SUBSURFACE INVESTIGATION & GEOTECHNICAL DESIGN CONSIDERATIONS FOR A SOIL NAIL RETAINING WALL ON THE MORETOWN-MIDDLESEX RS 0167(9) PROJECT

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION

Prepared by:

Chad A. Allen
Geotechnical Engineer

Reviewed by:

Christopher C. Benda, P.E.
Soils and Foundations Engineer

Date: 10/27/98

1.0 INTRODUCTION

This report documents the geological and geotechnical investigation conducted for the construction of a retaining wall along VT 100B in Moretown, VT adjacent to the Winooski River. The proposed project consists of replacing the existing temporary 265 ft span, BR 8, crossing over the Winooski River on a new alignment along with related approach work. This preliminary report documents our subsurface investigation, analyses, and recommendations for the retaining wall portion of the proposed project. Contained herein are the results of field sampling and testing, laboratory analyses of soil and rock samples, and geotechnical design recommendations.

2.0 SCOPE OF WORK

Three (3) standard penetration boreholes and twenty-four (24) auger borings were drilled for the proposed project in June of 1989. Additional subsurface information was requested by Warren Tripp, Structures Engineer on October 21, 1997. Once this request was received additional borings and field tests were scheduled. On November 18, 1997 a survey crew was instructed to stake out standard penetration boreholes off the survey centerline for the proposed soil nail wall. The proposed construction would take place between Station 194+00 and Station 198+40 of the revised line.

3.0 FIELD INVESTIGATION & LABORATORY TESTING

3.1 Field Investigation

A total of ten standard penetration bore holes, twenty-four auger holes, one hand steel sounding (R11), three monitoring wells, and two test excavations represent the subsurface profile for the proposed soil nail wall. Soil samples were visually classified in the field and SPT blow counts were recorded on the boring logs. When bedrock was encountered BX size (1.63") cores were drilled, in five foot runs for ten feet and recorded on boring logs except for R1, R2, and R3 where AX size (1.38") cores were drilled. The locations of all field data were originally referenced from the survey centerline, only the CADD generated boring logs have been changed to reflect the revised centerline stations and offsets.

3.1.1 Standard Penetration Borings/Hand Steel Soundings: Subsurface investigations were conducted on two separate occasions between June 22, 1989 and February 9, 1998. During the boring operations, split spoon samples and standard penetration tests (SPT) were taken at five foot intervals until bedrock was encountered. Soil samples were visually classified in the field and SPT blow counts were recorded on the boring logs. When bedrock was encountered BX size (1.63") cores were drilled, in five foot runs for ten feet, and recorded on boring logs except for R1, R2, and R3 where AX size (1.38") cores were drilled. One exception was R-11 where hand steel was driven for 35 feet without encountering bedrock. Soil and rock samples were preserved and returned to the Materials and Research Laboratory for testing and further evaluation by the geologist. Borings were sampled at the following locations:

Hole No.	Survey Station	Offset
R-1	195+00	40' - Right
R-2	196+25	40' - Right
R-3	196+90	30' - Right
R-4*	194+50	14' - Right
R-5	194+50	41' - Right
R-7	195+50	42' - Right
R-8*	196+50	5' - Right
R-9	195+50	25' - Right
R-10	197+00	6' - Right
R-11 - hand steel sounding	197+50	4' - Right
R-12*	197+50	37' - Right

*denotes continued evaluation as a monitoring well

The original field boring logs can be reviewed in Appendix A. When each hole was stopped the depth was noted on the log and a monitoring well was installed, if requested.

3.1.2 Auger Borings: Auger boreholes were drilled in order to obtain a better profile of the ledge beneath the ground surface. The auger drilling notes can be examined in Appendix B. The auger holes were sampled at the following locations:

A-1	194+00	41' - Left
A-2	194+00	Centerline
A-3	194+00	30' - Right
A-4	194+00	60' - Right
A-5	195+00	48' - Left
A-6	195+00	Centerline
A-7	195+00	33' - Right
A-8	195+00	100' - Right
A-9	195+00	130' - Right
A-10	196+00	50' - Left
A-11	196+00	Centerline
A-12	196+00	32' - Right
A-13A	196+00	110' - Right
A-13B	196+00	130' - Right
A-14	197+00	50' - Left
A-15	197+00	Centerline
A-16	197+00	30' - Right
A-17	197+00	110' - Right
A-17B	197+00	110' - Right
A-18	198+00	46' - Left
A-19	198+00	Centerline

Hole No.	Survey Station	Offset
A-20	198+00	32' - Right
A-21	198+00	75' - Right
A-22	199+00	Centerline
A-23	199+00	32' - Right
A-24	199+00	65' - Right

3.1.3 Monitoring Wells: Monitoring wells were installed at locations of the following boreholes: R4, R8, and R12. Standard penetration testing and split spoon sampling were conducted at each location before the wells were installed. Groundwater information was recorded while conducting the subsurface investigations at each location. Each monitoring well consisted of a temporary polvinylchloride (PVC) pipe with a screen and removable cap. Monitoring wells were analyzed using a hand held, battery powered probe that is capable of measuring the elevation of water within a well.

No water was observed at any time in any of the wells. The monitoring wells have been observed during periods of dry weather and periods of high rainfall periodically from the time of installation. Actual monitoring well data can be reviewed in Appendix C.

3.1.4 Test Excavations: Two test excavations, TP1 & TP2, were conducted using a John Deere 310C backhoe on June 10, 1998, one each at Station 196+25 and 198+50. Each excavation consisted of cutting a nearly vertical face into the existing slope to expose 5 to 6 feet of soil. No problems were experienced during excavation of the cut face and groundwater was not encountered. Each cut face suffered minor raveling primarily due to an apparent loss of cohesion caused by loss of moisture. The excavations were left open for three days and remained stable with no significant overbreaks, major raveling or face failure occurring. Technical site assistance was provided by Golder Associates and the Federal Highway Administration (FHWA). Golder Associates' reports along with detailed observations of the excavations have been included in Appendix C.

3.2 Laboratory Testing: All laboratory testing was completed at the Materials and Research Laboratory in the Central Garage Complex in Berlin, Vermont. Laboratory testing consisted of testing the soil samples for composition, corrosivity, and shear strength characteristics.

3.2.1 Soil Properties: Selected specimens obtained from the standard penetration borings were tested to assess the physical properties of the soil, such as the moisture content and gradation of each sample. The moisture content of the soil was tested in accordance with AASHTO T-265. Gradations or particle size analyses were conducted on each sample retrieved from the split spoon sampler and tested in accordance with AASHTO T-27. Upon completion of the laboratory testing, the field boring logs were revised to reflect the results of the laboratory classification tests. The CADD generated boring logs, in Appendix A, indicate the types of soils and strata encountered and include the laboratory test results, SPT data, and any pertinent observations made by the boring crew.

3.2.2 Electrochemical Properties: Selected specimens were tested to measure the corrosivity of the soil environment. Soil samples were collected and organized to represent the various layers of subsurface material. The samples were measured for pH and chloride content. The samples were recovered during the drilling of standard penetration boreholes located at the following locations:

Hole No.	Station	Offset
R-12	197+50	37' - Right
R-15	201+00	12' - Right
R-16	201+25	7' - Right
R-17	201+50	10' - Right
R-18	202+00	3' - Left
R-19	202+00	23' - Right
R-21	202+50	20' - Right
R-24	203+00	5' - Right

These samples were tested before it was determined that only one soil nail wall would be built. However, the soil properties that were tested between Stations 201+00 and 203+00 are expected to be representative of the soil conditions for the proposed soil nail wall. Chloride values were tested to be between 4 ppm and 33 ppm with the exception of two samples which tested between 237 ppm and 341 ppm. Acidity or pH values ranged from 5.6 to 7.0 for all samples tested. The electrochemical testing was performed by the Agency's Chemist, on May 15, 21, and 22, 1998. A copy of the complete test results is included in Appendix C.

3.2.3 Laboratory Shear Strength: The same specimens selected for electrochemical testing were also tested to determine the approximate insitu shear strength of the existing soil for design purposes. The insitu shear strengths were determined using the triaxial test apparatus in our laboratory. In order to simulate insitu conditions the unit weight was estimated based on the SPT blow counts. The in-situ density was then replicated by compacting the triaxial specimen in equal layers to attain a unit weight equal to the estimated value.

Each specimen was tested at three different confining pressures which were based on the average amount of overburden pressure experienced before sampling. The specimens were then placed in an air solution, at a specific confining pressure held constant throughout the test, and loaded to failure to determine the cohesion and the internal friction angle of the soil for design purposes. From the laboratory data the average cohesion and internal friction angle of the soil were calculated to be 186 psi and 31.7° respectively. Based upon these tests and field observation of the existing slope, an internal friction angle of 32° and a cohesion value of 185 psi were used for design purposes. A spreadsheet tabulating the data and results can be reviewed in Appendix C.

4.0 SOIL PROFILE

The soils below the surface along the proposed alignment of the soil nail retaining wall are predominantly a loose to medium sandy silt with some gravel interspersed. Just above the top of bedrock lies some thin (less than 10 feet), medium to dense layers of silty sand. Moisture contents of the overlying strata average 24.6 %. No groundwater was encountered. Bedrock is shallowest between Station 196+25 and Station 196+50 at an elevation of approximately 513 feet. The bedrock drops off on both sides with the slope steeper to the east (Station 198+00) than the west (Station 194+00). The ledge is rolling and dipping and therefore is not considered uniform. The soil profile and location of the boreholes and auger holes may be identified and further evaluated by referring to Appendix D.

5.0 PROPOSED SOIL NAIL WALL DESIGN

5.1 Overview: At this site there are a few mitigating factors that have controlled how the design process has evolved. The existing roadway must be realigned to increase sight distances and clear zones. As a result of this alignment the toe of the existing slope must be removed, which would negatively effect the stability of the slope. Located at the top of the existing slope are power lines owned by Green Mountain Power. In accordance with AASHTO's *Standard Specifications for Highway Bridges*, Section 5.2.2.3, slopes supporting critical utilities must maintain a global stability with a minimum safety factor of 1.5. The goal is to design a structure that would effectively support the existing slope with an adequate safety factor.

5.2 Wall System Selection Process: There are two basic methods of constructing retaining wall systems: 1) Fill wall or "bottom -up" construction and 2) Cut wall or "top down" construction. Both types of walls were initially considered at this site. However, the excavation required to construct a fill wall would severely impact the existing slope and would require extensive temporary shoring to keep the transmission lines stable. Therefore this type of structure was excluded from further study.

There are three categories of cut wall construction applications 1) Non-gravity Cantilevered Walls 2) In-situ Reinforced Walls and 3) Anchored Walls. Retaining walls are also classified as either externally or internally stabilized wall systems. Externally stabilized wall systems utilize an external structural wall, against which stabilizing forces are mobilized. Internally stabilized wall systems employ reinforcement which extends beyond the potential failure mass.

As for narrowing down the specific category of a cut wall system, factors such as aesthetics, cost, and reliability were reviewed. The non-gravity cantilevered walls are externally stabilized systems which include sheet pile walls and soldier pile walls. Due to the relatively shallow depth of bedrock in certain areas along the length of the proposed retaining wall, the piles would not be able to develop the amount of passive resistance required to stabilize the existing slope. Anchored walls are also externally stabilized wall systems utilizing either ground or deadman anchors. One disadvantage is that every anchor would require testing to develop a certain confidence in the system. Another disadvantage is that underground easements would have to be purchased.

A soil nail wall system is an internally stabilized system that uses reinforcing bars that extend beyond the failure surface. Although the cost of a soil nail wall is more than a typical soldier pile wall, the cost is similar to that of an anchored wall. Underground easements would also need to be purchased for a soil nail wall. One advantage to constructing a soil nail wall is that it can be constructed to be aesthetically pleasing. The soil nail wall can be built in two levels with the upper level set back ten to twenty feet so that the overall height of the wall appears to be somewhat less to the public. Vegetation can be grown to hide the second wall, leaving only the lower wall noticeable. Both walls can be designed with either contemporary or traditional facings utilizing either precast concrete, cast-in-place concrete, or wood. Not all of the soil nails need to be tested although there are more nails to install, when compared with an anchored wall system. The silty sandy soils and groundwater conditions provide for an optimum site for a soil nail wall.

5.3 Design: As a result of the soil profile, construction application, and aesthetics it was determined that a soil nail wall would be the most appropriate alternative. Several designs were reviewed that were constructed by state transportation agencies in New Hampshire and Maine. Technical assistance was requested to help assess the site, develop and review the design, and troubleshoot problems in construction if needed. Technical assistance was provided by the Federal Highway Administration and Golder Associates in conjunction with FHWA's Demonstration project 82. FHWA's <u>Manual for Design & Construction Monitoring of Soil Nail Walls</u>, was used as a reference guide throughout the design process. GOLDNAIL, a computer software program developed by Golder Associates for the FHWA, was utilized to confirm the overall wall stability, facing design, and the internal stability of the nails. Geometric properties, soil properties, groundwater conditions, and the soil profile were entered to obtain nail loads, nail head loads, and nail lengths. The results generated from the computer software program were verified by hand calculations using the guidelines and format from the manual. To minimize the cost of the proposed soil nail wall, a permanent facing was designed using a minimum thickness of shotcrete and insulation. The insulation was necessary to prevent surface water from freezing behind the wall. A heat transfer analysis was conducted to determine the correct thickness and type of insulation needed to keep temperatures behind the soil nail wall above freezing. Drawings showing the typical cross section, wall details, drainage details, and facing details can be referenced in Appendix E. The elevation views of the soil nail wall showing the proposed wall grades and nail locations and elevations are included in Appendix F.

6.0 RESULTS

6.1 Laboratory and Field Testing: The soil beneath the ground surface is mainly silty sand or sandy silt of medium density with an average moisture content of approximately 25%. The electrochemical results show that the chloride levels are acceptable with the majority of samples below the critical value of 100 ppm. Also, the pH levels of all the samples indicate a pH between 5.5 and 7.0, above the recommended minimum of 5.0. All of the monitoring wells exhibited no groundwater throughout the course of the six-month long observation period.

6.2 Soil Nail Wall Calculations: The hand and computer calculations for nail size, nail head strengths and loads, and nail lengths are presented in Appendix G. The computer solution using GOLDNAIL was used to verify and refine the hand calculations. The results of the heat transfer calculations are depicted in Appendix I.

6.3 Stability Analyses: There is a natural drainage swale at approximately 196+65 which divides the upper wall into two separate walls. Therefore, stability analyses were completed for each retaining wall segment as detailed in Appendix H.

6.3.1 Station 194+00 to Station 196+65: The critical cross section that governed the nail lengths for this portion of the retaining wall is located at 195+50. GOLDNAIL computed the nails to be No. 8 reinforcing bars (1.0" diameter) with nail lengths of 60 ft for the upper wall and 55 ft for the lower wall resulting in a safety factor of 1.50. The nails were spaced at five feet on center to the horizontal and the vertical. This satisfies the AASHTO criteria for critical slopes of 1.50. The nail loads and nail head loads were examined and found to have a safety factor of 1.50 when compared with the allowable loads.

6.3.2 Station 196+65 to Station 198+40: The critical cross section that governed the nail lengths for this portion of the retaining wall is located at 197+50. GOLDNAIL computed the nails to be No. 8 reinforcing bars (1.0" diameter) with allowable nail lengths of 50 ft for the upper wall and 45 ft for the lower wall resulting in a safety factor of 1.65. This satisfies the AASHTO criteria for critical slopes of 1.50. The nails were spaced at five feet on center to the horizontal and the vertical. The nail loads and nail head loads were examined and found to have a safety factor of 1.50 when compared with the allowable loads.

7.0 RECOMMENDATIONS

Due to favorable site conditions a soil nail retaining wall is recommended for the Moretown RS 0167(9) project between Station 194+00 and Station 198+40. The retaining wall shall consist of soil nails (No. 8 Grade 60 reinforcing bars), 6.75" of shotcrete, 5.5" insulation, and a wood facing according to the plans and details in Appendix E. The total length of the soil nails varies as shown in Table 1. The horizontal and vertical spacing of the soil nails shall be five feet on center. The

	Upper Wall Nail Lengths (ft)	Lower Wall Nail Lengths (ft)
Station 194+00 to Station 196+65	60	55
Station 196+65 to Station 198+40	50	45

Table 1: Moretown-Middlesex RS 0167(9) Soil Nail Lengths

insulation installed at the shotcrete face shall be a total of 5.5" with 2 layers of 2" Styrofoam® SM grade polystyrene or equivalent and 1 layer of 1.5" of Styrofoam® Perimate grade polystyrene or equivalent.

It is recommended that inclinometers be installed for the upper and lower walls at Stations 195+50 and 197+50. It is also recommended that survey control points be installed in the wall facing to monitor any horizontal or vertical displacements along the length of the walls during construction. The column of soil nails at 195+47.5 should be instrumented with vibrating wire strain gauges and a vibrating wire load cell to measure the actual soil nail and nail head loads. For the column of soil nails located at Station 197+47.5, vibrating wire temperature sensors should be installed such that the atmospheric and the soil directly behind the permanent shotcrete facing can be monitored effectively.

APPENDIX A

- Standard Penetration Boring Results

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-1
SHEET 1 OF 1
DATE STARTED: 6/22/89
DATE COMPLETED:

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 194+93.79
GROUND EL.: 540.20

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 50.78
G.W. DEPTH: 55.8'

BORING CREW
CREW CHIEF: MCGLYNN
DRILLER:
LOGGER:

BORING RIG: TRUCK
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4, SaSi, Moist, brn	5	24.6					
10		A-4, SaSi, Moist, brn	9	29					
15		A-4, SaSi, Moist, gry	11	22.2					
20		A-4, SaSi, Moist, gry	15	26					
25		A-4, SaSi, Moist, gry	18	23.1					
30		A-4, SaSi, Moist, gry	12	28.9					
35		A-2-4, SiSa, Moist, gry	45	17.1					
40		A-4, Si, MTW, gry	24	29.5					
45		A-4, SiSa, Moist, gry	28	24.6					
50		A-4, SiSa, Moist, gry	33	23.4					
55		A-1-b, GrSa, Moist, gry	R	13.3	Top of bedrock @ 55.8'				

RUN	REC	DIP
1	70	50-70
2	40	50-70
3	100	50-70

Run 1: AXMDC, 55.8'-60.8', Rec. = 3.5', See Geologist's Report.

Run 2: AXMDC, 60.8'-65.8', Rec. = 2.0', See Geologist's Report.

Run 3: AXMDC, 65.8'-68.8', Rec. = 3.0', See Geologist's Report.

Hole stopped @ 68.8' In bedrock.

Geologist's Report

Run 1: Core consist of quartz-sericite chlorite schist. The rock contains pyrite and magnetite which weathers to iron oxides. The rock is moderately soft, slightly weathered and competent.

