

**Assessment of Slope Stability,
Fredericksburg National Military Cemetery,
Fredericksburg, Virginia**

**October 5, 1990
Our Reference V901098**

SCHNABEL ENGINEERING ASSOCIATES

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October 5, 1990

National Park Service
Mining and Minerals Branch
12795 W. Alameda Parkway
P.O. Box 25287
Denver, Colorado 80225

Attn: Ms. Sylvia Arbelbide

Dear Ms. Arbelbide,

We are pleased to submit herewith two copies of our report of Assessment of Slope Stability at the Fredericksburg National Military Cemetery in Fredericksburg, Virginia. The results of these investigations indicate that the slope is marginally stable in its current configuration but will probably not fail in a catastrophic manner that could disrupt the existing walls and graves. Instead, the slope will probably gradually erode into a flatter configuration by headwall erosion similar to what appears to be currently happening on site. Some remedial measures could be implemented and are outlined in this report.

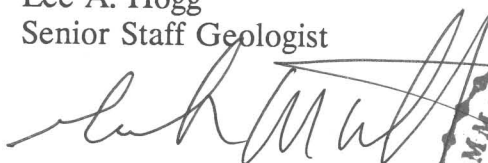
We appreciate the opportunity to be of service on this project. Please feel free to contact us if you have any questions.

Very truly yours,

SCHNABEL ENGINEERING ASSOCIATES, INC.



Lee A. Hogg
Senior Staff Geologist



Gordon M. Matheson, Ph.D., P.E.
Principal



LAH/GMM/gmc

CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS
BETHESDA, MD • BALTIMORE, MD • LANDOVER, MD • WEST CHESTER, PA • PARAMUS, NJ • LAKEWOOD, CO
RICHMOND, VA • HAMPTON, VA • VIENNA, VA • BLACKSBURG, VA

INTRODUCTION

This report presents the findings of our slope stability evaluation for the Fredericksburg National Military Cemetery in Fredericksburg, Virginia. This evaluation was completed at the request of the National Park Service. A site background is presented along with a description of area geology, a summary of our field reconnaissance of the site, and laboratory testing results. The slope stability analysis completed synthesized the findings of the site geology, field reconnaissance and laboratory testing. Conclusions concerning potential slope movement and danger to the cemetery wall and graves are provided.

SCOPE OF WORK

The purpose of this project was to perform a slope stability evaluation for the highwall of the abandoned Atkins quarry which borders the Fredericksburg National Military Cemetery to assess the potential for slope movement that could endanger the cemetery wall and/or graves. In order to accomplish this purpose, the following scope of work was completed.

1. Review of existing data on the site history and geology.
2. Engineering geological reconnaissance of the site to map the site geology and collect samples for laboratory testing.
3. Laboratory testing of the site materials to document the index properties of the soils.
4. Engineering analysis of the slope stability to estimate the factor of safety of the slope and the potential for long-term slope degradation.
5. Preparation of this report that summarizes our findings and presents conclusions and recommendations.

SITE BACKGROUND AND DESCRIPTION

Site Conditions

The Fredericksburg National Military is located northwest of Lafayette Boulevard in Fredericksburg, Virginia. The Atkins quarry, an abandoned sand and gravel quarry, borders the cemetery to the southwest. The Atkins quarry ceased operations at least fifteen years ago and, since that time, has become overgrown with locally indigenous vegetation consisting of grasses, weeds, bushes and trees.

The highwall of the quarry is approximately thirty feet from the brick wall surrounding the cemetery. The angle of the highwall in the area of concern is approximately 2.5H:1V near the toe of the slope, approximately 0.75H:1V in the middle portion of the slope, and nearly vertical in the upper ten feet of the slope. The cemetery grounds in the area are relatively flat. The ground in front of the toe of the highwall is hummocky, probably resulting from quarry operations and eroded material from the highwall. Most of the quarry site is wooded, except for the middle to upper portions of the highwall, which are sparsely vegetated to bare. Figure 1 present the general topography and cultural features in the area of concern.

