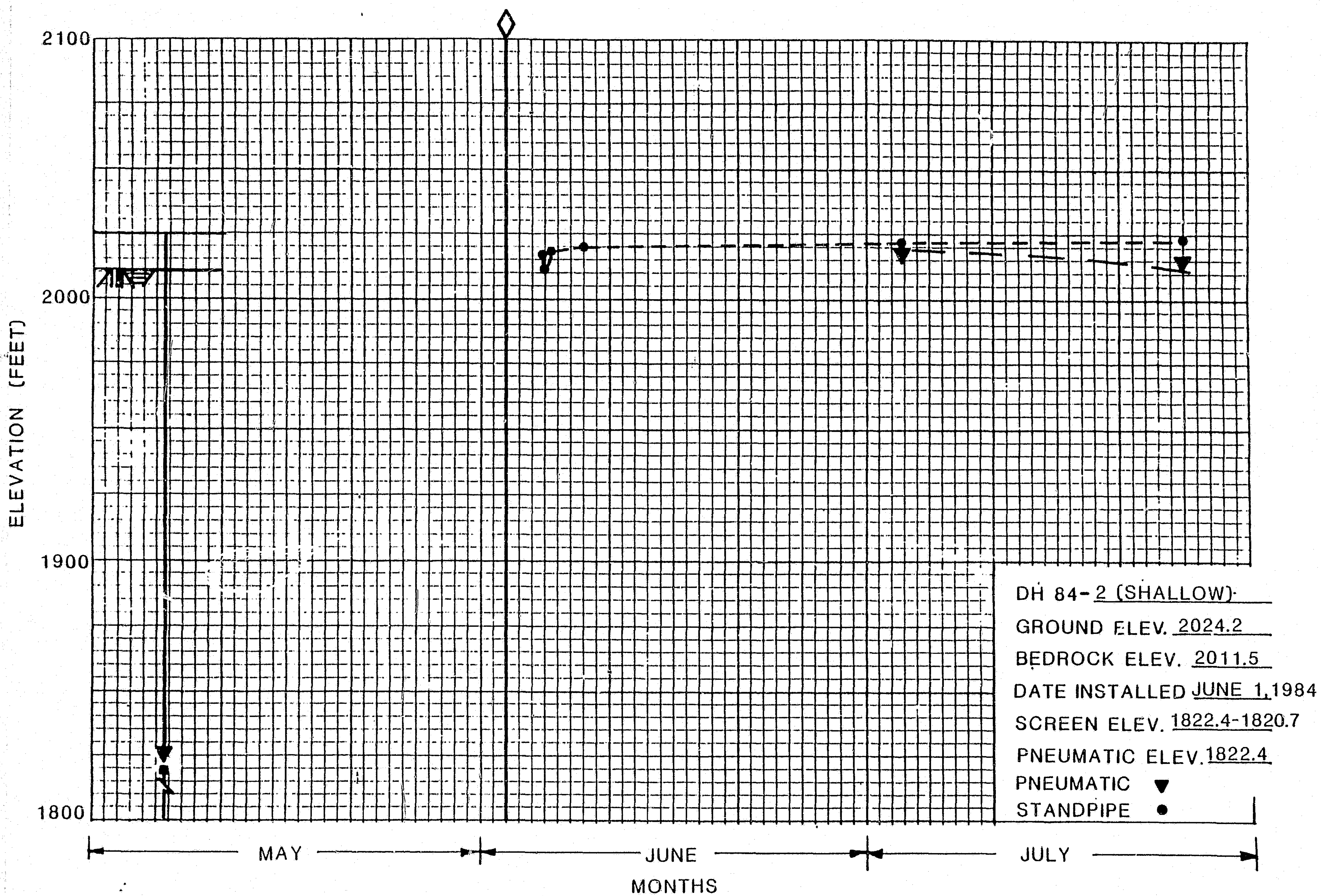
APPROVED | DATE | CONTRACT NUMBER

EXHIBIT F-2



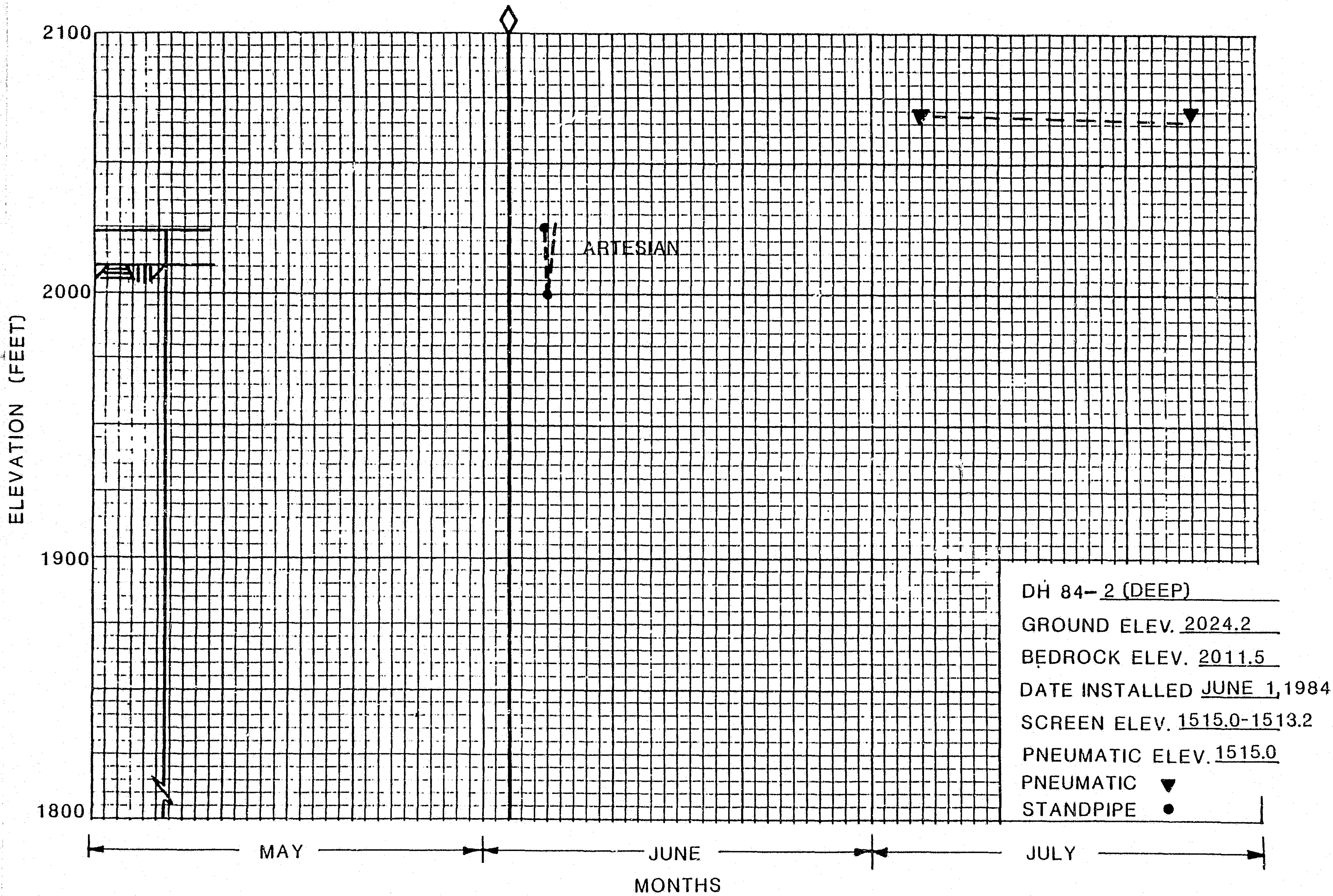
GROUNDWATER MONITORING CURVE

Appendix G



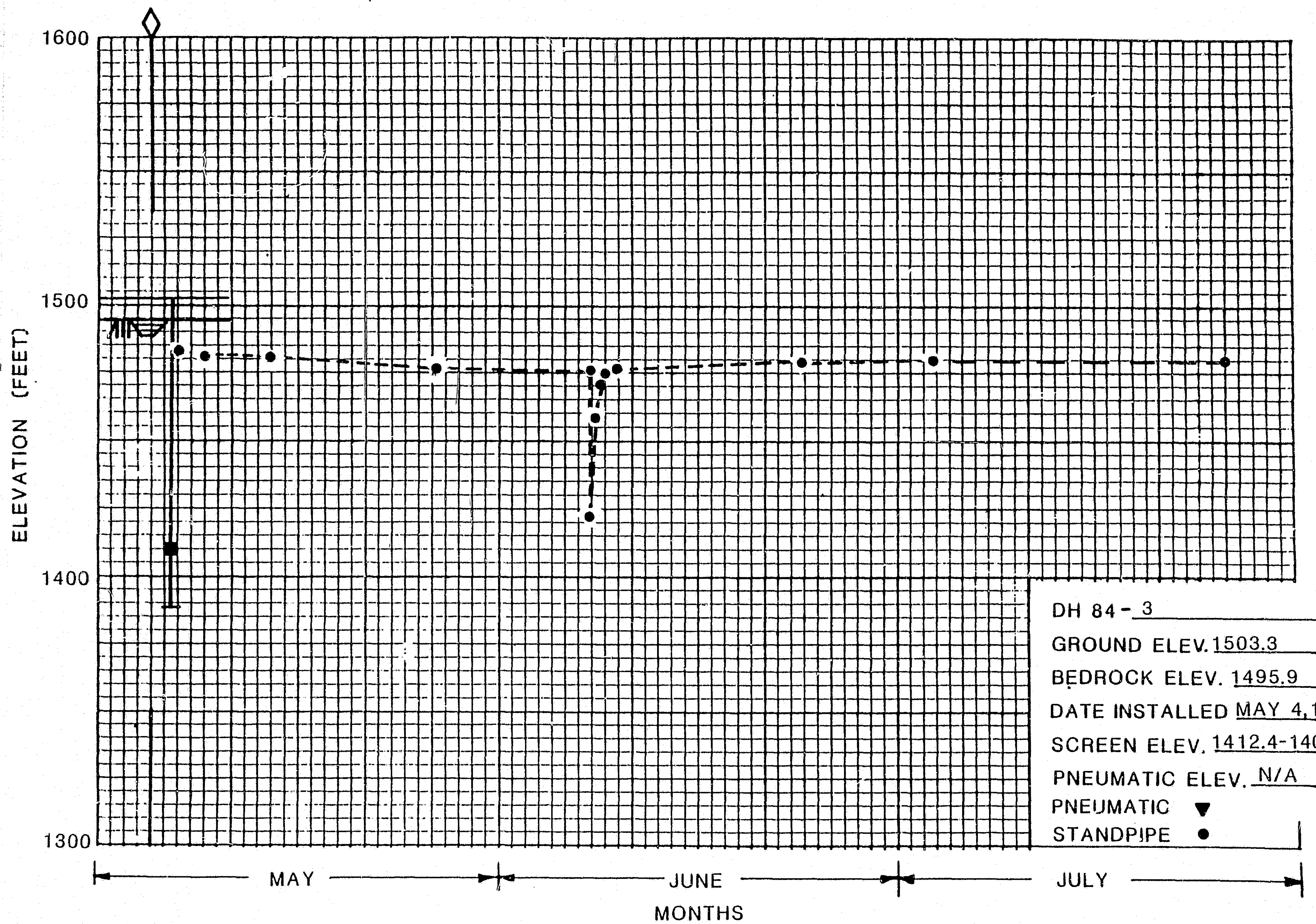
GROUNDWATER MONITORING CURVE

Appendix G



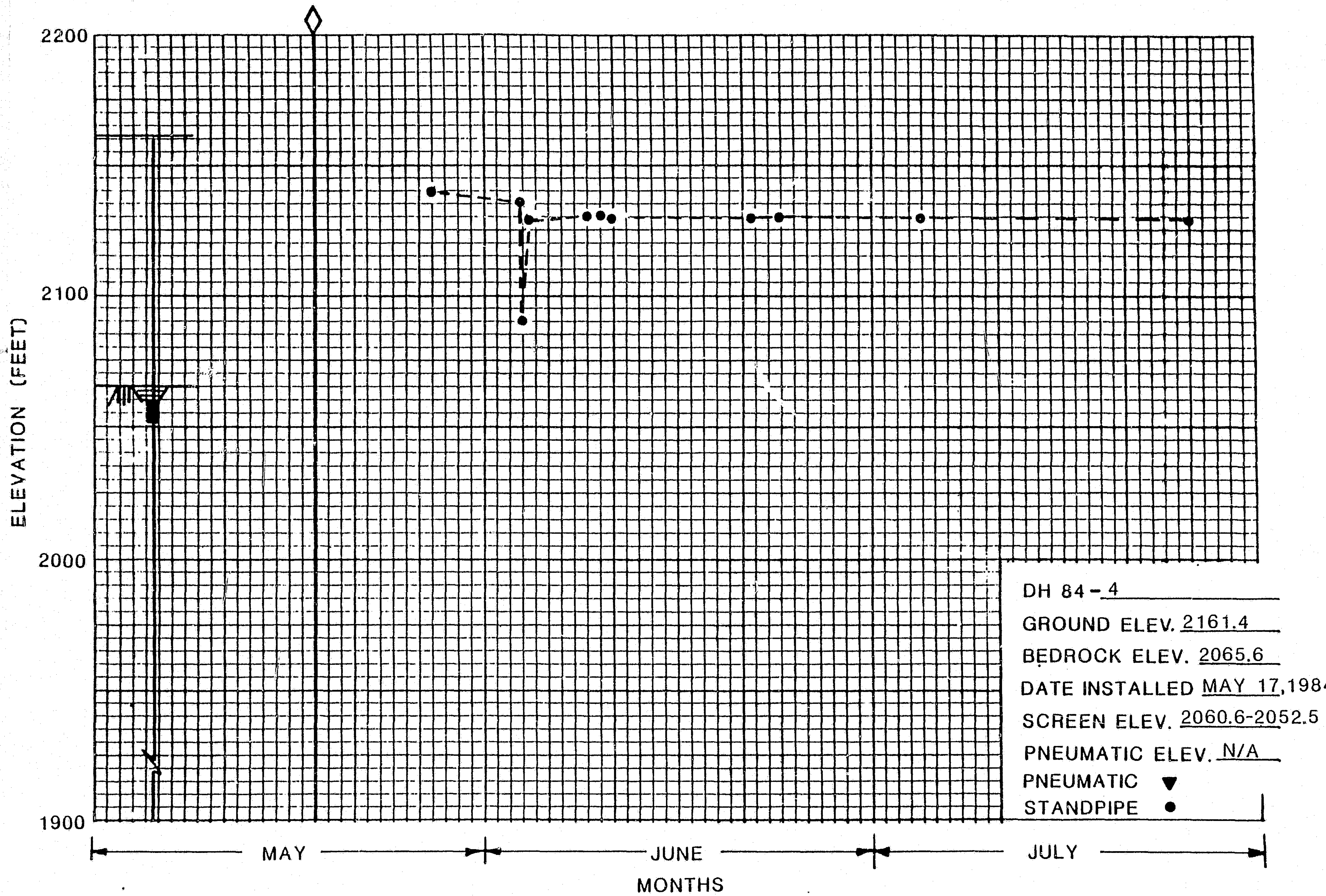
GROUNDWATER MONITORING CURVE

Appendix G

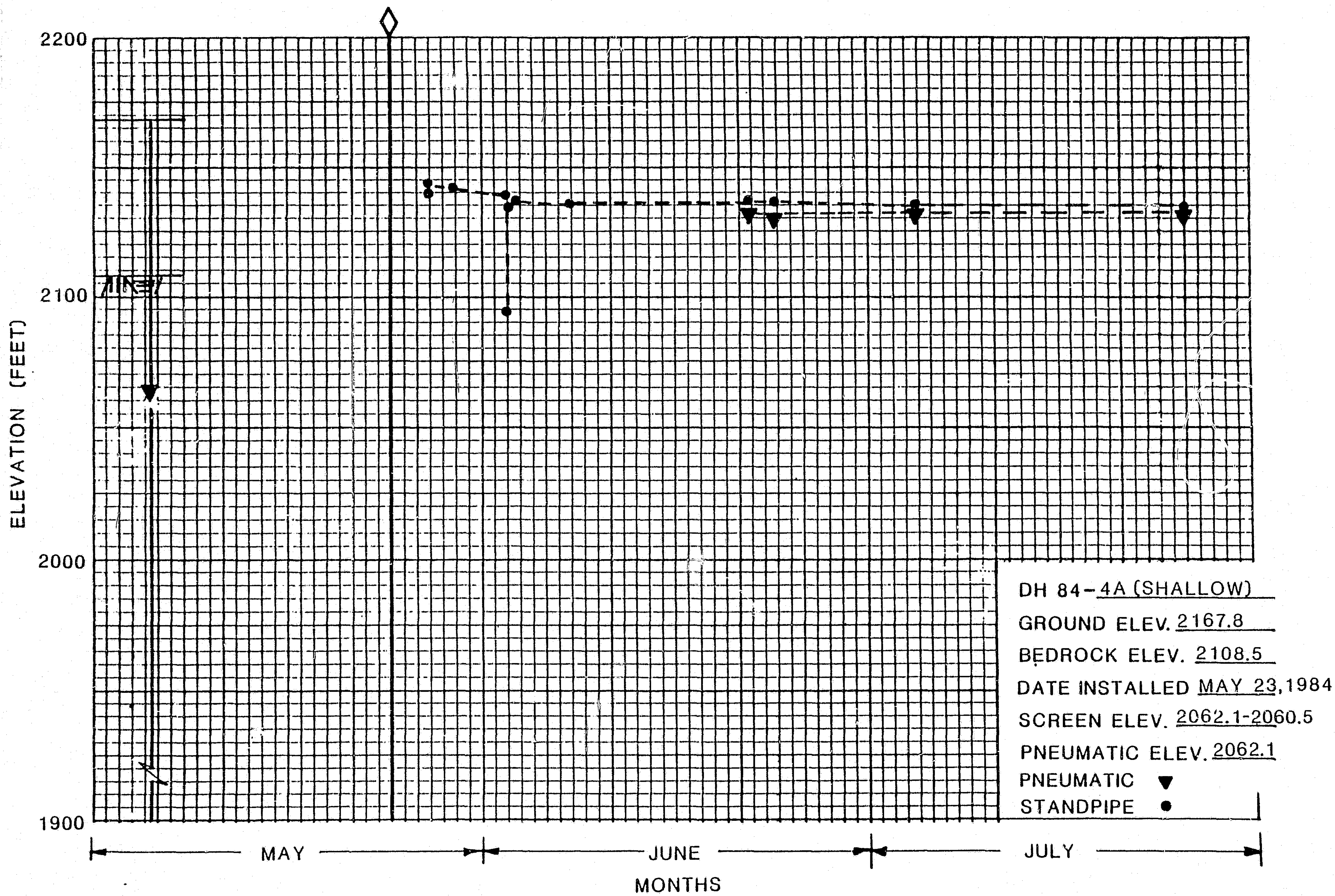


GROUNDWATER MONITORING CURVE

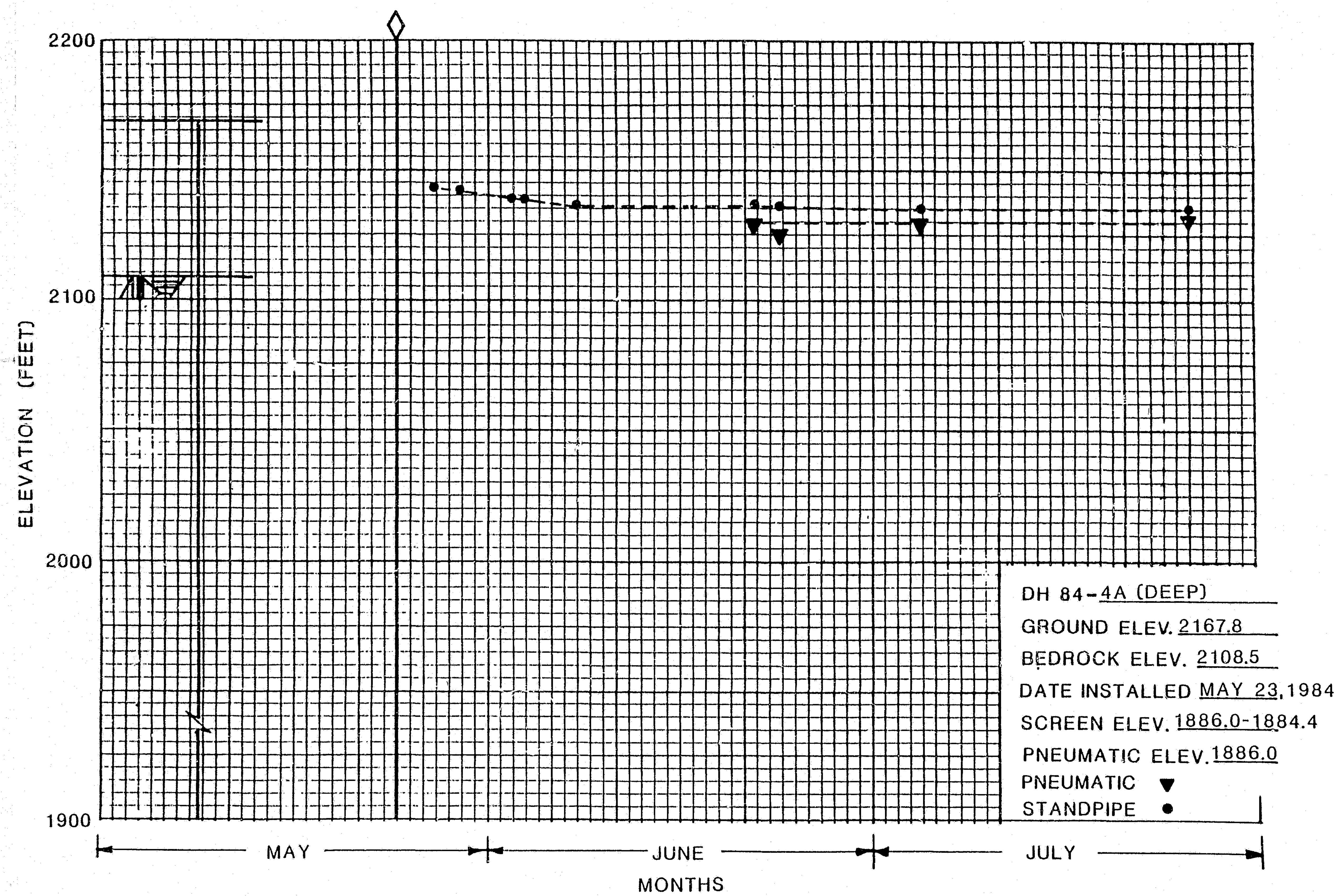
Appendix G



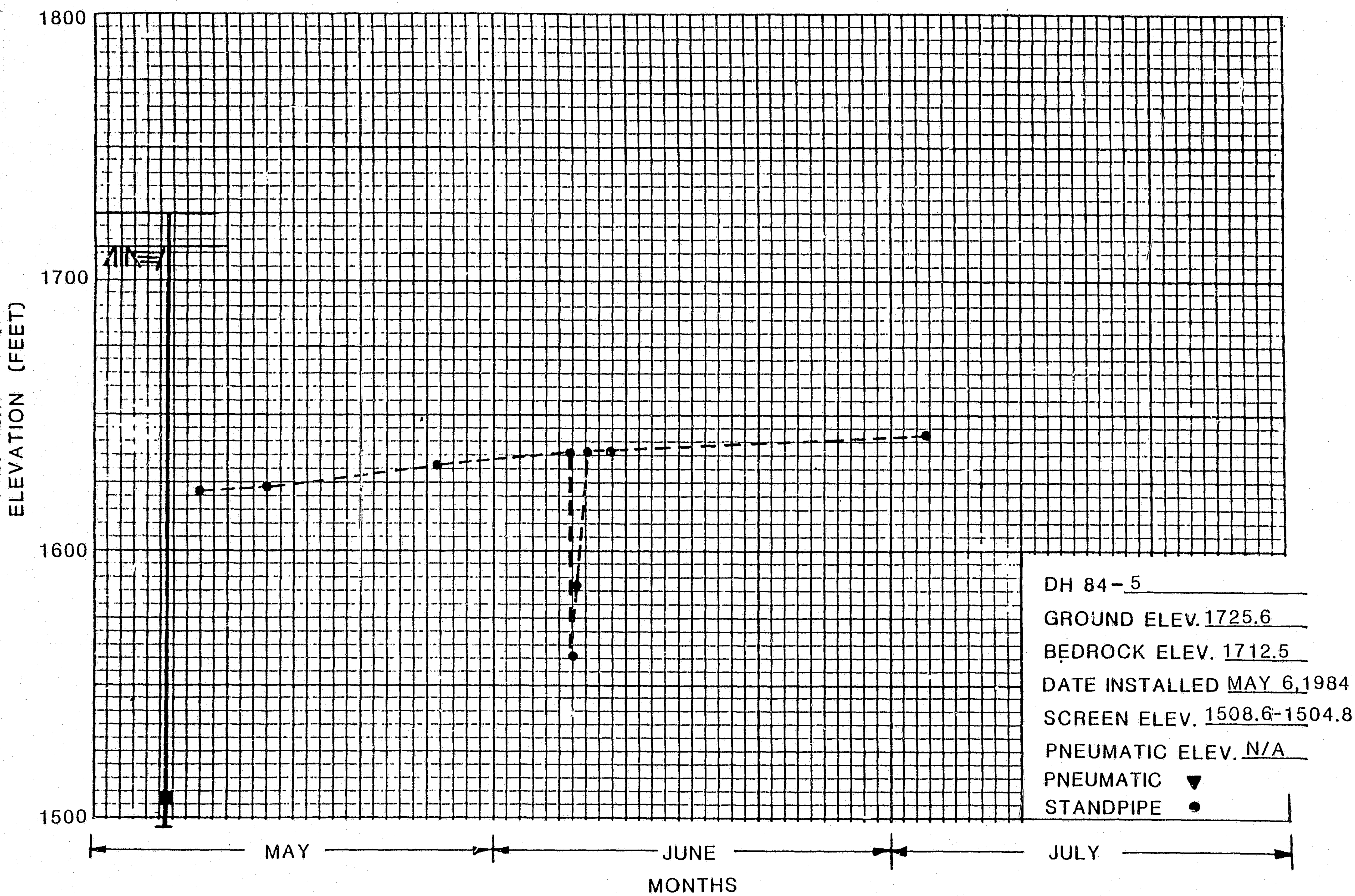
GROUNDWATER MONITORING CURVE



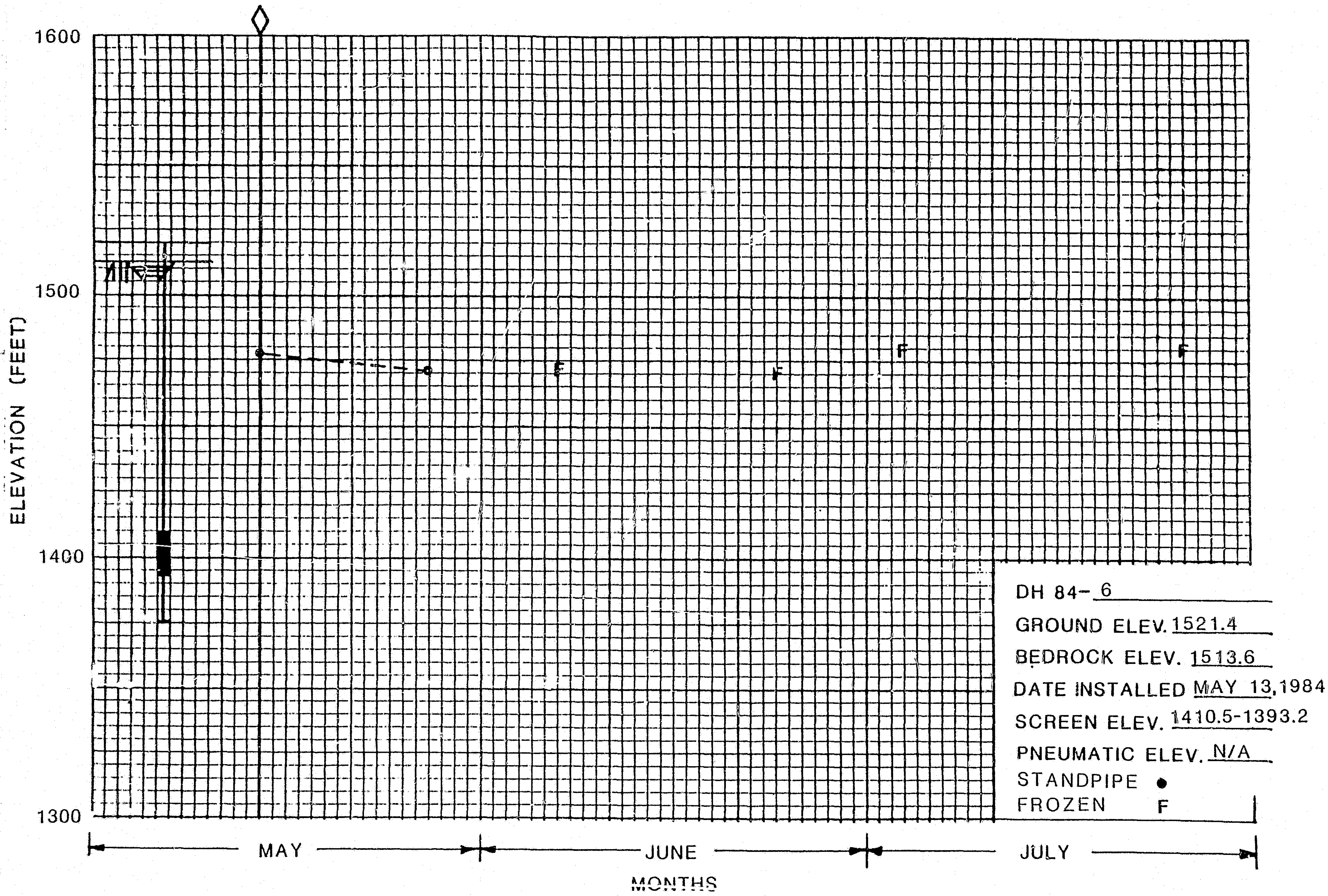
GROUNDWATER MONITORING CURVE



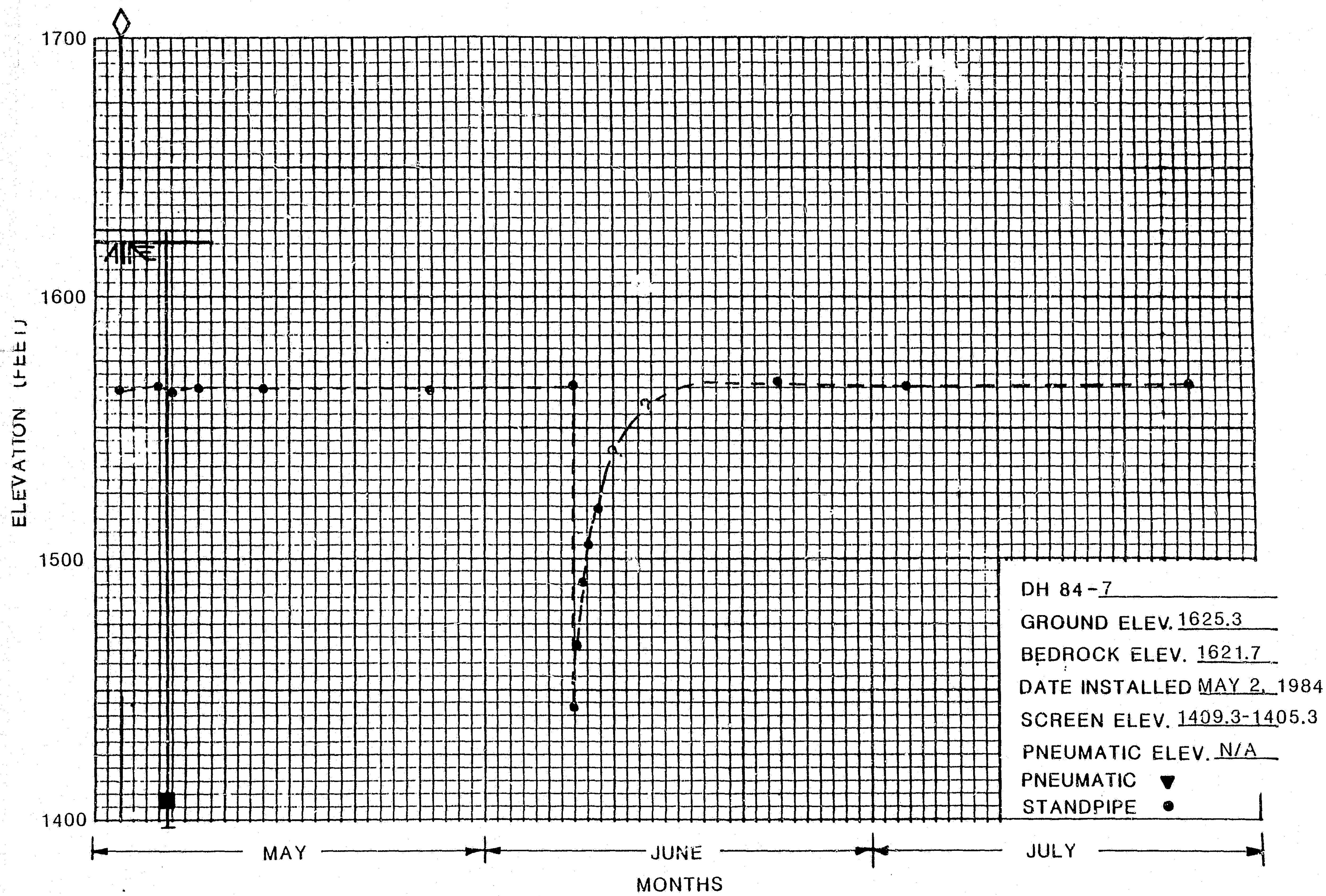
GROUNDWATER MONITORING CURVE



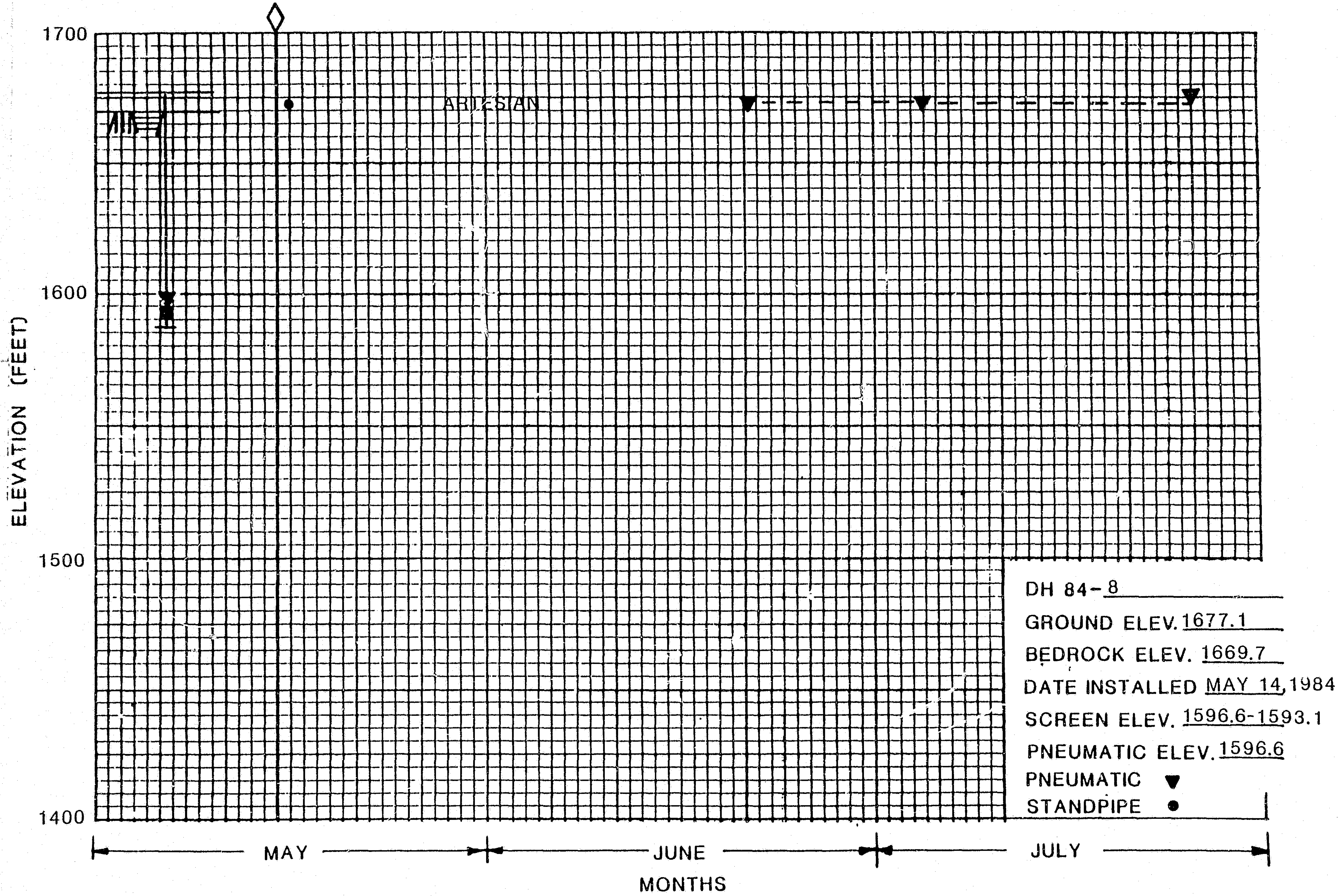
GROUNDWATER MONITORING CURVE



GROUNDWATER MONITORING CURVE

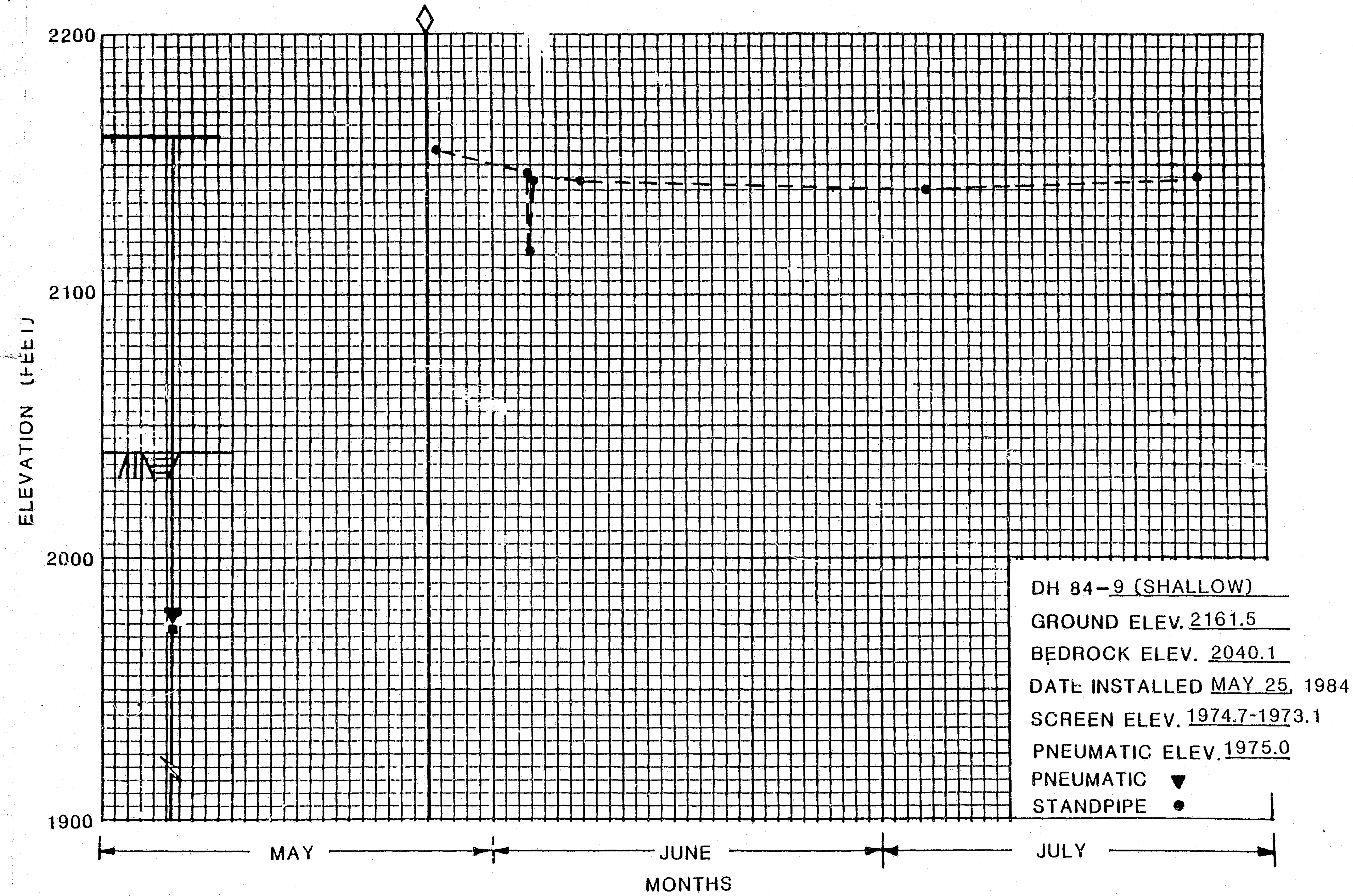


GROUNDWATER MONITORING CURVE



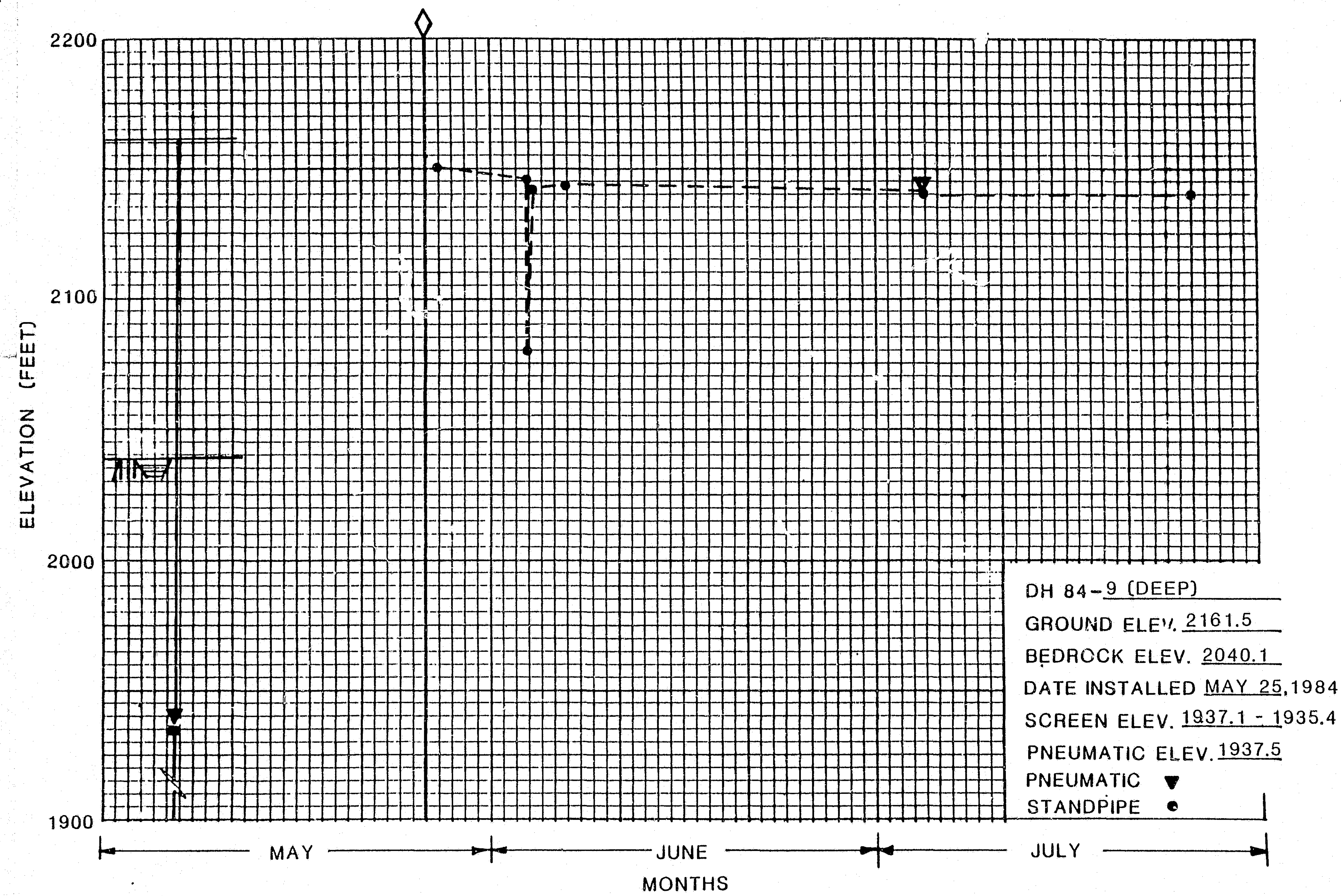
GROUNDWATER MONITORING CURVE

Appendix G