Run 2: A moderate amount of weathering occurs between 60.8' and 65.8'. The weathering is confined to the quartz-rich zones.

Run 3: Same as Run 1.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-2
SHEET 1 OF 1
DATE STARTED: 6/26/89
DATE COMPLETED:

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 196+18.85
GROUND EL.: 539.00

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 55.12
G.W. DEPTH: No Groundwater

BORING CREW
CREW CHIEF: MCGLYNN
DRILLER:
LOGGER:

BORING RIG: TRUCK
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4, SaGrSi, Moist, brn	15	11.9					
10		A-4, SaGrSi, Moist, gry	22	22.1					
15		A-4, Si, Moist, gry	20	26.3					
20		A-4, SiSa, Moist, brn	19	16.4					
			Top of bedrock @ 22.5'						

RUN	REC	DIP
1	44	50-70
2	76	50-70

Run 1: AXMDC, 22.5'-27.5', Rec. = 2.2', See Geologist's Report.

Run 2: AXMDC, 27.5'-32.5', Rec. = 3.8', See Geologist's Report.

Hole stopped @ 32.5' In bedrock

Geologist's Report

Run 1: Core consist of quartz-sericite-chorite schist. The rock is moderately soft, slightly weathered and competent overall. Poor core recovery may be due to a weathered quartz-rich zone which could not be recovered. Upper 5.0' of the rock may be poorer quality then indicated by the recovered core.

Run 2: Same as Run 1

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-3
SHEET 1 OF 1
DATE STARTED: 6/27/89
DATE COMPLETED:

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 196+73.89
GROUND EL.: 539.00

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 47.36
G.W. DEPTH: No Groundwater

BORING CREW
CREW CHIEF: MCGLYNN
DRILLER:
LOGGER:

BORING RIG: TRUCK
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4, SiSa, Moist, brn	5						
10		A-4, SaSi, Moist, brn	12	23					
15		A-4, SaSi, Moist, brn	14	24.7					
20		A-4, SaSi, Moist, brn	13	29.2					
25		No Rec.	21						
			Top of bedrock @ 29.0'						
			RUN	REC	Dip°				
30		Run 1: AXMDC, 29.0'-34.0', Rec. = 2.4', See Geologist's Report.	1	48	40-60				
35		Run 2: AXMDC, 34.0'-39.0', Rec. = 5.0', See Geologist's Report.	2	100	40-60				

Hole stopped @ 39.0' In bedrock.

Geologist's Report

Run 1: Core consists of quartz-sericite-chlorite schist. Poor recovery in the upper 5.0' may indicate an extensive zone of fracturing and weathering. Below this the rock is moderately soft, slightly weathered and competent overall.

Run 2: Same as Run 1.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-4
SHEET 1 OF 1
DATE STARTED: 1/9/98
DATE COMPLETED: 1/13/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 194+43.76
GROUND EL.: 518.45

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 23.05
G.W. DEPTH: NO GROUNDWATER

BORING CREW
CREW CHIEF: E. WILLIS
DRILLER: R. TALLMAN
LOGGER: E. CHABOT

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4,SaSi,M,brn,rec.=1.1'	5	28.4		28.2	71.8		
10		A-4,SaSi,M,brn,rec.=1.5'	13	32.7		23.1	76.9		
15		A-1-b,GrSa,M,brn,rec.=1.5'	33	14.1	21.4	62.6	16		
20		A-4,SaSi,M,brn,rec.=1.1'	23	27	1	20.4	78.6		
25		A-4,SiSa,M,brn,rec.=1.2'	15	23.5		55.2	44.8		
30		A-4,SaSi,M,brn,rec.=1.5'	11	30.3	4.5	23.8	71.7		
			Top of bedrock @ 33.5'						
			RUN	REC %	RQD %	Dip°			
35		Run #1: BXMDC 33.5'-34.5' rec.=0.3'-See Geologist's Report	1	30	0	70			
		Run #2: BXMDC 34.5'-39.5' rec.=4.2'-See Geologist's Report	2	84	72	70			
40		Run #3: BXMDC 39.5-44.5 rec.=4.7'-See Geologist's Report	3	94	90	70			

Hole stopped @ 44.5' in bedrock.

Note: Monitoring Well set to 25'; 20' Screen 5' Solid

Note: 02/13/98 - No water in monitoring well

Geologist's Report:

Run 1: Core consists of green quartz-chlorite schist with quartz veins. Very hard. Poor RQD.

Run 2: Core consists of green quartz-chlorite schist with quartz veins. Hard. Unweathered. Competent

Run 3: Core consists of dark green quartz-chlorite schist with minor quartz veins. Hard. Unweathered. Moderately weathered zones along foliation at 40' and 44.7'. Competent

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-5
SHEET 1 OF 1
DATE STARTED: 12/22/97
DATE COMPLETED: 12/24/97

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 194+43.76
GROUND EL.: 541.84

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 50.05
G.W. DEPTH: NO GROUNDWATER

BORING CREW
CREW CHIEF: E. WILLIS
DRILLER: R. TALLMAN
LOGGER: E. CHABOT

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4,SaSi,M,brn,rec.=1.2'	8	24.2		24.8	75.2		
10		A-4,SiSa,M,brn,rec.=1.2'	10	20.9		58.9	41.1		
15		A-4,SaSi,M,brn,rec.=2.0'	9	21.9		38.5	61.5		
20		A-4,SaSi,M,brn,rec.=1.0'	12	24.5	1.7	26.6	71.7		
25		A-4,SaSi,M,brn,rec.=1.2'	13	24.9	0.7	30	69.3		
30		A-4,SaSi,M,brn,rec.=1.3'	12	27.9	1.1	26.7	72.2		
35		A-4,SaSi,M,brn,rec.=1.2'	15	28.8		35.4	64.6		
40		A-4,SaSi,M,brn,rec.=1.0'	27	22.4	18	39.2	42.8		
45		Hole stopped @ 42.0'							
50									
55									
60									
65									
70									
75									
80									
85									
90									
95									

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-7
SHEET 1 OF 1
DATE STARTED: 1/15/98
DATE COMPLETED: 1/20/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 195+43.82
GROUND EL.: 555.50

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 54.51
G.W. DEPTH: NO GROUNDWATER

BORING CREW
CREW CHIEF: E. WILLIS
DRILLER: R. MCGLYNN
LOGGER: R. TALLMAN

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4,SaSi,M,brn,rec.=1.6'	4	26.5		43.3	56.7		
10		A-4,Si,M,brn,rec.=1.5'	5	29.1		17.6	82.4		
15		A-4,SiSa,M,brn,rec.=1.0'	10	17.4		55.5	44.5		
20		A-4,Si,M,brn,rec.=1.1'	15	27.3		19.1	80.9		
25		A-4,SaSi,M,brn,rec.=1.2'	15	33.6		38.9	61.1		
30		A-4,SaSi,M,brn,rec.=1.2'	15	24.7		33	67		
35		A-4,SaSi,M,brn,rec.=1.4'	14	27.5		29.1	70.9		
40		A-4,Si,M,brn,rec.=1.4'	15	26.7		19	81		
45		A-4,SaSi,M,brn,rec.=1.1'	19	28	0.3	31.5	68.2		
50		A-4,SiSa,M,brn,rec.=1.9'	23	19.9		50.4	49.6		
55		A-4,SiSa,M,brn,rec.=1.5'	25	21.4		58.2	41.8		
			Top of bedrock @ 59.0'						
			RUN	REC %	RQD %	Dip°			
60		Run #1: BXMDC 59.0'-64.0' rec.=4.9'-See Geologist's Report	1	98	79	70			
65		Run #2: BXMDC 64.0'-69.0' rec.=5.0'-See Geologist's Report	2	100	98	70			
70			Hole stopped @ 69.0'						
75									

Geologist's Report:

Run 1: Core consists of green quartz-chlorite schist with minor calcite veins. Unweathered. Hard Competent.

Run 2: Same as Run #1. Competent.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-8
SHEET 1 OF 1
DATE STARTED: 1/28/98
DATE COMPLETED: 1/28/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 196+43.88
GROUND EL.: 518.07

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 20.98
G.W. DEPTH: NO GROUNDWATER

BORING CREW
CREW CHIEF: E. WILLIS
DRILLER: R. MCGLYNN
LOGGER: R. TALLMAN .

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		No sample - bouiders							
10		A-1-b,SiSaGr,M,brn rec.=0.5	10	13.3	46.6	30.8	22.6		
			Top of bedrock @ 14.0'						
15		Run #1: BXMDC 14.0'-19.0' rec.=3.8'-See Geologist's Report	RUN	REC %	RQD %	Dip°			
			1	76	74	70			
20		Run #2: BXMDC 19.0'-24.0' rec.=3.1'-See Geologist's Report	2	60	50	70			

Hole stopped @ 24.0'

Note: Monitoring Well set to 14'; 10' Screen 5' Solid

Note: 02/13/98 - No water in monitoring well

Geologist's Report:

Run 1: Core consists of green quartz-chlorite schist with quartz veins. Moderately hard. Unweathered. Competent.

Run 2: Same as Run #1.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-9
SHEET 1 OF 1
DATE STARTED: 1/29/98
DATE COMPLETED: 1/30/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 196+43.82
GROUND EL.: 526.43

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 40.98
G.W. DEPTH: No Groundwater

BORING CREW
CREW CHIEF:
DRILLER: CHABOT E J
LOGGER: LAPORTE

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		Boulders-No Sample							
10		A-2-4,SiSa,W,brn rec.=0.4	22	25.9	2.8	63.5	33.7		
15		A-4,SaSi,M,brn,rec.=0.5	R	23.1	1.2	49	49.8		
		Run #1: BXMDC 16.4'-21.4' rec.=2.6'-See Geologist's Report	Top of bedrock @ 16.4'						
20			RUN	REC %	RQD %	Dip°			
		Run #1: BXMDC 21.4'-26.4' rec.=3.1'-See Geologist's Report	1	52	52	70			
25			2	62	58	70			

Hole stopped @ 26.4'

Geologist's Report:

Run 1: Core consists of light green quartz-chlorite schist. Moderately hard. Unweathered. Recovered rock is competent.

Run 2: Same as Run #1, but with quartz veins.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-10
SHEET 1 OF 1
DATE STARTED: 2/2/98
DATE COMPLETED: 2/3/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 196+93.91
GROUND EL.: 534.65

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 23.71
G.W. DEPTH: No Groundwater

BORING CREW
CREW CHIEF: E. WILLIS
DRILLER: R. MCGLYNN
LOGGER: W. LAPORTE

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		A-4,SaSi,M,brn,rec.=0.8'	5	25		44.7	55.3		
10		A-4,SaSi,M,brn,rec.=1.2'	15	23.8		34.6	65.4		
15		A-4,SaSi,M,brn,rec.=1.3'	13	29.6		31.3	68.7		
20		A-4,SaSi,M,brn,rec.=1.1'	28	25.1		36.5	63.5		
25		A-4,SaSi,M,brn,rec.=1.3'	30	21.6	0.3	29.2	70.5		
30		A-4,SaSi,M,brn,rec.=1.0'	21	24.3	0.1	29.3	70.6		
			Top of bedrock @ 34.0'						
			RUN	REC %	RQD %	Dip°			
35		Run #1: BXMDC 34.0'-39.0' rec.=4.2'-See Geologist's Report	1	84	68	70			
40		Run #2: BXMDC 39.0'-44.0' rec.=5.0'-See Geologist's Report	2	100	98	70			

Hole stopped @ 44.0'

Geologist's Report:

Run 1: Core consists of light grayish-green quartz chlorite schist with minor quartz veins. Moderately Hard. Unweathered. Competent.

Run 2: Same as Run #1.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SUBSURFACE INFORMATION

HOLE NO.: R-12
SHEET 1 OF 1
DATE STARTED: 2/5/98
DATE COMPLETED: 2/9/98

PROJECT NAME: MORETOWN
SITE NAME: RETAINING WALL
STATION: 197+43.00
GROUND EL.: 549.29

PROJECT NUMBER: RS0167(9)
SITE NO.:
OFFSET: 42.00
G.W. DEPTH: No Groundwater

BORING CREW
CREW CHIEF: R. MCGLYNN
DRILLER: E. CHABOT
LOGGER: R. TALLMAN

BORING RIG: SKID RIG
BORING TYPE: WASH BORE
SAMPLE TYPE: SPLIT BARREL

DEPTH	SYMBOL	CLASSIFICATION OF MATERIALS (Description)	BLOWS PER FOOT	M.C. %	GRAVEL %	SAND %	FINES %	LL	PI
5		Combined Sample A-4,GrSaSi,M,brn rec. varies 1.0 to 1.5 Friction Angle = 29° Cohesion, c, = 225 psf	4	22.3	20.4	34	45.6		
10			12						
15			15	10.3					
20			11	19.6					
25			11	24					
30		Combined Sample A-4,SaSi,M,brn rec. varies 1.0 to 1.3 Friction Angle = 33° Cohesion, c, = 0 psf	18	20.5	0.2	46.3	53.5		
35			17	25.4					
40			13	24.8					
45			15	24.9					
50		Combined Sample A-4,SiSa,M,brn rec. varies 1.1 to 1.2 Friction Angle = 31° Cohesion, c, = 360 psf	15	26.3	4.6	52.5	42.9		
55			19	20.7					
60			22	14.8					
			Top of bedrock @ 65.0'						
65		Rock Particles,rec.=2.0	23	3.3					
			RUN	REC %	RQD %	Dip°			
70		Run #1: BXMDC, 67.0'-72.0' rec.=1.0-See Geologist's Report	1	20	8	70			
75		Run #1: BXMDC, 72.0'-77.0' rec.=2.4-See Geologist's Report	2	48	40	70			

Hole stopped @ 77.0'

Note: During coring of bedrock 67.0'-77.0' rock particles being washed away by core water.

Monitoring Well installed to 47.5'
30' Screen & 20' Solid

Geologist's Report:
Run 1: Core consists of light green quartz-chlorite schist. Moderately Hard. Unweathered. Poor RQD and recovery.
Run 2: Same as Run #1.

APPENDIX B

- ♦ Auger Boring Results
- ♦ Hand Steel Soundings

P5

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SOILS SUBDIVISION

AUGER DRILLING NOTES

PROJECT/PROJECT NO.: Moretown-Middlesex RS0167 (9)
DRILLER McGlynn DATE: 9 Feb. 1987
NOTES FROM STATION 194+0 TO STATION 196+0 32'Rt

CHECKED BY GBA
DATE CHECKED 3-26-87

STATION	OFFSET	DEPTH	SOIL DESCRIPTION – Field – Soil Type	Color	Moisture	LABORATORY CLASSIFICATION
194+0	℄ (S)	0.0-8.0	SiSa	Brn	Moist	A-2-4 Silty Sand
		✓	NLTD			
	30'Rt.	17.0	NLTD	(Hand)		
	60'Rt.	14.0	NLTD	(Hand)		
	40'Lt.	0.0-8.0	SiSa	Brn	Moist	
		✓	NLTD			
195+0	℄	21.0	NLTD	(Hand)		
	33'Rt.	0.0-45.0	Si	Brn	Moist	
		✓	NLTD			
	100'Rt.	0.0-10.0	SaGl	Brn	Moist	
		10.0-75.0	Si	✓	✓ !	
		✓	NLTD			
	130'Rt. (S)	0.0-15.0	SaGl	Brn	Moist	A-1-b Sandy Gravel
	(S)	15.0-78.0	SiSa	✓	✓	A-4 Sandy Silt
		✓	TLOB			
	48'Lt.	0.0-14.0	SiSa	Brn	Moist	
		✓	NLTD			
196+0	℄ (S)	0.0-27.0	SiSa	Brn	Moist	A-4 Silt
		✓	TLOB			
	32'Rt.	0.0-31.0	SiSa	Brn	Moist	
		✓	TLOB			

TA 407D 5C 8/83
5C 3/85

P6

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SOILS SUBDIVISION

AUGER DRILLING NOTES

PROJECT/PROJECT NO.: Moretown-Middlesex RS0167(9)
DRILLER McGlynn DATE: 9 Feb. 1987
NOTES FROM STATION 196+0 110'Rt. TO STATION 198+0

CHECKED BY CBA
DATE CHECKED 3-26-87

Auger I.D.	STATION	OFFSET	DEPTH	SOIL DESCRIPTION			
				Field			
				Soil Type	Color	Moisture	LABORATORY CLASSIFICATION
A13	196+0	110'Rt.	0.0-45.0	SiSa	Brn	Moist	
			✓	NLTD			
A10		50'Lt.	0.0-14.0	SiSa	Brn	Moist	
			✓	NLTD			
A15	197+0	℄	0.0-35.0	Si	Brn	Moist	
			✓	NLTD			
A16		S 30'Rt.	0.0-31.0	Si	Brn	Moist	A-4 Silt
			✓	TLOB			
A 7		110'Rt.	0.0-35.0	Si	Brn	Moist	
			✓	NLTD			
A 4		S 50'Lt.	0.0-14.0	SiSa	Brn	Moist	A-4 Silt
			✓	NLTD			
A 1	198+0	℄ S	0.0-14.0	Si	Brn	Moist	A-2-4 Silty Sand
			✓	NLTD			
A 2		32'Rt.	0.0-35.0	Si	Brn	Moist	
			✓	NLTD			
A 1		75'Rt.	0.0-30.0	Si	Brn	Moist	
			✓	NLTD			
A 3		46'Lt.	0.0-8.0	SiSa	Brn	Moist	
			✓	NLTD			

TA 407D 5C 8/83
5C 3/85

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SOILS SUBDIVISION

P7

AUGER DRILLING NOTES

PROJECT/PROJECT NO.: Moretown-Middlesex RS0167(9)
DRILLER McGlynn DATE: 9 Feb. 1987
NOTES FROM STATION 199+0 TO STATION 201+0

CHECKED BY GBA
DATE CHECKED 3-26-87

Auger I.D.	STATION	OFFSET	DEPTH	SOIL DESCRIPTION Field Soil Type	Color	Moisture	LABORATORY CLASSIFICATION
A22	199+0	℄	0.0-5.0	Si	Brn	Moist	
			✓	NLTD			
A23		(S) 32'Rt.	0.0-8.0	Gr	Brn	Moist	A-1-b Silty Gravel
			✓	TLOB			
A24		65'Rt.	0.0-7.0	Gr	Brn	Moist	
			✓	TLOB			
	200+0	℄	0.0-1.0	Si	Brn	Moist	
			✓	TLOB			
		(S) 36'Rt.	0.0-5.0	SiSa	Brn	Moist	A-2-4 Silty Sand
			✓	TLOB			
		70'Rt.	0.0-5.0	SiSa	Brn	MTW	
			✓	TLOB			
		20'Lt.	0.0-3.0	SiSa	Brn	Moist	
			✓	TLOB			
	201+0	℄	11.0	TLOB (Hand)			
		(S) 36'Rt.	0.0-11.0	Gr	Brn	Moist	A-1-a Sandy Gravel
		(S)	11.0-29.0	SiSa	✓	✓	A-2-4 Gravelly Sand
			✓	TLOB			
		80'Rt.	0.0-2.5	SiSa	Brn	Moist.	
			✓	TLOB			
		36'Lt.	0.0-4.0	SiSa	Brn	Moist	
			✓	TLOB			

TA 407D 5C 8/83
5C 3/85

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION
SOILS SUBDIVISION

AUGER DRILLING NOTES

PROJECT/PROJECT NO.: MORETOWN RSEGC-RS 0167(9)
DRILLER ______ DATE: 7-19-89
NOTES FROM STATION 195+00 TO STATION 197+00

CHECKED BY ______
DATE CHECKED ______

STATION	OFFSET	DEPTH	SOIL DESCRIPTION - Field - Soil Type	Color	Moisture	LABORATORY CLASSIFICATION
195+0	100' RT	0.0-11.0	SiSa	brn	MOIST	A-4 SaSi
		11.0-50.0	SILT	brn	MOIST	A-4 SaSi
		NLTD @ 50.0' NO WATER TO DEPTH				
B 196+0	130' RT	0.0-7.0	SaSi	brn	MOIST	A-4 SiSa
		7.0-57.0	SILT	brn	MOIST	A-4 SaSi
		LEDGE OR BOULDER @ 57.0'				
		NO WATER TO DEPTH				
B3 197+0	110' RT	0.0-6.0	SaSi	brn	MOIST	A-4 SiSa
		6.0-9.0	GRAVEL	brn	MOIST	A-2-4 SiSaGr
		9.0-59.0	SILT	brn	MOIST	A-4 SaSi
		LEDGE OR BOULDER @ 59.0'				
		NO WATER TO DEPTH				

APPENDIX C

- Field and Laboratory Results
  - Report on Test Excavations
    - Consultant Report
    - VAOT Report
  - Electrochemical Test Results
  - Triaxial Test Results
  - Monitoring Well Results

Golder Associates Inc.

