1.0 SUMMARY AND PURPOSE

Civil & Environmental Consultants, Inc. (CEC) prepared this Design Narrative for stabilizing the slope at the rear of the 51 Harborview Road property in Hull, Massachusetts. The slope is located at approximate coordinates 42.307492°, -70.906191° (latitude, longitude). Based on the existing slope conditions and subsurface conditions at the site, CEC is recommending stabilizing the slope with a combination of soil nails, slope re-grading, and the installation of gabion baskets near the east property line.

The purpose of this design narrative is to provide a detailed description of the analyses performed to support our conceptual remediation design (Concept Design), included as Attachment 1, for stabilization of the slope. This narrative includes the results of analyses performed to develop the remedial design, site observations, laboratory testing, soil and imported stone material properties, structural reinforcement elements associated with the soil nail and shotcrete facing, and our design assumptions. The proposed slope remediation uses a combination of a site grading, soil nails with shotcrete facing, and gabion baskets.

2.0 REFERENCES AND ATTACHMENTS

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The following attachments are included with this design narrative:

1. Conceptual Remediation Design Drawings
2. Stability Cross Section Location Plan
3. Back Analysis Outputs
4. Global Stability Analysis Outputs – Soil Nails
5. SNAIL Analysis Outputs
6. Gabion Basket Stability Analysis
7. Test Boring Log
8. Laboratory Test Results
9. FHWA Soil Nail Reference Manual, Publication No. FHWA-NHI-14-007, February 2015 (Partial Version)
10. Williams Form Engineering – Grade 75 All-Thread Rebar Properties

References (not included as attachments):

1. FHWA Soil Nail Reference Manual, Publication No. FHWA-NHI-14-007, February 2015 (Complete Version)
2. California Department of Transportation (Caltrans) SNAIL User Guide – March 2020
3. "Standard Handbook for Civil Engineers" McGraw -Hill, 1983

3.0 BACKGROUND INFORMATION

3.1 Site Conditions: CEC performed an initial reconnaissance at the site on July 18, 2022, to document the site and slope conditions and again on June 7, 2023, to note any visual changes to site conditions. The existing Retaining Wall was constructed at the top of the coastal bluff and parallels the existing patio and deck structure constructed behind the wall. The patio is supported on wood columns and concrete piers. A copy of the Retaining Wall drawings was provided to CEC by the Client.

Since the initial slope failure, the area below and immediately behind the existing Retaining Wall has been subjected to significant erosion which has resulted in rills, outwash of portions of the retained soils, and partial undermining of the solider piles for approximately two-thirds of the wall length. CEC understands the Client placed quick setting foam behind the wall as a measure to backfill outwashed portions of the retained material and reduce the potential for additional erosion from surface water.

3.2 Proposed Slope Remediation: The proposed remediation will use a combination of site grading, construction of soil nails with shotcrete facing, and placement of gabion baskets to stabilize the slope. As part of stabilizing the slope, the existing retaining wall will be removed, and the slope flattened. This will require a staged deconstruction of the existing Retaining Wall to maintain stability of the slope during the staged excavation and installation of the proposed soil nails.

CEC provided two design alternatives for stabilizing the slope between the end of the existing Retaining Wall and the east property line. Alternative 1 includes a concept to end the soil nail facing about 6.5- feet from the property line and install gabion baskets adjacent to the east property line to improve the stability of the slope in this area and keep all improvements within the 51 Harborview Road property. Alternative 2 includes a concept to extend the soil nails into the east abutter's property with the abutter's permission. Both alternatives are shown in the drawings included in Attachment I.

3.3 Subsurface Investigation and Laboratory Testing: CEC subcontracted Soil X Corporation (Soil X) to drill one test boring at the site on June 28, 2023, to evaluate the subsurface conditions. Due to access restrictions, the test boring (Test Boring B-1) was performed at the front of the property. The ground surface elevation at the test boring location was approximate Elevation 58', or approximately 5-feet above the top of the Retaining Wall elevation.

Soil X sampled the soil zone using hollow-stem auger and split-spoon sampling methods in general accordance with the standard penetration test (SPT) outlined in ASTM D1586. Soil samples were collected at approximate 3-foot center-to-center intervals from at each test boring. A split-spoon sampler is a 2-inch outside-diameter (OD) tube that captures soil material inside when driven below ground. Upon retrieval, the sampler is split open for removal and identification of the captured soils. The SPT consists of driving a split-spoon sampler through soil using a 140-pound hammer freely falling a distance of 30 inches and recording the number of blows required to drive the split-spoon sampler through three successive 6-inch increments. The sum of the number of blows required to drive the split-spoon sampler through the second and third increments is the N-value of the soil. Soil N-values are commonly used to estimate soil density, compressibility, and shear strength. The test boring extended to approximately 30.1-feet below the existing ground surface (bgs).

CEC encountered existing fill to a depth of approximately 3-feet bgs, then glacial till to the bottom of the test boring. CEC defines existing fill as soil derived from natural soil, bedrock, or processed materials that were placed by artificial methods, such as construction, waste disposal, or dumping. The existing fill sampled consisted of loose silty sand. Glacial till is soil deposited by and underneath a glacier, generally consisting of a heterogeneous, unstratified mixture of clay, sand, gravel, and boulders. The glacial till encountered primarily consisted of very dense silty sand with gravel.

CEC subcontracted Thielsch Engineering, Inc. to perform laboratory material properties testing on select samples of glacial till from Test Boring B-1 (Sample S-4, 15-16.4' bgs) and surficial bulk samples (Samples GS-1, 0-1' bgs and AS-1, 2-3' bgs) obtained in the vicinity of the Retaining Wall. Laboratory testing included ASTM D2216 (moisture content), ASTM D6913 (particle size distribution), ASTM G57 (soil resistivity), ASTM G51 (pH), and ASTM D4327 (sulfate and chloride) tests. The tested samples classified as SP (poorly graded sand with gravel) and SM (silty sand with gravel; clayey silty sand with gravel) according to the Unified Soil Classification System (USCS). Moisture contents of the samples ranged from 1.9% to 10.1%. Samples GS-1 and AS-1 classified as non-plastic. The sample obtained from Test Boring B-1 visually classified as plastic, however, Atterberg limits testing was not performed. Fines contents of the samples ranged from 1.9% to 41.0%. Chloride, sulfate, and pH contents measured in Sample GS-1 were 16 mg/L, 13 mg/L, and 9.1, respectively. Electrical resistivity testing performed on this sample yielded resistivities of 33,600 Ohm-cm and 17,400 Ohm-cm for the as-received and saturated conditions, respectively. Attachment 8 includes the complete laboratory testing results.

4.0 MATERIAL PARAMETERS

The parameters used for the various materials modeled in the analyses represent the effective strength parameters and are based on the data obtained from the test boring information, laboratory testing, visual observation of the landslide geometry and conditions, and our slope stability back analysis.

Existing Fill behind the Retaining Wall (Existing Fill): CEC defined the material properties for the existing fill placed behind the Retaining Wall based on assumed values typical of the material gradation reflected in the laboratory testing. CEC also assumed the material is relatively use. Therefore, values typical of loose to medium dense silty sand were utilized (reference 3).

Colluvium: CEC defined the existing colluvium soils towards the bottom of the slope based on the gradation laboratory test results from the Glacial Till soils, with the assumption that the material is relatively loose from previous disturbance.

Glacial Till: CEC defined the material properties for the glacial till based on the back-analysis, laboratory testing, and empirical correlations from SPT N-values.

Riprap: CEC defined the proposed riprap material based on the gradation/weight requirements of Dumped Riprap in accordance with Table M2.02.2-1 of the Massachusetts DOT Standard Specifications for Highways and Bridges, 2023 Edition.

Gabion Stone: CEC defined the proposed gabion stone based on typical values for loose gravel (reference 3).

Leveling Pad: CEC defined the proposed leveling pad which would be placed below the gabion baskets based on the gradation of MassDOT Processed Gravel.

The material strength properties utilized in our slope stability and soil nail analyses are shown in Table 1 below. Tables 2 – 5 include the material properties of the components of the soil nails and facing.

Table 1 – Material Strength Parameters

Material	Unit Weight (pcf)	Angle of Friction (degrees)	Cohesion (psf)	Nominal Bond Strength (psi)
Existing Fill	130	32	0	1.5
Colluvium	120	32	0	--
Glacial Till	135	36	50	20
Riprap	120	45	0	--
Gabion Stone	120	35	0	--
Leveling Pad	140	38	0	--

Table 2 – Soil Nail Parameters

Soil Nail	Nail Diameter (inch)	Borehole Diameter (inch)	Grout Compressive Strength (psi)	Steel Yield Strength (ksi)
#8 Grade 75 All-Thread Rebar	1.00	4	4,000	75

Table 3 – Bearing Plate Parameters

Item	Dimensions (inch)			Hole Diameter (inch)	Steel Yield Strength (ksi)
	Width	Height	Thickness		
Bearing Plate	8	8	0.750	1.5	50

Table 4 – Bearing Plate Stud Parameters

Item	No. per bearing plate	Head Diameter (inch)	Head Thickness (inch)	Length (inch)	Shaft Diameter (inch)	Spacing (inch)	Tensile Strength (ksi)
Bearing Plate Studs	4	1.25	0.380	5	0.750	5	65

Table 5 – Shotcrete Facing Parameters

Shotcrete Facing	Thickness (inch)	Shotcrete Compressive Strength (psi)	Welded Wire Mesh Reinforcement	Vertical Waler Reinforcement[1]	Horizontal Waler Reinforcement[1]	Reinforcement Yield Strength (ksi)
				Type – Length (L) – Spacing (S)		
Initial	4	4,000	4x4 W4.0x4.0	#4 Rebar L = 3 feet S = 12-inch c.c.	#4 Rebar L = 3 feet S = 12-inch c.c.	60
Final	8	4,000	--	#4 Rebar L = continuous S = 12-inch c.c.	#4 Rebar L = continuous S = 12-inch c.c.	60

1. Initial shotcrete facing layer includes two vertical and two horizontal waler bars at each soil nail.

5.0 DESIGN CONSIDERATIONS AND ASSUMPTIONS

CEC utilized the following design considerations and assumptions to perform the analysis.

5.1 Back-Analysis on Existing Conditions:

- To develop strength parameters for the Glacial Till soils, CEC performed a back analysis based on the slope to the west of the site.
- The existing slope to the west of the site is vegetated and appears stable. It slopes from approximate El. 63 feet to about El. 20 feet on an approximate 1.6H:1V grade. An approximately 5-foot-high stone revetment is present at the toe of the slope with a beach beyond.
- CEC considered that the slope to the west of the site is stable and selected this slope due to its consistent geometry in the out of plane (i.e. east to west) direction.

5.2 Soil Nail Construction:

Installation of the proposed soil nails will involve staged deconstruction/excavations. Up to four rows of soil nails will be installed in the area shown on Attachment 1. Towards the west and east end of the soil nail

alignment, the height will decrease to match the re-graded slope. The proposed soil nail elevations, inclinations, and embedment depths are described herein and listed on Table 6 in Section 6.2. The soil nails will be spaced 4-feet center-to-center (c.c.) vertically and 4-feet c.c. horizontally, with the upper soil nail row positioned at approximate Elevation 52. The staging will consist of performing excavations to approximately 2-feet below the proposed soil nail elevations; drilling, installing soil nail tendons, and backfilling the boreholes with grout; and applying an initial shotcrete facing within a 2-day period following the excavations for each stage. After completing the final excavation stage, a final shotcrete facing layer will be applied over the entire soil nail array. The proposed soil nails will have a 15-degree batter with the top of the facing positioned approximately 4-feet behind the existing Retaining Wall. The proposed soil nails will also incorporate drainage strips at the rear of the shotcrete facing and weep holes to reduce the potential for hydrostatic pressures behind the facing. The drainage strips will tie into a riprap buttress that will be installed at the bottom of the facing, with erosion control plantings installed beyond the buttress.

Slope Preparation: During soil nail construction, the temporary excavations will not exceed 4-feet before application of the temporary shotcrete facing. Excavation for the next row of soil nails will not proceed until the shotcrete facing has adequately cured. The contractor performing the work will stage the deconstruction of the existing Retaining Wall to maintain temporary stability during installation of the soil nails.

5.3 Gabion Basket Construction:

The gabion baskets construction will utilize of 4mm galvanized steel wire mesh baskets with dimensions of 3'x3'x3' (length x width x height). Each row of baskets will be stepped back 6-inches from the front face of the lower row. The gabion baskets will be installed perpendicular to and in front of the slope stabilized using soil nails to reduce the height of the temporary excavation (see Attachment 1 for additional details). The conceptual design shows the soil nail installation being constructed from approximate Elevation 53' to Elevation 44' followed by installing gabions between approximate Elevation 41' to Elevation 50'. The alignment of the gabion baskets will be perpendicular to the soil-nail-stabilized slope for a distance of about 12 feet, then returning the gabion baskets parallel to the soil nails. This will allow regrading of the top of the slope where existing grades near the property line are steeper than 1:1. Construction of the gabion baskets will generally result in temporary excavation heights of around 3 to 8 feet at the rear of the baskets. The total height of the gabion baskets will range from 3 to 9 feet with the embedment of the lowest row ranging from 1 to 3 feet. Refer to Attachment 1 for additional details.

6.0 ANALYSIS METHODOLOGY

CEC performed the analyses for this project in four general stages. The first stage involved performing a back analysis to estimate the material properties of the glacial till based on the adjacent stable slope geometry, subsurface conditions, and groundwater conditions for the existing slope. The back-analysis consisted of iteratively modifying the material strength properties for the glacial till to obtain a conservative factor of safety of the stable slope to the west of the site.

The second stage involved the dimensioning of the proposed soil nail layout utilizing SNAIL geotechnical engineering software developed by the California Department of Transportation (Caltrans). The SNAIL software evaluates the suitability of the reinforcing elements for the soil nail and shotcrete facing components

of the system. CEC selected input parameters regarding soil properties, slope geometry, and the system components based on the information provided herein.

The third stage of the analysis was a global stability analysis. The objective of this analysis was to evaluate the length of the soil nails regarding the overall stability of the slope. CEC performed the global stability analysis using slope stability software Slide Version 9.0 to calculate the minimum factor of safety (FS) for our anticipated critical scenario represented by Cross Sections A-A as shown on the Conceptual Design. The program used 2D limit equilibrium methods to determine the minimum FS. CEC utilized a conservative non-circular failure analysis to determine the minimum FS within the observed failure limits. Our analysis used the Spencer's Method considering a Cuckoo, non-circular search with optimization to calculate all FS. During the analysis process, the soil nail geometry was iteratively modeled to determine the combination of features that resulted in a FS of 1.5 or greater.

The fourth and final stage of the analysis included performing stability analyses near the east property line where it is necessary to transition into the existing property and therefore, soil nails cannot be utilized. In this area, CEC is proposing the upper portion of the slope be supported with stacked gabion baskets.

6.1 Back Analysis (Existing Conditions)

CEC performed a global stability analysis on the existing stable slope to the west of the site as a basis to develop strength parameters for the glacial till present at the site. A back analysis was also considered along the steep slope at the east property line, but due to inconsistent geometry in the out of plane dimension, the west slope was considered more reliable. It is CEC's opinion that the existing conditions factor of safety for the existing slope to the west of the site should be above 1.0. CEC evaluated the slope based on strength parameters equal to a cohesion of 50 psf and a friction angle of 36 degrees, which resulted in a factor of safety of 1.17.

While groundwater was not encountered in the boring performed on the property, for conservatism CEC calculated a groundwater level for the back analysis by utilizing the Frimpter method. CEC selected two index wells located in Hanson and Dover, MA that were installed in a similar geological setting to the site to estimate the probable high groundwater level at the site. The probable high groundwater level at the site was determined to be at El. 29.3 based on this analysis. In the stability model, CEC assumed the phreatic surface was a straight line between El. 29.3 and the FEMA flood zone El. 20 at the bottom of the slope. A worksheet utilized to calculate the probable high groundwater level is provided in Attachment 3 along with the results of CEC's back analysis. The locations of the stability cross sections are shown in Attachment 2.

6.2 SNAIL Evaluation

CEC utilized the geometry depicted on the cross sections and material parameters discussed in Section 4.0 as the basis for the site-specific subsurface conditions considered in the SNAIL evaluation. With this combination of inputs, the software checks a variety of potential failure modes. Snail analyzes soil nail system stability based on force limit equilibrium. The software generates bi-linear surfaces through the toe of the facing, or tri-linear surfaces which pass below the toe and daylight in front of the facing, to calculate and search for the minimum factor of safety of the selected analysis scenario. The software evaluates pullout along the length of the soil nail; yield of the soil nail; punching shear, flexure, and stud tensile of the facing; flexure and bearing stress of the

bear plate; and bearing stress of the facing shotcrete with regard to the bearing plate. CEC's analysis also evaluated the slope FS for the various construction stages correlating to temporary excavations.

CEC also input approximate loads from the columns supporting the deck above the top of the slope. Three rows of columns exist at the site; the first row is about 5 feet back from the existing soldier pile and lagging wall and will be underpinned by the contractor before the soil nails are installed. The second row of columns is about 20 feet back from the first row of columns and was considered in the analysis. The third row of columns is beyond the limits of the soil nails and was not included. CEC assumed a deck load of 55 psf between dead and live loads, and calculated the approximate tributary area based on the column spacing. Using a 10-inch diameter concrete pier, CEC estimated 12,664 psf for the deck load per column.

The proposed slope considers the soil nail facing with a 15-degree batter, which involves an excavation extending approximately 4-feet behind the top of the existing Retaining Wall. The soil nail system utilizes a nail layout spaced at 4-feet c.c. vertically by 4-feet c.c. horizontally, with the upper row of soil nails starting approximately 1-foot below the proposed ground surface. The shotcrete facing for the soil nails extends from the ground surface, at approximate Elevation 53', to approximate Elevation 38'at its lowest point. The soil nail installation considers a 4-inch borehole and the grout-to-ground bond strengths listed in Table 1 in Section 4.0. The proposed soil nail lengths based on the critical section are shown in Table 6 below.

Table 6 – Soil Nail Elevations, Embedment, and Inclination

Soil Nail Row	Approximate Soil Nail Elevation	Embedment Length (ft)	Soil Nail Inclination (degrees)
1	52	35	15
2	48	25	10
3	44	20	10
4	40	20	10

The FHWA minimum recommended factor of safety values are provided in in Table 7 below, and each criteria was met in the SNAIL analysis. Full SNAIL outputs are included in Attachment 5.

Table 7 – FHWA Minimum Recommended Safety Factors

Failure Mode	Factor of Safety
Overall	1.5
Short Term Conditions	1.3
Pullout Resistance	2.0
Tendon Tensile Strength (Grades 60 and 75 Steel)	1.8
Facing Flexure	1.5
Facing Punching Shear	1.5
Headed Stud Tensile Strength	2.0

6.3 Global Stability Analysis – Soil Nails

CEC utilized the geometry depicted on the cross sections and material parameters discussed in Section 4.0 and the design consideration discussed in Section 5.0 as the basis for the site-specific subsurface conditions considered in global stability analysis.

Soil Nails: In addition to the geometry components of the proposed soil nail arrangement, which are shown on the geotechnical cross section, soil nail inputs required in the global stability analysis include the force application method, tensile force orientation, bond strength per linear foot of soil nail, the tensile strength of the soil nail, the shear strength of the soil nail, and the plate capacity at the soil nail head. CEC selected the active force application method for use in the analysis. In accordance with generally accepted practice when modeling supports in slope stability programs using the active force application method, the input value for the tensile strength of the soil nail is its ultimate strength divided by a factor of safety of 1.8 per FHWA Soil Nail Reference manual (Attachment 9). The tensile force orientation was selected as parallel to the reinforcement as significant deformation would have to take place for the force to be oriented in another manner. The plate capacity utilized in the stability model was selected based on capacity of the shotcrete facing determined in the SNAIL analysis. CEC conservatively used the facing capacity of the temporary condition for all modeled scenarios.

In addition, CEC utilized an assumed foundation load of 2,000 psf from the existing house set back about 37-feet from the slope crest and a 12,664 psf point load in the location of the second row of existing columns, which is the approximate load per column. This load was modeled conservatively considering the column is not continuous in the out of plane dimension. The third row of columns is immediately offset from the foundation load and was not considered in the analysis. The first row of columns was not considered in the global stability analysis because these columns will be underpinned.

The results of CEC's global stability analysis for the soil nails are provided as Attachment 4. The location of the global stability cross section is shown in Attachment 2.

6.4 Stability Analyses for Gabion Baskets near East Property Line

CEC utilized the geometry for the gabion baskets shown on sheet C800 in Attachment 1. CEC also utilized the material parameters discussed in Section 4.0 and the design consideration discussed in Section 5.0 as the basis for the site-specific subsurface conditions considered in the internal and global stability analyses for the gabion baskets.

CEC performed a calculation to determine the frictional resistance of the gabion basket steel mesh and the underlying subsoil. CEC's calculations conservatively assumed the gabion stone would not extrude through the steel mesh, and therefore, only considered the steel mesh-to-subsoil frictional resistance as part of our calculation. CEC determined a steel mesh-to-subsoil friction coefficient of 0.90 based on the steel mesh diameter, opening size, subsoil friction angle, and steel to soil friction angle between dissimilar materials. For the purposes of our calculation, CEC conservatively reduced the frictional coefficient to 0.70 to better represent typical values for sliding at the base of retaining structures.

CEC utilized SRwall to evaluate sliding, overturning, bearing capacity, and the internal stability for the gabions. Typically, gravity block retaining structures develop a unit-unit interface friction that depends on the applied normal force and friction angle between the blocks. However, the infilled weight of one gabion basket would achieve a normal force that would exceed the weld shear strength. Therefore, our analysis utilized a unit-unit interface shear capacity between the gabion baskets equivalent to the weld shear strength for the welded wire mesh. According to ASTM A974 "Standard Specification for Welded Wire Fabric Gabions and Gabion Mattresses", the average weld shear strength is generally around 70% of the breaking strength of the wire (i.e. ultimate tensile strength). Other manufacturer recommendations suggest the minimum shear weld shear strength should be at least 60% of the ultimate tensile strength. CEC utilized a unit-unit shear strength of 880 lb/ft for the analysis.

CEC then utilized Slide Version 9.0 to evaluate the global stability of the gabion baskets. The global stability analysis assumed failure surfaces could only propagate from below the gabion baskets. The results of the SRwall and global stability analysis are presented in Table 9, and the analysis outputs are included in Attachment 6.

7.0 CALCULATED FACTORS OF SAFETY

The following table summarizes the results of the global slope stability analyses and includes a global stability FS for both the back-analysis based on existing conditions and the soil nails.

Table 8 – Back Analysis and Soil Nail Global Stability Factors of Safety

Cross Section	Analysis	Global Minimum Calculated FS	SNAIL Analysis Calculated FS	Minimum Target FS
West Slope	Existing Conditions – Back Analysis	1.17	--	1.0
Cross Section A-A	Proposed Conditions	1.67	1.54	1.5
	Stage 1 – Excavation	1.03	--	1.0
	Stage 1 – Excavation – Temporary Conditions	1.33	1.93	1.3
	Stage 2 – Excavation	1.26	--	1.0
	Stage 2 – Excavation – Temporary Conditions	1.69	1.81	1.3
	Stage 3 – Excavation	1.60	--	1.0
	Stage 3 – Excavation – Temporary Conditions	1.79	1.60	1.3
	Stage 4 – Excavation	1.63	--	1.0
	Stage 4 – Excavation – Temporary Conditions	1.85	1.54	1.3

The following table summarizes the results of the stability analyses performed for the proposed gabion baskets near the east property line.

Table 9 – Gabion Baskets Calculated Factors of Safety

Cross Section	Analysis	Global Minimum Calculated FS	Minimum Target FS
East Gabion Baskets	Bearing Capacity	16.6	2.5
	Sliding Resistance	1.8	1.5
	Overturning	2.2	2.0
	Global Stability (East to West)	1.51	1.5
	Global Stability (North to South)	1.15	1.5
	Global Stability (North to South) with Pile Support	1.51	1.5

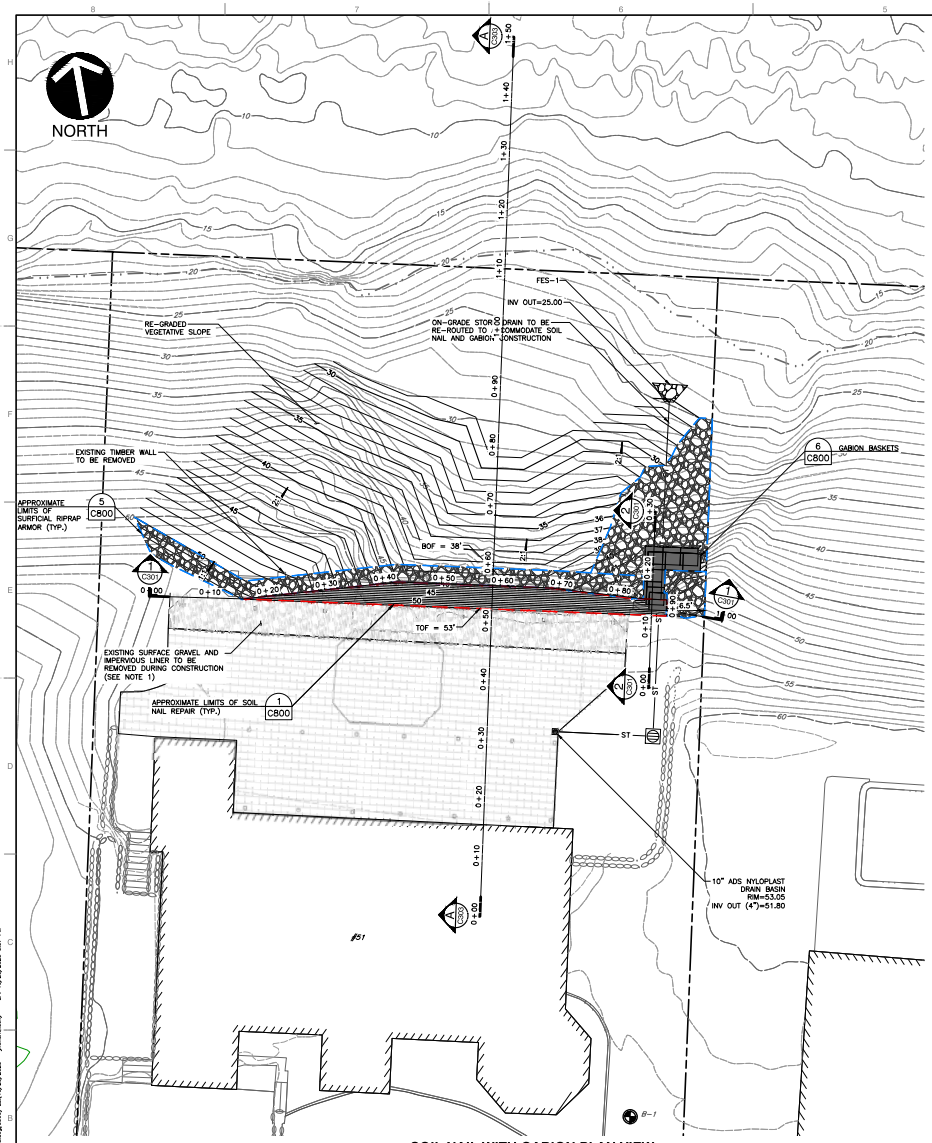
Note the Global Stability FS for the north to south cross section across the proposed gabion baskets is less than the target value of 1.5. To increase the global stability factor of safety, additional support will be required. CEC performed additional analyses to determine a lateral pile capacity that would be required to increase the global stability factor of safety to at least 1.5 and determined that an 11-kip lateral capacity pile spaced every 3-feet along the base of the gabion baskets would result in a global stability factor of safety greater than 1.5. CEC discussed vertical support options with a specialty contractor; installation of vertical soil nails from the top of the slope may be a feasible option to increase the global stability of the slope near the east abutter. CEC will work with the selected contractor to design the contractor's chosen vertical support to increase the global stability factor of safety of the gabion baskets.

8.0 Limitations

This calculation package is for conceptual design purposes only. The proposed infrastructure has not been approved and the final design may change with respect to the concepts described in this calculation package and attachments. CEC will update the calculation package as required to incorporate changes that are made to the proposed slope improvements as the project advances into the final design phase.

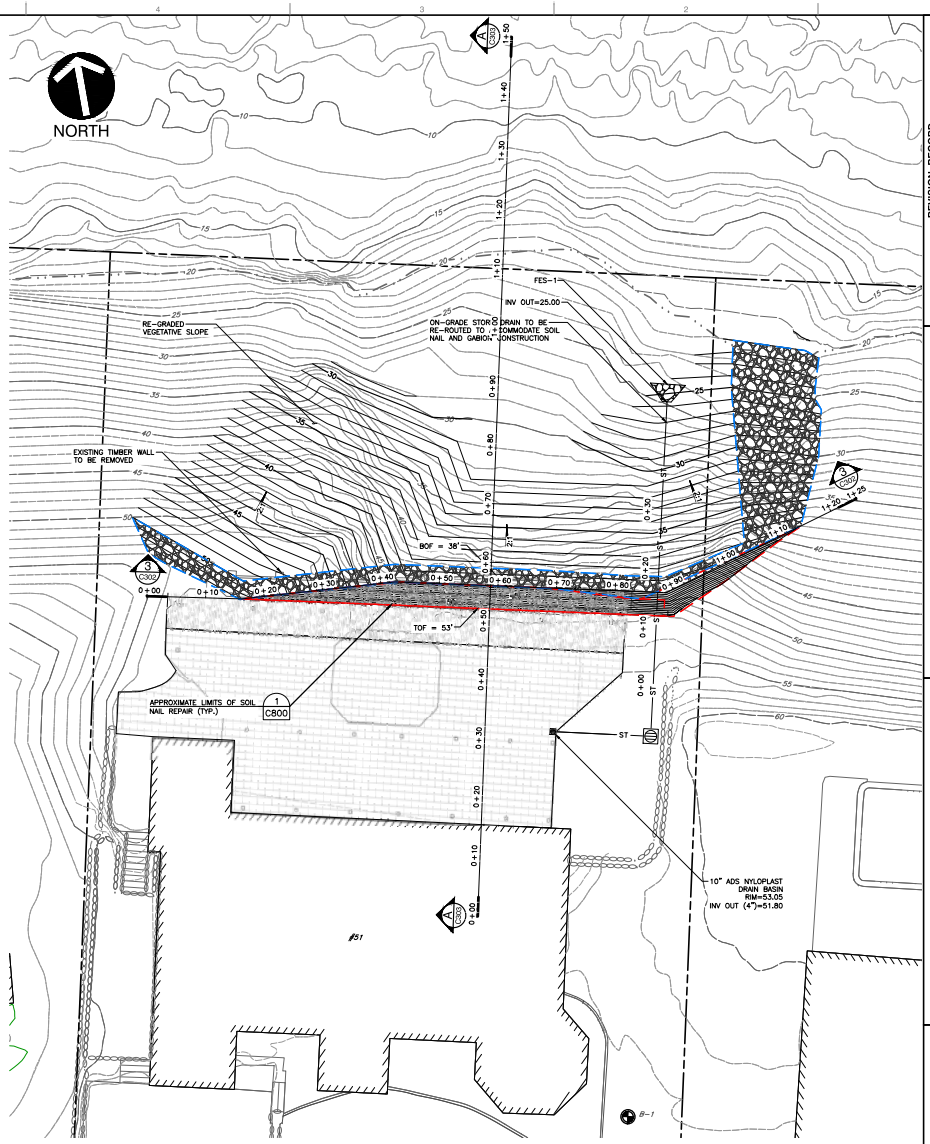
ATTACHMENT 1

CONCEPTUAL REMEDIATION DESIGN DRAWINGS



SOIL NAIL WITH GABION PLAN VIEW (OPTION 1)

SCALE IN FEET
0 10 20



SOIL NAIL PLAN VIEW (OPTION 2)

SCALE IN FEET
0 10 20

NOTE

1. REMOVE EXISTING SURFACE GRAVEL AND IMPERVIOUS LINER BEHIND EXISTING TIMBER WALL DURING CONSTRUCTION OF THE SOIL NAIL WALL

REFERENCE

1. FIELD SURVEY BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC. DATED 06/22/2023.

LEGEND

EXISTING SUBJECT PROPERTY LINE	PROPOSED INDEX CONTOUR
EXISTING INDEX (MAJOR) CONTOUR	PROPOSED INTERMEDIATE CONTOUR
EXISTING INTERMEDIATE (MINOR) CONTOUR	APPROXIMATE EXTENT OF RIPRAP SURFACE REPAIR
EXISTING FEMA FLOOD ZONE	APPROXIMATE EXTENT OF PROPOSED SOIL NAILS
EXISTING CURB	TOF= TOP OF FACING BOF= BOTTOM OF FACING
EXISTING EDGE OF PAVEMENT	SOIL TEST BORING
EXISTING STRUCTURE	
PROPOSED STORM PIPE	