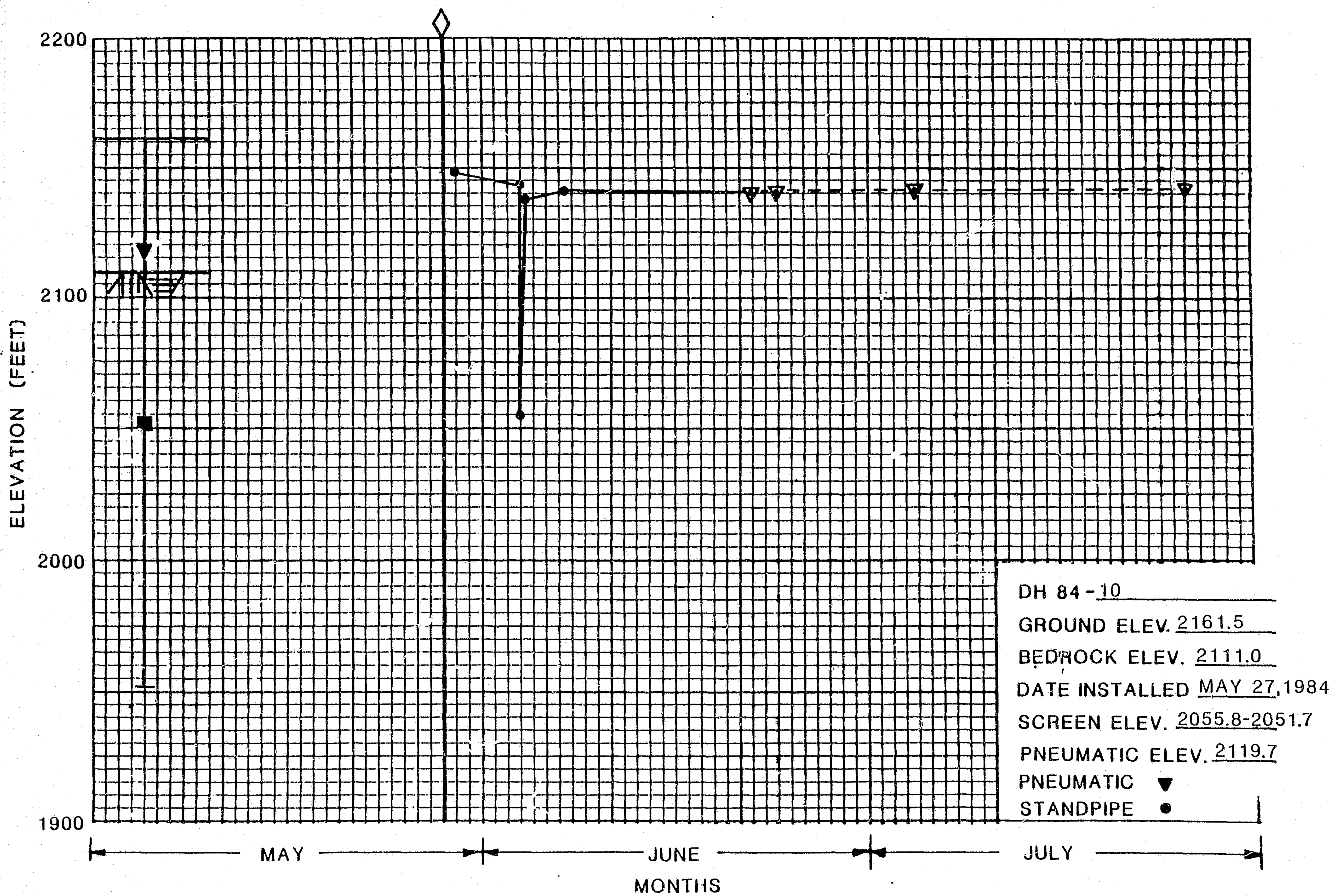
GROUNDWATER MONITORING CURVE

Appendix G

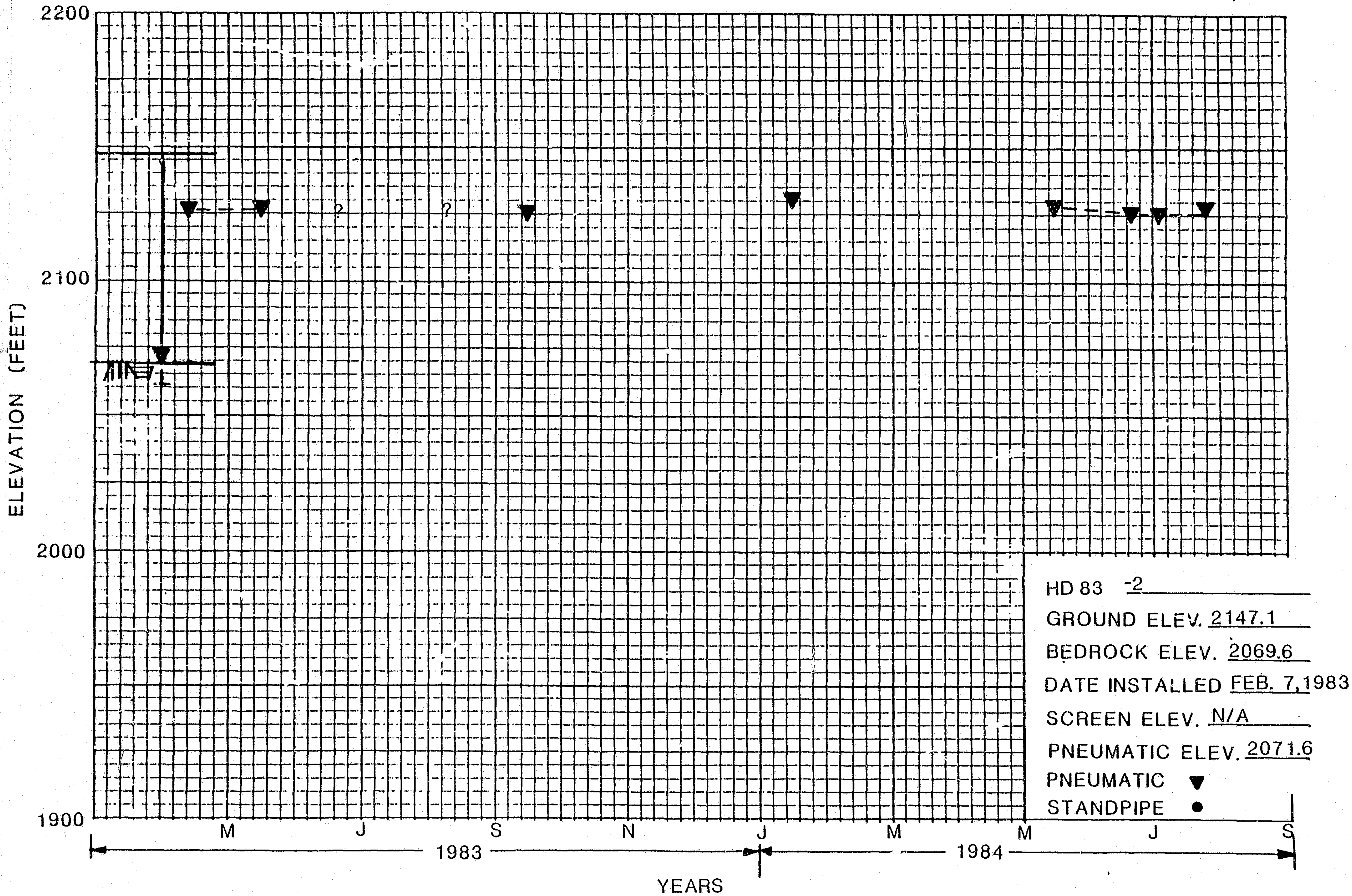


GROUNDWATER MONITORING CURVE

Appendix G



GROUNDWATER MONITORING CURVE



GROUNDWATER MONITORING CURVE

1984 GEOTECHNICAL EXPLORATION PROGRAM

WATANA DAMSITE

APPENDIX G - POINT LOAD TEST DATA

APPENDIX G

Point Load Test Results

Notes

1. All samples were tested according to the diametral pointload test method, where $L \geq 1.4D$.

2. Where healed fractures were visible in the sample, the load was applied perpendicular to the plane of weakness. If failure occurred along a healed fracture or other plane of weakness, it was noted on the data sheets.

3. A brief discussion of the results is presented below.

Abbreviations

Lithology:

- D - Diorite
- QD - Quartz Diorite
- AD - Altered Diorite
- A - Andesite Porphyry
- G - Granite

Code:

- 1 - Failure along a healed or tight fracture.
- 2 - Failure by chipping of rock sample