4104 -148th Avenue, N.E.
Redmond, WA 98052
Telephone (425) 883-0777
Fax (425) 882-5498

Golder Associates

June 25, 1998

Our ref.: 943-1524.J.027

Federal Highway Administration
Office of Engineering
Bridge Division HNG-31
400 - 7th Street S. W., Room 3113
Washington, DC 20590

ATTENTION: Mr. Richard S. Cheney, P.E.

RE: TECHNICAL SITE ASSISTANCE AND STAFF TRAINING
VERMONT AGENCY OF TRANSPORTATION
HIGHWAY 100B SOIL NAIL PROJECT
MORETOWN-MIDDLESEX RSEGC RS 0167(9)
FHWA DP 103

Dear Richard:

In accordance with Work Task J, FHWA DP 103 contract, we are pleased to submit the following report detailing the results of our technical site assistance completed for the Vermont Agency of Transportation (VAOT) on the subject project.

The technical assistance was conducted at the VAOT Materials and Research office located in Montpelier, Vermont, at the proposed construction site located along Highway 100B near Middlesex, Vermont and at several soil nail walls constructed by the New Hampshire Department of Transportation. In general, the purpose of our work was to assist VAOT in their evaluation of the site conditions as they relate to the planned soil nail wall design and construction. The assistance and site work was conducted from June 10 through 11, 1998, by Richard Cheney, FHWA Geotechnical Engineer, and James Porterfield, subconsultant to Golder Associates Inc. (GAI), Redmond, Washington.

The project involves removal of the toe of an existing slope to allow re-alignment of the highway. The slope excavation will be retained by a battered (1H:6V) soil nail shoring system, either a stepped series of two walls or by a single wall. In general, the existing slope appears to be stable with no indications of obvious slope instability nor adverse surface water runoff conditions being observed during our field work.

The following provides a general summary of the technical assistance and topics covered during each day of our visit.

WEDNESDAY, JUNE 10

The morning of the first day of the site visit was spent at the Highway 100B construction site observing the existing geotechnical conditions as they relate to soil nail retaining wall design and construction. In addition, we discussed the proposed construction with the VAOT design team and various other FHWA personnel and specialty shoring wall contractors and designers. A list of the site attendees has been prepared by VAOT and is included in Appendix A.

As part of our site evaluation, two test cut face excavations were completed using a rubber-tired, John Deere 310C backhoe. Each of these are described as follows:

- TEST CUT FACE 1

The first test cut face was excavated from approximately 10:30 AM to 11:07 AM along the edge of an existing driveway located at approximate Station 198+50. The cut face was excavated at an approximately vertical inclination and was approximately 5 to 6 feet high by 15 feet in length. Difficulties were not experienced during excavation of the cut face and groundwater was not encountered. Significant overbreaks or raveling of the cut face did not occur during excavation. The following soil conditions were exposed in the cut face.

0′ to 0.5′	Very loose, dark brown to black, fine sandy silt, highly organic (Topsoil)
0.5′ to 4′	Loose to compact, light orangish-brown, fine sandy silt to silty fine sand, slightly micaceous (Weathered Alluvium)
4′ to 5′	Compact, light gray, silty fine sand, slightly micaceous, including a little fine to coarse, subrounded to rounded gravel with depth (Alluvium)

The cut face exposure was left open for three days and remained globally stable with no significant overbreaks or face failure occurring. Some minor raveling occurred during the exposure period, mainly after the first 48 hours of exposure and most likely due to loss of apparent cohesion due to drying back of the exposed soils. Detailed observations of the cut face were completed by VAOT and their observations are included in Appendix A.

- TEST CUT FACE 2

The second test cut face was excavated from approximately 11:42 AM to 12:07 PM along the shoulder of the existing highway located at approximate Station 196+25. The cut face was excavated at an approximately vertical inclination and was approximately 6 feet high by 18 feet in length. Difficulties were not experienced during excavation of the cut face and groundwater was not encountered. Significant overbreaks or raveling of the cut face did not occur during excavation. The following soil conditions were exposed in the cut face.

0′ to 0.75′	Very loose, dark brown to black, fine sandy silt, highly organic (Topsoil)
0.75′ to 4.5′	Loose to compact, light orangish-brown, fine sandy silt to silty fine sand, little fine to coarse rounded to subrounded gravel and cobbles, slightly micaceous (Weathered Alluvium)
4.5′ to 6	Compact, light gray, fine sandy silt to silty fine sand, trace fine to coarse rounded to subrounded gravel and cobbles, slightly micaceous (Alluvium)

The cut face exposure was left open for three days and remained globally stable with no significant overbreaks or face failure occurring. Some minor raveling of exposed gravel/cobble clasts occurred during the exposure period. Loss of apparent cohesion due to drying back of the exposed soils was not a significant concern at this location. Detailed observations of the cut face were completed by VAOT and their observations are included in Appendix A.

We understand each of the cut face excavations were to be bermed back with the excavation spoils by VAOT following the period of observation.

The afternoon of the first day was spent at the VAOT Materials and Research office located in Montpelier, Vermont. An informational meeting was held by VAOT at which time various design and construction considerations were discussed amongst the parties present at the mornings cut face excavations. Detailed minutes of the meeting were compiled by VAOT and are included in Appendix A. Following the meeting, several runs of Goldnail were completed by VAOT at one critical wall section to allow Richard Cheney the opportunity to assist VAOT in the use and application of the computer program.

THURSDAY, JUNE 11

The second day of our site work involved traveling to New Hampshire and visiting two existing soil nail walls and one soil nail wall under construction along the Kancamagus Highway (NH 112). All three of the walls involved similar designs and rather similar ground conditions. The finish facings for each of the walls consisted of a natural board finish. This is the same type of finish face being considered by VAOT and we were able to visually assess this type of finish face. Observations of the on-going construction for the wall currently being built afforded the opportunity to discuss and observe actual field construction conditions at the time of our site visit. Detailed notes regarding our observations and findings at each of the soil nail walls were compiled by VAOT and are included in Appendix A.

AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Christopher C. Benda, Soils and Foundations Engineer

From: Chad A. Allen, Geotechnical Engineer

Date: Original: June 15, 1998 Revised: October 21, 1998

Subject: Moretown-Middlesex RSEGC RS 0167(9)

SOIL NAIL WALL TEST CUTS

TP #1 - Station 198+50 6/10/98 - 10:30 am
TP #2 - Station 196+25 6/10/98 - 12:00 pm

Attendees:
Dave Hall, FHWA
Jim Bush, FHWA
Dick Cheney, FHWA
Peter Osborn, FHWA
Chris Benda, VAOT
Jim Porterfield, Golder Assoc. Inc.
Robert Houghton, Spencer, White, & Prentice
Harry Schnabel, Schnabel Foundation Co.
Rich Telgener, Haley & Aldrich, Inc.
Reggie Holt, VAOT
Roger Whitcomb, VAOT
Chad Allen, VAOT
Bob Della Santa, VAOT

SOIL NAIL WALL TEST CUT INSPECTIONS 6/11/98 - 6:45 am

TP #1: STATION 198+50

The face has dried out some resulting in a small quantity of fine sand and silty material falling to the base of the wall. No over breaks or sloughing of the face was witnessed. Stable to date.

TP #2: STATION 196+25

The face has dried out relatively little, which may be in part to limited exposure to the sun. A few small cobbles approximately 4 inches in diameter fell from the excavated face to the base of the wall. No sloughing or over breaks resulted. Stable to date.

MORETOWN-MIDDLESEX RSEGC RS 0167(9)

SOIL NAIL WALL TEST CUT INSPECTIONS 6/11/98 - 3:30 pm

TP #1: STATION 198+50

The face has dried out further resulting in a small quantity (approx. 4-5 shovels) of fine sand and silty material falling to base of wall. No over breaks, however sloughing of the face may become an issue. Stable to date.

TP #2: STATION 196+25

The face has dried out little in comparison with this morning's inspection. It looks like sections of the face are getting ready to separate themselves from the wall. Cracks can be observed and over breaks may occur. A few more small cobbles approximately 4 inches in diameter fell from the excavated face to the base of the wall. Stable to date.

SOIL NAIL WALL TEST CUT INSPECTIONS 6/12/98 - 11:00 am

TP #1: STATION 198+50

The face has dried out some resulting in a small quantity of fine sand and silty material falling to the base of the wall. No over breaks or sloughing of the face was witnessed. Stable to date.

TP #2: STATION 196+25

The face has dried out relatively little, which may be in part to limited exposure to the sun. A few small cobbles approximately 4 inches in diameter fell from the excavated face to the base of the wall. No sloughing or over breaks resulted. Stable to date.

SOIL NAIL WALL TEST CUT INSPECTIONS 6/13/98 - 10:30 am

TP #1: STATION 198+50

The face has experienced two overbreaks. One overbreak is approx. 8 in. deep by 2 ft square. This overbreak looks like it was due to the fact that the overlying are of cantilevered topsoil dried out and fell down. You could tell this by the color and volume of dirt that it had just recently happened.

Another overbreak measured 6 inches deep by one foot square.

Temperatures for the two day period ranged from lows down to 50 °F to highs up to 76 °F.

MORETOWN-MIDDLESEX RSEGC RS 0167(9)

FINAL ANALYSIS OF TEST PIT No. 1:

Stable face, no major overbreaks, sloughing, raveling, or other failures.

TP #2: STATION 196+25

Three slight overbreaks occurred at this location. The first one was approximately 10 inches in depth, 1' wide and 2' long, while the second was approximately 4-6 inches deep and 1' wide and 1.5' long. The third major loss of soil was due to a 4 to 6 inch cobble that fell as I stood at the base of the wall making observations. The loss of material left a 4 to 6 inch deep indentation in the cut face approximately 10 inches in diameter.

The face appears to be holding stability very well. This face did not dry out as fast as the first cut face did, however, exposure to sunlight was minimal.

FINAL ANALYSIS OF TEST PIT No. 2:

Stable face, no major overbreaks, sloughing, raveling, or other failures.

To: Chad Allen, Geotechnical Engineer
From: Tracy Phillips, Chemist
Date: 05/25/98
Subject: Electrochemical results for soil samples collected from Moretown-Middlesex RSEGC RS0167(9) between Febrary 5, 1998 and March 20, 1998. Testing performed on May 15, 1998, May 21, 1998 and May 22,1998.

Sample ID	pH Value	Chloride Value
R12	6.65	27 / 25*
R12A	6.25	268 / 295*/ 308**
R12B	6.82	33
R12C	6.97	13
R15A	6.66	20
R15B	5.55	279 / 237* / 341**
R16	6.32	30
R17 / R18B	6.14	21
R18A / R19A	6.22	8
R19B	6.03	12
R19C	6.24	13
R21A	5.85	25
R21B	6.33	18
R24A	6.52	19
R24B	6.87	0 / 4*

Initial test results identified two samples, (R12A and R15B) with an increased amount of chlorides in comparison to the rest of the samples. We were not able to find a trend or pattern in the results, so repeat testing of the initial samples was performed. These are noted with the * symbol. To further verify these two test results, new samples were tested. These results are noted with **symbol.

cc: C.Benda
A.Schneck

Sample I.D.	Sample Location (ft)	Offset (ft)	Date Sampled	Depth Represented (ft)	Depth to Mid-Layer (ft)	avg. N	Estimated Unit Weight (pcf)	Overburden Pressure (psf) (@ mid-layer)	Trial No.	Cell Pressure (psi)	Cell Pressure (psf)	Average Moisture Content (%)	Weight of Sample (grams)	Weight of Sample (lbs)	Height of Sample (in.)	Diameter of Sample (in.)	Volume of Sample (cu. inches)	Unit Weight of Sample (pcf)	Laboratory Classification	Cohesion (psf)	Friction Angle (degrees)
R-12A	197+50	+37	02/05/98	15 - 27	21	12.3	115	2340	1	10	1440	18	1073.5	2.36	5.69	2.8	35.04	116.48	GrSaSi	225	29
									2	15	2160		1080	2.38	5.69	2.8	35.04	117.19			
									3	20	2880		1049.3	2.31	5.69	2.8	35.04	113.85			
R12-B	197+50	+37	02/05/98	30 - 47	38.5	16	115	4565	1	25	3600	24.4	1052.3	2.32	5.69	2.8	35.04	114.18	SaSi	0	33
									2	30	4320		1061.6	2.34	5.69	2.8	35.04	115.19			
									3	35	5040		1064.3	2.34	5.69	2.8	35.04	115.48			
R12-C	197+50	+37	02/05/98	50 - 62	56	19	120	6595	1	25	3600	20.6	1104.4	2.43	5.69	2.8	35.04	119.83	SiSa	360	31
									2	35	5040		1094.7	2.41	5.69	2.8	35.04	118.78			
									3	45	6480		1122	2.47	5.69	2.8	35.04	121.74			
R15-A	201+00	+12	02/18/98	5 - 12	8.5	6.5	105	893	1	5	720	17.3	942.4	2.07	5.69	2.8	35.04	102.25	SaSi	300	31
									2	10	1440		972.5	2.14	5.69	2.8	35.04	105.52			
									3	15	2160		984.7	2.17	5.69	2.8	35.04	106.84			
R15-B	201+00	+12	02/18/98	15 - 22	18.5	12	110	1960	1	5	720	20.9	1011.4	2.23	5.69	2.8	35.04	109.74	SiSa	540	30
									2	10	1440		1042.8	2.29	5.69	2.8	35.04	113.15			
									3	15	2160		1009.5	2.22	5.69	2.8	35.04	109.54			
R16	201+25	+7	02/19/98	10 - 17	13.5	20.5	120	1520	1	5	720	14.1	1009.4	2.22	5.69	2.8	35.04	109.52	SaSi	0	34
									2	10	1440		1008.6	2.22	5.69	2.8	35.04	109.44			
									3	15	2160		1004.6	2.21	5.69	2.8	35.04	109.00			
R17 & R18B	201+50 & 202+00	+10 & -3	2/23/98 & 3/11/98	10 - 12	11	10	105	1155	1	5	720	18	972.1	2.14	5.69	2.8	35.04	105.48	SiSa	157	30
									2	10	1440		975.4	2.15	5.69	2.8	35.04	105.84			
									3	15	2160		989.2	2.18	5.69	2.8	35.04	107.33			
R18A & R19A	202+00	-3 &+23	03/11/98 & 03/05/98	5 - 7	6	8.5	105	630	1	4	576	8.8	952.7	2.10	5.69	2.8	35.04	103.37	GrSa	96	32.5
									2	8	1152		953.1	2.10	5.69	2.8	35.04	103.42			
									3	12	1728		978.4	2.15	5.69	2.8	35.04	106.16			
R19B	202+00	+23	03/05/98	10 - 17	13.5	16.5	115	1553	1	5	720	25.6	1020.1	2.24	5.69	2.8	35.04	110.69	SaSi	270	28
									2	10	1440		1020.6	2.25	5.69	2.8	35.04	110.74			
									3	15	2160		1043.2	2.30	5.69	2.8	35.04	113.19			
R19C	202+00	+23	03/05/98	20 - 27	23.5	39	130	2755	1	15	2160	15.7	1189.5	2.62	5.69	2.8	35.04	129.07	GrSaSi	270	33
									2	20	2880		1200.7	2.64	5.69	2.8	35.04	130.28			
									3	25	3600		1129.5	2.48	5.69	2.8	35.04	122.56			
R21A	202+50	+20	03/16/98	5 - 12	8.5	8.5	105	892.5	1	5	720	15	929.7	2.05	5.69	2.8	35.04	100.88	SiSa	203	31
									2	10	1440		997.2	2.19	5.69	2.8	35.04	108.20			
									3	15	2160		964.2	2.12	5.69	2.8	35.04	104.62			
R21B	202+50	+20	03/16/98	15 - 27	21	20.3	120	2295	1	10	1440	19.1	1064.2	2.34	5.69	2.8	35.04	115.47	SiSa	"Unreliable data	"Unreliable data
									2	15	2160		1087.6	2.39	5.69	2.8	35.04	118.01			
									3	20	2880		1082.2	2.38	5.69	2.8	35.04	117.42			
R24A	203+50	+30	03/19/98	5 - 12	8.5	4	100	850	1	5	720	13.1	1054.2	2.32	5.69	2.8	35.04	114.39	GrSa	0	35
									2	10	1440		1045.6	2.30	5.69	2.8	35.04	113.45			
									3	15	2160		1036.5	2.28	5.69	2.8	35.04	112.47			
R24B	203+50	+15	03/19/98	15 - 22	18.5	12	110	1885	1	10	1440	11.6	1062.4	2.34	5.69	2.8	35.04	115.28	GrSa	0	34
									2	15	2160		1047.5	2.30	5.69	2.8	35.04	113.66			
									3	20	2880		1047.4	2.30	5.69	2.8	35.04	113.65			
																			Average Values:	***186.23***	***31.65***

AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Chad Allen, Geotechnical Engineer,
From: Christopher Rea, Geologic Technician C. Rea
Subject: Moretown Monitoring Wells
Date: 10/20/98

Three ground water monitoring wells were installed for the Moretown RS 0167(9) project in April 1998, the results of the monitoring are listed below.

