DEPARTMENT OF THE INTERIOR

U.S. Geological Survey

Summary of Geotechnical and Hydrologic Data Collected Through April 30, 1990, for the Alani-Paty Landslide, Manoa Valley, Honolulu, Hawaii

by

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INTRODUCTION

Following mapping of slow-moving landslides on the east side of Manoa Valley (Baum and others, 1989) we began a detailed investigation of the Alani-Paty landslide (fig. 1) in order to understand the physical processes active in it and similar landslides on Oahu. We have compiled observations and measurements collected during the first 8 months (from September 1989 through April 1990) of our investigation in order to make these basic data available to all parties that have interest in the landslide. The following brief summary highlights our preliminary observations of the depth, composition, and behavior of the Alani-Paty landslide, as well as the behavior of subsurface water. Five appendices containing logs of borings, laboratory test results, estimates of depth of the landslide, and graphs of subsurface water conditions, daily precipitation, and displacement follow the summary. Each appendix is preceded by a few paragraphs that describe the methods used to obtain the data.

SUMMARY OF MEASUREMENTS AND OBSERVATIONS

Subsurface exploration and laboratory testing -- The landslide material, as sampled by means of borings (fig. 2), consists of about 20 to 50 percent boulder-, cobble- and gravel-sized clasts of weathered basalt in a fine-grained matrix (Appendix A). The matrix is brown to gray, sandy to slightly sandy, highly plastic, clayey silt interlayered with dark brown to gray, highly plastic silty clay. At the time of drilling, most matrix material within the landslide was wetter than its plastic limit, while much of the material beneath the landslide (deeper than about 30 ft) was drier than its plastic limit.

Laboratory testing of several specimens (Appendix B) indicates that the matrix material has high plasticity and low residual shear strength. Plastic limits range from 29 to 54, and Liquid limits range from 59 to 137. The matrix contains roughly 50-75 percent clay, 10-30 percent silt, and 5-25 percent sand. Specimens that are rich in clay and have high liquid limits have residual strength parameters in the following ranges: friction angle from 6 to 11°, with cohesion intercepts from 0 to 217 lbf/ft^2. One specimen having a relatively low clay content (48 percent) and low liquid limit (59) had a higher residual strength, characterized by a friction angle of 25° and cohesion intercept of 231 lbf/ft^2.

Most of the matrix material has no recognizable structure at the scale of the cores. However, some of the clay (called fissured clay in the logs, Appendix A) from depths greater than 20 ft crumbles into shiny flakes and blocks from 1/8 in. to 1/2 in. across. Slickensided shear surfaces were present in samples from several borings. The shear surfaces were from a variety of depths, and some of the shear surfaces were from different depths than the basal slip surface of the landslide.

Depth of the landslide -- The landslide is approximately 20 to 25 ft deep (Appendix C) in the vicinity of its head, at the hairpin-curve intersection of Alani Drive and Paty Drive and between the extension of Paty Drive and Kahaloa Place (fig. 2). Between Kahaloa Place and Lono Place, thickness of the landslide ranges from about 25 ft to perhaps 33 ft.

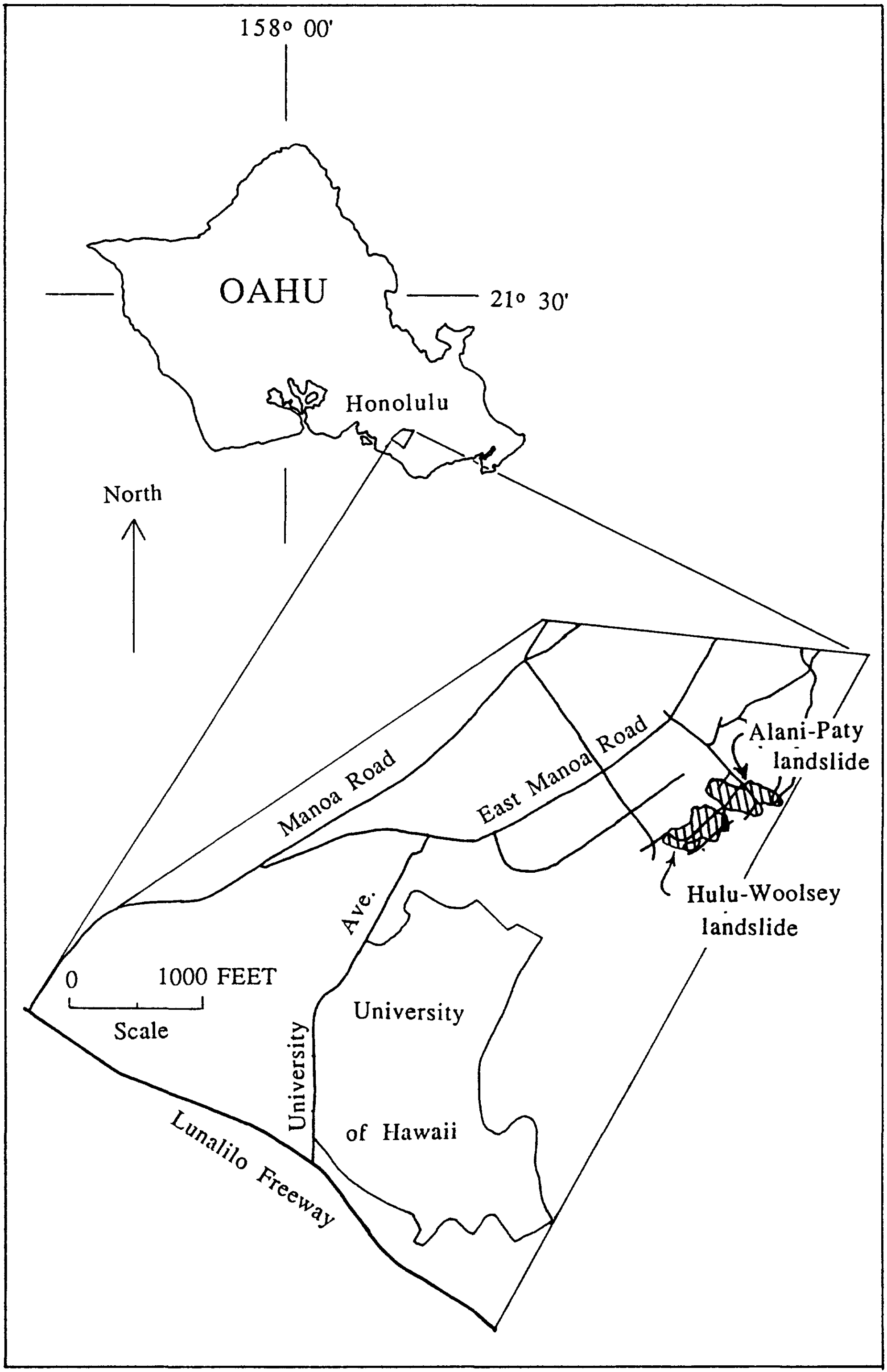


Figure 1. Map showing location of landslides in the Woodlawn area, Manoa Valley, Honolulu, Hawaii.

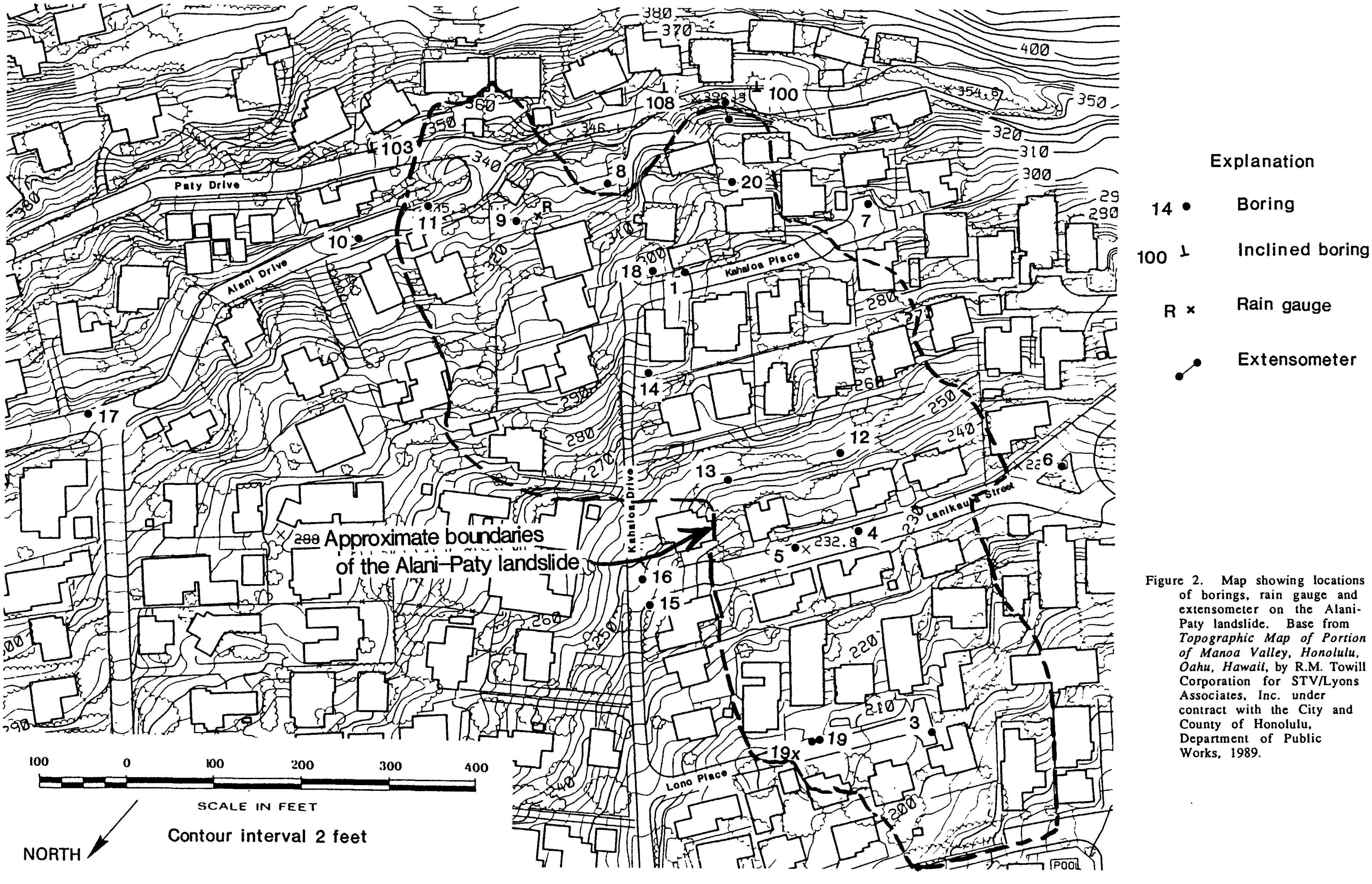


Figure 2. Map showing locations of borings, rain gauge and extensometer on the Alani-Paty landslide. Base from *Topographic Map of Portion of Manoa Valley, Honolulu, Oahu, Hawaii*, by R.M. Towill Corporation for STV/Lyons Associates, Inc. under contract with the City and County of Honolulu, Department of Public Works, 1989.

Instrumentation -- Instrumentation was installed at the surface of the landslide and in borings in order to measure rainfall, displacement, depth of the landslide, and ground-water levels. Surface instrumentation (fig. 2) consisted of rain gauges and an extensometer (for measuring displacement). Bore-hole instrumentation consisted of anchored cables for measuring displacement and open-tube piezometers for measuring water levels. Three borings each were cased for inclinometer and neutron-probe measurements. Rainfall observations are compiled in Appendix D and summarized below. Measurements of displacement are compiled in Appendix E. Difficulties resulting from materials at the site and from installation of the casing made the neutron probe ineffective for monitoring soil-moisture conditions. Displacement of the landslide since installation of the anchored cables has been insufficient (less than the diameter of a boring) to pull the cables down the hole a measurable amount. Consequently, no data from neutron-probe measurements or measurement of the cables are included in this report. The data collected from our piezometer and inclinometer measurements are compiled in Appendix C.

Rainfall and movement of the landslide -- Rainfall for the period from September 26, 1989, to April 24, 1990, totaled 44 in. at the head of the landslide. Most of this fell during October 1989 and January, February, and March 1990. Surface displacement (at the headscarp, fig. 2) from September through April totaled approximately 0.3 ft, and much of the displacement occurred during and after storms (Appendix E). Approximately 0.05 ft of movement occurred during and after a storm on October 3, 1989. Also, 0.1 ft of movement occurred from January 15 to 19, during and after a storm that lasted from January 14 to 18, 1990. An additional 0.1 ft of movement was recorded a few days later, from January 23 to 29, 1990. The nature of this additional movement is uncertain; our recorder appeared to have been disturbed during this time but tape and level surveys indicate that cumulative displacement at the extensometer site from September 13 to April 27 was slightly greater than that recorded by the extensometer (Appendix E). Creeping movements between storms account for the remaining displacement.

Crude measurements indicate that the head of the landslide moved approximately 1 ft between April 1989 and April 1990. Most of this movement must have occurred before our extensometer was put into operation.

Ground-water conditions -- Several trends are obvious in the ground-water observations. Water levels in several piezometers (in borings 1, 8, 9, 20 and 100) upslope from Kahaloa Place (fig. 2 and Appendix C) increased and then gradually returned to normal within a few days of the rainy period of January 14-18 as well as the rainy period of February 24 to March 1. Increases in water levels during January ranged from 1 to 10 ft. Water levels in most piezometers (except 16) downslope from Kahaloa Place changed insignificantly during and after storms. Water levels in piezometers at shallow and intermediate depths downslope from Kahaloa Place (borings 3, 4, 5, 13, 14, 16, 19, and 19x) have generally been steady since shortly after installation. Deep piezometers in borings 3 and 9 and the intermediate piezometer in boring 16 showed steadily declining or steadily increasing water levels, indicating that the water levels in these piezometers had not yet reached equilibrium with their surroundings. Many of the deep (30-40 ft) piezometers are always dry (see table C1 in Appendix C).

Displacement in areas outside the mapped boundaries of the landslide -- Inclinometer measurements were made in two locations (borings 10 and 15, see fig. 2 and Appendix C) where incipient movement was suspected (Baum and others, 1989) and in one place (boring 6) that appears to be stable ground between the Hulu-Woolsey and Alani-Paty landslides. The inclinometer in Boring 15 indicates sliding occurred at a depth of 26 ft during January 1990. Thus far, borings 6 and 10 have shown only small random deflections but no unequivocal evidence of sliding.

ACKNOWLEDGEMENTS

We thank Sam Callejo and his staff of the Department of Public Works, City and County of Honolulu, for coordinating access to sites for drilling and instrumentation. We also thank residents and owners of property in the landslide area for their cooperation in providing access to sites for drilling and instrumentation of the landslide. George Erickson performed the laboratory tests reported in appendix B.

REFERENCES

Baum, R.L., Fleming, R.W., and Ellen, S.D., 1989, Maps showing landslide features and related ground deformation in the Woodlawn area of the Manoa Valley, City and County of Honolulu, Hawaii: U.S. Geological Survey Open-File Report 89-290, 16 p. + 2 oversize plates.

APPENDIX A

Subsurface Exploration

This appendix contains logs of borings made in the study area and an explanation of symbols used in the logs (figs. A1, ..., A20). The logs describe the materials encountered in the borings, indicate where samples were taken, and show graphically the moisture content and penetration resistance of the materials. Boundaries between different materials indicated in the logs are located only approximately. Boring and sampling operations were performed by Geolabs-Hawaii, under contract with the City and County of Honolulu, Department of Public Works. We observed drilling, wrapped samples for storage, and recorded our observations. We kept records in the field of the progress of drilling, sample intervals, penetration resistance, materials encountered, locations of moisture samples, and so forth. Later, in the laboratory, we examined and described the samples in greater detail. The finished logs were constructed by combining information from our laboratory examinations with the data in our field logs.

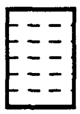
Personnel from the City and County of Honolulu determined the surface elevations of most borings by leveling. USGS personnel extended the City/County surveys to most of the remaining borings. The surveyed elevations reported here have been rounded to the nearest 0.1 ft. We estimated elevations of the few borings that had not been surveyed using a topographic map made by R.M. Towill Corp. for STV/Lyon Associates.

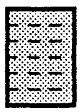
All samples were collected either by driving a ring sampler or by coring with a diamond bit. The ring sampler was driven by the blows of a 140-lb hammer falling 30 in. Penetration resistance is reported as the number of blows required to drive the ring sampler through the last 12 in. of an 18-in. run. Where sample runs were shorter than 18 in., the penetration resistance is reported as the number of blows required to drive the sampler over the shorter interval. For example, 50:0.3' indicates that 50 blows were required to drive the sampler 0.3 ft.

Explanation of symbols used in logs of borings

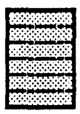

Ring sample, approximately 2-1/4 inches in diameter

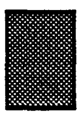

NX-size core


Clay or silty clay


Sandy clay or sandy silty clay


Clayey silt or mixture of clayey silt and silty clay


Sandy clayey silt or mixture of sandy clayey silt and sandy silty clay


Basalt (bedrock)

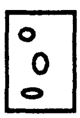

Gravel and cobble sized clasts of weathered basalt (boulders represented by larger ovals)

Figure A1

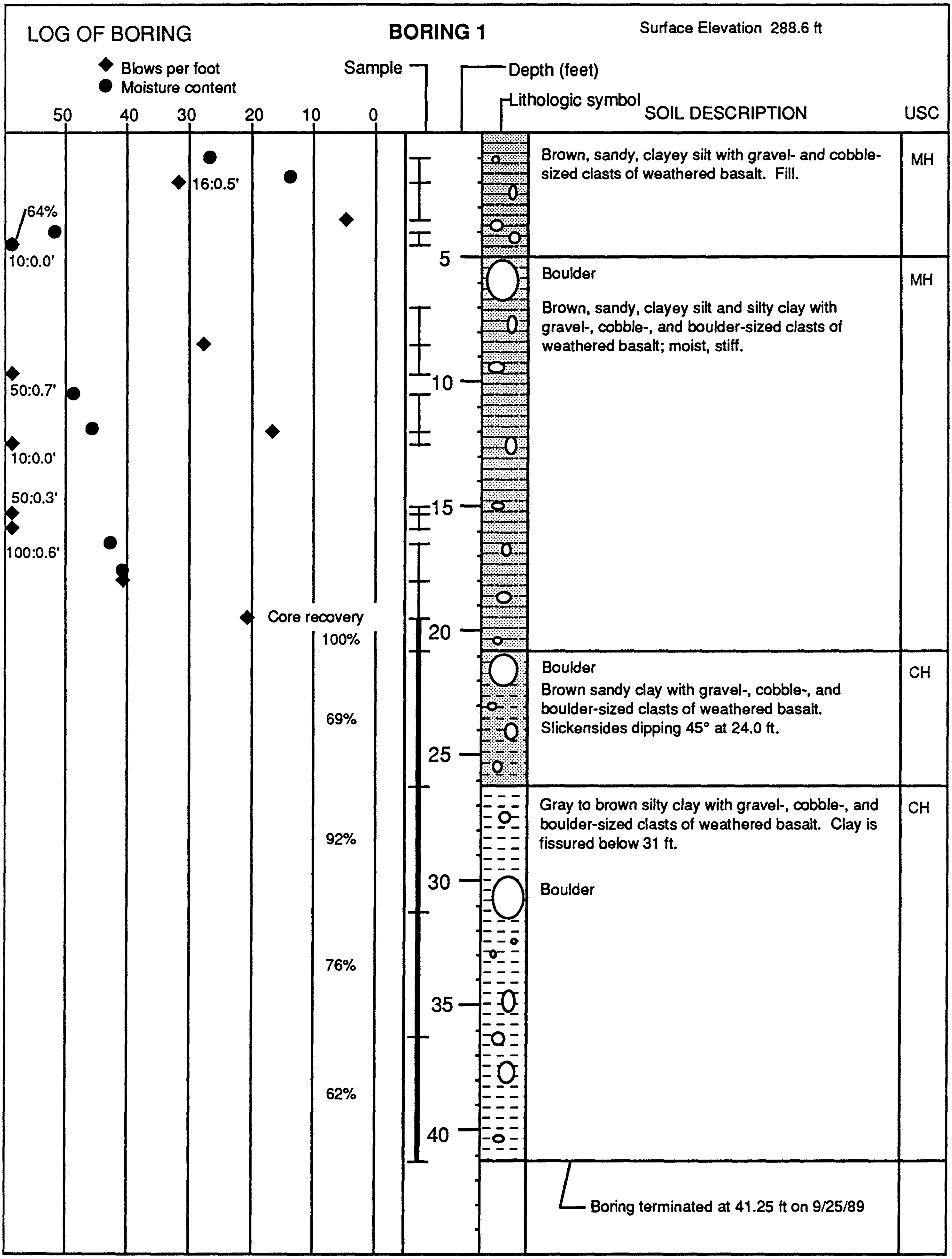

LOG OF BORING
BORING 1
Surface Elevation 288.6 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
16:0.5'
64%
10:0.0'
50:0.7'
10:0.0'
50:0.3'
100:0.6'
Core recovery
100%
69%
92%
76%
62%
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt. Fill.
MH
Boulder
Brown, sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; moist, stiff.
MH
Boulder
Brown sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt. Slickensides dipping 45° at 24.0 ft.
CH
Gray to brown silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt. Clay is fissured below 31 ft.
CH
Boulder
Boring terminated at 41.25 ft on 9/25/89

Figure A2

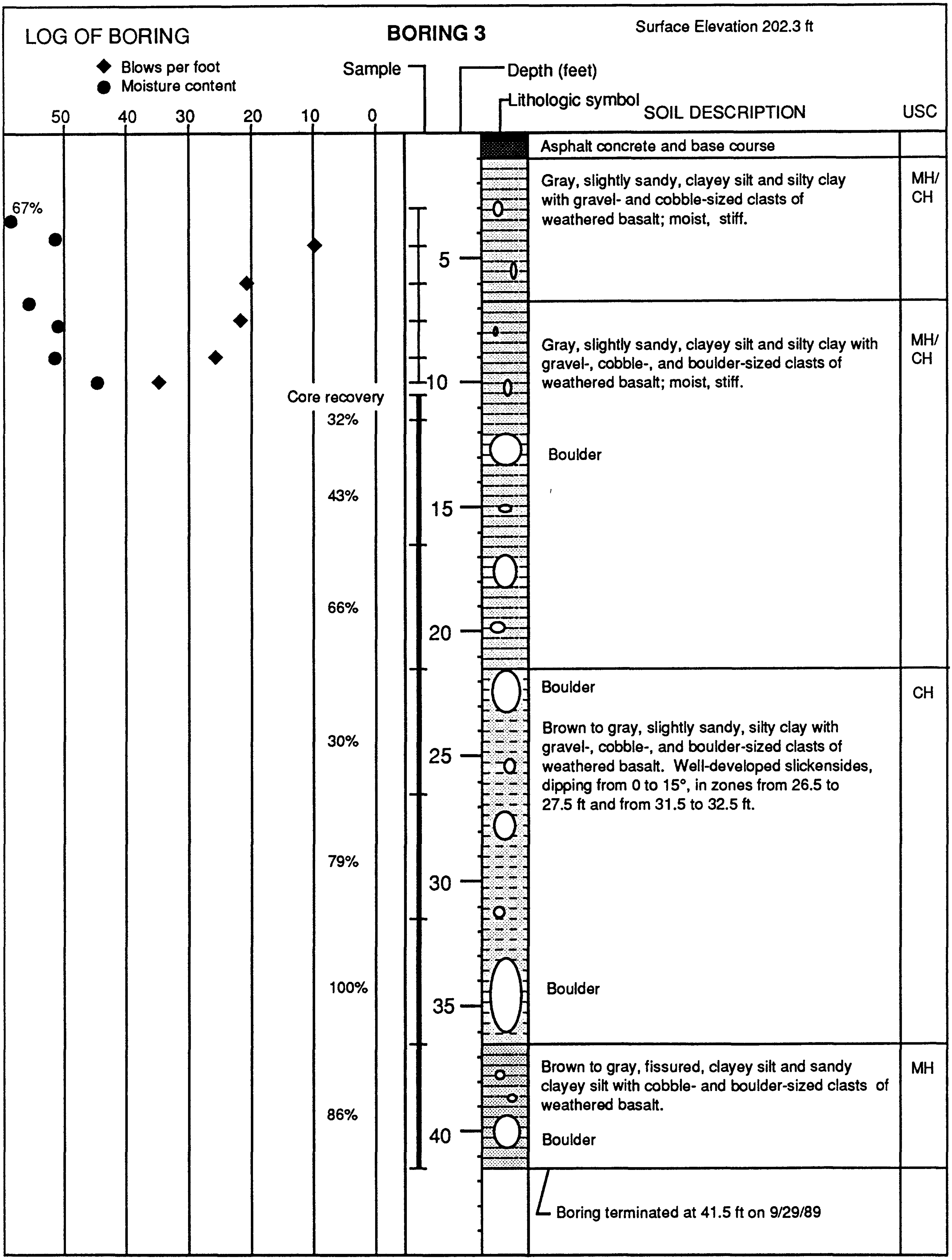

LOG OF BORING
BORING 3
Surface Elevation 202.3 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
67%
Core recovery
32%
43%
66%
30%
79%
100%
86%
5
10
15
20
25
30
35
40
Asphalt concrete and base course
Gray, slightly sandy, clayey silt and silty clay with gravel- and cobble-sized clasts of weathered basalt; moist, stiff.
MH/CH
Gray, slightly sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; moist, stiff.
MH/CH
Boulder
Boulder
Brown to gray, slightly sandy, silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt. Well-developed slickensides, dipping from 0 to 15°, in zones from 26.5 to 27.5 ft and from 31.5 to 32.5 ft.
CH
Boulder
Brown to gray, fissured, clayey silt and sandy clayey silt with cobble- and boulder-sized clasts of weathered basalt.
MH
Boulder
Boring terminated at 41.5 ft on 9/29/89

Figure A3

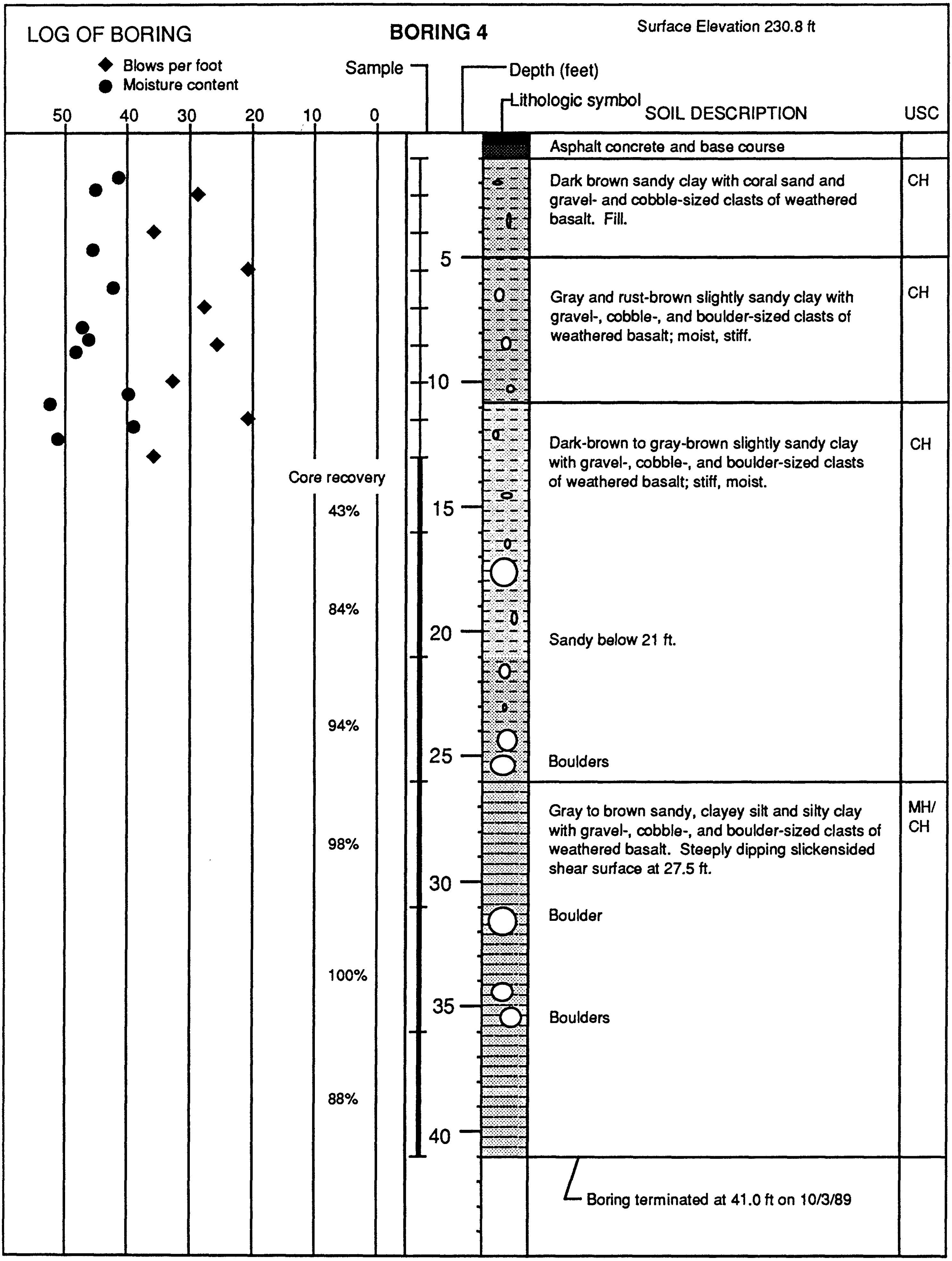

LOG OF BORING
BORING 4
Surface Elevation 230.8 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
Core recovery
43%
84%
94%
98%
100%
88%
5
10
15
20
25
30
35
40
Asphalt concrete and base course
Dark brown sandy clay with coral sand and gravel- and cobble-sized clasts of weathered basalt. Fill.
CH
Gray and rust-brown slightly sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; moist, stiff.
CH
Dark-brown to gray-brown slightly sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
CH
Sandy below 21 ft.
Boulders
Gray to brown sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt. Steeply dipping slickensided shear surface at 27.5 ft.
MH/ CH
Boulder
Boulders
Boring terminated at 41.0 ft on 10/3/89

Figure A4

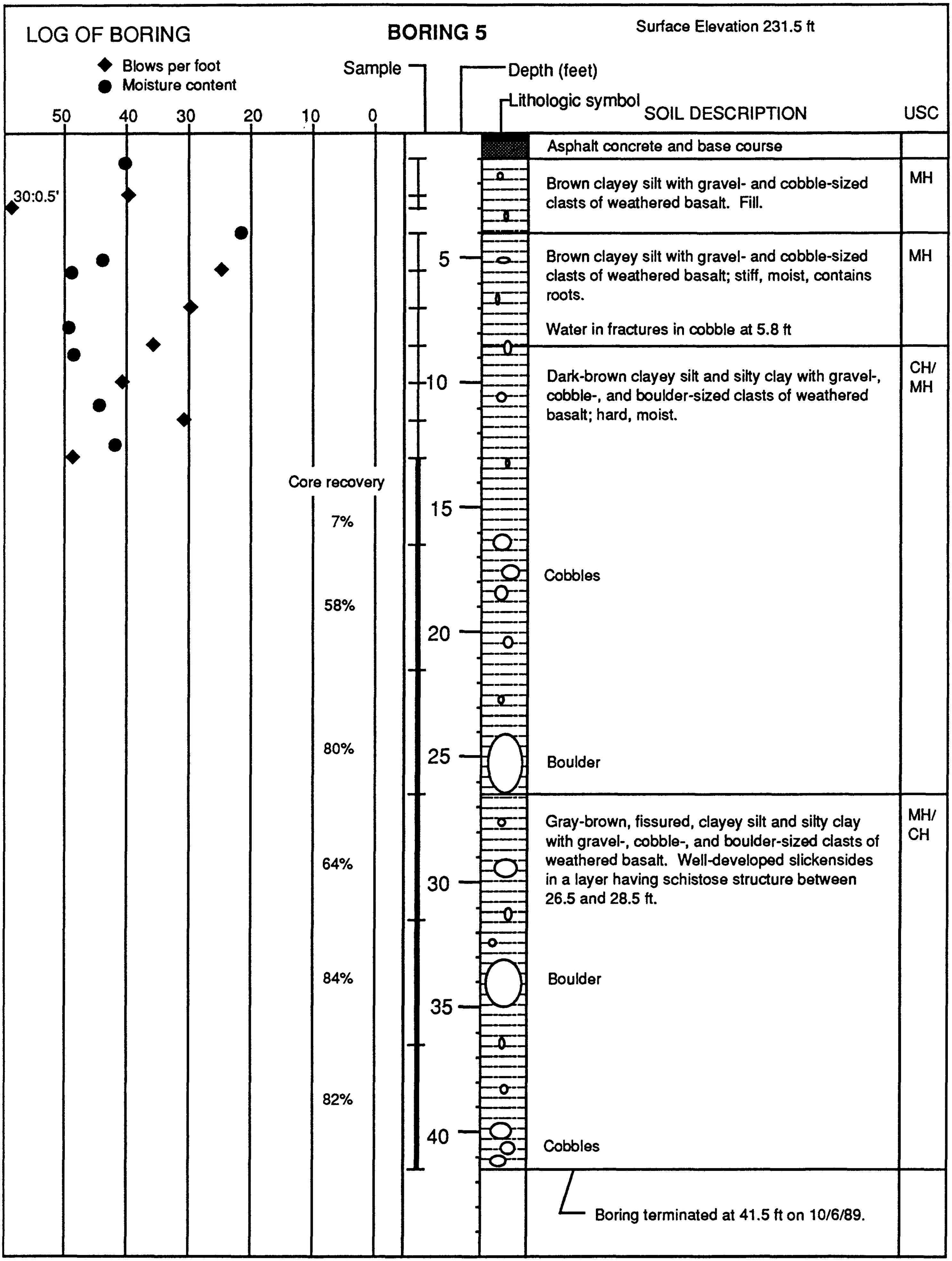

LOG OF BORING
BORING 5
Surface Elevation 231.5 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50 40 30 20 10 0
30:0.5'
Core recovery
7%
58%
80%
64%
84%
82%
5
10
15
20
25
30
35
40
Asphalt concrete and base course
Brown clayey silt with gravel- and cobble-sized clasts of weathered basalt. Fill.
MH
Brown clayey silt with gravel- and cobble-sized clasts of weathered basalt; stiff, moist, contains roots.
Water in fractures in cobble at 5.8 ft
MH
Dark-brown clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, moist.
CH/ MH
Cobbles
Boulder
Gray-brown, fissured, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt. Well-developed slickensides in a layer having schistose structure between 26.5 and 28.5 ft.
MH/ CH
Boulder
Cobbles
Boring terminated at 41.5 ft on 10/6/89.