- 3 - Plane of weakness; kaolin, alteration, etc.

Calculations

$I_s = P/D^2$ where I_s = Point load strength
P = Pressure at failure
D = Diameter of sample in inches

The relationship of point load strength to uniaxial compressive strength is

$\sigma_c = KI_s$ where K = Conversion factor, size correlation (Bieniawski, 1974)

$K_{HQ} = 24.9$

$K_{NQ} = 21.8$

A total of 149 point load tests were measured on core samples recovered during the 1984 drilling program. Table G-1 is a summary of the data according to lithology, considering weathering/alteration characteristics; just lithology; and for the total sample population. In addition, under each of these categories, the summary is organized to compare the total population with those samples which had no apparent planes of weakness.

The results of the point load testing of all samples indicate a mean unconfined compressive strength of 15,315 psi with a standard deviation of ± 7,745 psi. Subdividing the results into the two basic lithologies indicates a mean value of 19,617 psi for the andesite porphyry and 14,995 psi for the diorite suite. These values defined in unconfined compressive strength tests performed by Acres American (1982; andesite porphyry = 18,361 psi, diorite = 17,593 psi). The results are in general agreement with previous work, and it is possible that the lower values for the diorite suite is in part due to the number of weathered/altered samples tested.

In classifying the rock material for strength, tests show the intact rock to be of medium to high strength (Bieniawski, 1973).

TABLE G-1 SUMMARY OF POINT LOAD TEST RESULTS

Lithology – Weath/Alteration	All Samples			Samples with No Apparent Planes of Weakness		
	n	Mean	n	n	Mean	n
Andesite Porphyry	6	19,617	3147		N/A	N/A
Diorite						
Fresh	66	14,969	7800	45	19,163	5648
Slight Weath	13	12,013	6610	7	14,324	5548
Quartz Diorite						
Fresh	46	18,022	6303	36	19,942	5370