ID	STA.	Offset	Depth
R4	194+50	14' Rt.	25'
R8	196+50	5' Rt.	14'
R12	197+50	37' Rt.	47.5'

4/30/98:
Took readings on monitoring wells, no water detected in any well. Weather conditions were sunny and 60 degrees F.

5/4/98:
Took readings on monitoring wells, no water detected in any well. Weather conditions were rain and 60 degrees F.

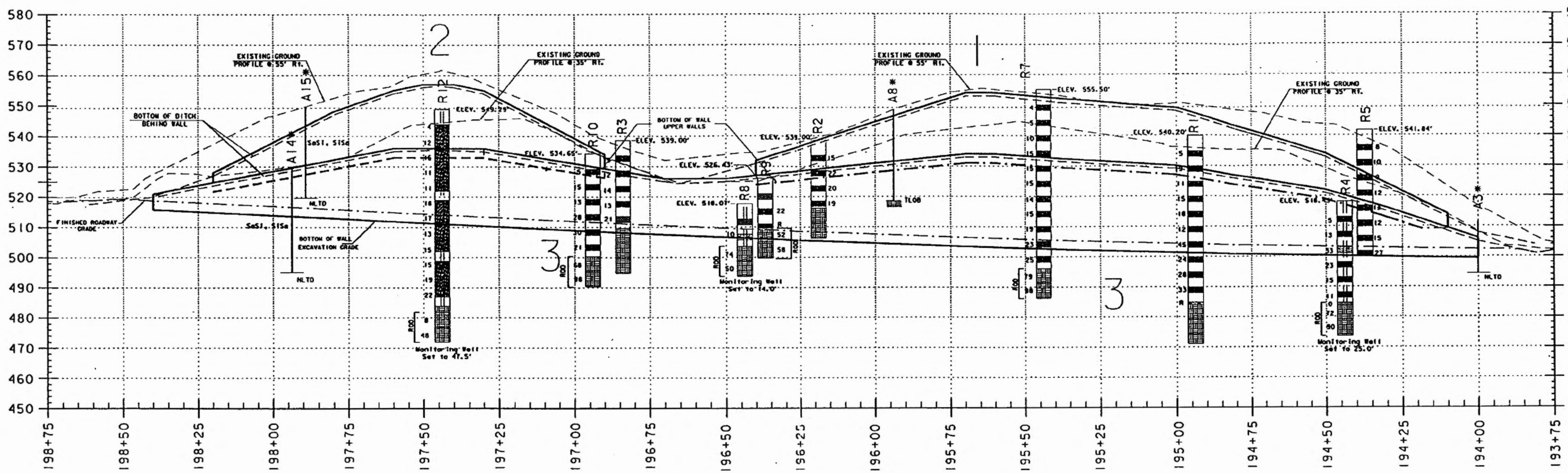
6/9/98:
Took readings on monitoring wells, no water detected in any well. Readings were taken after 8 days of heavy rains that caused damage throughout the state. Weather conditions on the day of the readings were sunny and 78 degrees F.

9/9/98:
Took readings on monitoring wells, no water detected in any well. Readings were taken in a heavy down pour. Weather conditions were rain and 50 degrees F.

10/20/98:
Took readings on monitoring wells, no water in any well. Weather conditions were cloudy and 50 degrees F.

APPENDIX D

- ♦ Elevation of the Soil Profile
- ♦ Site Plan

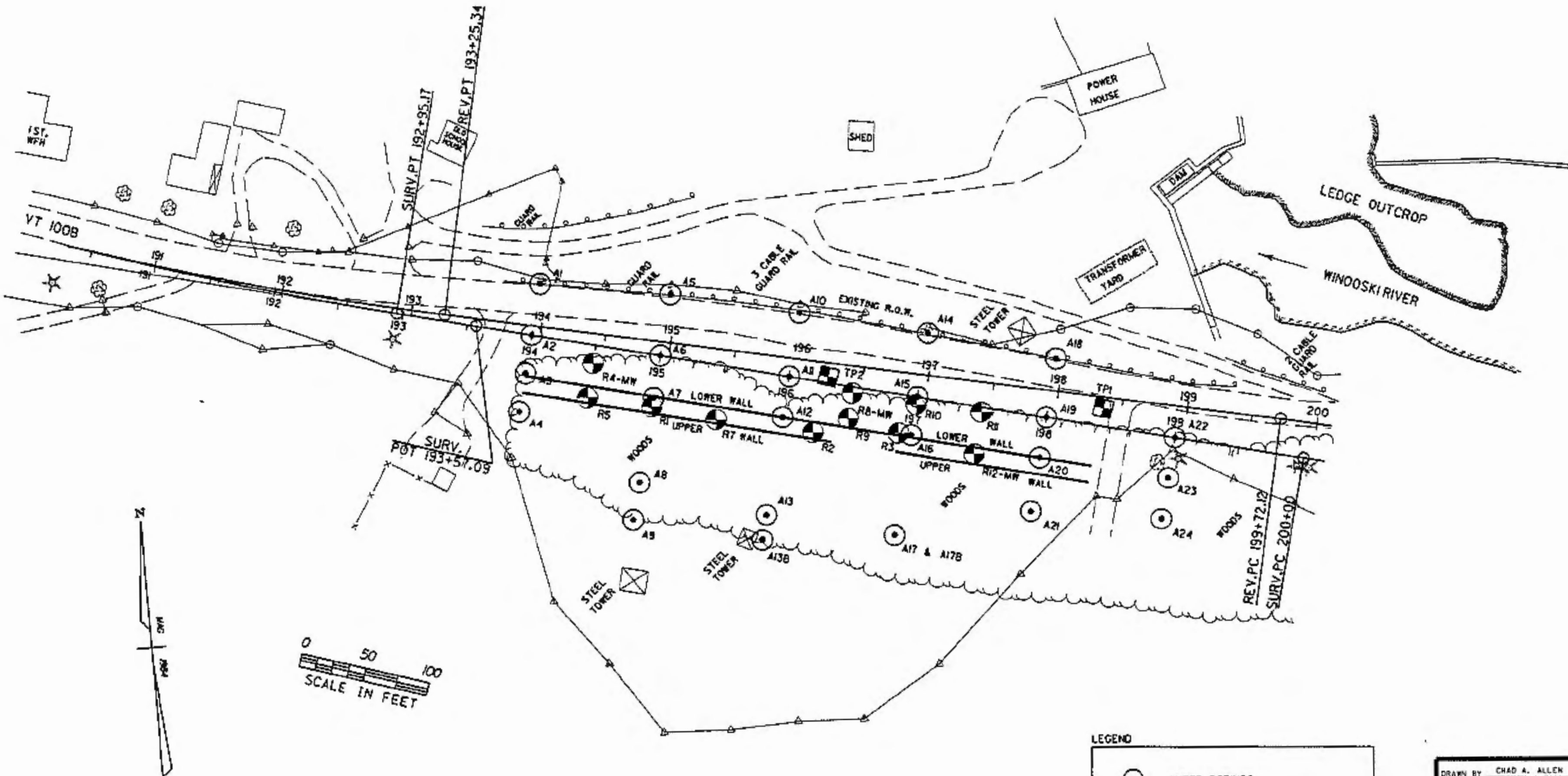


***NOTE:** Auger borings are shown at approximate locations only. They have been inserted so that the estimated bedrock profile may be further defined. The contractor is directed to the Agency's Geotechnical Report for further details.

LEGEND	
SPT BLOW COUNTS	
5–10 loose to medium SaSI, SISa	No Recovery
10–30 medium to dense SISa	Bedrock
30–50 dense to very dense GrSa	

WALL ELEVATION

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0167 (9)
DESIGN FILE NAME: MORETWN3.DGN	
IPARM FILE NAME:	PLOT DATE: 09/08/98
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
TERRACED WALL WITH SLOPED TOP	SHEET: 1 OF 1



LEGEND

AUGER BORINGS

STANDARD PENETRATION BORINGS

DRAWN BY CHAD A. ALLEN DATE 10/05/98

SQUAD LEADER CHRISTOPHER C. BENDA

DESIGN FILE NO. /MATRES/T8E132/BOREPLAN.DGN

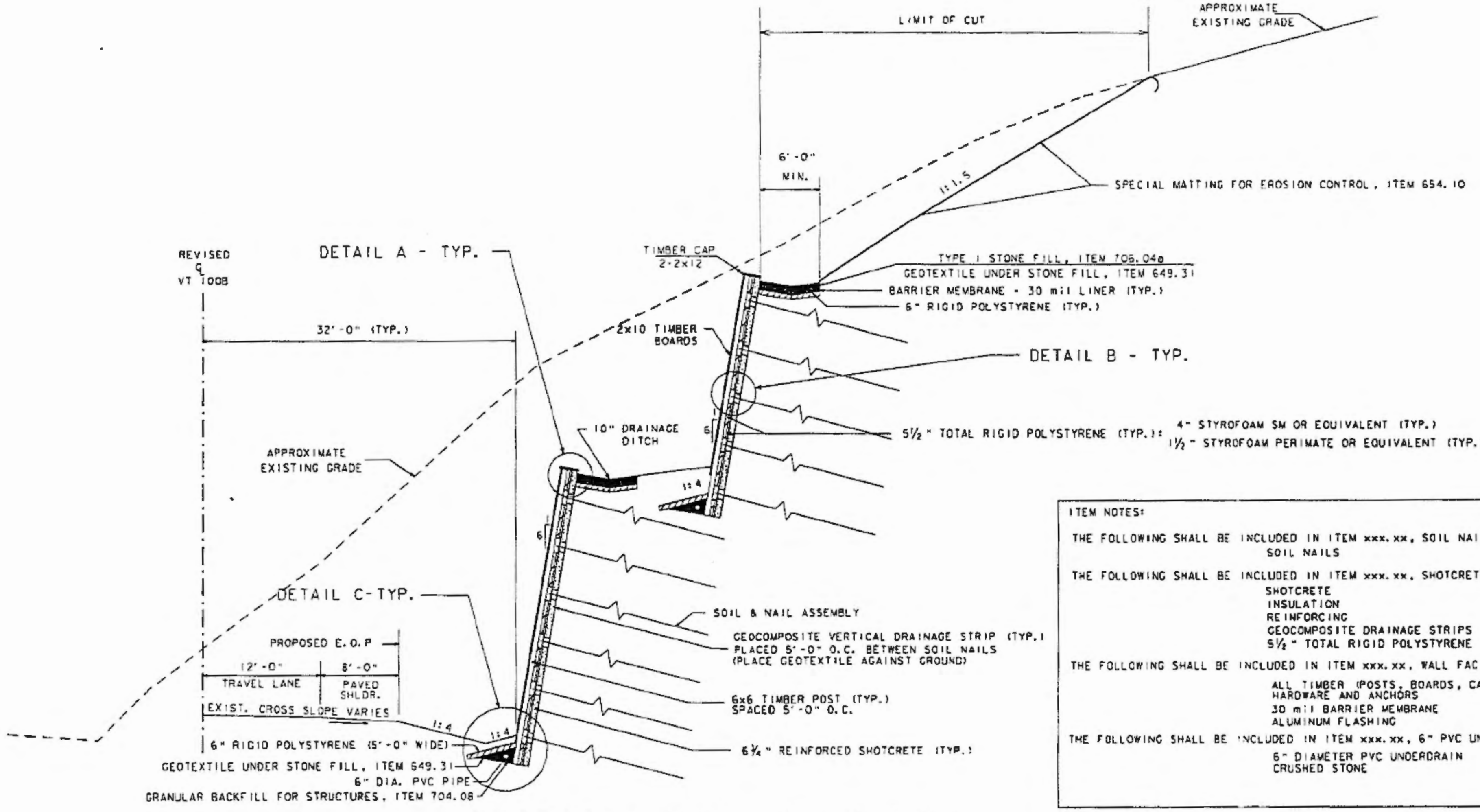
PROJ. NAME MORETOWN-MIDDLESEX

PROJ NO. RS 0167 (9) S

SHEET 1 OF 1 SHEETS

APPENDIX E

- Soil Nail Wall Design Details
    - Typical Cross Section
    - Cap Detail
    - Drainage & Shotcrete Facing Detail



ITEM NOTES:

THE FOLLOWING SHALL BE INCLUDED IN ITEM xxx.xx, SOIL NAILS:
- SOIL NAILS

THE FOLLOWING SHALL BE INCLUDED IN ITEM xxx.xx, SHOTCRETE:
- SHOTCRETE
- INSULATION
- REINFORCING
- GEOCOMPOSITE DRAINAGE STRIPS
- 5½" TOTAL RIGID POLYSTYRENE (TYP.):

THE FOLLOWING SHALL BE INCLUDED IN ITEM xxx.xx, WALL FACING:
- ALL TIMBER (POSTS, BOARDS, CAP, ETC.) HARDWARE AND ANCHORS
- 30 mil BARRIER MEMBRANE
- ALUMINUM FLASHING

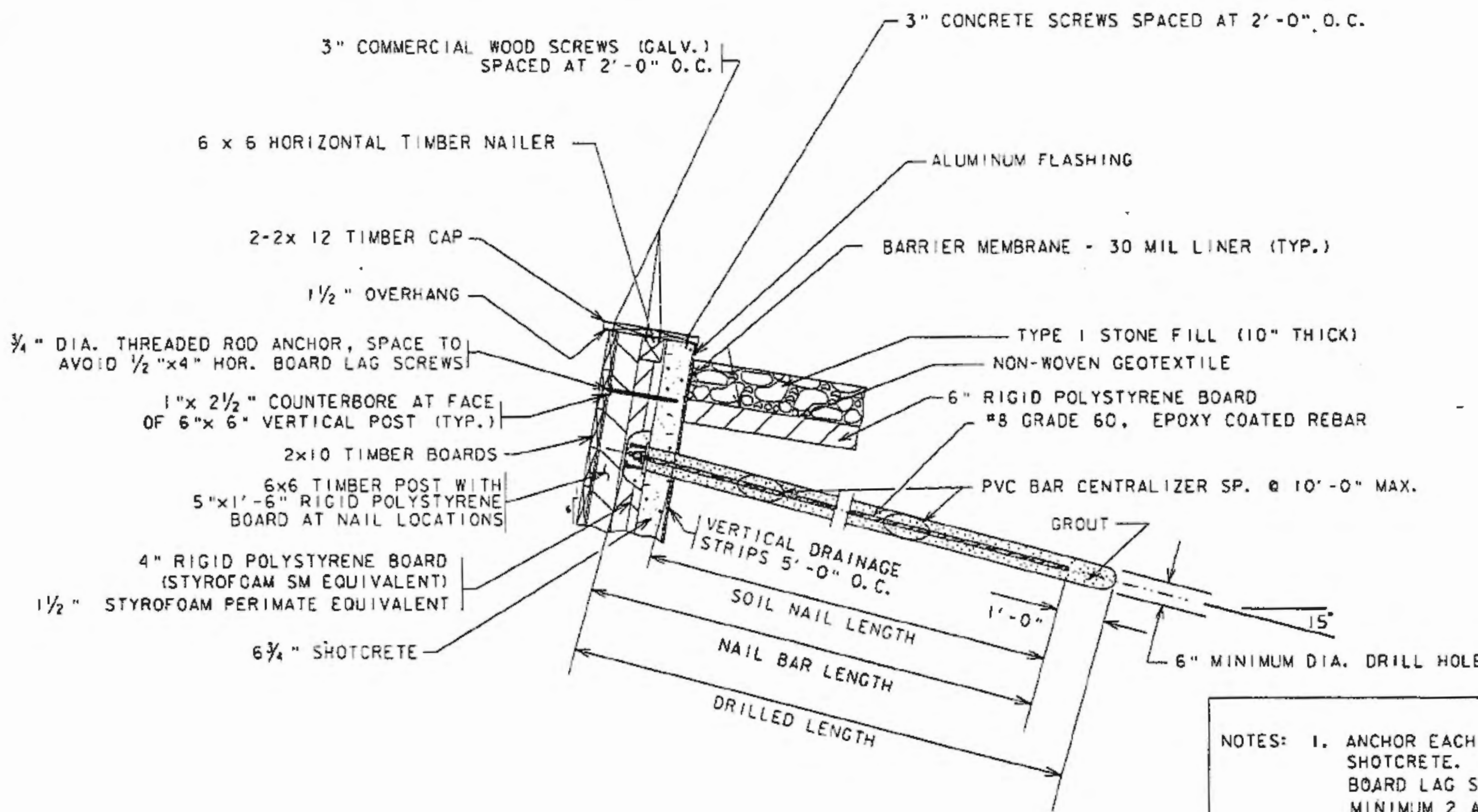
THE FOLLOWING SHALL BE INCLUDED IN ITEM xxx.xx, 6" PVC UNDERDRAIN:
- 6" DIAMETER PVC UNDERDRAIN
- CRUSHED STONE

PROPOSED RETAINING WALL TYPICAL CROSS SECTION

SCALE: 1/16" = 1'-0"

DATUM
VERTICAL ________
HORIZONTAL ________

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0167(9)
DESIGN FILE NAME: /MATRES/78C132/SNWDETAL.DGN	
IPARW FILE NAME:	PLOT DATE: 10/22/99
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
	SHEET: 1 OF 3



DETAIL A

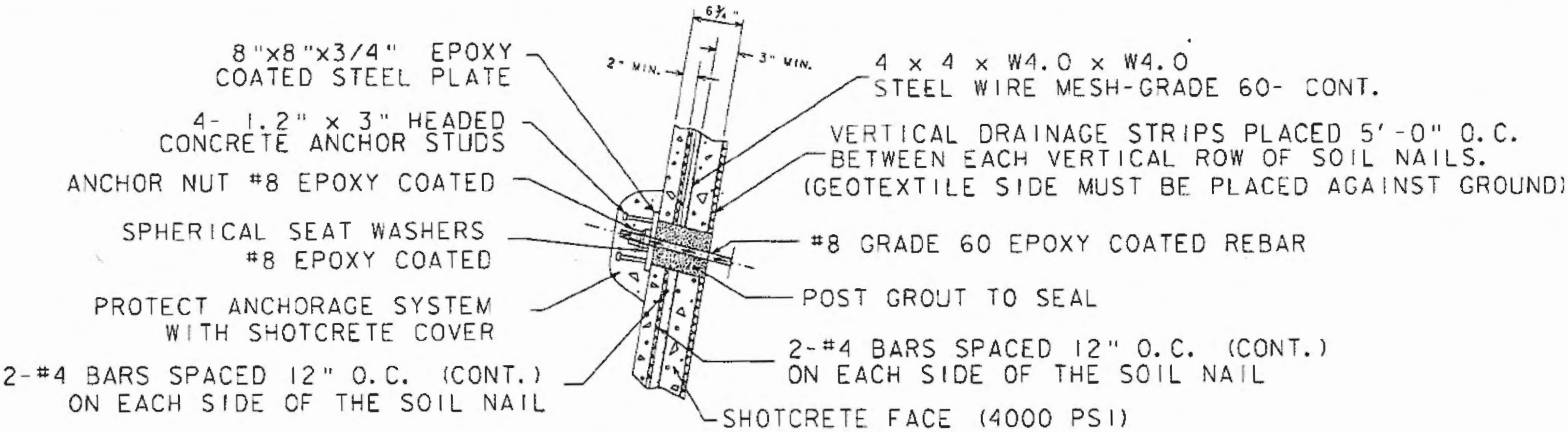
SCALE: ¼" = 1'-0"

NOTES:

1. ANCHOR EACH VERTICAL 6x6 TIMBER POST TO SHOTCRETE. SPACE TO AVOID ½" x 4" HORIZONTAL BOARD LAG SCREWS. (MAXIMUM 5'-0" O.C. SPACING MINIMUM 2 ANCHORS PER POST).
2. PLACE ALUMINUM FLASHING TOP & DOWN 4" IN BACK OF HORIZONTAL TIMBER BOARDS AND 3" ON BACK OF SHOTCRETE.
3. PLACE BARRIER MEMBRANE ACROSS TOP OF THE WALL DOWN ALONG THE SHOTCRETE AND ON TOP OF THE INSULATION.
4. SPACE VERTICAL DRAINAGE STRIPS 5'-0" O.C. - CENTERED VERTICALLY BETWEEN EACH VERITCAL ROW OF SOIL NAILS.
5. PLACE VERTICAL DRAINAGE STRIPS WITH THE GEOTEXTILE AGAINST THE GROUND.

