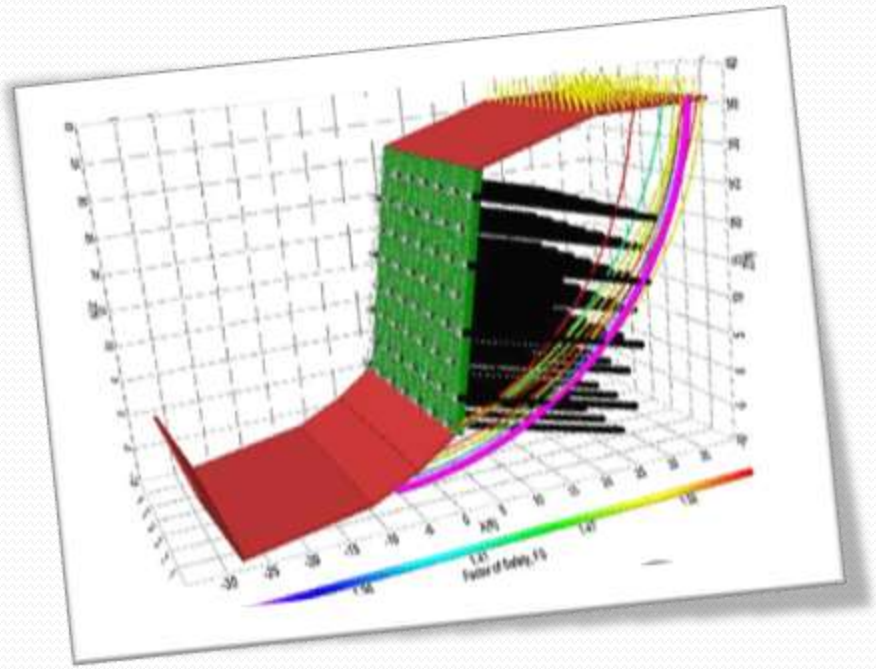
Soil Nail Analysis Program SNAP



Rick Andrew, Yeh & Associates, Inc.
Khamis Haramy, FHWA Central Federal Lands
Ben Arndt, Yeh & Associates, Inc.
Sara Hansen, Yeh & Associates, Inc.
Alan Rock, GAP Engineering, Inc.
Runing Zhang, PhD, Metro State College

Yeh and Associates, Inc.
Consulting Engineers & Scientist

Central Federal Lands Highway Division
US Department of Transportation - Federal Highway Administration

GAP Engineering, Inc.
Geostructural Analysis Professionals

Program Objectives

- Develop a complete soil nail analysis package following AASHTO requirements
  - Soil nail elements
  - Facing Elements
  - External Stability Analysis
  - Slope stability analysis (Modified Bishop)
  - Seismic analysis
- Manual for Design and Construction of Soil Nail Walls Report No. FHWA-SA-96-069R

FHWA Guidelines

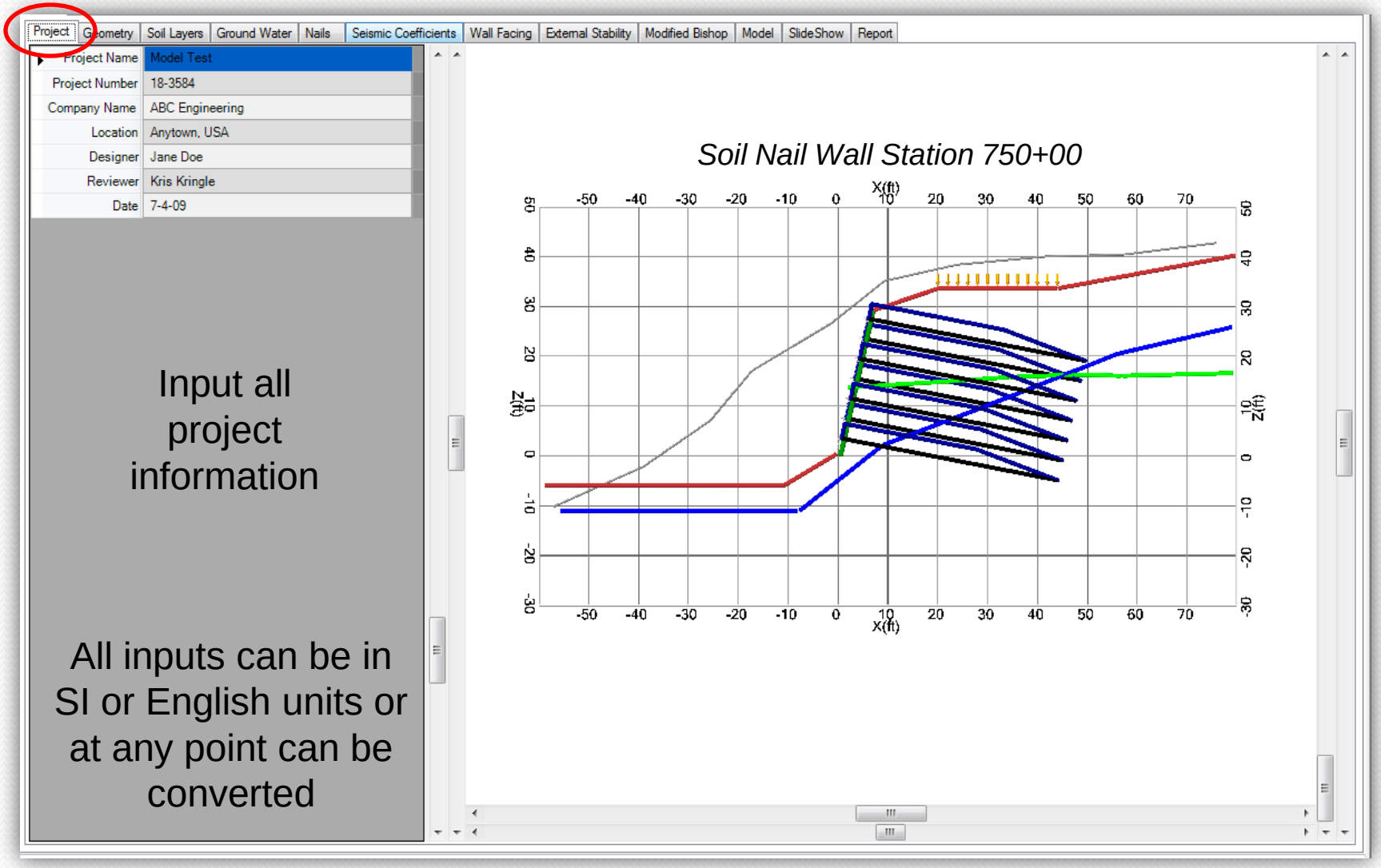
- Manual for Design and Construction of Soil Nail Walls Report No. FHWA-SA-96-069R

  Calculates the coulomb active earth load and uniformly distributes the load to the nails with consideration of nail spacing (tributary area).

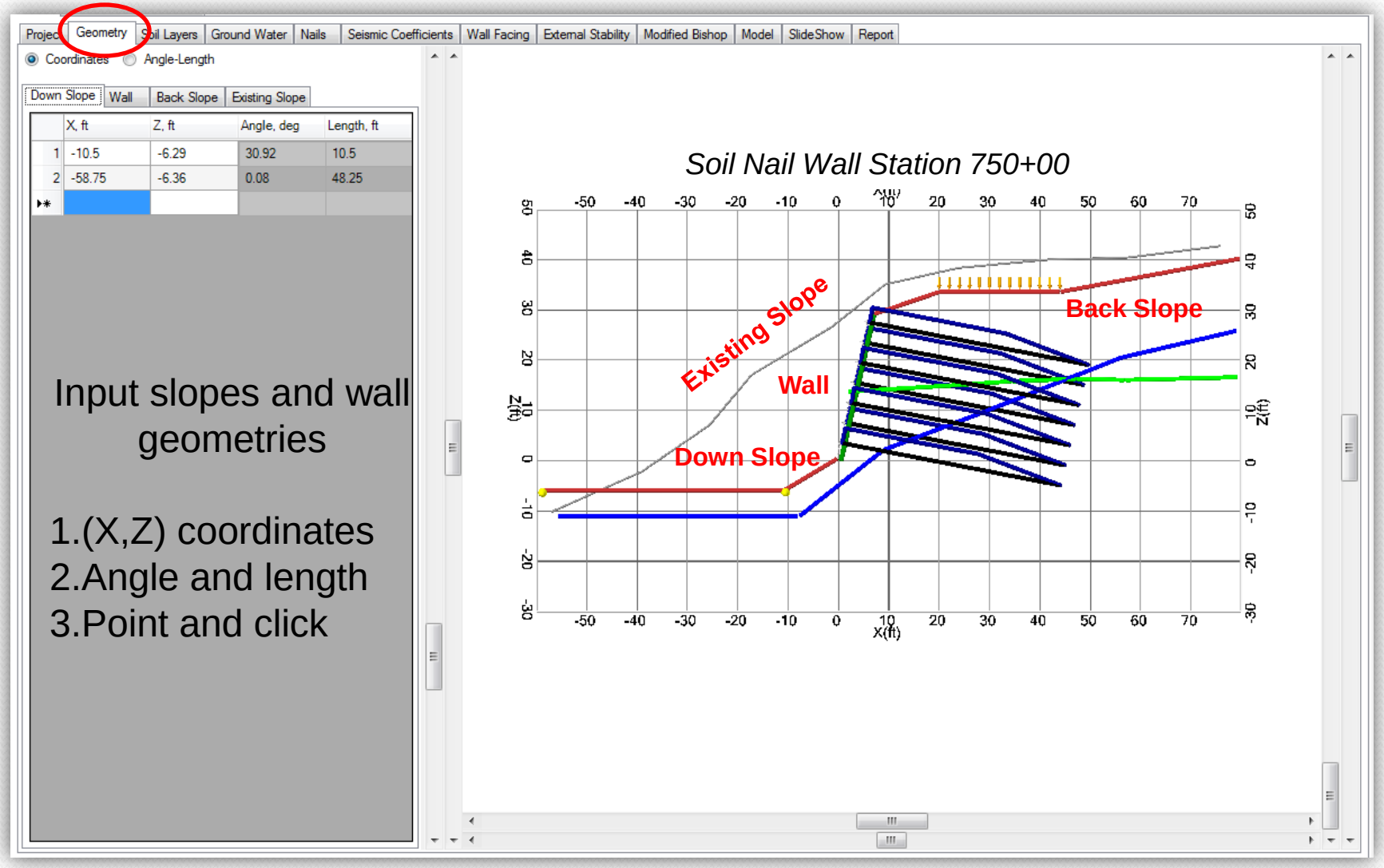
- Geotechnical Engineering Circular No. 7 Soil Nail Walls Report No. FHWA-IF-03-017

  Uses the SNAIL program, searching for “internal” slip surfaces with consideration for available nail resistances (controlled by facing, tensile yield or pullout) to determine the maximum average nail loading at a FS=1.0 (active state).

