Subsurface Conditions
Data Report
Borrow Areas 1, 3, and 4
Sea-Tac Airport Third Runway

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Prepared for
HNTB and the Port of Seattle

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SUBSURFACE CONDITIONS DATA REPORT
BORROW AREAS 1, 3, AND 4
SEA-TAC AIRPORT THIRD RUNWAY

INTRODUCTION

This data report presents technical documentation of subsurface conditions, laboratory testing, and relevant geotechnical and hydrogeologic field testing of three Third Runway Borrow Areas. Borrow Areas 1, 3, and 4 have been identified as potential sources of construction materials available for the construction of the Third Runway Embankment Project. These borrow areas are located south of the Sea-Tac International Airport, in the cities of Des Moines and SeaTac, Washington (refer to Figure 1, Vicinity Map).

Figure 1 shows specific areas within the airport vicinity where we have performed geotechnical and hydrogeologic explorations for this study. These areas are characterized in greater detail in the site and exploration plans labeled Figures 2 and 3. Cross sections showing inferred geologic conditions are provided on Figures 4 and 5. Groundwater elevations and a groundwater elevations contour map for the Regional Shallow Aquifer are shown on Figures 6 and 7 for Borrow Area 1 and Borrow Area 3, respectively. A groundwater contour map and cross section for the Perched Water-Bearing Zone in Borrow Areas 3 and 4 are shown on Figures 8 and 9.

We have organized this report into several sections. The main text starts with a discussion of site surficial geology and is followed by a discussion of the hydrogeologic conditions obtained from explorations conducted to date. Appendices A through C follow the main text and present results of our subsurface explorations, laboratory data, and hydrogeologic data, respectively, for Borrow Areas 1, 3, and 4.

PURPOSE AND SCOPE

This report provides information on subsurface soil and groundwater conditions in Borrow Areas 1, 3, and 4. The purpose of this data report is to present soil, geotechnical and hydrogeological information to support planning, permitting, and engineering design of the construction material borrow sites for the Third Runway Embankment. The scope of Hart Crowser's work included completion of exploratory soil borings, laboratory tests on representative soil samples, monitoring groundwater elevations, and completion of groundwater slug tests in selected wells.

GENERALIZED GEOLOGIC DESCRIPTION AND SUBSURFACE SOIL CONDITIONS

This section provides a description of the geologic and subsurface soil conditions within the areas shown on Figures 2 and 3 based on our recent explorations at the site and explorations by others. Previous studies of the local geologic and hydrologic conditions at Borrow Areas 1, 3, and 4 have been accomplished by AGI Technologies (AGI, 1995 and 1996).

Generalized Geologic Conditions

The site is located on the Des Moines Drift Plain in the Puget Sound Lowland. Glacial soils have been deposited and extensively reworked by glacial episodes, the most recent being the Vashon glaciation.

In summary, the following geologic units have been identified at Borrow Areas 1, 3, and 4:

- Fill (variably graded, silt, sand, and gravel);
- Alluvium (peats and silts; and medium dense, fine to medium sand);
- Recessional Outwash (primarily silty, sand and gravel, and/or sandy silt or sandy clay);
- Glacial Till (silty sands and gravels);
- Advance Outwash (non-silty to silty sand and gravel);
- Lawton Clay (very stiff to hard silt and clay); and
- Puyallup Formation (fine sand and silty sand)

The surficial geology in Borrow Area 1 has been identified as consisting of glacial till and recessional outwash materials. The glacial till occupies the southern and central portions of the site, while recessional outwash covers the lower elevations to the north. Surficial soils in Borrow Areas 3 and 4 have been mapped as glacial till with localized surficial deposits of recessional outwash. Our explorations within Borrow Areas 3 and 4 suggest that these areas are part of a north-south trending ridge known as a drumlin.

Subsurface Conditions

Subsurface soil and hydrogeologic conditions interpreted from data and observations collected during explorations at the site, and previously mentioned AGI studies, formed the basis for the information contained within this report. Variations between explorations may occur as irregularities in gradation, moisture content, and density/consistency of soils at the site. The nature and extent of these variations may not become evident until construction. Exploration boring logs for the three borrow areas are presented in Appendix A.

Subsurface conditions in the southern and central portions of Borrow Area 1 (shown on Figures 2 and 4), generally consist of a glacial sequence (glacial till over silty advance outwash). This glacial sequence is modified in lower elevations in the northern portion of the site where recessional outwash appears to overlay glacial till deposited on top of advance outwash. Subsurface conditions encountered in Borrow Areas 3 and 4 (shown on Figures 3 and 5) consist of a thin mantle of recessional outwash over glacial till, which in turn overlies advance outwash materials. These glacial sequences overlie earlier deposits of Vashon glacial till which has been shown to overlay the Puyallup Formation. Figure 4 is a generalized geologic cross section oriented southeast-northwest through Borrow Area 1. Figure 5 is a generalized north-south cross section through Borrow Areas 3 and 4. Detailed descriptions of the materials we encountered are provided below.

Topsoil. This soil was not consistently encountered in our explorations. Typically, this soil consists of a loose mixture of silt and sand with roots and other organic material. Topsoil is generally 1/2 to 1 foot thick where encountered. Many of the surficial soils at the site appear to be glacial soils at different stages of weathering. This is further discussed in the **Recessional Outwash** and **Glacial Till** sections below.

Fill Soils. Fill soils were encountered in all three proposed borrow areas, typically associated with paved streets, or general grading associated with past use of the sites. Fill soils are generally loose to medium dense, variable mixtures of silt, sand, and gravel. The density and granular nature of the fill materials resembles the recessional outwash deposits and the fill is sometimes difficult to distinguish from the outwash.

Alluvial Deposits. These soils occur in the low-lying areas and generally consist of soft/loose, moist to wet, interlayered silt, sand, and peat. While these soils have been observed in the field, none were noted in the exploration borings.

Recessional Outwash. This material is generally slightly silty to silty, slightly gravelly to gravelly sand. Recessional outwash overlies the glacial till, or advance outwash where the glacial till has been eroded. Thickness of the recessional deposits varies over the site, but is generally less than 20 feet. Localized areas have thicker deposits of recessional outwash, such as in the northern portions of Borrow Area 1. Thicker deposits also occur in southern portions of Borrow Area 3 which show historical signs of borrow development activities possibly related to previous airport construction. Recessional outwash forms a thin veneer over much of Borrow Areas 3 and 4, generally measuring less than 5 feet thick.

Where recessional soils are located at the ground surface, the soil is in a weathered condition. This layer may become colluvium where deposits are on sufficiently sloping ground.

Glacial Till. The till soils comprise the predominant glacially overridden soil unit underlying the surficial materials discussed above. This material is generally comprised of a dense, slightly gravelly to gravelly, silty to very silty sand. The gradation of the till soils varies both vertically and laterally.

In general, glacial till differs from the overlying recessional soils by having a higher silt content and much higher density. The top of the glacial till soils is generally within 5 feet of the ground surface at each of the borrow areas, except in the northern portions of Borrow Area 1 and southern portions of Borrow Area 3. The drumlin feature noted in Borrow Areas 3 and 4 is dominated by glacial till within the central and northern portions of Borrow Area 3. Glacial till is present throughout most of Borrow Area 4. Some weathering has been noted near the surface of the glacial till soils in explorations for each borrow area.

Advance Outwash Sand. This material is generally dense to very dense, slightly silty, slightly gravelly to gravelly sand. In general, the advance outwash can be distinguished from the glacial till by lower silt content. However, observations at the borrow areas where this material was encountered suggest that some areas of advance outwash may be silty. It occurs beneath the glacial till noted in each borrow area.

Lawton Silt/Pre-Vashon Deposits. The hard silt soils interpreted to be part of these geologic units in previous studies were not encountered in our explorations, but would likely be encountered at greater depths. These hard silt soils may be laminated or contain planes of separation (partings). Furthermore, these silt deposits are typically reported to be relatively plastic and are often slickensided (i.e., showing evidence of previous deformation).

Borrow Area Generalized Hydrogeologic Regime

On a regional scale, the glacial deposits beneath Borrow Areas 1, 3, and 4 consist of "relatively permeable" slightly silty to silty sands and gravels, with intervening layers of low-permeability glacial till and predominantly fine-grained sediments (e.g., silt and gravelly, sandy silt). Regional aquifers (indicated below in **bold** type) occur within the glacially derived soils, below the proposed borrow areas (AGI, 1996):

- Fill, Alluvium, Vashon Recessional Outwash - Perched Water-Bearing Zones
- Vashon Till - Aquitard
- Vashon Advance Outwash - **Shallow Regional Aquifer**
- Lawton Clay - Aquitard
- "Third" Coarse-Grained Deposit - **Intermediate Regional Aquifer**
- Puyallup Formation - Aquitard
- "Fourth" Coarse-Grained Deposit - **Deep Regional Aquifer**

Hydrogeologic Conditions

Borrow Areas 1, 3, and 4 are located within the Des Moines Creek drainage. The glacial till appears to thicken as one moves away from the banks of the creek basin. This appears to be less evident in Borrow Area 1 than in Borrow Areas 3 and 4 as seen on Figures 4 and 5. The glacial till as a semi-perching layer, allowing some portion of local precipitation to infiltrate down to the underlying Advance Outwash, which is typically more permeable. The Advance Outwash, also known as the Shallow Regional Aquifer, discharges to Des Moines Creek, and via underflow, into Puget Sound and the Green River valley (AGI, 1996).

Groundwater elevation data were collected from explorations in Borrow Areas 1, 3, and 4. Slug testing was performed in Borrow Area 3 to obtain data for estimating hydraulic conductivity values to evaluate the perched water-bearing zone characteristics as they relate to the wetlands and borrow material development. These data and analyses are discussed below. Water levels in these borrow areas vary over time, as indicated in Tables 1, 2, and 3.

The borrow areas are generally situated within the upper sequence of recessional outwash and glacial till deposits, and extend into the upper part of the advance outwash deposits, above the water table referred to as the Shallow Regional Aquifer. Figures 4 and 5 are conceptual cross sections through Borrow Areas 1, 3, and 4. Figure 4 shows water levels within Borrow Area 1. Figure 5

reveals the local perched water-bearing zone and the underlying Shallow Regional Aquifer in Borrow Areas 3 and 4.

Borrow Area 1. Observed water levels from the Hart Crowser borings and two AGI borings were utilized in evaluating groundwater elevations, see Figure 6. The groundwater elevation data are summarized in Table 1. Borrow Area 1 apparently overlies the Shallow Regional Aquifer, and appears to contain perched zone(s) which may be discontinuous in this area.

Wet soils were occasionally encountered within a few feet of the ground surface. These are likely to be isolated perched or interflow zones of limited lateral extent that exist above the glacial till layer. Additional indications of groundwater occurrence were observed during drilling and are noted on the boring logs in Appendix A.

Groundwater elevations on Figure 6 indicate flow is generally toward the northwest, consistent with recharge entering from higher ground southeast of Borrow Area 1. Locally a relatively steep hydraulic gradient mimicking surface contours is indicated by some of the water levels. The water table generally appears to contribute to Des Moines Creek baseflow.

Borrow Areas 3 and 4. Borrow Areas 3 and 4 are located above the Shallow Regional Aquifer. Soil borrow excavations are anticipated to encounter local perched water-bearing zones in Borrow Area 3. Groundwater observations and monitoring well elevation data are summarized in Tables 2 and 3.

Our interpretation of groundwater conditions is based on current observations as well as information previously reported (AGI, 1995). The reported information included water level observations in two wells previously drilled by AGI which could not be located in the field at the time of our work, as well as notations of wet soils (indicating perched water-bearing zones) in the AGI boring logs.

Hart Crowser installed thirteen monitoring wells in Borrow Areas 3 and 4, which were used along with observations in four existing wells to improve definition of groundwater conditions. Limited information previously available suggested the borrow areas might be underlain by a groundwater with a relatively steep sloping gradient to south (AGI, 1995). Current observations based on the available wells indicate a somewhat different picture: a relatively flat perched water-bearing zone in the north part of Borrow Area 3 and in Area 4 overlies the relatively flat Shallow Regional Aquifer (see Figure 5).

Groundwater Flow Mapping

Groundwater levels for Area 1 were measured in eight wells. Groundwater elevations are shown on Figure 6 for the Shallow Regional Aquifer, and possible discontinuous perched zone(s). Groundwater flow appears to be generally toward Des Moines Creek from the higher ground to the east. It appears that recharge occurs on the higher ground to the east of Borrow Area 1, and that water moves down into the Shallow Regional Aquifer, and discharges to the creek drainage.

Groundwater levels for Areas 3 and 4 were measured in seventeen monitoring wells. Groundwater elevations are contoured on Figure 7 for the Shallow Regional Aquifer, illustrating groundwater flow directions. Groundwater elevations for the perched water-bearing zone are contoured on Figure 8.

Continuous groundwater flow through Borrow Areas 3 and 4 occurs in the Shallow Regional Aquifer, which underlies both areas and is fed by infiltration from the surface and discontinuous overlying perched water-bearing zones. Groundwater from this aquifer can be seen on Figure 7 to flow toward Des Moines Creek.

Perched Water-Bearing Zone - Borrow Area 3

Of the thirteen wells Hart Crowser installed in Borrow Areas 3 and 4, five are newer explorations (A3-B13-99 through A3-B17-99) as seen on Figure 2, along with previous borings and monitoring wells installed by Hart Crowser in 1998 and AGI (1995). The newer wells in Area 3 were drilled to penetrate the perching horizon, which consists of a sub-horizontal layer of till-like material approximately 5 to 10 feet thick. Slug tests were performed in the new wells to estimate the hydraulic conductivity of the perched groundwater zone; the test plot-graphs can be found in Appendix C in Figures C-1 through C-4.

The perched water-bearing zone apparently extends west of Borrow Areas 3 and 4, based on local surface topography and is recharged by infiltration of rainfall on the higher ground to the west. The resulting perched groundwater flow direction is generally from the west, toward the southeast into Area 3. The overall flow pattern is also affected locally by outward radial flow from the high ground in Area 4. Approximate groundwater elevation contours and general flow direction for the perched water-bearing zone are illustrated on Figure 8. A conceptual cross section illustrating the perched water-bearing zone and the Shallow Regional Aquifer beneath it is presented on Figure 9.

USE OF THIS REPORT

Hart Crowser completed this work in general accordance with our proposal dated January 28, 1999 and our contract dated May 1, 1998. This report is for the exclusive use of HNTB, the Port of Seattle, and their design consultants for specific application to the Third Runway project and site. We completed this study in accordance with generally accepted geotechnical/hydrogeologic practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. We make no other warranty, express or implied.

Sincerely,

HART CROWSER, INC.

JAMES R. BEAVER, E.I.T.
Senior Staff Geotechnical Engineer

for **REESE P. HASTINGS, J.D.**
Senior Associate, Geologist

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AGI Technologies, 1995. Borrow Source Study, Proposed New Runway, Seattle-Tacoma International Airport, SeaTac, Washington. Draft Report prepared for HNTB, April 3, 1995.

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Bouwer, H. and R.C. Rice, 1976. A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, V.12 No. 3, 423-428, Water Resources Research.

Butler, James J., 1998. The Design, Performance, and Analysis of Slug Tests. CRC Press, Boca Raton, Florida.

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Table 1 - Borrow Area 1 Water Level Data

		A1-B3-94		A1-B9-94	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Top of Monument		*-0.25*	**304.67**	*-0.25*	**279.29**
Measuring Point	(Top of Casing)	0.00	304.42	0.00	279.04
Ground Level	(Stick-Up)	1.90	302.5	1.52	277.5
Top of Screen	(below GS)	43.0	259.52	53.0	224.52
Bottom of Well	(below GS)	53.5	249.02	63.0	214.52
Water Levels	12/28/94	30.5	272.02	49.9	227.62
	1/26/95	29.5	273.02	48.7	228.82
	2/19/99	28.57	275.85	47.34	231.70
	5/5/99	28.94	275.48	46.71	232.33
	6/14/99	29.22	275.20	47.60	231.44
	7/15/99	29.65	274.77	48.24	230.80
Water Column	5/5/99	26.46		17.81	

		A1-B10-99		A1-B11-99		A1-B12-99		A1-B12S-99		A1-B13-99		A1-B14-99	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Ground Level	(Monument)	-0.68	**273.30**	-0.35	**322.41**	-0.25	**324.78**	-0.40	**324.64**	-0.58	**288.57**	-0.45	**283.25**
Measuring Point	(Top of Casing)	0.00	272.90	0.00	322.06	0.00	324.53	0.00	324.24	0.00	287.99	0.00	282.80
Top of Screen	(below GS)	59.0	213.90	55.0	267.06	79.0	245.53	59.0	265.24	58.9	229.09	55.0	227.80
Bottom of Well	(below GS)	69.0	203.90	65.0	257.06	89.0	235.53	64.0	260.24	69.2	218.79	65.0	217.80
Water Levels	(ATD)	52.7	220.20	41.0	281.06	62.0	262.53	61.5	262.74	62.5	225.49	53.0	229.80
	2/16/99	52.8	220.10	41.25	280.81	61.1	263.43			41.9	246.09	52.6	230.20
	2/19/99	53.10	219.80	41.08	280.98	61.55	262.98	61.26	262.98	40.33	247.66	53.41	229.39
	5/5/99	53.87	219.03	40.84	281.22	60.56	263.97	60.53	263.71	39.76	248.23	52.44	230.36
	6/14/99	53.65	219.25	40.84	281.22	59.90	264.63	59.93	264.31	40.33	247.66	53.17	229.63
	7/15/99	54.20	218.70	41.23	280.83	60.04	264.49	59.97	264.27	40.96	247.03	53.16	229.64
Water Column	5/5/99	15.13		24.16		28.44		3.47		29.44		12.56	

Notes:
Italics = Estimated.
Depth* = All depths are below Measuring Point (NOT below the ground surface).
1) AGI Borings have stick-up monuments.
2) Hart Crowser borings are completed with flush monuments.
3) Water levels are measured as depths below the Measuring Point.
4) Measuring Point is top of PVC casing
5) Figures in **Bold** are survey data measurements.

Table 2 - Borrow Area 3 Water Level Data

	A3-B3-94		A3-B7-94		A3-B8-98		A3-B9-98		A3-B10-98		A3-B11-98		A3-B12-98	
	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Top of Monument	-0.90	**248.94**	*NOT SURVEYED*		-0.35	**283.22**	-0.55	**272.83**	-0.30	**321.44**	-0.75	**350.90**	-0.40	**244.32**
Measuring Point	0.00	**248.04**	0.00	317.0	0.00	**282.87**	0.00	**272.28**	0.00	**321.14**	0.00	**350.15**	0.00	**243.92**
Ground Level*	1.84	**246.2**	2.00	*315.0*	2.37	**280.5**	2.28	**270.0**	2.54	**318.6**	1.75	**348.4**	2.82	**241.1**
Top of Screen*	38.84	209.20	94.50	222.5	71.77	211.10	53.78	218.50	87.54	233.60	132.95	217.20	27.62	216.30
Bottom of Well*	50.84	197.20	104.50	212.5	82.27	200.60	64.16	208.12	97.84	223.30	143.25	206.90	37.92	206.00
Water Column	20.82		#N/A		31.10		23.05		9.71		22.86		17.53	
Water Levels														
Date: 12/28/94	35.1	211.1	87.3	227.7										
1/26/95	33.8	212.4	86.6	228.4										
5/15/98	#N/A	#N/A	#N/A	#N/A	51.09	231.78	41.25	231.03	88.16	232.98	120.55	229.60	20.03	223.89
5/22/98	29.94	218.10	#N/A	#N/A	51.16	231.71	41.15	231.13	*88.16*	232.98	120.35	229.80	20.21	223.71
6/2/98	30.02	218.02	#N/A	#N/A	51.17	231.70	41.11	231.17	88.13	233.01	120.39	229.76	20.39	223.53
6/14/99	28.28	219.76	#N/A	#N/A	50.13	232.74	39.69	232.59	87.01	234.13	119.32	230.83	18.71	225.21
7/13/99	29.10	218.94	-	-	49.66	233.21	40.13	232.15	88.79	232.35	120.06	230.09	19.65	224.27

		A3-B13-99		A3-B14-99		A3-B15-99		A3-B16-99		A3-B17-99	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Ground Level	(Monument)	-1.5	**284.85**	-2.5	**290.55**	-3.3	**299.69**	-2.0	**344.02**	-1.8	**302.59**
Measuring Point	(Top of Casing)	0.00	**286.35**	0.00	**293.00**	0.00	**303.02**	0.00	**346.02**	0.00	**304.38**
Top of Screen	(below GS)	53	233.35	35	258.00	19	284.02	53	293.02	16.5	287.88
Bottom of Well	(below GS)	58	228.35	40	253.00	24	279.02	58	288.02	21.5	282.88
Water Levels	(ATD)	54.5	231.85	38.0	255.00	21.5	281.52	51.0	295.02	18.0	286.38
	4/23/99	54.65	231.70	37.75	255.25	21.81	281.21	50.6	295.42	18.25	286.13
	4/27/99	54.69	231.66	37.73	255.27	21.44	281.58	50.65	295.37	18.37	286.01
	5/5/99	54.87	231.48	37.87	255.13	21.66	281.36	50.76	295.26	18.59	285.79
	6/14/99	55.52	230.83	38.60	254.40	22.28	280.74	51.23	294.79	19.37	285.01
	7/13/99	55.94	177.41	39.01	218.99	22.85	261.17	51.82	241.20	19.88	268.00
Water Column	5/5/99	3.13		2.13		2.34		7.24		2.91	

Notes:

Italics = Estimated.

Depth* = All depths are below Measuring Point (NOT below the ground surface).

1) AGI Borings have stick-up monuments.

2) Hart Crowser borings are completed with flush monuments.

3) Water levels are measured as depths below the Measuring Point.

4) Measuring Point is top of PVC casing

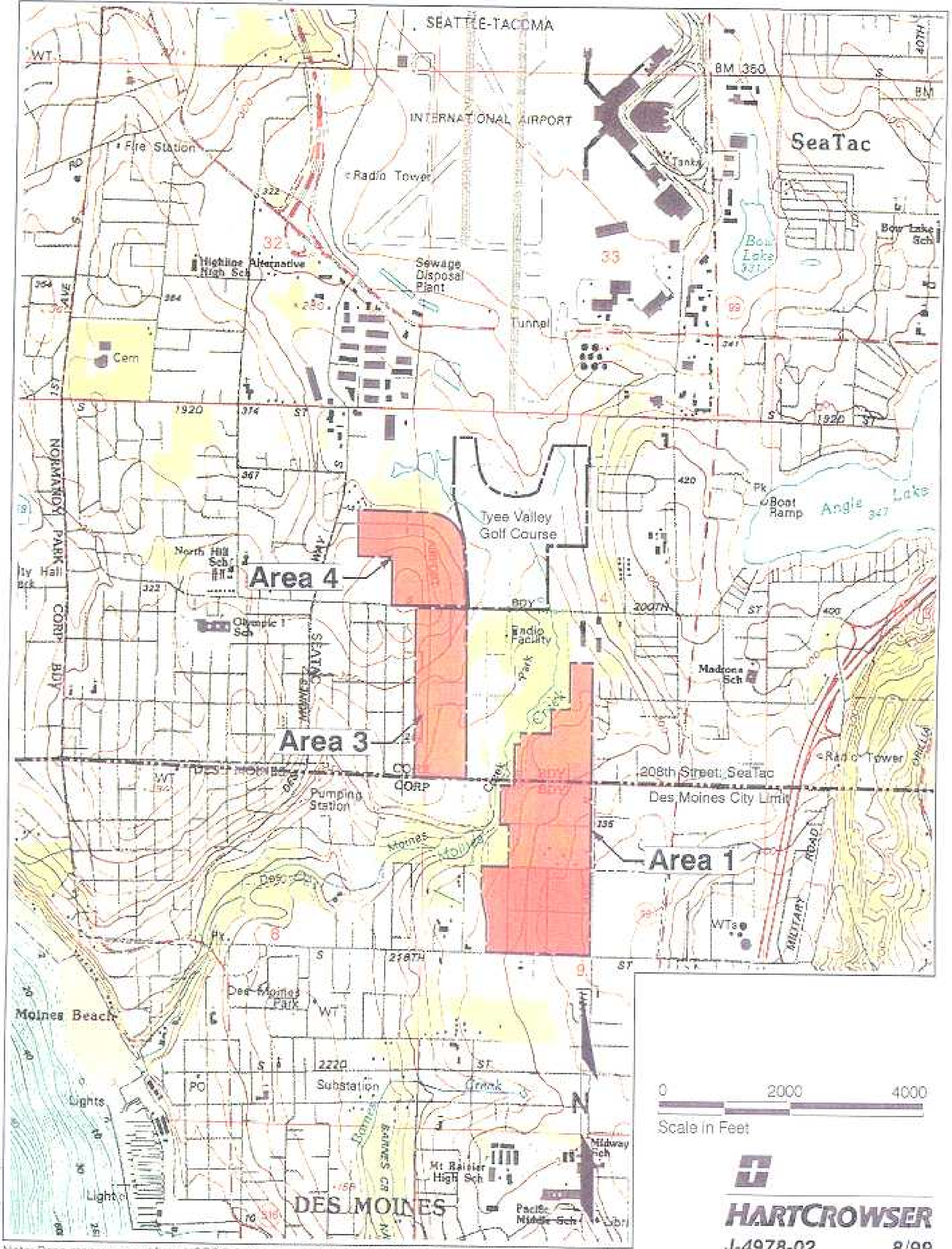
5) Figures in **Bold** are survey data measurements.

Table 3 - Borrow Area 4 Water Level Data

		A4-B1-94		A4-B2-94		A4-B4-98		A4-B5-98		A4-B6-98	
		Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Top of Monument		-0.50	**392.84**	*NOT SURVEYED*		-0.35	**385.71**	-0.30	**371.26**	-0.26	**401.48**
Measuring Point		0.00	**392.34**	0.00	345	0.00	**385.36**	0.00	**370.96**	0.00	**401.22**
Ground Level*		1.94	**390.4**	2.00	*343*	2.36	**383.0**	2.66	**368.3**	2.72	**398.5**
Top of Screen*		109.44	282.90	12.00	333	97.86	287.50	72.86	298.10	118.52	282.70
Bottom of Well*		119.44	272.90	22.00	323	108.06	277.30	83.11	287.85	128.72	272.50
Water Levels											
Date:	12/28/94	100.2	290.2	9.9	333.1						
	1/26/95	102.3	288.1	10.9	332.1						
	5/15/98	#N/A	#N/A	#N/A	#N/A						
	5/22/98	100.98	291.36	#N/A	#N/A	93.29	292.07	80.67	290.29	107.37	293.85
	6/2/98	100.70	291.64	#N/A	#N/A	92.98	292.38	80.43	290.53	106.92	294.30
	6/15/99	#N/A	#N/A	#N/A	#N/A	90.71	294.65	78.65	292.31	104.97	296.25
	7/13/99	-	-	-	-	91.09	294.27	78.80	292.16	105.23	295.99
Water Column	5/22/98	18.74		#N/A		15.08		2.68		21.80	

Notes:
Italics = Estimated.
Depth* = All depths are below Measuring Point (NOT below the ground surface).
1) AGI Borings have stick-up monuments.
2) Hart Crowser borings are completed with flush monuments.
3) Water levels are measured as depths below the Measuring Point.
4) Measuring Point is top of PVC casing
5) Figures in **Bold** are survey data measurements.

Site Location Map



Note: Base map prepared from USGS 7.5 minute quadrangle maps of Seattle South, Washington, revised 1995.

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Figure 1

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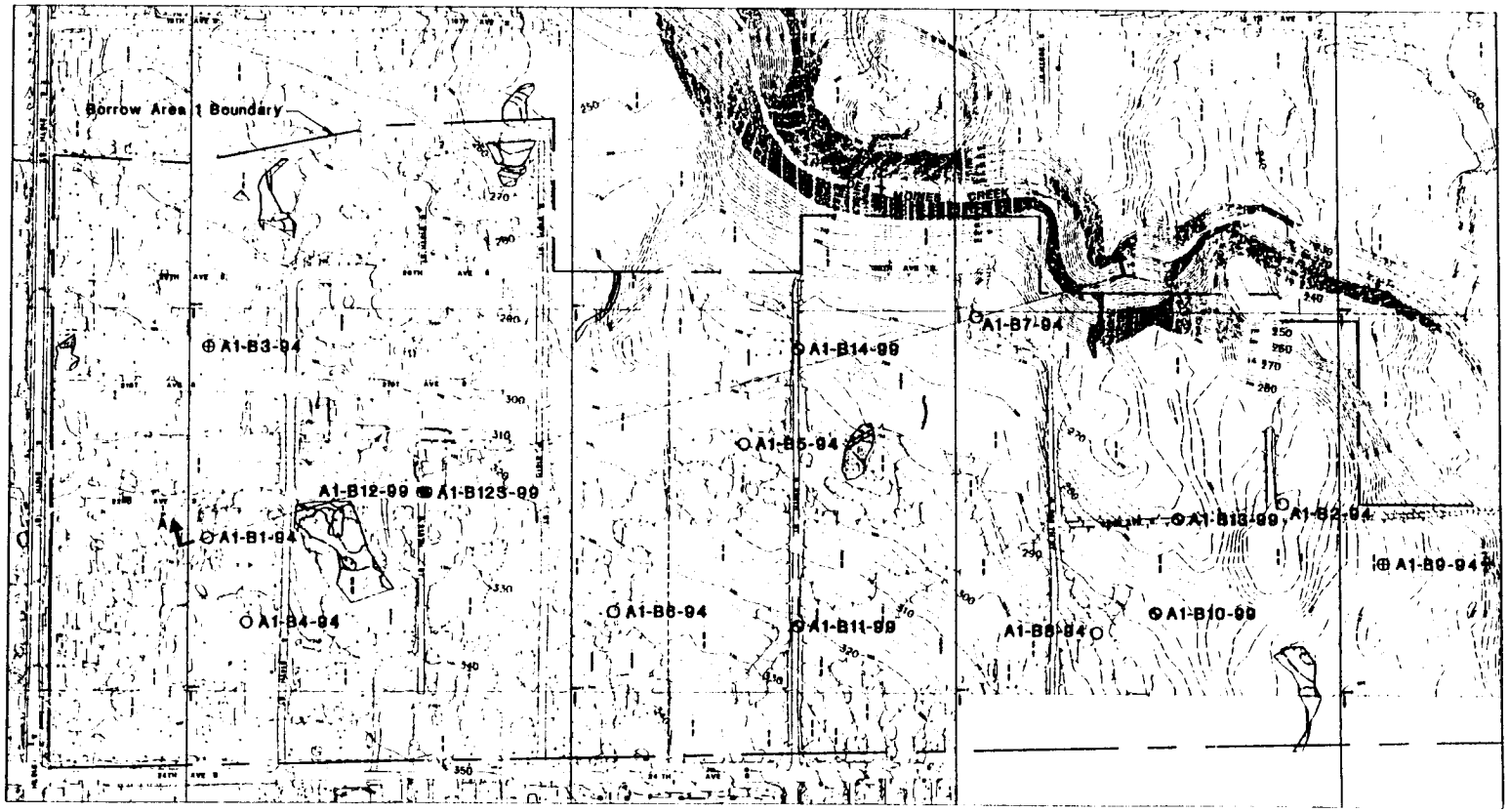
Site and Exploration Plan

Borrow Area 1



Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan", dated April 13, 1998

Exploration Location and Number

- ⊕A1-B13-99 Boring with Observation Well (by Hart Crowser)
- ⊕A1-B9-94 Boring with Observation Well (by AGI)
- ○A1-B5-94 Boring (by AGI)
- Wetlands
- CC' Cross Section Location and Designation (See Figure 4)