Figure A5

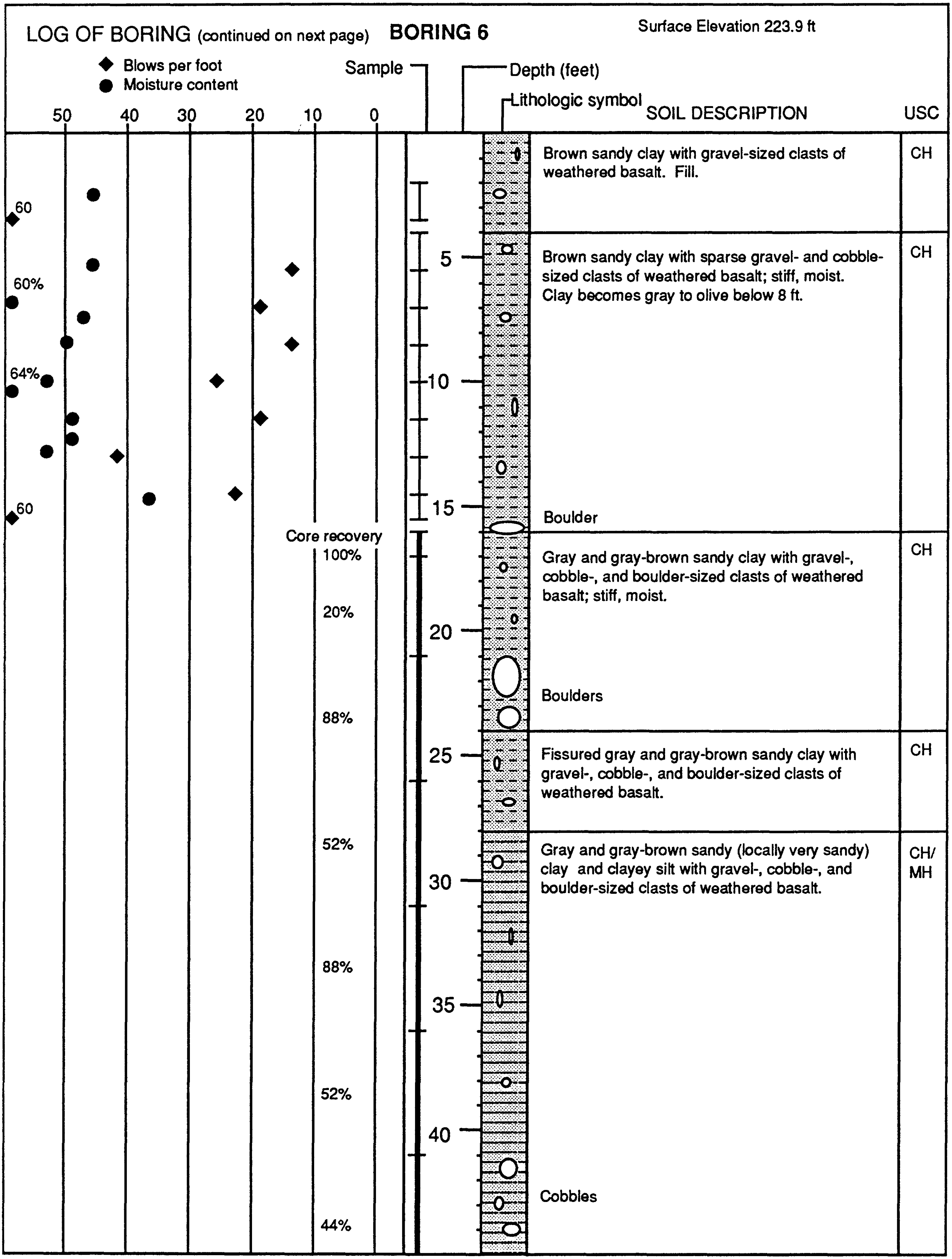

LOG OF BORING (continued on next page)
BORING 6
Surface Elevation 223.9 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
60
60%
64%
60
Core recovery
100%
20%
88%
52%
88%
52%
44%
5
10
15
20
25
30
35
40
Brown sandy clay with gravel-sized clasts of weathered basalt. Fill.
CH
Brown sandy clay with sparse gravel- and cobble-sized clasts of weathered basalt; stiff, moist. Clay becomes gray to olive below 8 ft.
CH
Boulder
Gray and gray-brown sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
CH
Boulders
Fissured gray and gray-brown sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt.
CH
Gray and gray-brown sandy (locally very sandy) clay and clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt.
CH/
MH
Cobbles

Figure A6a

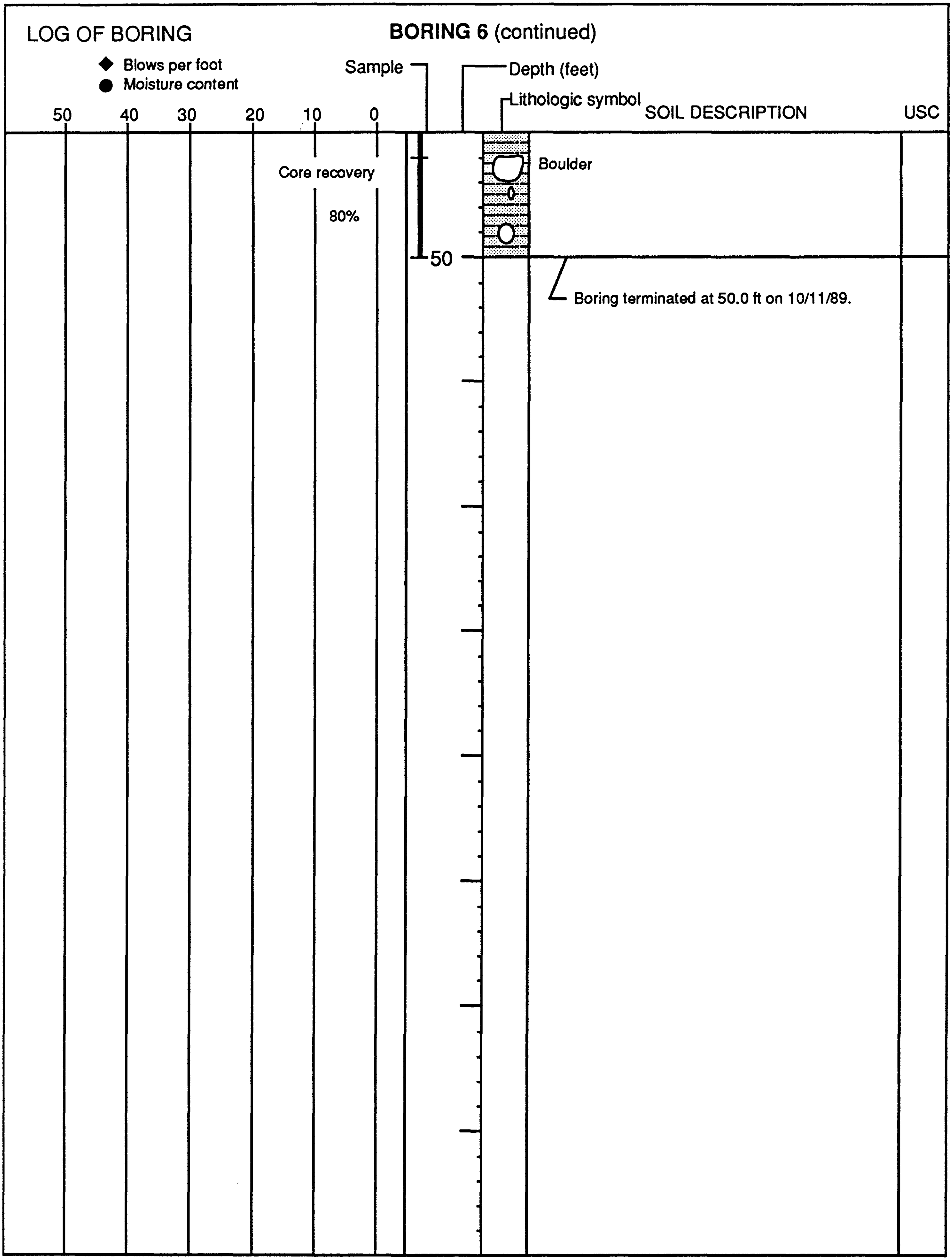

LOG OF BORING
BORING 6 (continued)
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
Core recovery
80%
Boulder
50
Boring terminated at 50.0 ft on 10/11/89.

Figure A6b

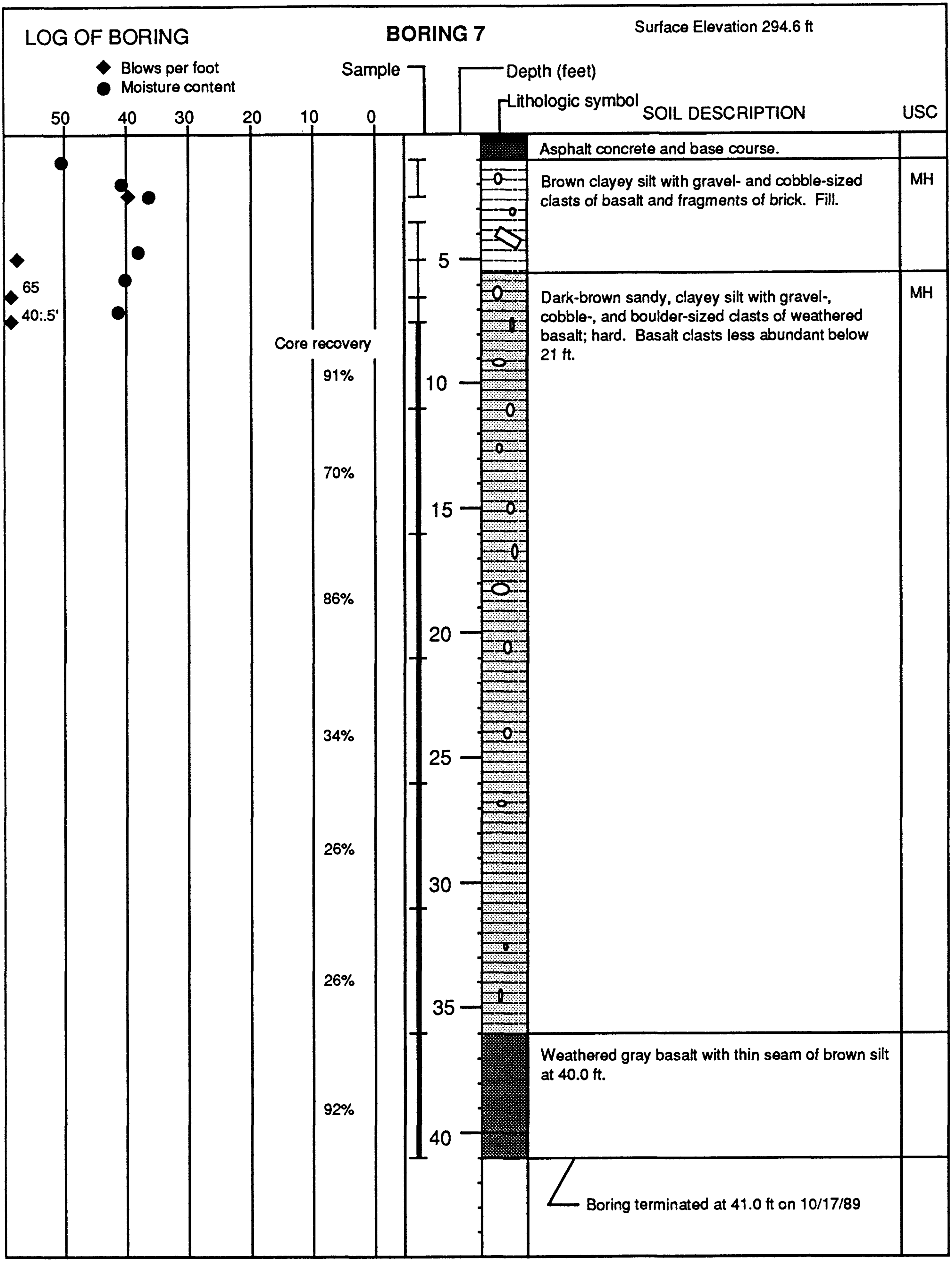

LOG OF BORING
BORING 7
Surface Elevation 294.6 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
65
40:.5'
Core recovery
91%
70%
86%
34%
26%
26%
92%
5
10
15
20
25
30
35
40
Asphalt concrete and base course.
Brown clayey silt with gravel- and cobble-sized clasts of basalt and fragments of brick. Fill.
MH
Dark-brown sandy, clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard. Basalt clasts less abundant below 21 ft.
MH
Weathered gray basalt with thin seam of brown silt at 40.0 ft.
Boring terminated at 41.0 ft on 10/17/89

Figure A7.

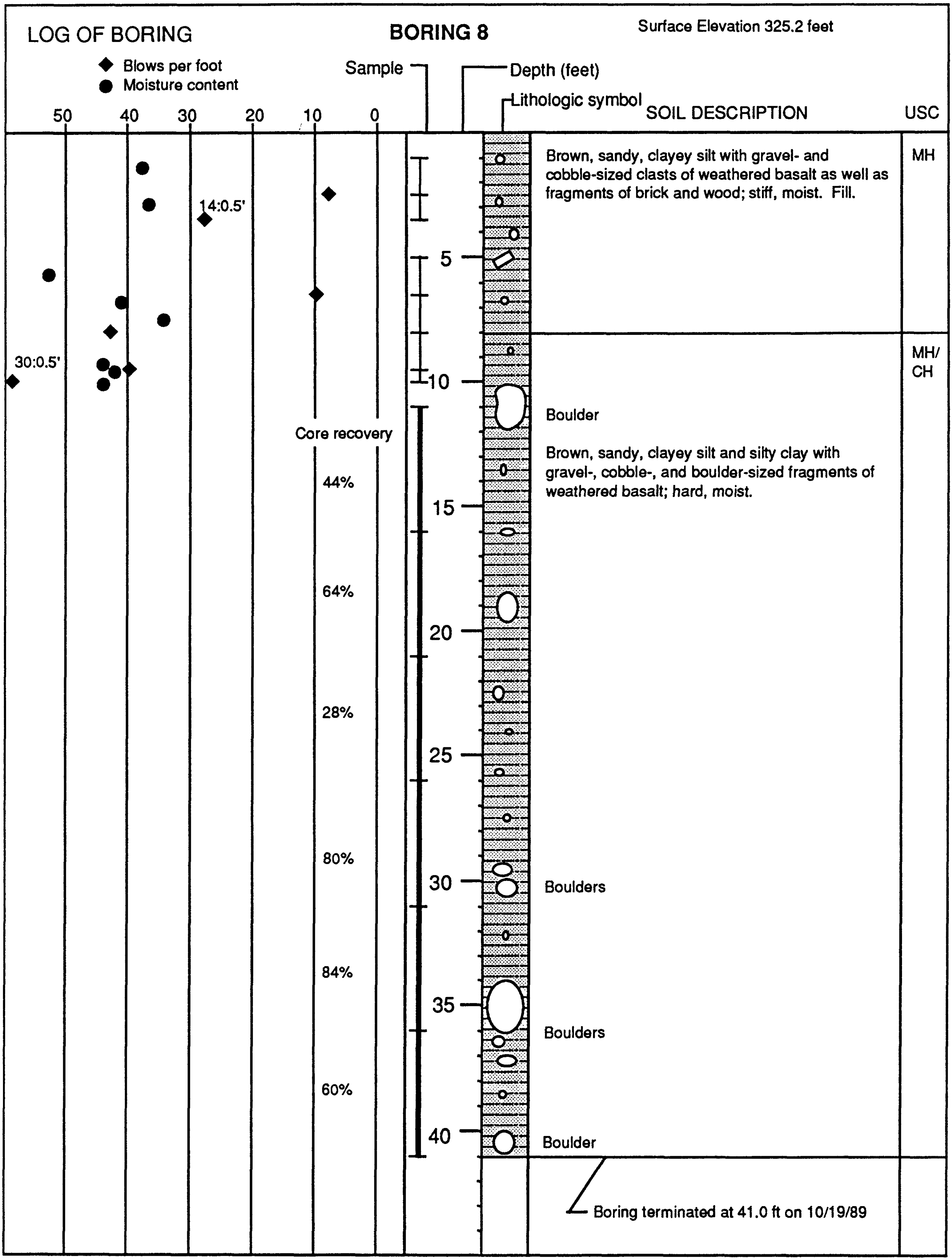

LOG OF BORING
BORING 8
Surface Elevation 325.2 feet
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
14:0.5'
30:0.5'
Core recovery
44%
64%
28%
80%
84%
60%
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt as well as fragments of brick and wood; stiff, moist. Fill.
MH
MH/ CH
Boulder
Brown, sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized fragments of weathered basalt; hard, moist.
Boulders
Boulders
Boulder
Boring terminated at 41.0 ft on 10/19/89

Figure A8.

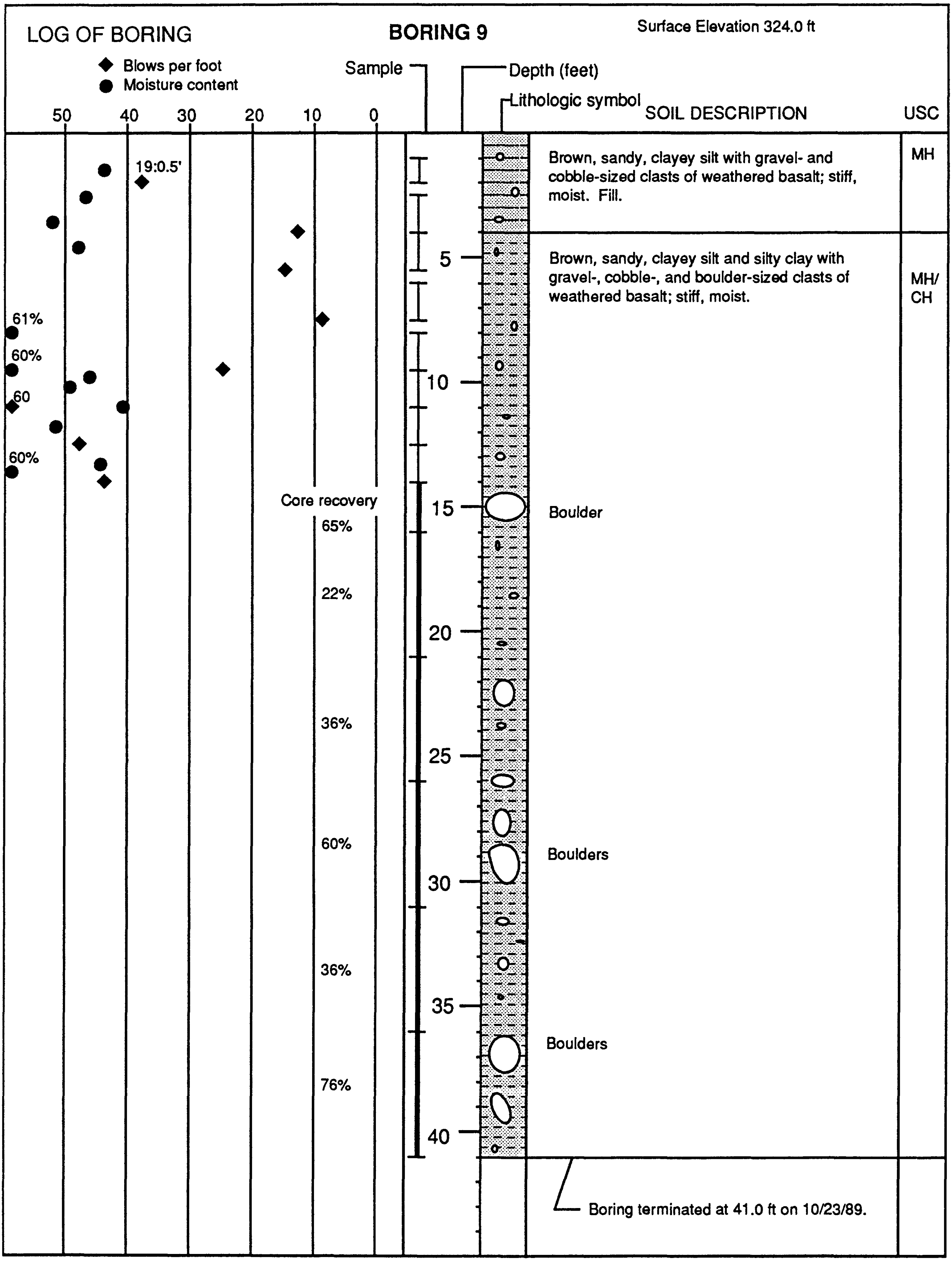

LOG OF BORING
BORING 9
Surface Elevation 324.0 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50 40 30 20 10 0
19:0.5'
61%
60%
60
60%
Core recovery
65%
22%
36%
60%
36%
76%
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt; stiff, moist. Fill.
MH
Brown, sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
MH/CH
Boulder
Boulders
Boulders
Boring terminated at 41.0 ft on 10/23/89.

Figure A9.

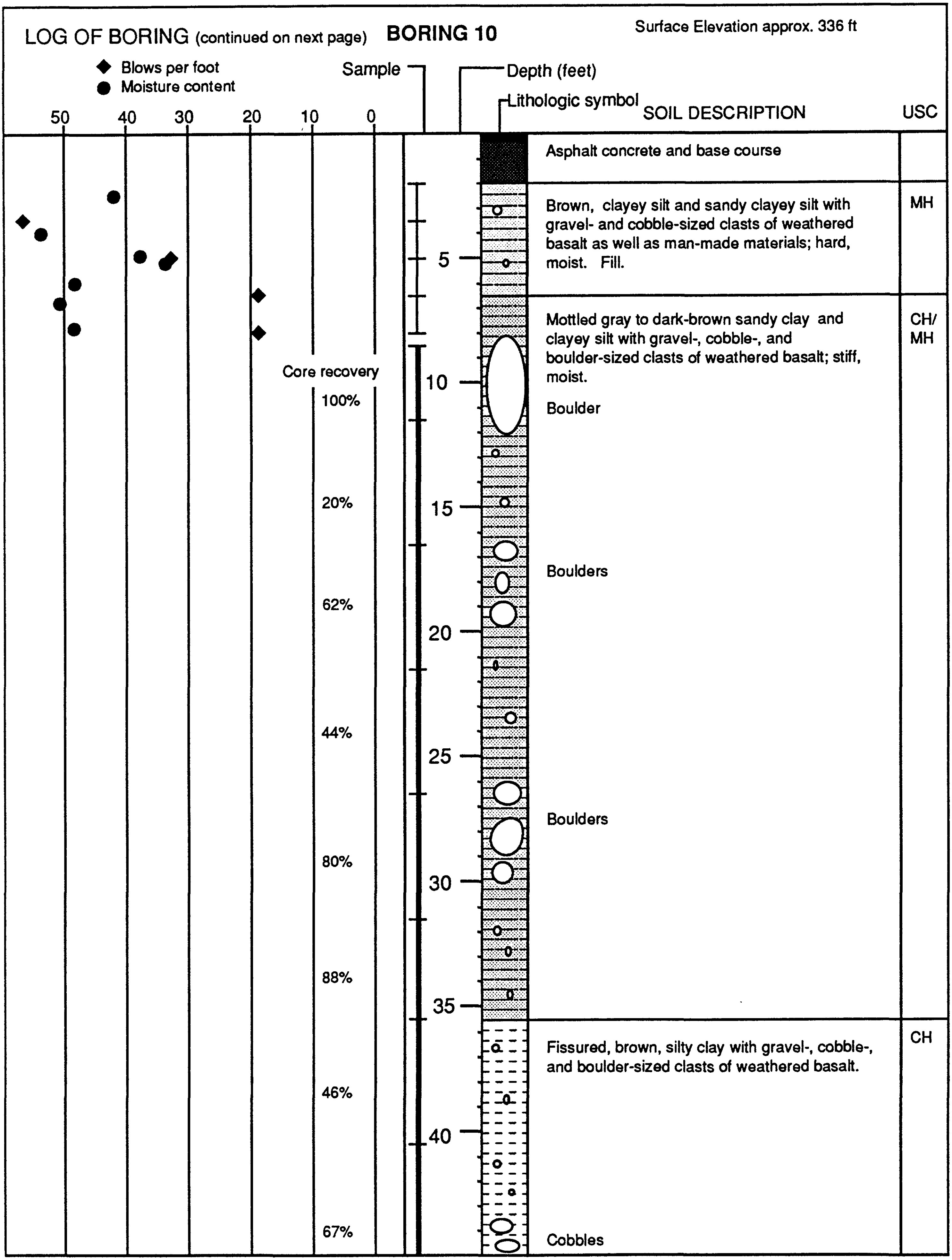

LOG OF BORING (continued on next page)
BORING 10
Surface Elevation approx. 336 ft
Blows per foot
Moisture content
50 40 30 20 10 0
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
Asphalt concrete and base course
Brown, clayey silt and sandy clayey silt with gravel- and cobble-sized clasts of weathered basalt as well as man-made materials; hard, moist. Fill.
MH
Mottled gray to dark-brown sandy clay and clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
CH/ MH
Boulder
Boulders
Boulders
Fissured, brown, silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt.
CH
Cobbles
Core recovery
100%
20%
62%
44%
80%
88%
46%
67%
5
10
15
20
25
30
35
40

Figure A10a

LOG OF BORING

BORING 10 continued

◆ Blows per foot
● Moisture content

Sample

Depth (feet)

Lithologic symbol

SOIL DESCRIPTION

USC

50 40 30 20 10 0

Core recovery

0%

Cobbles

50

Boring teriminiated at 48.5 ft on 10/27/89

Figure A10b.

