GeoStabilization International®

GEOHAZARD MITIGATION TECHNOLOGIES

Andy Bowman, P.E.
Cameron Lobato, P.E.


←HIGH PRESSURE PIPELINE


200 yards
Google Maps


REIS
CONCRETE

TECHNOLOGIES HIGHLIGHTED

- Launched Soil Nails
- SuperNails®
- Hollow Bar Soil Nails
- Facing (Shotcrete/Mesh Facing)
- Small Diameter Micropiles
- GCS® Geosynthetically Confined Soil

- Technologies in Action

The Soil Nail Launcher

Declassified British Military Cannon modified to Launch Soil Nails – War on shallow landslides

The Soil Nail Launcher

The Soil Nail Launcher

Accelerates a 1.5” diameter, 20’ long, bar or tube
Into the ground in a single shot utilizing air pressure

The Soil Nail Launcher

Powered by a custom mounted auxiliary air compressor

The Soil Nail Launcher

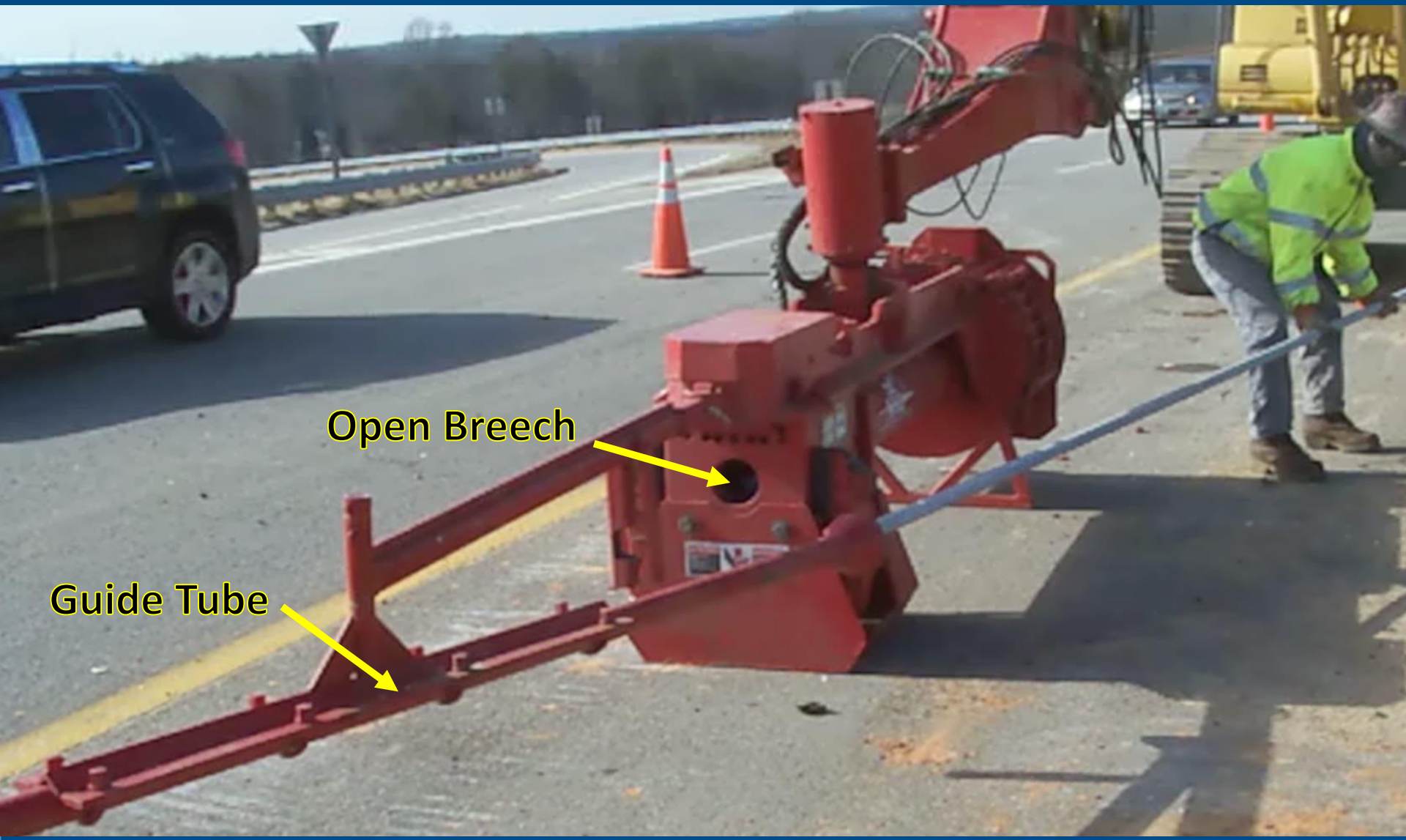
Building Launched Soil Nails

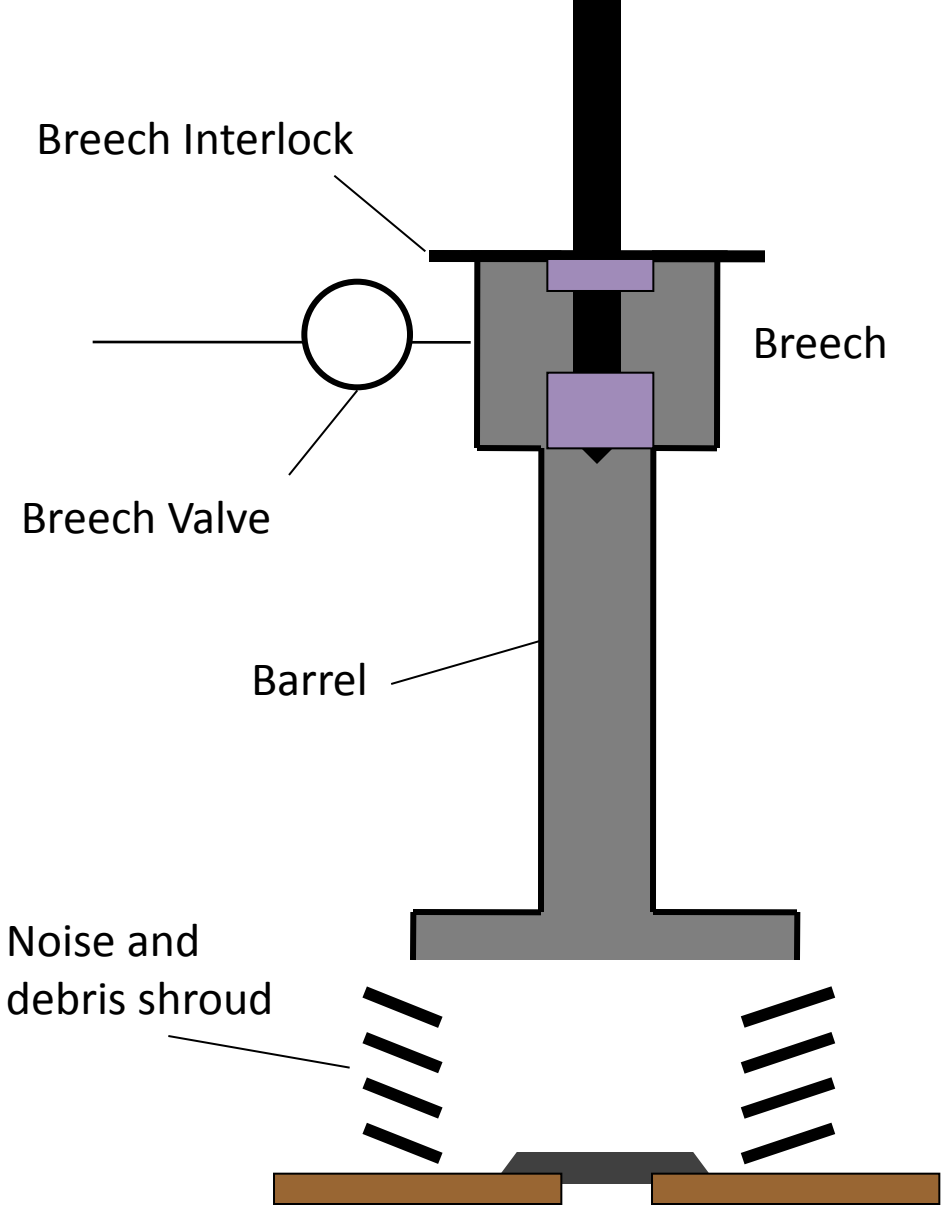
Barbed End

Collet

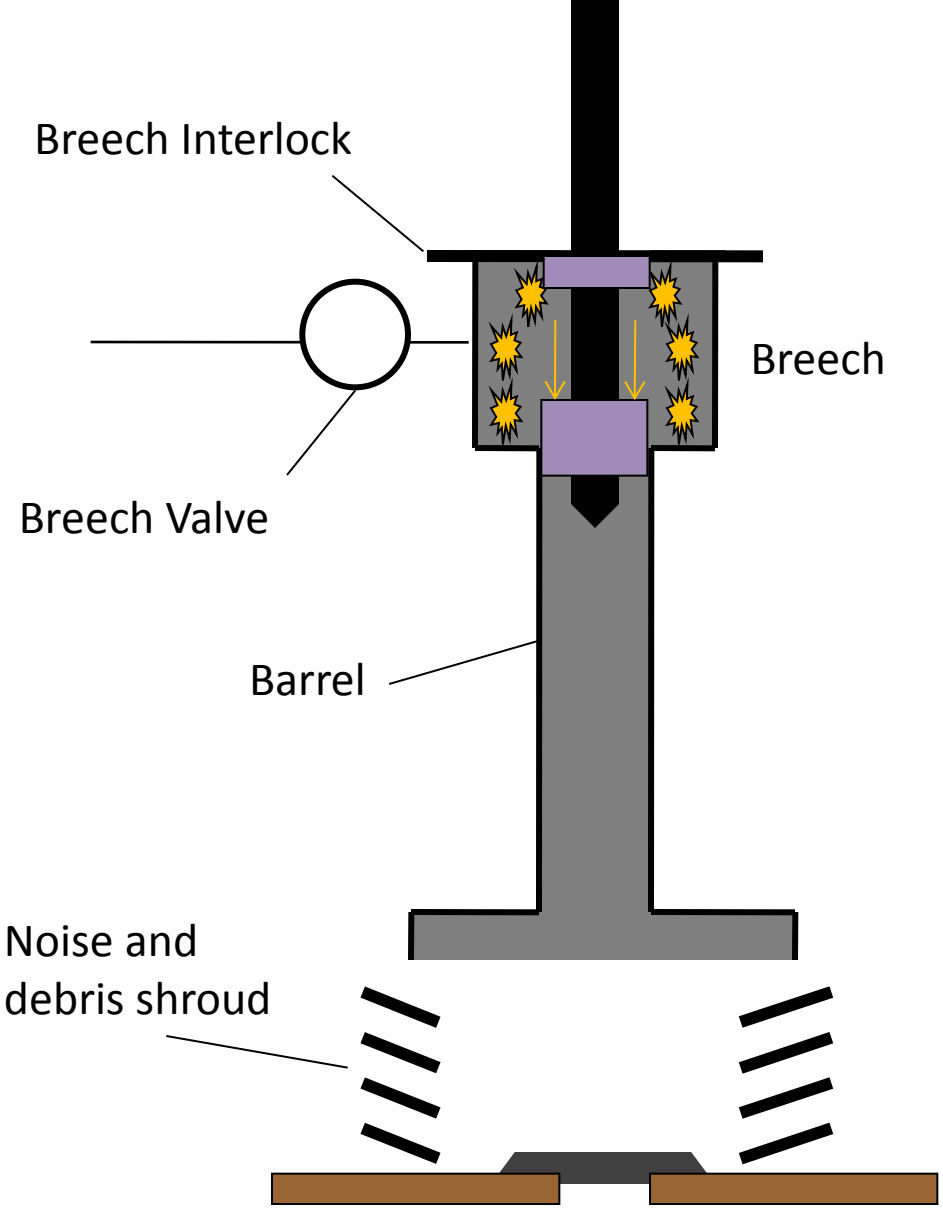
Assembled Nails

Loading Launcher

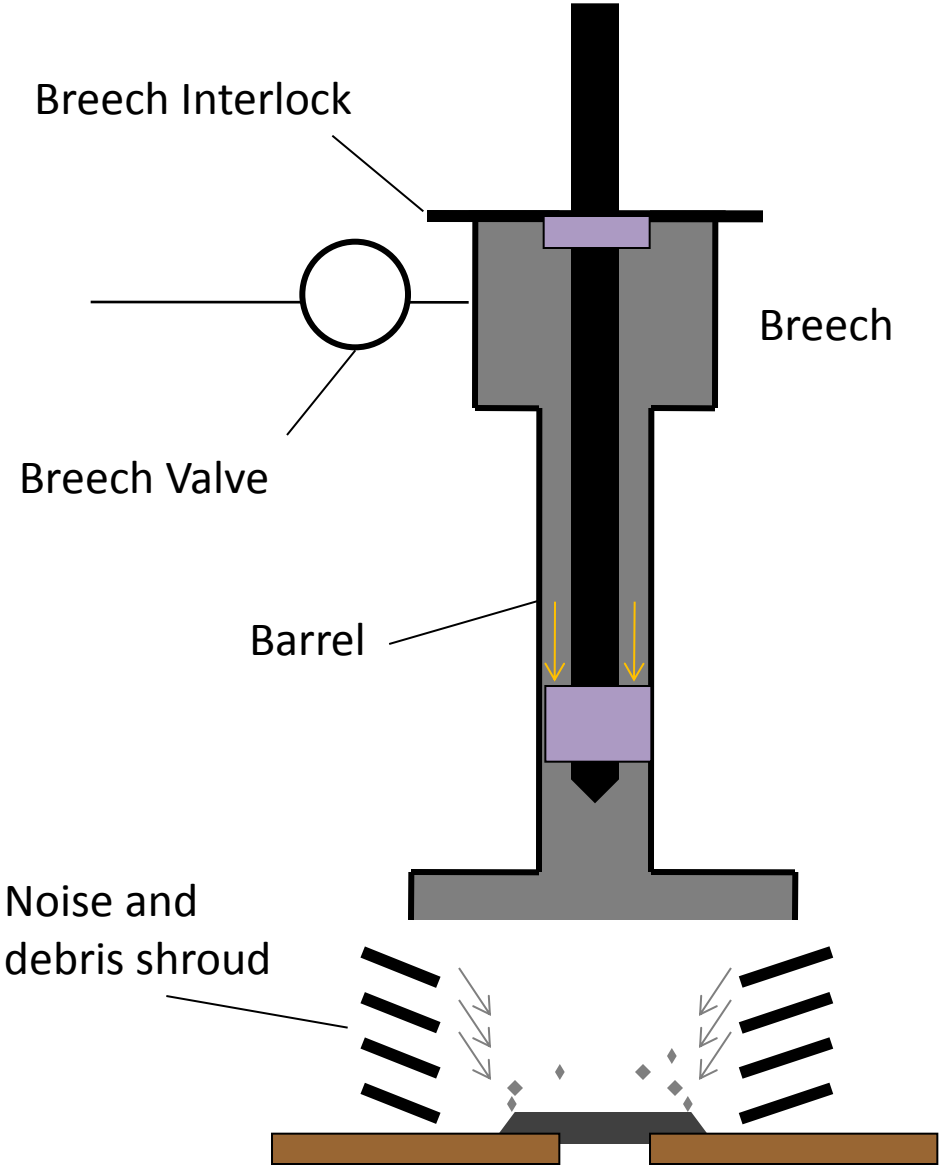




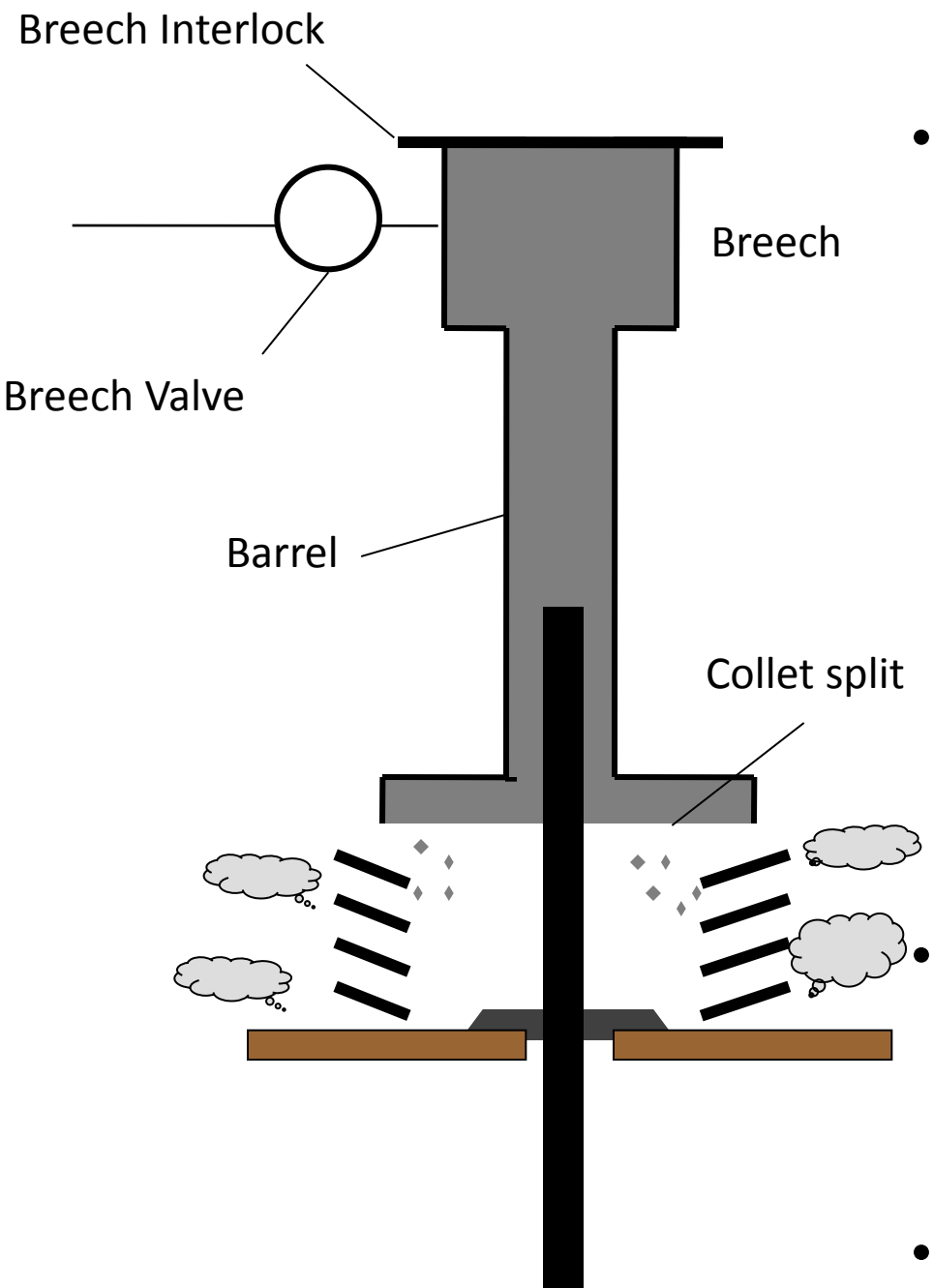
- Nail engaged within cylinder and breech closed.
- The onboard accumulator is charged to the desired air pressure.
- The maximum air pressure is ~4,000psi but can be varied depending on soil type and design requirements.



- Launched Nail is lifted into position and aligned in the desired direction.
- Baseplate must be in contact with ground to fire and personnel must be clear of the area.
- Following a sequence of auditory warning sirens, the nail is fired.



- The compressed air suddenly released against the collet forces the collet and nail through the barrel, much like a dart through a blowgun.
- The force acts upon the tip of the nail, placing the nail temporarily in tension, and preventing it from buckling.