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REVISION RECORD

NO.	DATE	DESCRIPTION

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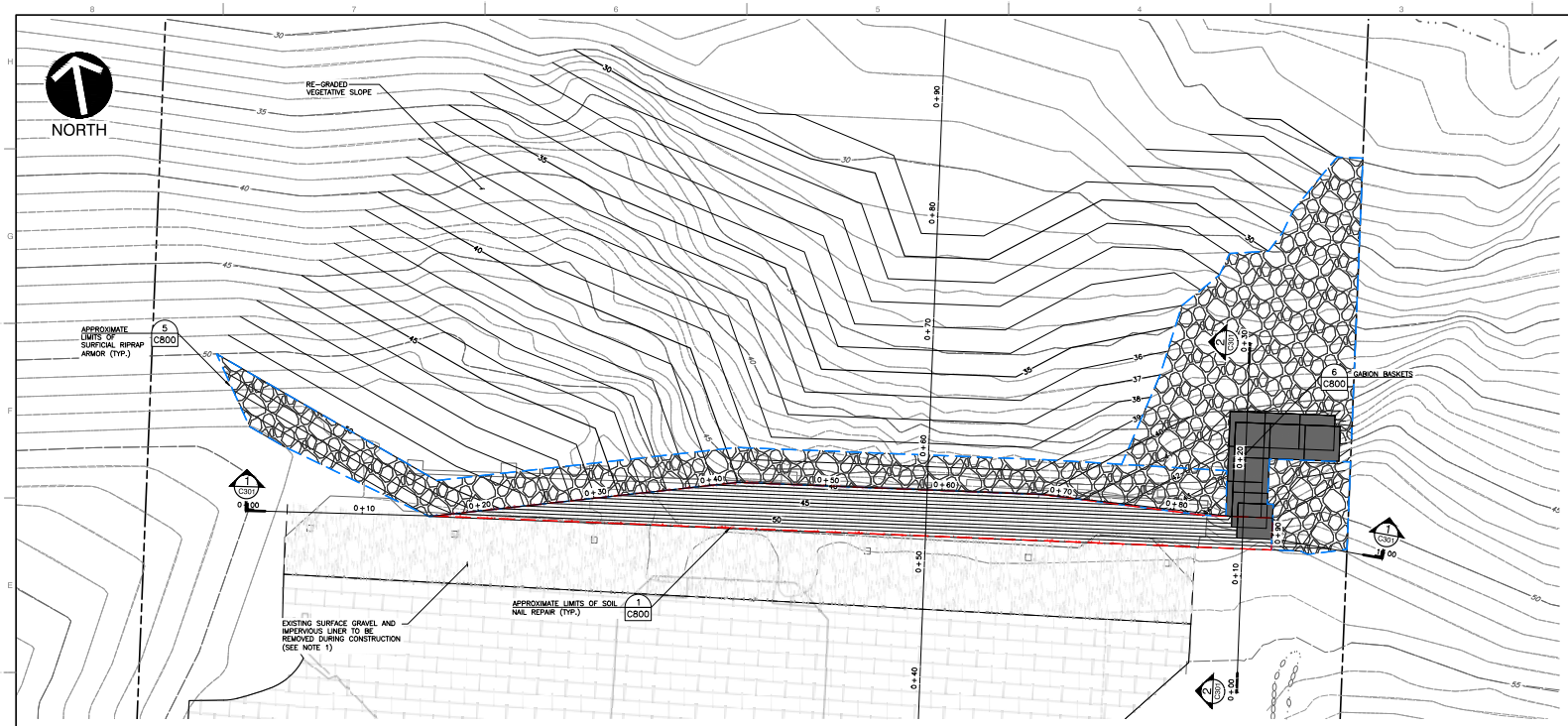
THOMAS P. FITZGERALD
51 HARBORVIEW ROAD
HULL, MASSACHUSETTS 02045

OVERALL PLAN VIEW

DATE:	OCTOBER 2023
DWG SCALE:	AS SHOWN
DRAWN BY:	JAH
CHECKED BY:	TES
PROJECT NO:	324-991
APPROVED BY:	KPS

DRAWING NO.: C300

P:\330-0001\324-0911-2400\dwg\0911\324991-0911-C300-MasterPlans.dwg(C300) LAYOUT(Layout) - LP: 10/20/2023 3:57 PM

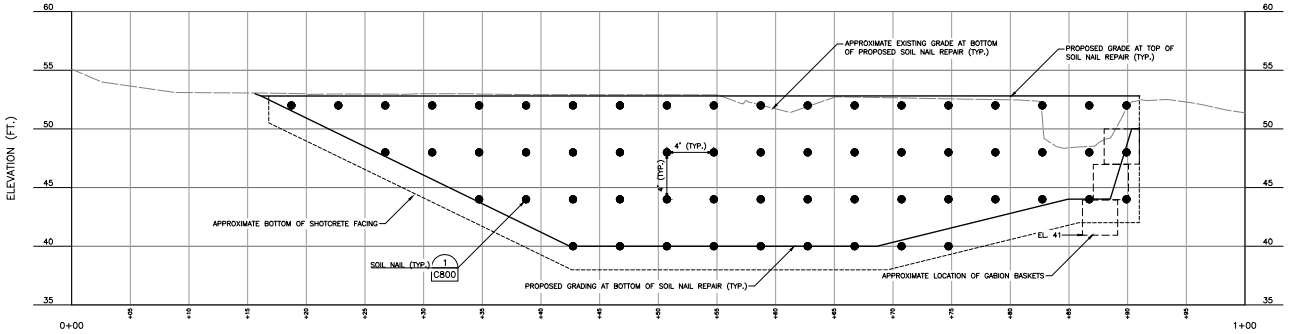


SOIL NAIL WITH GABION PLAN VIEW (OPTION 1)

SCALE IN FEET
0 5 10

LEGEND

- EXISTING SUBJECT PROPERTY LINE
- 100 EXISTING INDEX (MAJOR) CONTOUR
- EXISTING INTERMEDIATE (MINOR) CONTOUR
- EXISTING FEMA FLOOD ZONE
- EXISTING STRUCTURE
- 35 PROPOSED INDEX CONTOUR
- PROPOSED INTERMEDIATE CONTOUR
- APPROXIMATE EXTENT OF RIPRAP SURFACE REPAIR
- APPROXIMATE EXTENT OF PROPOSED SOIL NAILS
- TOF= TOP OF FACING
  BOF= BOTTOM OF FACING



PROFILE 1

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SCALE IN FEET
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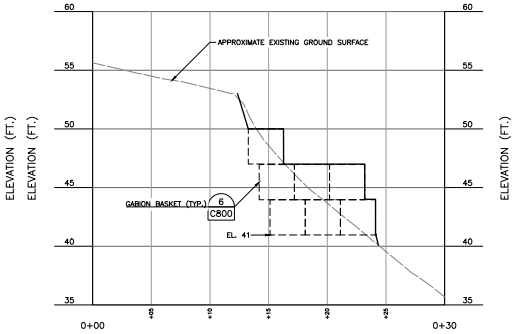


PROFILE 2

SCALE H:1"=5'; V:1"=5'

SCALE IN FEET
0 5 10

LEGEND

- PROPOSED GRADE AT TOP/BOTTOM OF SOIL NAIL REPAIR
- APPROXIMATE EXISTING GRADE AT BOTTOM OF PROPOSED SOIL NAIL REPAIR
- APPROXIMATE BOTTOM OF SHOTCRETE FACING
- GABION BASKET
- SOIL NAIL

REFERENCE

1. FIELD SURVEY BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC. DATED 08/22/2023.

For Review
10/20/2023 4:19:43 PM

REVISION RECORD

NO.	DATE	DESCRIPTION

Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
Ph: 774.501.2176 · 866.312.2024 · Fax: 774.501.2669
www.cecinc.com

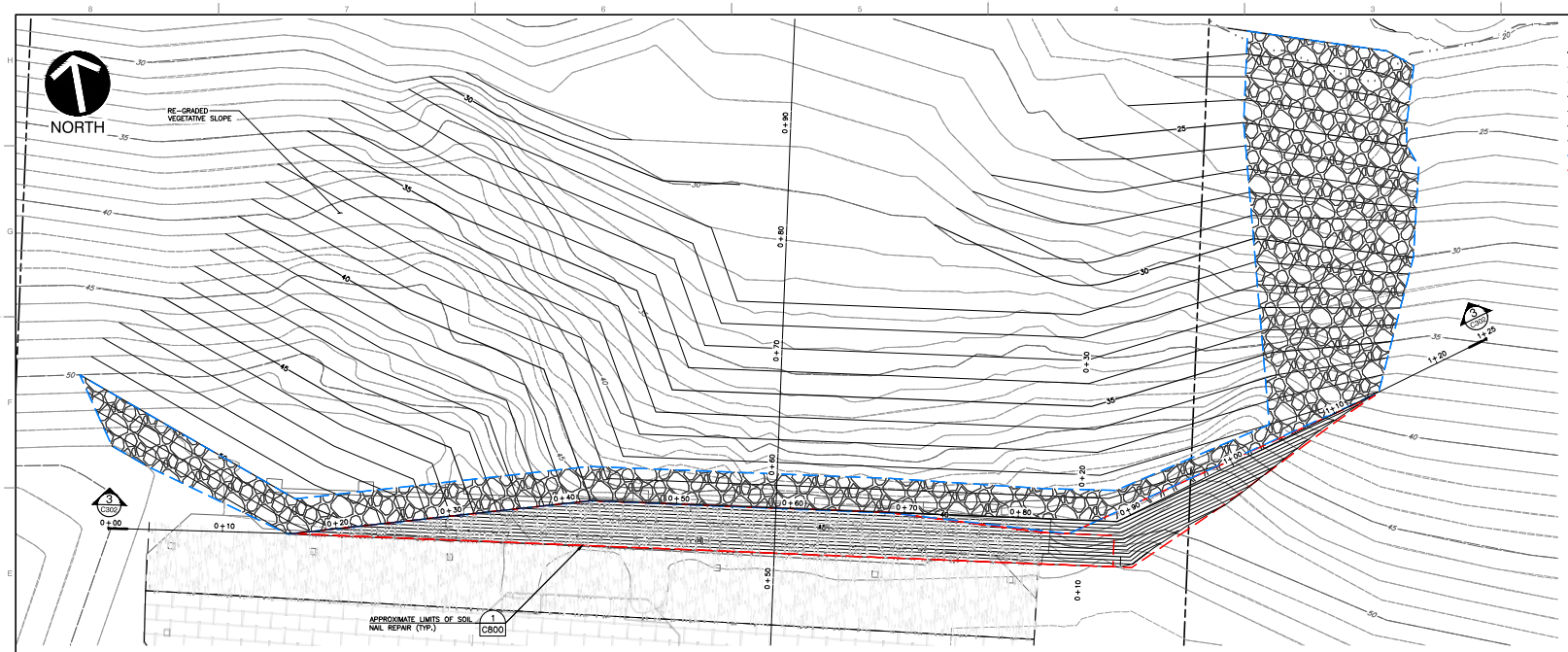
THOMAS P. FITZGERALD
51 HARBORVIEW ROAD
HULL, MASSACHUSETTS 02045

SOIL NAILS WITH GABIONS (OPTION 1)
PLAN AND PROFILES

DATE:	OCTOBER 2023
DWG SCALE:	AS SHOWN
DRAWN BY:	JAH
CHECKED BY:	TES
PROJECT NO:	324-991
APPROVED BY:	KPS

DRAWING NO.: C301

P:\324-991\324-991-C800\dwg\STF\324991-C800-WallPlans.dwg(C301) LAYOUT(Layout) - LP: 10/20/2023 3:57 PM

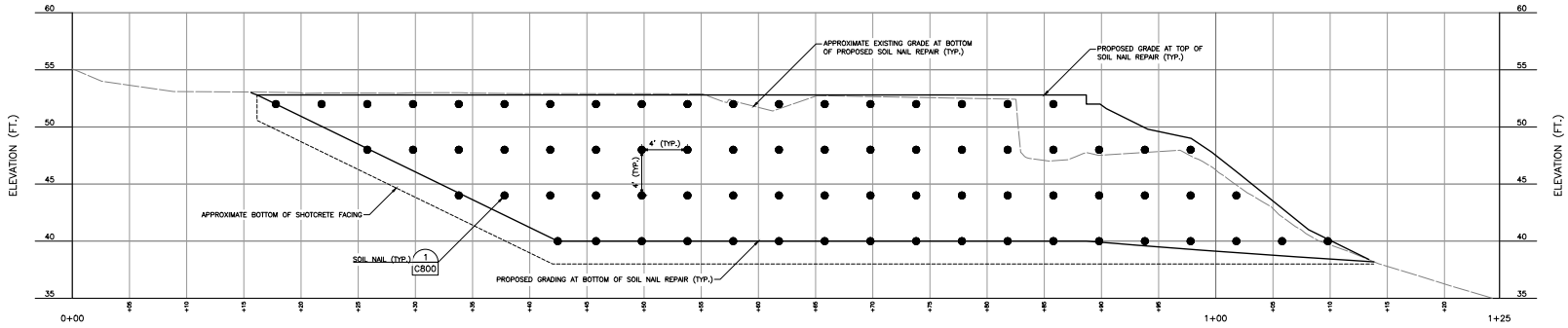


LEGEND

- EXISTING SUBJECT PROPERTY LINE
- 100 EXISTING INDEX (MAJOR) CONTOUR
- EXISTING INTERMEDIATE (MINOR) CONTOUR
- EXISTING FEMA FLOOD ZONE
- EXISTING STRUCTURE
- 35 PROPOSED INDEX CONTOUR
- PROPOSED INTERMEDIATE CONTOUR
- APPROXIMATE EXTENT OF RIPRAP SURFACE REPAIR
- APPROXIMATE EXTENT OF PROPOSED SOIL NAILS

SOIL NAIL PLAN VIEW (OPTION 2)

SCALE IN FEET
0 10 20



PROFILE 3

SCALE H:1"=5'; V:1"=5'

SCALE IN FEET
0 5 10

LEGEND

- PROPOSED GRADE AT TOP/BOTTOM OF SOIL NAIL REPAIR
- APPROXIMATE EXISTING GRADE AT BOTTOM OF PROPOSED SOIL NAIL REPAIR
- APPROXIMATE BOTTOM OF SHOTCRETE FACING
- SOIL NAIL

REFERENCE

1. FIELD SURVEY BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC. DATED 06/22/2023.

For Review
10/20/2023 4:19:54 PM

REVISION RECORD

NO.	DATE	DESCRIPTION

Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
Ph: 774.501.2176 · 866.312.2024 · Fax: 774.501.2669
www.cecinc.com

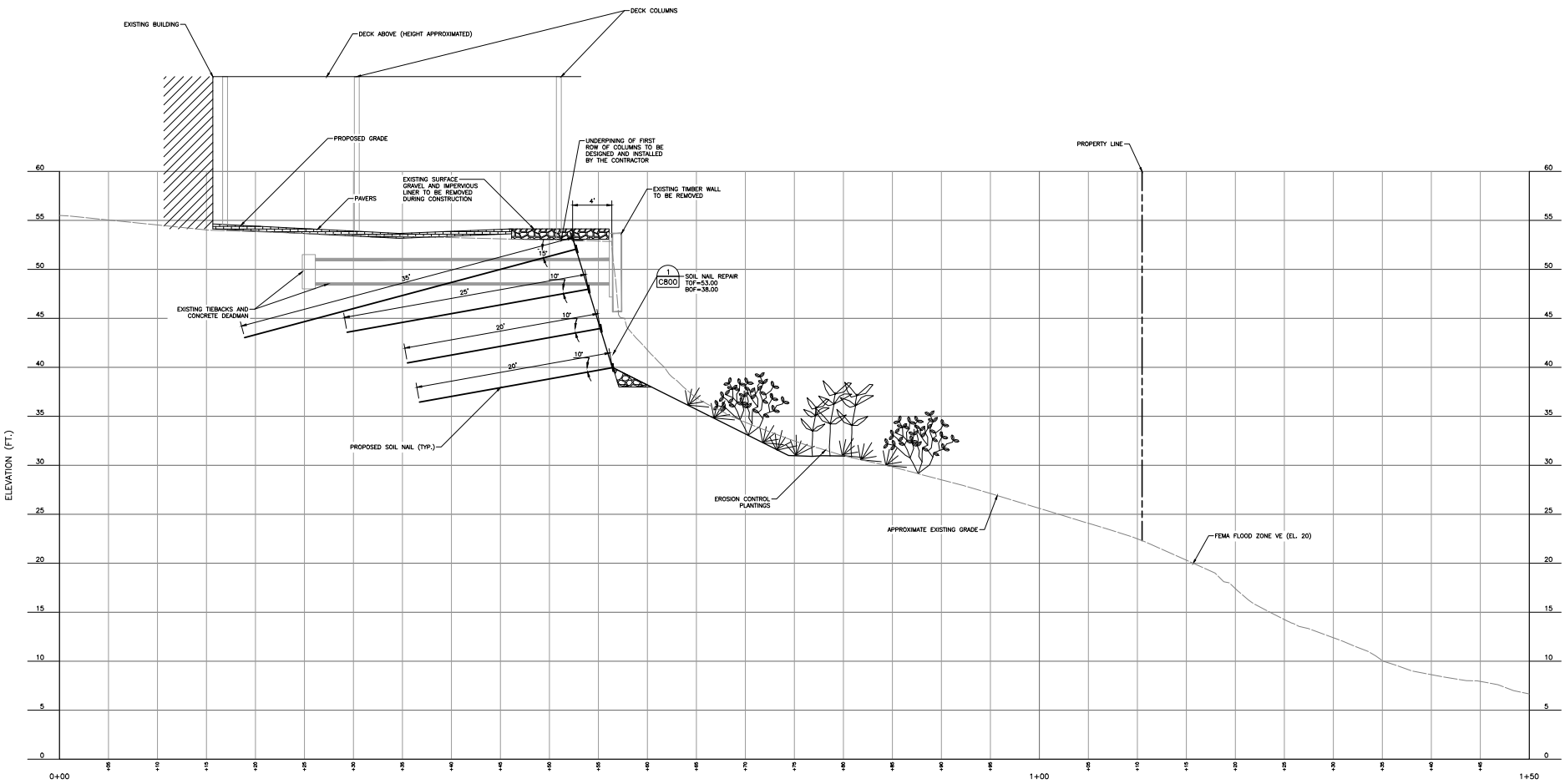
THOMAS P. FITZGERALD
51 HARBORVIEW ROAD
HULL, MASSACHUSETTS 02045

SOIL NAILS (OPTION 2)
PLAN AND PROFILE

DATE:	OCTOBER 2023
DRAWN BY:	JAH
DWG SCALE:	AS SHOWN
CHECKED BY:	TES
PROJECT NO:	324-991
APPROVED BY:	KPS

DRAWING NO.: C302

P:\324-0001\324-991\-C800\dwg\STF\LSA991-STF1-C300-WallPlans.dwg\C302 (3)\10/20/2023 - jhanchinson) - LP: 10/20/2023 5:57 PM



PROFILE A

SCALE H:1"=5'; V:1"=5'

SCALE IN FEET

0 5 10

For Review

10/20/2023 4:20:11 PM

REVISION RECORD		
NO.	DATE	DESCRIPTION

Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
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www.cecinc.com

THOMAS P. FITZGERALD
51 HARBORVIEW ROAD
HULL, MASSACHUSETTS 02045

GEOTECHNICAL CROSS SECTION

DATE:	OCTOBER 2023
DRAWN BY:	JAH
DWG SCALE:	AS SHOWN
CHECKED BY:	TES
PROJECT NO:	324-991
APPROVED BY:	KPS

DRAWING NO.: C303

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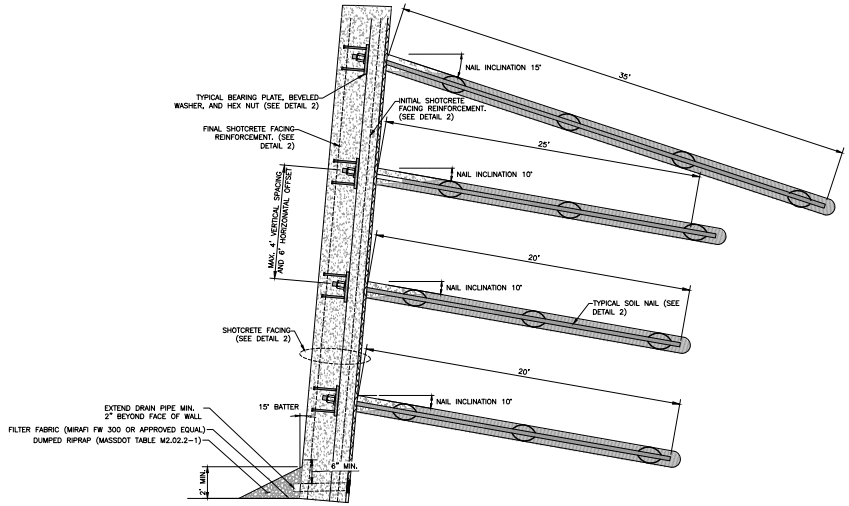
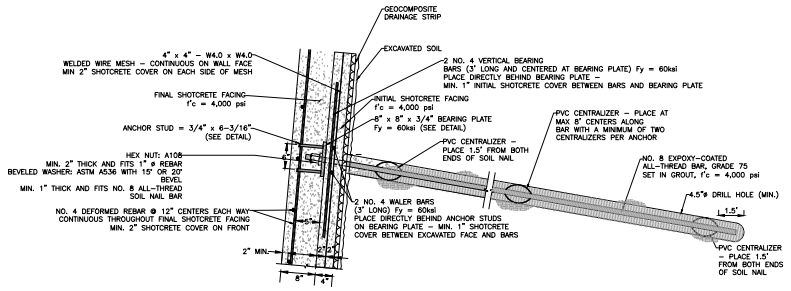
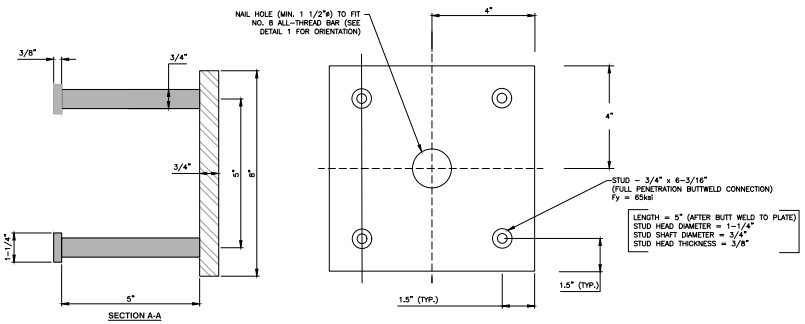


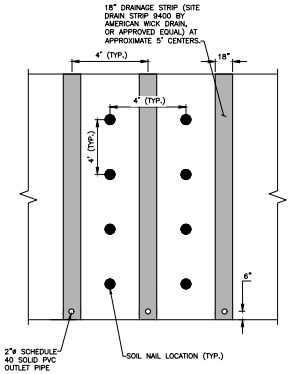
DETAIL 1
SOIL NAIL REPAIR
N.T.S.



DETAIL 2
SHOTCRETE FACING AND SOIL NAIL
N.T.S.

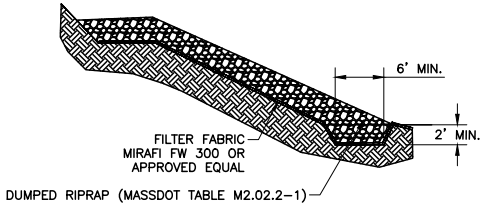


DETAIL 3
BEARING PLATE WITH STUD
N.T.S.



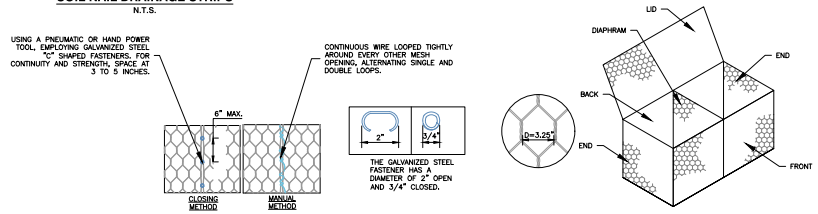
NOTE:
1. SPLICE DRAINAGE STRIPS ACCORDING TO MANUFACTURER'S RECOMMENDATIONS. (12" MIN.)
2. INSTALL ADDITIONAL DRAINAGE STRIPS AT SEEP LOCATIONS AS NECESSARY.

DETAIL 4
SOIL NAIL DRAINAGE STRIPS
N.T.S.



NOTE:
1. ARMOR SLOPE WITH RIPRAP (MASSDOT TABLE M2.02-1) AT A MINIMUM THICKNESS OF 1-FOOT WHERE APPLICABLE FOR EROSION CONTROL

DETAIL 5
SURFICIAL RIPRAP ARMOR
N.T.S.



DETAIL 6
GABION BASKETS
N.T.S.

GENERAL NOTES:

1. ESTABLISH EROSION CONTROL PLANTINGS ON SLOPES WHERE RIP RAP IS NOT PROPOSED. PLANTINGS SHALL BE ESTABLISHED IN ACCORDANCE WITH MEMORANDUM BY WOODS HOLE GROUP ENTITLED '51 HARBORVIEW ROAD, HULL MA - SITE RESTORATION AND REVEGETATION', DATED NOVEMBER 19, 2019.

GABION NOTES:

1. GABIONS SHALL BE CONSTRUCTED OF NON-WELDED (TWISTED) GALVANIZED WIRE MESH AND CONFORM TO ASTM A975. THE USE OF FASTENER RINGS IN THE ASSEMBLY OF THE GABION BASKETS IS ALSO PERMITTED. PROVIDING THE RINGS HAVE AT LEAST THE SAME TENSILE STRENGTH, ZINC COATING, AND SIZE AS THE WIRE USED IN THE BODY OF THE GABION.
2. INSTALL GABIONS IN ACCORDANCE WITH THE DESIGN DRAWINGS AND THE MANUFACTURER'S SPECIFICATIONS.
3. PLACE GABIONS ON A MINIMUM 6-INCH THICK LAYER OF SAND AND GRAVEL (MASSDOT TABLE M1.03.1) COMPACTED TO 95% OF THE MAXIMUM DRY DENSITY) AS DETERMINED BY ASTM D698.
4. FILL MATERIAL FOR GABIONS SHALL CONSIST OF GABION STONE. THE DIMENSIONS OF THE ROCK OR STONE FILLINGS SHALL BE SUCH AS TO PREVENT LOSS OF MATERIAL THROUGH MESH OPENINGS WITH A MINIMUM AMOUNT OF VOIDS.
5. ROCK SHALL BE PLACED IN 12-INCH LIFTS. THE FILL LAYER SHALL NEVER BE MORE THAN 12 INCHES HIGHER THAN ANY ADJOINING CELL.
6. SUFFICIENT HAND MANIPULATION OF THE ROCK SHALL BE PERFORMED TO MINIMIZE VOIDS AND ACHIEVE A MAXIMUM DENSITY OF ROCK IN THE GABION.

For Review
10/20/2023 4:20:21 PM

REVISION RECORD

NO.	DATE	DESCRIPTION

Civil & Environmental Consultants, Inc.
31 Bellows Road · Raynham, MA 02767
Ph: 774.501.2176 · 866.312.2024 · Fax: 774.501.2669
www.cecinc.com

THOMAS P. FITZGERALD
51 HARBORVIEW ROAD
HULL, MASSACHUSETTS 02045

DETAILS

DATE:	OCTOBER 2023
DWG SCALE:	AS SHOWN
DRAWN BY:	JAH
CHECKED BY:	TES
PROJECT NO:	324-891
APPROVED BY:	KPS

DRAWING NO.
C800

P:\330-0001\324-891\-CADD\Dwg\STF\324891-STF1-C800-Details.dwg\C800 LS:(10/20/2023 - Pwadkins) - LP: 10/20/2023 3:42 PM

ATTACHMENT 2

STABILITY CROSS SECTION LOCATION PLAN

P:\320-000\324-891\-CADD\Dwg\GT01\324891-GT01-Slope Stability Exhibit.dwg[1] LS(10/20/2023 - jhendrickson) - LP: 10/20/2023 3:52 PM

EXHIBIT 1

STABILITY CROSS SECTION LOCATIONS

DATE:	OCTOBER 2023	DRAWN BY:	JAH
DWG SCALE:		CHECKED BY:	DRAFT
PROJECT NO:			324-981
APPROVED BY:			DRAFT

THOMAS P. FITGERALD
HARBORVIEW ROAD
SLOPE REMEDIATION
HULL, MASSACHUSETTS

CEC
Civil & Environmental Consultants, Inc.
700 Cherrington Parkway · Moon Township, PA 15108
412-429-2324 · 800-365-2324
www.cecinc.com

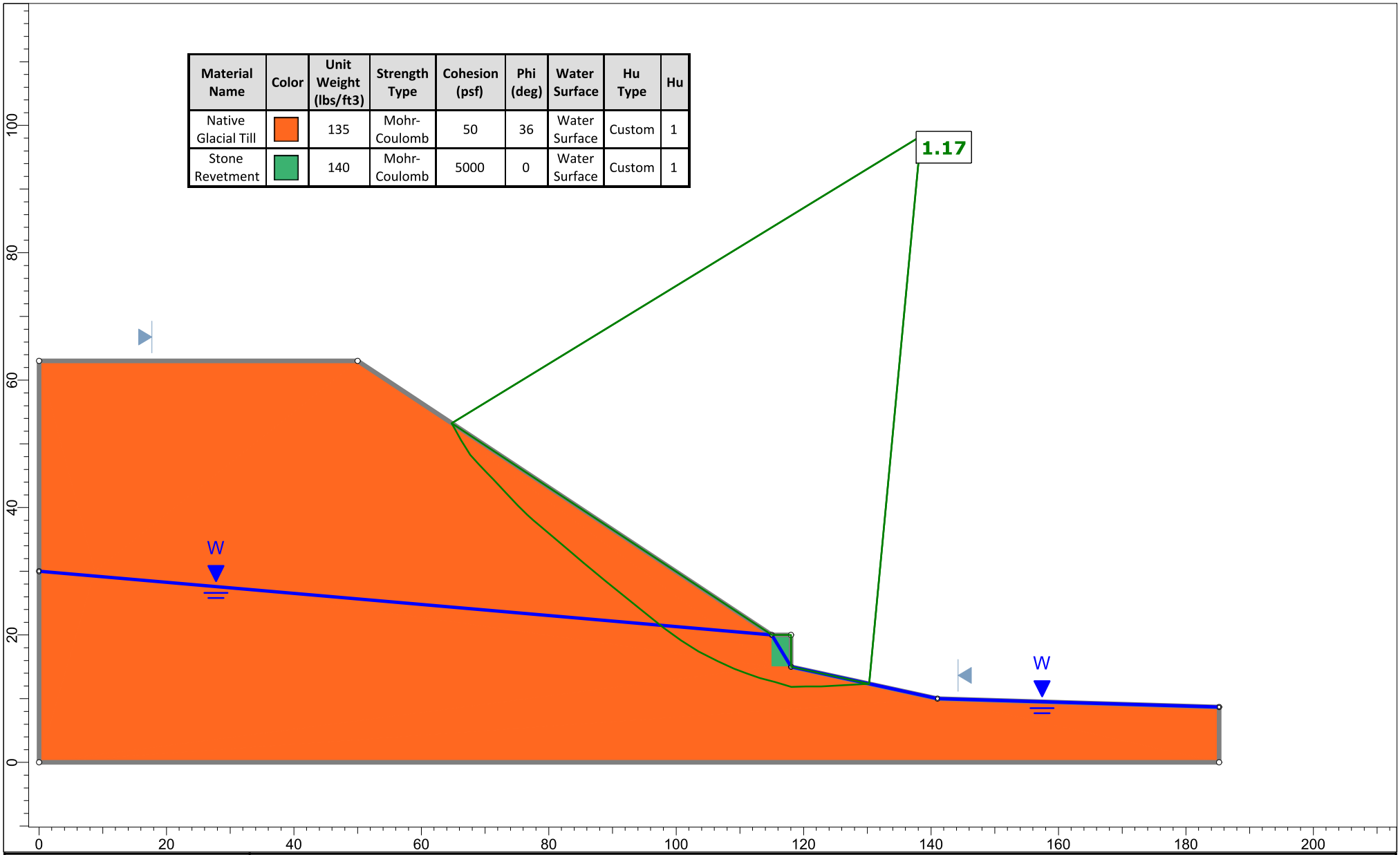
REVISION RECORD

NO	DATE	DESCRIPTION

ATTACHMENT 3

BACK ANALYSIS OUTPUTS

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Native Glacial Till		135	Mohr-Coulomb	50	36	Water Surface	Custom	1
Stone Revetment		140	Mohr-Coulomb	5000	0	Water Surface	Custom	1



Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	West Slope Existing Conditions Back Analysis	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	9/5/23	*File Name*	Till Back Analysis West Slope.slmd

Civil & Environmental Consultants, Inc.

Project Name:	51 Harborview Rd Slope Stabilization	**Date:**	10/3/2023
Project Location:	Hull, MA	**Calculated By:**	MT
Project Number:	324-891	**Checked By:**	TS

FRIMPTER METHOD

Frimpter Equation

$$\frac{S_c - S_h}{Ow_c - Ow_{max}} = \frac{S_r}{Ow_r}$$

S_h	Maximum water level height at site
S_c	Current water level at site
S_r	Probable "range" at the site
Ow_c	Current water level at observation well
Ow_r	Observation well range
Ow_{max}	Maximum water level height at observation well

$$S_h = S_c - \left(\frac{S_r * (Ow_c - Ow_{max})}{Ow_r}\right)$$

Observation Hole/Well #

https://newengland.water.usgs.gov/web_app/frimpter/frimpter.html

Site	MA-HGW 76R HANSON, MA		
Type	Stratified Drift		
Setting	Valley Flat		
Ow_c	4.63	ft	BGS
Ow_r	3.23	ft	BGS
Ow_{max}	2.4	ft	BGS

Site Range

Till	17.0	ft	
Terraces	10.0	ft	
Valley Flat	4.2	ft	
S_r	4.2	ft	BGS

Site Condition

S_c	30.0	ft	BGS
S_h	29.39	ft	BGS

Civil & Environmental Consultants, Inc.