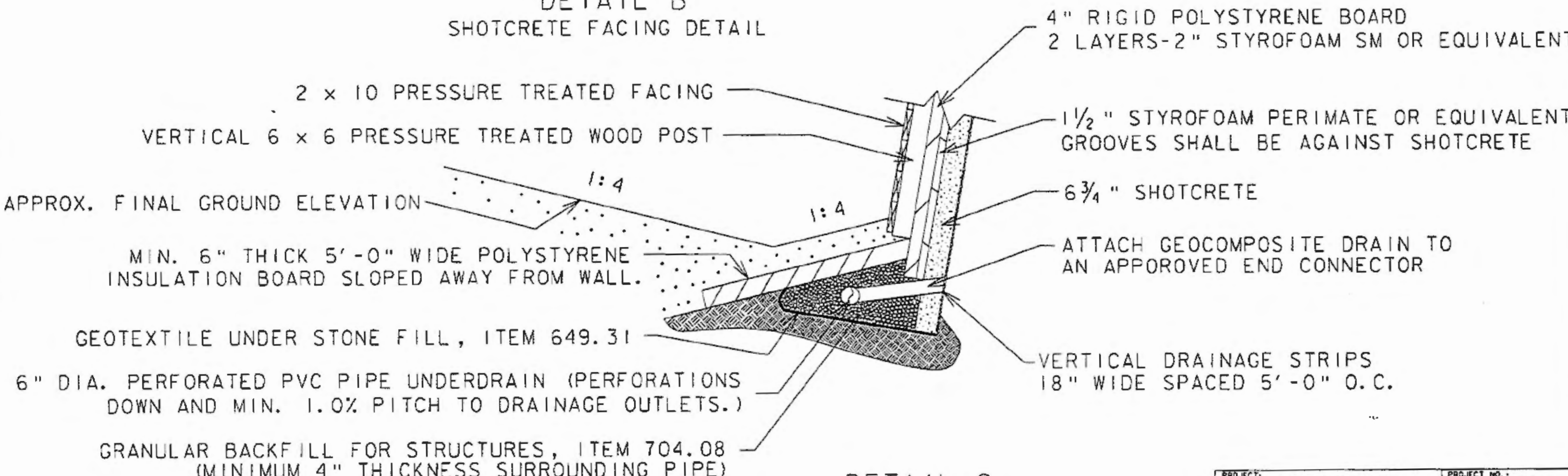
DATUM	
VERTICAL	
HORIZONTAL	

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0167(9)
DESIGN FILE NAME: /MATRES/78E132/SNWDETAL.DGN	
PARM FILE NAME:	PLOT DATE: 10/22/98
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
TERRACED WALL X-SECTION	SHEET: 2 OF 3



DETAIL B

SHOTCRETE FACING DETAIL



DATUM
VERTICAL ______
HORIZONTAL ______

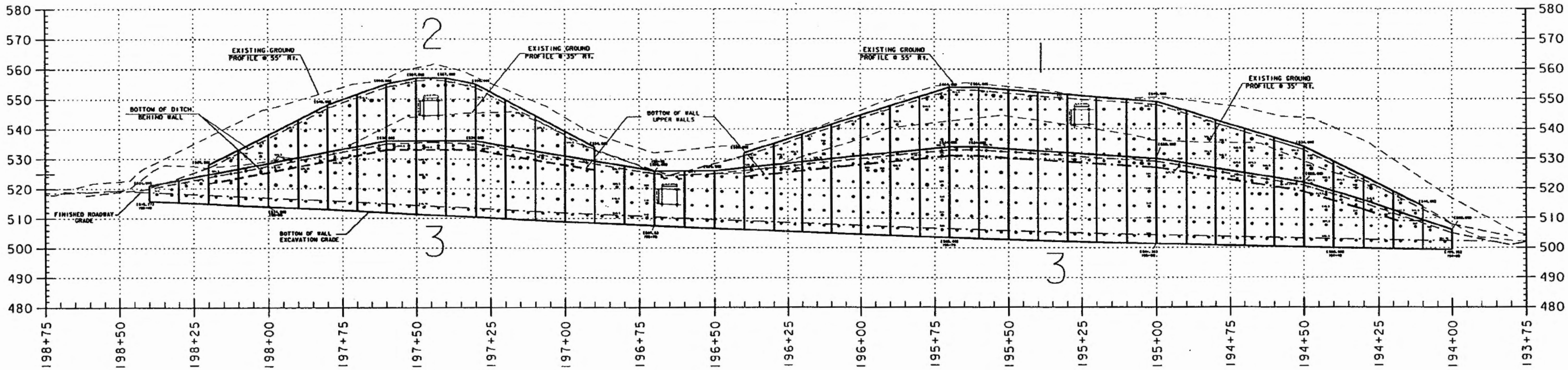
DETAIL C

TYPICAL DRAINAGE DETAIL. .

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0157 (9)
DESIGN FILE NAME: /MATRES/78E132/SNWDETAL.DGN	
IPARM FILE NAME:	PLOT DATE: 10/22/98
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
	SHEET: 3 OF 3

APPENDIX F

- Location and Elevation of Soil Nails
- Wall Elevations



512.75 NAIL ELEVATION

(500.00) GRADE ELEVATION

- INDICATES SOIL NAIL
- INDICATES SOIL NAIL TO BE PROOF TESTED
- INDICATES LOCATION OF VERIFICATION TEST OF SACRIFICIAL SOIL NAIL

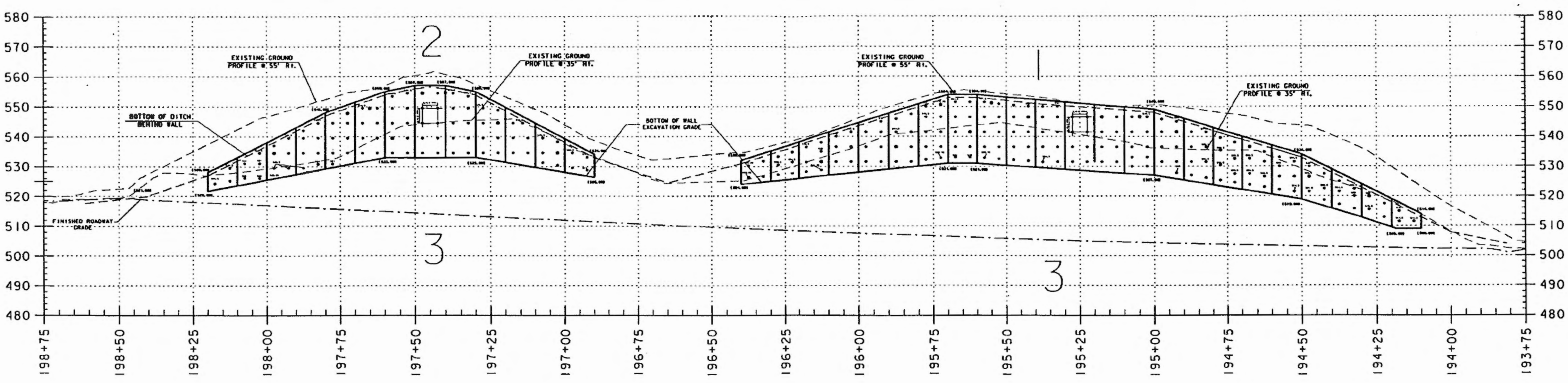
NOTES:

1. NAIL ELEVATIONS NOT SHOWN SHALL BE LINEARLY INTERPOLATED BETWEEN THOSE SHOWN.
2. THE EXPANSION JOINT LOCATIONS SHALL BE LOCATED PRIOR TO THE CONSTRUCTION OF SOIL NAILS AND AT LEAST 12 IN. CLEAR DISTANCE SHALL BE PROVIDED BETWEEN THE JOINT AND THE NAILS.
3. IF REINFORCING BARS WITH CUT THREADS ARE USED FOR NAILS , THE NEXT LARGER SIZE ABOVE THAT SHOWN SHALL BE PROVIDED AT NO ADDITIONAL COST.
4. ALL DIMENSIONS AND ELEVATIONS SHOWN ARE IN ENGLISH UNITS.

STATION	STATION	NAIL SIZE	NAIL LENGTH	WALL
194+00	196+40	#8	60 ft	2
194+00	196+40	#8	55 ft	3
196+40	196+90	#8	45 ft	3
196+90	198+40	#8	50 ft	1
196+90	198+40	#8	45 ft	3

WALL ELEVATION

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0167 (9)
DESIGN FILE NAME: /MATRES/78E132/MORETWN3.DGN	
IPARM FILE NAME:	PLOT DATE: 10/22/98
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
TERRACED WALL WITH SLOPED TOP	SHEET: 1 OF 2



512.75 NAIL ELEVATION
(500.00) GRADE ELEVATION

• INDICATES SOIL NAIL

● INDICATES SOIL NAIL TO BE PROOF TESTED

● INDICATES LOCATION OF VERIFICATION TEST OF SACRIFICIAL SOIL NAIL

NOTES:

1. NAIL ELEVATIONS NOT SHOWN SHALL BE LINEARLY INTERPOLATED BETWEEN THOSE SHOWN.
2. THE EXPANSION JOINT LOCATIONS SHALL BE LOCATED PRIOR TO THE CONSTRUCTION OF SOIL NAILS AND AT LEAST 12 IN. CLEAR DISTANCE SHALL BE PROVIDED BETWEEN THE JOINT AND THE NAILS.
3. IF REINFORCING BARS WITH CUT THREADS ARE USED FOR NAILS , THE NEXT LARGER SIZE ABOVE THAT SHOWN SHALL BE PROVIDED AT NO ADDITIONAL COST.
4. ALL DIMENSIONS AND ELEVATIONS SHOWN ARE IN ENGLISH UNITS.

S ATION	STATION	NAIL SIZE	NAIL LENGTH	WALL
194+00	196+40	#8	60 ft	2
194+00	196+40	#8	55 ft	3
196+40	196+90	#8	45 ft	3
196+90	198+40	#8	50 ft	1
196+90	198+40	#8	45 ft	3

WALL ELEVATION

PROJECT: MORETOWN-MIDDLESEX	PROJECT NO.: RS 0167 (9)
DESIGN FILE NAME: /MATRES/78C132/MORETWN3.DGN	
IPARM FILE NAME:	PLOT DATE: 10/22/98
SURVEYED BY:	SURVEY DATE:
SQUAD LEADER: CHRISTOPHER C. BENDA	DRAWN BY: CHAD A. ALLEN
TERRACED WALL WITH SLOPED TOP	SHEET: 2 OF 2

APPENDIX G

- Soil Nail Wall Hand and Computer Calculations
    - Nail Size
    - Nail Lengths
    - Nail Head Strengths and Loads

BY CAA DATE 7/24/98 SUBJECT MORETOWN - MIDDLESEX SHEET NO. 1 OF 6
CHKD. BY CAB DATE 10-5-98 RS 0167(9) JOB NO.
SOIL NAIL WALL CALCS.

Assume : 1. γ = 115 pcf (18.1 kN/m³).

2. ϕ = 32°; c_u = 185 psf (8.9 kPa).

3. No groundwater

eference
: ' JA SA 96-069
SNW MANUAL pg. 60 ∴

4. Ultimate Bond Stress - Open Hole Method - TABLE 3.2 WHAT IF CASED?

material: Medium dense Sa or SaSi / SiSa

range: 7 - 11 psi choose 9 psi (62.5 kN/m²).

5. NAIL HOLE DRILL DIAMETER OF 6" (150 mm) (D)

6. FACTOR OF SAFETY - SLOPES

FOR CRITICAL STRUCTURES - 1.5 = F_s = F_c.

7. NAILS TREMIE OR LOW PRESSURE GROUTED.

8. S_V = 5' (1.5 m) S_H = 5' (1.5 m)

9. BATTERED FACE $\frac{4}{1}$ 6.

pg 61

ULTIMATE PULLOUT RESISTANCE, Q_u

$$Q_u = \text{Unit Ultimate Bond Stress} * D * \pi * 1\text{ FT}.$$
$$= (9\text{ psi})(0.5')(3.14159)(1')\ \frac{144\text{ IN}^2}{1\text{ FT}^2}$$
$$= 2036\text{ lb/ft}\quad (29.71\text{ kN/m}).$$

SIMPLIFIED DESIGN CHARTS where ϕ_u = ultimate friction ∠

pg 287

$$\tan \phi_D = \frac{\tan \phi_u}{F}$$

$$\phi_D = \tan^{-1}\left(\frac{\tan 32°}{1.5}\right) = 22.6°$$

$\tan \phi_D = 0.42$

$$C_D = \frac{C_u}{F_c \, \gamma \, H} = \frac{185\,psf}{(1.5)(115\,pcf)(49')} = 0.0219$$

ssume critical section
@ 195+50, H = 49' with Backslope = 20° and a batter = ~~10°~~ 24.7° STEPPED WALL.

pg 279, Fig. 5.33a

$\tan\phi_D = 0.42$, $C_D = 0.022$

$C_D = 0.01$, $\tan\phi_D = 0.42$; $T_D = 0.34$.
$C_D = 0.03$, $\tan\phi_D = 0.42$, $T_D = 0.268$.

$T_D = \cancel{0.31}$ 0.297 ✓

$$T_D = T_{NN}\,\alpha_N / \gamma H S_V S_H \therefore T_{NN} = T_D * \gamma * H * S_V * S_H / \alpha_N \text{ , where } \alpha_N = 0.$$

Required Nominal Strength ∴

$$T_{NN} = (115\,pcf)(\cancel{0.31}\ 0.297)(49')(5')(5') / 0.55 = \cancel{79{,}402.3\ lbs}\ 76.1\ K \ \ 79.4\ kips \text{ or } 353.2\ kN$$

Allowable Nail Tendon Load, TNN

$$A_{bar} = \frac{T_{NN}}{F_y} \qquad F_y = 60\,ksi \text{ or } 0.4137\,\frac{kN}{mm^2} \qquad \frac{76.1k}{60} = 1.27\,in^2$$

$$A_{bar} = \cancel{1.32}\ 1.26\,in^2 \text{ OR } 854\,mm^2$$

$$\boxed{\text{Use } \#\cancel{11}\ \#10\ [36] \text{ Bar}, A_{bar_{11}} = \cancel{1.56}\ 1.27\,in^2 \text{ or } 1006\,mm^2}$$

DIMENSIONLESS Pullout Resistance ∴

$$Q_D = \alpha_Q Q_u / \gamma S_V S_H \qquad pg\ 99;\ \alpha_Q = 0.50 .$$

$$Q_D = (0.50)(2036\ lb/ft) / ((115\ lb/cf)(5')(5')) = 0.354 .$$

$$\frac{0.297}{0.354} = 0.84$$

$L/H = 1.37$

$L = 67'$

CJB 10/5/98

6.97

MINIMUM ALLOWABLE NAIL HEAD SERVICE LOAD

$t_F = F_F\, K_a\, \gamma\, H\, S_H\, S_V$

$F_F = 0.5$ $H = 49'$
$S_H = 5'$ $\gamma = 0.115\ k/ft^3$
$S_V = 5'$

Use Das formula for Columbs lat. e.p coeff., DAS pg 383

$$K_a = \frac{\cos^2(\phi-\alpha)}{(\cos^2\alpha)(\cos(\phi_w+\alpha))\left[1+\sqrt{\dfrac{\sin(\phi_w+\alpha)\ \sin(\phi - \beta)}{\cos(\phi_w+\alpha)\ \cos(\alpha-\beta)}}\right]^2}$$

$\phi = 32°$
$\phi_w = 2/3\,\phi = \delta = 21.44$
$\beta = 20°$ (backslope)
$\alpha = 9.46°$ (batter)

24.7

CHECK FORMULA

$$K_a = \frac{(0.8531)}{(0.973)(0.8581)\left[1+\sqrt{\dfrac{(0.5135)(\cancel{0.7880})}{(0.8581)(0.9231)}}\right]^2} = \cancel{0.3567}\ 0.167$$

0.701

see next page 3B

$$\boxed{t_F = 0.5(\cancel{0.3567}\ .167)(0.115)(49)(5)(5) = \cancel{25.12}\ \text{kips}\ \ 11.76^k}$$

FACING DESIGN: PERMANENT SHOTCRETE FACING

pg F4

#4 [13] BARS @ 12" SPACING - 6.75" THICK FACING
* 5.50" THICK FACING

A. FACING FLEXURE

NEGLECTED MESH (CONSERVATIVE)

$$^{(+)}A_s = {}^{(-)}A_s = \frac{(0.20\ in^2)(60")}{12"} = 1.00\ in^2$$

$$^{(+)}m_v = {}^{(-)}m_v = \frac{(1.00\ in^2)(60{,}000\ psi)}{(60\ in)}\left(\left(\frac{6.75"}{2}\right) - \frac{(1.00\ in^2)(60{,}000\ psi)}{(1.7)(4000\ psi)(60\ in)}\right)$$