Site Geology

Geologic maps of the area indicate that the quarry, slope and cemetery are underlain by the Patuxent formation of Cretaceous geologic age. The Patuxent formation is fluvial in origin and generally consists of fine sands with interbedded clays and gravel. Cemented sand and ironite layers are also commonly found within the sand. The formation is capped

by the river Terrace sand and gravel deposits of Pleistocene Age. These deposits consist mostly of gravel with minor sand content, and may contain cobble to boulder size materials.

The upper, near-vertical portion of the headwall consists of the Terrace gravels and sands. The Terrace deposits are approximately ten feet thick at the thickest point on the headwall and are very dense. This portion of the slope is not vegetated. The middle and lower portions of the slope consist of the Patuxent formation sands. Several cemented sand and ironite layers were noted within the Patuxent formation sands, approximately half way up the slope. The geologic contact between the Terrace and Patuxent formation is at approximately EL 989 feet.

No evidence of large scale slumping or sliding was noted during our reconnaissance. No springs or seeps were noted on the slope. As indicated previously, hummocky ground and several soil piles were noted at the toe of the slope, probably related to the quarry operations. No bedrock was observed on the site although cemented sands are present in some areas.

Two soil samples of the Terrace deposits were obtained between the crest of the slope and the cemetery wall. One additional Terrace deposit sample was obtained from the face of the vertical slope section. Due to the cementation of the Terrace material it was necessary to use a geologists pick to dislodge this sample. One bulk sample of the Patuxent formation was obtained at the toe of the slope.

A site plan and geologic map summarizing the site geology is presented on Figure 1. A profile through one of the steepest portions of the slope is presented as Figure 2. We have assumed in this profile that the contact between the Terrace deposits and the Patuxent formation is horizontal. Soil sampling locations are also indicated on Figure 1.

Normally for a permanent slope, we recommend a minimum factor of safety of 1.3. Our analysis indicates factors of safety of 1.09 and 1.12 for the two most critical potential failure surfaces. This indicates that the steeper portions of the slope have a lower factor of safety than would be considered sufficient for most long-term design purposes. However, since the slope has been standing for sometime and shows no signs of distress (other than the head wall erosion), it is our opinion that it will probably remain in approximately the present configuration for some time. This can be attributed somewhat to the dense vegetation on the slope that provides additional strength to the near surface materials and is not accounted for in the stability analysis. Headwall erosion will continue to occur, however, and will tend to gradually flatten the slope. Based on the analyses completed, none of the twenty most critical potential failure surfaces calculated extended to the cemetery wall. We believe, therefore, that there is a low potential for immediate damage to the wall or the cemetery from the slope even if it should fail. It should be noted that changes in the configuration of the slope, the addition of water to the slope or other factors could reduce the factor of safety and induce failure.