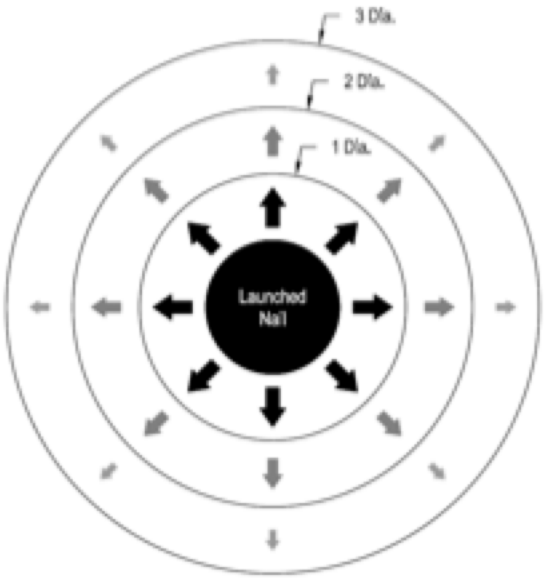


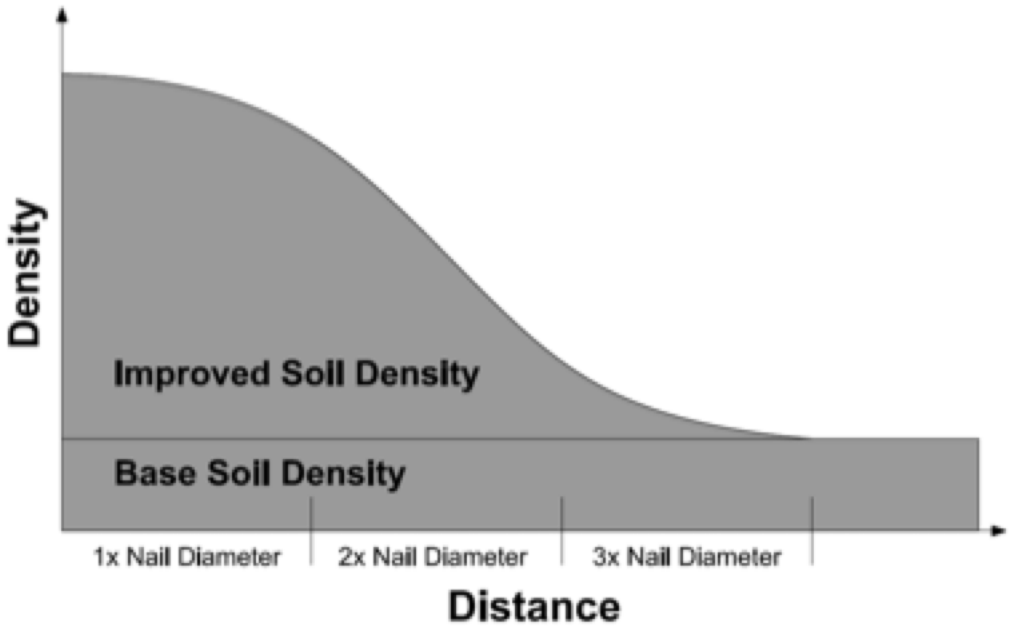
- The collet breaks away as the nail enters the soil.
- The ground around the nail is displaced by compression at the tip, creating a shockwave in front of the nil tip that causes the soil particles to “jump away” from the main shaft of the nail. The nail subsequently enters the earth without significant abrasion or coating damage.
- The soil particles then collapse onto the nail providing a high pullout resistance.
- Nail is launched in 1/5 of a sec.

Double Barrel


KOMATSU

Improved Soil Density





Driven Nails

- Pounding, vibrating, or driving a nail into the ground disturbs the soil around the nail.
- Launched soil nails have a bond strength >10x that of driven nails.

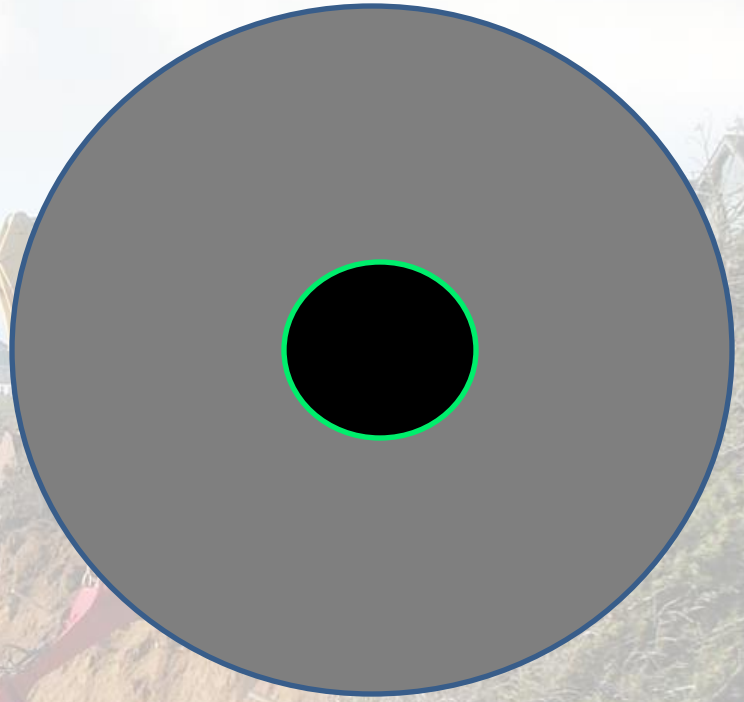
Grouting Launched Soil Nails

Inserting Inner Bar

Comparative Cross Sections

LAUNCHED SuperNail™
SUPERIOR CORROSION PROTECTION

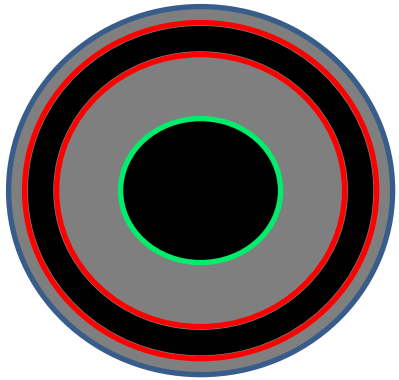
Traditional Drilled Soil Nail



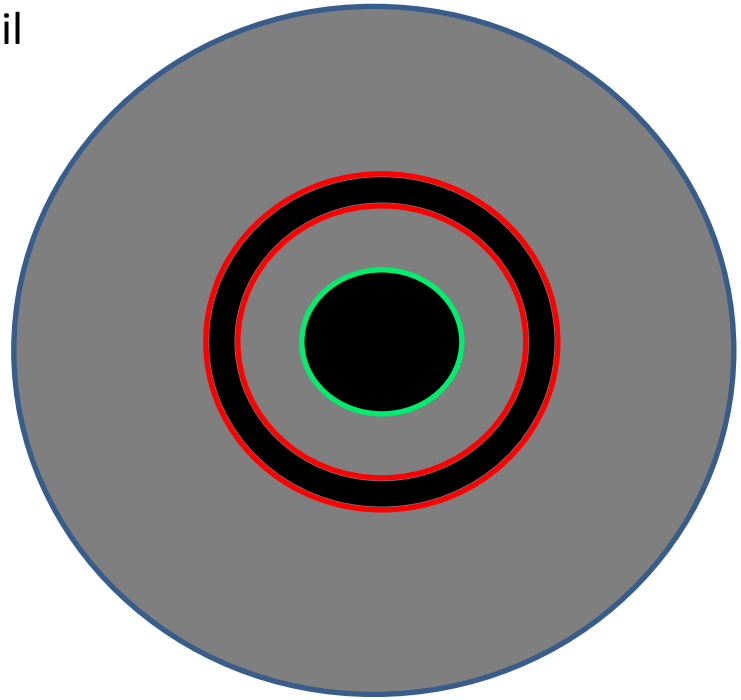
Grout
Galvanization
Steel
Epoxy

SuperNails®

Post Grouted Launched Soil Nail
(Launched SuperNail®)



Drilled SuperNail®

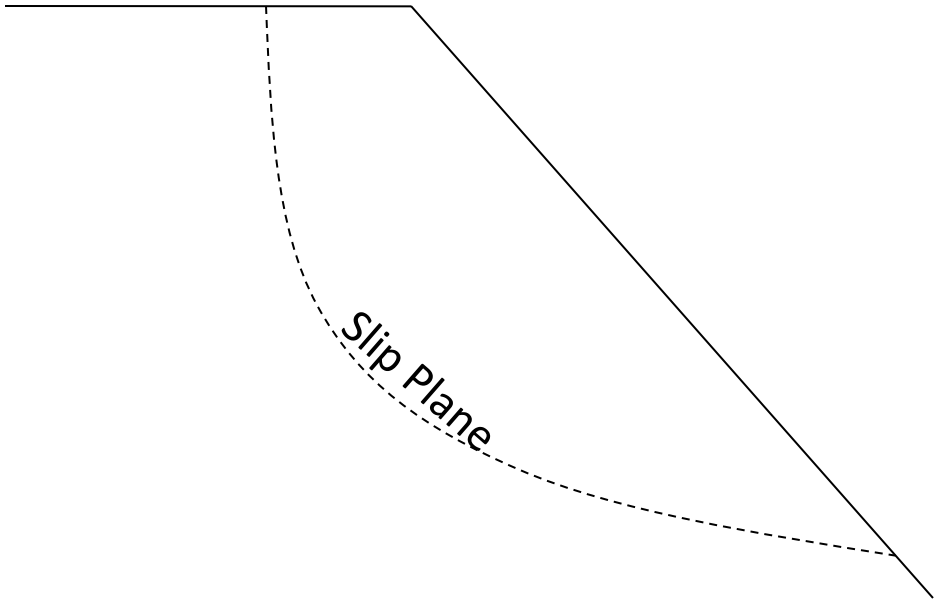


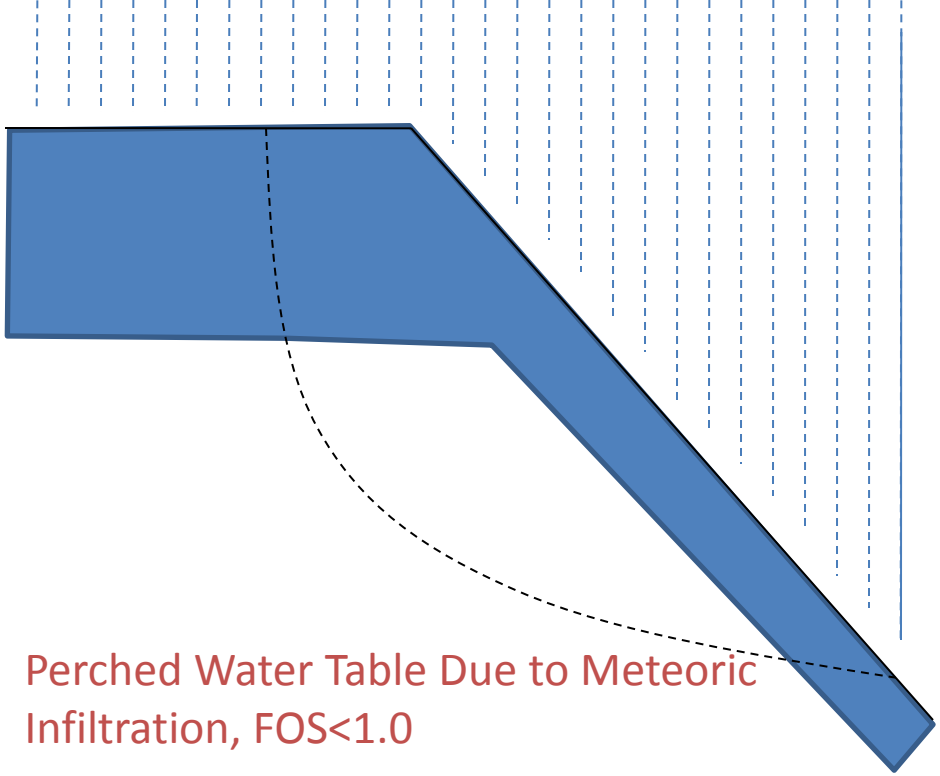
Grout
Galvanization
Steel
Epoxy

Verification Testing

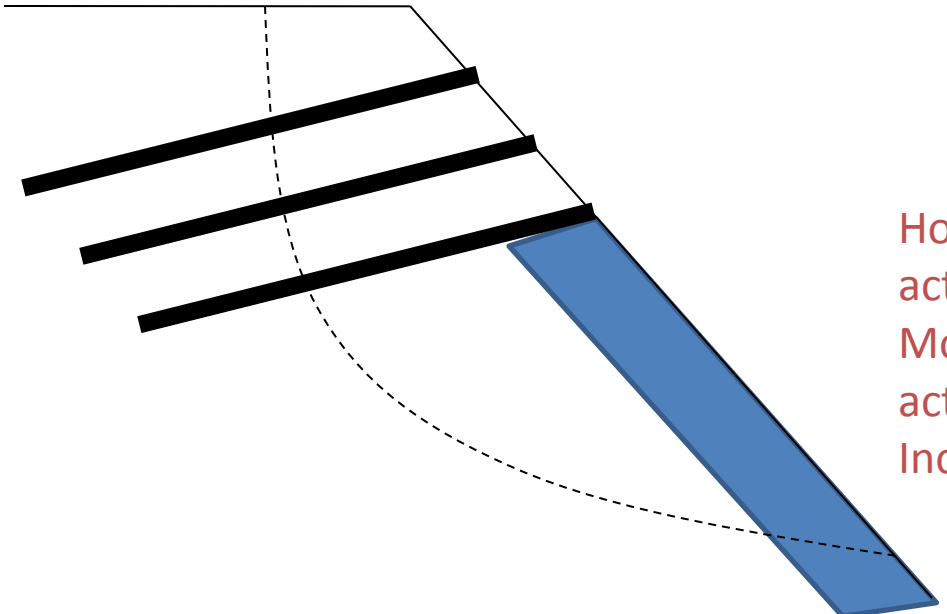
Launched Soil Nails - Drains

Landslide in dry conditions, FOS>1.0





Perched Water Table Due to Meteoric Infiltration, FOS<1.0



Hollow, Perforated Launched Soil Nails act as drains during high Moisture events, allowing drainage and acting as tensile Inclusions, FOS>>1.0

Material Types

- Any type of material can be utilized as long as it has the desired physical properties.
- Solid bar, threaded bar, or pipe. Steel bars can be left mill finish, galvanized, epoxy coated, plastic sheathing or a combination.

Advantages – Speed of Installation

Advantages – Limited Access

Advantages – Immediate Contribution

Advantages – Reduced Cost

Advantages – Rapid Ingress/Egress

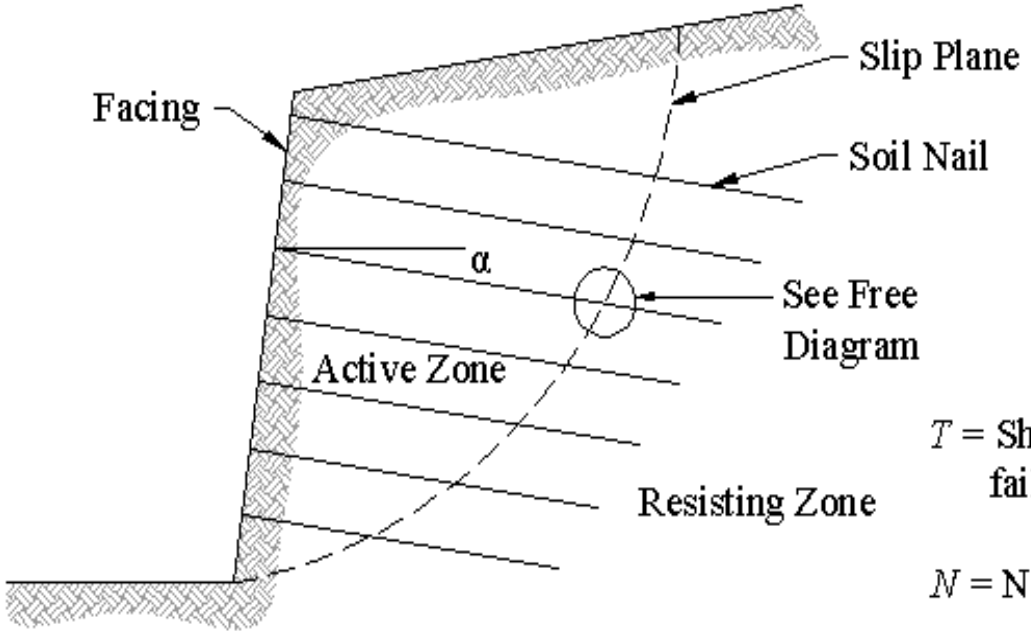
Advantages – Construction Footprint

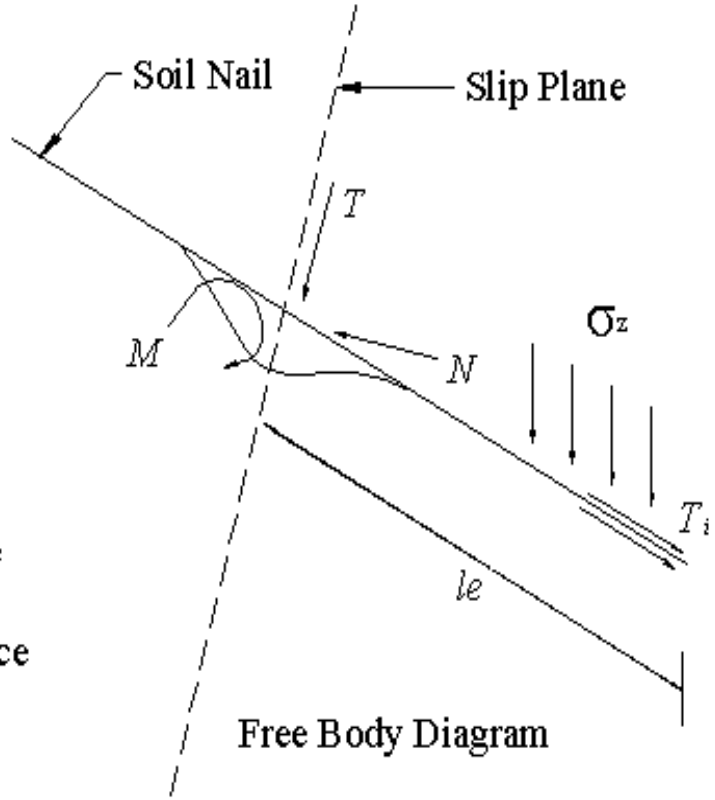
Advantages – Fun to Watch

Site Analysis

- Works well in sands, gravels, silts, and clays.
- Works well for shallow failures. Embedment depth limited to 20’.
- Sites with large cobbles, boulders, are bedrock are not suitable.

Soil Nail Failure Mechanism





T = Shear along failure plane

N = Normal force

M = Moment

T_i = Interface Shear

le = Effective length

σ_z = Soil pressure

The nail is fired generally ungrouted and penetrates beyond the slip surface to a limited extent. In this case the tension is a small proportion of the fracture strength and the shear capacity requires to be exploited.