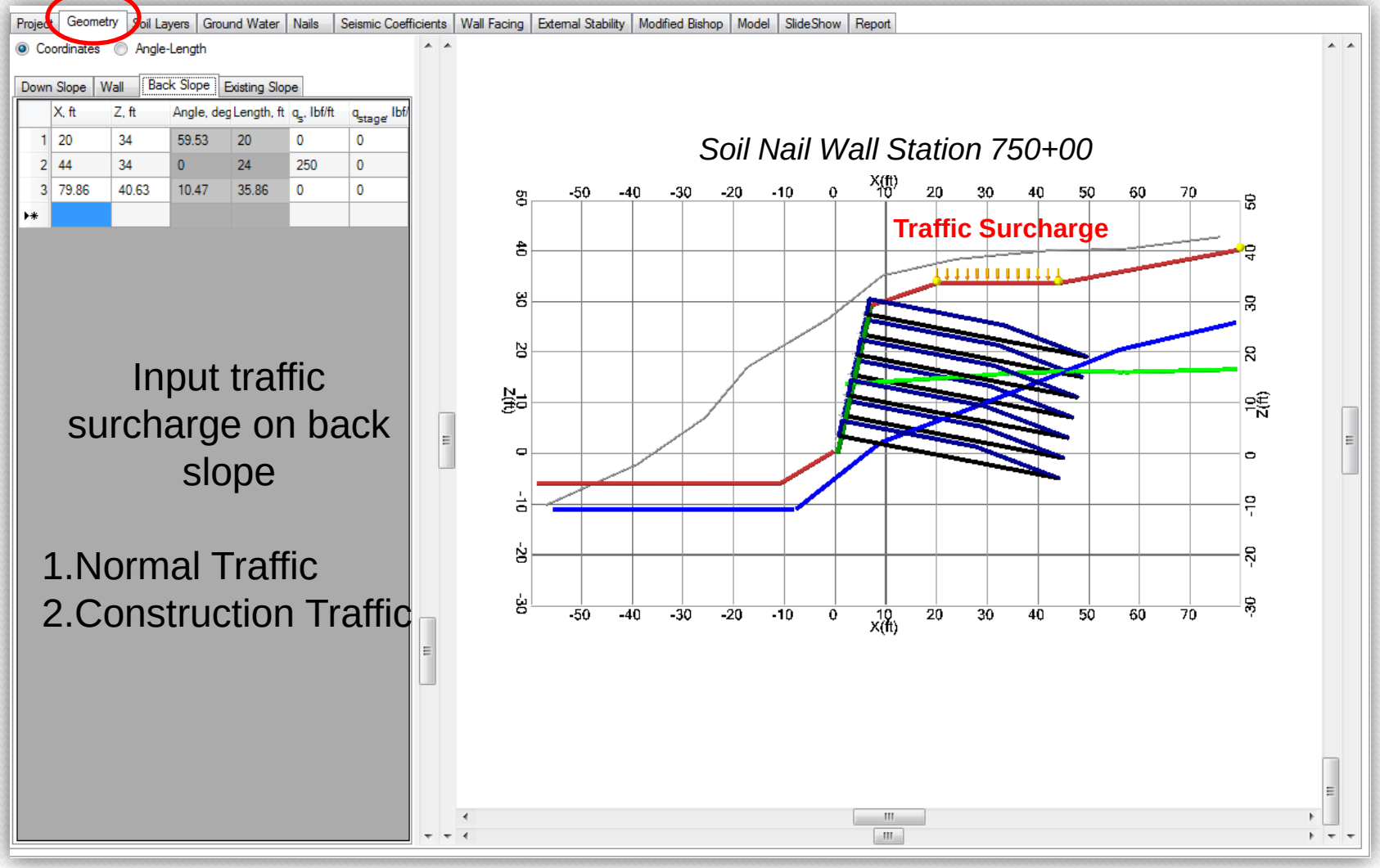
Project Information



Slope Geometry



Slope Geometry



Soil Layer Boundary & Properties

Project | Geometry | Soil Layers | Ground Water | Nails | Seismic Coefficients | Wall Facing | External Stability | Modified Bishop | Model | SlideShow | Report

Calc Bearing Capacity Factors

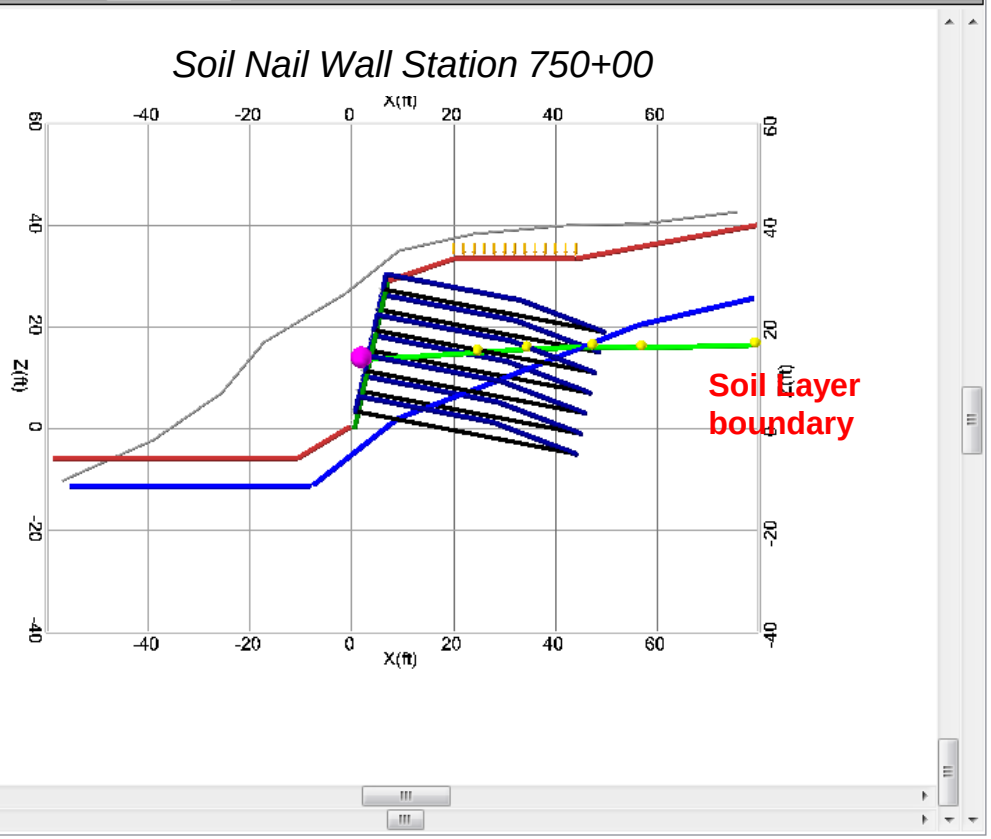
	Description	Color	γ, pcf	ϕ, deg	C_U, psf	q_u, psi	Q_u, lbf/ft	Nc	Nγ	N_q	Modulus, psi	Tensile Strength,	Consolidation, %
1	A	Yellow	125	36	150	20	3958	50.6	56.3	37.8	10000	1000	50
2	B	Green	125	36	150	20	3958	50.6	56.3	37.8	10000	1000	50

Soil Layer B Points

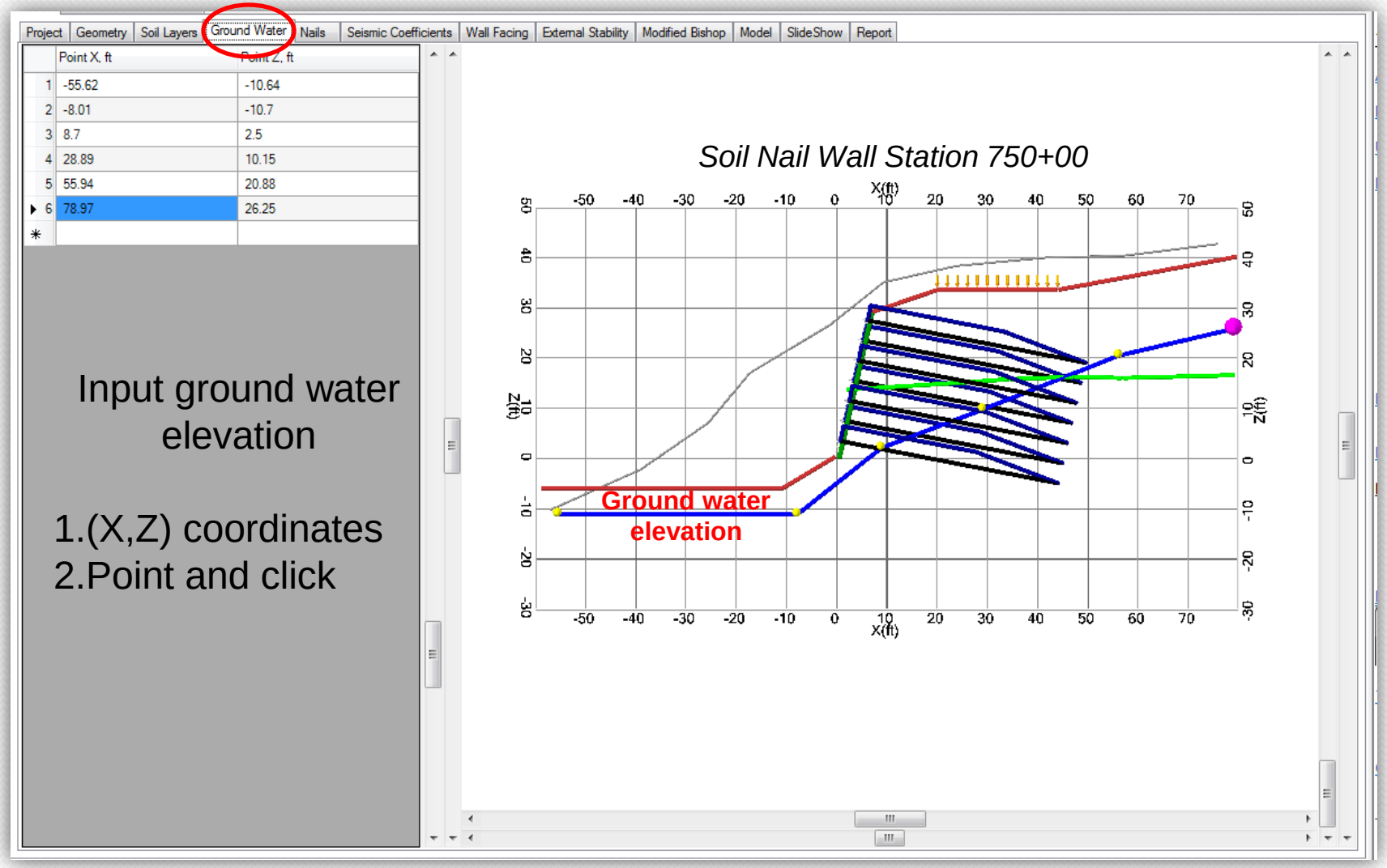
	Point X, ft	Point Z, ft
1	1.88	14.12
2	24.69	15.53
3	34.33	16.23
4	47.27	16.7
5	56.91	16.47
6	79.27	17.03