Project Name:	51 Harborview Rd Slope Stabilization	**Date:**	10/3/2023
Project Location:	Hull, MA	**Calculated By:**	MT
Project Number:	324-891	**Checked By:**	TS

FRIMPTER METHOD

Frimpter Equation

$$\frac{S_c - S_h}{Ow_c - Ow_{max}} = \frac{S_r}{Ow_r}$$

S_h	Maximum water level height at site
S_c	Current water level at site
S_r	Probable "range" at the site
Ow_c	Current water level at observation well
Ow_r	Observation well range
Ow_{max}	Maximum water level height at observation well

$$S_h = S_c - \left(\frac{S_r * (Ow_c - Ow_{max})}{Ow_r}\right)$$

Observation Hole/Well #

https://newengland.water.usgs.gov/web_app/frimpter/frimpter.html

Site	MA-DVW 10R DOVER, MA		
Type	Stratified Drift		
Setting	Terrace		
Ow_c	31.42	ft	BGS
Ow_r	5.65	ft	BGS
Ow_{max}	28.92	ft	BGS

Site Range

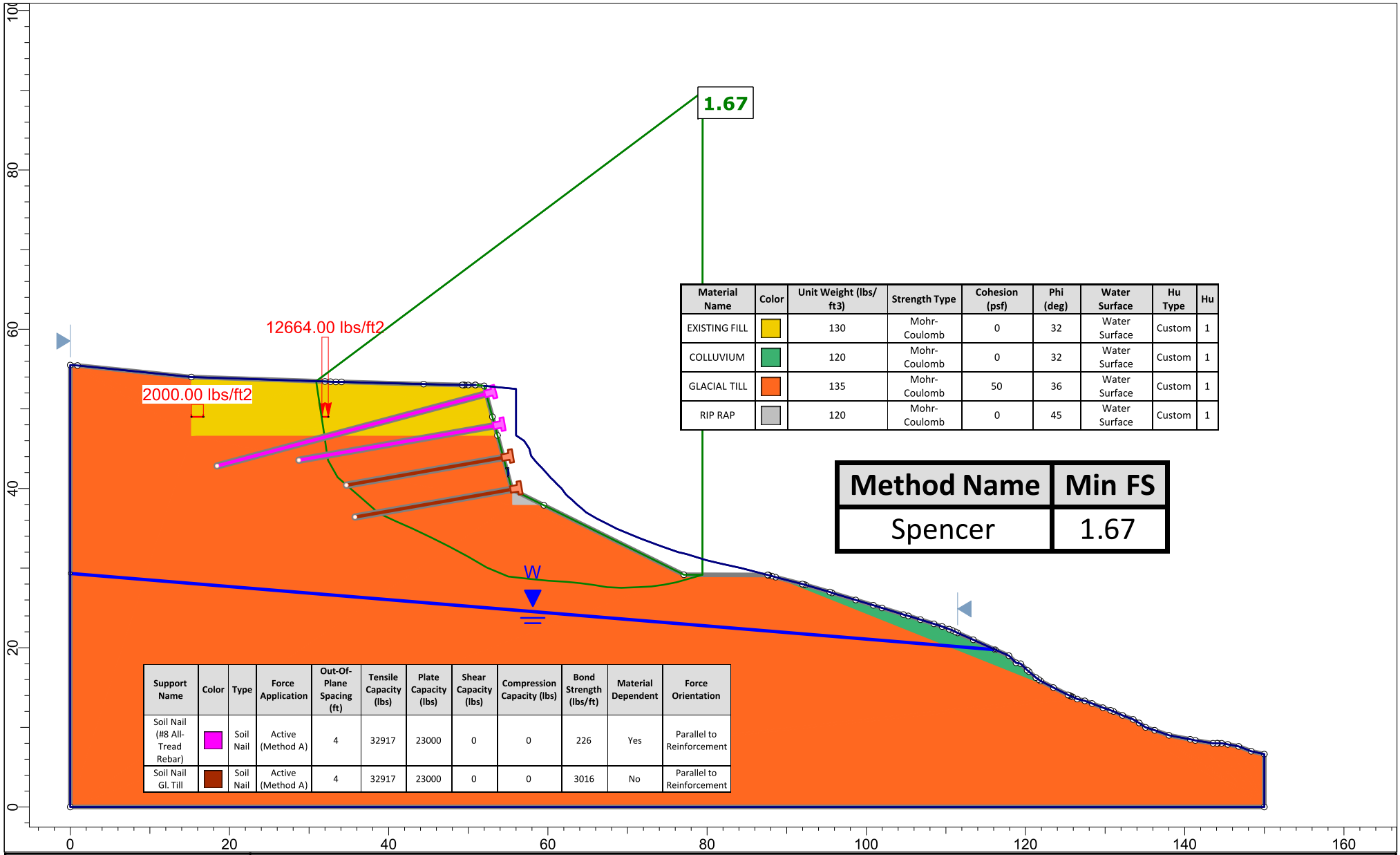
Till	17.0	ft	
Terrace	10.0	ft	
Valley Flat	4.2	ft	
S_r	10.0	ft	BGS

Site Condition

S_c	30.0	ft	BGS
S_h	28.67	ft	BGS

ATTACHMENT 4

GLOBAL STABILITY ANALYSIS OUTPUTS
SOIL NAILS



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1
RIP RAP		120	Mohr-Coulomb	0	45	Water Surface	Custom	1

Method Name	Min FS
Spencer	1.67

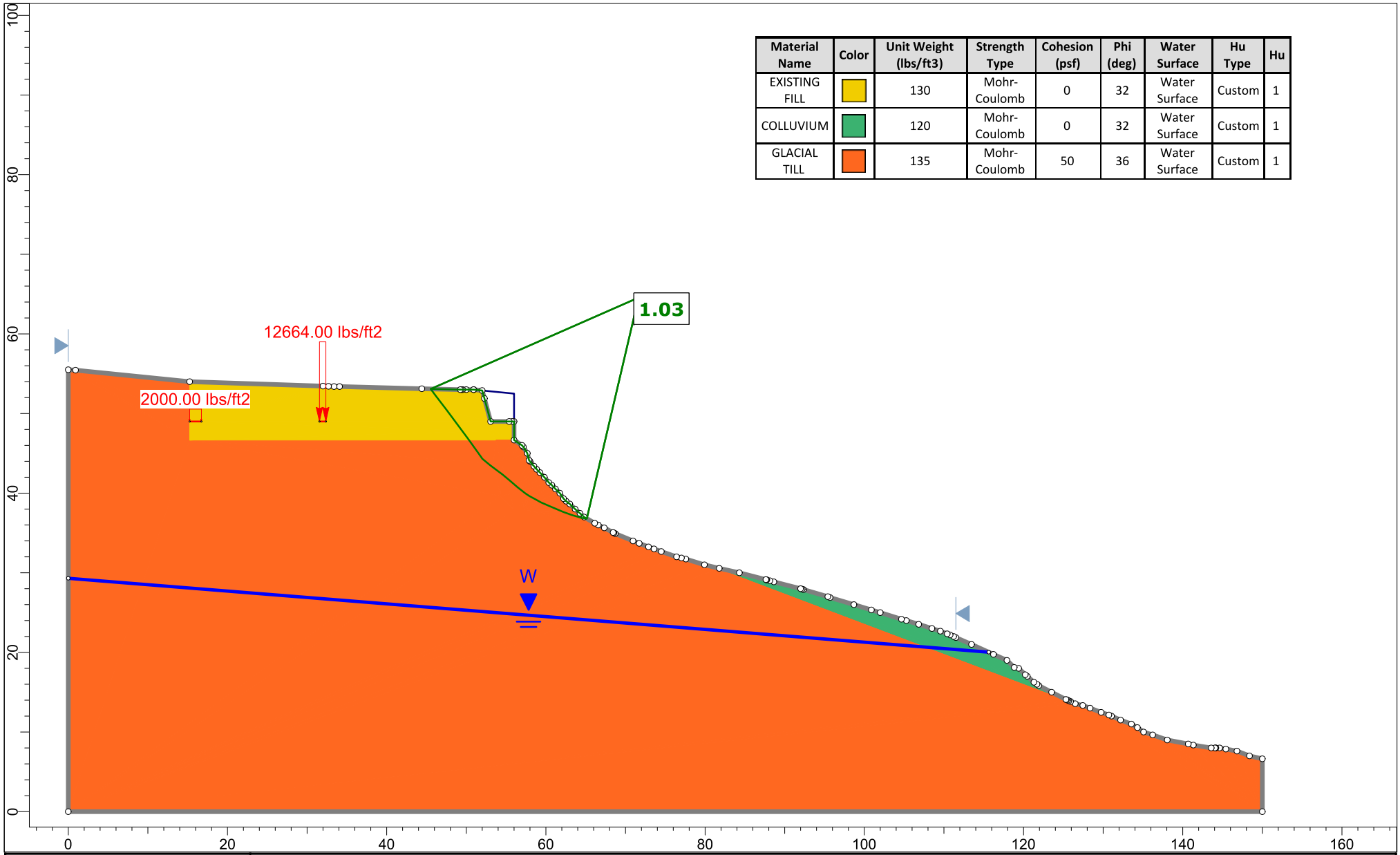
Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement
Soil Nail Gl. Till		Soil Nail	Active (Method A)	4	32917	23000	0	0	3016	No	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborveiw Rd Hull, MA Slope Stabilization		
Analysis Description	Proposed Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd

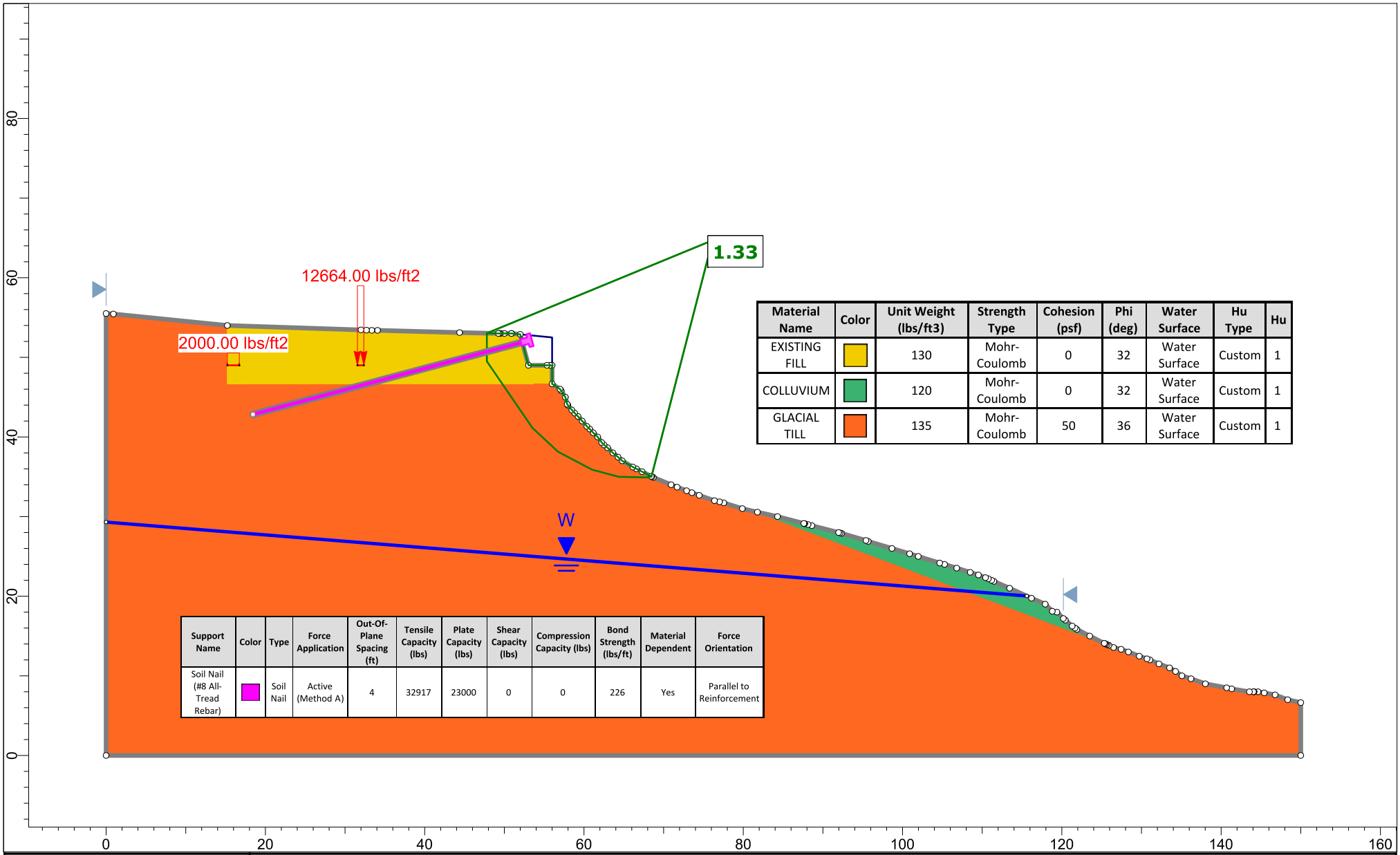
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1



Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hul, MA Slope Stabilization		
Analysis Description	Stage 1 Excavation	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



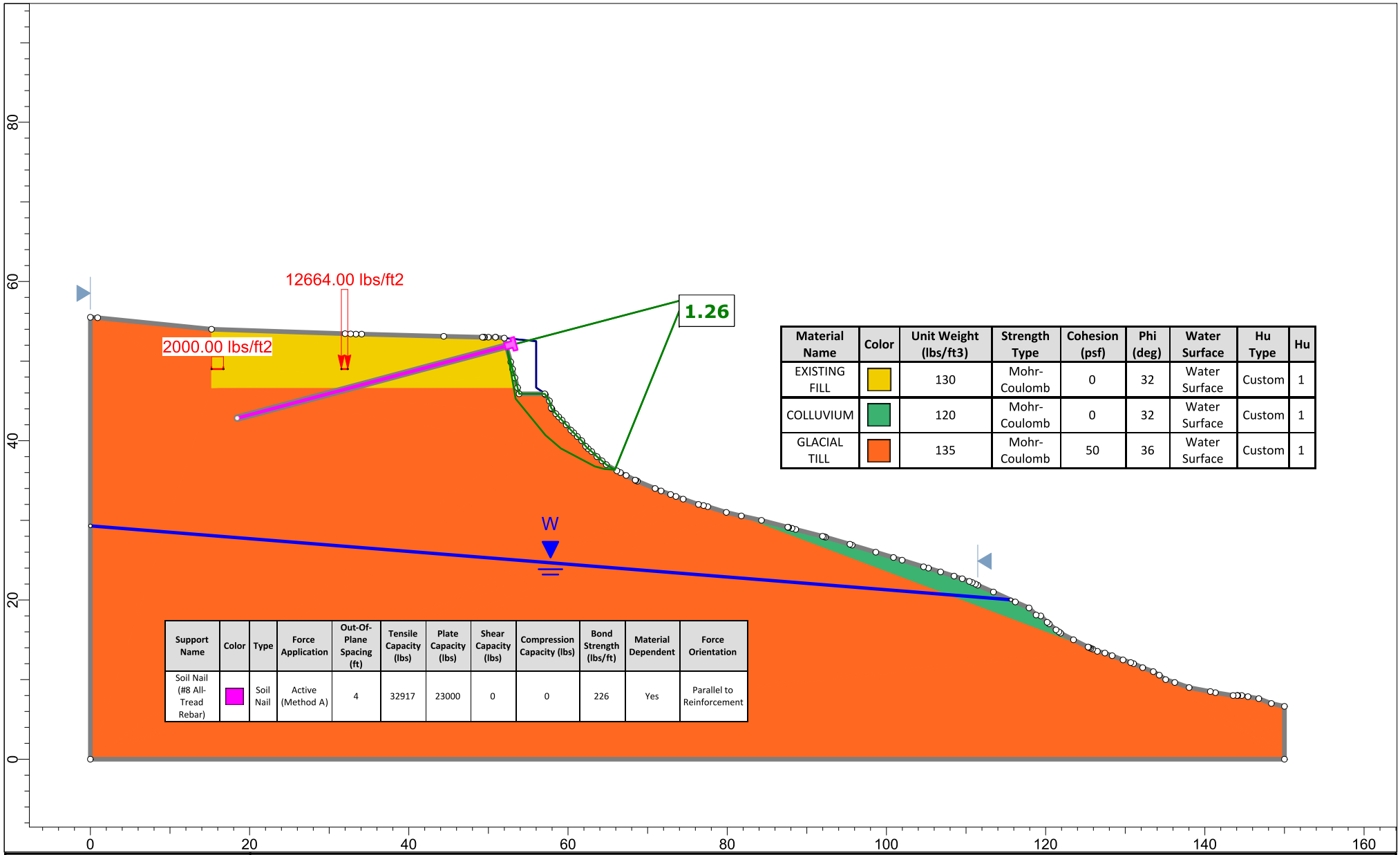
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hul, MA Slope Stabilization		
Analysis Description	Stage 1 Temporary Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



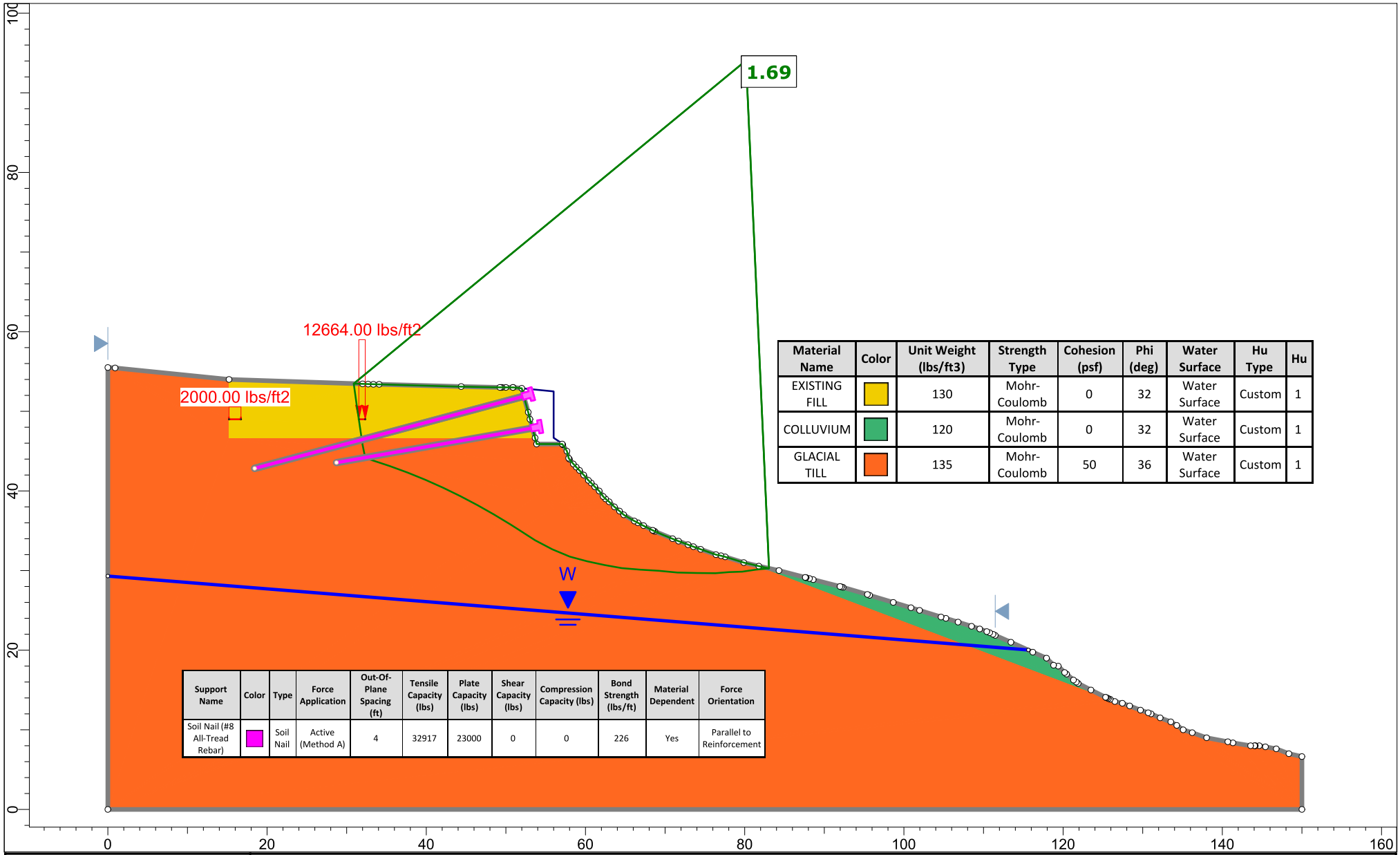
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hul, MA Slope Stabilization		
Analysis Description	Stage 2 Excvavation	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



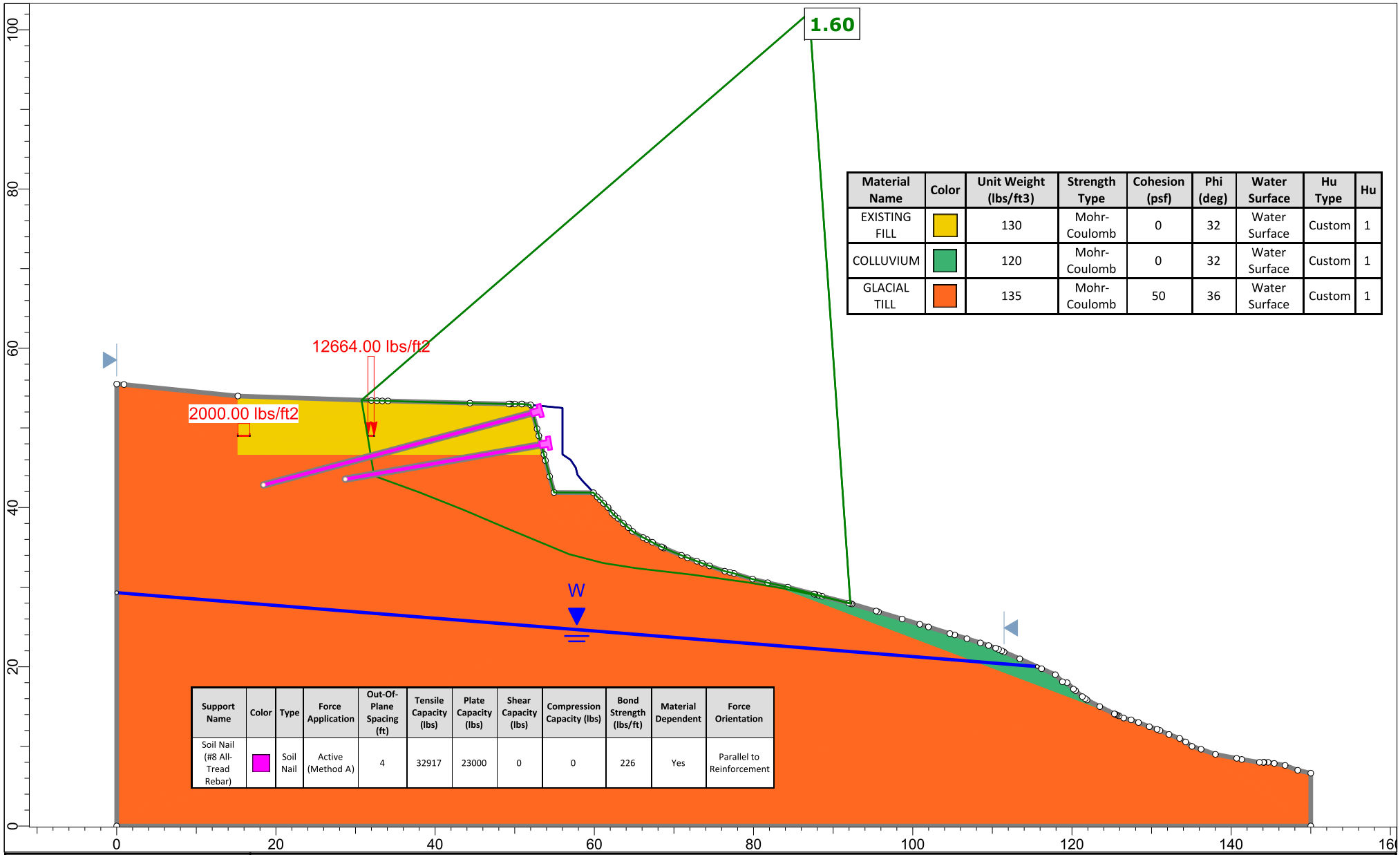
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hul, MA Slope Stabilization		
Analysis Description	Stage 2 Temporary Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



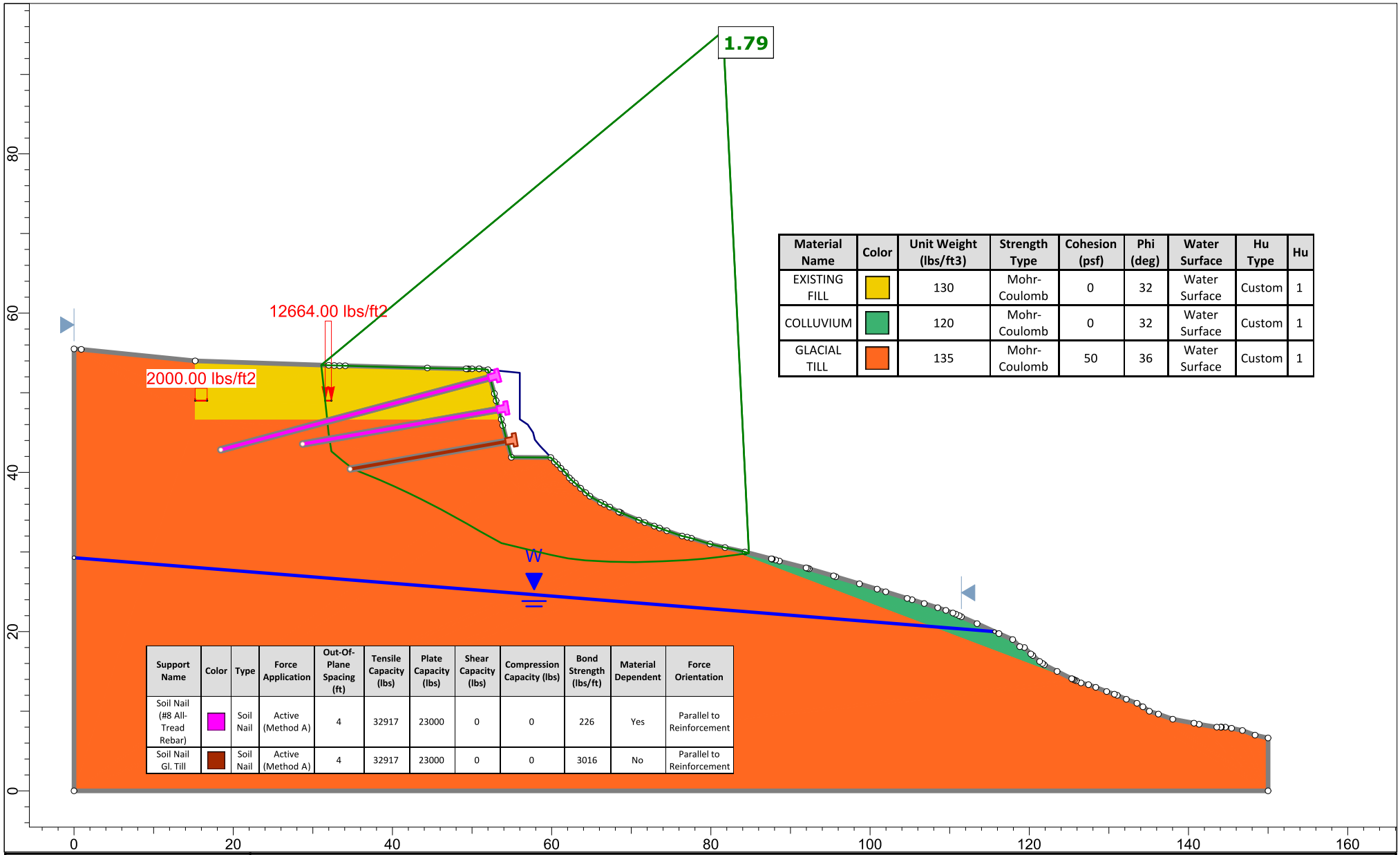
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	Stage 3 Excvavation	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



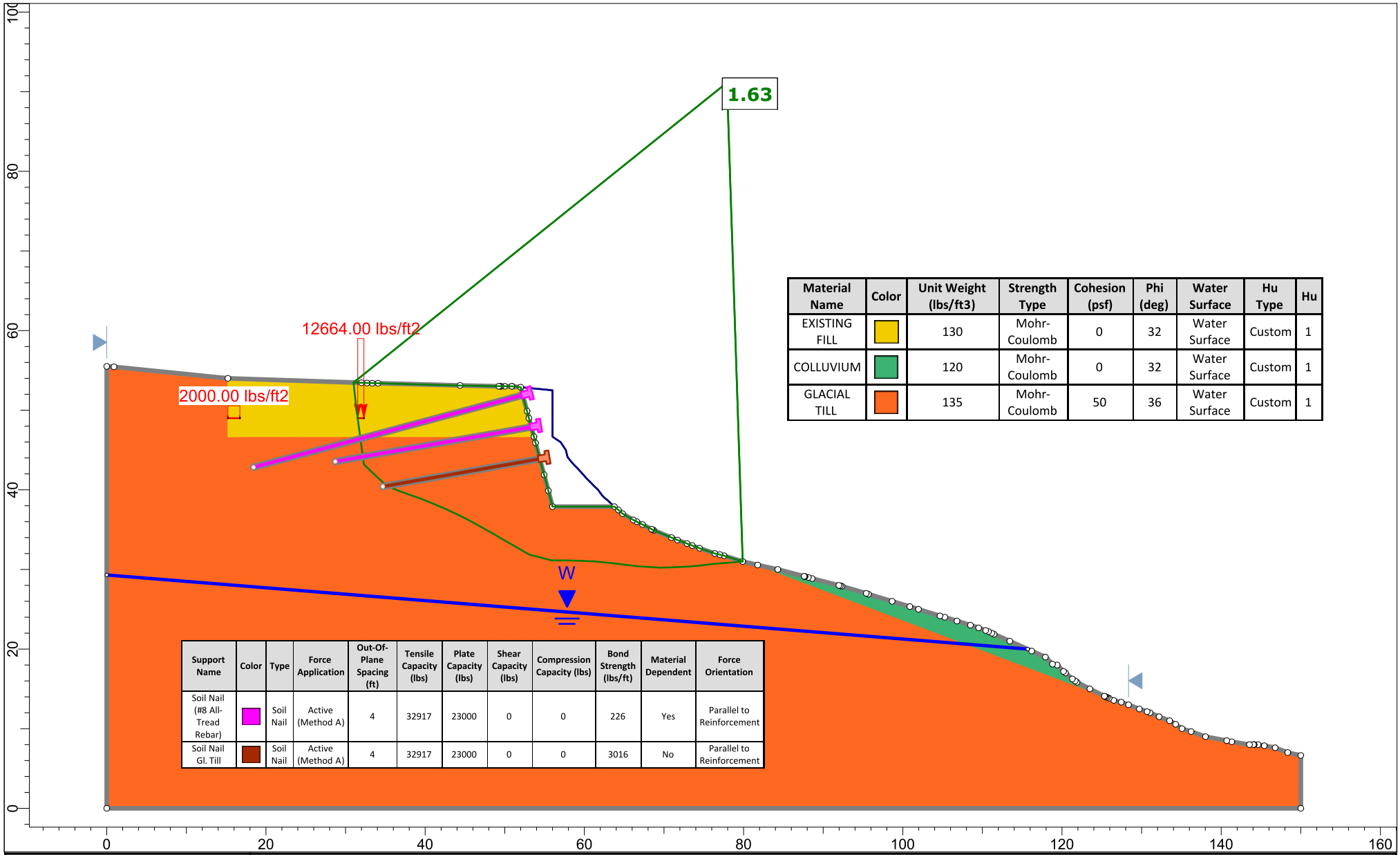
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement
Soil Nail Gl. Till		Soil Nail	Active (Method A)	4	32917	23000	0	0	3016	No	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	Stage 3 Temporary Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



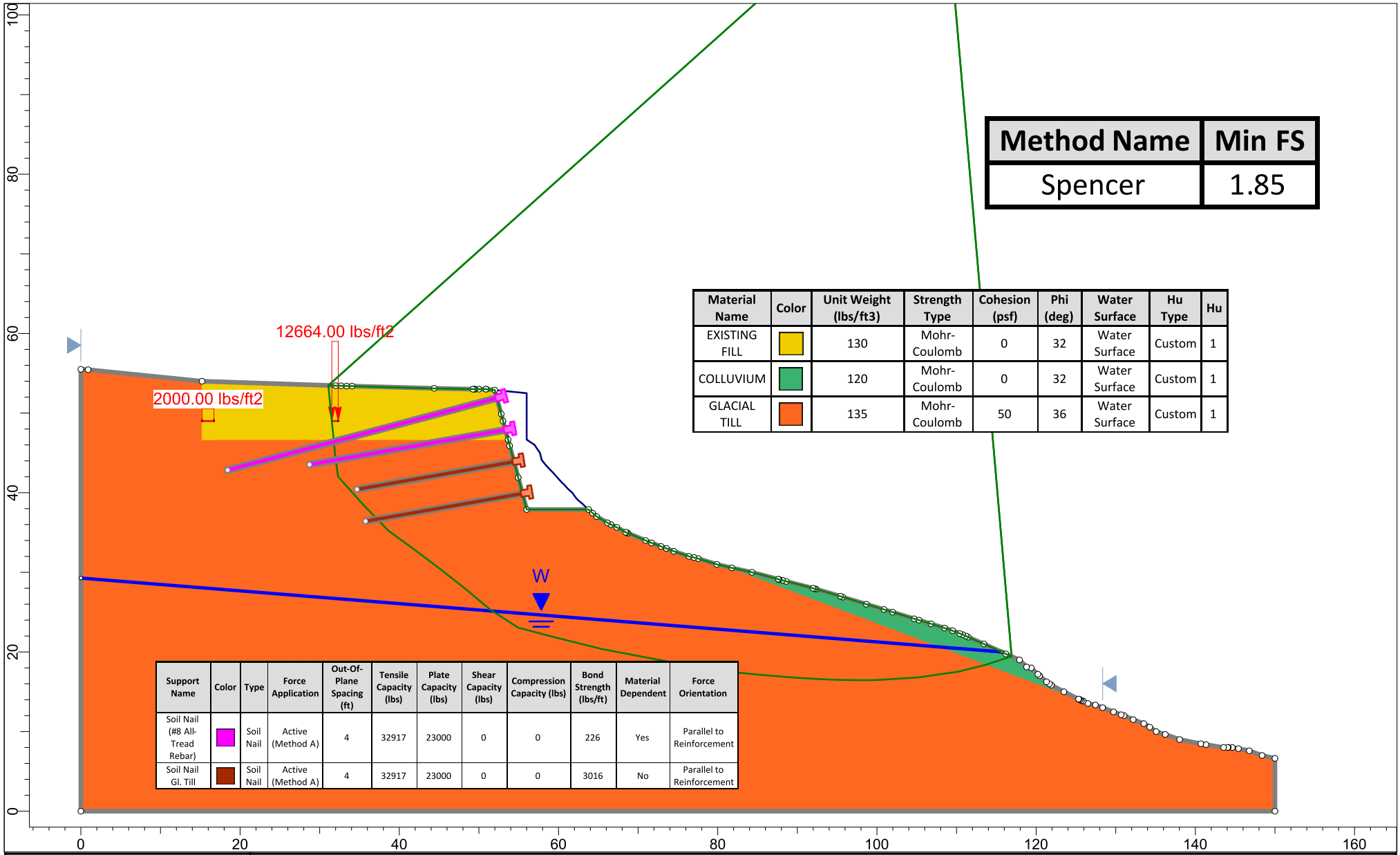
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement
Soil Nail Gl. Till		Soil Nail	Active (Method A)	4	32917	23000	0	0	3016	No	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	Stage 4 Temporary Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd



Method Name	Min FS
Spencer	1.85

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
EXISTING FILL		130	Mohr-Coulomb	0	32	Water Surface	Custom	1
COLLUVIUM		120	Mohr-Coulomb	0	32	Water Surface	Custom	1
GLACIAL TILL		135	Mohr-Coulomb	50	36	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Tensile Capacity (lbs)	Plate Capacity (lbs)	Shear Capacity (lbs)	Compression Capacity (lbs)	Bond Strength (lbs/ft)	Material Dependent	Force Orientation
Soil Nail (#8 All-Tread Rebar)		Soil Nail	Active (Method A)	4	32917	23000	0	0	226	Yes	Parallel to Reinforcement
Soil Nail Gl. Till		Soil Nail	Active (Method A)	4	32917	23000	0	0	3016	No	Parallel to Reinforcement

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

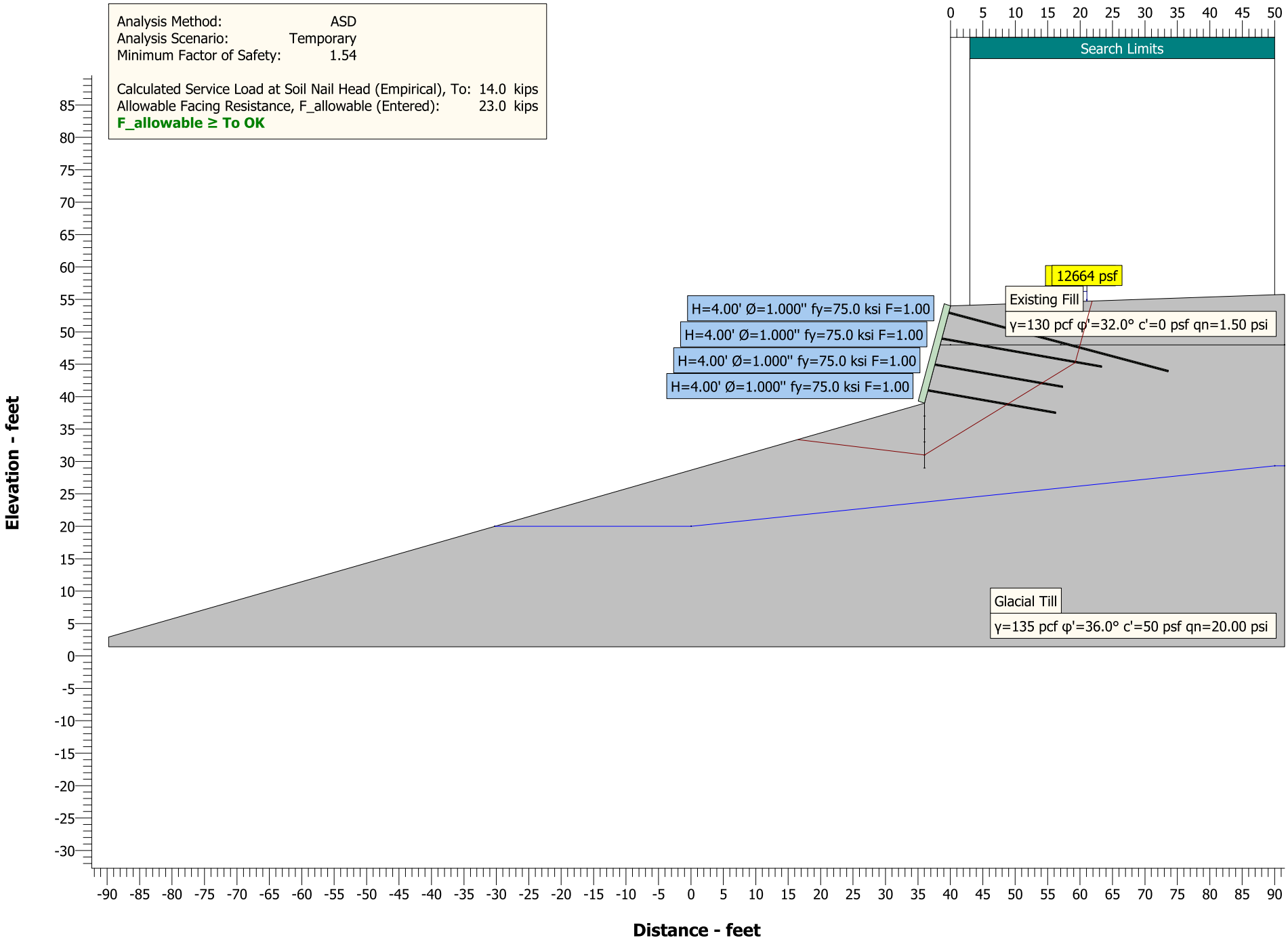
Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	Stage 4 Temporary Conditions	*Figure*	
Drawn By	TS	*Company*	CEC Inc
Date	10/18/23	*File Name*	324-891 - Cross Section A-A.slmd

ATTACHMENT 5

SNAIL ANALYSIS OUTPUTS

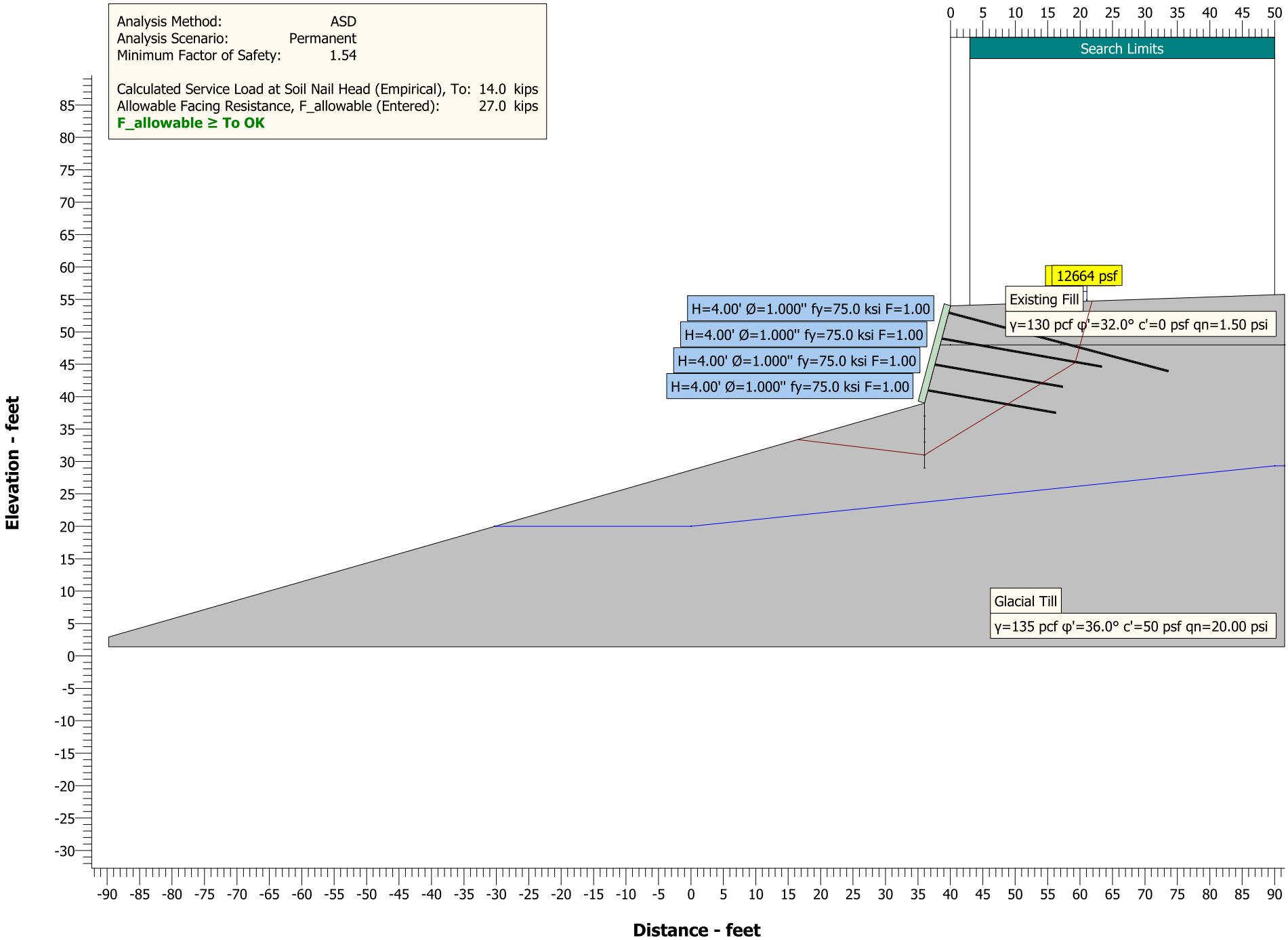
Analysis Method: ASD
Analysis Scenario: Temporary
Minimum Factor of Safety: 1.54

Calculated Service Load at Soil Nail Head (Empirical), To: 14.0 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK



Analysis Method: ASD
Analysis Scenario: Permanent
Minimum Factor of Safety: 1.54

Calculated Service Load at Soil Nail Head (Empirical), To: 14.0 kips
Allowable Facing Resistance, F_allowable (Entered): 27.0 kips
F_allowable ≥ To OK



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Snail

Version: 2.2.2

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File Information

==========

File Name: 324-891 Proposed Final Conditions.snz
Run Date: 10/20/23
Run Time: 13:37:48

==========

Project Information

==========

Description: Permanent Conditions
Location:
EA:
Project ID: 324-891
Wall No.:
Structure No.:
Station:
Engineer: GSS
Designer

Comments:

51 Harborview

==========

Geometry

==========

Layout:

Reference Point:

At: Top of Wall
Distance From Origin: 40.00 feet
Elevation Above Origin: 54.00 feet

Wall Dimensions:

Wall Height: 15.00 feet
Facing Angle: 75.00 degrees
Facing Batter: 3.215 :12 H:V

Ground Surface:

Number of lines that define the ground surface above the wall: 1

No.	Angle degrees	Distance feet
1	2	

Number of lines that define the ground surface in front of the toe: 1

No.	Angle degrees	Distance feet
1	-16	

Soil Layers:

Number of Layers: 2

Layers Below the Top Layer:

Coordinates of the Top of the Layer: feet

Layer	Point 1 Distance	Point 1 Elevation	Point 2 Distance	Point 2 Elevation
2	40.00	48.00	57.00	48.00

Ground Water:

Include Ground Water: Yes

Phreatic Correction: No
Number of Points: 2

No.	Distance feet	Elevation feet
1	0.00	20.00
2	90.00	29.33

Soil Nails

Dimensions and Properties:

Maximum Vertical Spacing: 4.00 feet
Number of Soil Nail Rows: 4
Soil Nail Design Parameters: Varying

No.	Soil Nail Length feet	Inclination From Horizontal degrees	Vertical Spacing feet	Horizontal Spacing H feet	Nail Bar Diameter Ø inches	Nail Bar Yield Strength fy ksi	Bond Strength Factor F
1	35.00	15	1.00	4.00	1.000	75.0	1.00
2	25.00	10	4.00	4.00	1.000	75.0	1.00
3	20.00	10	4.00	4.00	1.000	75.0	1.00
4	20.00	10	4.00	4.00	1.000	75.0	1.00

Facing Resistance:

	Temporary	Permanent	Seismic
ASD Allowable Facing Resistance:	23.0	27.0	36.8 kips

Soil Properties

Layer	Description	Unit Weight γ pcf	Friction Angle φ' degrees	Cohesion c' psf
1	Existing Fill	130	32.0	0
2	Glacial Till	135	36.0	50

Loads

Applied Loads:

Seismic:

Horizontal Seismic Coefficient Kh:

External Load:

Apply external load: No

Surcharges:

Apply surcharges: Yes

No.	Distance from Top of Wall Begin feet	End feet	Load Begin psf	Load End psf
1	20.00	21.00	12664	12664

Factors of Safety

	Temporary	Permanent	Seismic
Pullout (Distal):	2.00	2.00	1.50
Pullout (Proximal):	2.00	2.00	1.50
Nail Bar Yield:	1.80	1.80	1.35

Search Options

Search Limits:

Begin: 3.00 feet

End: 50.00 feet

Below Toe Searches (BTS):

Perform below Toe Search: Yes
Number of BTS Points: 5
BTS Depth: 10.00 feet
Interface Friction
Reduction Factor: 0.33

Advanced Search Options:

Use Advanced Search Options: No

==========

Results

==========

Analysis:

Method: ASD
Scenario: Permanent

Factor of Safety:

Minimum: 1.54
Found at Search Point: 5
Found at Grid Point: 47
Found at Search Level: 8.00 feet below the toe of the wall

Load at Soil Nail Head:

Calculated Service Load at Soil Nail Head (Empirical), To: 14.0 kips
Allowable Facing Resistance, F_allowable (Entered): 27.0 kips
F_allowable ≥ To OK

Nominal Pullout Resistance:

Layer	Description	Nominal Pullout Resistance klf
1	Existing Fill	0.226
2	Glacial Till	3.016

Results by Search Level:

** Indicates Minimum Factor of Safety

Search Level: At the toe of the wall Facing Design Force = 15.6 kips (Clouterre)

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Failure Planes Lower Angle degrees	Failure Planes Lower Length feet	Failure Planes Upper Angle degrees	Failure Planes Upper Length feet	Reinforcement Level	Reinforcement Stress ksi	Reinforcement Controlling Resistance Failure Mode
1	4.45	7.02	0.00	6.32	87.34	15.12	1	32.4	Pullout
							2	35.0	Facing
							3	28.8	Pullout
							4	27.0	Pullout
2	5.22	11.72	0.00	10.55	85.61	15.31	1	31.7	Pullout
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	7.01	16.42	11.80	15.10	82.43	12.46	1	31.1	Pullout
							2	23.2	Pullout
							3	12.6	Pullout
							4	28.8	Pullout
4	7.50	21.12	4.69	19.07	81.45	14.20	1	30.4	Pullout
							2	14.6	Pullout
							3	4.1	Pullout
							4	23.6	Pullout
5	2.07	25.82	15.18	24.08	74.73	9.80	1	27.2	Pullout
							2	7.9	Pullout
							3	14.2	Pullout
							4	30.3	Pullout
6	2.80	30.52	4.26	21.42	57.43	17.01	1	23.9	Pullout
							2	5.9	Pullout

							3	0.0	Pullout
							4	23.2	Pullout
7	3.06	35.22	0.00	21.13	48.80	21.39	1	19.5	Pullout
							2	2.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
8	3.22	39.92	0.00	23.95	45.51	22.78	1	13.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
9	3.45	44.62	0.00	22.31	36.35	27.70	1	12.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
10	3.66	49.32	0.00	19.73	29.26	33.92	1	12.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
11	3.83	54.02	0.00	21.61	27.32	36.48	1	8.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout

Search Level: 2.00 feet below the toe of the wall Facing Design Force = 13.8 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.77	7.02	15.15	6.54	87.39	15.41	1	32.4	Pullout
							2	35.0	Facing
							3	28.7	Pullout
							4	27.0	Pullout
2	4.21	11.72	9.30	10.69	85.69	15.59	1	31.7	Pullout
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	4.48	16.42	19.49	15.68	82.34	12.31	1	31.1	Pullout
							2	23.2	Pullout
							3	12.6	Pullout
							4	24.4	Pullout
4	4.70	21.12	15.52	19.73	80.27	12.50	1	30.5	Pullout
							2	14.9	Pullout
							3	6.0	Pullout
							4	21.9	Pullout
5	1.80	25.82	17.00	24.30	76.38	10.97	1	26.8	Pullout
							2	7.3	Pullout
							3	8.0	Pullout
							4	22.9	Pullout
6	2.29	30.52	9.53	21.66	57.44	17.01	1	23.9	Pullout
							2	5.8	Pullout
							3	0.0	Pullout
							4	16.2	Pullout
7	2.48	35.22	4.89	21.21	49.13	21.53	1	19.3	Pullout
							2	1.9	Pullout
							3	0.0	Pullout
							4	9.0	Pullout
8	2.58	39.92	8.67	24.23	42.44	21.64	1	15.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	15.2	Pullout
9	2.72	44.62	0.00	17.85	34.53	32.50	1	13.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	2.5	Pullout
10	2.83	49.32	0.00	19.73	32.13	34.94	1	9.4	Pullout
							2	0.0	Pullout

							3	0.0	Pullout
							4	0.0	Pullout
11	2.96	54.02	0.00	16.21	26.37	42.21	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.3	Pullout

Search Level: 4.00 feet below the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

			Failure Planes				Reinforcement		
	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower		Upper				
Search Point			Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.22	7.02	31.17	7.38	87.37	15.30	1	32.4	Pullout
							2	35.0	Facing
							3	28.7	Pullout
							4	27.0	Pullout
2	3.37	11.72	20.07	11.23	85.65	15.46	1	31.7	Pullout
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	3.55	16.42	21.53	15.89	83.12	13.70	1	31.1	Pullout
							2	23.0	Pullout
							3	12.3	Pullout
							4	18.6	Pullout
4	3.38	21.12	22.41	20.56	79.82	11.95	1	30.5	Pullout
							2	15.1	Pullout
							3	7.5	Pullout
							4	19.3	Pullout
5	1.62	25.82	23.04	25.25	75.36	10.21	1	27.1	Pullout
							2	7.7	Pullout
							3	8.2	Pullout
							4	19.7	Pullout
6	2.00	30.52	15.63	22.18	56.72	16.68	1	24.1	Pullout
							2	6.2	Pullout
							3	0.0	Pullout
							4	13.4	Pullout
7	2.16	35.22	15.92	21.97	44.95	19.91	1	21.2	Pullout
							2	4.2	Pullout
							3	0.0	Pullout
							4	13.7	Pullout
8	2.23	39.92	14.23	24.71	41.60	21.35	1	15.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	11.8	Pullout
9	2.38	44.62	10.37	22.68	36.21	27.65	1	12.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	6.4	Pullout
10	2.48	49.32	5.96	19.83	32.05	34.91	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.0	Pullout
11	2.58	54.02	7.30	16.34	26.28	42.17	1	9.6	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.5	Pullout

Search Level: 6.00 feet below the toe of the wall Facing Design Force = 13.8 kips (Clouterre)

			Failure Planes				Reinforcement		
	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower		Upper				
Search Point			Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	2.92	7.02	45.06	8.94	87.28	14.79	1	32.4	Pullout
							2	35.0	Facing
							3	28.8	Pullout

							4	27.1	Pullout
2	2.99	11.72	34.24	11.34	81.05	15.07	1	31.8	Pullout
							2	32.4	Pullout
							3	22.0	Pullout
							4	21.1	Pullout
3	2.86	16.42	30.12	17.08	82.73	12.96	1	31.1	Pullout
							2	23.1	Pullout
							3	12.5	Pullout
							4	18.6	Pullout
4	2.75	21.12	24.44	20.88	80.74	13.13	1	30.4	Pullout
							2	14.8	Pullout
							3	4.4	Pullout
							4	14.4	Pullout
5	1.57	25.82	25.09	25.66	76.65	11.18	1	26.7	Pullout
							2	7.3	Pullout
							3	4.4	Pullout
							4	15.0	Pullout
6	1.86	30.52	22.32	23.09	55.16	16.03	1	24.6	Pullout
							2	6.8	Pullout
							3	0.7	Pullout
							4	12.6	Pullout
7	1.98	35.22	17.41	22.15	47.66	20.92	1	20.0	Pullout
							2	2.7	Pullout
							3	0.0	Pullout
							4	7.2	Pullout
8	2.04	39.92	20.39	25.55	39.90	20.81	1	16.8	Pullout
							2	0.1	Pullout
							3	0.0	Pullout
							4	10.6	Pullout
9	2.16	44.62	14.10	18.40	33.82	32.22	1	14.3	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	3.6	Pullout
10	2.25	49.32	12.90	20.24	31.40	34.67	1	10.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.7	Pullout
11	2.35	54.02	15.68	16.83	25.70	41.96	1	10.3	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	5.8	Pullout

Search Level: 8.00 feet below the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.18	7.02	50.99	8.92	85.04	16.23	1	32.4	Pullout
							2	34.9	Facing
							3	29.5	Pullout
							4	28.1	Pullout
2	2.81	11.72	47.81	15.70	84.25	11.69	1	31.8	Pullout
							2	31.7	Pullout
							3	20.8	Pullout
							4	24.1	Pullout
3	2.69	16.42	32.39	17.50	83.34	14.16	1	31.1	Pullout
							2	23.0	Pullout
							3	12.2	Pullout
							4	15.2	Pullout
4	2.50	21.12	36.68	23.70	77.39	9.67	1	30.5	Pullout
							2	15.8	Pullout
							3	11.3	Pullout
							4	18.1	Pullout
** 5	1.54	25.82	31.53	27.26	74.80	9.85	1	27.2	Pullout
							2	7.9	Pullout
							3	6.3	Pullout

							4	14.5	Pullout
6	1.80	30.52	24.13	23.41	57.47	17.03	1	23.8	Pullout
							2	5.8	Pullout
							3	0.0	Pullout
							4	7.9	Pullout
7	1.90	35.22	24.51	23.22	45.74	20.18	1	20.8	Pullout
							2	3.7	Pullout
							3	0.0	Pullout
							4	8.3	Pullout
8	1.96	39.92	22.05	25.84	42.35	21.60	1	15.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	5.6	Pullout
9	2.06	44.62	18.18	23.48	37.46	28.10	1	11.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.4	Pullout
10	2.14	49.32	20.50	21.06	30.18	34.23	1	11.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	3.7	Pullout
11	2.21	54.02	18.96	22.85	28.12	36.75	1	7.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	1.6	Pullout

Search Level: 10.00 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.21	7.02	60.79	11.51	84.68	15.13	1	32.4	Pullout
							2	34.9	Facing
							3	29.6	Pullout
							4	28.3	Pullout
2	2.64	11.72	43.78	14.61	85.58	15.21	1	31.7	Pullout
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.9	Pullout
3	2.51	16.42	40.71	19.50	82.64	12.82	1	31.1	Pullout
							2	23.1	Pullout
							3	12.5	Pullout
							4	16.7	Pullout
4	2.38	21.12	33.95	22.91	80.63	12.97	1	30.4	Pullout
							2	14.8	Pullout
							3	4.4	Pullout
							4	11.7	Pullout
5	1.57	25.82	33.63	27.91	75.93	10.62	1	26.9	Pullout
							2	7.5	Pullout
							3	3.8	Pullout
							4	11.4	Pullout
6	1.81	30.52	25.89	23.75	59.52	18.05	1	23.2	Pullout
							2	5.0	Pullout
							3	0.0	Pullout
							4	3.8	Pullout
7	1.87	35.22	26.28	23.57	48.01	21.06	1	19.8	Pullout
							2	2.5	Pullout
							3	0.0	Pullout
							4	4.3	Pullout
8	1.93	39.92	23.68	26.15	44.61	22.43	1	14.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	1.1	Pullout
9	2.01	44.62	25.35	24.69	35.39	27.37	1	13.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

							4	3.2	Pullout
10	2.08	49.32	22.01	21.28	32.16	34.96	1	9.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.0	Pullout
11	2.16	54.02	26.34	60.28	0.00	0.00	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.3	Pullout

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END OF REPORT

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Snail

Version: 2.2.2

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File Information

==========

File Name: 324-891 Proposed Final Conditions.snz
Run Date: 10/20/23
Run Time: 13:36:26

==========

Project Information

==========

Description: Temporary Conditions
Location:
EA:
Project ID: 324-891
Wall No.:
Structure No.:
Station:
Engineer: GSS
Designer

Comments:

51 Harborview

==========

Geometry

==========

Layout:

Reference Point:

At: Top of Wall
Distance From Origin: 40.00 feet
Elevation Above Origin: 54.00 feet

Wall Dimensions:

Wall Height: 15.00 feet
Facing Angle: 75.00 degrees
Facing Batter: 3.215 :12 H:V

Ground Surface:

Number of lines that define the ground surface above the wall: 1

No.	Angle degrees	Distance feet
1	2	

Number of lines that define the ground surface in front of the toe: 1

No.	Angle degrees	Distance feet
1	-16	

Soil Layers:

Number of Layers: 2

Layers Below the Top Layer:

Coordinates of the Top of the Layer: feet

Layer	Point 1 Distance	Point 1 Elevation	Point 2 Distance	Point 2 Elevation
2	40.00	48.00	57.00	48.00

Ground Water:

Include Ground Water: Yes

Phreatic Correction: No
Number of Points: 2

No.	Distance feet	Elevation feet
1	0.00	20.00
2	90.00	29.33

Soil Nails

Dimensions and Properties:

Maximum Vertical Spacing: 4.00 feet
Number of Soil Nail Rows: 4
Soil Nail Design Parameters: Varying

No.	Soil Nail Length feet	Inclination From Horizontal degrees	Vertical Spacing feet	Horizontal Spacing H feet	Nail Bar Diameter Ø inches	Nail Bar Yield Strength fy ksi	Bond Strength Factor F
1	35.00	15	1.00	4.00	1.000	75.0	1.00
2	25.00	10	4.00	4.00	1.000	75.0	1.00
3	20.00	10	4.00	4.00	1.000	75.0	1.00
4	20.00	10	4.00	4.00	1.000	75.0	1.00

Facing Resistance:

	Temporary	Permanent	Seismic
ASD Allowable Facing Resistance:	23.0	27.0	36.8 kips

Soil Properties

Layer	Description	Unit Weight γ pcf	Friction Angle φ' degrees	Cohesion c' psf
1	Existing Fill	130	32.0	0
2	Glacial Till	135	36.0	50

Loads

Applied Loads:

Seismic:

Horizontal Seismic Coefficient Kh:

External Load:

Apply external load: No

Surcharges:

Apply surcharges: Yes

No.	Distance from Top of Wall Begin feet	End feet	Load Begin psf	Load End psf
1	20.00	21.00	12664	12664

Factors of Safety

	Temporary	Permanent	Seismic
Pullout (Distal):	2.00	2.00	1.50
Pullout (Proximal):	2.00	2.00	1.50
Nail Bar Yield:	1.80	1.80	1.35

Search Options

Search Limits:

Begin: 3.00 feet

End: 50.00 feet

Below Toe Searches (BTS):

Perform below Toe Search: Yes
Number of BTS Points: 5
BTS Depth: 10.00 feet
Interface Friction
Reduction Factor: 0.33

Advanced Search Options:

Use Advanced Search Options: No

==========

Results

==========

Analysis:

Method: ASD
Scenario: Temporary

Factor of Safety:

Minimum: 1.54
Found at Search Point: 5
Found at Grid Point: 47
Found at Search Level: 8.00 feet below the toe of the wall

Load at Soil Nail Head:

Calculated Service Load at Soil Nail Head (Empirical), To: 14.0 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK

Nominal Pullout Resistance:

Layer	Description	Nominal Pullout Resistance klf
1	Existing Fill	0.226
2	Glacial Till	3.016

Results by Search Level:

** Indicates Minimum Factor of Safety

Search Level: At the toe of the wall Facing Design Force = 15.6 kips (Clouterre)

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Failure Planes Lower Angle degrees	Failure Planes Lower Length feet	Failure Planes Upper Angle degrees	Failure Planes Upper Length feet	Reinforcement Level	Reinforcement Stress ksi	Reinforcement Controlling Resistance Failure Mode
1	4.47	7.02	0.00	6.32	87.34	15.12	1	29.8	Facing
							2	29.9	Facing
							3	28.8	Pullout
							4	27.0	Pullout
2	5.25	11.72	0.00	10.55	85.61	15.31	1	30.4	Facing
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	7.01	16.42	11.80	15.10	82.43	12.46	1	31.1	Facing
							2	23.2	Pullout
							3	12.6	Pullout
							4	28.8	Pullout
4	7.50	21.12	4.69	19.07	81.45	14.20	1	30.4	Pullout
							2	14.6	Pullout
							3	4.1	Pullout
							4	23.6	Pullout
5	2.07	25.82	15.18	24.08	74.73	9.80	1	27.2	Pullout
							2	7.9	Pullout
							3	14.2	Pullout
							4	30.3	Pullout
6	2.80	30.52	4.26	21.42	57.43	17.01	1	23.9	Pullout
							2	5.9	Pullout

							3	0.0	Pullout
							4	23.2	Pullout
7	3.06	35.22	0.00	21.13	48.80	21.39	1	19.5	Pullout
							2	2.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
8	3.22	39.92	0.00	23.95	45.51	22.78	1	13.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
9	3.45	44.62	0.00	22.31	36.35	27.70	1	12.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
10	3.66	49.32	0.00	19.73	29.26	33.92	1	12.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout
11	3.83	54.02	0.00	21.61	27.32	36.48	1	8.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	16.3	Pullout

Search Level: 2.00 feet below the toe of the wall Facing Design Force = 13.8 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.76	7.02	15.15	6.54	87.39	15.41	1	29.8	Facing
							2	29.9	Facing
							3	28.7	Pullout
							4	27.0	Pullout
2	4.22	11.72	9.30	10.69	85.69	15.59	1	30.4	Facing
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	4.48	16.42	19.49	15.68	82.34	12.31	1	31.1	Facing
							2	23.2	Pullout
							3	12.6	Pullout
							4	24.4	Pullout
4	4.70	21.12	15.52	19.73	80.27	12.50	1	30.5	Pullout
							2	14.9	Pullout
							3	6.0	Pullout
							4	21.9	Pullout
5	1.80	25.82	17.00	24.30	76.38	10.97	1	26.8	Pullout
							2	7.3	Pullout
							3	8.0	Pullout
							4	22.9	Pullout
6	2.29	30.52	9.53	21.66	57.44	17.01	1	23.9	Pullout
							2	5.8	Pullout
							3	0.0	Pullout
							4	16.2	Pullout
7	2.48	35.22	4.89	21.21	49.13	21.53	1	19.3	Pullout
							2	1.9	Pullout
							3	0.0	Pullout
							4	9.0	Pullout
8	2.58	39.92	8.67	24.23	42.44	21.64	1	15.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	15.2	Pullout
9	2.72	44.62	0.00	17.85	34.53	32.50	1	13.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	2.5	Pullout
10	2.83	49.32	0.00	19.73	32.13	34.94	1	9.4	Pullout
							2	0.0	Pullout

							3	0.0	Pullout
							4	0.0	Pullout
11	2.96	54.02	0.00	16.21	26.37	42.21	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.3	Pullout

Search Level: 4.00 feet below the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

			Failure Planes				Reinforcement		
	Minimum	Distance	Lower		Upper				
Search Point	Factor of Safety	From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.19	7.02	31.17	7.38	87.37	15.30	1	29.8	Facing
							2	29.9	Facing
							3	28.7	Pullout
							4	27.0	Pullout
2	3.37	11.72	20.07	11.23	85.65	15.46	1	30.4	Facing
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.8	Pullout
3	3.55	16.42	21.53	15.89	83.12	13.70	1	31.1	Pullout
							2	23.0	Pullout
							3	12.3	Pullout
							4	18.6	Pullout
4	3.38	21.12	22.41	20.56	79.82	11.95	1	30.5	Pullout
							2	15.1	Pullout
							3	7.5	Pullout
							4	19.3	Pullout
5	1.62	25.82	23.04	25.25	75.36	10.21	1	27.1	Pullout
							2	7.7	Pullout
							3	8.2	Pullout
							4	19.7	Pullout
6	2.00	30.52	15.63	22.18	56.72	16.68	1	24.1	Pullout
							2	6.2	Pullout
							3	0.0	Pullout
							4	13.4	Pullout
7	2.16	35.22	15.92	21.97	44.95	19.91	1	21.2	Pullout
							2	4.2	Pullout
							3	0.0	Pullout
							4	13.7	Pullout
8	2.23	39.92	14.23	24.71	41.60	21.35	1	15.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	11.8	Pullout
9	2.38	44.62	10.37	22.68	36.21	27.65	1	12.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	6.4	Pullout
10	2.48	49.32	5.96	19.83	32.05	34.91	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.0	Pullout
11	2.58	54.02	7.30	16.34	26.28	42.17	1	9.6	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.5	Pullout

Search Level: 6.00 feet below the toe of the wall Facing Design Force = 13.8 kips (Clouterre)

			Failure Planes				Reinforcement		
	Minimum	Distance	Lower		Upper				
Search Point	Factor of Safety	From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	2.89	7.02	45.06	8.94	87.28	14.79	1	29.8	Facing
							2	29.9	Facing
							3	28.8	Pullout