N

0 300 600

Scale in Feet

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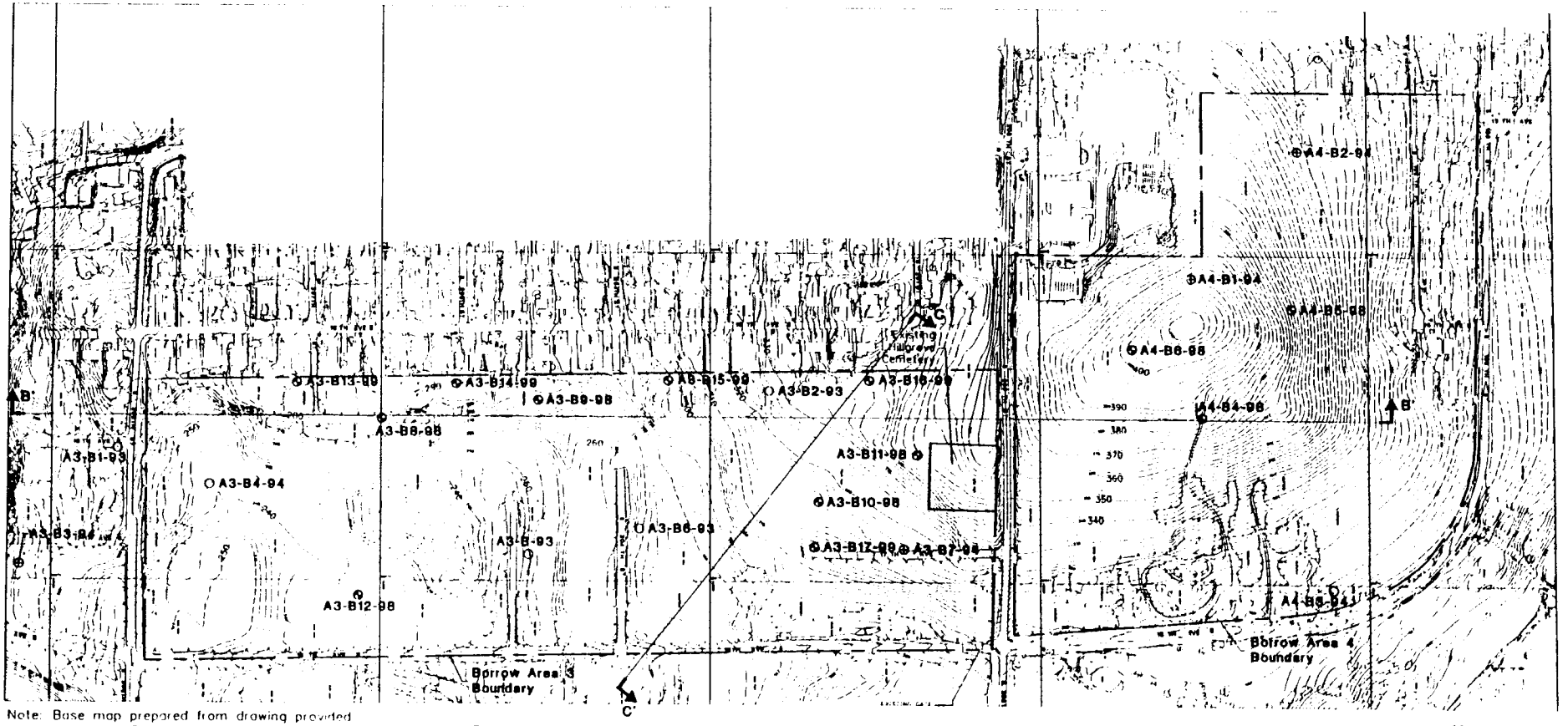
Figure 2

AR 043004

Site and Exploration Plan

Borrow Areas 3 and 4



Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan", dated April 13, 1998

Exploration Location and Number

⊕ **A3-B10-98** Boring with Observation Well (by Hart Crowser)

○ **A3-B1-93** Boring (by AGI)

⊕ **A3-B3-94** Boring with Observation Well (by AGI)

BB' Cross Section Location and Designation (See Figures 5 and 9)

N

0 300 600

Scale in Feet

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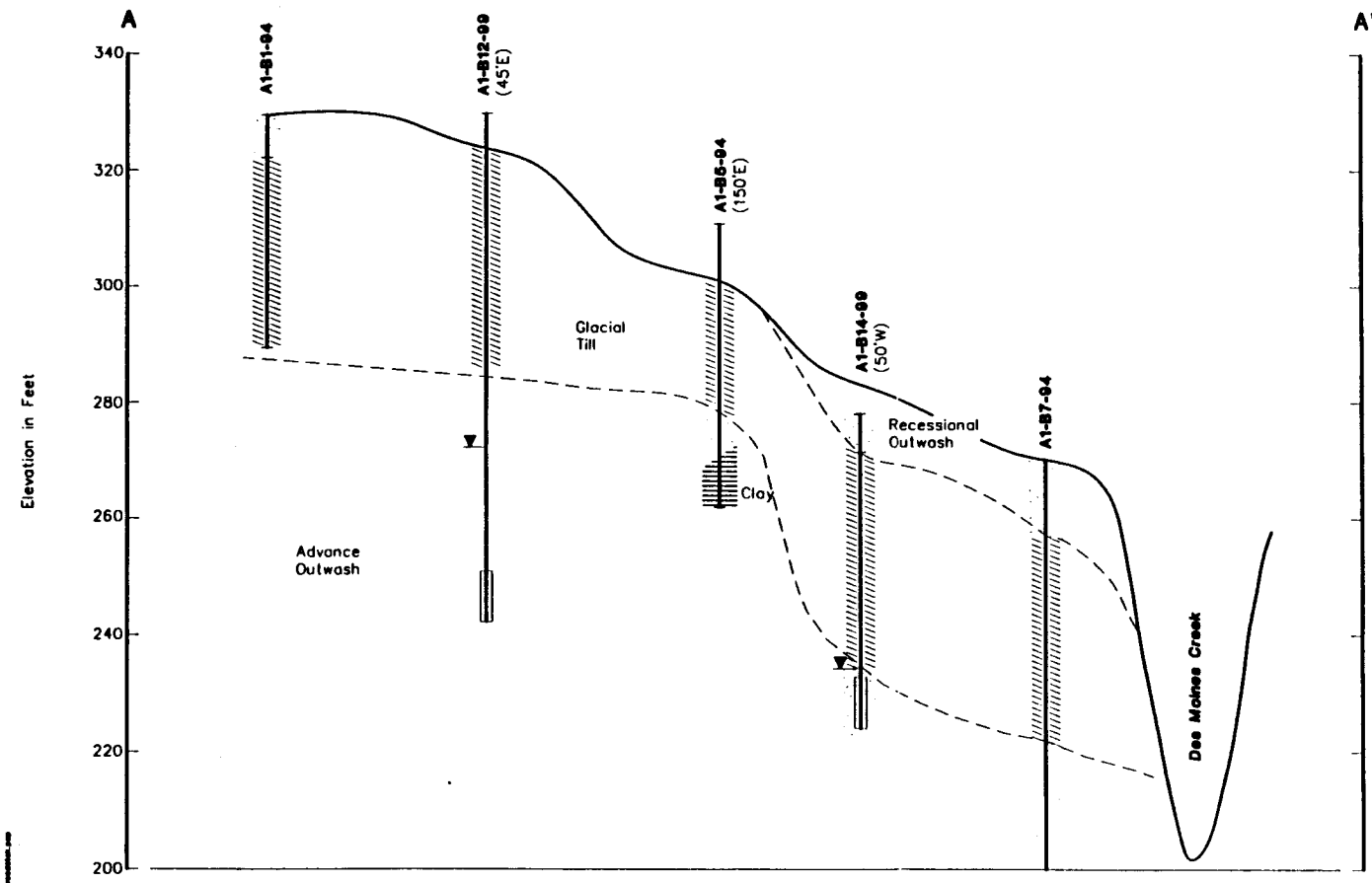
Figure 3

AR 043005

Geologic Cross Section A-A'
Borrow Area 1



Boring Number
Offset Distance and
Direction from Section Line

Boring Location

Water Level

Outwash
(Recessional/Advanced)

Glacial Till

Clay

Screen Section

Notes: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Horizontal Scale in Feet
0 300 600

0 20 40
Vertical Scale in Feet
Vertical Exaggeration x 15

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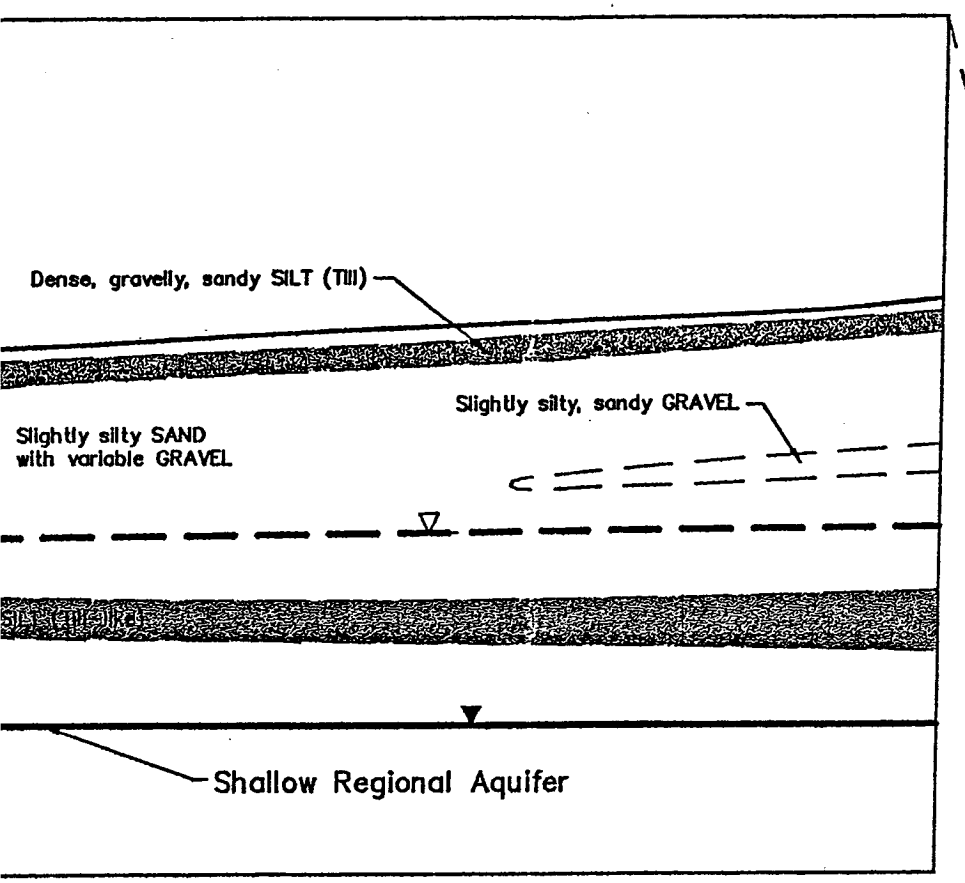
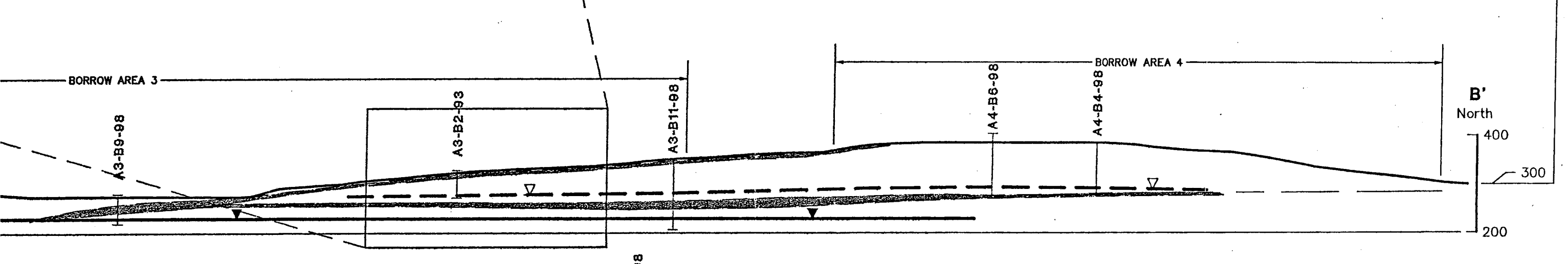
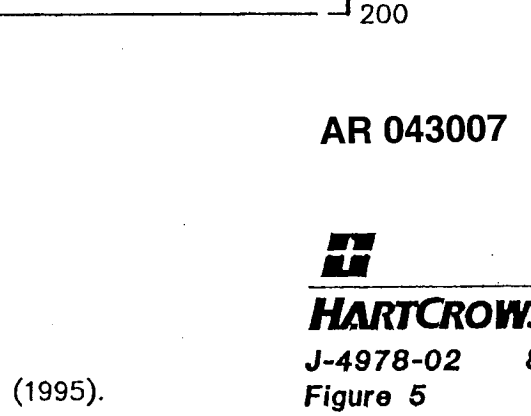
Figure 4

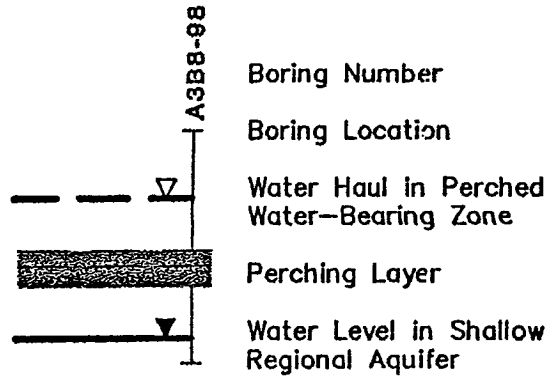
AR 043006

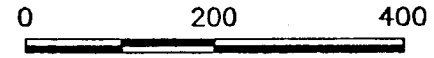
Generalized Regional Stratigraphy	
Formation	Aquifer/Aquitard
Fill, Alluvium, Vashon Recessional Outwash	Perched Zones
Vashon Till	Aquitard
Vashon Advance Outwash	Shallow Regional Aquifer
Lawton Clay	Aquitard
"Third" Coarse-Grained Deposit	Intermediate Regional Aquifer
Puyallup Formation	Aquitard
"Fourth" Coarse-Grained Deposit	Deep Regional Aquifer











Note: Some borehole information is from AGI (1995).

AR 043007

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Figure 5

Groundwater Elevations

Borrow Area 1

Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan," dated April 13, 1998

Exploration Location and Number

- ⊕ A1-B10-99 — Boring with Observation Well (by Hart Crowser)
- ⊕ A1-B3-94 — Boring with Observation Well (by AGI)
- ○ A1-B5-94 — Boring (by AGI)

274 — Spot Groundwater Elevation in Feet

300 — Existing Contour in Feet

Wetland

AA' — Cross Section Location and Designation (See Figure 4)

N

0 300 600

Scale in Feet

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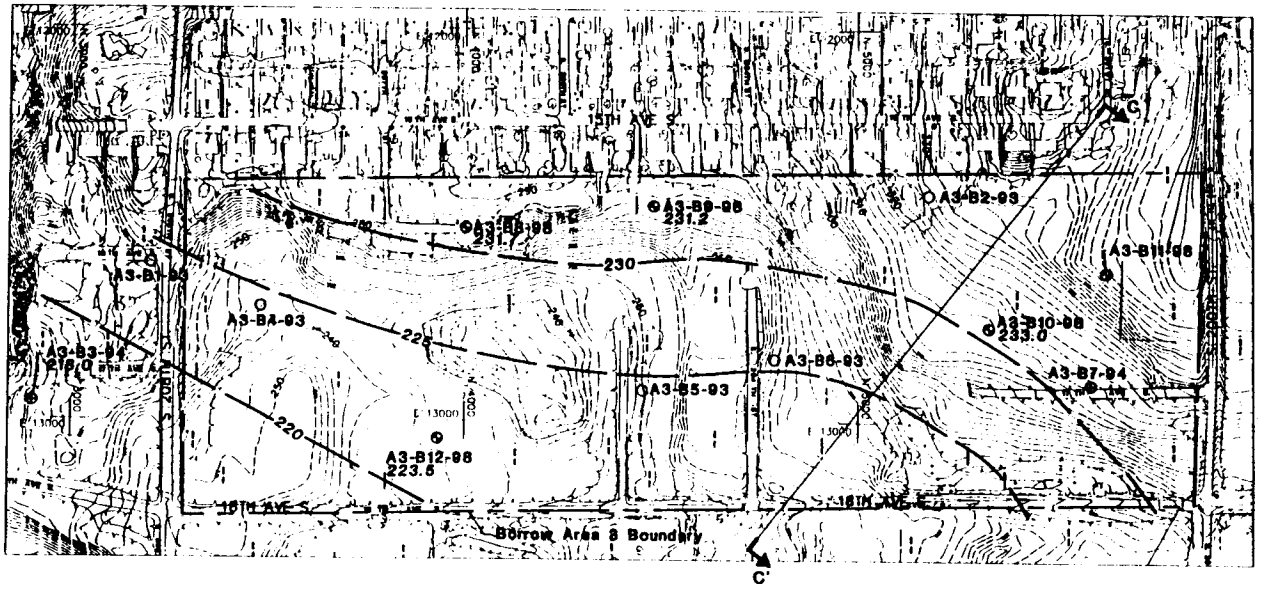
Figure 8

AR 043008

Groundwater Elevation Contour Map - Shallow Regional Aquifer

Borrow Area 3



Exploration Location and Number

- ⊕A3-B8-98 — Boring with Observation Well (by Hart Crowser)
- OA3-B1-93 — Boring (by AGI)
- ⊕A4-B-94 — Boring with Observation Well (by AGI)
- 231.2 — Spot Groundwater Elevation in Feet for Shallow Regional Aquifer
- — 220 — Water Level Elevation Contour in Feet for Shallow Regional Aquifer (June 1998)
- CC' — Cross Section Location and Designation (See Figure 9)

Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan", dated April 13, 1998

N

0 300 600

Scale in Feet

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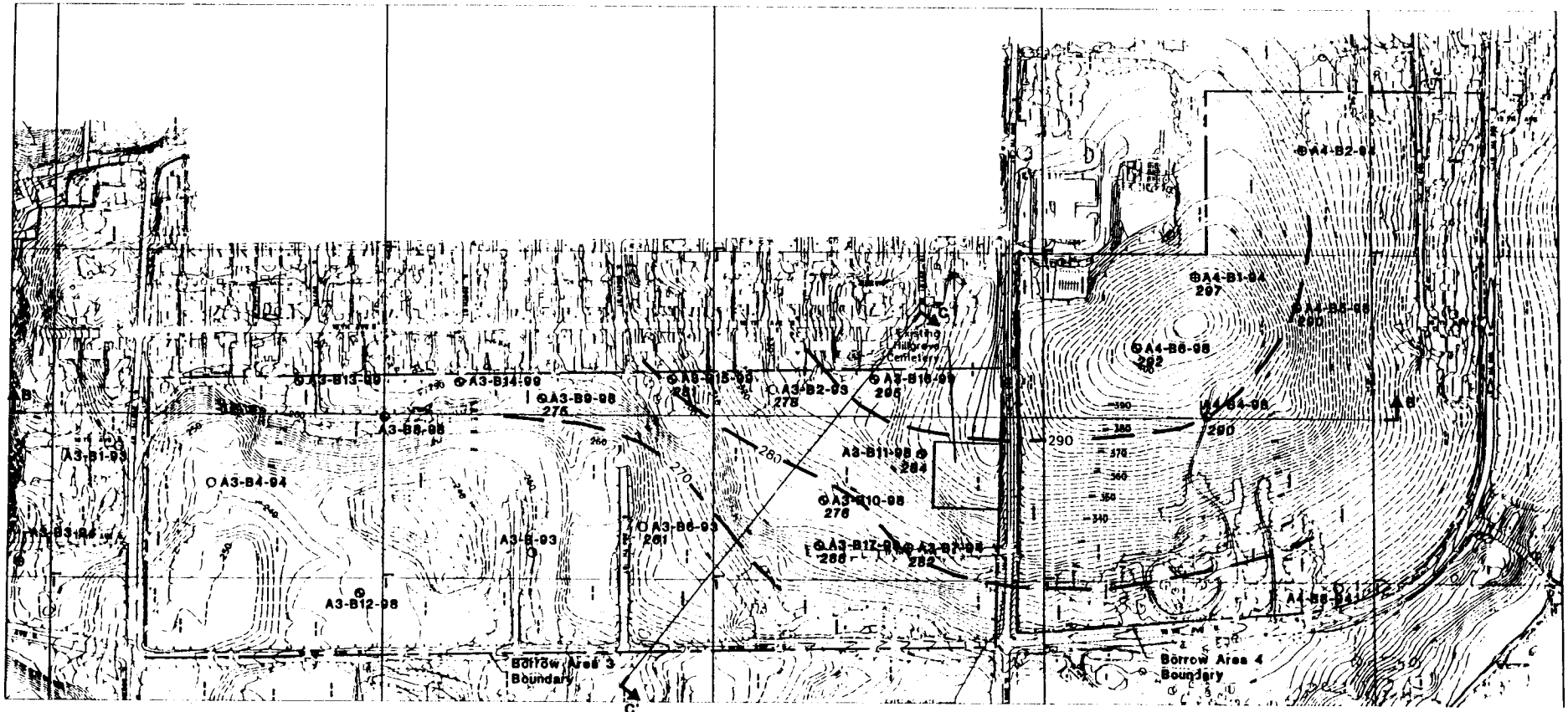
Figure 7

AR 043009

Groundwater Elevation Contour Map - Perched Water-Bearing Zone

Borrow Areas 3 and 4



Note: Base map prepared from drawing provided by HNTB entitled "Borrow Site Areas 3 & 4 Grading Plan", dated April 13, 1998.

Exploration Location and Number

- ⊕A3-B10-98 Boring with Observation Well (by Hart Crowser)
- OA3-B1-93 Boring (by AGI)
- ⊕A3-B3-94 Boring with Observation Well (by AGI)

AA' Cross Section Location and Designation (See Figure 5 and 9)

—290— Groundwater Elevation Contour in Feet for Perched Water-Bearing Zone

276 Spot Groundwater Elevation in Feet for Perched-Water Bearing Zone

N

0 300 600

Scale in Feet

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Figure 8

AR 043010

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Perched Water-Bearing Zone Cross Section C-C'

Borrow Area 3

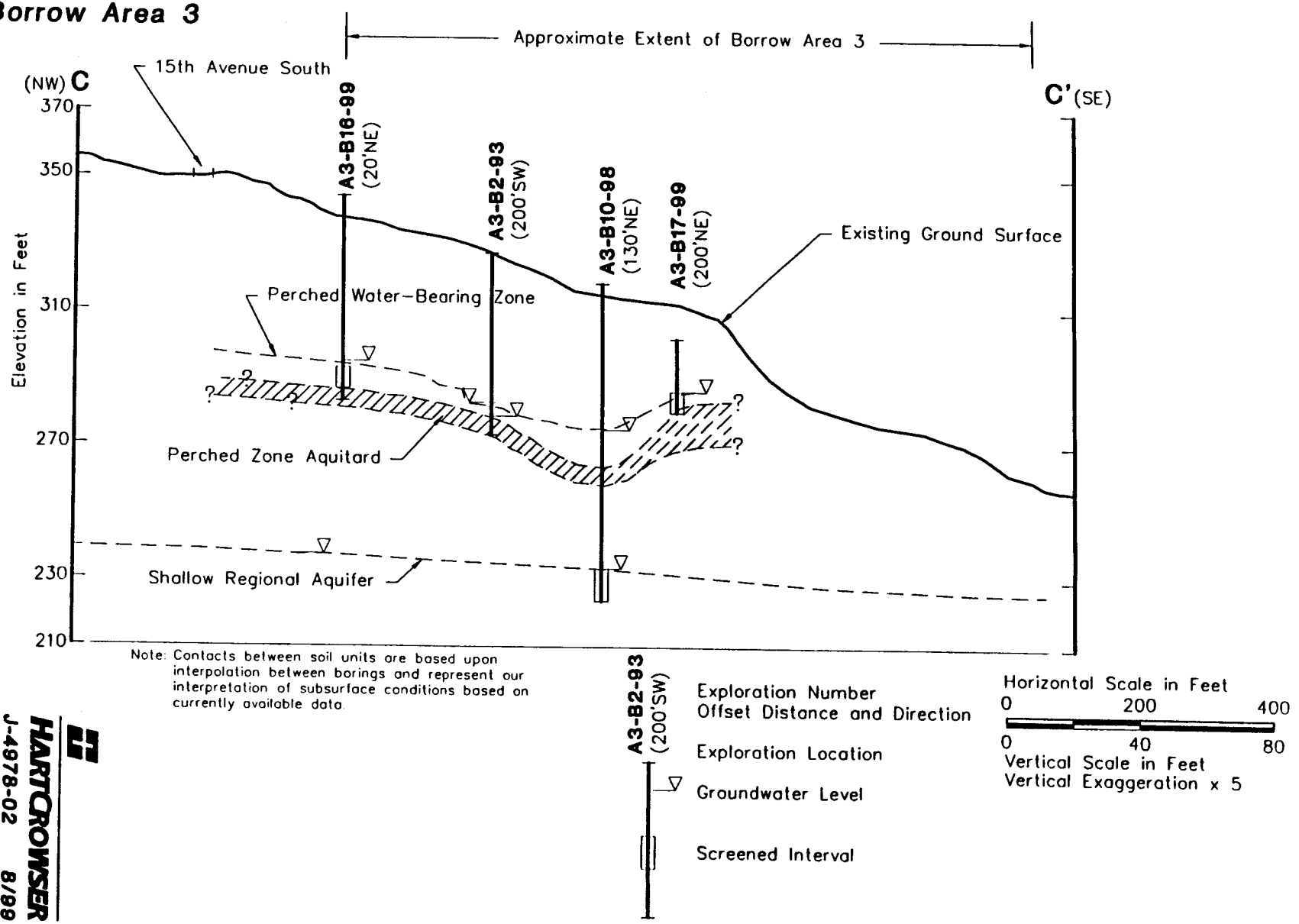

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Figure 9

AR 043011

APPENDIX A
FIELD EXPLORATIONS METHODS AND ANALYSIS

APPENDIX A
FIELD EXPLORATIONS METHODS AND ANALYSIS

This appendix documents the processes Hart Crowser uses in determining the nature of the soils underlying the project site addressed by this report. The discussion includes information on the following subjects:

- Explorations and Their Location;
- The Use of Dual-Wall Percussion Hammer Drilling with Reverse Circulation;
- Penetration Test Procedures; and
- Groundwater Observation Well Installation.

Explorations and Their Location

Subsurface explorations by Hart Crowser for Borrow Area 1 consisted of six dual-wall percussion hammer (DWPH) borings, which were completed as monitoring wells. The borings were designated A1-B10-99 through A1-B14-99. Borings are designated using a system developed by others for the Third Runway Project, where 'A1' represents Borrow Area 1. 'B10' represents boring number 10, and '99' indicates the year the boring was completed. These logs are presented in this appendix on Figures A-2 to A-7.

Subsurface explorations by Hart Crowser for Borrow Areas 3 and 4 consisted of thirteen DWPH borings, which were completed as monitoring wells. The borings were designated A3-B8-98 through A3-B12-98; A3-B13-99 through A3-B17; and A4-B4-98 through A4-B6-98. These logs are presented in this appendix on Figures A-8 to A-20.

Subsurface explorations by AGI for Borrow Areas 1, 3, and 4 consisted of six hollow-stem auger borings which were completed as monitoring wells. The borings were designated A1-B3-94 and A1-B9-94 (Borrow Area 1), A3-B3-94 and A3-B7-94 (Borrow Area 3), and A4-B1-94 and A4-B2-94 and logs are presented in this appendix on Figures A-22 to A27.

The boring logs within this appendix show Hart Crowser's interpretation of the drilling, sampling, and testing data. The logs indicate the depth where the soil characteristics change as follows:

- A hard line is used to show the contact between two geologically distinct units;

- A dashed line is used to show the contact between two dissimilar soils within a specific geologic unit; and

- The words "grades to" are used to mark the location of a gradual change in soil gradation or grain size distribution with increasing depth. Note that the new gradation indicated in this way persists over a distinct interval. Characteristics identified by "grades to" are intended to apply to the remainder of the unit below the notation on the log, or until a different change in gradation is indicated.

In the field, we classified the samples taken from the explorations according to the methods presented on Figure A-1 - Key to Exploration Logs. Figure A-21 presents AGI's Soil Classification/Legend. These figures provide a legend explaining the symbols and abbreviations used in the logs. The remainder of this appendix discusses exploration techniques utilized by Hart Crowser. Additional information on the techniques used by AGI is presented in AGI Technologies, 1995.

Location of Explorations. Figures 2 and 3, which follow the main text, show the location of explorations. In the field, they were originally located by hand taping from existing physical features. This report shows the actual locations and ground surface elevations, presented on the exploration logs, as they were established during a site survey by the Port of Seattle, dated May 28, 1998, except for A3-B13-99 to A3-B17-99, which were surveyed in May 1999.

The Use of Dual-Wall Percussion Hammer Drilling with Reverse Circulation

With depths ranging from 64.0 to 89.5 feet below the ground surface, five dual-wall percussion hammer borings, designated A1-B10-99 through A1-B14-99, were drilled from February 10 to 16, 1999.

With depths ranging from 22.0 to 141.2 feet below the ground surface, thirteen dual-wall percussion hammer borings, designated A3-B8 through A3-B12; and A4-B4 through A4-B6 were drilled from May 11 to 18, 1998. Explorations A3-B13-99 to A3-B17-99 were drilled later on April 15 to 23, 1999.

These eighteen borings incorporated a 9-inch-outside-diameter (6-inch-inside-diameter) dual-wall drive pipe and were advanced with a Becker diesel, pile-driving hammer on a truck-mounted drill rig (AP1000). Layne Christensen Company was subcontracted by Hart Crowser to perform the drilling.

Dual-wall percussion hammer drilling with reverse circulation consists of a dual-walled pipe driven with a diesel drive hammer, while air is forced down the

annulus of the double-wall drive pipe to the bit. The air returns up the inside pipe, carrying with it a continuous flow of drill cuttings that are discharged to an air cyclone. The air cyclone slows down the velocity of the air and drill-cutting mixture, separates the air from the cuttings, and allows for sample collection from the base of the cyclone.

The driving/drilling and sampling were continuously observed by an engineering geologist from Hart Crowser. Detailed field logs were prepared of each boring and each sample was visually and texturally classified in the field. Samples were collected from the air cyclone at 2 1/2- to 5-foot-depth intervals and placed into plastic bags tied with wire. Samples were collected to fill the plastic bags and represent the 2 1/2- to 5-foot sample collection interval; however, for clarity, cyclone samples are represented as 1-foot-thick samples on the logs. After soil sample collection, they were taken to Hart Crowser's laboratory for further testing.

Penetration Test Procedures

This test is an approximate measure of soil density and consistency. To be useful, the results must be used with engineering judgment in conjunction with other tests. Penetration tests similar to the Standard Penetration Test (SPT; as described in ASTM D 1586) were performed to obtain disturbed samples. The tests employed a 3-inch outside diameter split-spoon sampler. Using a 140-pound hammer, free-falling about 30 inches (down-hole techniques were used), the sampler is driven into the soil for 18 inches. The number of blows required to drive the sampler the last 12 inches only is the penetration resistance. This resistance, or blow count, measures the relative density of granular soils and the consistency of cohesive soils. The blow counts are plotted on the boring logs at their respective sample depths.

Soil samples are recovered from the split-spoon sampler, field classified, and placed into water tight jars. They are then taken to Hart Crowser's laboratory for further testing.

In the Event of Hard Driving

Occasionally very dense materials preclude driving the total 18-inch sample. When this happens, the penetration resistance is entered on logs as follows:

Penetration less than six inches. The log indicates the total number of blows over the number of inches of penetration.

Penetration greater than six inches. The blow count noted on the log is the sum of the total number of blows completed after the first 6 inches of penetration. This sum is expressed over the number of inches driven that exceed the first 6 inches. The number of blows needed to drive the first 6 inches are not reported. For example, a blow count series of 12 blows for 6 inches, 30 blows for 6 inches, and 50 (the maximum number of blows counted within a 6-inch increment for SPT) for 3 inches would be recorded as 80/9.

Groundwater Observation Well Installation

Observation wells were installed in the eighteen soil borings. The wells were constructed with flush-threaded 2-inch-diameter PVC and 10-foot-long screens (0.020-inch slot size). The following procedure was used to install the wells:

- Following completion of each soil boring to the target depth, the bottom of each boring was backfilled to the bottom-of-screen depth with native soil and bentonite chips (as-needed).

- A 2-inch inside diameter, flush-threaded, Schedule 40 PVC screen (0.020-inch slots) and riser pipes were lowered through the dual-wall drive pipe.

- As the drive pipe was pulled out, silica sand (No. 10-20) was placed around and approximately 5 feet above the screened section. The depth to the top of the sand pack was recorded by sounding inside the annular space with a weighted measuring tape.