CONCLUSIONS AND RECOMMENDATIONS

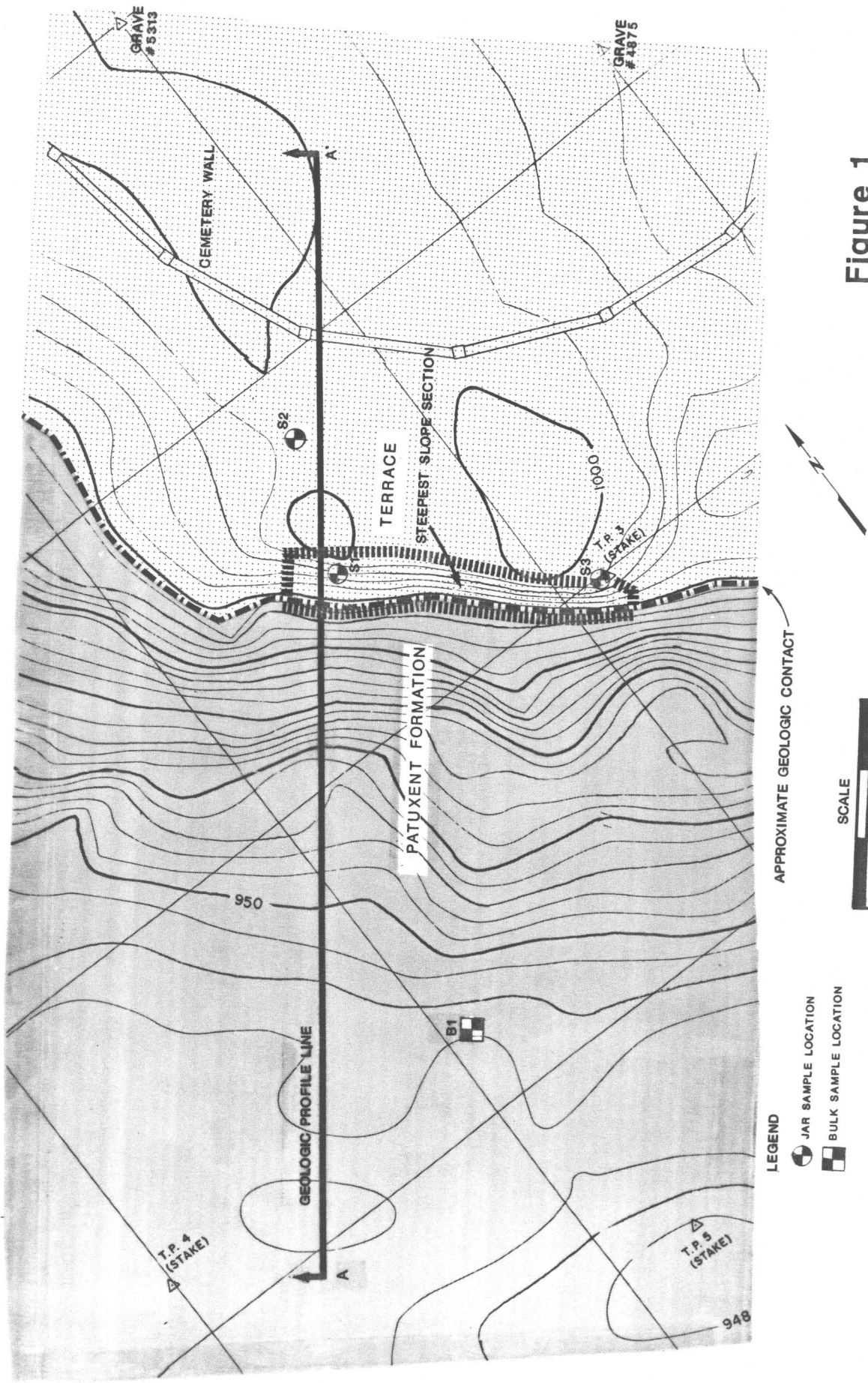
Based on the analysis results it is our opinion that the major stability concern of the slope will be the continued erosion of the currently exposed sands and gravels at the slope crest. The overall slope is steeper than would be designed for a permanent slope, however, the presence of vegetation tends to help stabilize much of the slope surface in its current condition. There is no real assurance, however, that sometime in the future the slope will not fail. This could be triggered by a high rainfall event or other factors.

At this time several alternatives are available to address the slope stability. These are:

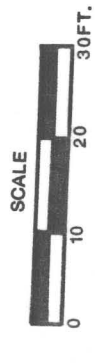
- Survey pins
3 lines*
1. Leave the existing slope as is and initiate monitoring of the area to identify changes in the slope conditions through periodic inspections. If changes that are considered significant occur then remedial action can be taken. It may be desirable in this case to alter the surface drainage away from the steeper slope areas to reduce future erosion.
 2. Place an erosion prevention system over the upper portions of the slope to control surface runoff, erosion, and undercutting. This could take the form of some sort of netting or fabric that would promote plant growth. Again, it would be of value to alter the surface drainage away from the steeper slope areas.
 3. Regrade the slope to a flatter configuration by cutting the upper headwall and filling at lower portion of the slope creating a berm. This would require extensive disturbance and re-vegetation in the area of the slope.

It is our opinion that the first or second alternative should be implemented unless the observed stability of the slope changes. The detailed design of slope protection measures are beyond the scope of this proposal.