Design Guidance

United States Department of Agriculture

Forest Service

Engineering Staff

EM 7170-12A

United States Department of Transportation

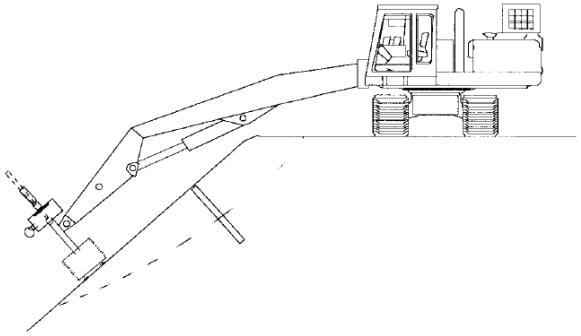
Federal Highway Administration

FHWA-FPL-93-003

July 1994

Application Guide For Launched Soil Nails

Volume I



United States Department of Agriculture

Forest Service

Engineering Staff

EM 7170-12B

United States Department of Transportation

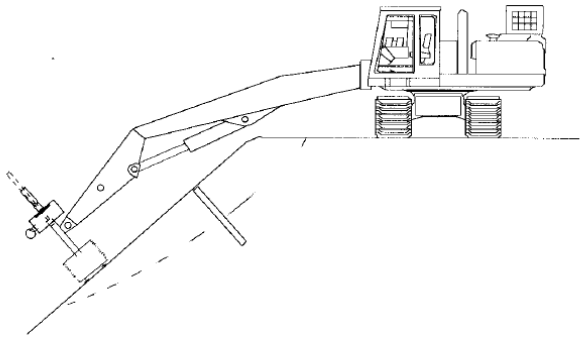
Federal Highway Administration

FHWA-FPL-93-004

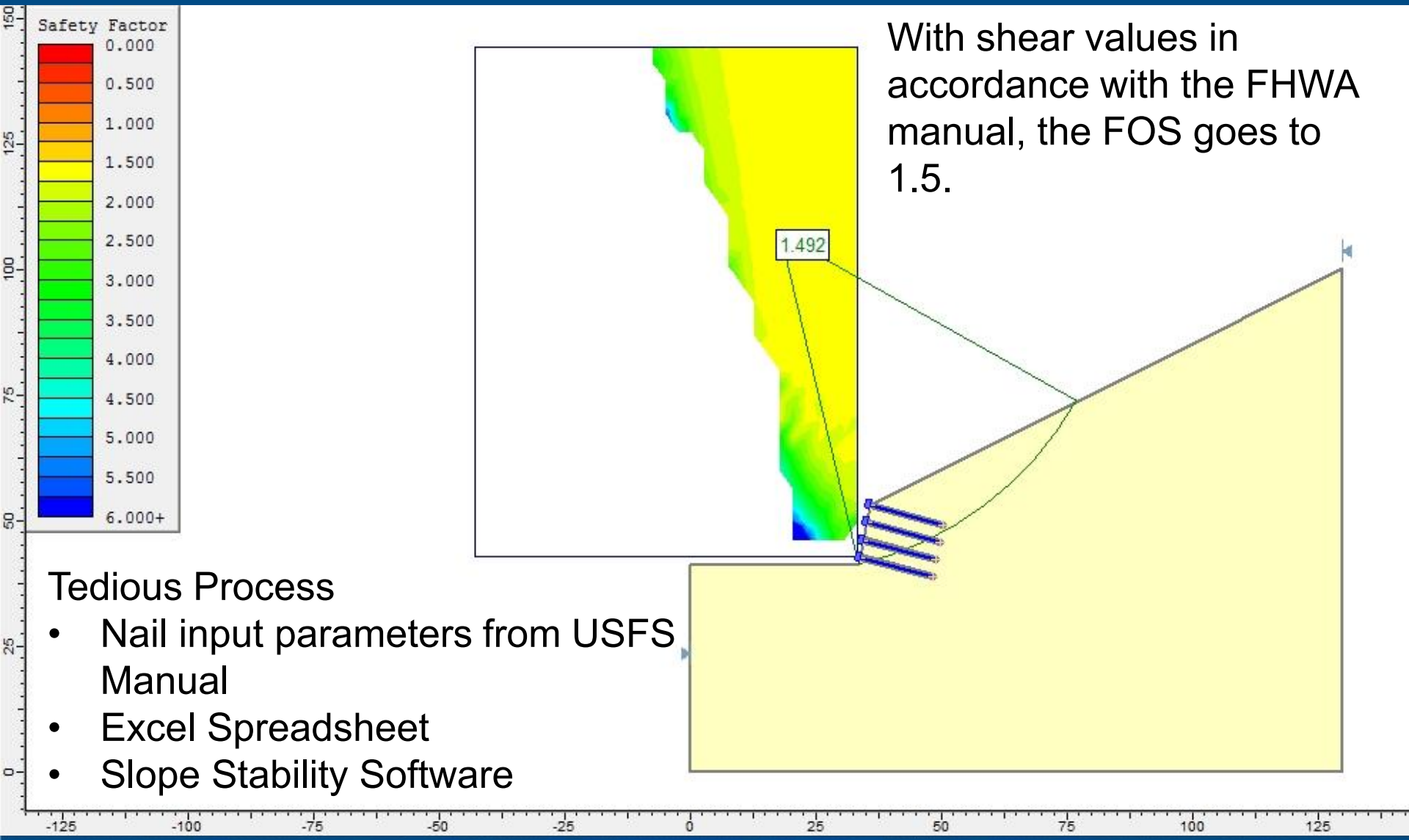
July 1994

Project Report for Launched Soil Nails—1992 Demonstration Project

Volume 2



Slope Stability Modeling

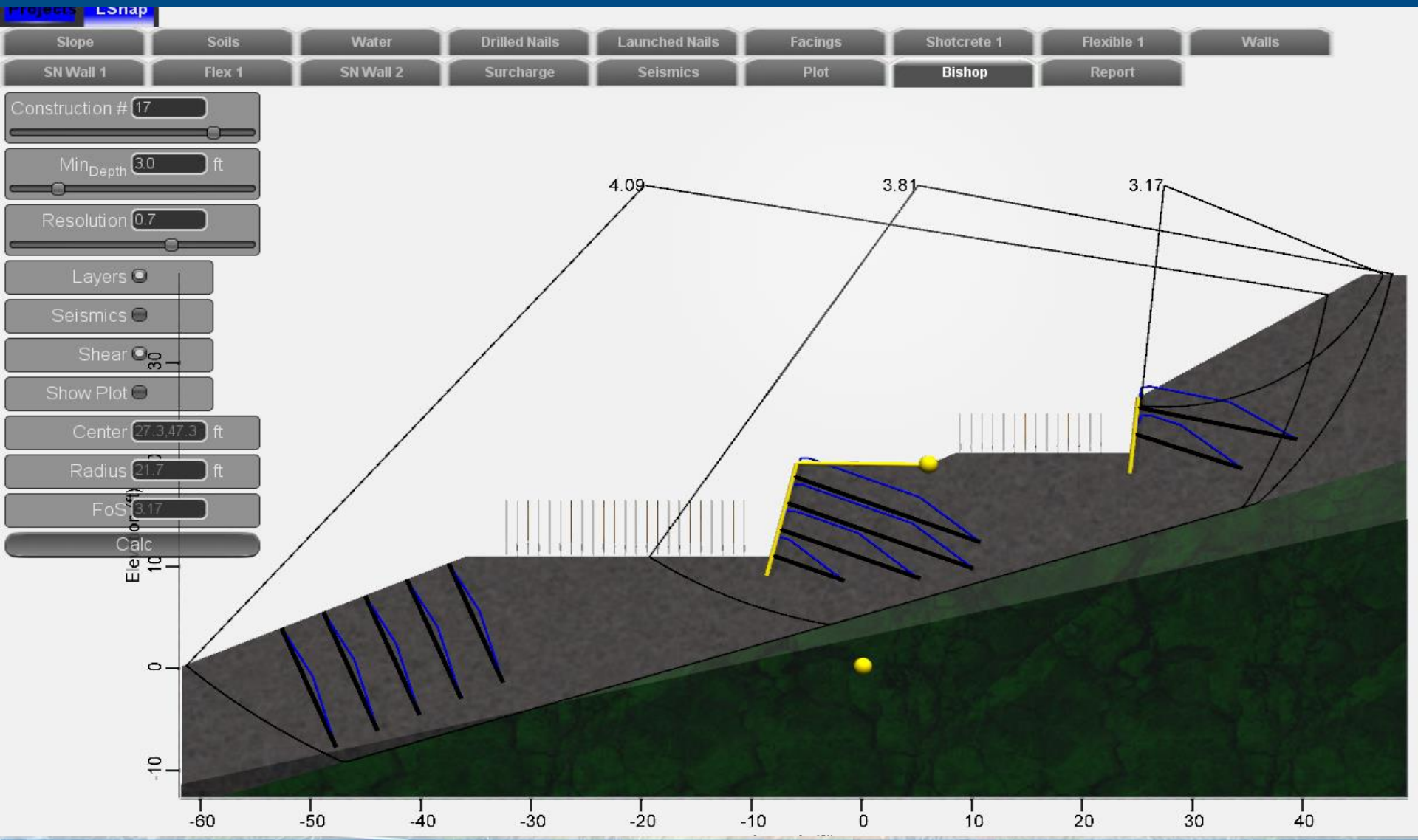


With shear values in accordance with the FHWA manual, the FOS goes to 1.5.

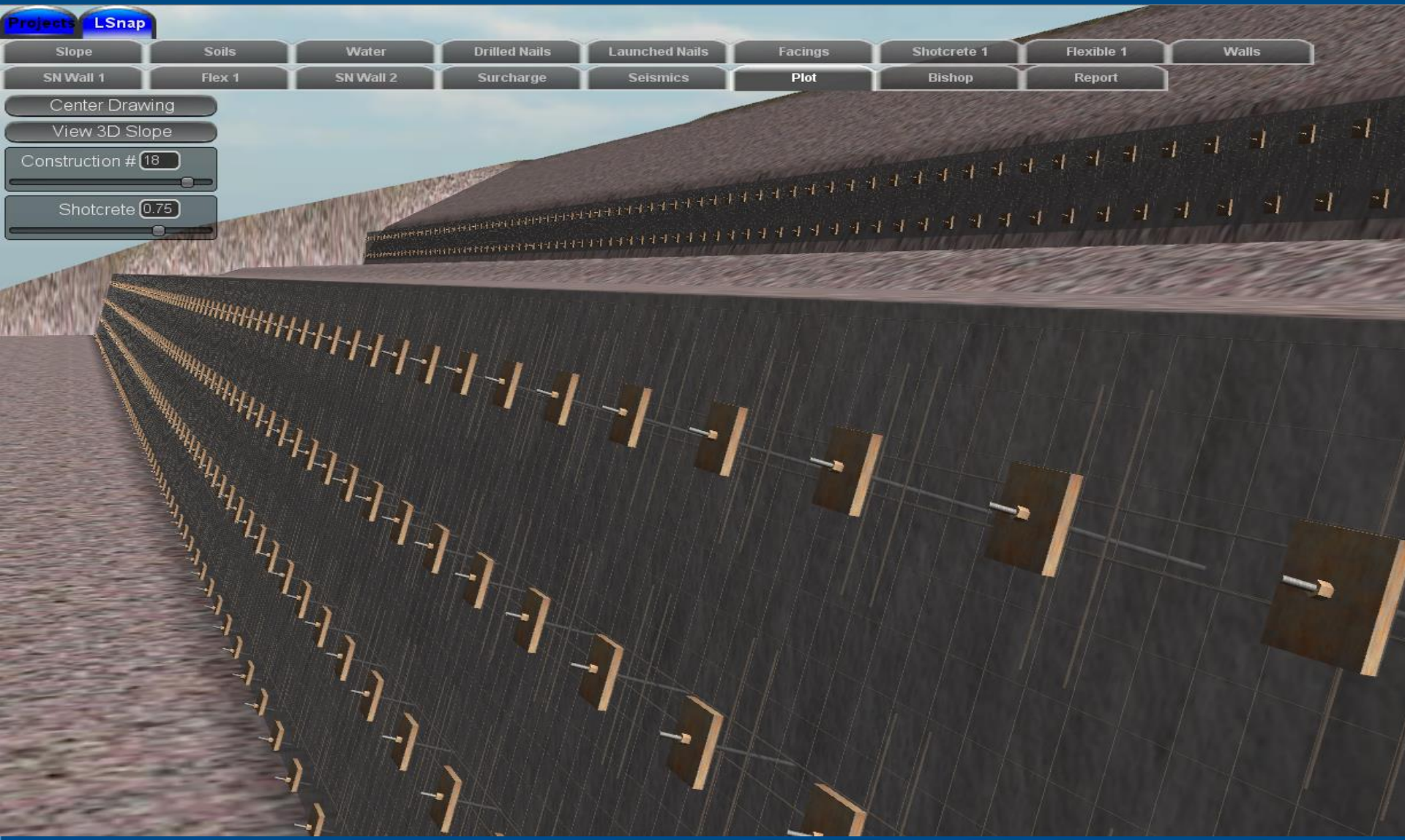
Tedious Process

- Nail input parameters from USFS Manual
- Excel Spreadsheet
- Slope Stability Software

LSNAP


Projects
LSnap
Slope
Soils
Water
Drilled Nails
Launched Nails
Facings
Shotcrete 1
Flexible 1
Walls
SN Wall 1
Flex 1
SN Wall 2
Surcharge
Seismics
Plot
Bishop
Report
Construction # 17
Min Depth 3.0 ft
Resolution 0.7
Layers
Seismics
Shear
Show Plot
Center 27.3,47.3 ft
Radius 21.7 ft
FoS 3.17
Calc
4.09
3.81
3.17
30
10
0
-10
-60
-50
-40
-30
-20
-10
0
10
20
30
40

LSNAP

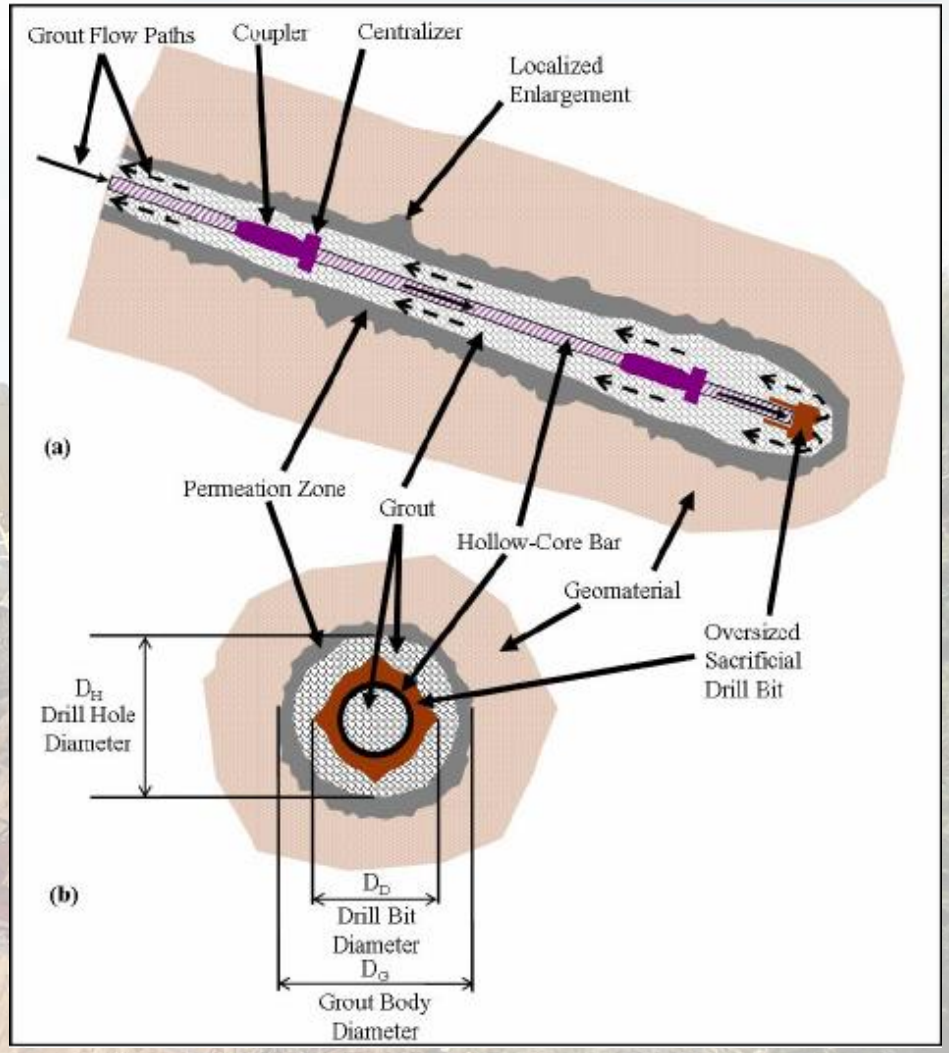

Projects
LSnap
Slope
Soils
Water
Drilled Nails
Launched Nails
Facings
Shotcrete 1
Flexible 1
Walls
SN Wall 1
Flex 1
SN Wall 2
Surcharge
Seismics
Plot
Bishop
Report
Center Drawing
View 3D Slope
Construction # 18
Shotcrete 0.75

Hollow Bar Soil Nails

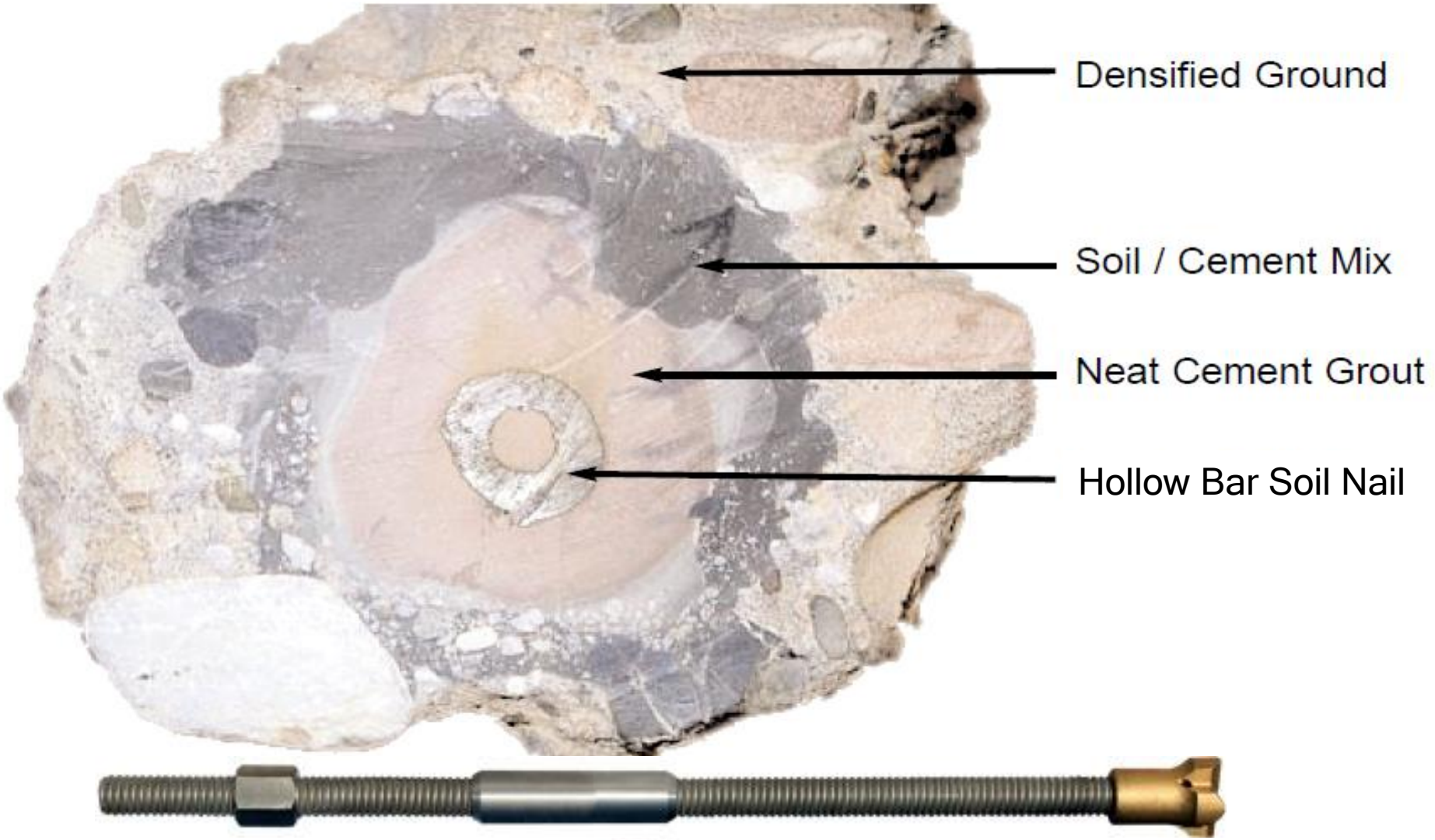
AKA- Titan Bar, Injection Anchors, Self-Drilling Soil Nail, B7X Bar, Etc.

Self-Drilling Soil Nails

- Suitable for collapsing soil
- Suitable for actively moving landslides
- High installation rates
- High pullout capacity
- High bending/shear capacity
- Suitable for rock and soil
- FHWA design guidance



Drilled Soil Nails



Corrosion

	Suitable for Collapsing Soils	Suitable for Actively Moving Landslides	Typical Depth Limitations	# of Corrosion Protection Layers	Typical Installation Rates (LF/Day)			Relative Pullout Capacity			Relative Cost ($,$$,or $$$)			Design Guidance from FHWA	Design Guidance from FHWA for use in Landslide Repair	Can be Single Stage Pressure Grouted	Can Serve as a Horizontal Drain	Can be Installed in Rock	Can be Used in Areas with Voids	Bending/Shear Capacity			New Technology
					Low	Med	High	Low	Med	High	Low	Med	High							Low	Med	High	
Launched Soil Nails	Y	Y	20	3										Y	Y	Y	Y	N	Y			Y
Solid Bar (Open Hole)	N	N	60	2										Y	N	N	N	Y	N			N
Solid Bar (Cased Hole)	Y	N	200	2										Y	N	N	N	Y	N			N
SuperNail®	Y	Y	80	4										Y	Y	N	N	Y	Y			Y
Self Drilling Soil Nail	Y	Y	120	1										Y	N	N	Y	Y	N			Y

	Corrosion Protection
Launched Soil Nails	3 Layers (outer galvanized tube, inner grout, inner bar epoxy)
Solid Bar (Open Hole)	2 Layers (outer grout, inner bar epoxy)
Solid Bar (Cased Hole)	2 Layers (outer grout, inner bar epoxy)
SuperNail®	4 Layers (outer grout, galvanized tube, inner grout, inner bar epoxy)
Self Drilling Soil Nail	Typically only 1 Layer calculated (outer grout or sacrificial steel)


UNION PACIFIC

Shotcrete Facing

Shotcrete Facing


© 2010 Landslide Solutions, Inc.