- The annular space of the well was sealed between the top of the sand pack to the bottom of the surface monument by placing bentonite chips in the hole.

- A concrete surface seal was then placed above the bentonite seal at ground surface, and a stickup-mounted monument set in concrete was placed over the finished groundwater observation well.

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Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 – 4	Very soft	0 – 2	<0.125
Loose	4 – 10	Soft	2 – 4	0.125 – 0.25
Medium dense	10 – 30	Medium stiff	4 – 8	0.25 – 0.5
Dense	30 – 50	Stiff	8 – 15	0.5 – 1.0
Very dense	>50	Very stiff	15 – 30	1.0 – 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Trace or Not identified in description	0 – 5
Slightly (clayey, silty, etc.)	5 – 12
Clayey, silty, sandy, gravelly	12 – 30
Very (clayey, silty, etc.)	30 – 50

Legends

Sampling Test Symbols

BORING SAMPLES

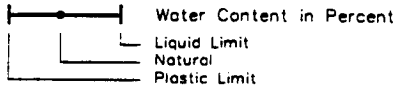
- ☒ Split Spoon
- ▨ Shelby Tube
- ▥ Cuttings
- ◫ Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- ☒ Grab (Jar)
- ▨ Bag
- ▨ Shelby Tube

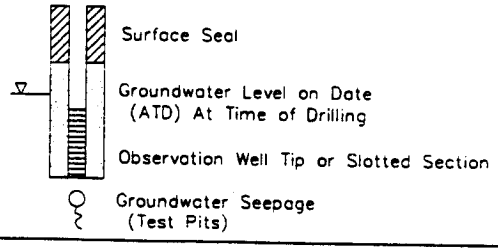
Test Symbols

- GS Grain Size Classification (ASTM D 422)
- GS_{200} Grain Size Classification (ASTM D 1140)
- AL Atterberg Limits



Note: Within a soil unit the indication "grades to" implies a relatively gradual transition from the proceeding soil gradation to the indicated gradation. This changed gradation is predominant for the remainder (deeper portion) of the unit, unless further modified as shown on the log.

Groundwater Observations



1=1 A-1_4978

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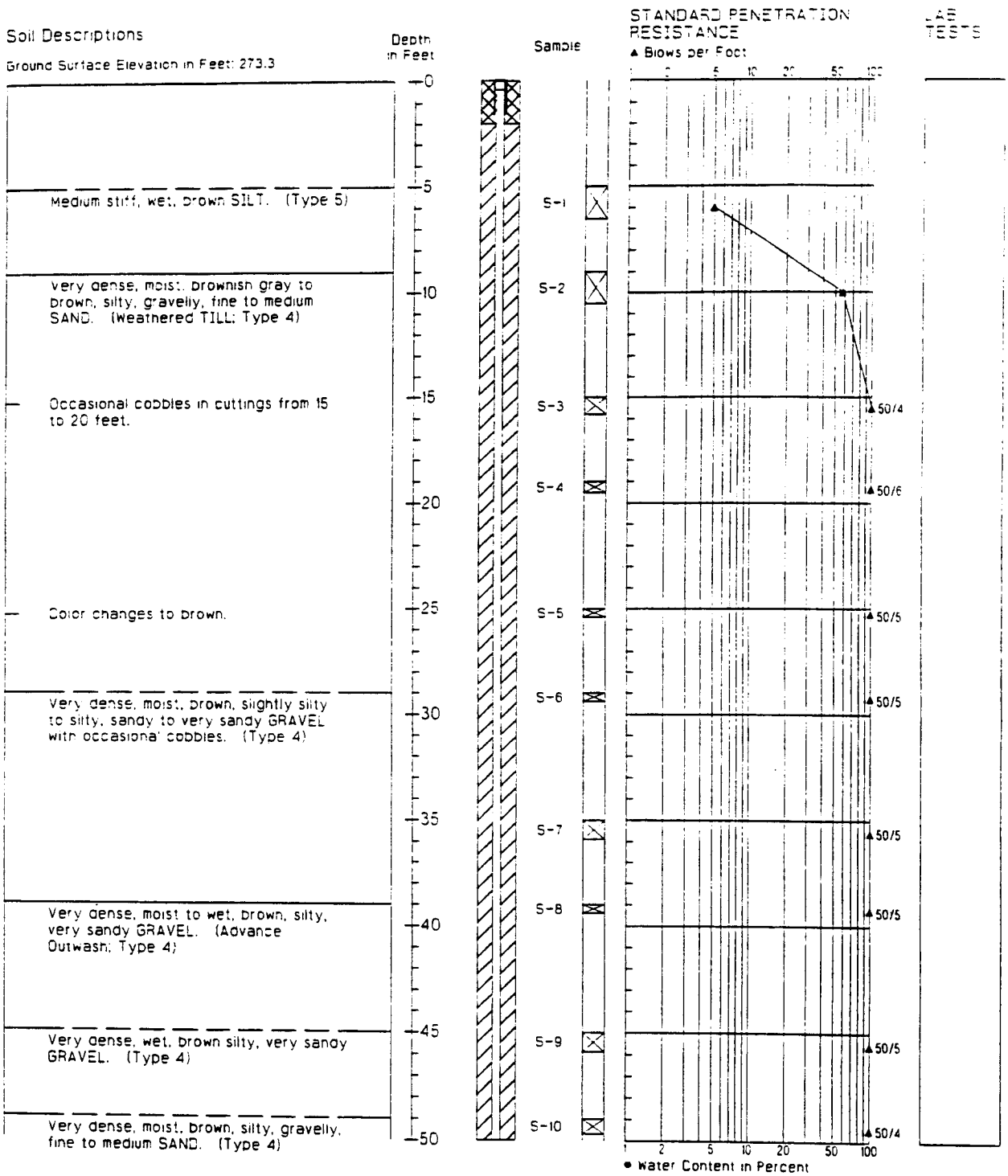
Figure A-1

AR 043017

Boring Log A1-B10-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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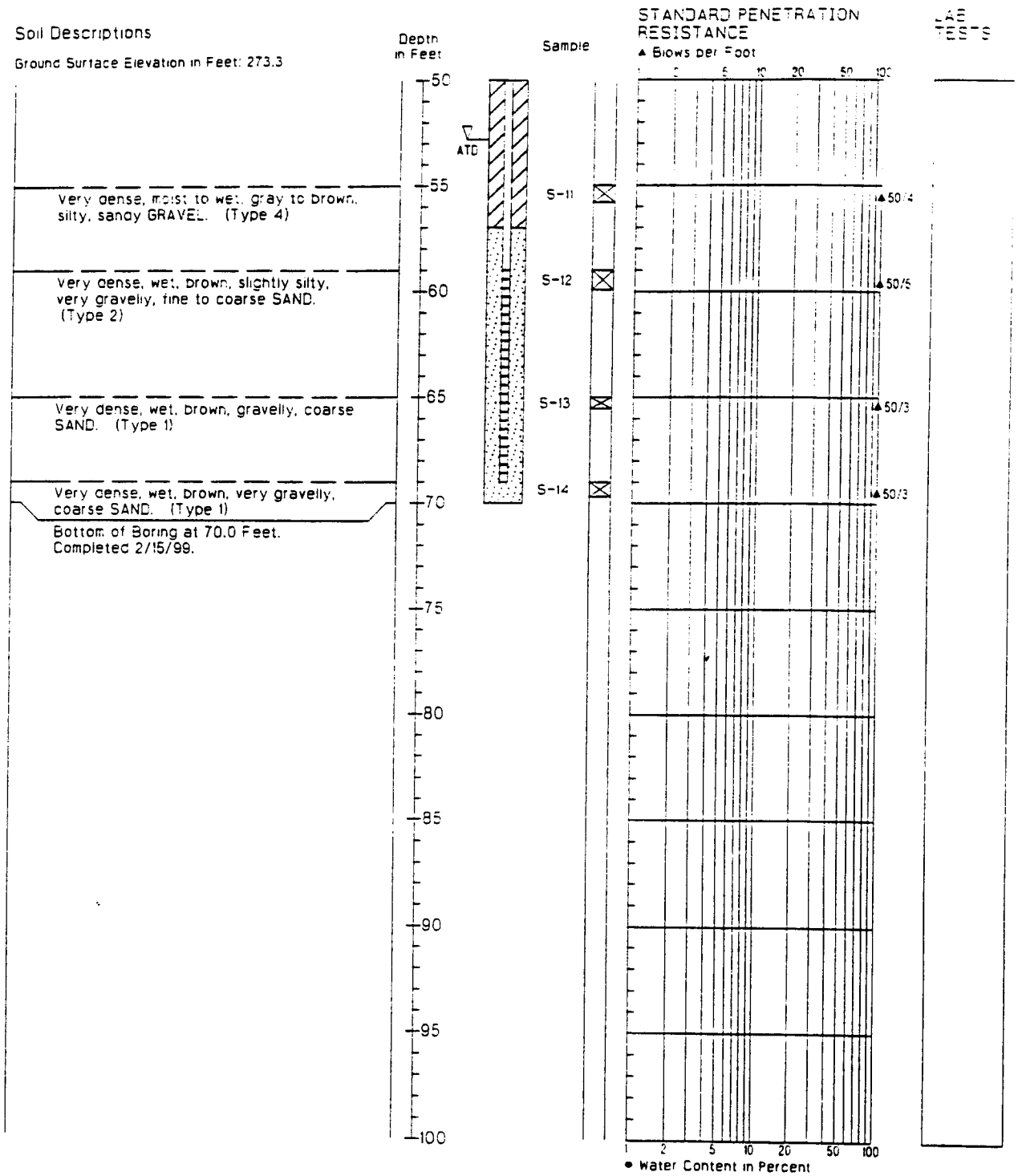
Figure A-2 1/2

AR 043018

Boring Log A1-B10-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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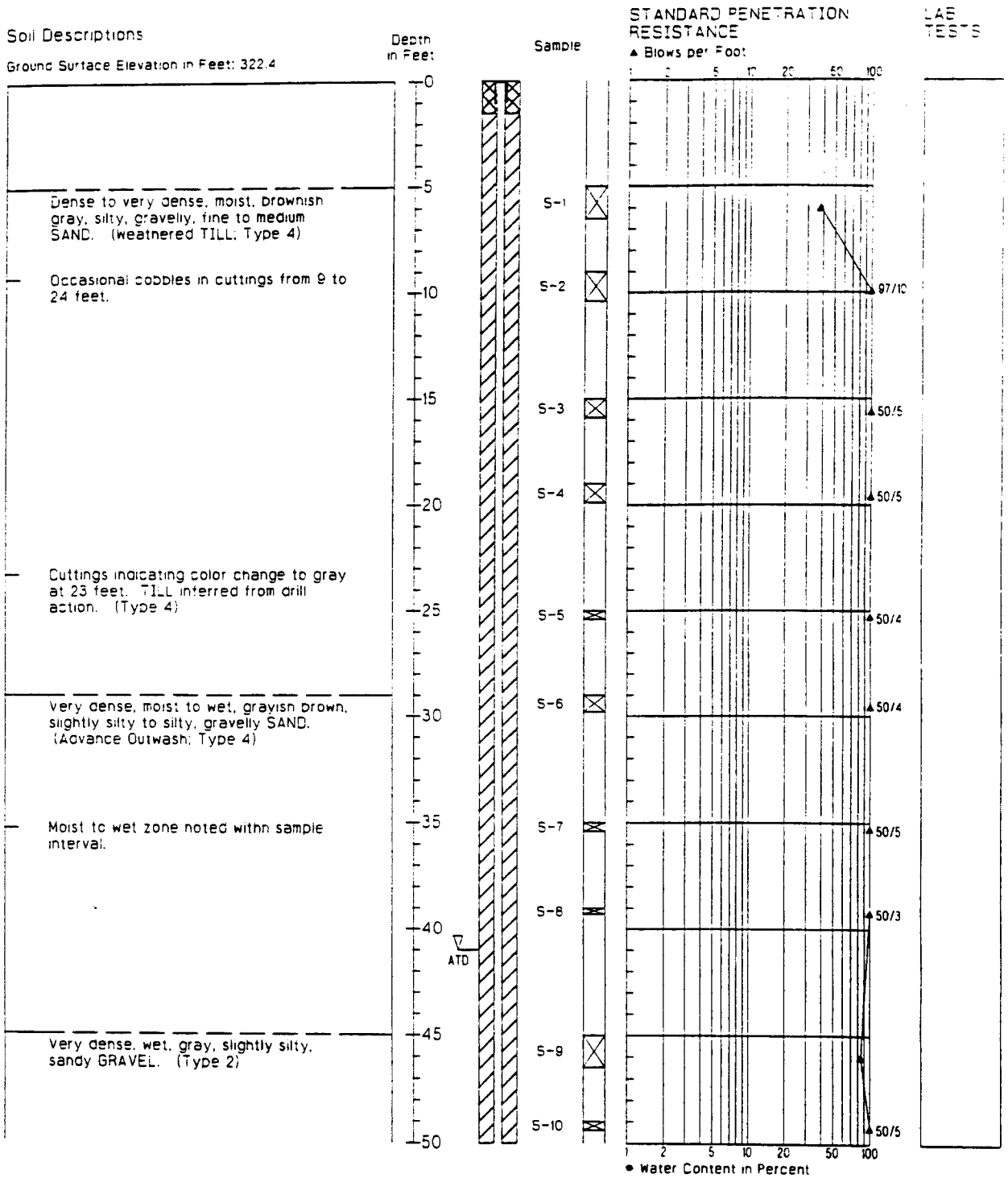
Figure A-2 2/2

AR 043019

Boring Log A1-B11-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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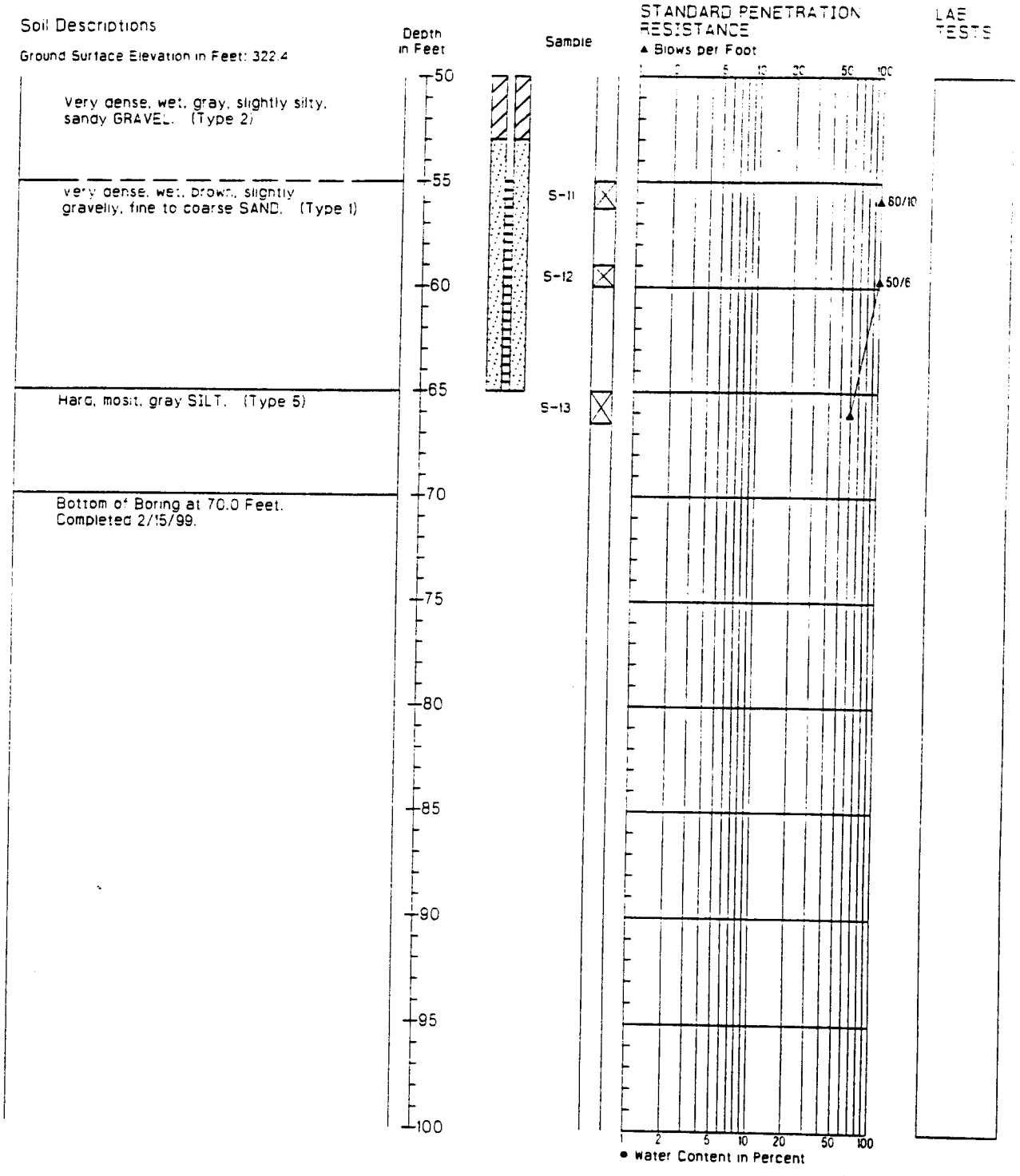
Figure A-3 1/2

AR 043020

Boring Log A1-B11-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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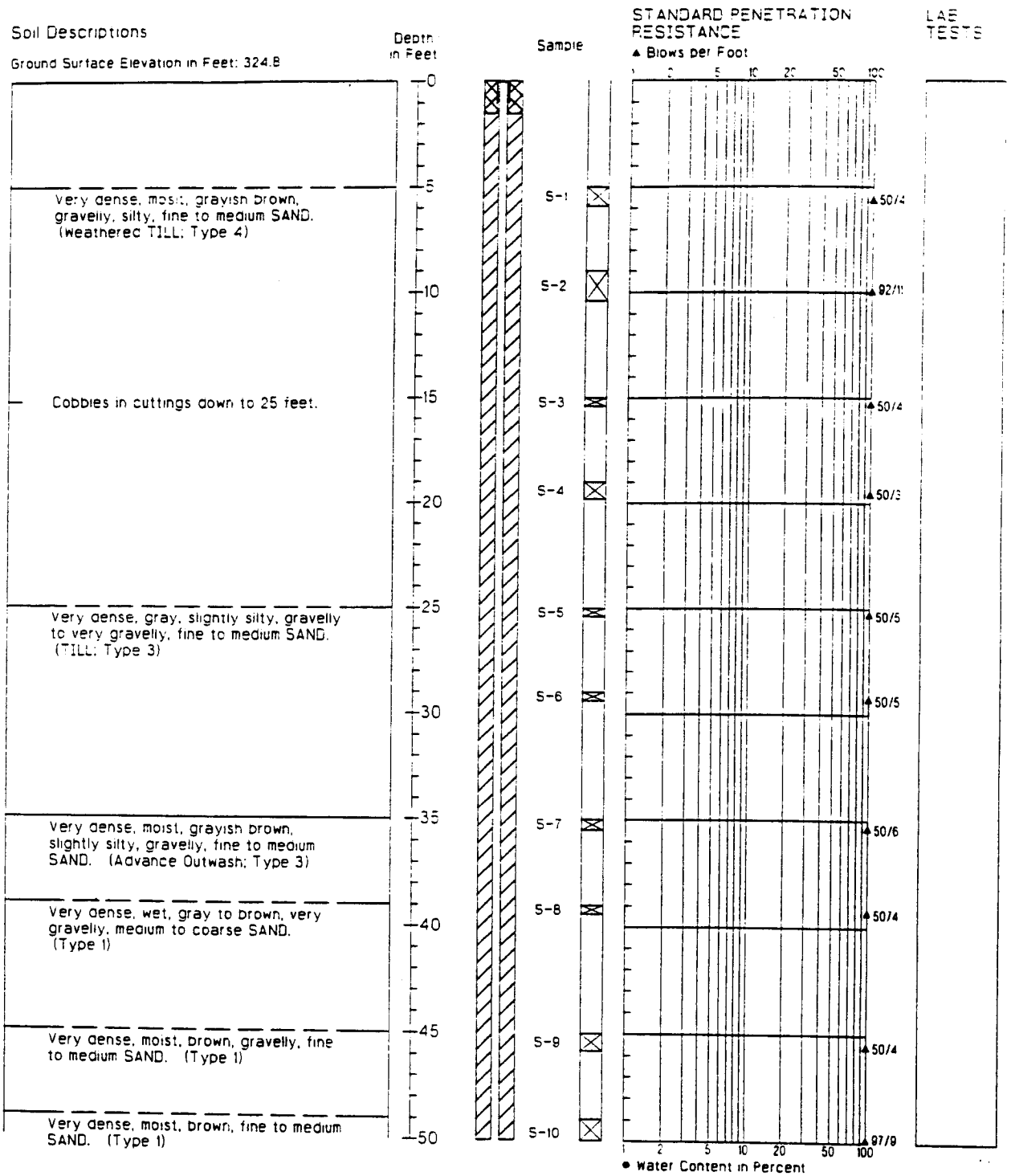
Figure A-3 2/2

AR 043021

Boring Log A1-B12-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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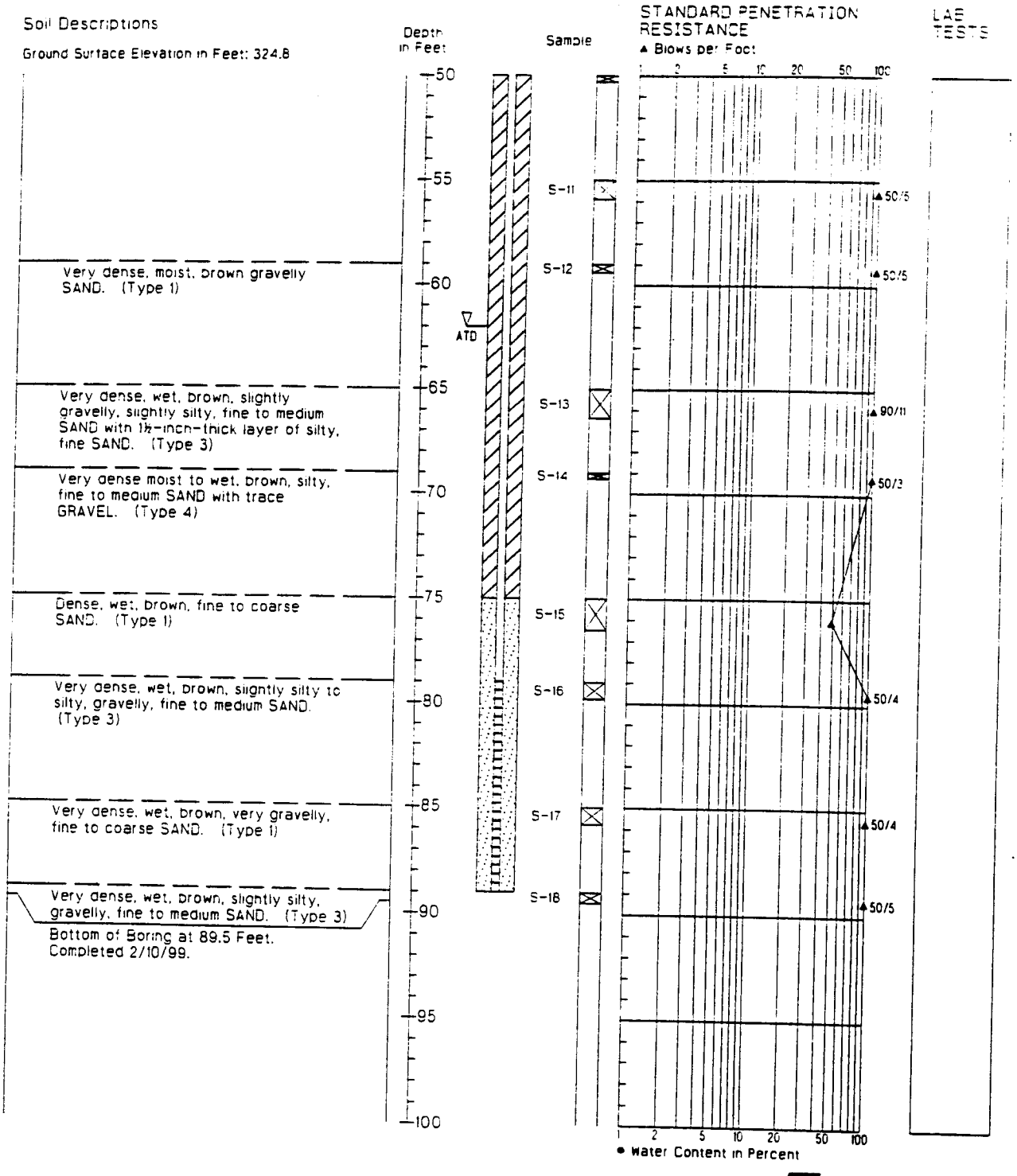
Figure A-4 1/2

AR 043022

Boring Log A1-B12-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-4 2/2

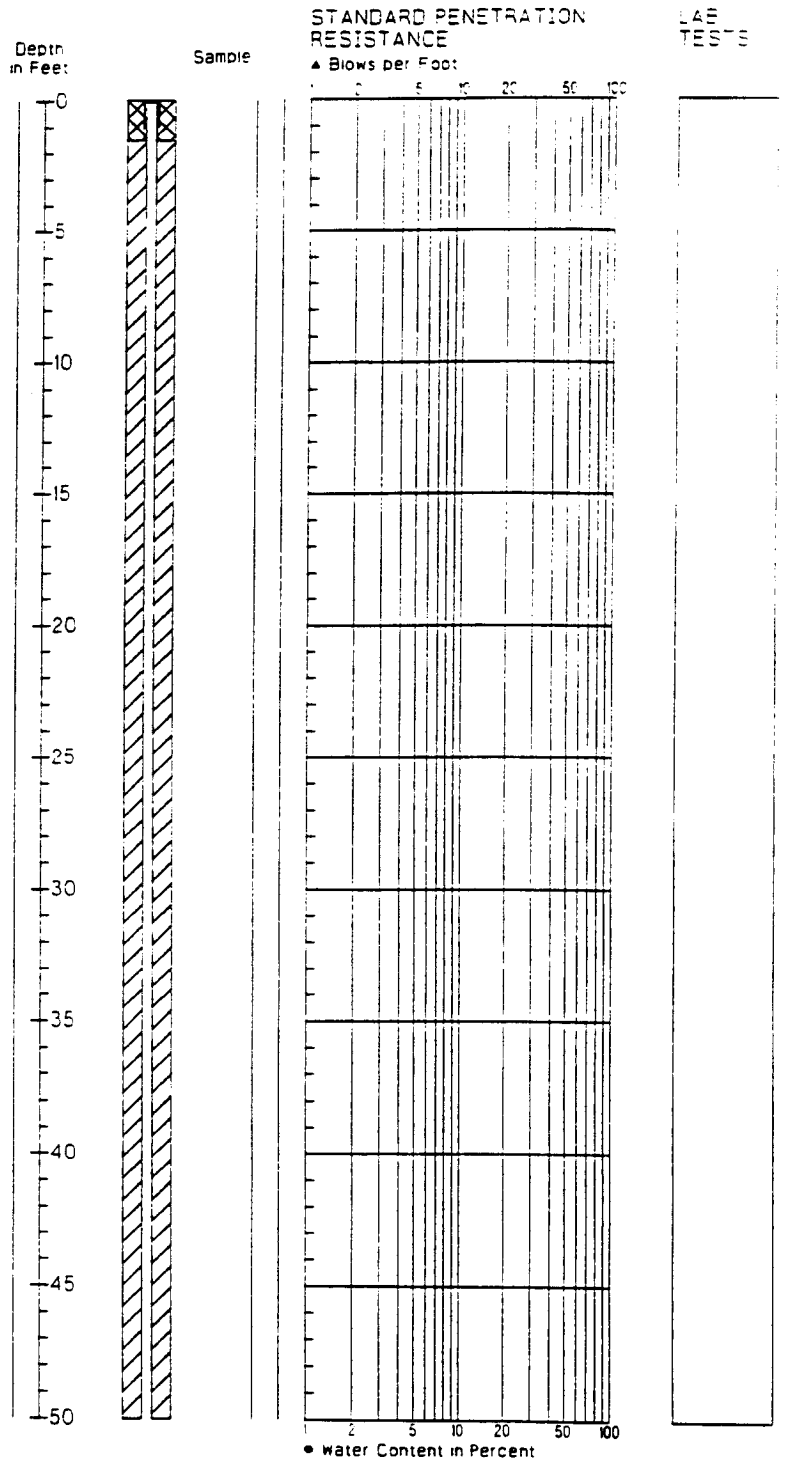
AR 043023

Boring Log A1-B12S-99

Soil Descriptions

Ground Surface Elevation in Feet: 324.6

Drilled adjacent to A1-B12-99 (approximately 10 feet north); no samples taken for logging.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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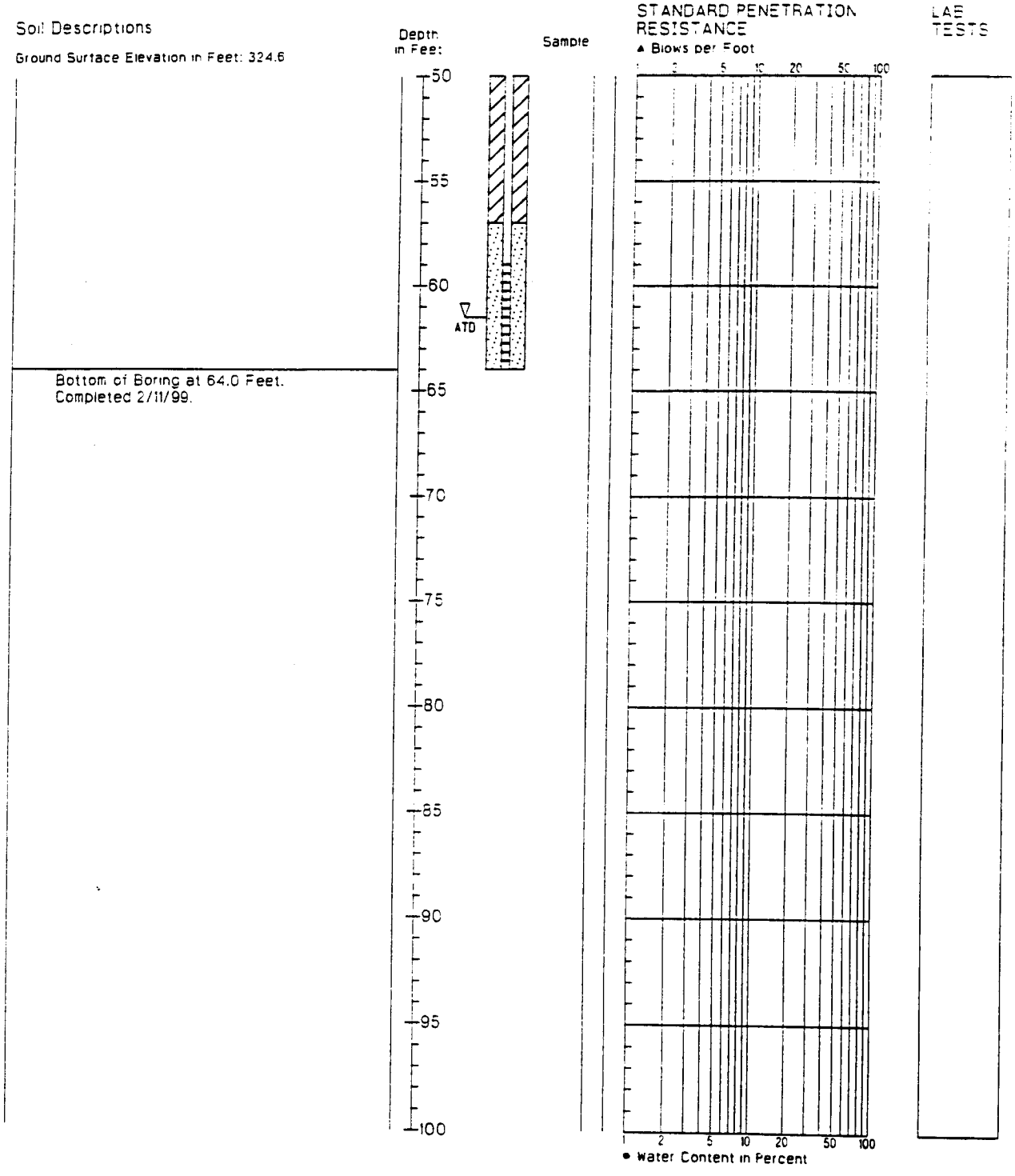
Figure A-5 1/2