Input each soil layer boundary and soil properties

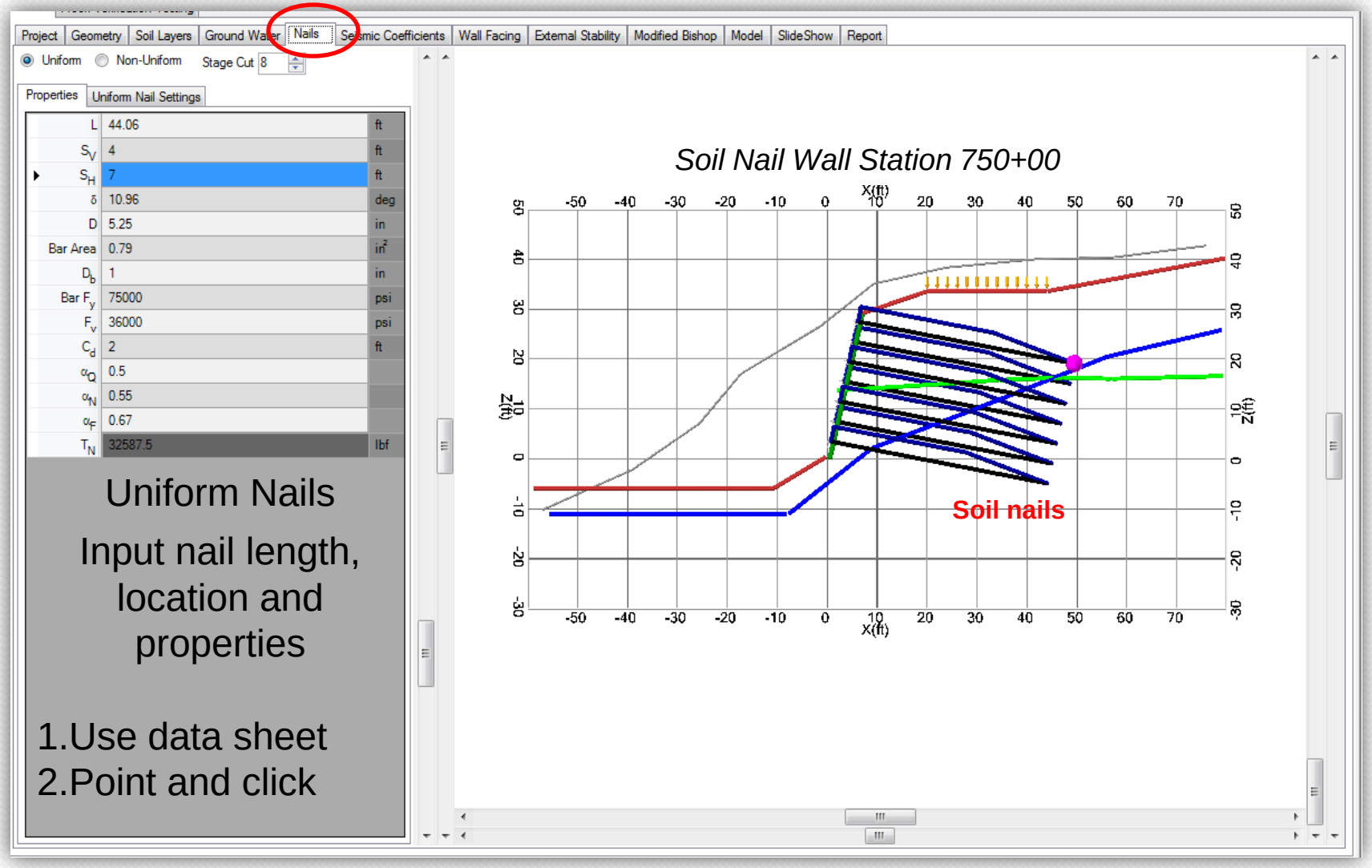
1.(X,Z) coordinates
2.Point and click



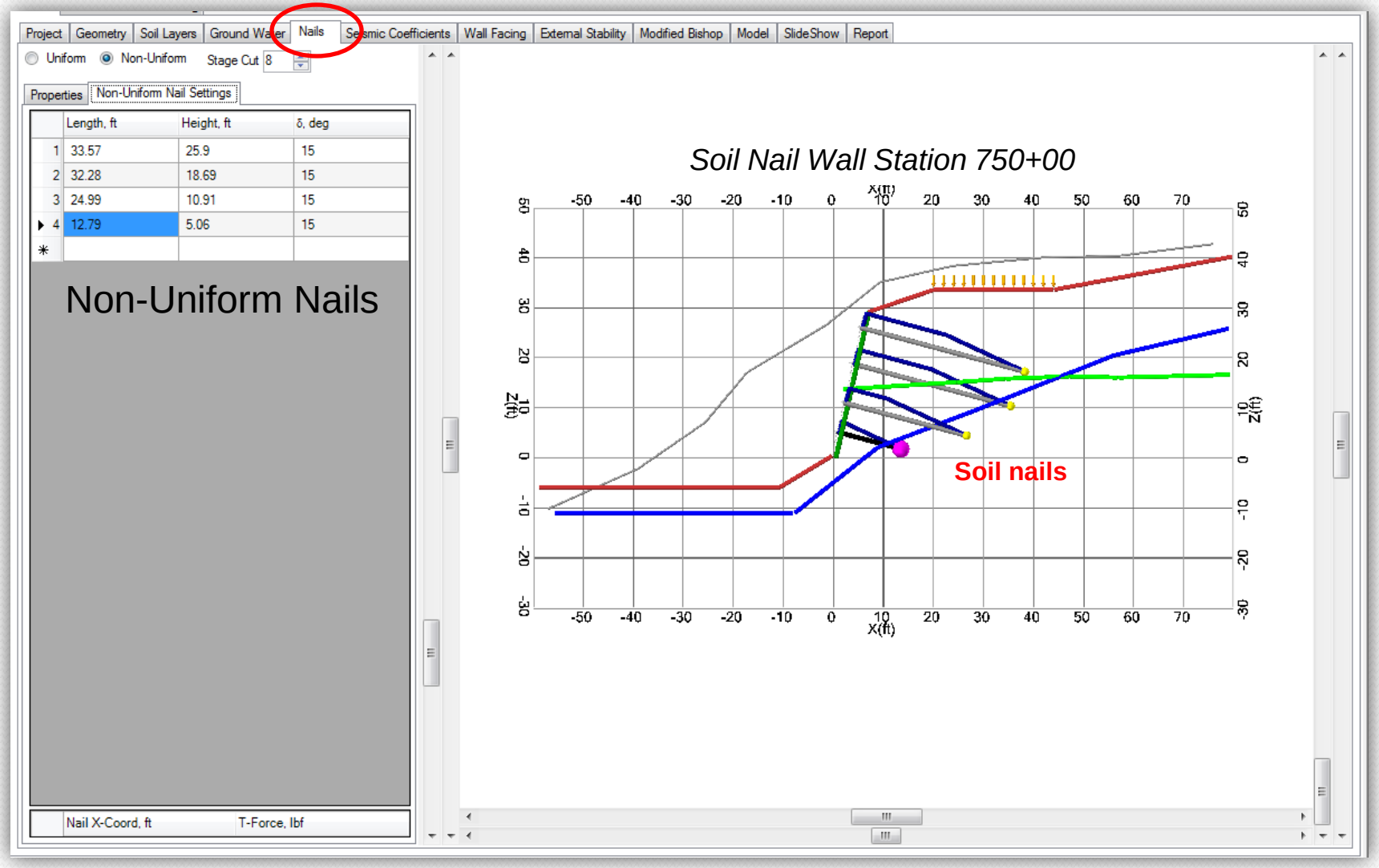
Ground Water Elevation



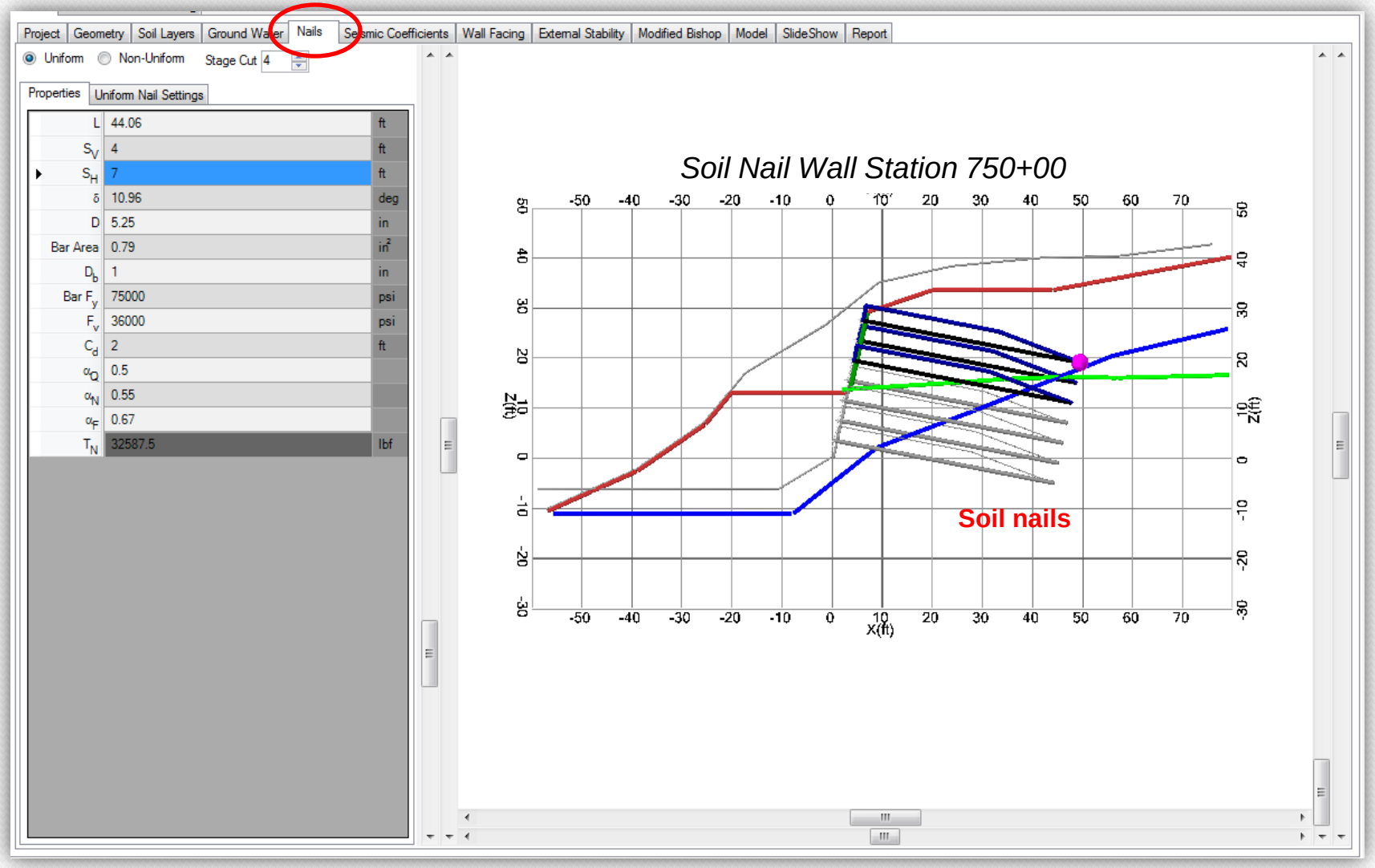
Soil Nail Properties



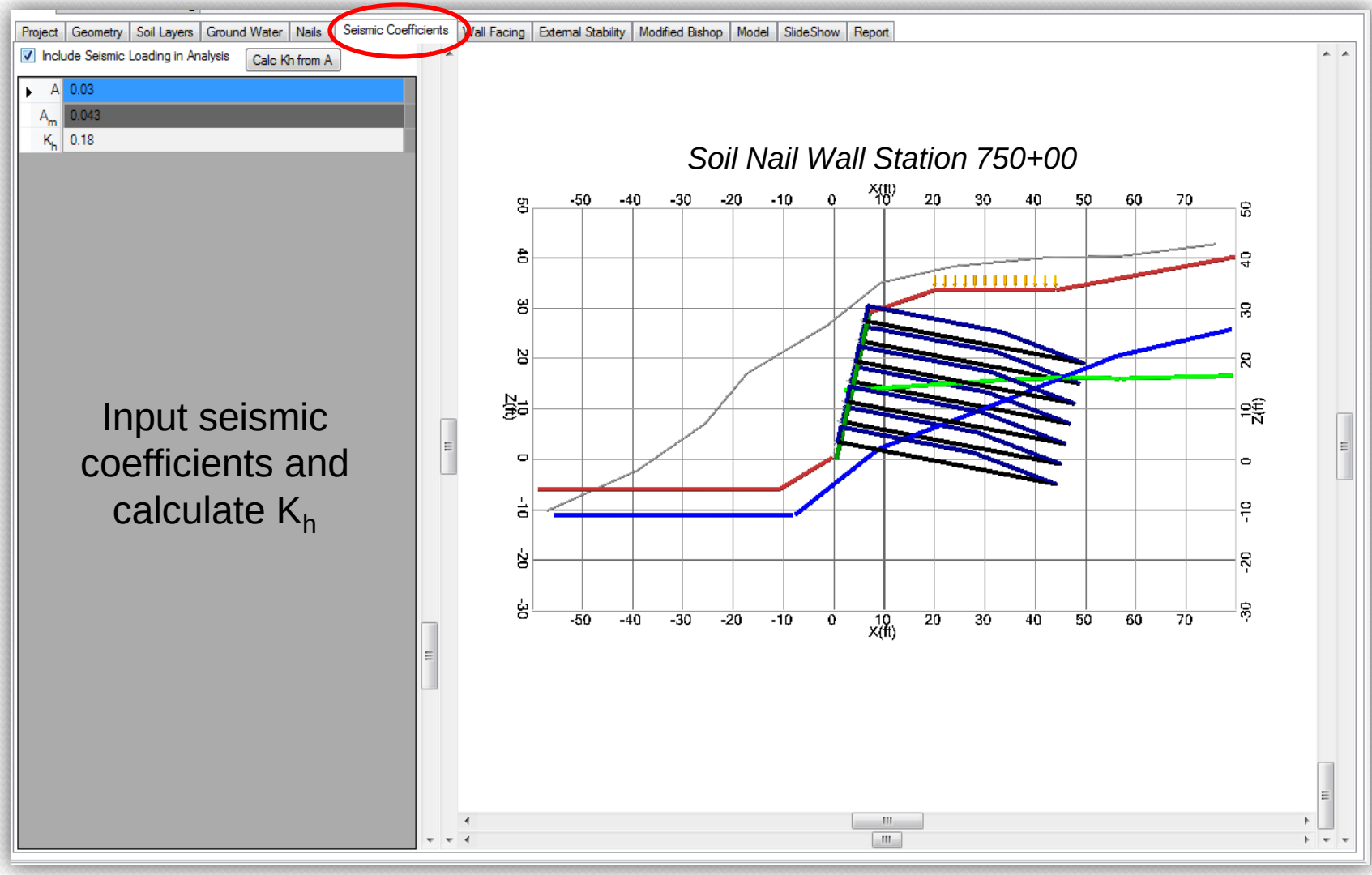
Soil Nail Properties