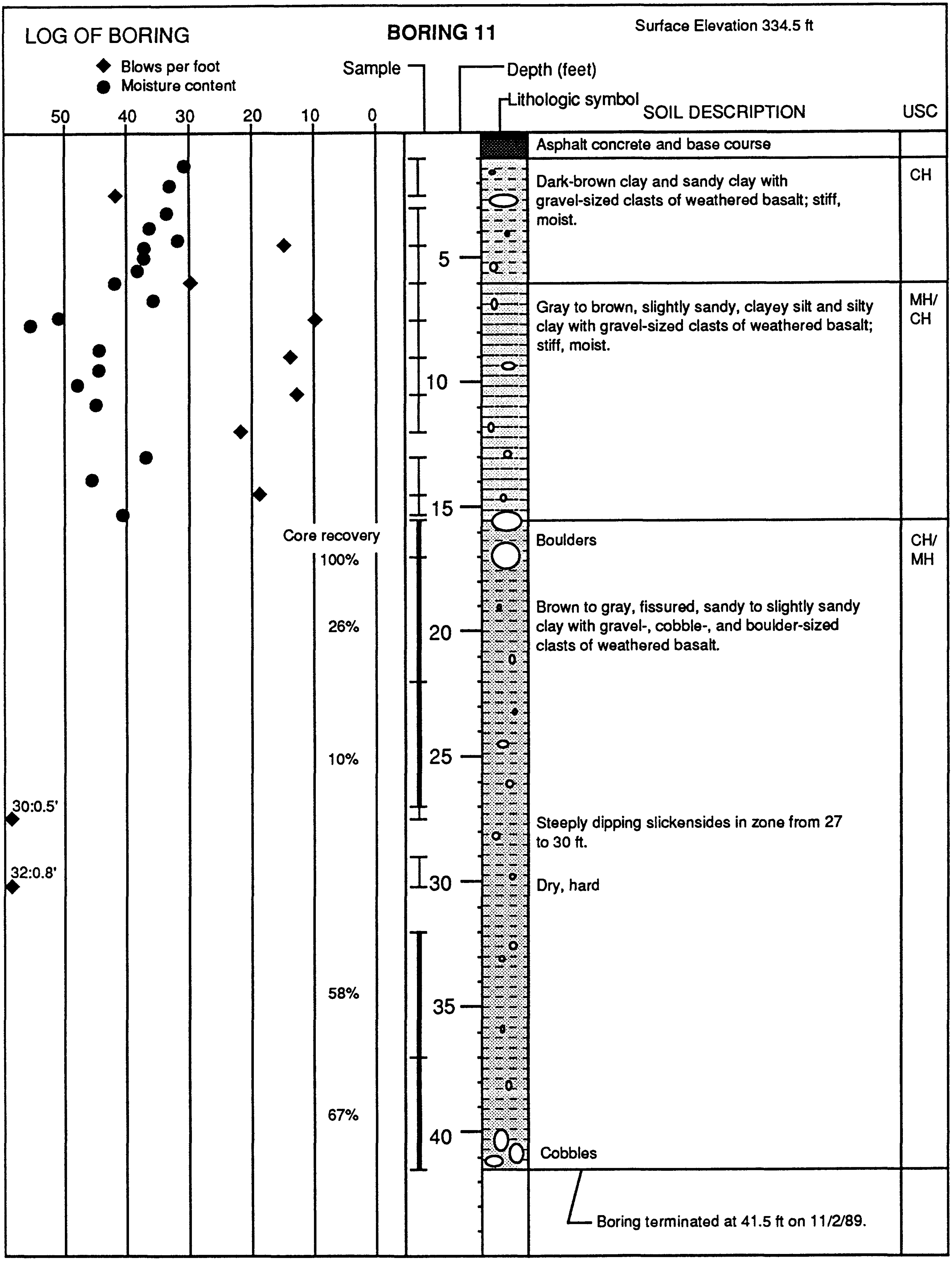
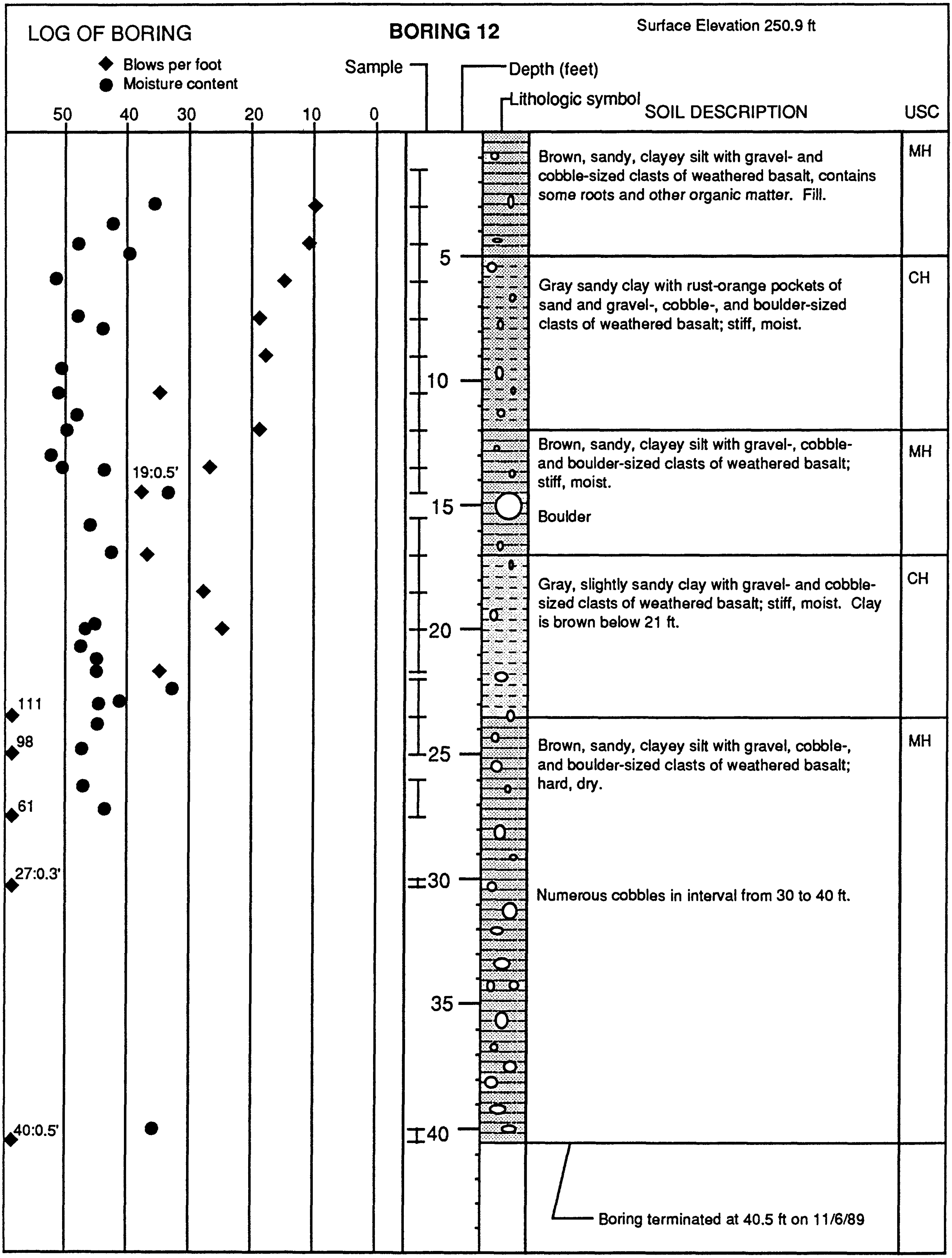

LOG OF BORING
BORING 11
Surface Elevation 334.5 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50 40 30 20 10 0
Asphalt concrete and base course
Dark-brown clay and sandy clay with gravel-sized clasts of weathered basalt; stiff, moist.
CH
Gray to brown, slightly sandy, clayey silt and silty clay with gravel-sized clasts of weathered basalt; stiff, moist.
MH/ CH
Core recovery
100%
26%
10%
58%
67%
Boulders
CH/ MH
Brown to gray, fissured, sandy to slightly sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt.
Steeply dipping slickensides in zone from 27 to 30 ft.
Dry, hard
Cobbles
30:0.5'
32:0.8'
5
10
15
20
25
30
35
40
Boring terminated at 41.5 ft on 11/2/89.

Figure A11.



LOG OF BORING
BORING 12
Surface Elevation 250.9 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50 40 30 20 10 0
19:0.5'
111
98
61
27:0.3'
40:0.5'
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt, contains some roots and other organic matter. Fill.
MH
Gray sandy clay with rust-orange pockets of sand and gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
CH
Brown, sandy, clayey silt with gravel-, cobble- and boulder-sized clasts of weathered basalt; stiff, moist.
MH
Boulder
Gray, slightly sandy clay with gravel- and cobble-sized clasts of weathered basalt; stiff, moist. Clay is brown below 21 ft.
CH
Brown, sandy, clayey silt with gravel, cobble-, and boulder-sized clasts of weathered basalt; hard, dry.
MH
Numerous cobbles in interval from 30 to 40 ft.
Boring terminated at 40.5 ft on 11/6/89

Figure A12.

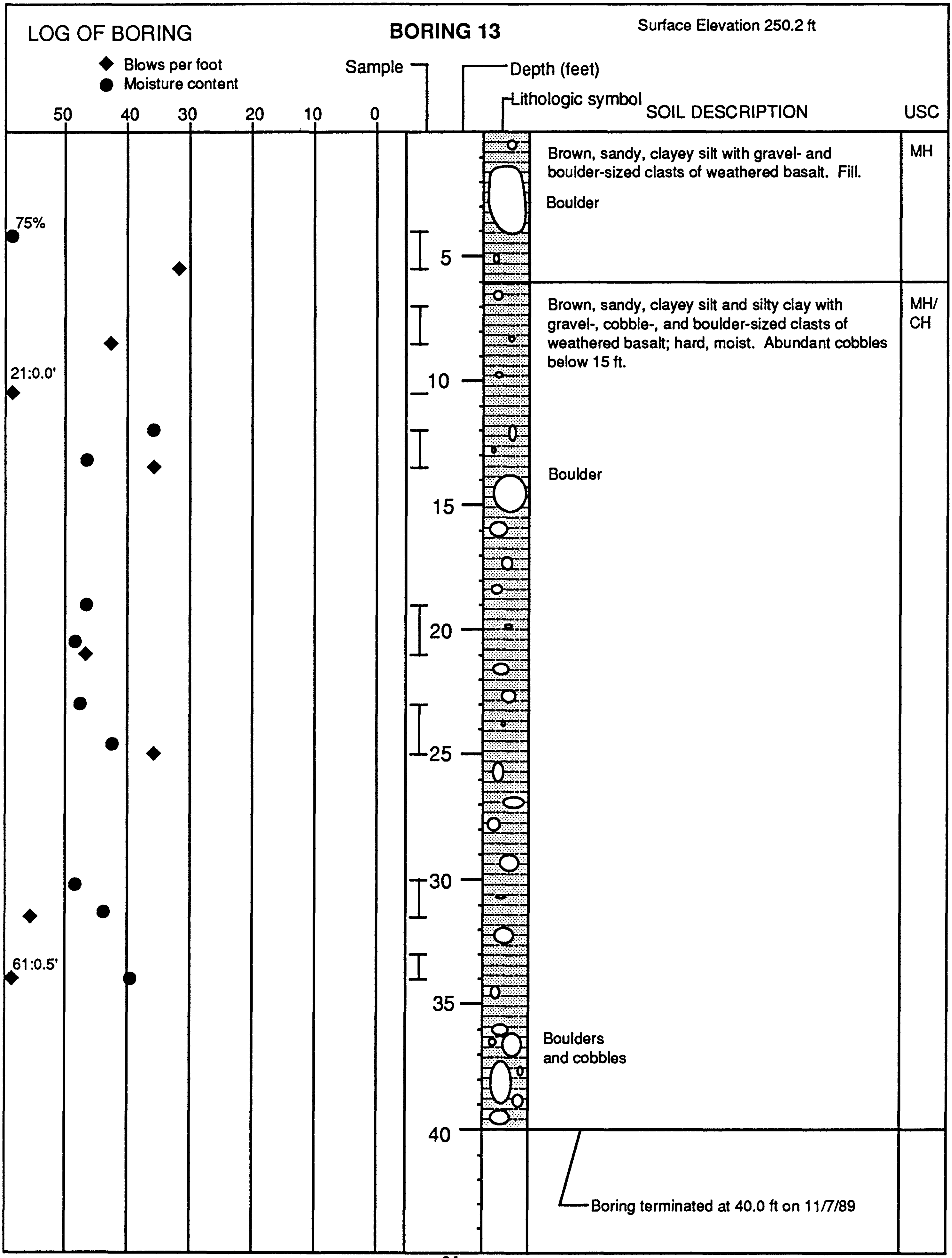

LOG OF BORING
BORING 13
Surface Elevation 250.2 ft
Blows per foot
Moisture content
50 40 30 20 10 0
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
75%
21:0.0'
61:0.5'
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and boulder-sized clasts of weathered basalt. Fill.
Boulder
MH
Brown, sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, moist. Abundant cobbles below 15 ft.
MH/ CH
Boulder
Boulders and cobbles
Boring terminated at 40.0 ft on 11/7/89

Figure A13.

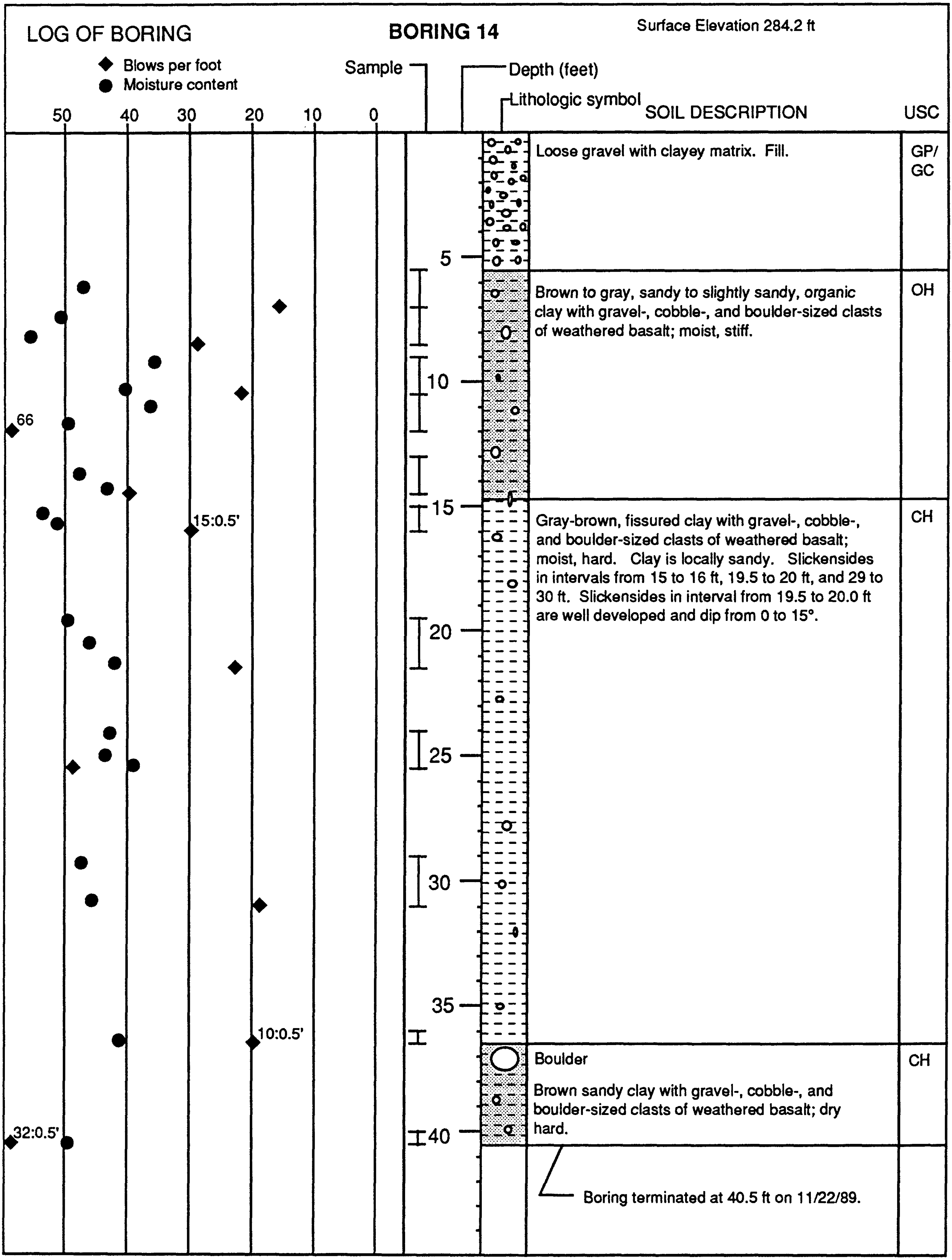
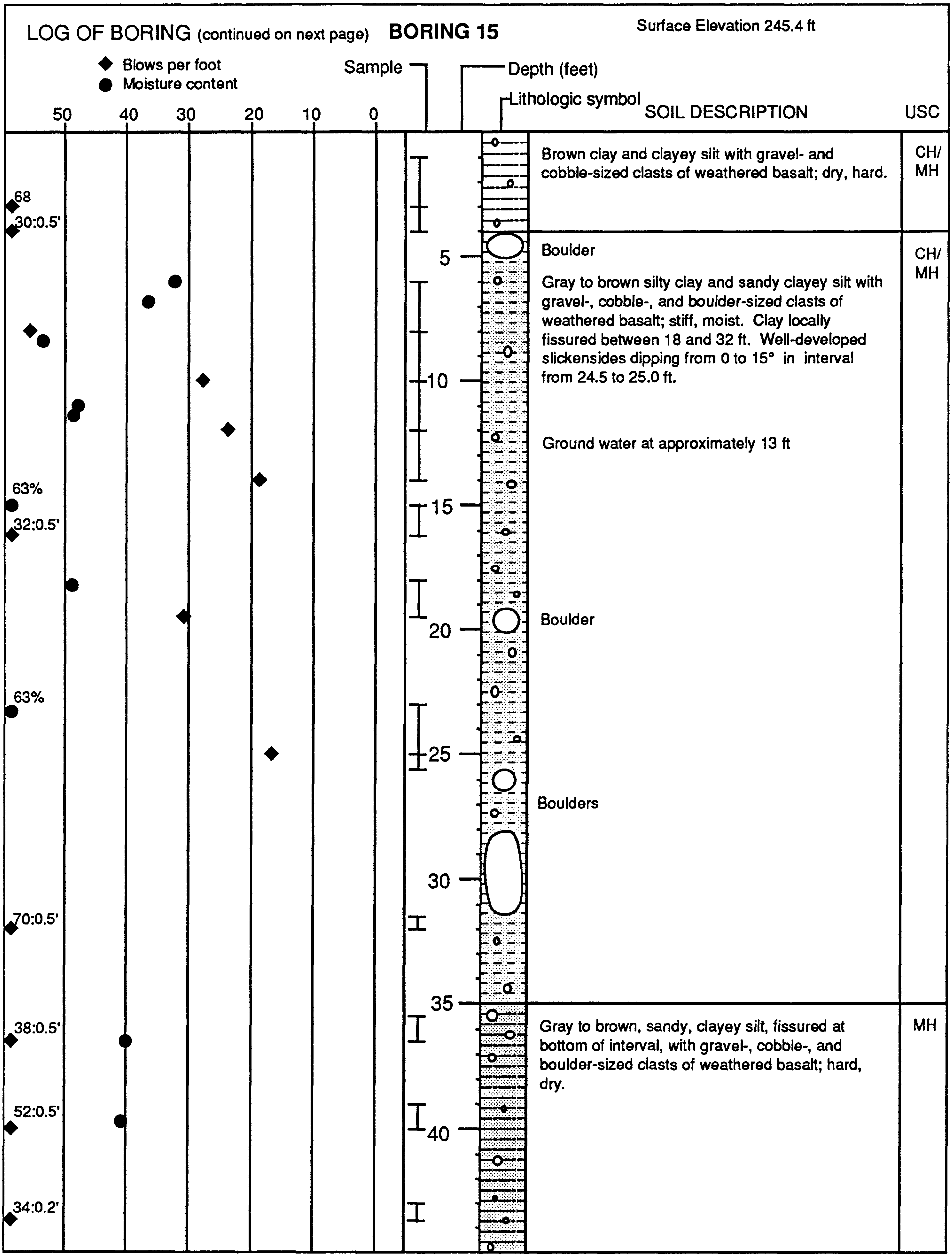

LOG OF BORING
BORING 14
Surface Elevation 284.2 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
5
10
15
20
25
30
35
40
66
15:0.5'
10:0.5'
32:0.5'
Loose gravel with clayey matrix. Fill.
GP/GC
Brown to gray, sandy to slightly sandy, organic clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; moist, stiff.
OH
Gray-brown, fissured clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; moist, hard. Clay is locally sandy. Slickensides in intervals from 15 to 16 ft, 19.5 to 20 ft, and 29 to 30 ft. Slickensides in interval from 19.5 to 20.0 ft are well developed and dip from 0 to 15°.
CH
Boulder
Brown sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; dry hard.
CH
Boring terminated at 40.5 ft on 11/22/89.

Figure A14.



LOG OF BORING (continued on next page)
BORING 15
Surface Elevation 245.4 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
68
30:0.5'
63%
32:0.5'
63%
70:0.5'
38:0.5'
52:0.5'
34:0.2'
5
10
15
20
25
30
35
40
Brown clay and clayey slit with gravel- and cobble-sized clasts of weathered basalt; dry, hard.
CH/ MH
Boulder
Gray to brown silty clay and sandy clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist. Clay locally fissured between 18 and 32 ft. Well-developed slickensides dipping from 0 to 15° in interval from 24.5 to 25.0 ft.
CH/ MH
Ground water at approximately 13 ft
Boulder
Boulders
Gray to brown, sandy, clayey silt, fissured at bottom of interval, with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, dry.
MH

Figure A15a.

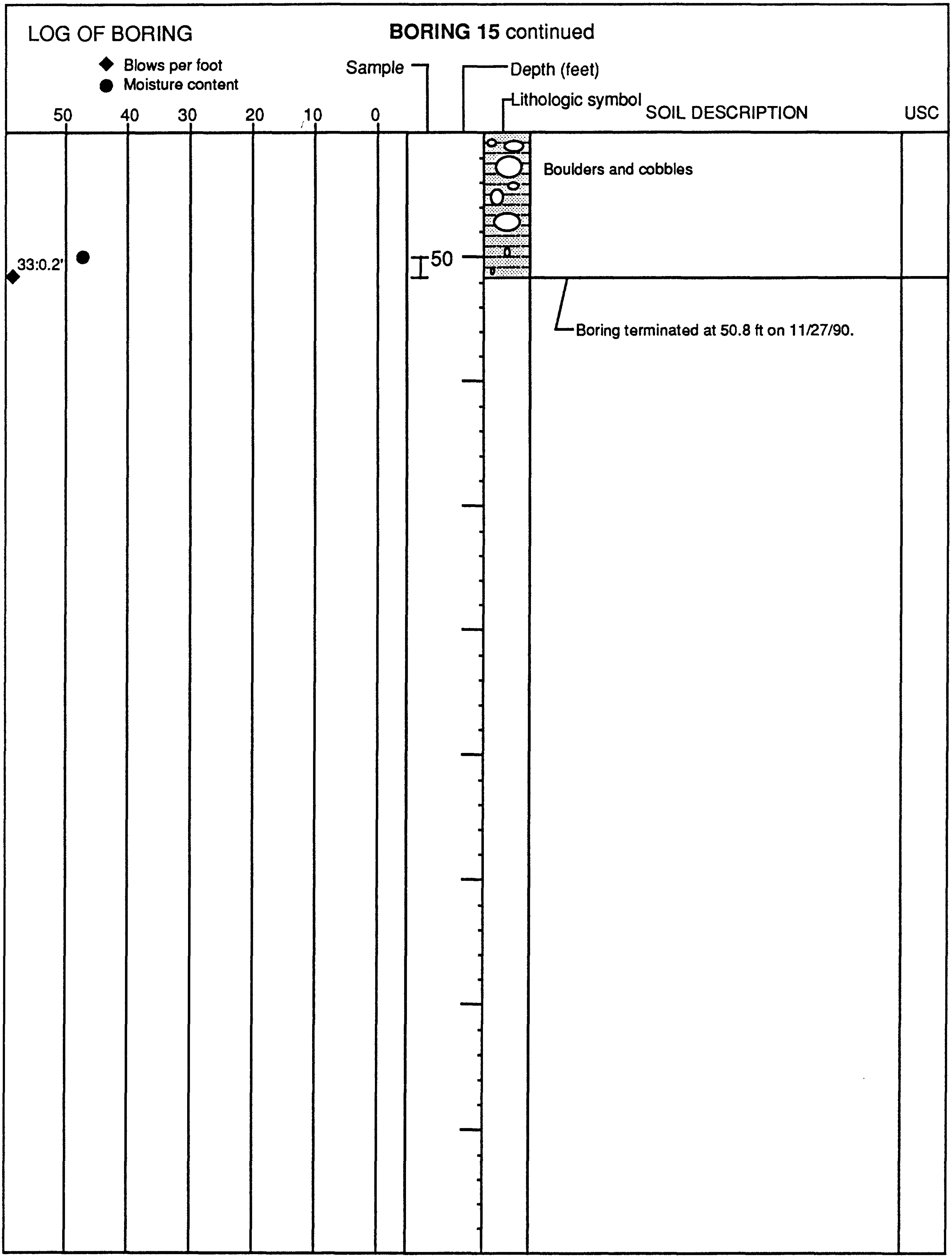

LOG OF BORING
BORING 15 continued
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
Boulders and cobbles
33:0.2'
50
Boring terminated at 50.8 ft on 11/27/90.

Figure A15b.

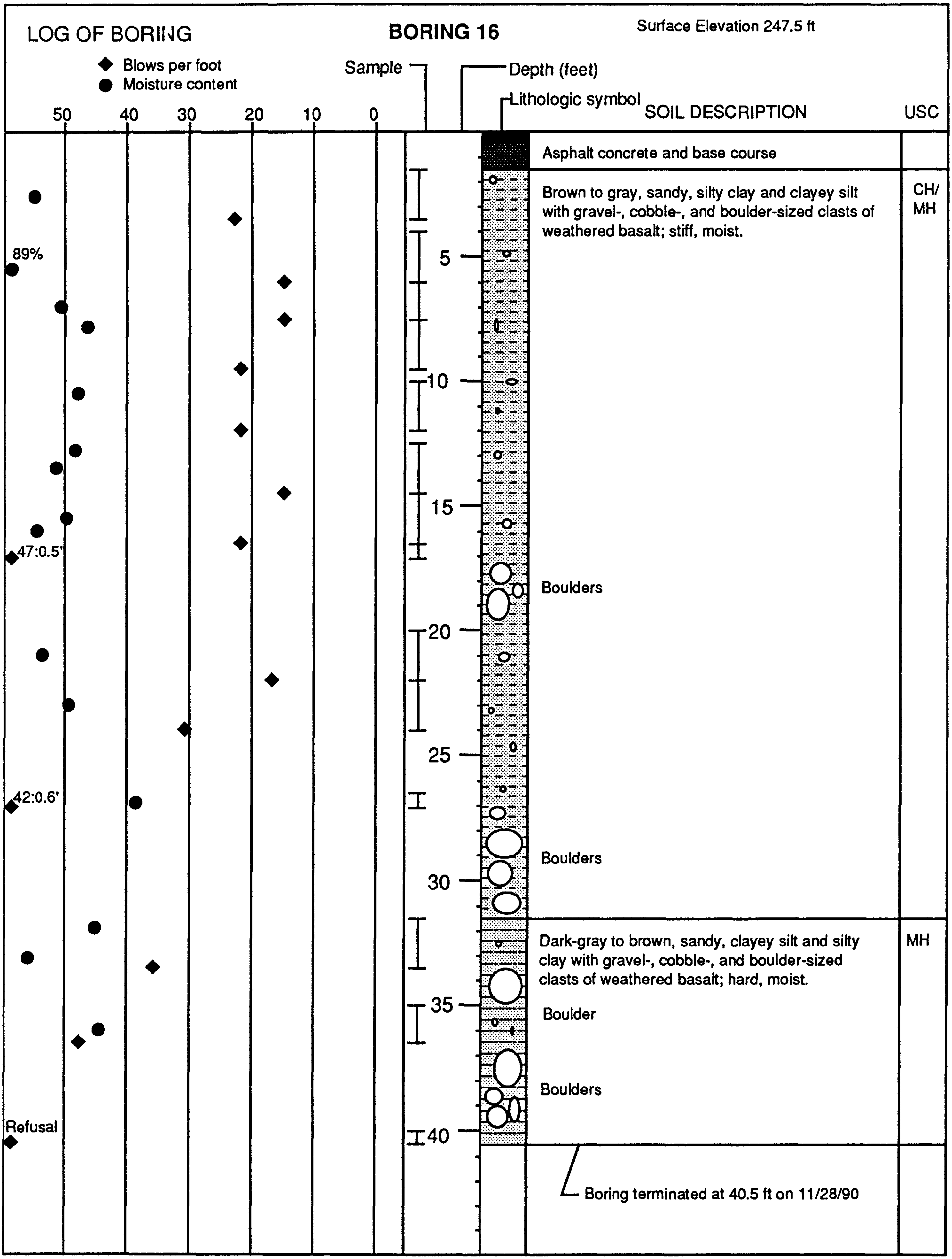

LOG OF BORING
BORING 16
Surface Elevation 247.5 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50 40 30 20 10 0
Asphalt concrete and base course
Brown to gray, sandy, silty clay and clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist.
CH/MH
89%
5
10
15
47:0.5'
Boulders
20
25
42:0.6'
Boulders
30
Dark-gray to brown, sandy, clayey silt and silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, moist.
MH
35
Boulder
Boulders
Refusal
40
Boring terminated at 40.5 ft on 11/28/90

Figure A16.