AR 043024

Boring Log A1-B12S-99



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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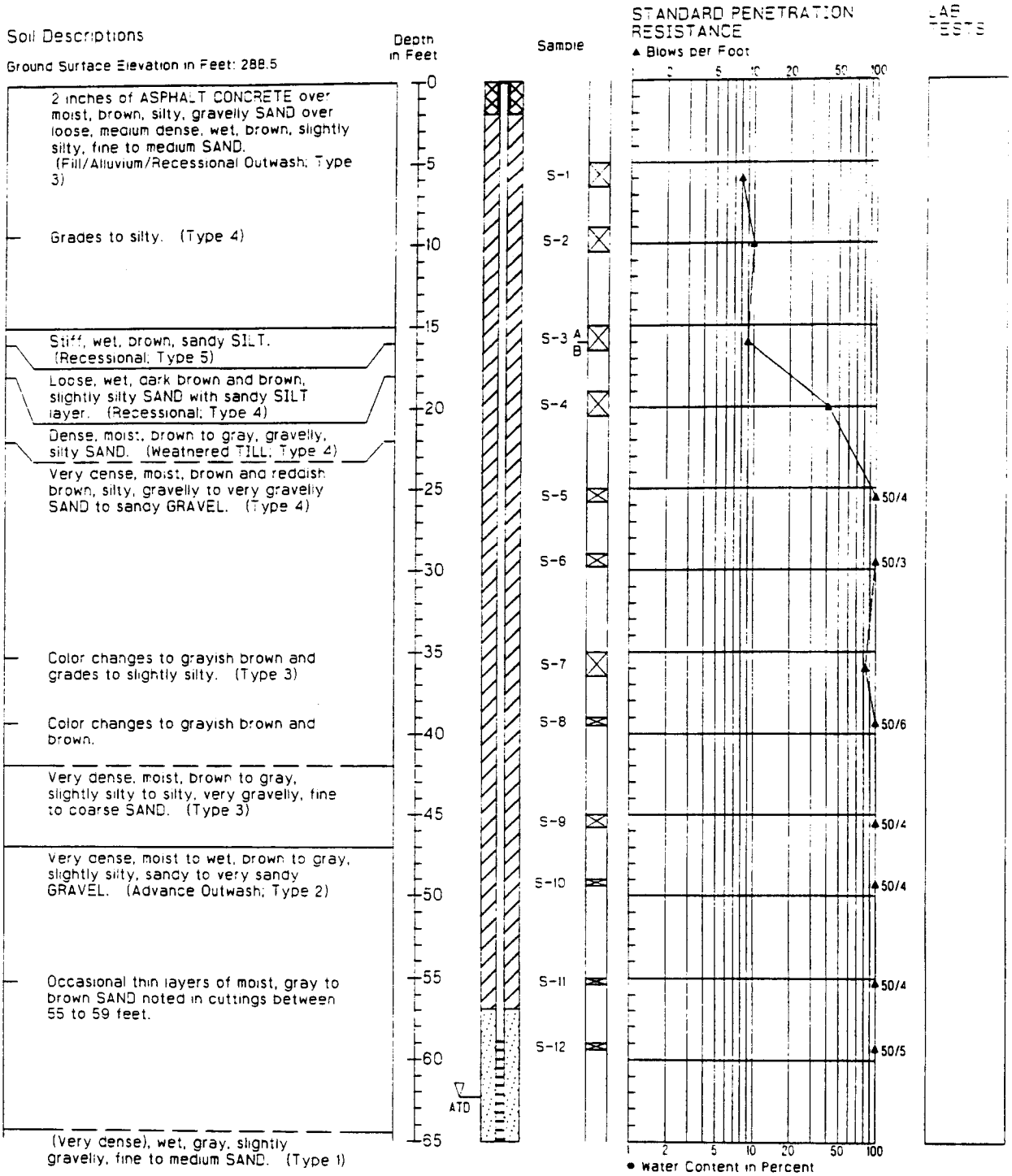
Figure A-5 2/2

AR 043025

Boring Log A1-B13-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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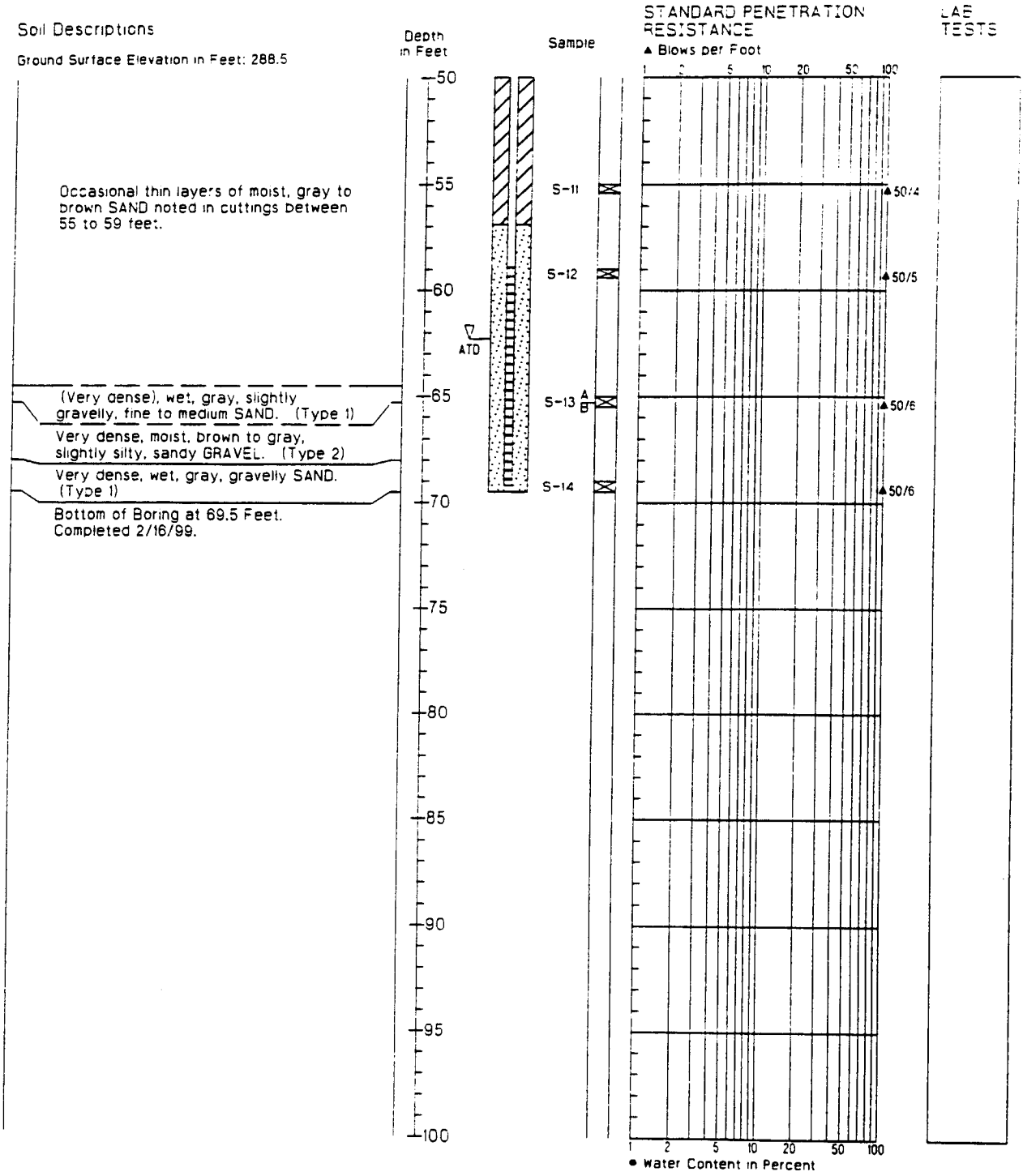
J-4978-02 2/99

Figure A-8 1/2

Boring Log A1-B13-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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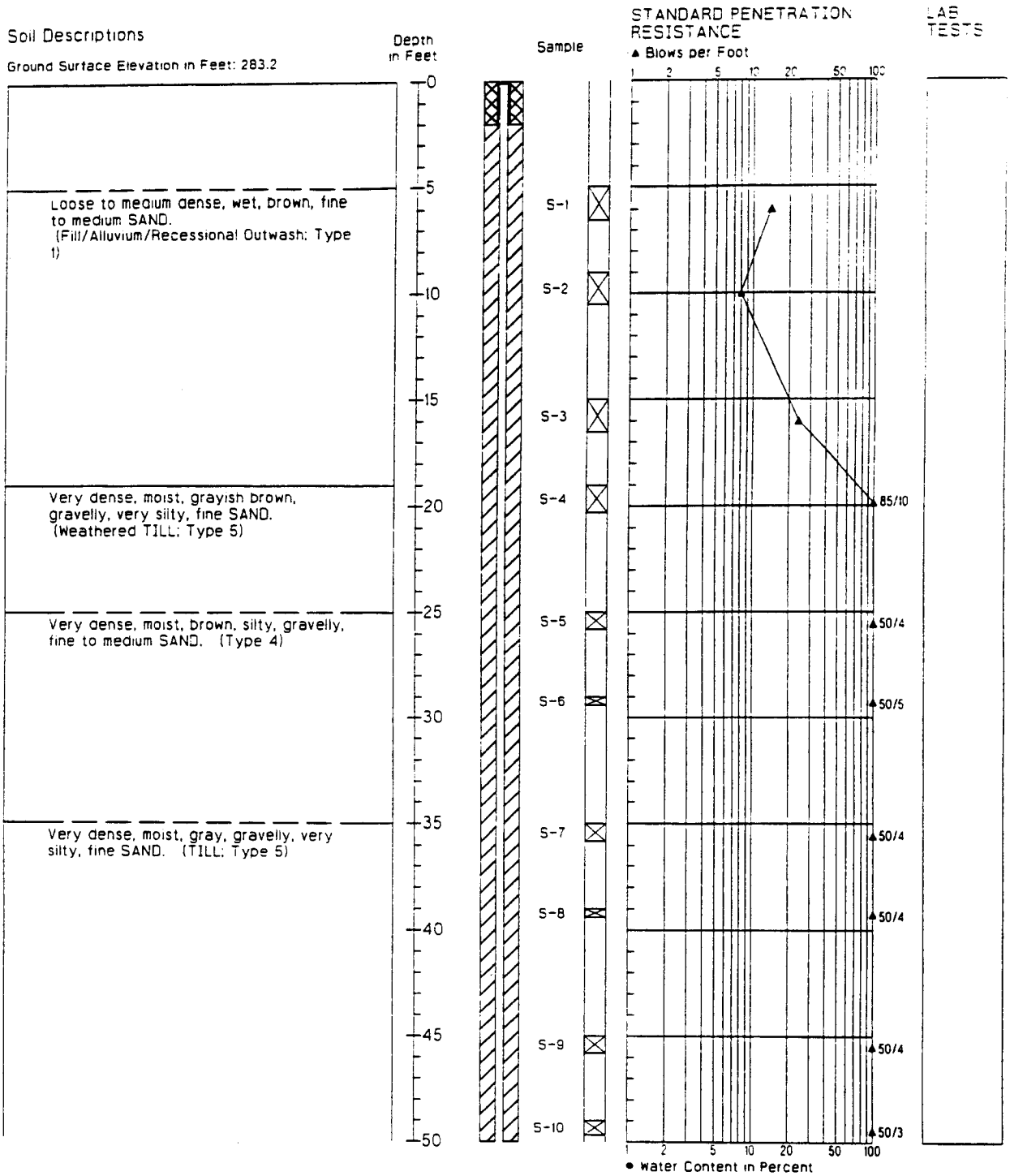
J-4978-02 2/99