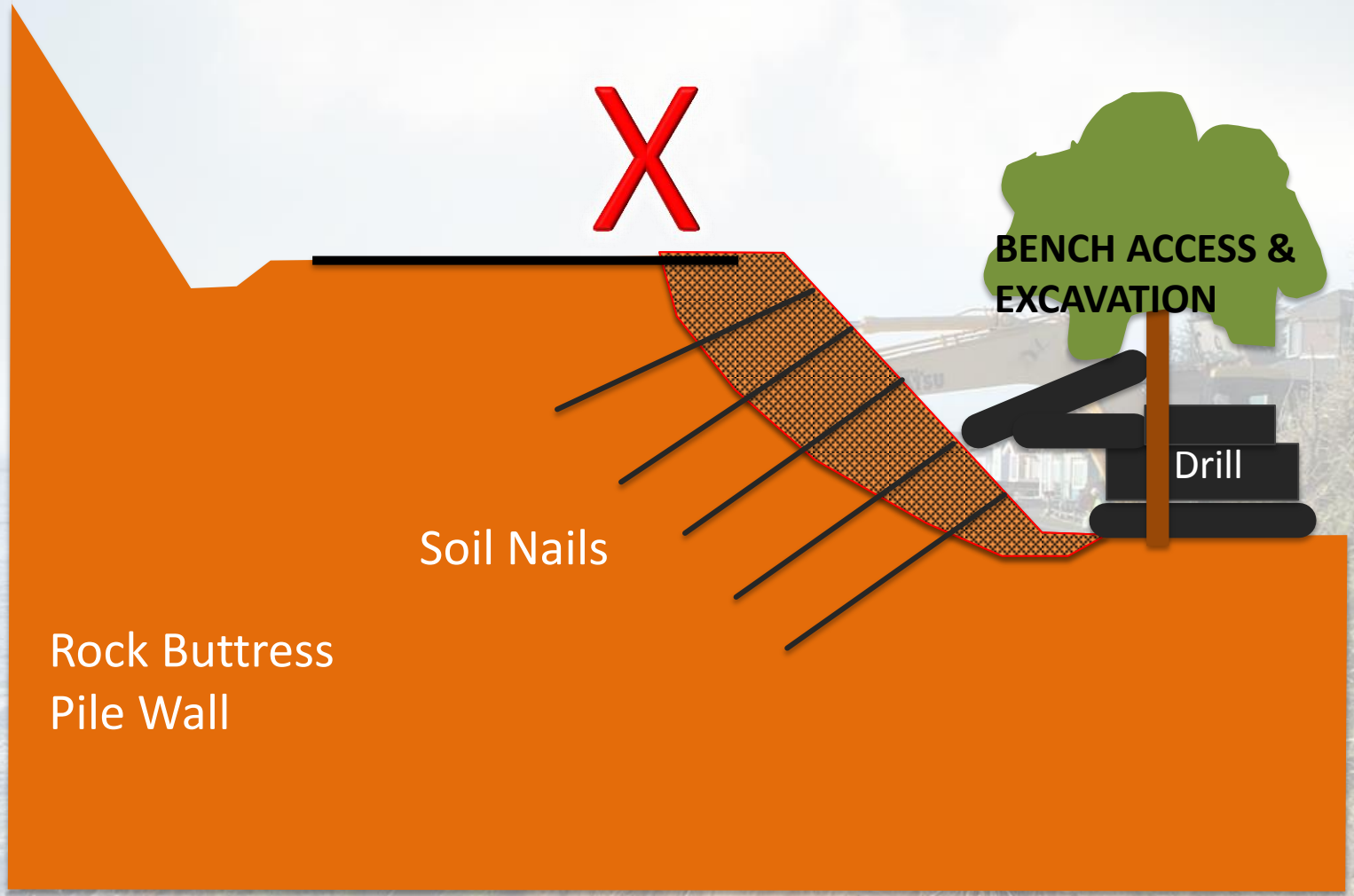
Mesh Facing

Mesh Facing

Small Diameter Micropiles

- Near Vertical Elements, 6’’ in diameter or less
- Work Primarily in Bending/Shear/Compression
- A good complement to tensile elements (Soil Nails)
- Can be used for Shoring and Bearing

Traditional Re-Construction




GCS Fill

DESIGN

J. Erik Loehr
University of Missouri

Short Course for Soil Nail Launcher, Inc.
Grand Junction, CO
June 11, 2012

Analysis of Soil-Structure Interaction Problems Using LPile 2012

Presented by
Bill Isenhower

ENSOFT, INC.

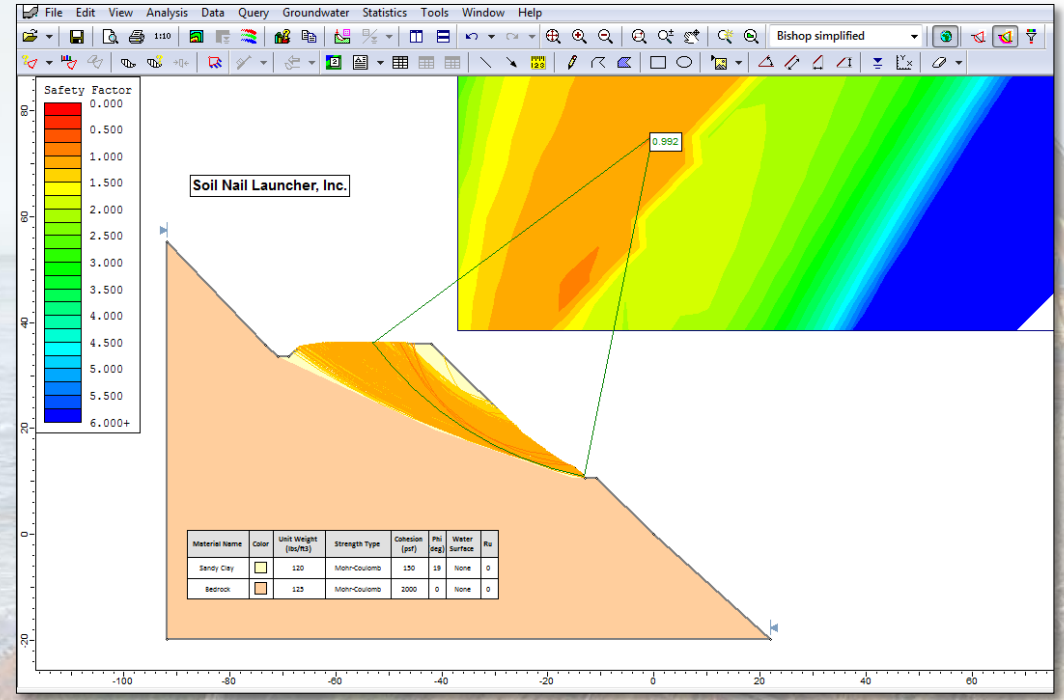
John Curran & Team

rocscience
software tools for rock and soil

GSI
GeoStabilization International
ENGINEER TEAM

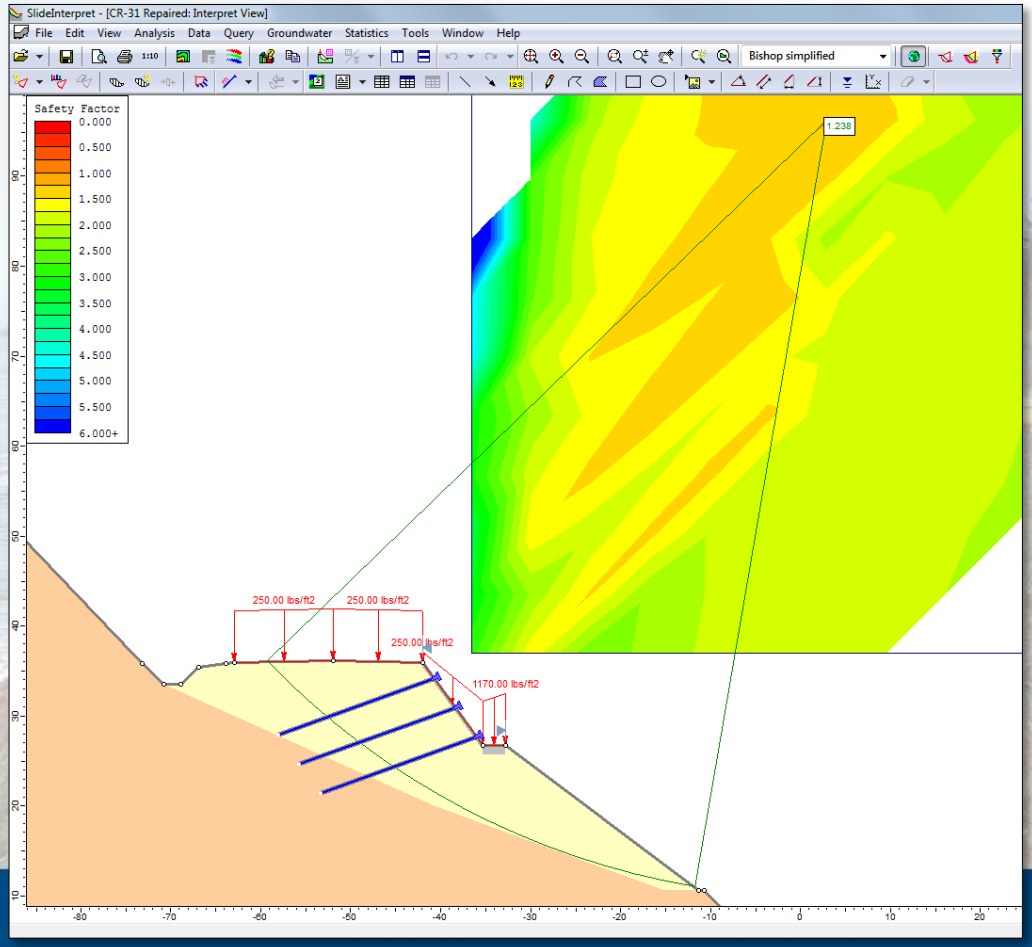
DESIGN – EXAMPLE

- Initial model FS = 0.992



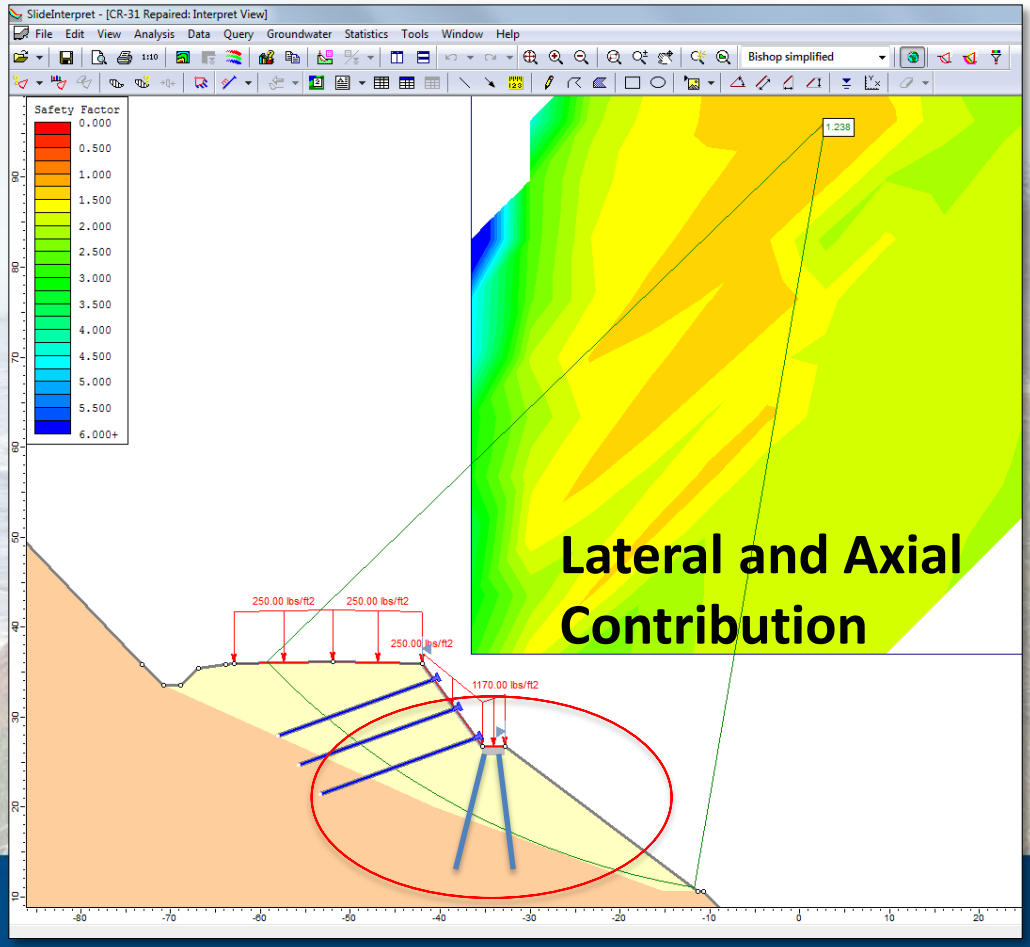
DESIGN – EXAMPLE

- Soil nail factor of safety = 1.238



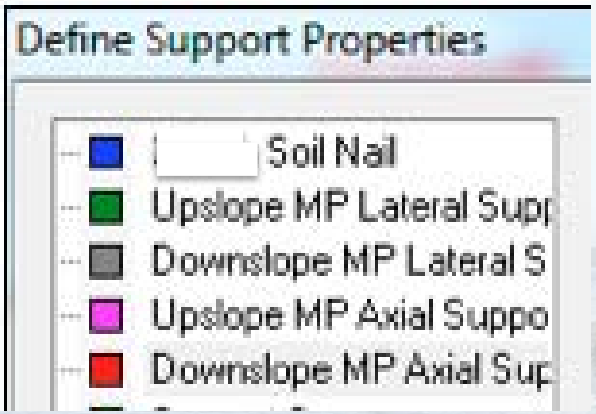
DESIGN – EXAMPLE

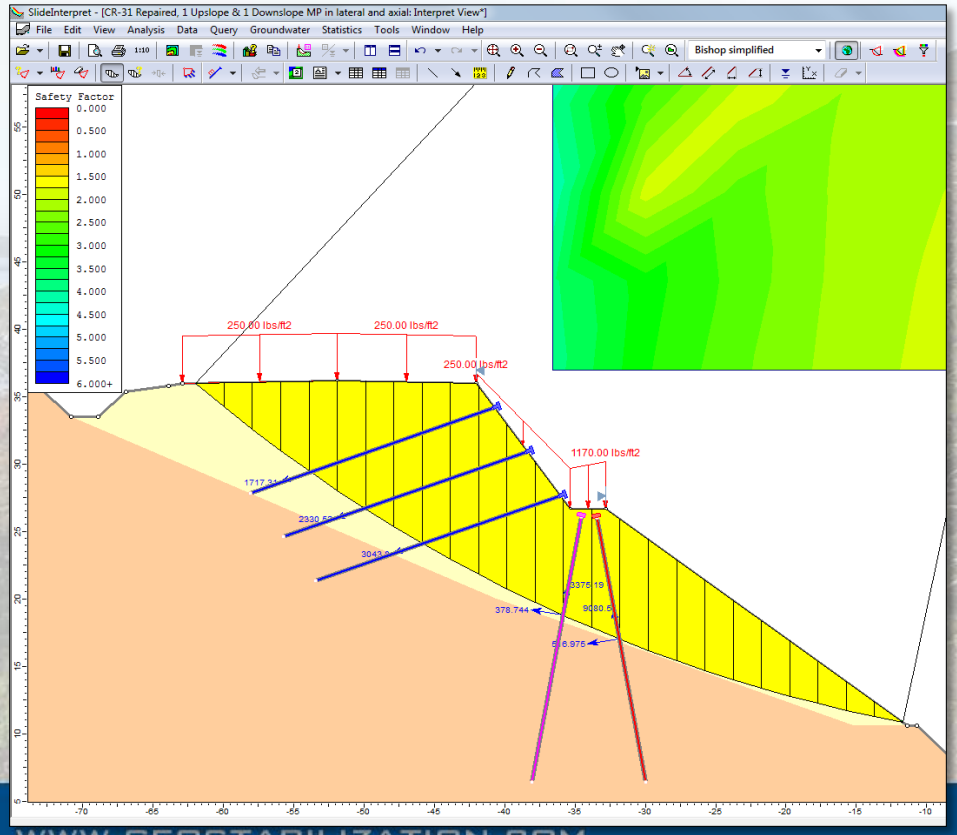
- Micropiles included



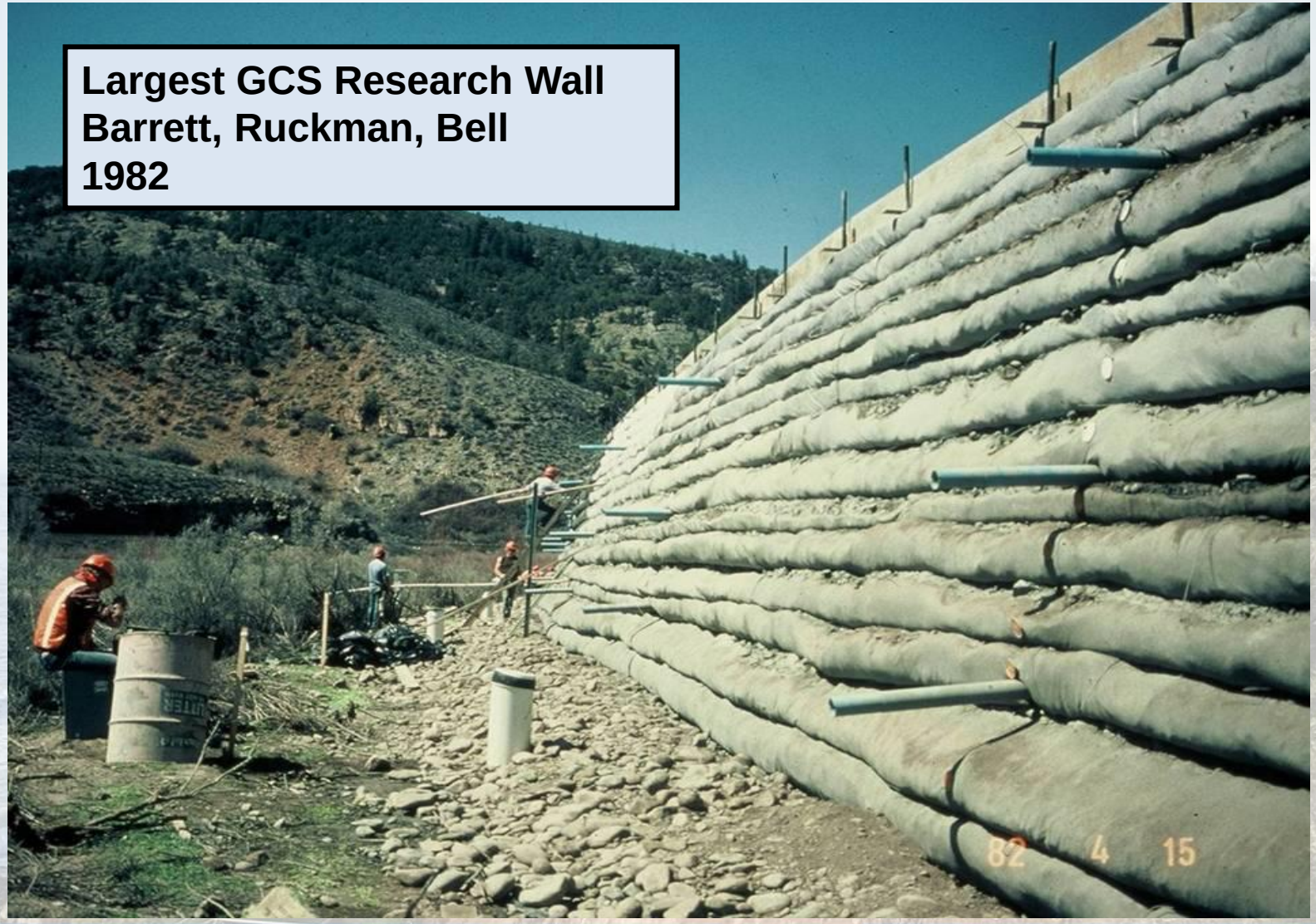
DESIGN – EXAMPLE

- Lateral and axial resistance of both upslope and downslope piles
  - Increase FS from 1.238 to 1.680