$\frac{5.50"}{2}$

$$^{(+)}m_v = {}^{(-)}m_v = 3.227\ k\cdot ft/ft\ \ [14.36\ kN\cdot m/m]\ \ {*}2.603\ k\cdot ft/ft$$

$$T_{FN} = \frac{(C_F)(m_v^{(-)} + m_v^{(+)})(8)(S_H)}{S_V}$$

$$\boxed{T_{FN} = \frac{(1.0)(3.227+3.227)(8)(5)}{5} = 51.6\ \text{kips}\ [230\ kN]\quad {*}\ 41.65\ \text{kips}\ [185\ kN]}$$

CALCULATION OF K_a; (BOWLES)

3B/6

$$\frac{\sin^2(114.7+32)}{\sin^2(114.7)\cdot\sin(\overset{93.26}{114.7-21.44})\left[1+\sqrt{\frac{\sin(53.44)\cdot\sin(12)}{\sin(93.26)\cdot\sin(134.7)}}\right]^2}$$

$$\frac{0.3014}{0.8254\cdot 0.9984\left[1+\sqrt{\frac{0.1670}{0.7096}}\right]^2}$$

$$\frac{0.3014}{\cancel{1.2576}\ 1.8174} = \cancel{0.2396}\ \boxed{0.1660}$$

$\beta = 114.7$

$\alpha = 20^\circ$

$\phi = 32$

$\delta = 21.44$

B. PUNCHING SHEAR

PROVISION #1

$$d_H \geq \sqrt{2.5}\ d_{HS}$$

$$1.00'' \geq \sqrt{2.5}\ (0.5'')$$

$$1.00'' \geq 0.79'' \therefore OK$$

PROVISION #2

$$t_H \geq 0.5(d_H - d_{HS})$$

$$0.312'' \geq 0.5(1.00'' - 0.5'')$$

$$0.312'' \geq 0.25'' \therefore OK$$

Try NHDOT DESIGN
1/2" x 3" ANCHOR STUDS
w/ 8" x 8" x 3/4" BEARING PLATE

Head ϕ = 1.00" $\therefore d_H$
Head thickness = 0.312" $\therefore t_H$
1/2" x 3" ANCHOR STUD
$d_{HS} = 0.5''$

S_{HS} = Anchor stud spacing

D'_c = effective punching cone diameter

h_c = effective punching cone depth.

b_{pl} = width of base plate

$D'_c = b_{pl} + h_c$ where $b_{pl} = 8''$

h_c = thickness of shotcrete = 6.75".

$$D'_c = 8 + 6.75 = 14.75''.$$

NOMINAL INTERNAL PUNCHING SHEAR STRENGTH OF THE FACING, V_N :

$$V_N = 0.33 \sqrt{f'_c(MPa)}\, D'_c\, h_c\, \pi$$

$$= (0.33)\sqrt{28\,MPa}\left(14.75'' * \frac{25.4\,mm}{INCH}\right)\left(6.75'' * \frac{25.4\,mm}{INCH}\right)(\pi)$$

$$\boxed{V_N = 352\ kN \text{ OR } 79.2\ kips.}$$

FROM TABLE 4.2 : $C_F = C_S = 1.0$

$$T_{FN} = V_N * \left(\frac{1}{1 - \dfrac{C_S(A_c - A_g)}{S_V S_H - A_g}}\right)$$

$$= 79.2 * \left(\frac{1}{\left(1 - \dfrac{1.0(170.9 - 28.27)}{(60)(60) - 28.27}\right)}\right)$$

A_{gc} = Diameter of Nail Hole to groi
$= \pi(6'')^2/4 = 28.27\ in^2.$

A_c = Failure cone diameter
$= \pi(D'_c)^2/4$
$= \pi(14.75\,in)^2/4 = 170.9\ in^2$

$$\boxed{T_{FN} = 82.5\ kips \text{ OR } 367\ kN}$$

FAILURE MODE	NOMINAL NAIL HEAD STRENGTH T_{FN}	FACTOR	ALLOWABLE NAIL HEAD STRENGTH T_F
FACING FLEXURE	51.6 kips ✓	0.67	• 34.6 kips - 153.8 k
☆ 5.5" THICK SHOTCRETE FACING :-	☆ 41.6 kips	0.67	27.9 kips
PUNCHING SHEAR	82.5 kips ✓	0.67	• 55.3 kips - 246 k

$t_F = 25.1$ kips $<$ 34.6 kips ∴ OK - service load does not exceed estimated allowable nail head load

☆ 27.9 kips ∴ 5.5" SHOTCRETE FACING IS OK

Define Allowable Nail Support Diagram

$T_{FN} = 34.6$ kips — Allowable Nail Head Load

$Q = 0.5 \times Q_u = 0.5 \times 2036 = 1.018$ k/ft — Allowable Pullout Resistance

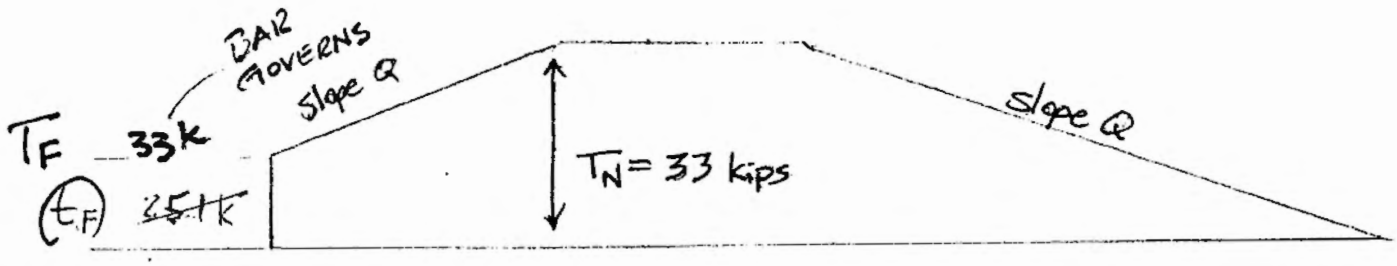
$T_N = 0.55\, T_{NN}$ — Allowable Nail Tendon Tensile Load.

$$T_{NN} = A_{Nail} * F_y = (1.00\ in^2)(60\ ksi) = 60\ kips$$

$\therefore T_N = 0.55 * 60 = 33$ kips [146.8 kN] - USING #8 BAR

NOTE: 5.5" SHOTCRETE FACING DOESN'T MEET COVER REQUIREMENTS

DESIGN DIAGRAM: - See Figure 4.3



Select Trial Nail Length / spacing

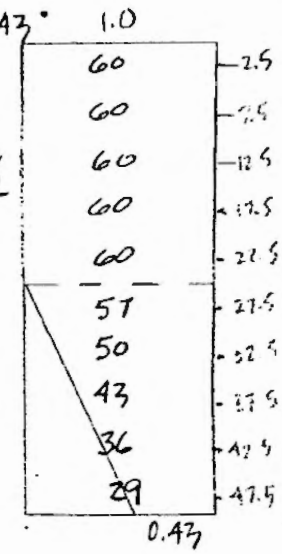
$Q_D = \alpha_Q Q_u / \gamma S_H S_V = 0.354$. Assume $L = 60'$

$\frac{L}{H} = 0.87$ ~~1.22~~ OK

$H * 1.3 = \text{eff } H$ $\quad 1.3 \times 49 = 64'$ $\quad \frac{Q_D}{L/H} = \frac{0.354}{0.87} = 0.41 \therefore R = 0.43$

H_e 64' behind wall $= H_{eff} = 69'$ $\quad \frac{60}{69}$

$24.5 = H/2$



1.5 $\quad$ 0.46

$\frac{2.5}{24.5}(0.57) + 0.43 = 0.49 * 60$ $\quad$ 29' 28'

0.46

$\frac{5}{24.5}(0.57) + 0.49 = 0.60$ .58 $\quad$ 36' 35'

0.72 0.70 $\quad$ 43' 42'

0.84 0.82 $\quad$ 50' 49'

0.95 0.93 $\quad$ 57' 56'

Use goldnail to analyze.

APPENDIX H

♦ Local and Global Stability

- Critical Section at Station 195+50
- Critical Section at Station 197+50

STATION 195+50
Local Stability

Input File Version = 311
MORETOWN RS 0167(9)

General Data	
File Indentifier	195-50.GNI
Unit weight of water	62.4
Base depth for analysis	0.0
Seismic Coefficient	0.0
Minimum Base Exit Angle	-10.0
X Search limit (left)	55.5
X Search limit (right)	110.0
Number of slip circles	100
No. of slip circle exits	10

LRFD and Safety Factor Data	
Analysis Mode: (L)RFD or (S)LD (specify L or S)	S
SLD Safety and Strength Factors (mode S only)	
FS for Soil Cohesion	1
FS for Soil Friction	1
Strength Factor for Head Strength	0.67
Strength Factor for Nail Tendon Strength	0.55
Strength Factor for Nail Pullout Resistance	0.5
LRFD Load Factors (mode L only)	
LF for Unit Weight of Water	1
LF for Unit Weight of Soil	1.35
LF for Surcharge Loads	1.75
LF for Seismic Loads	1
LRFD Resistance Factors (mode L only)	
RF for Soil Cohesion	1
RF for Soil Friction Angle	0.75
RF for Head Strength	0.9
RF for Nail Pullout Resistance	0.7
RF for Nail Tendon Strength	0.9

PIEZOMETRIC DATA	X-Value	Piez. Level
Point 1	0	120
Point 2	170	77
Point 3		

Nodal Data

Node No	X-Value	Y-Value	Node No	X-Value	Y-Value	Node No	X-Value	Y-Value
1	33	97	16			31		
2	55.5	48	17			32		
3	60.5	50	18			33		
4	64.5	49	19			34		
5	101	25	20			35		
6	140	15	21			36		
7	165.5	12	22			37		
8	190	12.8	23			38		
9	0	120	24			39		
10	170	77	25			40		
11			26			41		

Wall Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID

1	1	2	1	1	11				
2					12				

Surface Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Seg. No.	Node 1	Node 2	Soil ID
1	2	3	1	11			
2	3	4	1	12			
3	4	5	1	13			
4	5	6	1	14			
5	6	7	1	15			
6	7	8	1	16			
7				17			

Internal Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID
1	9	10	2	2	11				

Soil Strength & Pullout Resist. Data

Material ID No.	c	ì	Unit Weight	Pullout Res.
1	185	32	115	2036
2	0	42	140	4523.8

Surcharge Pressure Data

Load No	X-value	Vert.	Horiz.
1			

Nail Data	Nail Depth	Nail Length	Tendon Strength	Head Strength	Fixed Nail?
Nail Row 1	2.5	58	47400	51600	
Nail Row 2	7.5	58	47400	51600	
Nail Row 3	12.5	58	47400	51600	
Nail Row 4	17.5	52	47400	51600	
Nail Row 5	22.5	52	47400	51600	
Nail Row 6	25	50	47400	51600	
Nail Row 7	27.5	48	47400	51600	
Nail Row 8	32.5	44	47400	51600	
Nail Row 9	37.5	38	47400	51600	
Nail Row 10	42.5	32	47400	51600	
Nail Row 11	47.5	24	47400	51600	y
Nail Row 12					
Nail Row 13					
Nail Row 14					
Nail Row 15					

Horiz. Spacing	5
Nail Declination	15

Facing Data	
Maximum Facing Pressure	1800.0
Facing Pressure angle	15.0
Press. Distribution type	4
Press. Distribution type	Trapezoidal

Analysis Options	
Analysis Mode	FOS
Soil Model	Linear
Analysis with nails?	Yes

STATION 195+50
LOCAL STABILITY

Output Data

Wall Height = 49.00
Wall Slope = 65.34

Circle Number	Circle X-Intercept	Circle Base Angle	Circle X-Center	Circle Y-Center	Moment Ratio	Factor of Safety
1	55.55	65.22	-24445.69	-11202.55	This slip circle requires zero soil strength for stability	
2	55.55	61.46	-322.38	-96.30	This slip circle requires zero soil strength for stability	
3	55.55	57.69	-139.63	-12.16	This slip circle requires zero soil strength for stability	
4	55.55	53.93	-77.74	16.33	1.003	81.84
5	55.55	50.17	-46.41	30.76	1.004	12.60
6	55.55	46.40	-27.35	39.54	1.006	7.00
7	55.55	42.64	-14.44	45.48	1.009	5.03
8	57.20	63.34	-24115.32	-12026.09	This slip circle requires zero soil strength for stability	
9	57.20	59.58	-316.63	-108.30	This slip circle requires zero soil strength for stability	
10	57.20	55.81	-136.33	-18.02	1.001	152.53
11	57.20	52.05	-75.27	12.56	1.002	13.51
12	57.20	48.29	-44.36	28.04	1.004	7.24
13	57.20	44.52	-25.56	37.46	1.006	5.05
14	57.20	40.76	-12.83	43.83	1.009	3.95
15	57.20	36.99	-3.56	48.47	1.001	3.37
16	58.99	61.31	-23755.78	-12922.35	This slip circle requires zero soil strength for stability	
17	58.99	57.54	-310.36	-121.37	1.000	280.42
18	58.99	53.78	-132.74	-24.39	1.001	14.21
19	58.99	50.02	-72.59	8.45	1.002	7.47
20	58.99	46.25	-42.14	25.08	1.004	5.17
21	58.99	42.49	-23.61	35.19	1.006	4.03
22	58.99	38.72	-11.07	42.04	1.008	3.36
23	58.99	34.96	-1.94	47.02	1.001	2.98
24	61.07	59.17	-23523.98	-13960.65	1.000	3015.83
25	61.07	55.41	-305.87	-136.69	1.000	15.45
26	61.07	51.65	-129.97	-31.96	1.001	7.94
27	61.07	47.88	-70.40	3.51	1.002	5.45
28	61.07	44.12	-40.24	21.46	1.004	4.22
29	61.07	40.35	-21.90	32.39	1.006	3.48
30	61.07	36.59	-9.48	39.78	1.009	2.98
31	61.07	32.83	-0.44	45.16	0.991	2.69
32	61.07	29.06	6.48	49.29	0.992	2.45
33	64.12	56.93	-23904.44	-15488.99	1.000	15.44
34	64.12	53.17	-310.06	-159.94	1.000	7.89
35	64.12	49.40	-131.31	-43.82	1.001	5.40
36	64.12	45.64	-70.78	-4.49	1.002	4.16
37	64.12	41.88	-40.13	15.42	1.004	3.44
38	64.12	38.11	-21.49	27.53	1.006	2.97
39	64.12	34.35	-8.87	35.74	1.009	2.65
40	64.12	30.58	0.32	41.70	0.992	2.50
41	64.12	26.82	7.36	46.28	0.993	2.33
42	69.32	54.58	-25532.14	-18086.53	1.000	7.59
43	69.32	50.81	-331.87	-200.44	1.000	5.29
44	69.32	47.05	-140.96	-64.94	1.001	4.11
45	69.32	43.29	-76.31	-19.05	1.002	3.39
46	69.32	39.52	-43.57	4.18	1.003	2.93
47	69.32	35.76	-23.66	18.31	1.005	2.62
48	69.32	31.99	-10.18	27.88	1.007	2.40
49	69.32	28.23	-0.37	34.85	1.009	2.24
50	69.32	24.47	7.15	40.18	0.993	2.18
51	69.32	20.70	13.13	44.43	0.994	2.09
52	76.32	52.11	-27831.02	-21590.36	1.000	4.82
53	76.32	48.34	-362.84	-255.17	1.000	3.79
54	76.32	44.58	-154.75	-93.54	1.000	3.18
55	76.32	40.81	-84.27	-38.80	1.001	2.79
56	76.32	37.05	-48.60	-11.09	1.002	2.51

57	76.32	33.29	-26.89	5.77	1.003	2.31
58	76.32	29.52	-12.20	17.19	1.004	2.17
59	76.32	25.76	-1.50	25.49	1.005	2.06
60	76.32	21.99	6.69	31.85	1.006	1.99
61	76.32	18.23	13.21	36.92	1.008	1.93
62	76.32	14.47	18.58	41.09	1.010	1.88
63	85.87	49.51	-30967.19	-26370.36	1.000	3.42
64	85.87	45.75	-405.09	-329.83	1.000	2.89
65	85.87	41.98	-173.56	-132.55	1.000	2.55
66	85.87	38.22	-95.15	-65.74	1.000	2.31
67	85.87	34.45	-55.45	-31.92	1.000	2.15
68	85.87	30.69	-31.30	-11.34	1.000	2.03
69	85.87	26.93	-14.95	2.59	1.001	1.95
70	85.87	23.16	-3.05	12.73	1.000	1.90
71	85.87	19.40	6.06	20.49	1.000	1.86
72	85.87	15.63	13.32	26.68	1.001	1.83
73	85.87	11.87	19.29	31.76	1.001	1.81
74	99.73	46.78	-35516.16	-33303.69	1.000	2.59
75	99.73	43.02	-466.37	-438.12	1.000	2.29
76	99.73	39.26	-200.84	-189.14	1.000	2.08
77	99.73	35.49	-110.92	-104.82	1.000	1.94
78	99.73	31.73	-65.39	-62.13	0.999	1.85
79	99.73	27.97	-37.70	-36.16	0.999	1.78
80	99.73	24.20	-18.94	-18.58	0.998	1.74
81	99.73	20.44	-5.30	-5.78	0.997	1.72
82	99.73	16.67	5.15	4.02	0.995	1.70
83	99.73	12.91	13.48	11.83	0.994	1.67
84	99.73	9.15	20.32	18.24	0.991	1.67
85	99.73	5.38	26.09	23.65	1.008	1.61
86	110.00	43.92	-37082.33	-38440.14	1.000	2.09
87	110.00	40.16	-484.76	-516.57	1.000	1.92
88	110.00	36.40	-207.51	-229.27	1.000	1.81
89	110.00	32.63	-113.61	-131.97	0.999	1.73
90	110.00	28.87	-66.07	-82.71	0.999	1.68
91	110.00	25.10	-37.16	-52.75	0.998	1.65
92	110.00	21.34	-17.58	-32.46	0.996	1.62
93	110.00	17.58	-3.33	-17.69	0.995	1.60
94	110.00	13.81	7.58	-6.39	0.993	1.57
95	110.00	10.05	16.28	2.62	0.990	1.55
96	110.00	6.28	23.42	10.03	1.003	1.51
97	110.00	2.52	29.45	16.27	1.001	1.52
98	110.00	-1.24	34.64	21.65	0.999	1.54