Figure A-8 2/2

AR 043027

Boring Log A1-B14-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

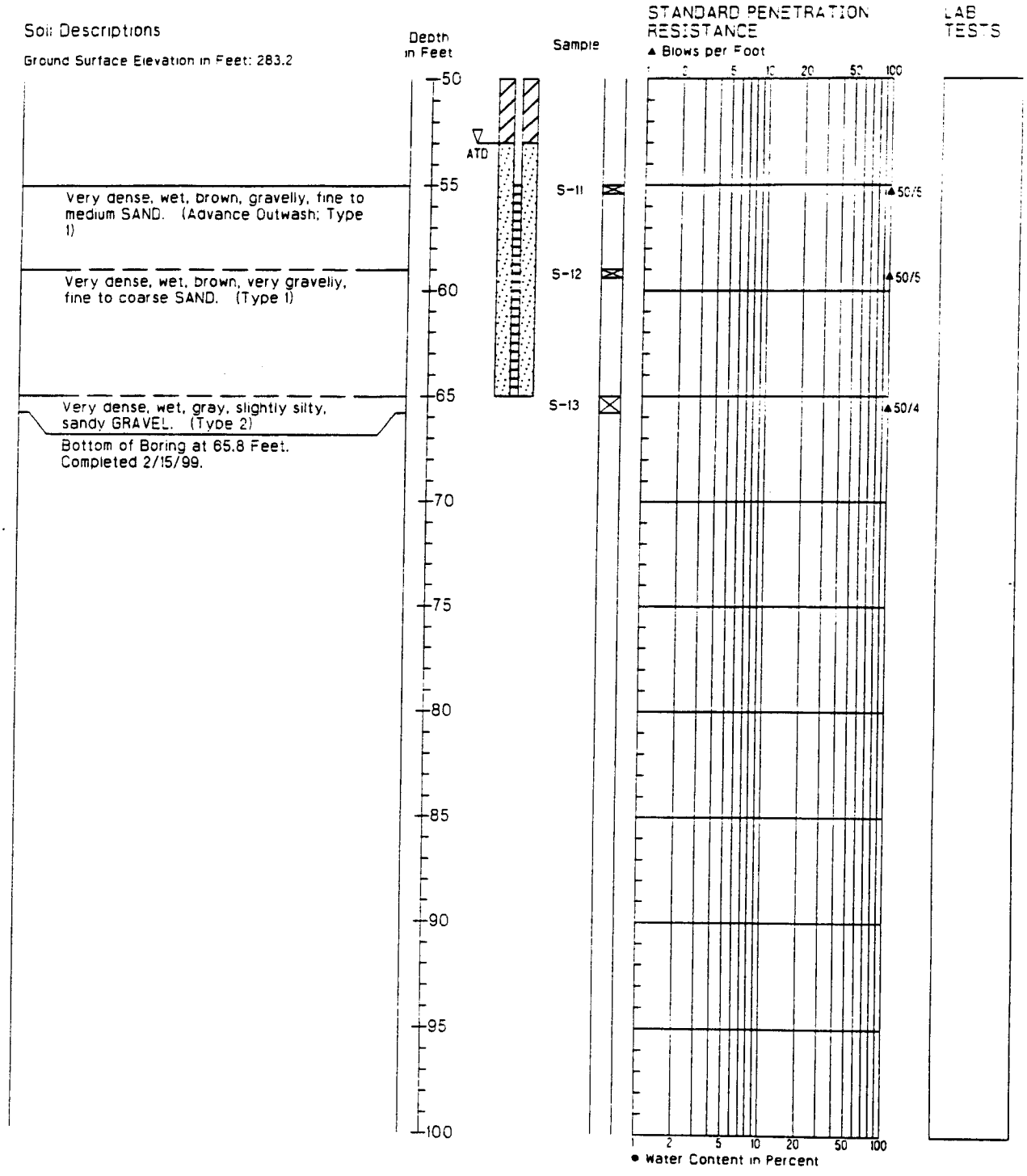
HARTCROWSER

J-4978-02 2/99

Figure A-7 1/2

AR 043028

Boring Log A1-B14-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

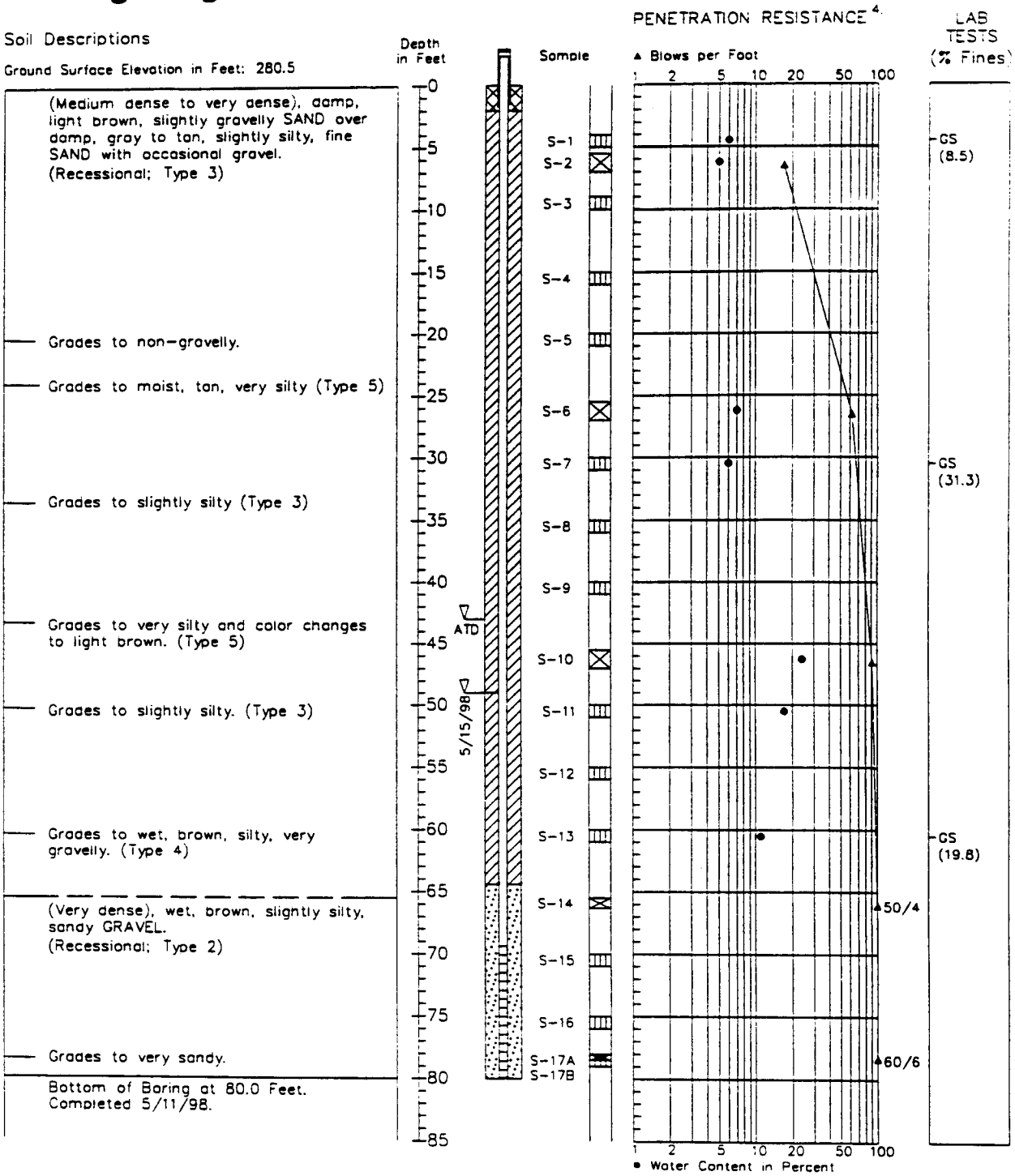
HARTCROWSER

J-4978-02 2/99

Figure A-7 2/2

AR 043029

Boring Log A3-B8-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

HARTCROWSER

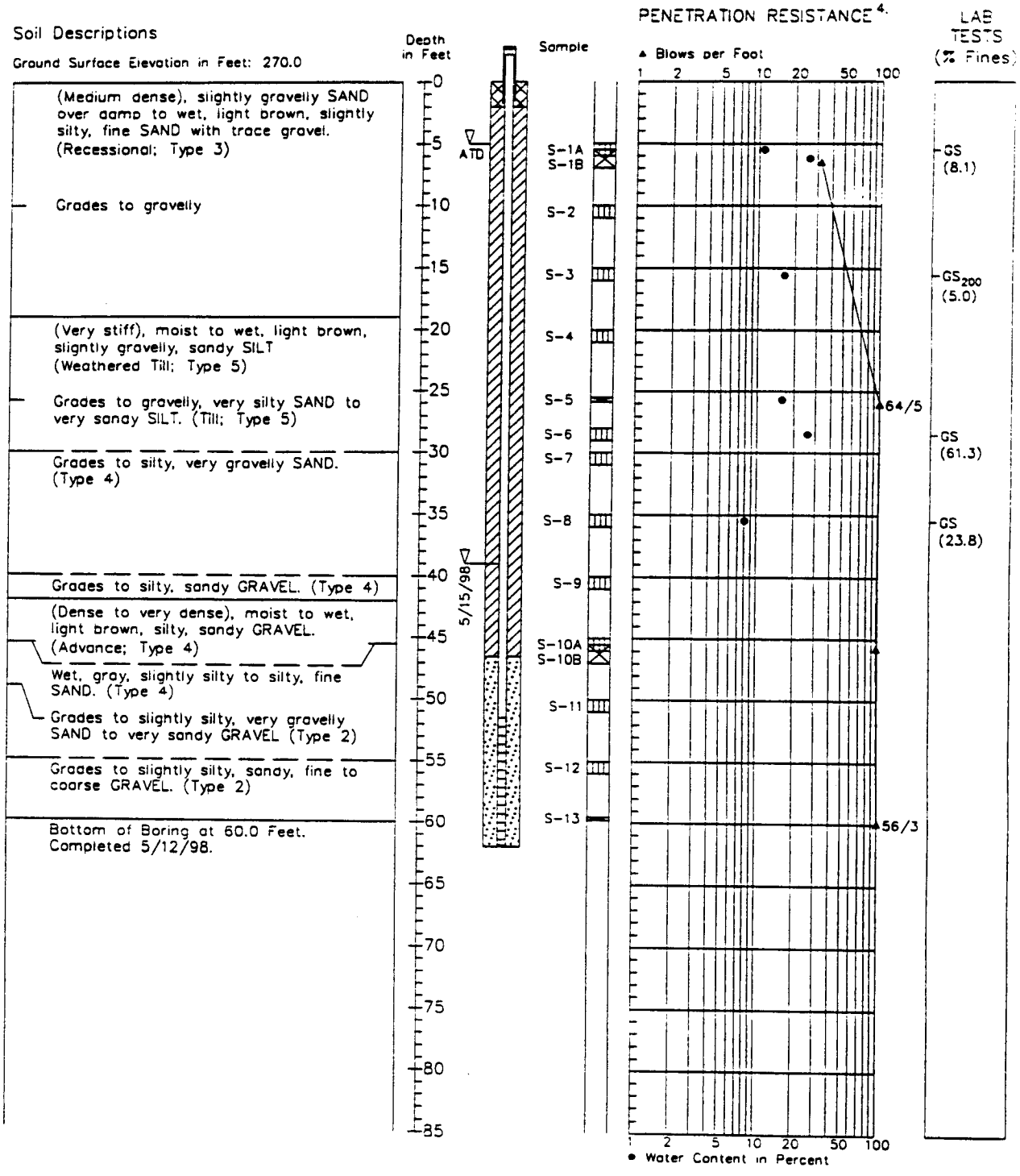
J-4978 5/98

Figure A-8

ACAD Log

AR 043030

Boring Log A3-B9-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

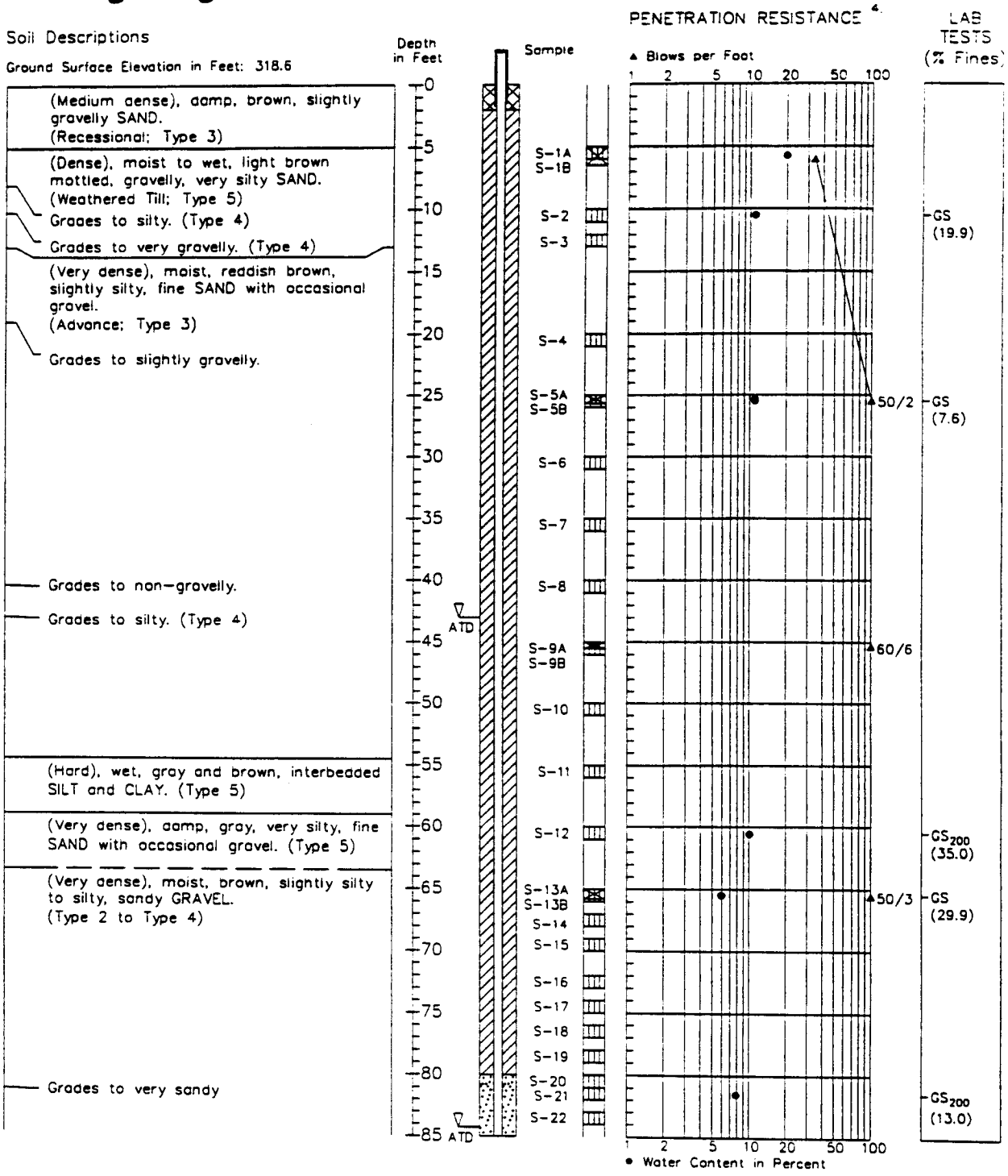
HARTCROWSER

J-4978 5/98

Figure A-9

AR 043031

Boring Log A3-B10-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

HARTCROWSER

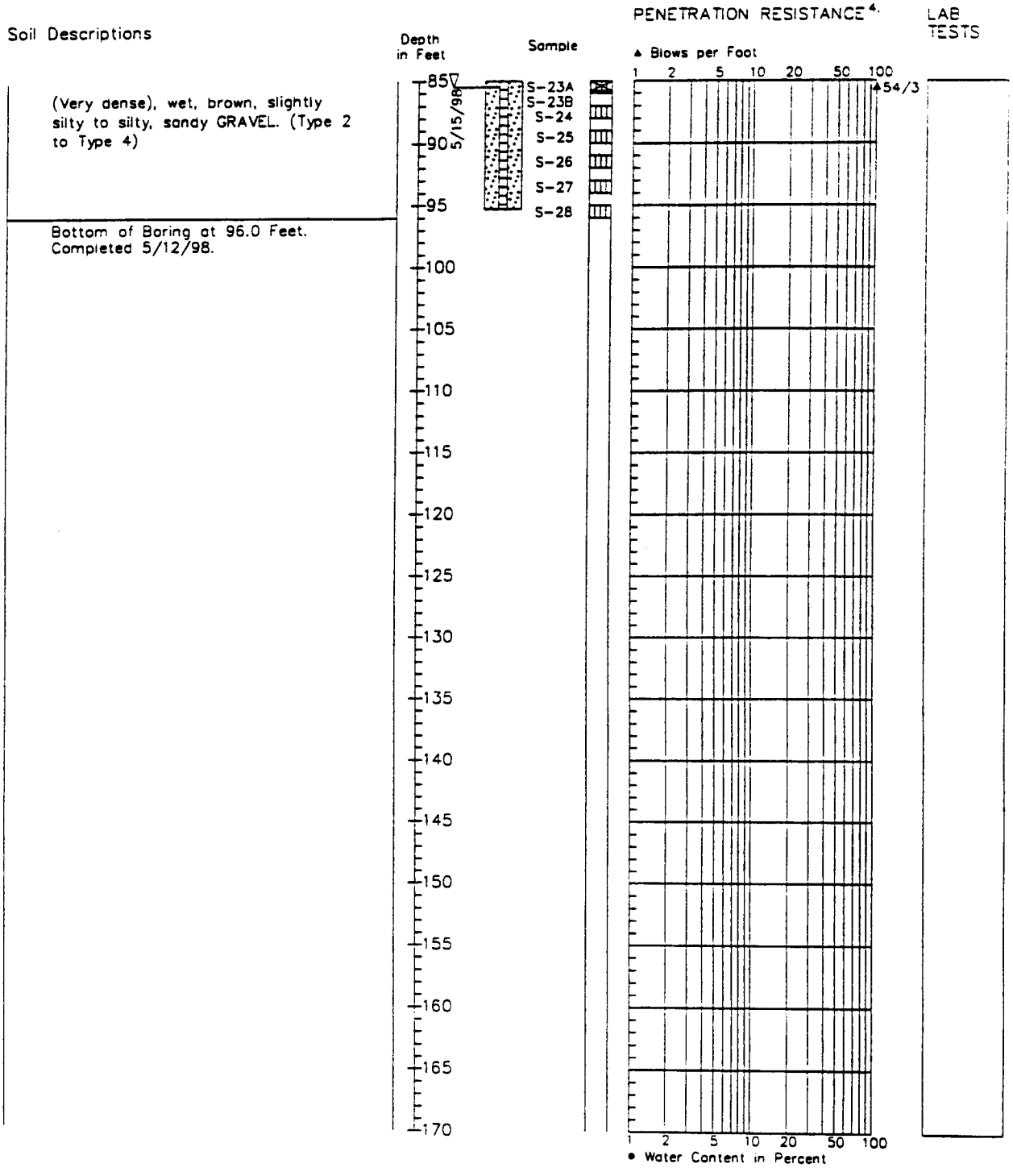
J-4978 5/98

Figure A-10 1/2

ACAD Log

AR 043032

Boring Log A3-B10-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

HARTCROWSER

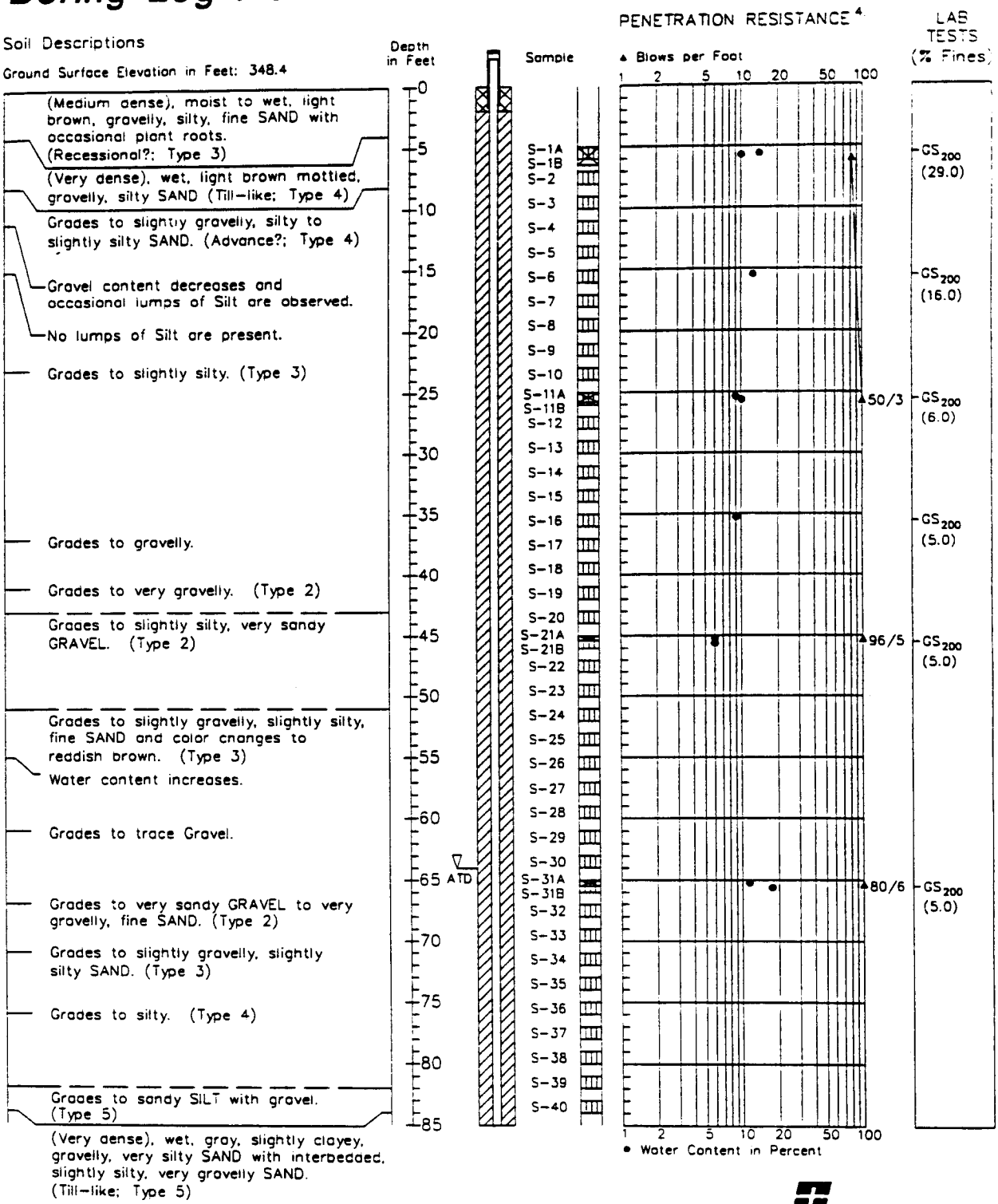
J-4978 5/98

Figure A-10 2/2

ACAD Log

AR 043033

Boring Log A3-B11-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

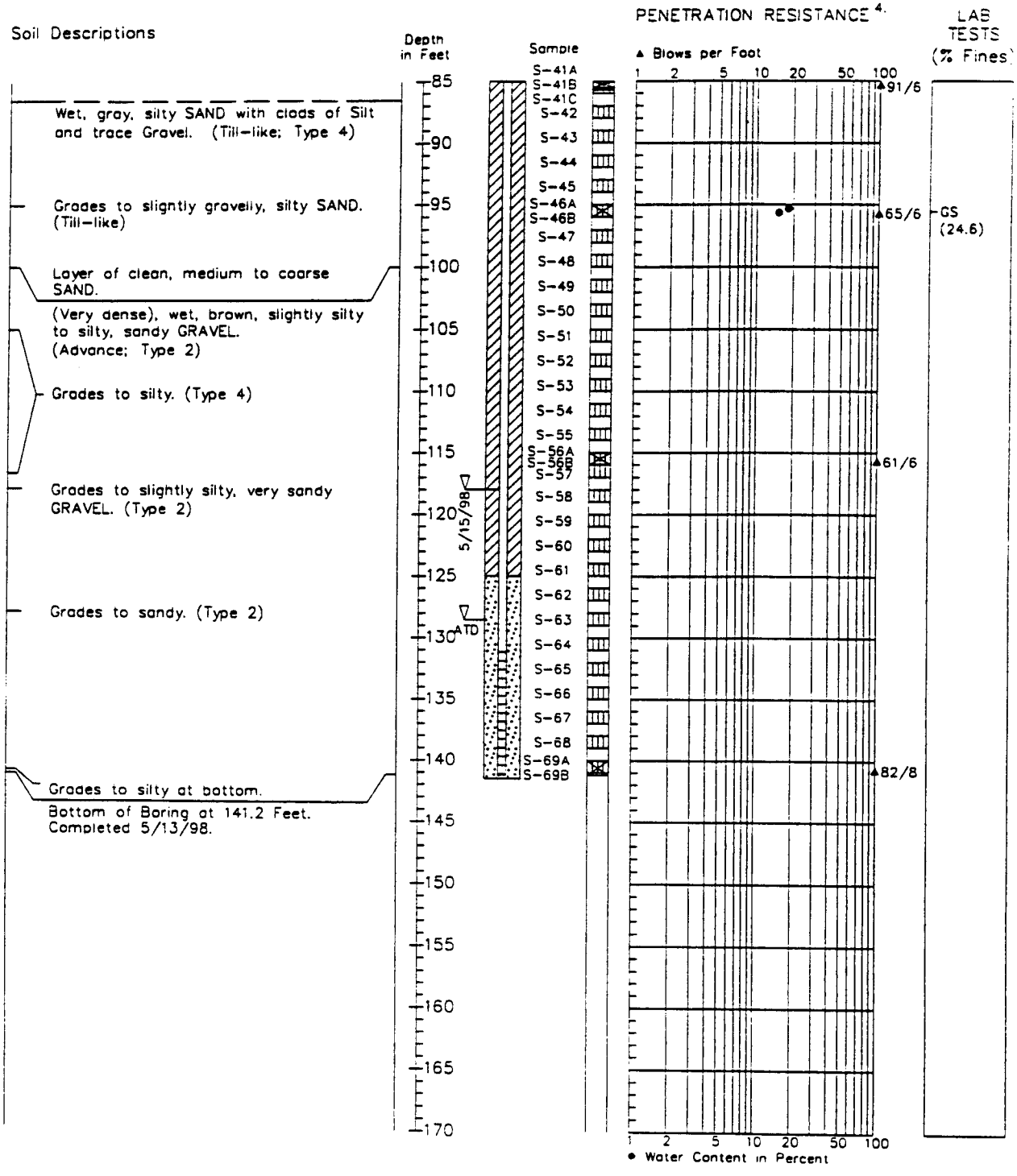
HARTCROWSER

J-4978 5/98

Figure A-11 1/2

AR 043034

Boring Log A3-B11-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

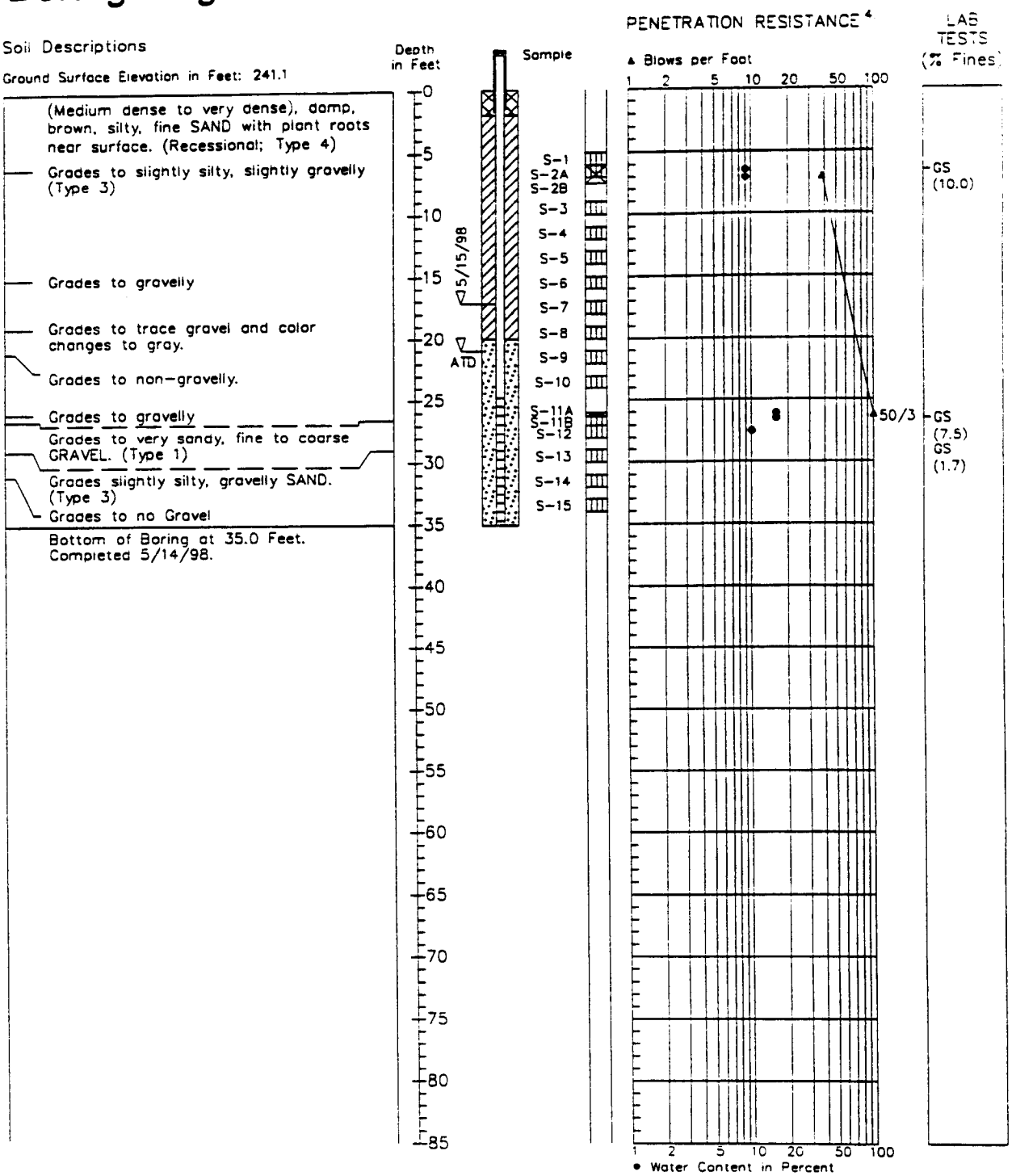
HARTCROWSER

J-4978 5/98

Figure A-11 2/2

AR 043035

Boring Log A3-B12-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

HARTCROWSER

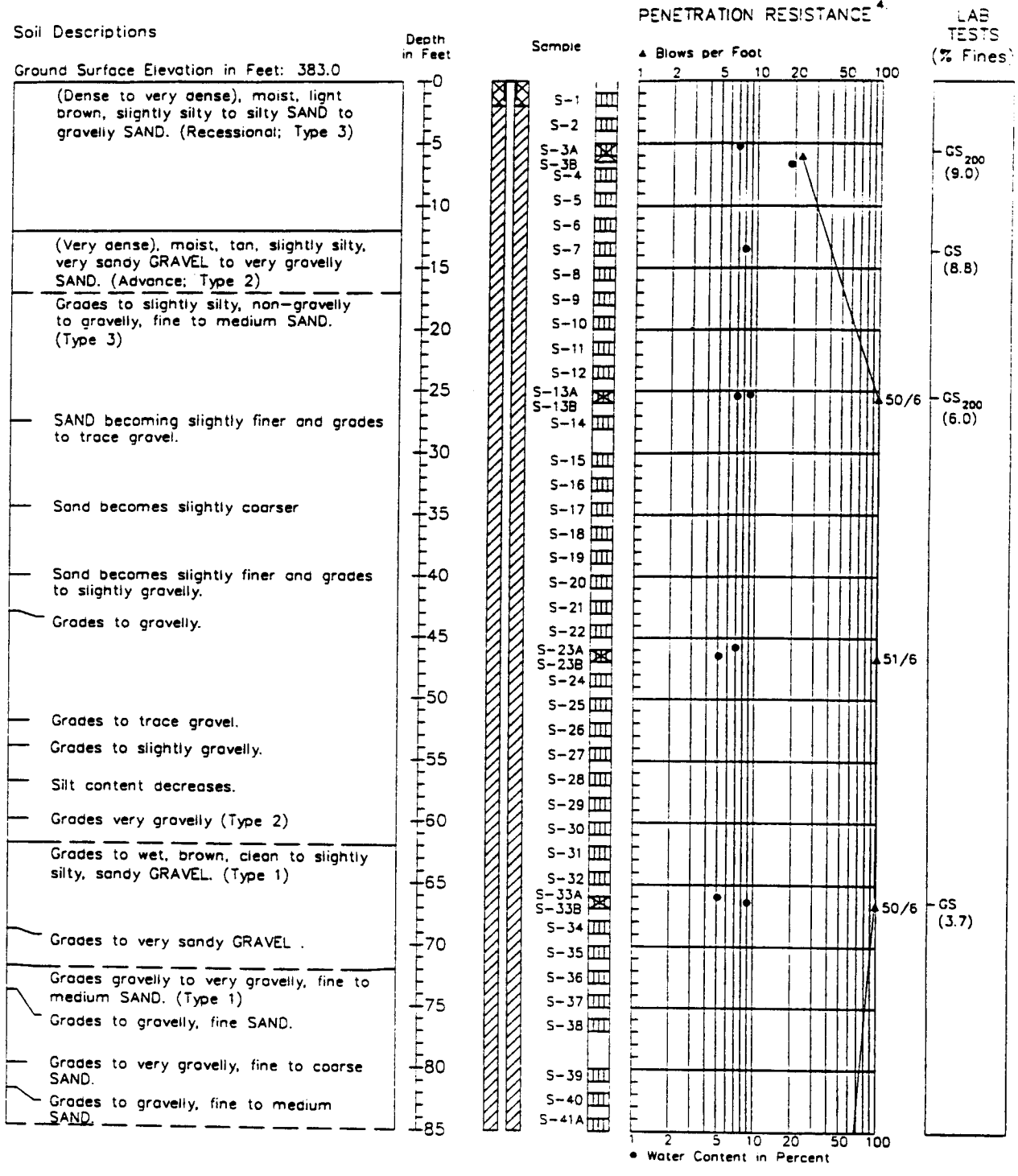
J-4978 5/98

Figure A-12

ACAD Log

AR 043036

Boring Log A4-B4-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

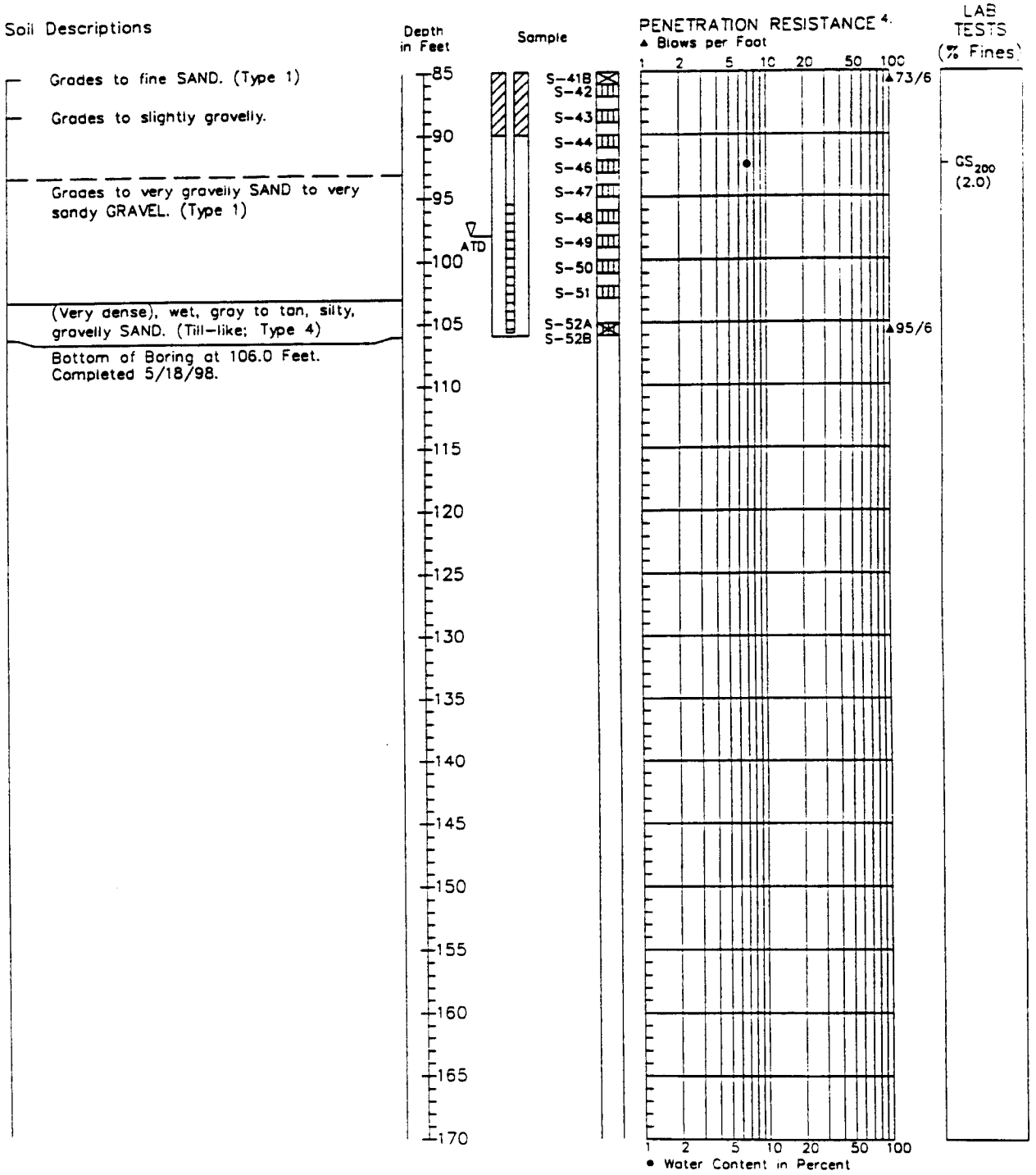
HARTCROWSER

J-4978 5/98

Figure A-13 1/2

AR 043037

Boring Log A4-B4-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

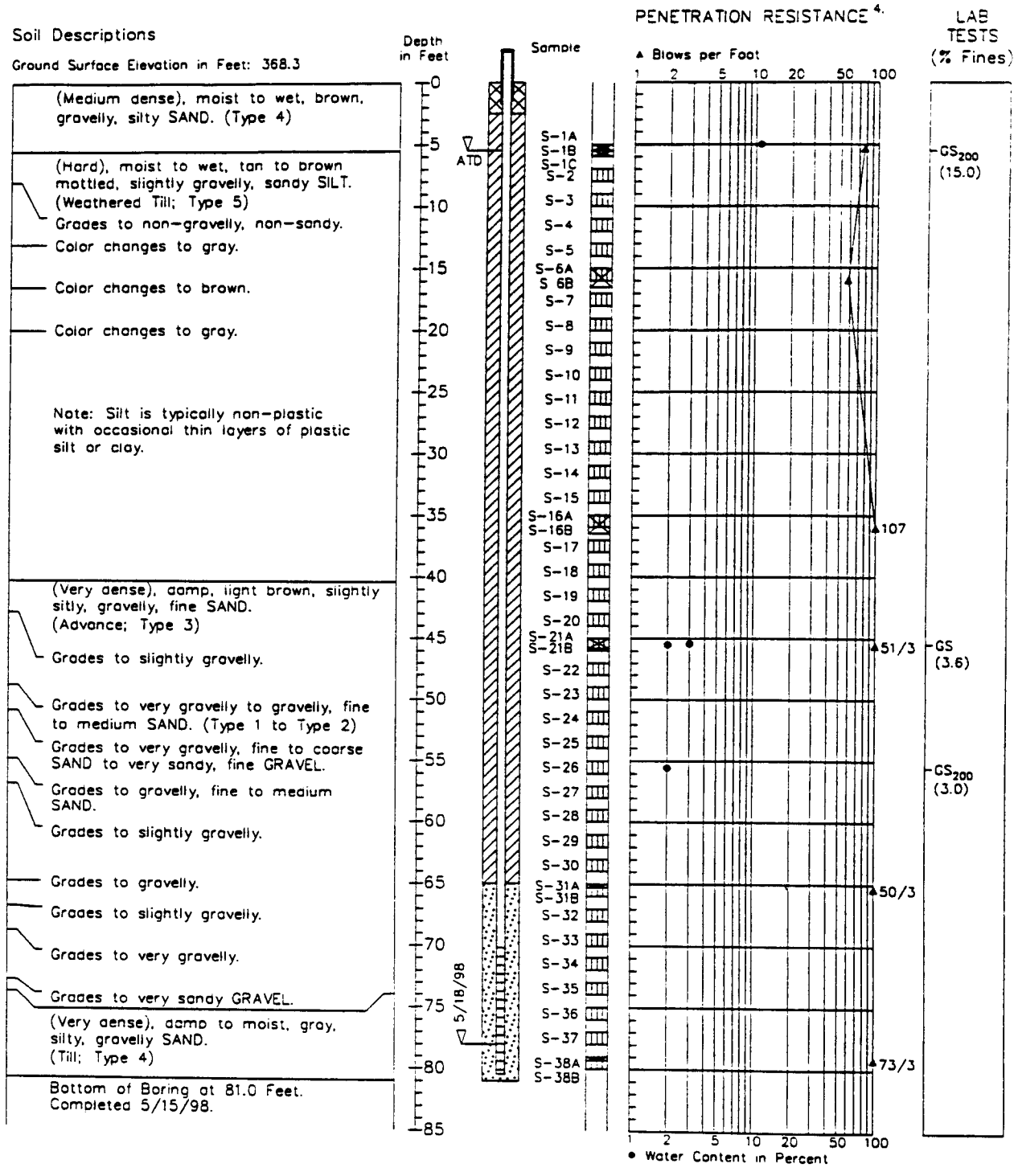
HARTCROWSER

J-4978 5/98

Figure A-13 2/2

AR 043038

Boring Log A4-B5-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

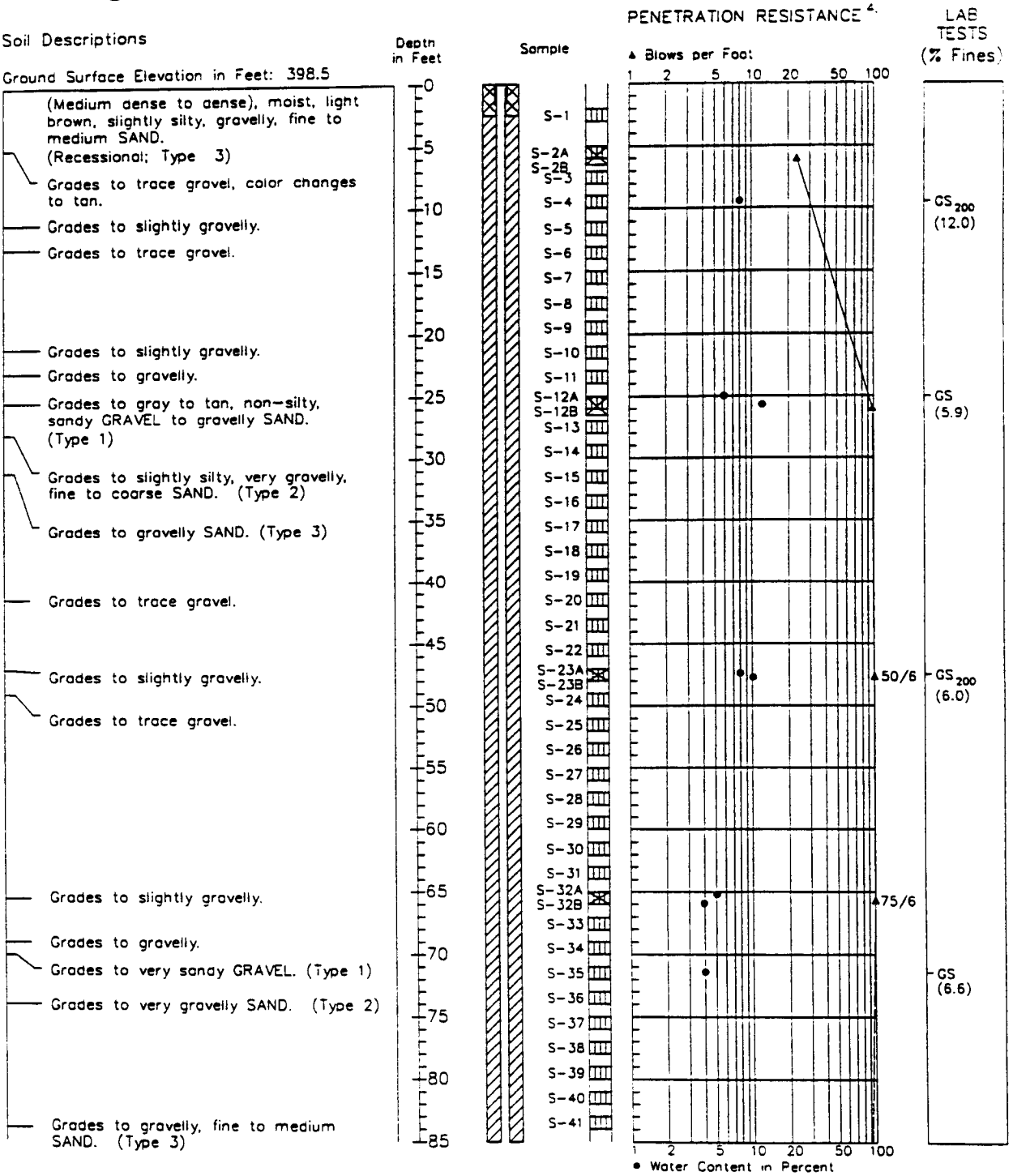
HARTCROWSER

J-4978 5/98

Figure A-14

AR 043039

Boring Log A4-B6-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

ACAD Log

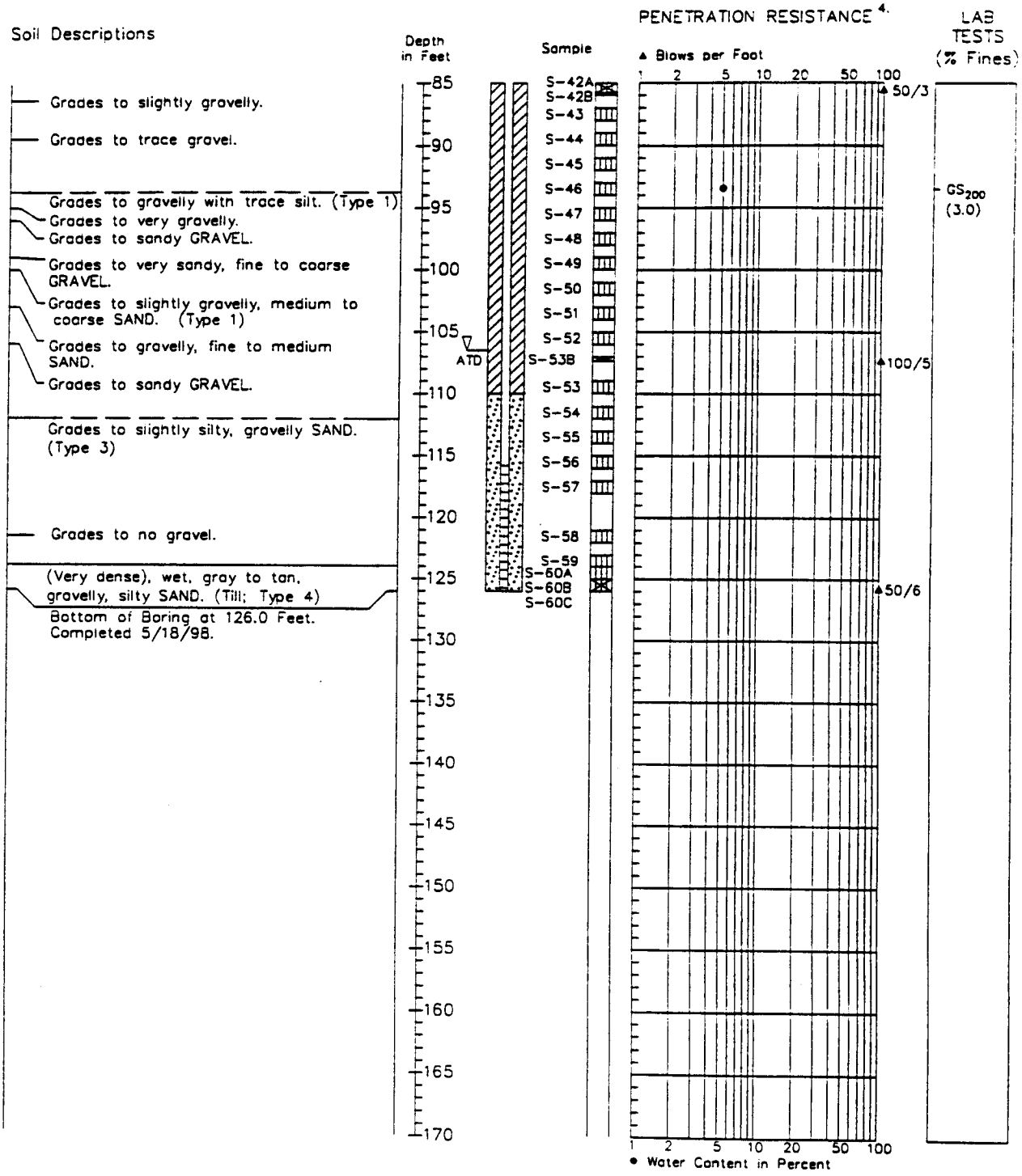
HARTCROWSER

J-4978 5/98

Figure A-15 1/2

AR 043040

Boring Log A4-B6-98



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts are for 140 pound hammer and 3-inch-diameter split-spoon sampler (i.e., Not conforming to ASTM D 1586) using down-hole techniques.
5. Refer to text for soil types.

HARTCROWSER

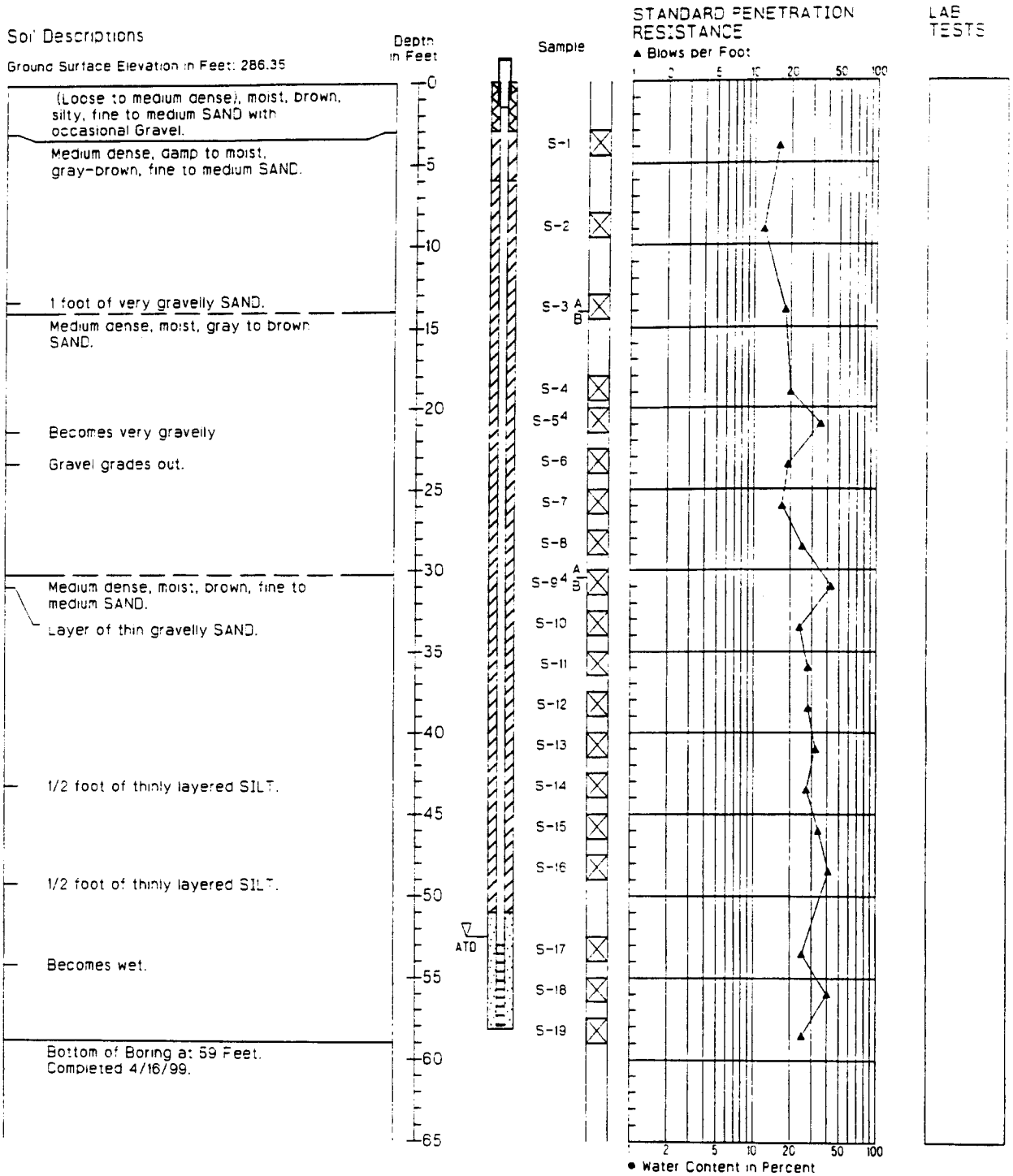
J-4978 5/98

Figure A-15 2/2

ACAD log

AR 043041

Boring Log A3-B13-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts may not be representative of density due to gravel.