GCS®



Spacing Controls Performance ….Not Strength of the Inclusion

BASED ON

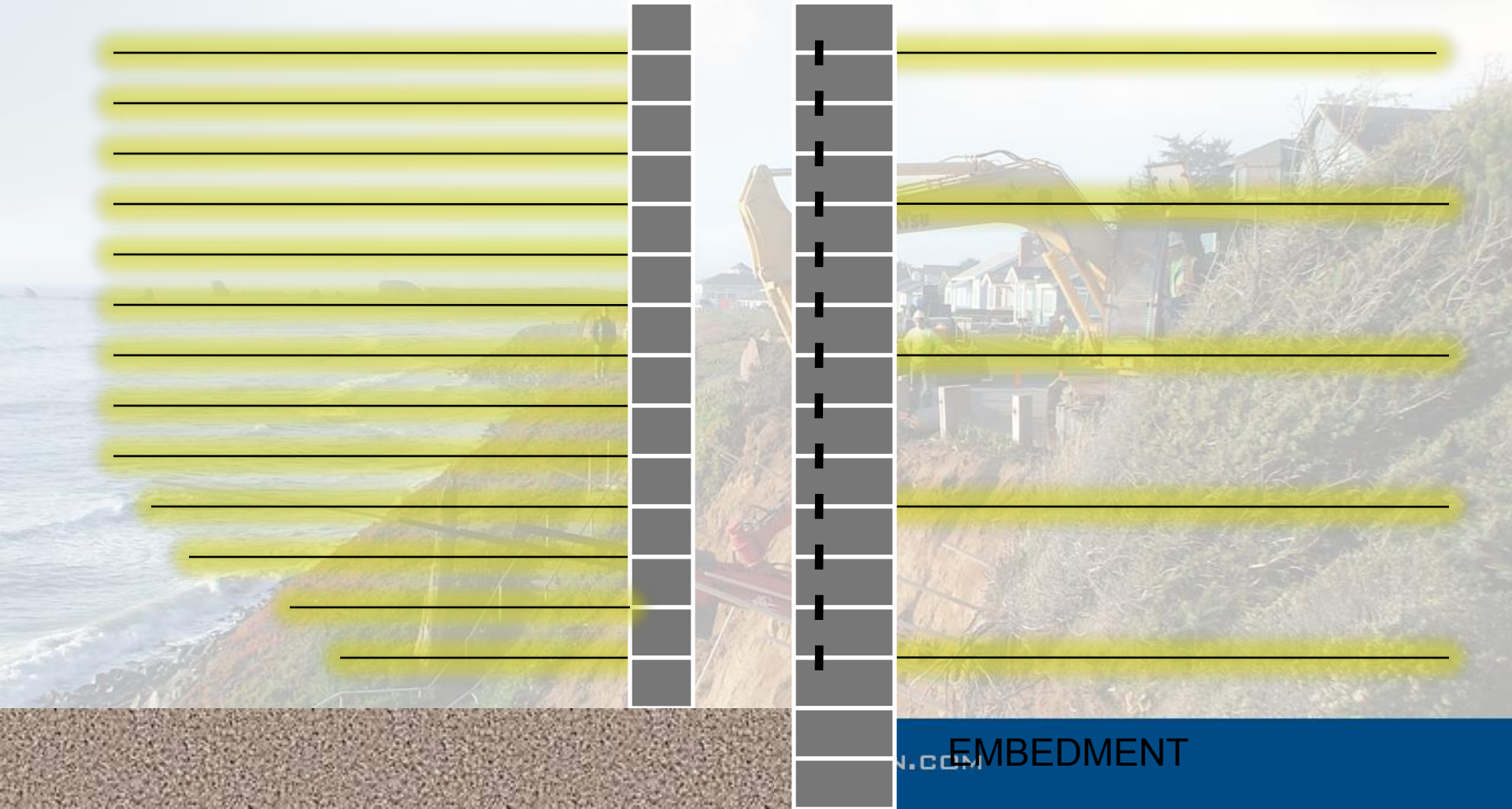
NCHRP REPORT 556

GCS®

UNIQUE COMPOSITE BEHAVIOR
i.e. SIMILAR TO CONCRETE AND ASPHALTIC CONCRETE

MSE

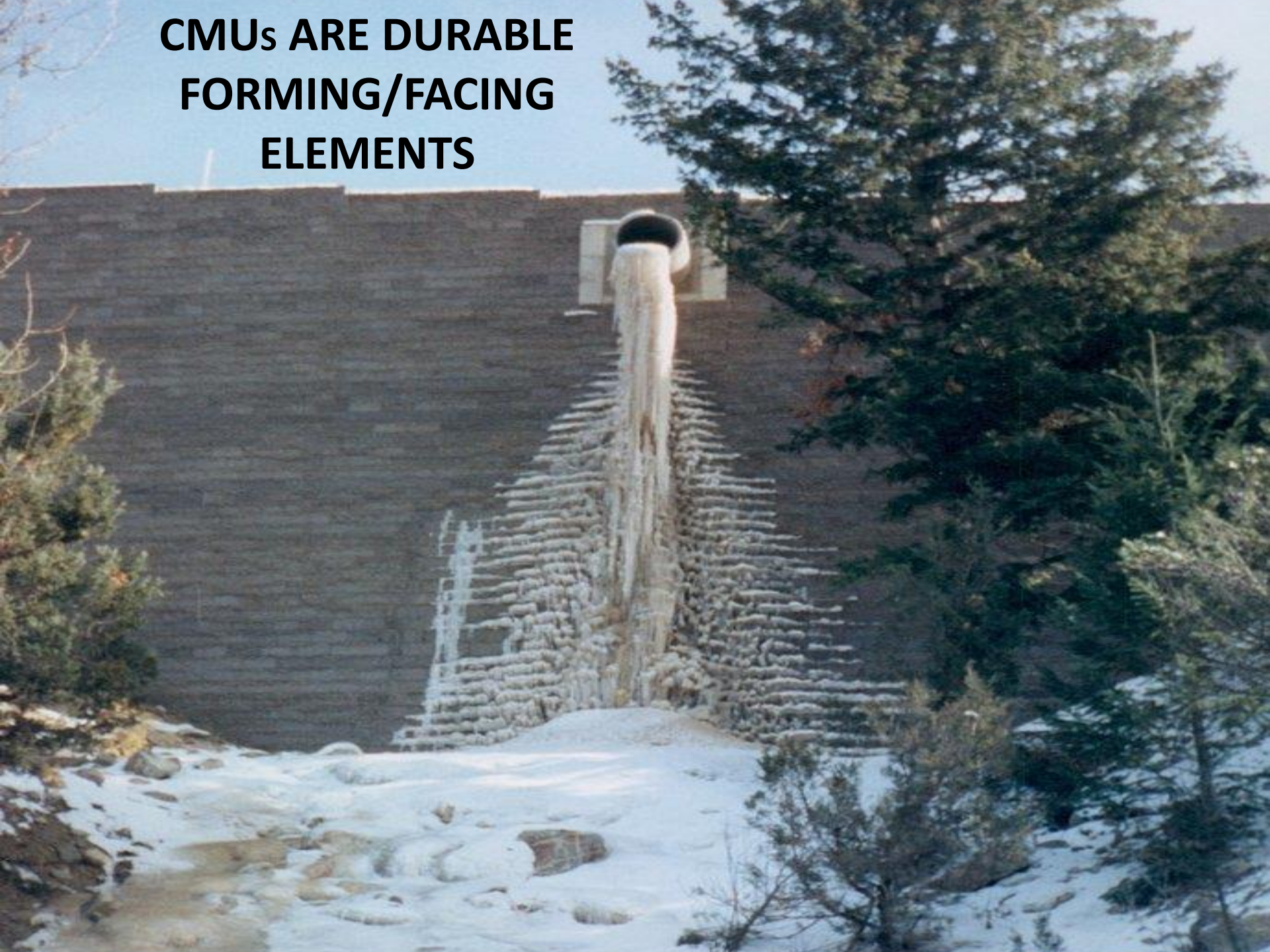
SIMPLE COMPOSITE
TIEBACK BEHAVIOR



EMBEDMENT

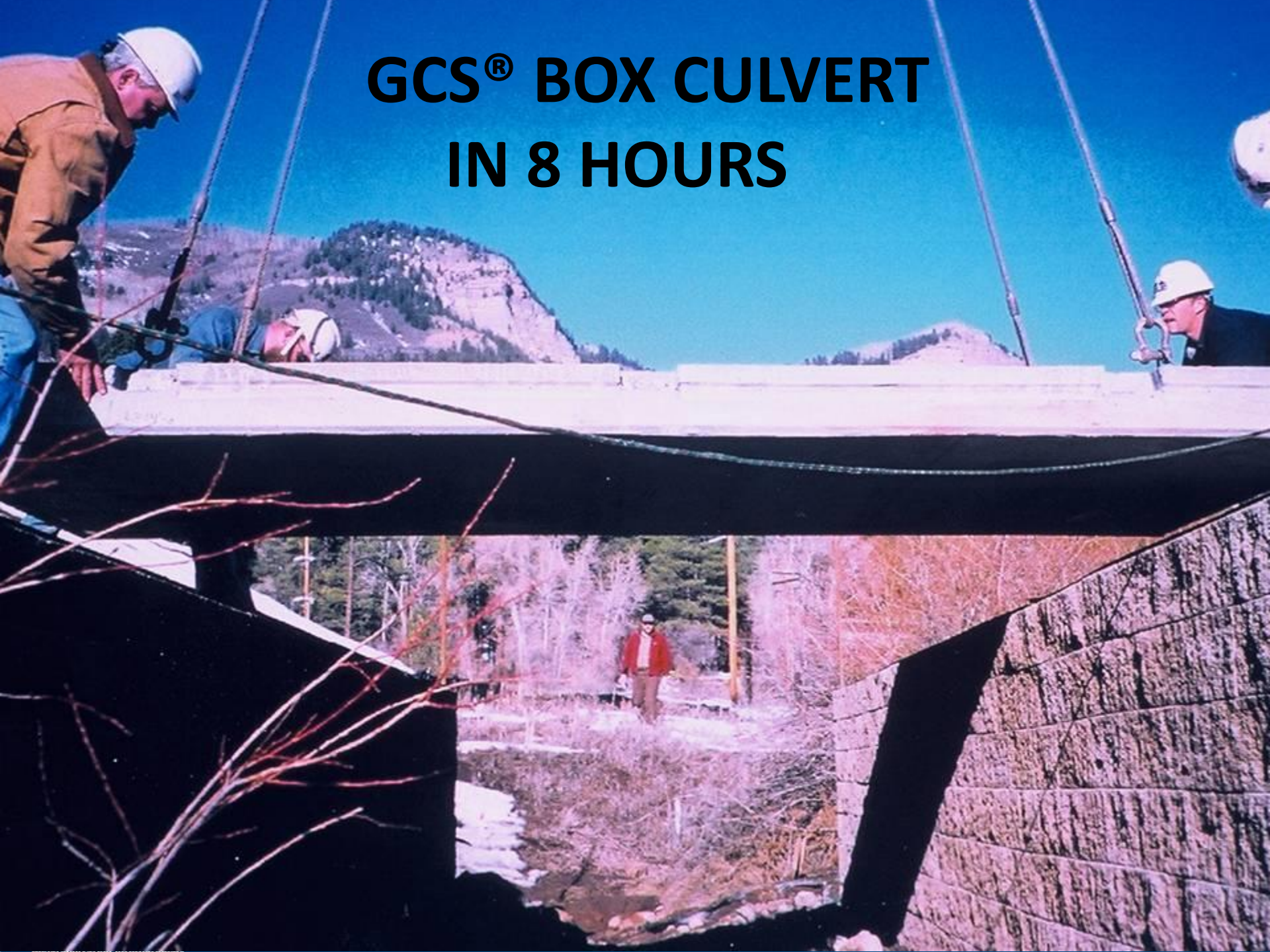

VIRTUALLY NO LOAD
ON FACING ELEMENTS
NO MATTER
HOW TALL

CMUs ARE DURABLE FORMING/FACING ELEMENTS



Negative Batter

GCS® BOX CULVERT IN 8 HOURS



GCS® BRIDGE IN LESS THAN 24 HOURS

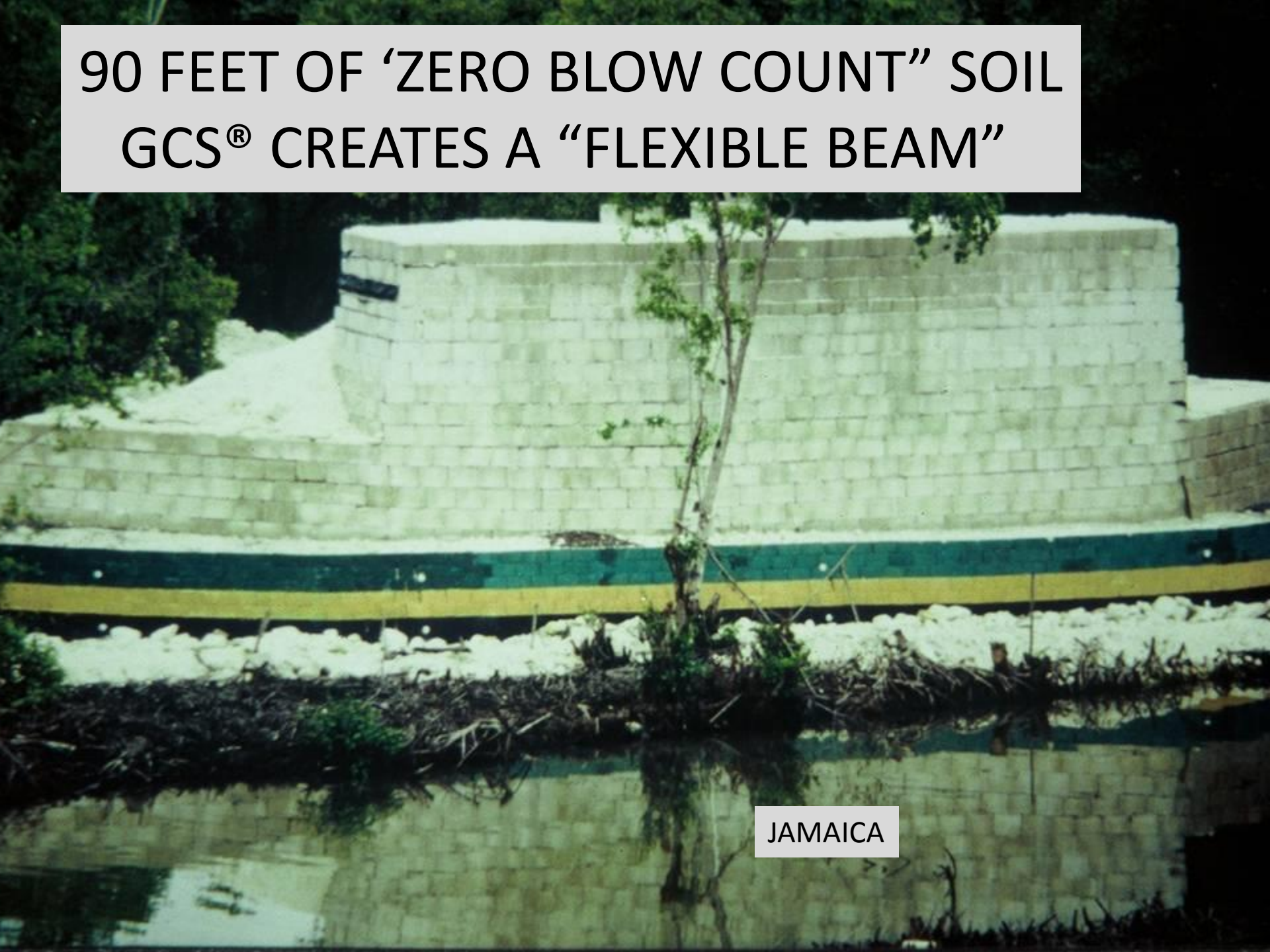
Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide

PUBLICATION NO. FHWA-HRT-11-026

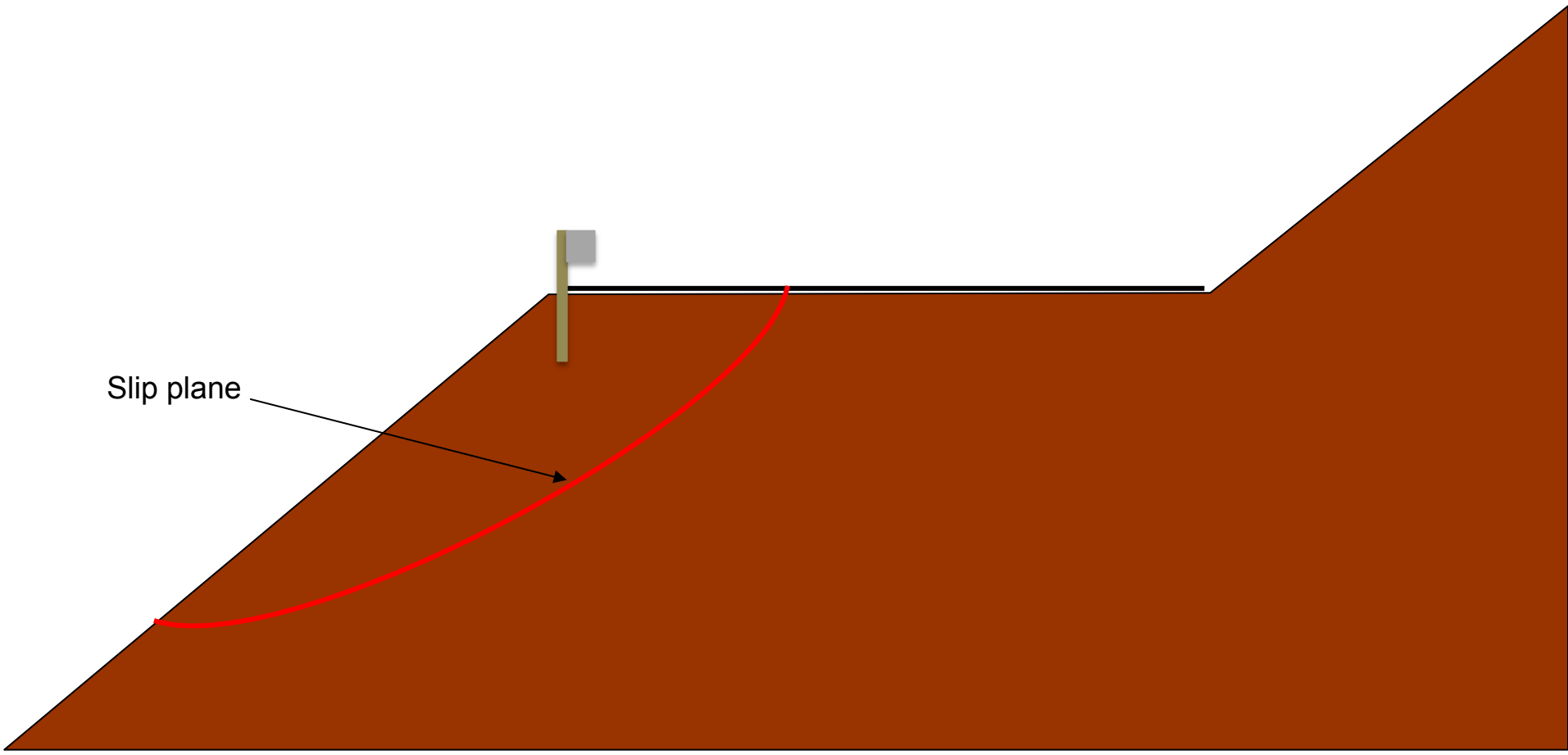
JANUARY 2011

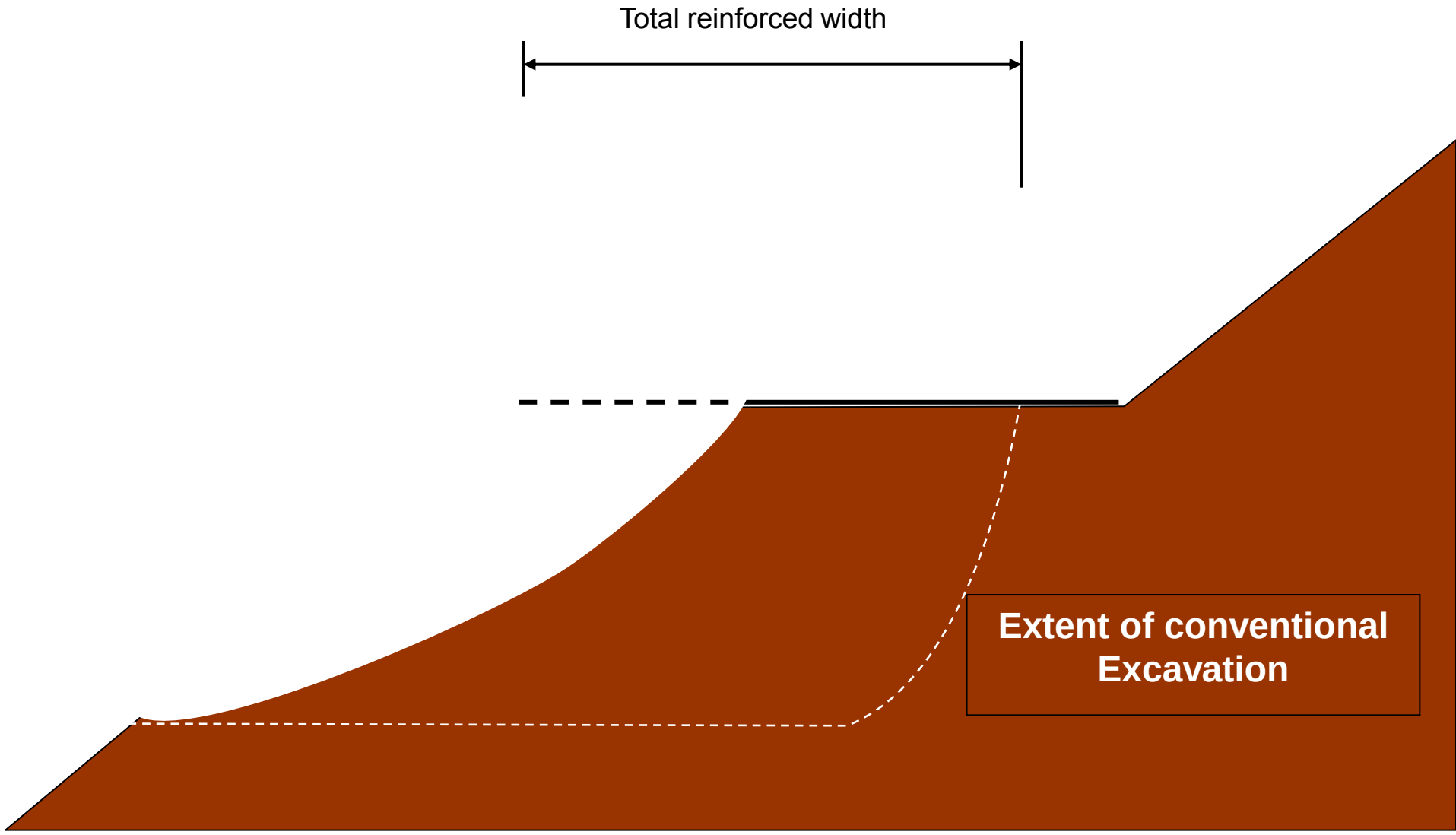

UNAFFECTED BY
RAPID DRAWDOWN

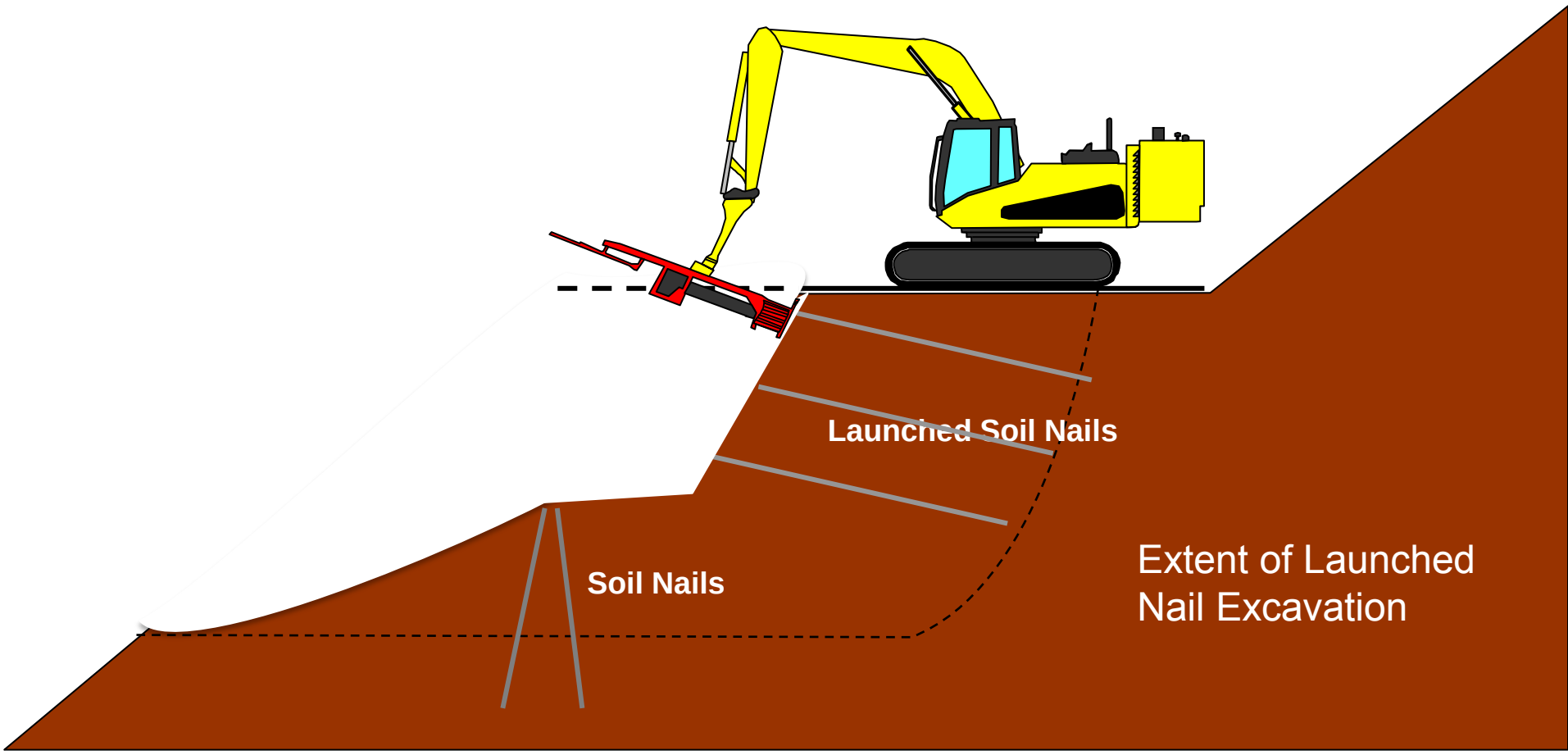
90 FEET OF ‘ZERO BLOW COUNT” SOIL GCS® CREATES A “FLEXIBLE BEAM”

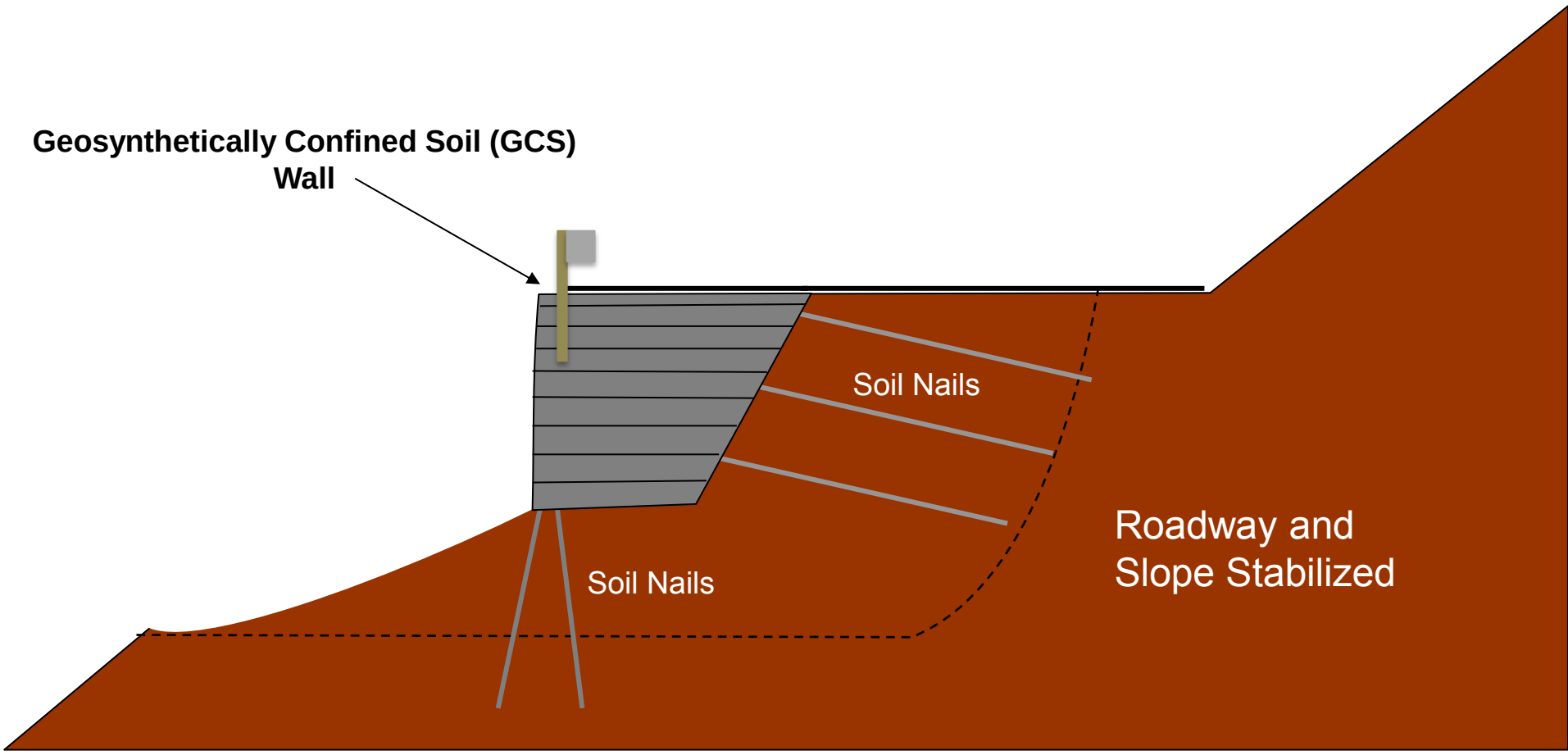


Roadway/Slope Repair Example



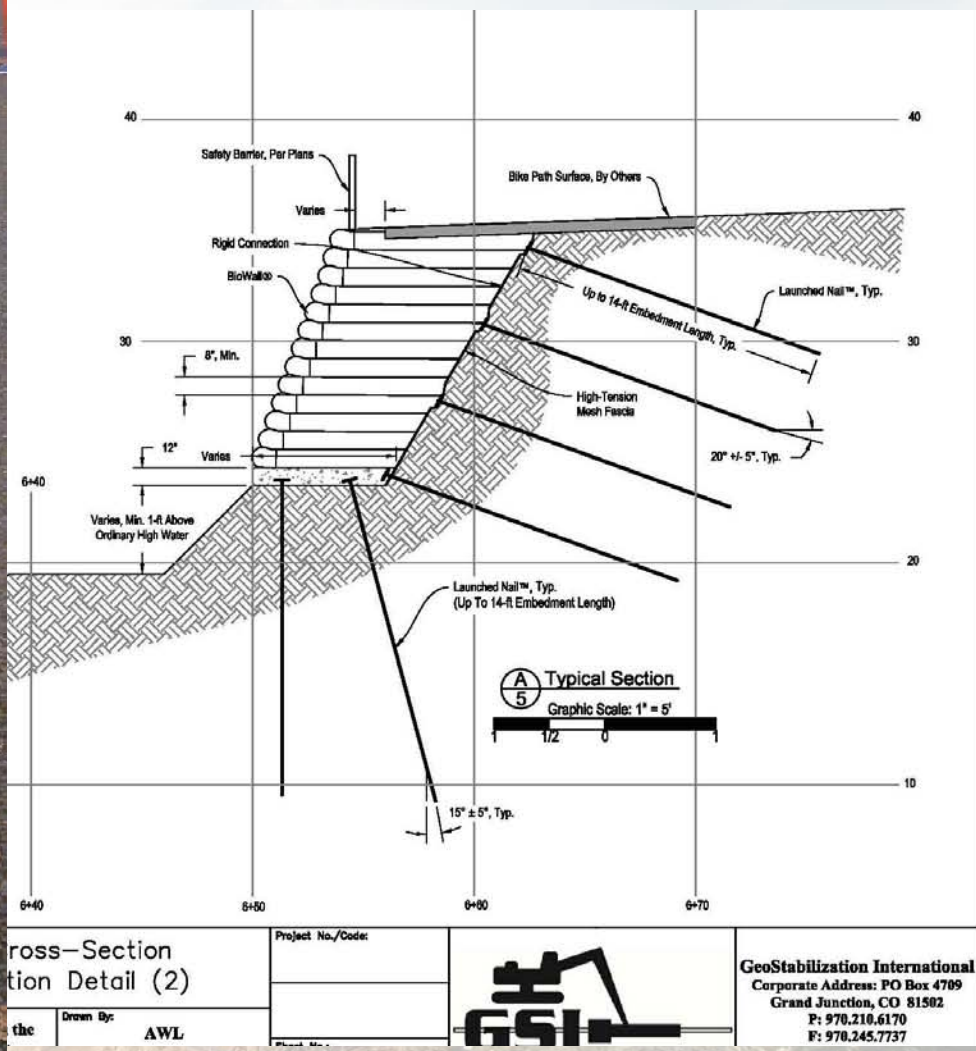

Total reinforced width
Extent of conventional Excavation


Launched Soil Nails
Soil Nails
Extent of Launched
Nail Excavation


Geosynthetically Confined Soil (GCS) Wall
Soil Nails
Soil Nails
Roadway and Slope Stabilized

Road Stabilization

Bike Path Stabilization



ross–Section
tion Detail (2)

Project No./Code:

the

Drawn By:
AWL

GeoStabilization International
Corporate Address: PO Box 4709
Grand Junction, CO 81502
P: 970.210.6170
F: 970.245.7737

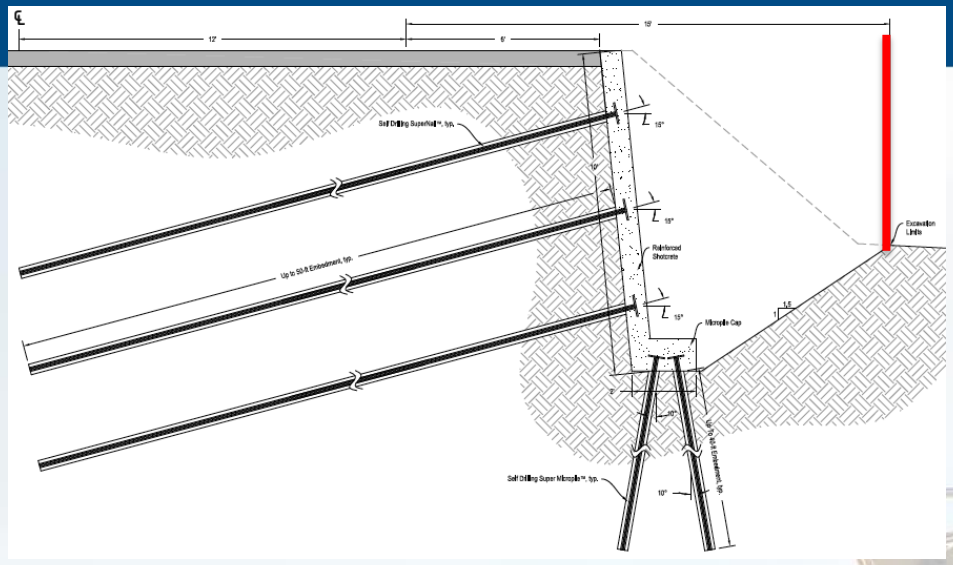

315C L
CAT
CAT

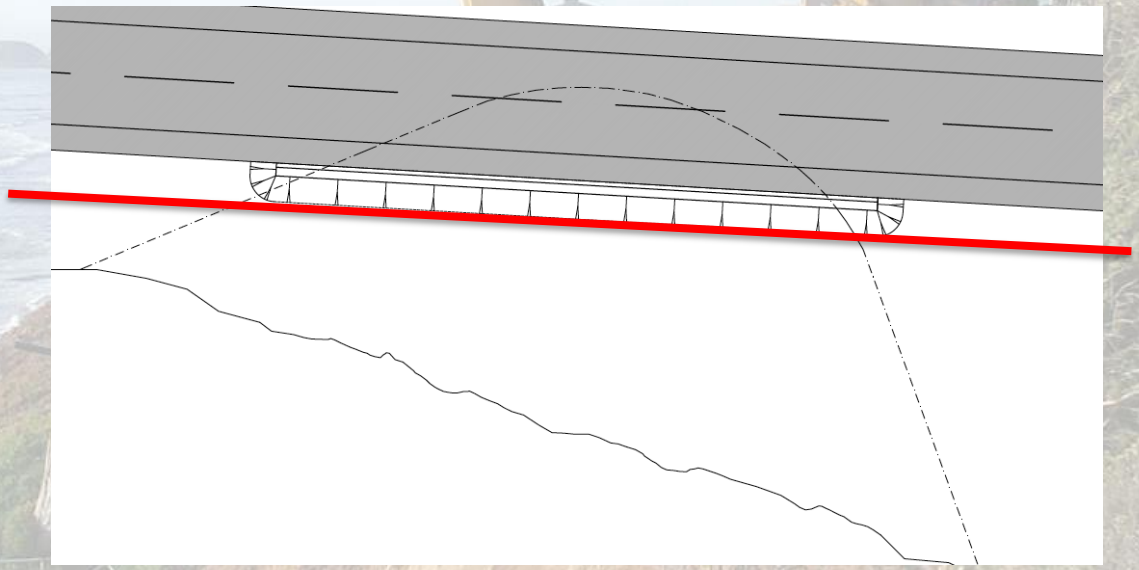
NDDOT Hwy 46

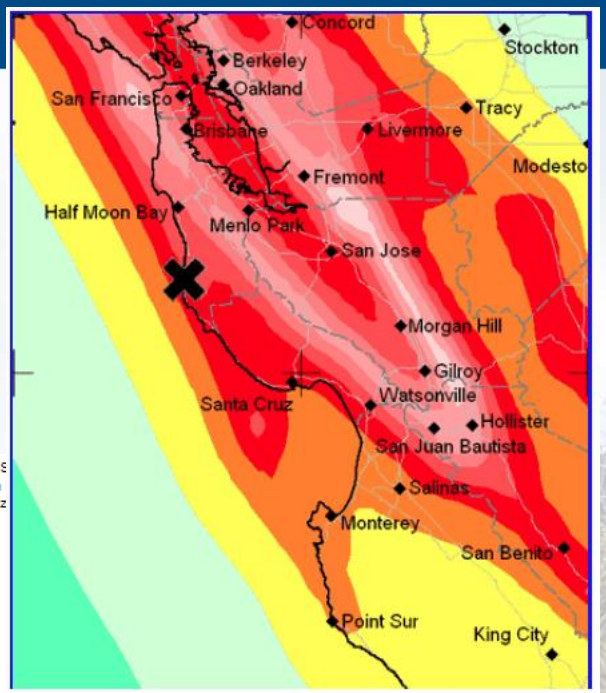

Soil Nail Launcher, Inc.

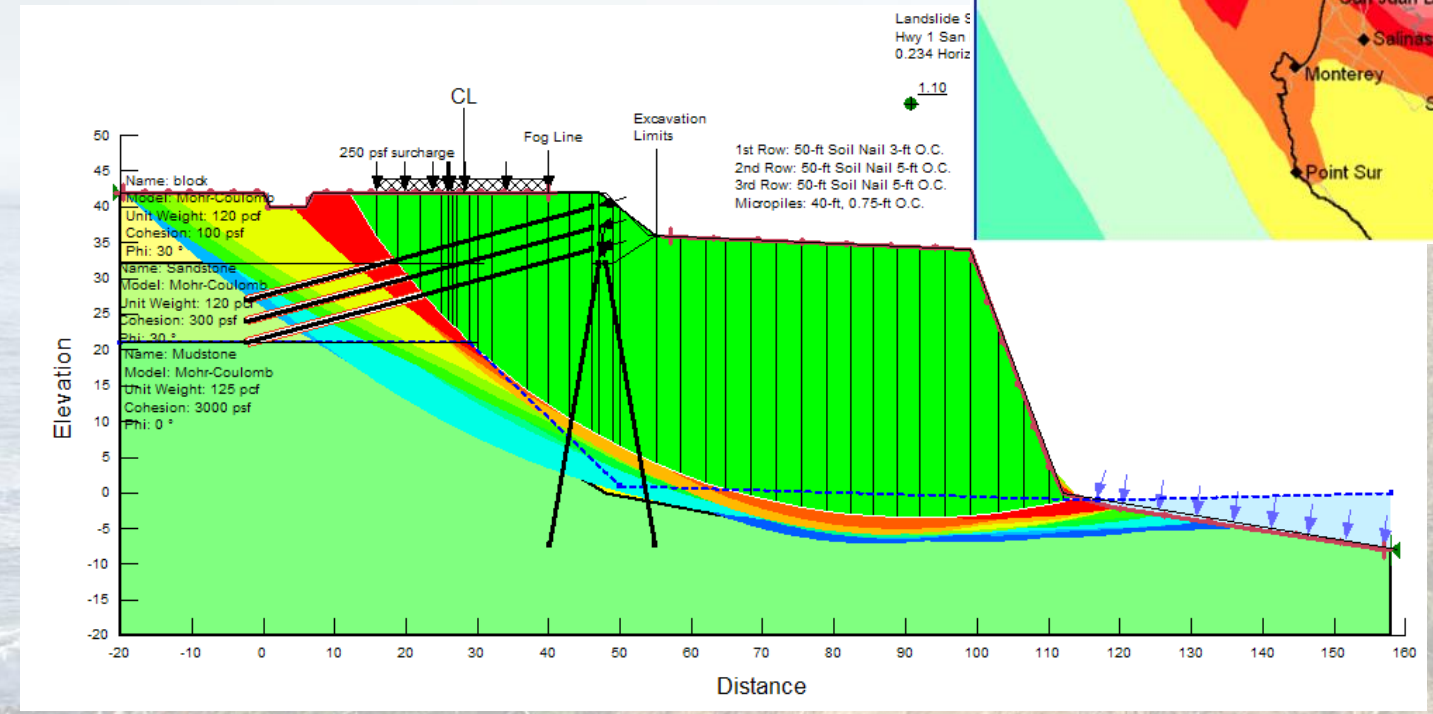
Hwy 1– Pescadero, CA


© 2010 Landslide Solutions, Inc.


12'
6'
15'
Self Drilling Superhaul™, typ.
15°
10'
15°
Up to 50 ft Embedment, typ.
Reinforced Shotcrete
15°
Excavation Limits
1:1
Mikropile Cap
Self Drilling Super Mikropile™, typ.
10°
50 ft Max Embedment, typ.