Global Stability

Minimum global safety factor = 1.510 for circle no. 96

STATION 195+50
Global Stability

Output Data

Wall Height = 49.00
Wall Slope = 65.34

Circle Number	Circle X-Intercept	Circle Base Angle	Circle X-Center	Circle Y-Center	Moment Ratio	Factor of Safety
1	55.55	65.22	-24445.69	-11202.55	This slip circle requires zero soil strength for stability	
2	55.55	61.26	-304.26	-87.95	This slip circle requires zero soil strength for stability	
3	55.55	57.30	-130.39	-7.91	This slip circle requires zero soil strength for stability	
4	55.55	53.34	-71.50	19.21	1.002	17.68
5	55.55	49.37	-41.67	32.94	1.003	7.50
6	55.55	45.41	-23.50	41.31	1.004	4.91
7	55.55	41.45	-11.17	46.98	1.006	3.79
8	58.46	61.91	-23862.64	-12655.95	This slip circle requires zero soil strength for stability	
9	58.46	57.95	-294.53	-108.06	1.000	59.02
10	58.46	53.99	-124.79	-17.69	1.001	10.57
11	58.46	50.03	-67.30	12.91	1.002	5.96
12	58.46	46.06	-38.17	28.42	1.003	4.24
13	58.46	42.10	-20.43	37.87	1.004	3.36
14	58.46	38.14	-8.40	44.27	1.006	2.83
15	58.46	34.18	0.37	48.94	1.008	2.49
16	62.13	58.38	-23655.84	-14490.36	1.000	18.11
17	62.13	54.41	-289.77	-133.97	1.000	7.83
18	62.13	50.45	-121.49	-30.57	1.001	5.09
19	62.13	46.49	-64.50	4.45	1.002	3.81
20	62.13	42.53	-35.62	22.19	1.003	3.08
21	62.13	38.57	-18.03	32.99	1.005	2.64
22	62.13	34.60	-6.10	40.32	1.007	2.33
23	62.13	30.64	2.59	45.66	1.009	2.12
24	69.10	54.66	-25461.45	-17978.78	1.000	5.97
25	69.10	50.70	-312.03	-185.40	1.000	4.30
26	69.10	46.74	-130.91	-57.25	1.001	3.41
27	69.10	42.78	-69.56	-13.85	1.002	2.85
28	69.10	38.81	-38.48	8.14	1.003	2.49
29	69.10	34.85	-19.55	21.54	1.004	2.25
30	69.10	30.89	-6.71	30.62	1.006	2.07
31	69.10	26.93	2.64	37.24	1.007	1.95
32	69.10	22.97	9.83	42.32	1.009	1.87
33	80.91	50.76	-29338.32	-23887.72	1.000	3.42
34	80.91	46.80	-361.39	-273.32	1.000	2.83
35	80.91	42.84	-152.70	-103.25	1.000	2.46
36	80.91	38.88	-82.01	-45.65	1.000	2.21
37	80.91	34.92	-46.20	-16.46	1.001	2.04
38	80.91	30.95	-24.39	1.31	1.001	1.93
39	80.91	26.99	-9.60	13.37	1.001	1.84
40	80.91	23.03	1.18	22.15	1.002	1.79
41	80.91	19.07	9.46	28.90	1.002	1.76
42	80.91	15.11	16.07	34.29	1.003	1.74
43	100.42	46.67	-35744.02	-33650.98	1.000	2.33
44	100.42	42.71	-442.93	-418.59	1.000	2.06
45	100.42	38.75	-188.70	-179.25	1.000	1.89
46	100.42	34.79	-102.59	-98.19	0.999	1.77
47	100.42	30.82	-58.96	-57.12	0.999	1.70
48	100.42	26.86	-32.39	-32.10	0.998	1.65
49	100.42	22.90	-14.37	-15.14	0.997	1.62
50	100.42	18.94	-1.23	-2.77	0.995	1.62
51	100.42	14.98	8.85	6.72	0.994	1.63
52	100.42	11.01	16.91	14.30	0.992	1.66
53	100.42	7.05	23.54	20.55	1.005	1.68
54	115.96	42.37	-37843.50	-41421.07	1.000	1.81
55	115.96	38.41	-465.15	-531.25	1.000	1.69
56	115.96	34.45	-195.96	-236.76	1.000	1.62
57	115.96	30.49	-104.78	-137.02	0.999	1.57
58	115.96	26.53	-58.58	-86.48	0.998	1.54

59	115.96	22.56	-30.45	-55.71	0.997	1.53
60	115.96	18.60	-11.37	-34.83	0.995	1.53
61	115.96	14.64	2.54	-19.62	0.993	1.54
62	115.96	10.68	13.21	-7.94	0.990	1.56
63	115.96	6.72	21.74	1.39	1.001	1.55
64	115.96	2.75	28.77	9.08	0.999	1.58
65	115.96	-1.21	34.72	15.58	0.996	1.62
66	137.41	37.86	-40582.93	-52149.45	1.000	1.64
67	137.41	33.90	-493.57	-686.64	1.000	1.58
68	137.41	29.94	-204.85	-316.01	1.000	1.55
69	137.41	25.98	-107.06	-190.47	0.999	1.52
70	137.41	22.01	-57.51	-126.87	0.999	1.50
71	137.41	18.05	-27.34	-88.14	0.998	1.50
72	137.41	14.09	-6.87	-61.87	0.996	1.50
73	137.41	10.13	8.04	-42.72	0.993	1.51
74	137.41	6.16	19.50	-28.02	0.990	1.53
75	137.41	2.20	28.64	-16.28	1.004	1.52
76	137.41	-1.76	36.18	-6.60	1.003	1.55
77	137.41	-5.72	42.56	1.59	0.999	1.60
78	137.41	-9.68	48.07	8.66	0.994	1.67
79	162.44	33.12	-42222.36	-64666.10	1.000	1.63
80	162.44	29.16	-504.56	-866.40	1.000	1.59
81	162.44	25.20	-204.11	-406.92	1.000	1.56
82	162.44	21.24	-102.35	-251.29	1.000	1.55
83	162.44	17.27	-50.79	-172.44	0.999	1.54
84	162.44	13.31	-19.39	-124.43	0.998	1.53
85	162.44	9.35	1.90	-91.86	0.997	1.53
86	162.44	5.39	17.43	-68.12	0.994	1.55
87	162.44	1.43	29.34	-49.89	0.991	1.58
88	162.44	-2.54	38.86	-35.34	1.008	1.58
89	162.44	-6.50	46.71	-23.34	1.005	1.64
90	190.00	28.15	-41988.48	-78445.07	1.000	1.73
91	190.00	24.19	-487.65	-1062.28	1.000	1.70
92	190.00	20.22	-188.76	-504.98	1.000	1.68
93	190.00	16.26	-87.53	-316.21	1.000	1.66
94	190.00	12.30	-36.24	-220.58	1.000	1.65
95	190.00	8.34	-5.01	-162.34	0.999	1.66
96	190.00	4.38	16.18	-122.83	0.997	1.68
97	190.00	0.41	31.62	-94.04	0.995	1.72
98	190.00	-3.55	43.48	-71.94	0.992	1.78
99	190.00	-7.51	52.95	-54.28	1.001	1.83

Global Stability

Minimum global safety factor = 1.500 for circle no. 71

Station 197+50
Local Stability

Input File Version = 311
MORETOWN RS 0167(9)

General Data

File Indentifier	197-50.GNI
Unit weight of water	62.4
Base depth for analysis	0.0
Seismic Coefficient	0.0
Minimum Base Exit Angle	-10.0
X Search limit (left)	55.0
X Search limit (right)	109.0
Number of slip circles	100
No. of slip circle exits	10

LRFD and Safety Factor Data

Analysis Mode: (L)RFD or (S)LD (specify L or S)	S
SLD Safety and Strength Factors (mode S only)	
FS for Soil Cohesion	1
FS for Soil Friction	1
Strength Factor for Head Strength	0.67
Strength Factor for Nail Tendon Strength	0.55
Strength Factor for Nail Pullout Resistance	0.5
LRFD Load Factors (mode L only)	
LF for Unit Weight of Water	1
LF for Unit Weight of Soil	1.35
LF for Surcharge Loads	1.75
LF for Seismic Loads	1
LRFD Resistance Factors (mode L only)	
RF for Soil Cohesion	1
RF for Soil Friction Angle	0.75
RF for Head Strength	0.9
RF for Nail Pullout Resistance	0.7
RF for Nail Tendon Strength	0.9

PIEZOMETRIC DATA	X-Value	Piez. Level
Point 1	30	110
Point 2	140	80

Nodal Data

Node No	X-Value	Y-Value	Node No	X-Value	Y-Value	Node No	X-Value	Y-Value
1	33	87.5	16			31		
2	55	42.5	17			32		
3	60	43	18			33		
4	64	42	19			34		
5	81	31.5	20			35		
6	142.5	27	21			36		
7	167.5	26	22			37		
8	30	110	23			38		
9	140	80	24			39		

Wall Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID
1	1	2	1	1	11				

Surface Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Seg. No.	Node 1	Node 2	Soil ID
1	2	3	1	11			
2	3	4	1	12			
3	4	5	1	13			
4	5	6	1	14			
5	6	7	1	15			

Internal Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID
1	8	9	2	2	11				

Soil Strength & Pullout Resist. Data

Material ID No.	c	i	Unit Weight	Pullout Res.
1	185	32	115	2036
2	0	42	140	4523.8

No Surcharge Pressure Data

Load No	X-value	Vert.	Horiz.

Nail Data	Nail Depth	Nail Length	Tendon Strength	Head Strength	Fixed Nail?
Nail Row 1	2.5	47	47400	51600	
Nail Row 2	7.5	47	47400	51600	
Nail Row 3	12.5	47	47400	51600	
Nail Row 4	17.5	47	47400	51600	
Nail Row 5	22.5	47	47400	51600	
Nail Row 6	25	42	47400	51600	
Nail Row 7	27.5	38	47400	51600	
Nail Row 8	32.5	31	47400	51600	
Nail Row 9	37.5	24	47400	51600	
Nail Row 10	42.5	18	47400	51600	y

Horiz. Spacing	5
Nail Declination	15

Facing Data

Maximum Facing Pressure	1800.0
Facing Pressure angle	15.0
Press. Distribution type	4
Press. Distribution type	Trapezoidal

Analysis Options

Analysis Mode	FOS
Soil Model	Linear
Analysis with nails?	Yes

STATION 197+50
LOCAL STABILITY

Output Data

Wall Height = 45.00
Wall Slope = 63.95

Circle Number	Circle X-Intercept	Circle Base Angle	Circle X-Center	Circle Y-Center	Moment Ratio	Factor of Safety
1	55.05	63.83	-22453.31	-10961.58	This slip circle requires zero soil strength for stability	
2	55.05	59.73	-265.12	-86.52	This slip circle requires zero soil strength for stability	
3	55.05	55.62	-110.81	-10.89	This slip circle requires zero soil strength for stability	
4	55.05	51.52	-58.53	14.73	1.002	87.20
5	55.05	47.41	-32.03	27.72	1.004	11.46
6	55.05	43.31	-15.88	35.64	1.005	6.34
7	55.05	39.20	-4.92	41.01	1.007	4.56
8	57.27	61.48	-22341.22	-12071.22	This slip circle requires zero soil strength for stability	
9	57.27	57.37	-262.48	-101.66	This slip circle requires zero soil strength for stability	
10	57.27	53.27	-108.93	-18.41	1.001	80.88
11	57.27	49.16	-56.92	9.79	1.002	11.26
12	57.27	45.06	-30.55	24.08	1.003	6.21
13	57.27	40.95	-14.48	32.79	1.005	4.37
14	57.27	36.85	-3.56	38.71	1.007	3.44
15	59.75	58.95	-22216.26	-13308.32	This slip circle requires zero soil strength for stability	
16	59.75	54.84	-259.55	-118.53	1.000	65.98
17	59.75	50.74	-106.85	-26.80	1.001	11.19
18	59.75	46.63	-55.12	4.27	1.002	6.23
19	59.75	42.53	-28.89	20.02	1.004	4.40
20	59.75	38.42	-12.91	29.62	1.005	3.45
21	59.75	34.32	-2.06	36.14	1.007	2.87
22	59.75	30.21	5.86	40.90	1.009	2.50
23	63.15	56.29	-22595.23	-15008.38	1.000	44.25
24	63.15	52.19	-263.08	-142.27	1.000	10.73
25	63.15	48.08	-107.77	-38.88	1.001	6.20
26	63.15	43.98	-55.15	-3.86	1.002	4.37
27	63.15	39.87	-28.48	13.90	1.004	3.45
28	63.15	35.77	-12.23	24.72	1.005	2.88
29	63.15	31.66	-1.19	32.07	1.007	2.50
30	63.15	27.56	6.87	37.43	1.009	2.24
31	63.15	23.45	13.07	41.55	0.992	2.12
32	68.77	53.50	-24172.74	-17822.60	1.000	9.19
33	68.77	49.40	-281.98	-182.50	1.000	5.71
34	68.77	45.29	-115.83	-59.82	1.001	4.22
35	68.77	41.19	-59.55	-18.26	1.001	3.39
36	68.77	37.08	-31.01	2.81	1.002	2.83
37	68.77	32.98	-13.62	15.65	1.004	2.47
38	68.77	28.87	-1.81	24.37	1.005	2.23
39	68.77	24.77	6.81	30.73	1.007	2.05
40	68.77	20.66	13.44	35.63	1.009	1.92
41	76.84	50.57	-26661.54	-21861.12	1.000	4.88
42	76.84	46.47	-312.20	-240.45	1.000	3.72
43	76.84	42.36	-128.95	-90.09	1.000	3.06
44	76.84	38.26	-66.87	-39.15	1.001	2.63
45	76.84	34.15	-35.40	-13.33	1.001	2.34
46	76.84	30.05	-16.22	2.41	1.001	2.14
47	76.84	25.94	-3.20	13.09	1.002	1.99
48	76.84	21.84	6.31	20.89	1.003	1.87
49	76.84	17.73	13.62	26.89	1.004	1.79
50	76.84	13.63	19.47	31.69	1.007	1.72
51	84.45	47.50	-28067.43	-25664.81	1.000	3.26
52	84.45	43.39	-327.77	-294.11	1.000	2.75
53	84.45	39.29	-134.85	-117.67	1.000	2.42
54	84.45	35.18	-69.50	-57.90	1.000	2.19
55	84.45	31.08	-36.37	-27.60	1.000	2.02
56	84.45	26.97	-16.18	-9.13	1.000	1.90

57	84.45	22.87	-2.46	3.41	1.000	1.80
58	84.45	18.76	7.55	12.57	1.000	1.72
59	84.45	14.66	15.24	19.61	1.000	1.65
60	84.45	10.55	21.40	25.24	1.000	1.61
61	84.45	6.45	26.49	29.89	1.000	1.58
62	91.09	44.27	-28307.19	-28987.21	1.000	2.58
63	91.09	40.16	-327.79	-340.01	1.000	2.30
64	91.09	36.06	-133.20	-140.78	1.000	2.10
65	91.09	31.95	-67.28	-73.29	1.000	1.95
66	91.09	27.85	-33.87	-39.07	0.999	1.83
67	91.09	23.74	-13.50	-18.22	0.999	1.74
68	91.09	19.64	0.33	-4.06	0.998	1.66
69	91.09	15.53	10.43	6.28	0.996	1.63
70	91.09	11.43	18.19	14.23	0.996	1.57
71	91.09	7.32	24.40	20.59	0.996	1.55
72	91.09	3.22	29.53	25.84	0.995	1.54
73	91.09	-0.89	33.89	30.30	0.995	1.55
74	99.10	40.88	-28596.12	-32990.91	1.000	2.25
75	99.10	36.77	-327.81	-395.31	1.000	2.06
76	99.10	32.67	-131.21	-168.62	1.000	1.92
77	99.10	28.56	-64.62	-91.83	0.999	1.81
78	99.10	24.46	-30.85	-52.90	0.999	1.72
79	99.10	20.35	-10.28	-29.17	0.999	1.63
80	99.10	16.25	3.70	-13.06	0.998	1.58
81	99.10	12.14	13.90	-1.30	0.997	1.54
82	99.10	8.04	21.74	7.74	0.994	1.53
83	99.10	3.93	28.02	14.98	0.992	1.53
84	99.10	-0.17	33.20	20.96	1.009	1.50
85	99.10	-4.28	37.60	26.03	1.009	1.52
86	109.00	37.32	-28953.38	-37941.51	1.000	2.06
87	109.00	33.21	-327.83	-463.70	1.000	1.92
88	109.00	29.11	-128.76	-203.05	1.000	1.80
89	109.00	25.00	-61.32	-114.76	1.000	1.70
90	109.00	20.90	-27.13	-70.00	0.999	1.63
91	109.00	16.79	-6.29	-42.72	0.998	1.57
92	109.00	12.69	7.86	-24.19	0.997	1.54
93	109.00	8.58	18.19	-10.67	0.995	1.52
94	109.00	4.48	26.13	-0.27	0.993	1.52
95	109.00	0.37	32.49	8.05	1.007	1.50
96	109.00	-3.73	37.74	14.93	1.004	1.53
97	109.00	-7.84	42.19	20.76	1.001	1.57

Global Stability

Minimum global safety factor = 1.500 for circle no. 84

STATION 195+50
Global Stability

GLOBSTAB.GNI

Input File Version = 311
MORETOWN RS 0167(9)

General Data

File Indentifier	GLOBSTAB.GNI
Unit weight of water	62.4
Base depth for analysis	0.0
Seismic Coefficient	0.0
Minimum Base Exit Angle	-10.0
X Search limit (left)	0.0
X Search limit (right)	190.0
Number of slip circles	100
No. of slip circle exits	10

LRFD and Safety Factor Data

Analysis Mode: (L)RFD or (S)LD (specify L or S)	S
SLD Safety and Strength Factors (mode S only)	
FS for Soil Cohesion	1
FS for Soil Friction	1
Strength Factor for Head Strength	0.67
Strength Factor for Nail Tendon Strength	0.55
Strength Factor for Nail Pullout Resistance	0.5
LRFD Load Factors (mode L only)	
LF for Unit Weight of Water	1
LF for Unit Weight of Soil	1.35
LF for Surcharge Loads	1.75
LF for Seismic Loads	1
LRFD Resistance Factors (mode L only)	
RF for Soil Cohesion	1
RF for Soil Friction Angle	0.75
RF for Head Strength	0.9
RF for Nail Pullout Resistance	0.7
RF for Nail Tendon Strength	0.9

PIEZOMETRIC DATA	X-Value	Piez. Level
Point 1	0	120
Point 2	170	77
Point 3		
Point 4		
Point 5		
Point 6		
Point 7		
Point 8		
Point 9		
Point 10		

Nodal Data

Node No	X-Value	Y-Value	Node No	X-Value	Y-Value	Node No	X-Value	Y-Value
1	33	97	16			31		
2	55.5	48	17			32		
3	60.5	50	18			33		
4	64.5	49	19			34		
5	101	25	20			35		
6	140	15	21			36		
7	165.5	12	22			37		
8	190	12.8	23			38		
9	0	120	24			39		
10	170	77	25			40		
11			26			41		
12			27			42		

13			28			43		
14			29			44		
15			30			45		

Wall Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID
1	1	2	1	1	11				
2					12				
3					13				
4					14				
5					15				
6					16				
7					17				
8					18				
9					19				
10					20				