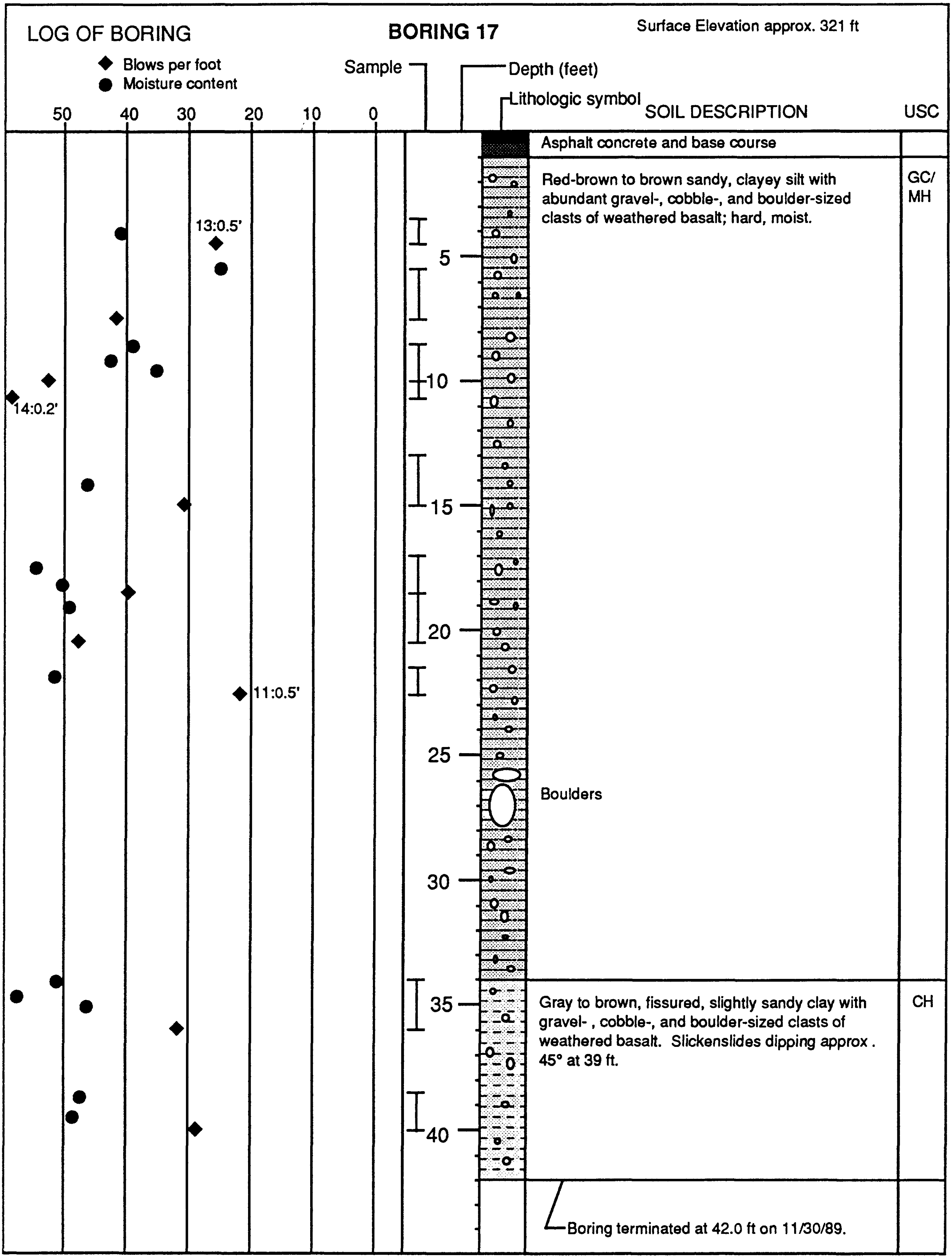
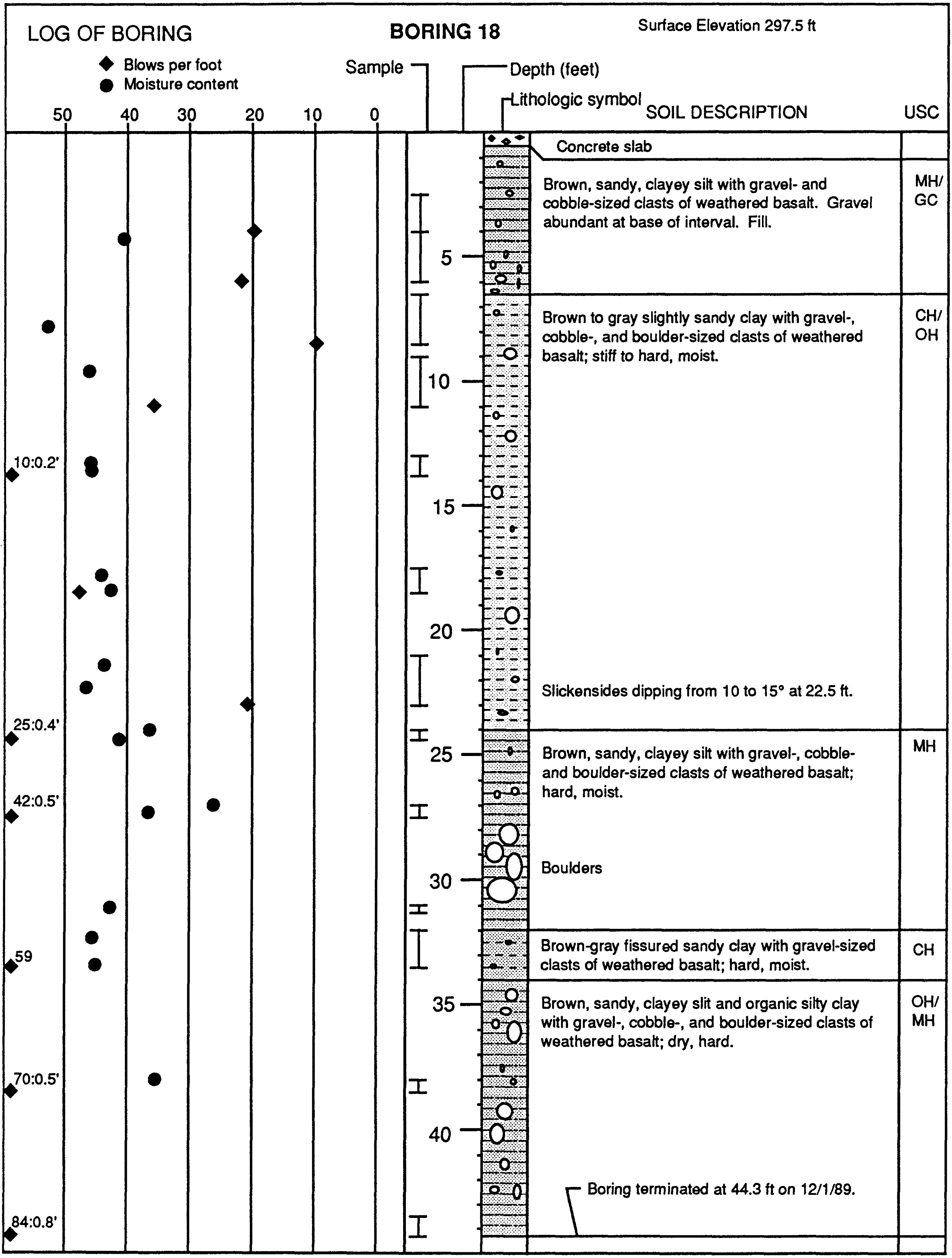

LOG OF BORING
BORING 17
Surface Elevation approx. 321 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
13:0.5'
14:0.2'
11:0.5'
5
10
15
20
25
30
35
40
Asphalt concrete and base course
Red-brown to brown sandy, clayey silt with abundant gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, moist.
GC/ MH
Boulders
Gray to brown, fissured, slightly sandy clay with gravel- , cobble-, and boulder-sized clasts of weathered basalt. Slickenslides dipping approx . 45° at 39 ft.
CH
Boring terminated at 42.0 ft on 11/30/89.

Figure A17



LOG OF BORING
BORING 18
Surface Elevation 297.5 ft
Blows per foot
Moisture content
50 40 30 20 10 0
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
Concrete slab
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt. Gravel abundant at base of interval. Fill.
MH/ GC
Brown to gray slightly sandy clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff to hard, moist.
CH/ OH
Slickensides dipping from 10 to 15° at 22.5 ft.
Brown, sandy, clayey silt with gravel-, cobble- and boulder-sized clasts of weathered basalt; hard, moist.
MH
Boulders
Brown-gray fissured sandy clay with gravel-sized clasts of weathered basalt; hard, moist.
CH
Brown, sandy, clayey slit and organic silty clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; dry, hard.
OH/ MH
Boring terminated at 44.3 ft on 12/1/89.
5
10
15
20
25
30
35
40
10:0.2'
25:0.4'
42:0.5'
59
70:0.5'
84:0.8'

Figure A18.

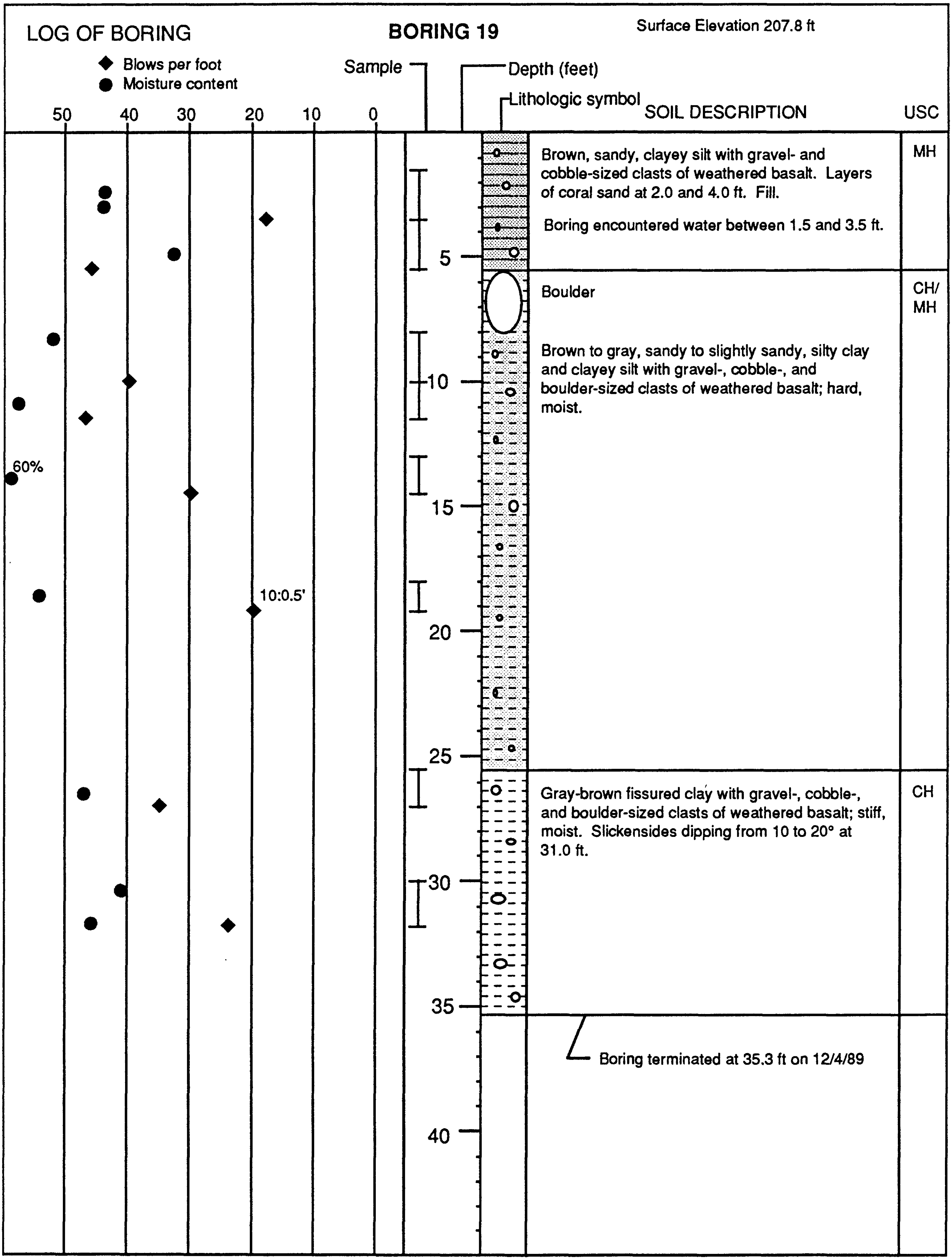

LOG OF BORING
BORING 19
Surface Elevation 207.8 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
60%
10:0.5'
5
10
15
20
25
30
35
40
Brown, sandy, clayey silt with gravel- and cobble-sized clasts of weathered basalt. Layers of coral sand at 2.0 and 4.0 ft. Fill.
Boring encountered water between 1.5 and 3.5 ft.
MH
Boulder
CH/
MH
Brown to gray, sandy to slightly sandy, silty clay and clayey silt with gravel-, cobble-, and boulder-sized clasts of weathered basalt; hard, moist.
Gray-brown fissured clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt; stiff, moist. Slickensides dipping from 10 to 20° at 31.0 ft.
CH
Boring terminated at 35.3 ft on 12/4/89

Figure A19.

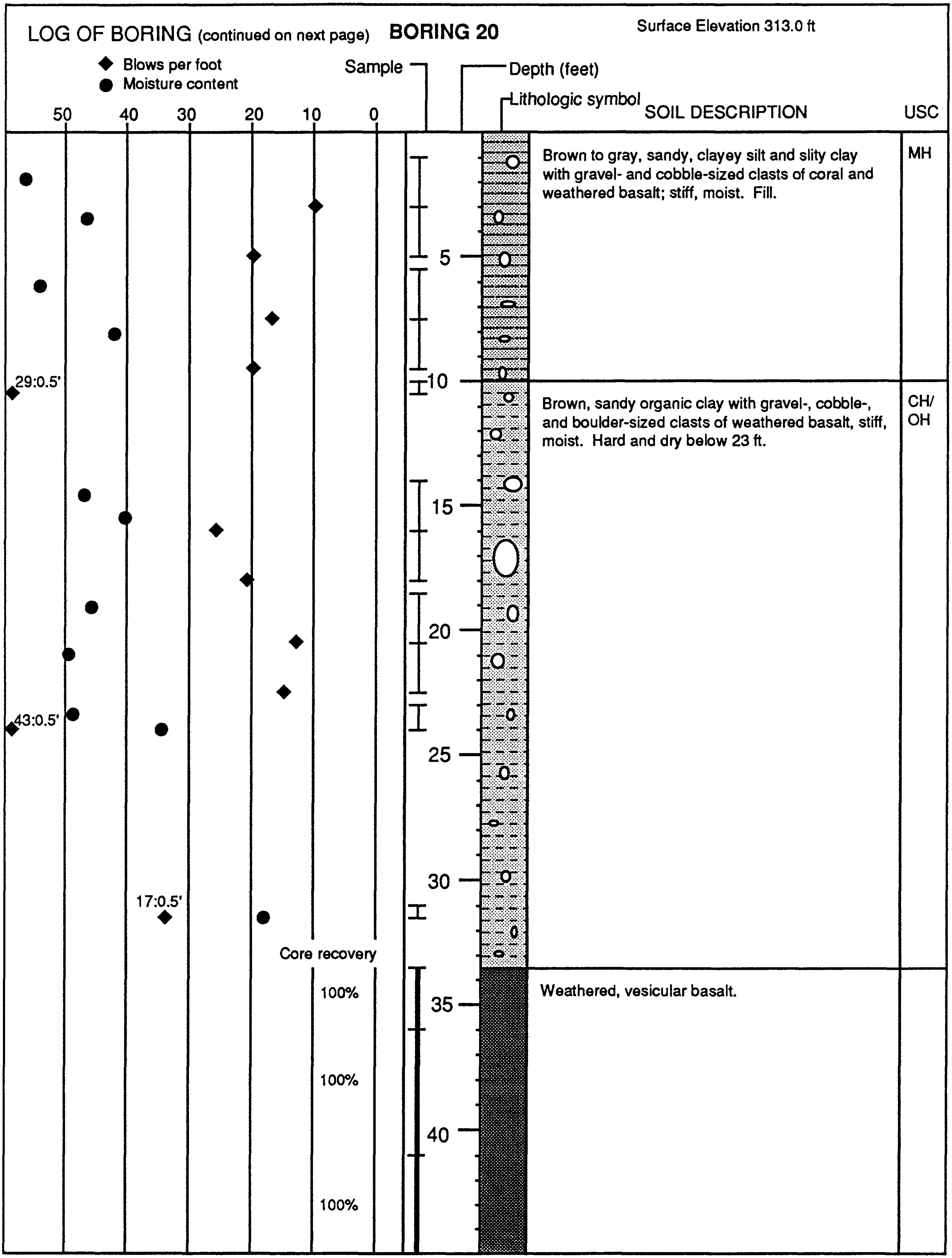

LOG OF BORING (continued on next page)
BORING 20
Surface Elevation 313.0 ft
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
29:0.5'
43:0.5'
17:0.5'
Core recovery
100%
100%
100%
5
10
15
20
25
30
35
40
Brown to gray, sandy, clayey silt and slity clay with gravel- and cobble-sized clasts of coral and weathered basalt; stiff, moist. Fill.
MH
Brown, sandy organic clay with gravel-, cobble-, and boulder-sized clasts of weathered basalt, stiff, moist. Hard and dry below 23 ft.
CH/
OH
Weathered, vesicular basalt.

Figure A20a.

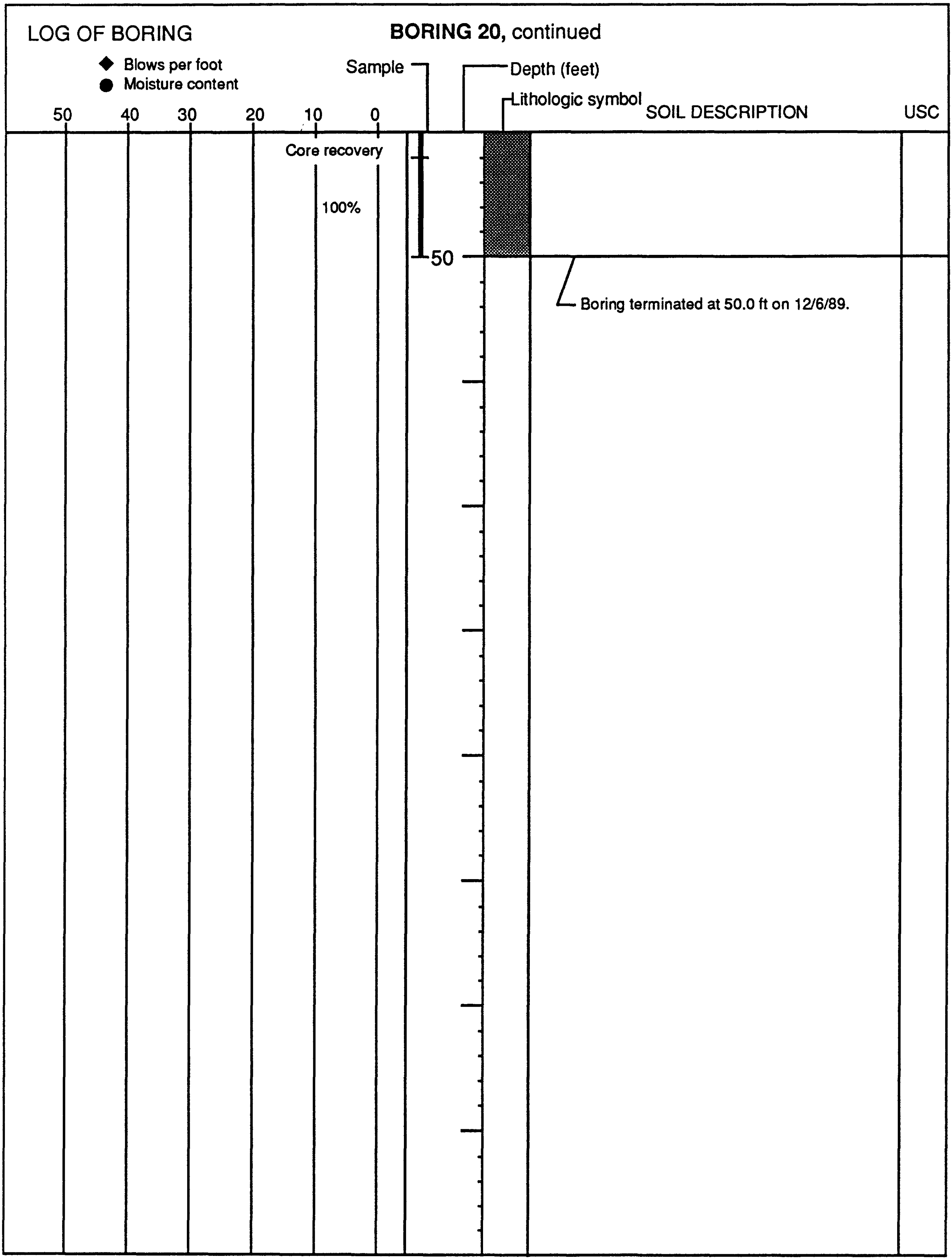

LOG OF BORING
BORING 20, continued
Blows per foot
Moisture content
Sample
Depth (feet)
Lithologic symbol
SOIL DESCRIPTION
USC
50
40
30
20
10
0
Core recovery
100%
50
Boring terminated at 50.0 ft on 12/6/89.

Figure A20b.

APPENDIX B

Laboratory test results

This appendix contains a table (table B1) of engineering properties determined for samples tested thus far in our laboratory, a soil plasticity chart (fig. B1), and graphs (figs B2, ..., B7) showing results of direct-shear tests on the samples. Grain-size distributions were determined by standard methods of sieving and hydrometer analysis. Atterberg limits were determined by standard methods on materials that were air-dried prior to testing. Grain density was determined by means of a pycnometer using standard methods.

Residual strength tests were performed in a direct-shear device using remolded samples having pre-cut shear surfaces. Each sample was tested at normal loads of 720, 1440, and 3600 lbf/ft^2. Before testing, the samples were sieved to remove particles coarser than medium sand. Sufficient moisture was added to the material to bring it to the plastic limit, and it was compacted into a 2.5-in.-diameter frame. Each sample was consolidated at twice the normal load used to measure the shear strength. After consolidation was complete, the shear plane was cut with a wire while the sample was under the normal load. Each sample was sheared in forward and reverse cycles to a total displacement of 60 mm in order to develop the shear surface and reduce the strength to its residual value. Each sample was then sheared at a rate of 0.12 or 0.024 mm/min for a distance of 9 mm to determine the residual strength. The rate of shear was increased by a factor of three and then reduced by a factor of 10 to check for the development of pore pressures during the test.

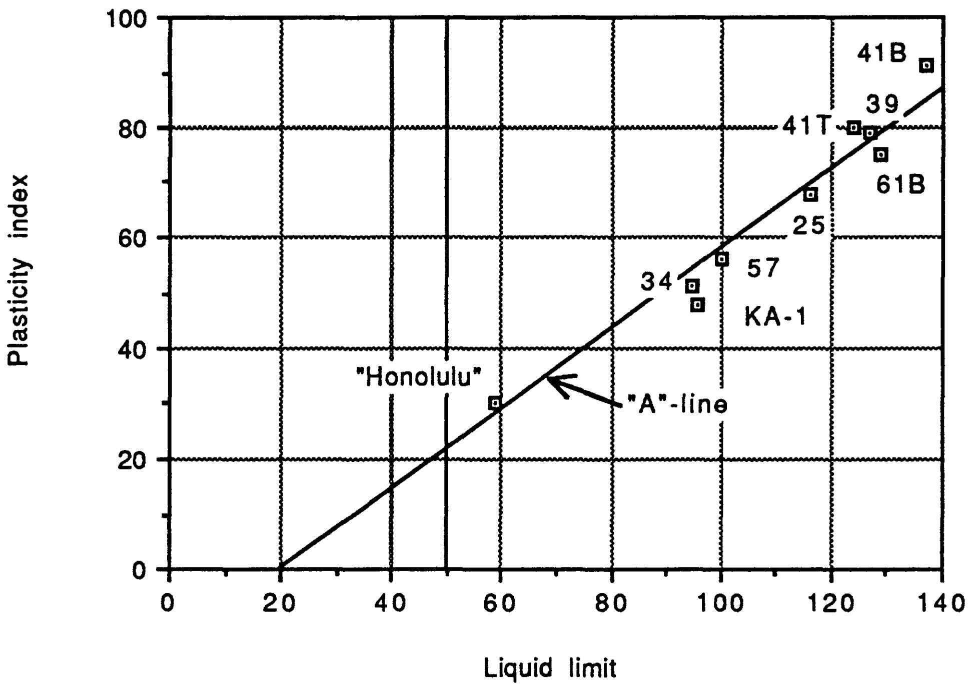
Our laboratory uses SI (meter/kilogram/second) units. The following table of conversion factors can be used to convert the test results to engineering (foot/pound/second) units:

To convert from	to	multiply by
m	ft	3.281
m^2	ft^2	10.76
mm	in.	0.0394
mm/min.	in./min.	0.0394
kN	lb	224.8
kPa	lb/ft^2	20.89

Table B1. Soil Sample Test Results

Boring Number	Sample Number	Depth range (feet)	Particle Size Distribution[1] A.S.T.M. Classification: Gravel >4.76 (mm)	Sand <4.76- >0.075 (mm)	Silt <0.075- >0.005 (mm)	Clay <0.005 (mm)	Atterberg Limits[1] LL	PL	PI	Grain density (g/cc)
3	R-25	6.0-7.5	5	7	15	73	116	48	68	2.72
3	TT-34	36.5-41.5	24	12	14	50	95	44	51	2.80
4	39	7.0-8.5	2	6	13	79	127	48	79	----
4	41T	10.0-10.8	43	8	9	40	124	44	80	----
4	41B	10.8-11.5	1	9	16	74	137	46	91	----
5	R-57	11.5-13.0	24	8	17	51	100	44	56	2.71
5	TT-61B	26.5-31.5	34	6	15	45	129	54	75	2.74
-	Honolulu[2]	surface	0	24	28	48	59	29	30	----
-	KA1[3]	surface	4	15	23	58	96	48	48	2.74

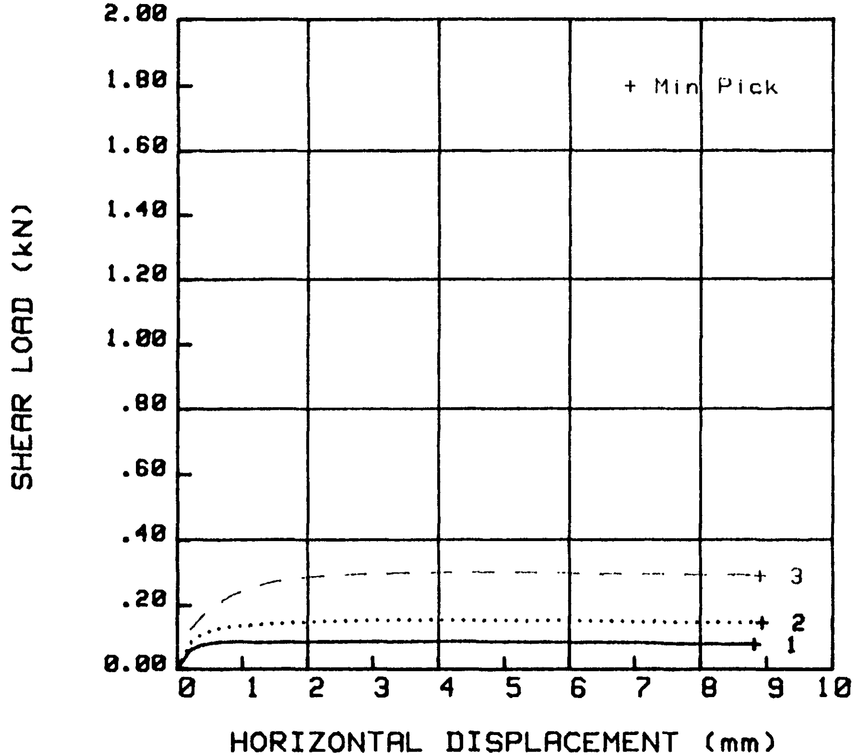
[1]Percentage of dry sample weight
[2]Cuttings left from private drilling operation behind house at 3022 Kahaloa Place.
[3]From under house at 3065 Kalawao Street.

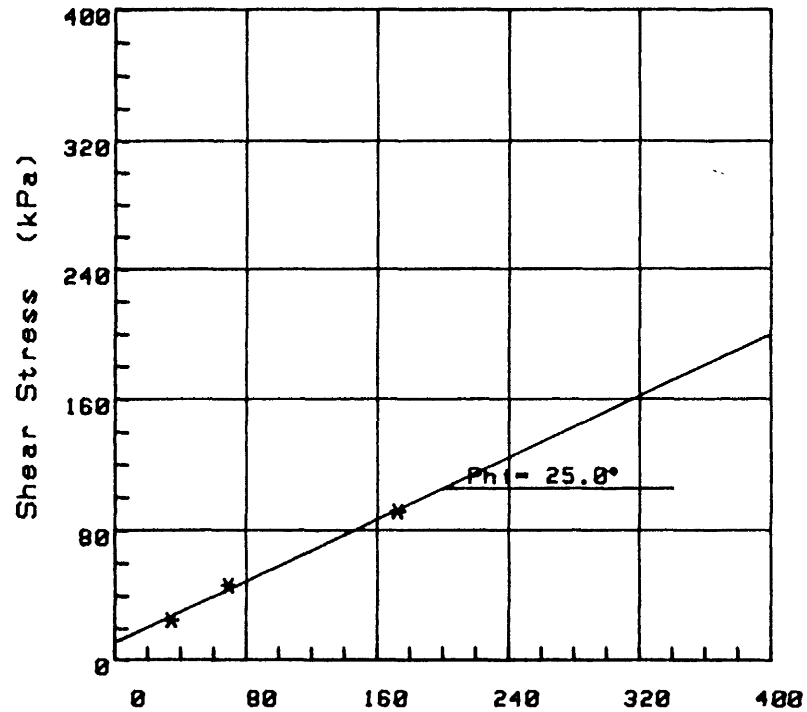


Plasticity chart for soil samples from the Alani-Paty landslide

Figure B1

DIRECT SHEAR TEST RESULTS
Sample I.D. HONOLULU
Submitter: BAUM
Date: 6/1/89





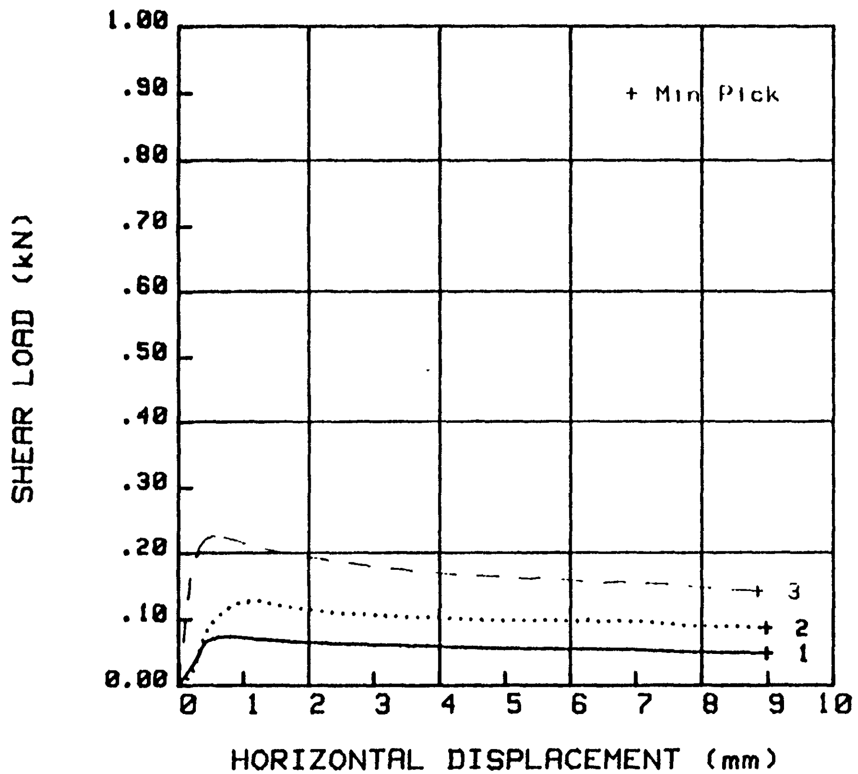
Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H1	.0798	.1092
2	H21	.1467	.2184
3	H31	.2900	.5460

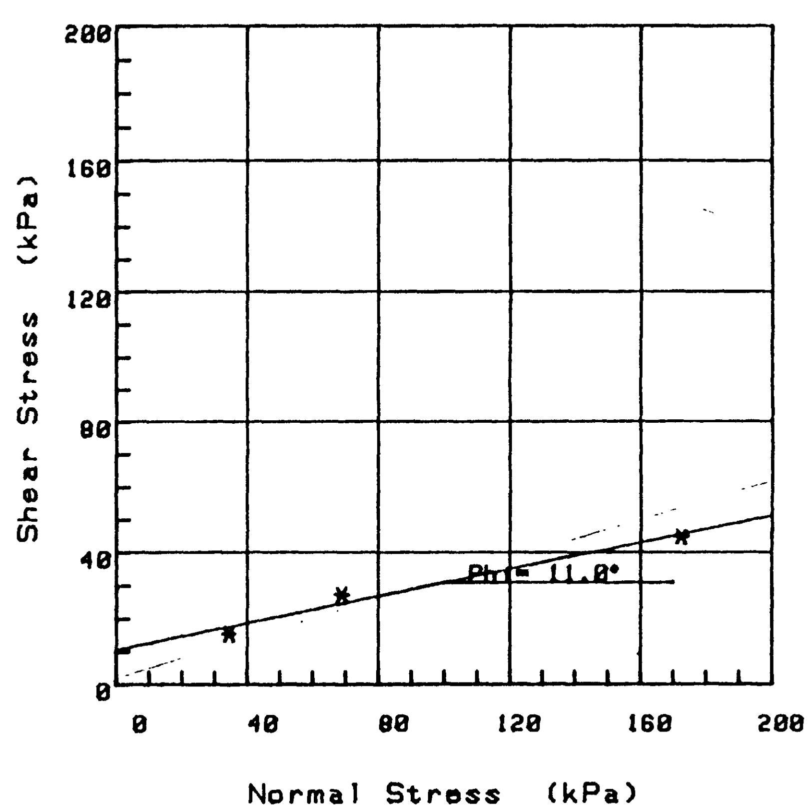
Cohesion: 11.0459 kPa

Sample area: .003167 meters squared

Figure B2.