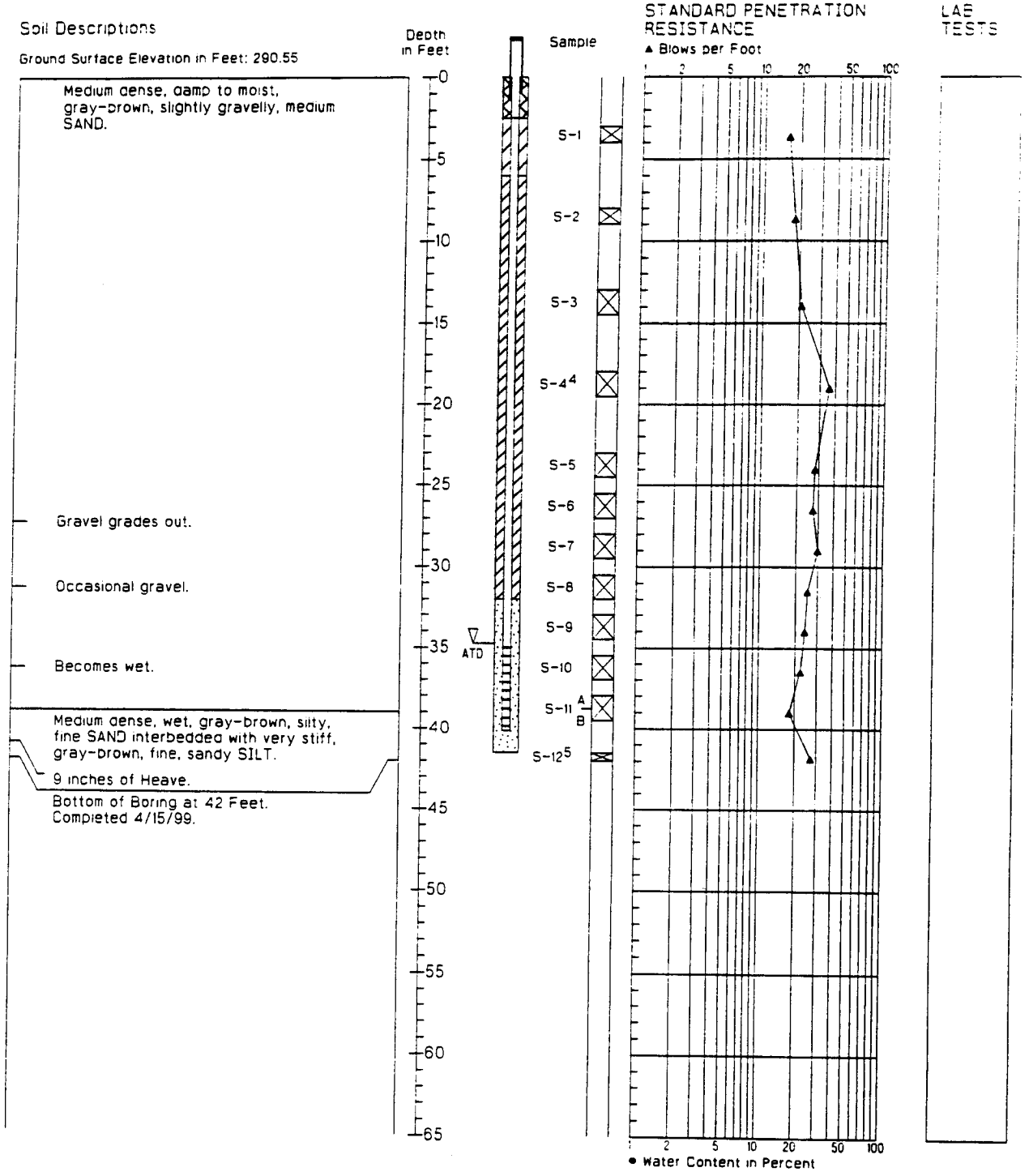
HARTCROWSER

J-4978-02 4/99

Figure A-18

AR 043042

Boring Log A3-B14-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts may not be representative of density due to gravel.
5. Blow count may not be representative due to heave.

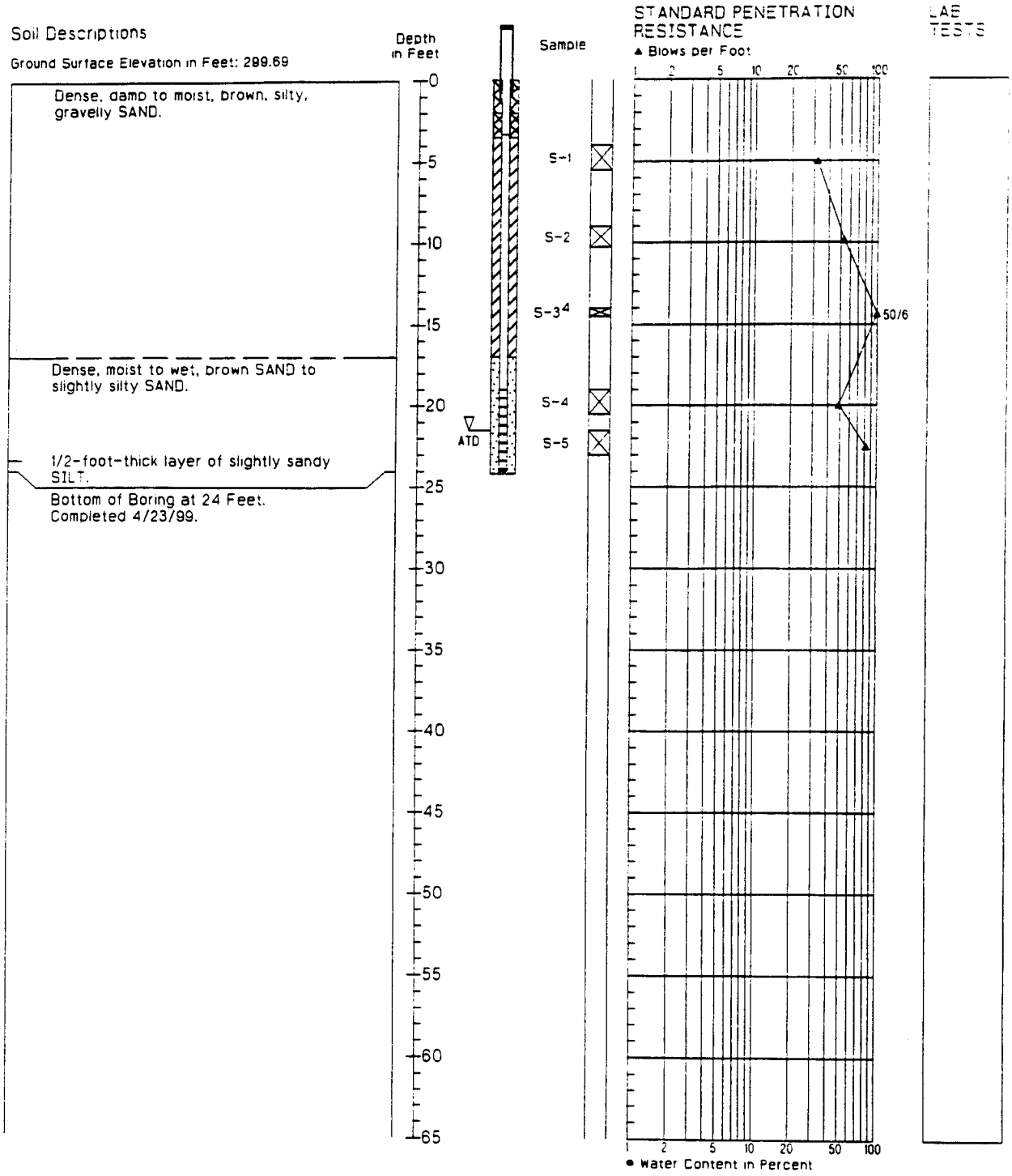
HARTCROWSER

J-4978-02 4/99

Figure A-17

AR 043043

Boring Log A3-B15-99



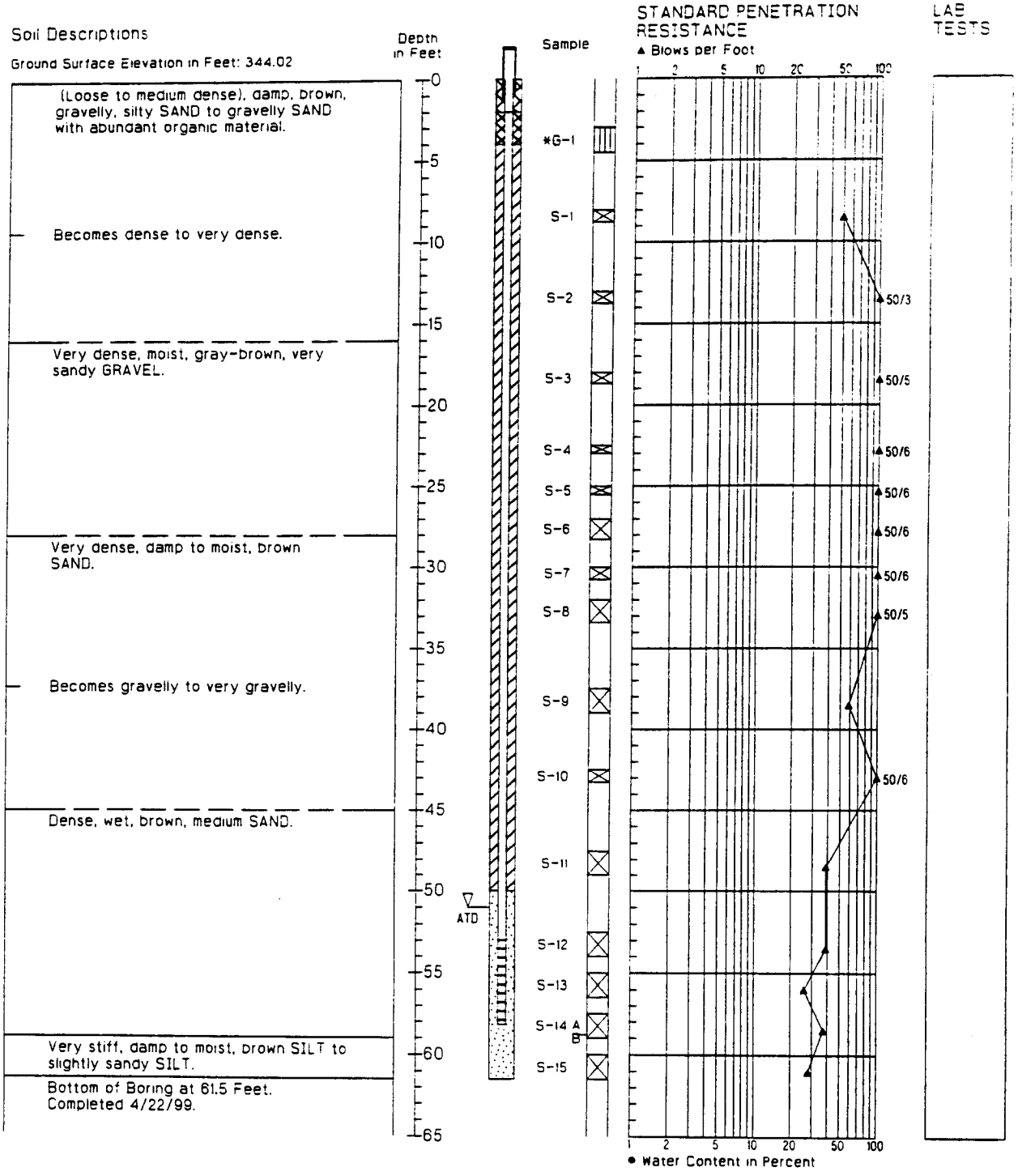
1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Blow counts may not be representative of density due to gravel.

HARTCROWSER

J-4978-02 4/99

Figure A-18

Boring Log A3-B16-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

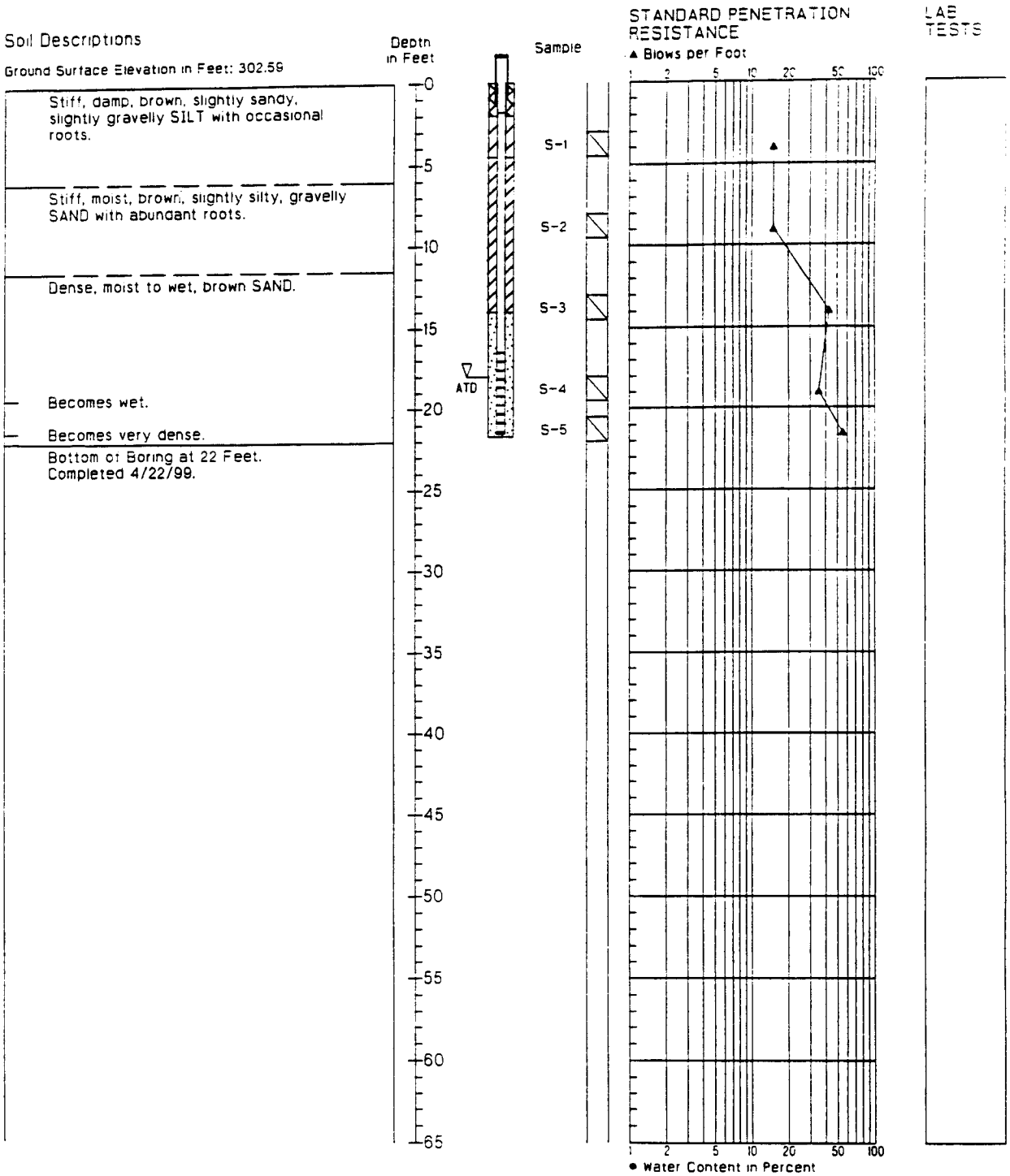
HARTCROWSER

J-4978-02 4/99

Figure A-10

AR 043045

Boring Log A3-B17-99



1. Refer to Figure B-2 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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J-4978-02 4/99

Figure A-20

AR 043046

UNIFIED SOIL CLASSIFICATIONS SYSTEM

MAJOR DIVISIONS				TYPICAL NAMES
COARSE GRAINED SOILS (More than half is larger than No. 200 Sieve)	GRAVELS (More than half coarse fraction is larger than No. 4 sieve size)	Clean gravels with little or no fines	GW	Well graded gravels, gravel-sand mixtures
			GP	Poorly graded gravels, gravel-sand mixtures
		Gravels with over 12% fines	GM	Silty Gravels, poorly graded gravel-sand-silt mixtures
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures
	SANDS (More than half coarse fraction is larger than No. 4 sieve size)	Clean sands with little or no fines	SW	Well graded sands, gravelly sands
			SP	Poorly graded sands, gravelly sands
		Sands with over 12% fines	SM	Silty sand, poorly graded sand-silt mixtures
			SC	Clayey sands, poorly graded sand-clay mixtures
FINE GRAINED SOILS (More than half is smaller than No. 200 Sieve)	SILTS AND CLAYS (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic clays and organic silty clays of low plasticity
	SILTS AND CLAYS (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomacious fine sandy or silty soils, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils

SAMPLE
- "Undisturbed"
- Bulk/Grab
- Not Recovered
- Recovered, Not Retained

CONTACT BETWEEN UNITS
- Well Defined Change
- Gradational Change
- Obscure Change
- End of Exploration

PHYSICAL PROPERTY TESTS

Consol	-	Consolidation
LL	-	Liquid Limit
PL	-	Plastic Limit
Gs	-	Specific Gravity
SA	-	Size Analysis
TxS	-	Triaxial Shear
TxP	-	Triaxial Permeability
Perm	-	Permeability
Po	-	Porosity
MD	-	Moisture/Density
DS	-	Direct Shear
VS	-	Vane Shear
Comp	-	Compaction

UU - Unconsolidated, Undrained
CU - Consolidated, Undrained
CD - Consolidated, Drained

BLOWS PER FOOT

Hammer is 140 pounds with 30-inch drop, unless otherwise noted
- S - SPT Sampler (2.0-Inch O.D.)
- T - Thin Wall Sampler (2.8-Inch Sample)
- H - Split Barrel Sampler (2.4-Inch Sample)

MOISTURE DESCRIPTION

Dry	- Considerably less than optimum for compaction
Moist	- Near optimum moisture content
Wet	- Over optimum moisture content
Saturated	- Below water table, in capillary zone, or in perched groundwater

AGI TECHNOLOGIES

Soil Classification/Legend

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE **A1**

soilclass.cdr	PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
	14.190.208	SES	6 December 94			

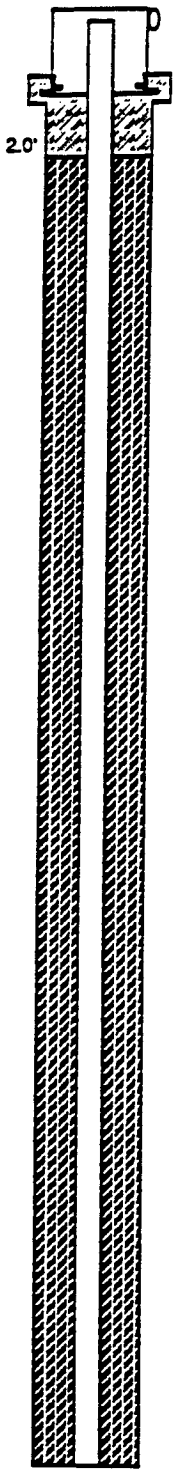
Figure A-21

AR 043047

P.O.S. Coordinates: N 1050 E 14,100

Equipment Mobile B-61

Land Surface Elevation 302 feet Date 12/5/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
				0	
MD,SA	16.5	100	18		
				5	
			50/5"		
				10	
MD,SA, COMP	5.7	126	50/5"		
				15	
			50/5"		
				20	
MD	9.5	125	50/2"		
				25	
			50/5"		
				30	
			50/5"		
				35	
			50/0"		
				40	

BROWN SILT (ML) stiff, moist; slightly mottled, with coarse sand (Topsoil).

BROWN SILTY SAND (SM) dense, moist; fine to coarse grained, with gravel (Weathered Till).

GRAY SILTY SAND (SM) very dense, moist; fine to coarse grained, with gravel (Till - Unit 1).

AGI TECHNOLOGIES

Log of Area 1 Boring 3 (0-40')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A5a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
14.190.208	ECR	6 December 94			

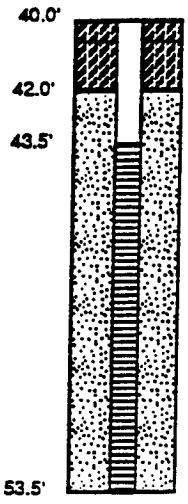
H1mw.cdr

Figure A-22 1/2

P.O.S. Coordinates: N 1050 E 14,100

Equipment Mobile B-61

Land Surface Elevation 302 feet Date 12/5/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
				40	
			50/5"	45	
			50/4"	50	
			50/6"	55	
				60	
				65	
				70	
				75	
				80	

GRAY SAND (SP) very dense, wet; fine to medium grained, with silt (Advance Outwash - Unit 1).

Becomes saturated.

Groundwater encountered at 36 feet during drilling.

Boring converted into piezometer on 12/6/94.

AGI TECHNOLOGIES

Log of Area 1 Boring 3 (40-53.5')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE **A5b**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H1-40.cdr 14,190.208	ECR	6 December 94			

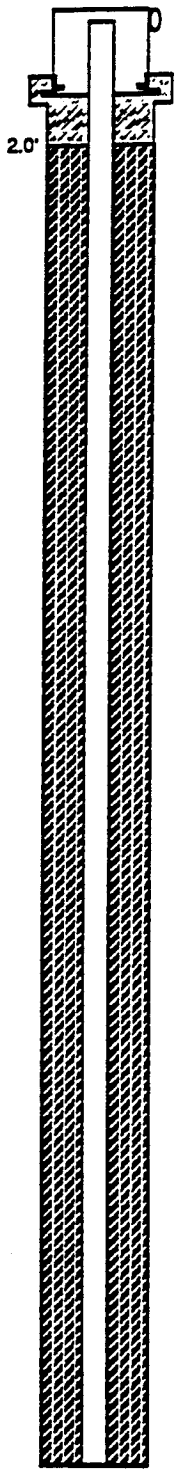
Figure A-22 2/2

AR 043049

P.O.S. Coordinates: N 4095 E 14,715

Equipment Mobile B-61

Land Surface Elevation 277 feet Date 12/1/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample	
				0		LIGHT BROWN SAND (SP) loose, dry; fine grained, with gravel and a trace of silt (Recessional Outwash - Unit 1).
MD,SA COMP	6.3	96	7	5		
			9	10		
MD,SA	3.3	97	15	15		Becomes medium dense with some silt.
			17	20		
MD	3.4	99	13	25		Color changes to light gray.
			15	30		
MD,SA	4.5	92	15	35		
			25	40		

AGI TECHNOLOGIES

Log of Area 1 Boring 9 (0-40')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A11a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H1Bmw.cdr 14,190.208	ECR	6 December 94			

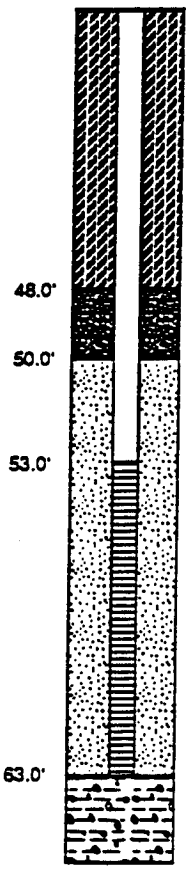
Figure A-23 1/2

AR 043050

P.O.S. Coordinates: N 4095 E 14,715

Equipment Mobile B-61

Land Surface Elevation 277 feet Date 12/1/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample	
				40		
MD	4.1	107	31			Becomes wet and dense.
				45		
			12			LIGHT BROWN SILTY SAND (SM) medium dense, saturated, fine grained (Recessional Outwash - Unit 2).
				50		
MD,SA	25.6	96	23			LIGHT BROWN SANDY SILT (ML) very stiff, saturated, (Recessional Outwash - Unit 2).
				55		
MD	6.5	140	50/5"			DARK GRAY GRAVEL (GP) very dense, saturated; fine grained gravel and fine to coarse grained sand, with a trace of silt (Advance Outwash - Unit 3).
				60		
			57			DARK GRAY SILTY GRAVEL (GM) very dense, saturated; fine to coarse grained gravel and sand, with silt (Advance Outwash - Unit 3).
				65		Groundwater encountered at 48 feet during drilling.
						Boring converted into piezometer on 12/23/94.
				70		
				75		
				80		

AGI TECHNOLOGIES

Log of Area 1 Boring 9 (40-64.5')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE **A11b**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H1-40.cdr	14,190.208	ECR	6 December 94		

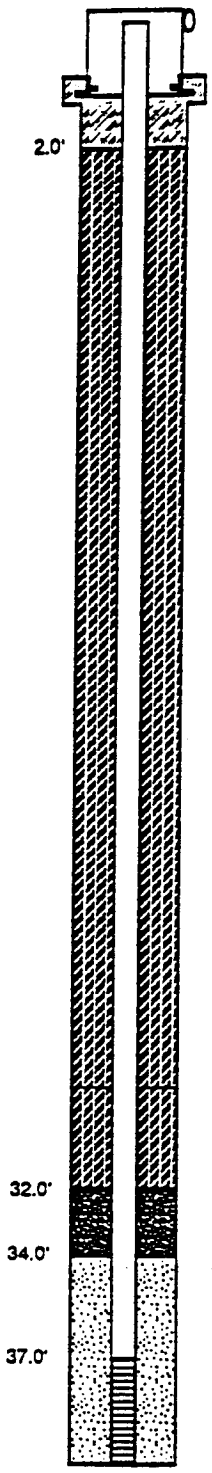
Figure A-23 2/2

AR 043051

P.O.S. Coordinates: N 2930 E 12,950

Equipment Mobile B-61

Land Surface Elevation 250 feet Date 12/2/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample	
				0		BROWN SAND (SP) medium dense, moist; fine to medium grained, with a trace of gravel (Recessional Outwash - Unit 1).
MD	5.4	101	11	5		
MD,SA	6.8	94	9	10		Becomes loose.
MD	3.7	95	15	15		Becomes gray and medium dense.
COMP						BROWN SILTY SAND (SM) medium dense, moist; gravelly silt interbeds (Recessional Outwash - Unit 2).
MD,SA	15.6	112	14	20		
MD	11.6	96	18	25		RED BROWN SAND (SP) medium dense, moist; fine grained (Recessional Outwash - Unit 1).
MD,SA	6.2	102	17	30		
MD	22.3	101	44	35		Becomes gray, dense, and fine to medium grained.
MD	23.6	99	19	40		Becomes medium dense and saturated, with silt.

AGI TECHNOLOGIES

Log of Area 3 Boring 3 (0-40')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A18a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
14.190.208	ECR	6 December 94			

H3mw.cdr

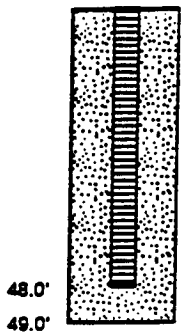
Figure A-24 1/2

AR 043052

P.O.S. Coordinates: N 2930 E 12,950

Equipment Mobile B-61

Land Surface Elevation 250 feet Date 12/2/94



48.0'
49.0'

Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
				40	
			22		
SA COMP				45	
			30		
				50	
				55	
				60	
				65	
				70	
				75	
				80	

Groundwater encountered at 37.5 feet during drilling.

Boring converted into piezometer on 12/2/94.

AGI TECHNOLOGIES

Log of Area 3 Boring 3 (40-49')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE **A18b**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H3-40.cdr	14.190.208	ECR	6 December 94		

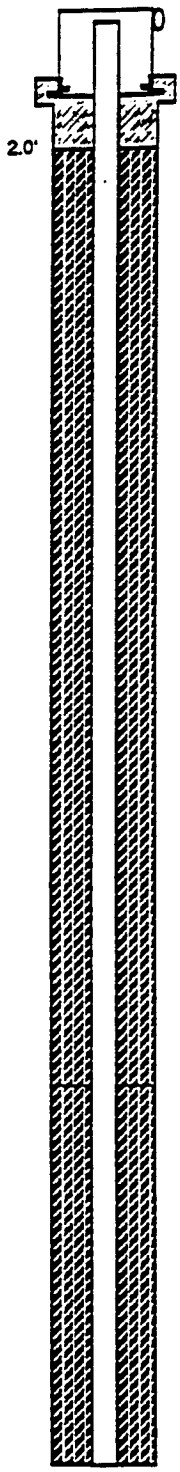
Figure A-24 2/2

AR 043053

P.O.S. Coordinates: N 5590 E 12,900

Equipment Mobile B-61

Land Surface Elevation 315 feet Date 12/22/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample	
				0		BROWN SAND (SP) loose, moist; fine to medium grained, with a trace of fine gravel and silt (Recessional Outwash - Unit 1).
MD,SA COMP	12.3	99	4	5		
			13	10		BROWN SILTY SAND (SM) medium dense, moist; fine to coarse grained, with gravel (Recessional Outwash - Unit 2).
MD,SA	13.7	120	70	15		BROWN SAND (SM) very dense, wet; fine to coarse grained, with gravel (Advance Outwash - Unit 1).
SA,COMP	8.6		50/6"	20		BROWN SAND (SW-SM) very dense, wet; fine to coarse grained, with gravel and silt (Advance Outwash - Unit 1)
MD	5.8	129	50/5"	25		BROWN GRAVEL (GP) very dense, moist; fine to coarse grained gravel, medium grained sand (Advance Outwash - Unit 3).
			62	30		BROWN SAND (SP) very dense, moist; fine to medium grained (Advance Outwash - Unit 1).
MD,SA	15.5	111	13	35		BROWN SAND (SW-SM) medium dense, saturated; fine to coarse grained, with fine gravel and silt (Advance Outwash - Unit 1).
			D278			BROWN SANDY SILT (ML) hard, saturated, fine grained (Advance Outwash - Unit 2).
COMP			50/6"	40		

AGI TECHNOLOGIES

Log of Area 3 Boring 7 (0-40')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A22a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H3mw.cdr 14,190.208	ECR	6 December 94			

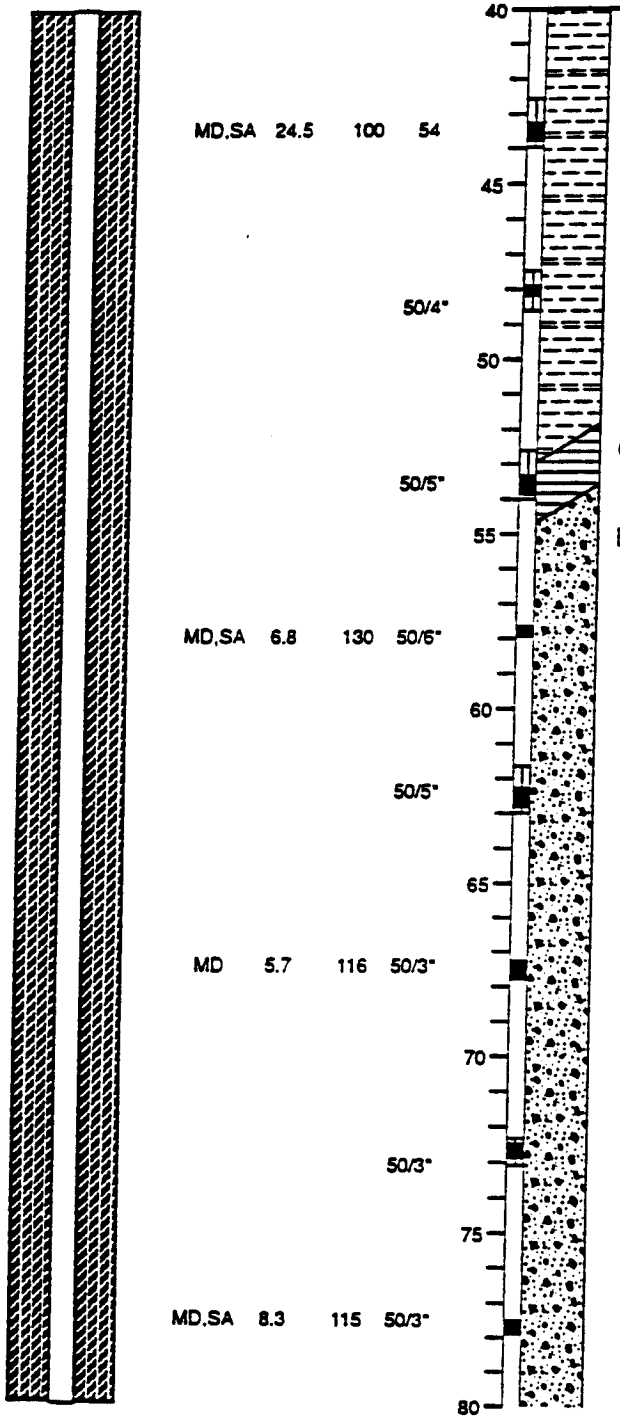
Figure A-25 1/3

AR 043054

P.O.S. Coordinates: N 5590 E 12,900

Equipment Mobile B-61

Land Surface Elevation 315 feet Date 12/22/94



GRAY CLAY (CL) hard, moist; with some fine gravel (Advance Outwash - Unit 2).