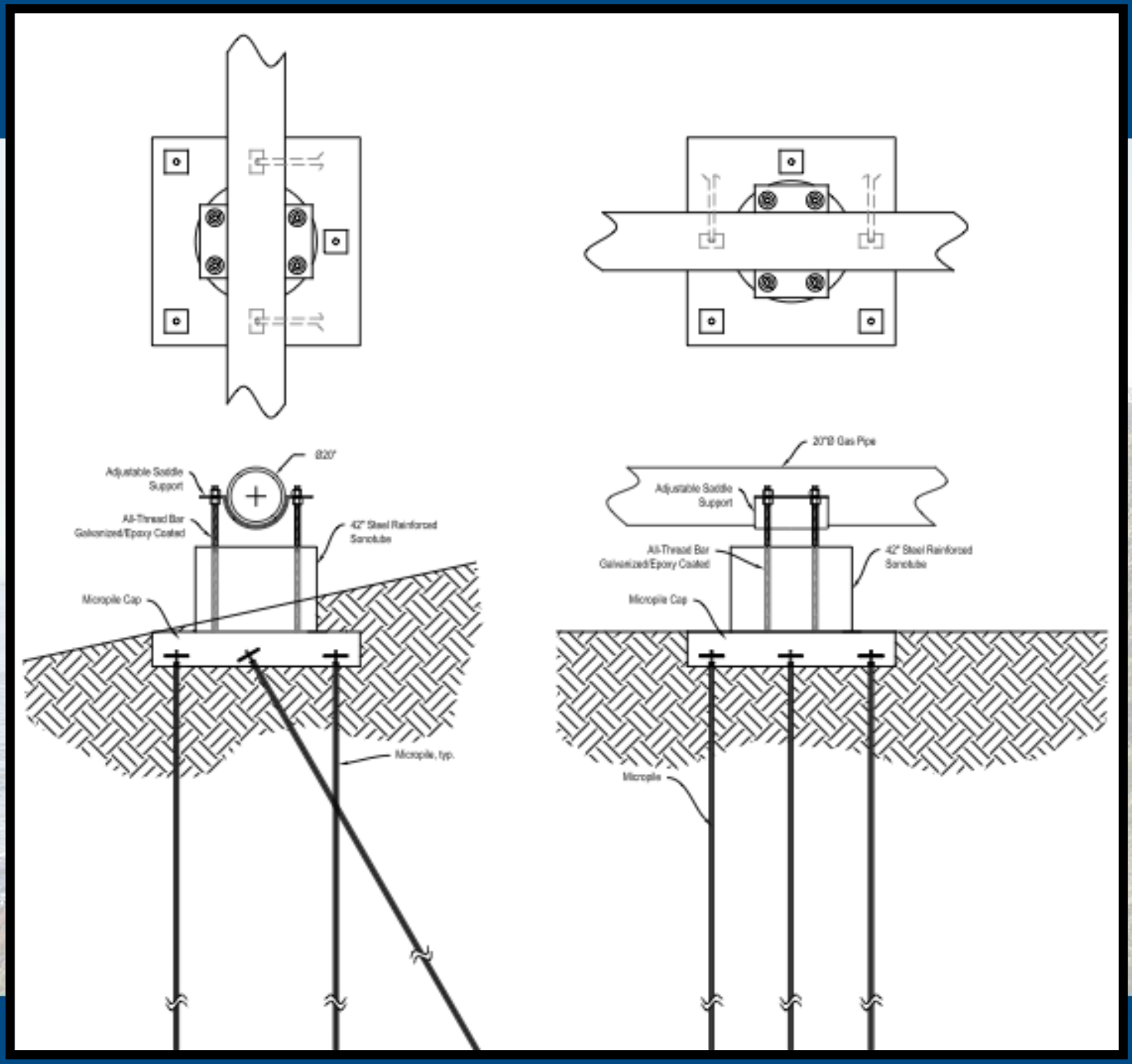


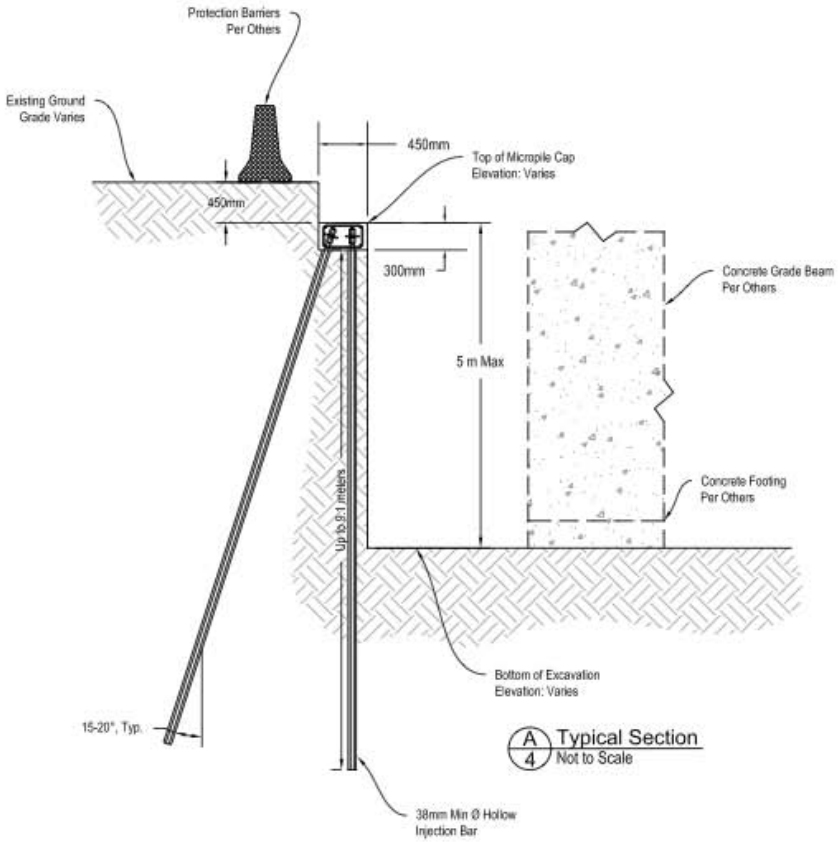

Concord
Stockton
Berkeley
Oakland
San Francisco
Tracy
Brisbane
Livermore
Modesto
Fremont
Half Moon Bay
Menlo Park
San Jose
Morgan Hill
Gilroy
Watsonville
Santa Cruz
Hollister
San Juan Bautista
Salinas
Monterey
San Benito
Point Sur
King City


Landslide S
Hwy 1 San
0.234 Horiz
1.10
CL
250 psf surcharge
Fog Line
Excavation Limits
1st Row: 50-ft Soil Nail 3-ft O.C.
2nd Row: 50-ft Soil Nail 5-ft O.C.
3rd Row: 50-ft Soil Nail 5-ft O.C.
Micropiles: 40-ft, 0.75-ft O.C.
Name: block
Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 100 psf
Phi: 30 °
Name: Sandstone
Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 300 psf
Phi: 30 °
Name: Mudstone
Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 3000 psf
Phi: 0 °
Elevation
Distance


© Landslide Solutions, Inc.

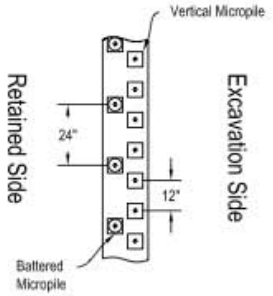

© 2010 Landslide Solutions, Inc.


Adjustable Saddle Support
All-Thread Bar Galvanized/Epoxy Coated
42" Steel Reinforced Sonotube
Micropile Cap
Micropile, typ.
20"Ø Gas Pipe
Adjustable Saddle Support
All-Thread Bar Galvanized/Epoxy Coated
42" Steel Reinforced Sonotube
Micropile Cap
Micropile



A 4 Typical Section
Not to Scale

Note: ~ 24 Lineal Meters of Stabilization As Shown for Each Repair Area



B 4 Micropile Cap (Plan View)
Not to Scale

Sheet Revision

Date:		By:

Typical Cross-Section

Project: Hwy 97 at the Sneena Intersection

Drawn By: JDP

Date: January 5, 2014

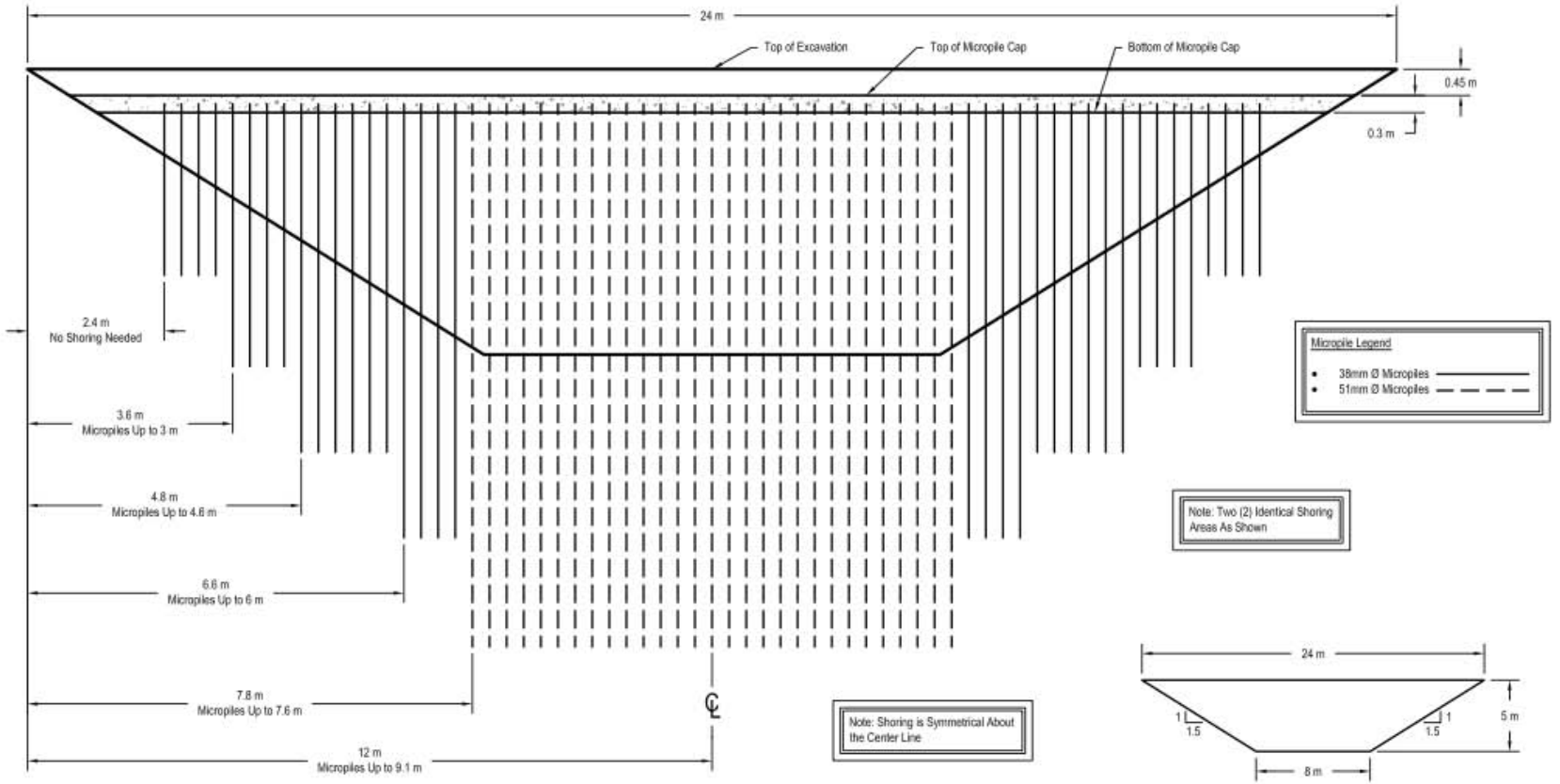
Checked By:

Project No./Code:

Sheet No.: 4

GSI GeoStabilization International

GeoStabilization International
1200 Waterfront Centre
200 Burrard Street
Vancouver, BC V6J 1P3
P: 970.210.6170
F: 970.245.7737
www.geostabilization.com



A/3 Elevation View
Not to Scale

B/3 Shoring Geometry
Not to Scale

Sheet Revision

Date:		By:

Elevation View

Project: Hwy 97 at the Sneena Intersection

Drawn By: JDP

Date: January 5, 2014

Checked By:

Project No./Code:

Sheet No.: 3

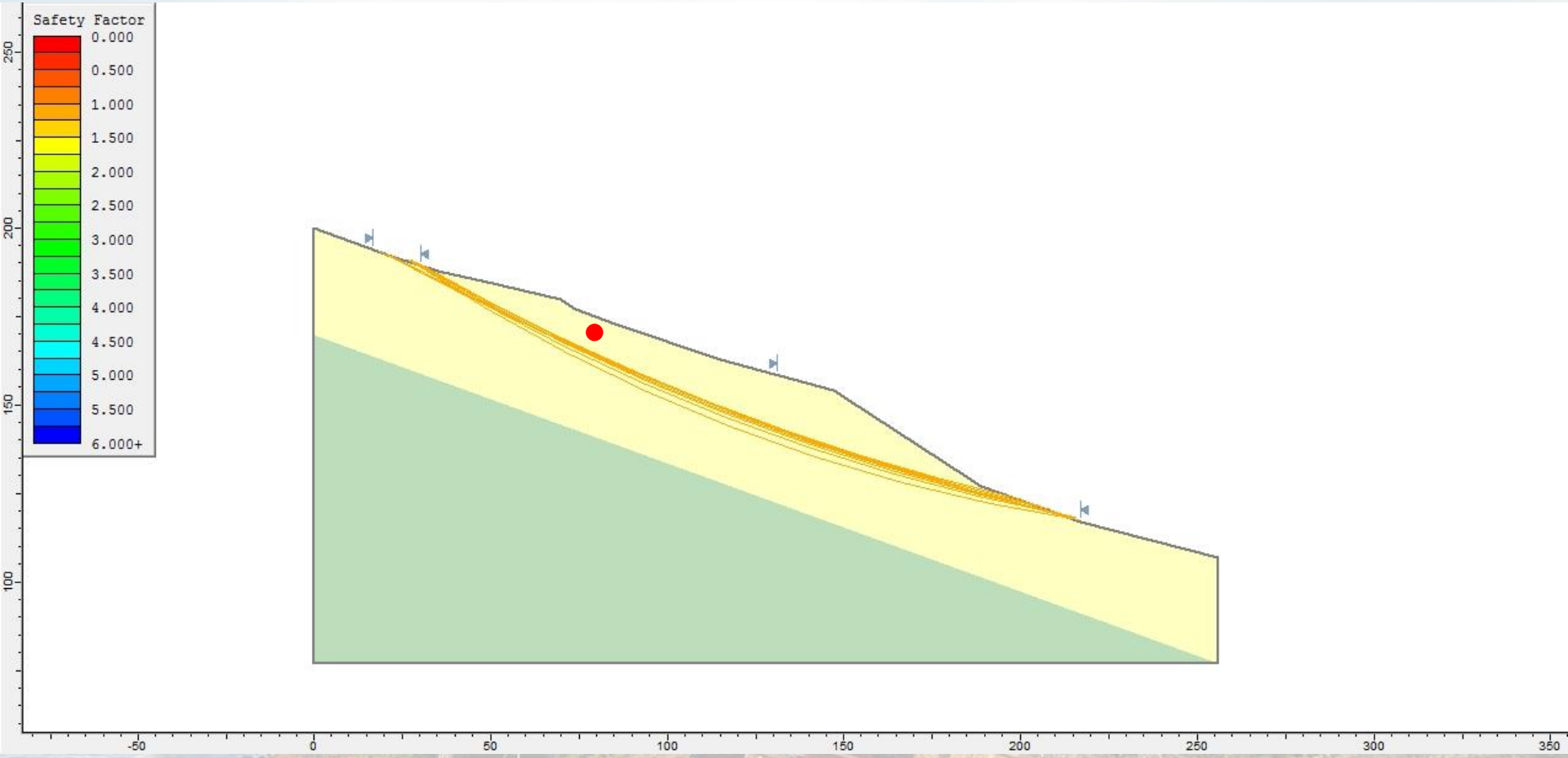
GeoStabilization International
1200 Waterfront Centre
200 Burrard Street
Vancouver, BC V6J 1P3
P: 970.210.6170
F: 970.245.7737
www.geostabilization.com


53H526
PINNACLE

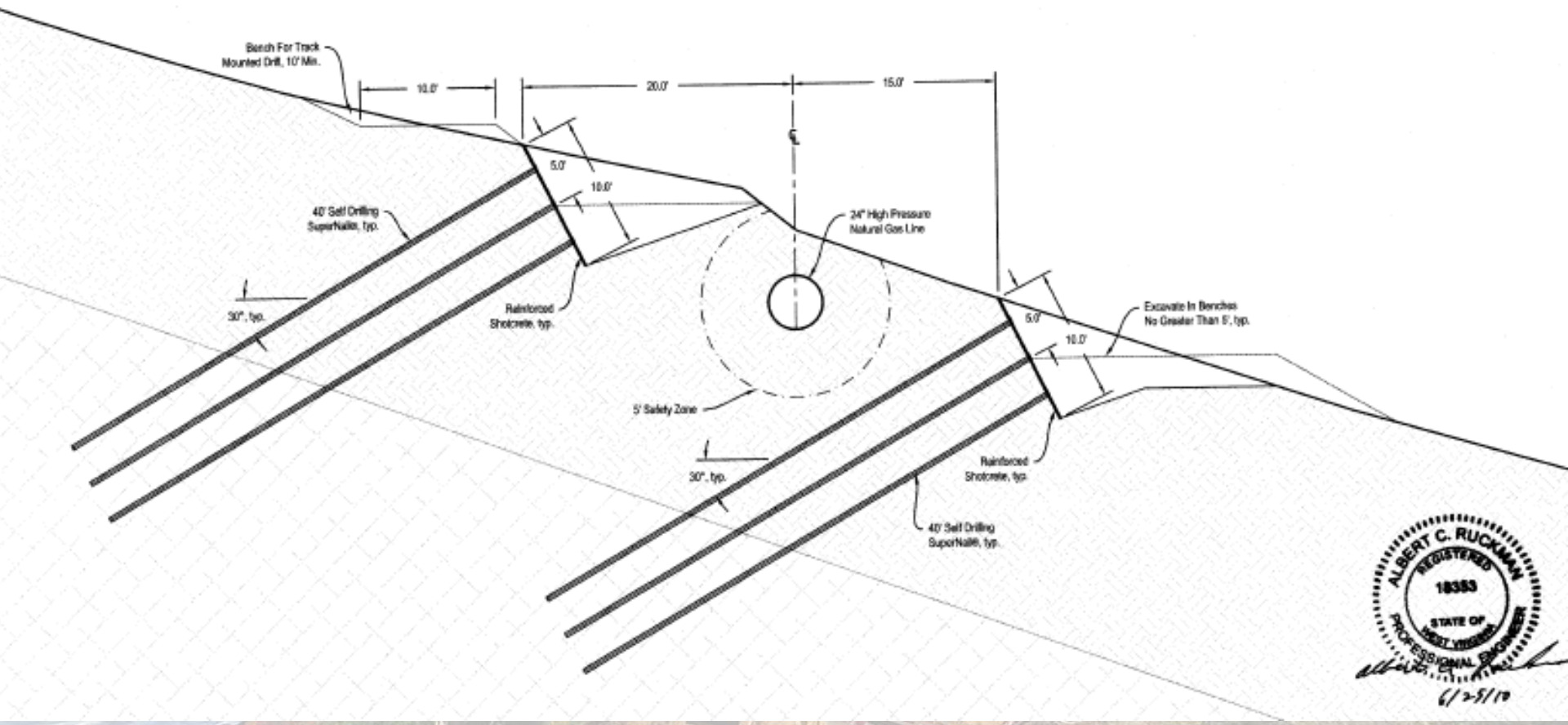

SupAnchor
SELF-DRILLING

ABILIZA


HDR


Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
250
200
150
100
-50
0
50
100
150
200
250
300
350


03/12/2010


Bench For Track Mounted Drill, 10' Min.
10.0'
20.0'
15.0'
5.0'
10.0'
40' Self Drilling SuperNails, typ.
24" High Pressure Natural Gas Line
30°, typ.
Reinforced Shotcrete, typ.
5.0'
10.0'
Excavate In Benches No Greater Than 5', typ.
5' Safety Zone
30°, typ.
Reinforced Shotcrete, typ.
40' Self Drilling SuperNails, typ.
ALBERT C. RUCKMAN
REGISTERED
18353
STATE OF
WEST VIRGINIA
PROFESSIONAL ENGINEER
6/25/10


KOBELCO

I-75 in Tennessee

Initial Design (DOT BID)