DIRECT SHEAR TEST RESULTS
Sample I.D. KA-1
Submitter: FLEMING
Date: 7/10/89





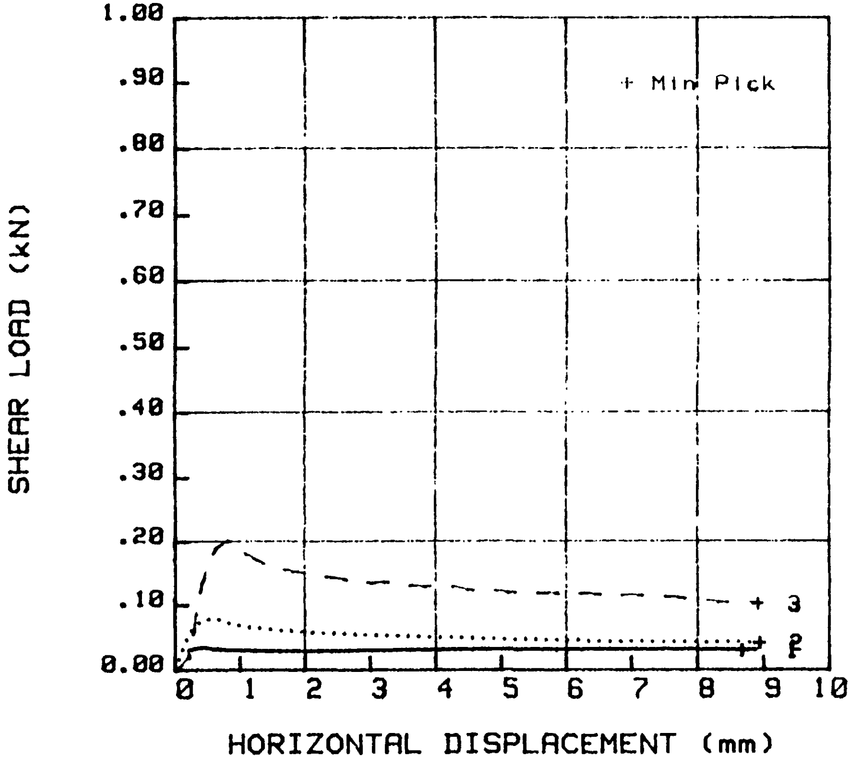
Cohesion: 10.3838 kPa

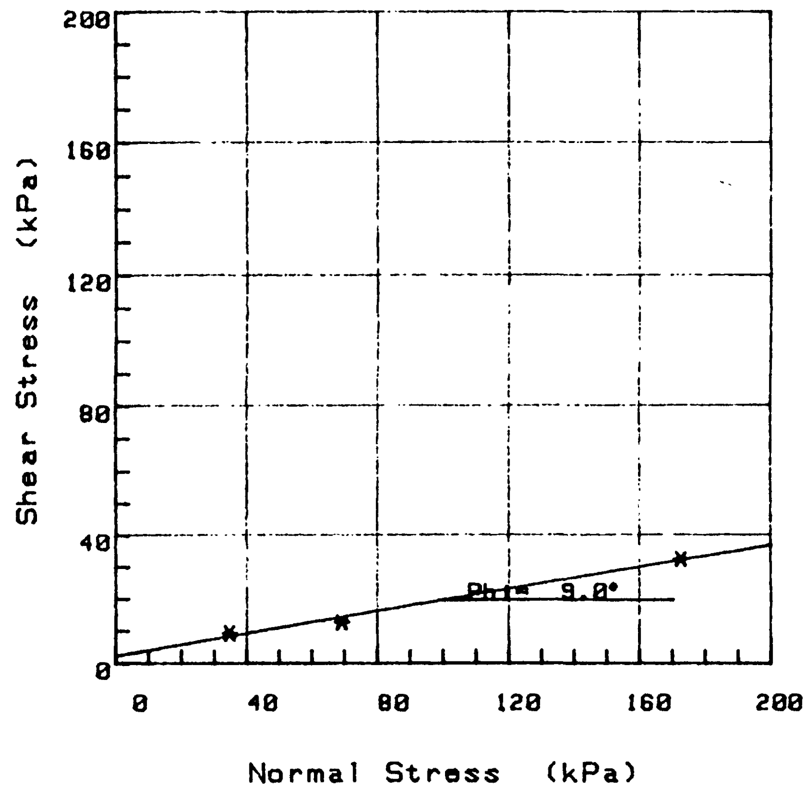
Sample area: .003167 meters squared

Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H41	.0485	.1092
2	H51	.0861	.2184
3	H61	.1416	.5460

Figure B3.

DIRECT SHEAR TEST RESULTS
Sample I.D. R-25
Submitter: BAUM
Date: 1/31/89





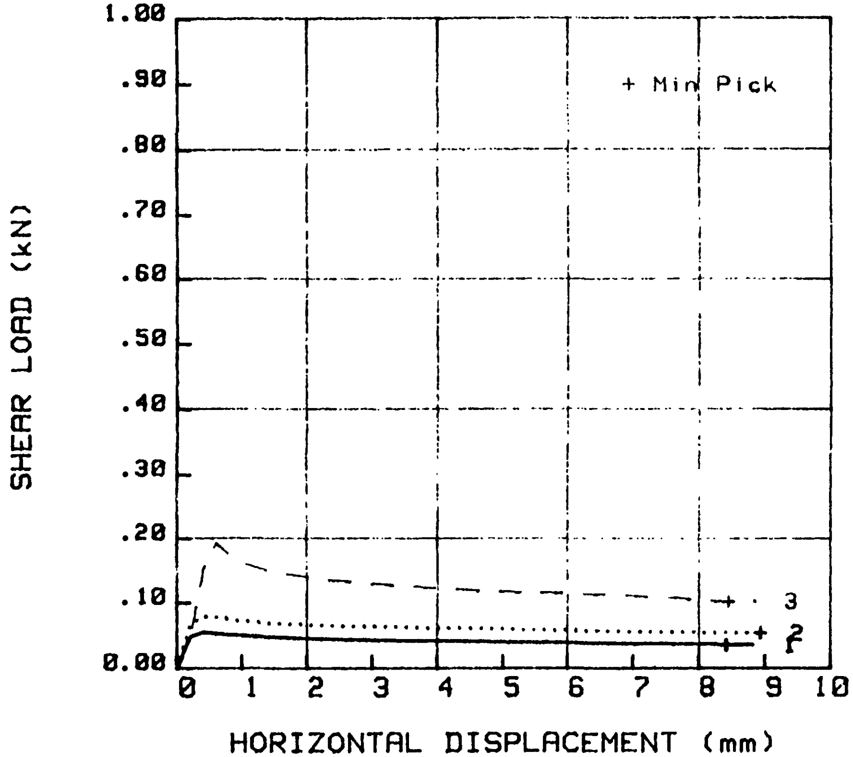
Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H171	.0293	.1092
2	H181	.0399	.2184
3	H191	.1025	.5460

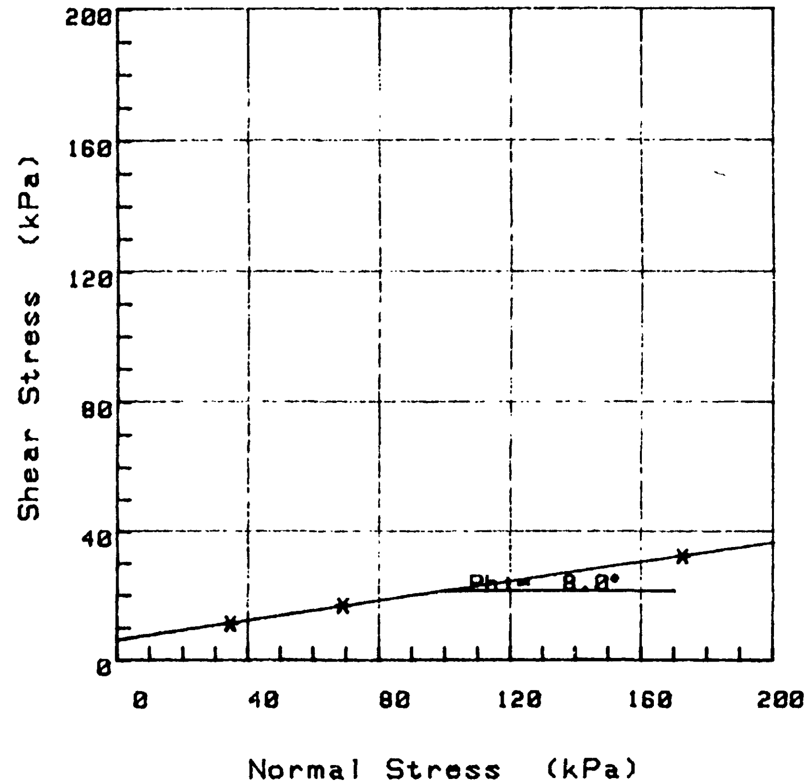
Cohesion: 2.16551 kPa

Sample area: .003167 meters squared

Figure B4.

DIRECT SHEAR TEST RESULTS
Sample I.D. TT-34
Submitter: BAUM
Date: 2/8/90





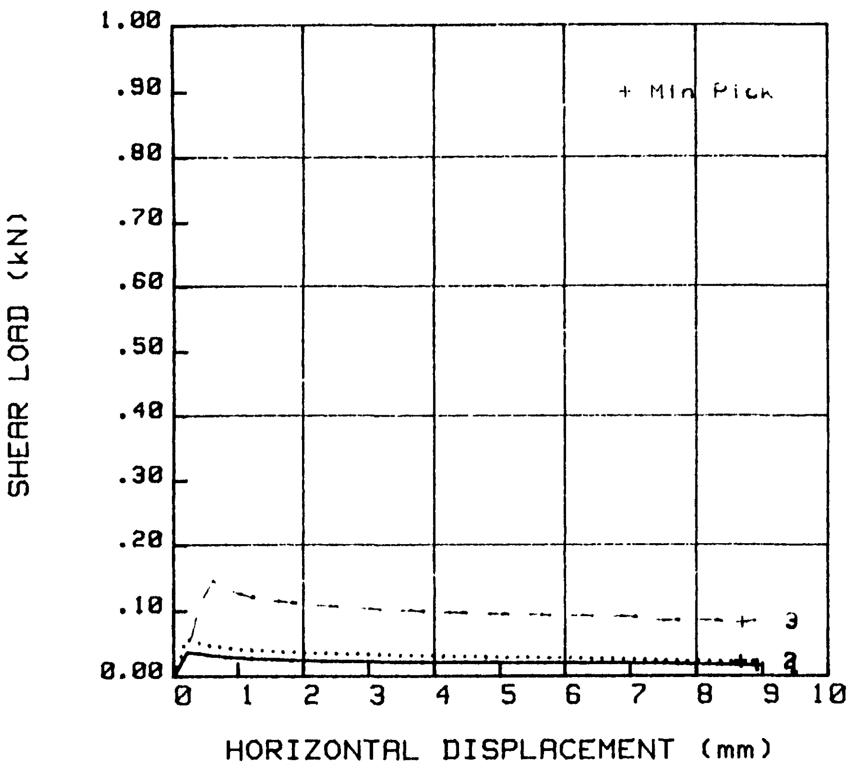
Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H201	.0355	.1092
2	H211	.0531	.2184
3	H221	.1018	.5460

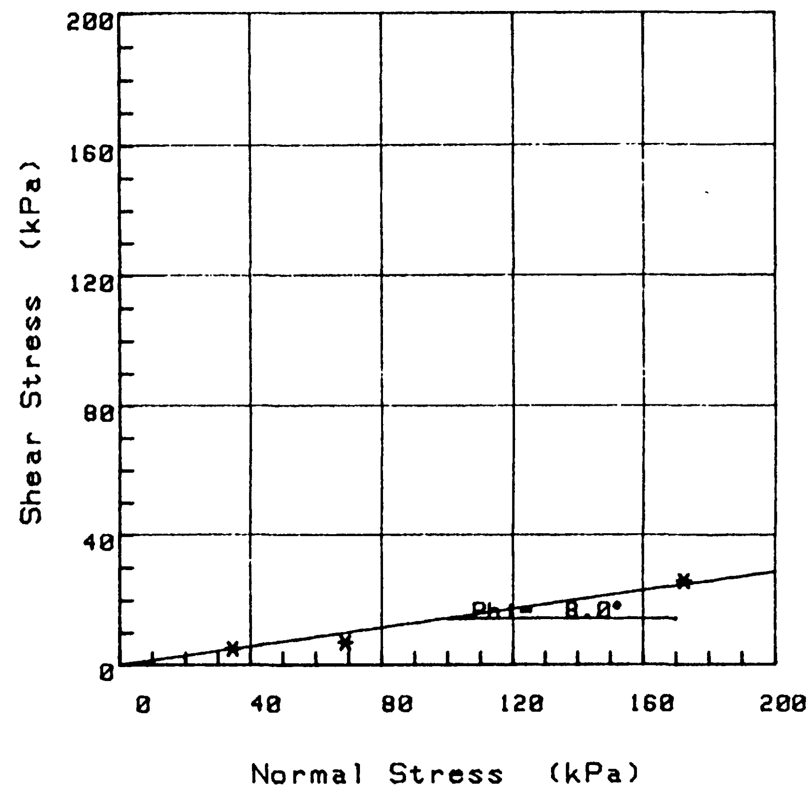
Cohesion: 6.14169 kPa

Sample area: .003167 meters squared

Figure B5.

DIRECT SHEAR TEST RESULTS
Sample I.D. 41-B
Submitter: BAUM
Date: 11/29/89





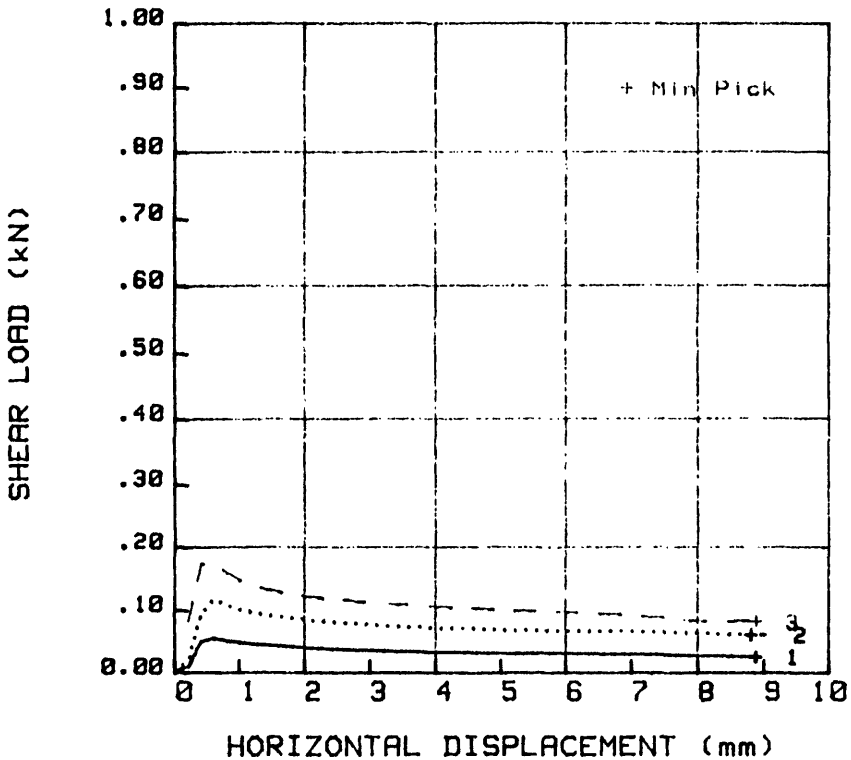
Sample area: .003167 meters squared

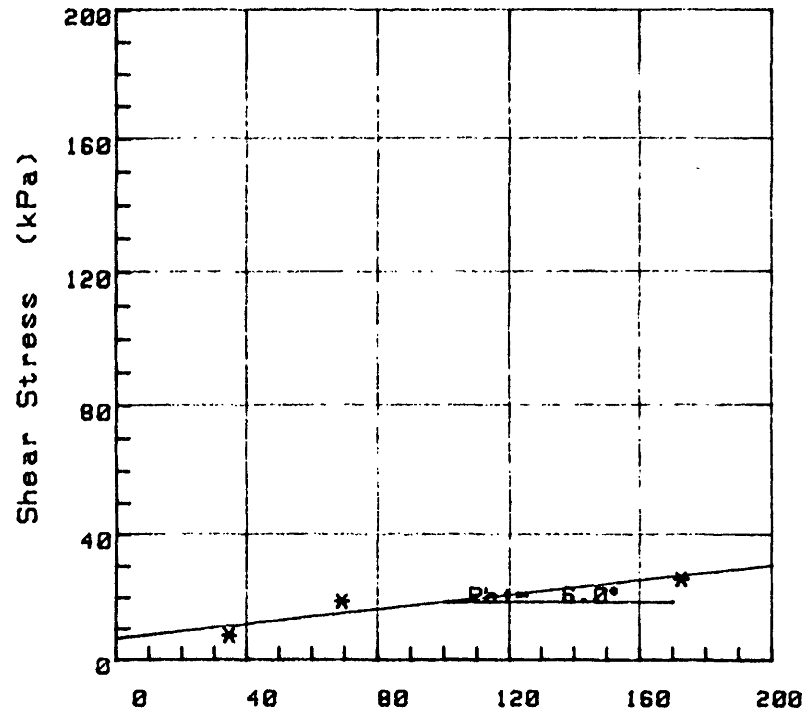
Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H141	.0156	.1092
2	H151	.0218	.2184
3	H161	.0816	.5460

Figure B6

DIRECT SHEAR TEST RESULTS

Sample I.D. TT-61B
Submitter: BAUM
Date: 2/16/90





Normal Stress (kPa)

Cohesion: 6.65116 kPa

Sample area: .003167 meters squared

Plot No.	File ID	Residual Strength (kN)	Normal load (kN)
1	H231	.0245	.1092
2	H241	.0594	.2184
3	H251	.0823	.5460

Figure B7.

APPENDIX C

Subsurface Instrumentation

This appendix contains a table listing the instrumentation installed in the borings (table C1), a table listing estimated thickness of the landslide (table C2), graphs of water levels in our piezometers (figs. C1, ..., C11), and graphs of inclinometer measurements (figs. C12, ..., C17). A completion diagram for boring 4 shows schematically how the piezometers and anchored cables were installed (fig. C18).

Each piezometer consists of 1-in.-nominal diameter PVC pipe with a 6-in.-long porous tip. The tip is embedded in a column of coral sand 2 to 3 ft high and sealed above and below with columns of bentonite 2 to 3 ft high. Water levels were measured by means of a probe lowered from the surface down the PVC pipe. Measurements were made approximately weekly.

Anchored cables consist of a 5/16-in.-diameter wire rope connected to a short section of steel pipe that is capped at both ends and filled with shot. The pipe anchor was lowered to the bottom of the hole, presumed to be below the basal slip surface of the landslide. Back-fill materials placed in the boring hold the anchored end of the cable in place so that the cable is pulled down the hole as sliding occurs. A length of the cable was left protruding from the ground surface and movement is detected by repeatedly measuring the length of the protruding cable.

Depth of the failure surface was estimated from the locations of bends in many of the deep piezometer pipes. The bends were located by lowering sections of metal tubing (nominal 1/2-in.-diameter galvanized electrical conduit), suspended from nylon fishing line, down the piezometers and measuring the depths where the sections stopped. We used sections of tubing 6, 12 and 18 in. long to locate the bends; the different lengths were used to estimate how sharp the bends were. The estimated depths reported in the appendix are accurate to about ±2 ft, or better. Our confidence in the measurements will increase if movement occurs in the coming year and sharpens the bends in the pipes.

Holes for inclinometer measurements were cased with ABS (acrylonitrile--butadiene-styrene) tubing having special groves to align the inclinometer probe. The casing was secured in the holes by pouring grout down the annular space between the sides of the hole and outside of the casing. The cased holes are surveyed approximately monthly according to standard methods using an inclinometer probe. The algebraic signs of the deflections indicated in the graphs follow the convention that positive deflection on the A axis is upslope and negative is downslope; positive deflection on the B-axis is to the left of an observer looking downslope and negative is to the right.

Table C1. Summary of depths of instruments in USGS borings in the Alani-Paty landslide

Boring #	Depth (feet)	Instrument	Depth (feet)	Comments
1	41.3			
		piezometer	13.2	
		piezometer	25.5	
		anchor	27.8	
3	41.5			
		piezometer	5.0	
		piezometer	30.0	
		anchor	36.3	
4	41.0			
		piezometer	20.2	
		piezometer	39.5	dry
		anchor	39.9	
5	41.5			
		piezometer	5.7	
		piezometer	34.4	dry
		anchor	38.0	
6	50.0			
		inclinometer	47.6 (depth of lowest measurement)	
7	41.0			
		piezometer	8.0	dry
		piezometer	37.3	
8	41.0			
		piezometer	12.0	
		piezometer	35.1	
		anchor	40.2	
9	41.0			
		piezometer	8.6	
		piezometer	25.1	
		anchor	41.0	
10	48.5			
		inclinometer	47.6	
11	41.5			
		neutron probe	40.0	
12	40.5			
		piezometer	18.0	flooded
		piezometer	35.8	flooded
		anchor	39.9	

Table C1. (continued)

Boring #	Depth (feet)	Instrument	Depth (feet)	Comments
13	40.0			
		piezometer	12.0	
		piezometer	32.1	dry
		anchor	37.5	
14	40.5			
		piezometer	9.4	
		piezometer	21.9	
		piezometer	38.2	dry
15	50.8			
		inclinometer	49.2	
16	40.5			
		piezometer	15.4	
		piezometer	20.7	
		piezometer	36.7	dry
17	42.0			
		neutron probe	40.0	
18	44.3			
		neutron probe	40.0	
19	35.3			
		piezometer	14.4	
		piezometer	31.8	dry
		anchor	35.3	
19x	5.6			
		piezometer	5.4	
20	50.0			
		piezometer	9.5	
		piezometer	21.5	
		piezometer	30.0	dry
		anchor	40.0	

Table C1. (continued)

INCLINED BORINGS

These borings were made by PR Drilling Co., Inc., for STV/Lyon Associates, to determine the distance to bedrock. STV/Lyon had no plans to instrument the holes, so we plugged the holes at shallow or intermediate depths and installed open-tube piezometers. Depths in the table below indicate slope distances down the borings, which slope 40° from the horizontal.

Boring #	Depth (feet)	Instrument	Depth (feet)	Comments
100	15.0			
		piezometer	10.1	
103	80.0			
		piezometer	5.8	dry
		piezometer	56.0	dry
108	19.8			
		piezometer	19.4	dry

Table C2. Approximate thickness of the Alani-Paty landslide

Boring #	Thickness (feet)	Remarks
1	21	
3	27	
4	28	
5	29	
6 (inclinometer, see graph)	--	Sliding not observed; in area between mapped boundaries of the Alani-Paty and Hulu-Woolsey landslides.
7	--	Outside mapped boundaries of landslide.
8	--	Outside mapped boundaries of landslide.
9	>24.5	
10 (inclinometer, see graph)	--	Sliding not observed; in area of suspected incipient movement.
11	--	Casing not sufficiently bent to determine depth of sliding.
12	33(?)	Uncertain, presumed bend is near bottom of piezometer pipe.
13	27	
14	20	
15 (inclinometer, see graph)	26	In area of incipient movement outside mapped boundaries of landslide.

Table C2. (continued)

Boring #	Depth of sliding (feet)	Remarks
16	--	In area of incipient movement outside mapped boundaries of landslide; pipe not sufficiently bent to determine depth of sliding.
17	--	outside mapped boundaries of landslide.
18	--	casing not sufficiently bent to determine depth of sliding.
19	13	
20	23	