We have performed our services and prepared this report in accordance with generally accepted geotechnical engineering practices and make no other warranties, either expressed or implied, as to the professional services provided under the terms of our agreement.

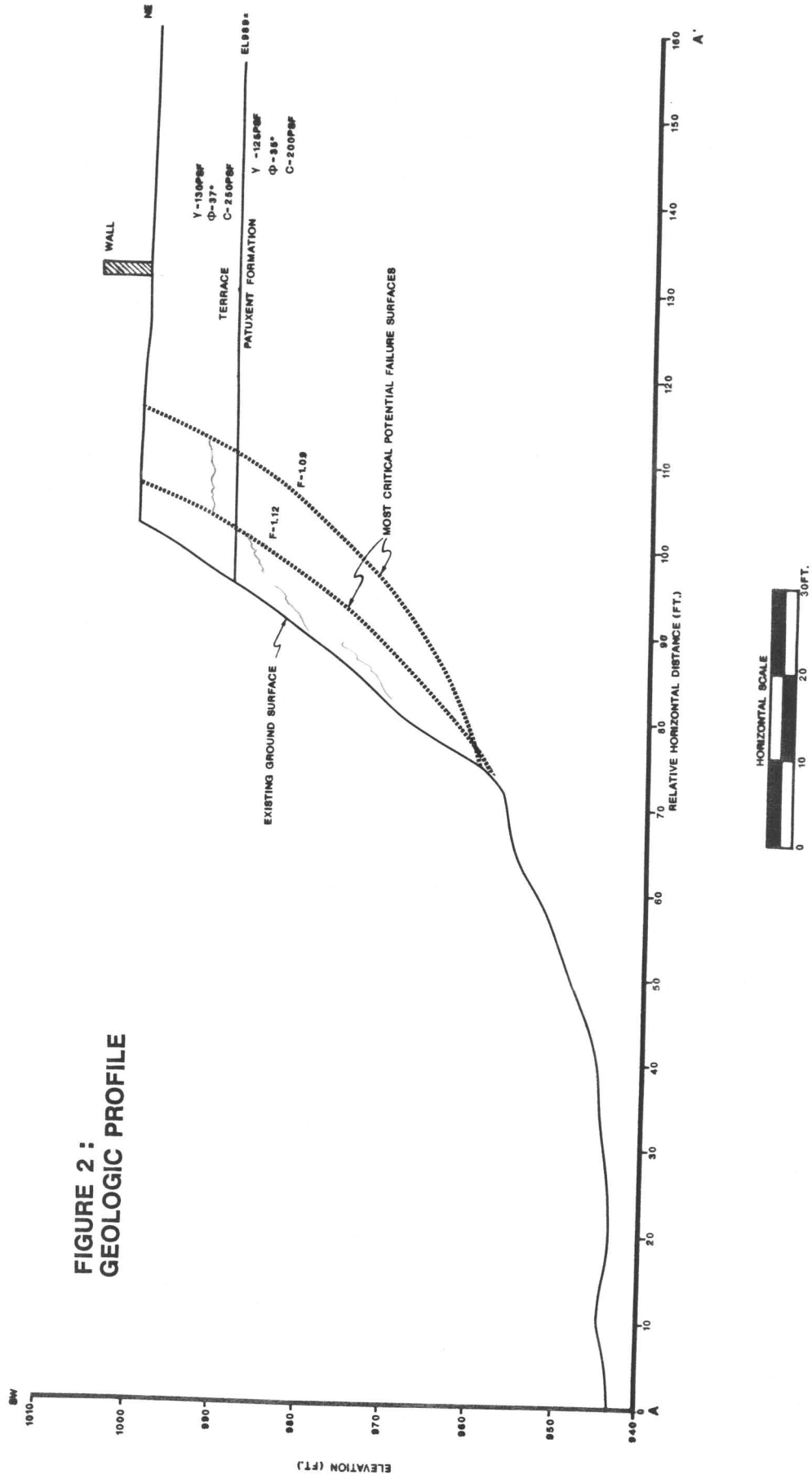


- LEGEND**
- JAR SAMPLE LOCATION
 - BULK SAMPLE LOCATION



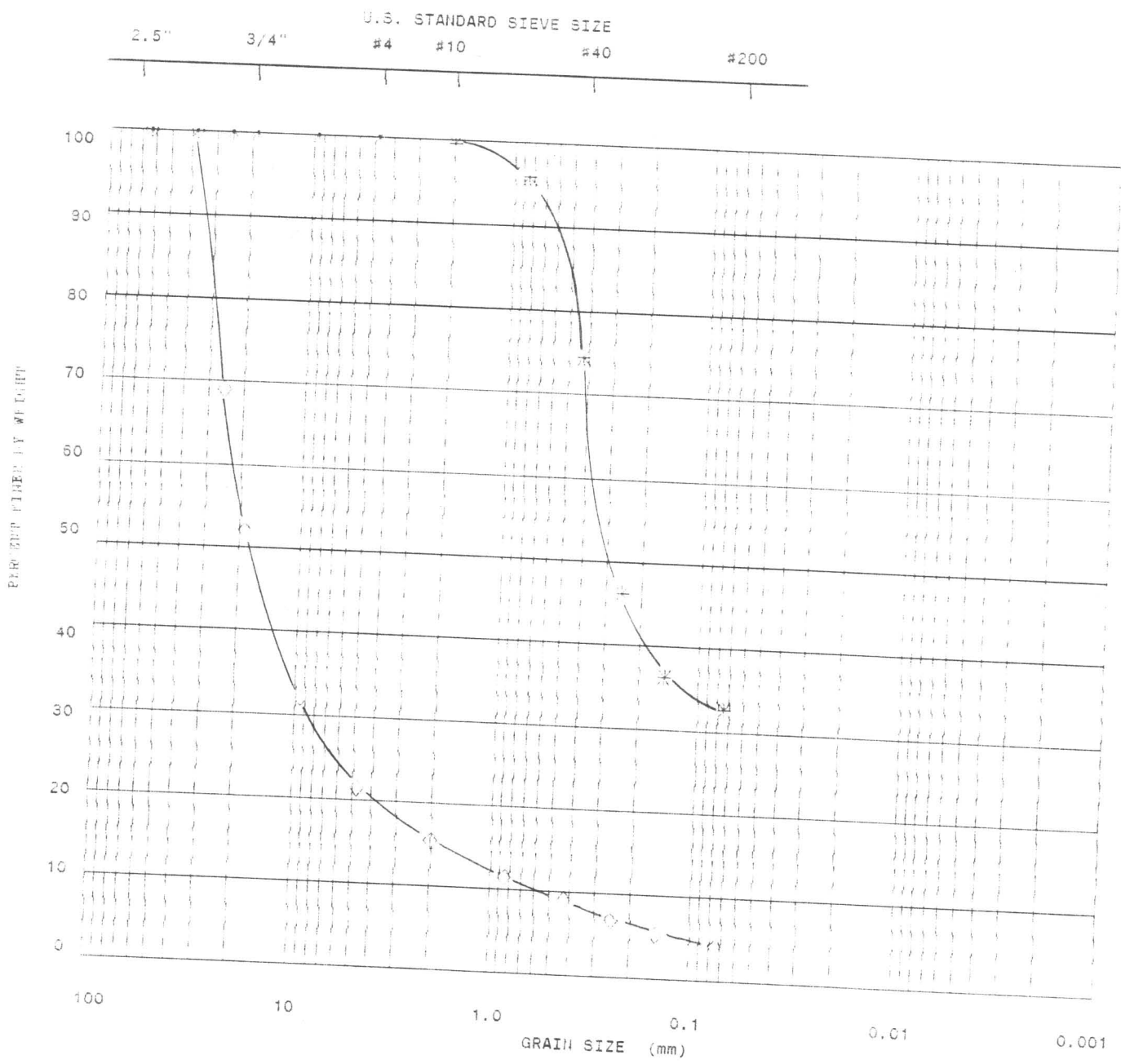
SEE FIGURE 2 FOR GEOLOGIC PROFILE

Figure 1
Site Plan and Geologic Map



Appendix
Gradation Curves From Soil Laboratory Testing
PCSTABL5 Printout

Schnabel Engineering Associates



GRAVEL	SAND			SILT or CLAY
	coarse	medium	fine	

KEY	BORING	DEPTH	DESCRIPTION OF SOIL SPECIMEN	CLASS.	LL	PI	SCHNABEL ENGINEERING ASSOCIATES GRADATION CURVES Project: FREDERICKSBURG NATIONAL MILITARY CEMETARY Contract No.: V901098
*	B-1	0.2-1.5	silty SAND, brown	SM	---	---	
◇	S-1	2.0-4.0	POORLY GRADED GRAVEL with sand, brown	GP	---	---	

1

PCSTABL5

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: LEE1.INP
Output Filename: LEE2.OUT
Plotted Output Filename: LEE2.PLT

PROBLEM DESCRIPTION FREDERICKSBURG BATTLEFIELD SLOPE STABIL
TY

BOUNDARY COORDINATES

9 Top Boundaries
10 Total Boundaries

1