Surface Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Seg. No.	Node 1	Node 2	Soil ID
1	2	3	1	11			
2	3	4	1	12			
3	4	5	1	13			
4	5	6	1	14			
5	6	7	1	15			
6	7	8	1	16			
7				17			
8				18			
9				19			
10				20			

Internal Segment Data

Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID	Seg. No.	Node 1	Node 2	Soil ID	Pullout Res. ID
1	9	10	2	2	11				
2					12				
3					13				
4					14				
5					15				
6					16				
7					17				
8					18				
9					19				
10					20				

Soil Strength & Pullout Resist. Data

Material ID No.	c	i	Unit Weight	Pullout Res.
1	185	32	115	2036
2	0	42	140	4523.8
3				
4				
5				
6				

7					
8					
9					
10					
11					
12					
13					
14					

Surcharge Pressure Data

Load No	X-value	Vert.	Horiz.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Nail Data	Nail Depth	Nail Length	Tendon Strength	Head Strength	Fixed Nail?
Nail Row 1	2.5	60	47400	36200	
Nail Row 2	7.5	60	47400	36200	
Nail Row 3	12.5	60	47400	36200	
Nail Row 4	17.5	60	47400	36200	
Nail Row 5	22.5	60	47400	36200	
Nail Row 6	25	55	47400	36200	
Nail Row 7	27.5	55	47400	36200	
Nail Row 8	32.5	55	47400	36200	
Nail Row 9	37.5	55	47400	36200	
Nail Row 10	42.5	55	47400	36200	
Nail Row 11					
Nail Row 12					
Nail Row 13					
Nail Row 14					
Nail Row 15					

Horiz. Spacing	5
Nail Declination	15

Facing Data

Maximum Facing Pressure	1800.0
Facing Pressure angle	15.0
Press. Distribution type	4
Press. Distribution type	Trapezoidal

Analysis Options

Analysis Mode	FOS
Soil Model	Linear
Analysis with nails?	Yes

STATION 197+50
Global Stability

GLOBSTAB.GNI

Input File Version = 311
MORETOWN RS 0167(9)

General Data	
File Indentifier	GLOBSTAB.GNI
Unit weight of water	62.4
Base depth for analysis	0.0
Seismic Coefficient	0.0
Minimum Base Exit Angle	-10.0
X Search limit (left)	0.0
X Search limit (right)	160.0
Number of slip circles	100
No. of slip circle exits	10

LRFD and Safety Factor Data	
Analysis Mode: (L)RFD or (S)LD (specify L or S)	S
SLD Safety and Strength Factors (mode S only)	
FS for Soil Cohesion	1
FS for Soil Friction	1
Strength Factor for Head Strength	0.67
Strength Factor for Nail Tendon Strength	0.55
Strength Factor for Nail Pullout Resistance	0.5
LRFD Load Factors (mode L only)	
LF for Unit Weight of Water	1
LF for Unit Weight of Soil	1.35
LF for Surcharge Loads	1.75
LF for Seismic Loads	1
LRFD Resistance Factors (mode L only)	
RF for Soil Cohesion	1
RF for Soil Friction Angle	0.75
RF for Head Strength	0.9
RF for Nail Pullout Resistance	0.7
RF for Nail Tendon Strength	0.9

PIEZOMETRIC DATA	X-Value	Piez. Level
Point 1	30	110
Point 2	140	80
Point 3		
Point 4		
Point 5		
Point 6		
Point 7		
Point 8		
Point 9		
Point 10		

Nodal Data

Node No	X-Value	Y-Value	Node No	X-Value	Y-Value	Node No	X-Value	Y-Value
1	33	87.5	16			31		
2	55	42.5	17			32		
3	60	43	18			33		
4	64	42	19			34		
5	81	31.5	20			35		
6	142.5	27	21			36		
7	167.5	26	22			37		
8	30	110	23			38		
9	140	80	24			39		
10			25			40		
11			26			41		
12			27			42		

7					
8					
9					
10					
11					
12					
13					
14					

Surcharge Pressure Data			
Load No	X-value	Vert.	Horiz.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Nail Data	Nail Depth	Nail Length	Tendon Strength	Head Strength	Fixed Nail?
Nail Row 1	2.5	50	47400	36200	
Nail Row 2	7.5	50	47400	36200	
Nail Row 3	12.5	50	47400	36200	
Nail Row 4	17.5	50	47400	36200	
Nail Row 5	22.5	50	47400	36200	
Nail Row 6	25	45	47400	36200	
Nail Row 7	27.5	45	47400	36200	
Nail Row 8	32.5	45	47400	36200	
Nail Row 9	37.5	45	47400	36200	
Nail Row 10					
Nail Row 11					
Nail Row 12					
Nail Row 13					
Nail Row 14					
Nail Row 15					

Horiz. Spacing	5
Nail Declination	15

Facing Data	
Maximum Facing Pressure	1800.0
Facing Pressure angle	15.0
Press. Distribution type	4
Press. Distribution type	Trapezoidal

Analysis Options	
Analysis Mode	FOS
Soil Model	Linear
Analysis with nails?	Yes

STATION 197+50
Global Stability

Output Data

Wall Height = 45.00
Wall Slope = 63.95

Circle Number	Circle X-Intercept	Circle Base Angle	Circle X-Center	Circle Y-Center	Moment Ratio	Factor of Safety
1	55.05	63.83	-22453.31	-10961.58	This slip circle requires zero soil strength for stability	
2	55.05	59.73	-265.12	-86.52	This slip circle requires zero soil strength for stability	
3	55.05	55.62	-110.81	-10.89	This slip circle requires zero soil strength for stability	
4	55.05	51.52	-58.53	14.73	1.002	34.38
5	55.05	47.41	-32.03	27.72	1.003	9.38
6	55.05	43.31	-15.88	35.64	1.004	5.60
7	55.05	39.20	-4.92	41.01	1.005	4.17
8	58.29	60.42	-22289.67	-12581.56	This slip circle requires zero soil strength for stability	
9	58.29	56.32	-261.27	-108.62	This slip circle requires zero soil strength for stability	
10	58.29	52.21	-108.07	-21.87	1.001	14.76
11	58.29	48.11	-56.18	7.51	1.002	7.02
12	58.29	44.00	-29.87	22.41	1.003	4.71
13	58.29	39.90	-13.83	31.49	1.004	3.63
14	58.29	35.79	-2.94	37.65	1.006	3.02
15	58.29	31.69	5.01	42.15	1.007	2.64
16	62.48	56.78	-22512.14	-14674.62	1.000	33.20
17	62.48	52.68	-262.26	-137.60	1.000	9.65
18	62.48	48.57	-107.52	-36.50	1.001	5.78
19	62.48	44.47	-55.11	-2.25	1.002	4.17
20	62.48	40.36	-28.53	15.11	1.003	3.29
21	62.48	36.26	-12.34	25.69	1.005	2.79
22	62.48	32.15	-1.34	32.87	1.006	2.46
23	62.48	28.05	6.69	38.12	1.008	2.24
24	62.48	23.94	12.86	42.15	0.991	2.14
25	70.10	52.96	-24581.55	-18485.97	1.000	6.59
26	70.10	48.86	-286.94	-192.02	1.000	4.57
27	70.10	44.75	-117.98	-64.79	1.000	3.57
28	70.10	40.65	-60.75	-21.69	1.001	2.96
29	70.10	36.54	-31.73	0.16	1.002	2.58
30	70.10	32.44	-14.05	13.47	1.003	2.32
31	70.10	28.33	-2.04	22.51	1.004	2.15
32	70.10	24.23	6.73	29.12	1.006	2.02
33	70.10	20.12	13.47	34.19	1.007	1.94
34	81.71	48.95	-27968.68	-24296.48	1.000	3.50
35	81.71	44.85	-327.76	-275.21	1.000	2.88
36	81.71	40.74	-135.53	-108.15	1.000	2.50
37	81.71	36.64	-70.41	-51.56	1.000	2.25
38	81.71	32.53	-37.40	-22.87	1.000	2.08
39	81.71	28.43	-17.28	-5.39	1.000	1.97
40	81.71	24.32	-3.61	6.49	1.000	1.89
41	81.71	20.22	6.36	15.16	1.000	1.84
42	81.71	16.11	14.03	21.82	1.000	1.81
43	81.71	12.01	20.17	27.15	1.001	1.80
44	90.07	44.74	-28270.31	-28476.23	1.000	2.49
45	90.07	40.63	-327.78	-332.95	1.000	2.24
46	90.07	36.53	-133.45	-137.22	1.000	2.07
47	90.07	32.42	-67.62	-70.92	1.000	1.94
48	90.07	28.32	-34.25	-37.31	0.999	1.86
49	90.07	24.21	-13.91	-16.82	0.999	1.81
50	90.07	20.11	-0.10	-2.91	0.998	1.77
51	90.07	16.00	9.98	7.25	0.996	1.77
52	90.07	11.90	17.74	15.05	0.994	1.76
53	90.07	7.79	23.94	21.30	0.995	1.73
54	90.07	3.69	29.07	26.47	0.994	1.73
55	100.55	40.31	-28648.42	-33715.61	1.000	2.14
56	100.55	36.21	-327.81	-405.32	1.000	2.00
57	100.55	32.10	-130.85	-173.66	1.000	1.90

58	100.55	28.00	-64.13	-95.19	0.999	1.83
59	100.55	23.89	-30.31	-55.40	0.999	1.78
60	100.55	19.79	-9.69	-31.16	0.998	1.73
61	100.55	15.68	4.31	-14.69	0.997	1.70
62	100.55	11.58	14.52	-2.67	0.995	1.68
63	100.55	7.47	22.38	6.57	0.993	1.68
64	100.55	3.37	28.67	13.97	0.990	1.69
65	100.55	-0.74	33.87	20.08	1.007	1.67
66	100.55	-4.84	38.27	25.26	1.006	1.70
67	100.55	-8.95	42.09	29.75	1.005	1.73
68	114.24	35.67	-29142.35	-40560.12	1.000	2.01
69	114.24	31.56	-327.85	-499.87	1.000	1.91
70	114.24	27.46	-127.46	-221.27	1.000	1.83
71	114.24	23.35	-59.57	-126.89	0.999	1.78
72	114.24	19.25	-25.16	-79.04	0.999	1.73
73	114.24	15.14	-4.18	-49.88	0.998	1.69
74	114.24	11.04	10.06	-30.08	0.996	1.68
75	114.24	6.93	20.46	-15.63	0.994	1.67
76	114.24	2.83	28.45	-4.51	0.991	1.68
77	114.24	-1.28	34.85	4.39	1.005	1.66
78	114.24	-5.38	40.14	11.73	1.001	1.71
79	114.24	-9.49	44.62	17.96	0.997	1.76
80	133.14	30.79	-29824.61	-50014.14	1.000	1.99
81	133.14	26.69	-327.90	-630.46	1.000	1.91
82	133.14	22.58	-122.76	-287.02	1.000	1.85
83	133.14	18.48	-53.27	-170.68	1.000	1.79
84	133.14	14.37	-18.04	-111.70	0.999	1.76
85	133.14	10.27	3.43	-75.75	0.998	1.73
86	133.14	6.16	18.01	-51.34	0.996	1.73
87	133.14	2.06	28.65	-33.52	0.994	1.75
88	133.14	-2.05	36.84	-19.82	0.990	1.78
89	133.14	-6.15	43.39	-8.85	1.001	1.80
90	160.00	25.67	-30503.49	-63443.08	1.000	2.07
91	160.00	21.57	-323.99	-815.68	1.000	2.00
92	160.00	17.46	-114.10	-380.13	1.000	1.95
93	160.00	13.36	-43.00	-232.59	1.000	1.92
94	160.00	9.25	-6.96	-157.79	0.999	1.91
95	160.00	5.15	15.01	-112.20	0.998	1.93
96	160.00	1.04	29.93	-81.24	0.996	1.96
97	160.00	-3.06	40.82	-58.64	0.993	2.00
98	160.00	-7.17	49.19	-41.27	1.001	2.06

° Global Stability °

° Minimum global safety factor = 1.664 for circle no. 77 °

APPENDIX I

♦ Calculation of Type and Thickness of Insulation

- Heat Transfer Calculations

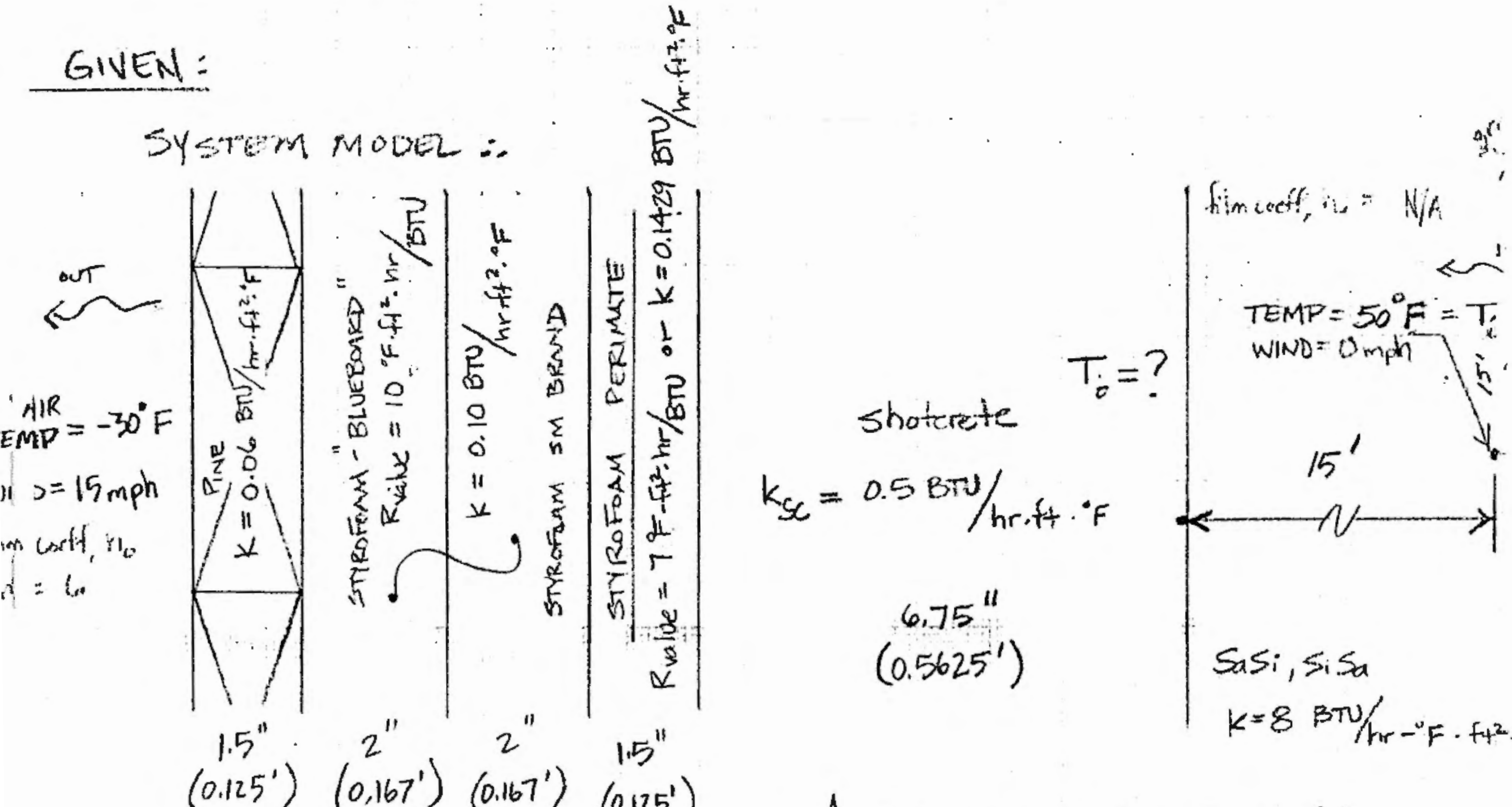
Chad A. Allen
10-14-98

MORETOWN RS0167(9)

VERIFICATION/ESTIMATE OF AMOUNT/TYPE OF INSULATION NECESSARY TO KEEP ANY MOISTURE BEHIND THE WALL FROM FREEZING.

GIVEN:

SYSTEM MODEL:



A_{wall}, AREA OF SNW = 12,170 ft²

ASSUMPTIONS: EARTH - SaSi w/ 25.0% MOISTURE @ dry density = 90 pcf
Frost penetration doesn't exceed 4' so $T_{earth} \geq 32°F$, Assume $T_{earth} = 33°F$
AIR TEMPERATURE @ FACE OF WALL WILL NOT DROP BELOW -30°F
No film coefficient in soil

FIND: THE TEMPERATURE BEHIND THE SOIL NAIL WALL GIVEN THE ABOVE CONDITIONS

FORMULAS:

$$U = \frac{1}{\sum_i \frac{L_i}{k_i} + \sum_j \frac{1}{h_j}} \qquad q = U A_{wall} (T_i - T_o)$$

$$q = \frac{k}{L} A \Delta T$$

Chad A. Allen
10-14-98

MORETOWN RS 0167(9)

2/2

CALCULATIONS:

Overall heat transfer coefficient, U

$$\frac{1}{U} = \frac{L_{wood}}{k_{wood}} + \frac{L_{insulation}}{k_{insulation}} + \frac{L_{perimate}}{k_{perimate}} + \frac{L_{shotcrete}}{k_{shotcrete}} + \frac{L_{earth}}{k_{earth}} + \frac{1}{h_o} + \frac{1}{h_i}$$

$$= \frac{0.125'}{0.06} + \frac{0.33'}{0.10} + \frac{0.125}{0.1429} + \frac{0.5625}{0.5} + \frac{4.0}{8} + \frac{1}{6}$$

$$\frac{1}{U} = 8.638 \quad \therefore U = \frac{1}{8.05} = 0.1242 \ BTU/hr \cdot ft^2 \cdot {}^\circ F$$

heat transfer, q

$$q = U A_{wall} (T_i - T_o)$$

$$= \left(0.1242 \ BTU/hr \cdot ft^2 \cdot {}^\circ F\right)\left(12,170 \ ft^2\right)\left(33 - (-30)\right)$$

$$q = 95,246.26 \ BTU/hr$$

Temperature behind SNW

$$q = \frac{-k_{earth} A_{wall} (T_{earth} - T_{shotcrete})}{L_{earth}}$$

$$95,246.26 = \frac{\left(8 \ BTU/hr \cdot ft^2 \cdot {}^\circ F\right)\left(12,170 \ ft^2\right)\left(50^\circ F - T_{shotcrete}\right)}{15'}$$

$$\boxed{T_{shotcrete} = 35.3 \ {}^\circ F}$$

NOTE: $8 \ BTU/hr \cdot ft^2 \cdot {}^\circ F = 8 \ BTU/hr \cdot ft \ {}^\circ F$