Figure C1. Piezometers in boring 1

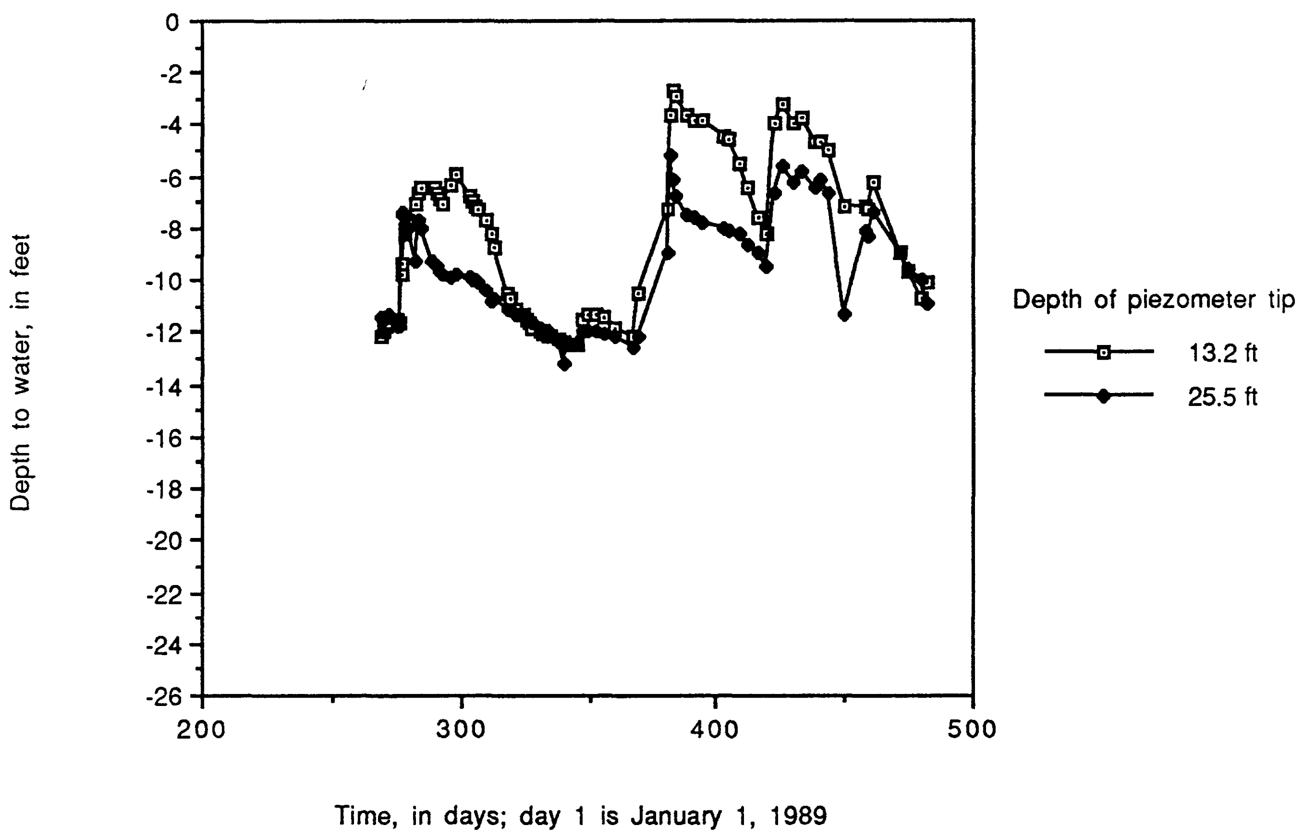


Figure C2. Piezometers in boring 3

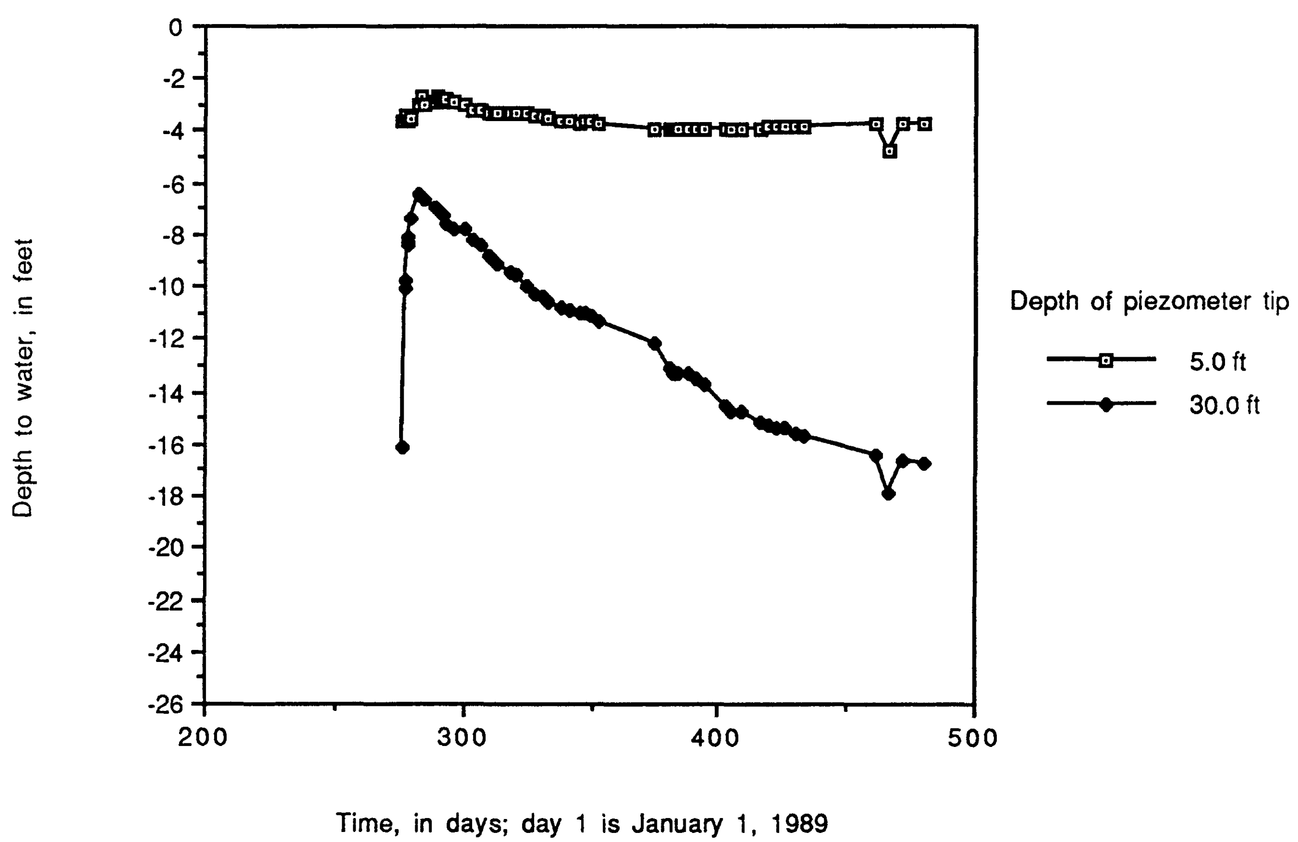


Figure C3. Piezometers in borings 4 and 5

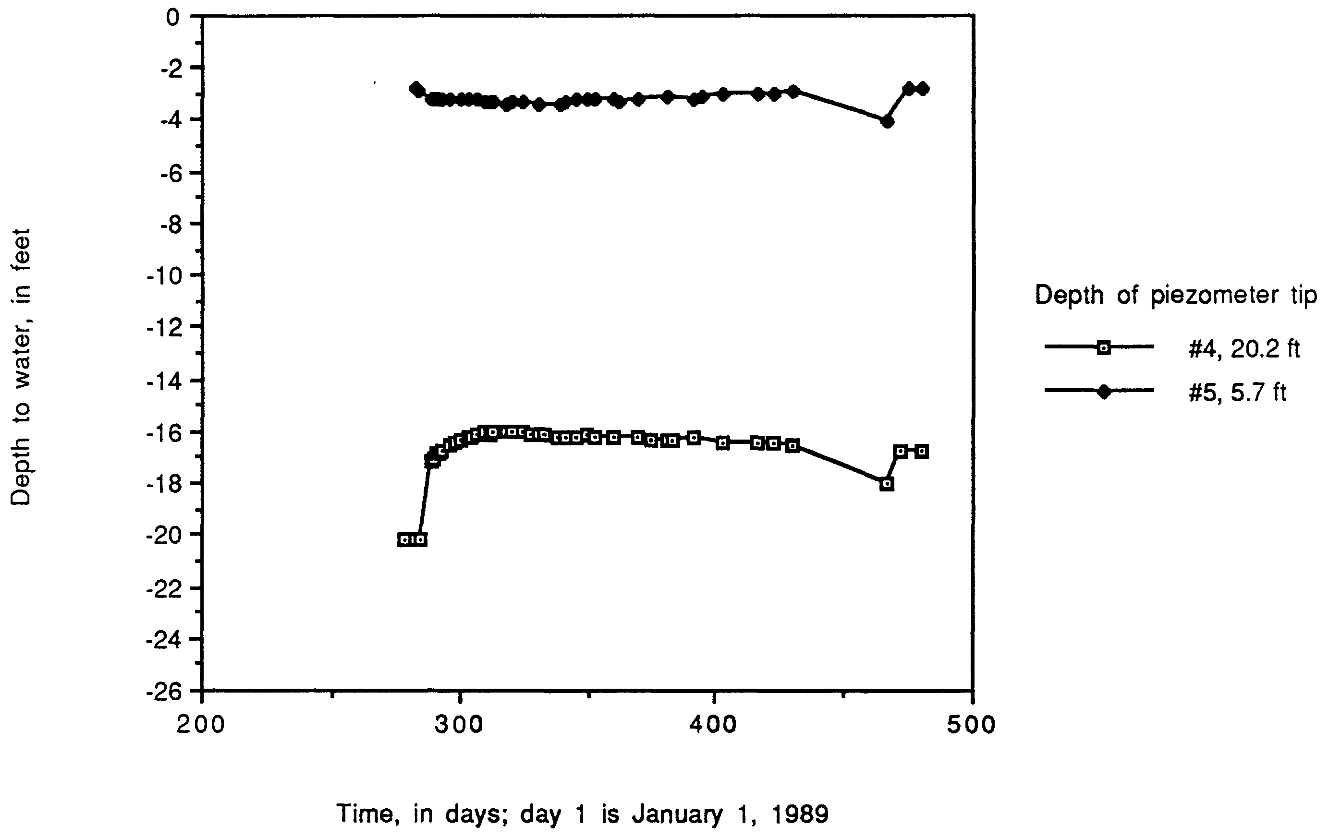


Figure C4. Piezometer in boring 7

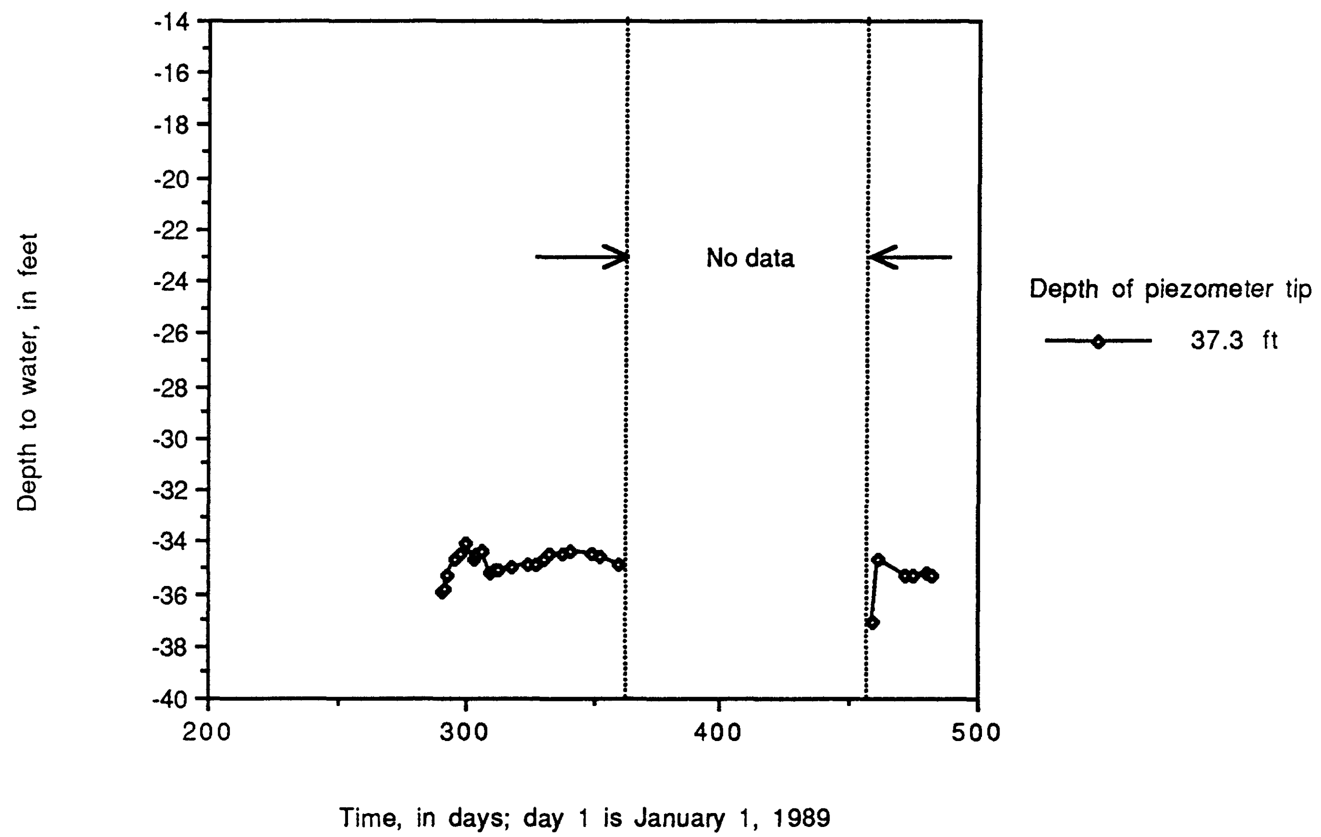


Figure C5. Piezometers in boring 8

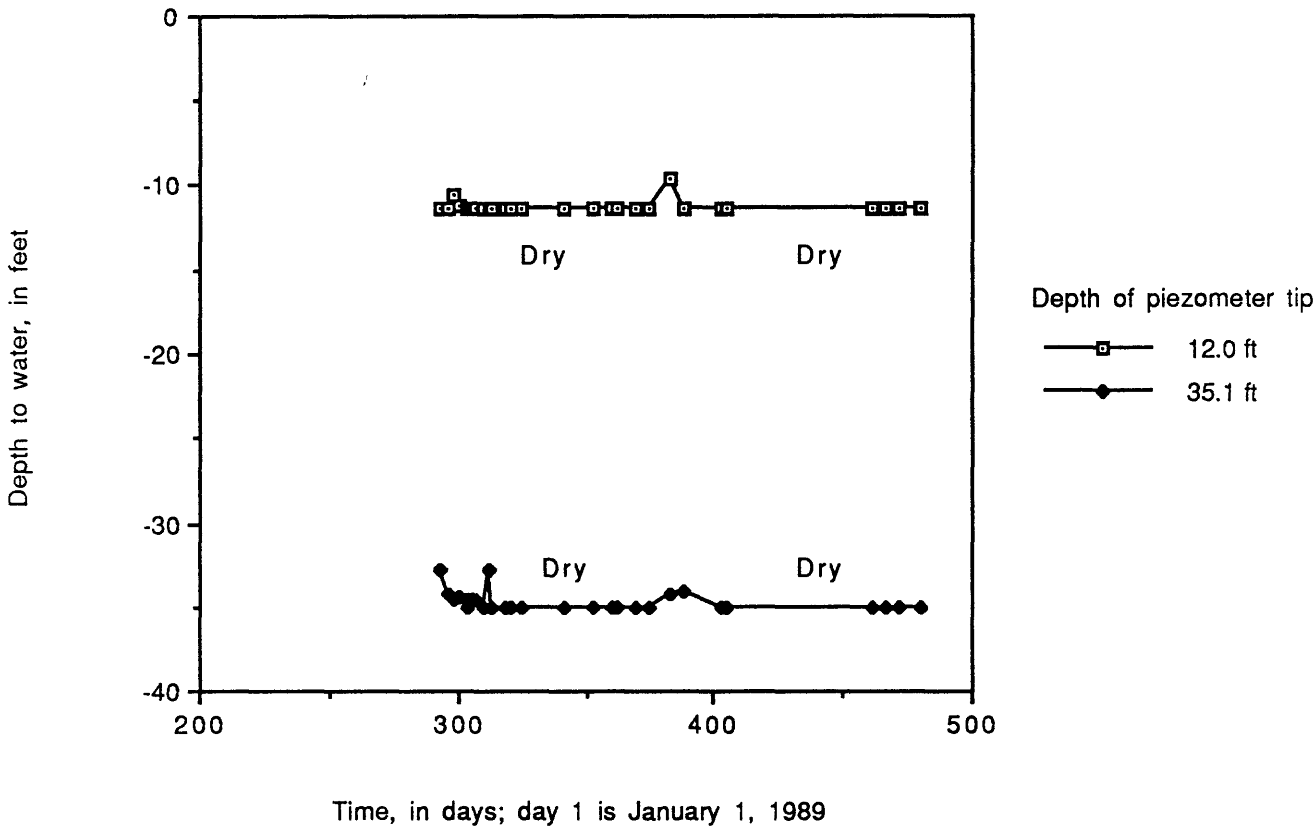


Figure C6. Piezometers in boring 9

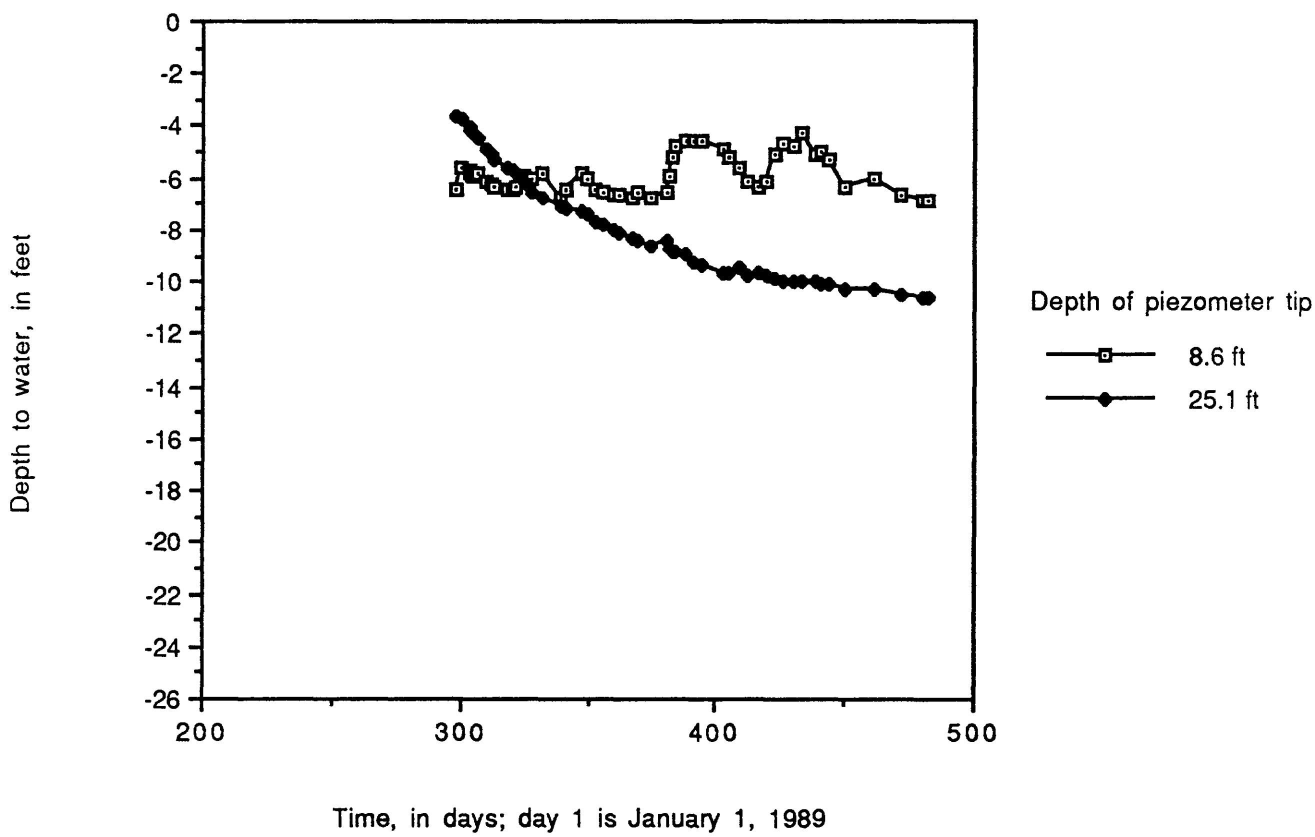


Figure C7. Piezometers in borings 13 and 14

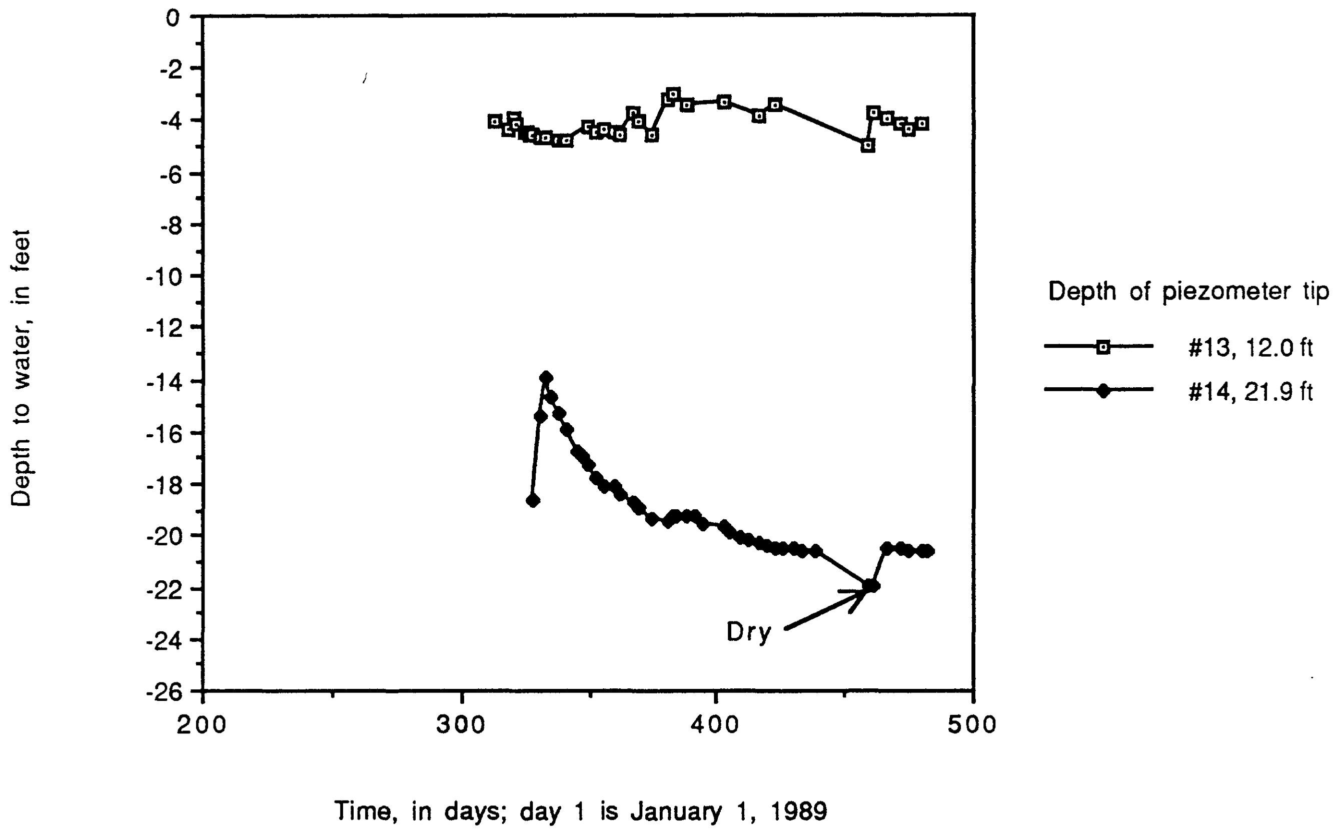


Figure C8. Piezometers in boring 16

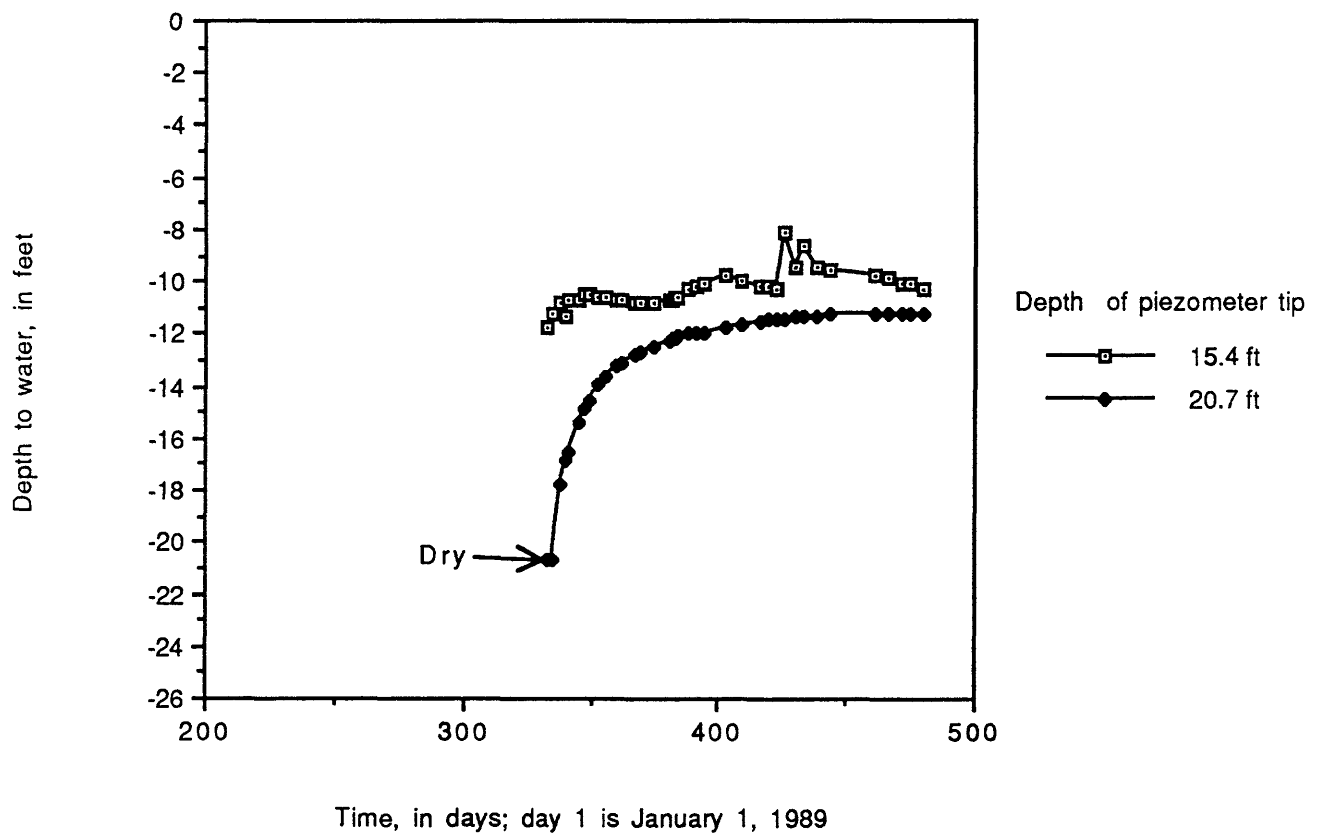


Figure C9. Piezometers in borings 19 and 19x

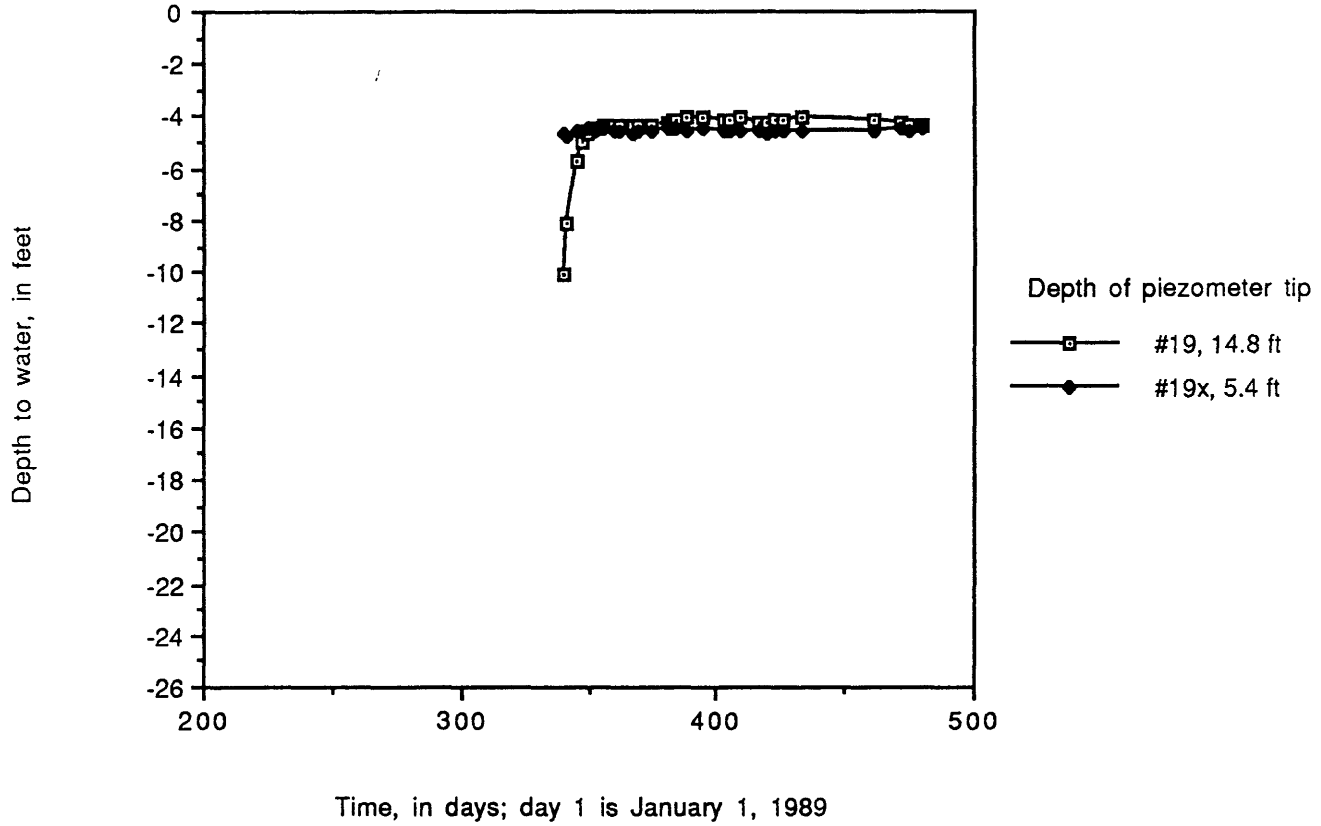


Figure C10. Piezometers in boring 20

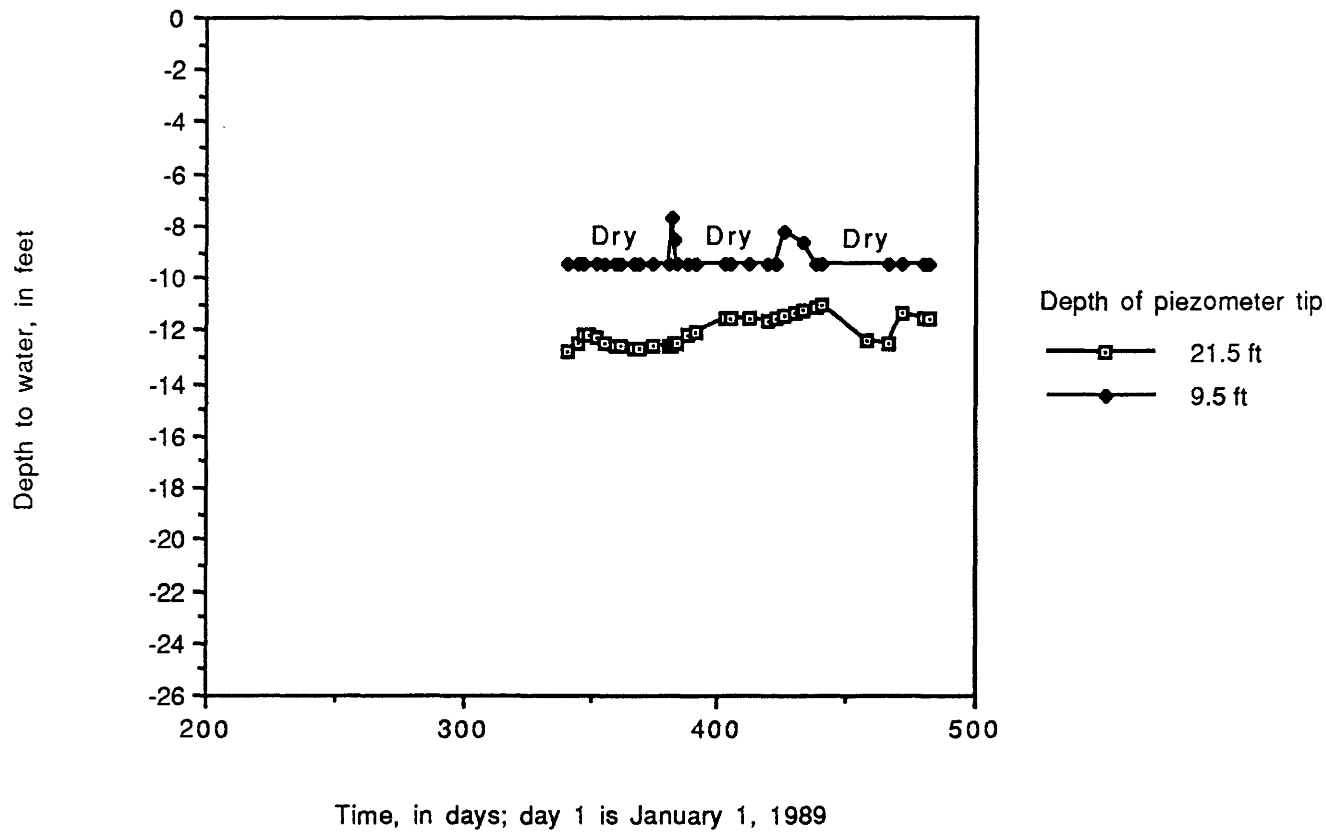
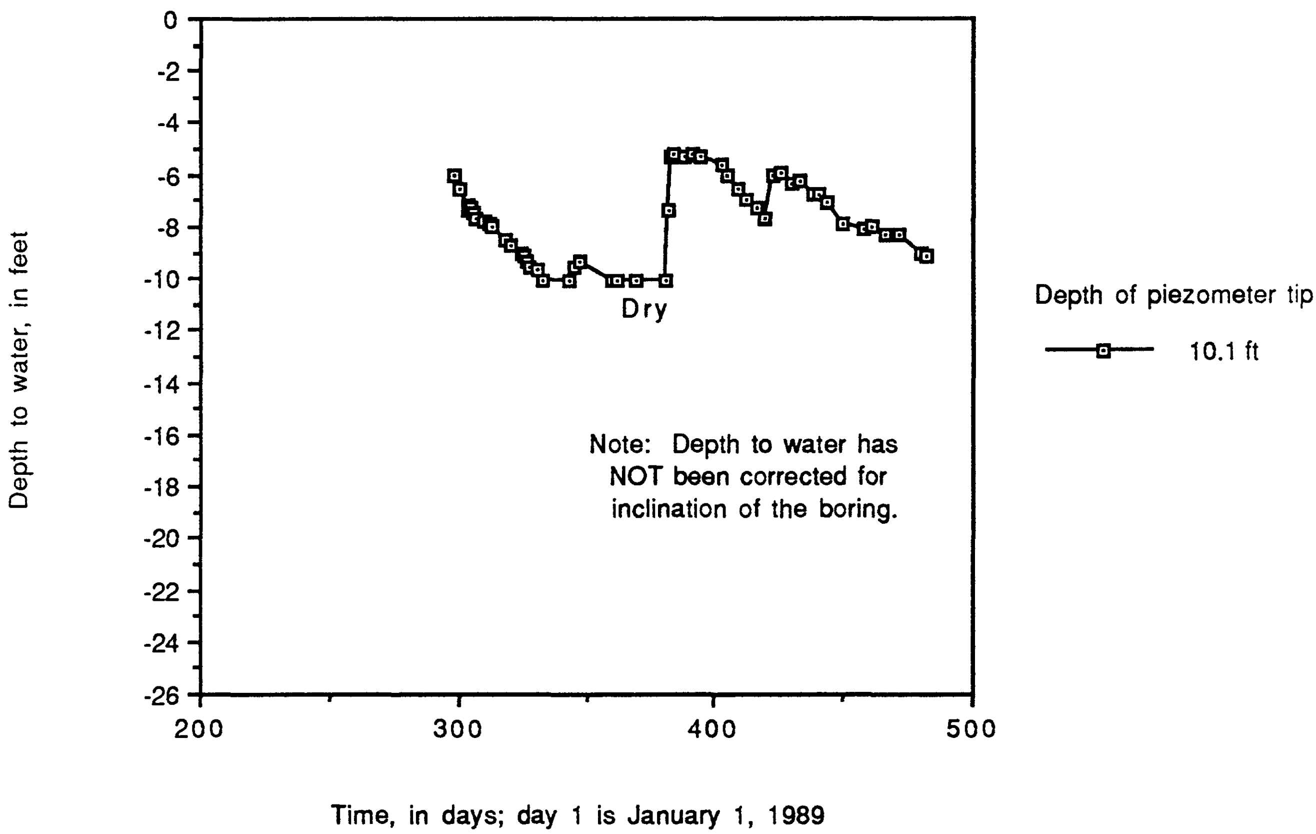
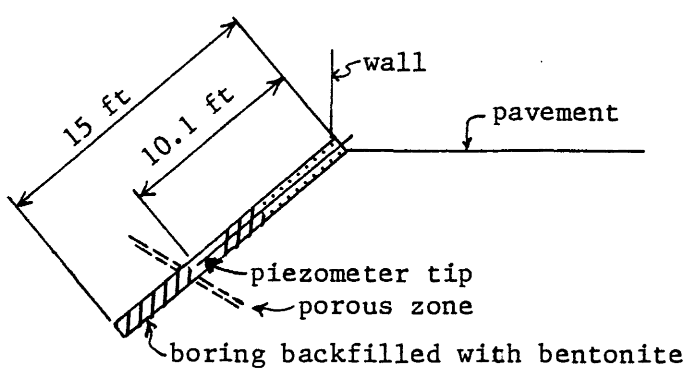