Slight Weath	9	6,205	7661	5	9,871	8311
Altered Diorite						
Slight Weath	6	13,189	7129		N/A	N/A
Moderate	3	8,718	N/A		N/A	N/A
Lithology						
Andesite Porphyry	6	19,617	3147	6	19,617	3147
Diorite	79	14,863	7799	52	18,512	5872
Quartz Diorite	55	16,087	7870	41	18,714	6679
Altered Diorite	9	11,699	6583	8	11,293	6950
Diorite Suite	143	14,995	7758	101	17,874	6522
Total Samples	149	15,315	7745	107	18,158	6420

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-1

Overburden Thickness 18.5 Ft.

Azimuth 244°

Total Depth 848.5 Ft.

Dip 56°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
35.7 - 36.1	A		2.40	5500	954.9	23,804.7
140.3 - 140.7	A		2.40	4600	798.6	19,909.4
177.6 - 178.0	A	2	2.40	>5000	>868.1	>21,640.6
198.7 - 199.1	A		2.40	4000	694.4	17,312.5
255.0 - 255.4	QD	1	2.40	3100	538.2	13,417.2
458.4 - 458.8	D	1	2.40	0	0	0
426.6 - 427.0	QD	1	2.40	0	0	0
511.0 - 511.4	D		2.40	800	138.9	3,462.5
558.1 - 558.5	D	1	2.40	300	52.1	1,298.4