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	43.00	11.00	45.00	1
2	11.00	45.00	20.00	44.00	1
3	20.00	44.00	37.00	45.00	1
4	37.00	45.00	64.00	55.00	1
5	64.00	55.00	74.00	58.00	1
6	74.00	58.00	85.00	74.00	1
7	85.00	74.00	96.00	89.00	1
8	96.00	89.00	103.00	100.00	2
9	103.00	100.00	160.00	99.00	2
10	96.00	89.00	160.00	89.00	1

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

1

Soil Type	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param. (psf)	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	200.0	35.0	.00	.0	0
2	130.0	130.0	250.0	37.0	.00	.0	0

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between $X = 40.00$ ft.
and $X = 75.00$ ft.

Each Surface Terminates Between $X = 105.00$ ft.
and $X = 140.00$ ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is $Y = .00$ ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	75.00	59.46
2	79.68	61.22
3	84.20	63.35
4	88.55	65.83
5	92.68	68.64
6	96.58	71.76
7	100.23	75.18
8	103.60	78.88
9	106.66	82.83
10	109.41	87.01
11	111.82	91.39
12	113.88	95.95
13	115.26	99.78

Circle Center At $X = 54.8$; $Y = 119.9$ and Radius, 63.7

*** 1.086 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	67.22	55.97
2	72.16	56.77
3	77.00	58.02
4	81.70	59.72
5	86.23	61.84