BROWN GRAVEL (GP-GM) very dense, wet; fine to medium grained gravel, with sand and pockets of silt (Advance Outwash - Unit 3).

AGI TECHNOLOGIES

Log of Area 3 Boring 7 (40-80')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A22b

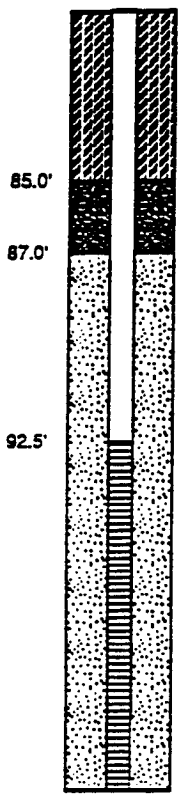
PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H3-40.cdr	14,190.208	ECR	6 December 94			

AR 043055

P.O.S. Coordinates: N 5590 E 12,900

Equipment Mobile B-61

Land Surface Elevation 315 feet Date 12/22/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
				80	
			50/6"		
				85	
MD	20.4	103	50/2"		
				90	
			50/2"		
				95	
			50/4"		
				100	
				105	
				110	
				115	
				120	

Becomes saturated.

DARK GRAY GRAVEL (GW) very dense, saturated; fine to coarse grained gravel, with some sand and silt (Advance Outwash - Unit 3).

Groundwater encountered at 82 feet during drilling.

Perched groundwater encountered at 33 feet during drilling.

Boring converted into piezometer on 12/22/94.

AGI TECHNOLOGIES

Log of Area 3 Boring 7 (80-102.5')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A22c

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H3-80.ccr 14,190.208	ECR	6 December 94			

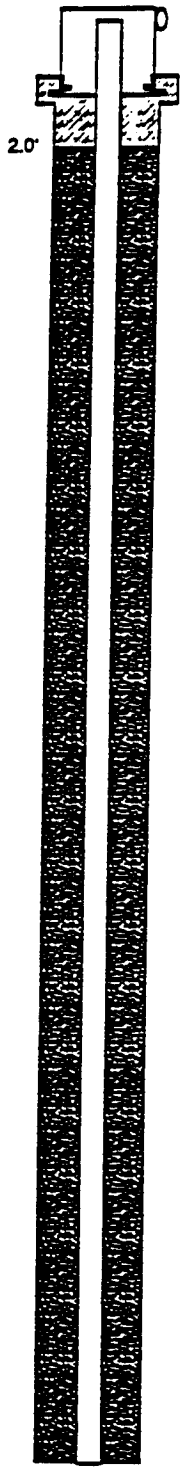
Figure A-25 2/3

AR 043056

P.O.S. Coordinates: N 6465 E 12,070

Equipment Mobile B-61

Land Surface Elevation 395 feet Date 12/21/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
MD,SA	20.5	85	9	0	
				5	
			67		
				10	
SA, COMP			50/6"		
				15	
SA	7.5		50/5"		
				20	
MD	7.1	11.5	67		
				25	
			50/5"		
				30	
MD,SA	6.3	106	50/6"		
				35	
			50/5"		
				40	

DARK BROWN SILT (ML) medium stiff, moist; with some sand and organics (Alluvium).

REDDISH BROWN SILTY SAND (SM) loose, moist; fine to coarse grained, with gravel (Alluvium).

GRAY SAND (SW-SM) very dense, moist; fine to coarse grained, with gravel and silt (Advance Outwash - Unit 1).

GRAY SAND (SP) very dense, moist; fine grained, with trace silt (Advance Outwash - Unit 1).

AGI TECHNOLOGIES

Log of Area 4 Boring 1 (0-40')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A23a

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
14,190.208	ECR	6 December 94			

H4mw.ccr

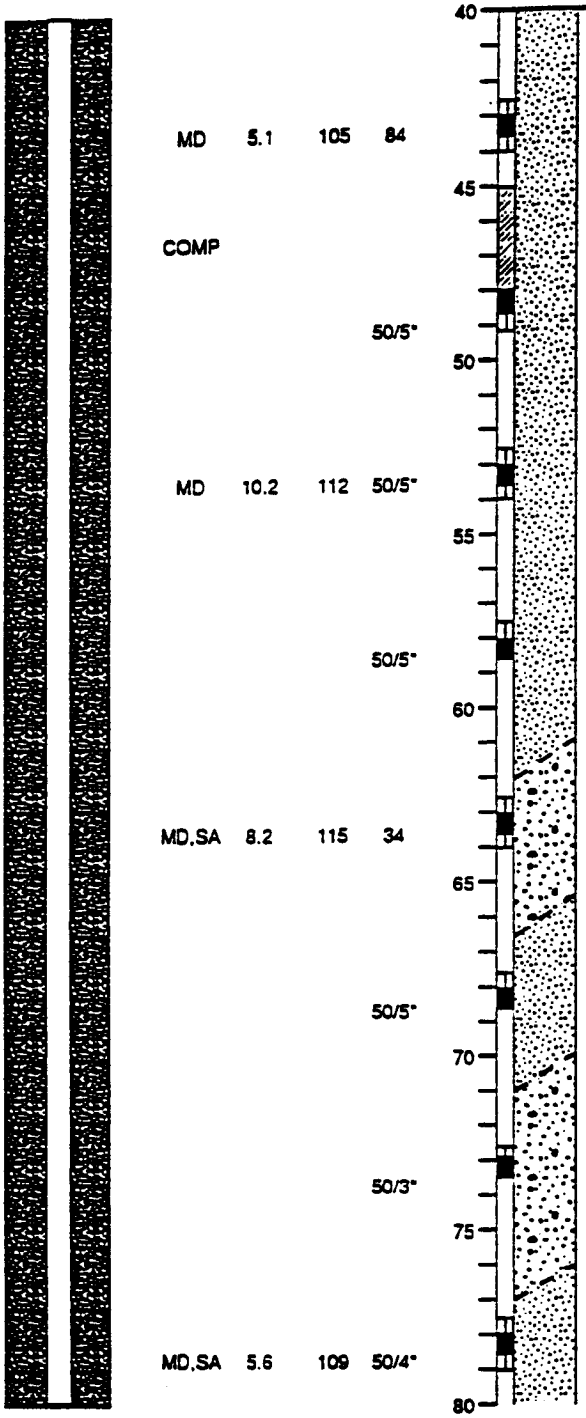
Figure A-26 1/2

AR 043057

P.O.S. Coordinates: N 6465 E 12,070

Equipment Mobile B-61

Land Surface Elevation 395 feet Date 12/21/94



GRAY SAND (SW) very dense, moist; fine to coarse grained, with silt and a trace of fine gravel (Advance Outwash - Unit 1).

GRAY SAND (SP) very dense, moist; fine grained (Advance Outwash - Unit 1).

GRAY SAND (SW) very dense, wet; fine to coarse grained, with fine gravel (Advance Outwash - Unit 1).

GRAY SAND (SP-SM) very dense, wet; fine to medium grained, with trace fine gravel and silt (Advance Outwash - Unit 1).

AGI TECHNOLOGIES

Log of Area 4 Boring 1 (40-80')

HNTB/Runway Borrow Source Study
SeaTac, Washington

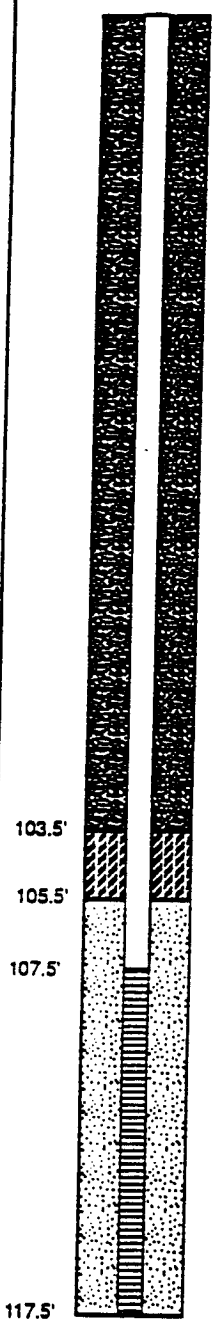
PLATE **A23b**

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H4-40.cdr 14,190.208	ECR	6 December 94			

P.O.S. Coordinates: N 6465 E 12,070

Equipment Mobile B-61

Land Surface Elevation 395 feet Date 12/21/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
			50/5"	80	
				85	
			50/3"		
				90	
MD,SA	6.8	110	50/5"		
				95	
			50/6"		
				100	
MD	11.0	127	50/6"		
				105	
			50/3"		
				110	
			50/6"		
				115	
			50/3"		
				120	

GRAY SAND (SW) very dense, wet; fine to coarse grained, with gravel and a trace of silt (Advance Outwash - Unit 1).

GRAY SAND (SP) very dense, saturated, fine to medium grained, with silt interbeds (Advance Outwash - Unit 1).

BROWN GRAVEL (GP-GM) very dense, saturated; fine to coarse grained, with sand and silt (Advance Outwash - Unit 3).

BROWN SILTY SAND (SM) very dense, saturated; fine grained (Advance Outwash - Unit 2).

Color changes to dark gray.

Groundwater encountered at 98 feet during drilling.
Boring converted into piezometer on 12/22/94.

AGI TECHNOLOGIES

Log of Area 4 Boring 1 (80-118.3')

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE **A23c**

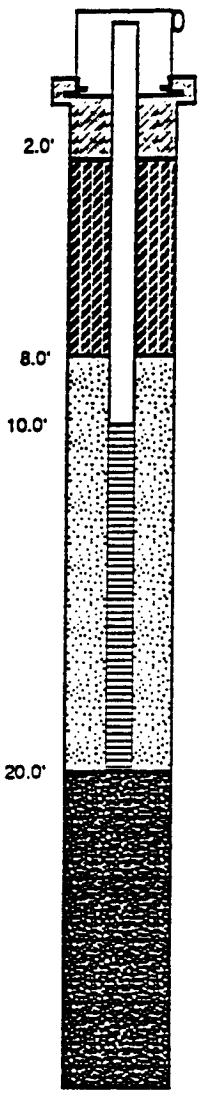
PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
H4-80.cdr 14,190.208	ECR	6 December 94			

AR 043059

P.O.S. Coordinates: N 6790 E 11,680

Equipment Mobile B-61

Land Surface Elevation 343 feet Date 12/5/94



Laboratory Tests	Moisture Content (%)	Dry Density (pcf)	Blows per Foot	Depth (feet)	Sample
MD,SA	6.2	119	41	0	
				5	
			50/3"		
				10	
MD,SA	13.3	119	50/6"		
				15	
			44		
				20	
			50		
				25	
MD,PL LL	25.1	103	49		
				30	
				35	
				40	

BROWN SAND (SW) dense, dry; fine to coarse grained, with gravel and a trace of silt (Advance Outwash - Unit 1).

Becomes very dense, saturated.

GRAY SILT (ML) hard, moist (Pre-Vashon Drift).

Groundwater encountered at 6.5 feet during drilling.

Boring converted into piezometer on 12/5/94.

AGI TECHNOLOGIES

Log of Area 4 Boring 2

HNTB/Runway Borrow Source Study
SeaTac, Washington

PLATE A24

PROJECT NO.	DRAWN	DATE	APPROVED	REVISED	DATE
14,190.208	ECR	6 December 94			

H4mw.cdr

Figure A-27

AR 043060

APPENDIX B
LABORATORY TESTING PROGRAM

APPENDIX B
LABORATORY TESTING PROGRAM

Hart Crowser completed a laboratory testing program to evaluate the basic index and geotechnical engineering properties of the site soils. Disturbed bag samples from the drill rig cyclone and jar samples from penetration tests were selected for laboratory testing with the following items in mind:

- Suitability of soils for use as wet weather fill;
- Soils representative of the geologic unit;
- Consistency within a geologic unit; and
- Sampling soils generally within the depth of the proposed excavation (based on existing information).

The tests performed and the procedures followed are outlined below.

Soil Classification

Field Observation and Laboratory Analysis. Soil samples from the explorations were visually classified in the field and then taken to our laboratory where the classifications were verified in a relatively controlled laboratory environment. Field and laboratory observations include density/consistency, moisture condition, and grain size and plasticity estimates.

The classifications of selected samples were checked by laboratory tests such as grain size analyses and 200 wash. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure B-1.

Water Content Determinations

Water contents were determined for specific samples recovered in the explorations in general accordance with ASTM D 2216, as soon as possible following their arrival in our laboratory. Water contents were not determined for very small samples nor samples where large gravel contents would result in values considered unrepresentative. The results of these tests are plotted at the respective sample depth on the exploration logs. In addition, water contents are routinely determined for samples subjected to other testing. These are also presented on the exploration logs.

Water contents were compared for samples of cuttings from the drill cyclone bag samples with water contents obtained from conventional SPT split-spoon samples, as shown on the drill logs. In some, but not all, cases it appeared that the cuttings samples were slightly drier than the SPT samples, as might be expected. Superficially it appears that the more silty samples typically exhibited less drying due to drill action compared to coarser-grained samples. In general we recommend that moisture content of SPT samples be considered more representative of *in situ* conditions compared to those of cuttings samples.

Grain Size Analysis (GS)

Grain size distribution was analyzed on representative samples in general accordance with ASTM D 422. Wet sieve analysis was used to determine the size distribution greater than the U.S. No. 200 mesh sieve. The size distribution for particles smaller than the No. 200 mesh sieve was determined by the hydrometer method for a selected number of samples. The results of the tests are presented as curves on Figures B-2 through B-7 plotting percent finer by weight versus grain size.

200-Wash Based on the Fraction Less Than the 3/4-inch Sieve (GS_{200})

Several samples were subjected to a modified grain size classification known as a 200-wash. The portion of individual samples passing the 3/4-inch sieve was "washed" through the No. 200 mesh sieve to determine the relative percentages of coarse- and fine-grained material in the samples. The tests were performed in general accordance with ASTM D 1140. The results are presented on the boring logs.

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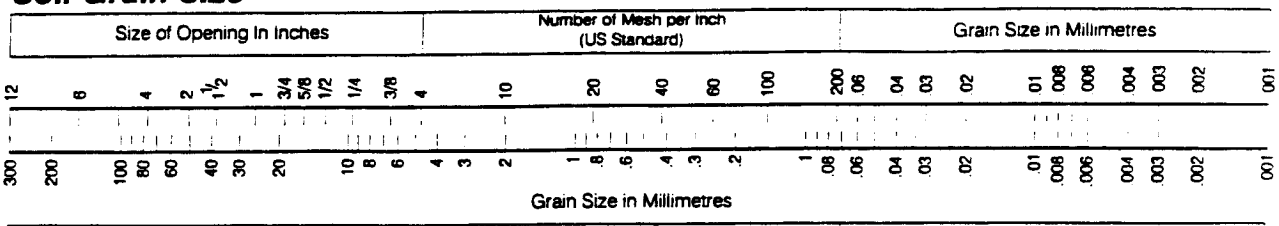
Unified Soil Classification (USC) System

Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines	*	GRAVEL with >12% fines		Clean SAND <5% fines	*	SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right) > 4$ for G W, > 6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

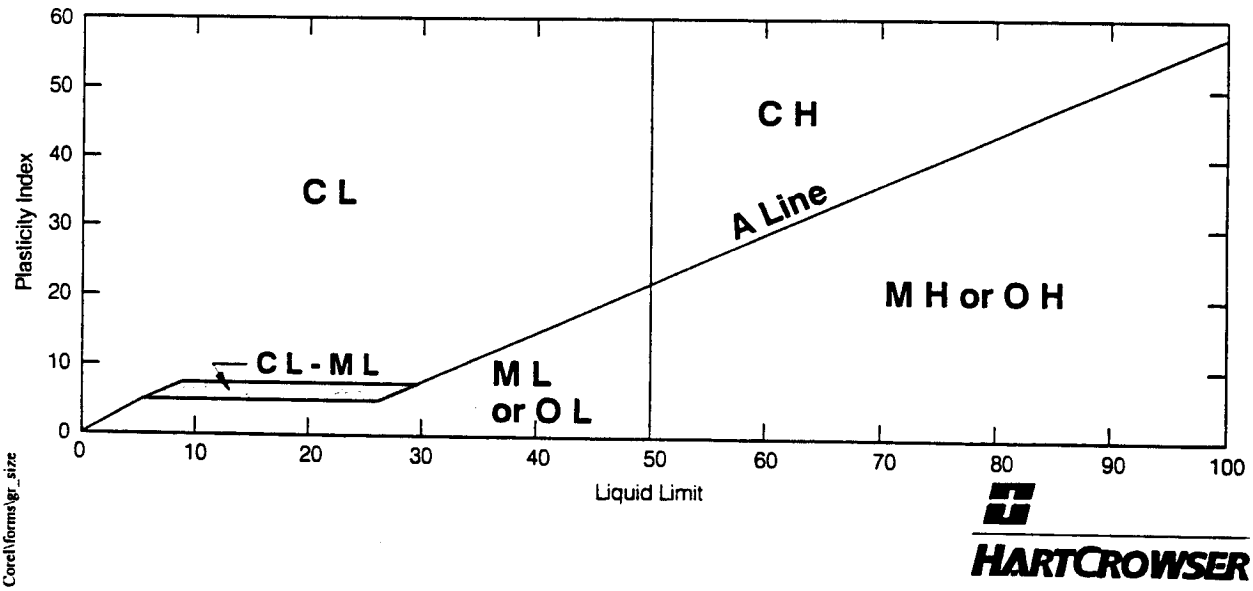
G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases required use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						



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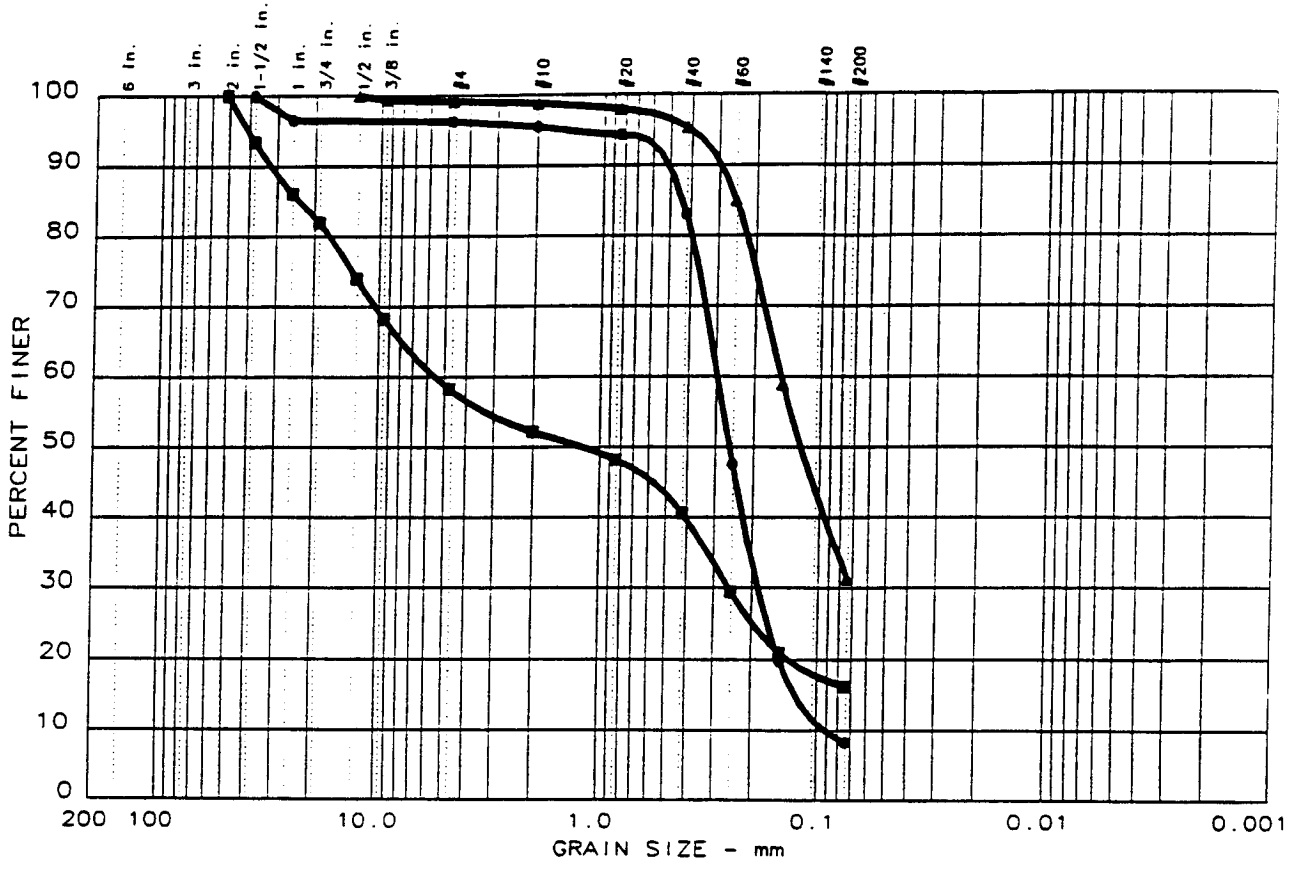
HARTCROWSER

J-4978-02 8/99

Figure B-1

AR 043064

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	3.6	88.1	8.3	
▲	0.0	0.8	67.9	31.3	
■	0.0	41.7	42.1	16.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.44	0.30	0.26	0.188	0.1255	0.0909	1.31	3.2
▲			0.25	0.15	0.12					
■			23.17	5.50	1.17	0.254				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty SAND	SP-SM	6%
▲ Very silty SAND	SM	6%
■ Silty, very gravelly SAND	SM	11%

Remarks:

Project: 3rd Runway

- ● Location: A3-B8-98, S-1, Depth 5 Feet
- ▲ Location: A3-B8-98, S-7, Depth 30 Feet
- ■ Location: A3-B8-98, S-13, Depth 60 Feet

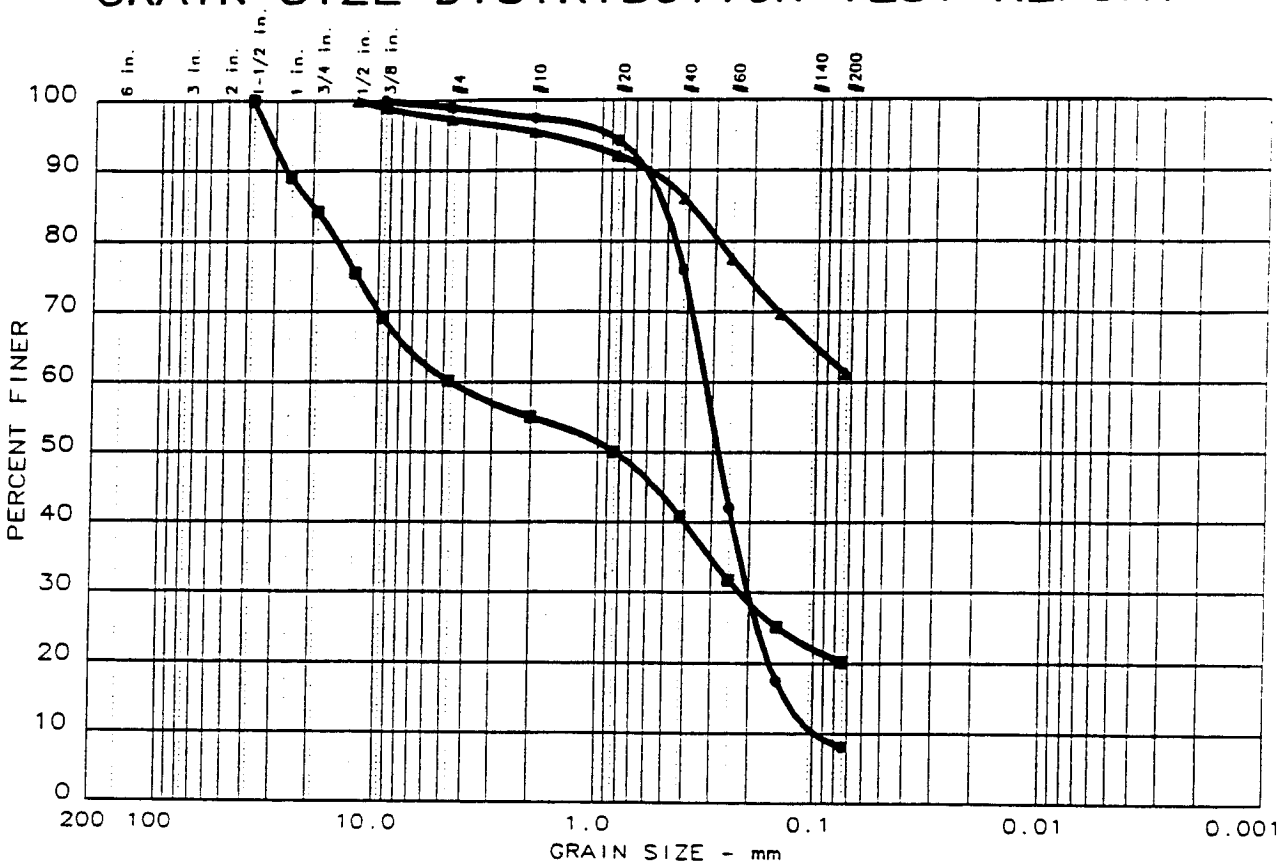
HART CROWSER

J-4978-02 5/14/98

Figure B-2

AR 043065

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	1.0	90.9	8.1	
▲	0.0	2.7	36.0	61.3	
■	0.0	39.8	40.0	20.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.52	0.33	0.28	0.203	0.1354	0.0981	1.29	3.3
▲			0.38							
■			19.72	4.62	0.83	0.221				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty SAND	SP-SM	11%
▲ Very sandy SILT	ML	26%
■ Silty, very gravelly SAND	SM	8%

Remarks:

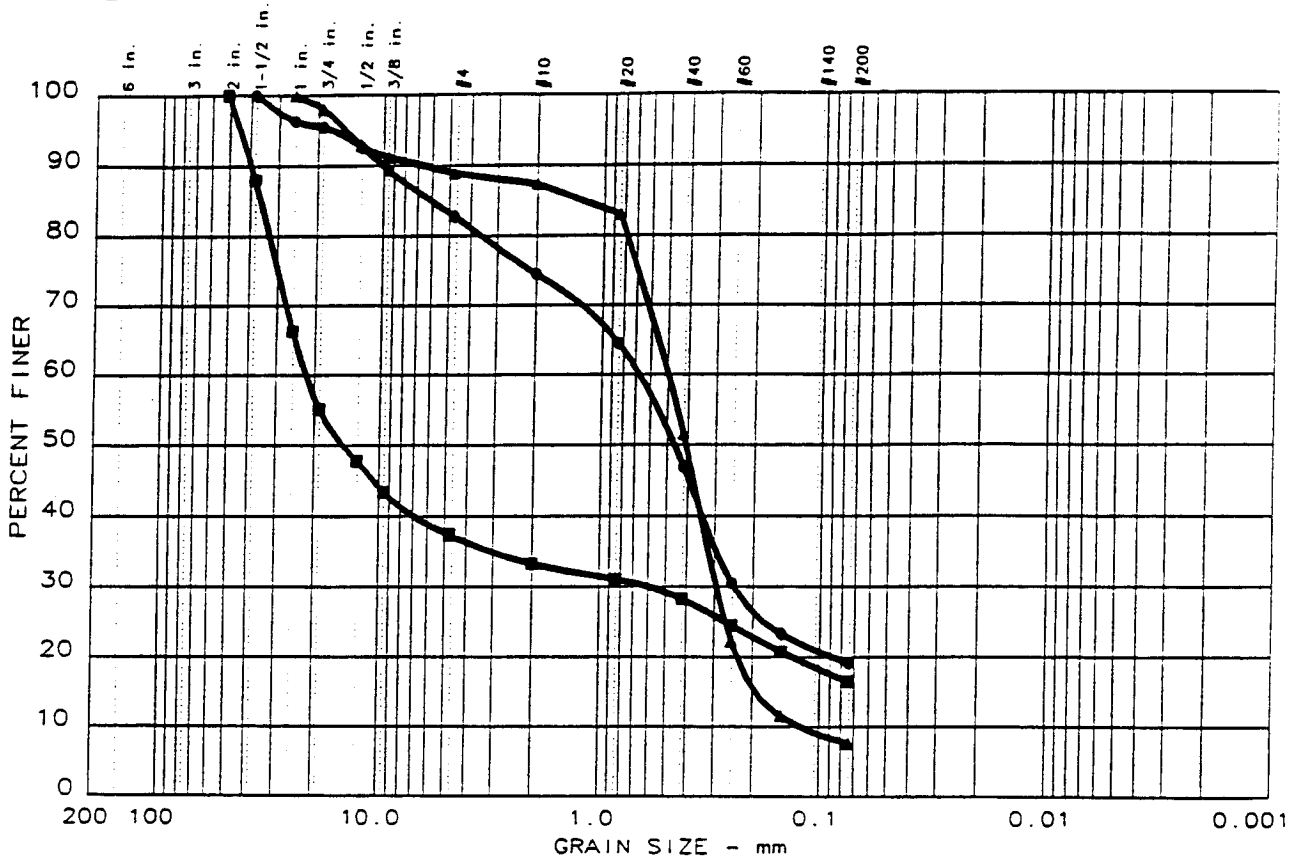
Project: 3rd Runway

- ● Location: A3-B9-98, S-1A, Depth 5 Feet
- ▲ Location: A3-B9-98, S-6, Depth 28 Feet
- ■ Location: A3-B9-98, S-8, Depth 35 Feet

HARTCROWSER J-4978-02 5/18/98

Figure B-3

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	17.3	63.6	19.1	
▲	0.0	11.0	81.3	7.7	
■	0.0	62.4	21.0	16.6	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			5.96	0.67	0.46	0.242				
▲			1.24	0.50	0.41	0.293	0.1936	0.1180	1.47	4.2
■			35.77	21.98	14.69	0.578				

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Gravelly, silty SAND	SM	11%
▲ Slightly silty, slightly gravelly SAND	SP-SM	11%
■ Silty, sandy GRAVEL	GM	6%

Remarks:

Project: 3rd Runway

- ● Location: A3-B10-98, S-2, Depth 10 Feet
- ▲ Location: A3-B10-98, S-5A, Depth 25 Feet
- ■ Location: A3-B10-98, S-13A, Depth 65