Figure C11. Piezometer in inclined boring 100





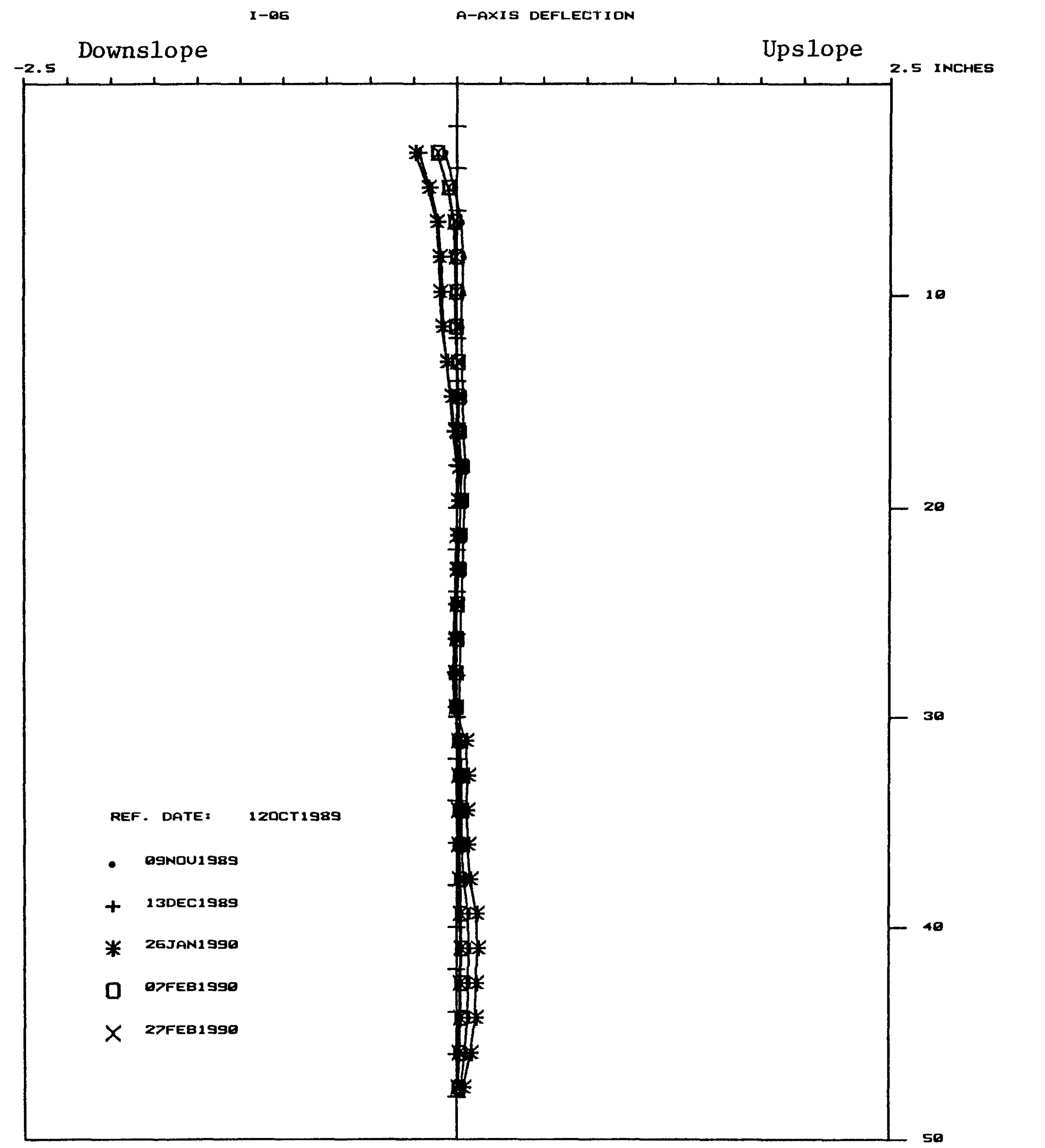


Figure C12. Inclinometer profile, Boring 6

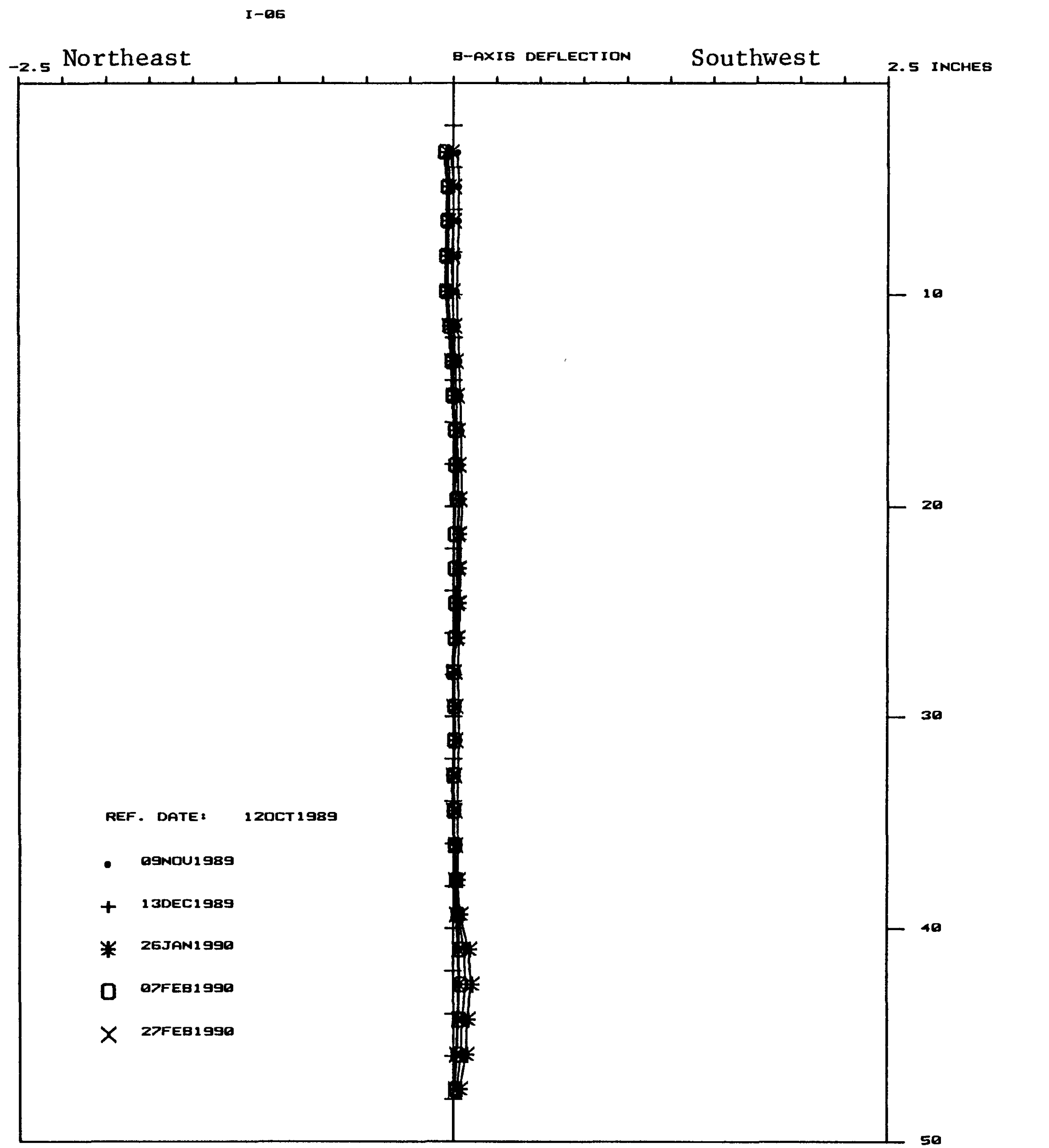


Figure C13. Inclinometer Profile, Boring 6

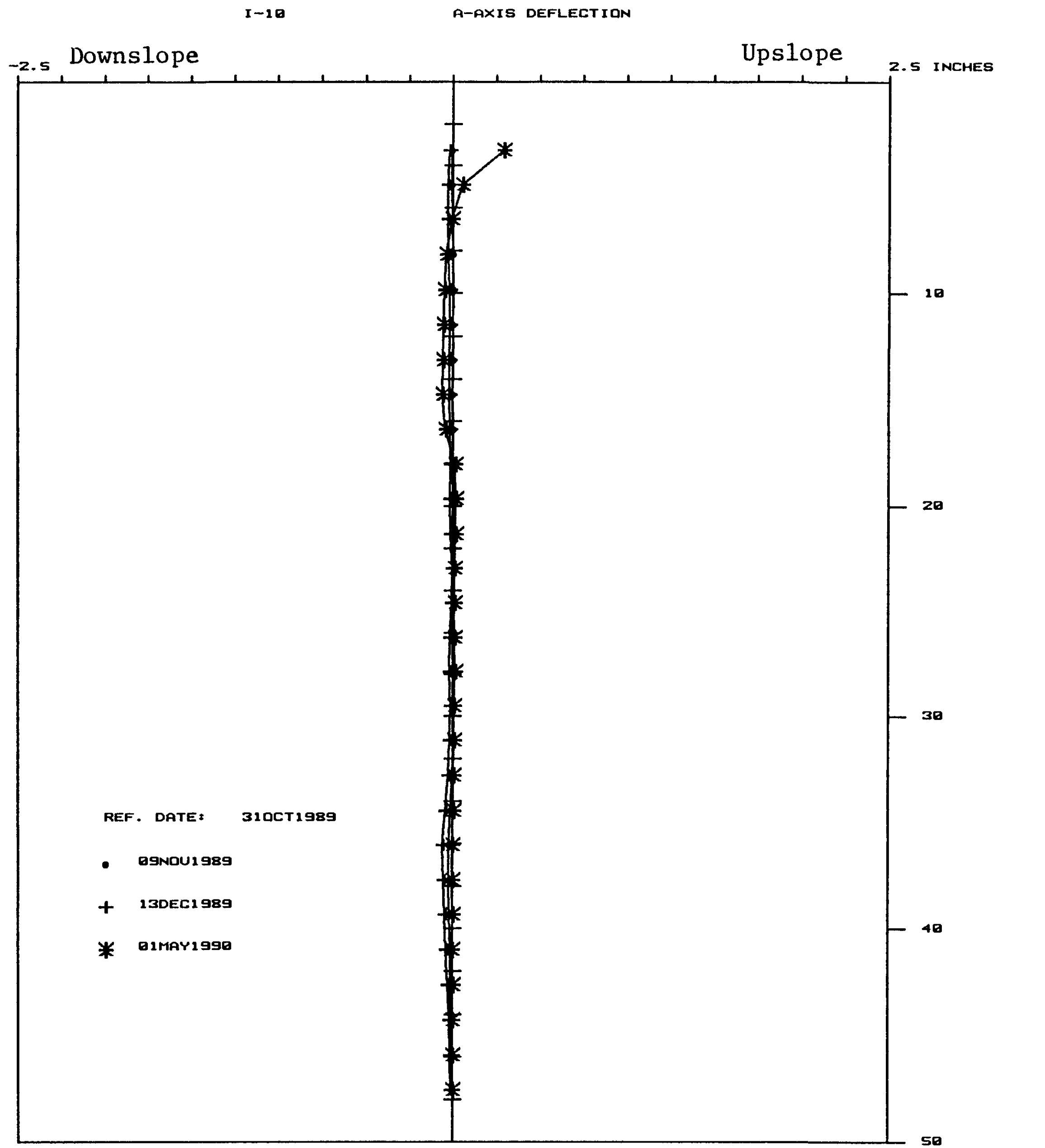


Figure C14. Inclinometer profile, Boring 10

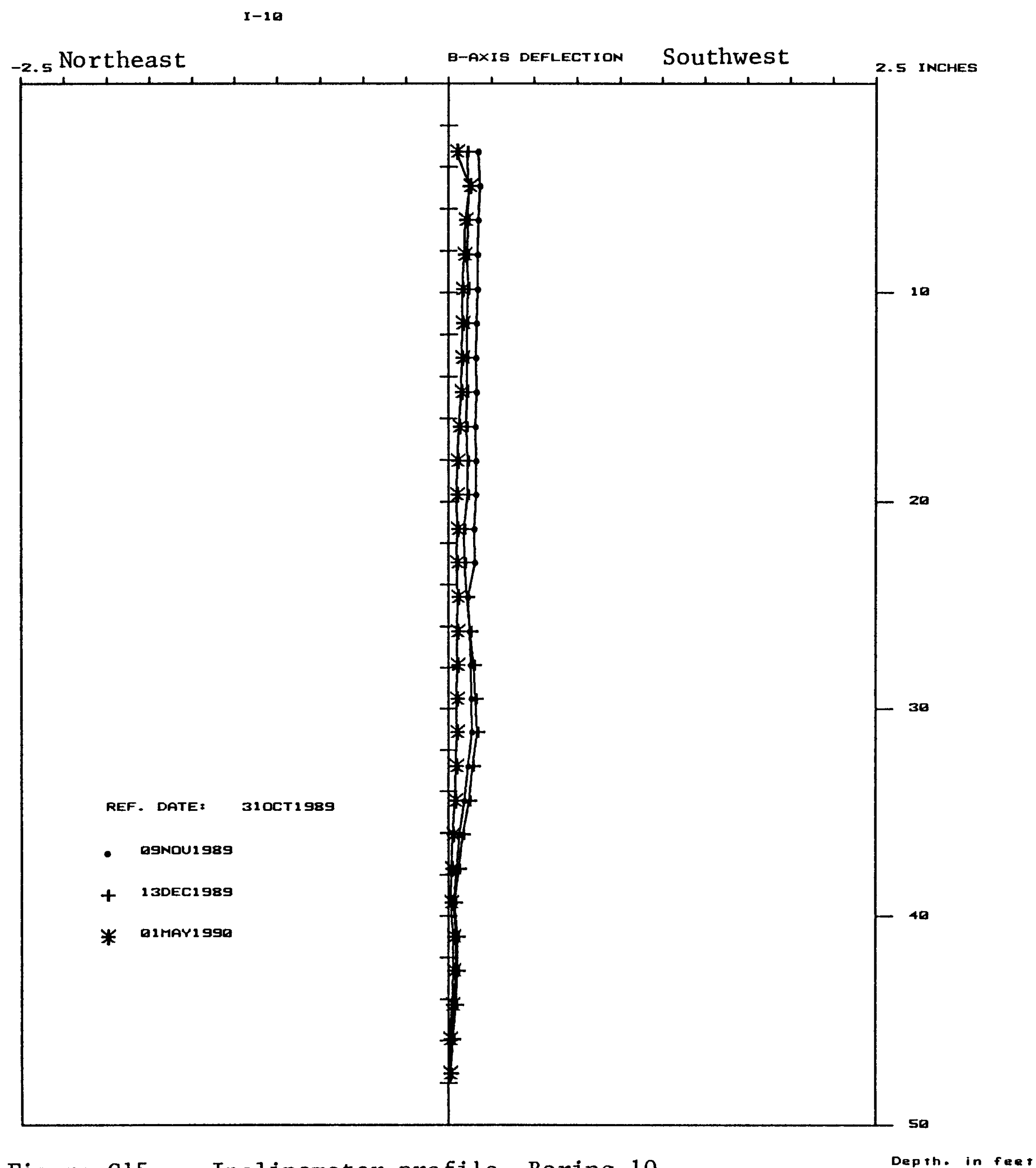


Figure C15. Inclinometer profile, Boring 10

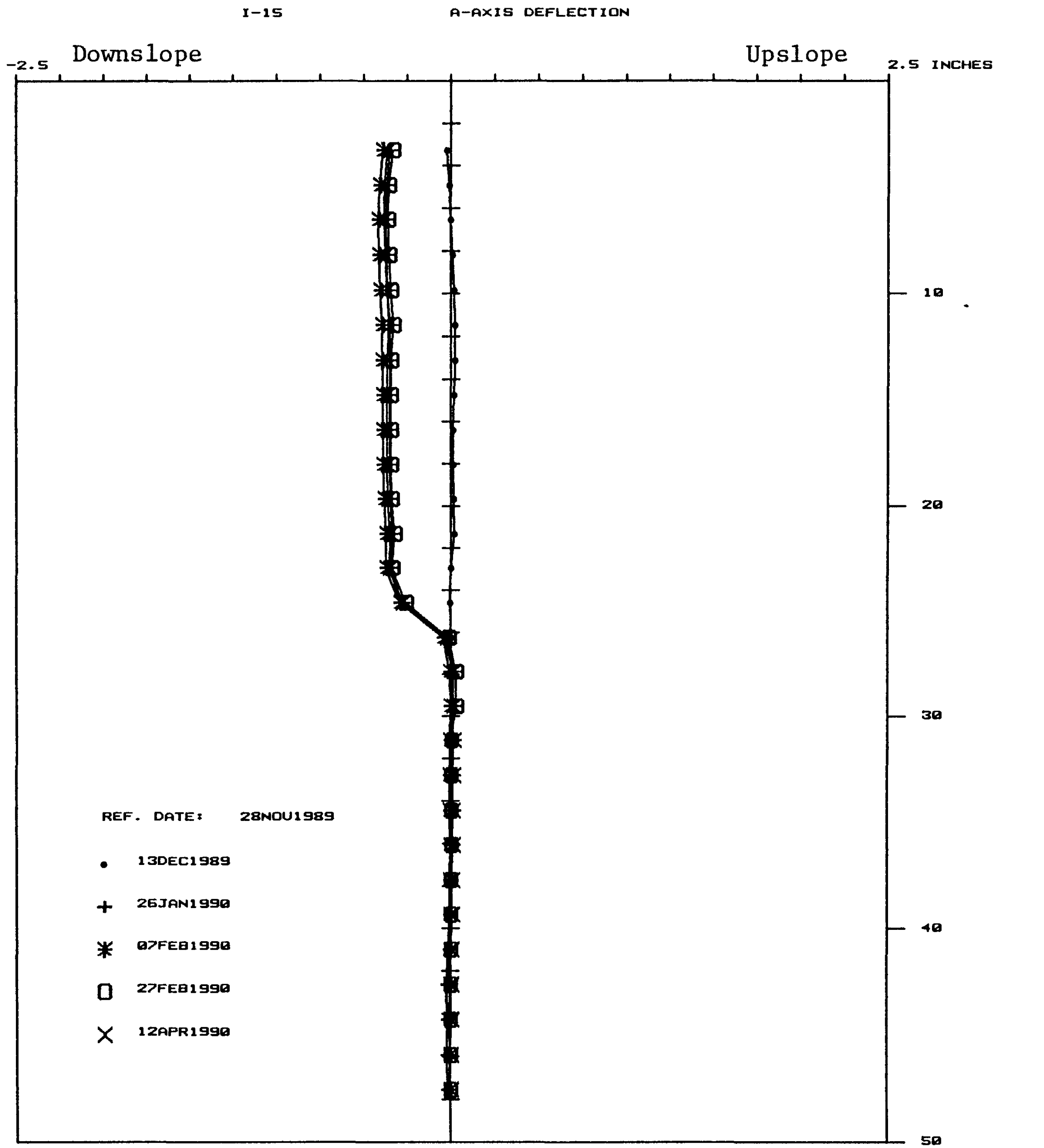


Figure C16. Inclinometer profile, Boring 15

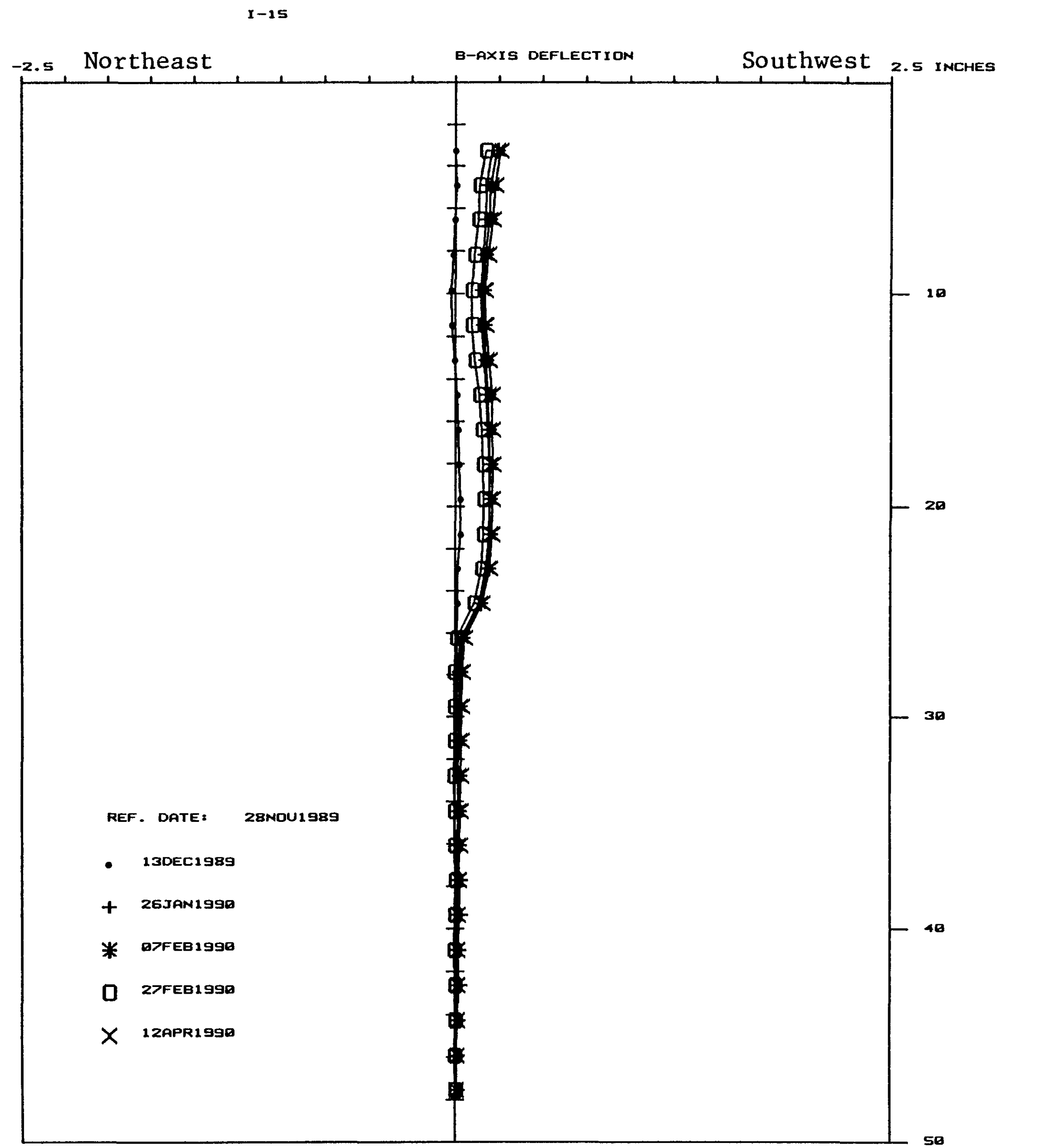


Figure C17. Inclinometer profile, Boring 15

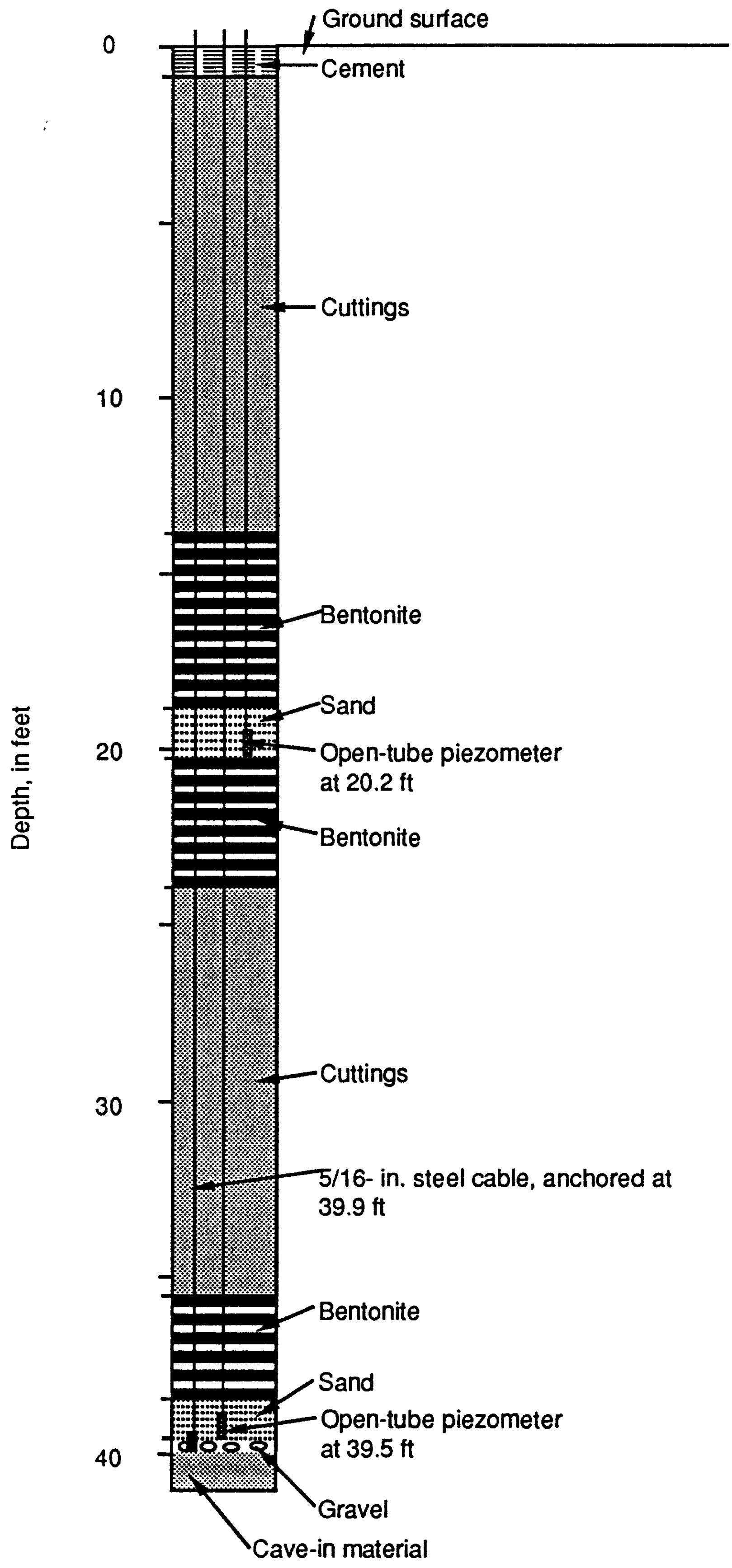


Figure C18. Sketch showing installation of instruments in boring 4

APPENDIX D

Measurement of Precipitation

This appendix contains graphs of daily rainfall at 3102 Alani Drive, in the head of the landslide (figs. D1, ..., D8 and fig. 2). A tipping-bucket rain gauge at this site is monitored continuously by a datalogger that records 15-minute and daily increments of rainfall.