6	90.55	64.36
7	94.61	67.28
8	98.39	70.55
9	101.85	74.16
10	104.96	78.07
11	107.70	82.25
12	110.05	86.67
13	111.98	91.28
14	113.47	96.05
15	114.28	99.80

Circle Center At X = 61.0 ; Y = 109.9 and Radius, 54.3

*** 1.135 ***

1

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	63.33	54.75
2	68.21	55.86
3	73.00	57.31
4	77.67	59.08
5	82.21	61.18
6	86.59	63.59
7	90.79	66.30
8	94.80	69.30
9	98.58	72.56
10	102.13	76.09
11	105.42	79.85
12	108.45	83.83
13	111.18	88.01
14	113.62	92.38
15	115.75	96.90
16	116.86	99.76

Circle Center At X = 49.9 ; Y = 125.1 and Radius, 71.7

*** 1.142 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	75.00	59.46
2	78.72	62.79
3	82.39	66.20
4	85.98	69.67
5	89.51	73.21
6	92.98	76.82
7	96.37	80.49
8	99.70	84.22
9	102.96	88.01
10	106.14	91.87
11	109.26	95.78
12	112.30	99.75
13	112.36	99.84

Circle Center At X = -101.6 ; Y = 260.3 and Radius, 267.5

*** 1.177 ***

1

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.56	51.87
2	60.54	52.25
3	65.49	53.00
4	70.36	54.11
5	75.14	55.58
6	79.79	57.41
7	84.30	59.58
8	88.63	62.07
9	92.76	64.89
10	96.67	68.00
11	100.34	71.40
12	103.75	75.06
13	106.87	78.97
14	109.69	83.10
15	112.20	87.42
16	114.37	91.92
17	116.21	96.57
18	117.19	99.75