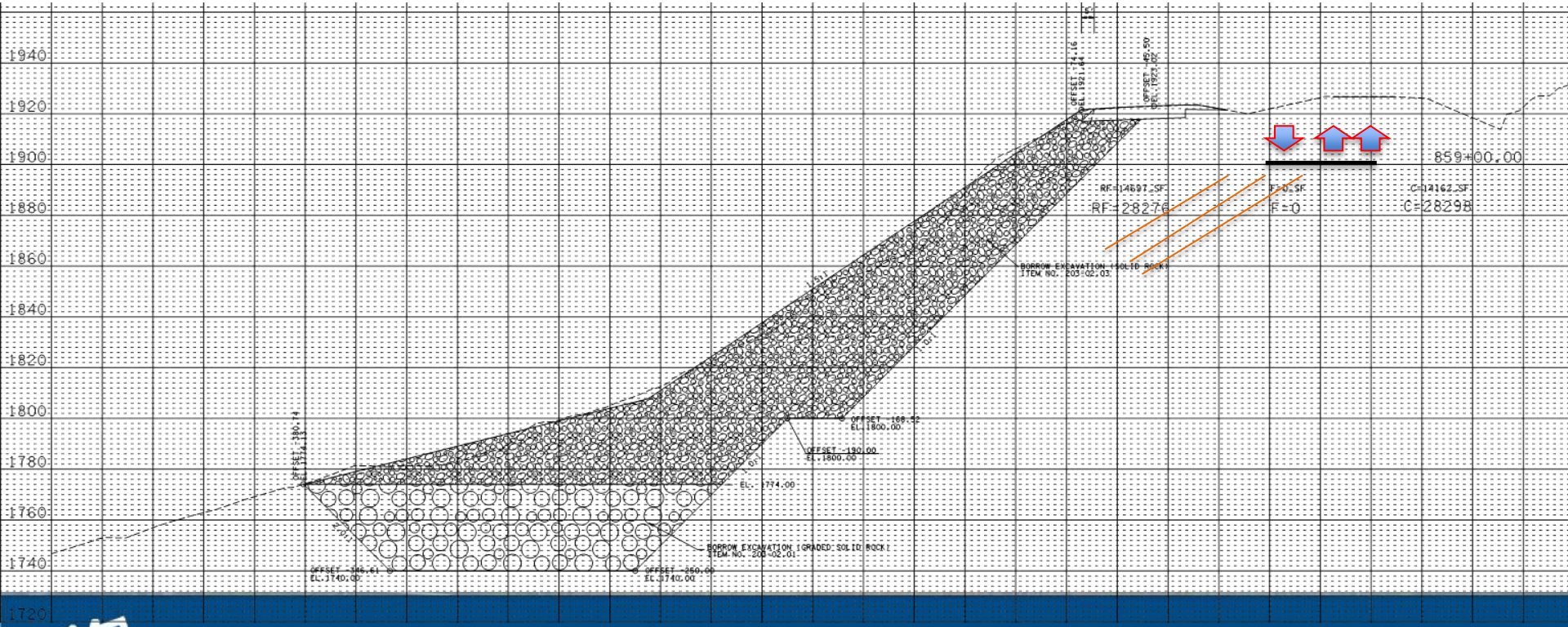
- Large Rip Rap Buttress

Initial Investigation

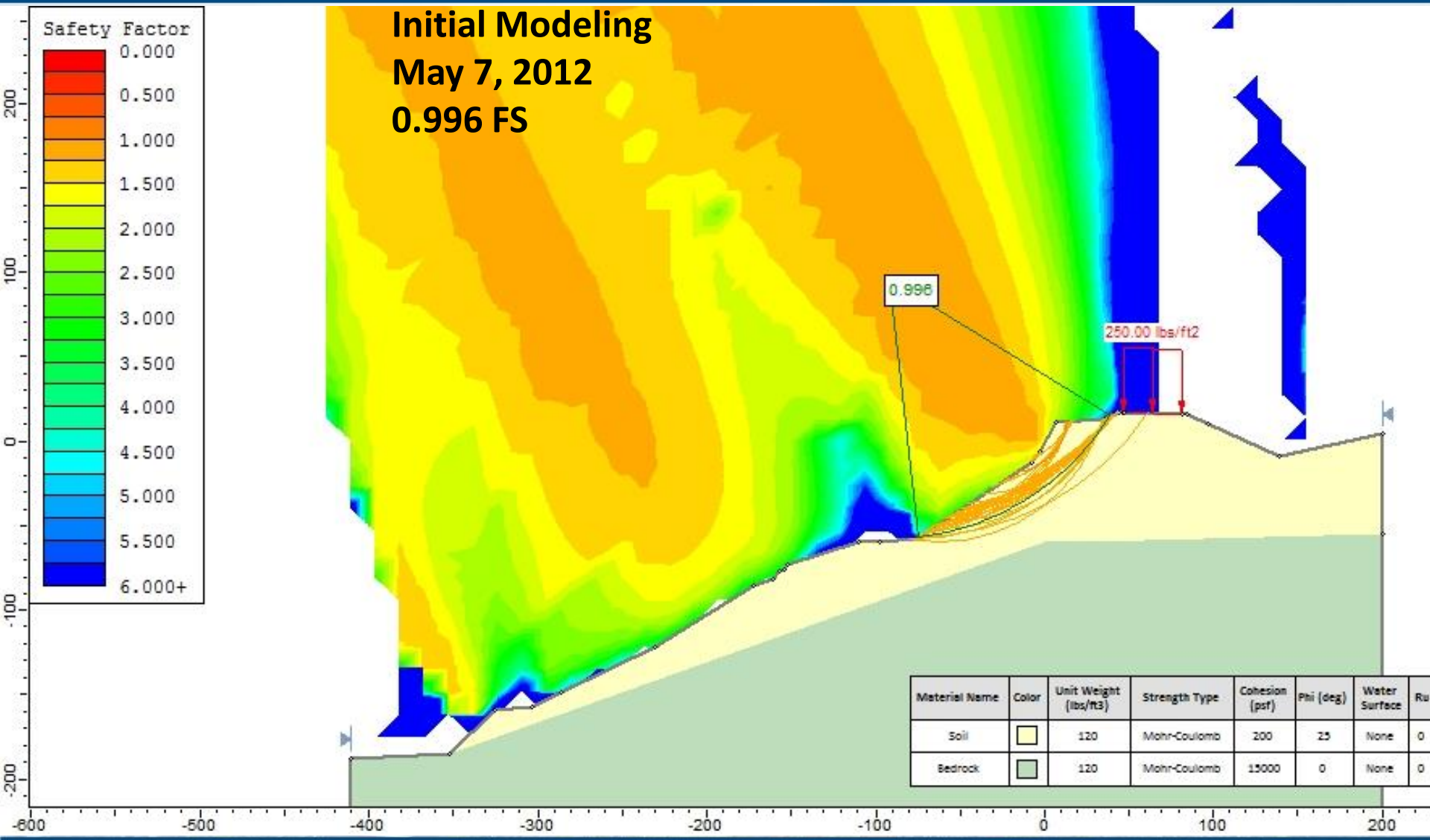
- Borings taken every 150 LF along SB Lane (resulted in 4 borings along road)

Unknowns

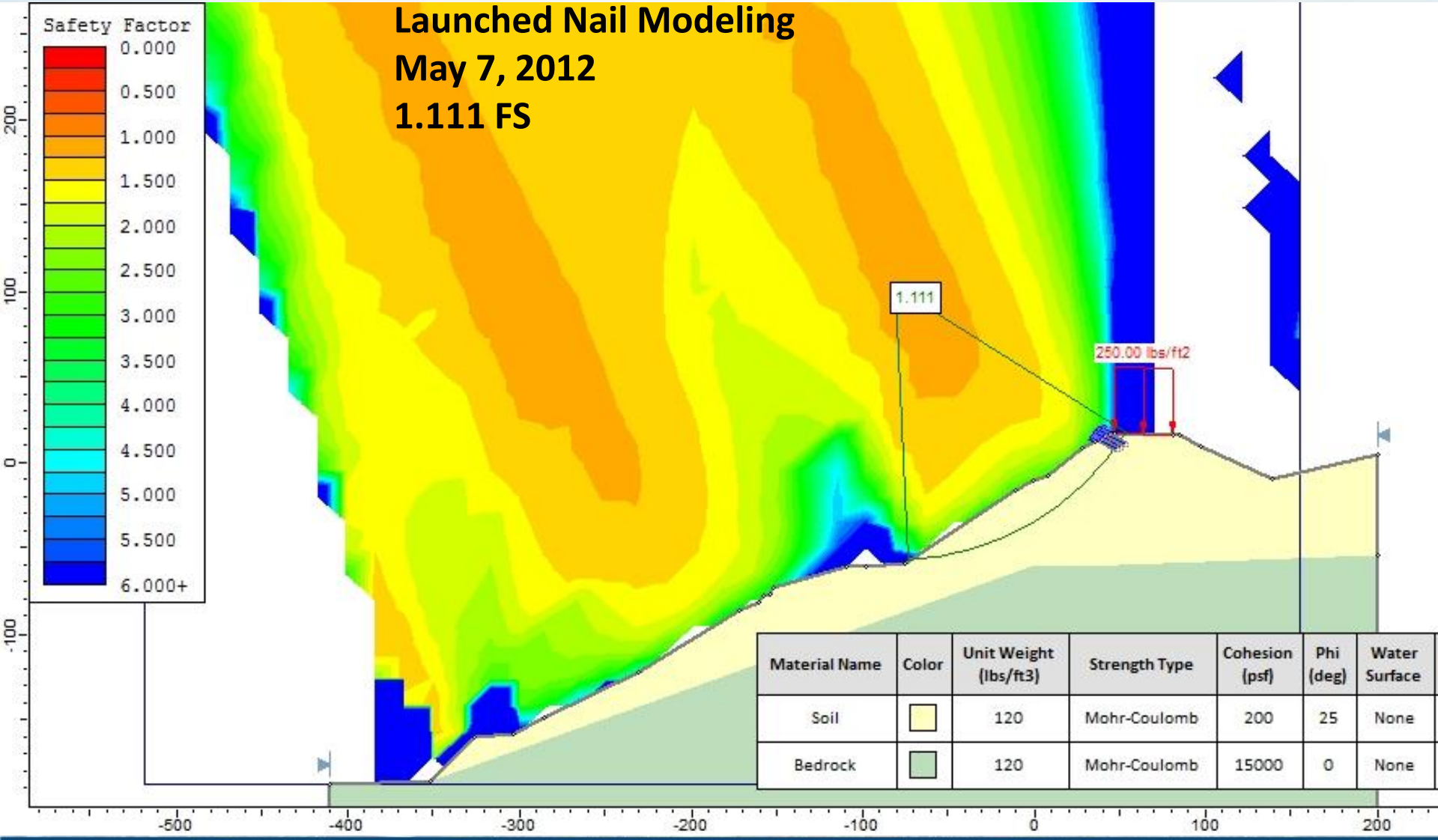
- Deeper than expected bedrock on south end
- Natural spring near south end
- Unknown abandoned coal mine




I-75 NB Lanes
10:30 pm
May 7, 2012

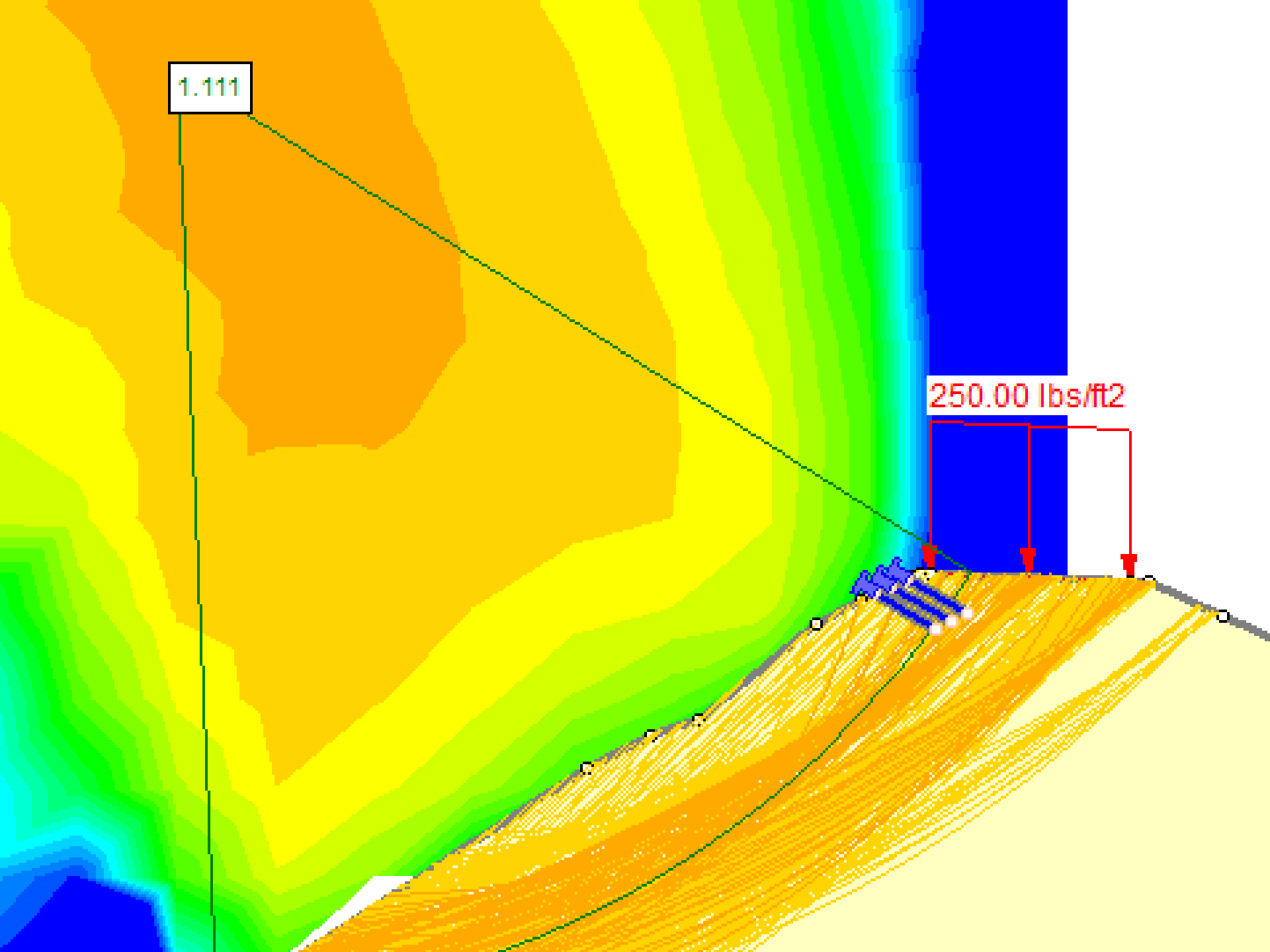

Initial Modeling
May 7, 2012
0.996 FS
Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
0.996
250.00 lbs/ft2
Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Water Surface | Ru
Soil | 120 | Mohr-Coulomb | 200 | 25 | None | 0
Bedrock | 120 | Mohr-Coulomb | 15000 | 0 | None | 0
200
100
0
-100
-200
-600
-500
-400
-300
-200
-100
0
100
200

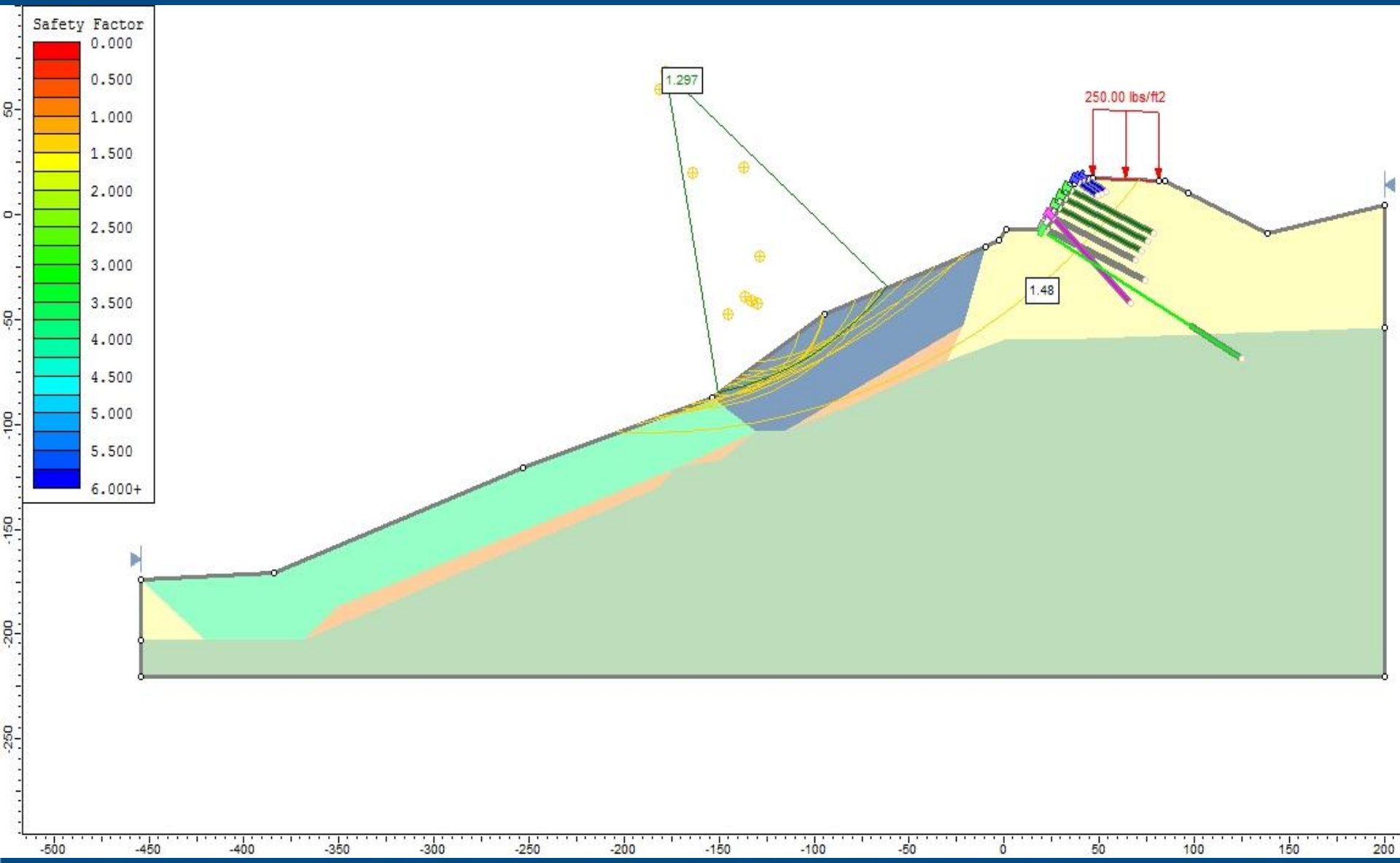
Launched Nail Modeling
May 7, 2012
1.111 FS

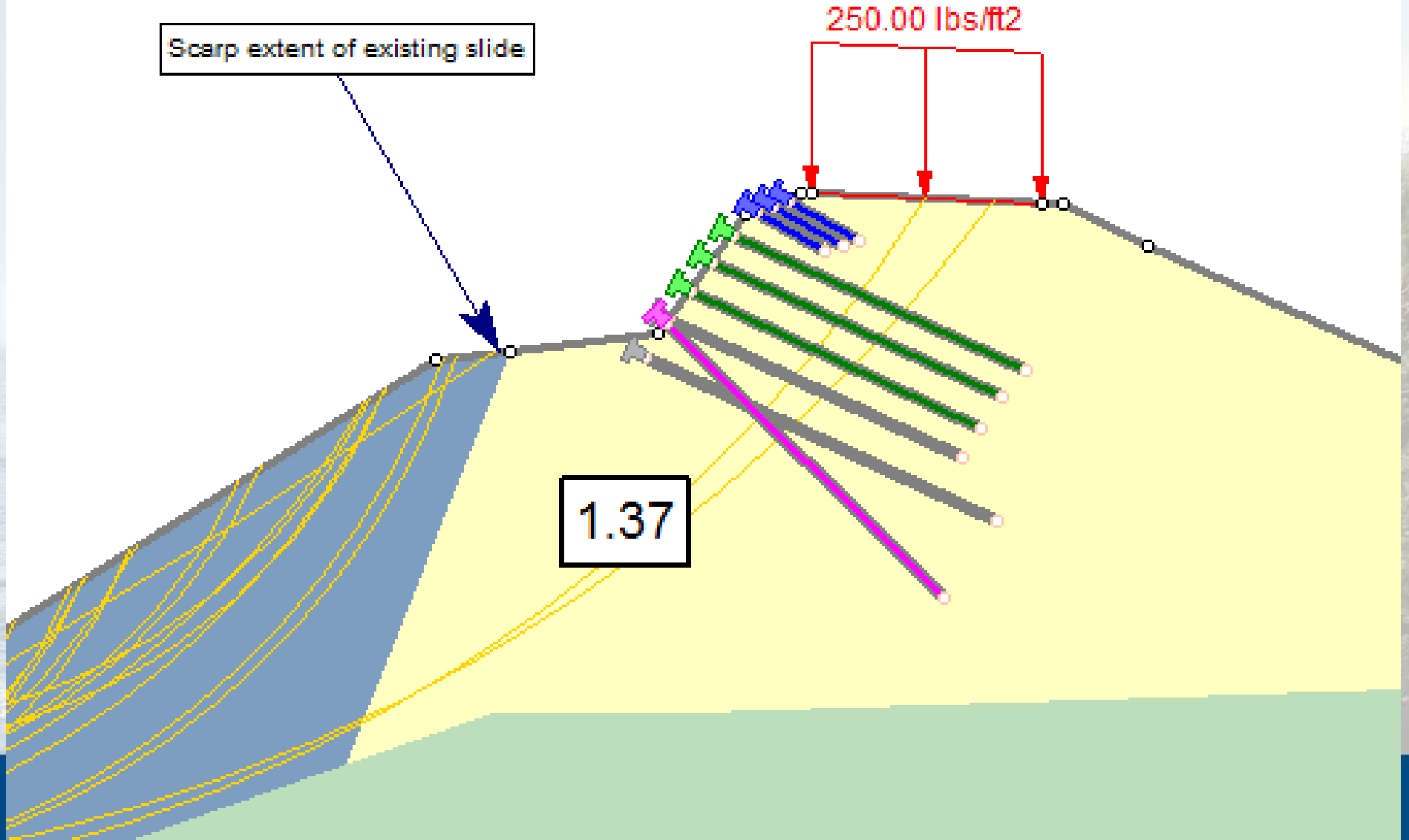


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil		120	Mohr-Coulomb	200	25	None
Bedrock		120	Mohr-Coulomb	15000	0	None


MACK


1.111
250.00 lbs/ft2


Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
1.297
250.00 lbs/ft2
1.48
50
0
-50
-100
-150
-200
-250
-500
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200


Scarp extent of existing slide
250.00 lbs/ft2
1.37


320C L
CAT


GSI
GeoStabilization International
GEOHAZARD MITIGATION EXPERTS