							4	27.1	Pullout
2	2.97	11.72	34.24	11.34	81.05	15.07	1	30.4	Facing
							2	32.4	Pullout
							3	22.0	Pullout
							4	21.1	Pullout
3	2.86	16.42	30.12	17.08	82.73	12.96	1	31.1	Facing
							2	23.1	Pullout
							3	12.5	Pullout
							4	18.6	Pullout
4	2.75	21.12	24.44	20.88	80.74	13.13	1	30.4	Pullout
							2	14.8	Pullout
							3	4.4	Pullout
							4	14.4	Pullout
5	1.57	25.82	25.09	25.66	76.65	11.18	1	26.7	Pullout
							2	7.3	Pullout
							3	4.4	Pullout
							4	15.0	Pullout
6	1.86	30.52	22.32	23.09	55.16	16.03	1	24.6	Pullout
							2	6.8	Pullout
							3	0.7	Pullout
							4	12.6	Pullout
7	1.98	35.22	17.41	22.15	47.66	20.92	1	20.0	Pullout
							2	2.7	Pullout
							3	0.0	Pullout
							4	7.2	Pullout
8	2.04	39.92	20.39	25.55	39.90	20.81	1	16.8	Pullout
							2	0.1	Pullout
							3	0.0	Pullout
							4	10.6	Pullout
9	2.16	44.62	14.10	18.40	33.82	32.22	1	14.3	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	3.6	Pullout
10	2.25	49.32	12.90	20.24	31.40	34.67	1	10.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.7	Pullout
11	2.35	54.02	15.68	16.83	25.70	41.96	1	10.3	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	5.8	Pullout

Search Level: 8.00 feet below the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.13	7.02	50.99	8.92	85.04	16.23	1	29.7	Facing
							2	29.8	Facing
							3	29.5	Pullout
							4	28.1	Pullout
2	2.80	11.72	47.81	15.70	84.25	11.69	1	30.4	Facing
							2	31.7	Pullout
							3	20.8	Pullout
							4	24.1	Pullout
3	2.69	16.42	32.39	17.50	83.34	14.16	1	31.1	Pullout
							2	23.0	Pullout
							3	12.2	Pullout
							4	15.2	Pullout
4	2.50	21.12	36.68	23.70	77.39	9.67	1	30.5	Pullout
							2	15.8	Pullout
							3	11.3	Pullout
							4	18.1	Pullout
** 5	1.54	25.82	31.53	27.26	74.80	9.85	1	27.2	Pullout
							2	7.9	Pullout
							3	6.3	Pullout

							4	14.5	Pullout
6	1.80	30.52	24.13	23.41	57.47	17.03	1	23.8	Pullout
							2	5.8	Pullout
							3	0.0	Pullout
							4	7.9	Pullout
7	1.90	35.22	24.51	23.22	45.74	20.18	1	20.8	Pullout
							2	3.7	Pullout
							3	0.0	Pullout
							4	8.3	Pullout
8	1.96	39.92	22.05	25.84	42.35	21.60	1	15.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	5.6	Pullout
9	2.06	44.62	18.18	23.48	37.46	28.10	1	11.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.4	Pullout
10	2.14	49.32	20.50	21.06	30.18	34.23	1	11.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	3.7	Pullout
11	2.21	54.02	18.96	22.85	28.12	36.75	1	7.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	1.6	Pullout

Search Level: 10.00 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower		Upper				
Search Point			Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.16	7.02	60.79	11.51	84.68	15.13	1	29.7	Facing
							2	29.8	Facing
							3	29.6	Pullout
							4	28.3	Pullout
2	2.64	11.72	43.78	14.61	85.58	15.21	1	30.4	Facing
							2	31.4	Pullout
							3	20.3	Pullout
							4	18.9	Pullout
3	2.51	16.42	40.71	19.50	82.64	12.82	1	31.1	Facing
							2	23.1	Pullout
							3	12.5	Pullout
							4	16.7	Pullout
4	2.38	21.12	33.95	22.91	80.63	12.97	1	30.4	Pullout
							2	14.8	Pullout
							3	4.4	Pullout
							4	11.7	Pullout
5	1.57	25.82	33.63	27.91	75.93	10.62	1	26.9	Pullout
							2	7.5	Pullout
							3	3.8	Pullout
							4	11.4	Pullout
6	1.81	30.52	25.89	23.75	59.52	18.05	1	23.2	Pullout
							2	5.0	Pullout
							3	0.0	Pullout
							4	3.8	Pullout
7	1.87	35.22	26.28	23.57	48.01	21.06	1	19.8	Pullout
							2	2.5	Pullout
							3	0.0	Pullout
							4	4.3	Pullout
8	1.93	39.92	23.68	26.15	44.61	22.43	1	14.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	1.1	Pullout
9	2.01	44.62	25.35	24.69	35.39	27.37	1	13.1	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

							4	3.2	Pullout
10	2.08	49.32	22.01	21.28	32.16	34.96	1	9.4	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	0.0	Pullout
11	2.16	54.02	26.34	60.28	0.00	0.00	1	9.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
							4	4.3	Pullout

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END OF REPORT

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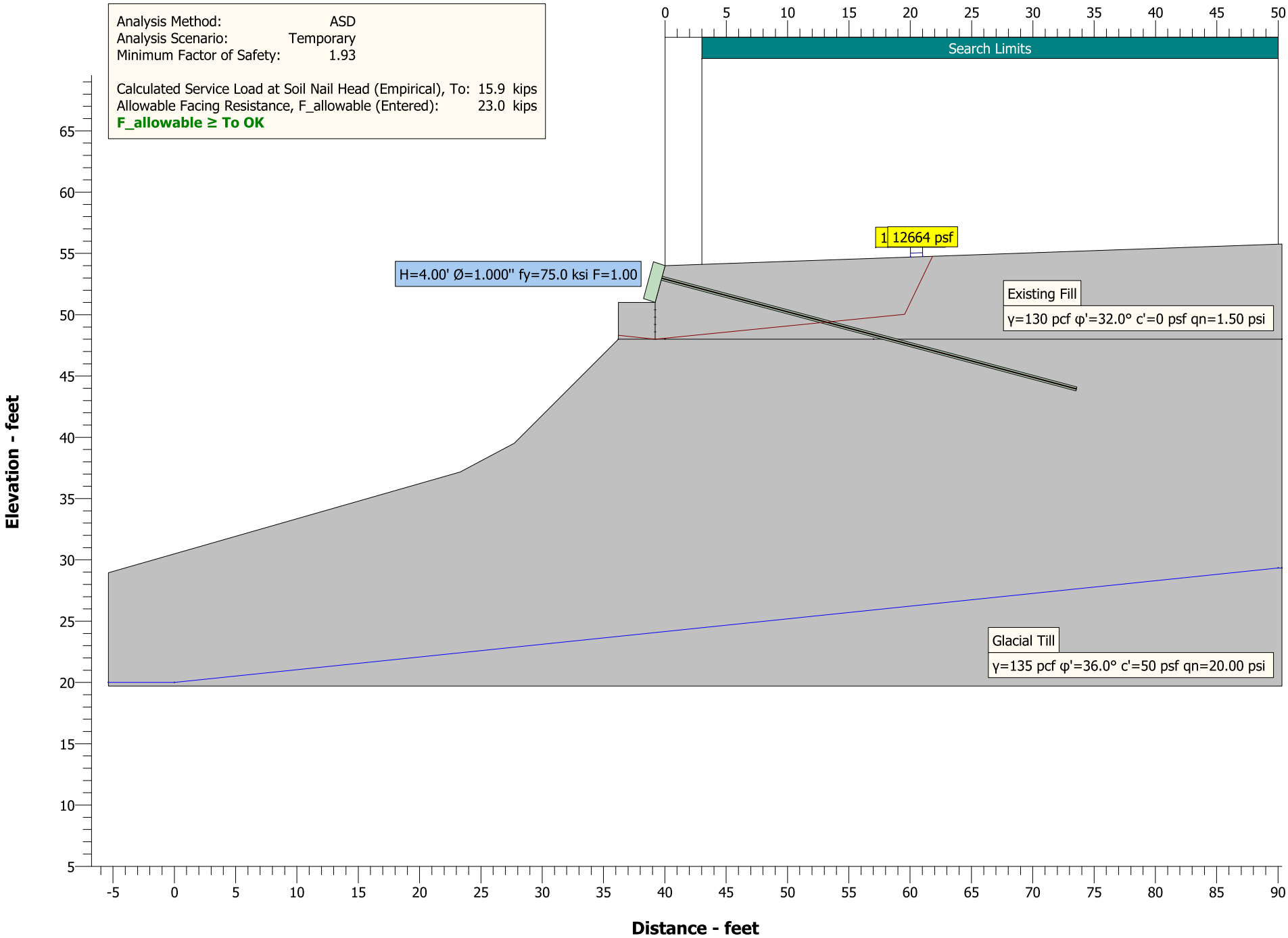
Analysis Method: ASD
Analysis Scenario: Temporary
Minimum Factor of Safety: 1.93
Calculated Service Load at Soil Nail Head (Empirical), To: 15.9 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK
Search Limits
1 12664 psf
H=4.00' Ø=1.000" fy=75.0 ksi F=1.00
Existing Fill
γ=130 pcf φ'=32.0° c'=0 psf qn=1.50 psi
Glacial Till
γ=135 pcf φ'=36.0° c'=50 psf qn=20.00 psi
Elevation - feet
Distance - feet

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Snail

Version: 2.2.2

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File Information

==========

File Name: 324-891 Stage No. 1 - Excavation.snz
Run Date: 10/20/23
Run Time: 13:29:28

==========

Project Information

==========

Description: Temporary Conditions
Location:
EA:
Project ID: 324-891
Wall No.:
Structure No.:
Station:
Engineer: GSS
Designer

Comments:

51 Harborview

==========

Geometry

==========

Layout:

Reference Point:

At: Top of Wall
Distance From Origin: 40.00 feet
Elevation Above Origin: 54.00 feet

Wall Dimensions:

Wall Height: 3.00 feet
Facing Angle: 75.00 degrees
Facing Batter: 3.215 :12 H:V

Ground Surface:

Number of lines that define the ground surface above the wall: 1

No.	Angle degrees	Distance feet
1	2	

Number of lines that define the ground surface in front of the toe: 5

No.	Angle degrees	Distance feet
1	0	3.00
2	-90	3.00
3	-45	12.00
4	-28	5.00
5	-16	

Soil Layers:

Number of Layers: 2

Layers Below the Top Layer:

Coordinates of the Top of the Layer: feet

Layer	Point 1 Distance	Point 1 Elevation	Point 2 Distance	Point 2 Elevation
2	40.00	48.00	57.00	48.00

Ground Water:

Include Ground Water: Yes
Phreatic Correction: No
Number of Points: 2

No.	Distance feet	Elevation feet
1	0.00	20.00
2	90.00	29.33

Soil Nails

Dimensions and Properties:

Maximum Vertical Spacing: 4.00 feet
Number of Soil Nail Rows: 1
Soil Nail Design Parameters: Varying

No.	Soil Nail Length feet	Inclination From Horizontal degrees	Vertical Spacing feet	Horizontal Spacing H feet	Nail Bar Diameter Ø inches	Nail Bar Yield Strength fy ksi	Bond Strength Factor F
1	35.00	15	1.00	4.00	1.000	75.0	1.00

Facing Resistance:

	Temporary	Permanent	Seismic	
ASD Allowable Facing Resistance:	23.0			kips

Soil Properties

Layer	Description	Unit Weight γ pcf	Friction Angle φ' degrees	Cohesion c' psf
1	Existing Fill	130	32.0	0
2	Glacial Till	135	36.0	50

Loads

Applied Loads:

Seismic:

Horizontal Seismic Coefficient Kh:

External Load:

Apply external load: No

Surcharges:

Apply surcharges: Yes

No.	Distance from Top of Wall Begin feet	End feet	Load Begin psf	Load End psf
1	20.00	21.00	12664	12664

Factors of Safety

	Temporary	Permanent	Seismic
Pullout (Distal):	2.00	2.00	1.50
Pullout (Proximal):	2.00	2.00	1.50
Nail Bar Yield:	1.80	1.80	1.35

Search Options

Search Limits:

Begin: 3.00 feet
End: 50.00 feet

Below Toe Searches (BTS):

Perform below Toe Search: Yes
Number of BTS Points: 5
BTS Depth: 3.00 feet
Interface Friction
Reduction Factor: 0.33

Advanced Search Options:

Use Advanced Search Options: No

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Results
==========

Analysis:

Method: ASD
Scenario: Temporary

Factor of Safety:

Minimum: 1.93
Found at Search Point: 5
Found at Grid Point: 32
Found at Search Level: 3.00 feet below the toe of the wall

Load at Soil Nail Head:

Calculated Service Load at Soil Nail Head (Empirical), To: 15.9 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK

Nominal Pullout Resistance:

Layer	Description	Nominal Pullout Resistance klf
1	Existing Fill	0.226
2	Glacial Till	3.016

Results by Search Level:

** Indicates Minimum Factor of Safety

Search Level: At the toe of the wall Facing Design Force = 15.6 kips (Clouterre)

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Failure Planes Lower Angle degrees	Failure Planes Lower Length feet	Failure Planes Upper Angle degrees	Failure Planes Upper Length feet	Reinforcement Level	Reinforcement Stress ksi	Reinforcement Controlling Resistance Failure Mode
1	4.41	3.80	0.00	3.42	83.02	3.13	1	29.7	Facing
2	19.96	8.50	0.00	0.85	23.13	8.32	1	29.7	Facing
3	N/A	13.20	0.00	1.32	16.11	12.37	1	29.9	Facing
4	N/A	17.90	0.00	1.79	12.58	16.51	1	30.0	Facing
5	2.13	22.60	0.00	20.34	59.00	4.39	1	30.4	Facing
6	15.27	27.30	0.00	2.73	9.08	24.89	1	30.1	Facing
7	N/A	32.00	0.00	3.20	8.08	29.09	1	30.1	Facing
8	N/A	36.70	0.00	3.67	7.34	33.31	1	30.2	Facing
9	N/A	41.40	0.00	4.14	6.76	37.52	1	30.2	Facing
10	N/A	46.10	0.00	4.61	6.30	41.75	1	30.3	Facing
11	N/A	50.80	0.00	5.08	5.93	45.97	1	30.3	Facing

Search Level: 0.60 feet below the toe of the wall Facing Design Force = 15.7 kips (Clouterre)

			Failure Planes	Reinforcement

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower Angle degrees	Lower Length feet	Upper Angle degrees	Upper Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.97	3.80	0.00	3.42	84.14	3.72	1	29.7	Facing
2	9.51	8.50	0.00	0.85	26.82	8.58	1	29.8	Facing
3	N/A	13.20	0.00	1.32	18.75	12.55	1	30.0	Facing
4	N/A	17.90	0.00	1.79	14.60	16.65	1	30.1	Facing
5	2.06	22.60	0.00	20.34	62.60	4.91	1	30.7	Facing
6	8.69	27.30	0.00	19.11	28.92	9.36	1	30.7	Facing
7	191.39	32.00	0.00	3.20	9.25	29.18	1	30.3	Facing
8	N/A	36.70	0.00	3.67	8.36	33.39	1	30.4	Facing
9	N/A	41.40	0.00	4.14	7.67	37.60	1	30.4	Facing
10	N/A	46.10	0.00	4.61	7.12	41.82	1	30.5	Facing
11	N/A	50.80	0.00	5.08	6.67	46.03	1	30.5	Facing

Search Level: 1.20 feet below the toe of the wall Facing Design Force = 15.6 kips (Clouterre)

			Failure Planes				Reinforcement		
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower Angle degrees	Lower Length feet	Upper Angle degrees	Upper Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.72	3.80	7.17	3.45	84.39	3.89	1	29.7	Facing
2	7.10	8.50	0.00	0.85	30.28	8.86	1	29.9	Facing
3	19.15	13.20	0.00	1.32	21.30	12.75	1	30.1	Facing
4	N/A	17.90	0.00	1.79	16.58	16.81	1	30.2	Facing
5	2.04	22.60	0.00	20.34	65.51	5.45	1	31.1	Facing
6	6.45	27.30	0.00	19.11	32.04	9.66	1	31.1	Facing
7	21.89	32.00	0.00	3.20	10.41	29.29	1	30.5	Facing
8	N/A	36.70	0.00	3.67	9.37	33.48	1	30.6	Facing
9	N/A	41.40	0.00	4.14	8.57	37.68	1	30.6	Facing
10	N/A	46.10	0.00	4.61	7.93	41.89	1	30.7	Facing
11	N/A	50.80	0.00	5.08	7.41	46.11	1	30.7	Facing

Search Level: 1.80 feet below the toe of the wall Facing Design Force = 15.6 kips (Clouterre)

			Failure Planes				Reinforcement		
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Lower Angle degrees	Lower Length feet	Upper Angle degrees	Upper Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.51	3.80	15.99	3.56	84.46	3.94	1	29.7	Facing
2	6.09	8.50	0.00	7.65	80.48	5.14	1	30.4	Facing
3	11.21	13.20	0.00	1.32	23.77	12.98	1	30.2	Facing
4	N/A	17.90	0.00	1.79	18.52	16.99	1	30.3	Facing
5	2.02	22.60	1.57	20.35	65.70	5.49	1	31.0	Pullout
6	5.20	27.30	0.00	19.11	34.95	9.99	1	30.8	Pullout
7	11.71	32.00	0.00	19.20	24.71	14.09	1	30.8	Pullout
8	50.50	36.70	0.00	18.35	18.26	19.32	1	30.8	Pullout
9	133.97	41.40	0.00	4.14	9.47	37.78	1	30.8	Facing

10	N/A	46.10	0.00	4.61	8.74	41.98	1	30.8	Facing
11	N/A	50.80	0.00	5.08	8.15	46.19	1	30.9	Facing

Search Level: 2.40 feet below the toe of the wall Facing Design Force = 15.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.20	3.80	25.75	3.80	84.36	3.87	1	29.7	Facing
2	5.36	8.50	4.24	7.67	80.54	5.17	1	30.4	Facing
3	8.51	13.20	0.00	1.32	26.14	13.24	1	30.2	Facing
4	14.11	17.90	0.00	1.79	20.41	17.19	1	30.4	Facing
5	1.98	22.60	3.47	20.38	65.37	5.42	1	30.9	Pullout
6	4.42	27.30	0.00	19.11	37.68	10.35	1	30.4	Pullout
7	8.23	32.00	0.00	19.20	26.88	14.35	1	30.4	Pullout
8	18.04	36.70	0.00	18.35	19.93	19.52	1	30.4	Pullout
9	24.66	41.40	0.00	20.70	18.23	21.80	1	30.4	Pullout
10	175.68	46.10	0.00	4.61	9.55	42.08	1	31.0	Facing
11	N/A	50.80	0.00	5.08	8.88	46.28	1	31.1	Facing

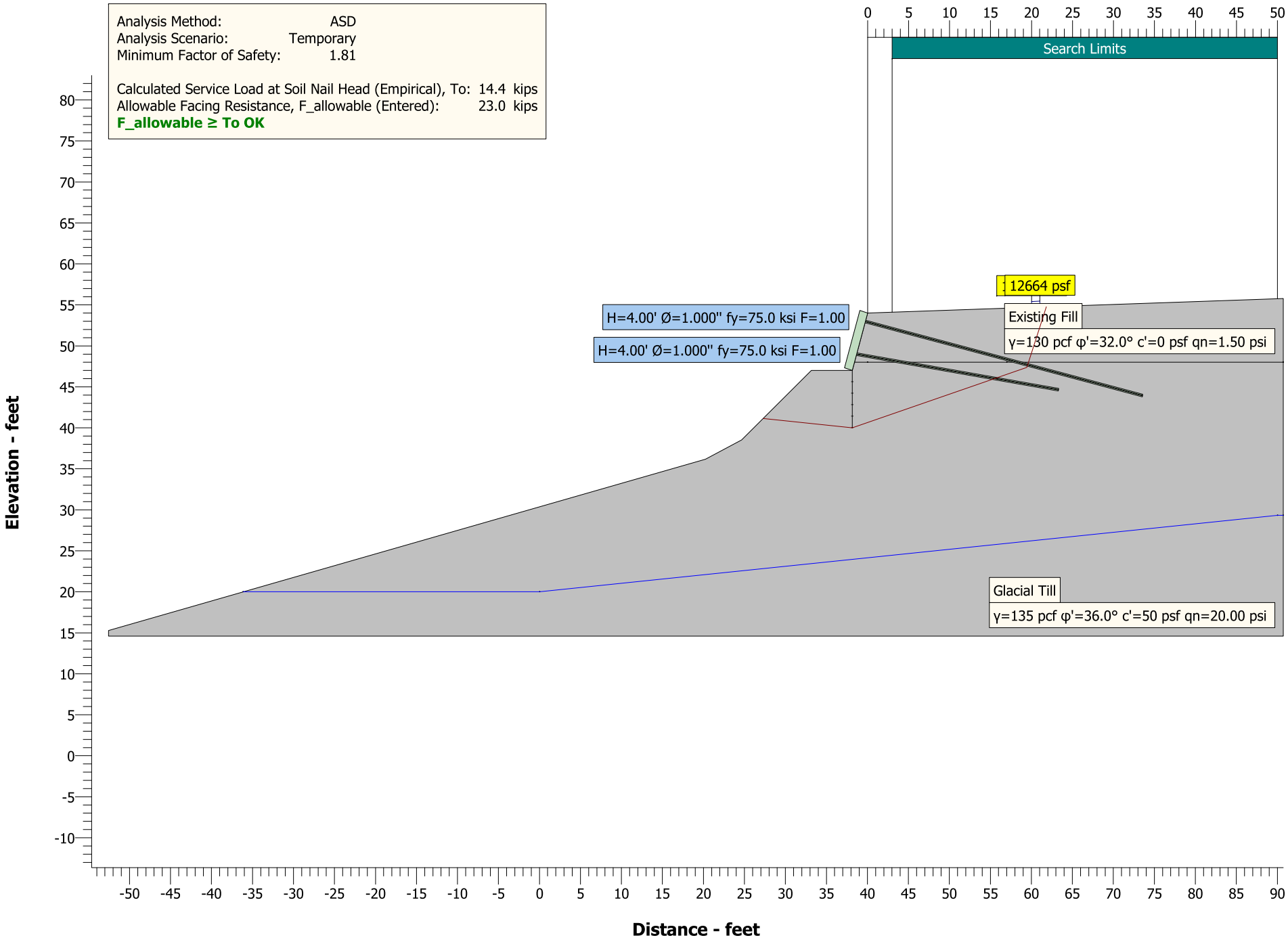
Search Level: 3.00 feet below the toe of the wall Facing Design Force = 15.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	2.93	3.80	35.50	4.21	84.07	3.68	1	29.7	Facing
2	4.68	8.50	9.30	7.76	80.38	5.09	1	30.4	Facing
3	7.18	13.20	0.00	11.88	78.40	6.57	1	31.0	Facing
4	10.28	17.90	0.00	1.79	22.27	17.41	1	30.5	Facing
** 5	1.93	22.60	5.69	20.44	64.47	5.24	1	30.9	Pullout
6	3.09	27.30	0.00	19.11	40.21	10.73	1	30.1	Pullout
7	5.74	32.00	0.00	19.20	28.98	14.63	1	30.1	Pullout
8	8.70	36.70	0.00	18.35	21.57	19.73	1	30.2	Pullout
9	14.15	41.40	0.00	20.70	19.71	21.99	1	30.1	Pullout
10	19.48	46.10	0.00	18.44	15.33	28.68	1	30.2	Pullout
11	34.96	50.80	0.00	20.32	14.26	31.45	1	30.1	Pullout

END OF REPORT

Analysis Method: ASD
Analysis Scenario: Temporary
Minimum Factor of Safety: 1.81

Calculated Service Load at Soil Nail Head (Empirical), To: 14.4 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK



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Snail

Version: 2.2.2

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File Information

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File Name: 324-891 Stage No. 2 - Excavation.snz
Run Date: 10/20/23
Run Time: 13:33:03

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Project Information

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Description: Temporary Conditions
Location:
EA:
Project ID: 324-891
Wall No.:
Structure No.:
Station:
Engineer: GSS
Designer

Comments:

51 Harborview

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Geometry

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Layout:

Reference Point:

At: Top of Wall
Distance From Origin: 40.00 feet
Elevation Above Origin: 54.00 feet

Wall Dimensions:

Wall Height: 7.00 feet
Facing Angle: 75.00 degrees
Facing Batter: 3.215 :12 H:V

Ground Surface:

Number of lines that define the ground surface above the wall: 1

No.	Angle degrees	Distance feet
1	2	

Number of lines that define the ground surface in front of the toe: 4

No.	Angle degrees	Distance feet
1	0	5.00
2	-45	12.00
3	-28	5.00
4	-16	

Soil Layers:

Number of Layers: 2

Layers Below the Top Layer:

Coordinates of the Top of the Layer: feet

Layer	Point 1 Distance	Point 1 Elevation	Point 2 Distance	Point 2 Elevation
2	40.00	48.00	57.00	48.00

Ground Water:

Include Ground Water: Yes
Phreatic Correction: No
Number of Points: 2

No.	Distance feet	Elevation feet
1	0.00	20.00
2	90.00	29.33

Soil Nails

Dimensions and Properties:

Maximum Vertical Spacing: 4.00 feet
Number of Soil Nail Rows: 2
Soil Nail Design Parameters: Varying

No.	Soil Nail Length feet	Inclination From Horizontal degrees	Vertical Spacing feet	Horizontal Spacing H feet	Nail Bar Diameter Ø inches	Nail Bar Yield Strength fy ksi	Bond Strength Factor F
1	35.00	15	1.00	4.00	1.000	75.0	1.00
2	25.00	10	4.00	4.00	1.000	75.0	1.00

Facing Resistance:

	Temporary	Permanent	Seismic	
ASD Allowable Facing Resistance:	23.0			kips

Soil Properties

Layer	Description	Unit Weight γ pcf	Friction Angle φ' degrees	Cohesion c' psf
1	Existing Fill	130	32.0	0
2	Glacial Till	135	36.0	50

Loads

Applied Loads:

Seismic:

Horizontal Seismic Coefficient Kh:

External Load:

Apply external load: No

Surcharges:

Apply surcharges: Yes

No.	Distance from Top of Wall Begin feet	End feet	Load Begin psf	Load End psf
1	20.00	21.00	12664	12664

Factors of Safety

	Temporary	Permanent	Seismic
Pullout (Distal):	2.00	2.00	1.50
Pullout (Proximal):	2.00	2.00	1.50
Nail Bar Yield:	1.80	1.80	1.35

Search Options

Search Limits:

Begin: 3.00 feet
End: 50.00 feet

Below Toe Searches (BTS):

Perform below Toe Search: Yes
Number of BTS Points: 5
BTS Depth: 7.00 feet
Interface Friction
Reduction Factor: 0.33

Advanced Search Options:

Use Advanced Search Options: No

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Results

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Analysis:

Method: ASD
Scenario: Temporary

Factor of Safety:

Minimum: 1.81
Found at Search Point: 5
Found at Grid Point: 43
Found at Search Level: 7.00 feet below the toe of the wall

Load at Soil Nail Head:

Calculated Service Load at Soil Nail Head (Empirical), To: 14.4 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK

Nominal Pullout Resistance:

Layer	Description	Nominal Pullout Resistance klf
1	Existing Fill	0.226
2	Glacial Till	3.016

Results by Search Level:

** Indicates Minimum Factor of Safety

Search Level: At the toe of the wall Facing Design Force = 15.8 kips (Clouterre)

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Failure Planes Lower Angle degrees	Failure Planes Lower Length feet	Failure Planes Upper Angle degrees	Failure Planes Upper Length feet	Reinforcement Level	Reinforcement Stress ksi	Controlling Resistance Failure Mode
1	4.01	4.88	9.20	4.45	85.64	6.41	1	29.8	Facing
							2	29.9	Facing
2	6.74	9.58	0.00	8.62	82.50	7.33	1	30.4	Facing
							2	32.1	Pullout
3	72.69	14.28	0.00	1.43	30.05	14.84	1	30.3	Facing
							2	29.8	Facing
4	N/A	18.98	0.00	1.90	23.98	18.69	1	30.6	Facing
							2	29.9	Facing
5	2.31	23.68	0.00	21.31	73.04	8.11	1	27.6	Pullout
							2	25.9	Pullout
6	5.94	28.38	0.00	19.86	42.95	11.63	1	29.1	Pullout
							2	25.9	Pullout
7	15.57	33.08	0.00	19.85	31.44	15.51	1	28.4	Pullout
							2	25.9	Pullout
8	N/A	37.78	0.00	3.78	13.65	34.99	1	31.0	Pullout
							2	32.0	Facing
9	N/A	42.48	0.00	4.25	12.42	39.14	1	30.9	Pullout
							2	32.9	Facing

10	N/A	47.18	0.00	4.72	11.43	43.32	1	30.8	Pullout
							2	33.3	Pullout
11	N/A	51.88	0.00	5.19	10.61	47.50	1	30.7	Pullout
							2	32.6	Pullout

Search Level: 1.40 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.57	4.88	30.18	5.08	85.32	5.97	1	29.7	Facing
							2	29.9	Facing
2	5.58	9.58	11.38	8.79	82.14	7.00	1	30.4	Facing
							2	32.2	Pullout
3	7.39	14.28	3.93	12.88	79.82	8.08	1	31.1	Facing
							2	23.9	Pullout
4	9.05	18.98	0.00	17.08	78.09	9.20	1	30.5	Pullout
							2	15.6	Pullout
5	2.07	23.68	0.00	21.31	75.51	9.46	1	27.0	Pullout
							2	10.4	Pullout
6	3.61	28.38	0.00	19.86	47.61	12.63	1	27.3	Pullout
							2	10.3	Pullout
7	5.45	33.08	0.00	19.85	35.65	16.28	1	25.9	Pullout
							2	10.4	Pullout
8	6.82	37.78	0.00	18.89	27.07	21.21	1	25.8	Pullout
							2	11.8	Pullout
9	7.22	42.48	0.00	21.24	24.81	23.40	1	22.4	Pullout
							2	10.4	Pullout
10	10.19	47.18	0.00	18.87	19.43	30.01	1	24.0	Pullout
							2	11.6	Pullout
11	10.19	51.88	0.00	20.75	18.05	32.74	1	21.5	Pullout
							2	10.4	Pullout

Search Level: 2.80 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.32	4.88	42.08	5.91	85.31	5.96	1	29.7	Facing
							2	29.9	Facing
2	4.66	9.58	19.32	9.13	82.26	7.11	1	30.4	Facing
							2	32.2	Pullout
3	5.87	14.28	9.05	13.01	80.11	8.31	1	31.1	Facing
							2	23.8	Pullout
4	7.08	18.98	3.48	17.11	78.54	9.55	1	30.5	Pullout
							2	15.4	Pullout
5	1.92	23.68	2.84	21.33	76.01	9.80	1	26.9	Pullout
							2	7.5	Pullout
6	2.97	28.38	3.09	19.89	48.59	12.87	1	26.9	Pullout
							2	9.8	Pullout
7	3.80	33.08	0.00	19.85	39.46	17.14	1	23.8	Pullout
							2	7.6	Pullout
8	4.80	37.78	0.00	18.89	30.34	21.88	1	23.1	Pullout
							2	8.2	Pullout
9	4.76	42.48	0.00	21.24	27.84	24.02	1	19.3	Pullout
							2	4.5	Pullout

10	6.00	47.18	0.00	18.87	21.91	30.51	1	20.5	Pullout
							2	7.0	Pullout
11	5.85	51.88	0.00	20.75	20.35	33.20	1	17.7	Pullout
							2	4.2	Pullout

Search Level: 4.20 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.17	4.88	45.86	6.30	85.89	6.80	1	29.8	Facing
							2	29.9	Facing
2	3.98	9.58	28.03	9.76	82.08	6.95	1	30.4	Facing
							2	32.2	Pullout
3	4.75	14.28	15.20	13.31	80.06	8.27	1	31.1	Facing
							2	23.8	Pullout
4	5.65	18.98	7.87	17.24	78.63	9.63	1	30.5	Pullout
							2	15.4	Pullout
5	1.88	23.68	6.41	21.44	76.10	9.86	1	26.9	Pullout
							2	7.4	Pullout
6	2.77	28.38	6.96	20.01	48.73	12.91	1	26.8	Pullout
							2	9.8	Pullout
7	3.40	33.08	0.00	19.85	42.89	18.06	1	22.1	Pullout
							2	5.4	Pullout
8	3.97	37.78	0.00	18.89	33.40	22.62	1	20.9	Pullout
							2	5.3	Pullout
9	4.00	42.48	0.00	21.24	30.72	24.70	1	16.8	Pullout
							2	1.2	Pullout
10	4.63	47.18	0.00	18.87	24.30	31.06	1	17.5	Pullout
							2	3.0	Pullout
11	4.61	51.88	0.00	20.75	22.58	33.71	1	14.4	Pullout
							2	0.0	Pullout

Search Level: 5.60 feet below the toe of the wall Facing Design Force = 14.2 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.08	4.88	55.36	7.72	85.61	6.37	1	29.7	Facing
							2	29.9	Facing
2	3.58	9.58	30.85	10.04	82.93	7.78	1	30.4	Facing
							2	32.0	Pullout
3	3.95	14.28	22.09	13.87	79.66	7.95	1	31.0	Facing
							2	23.9	Pullout
4	4.58	18.98	13.05	17.53	78.39	9.43	1	30.5	Pullout
							2	15.5	Pullout
5	1.86	23.68	14.08	21.97	73.55	8.36	1	27.5	Pullout
							2	13.9	Pullout
6	2.60	28.38	11.55	20.27	48.04	12.73	1	27.1	Pullout
							2	10.1	Pullout
7	3.12	33.08	3.95	19.89	42.96	18.08	1	22.1	Pullout
							2	5.4	Pullout
8	3.55	37.78	0.00	18.89	36.26	23.42	1	19.0	Pullout
							2	2.9	Pullout
9	3.61	42.48	3.78	21.28	30.71	24.70	1	16.8	Pullout
							2	1.2	Pullout

10	3.97	47.18	0.00	18.87	26.61	31.66	1	14.9	Pullout
							2	0.0	Pullout
11	4.10	51.88	3.96	20.80	22.53	33.70	1	14.5	Pullout
							2	0.0	Pullout