Circle Center At X = 53.0 ; Y = 118.8 and Radius, 67.0

*** 1.199 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	59.44	53.31
2	64.44	53.37
3	69.42	53.89
4	74.32	54.87
5	79.11	56.30
6	83.75	58.16
7	88.20	60.45
8	92.41	63.14
9	96.36	66.20
10	100.01	69.63
11	103.32	73.37
12	106.28	77.40
13	108.84	81.69
14	111.00	86.20
15	112.73	90.89
16	114.02	95.72
17	114.72	99.79

Circle Center At X = 61.3 ; Y = 107.2 and Radius, 53.9

*** 1.206 ***

1

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	71.11	57.13
2	76.04	57.97
3	80.88	59.22
4	85.61	60.85
5	90.19	62.86
6	94.58	65.25
7	98.77	67.98
8	102.72	71.05
9	106.40	74.43
10	109.80	78.09
11	112.88	82.03
12	115.64	86.20
13	118.04	90.59
14	120.07	95.16
15	121.66	99.67

Circle Center At X = 63.3 ; Y = 117.7 and Radius, 61.1

*** 1.213 ***

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	59.44	53.31
2	64.44	53.36
3	69.42	53.84
4	74.34	54.73
5	79.17	56.03
6	83.87	57.74
7	88.41	59.83
8	92.76	62.31
9	96.88	65.14
10	100.75	68.30
11	104.33	71.78
12	107.62	75.56
13	110.57	79.59
14	113.17	83.86
15	115.40	88.34
16	117.25	92.98
17	118.69	97.77
18	119.11	99.72

Circle Center At X = 61.3 ; Y = 112.5 and Radius, 59.2

*** 1.238 ***

1

Failure Surface Specified By 18 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	55.56	51.87
2	60.53	51.40
3	65.53	51.43
4	70.50	51.97
5	75.40	53.01
6	80.16	54.53
7	84.74	56.53
8	89.10	58.97
9	93.19	61.85
10	96.97	65.12
11	100.41	68.76
12	103.45	72.72
13	106.08	76.97
14	108.27	81.47
15	110.00	86.16
16	111.24	91.01
17	111.99	95.95
18	112.18	99.84

Circle Center At X = 62.7 ; Y = 100.9 and Radius, 49.5

*** 1.273 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	43.89	47.55
2	48.87	47.97
3	53.82	48.66
4	58.73	49.61
5	63.58	50.82
6	68.36	52.29
7	73.06	54.01
8	77.65	55.99
9	82.14	58.20
10	86.50	60.65
11	90.72	63.33
12	94.79	66.23
13	98.70	69.34
14	102.44	72.66
15	106.00	76.17
16	109.37	79.87
17	112.53	83.74
18	115.48	87.78
19	118.21	91.97
20	120.72	96.29
21	122.43	99.66

Circle Center At X = 38.5 ; Y = 141.0 and Radius, 93.6

*** 1.281 ***

Y A X I S F T

.00 20.00 40.00 60.00 80.00 100.00



PCSTABL5

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: LEE4.INP
Output Filename: LEE4.OUT
Plotted Output Filename: LEE4.PLT

PROBLEM DESCRIPTION FREDERICKSBURG BATTLEFIELD SLOPE STABIL
TY

BOUNDARY COORDINATES

9 Top Boundaries
10 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	43.00	11.00	45.00	1
2	11.00	45.00	20.00	44.00	1
3	20.00	44.00	37.00	45.00	1
4	37.00	45.00	64.00	55.00	1
5	64.00	55.00	74.00	58.00	1
6	74.00	58.00	85.00	74.00	1
7	85.00	74.00	96.00	89.00	1
8	96.00	89.00	103.00	100.00	2
9	103.00	100.00	160.00	99.00	2
10	96.00	89.00	160.00	89.00	1

1

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	200.0	35.0	.00	.0	0
2	130.0	130.0	250.0	37.0	.00	.0	0

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced
Along The Ground Surface Between $X = 74.00$ ft.
and $X = 97.00$ ft.