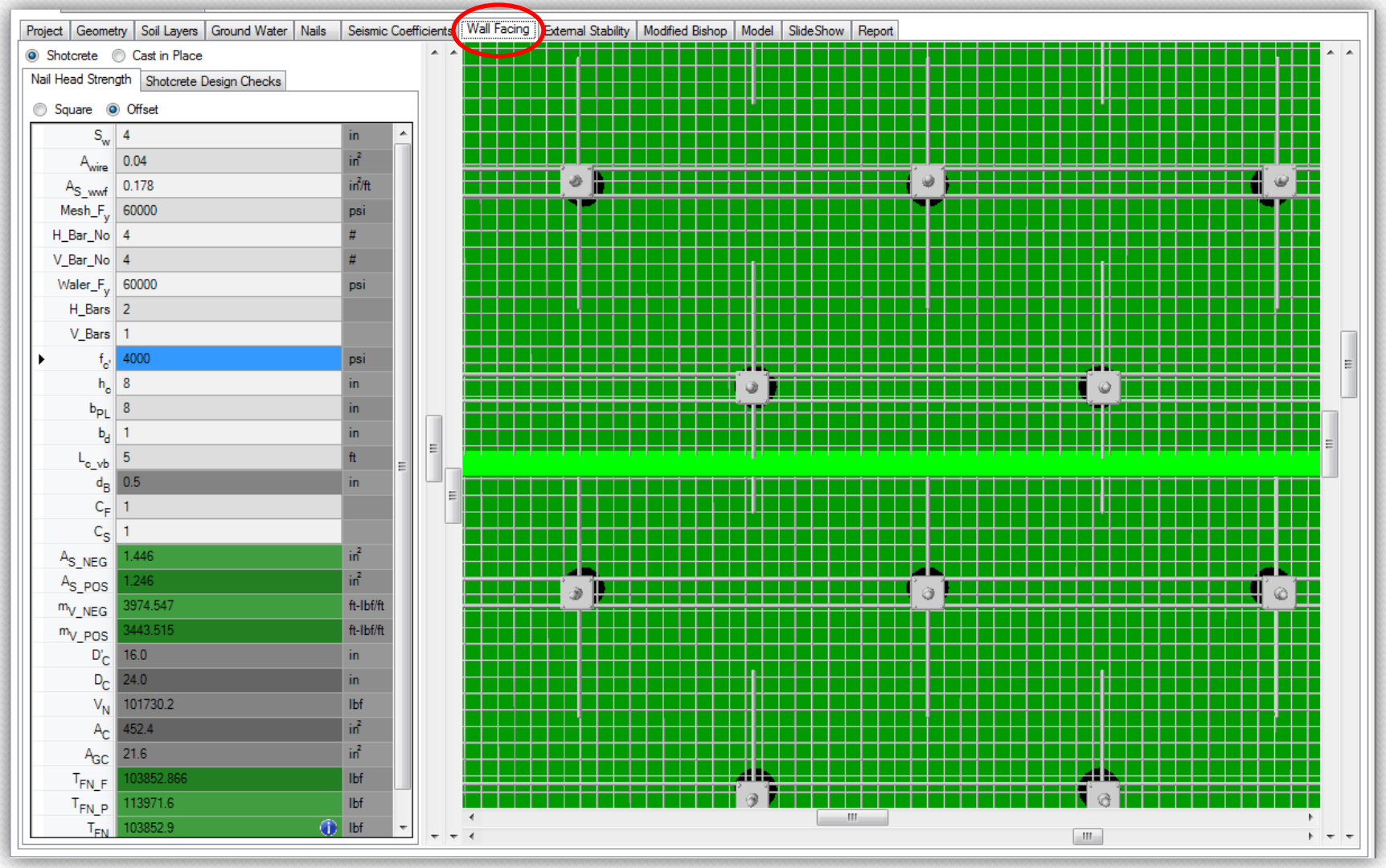
Nail Stress vs. Stage Cut



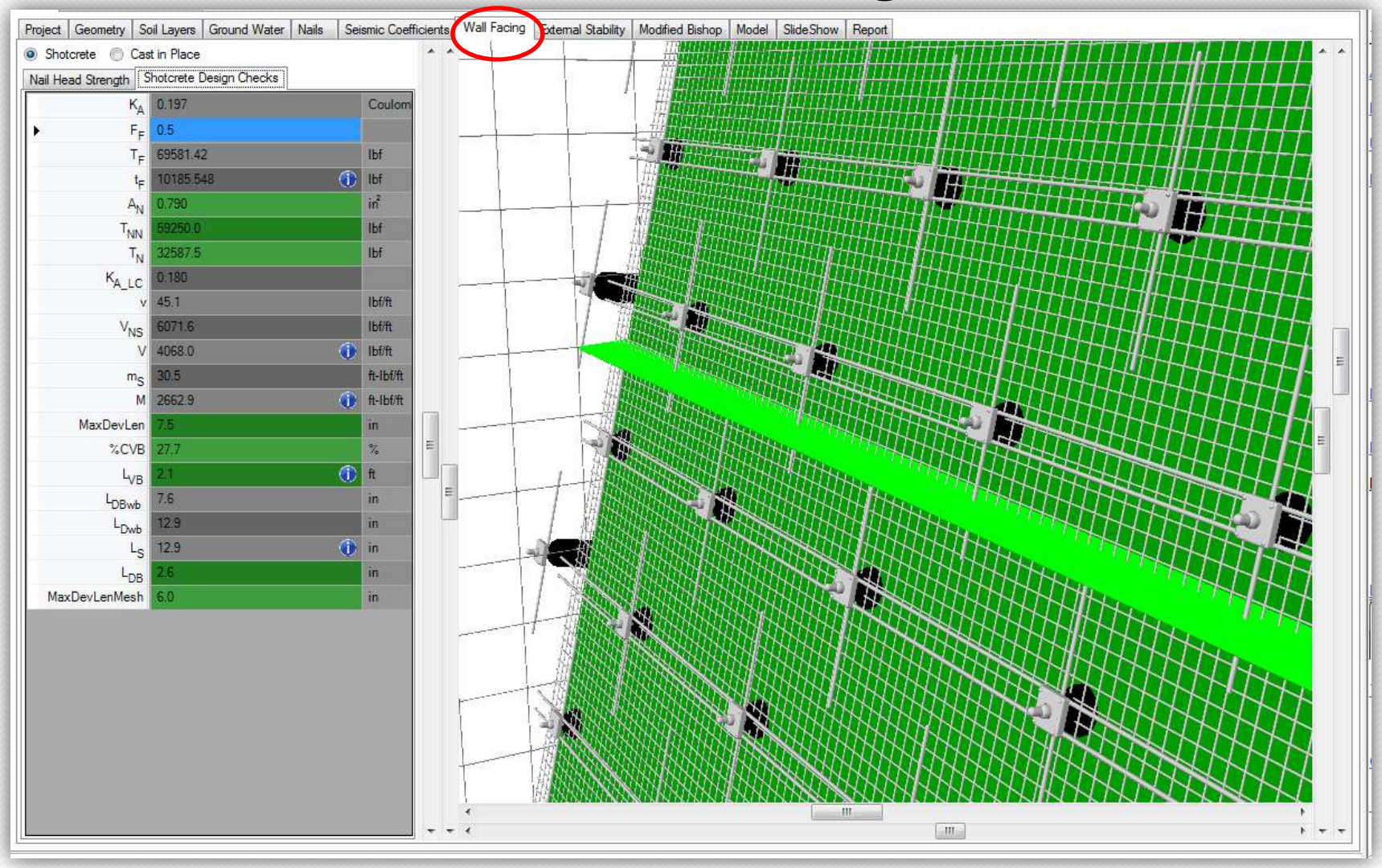
Seismic Loading



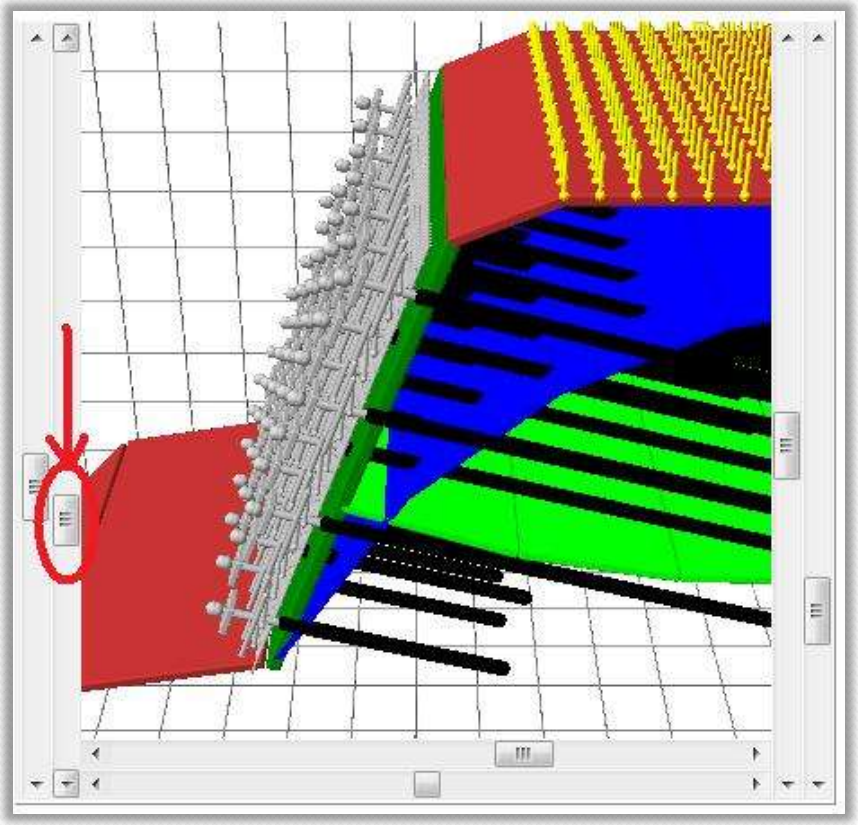
Soil Nail Wall Facing

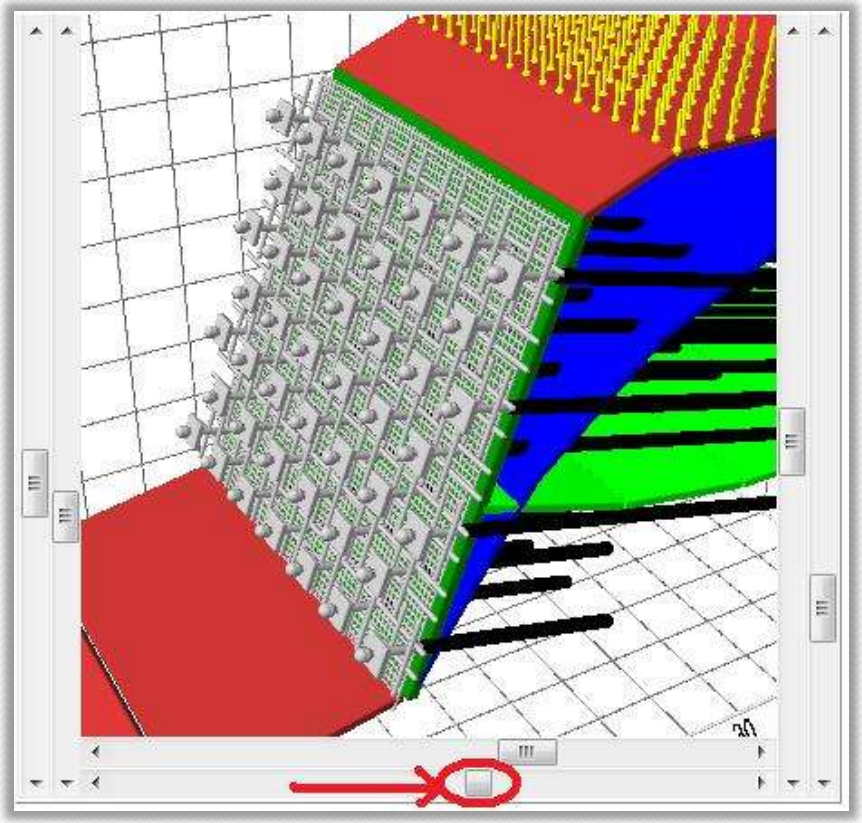


Soil Nail Wall Facing Checks

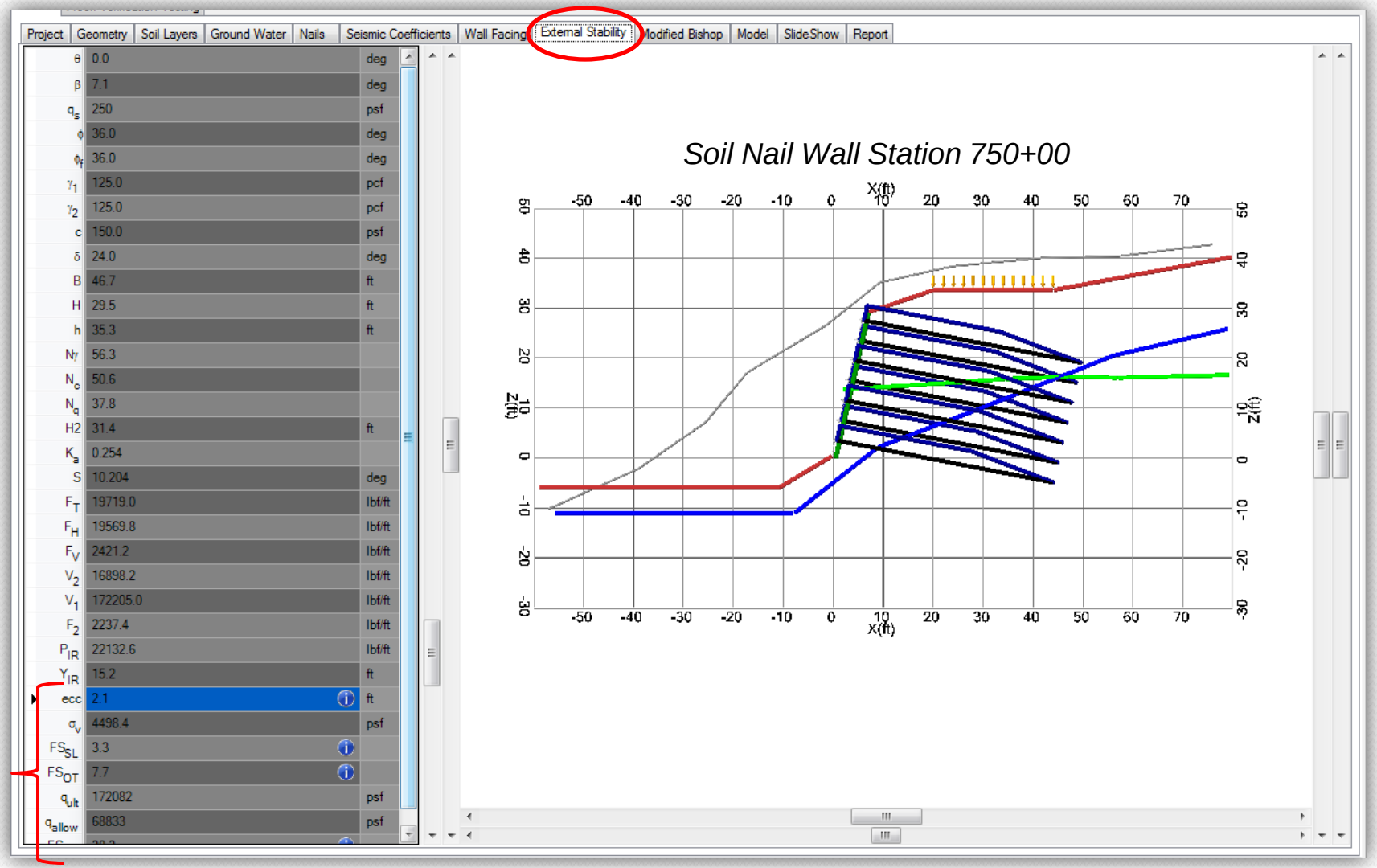


Interactive Display





External Stability Analysis



Global Stability Analysis

Project | Geometry | Soil Layers | Ground Water | Nails | Seismic Coefficients | Wall Facing | External Stabilit | Modified Bishop | Model | SlideShow | Report

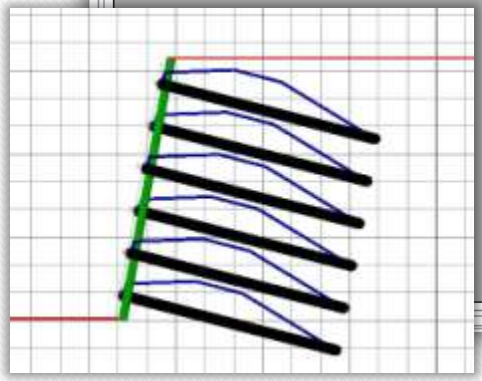
Failure Circles | Slices | Radius Control