623.5 - 623.9	D		2.40	2850	425.3	10,603.9
748.7 - 749.1	QD		2.40	4500	781.3	19,476.6
765.5 - 765.9	QD		2.41	1750	301.3	7,511.5

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-2

Azimuth 019°

Dip 60°

Overburden Thickness 14.7 Ft.

Total Depth 765.0 Ft.

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
22.9 - 23.7	D		2.38	5000	890.2	22,192.0
30.1 - 31.0	D		2.39	3200	560.2	13,966.1
46.9 - 47.4	D		2.38	3250	573.8	14,303.8
55.0 - 55.5	AD		2.37	1000	178.0	4,438.4
71.4 - 71.9	AD	1	2.38	2250	397.2	9,902.6
79.0 - 79.6	D		2.38	4500	794.4	19,805.3
87.0 - 87.7	D	1	2.38	1200	211.8	5,281.4
103.9 - 104.4	D		2.39	3100	542.7	13,529.7
118.7 - 119.3	D		2.37	4500	801.2	19,972.8
130.5 - 131.2	D	2	2.40	4750	824.7	20,558.6
142.0 - 142.7	D		2.38	4500	794.4	19,805.3
158.6 - 159.2	D	1	2.39	2750	481.4	12,002.2
166.1 - 166.7	D		2.40	5250	911.5	22,722.7
176.2 - 176.7	D		2.40	4600	798.6	19,909.4
191.0 - 191.5	D		2.39	4800	840.3	20,949.2