Each Surface Terminates Between $X = 104.00$ ft.
and $X = 160.00$ ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is $Y = .00$ ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	74.00	58.00
2	78.00	61.00
3	81.83	64.21
4	85.49	67.62
5	88.96	71.22
6	92.24	75.00
7	95.31	78.95
8	98.16	83.05
9	100.79	87.30
10	103.19	91.69
11	105.36	96.19
12	106.91	99.93

Circle Center At $X = 19.7$; $Y = 134.6$ and Radius, 93.9

*** 1.117 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	76.56	61.72
2	80.74	64.45
3	84.83	67.33
4	88.82	70.35
5	92.70	73.50
6	96.47	76.79
7	100.12	80.20
8	103.65	83.74
9	107.06	87.40
10	110.34	91.18
11	113.48	95.06
12	116.49	99.06
13	116.98	99.75

Circle Center At X = - .1 ; Y = 183.7 and Radius, 144.1

*** 1.129 ***

1

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.11	65.44
2	83.35	68.08
3	87.44	70.96
4	91.36	74.07
5	95.09	77.39
6	98.63	80.93
7	101.97	84.65
8	105.08	88.56
9	107.97	92.64
10	110.63	96.88
11	112.26	99.84

Circle Center At X = 34.6 ; Y = 141.5 and Radius, 88.2

*** 1.133 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	74.00	58.00
2	78.58	60.02
3	83.06	62.23
4	87.44	64.65
5	91.70	67.26
6	95.85	70.05
7	99.86	73.03
8	103.74	76.18
9	107.48	79.51
10	111.07	82.99
11	114.49	86.63
12	117.75	90.42
13	120.84	94.36
14	123.75	98.42
15	124.53	99.62

Circle Center At X = 31.0 ; Y = 161.7 and Radius, 112.3

*** 1.162 ***

1

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	84.22	72.87
2	88.96	74.46
3	93.39	76.78
4	97.41	79.76
5	100.90	83.34
6	103.80	87.41
7	106.02	91.89
8	107.51	96.67
9	107.99	99.91

Circle Center At X = 76.5 ; Y = 103.8 and Radius, 31.8

*** 1.236 ***

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	84.22	72.87
2	88.45	75.53
3	92.40	78.60
4	96.02	82.05
5	99.28	85.84
6	102.15	89.94
7	104.60	94.30
8	106.60	98.88
9	106.94	99.93

Circle Center At X = 59.6 ; Y = 116.7 and Radius, 50.3

*** 1.297 ***

1

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	81.67	69.15
2	86.20	71.26
3	90.63	73.59
4	94.93	76.13
5	99.11	78.88
6	103.14	81.84
7	107.02	84.99
8	110.74	88.33
9	114.30	91.85
10	117.67	95.53
11	120.86	99.38
12	121.08	99.68

Circle Center At X = 41.2 ; Y = 162.1 and Radius, 101.4

*** 1.314 ***

Failure Surface Specified By 9 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.78	76.42
2	91.52	78.00
3	95.98	80.27
4	100.04	83.19
5	103.63	86.67
6	106.65	90.65
7	109.04	95.04
8	110.75	99.74
9	110.78	99.86

Circle Center At X = 78.6 ; Y = 108.8 and Radius, 33.4

*** 1.326 ***

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Failure Surface Specified By 8 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.78	76.42
2	91.30	78.55
3	95.57	81.15
4	99.55	84.19
5	103.18	87.63
6	106.42	91.43
7	109.25	95.55
8	111.56	99.85

Circle Center At X = 69.0 ; Y = 120.1 and Radius, 47.1

*** 1.328 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.11	65.44
2	84.01	66.46
3	88.79	67.91
4	93.43	69.77
5	97.89	72.03
6	102.14	74.66
7	106.14	77.66
8	109.87	80.99
9	113.29	84.64
10	116.38	88.57
11	119.12	92.75
12	121.48	97.16
13	122.55	99.66

Circle Center At X = 69.8 ; Y = 122.0 and Radius, 57.4

*** 1.328 ***

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