☑ Show Contour Grid ☐ Show Radius Range

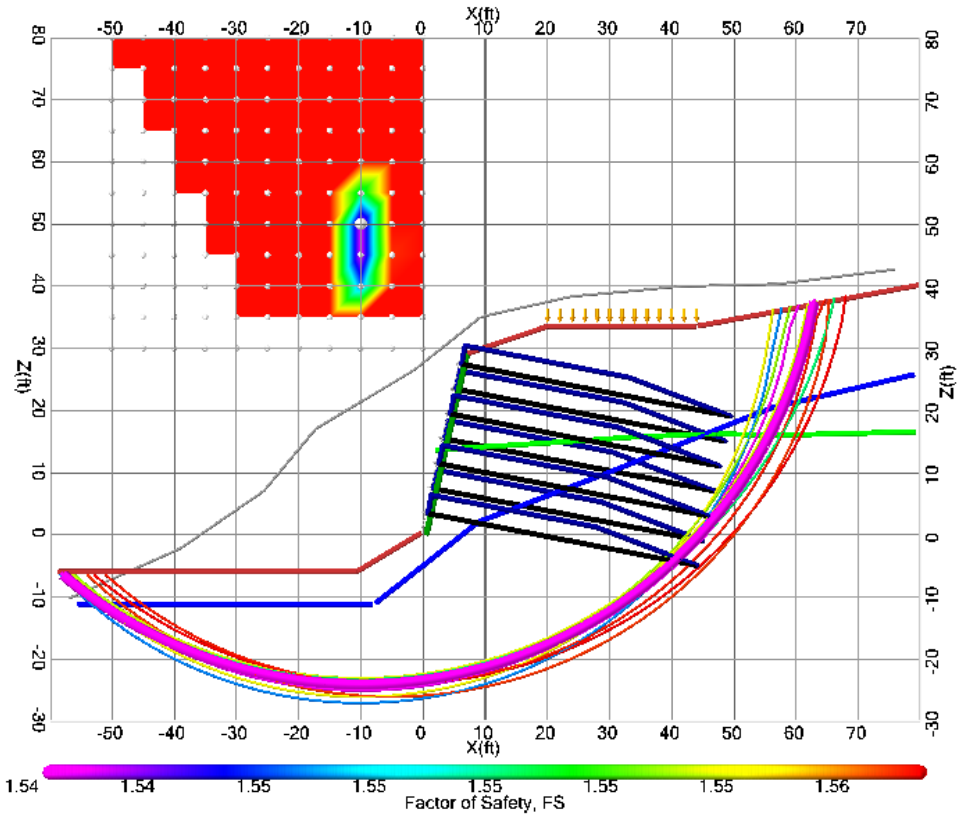
☑ Show Nail T Force Circle N: 10

	X, ft	Y, ft	R, ft	FS
▸ 1	-10	50	74	1.54
2	-10	45	70	1.54
3	-10	40	67	1.55
4	-10	55	78	1.55
5	-10	45	69	1.55
6	-10	50	73	1.55
7	-10	40	66	1.55
8	-5	45	71	1.56
9	-5	45	69	1.56
10	-5	50	74	1.56
*				

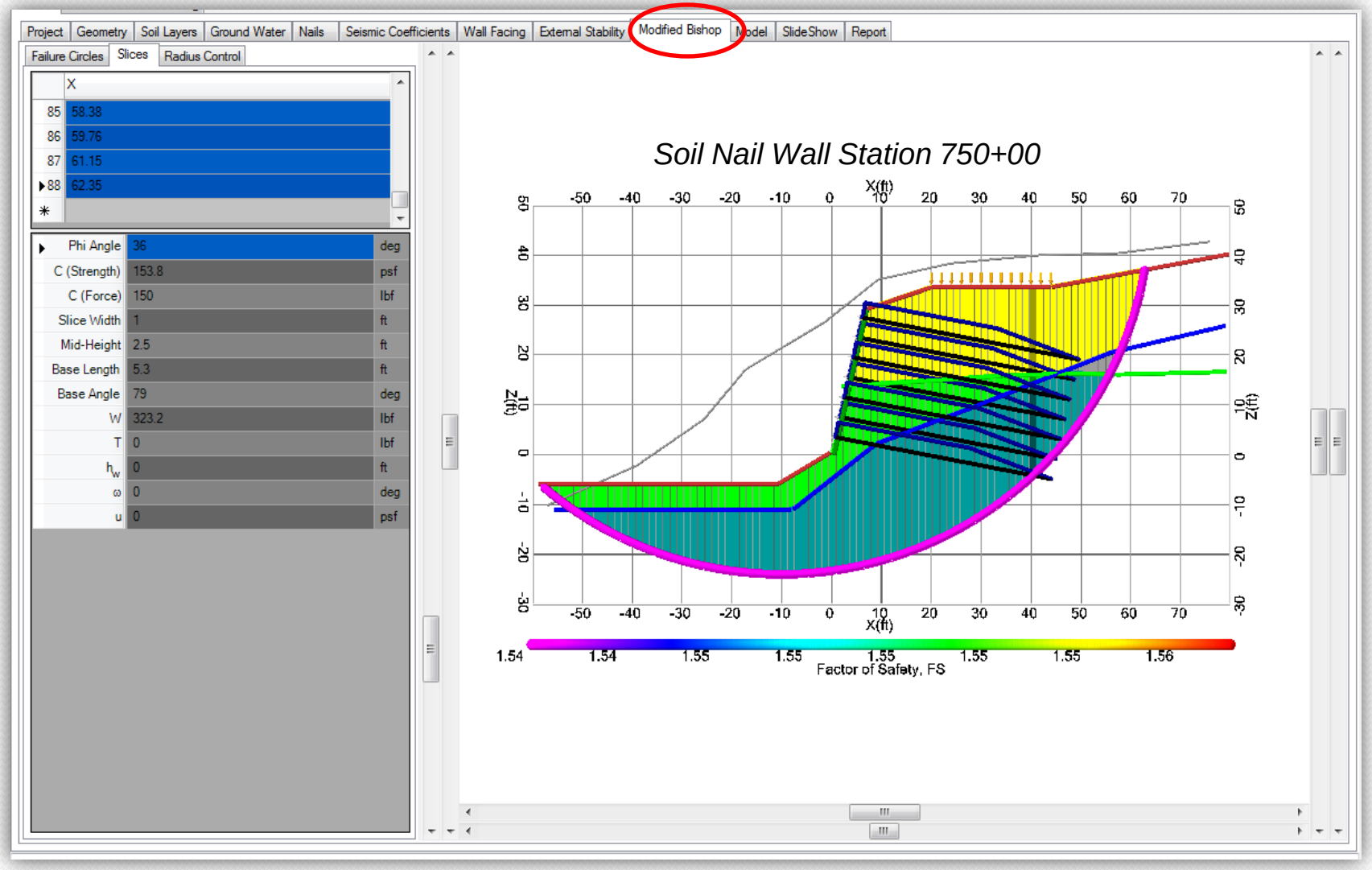
Nail tensile stress at the point of intersection is accounted for in the Global stability Calculations



Soil Nail Wall Station 750+00



Global Stability Analysis



Soil Nail Wall Design Report

Project | Geometry | Soil Layers | Ground Water | Nails | Seismic Coefficients | Wall Facing | External Stability | Modified Bishop | Model | SlideShow | Report

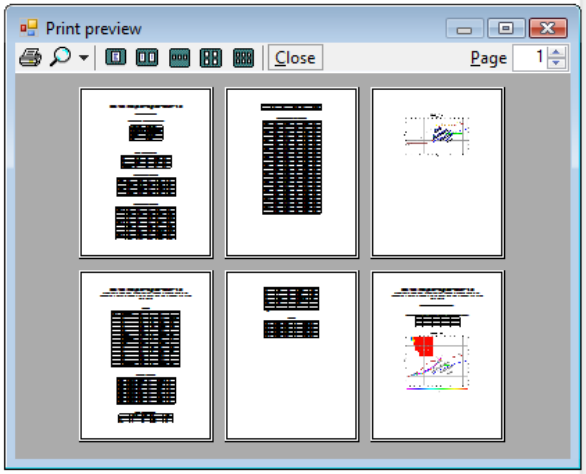
Generate | Page Setup | Print Preview | Print

Soil Nail Analysis Program--SNAP 1.0

SNAP Analysis

PROJECT INFORMATION

Project Name	Model Test
Project Number	18-3584
Company Name	ABC Engineering
Location	Anytown, USA
Designer	Jane Doe
Reviewer	Kris Kringle
Date	7-4-09