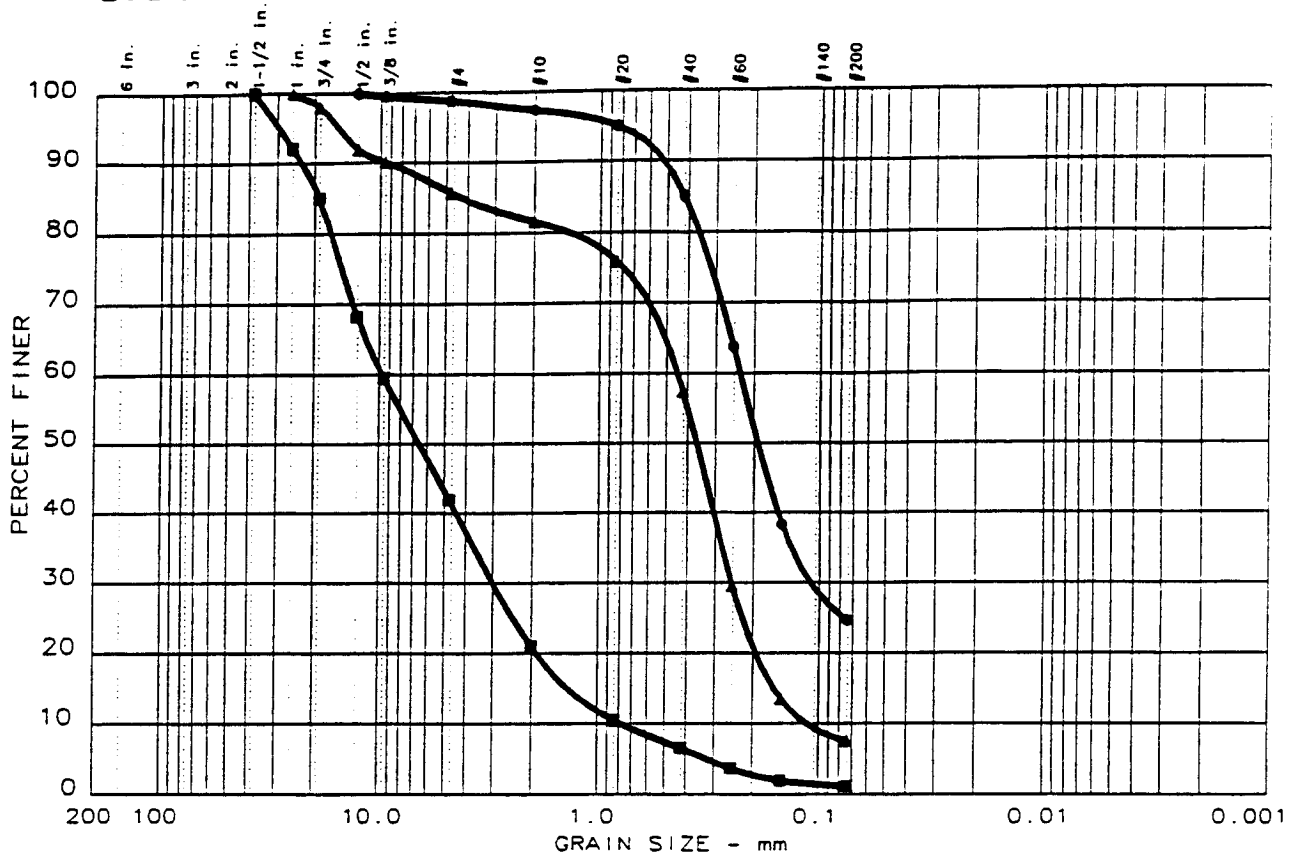
HART CROWSER

J-4978-02 5/18/98

Figure B-4

AR 043067

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	1.2	74.2	24.6	
▲	0.0	14.3	78.1	7.6	
■	0.0	58.0	40.8	1.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.42	0.23	0.19	0.111				
▲			4.22	0.44	0.36	0.251	0.1603	0.1135	1.25	3.9
■			19.03	9.65	6.52	2.982	1.3630	0.7754	1.19	12.4

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Silty SAND	SM	18%
▲ Slightly silty, gravelly SAND	SP-SM	16%
■ Very sandy GRAVEL	GW	10%

Remarks:

Project: 3rd Runway
- ● Location: A3-B11-98, S-46A, Depth 95 Feet
- ▲ Location: A3-B12-98, S-11A, Depth 25 Feet
- ■ Location: A3-B12-98, S-12, Depth 27 Feet

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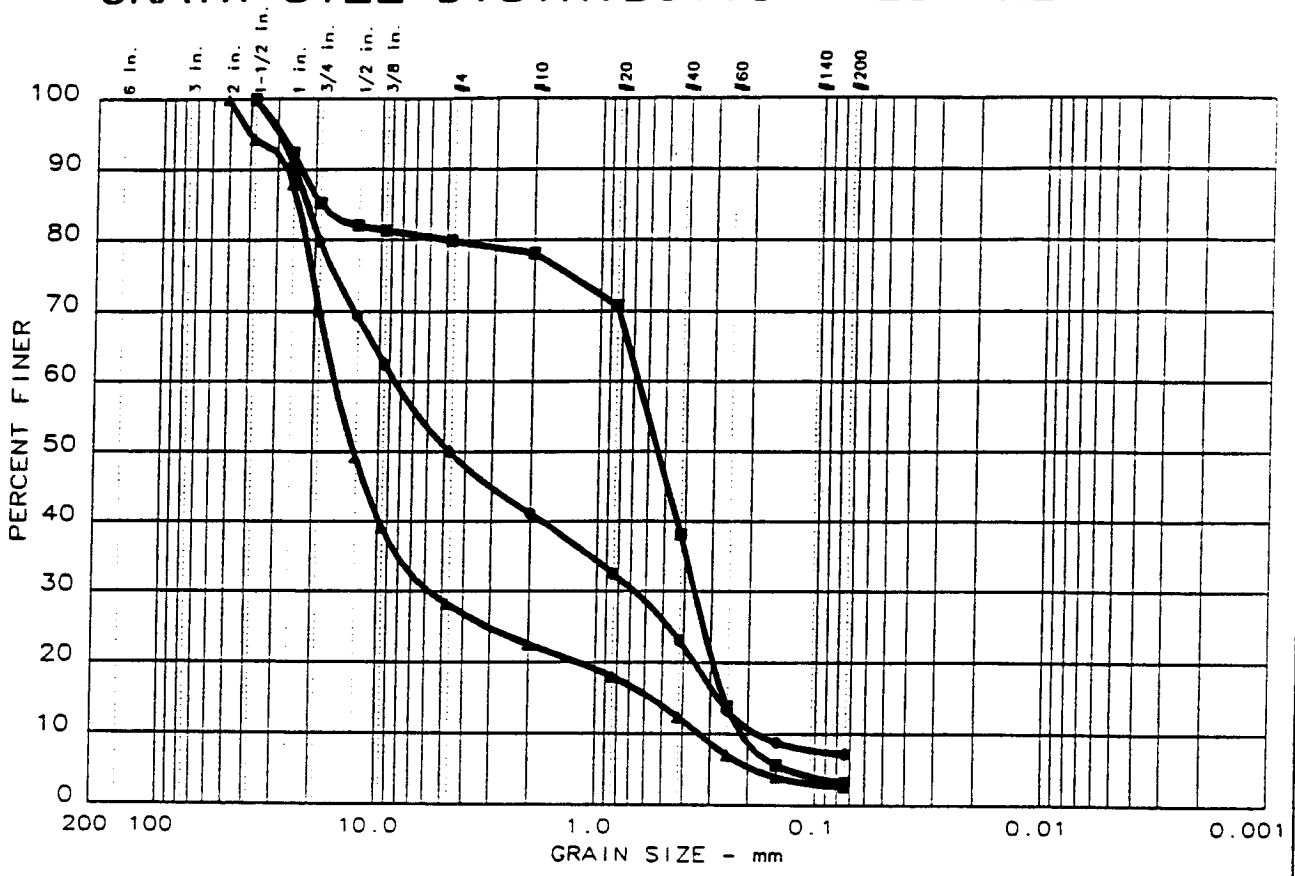
Figure B-5

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	49.9	42.9	7.2	
▲	0.0	71.7	25.6	2.7	
■	0.0	20.1	76.7	3.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			21.83	8.49	4.72	0.667	0.2748	0.1816	0.29	46.8
▲			23.88	16.01	12.87	5.682	0.5553	0.3308	6.10	48.4
■			18.62	0.67	0.54	0.361	0.2585	0.2150	0.91	3.1

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, very sandy GRAVEL	GP-GM	8%
▲ Sandy GRAVEL	GP	5%
■ Gravelly SAND	SP	2%

Remarks:

Project: 3rd Runway

- ● Location: A4-B4-98, S-7, Depth 13 Feet
- ▲ Location: A4-B4-98, S-33A, Depth 66 Feet
- ■ Location: A4-B5-98, S-21A, Depth 45 Feet

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Figure B-6

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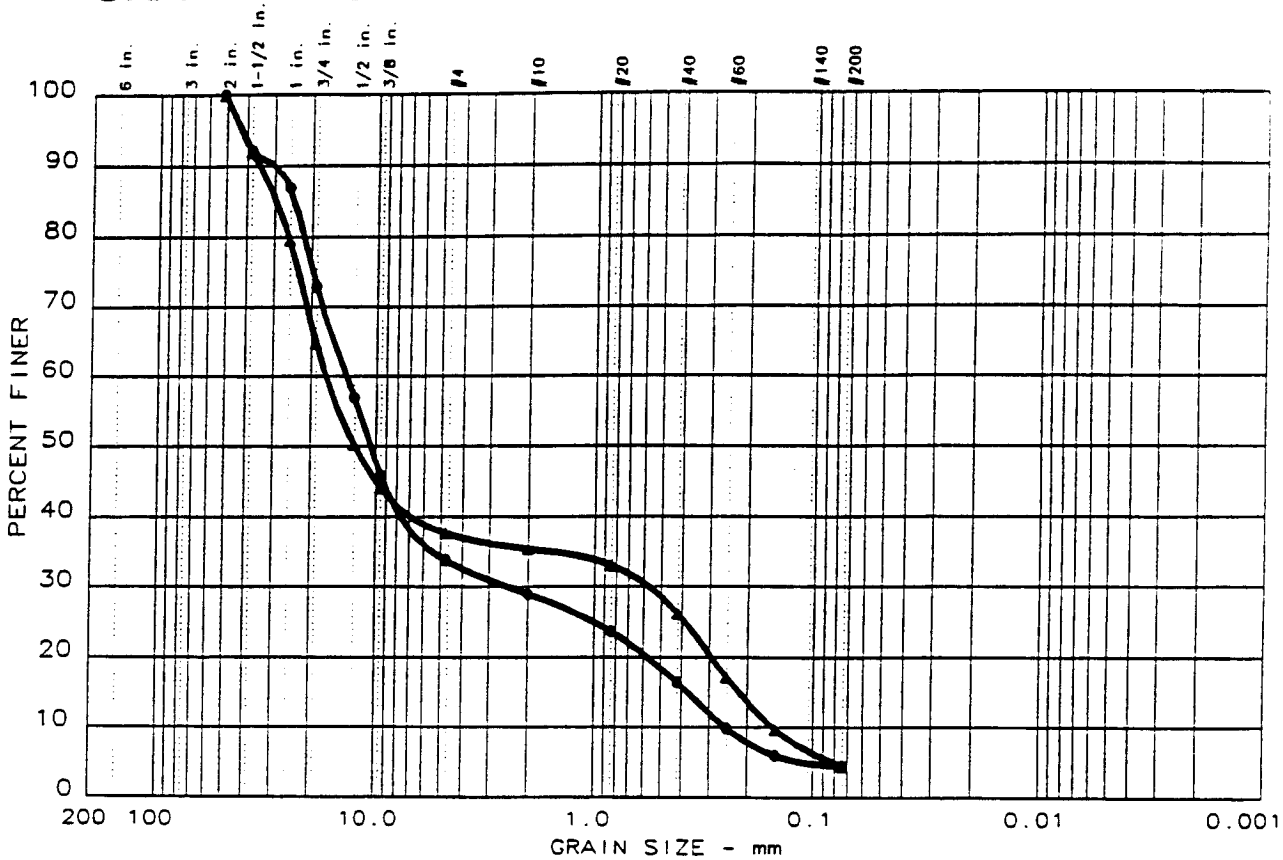
GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	66.2	29.4	4.4	
▲	0.0	62.3	33.3	4.4	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			24.13	13.72	10.63	2.380	0.3728	0.2521	1.64	54.5
▲			29.17	17.12	12.55	0.560	0.2205	0.1526	0.12	112.2

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Sandy GRAVEL	GW	6%
▲ Very sandy GRAVEL	GP	4%

Remarks:

Project: 3rd Runway

● Location: A4-B6-98, S-12A, Depth 25 Feet

▲ Location: A4-B6-98, S-35, Depth 35 Feet

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Figure B-7

AR 043070

APPENDIX C
BORROW AREA 3 PERCHED WATER-BEARING ZONE
SLUG TEST ANALYSIS

APPENDIX C
BORROW AREA 3 PERCHED WATER-BEARING ZONE
SLUG TEST ANALYSIS

This appendix documents the process Hart Crowser uses in conducting slug tests for purposes of evaluating the perched water-bearing zone in Borrow Area 3. The discussion addresses the Hydraulic Conductivity Testing (Slug Testing) conducted in four wells.

Hydraulic Conductivity Testing (Slug Testing)

Hydraulic conductivity testing was performed using the slug test method for explorations A3-13-99 through A3-17-99. In this method, the water level (hydraulic head) in the well is rapidly raised or lowered, and the rate at which it returns to its initial state is used to calculate hydraulic conductivity for the formation surrounding the wellscreen. Data were collected using an Aquistar data logger in conjunction with a Instrumentation Northwest PSI9000 pressure transducer. Tests were conducted as follows:

A transducer was set in the well and allowed to equilibrate with ambient conditions, and background water level data were collected.

One or two slug rods (solid PVC rods) were rapidly introduced into the well (causing a near-instantaneous rise in water level), to initiate a falling head test. Water level data were collected in logarithmically increasing time increments using the data logger and transducer. For wells where depth to water was small, a falling head test was not attempted.

Water level in the well was allowed to re-equilibrate.

The slug rod or rods were rapidly pulled from the well (causing a near-instantaneous drop in water level) to initiate a rising head test. Water level data were collected in logarithmically increasing time increments using the data logger and transducer.

Most of the wells responded reasonably quickly, and therefore multiple slug tests were performed for most wells.

Data were pre-processed as described in Butler (1998), and hydraulic conductivity values were estimated using the method of Bouwer and Rice (1976) for unconfined aquifers. The estimated values are reported in this appendix as Table C-1. Figures C-1 through C-4 include rising/falling head curves showing assumed parameters used to estimate hydraulic conductivity values.

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Table C-1 - Hydraulic Conductivity Calculations for Wells in Unconfined Aquifers
Proposed Borrow Area 3

	A3-B13	A3-B15	A3-B16	A3-B17
Well Depth	**58** ft	**24** ft	**58** ft	**21.5** ft
Screen Length	**5** ft	**5** ft	**5** ft	**5** ft
Depth to Screen	**53** ft	**19** ft	**53** ft	**16.5** ft
Depth to Aquitard	**56.5** ft	**23** ft	**59** ft	**21.75** ft
Depth to Water	**53.04** ft	**18.28** ft	**47.04** ft	**17.6** ft
Depth to Sandpack	**51** ft	**17** ft	**50** ft	**14** ft
H	3.46 ft	4.72 ft	11.96 ft	4.15 ft
n	**0.3**	**0.3**	**0.3**	**0.3**
r_c	**0.083** ft	**0.083** ft	**0.167** ft	**0.083** ft
r_w	**0.333** ft	**0.333** ft	**0.500** ft	**0.333** ft
r_eff	0.195 ft	0.195 ft	0.167 ft	0.195 ft
L_e	4.96 ft	5 ft	5 ft	3.9 ft
L_w	4.96 ft	5.72 ft	10.96 ft	3.9 ft
y1	**0.23** ft	**0.07** ft	**0.6** ft	**0.33** ft
t1	**10** sec	**20** sec	**0** sec	**0** sec
y2	**0.01** ft	**0.001** ft	**0.001** ft	**0.062** ft
t2	**32** sec	**65** sec	**43.5** sec	**2500** sec
L_e/r_w	14.88	15	10	11.7
A	2.0	2.0	1.8	1.9
B	0.3	0.3	0.3	0.3
C	1.4	1.4	1.2	1.3
Fully Penetrating Well				
ln(R_e/r_w)	2.001	2.088	2.106	1.804
K in cm/s	3.3E-02 cm/s	2.3E-02 cm/s	2.6E-02 cm/s	1.8E-04 cm/s
	F-M SAND	Fine SAND	Med. SAND	Fine SAND

Notes:
Bold values to be entered manually.
A, B, and C coefficients are calculated using regression equations of Van Rooy, 1988.

Log of Normalized Drawdown vs. Time for A3-B13-99

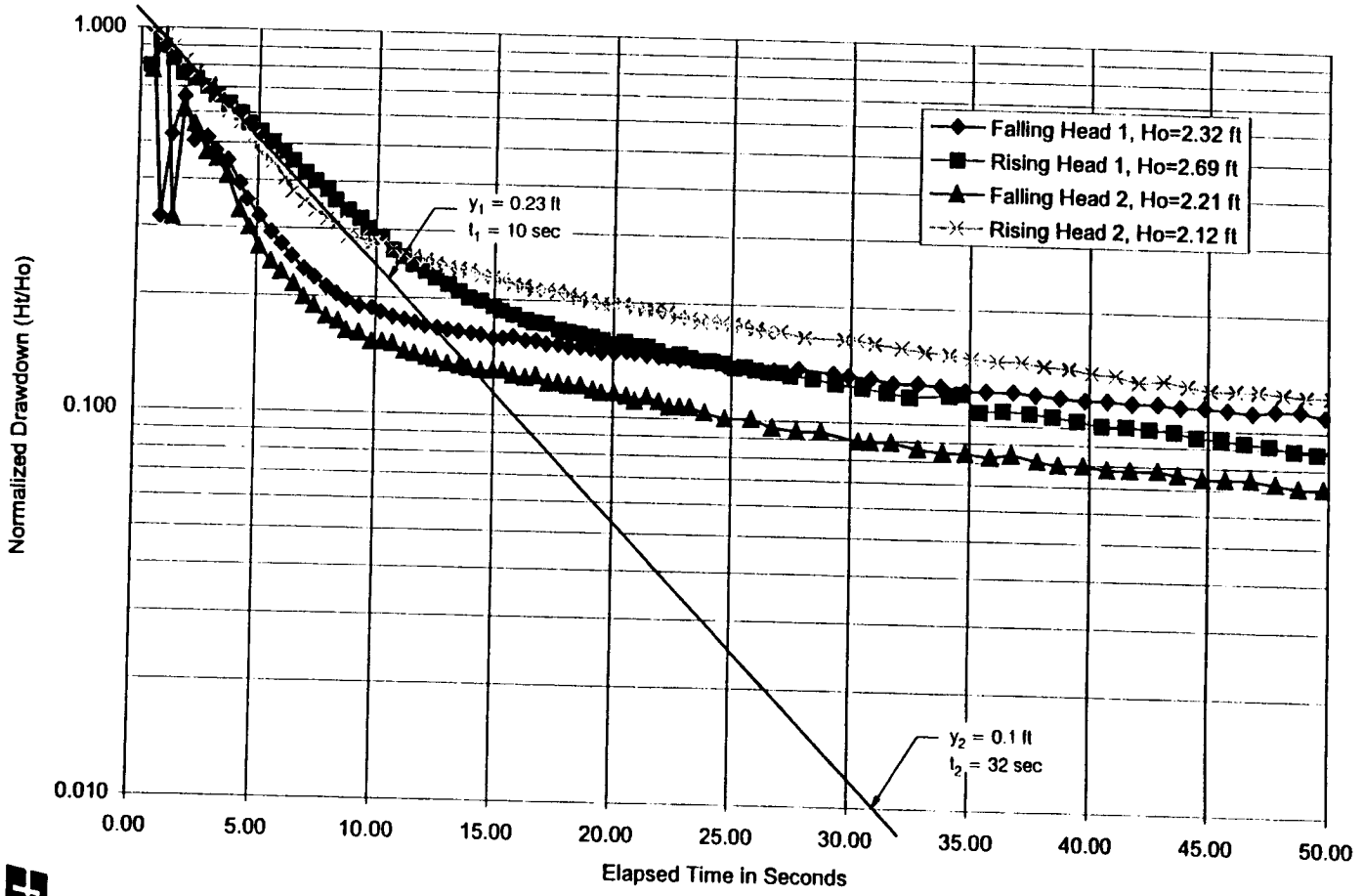

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Figure C-1

AR 043075

497802\core\A3 B13 Area3slug.xls

Log of Normalized Drawdown vs. Time for A3-B15-99

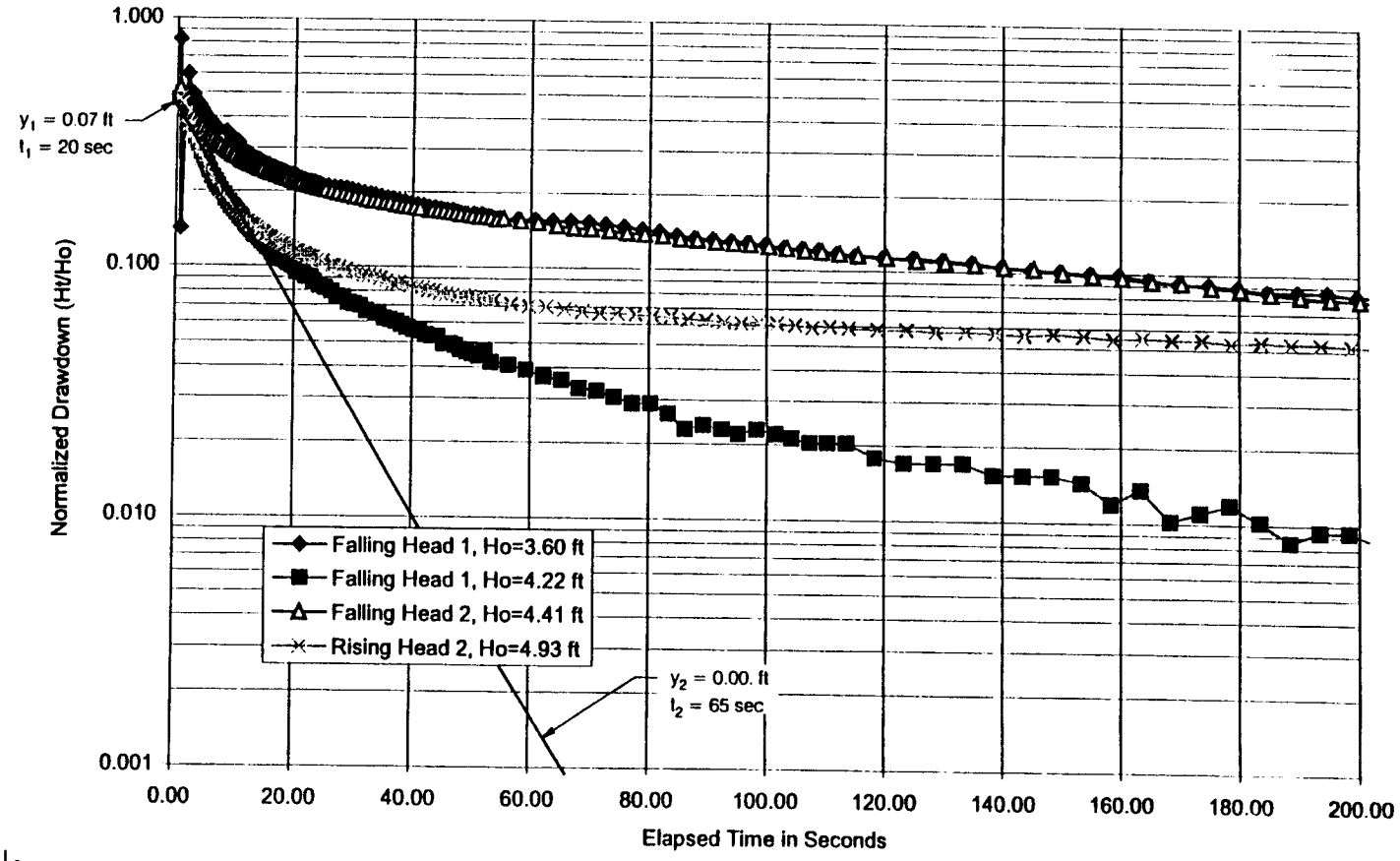

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Figure C-2

AR 043076

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Log of Normalized Drawdown vs. Time for A3-B16-99

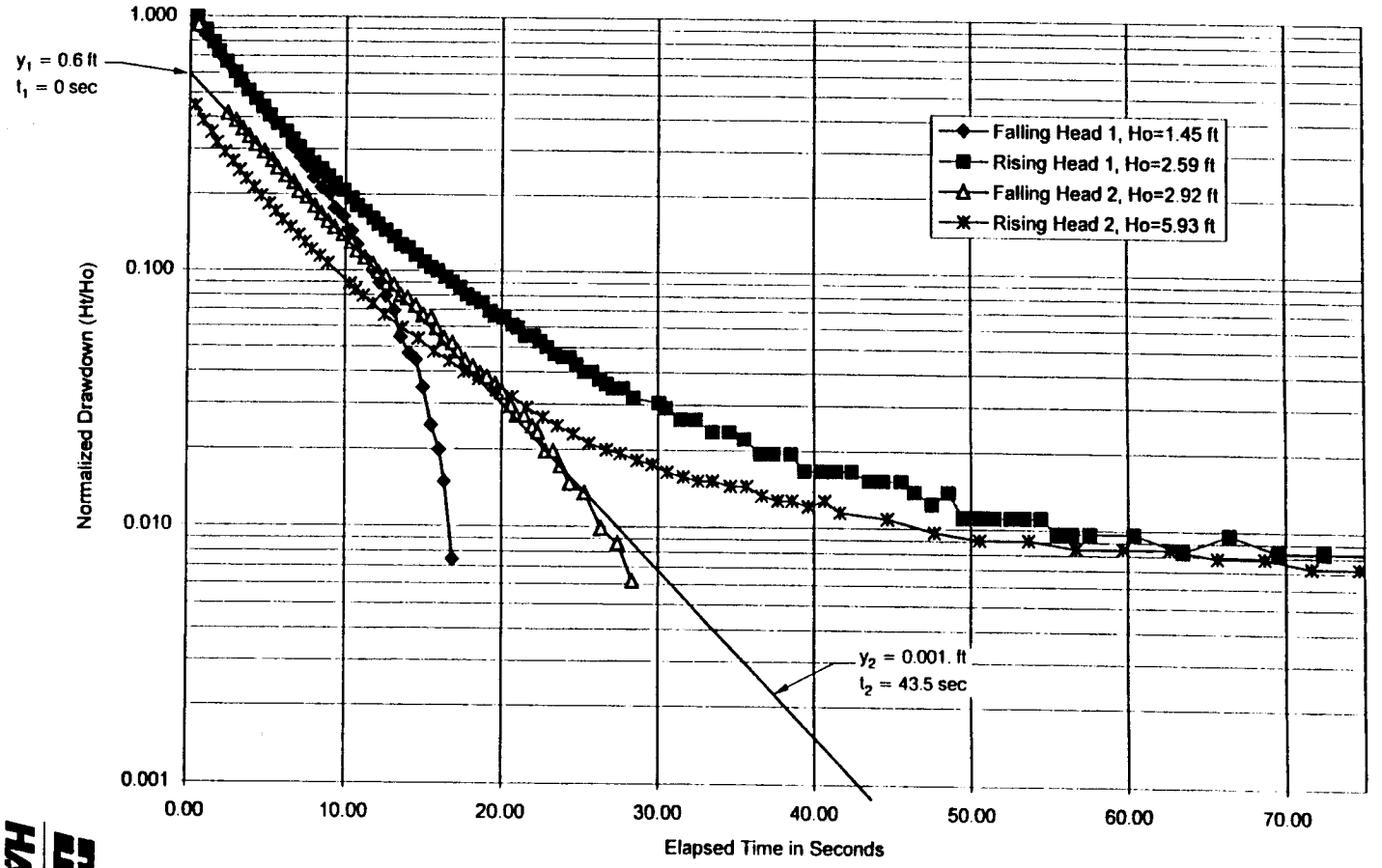

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Figure C-3

AR 043077

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Log of Normalized Drawdown vs. Time for A3-B17-99

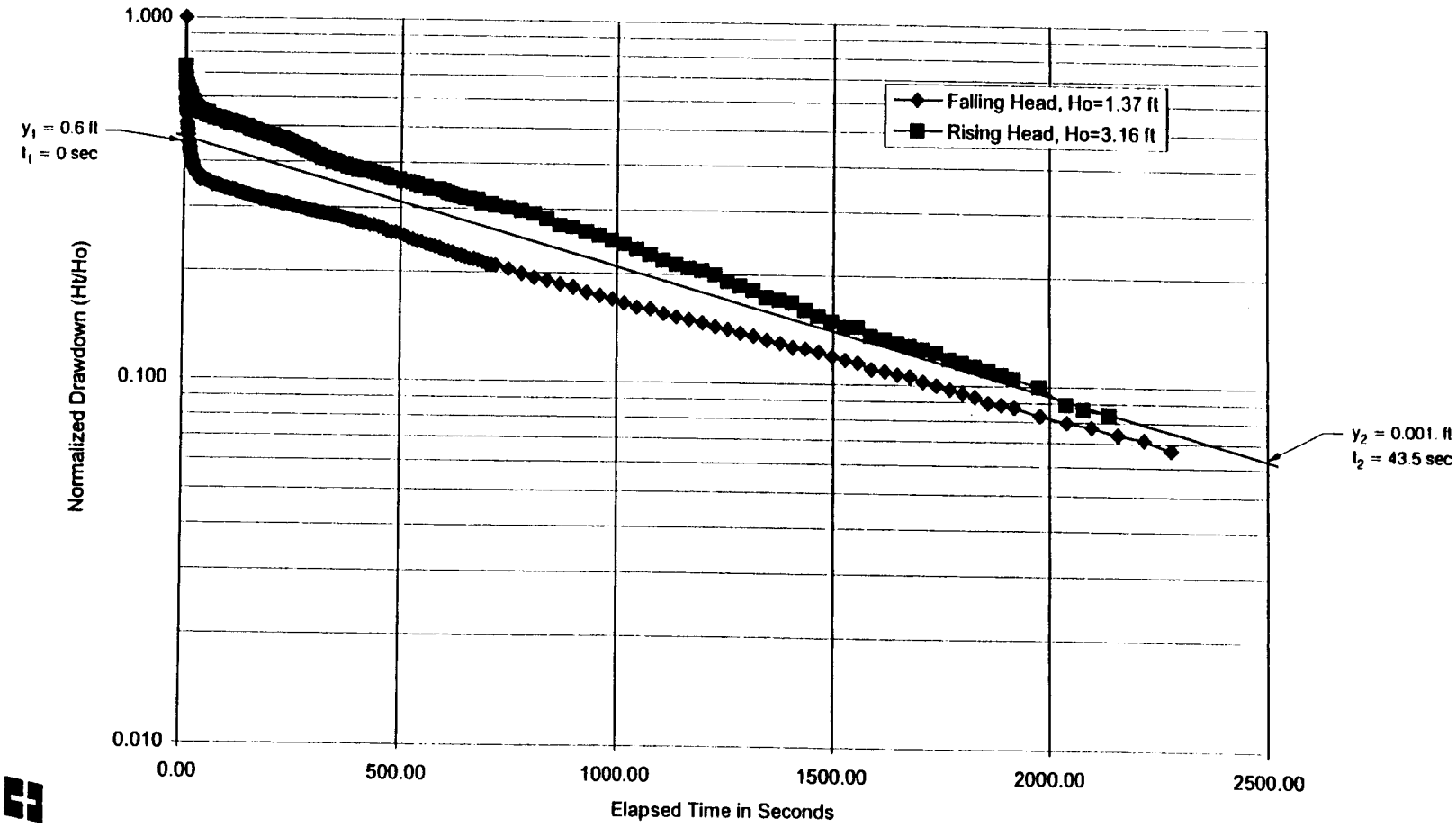

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Figure C-4

AR 043078

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