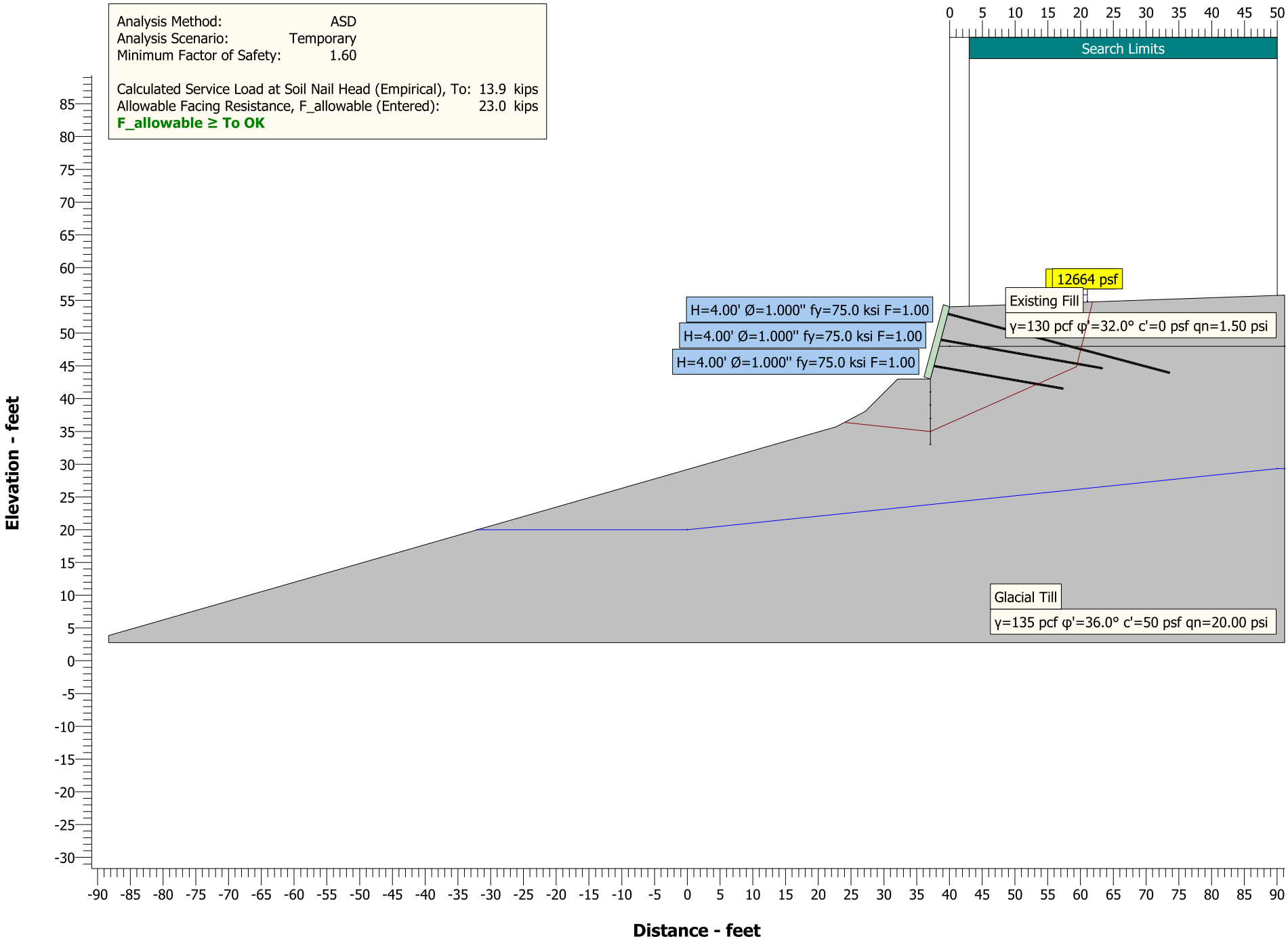
Search Level: 7.00 feet below the toe of the wall Facing Design Force = 14.4 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.02	4.88	58.11	8.31	86.05	7.07	1	29.8	Facing
							2	29.9	Facing
2	3.23	9.58	39.62	11.19	82.36	7.20	1	30.4	Facing
							2	32.1	Pullout
3	3.57	14.28	24.20	14.09	80.64	8.78	1	31.1	Facing
							2	23.7	Pullout
4	3.81	18.98	18.88	18.05	77.78	8.96	1	30.5	Pullout
							2	15.6	Pullout
** 5	1.81	23.68	19.11	22.55	72.22	7.75	1	27.8	Pullout
							2	15.1	Pullout
6	2.48	28.38	12.70	20.36	50.83	13.48	1	26.1	Pullout
							2	8.8	Pullout
7	2.88	33.08	8.65	20.07	42.38	17.91	1	22.4	Pullout
							2	5.7	Pullout
8	3.22	37.78	4.62	18.95	36.01	23.35	1	19.2	Pullout
							2	3.1	Pullout
9	3.32	42.48	8.26	21.46	30.15	24.56	1	17.3	Pullout
							2	1.8	Pullout
10	3.58	47.18	4.72	18.93	26.36	31.59	1	15.1	Pullout
							2	0.0	Pullout
11	3.73	51.88	4.34	20.81	24.48	34.20	1	11.8	Pullout
							2	0.0	Pullout

END OF REPORT

Analysis Method: ASD
Analysis Scenario: Temporary
Minimum Factor of Safety: 1.60

Calculated Service Load at Soil Nail Head (Empirical), To: 13.9 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK



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Snail

Version: 2.2.2

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==========

File Information

==========

File Name: 324-891 Stage No. 3 - Excavation.snz
Run Date: 10/20/23
Run Time: 13:34:35

==========

Project Information

==========

Description: Temporary Conditions
Location:
EA:
Project ID: 324-891
Wall No.:
Structure No.:
Station:
Engineer: GSS
Designer

Comments:

51 Harborview

==========

Geometry

==========

Layout:

Reference Point:

At: Top of Wall
Distance From Origin: 40.00 feet
Elevation Above Origin: 54.00 feet

Wall Dimensions:

Wall Height: 11.00 feet
Facing Angle: 75.00 degrees
Facing Batter: 3.215 :12 H:V

Ground Surface:

Number of lines that define the ground surface above the wall: 1

No.	Angle degrees	Distance feet
1	2	

Number of lines that define the ground surface in front of the toe: 4

No.	Angle degrees	Distance feet
1	0	5.00
2	-45	7.00
3	-28	5.00
4	-16	

Soil Layers:

Number of Layers: 2

Layers Below the Top Layer:

Coordinates of the Top of the Layer: feet

Layer	Point 1 Distance	Point 1 Elevation	Point 2 Distance	Point 2 Elevation
2	40.00	48.00	57.00	48.00

Ground Water:

Include Ground Water: Yes
Phreatic Correction: No
Number of Points: 2

No.	Distance feet	Elevation feet
1	0.00	20.00
2	90.00	29.33

Soil Nails

Dimensions and Properties:

Maximum Vertical Spacing: 4.00 feet
Number of Soil Nail Rows: 3
Soil Nail Design Parameters: Varying

No.	Soil Nail Length feet	Inclination From Horizontal degrees	Vertical Spacing feet	Horizontal Spacing H feet	Nail Bar Diameter Ø inches	Nail Bar Yield Strength fy ksi	Bond Strength Factor F
1	35.00	15	1.00	4.00	1.000	75.0	1.00
2	25.00	10	4.00	4.00	1.000	75.0	1.00
3	20.00	10	4.00	4.00	1.000	75.0	1.00

Facing Resistance:

	Temporary	Permanent	Seismic	
ASD Allowable Facing Resistance:	23.0			kips

Soil Properties

Layer	Description	Unit Weight γ pcf	Friction Angle φ' degrees	Cohesion c' psf
1	Existing Fill	130	32.0	0
2	Glacial Till	135	36.0	50

Loads

Applied Loads:

Seismic:

Horizontal Seismic Coefficient Kh:

External Load:

Apply external load: No

Surcharges:

Apply surcharges: Yes

No.	Distance from Top of Wall Begin feet	End feet	Load Begin psf	Load End psf
1	20.00	21.00	12664	12664

Factors of Safety

	Temporary	Permanent	Seismic
Pullout (Distal):	2.00	2.00	1.50
Pullout (Proximal):	2.00	2.00	1.50
Nail Bar Yield:	1.80	1.80	1.35

Search Options

Search Limits:

Begin: 3.00 feet
End: 50.00 feet

Below Toe Searches (BTS):

Perform below Toe Search: Yes
Number of BTS Points: 5
BTS Depth: 10.00 feet
Interface Friction
Reduction Factor: 0.33

Advanced Search Options:

Use Advanced Search Options: No

==========
Results
==========

Analysis:

Method: ASD
Scenario: Temporary

Factor of Safety:

Minimum: 1.60
Found at Search Point: 5
Found at Grid Point: 43
Found at Search Level: 8.00 feet below the toe of the wall

Load at Soil Nail Head:

Calculated Service Load at Soil Nail Head (Empirical), To: 13.9 kips
Allowable Facing Resistance, F_allowable (Entered): 23.0 kips
F_allowable ≥ To OK

Nominal Pullout Resistance:

Layer	Description	Nominal Pullout Resistance klf
1	Existing Fill	0.226
2	Glacial Till	3.016

Results by Search Level:

** Indicates Minimum Factor of Safety

Search Level: At the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Failure Planes: Lower Angle degrees	Lower Length feet	Upper Angle degrees	Upper Length feet	Reinforcement: Level	Stress ksi	Controlling Resistance Failure Mode
1	4.00	5.95	11.72	5.47	86.60	10.01	1	29.8	Facing
							2	29.9	Facing
							3	29.0	Pullout
2	5.64	10.65	0.00	9.58	84.60	11.32	1	30.4	Facing
							2	31.6	Pullout
							3	20.7	Pullout
3	9.41	15.35	0.00	13.81	82.36	11.54	1	31.1	Facing
							2	23.2	Pullout
							3	16.3	Pullout
4	10.87	20.05	0.00	18.04	80.19	11.77	1	30.5	Pullout
							2	14.9	Pullout
							3	16.3	Pullout
5	2.11	24.75	6.03	22.40	75.27	9.73	1	27.1	Pullout
							2	7.7	Pullout
							3	25.0	Pullout
6	3.35	29.45	0.00	20.61	53.47	14.84	1	25.2	Pullout
							2	7.6	Pullout
							3	16.3	Pullout
7	4.20	34.15	0.00	20.49	41.51	18.24	1	22.8	Pullout

							2	6.3	Pullout
							3	16.3	Pullout
8	5.26	38.85	0.00	19.42	32.25	22.97	1	21.7	Pullout
							2	6.4	Pullout
							3	16.3	Pullout
9	5.18	43.55	0.00	21.77	29.70	25.07	1	17.7	Pullout
							2	2.3	Pullout
							3	16.3	Pullout
10	6.46	48.25	0.00	19.30	23.49	31.56	1	18.5	Pullout
							2	4.3	Pullout
							3	16.3	Pullout
11	6.24	52.95	0.00	21.18	21.86	34.23	1	15.4	Pullout
							2	1.2	Pullout
							3	16.3	Pullout

Search Level: 2.00 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.52	5.95	26.09	5.96	86.75	10.50	1	29.8	Facing
							2	29.9	Facing
							3	29.0	Pullout
2	4.72	10.65	7.88	9.67	84.91	11.99	1	30.4	Facing
							2	31.6	Pullout
							3	20.6	Pullout
3	5.18	15.35	5.55	13.88	82.77	12.19	1	31.1	Facing
							2	23.1	Pullout
							3	12.4	Pullout
4	6.26	20.05	4.31	18.09	80.70	12.40	1	30.4	Pullout
							2	14.8	Pullout
							3	7.7	Pullout
5	1.91	24.75	10.50	22.65	75.59	9.95	1	27.0	Pullout
							2	7.6	Pullout
							3	17.4	Pullout
6	2.63	29.45	0.00	20.61	57.61	16.49	1	23.8	Pullout
							2	5.8	Pullout
							3	0.0	Pullout
7	2.92	34.15	0.00	20.49	45.89	19.62	1	20.7	Pullout
							2	3.7	Pullout
							3	0.0	Pullout
8	3.23	38.85	0.00	19.42	36.27	24.09	1	19.0	Pullout
							2	2.9	Pullout
							3	0.1	Pullout
9	3.33	43.55	0.00	21.77	33.51	26.11	1	14.5	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
10	3.60	48.25	0.00	19.30	26.74	32.41	1	14.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
11	3.77	52.95	0.00	21.18	24.90	35.02	1	11.3	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

Search Level: 4.00 feet below the toe of the wall Facing Design Force = 14.0 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.12	5.95	40.25	7.01	86.78	10.59	1	29.8	Facing
							2	29.9	Facing
							3	28.9	Pullout

2	3.85	10.65	17.68	10.06	85.02	12.26	1	30.4	Facing
							2	31.5	Pullout
							3	20.5	Pullout
3	4.09	15.35	12.60	14.15	82.92	12.44	1	31.1	Facing
							2	23.1	Pullout
							3	12.4	Pullout
4	4.38	20.05	19.07	19.09	77.91	9.57	1	30.5	Pullout
							2	15.6	Pullout
							3	16.7	Pullout
5	1.74	24.75	15.80	23.15	75.34	9.78	1	27.1	Pullout
							2	7.7	Pullout
							3	13.6	Pullout
6	2.33	29.45	8.78	20.86	55.26	15.50	1	24.6	Pullout
							2	6.8	Pullout
							3	3.5	Pullout
7	2.61	34.15	4.49	20.55	46.67	19.91	1	20.4	Pullout
							2	3.2	Pullout
							3	0.0	Pullout
8	2.82	38.85	4.78	19.49	36.98	24.32	1	18.6	Pullout
							2	2.3	Pullout
							3	0.0	Pullout
9	2.94	43.55	4.31	21.84	34.16	26.31	1	14.0	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
10	3.12	48.25	4.91	19.37	27.27	32.57	1	14.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
11	3.27	52.95	4.52	21.25	25.38	35.16	1	10.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

Search Level: 6.00 feet below the toe of the wall Facing Design Force = 14.1 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	2.88	5.95	51.96	8.69	86.68	10.28	1	29.8	Facing
							2	29.9	Facing
							3	29.0	Pullout
2	3.17	10.65	28.40	10.89	84.97	12.14	1	30.4	Facing
							2	31.5	Pullout
							3	20.6	Pullout
3	3.26	15.35	20.74	14.77	82.83	12.30	1	31.1	Facing
							2	23.1	Pullout
							3	12.4	Pullout
4	3.29	20.05	26.00	20.07	77.17	9.02	1	30.5	Pullout
							2	15.8	Pullout
							3	15.7	Pullout
5	1.69	24.75	21.74	23.98	74.43	9.22	1	27.3	Pullout
							2	9.5	Pullout
							3	12.0	Pullout
6	2.12	29.45	14.62	21.30	54.85	15.35	1	24.7	Pullout
							2	7.0	Pullout
							3	3.3	Pullout
7	2.35	34.15	10.01	20.81	46.66	19.90	1	20.4	Pullout
							2	3.2	Pullout
							3	0.0	Pullout
8	2.50	38.85	10.64	19.76	36.94	24.30	1	18.6	Pullout
							2	2.3	Pullout
							3	0.0	Pullout
9	2.62	43.55	9.60	22.08	34.09	26.29	1	14.1	Pullout
							2	0.0	Pullout

							3	0.0	Pullout
10	2.74	48.25	10.90	19.65	27.18	32.54	1	14.2	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
11	2.88	52.95	10.04	21.51	25.27	35.13	1	10.8	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

Search Level: 8.00 feet below the toe of the wall Facing Design Force = 13.9 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.13	5.95	58.09	9.00	84.08	11.52	1	29.7	Facing
							2	29.8	Facing
							3	29.8	Pullout
2	2.75	10.65	38.81	12.30	84.74	11.61	1	30.4	Facing
							2	31.6	Pullout
							3	20.6	Pullout
3	2.89	15.35	40.17	18.08	78.83	7.92	1	31.0	Facing
							2	24.1	Pullout
							3	20.2	Pullout
4	2.81	20.05	28.51	20.53	78.44	10.00	1	30.5	Pullout
							2	15.5	Pullout
							3	12.1	Pullout
** 5	1.60	24.75	23.92	24.37	75.94	10.19	1	26.9	Pullout
							2	7.5	Pullout
							3	7.7	Pullout
6	1.99	29.45	21.14	22.10	53.54	14.87	1	25.1	Pullout
							2	7.5	Pullout
							3	4.5	Pullout
7	2.15	34.15	16.39	21.36	45.83	19.60	1	20.8	Pullout
							2	3.7	Pullout
							3	0.0	Pullout
8	2.29	38.85	17.37	20.35	36.13	24.05	1	19.1	Pullout
							2	3.0	Pullout
							3	0.3	Pullout
9	2.37	43.55	15.71	22.62	33.28	26.05	1	14.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
10	2.49	48.25	17.74	20.26	26.46	32.34	1	15.0	Pullout
							2	0.0	Pullout
							3	0.3	Pullout
11	2.60	52.95	16.38	22.07	24.57	34.93	1	11.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout

Search Level: 10.00 feet below the toe of the wall Facing Design Force = 14.1 kips (Clouterre)

			Failure Planes				Reinforcement		
			Lower		Upper				
Search Point	Minimum Factor of Safety	Distance From Toe of Wall feet	Angle degrees	Length feet	Angle degrees	Length feet	Level	Stress ksi	Controlling Resistance Failure Mode
1	3.09	5.95	60.59	9.69	84.63	12.72	1	29.7	Facing
							2	29.8	Facing
							3	29.7	Pullout
2	2.71	10.65	41.60	12.81	85.23	12.81	1	30.4	Facing
							2	31.5	Pullout
							3	20.5	Pullout
3	2.64	15.35	42.95	18.87	79.85	8.71	1	31.1	Facing
							2	23.9	Pullout
							3	18.2	Pullout

4	2.52	20.05	35.69	22.21	76.94	8.87	1	30.5	Pullout
							2	15.9	Pullout
							3	13.1	Pullout
5	1.60	24.75	30.38	25.82	74.13	9.05	1	27.4	Pullout
							2	9.5	Pullout
							3	8.5	Pullout
6	1.90	29.45	23.05	22.40	56.12	15.85	1	24.3	Pullout
							2	6.4	Pullout
							3	0.3	Pullout
7	2.04	34.15	23.33	22.31	44.14	19.03	1	21.5	Pullout
							2	4.7	Pullout
							3	0.6	Pullout
8	2.17	38.85	18.97	20.54	38.73	24.90	1	17.5	Pullout
							2	0.9	Pullout
							3	0.0	Pullout
9	2.22	43.55	22.38	23.55	31.71	25.59	1	16.0	Pullout
							2	0.1	Pullout
							3	0.0	Pullout
10	2.35	48.25	19.34	20.45	28.64	32.98	1	12.7	Pullout
							2	0.0	Pullout
							3	0.0	Pullout
11	2.44	52.95	23.25	57.63	0.00	0.00	1	13.5	Pullout
							2	0.0	Pullout
							3	0.5	Pullout

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END OF REPORT

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ATTACHMENT 6

GABION BASKET STABILITY ANALYSIS

PREPARED BY VPC DATE 10/11/23 CHECKED BY GSS DATE 10/16/23

Friction coefficient between Gabion and subsoil

$$\alpha_{ds} = \frac{\alpha_s \tan\delta + (1-\alpha_s)\tan\phi}{\tan\phi}$$

α_{ds} = Friction coeff. between gabion and sub soil

α_s = ratio of steel area to gabion-soil contact area

δ = steel-soil friction angle = 0.3ϕ As per NAVFAC

ϕ = friction angle of sub soil = 38°

$\alpha_s = A_s/(3' \times 3') = A_s/9$ sqft ; A_s = Area of steel

As calc:

wire diameter = 4mm

opening diameter = 75mm

gabion length = 3ft = 914.4mm

−4mm for leading wire

wire to opening length → $\frac{910.4\text{ mm}}{(75\text{mm} + 4\text{mm})} \cong 11.5 \Rightarrow 12$ (round) $+ 1$ lead $= 13$ wires per direction

wire area = 4mm × (3ft = 914.4mm) = 3657.6 sqmm

4mm × 4mm = 16 sqmm/overlap

13 × 13 = 169 overlaps

16 × 169 = 2704 sqmm of overlapp

× 13 wires

= 47,548.8 sqmm

× 2 directions

= 95097.6 sqmm

− 2704 sqmm overlap

= 92,393.6 sqmm

= 0.99... sqft ≅ 1 sqft

$\alpha_s = 1\text{ sqft} / 9\text{ sqft} = 0.\overline{11}$

Friction coeff between gabion and subsoil cont.

$$\alpha_{ds} = \frac{(0.22)\tan(0.3(38°)) + (1-0.22)\tan(38°)}{\tan(38°)}$$

$$\boxed{\alpha_{ds} \cong 0.90}$$

Void Ratio in Gabions

- Not to exceed 0.3
  - Set as 0.25

$$e = 0.25 = \frac{V_v}{V_s} = \frac{0.25}{1} \rightarrow V_t = V_v + V_s \rightarrow \frac{0.25}{1+0.25} = 0.2 = 20\%$$

SRWall (Version 4) Report

Project Identification

Project ID	: **324-891**
Project Name	: **Harborview 51 - East Gabion Baskets**
Owner	:
Client	: **Tom Fitzgerald**
Prepared By	: **GSS**
Company	: **Civil & Environmental Consultants**
Address	:
Telephone	:
Section	:
Project File	: **324-891_10-16-23.prj**
Vendor Data File	:
Date and Time	: **10/13/2023 10:59:47**

Type of Structure	: **Gravity Wall**

Wall Geometry

Design Wall Height(ft)	: **9.00**
Embedment Wall Height(ft)	: **2.00**
Exposed Wall Design Height(ft)	: **7.00**
Number of Segmental Wall Units	: **3**
Wall Inclination(degrees)	: **9.46**

Grades

Top Slope(degrees)	: **27.00**
Broken Back Distance(ft)	: **5.00**

Uniform Distributed Surcharge

Live Load Surcharge(Psf)	: **0.00**
Dead Load Surcharge(Psf)	: **0.00**

Soil Data

Soil Zone	Description	Cohesion (c) (psf)	Friction Angle(Φ) (degrees)	Unit Weight (γ)(pcf)
Retained Soil	Glacial Till	N/A	36.00	135.00
Leveling Pad Soil	Crushed Stone	N/A	38.00	140.00
Foundation Soil	Glacial Till		36.00	135.00

Segmental Unit Data

Segmental Unit Name : **3'x3'x3' Gabion Basket**
Cap Height (Inches) : **0.00**
Unit Height (Hu)(Inches) : **36.00**
Unit Width (Wu)(Inches) : **36.00**
Unit Length (Inches) : **36.00**
Setback (Inches) : **6.00**
Weight (Infilled)(lb) : **3240.00**
Unit Weight (Infilled)(pcf) : **120.00**
Center of Gravity(Inches) : **18.00**

Unit-Unit Interface Properties

Minimum Shear Capacity(lb/ft)	Shear Friction Angle	Maximum Shear Capacity (lb/ft)
880.00	1.00	880.00

Vertical Components

Vertical Components of Earth Pressures Used : **No**

Cofficients of Earth Pressure and Failure Plane Orientation

Retained Soil(Static)(Ka) : **0.189**
Retained Soil(Static)(Kah Horizontal Component) : **0.169**
External Modified Back Slope(Bext) : **8.056**
Orientation of failure plane from horizontal(degrees) for External Stability : **54.775**

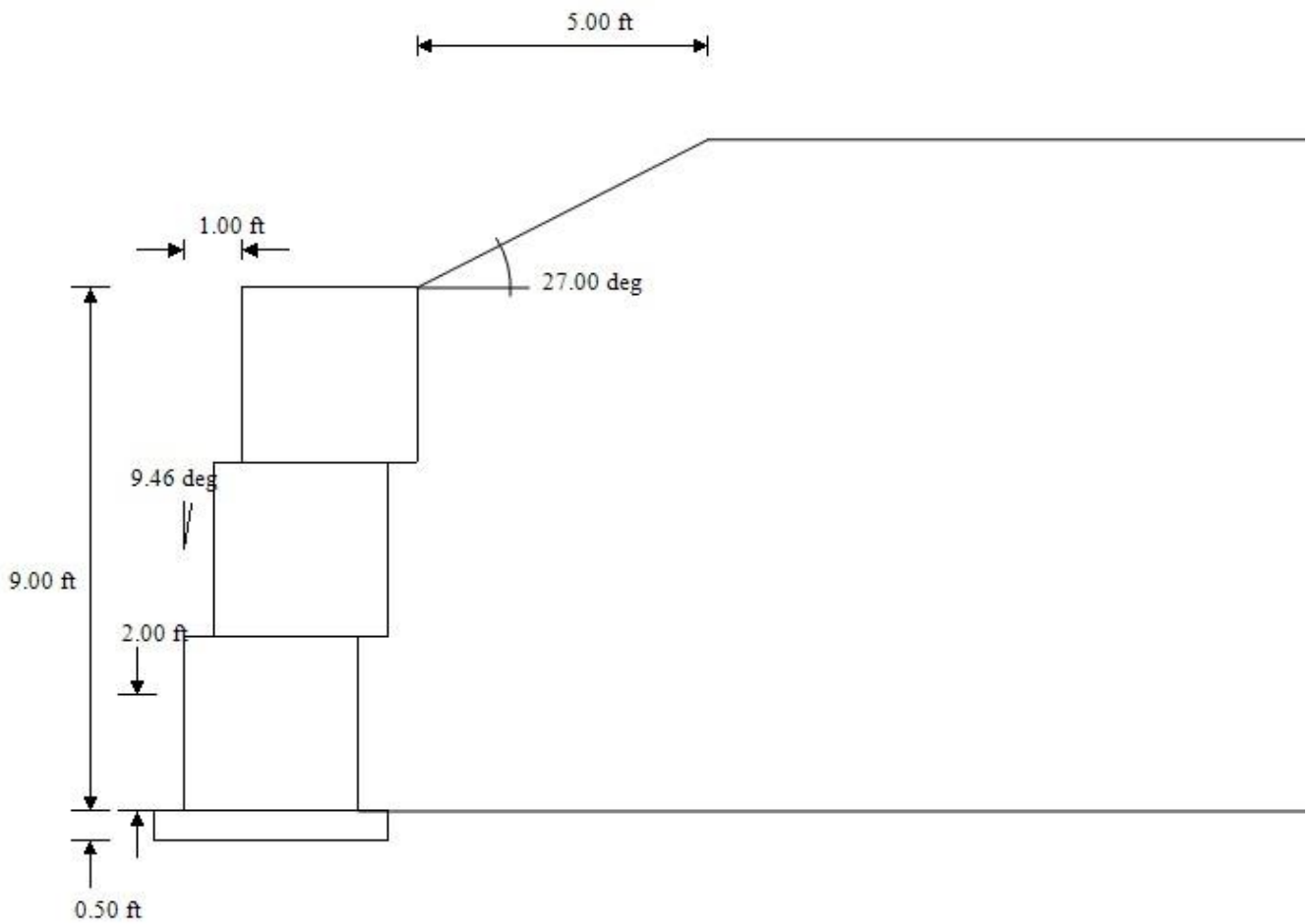
Result of External Stability Static Analysis

	Calculated	Design Criteria
FOS Sliding	1.77	> 1.50
FOS Overturning	2.16	> 2.00
FOS Bearing Capacity	16.58	> 2.50
Base Footing (B)(ft)	3.50	

Results of Internal Stability Static Analysis

SRW Unit #	Heel Elev (ft)	FOS Shear >=1.50
3	6.00	7.93
2	3.00	1.98

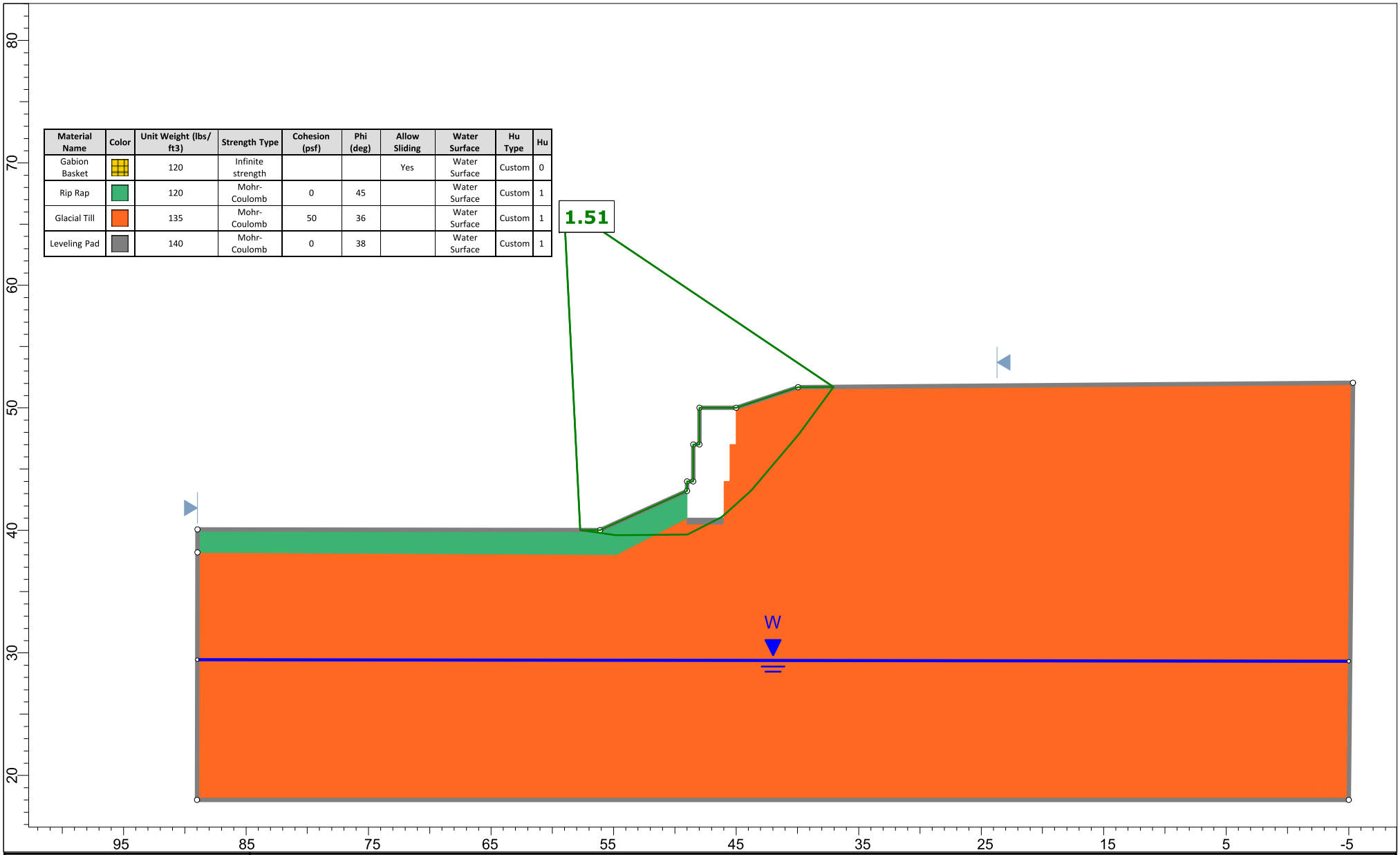
Wall Geometry Layout



Project Identification

Project ID	: **324-891**
Project Name	: **Harborview 51 - East Gabion Baskets**
Owner	:
Client	: **Tom Fitzgerald**
Prepared By	: **GSS**
Company	: **Civil & Environmental Consultants**
Address	:
Telephone	:
Section	:
Vendor Data File	:
Project File	: **324-891_10-16-23.prj**
Date and Time	: **10/13/2023 10:59:47**

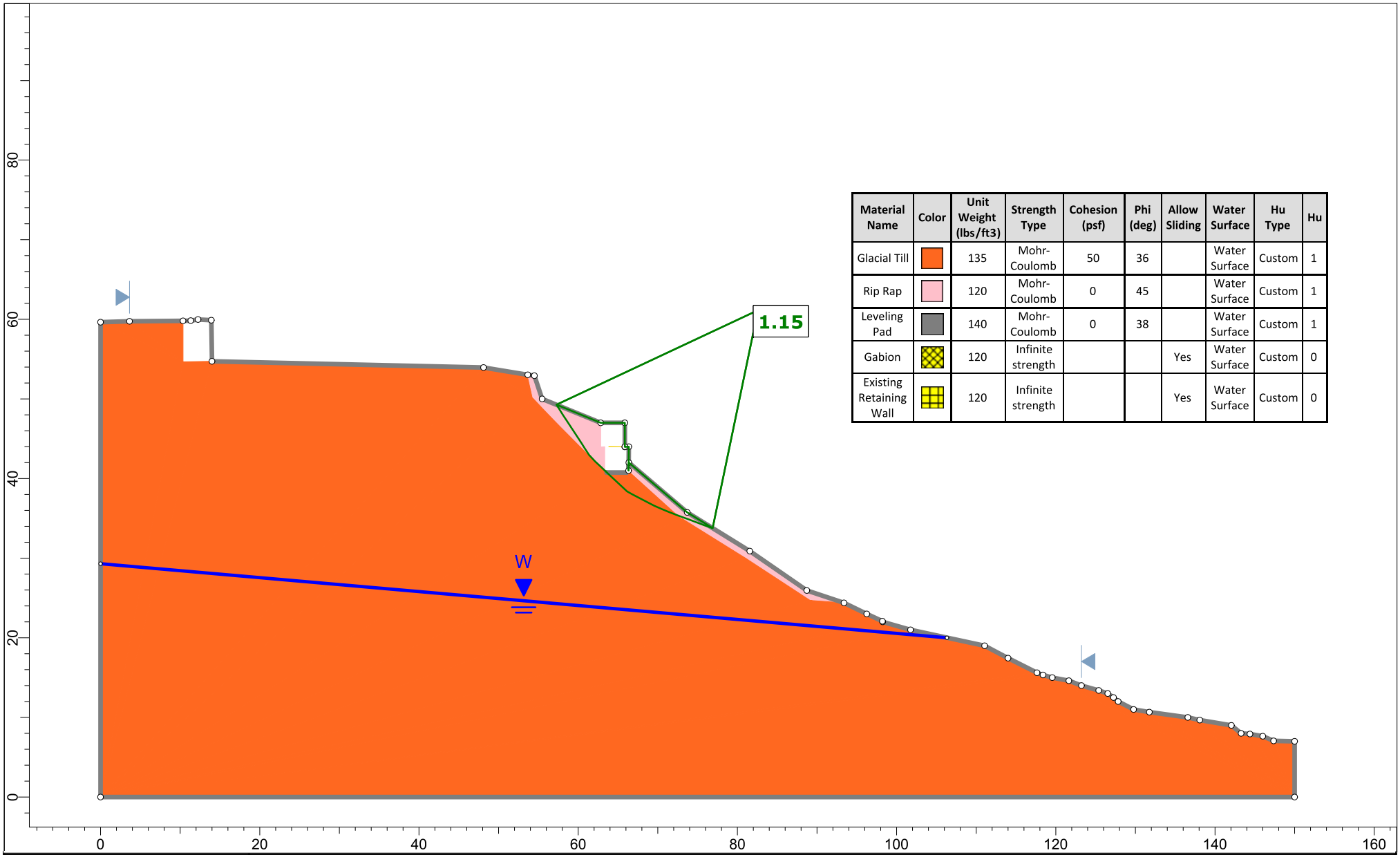
Material Name	Color	Unit Weight (lbs/ ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Hu Type	Hu
Gabion Basket		120	Infinite strength			Yes	Water Surface	Custom	0
Rip Rap		120	Mohr-Coulomb	0	45		Water Surface	Custom	1
Glacial Till		135	Mohr-Coulomb	50	36		Water Surface	Custom	1
Leveling Pad		140	Mohr-Coulomb	0	38		Water Surface	Custom	1



Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Road Slope Stability		
Analysis Description	East Gabion Baskets - East-West Section	Figure	
Drawn By	TS	Company	CEC Inc.
Date	10/11/2023	File Name	324-891 Harborview Gabion Gravity SRW - Global.slmd



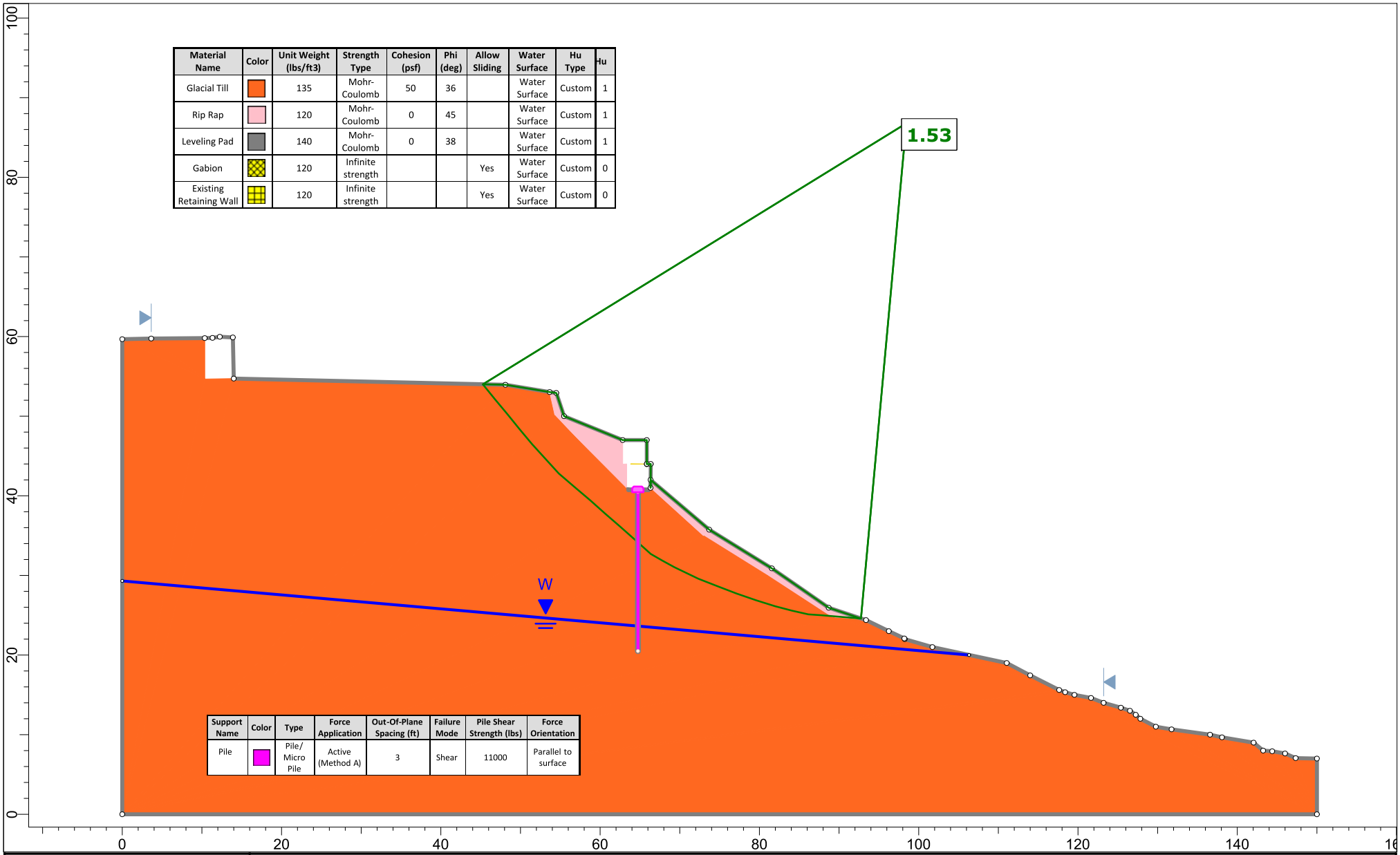
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Hu Type	Hu
Glacial Till		135	Mohr-Coulomb	50	36		Water Surface	Custom	1
Rip Rap		120	Mohr-Coulomb	0	45		Water Surface	Custom	1
Leveling Pad		140	Mohr-Coulomb	0	38		Water Surface	Custom	1
Gabion		120	Infinite strength			Yes	Water Surface	Custom	0
Existing Retaining Wall		120	Infinite strength			Yes	Water Surface	Custom	0

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	East Gabion Baskets - North-South Section	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/17/23	*File Name*	

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Allow Sliding	Water Surface	Hu Type	Hu
Glacial Till		135	Mohr-Coulomb	50	36		Water Surface	Custom	1
Rip Rap		120	Mohr-Coulomb	0	45		Water Surface	Custom	1
Leveling Pad		140	Mohr-Coulomb	0	38		Water Surface	Custom	1
Gabion		120	Infinite strength			Yes	Water Surface	Custom	0
Existing Retaining Wall		120	Infinite strength			Yes	Water Surface	Custom	0



Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (ft)	Failure Mode	Pile Shear Strength (lbs)	Force Orientation
Pile		Pile/ Micro Pile	Active (Method A)	3	Shear	11000	Parallel to surface

Civil & Environmental Consultants, Inc.

SLIDEINTERPRET 9.026

Project	51 Harborview Rd Hull, MA Slope Stabilization		
Analysis Description	East Gabion Baskets - North-South Section w/Piles	*Figure*	
Drawn By	TS	*Company*	CEC Inc.
Date	10/18/23	*File Name*	

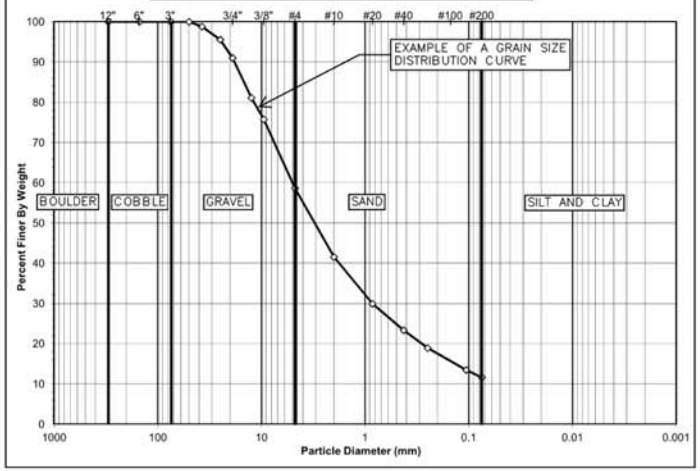
ATTACHMENT 7

TEST BORING LOG

Rock Types

Rock Name	Characteristics	Symbol
Claystone	Clay sized particles that are consolidated, lacking fissility.	
Coal	Black and shiny, can break into cubes or conchoidally.	
Conglomerate	Gravel sized grains and larger held together by finer material, called a breccia if clasts are angular.	
Limestone	Effervesses w/ diluted HCl, can be composed of clay up to gravel particles (fossils).	
Sandstone	Primarily sand sized particles modified w/ the descriptor fine, medium, or coarse.	
Shale	Clay sized particles, shale has fissility which is a horizontal sheet-like or laminated feature.	
Siltstone	Composed of silt, normally breaks as irregular chunks.	

Grain Size Distribution Curve



Rock Quality Descriptions

Weathering

Completely Weathered: All rock material is decomposed and/or disintegrated. The original rock structure may still be intact.

Highly Weathered: More than half of the rock material is decomposed. Fresh rock is present only as a discontinuous framework or as corestones.

Moderately Weathered: Less than half of the rock material is decomposed. Fresh rock is present at a discontinuous framework or as corestones.

Slightly Weathered: Discoloration or staining indicates weathering of rock material on discontinuity surfaces. Rock may be discolored and softened.

Fresh: No visible signs of rock material weathering.

RQD

Descriptor	%
Very Poor	<25
Poor	25-50
Fair	50-75
Good	75-90
Excellent	>90

Brokenness

Descriptor	Fracture Spacing (in & ft)
Very Broken	<1 (<0.08)
Broken	1-3 (0.08-0.25)
Moderately Broken	3-6 (0.25-0.5)
Slightly Broken	>6 (>0.5)

Rock Hardness

Descriptor	Field Criterion	Relative Unconfined Compressive Strength
Very Hard	Difficult to break w/ Hammer	> 30,000 psi
Hard	Hand-held sample breaks w/ Hammer	8,000 to 30,000 psi
Medium Hard	Cannot scrape surface w/ knife	2,000 to 8,000 psi
Soft	Cutting or scraping w/ knife difficult	500 to 2,000 psi
Very Soft	Can be cut w/ knife	< 500 psi

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
Clean Gravels (Less than 5% fines)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
Gravels with fines (More than 12% fines)		
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
Clean Sands (Less than 5% fines)		
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
Sands with fines (More than 12% fines)		
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

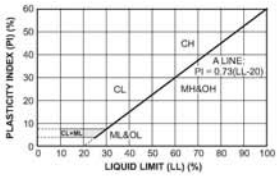
LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent ..... GW, GP, SW, SP
More than 12 percent ..... GM, GC, SM, SC
5 to 12 percent ..... Borderline cases requiring dual symbols

PLASTICITY CHART



Glossary

Alluvial Soil or Alluvium: Soil deposited by water in a river, stream, floodplain, or delta.

Bedrock: Materials underlying soil or other unconsolidated surficial materials in which refusal is consistently encountered on lithified, undisturbed, natural bedrock.

Colluvial Soil or Colluvium: Incoherent soil on or at the base of a slope deposited by gravity or slope movement.

Fill: Soil derived from natural soil, rock, or processed materials that was placed by artificial methods, such as construction, waste disposal, or dumping.

Glacial Outwash: Soil, typically sand and gravel, deposited by glacial streams or meltwater in a preexisting valley or over a plain.

Glacial Till: Soil deposited by and underneath a glacier, generally consisting of a heterogeneous, unstratified mixture of clay, sand, gravel, and boulders.

N-Value: The blow count representation of the penetration resistance of the soil determined by the Standard Penetration Test (SPT). It is the sum of the number of blows required to drive the sampler the second and third 6-inch increments (sample depth interval of 6 to 18 inches) and is recorded in blows per foot (bpf). The N-value is considered to be an indication of the relative density of coarse-grained soils (sand and gravel) or consistency of fine-grained soils (silt and clay).

Pocket Pen (PP): Field penetration test performed using a hand-held penetrometer that estimates unconfined compressive strength of cohesive soil in tons per square foot (tsf).

Recovery %: Total length of rock core or soil sample retrieved divided by the total length of the core run or sample interval, expressed as a percentage.

Refusal: The depth at which greater than 50 SPT hammer blows are required to drive the sampling spoon 6 inches or less.

Residual Soil or Residuum: Soil derived from the physical or chemical weathering of the underlying parent bedrock, generally with N-values less than 30 and 50 bpf in cohesive and cohesionless materials, respectively.

Rock Quality Designation (RQD): The sum of the length of intact rock core pieces longer than 4 inches (excluding mechanical breaks) divided by the total length of the core run, expressed as a percentage.

Shelby Tube: A 2" to 3" diameter, thin walled sampling tube that is pushed into the soil to obtain a relatively undisturbed soil sample for geotechnical laboratory tests.

Split Spoon Sampler: A soil sampling tube which is driven, retrieved, and split-open lengthwise for removal and visual inspection, and testing of the soil obtained.

Standard Penetration Test (SPT) ASTM D1586 : Field penetration test consisting of driving a 2-inch outside diameter split-spoon sampler 18 inches using a 140-pound hammer free falling a distance of 30 inches. The number of blows required to advance the spoon through successive 6-inch increments is recorded to determine the N-value.

Weathered Rock: Materials derived from lithified, undisturbed, natural bedrock which are able to be sampled with a split-spoon. Cohesive and cohesionless materials generally have N-values greater than 30 and 50 bpf, respectively.

N-Value Rating

Fine-Grained Soils (Silt and Clay)

Consistency	Blows/ft	PP (tsf)
Very Soft	0-2	<0.25
Soft	3-4	0.25-0.5
Medium Stiff	5-8	0.5-1
Stiff	9-15	1-2
Very Stiff	16-32	2-4
Hard	>32	>4

Coarse-Grained Soils (Sand and Gravel)

Relative Density	Blows/ft
Very Loose	0-4
Loose	5-10
Medium Dense	11-30
Dense	31-50
Very Dense	>50

Unconsolidated Material

Term	Grain Size in mm (in)	Approximate Example Size
Clay and Silt	<.075	can't see grains to barely visible
Fine Sand	0.075-0.4	table salt to sugar
Med. Sand	0.4-2.0 (~<1/16)	openings in a window screen
Coarse Sand	2.0-4.75 (~1/16-1/8)	sidewalk salt
Gravel	4.75-75 (~1/8-3)	pea to tennis ball
Cobble	75-300 (3-12)	tennis ball to basketball
Boulder	>300 (>12)	larger than a basketball

Other Features – Used to describe other identifiable, pertinent features (e.g., angularity of coarse-grained soils, organics, construction debris, etc.)

Term	%
Trace	< 5
Few	5-15
Some	15-45

Moisture Content
Dry: Sample is dusty or obviously dry.
Moist: Anything that does not fit the definition of dry or wet.
Wet: Sample contains free water.

Civil & Environmental Consultants, Inc.

Definitions of Standard Terms and Symbols

BORING NUMBER B-1

Civil & Environmental Consultants, Inc.
31 Bellows Road
Raynham, MA 02767

CLIENT Mr. Tom Fitzgerald
PROJECT NAME 51 Harborview Rd. Slope Stabilization
PROJECT NUMBER 324-891
PROJECT LOCATION Hull, MA
DATE STARTED 06/28/2023 **DATE COMPLETED** 06/28/2023
GROUND ELEVATION 58.00 ft **BACKFILL** with Grout
SAMPLING CONTRACTOR Soil X Corp.
LATITUDE 42.307225 **LONGITUDE** -70.906136
SAMPLING METHOD 4-1/4-in Hollow Stem Auger
WATER LEVELS AT END OF SOIL SAMPLING: 06/28/2023 Not observed; AT END OF CORING: N/A; 24 HRS AFTER DRILLING: N/A
CEC REP Tony Sousa, P.E. **CHECKED BY** Tyler Reynolds, P.E.
NOTES

DEPTH (ft)	GRAPHIC LOG	REMARKS	MATERIAL DESCRIPTION	ELEVATION (ft)	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOWS COUNTS (N VALUES)
0		Augers grinding intermittently from 3-30' bgs.	Brown, Silty Fine to Medium Sand, Trace Fine Gravel, Trace Roots, Dry, Loose, SM, **(FILL)**	58	SS S-1	25	4-3-2-3 (5)
3.0 ft				55.0			
5			Brown, Silty Fine to Medium Sand, Some Fine to Coarse Gravel, Damp, Very Dense, Slight Plasticity, SM **(GLACIAL TILL)**	53.0	SS S-2	75	15-19-39-23 (58)
7.0 ft				51.0			
10		Split spoon refusal at 11.5' bgs.	Brown, Silty Fine to Medium Sand, Some Fine to Coarse Gravel, Dry, Very Dense, SM **(GLACIAL TILL)**	48	SS S-3	100	27-40-60 (100)
10.0 ft / 11.5 ft				48.0 / 46.5			
15		Split spoon refusal at 16.4' bgs.	Brown, SILTY FINE TO COARSE SAND, SOME FINE GRAVEL, Dry, Very Dense, SM **(GLACIAL TILL)**	43.0	SS S-4	93	32-62-63/0.4' (125)
15.0 ft / 16.4 ft				41.6			
20		Split spoon refusal at 21.5' bgs.	Brown, Silty Fine to Medium Sand, Some Fine to Coarse Gravel, Dry, Very Dense, SM **(GLACIAL TILL)**	38	SS S-5	100	35-60-88 (148)
20.0 ft / 21.5 ft				38.0 / 36.5			
25		Split spoon refusal at 25.3' bgs.	No Recovery	33.0	SS S-6	0	75/0.3' (75)
25.0 ft / 25.3 ft				32.7			
30		Split spoon and auger refusal at 30.1' bgs. Possible bedrock at 30' bgs.	Gray, Coarse Gravel, Dry, Very Dense, GP **(GLACIAL TILL)**	28	SS S-7	100	70/0.1' (70)
30.0 ft / 30.1 ft			End of boring at 30.1 feet	28.0 / 27.9			

ATTACHMENT 8

LABORATORY TESTING RESULTS

Thielsch DIVISION OF THE RISE GROUP	195 Frances Avenue Cranston RI, 02910 Phone: (401)-467-6454 Fax: (401)-467-2398 thielsch.com *Let's Build a Solid Foundation*	Client Information: Civil & Environmental Consultants Raynham, MA 02767 Project Manager: Tony Sousa Assigned By: Tony Sousa Collected By: Client	Project Information: **Slope Stabilization** **51 Harborview Rd, Hull MA** Project Number: 324-891 Summary Page: 1 of 1 Report Date: 07.10.23

LABORATORY TESTING DATA SHEET, Report No.: 7423-G-101

Material Source	Sample ID	Depth (ft)	Laboratory No.	Identification Tests						Corrosivity Tests								Laboratory Log and Soil Description
				As Rcvd Moisture Content %	LL %	PL %	Gravel %	Sand %	Fines %	Resistivity (Mohms-cm)	Chloride (mg/kg)	Sulfate (mg/kg)	Sulfide (mg/kg)	Redox Potential (mv)	pH	Electrical Resist. As Rcvd Ohm-cm @ 60°F	Electrical Resist. Saturated Ohm-cm @ 60°F	
				D2216	D4318		D6913			EPA	D4327		EPA	G200	G51	G57		
Face of Steep Slope	GS-1	0-1	23-S-2805	5.9			25.0	73.1	1.9		16	13			9.1	33600	17400	Brown poorly graded sand with gravel
Top of Wall	AS-1	2-3	23-S-2806	1.9			18.8	40.2	41.0									Brown silty sand with gravel
B-1	S-4	15-16.4	23-S-2807	10.1			24.2	35.4	40.4									Brown clayey silty sand with gravel

4-Pole Resistivity tested by RB on 7/6/23.

Date Received: 07.03.23 Reviewed By: Date Reviewed: 07.10.23

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This report shall not be reproduced, except in full, without prior written approval from the Agency, as defined in ASTM E329.

These results are for the exclusive use of the client for whom they were obtained. This report only relates to items inspect and/or tested. No warranty, expressed or implied, is made.

Particle Size Distribution Report

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.3	13.7	6.6	23.6	42.9	1.9	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2"	100.0		
1 1/2"	95.7		
1"	90.5		
3/4"	88.7		
1/2"	84.2		
3/8"	81.4		
#4	75.0		
#10	68.4		
#20	57.8		
#40	44.8		
#60	32.2		
#100	18.6		
#200	1.9		

* (no specification provided)

Soil Description

Brown poorly graded sand with gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 23.7988 D_{85}= 13.7048 D_{60}= 0.9832
D_{50}= 0.5468 D_{30}= 0.2298 D_{15}= 0.1297
D_{10}= 0.1053 C_u= 9.34 C_c= 0.51

Classification

USCS= SP AASHTO= A-1-b

Remarks

Source of Sample: Face of Steep Slope **Depth:** 0-1
Sample Number: GS-1 **Date:** 07.07.23

Thielsch Engineering Inc.

Cranston, RI

Client: Civil & Environmental Consultants, Inc
Project: Slope Stabilization
51 Harborview Rd, Hull MA
Project No: 324-891 **Fig.** 23-S-2805

Tested By: GO / SP / JB **Checked By:**

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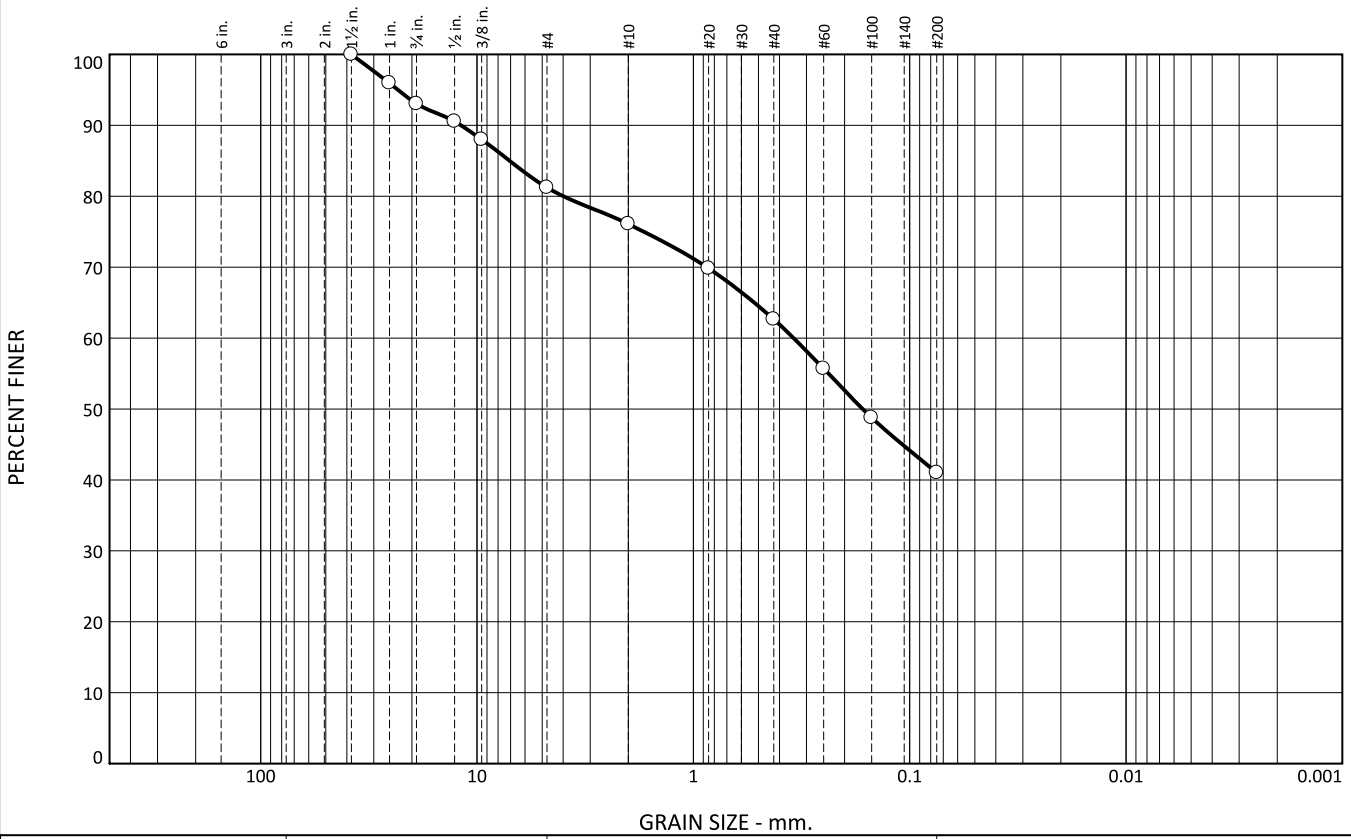
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	7.0	11.8	5.1	13.5	21.6	41.0	

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2"	100.0		
1"	96.0		
3/4"	93.0		
1/2"	90.6		
3/8"	88.0		
#4	81.2		
#10	76.1		
#20	69.8		
#40	62.6		
#60	55.7		
#100	48.8		
#200	41.0		

* (no specification provided)

Soil Description

Brown silty sand with gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 11.8336 D_{85}= 7.0685 D_{60}= 0.3442
D_{50}= 0.1650 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Source of Sample: Top of Wall **Depth:** 2-3'
Sample Number: AS-1 **Date:** 07.10.23

Thielsch Engineering Inc.

Cranston, RI

Client: Civil & Environmental Consultants, Inc
Project: Slope Stabilization
51 Harborview Rd, Hull MA
Project No: 324-891 **Fig.** 23-S-2806

Tested By: GO / SP / JB **Checked By:**

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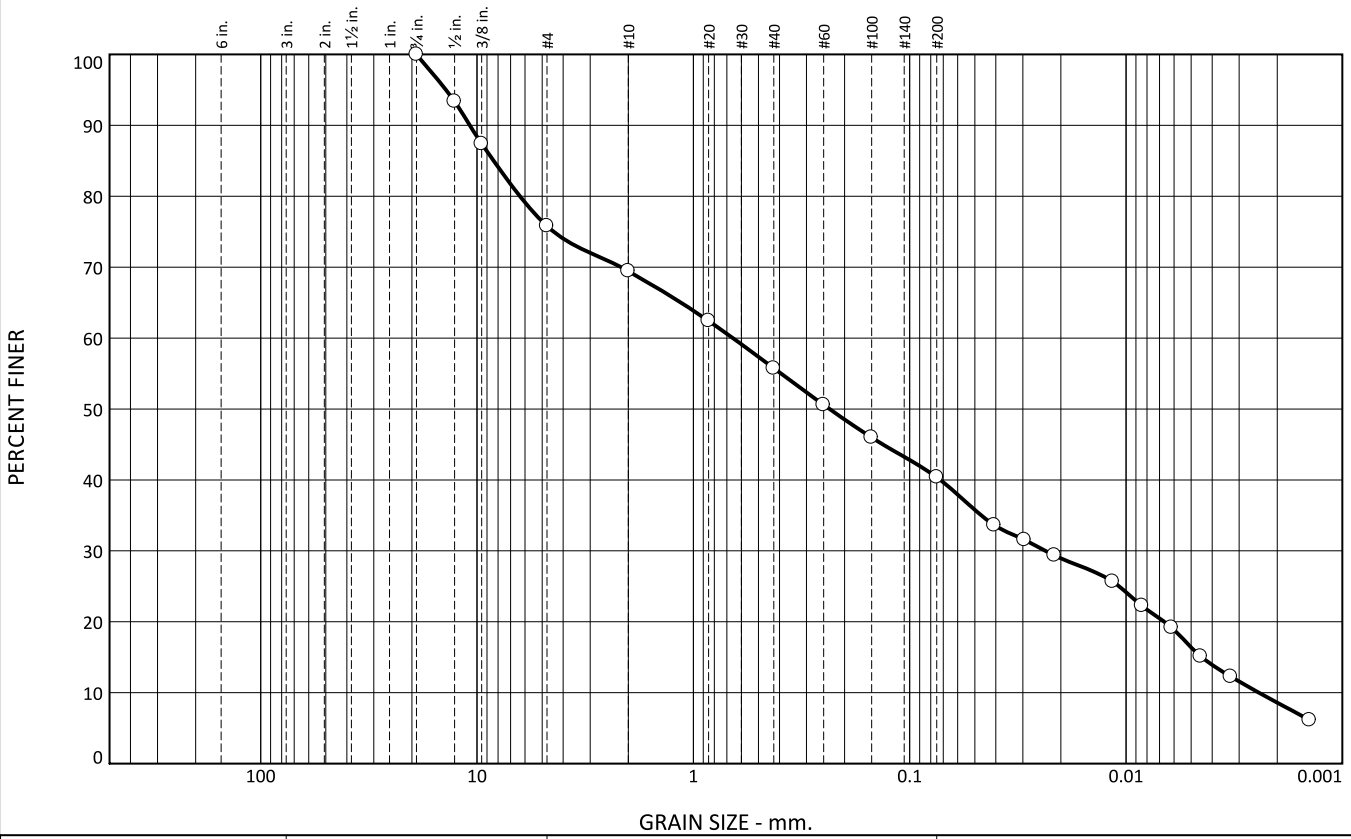
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	24.2	6.3	13.8	15.3	31.8	8.6

SIEVE SIZE OR DIAMETER	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100.0		
1/2"	93.4		
3/8"	87.4		
#4	75.8		
#10	69.5		
#20	62.4		
#40	55.7		
#60	50.6		
#100	46.0		
#200	40.4		
0.0406 mm.	33.6		
0.0295 mm.	31.5		
0.0214 mm.	29.3		
0.0115 mm.	25.7		
0.0084 mm.	22.2		
0.0062 mm.	19.2		
0.0045 mm.	15.1		
0.0033 mm.	12.3		
0.0014 mm.	6.1		

* (no specification provided)

Soil Description

Brown clayey silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 10.7967 D_{85}= 8.3763 D_{60}= 0.6550
D_{50}= 0.2348 D_{30}= 0.0236 D_{15}= 0.0045
D_{10}= 0.0024 C_u= 268.80 C_c= 0.35

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample visually classified as plastic. Sample rolled to 1/4"

Source of Sample: Boring **Depth:** 15-16.4'
Sample Number: B-1 / S-4 **Date:** 07.07.23

Thielsch Engineering Inc.

Cranston, RI

Client: Civil & Environmental Consultants, Inc
Project: Slope Stabilization
51 Harborview Rd, Hull MA
Project No: 324-891 **Fig.** 23-S-2807

Tested By: RB / SL **Checked By:**

CERTIFICATE OF ANALYSIS

Kris Roland
Thielsch Engineering, Inc.
CTS Cranston
Cranston, RI 02910

RE: Slope Stabilization - CEC (74-23-0002.202)
ESS Laboratory Work Order Number: 23G0006

This signed Certificate of Analysis is our approved release of your analytical results. These results are only representative of sample aliquots received at the laboratory. ESS Laboratory expects its clients to follow all regulatory sampling guidelines. Beginning with this page, the entire report has been paginated. This report should not be copied except in full without the approval of the laboratory. Samples will be disposed of thirty days after the final report has been delivered. If you have any questions or concerns, please feel free to call our Customer Service Department.

Laurel Stoddard
Laboratory Director

REVIEWED
By ESS Laboratory at 5:34 pm, Jul 11, 2023

Analytical Summary
The project as described above has been analyzed in accordance with the ESS Quality Assurance Plan. This plan utilizes the following methodologies: US EPA SW-846, US EPA Methods for Chemical Analysis of Water and Wastes per 40 CFR Part 136, APHA Standard Methods for the Examination of Water and Wastewater, American Society for Testing and Materials (ASTM), and other recognized methodologies. The analyses with these noted observations are in conformance to the Quality Assurance Plan. In chromatographic analysis, manual integration is frequently used instead of automated integration because it produces more accurate results.

The test results present in this report are in compliance with TNI and relative state standards, and/or client Quality Assurance Project Plans (QAPP). The laboratory has reviewed the following: Sample Preservations, Hold Times, Initial Calibrations, Continuing Calibrations, Method Blanks, Blank Spikes, Blank Spike Duplicates, Duplicates, Matrix Spikes, Matrix Spike Duplicates, Surrogates and Internal Standards. Any results which were found to be outside of the recommended ranges stated in our SOPs will be noted in the Project Narrative.

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC

ESS Laboratory Work Order: 23G0006

SAMPLE RECEIPT

The following samples were received on July 03, 2023 for the analyses specified on the enclosed Chain of Custody Record.

The client did not deliver the samples in a cooler.

Lab Number	Sample Name	Matrix	Analysis
23G0006-01	GS-1	Soil	D4327

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC

ESS Laboratory Work Order: 23G0006

PROJECT NARRATIVE

No unusual observations noted.

End of Project Narrative.

DATA USABILITY LINKS

To ensure you are viewing the most current version of the documents below, please clear your internet cookies for www.ESSLaboratory.com. Consult your IT Support personnel for information on how to clear your internet cookies.

Definitions of Quality Control Parameters

Semivolatile Organics Internal Standard Information

Semivolatile Organics Surrogate Information

Volatile Organics Internal Standard Information

Volatile Organics Surrogate Information

EPH and VPH Alkane Lists

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC

ESS Laboratory Work Order: 23G0006

CURRENT SW-846 METHODOLOGY VERSIONS

Analytical Methods

1010A - Flashpoint
6010C - ICP
6020A - ICP MS
7010 - Graphite Furnace
7196A - Hexavalent Chromium
7470A - Aqueous Mercury
7471B - Solid Mercury
8011 - EDB/DBCP/TCP
8015C - GRO/DRO
8081B - Pesticides
8082A - PCB
8100M - TPH
8151A - Herbicides
8260B - VOA
8270D - SVOA
8270D SIM - SVOA Low Level
9014 - Cyanide
9038 - Sulfate
9040C - Aqueous pH
9045D - Solid pH (Corrosivity)
9050A - Specific Conductance
9056A - Anions (IC)
9060A - TOC
9095B - Paint Filter
MADEP 04-1.1 - EPH
MADEP 18-2.1 - VPH

Prep Methods

3005A - Aqueous ICP Digestion
3020A - Aqueous Graphite Furnace / ICP MS Digestion
3050B - Solid ICP / Graphite Furnace / ICP MS Digestion
3060A - Solid Hexavalent Chromium Digestion
3510C - Separatory Funnel Extraction
3520C - Liquid / Liquid Extraction
3540C - Manual Soxhlet Extraction
3541 - Automated Soxhlet Extraction
3546 - Microwave Extraction
3580A - Waste Dilution
5030B - Aqueous Purge and Trap
5030C - Aqueous Purge and Trap
5035A - Solid Purge and Trap

SW846 Reactivity Methods 7.3.3.2 (Reactive Cyanide) and 7.3.4.1 (Reactive Sulfide) have been withdrawn by EPA. These methods are reported per client request and are not NELAP accredited.