203.6 - 204.1	AD		2.39	900	157.6	3,928.0
204.6 - 205.1	A		2.38	3200	564.9	14,083.8
220.4 - 220.9	D	2	2.39	3000	525.2	13,093.3
243.3 - 244.0	D		2.38	3750	662.0	16,504.4
257.0 - 257.7	D	2	2.39	4250	744.0	18,548.8
266.3 - 267.0	D	1	2.39	2750	481.4	12,002.2
282.2 - 282.8	D		2.38	5100	900.4	22,446.0
295.4 - 296.0	D		2.38	5500	971.0	24,206.5
306.7 - 307.2	D	1	2.40	1000	173.6	4,328.1
322.1 - 322.7	D	1	2.38	1250	220.7	5,501.5
341.9 - 342.4	D		2.39	1600	280.1	6,983.1
374.3 - 374.8	D	1	2.40	4250	737.8	18,394.5
434.3 - 434.8	D		2.40	2500	434.0	10,820.3
466.0 - 466.5	D	1	2.39	2650	463.9	11,565.7
479.5 - 480.0	D	1	2.40	1000	173.6	4,328.1
492.6 - 493.0	D		2.40	5500	954.9	23,804.7
517.6 - 518.1	D		2.39	5000	875.3	21,822.1
537.9 - 538.4	D	1	2.39	1500	262.6	6,546.6
540.0 - 540.5	D		2.39	5000	875.3	21,822.1
565.6 - 566.0	D		2.39	6500	1137.9	28,368.7

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-2 | Overburden Thickness 14.7 Ft.

Azimuth 019° | Total Depth 765.0 Ft.