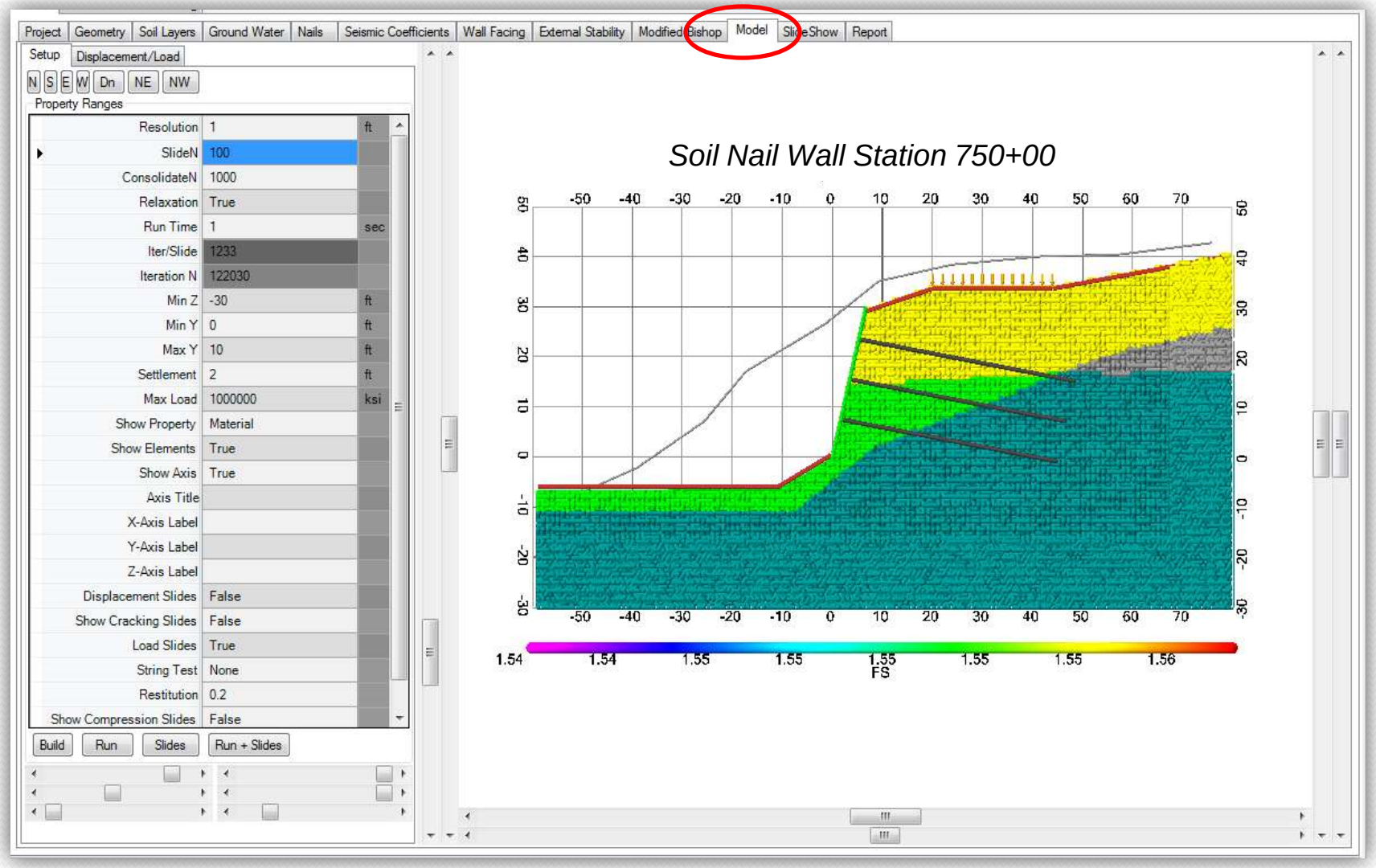
Wall Properties

	English	Units	SI	Units
X	6.65	ft	*2.03*	*m*
Z	29.47	ft	*8.98*	*m*
H	29.5	ft	*9.0*	*m*
θ	12.7	deg	*12.7*	*deg*
Embedment	0	ft	*0*	*m*

DownSlope Points

		English	Units	SI	Units
Point 1	*X*	-10.5	ft	*-3.2*	*m*
	Z	-6.29	ft	*-1.92*	*m*
	Angle	30.92	deg	*30.92*	*deg*
	Length	10.5	ft	*3.2*	*m*
Point 2	*X*	-58.75	ft	*-17.91*	*m*
	Z	-6.36	ft	*-1.94*	*m*
	Angle	0.08	deg	*0.08*	*deg*
	Length	48.25	ft	*14.71*	*m*

Numerical Modeling

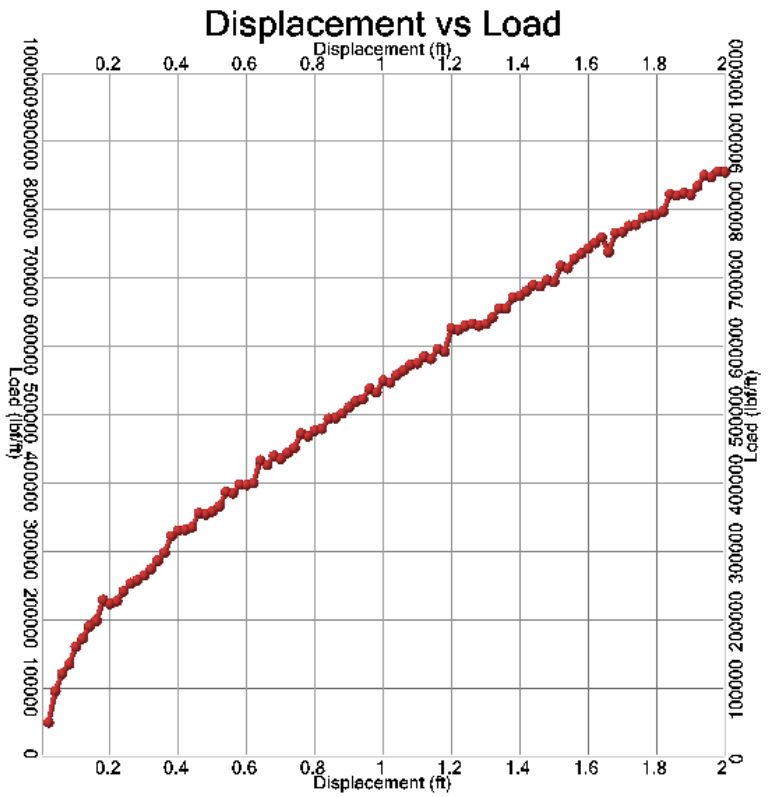


Numerical Modeling Results

Project | Geometry | Soil Layers | Ground Water | Nails | Seismic Coefficients | Wall Facing | External Stability | Modified Bishop | Model | SlideShow | Report

Setup | Displacement/Load

	Displacement, ft	Load, lbf/ft
1	0.02	49880.21
2	0.04	95742.8
3	0.06	121287.51
4	0.08	134780.37
5	0.1	160229.74
6	0.12	172372.57
7	0.14	190366.9
8	0.16	198283.29
9	0.18	228818.68
10	0.2	223217.75
11	0.22	227049.49
12	0.24	241746.86
13	0.26	253119.71
14	0.28	257994.38
15	0.3	264935.87
16	0.32	273994.58
17	0.34	286522.81
18	0.36	298134.05
19	0.38	322401.52
20	0.4	330293.82
21	0.42	331606.81
22	0.44	335188.51
23	0.46	355764
24	0.48	354135.36
25	0.5	358435.54
26	0.52	365602.98
27	0.54	386975.06
28	0.56	385156.85
29	0.58	397699.19
30	0.6	397254.77



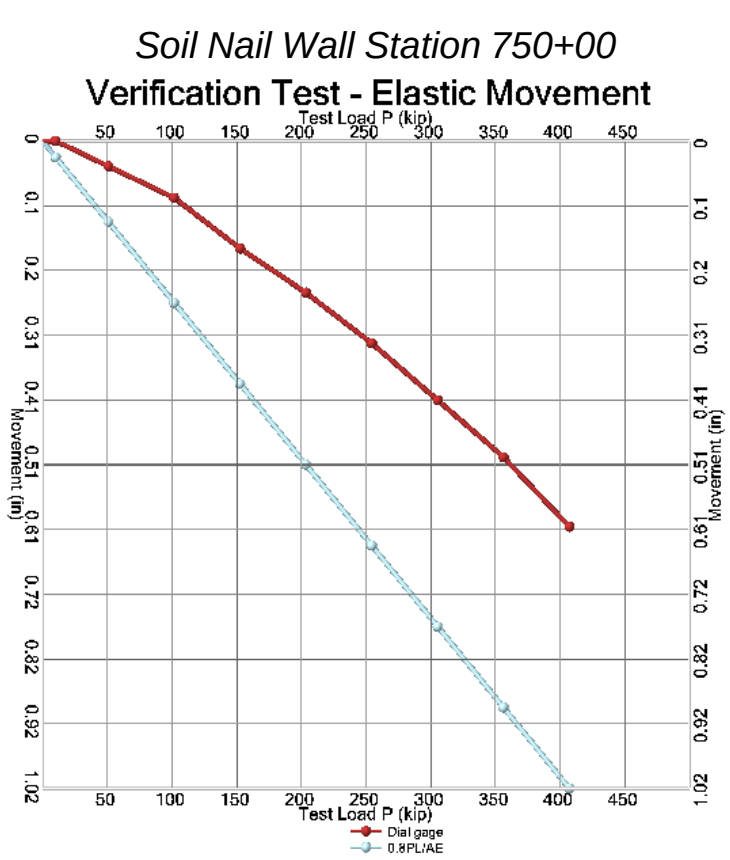
Verification & Proof Test Results

SNAP | Proof/Verification Testing

Design Test Load | Test Loading Data | Report

Verification Test | Proof Test

q_u	15	psi
D	6	in
FS	2.00	
f_y	75000.0	psi
C	0.9	
A_s	0.79	in^2
P_r	2.0	
$L_{BV\ used}$	10.0	ft
Q_u	40715.0	lbf/ft
Q_d	20357.5	lbf/ft
$L_{BV\ calc}$	9.8	ft
DTL	203.6	kip



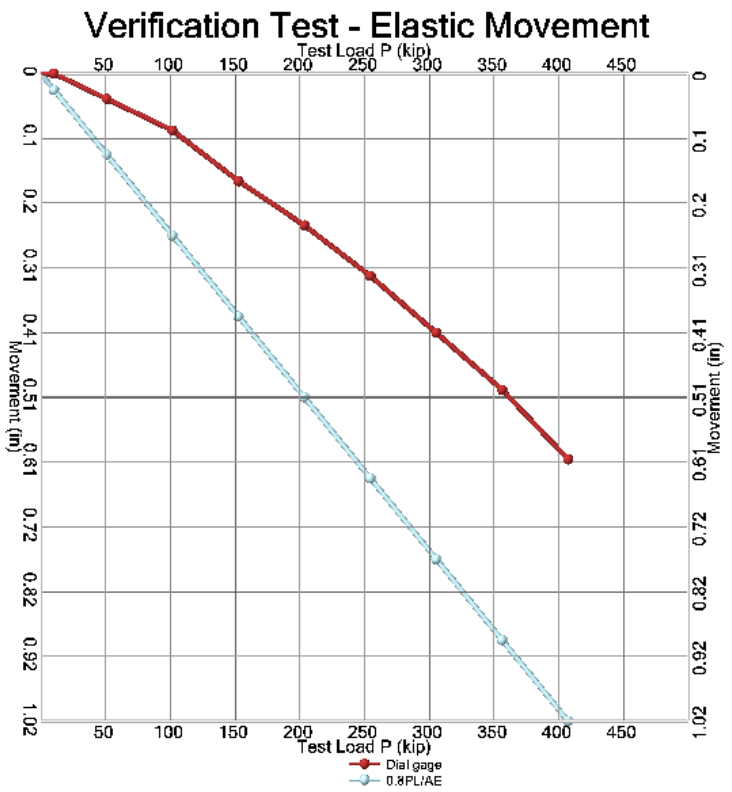
Verification & Proof Test Results

SNAP | Proof/Verification Testing

Design Test Load | Test Loading Data | Report

BL	15	ft
L	6	ft
DTL	203.6	kip
Creep Acceptance	0.0001000	in
TMA	12.2853	in
A	0.790	in^2
E	29000	ksi

	LI	HT	P, kip	ADG, in
1	0.05*DTL (Alig	1 min	10.18	0.0000
2	0.25*DTL	>10 min	50.90	0.0400
3	0.50*DTL	>10 min	101.80	0.0900
4	0.75*DTL	>10 min	152.70	0.1700
5	1.00*DTL	>10 min	203.60	0.2400
6	1.25*DTL	>10 min	254.50	0.3200
7	1.50*DTL	1 min	305.40	0.4100
8		2 min		0.4130
9		3 min		0.4150
10		5 min		0.4160
11		6 min		0.4164
12		10 min		0.4166
13		20 min		0.4167
14		30 min		0.4168
15		50 min		0.4168
16		60 min		0.4168
17	1.75*DTL	>10 min	356.30	0.5000
18	2.00*DTL	>10 min	407.20	0.6100