Figure D1. Daily rainfall during September 1989

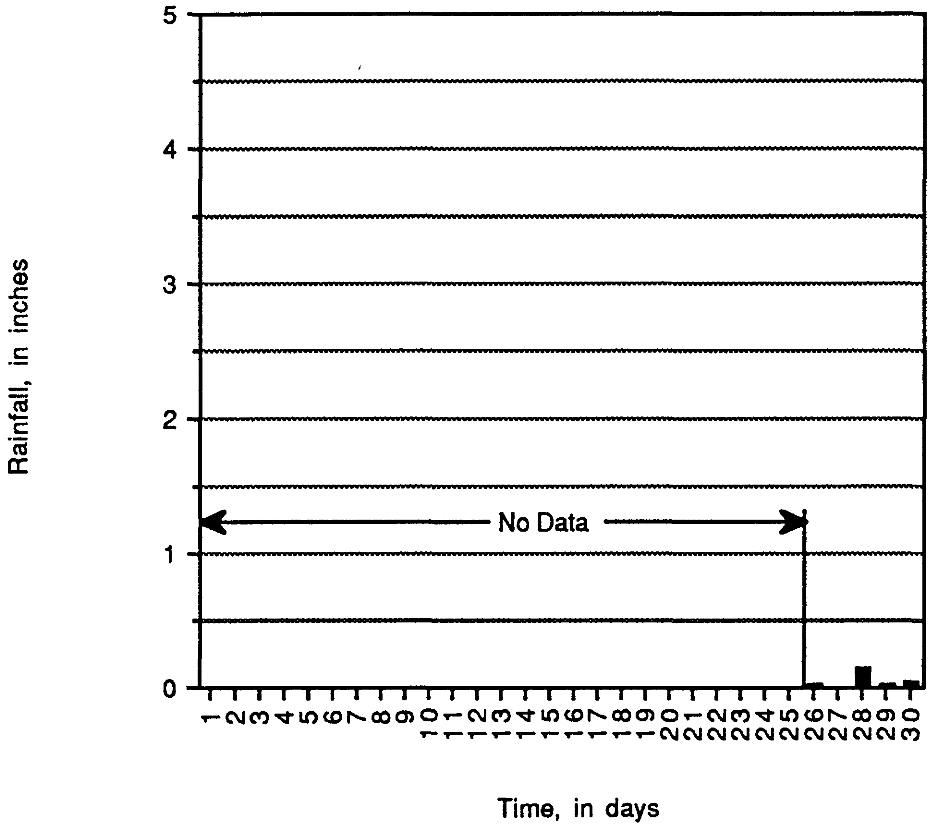


Figure D2. Daily rainfall during October 1989

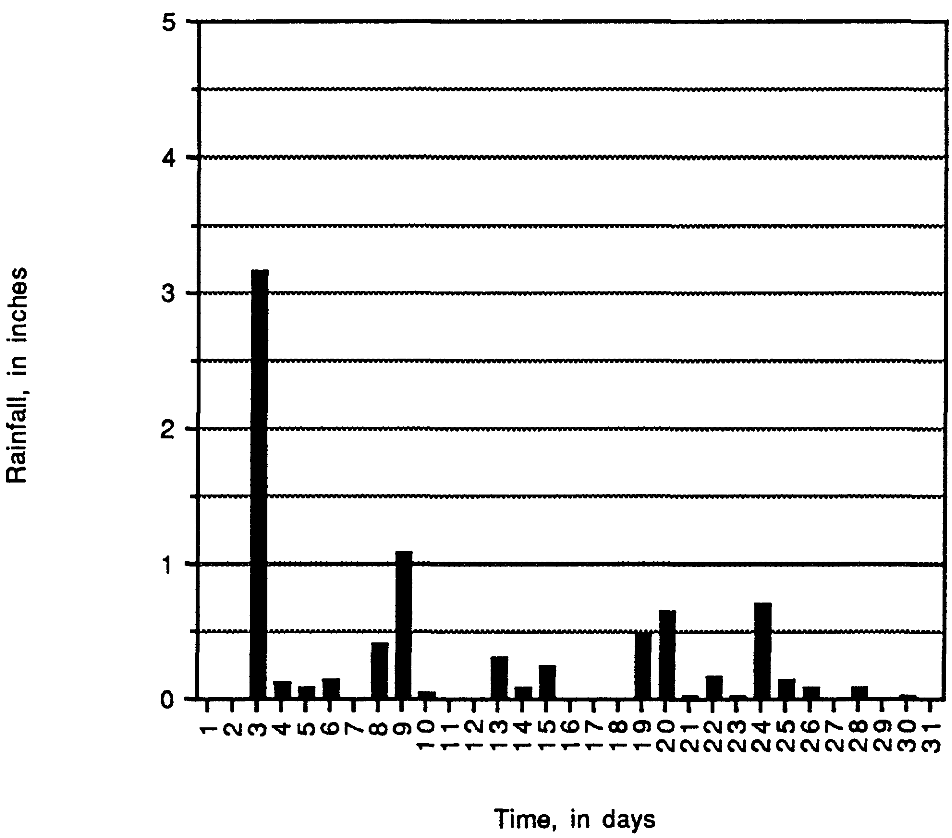


Figure D3. Daily rainfall during November 1989

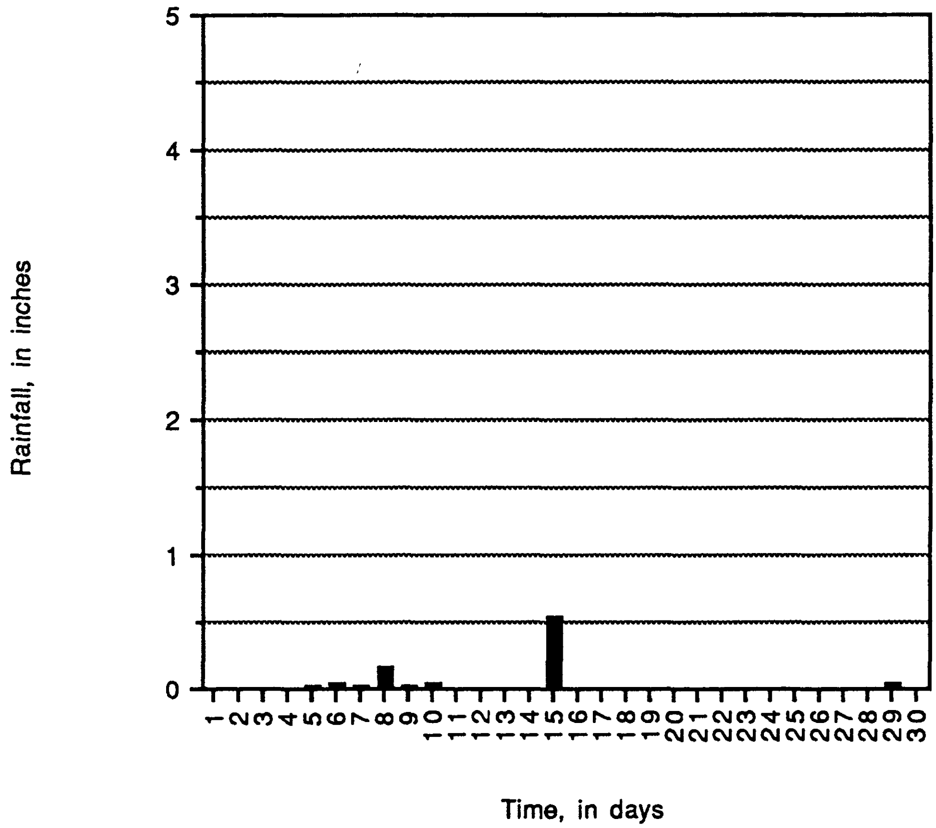


Figure D4. Daily rainfall during December, 1989

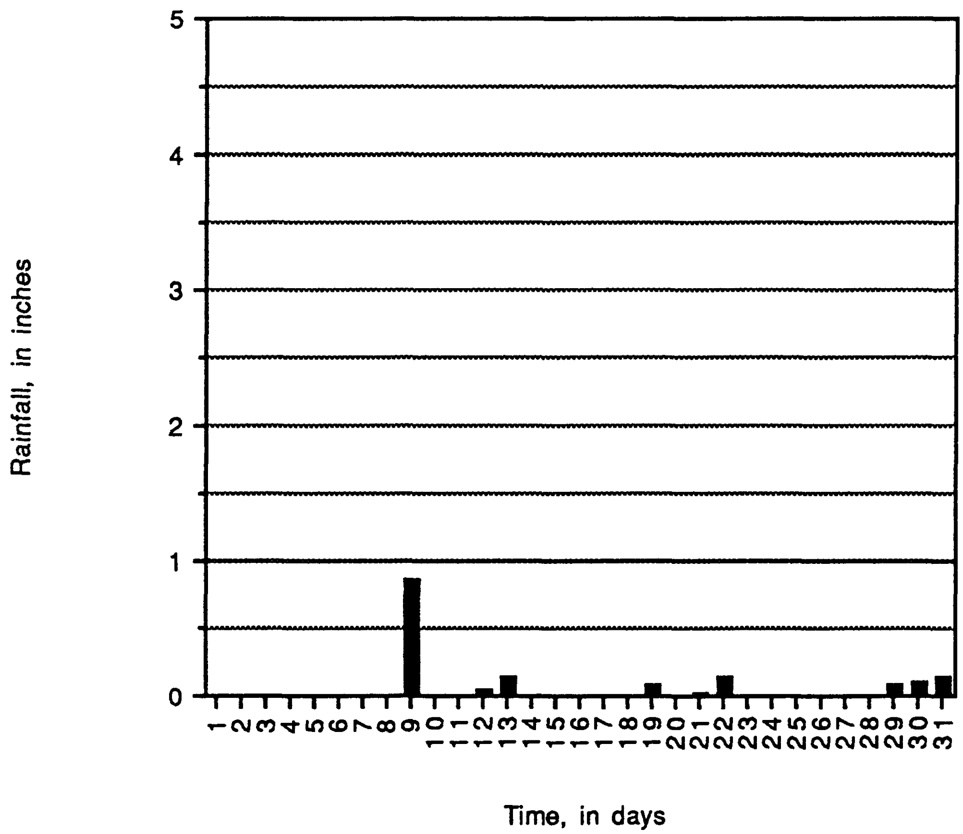


Figure D5. Daily rainfall during January 1990

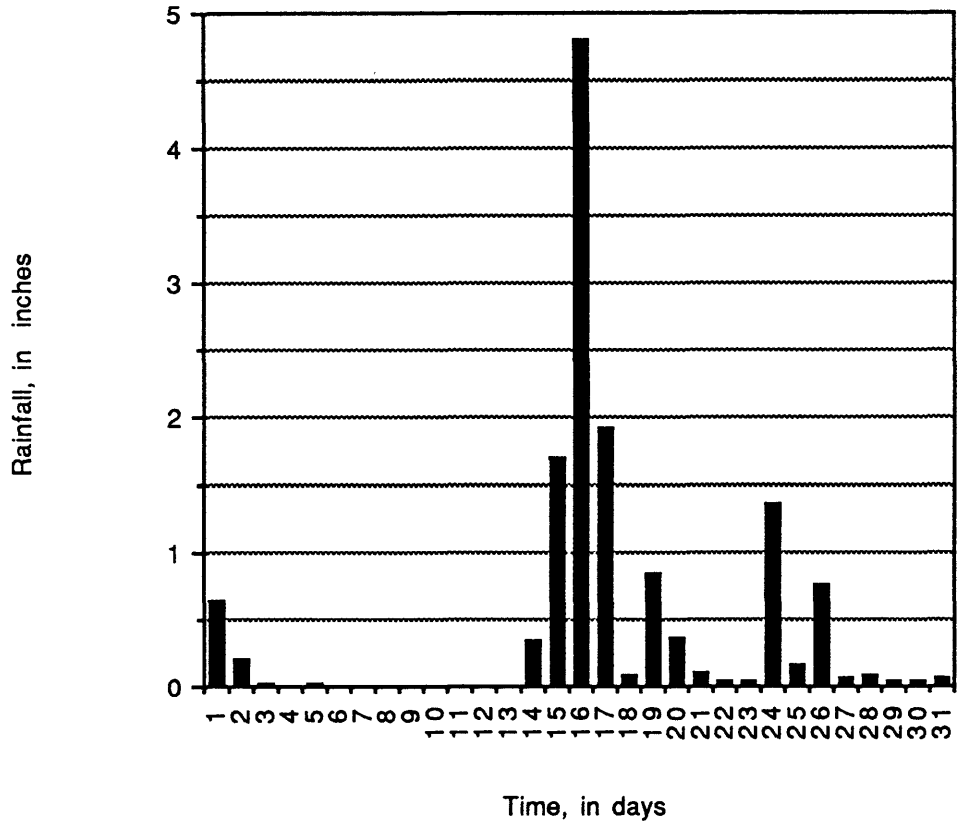


Figure D6. Daily rainfall during February 1990

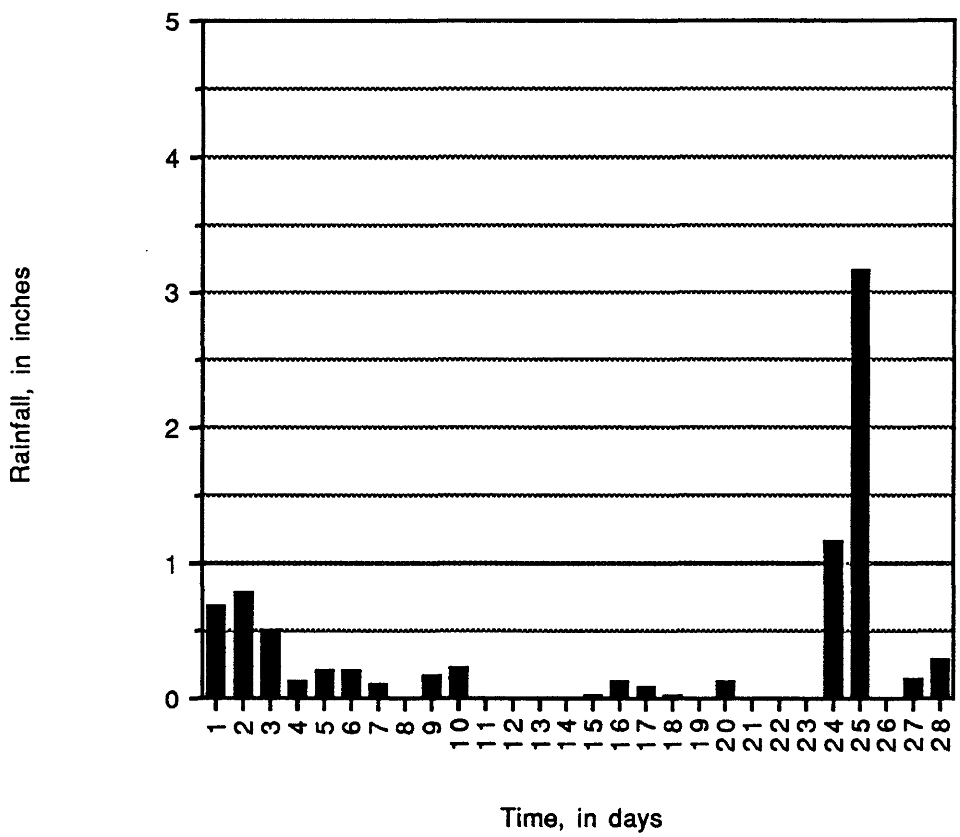


Figure D7. Daily rainfall during March 1990

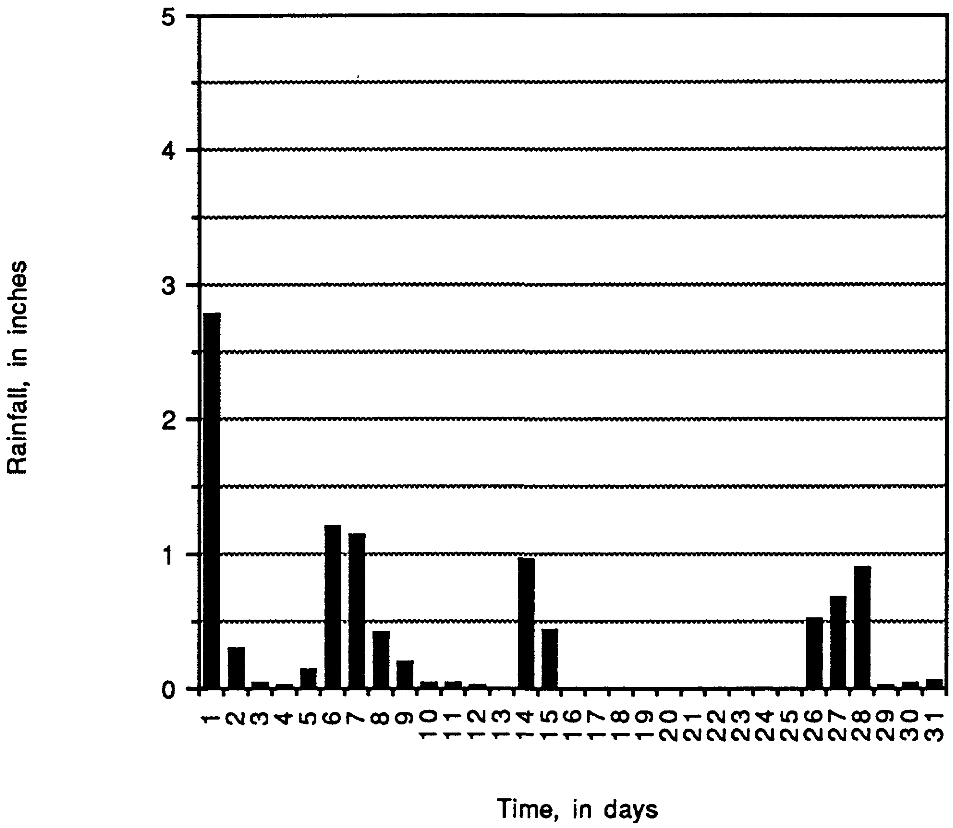
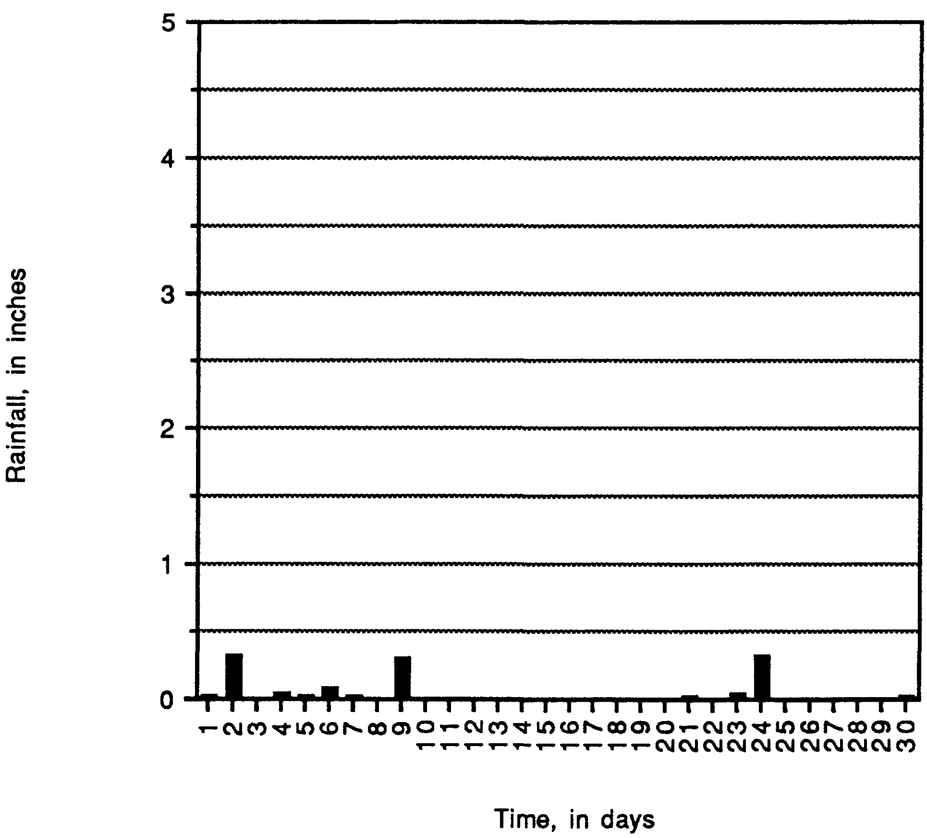


Figure D8. Daily rainfall during April 1990



APPENDIX E

Displacement of the landslide

This appendix contains a graph of cumulative displacement from September 1989 through April 1990, superimposed on a graph of cumulative rainfall (fig. E1), a detailed graph of displacement and rainfall during January 1990 (fig. E2), and a map showing crude estimates of total displacement measured in April 1989 (Baum and others, 1989) and 1990 (fig. E3).

We monitored displacement at the head of the landslide (fig. 2) by means of a simple extensometer consisting of a digital recorder and a wire cable. The recorder was anchored to a wall upslope from the headscarp of the landslide, on non-moving ground. The wire cable was attached to the trunk of a large tree growing on the head of the landslide. The cable causes a wheel on the recorder to turn as the distance between the tree and the recorder changes. The recorder mechanism keeps track of position by counting the revolutions of the wheel from an arbitrary zero position. The mechanism records the current position of the wheel once every 15 minutes. Later, in the office, the recorded changes in the position of the wheel are converted back into displacements.

We used monthly surveys to check the displacement recorded by the extensometer. Using tape and level, we measured the distance from a point on the wall where the recorder was anchored to two points on the tree where the cable was attached. Our surveys indicate that cumulative displacement from September 13, 1989, to April 27, 1990, ranges from 0.35 to 0.41 ft. Displacement determined by the surveys is slightly greater than the displacement of 0.33 ft recorded by the extensometer for the period from September 25, 1989 to April 30, 1990. The surveys indicate displacement ranging from 0.12 to 0.22 ft between December 13, 1989, and February 7, 1990. The extensometer recorded 0.22 ft of displacement during the same period, which includes the questionable movement recorded from January 23 to January 29, 1990.

We made crude estimates of total displacement by measuring offsets of curbs and walls where they cross the lateral boundaries of the landslide. We measured the offsets by standing on one side of the boundary and sighting along a curb or wall on the opposite side. We then measured the perpendicular distance from the wall or curb on our side of the boundary to the projection of the wall or curb on the opposite side. Precision of the measurements varies from site to site, but averages about ± 0.5 ft.

Figure E1. Rainfall and displacement at the head of the Alani-Paty landslide

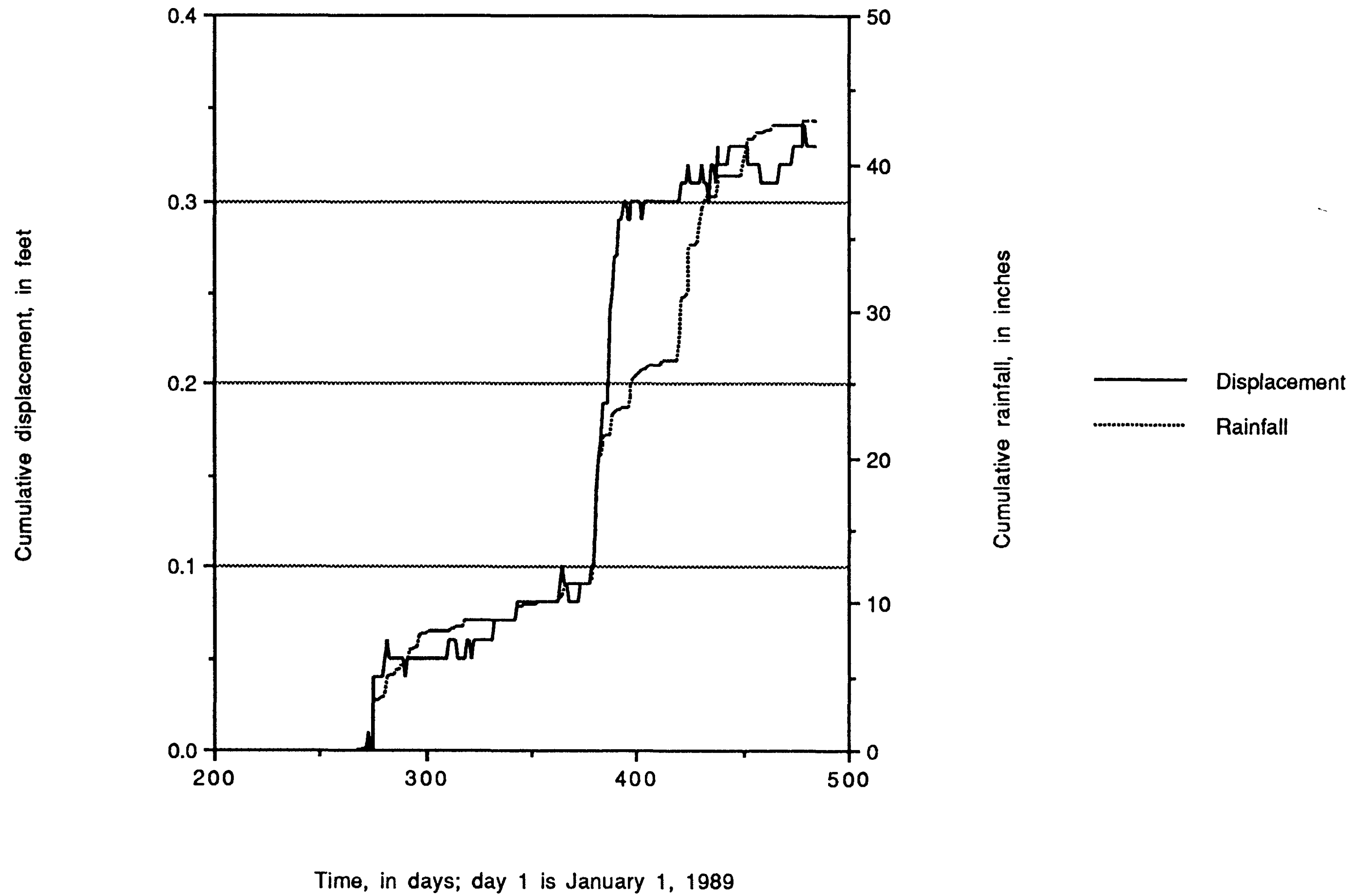
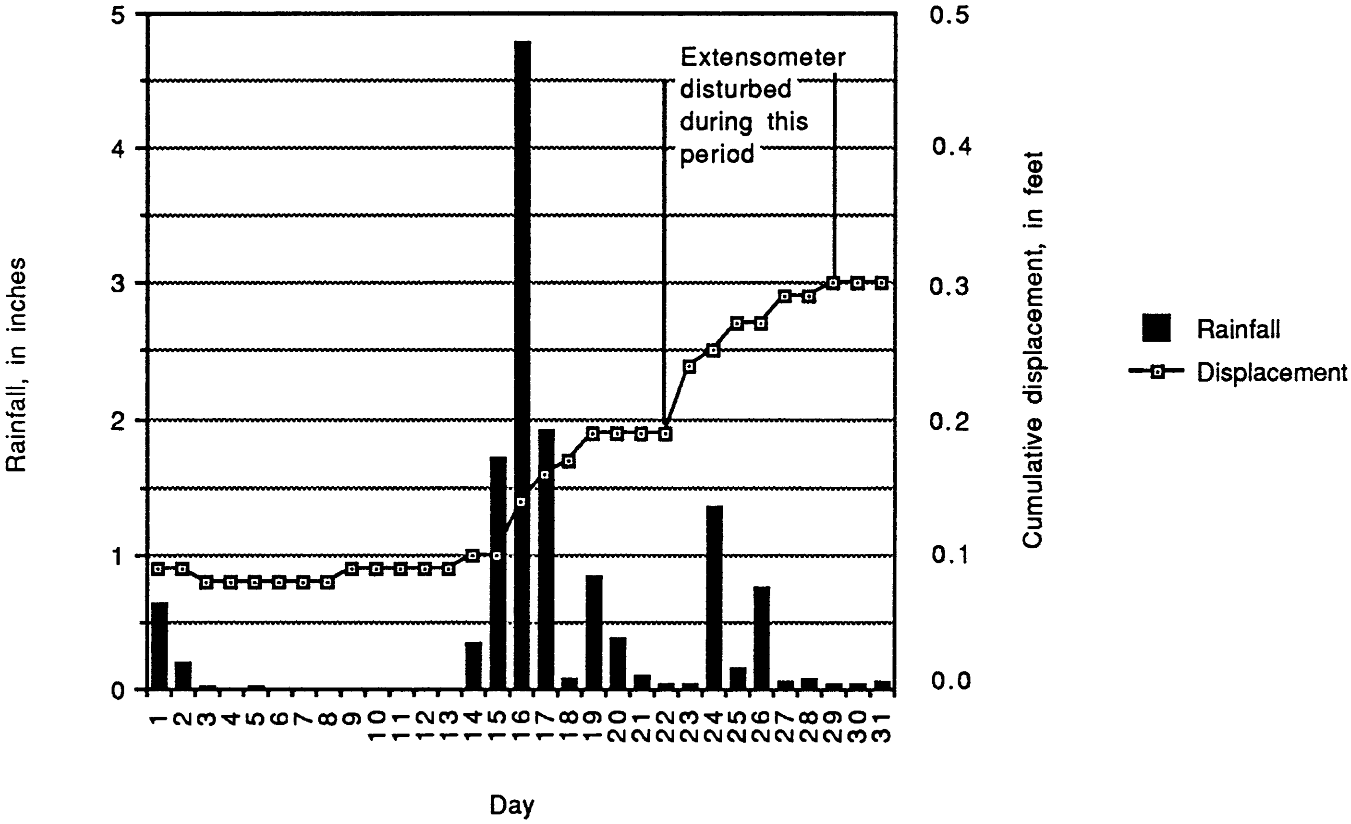


Figure E2. Daily increments rainfall and cumulative displacement at the head of the Alani-Paty landslide during January 1990



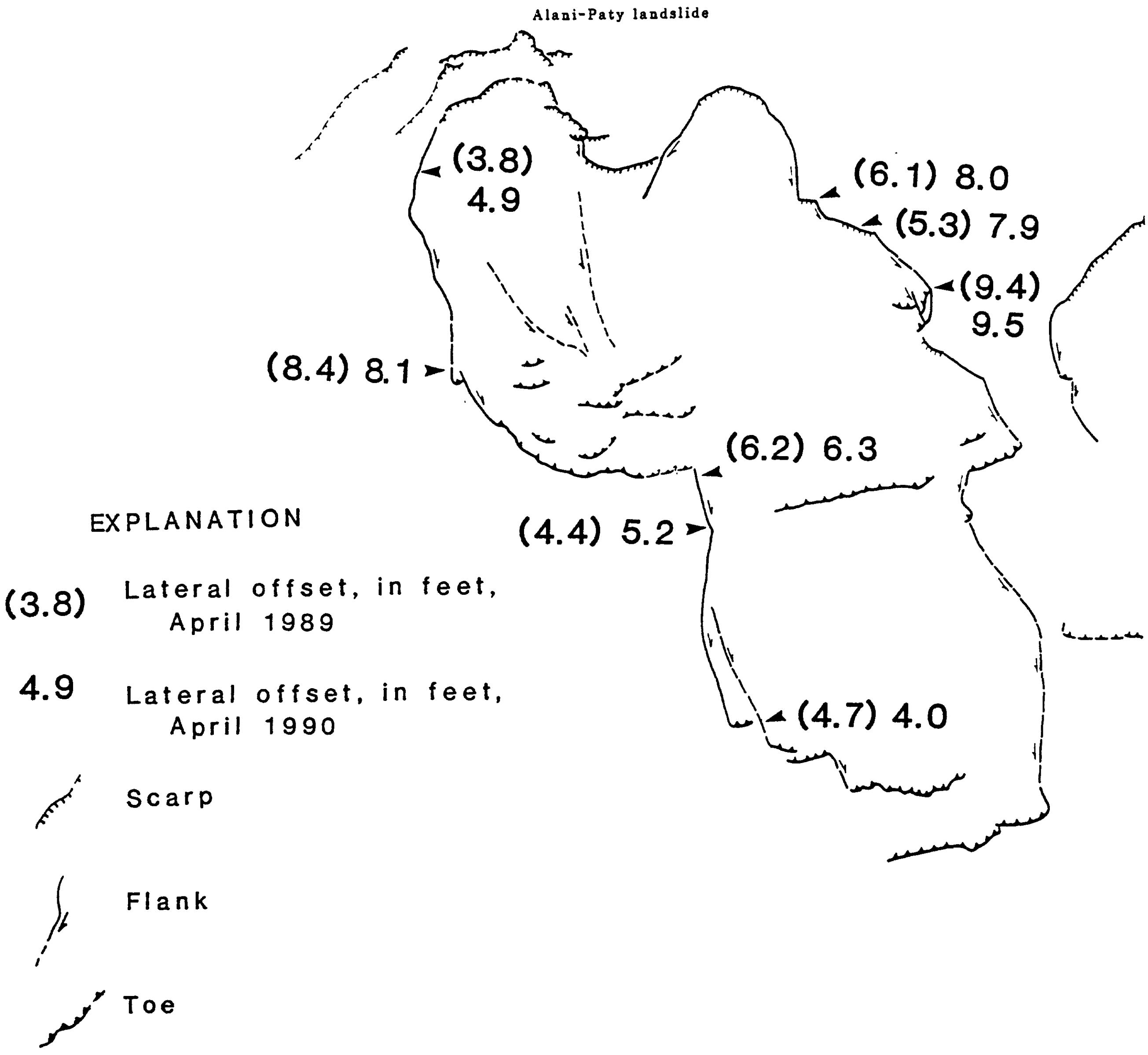


Figure E3. Map showing lateral offsets of curbs and stone walls at boundaries of the Alani-Paty landslide. Base (map of landslide boundaries) from Baum and others (1989).