Dip 60°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
581.9 - 582.3	D	1	2.39	0	0	0
609.1 - 609.5	D	1	2.39	1100	192.6	4,800.9
634.5 - 635.0	D	2	2.39	>4750	831.6	20,731.0
652.0 - 652.6	D		2.38	4100	723.8	18,044.8
676.5 - 676.9	D		2.38	1400	247.2	6,161.6
689.5 - 690.0	D		2.39	4700	822.8	20,512.8
705.3 - 705.8	D	1	2.39	1900	332.6	8,292.4
720.8 - 721.4	D		2.38	6250	1103.4	27,507.3
737.4 - 737.8	D		2.38	4750	838.6	20,905.6
761.6 - 762.2	D	1	2.38	500	88.3	2,200.6

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-3

Azimuth 025°

Dip 60°

Overburden Thickness 8.5 Ft.

Total Depth 132.2 Ft.

Depth Interval Feet	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
34.2 - 34.5	QD	2	2.40	4100	711.8	17,745.3
54.7 - 55.1	QD	2	2.38	4180	737.9	18,396.9
61.6 - 61.9	QD		2.39	5500	962.9	24,004.3
75.9 - 76.4	QD		2.40	4250	737.8	18,394.5
91.0 - 91.4	QD		2.40	6400	1111.1	27,700.0
108.5 - 108.9	QD		2.41	5550	955.6	23,822.2
117.5 - 117.9	QD		2.39	3250	569.0	14,184.4
129.9 - 130.3	QD	1	2.40	4300	746.5	18,610.9

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-4

Overburden Thickness 116.9 Ft.

Azimuth 050°

Total Depth 378.0 Ft.

Dip 55°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
223.6 - 223.9	QD		2.38	5200	918.0	22,886.1
249.5 - 250.0	QD		2.39	6250	1094.2	27,277.6
281.7 - 282.2	QD		2.40	4300	746.5	18,610.9
315.1 - 315.6	QD		2.40	6000	1041.7	25,968.8
334.0 - 334.5	QD		1.75	850	277.5	6,050.6
365.7 - 366.1	QD		1.75	1950	636.7	13,880.8

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-4A — Overburden Thickness 72.4 Ft.

Azimuth 040° — Total Depth 698.5 Ft.

Dip 55°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
181.4 - 181.9	QD		2.40	0	0	0
198.6 - 199.1	QD		2.40	1100	191.0	4,760.9
216.8 - 217.3	QD	1	2.40	1500	260.4	6,492.2
232.6 - 233.3	AD		2.40	4000	694.4	17,312.5
273.9 - 274.5	QD	1	2.40	2100	364.6	9,089.1
279.5 - 280.3	QD	2	2.40	5200	902.8	22,506.3
343.5 - 343.9	QD	1	2.40	0	0	0
400.0 - 400.5	QD		2.40	3200	555.6	13,850.0
436.8 - 437.3	QD		2.39	1400	245.1	6,110.2
451.6 - 451.9	QD		2.39	5000	875.3	21,822.1
495.1 - 495.6	QD		2.40	7050	1224.0	30,513.3
567.7 - 568.2	QD		2.40	4800	833.3	20,775.0
612.2 - 612.6	QD		2.40	6000	1041.7	25,968.8
655.7 - 656.1	QD	1	2.40	2200	381.9	9,521.9
692.1 - 692.7	QD		2.40	4200	729.2	18,178.1

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-5

Azimuth 010°

Dip 60°

Overburden Thickness 15.1 Ft.

Total Depth 265.0 Ft.

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
40.0 - 40.4	D		2.38	5500	971.0	24,206.4
67.8 - 68.3	D	1	2.39	3200	560.2	13,966.1
89.4 - 89.7	G		2.39	2100	367.6	9,165.3
103.4 - 103.8	QD		2.39	5750	1006.6	25,095.4
119.3 - 119.7	QD		2.39	4200	735.3	18,330.6
130.4 - 130.8	D	3	2.40	0	0	0
150.9 - 151.5	D	2	2.41	>5700	>997.9	>24,877.2
153.0 - 153.5	D		2.38	4100	723.8	18,044.8
178.0 - 178.5	QD		2.39	5100	892.8	22,258.5
202.5 - 202.9	AD		2.38	3050	538.5	13,423.6
220.9 - 221.5	AD		2.40	2050	355.9	8,872.7
257.5 - 258.0	QD	1	2.41	3500	602.6	15,023.0

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-6 — Overburden Thickness 9.0 Ft.

Azimuth 025° — Total Depth 167.8 Ft.

Dip 60°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
59.5 - 60.2	D		2.37	5500	979.2	24,411.2
67.6 - 68.2	D	1	2.37	3300	587.5	14,646.7
69.6 - 70.2	D		2.38	3800	670.9	16,724.5
76.9 - 77.5	D		2.40	2700	468.8	11,685.9
85.5 - 86.0	D	2	2.39	5950	1041.6	25,968.3
96.0 - 96.7	D		2.38	5900	1041.6	25,966.9
97.4 - 98.0	D	1	2.38	3100	547.3	13,643.6
106.0 - 106.6	D	1	2.37	4500	801.2	19,972.8
111.3 - 111.9	D		2.37	2200	391.7	9,764.5
117.9 - 118.4	D	1	2.40	1500	260.4	6,492.2
127.9 - 128.7	D		2.38	3100	547.3	13,643.6
134.8 - 135.4	D	1	2.39	0	0	0
135.4 - 136.0	D		2.39	5300	927.9	23,131.4
137.2 - 137.8	D	1	2.37	2500	445.1	11,096.0
149.6 - 150.0	D	2	2.39	4200	735.3	18,330.6
151.6 - 152.2	D	2	2.39	2750	481.4	12,002.2
164.2 - 164.8	D		2.38	2700	476.7	11,883.2
165.3 - 165.9	D	1	2.38	3700	653.2	16,284.3

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-7 — Overburden Thickness 4.2 Ft.

Azimuth 025° — Total Depth 263.5 Ft.

Dip 60°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
28.7 - 29.1	QD		2.41	5400	929.7	23,178.3
42.2 - 42.5	QD		2.40	3550	616.3	15,364.8
56.3 - 56.8	QD	1	2.40	3550	616.3	15,364.8
78.5 - 79.0	QD		2.41	5600	964.2	24,036.8
85.9 - 86.3	QD		2.40	4850	842.0	20,991.4
97.6 - 98.0	QD		2.40	3300	572.9	14,282.8
117.3 - 117.7	QD		2.40	3500	607.6	15,148.4
136.4 - 136.8	QD		2.40	4800	833.3	20,775.0
141.3 - 141.7	QD		2.40	>5800	>1006.9	>25,103.1
166.8 - 167.4	QD	3	2.40	0	0	0
193.1 - 193.5	QD	1	2.39	850	148.8	3,709.8
216.1 - 216.5	QD		2.41	4800	826.4	20,603.0
225.7 - 226.1	QD		2.41	4050	697.3	17,383.7
249.0 - 249.4	QD	1	2.40	2000	347.2	8,656.3
252.6 - 253.0	QD	1	2.40	1700	295.1	7,357.8
263.0 - 263.5	QD	2	2.40	3500	607.6	15,148.4

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-8 — Overburden Thickness 8.5 Ft.

Azimuth 012° — Total Depth 100.0 Ft.

Dip 60°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
40.6 - 41.0	D	1	2.38	3200	564.9	14,083.8
50.0 - 50.5	AD		2.38	2000	353.1	8,802.3
65.3 - 66.0	AD		2.39	6100	1067.9	26,623.0
76.0 - 76.8	D		2.38	3750	662.0	16,504.4
84.0 - 84.5	AD	2	2.37	2700	480.7	11,983.7
95.1 - 95.6	D		2.40	4400	763.9	19,043.8
99.0 - 99.5	D		2.38	3950	697.3	17,384.6

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-9 | Overburden Thickness 148.2 Ft.

Azimuth 225° | Total Depth 497.5 Ft.

Dip 55°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
236.8 - 237.2	D	1	2.39	1100	192.6	4,800.9
291.6 - 292.1	D	1	2.39	0	0	0
355.8 - 356.4	D		2.39	5100	892.8	22,258.5
386.6 - 387.1	D		2.40	6700	1163.2	28,998.4
415.8 - 416.2	QD		2.42	5850	998.9	24,902.8
492.2 - 492.7	D		2.39	5250	919.1	22,913.2

SUMMARY OF POINT LOAD TEST RESULTS

Borehole Number DH84-10 — Overburden Thickness 61.6 Ft.

Azimuth 230° — Total Depth 254.0 Ft.

Dip 55°

Depth Interval (Feet)	Lithology	Code	Diameter (Inches)	Pressure (Pounds)	I_s (PSI)	σ_c (PSI)
160.1 - 160.5	D		2.40	5000	868.1	21,640.6
191.4 - 191.8	QD	1	2.39	2350	411.4	10,256.4
219.1 - 219.5	QD		2.40	3300	572.9	14,282.8
237.0 - 237.4	A		2.39	4800	840.3	20,949.2