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC
Client Sample ID: GS-1
Date Sampled: 07/03/23 09:30
Percent Solids: 95

ESS Laboratory Work Order: 23G0006
ESS Laboratory Sample ID: 23G0006-01
Sample Matrix: Soil

Classical Chemistry

Analyte	Results (MRL)	MDL	Method	Limit	DF	Analyst	Analyzed	Units	Batch
Chloride	**WL 16** (5)		D4327		1	EEM	07/05/23 21:29	mg/kg dry	DG30529
Sulfate	**WL 13** (5)		D4327		1	EEM	07/05/23 21:29	mg/kg dry	DG30529

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC

ESS Laboratory Work Order: 23G0006

Quality Control Data

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Qualifier
Classical Chemistry										
Batch DG30529 - General Preparation										
Blank										
Chloride	ND	5	mg/kg wet							
Sulfate	ND	5	mg/kg wet							
LCS										
Chloride	10		mg/L	10.00		101	85-115			
Sulfate	10		mg/L	10.00		101	80-120			

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC
ESS Laboratory Work Order: 23G0006

Notes and Definitions

WL	Results obtained from a deionized water leach of the sample.
U	Analyte included in the analysis, but not detected
ND	Analyte NOT DETECTED at or above the MRL (LOQ), LOD for DoD Reports, MDL for J-Flagged Analytes
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference
MDL	Method Detection Limit
MRL	Method Reporting Limit
LOD	Limit of Detection
LOQ	Limit of Quantitation
DL	Detection Limit
I/V	Initial Volume
F/V	Final Volume
§	Subcontracted analysis; see attached report
1	Range result excludes concentrations of surrogates and/or internal standards eluting in that range.
2	Range result excludes concentrations of target analytes eluting in that range.
3	Range result excludes the concentration of the C9-C10 aromatic range.
Avg	Results reported as a mathematical average.
NR	No Recovery
[CALC]	Calculated Analyte
SUB	Subcontracted analysis; see attached report
RL	Reporting Limit
EDL	Estimated Detection Limit
MF	Membrane Filtration
MPN	Most Probable Number
TNTC	Too numerous to Count
CFU	Colony Forming Units

CERTIFICATE OF ANALYSIS

Client Name: Thielsch Engineering, Inc.
Client Project ID: Slope Stabilization - CEC

ESS Laboratory Work Order: 23G0006

ESS LABORATORY CERTIFICATIONS AND ACCREDITATIONS

ENVIRONMENTAL

Rhode Island Potable and Non Potable Water: LAI00179
http://www.health.ri.gov/find/labs/analytical/ESS.pdf

Connecticut Potable and Non Potable Water, Solid and Hazardous Waste: PH-0750
http://www.ct.gov/dph/lib/dph/environmental_health/environmental_laboratories/pdf/OutofStateCommercialLaboratories.pdf

Maine Potable and Non Potable Water, and Solid and Hazardous Waste: RI00002
http://www.maine.gov/dhhs/mecdc/environmental-health/dwp/partners/labCert.shtml

Massachusetts Potable and Non Potable Water: M-RI002
http://public.dep.state.ma.us/Labcert/Labcert.aspx

New Hampshire (NELAP accredited) Potable and Non Potable Water, Solid and Hazardous Waste: 2424
http://des.nh.gov/organization/divisions/water/dwgb/nhelap/index.htm

New York (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: 11313
http://www.wadsworth.org/labcert/elap/comm.html

New Jersey (NELAP accredited) Non Potable Water, Solid and Hazardous Waste: RI006
http://datamine2.state.nj.us/DEP_OPRA/OpraMain/pi_main?mode=pi_by_site&sort_order=PI_NAMEA&Select+a+Site:=58715

Pennsylvania: 68-01752
http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/Laboratory-Accreditation-Program.aspx

ESS Laboratory Sample and Cooler Receipt Checklist

Client: Thielsch Engineering, Inc - ESS

Shipped/Delivered Via: Client

ESS Project ID: 23G0006
Date Received: 7/3/2023
Project Due Date: 7/11/2023
Days for Project: 5 Day

1. Air bill manifest present? No
   Air No.: NA
2. Were custody seals present? No
3. Is radiation count <100 CPM? Yes
4. Is a Cooler Present? No
   Temp: 23 Iced with: None
5. Was COC signed and dated by client? Yes
6. Does COC match bottles? Yes
7. Is COC complete and correct? Yes
8. Were samples received intact? Yes
9. **Were labs informed about short holds & rushes?** Yes / No / NA
10. Were any analyses received outside of hold time? Yes / No

11. Any Subcontracting needed? Yes / No
    ESS Sample IDs:
    Analysis:
    TAT:
12. Were VOAs received? Yes / No
    a. Air bubbles in aqueous VOAs? Yes / No
    b. Does methanol cover soil completely? Yes / No / NA

13. Are the samples properly preserved? Yes / No
    a. If metals preserved upon receipt: Date: Time: By/Acid Lot#:
    b. Low Level VOA vials frozen: Date: Time: By:

Sample Receiving Notes:

No cooling media above

14. Was there a need to contact Project Manager? Yes / No
    a. Was there a need to contact the client? Yes / No
    Who was contacted? Date: Time: By:

Resolution:

Sample Number	Container ID	Proper Container	Air Bubbles Present	Sufficient Volume	Container Type	Preservative	Record pH (Cyanide and 608 Pesticides)
1	449644	Yes	N/A	Yes	8 oz jar	NP	

2nd Review

Were all containers scanned into storage/lab? Initials

Are barcode labels on correct containers? Yes / No
Are all Flashpoint stickers attached/container ID # circled? Yes / No / NA
Are all Hex Chrome stickers attached? Yes / No / NA
Are all QC stickers attached? Yes / No / NA
Are VOA stickers attached if bubbles noted? Yes / No / NA

Completed By: Date & Time: 7/3/23 10:46
Reviewed By: Date & Time: 7/3/23 1107

ESS Laboratory
Division of Thielsch Engineering, Inc.
185 Frances Avenue, Cranston, RI 02910-2211
Tel. (401) 461-7181 Fax (401) 461-4486
www.esslaboratory.com

CHAIN OF CUSTODY

ESS LAB PROJECT ID: 23G0506

Turn Time: Standard X Rush Approved By: _____

Reporting Limits -

State where samples were collected: MA

Is this project for any of the following: (please circle)
MA-MCP CT-RCP RGP DOD Other_____

Electronic Deliverable Yes_X_ No____
Format: Excel___ Access___ PDF_X_ Other_____

Project Manager: Kris Roland
Company: Thielsch Engineering
Address: 195 Frances Ave
Cranston, RI 02910

Project # 74-23-0002.202
Project Name / Client Name:
Slope Stabilization
Civil & Environmental Consultants
Contract Pricing __x___
Special Pricing WO#: _____

ESS Lab Sample ID	Date	Collection Time	Grab -G Composite-C	Matrix	Sample Identification	# of Container	Sulfate (ASTM D4327)	Chloride (ASTM D4327)									Comment #
1	07.03.23	0930	G	S	GS-1	1	X	X									
							1	1									
							AG	AG									

Analysis

Preservation Code: 1-NP, 2-HCl, 3-H2SO4, 4-HNO3, 5-NaOH, 6-MeOH, 7-Asorbic Acid, 8-ZnAct, 9-_CH_3OH_____

Container Type: P-Poly G-Glass AG-Amber Glass S-Sterile V-VOA

Matrix: S-Soil SD-Solid D-Sludge WW-Wastewater GW-Groundwater SW-Surface Water DW-Drinking Water O-Oil W-Wipes F-Filter

Cooler Present _____Yes ✓ No
Seals Intact _____ Yes ✓ No NA: _____
Cooler Temperature: 23 no ice

Sampled by : R. Blake

Comments: Please send reports to kroland@thielsch.com, mcolman@thielsch.com, and rroth@thielsch.com

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Sarah Lefday (CTS)	7.3.23 0949				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Please E-mail all changes to Chain of Custody in writing.

Page ____ of ____

ATTACHMENT 9

PUBLICATION NO. FHWA-NHI-14-007

economy to advance the bar and carry spoils to the surface. After the tendon is installed to the desired depth, a heavier final grout mixture is pumped through the hollow bar and the nail is considered complete when the heavier mixture returns to the excavation face, signaling that the lighter drilling grout was flushed from the drill hole and that all drilling spoils have also been removed.

10.3 Bond Strength

Thirty seven HBSNs were installed in four different sites across the U.S. and tested as part of an investigation co-sponsored by FHWA and the International Association of Foundation Drilling (ADSC) (Cadden et al. 2010). The goals of this investigation were to establish appropriate de-bonding procedures for proof-testing HBSNs and to create a database of bond strengths in different ground conditions. Gravity-grouted, solid bar soil nails were also installed and tested for comparison at each of the sites. The results of the tests are summarized in Table 10.1. The bond strength values provided in the table were calculated using the nominal drill bit diameter, not the actual grout body diameter of the HBSNs. Some of the tests did not reach failure; therefore, the range of resistance values for the HBSNs may be somewhat conservative. Note that presumptive values of bond strength, for pressure-grouted micropiles (Sabatini et al. 2005), are provided for similar soil types as a comparison.

Table 10.1: Nominal Bond Strength of Soil Nails in Granular Soils (after Cadden et al. 2010)

Soil Type	Gravity-Grouted Solid Bar Soil Nail (psi)	Hollow Bar Soil Nail (psi)	Pressure-grouted Micropiles (Sabatini et al. 2005) (psi)
Silty Sand (SM)	12.8-17.1	18.7-24.4	Sand (some silt) 10-27.5
Poorly Graded Sand (SP)	13.2	71.2-79.6	Sand (some Gravel) 17.5-52
SP with Gravel	50.5-82.2	-	Sand (some Gravel) 17.5-52
Poorly Graded Gravel (GP) with Sand	53.2-64.5	62.4-156.3	Gravel (some Sand) 17.5-52

Note: Bond strength values from tests are calculated using the nominal drill bit diameter.

The tests showed that HBSNs tend to develop larger bond strength values in granular soils than traditional, gravity-grouted solid bar nails. This is due to the larger drill hole diameter,

Table A.1a: Properties of Solid-Threaded Bars - Grade 60

Bar Designation	Maximum Diameter (w/ threads)	Minimum Cross-Sectional Area	Unit Weight	ASTM Grade	Yield Stress	Yield Load
Conventional	inch	$inch^2$	lb/ft	Conventional	ksi	kip
#6	0.86	0.44	1.50	60	60	26
#7	0.99	0.60	2.04	60	60	36
#8	1.12	0.79	2.67	60	60	47
#9	1.26	1.00	3.40	60	60	60
#10	1.43	1.27	4.30	60	60	76
#11	1.61	1.56	5.31	60	60	93
#14	1.86	2.25	7.65	60	60	135

Table A.1b: Properties of Solid-Threaded Bars - Grade 75

Bar Designation	Maximum Diameter (w/ threads)	Minimum Cross-Sectional Area	Unit Weight	ASTM Grade	Yield Stress	Yield Load
Conventional	inch	$inch^2$	lb/ft	Conventional	ksi	kip
#6	0.86	0.44	1.50	75	75	33
#7	0.99	0.60	2.04	75	75	45
#8	1.12	0.79	2.67	75	75	59
#9	1.26	1.00	3.40	75	75	75
#10	1.43	1.27	4.30	75	75	95
#11	1.61	1.56	5.31	75	75	117
#14	1.86	2.25	7.65	75	75	168

Sources: Dywidag, Williams and Contech

Table A.1c: Properties of Solid-Threaded Bars - Grade 150

Bar Designation (inch)	Maximum Diameter (w/ threads)	Minimum Cross-Sectional Area	Unit Weight	ASTM Grade	Ultimate Load (1)
Conventional	**inch**	**inch^2**	**lb/ft**	**Conventional**	**kip**
¾	0.75	0.37	1.32	150	57
1	1.00	0.85	3.01	150	128
1¼	1.25	1.25	4.39	150	188
1⅜	1.375	1.58	5.56	150	237
1¾	1.75	2.58	9.22	150	400

Sources: Dywidag, Williams and Stressteel

Note: (1) Based on ultimate strength.

Table A.2: Properties of Hollow Bars

CTS/Titan Bar Type

Bar Designation	Effective Outer Diameter	Cross-Sectional Area	Unit Weight	Yield Load (1)	Ultimate Load
Conventional	**inch**	**inch^2**	**lb/ft**	**kip**	**kip**
30/16	1.02	0.53	1.8	42.7	55.1
30/14	1.03	0.58	1.9	49.5	61.8
30/11	1.03	0.64	2.2	58.5	72.0
40/20	1.42	1.13	3.8	95.6	121.4
40/16	1.42	1.40	4.8	118.1	148.4
52/26	1.92	1.94	6.7	164.2	208.0
73/56	2.76	2.11	7.3	186.6	232.7
73/53	2.76	2.50	8.9	218.1	260.9
73/45	2.76	3.50	12.0	285.6	356.4
73/35	2.76	4.20	14.2	321.6	419.4

Source: Contech

Note: (1) These bars are alloy steel and have nominal yield strength of 87 ksi.

Table A.3: Properties of Hollow Bars

MAI Bar Type

Bar Designation	Outer Diameter	Cross-Sectional Area	Weight	Average Yield Stress (1)	Average Ultimate Tensile Stress (1)	Yield Load	Ultimate Load
Conventional	**inch**	**inch^2**	**lb/ft**	**ksi**	**ksi**	**kip**	**kip**
R25N	1.00	0.41	1.41	83	111	34	45
R32N	1.26	0.56	1.88	92	112	52	63
R32S	1.26	0.72	2.49	87	112	63	81
R38N	1.50	1.00	3.43	89	112	90	112
R51L	1.50	1.17	3.97	86	106	101	124
T40N	1.57	1.32	4.50	89	112	118	148
R51N	2.00	1.61	5.44	88	112	142	180
T76N	3.00	3.32	11.29	81	108	270	360
T76S	3.00	3.88	13.24	87	110	337	427

Source: Dywidag

Note: (1) The yield strength and ultimate tensile stresses of these bars vary as indicated above, per manufacturer's information.

Table A.4: Properties of Hollow Bars

GEO-Drill Bar Type

Bar Designation	Nominal Outer Diameter	Cross-Sectional Area	Weight	Yield Load (1)	Ultimate Load (1)
Conventional	**inch**	**inch^2**	**lb/ft**	**kip**	**kip**
B7X1-32	1.25	0.556	2.10	47.2	58.4
B7X1-32X	1.25	0.776	2.70	66.0	81.5
B7X1-38	1.50	1.067	3.76	90.7	112.0
B7X1-51	2.00	1.795	6.26	152.0	188.0
B7X1-76	3.00	3.880	13.79	329.0	407.0

Source: Williams

Note: (1) These bars have a yield strength of 85 ksi and an ultimate strength of 105 ksi.

Table A.5: Welded-Wire Mesh (1)

Mesh Designation(2) (3) (4)	Cross-Sectional Area per Unit Width (5)	Weight per Unit Area
in. × in. – in.^{2}/100 × in.^{2}/100	in.^{2}/ft	lb/cft^2 (6)
4x4 - W 1.4 x W 1.4	0.042	31
4x4 – W 2.0 x W 2.0	0.060	44
4x4 – W 2.9 x W 2.9	0.087	62
4x4 – W 4.0 x W 4.0	0.120	88
6x6 – W 1.4 x W 1.4	0.028	21
6x6 – W 2.0 x W 2.0	0.040	30
6x6 – W 2.9 x W 2.9	0.058	42
6x6 – W 4.0 x W 4.0	0.080	58

Source: WRI (2006)

Notes:
(1) These properties are applicable for WWM in Grades 60 or 65. Consult WRI (2006) for WWM properties for Grades 70, 75, and 80.
(2) The first pair of numbers (e.g., 4x4) indicate the mesh opening size (or wire spacing) in the longitudinal and transverse direction, respectively.
(3) Prefix "W" indicates plain wire. A prefix "D" would indicate pre-deformed wire.
(4) The second pair of numbers (e.g., 1.4x1.4) indicates the cross-sectional area of wires (in square inches x 100) in the longitudinal and transverse direction, respectively.
(5) The area per unit width is obtained by dividing the wire cross-sectional area by 100 and by the mesh opening size (or wire spacing, in feet). If the longitudinal and transverse spacings and wire sizes are different, the cross-sectional area per unit width will be different in each direction. Consult WRI (2006) for additional information.
(6) CSF = 100 square feet.

Table A.6: Reinforcing Bars

Bar Designation	Nominal Diameter	Nominal Area
#	inch	$inch^2$
3	0.375	0.11
4	0.500	0.20
5	0.625	0.31
6	0.750	0.44
7	0.875	0.60
8	1.000	0.79
9	1.128	1.00
10	1.270	1.27
11	1.410	1.56
14	1.693	2.25
18	2.257	4.00

Source: ACI 318-11

Table A.7: Headed-Studs

Headed Stud Size	Nominal Length (1) (2)	Head Diameter	Shaft Diameter	Head Thickness	Head Area / Shaft Area	Head Thickness / (Head Diameter-Shaft Diameter)
-	L_S	D_{SH}	D_{SC}	t_{SH}	A_{SH} / A_{SC}	t_{SH} / (D_{SH} - D_{SC})
-	inch	inch	inch	inch	-	-
¼ x 4⅛	4⅛	0.50	0.25	0.19	4.0	0.75
⅜ x 4⅛	4⅛	0.75	0.38	0.28	4.0	0.75
⅜ x 6⅛	6⅛	0.75	0.38	0.28	4.0	0.75
½ x 4⅛	4⅛	1.00	0.50	0.28	4.0	0.56
½ x $5^5/_{16}$	$5^5/_{16}$	1.00	0.50	0.28	4.0	0.56
½ x 6⅛	6⅛	1.00	0.50	0.28	4.0	0.56
⅝ x $6^9/_{16}$	$6^9/_{16}$	1.25	0.63	0.31	4.0	0.50
¾ x $3^{11}/_{16}$	$3^{11}/_{16}$	1.25	0.75	0.38	2.8	0.75
¾ x $4^3/_{16}$	$4^3/_{16}$	1.25	0.75	0.38	2.8	0.75
¾ x $5^3/_{16}$	$5^3/_{16}$	1.25	0.75	0.38	2.8	0.75
¾ x $6^3/_{16}$	$6^3/_{16}$	1.25	0.75	0.38	2.8	0.75
⅞ x $4^3/_{16}$	$4^3/_{16}$	1.40	0.86	0.38	2.5	0.73
⅞ x $5^3/_{16}$	$5^3/_{16}$	1.40	0.86	0.38	2.5	0.73
⅞ x $6^3/_{16}$	$6^3/_{16}$	1.40	0.86	0.38	2.5	0.73

Source: Stud Welding Associates, Inc.

Notes: (1) Nominal length indicated is before welding.
(2) After-welding lengths to be considered as follows: For $D_S \leq$ ½", L_S is approximately ⅛" shorter after welding. For $D_S >$ ⅝"L_S is approximately 3/16" shorter after welding.

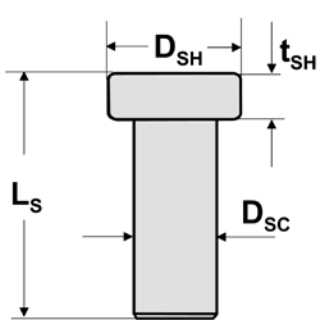


Figure A.1: Illustration. Geometry of headed studs.

Table 5.1: Minimum Recommended Factors of Safety for the Design of Soil Nail Walls Using the ASD Method (1)

Limit State	Condition	Symbol	Minimum Recomm. Factors of Safety, Static Loads	Minimum Recomm. Factors of Safety, Seismic Loads
Overall	Overall Stability	FS_{OS}	1.5(2)	1.1(6)
Overall	Short Term Condition, Excavation	FS_{OS}	1.25-1.33(3)	NA
Overall	Basal Heave	FS_{BH}	2.0(4), 2.5(5)	2.3(5)
Strength – Geotechnical	Pullout Resistance	FS_{PO}	2.0	1.5
Strength – Geotechnical	Lateral Sliding	FS_{LS}	1.5	1.1
Strength – Structural	Tendon Tensile Strength (Grades 60 and 75)	FS_T	1.8	1.35
Strength – Structural	Tendon Tensile Strength (Grades 95 and 150)	FS_T	2.0	1.50
Strength – Structural	Facing Flexural	FS_{FF}	1.5	1.1
Strength – Structural	Facing Punching Shear	FS_{FP}	1.5	1.1
Strength – Structural	Headed Stud Tensile (A307 Bolt)	FS_{FH}	2.0	1.5
Strength – Structural	Headed Stud Tensile (A325 Bolt)	FS_{FH}	1.7	1.3

Notes: (1) The limit state and symbol nomenclature differ from that presented in the previous version of this manual. Many of these changes reflect the move toward using LRFD terminology as presented in AASHTO (2014).

(2) For non-critical, permanent structures, some Owners may accept a design for static loads and long-term conditions with FS_{OS} = 1.35 when uncertainty is considered to be limited due to the availability of sufficient geotechnical information and successful local experience on soil nailing.

(3) This range of safety factors for global stability corresponds to the case of temporary excavation lifts that are unsupported for up to 2 days before nails are installed. The larger value may be applied to critical structures or when more uncertainty exists regarding soil conditions.

(4) This factor of safety for basal heave is applicable to permanent walls for short-term conditions.

(5) This factor of safety for basal heave is applicable to permanent walls for long-term conditions.

(6) The minimum FS_{OS} for seismic overall stability should be 1.0, when horizontal seismic coefficients are used and these were derived from estimated, allowable seismic deformations.

6.6, the soil pressure is smaller between nails, where the displacements are larger and tend to produce a stress relief. The soil pressure immediately behind the nails is larger than that in the mid-span because the soil confinement is greater.

Eqs. 6.9 through 6.14 are also valid for the final facing provided the parameters of the equations (thickness and material strengths) are selected appropriately for the final facing.

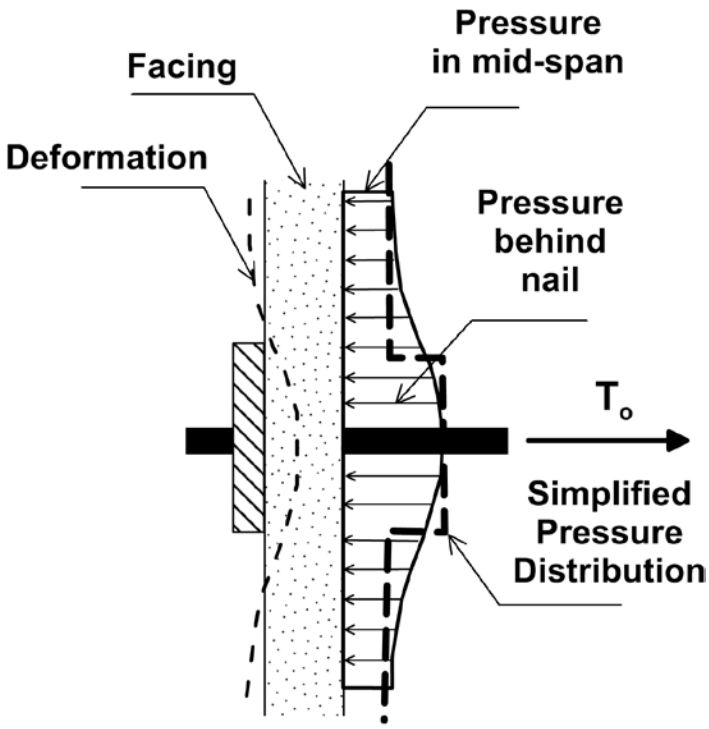


Figure 6.6: Illustration. Soil pressure distribution behind facing. Modified after Byrne et al. (1998).

If Grade 60 steel is used for WWM and rebar, and f'_c = 4,000 psi for shotcrete, the following simplified equations can be used:

$$R_{FF}[\text{kip}] = 3.8 \times C_F \times f_y[\text{ksi}] \times F = 228 \times C_F \times F$$

Equation 6.15: Nominal bending resistance for Grade 60 steel WWM/rebar and 4,000 psi shotcrete.

Where:

$$F = \text{smaller of} \begin{cases} \left(a_{vn} + a_{vm}\right)\left[\text{in}^2/\text{ft}\right] \times \left(\dfrac{S_H\ h\,[\text{ft}]}{S_V}\right) \\ \\ \left(a_{hn} + a_{hm}\right)\left[\text{in}^2/\text{ft}\right] \times \left(\dfrac{S_V\ h\,[\text{ft}]}{S_H}\right) \end{cases}$$

Equation 6.16: Definition of F.

Assuming that $a_{vn} = a_{vm}$ = and $a_{hn} = a_{hm} = a_s$, and $S_H = S_V$, the following equation can be used for the final facing, where $C_F = 1.0$:

$$R_{FF}\,[\text{kip}] = 456 \times a_s\,\left[\text{in}^2/\text{ft}\right] \times h_f\,[\text{ft}]$$

Equation 6.17: Nominal bending resistance.

C_F is selected from Table 6.5.

Table 6.5: Factor C_F

Facing	Facing Thickness, h_i or h_f (in.)	C_F
Initial	4	2.0
Initial	6	1.5
Initial	8	1.0
Final	All	1.0

The facing flexural nominal resistance (R_{FF}) for the initial facing is calculated using Equations 6.15 or 6.17. Alternatively, R_{FF} can be estimated from Table 6.6 using results for initial calculations (Section 6.6.5a).

Table 6.6: Nominal Flexure Resistance, R_{FF} (Initial Facing)

Facing thickness, h_i	Nail Spacing Ratio(1)	ρ_{tot} = 0.5 % (2)	ρ_{tot} = 1.0 % (2)	ρ_{tot} = 2.0 % (2)
(in.)	(ft/ft)	R_{FF} (kip) (3) (5)	R_{FF} (kip) (4) (5)	R_{FF} (kip) (4) (5)
4	0.67	12	24	48
4	1	18	36	71
6	0.67	20	40	81
6	1	30	60	120
8	0.67	24	48	95
8	1	36	71	143

(1) Nail spacing ratio = smaller of S_V/S_H or S_H/S_V.

(2) $\rho_{tot} = \rho_n + \rho_m$, ρ_n and ρ_m are the nail head and mid-span reinforcement ratios, respectively, in either direction.

(3) The above values are valid for Grade 60 steel. Multiply the values above by 1.24 for Grade 75 steel.

(4) Divide R_{FF} by 2 for final facing thickness h_f = 4 in. Divide R_{FF} by 1.5. for h_f = 6 in. For h_f = 8 in., use same R_{FF}.

Final Facing

The same steps shown above for the initial facing must be completed for the final facing, considering the appropriate reinforcement, section thickness and material properties.

The facing resistance is verified in LRFD for each of the facings as follows:

$$CDR = \frac{\phi_{FF} \; R_{FF}}{\gamma \; T_o} \geq 1.0$$

Equation 6.18: Capacity-to-demand ratio for bending in facing.

Where:

ϕ_{FF} = resistance factor for bending/flexure in the facing

R_{FF} = nominal resistance for bending/flexure of facing

γ = load factor selected for verifications

T_o = maximum tensile force at soil nail head, as estimated with Eq. 5.1 (Section 5.2.1)

If the resistance is insufficient, increase the thickness of facing, amount of steel, and/or strength of steel and/or of concrete.

6.6.6 Step 7e Verify Facing Punching Shear Resistance

For programs that do not have the capability of verifying the punching shear resistance, the designer must verify the punching shear resistance at the facing using the procedure presented below.

Connectors installed at the nail head may be subjected to a punching shear limit state, which may occur if the nominal shear resistance of the reinforced shotcrete/concrete section around the nails is exceeded. The nominal punching shear resistance must be evaluated for both initial and final facings (Figure 6.7) for:

- Initial facing: bearing plate connection
- Final facing: headed stud connection

At the limit state, a conical shear surface forms in the facing around the nail head. The size of the conical shear surface is affected by the thickness of the facing, and the dimension of the bearing plate (initial facing) and headed studs (final facing).

The nominal facing punching shear resistance, R_{FP}, for either situation must meet the following condition:

$$CDR = \frac{\phi_{FP} \; R_{FP}}{\gamma \, T_o} \geq 1.0$$

Equation 6.19: Capacity-to-demand ratio for punching shear resistance.

Where:

ϕ_{FP} = resistance factor for punching shear in the facing

γ = load factor selected for verification

T_o = maximum tensile force at soil nail head, as defined previously

R_{FP} is estimated as:

$$R_{FP} = C_P \; V_F$$

Equation 6.20: Nominal punching shear resistance at facing.

Where:

C_P = dimensionless factor that accounts for the contribution of the soil support under the nail head to the shear resistance

V_F = concrete punching shear basic resistance acting through the facing section

C_P can be as high as 1.15 if the soil reaction is considered. The contribution from the soil support behind the wall is conservatively assumed to be negligible; therefore, $C_P = 1.0$. The punching shear resistance, V_F, can be calculated as:

$$V_F\,[\text{kip}] = 0.58\,\sqrt{f'_c\ [\text{psi}]}\ \pi\ D'_c\,[\text{ft}]\,h_c\,[\text{ft}]$$

Equation 6.21: Nominal punching shear resistance through facing.

Where:

f'_c = as defined before

D'_c = effective equivalent diameter of the conical slip surface

h_c = effective depth of the conical surface

D'_c and h_c must be selected separately for the initial and final facing, as follows:

<u>Initial facing (Figure 6.7a)</u>

$$D'_c = L_{BP} + h_i$$

Equation 6.22: Effective, equivalent diameter of conical slip surface through initial facing.

$$h_c = h_i$$

Equation 6.23: Effective depth of the conical slip surface, initial facing.

Where:

L_{BP} = bearing plate size

h_i = thickness of initial facing

ATTACHMENT 10

WILLIAMS FORM ENGINEERING - GRADE 75 ALL-THREAD REBAR PROPERTIES

GRADE 75 & GRADE 80 ALL-THREAD REBAR

BAR DESIGNATION NOMINAL DIAMETER & PITCH	MINIMUM NET AREA THRU THREADS	MINIMUM ULTIMATE STRENGTH	GRADE 75 MINIMUM YIELD STRENGTH	GRADE 80 MINIMUM YIELD STRENGTH	NOMINAL WEIGHT	APPROXIMATE THREAD MAJOR DIAMETER	PART NUMBER
#6 – 3/4" – 5 (19 mm)	0.44 in^2 (284 mm^2)	44 kips (196 kN)	33 kips (147 kN)	35 kips (156 kN)	1.5 lbs/ft (2.4 kg/m)	7/8" (22 mm)	R61-06
#7 – 7/8" – 5 (22 mm)	0.60 in^2 (387 mm^2)	60 kips (267 kN)	45 kips (200 kN)	48 kips (214 kN)	2.0 lbs/ft (3.0 kg/m)	1" (25 mm)	R61-07
#8 – 1" – 3-1/2 (25 mm)	0.79 in^2 (510 mm^2)	79 kips (351 kN)	59 kips (264 kN)	63 kips (280 kN)	2.7 lbs/ft (3.9 kg/m)	1-1/8" (29 mm)	R61-08
#9 – 1-1/8" – 3-1/2 (29 mm)	1.00 in^2 (645 mm^2)	100 kips (445 kN)	75 kips (334 kN)	80 kips (356 kN)	3.4 lbs/ft (5.1 kg/m)	1-1/4" (32 mm)	R61-09
#10 – 1-1/4" – 3 (32 mm)	1.27 in^2 (819 mm^2)	127 kips (565 kN)	95 kips (424 kN)	102 kips (454 kN)	4.3 lbs/ft (5.5 kg/m)	1-3/8" (35 mm)	R61-10
#11 – 1-3/8" – 3 (36 mm)	1.56 in^2 (1006 mm^2)	156 kips (694 kN)	117 kips (521 kN)	125 kips (556 kN)	5.3 lbs/ft (7.9 kg/m)	1-1/2" (38 mm)	R61-11
#14 – 1-3/4" – 3 (43 mm)	2.25 in^2 (1452 mm^2)	225 kips (1001 kN)	169 kips (750 kN)	180 kips (801 kN)	7.65 lbs/ft (11.8 kg/m)	1-7/8" (48 mm)	R61-14
#18 – 2-1/4" – 3 (57 mm)	4.00 in^2 (2581 mm^2)	400 kips (1780 kN)	300 kips (1335 kN)	320 kips (1423 kN)	13.6 lbs/ft (19.6 kg/m)	2-7/16" (62 mm)	R61-18
#20 – 2-1/2" – 2-3/4 (64 mm)	4.91 in^2 (3168 mm^2)	491 kips (2184 kN)	368 kips (1637 kN)	393 kips (1748 kN)	16.7 lbs/ft (24.8 kg/m)	2-3/4" (70 mm)	R61-20
#24 – 3" – 2-3/4 (76 mm) *	6.82 in^2 (4400 mm^2)	682 kips (3034 kN)	512 kips (2277 kN)	546 kips (2429 kN)	24.0 lbs/ft (35.8 kg/m)	3-3/16" (81 mm)	R61-24
#28 – 3-1/2" – 2-3/4 (89 mm) *	9.61 in^2 (6200 mm^2)	961 kips (4274 kN)	720 kips (3206 kN)	769 kips (3421 kN)	32.7 lbs/ft (48.6 kg/m)	3-3/4" (95 mm)	R61-28
#32 – 4" – 2-3/4 (102 mm) *	12.56 in^2 (8103 mm^2)	1256 kips (5587 kN)	942 kips (4190 kN)	1004 kips (4466 kN)	43.0 lbs/ft (64.0 kg/m)	4-1/4" (108 mm)	R61-32