Verification & Proof Test Report

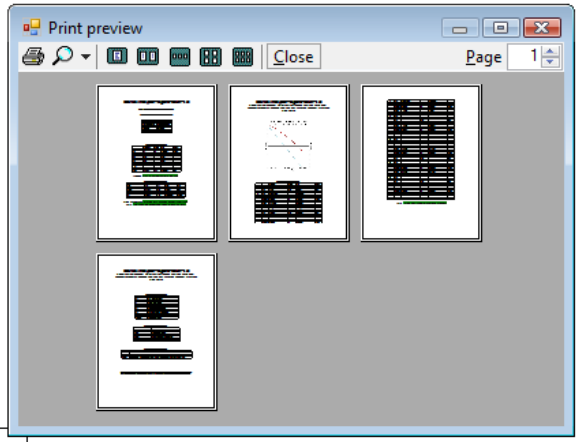
SNAP | Proof/Verification Testing

Design Test Load | Test Loading Data | Report

Generate | Page Setup | Print Preview | Print

Soil Nail Analysis Program--SNAP 1.0

Verification Testing Analysis



PROJECT INFORMATION

Project Name	Model Test
Project Number	18-3584
Company Name	ABC Engineering
Location	Anytown, USA
Designer	Jane Doe
Reviewer	Kris Kringle
Date	7-4-09

Design Test Load

	English	Units	SI	Units
q_u	15	psi	103.4	kPa
D	6	in	152.4	mm
FS	2.00		2.00	
f_y	75000.0	psi	517107.0	kPa
C	0.9		0.9	
A_s	0.79	in²	509.68	mm²
P_r	2.0		2.0	
$L_{BV\ used}$	10.0	ft	3.0	m
Q_u	40715.0	lbf/ft	594191.2	N/m
Q_d	20357.5	lbf/ft	297095.6	N/m
$L_{BV\ calc}$	9.8	ft	3	m
DTL	203.6	kip	905.5	kN

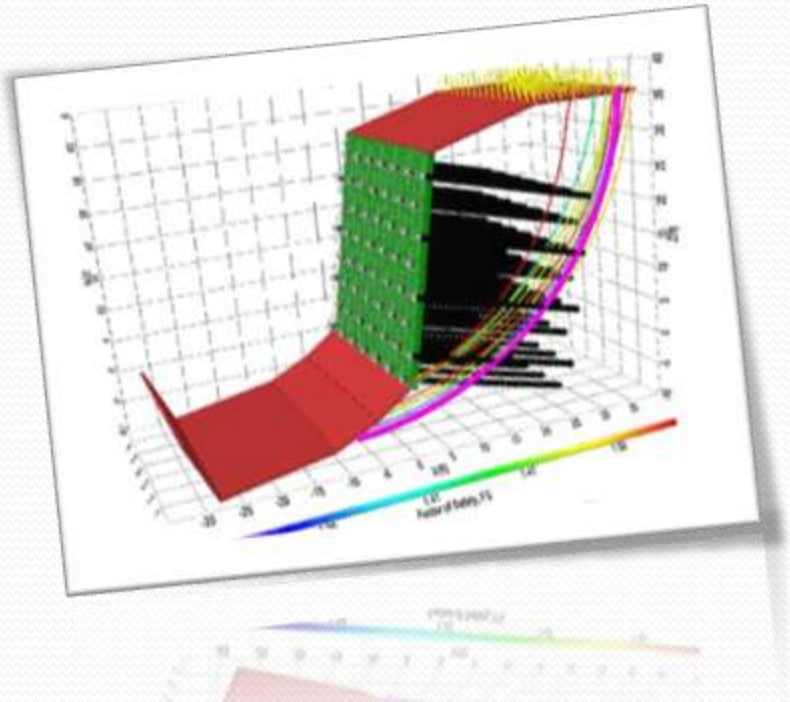
$L_{BV\ used}$: Must be a minimum of 10 feet - OK

Test Loading Data

	English	Units	SI	Units
BL	15	ft	4.6	m
L	6	ft	1.8	m

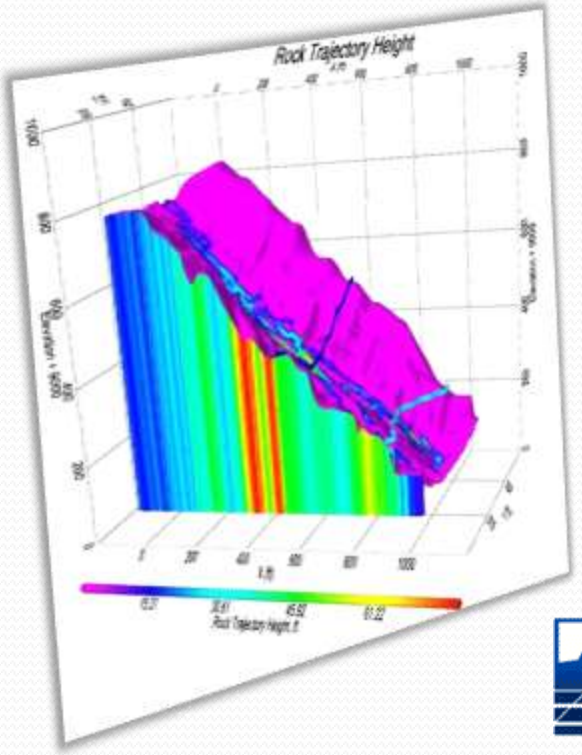
Summary

1. SNAP 1.0 is completed and was internally tested by the developers.
2. Beta testing by Dr. John Turner, University of Wyoming is in progress
3. The program should be available for free distribution once all testing is completed.



Colorado Rockfall Simulation Program

CRSP 3D



Rick Andrew, Yeh & Associates, Inc.
Matt DeMarco, FHWA Central Federal Lands
Ty Ortiz, Colorado Department of Transportation
Jerry Higgins, Colorado School of Mines
Howard Hume, PhD, Yeh & Associates, Inc.
Alan Rock, GAP Engineering, Inc.
Runing Zhang, PhD, Metro State College

DOT

Yeh and Associates, Inc.
Consulting Engineers & Scientist

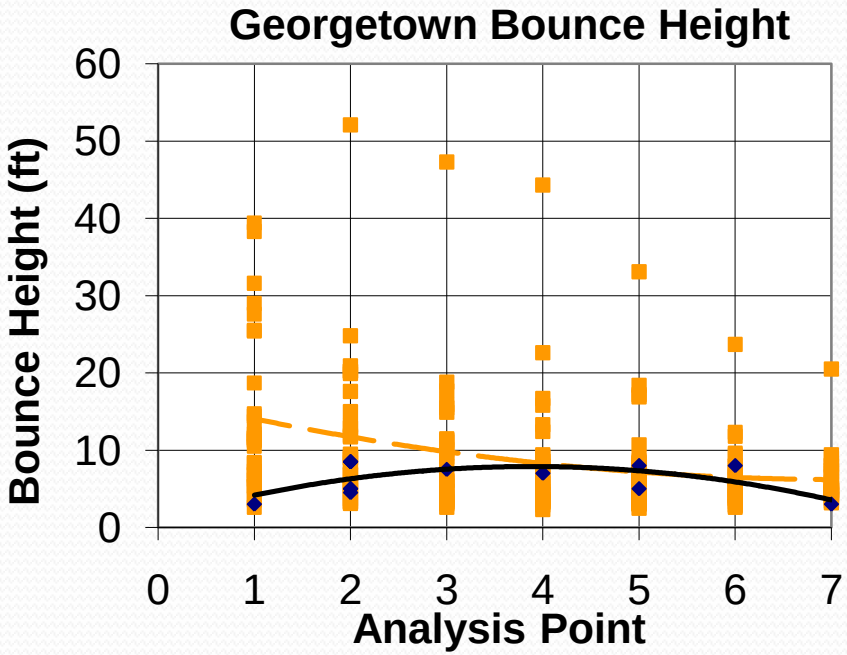
Central Federal Lands Highway Division
US Department of Transportation - Federal Highway Administration

GAP Engineering, Inc.
Geostructural Analysis Professionals

Program Objectives

- Develop an analyses and statistical predictions of rockfall behavior, providing the user with both 2D and 3D hazard characterization and mitigation tools.
  - Accept three-dimensional terrain data
  - Analysis of the final dispersion of rocks along slope
  - Ability to designate multiple rockfall origin locations
  - Incorporate rock and slope parameters
  - Ability to place analysis segments along the slope of user-defined dimension to evaluate mitigation alternatives
- Incorporate lessons learned from CRSP v1.0 – 4.0

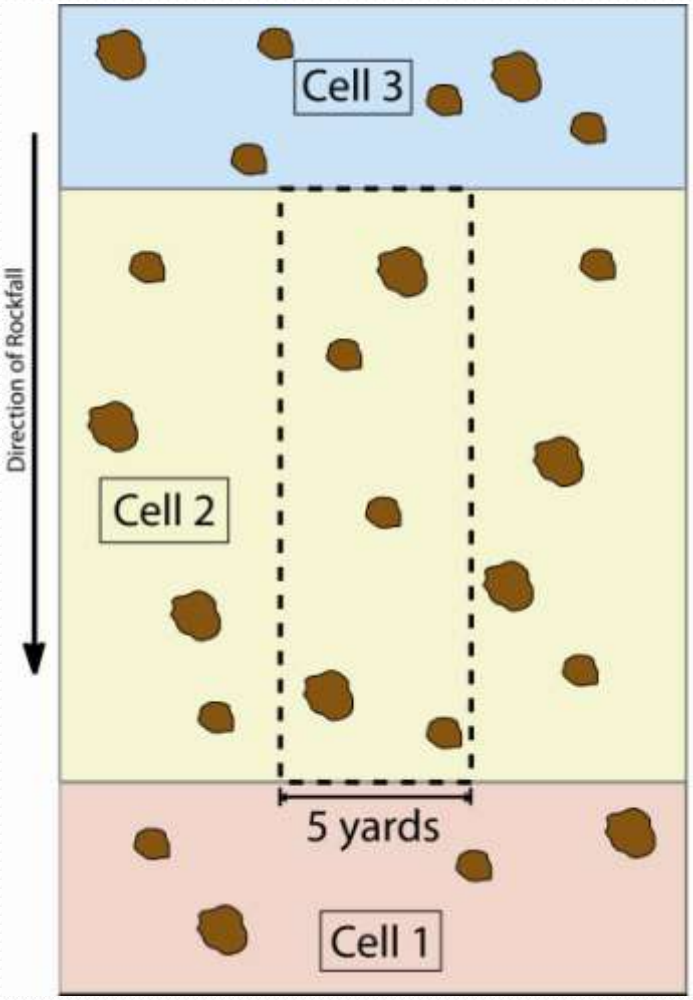
Program Calibration



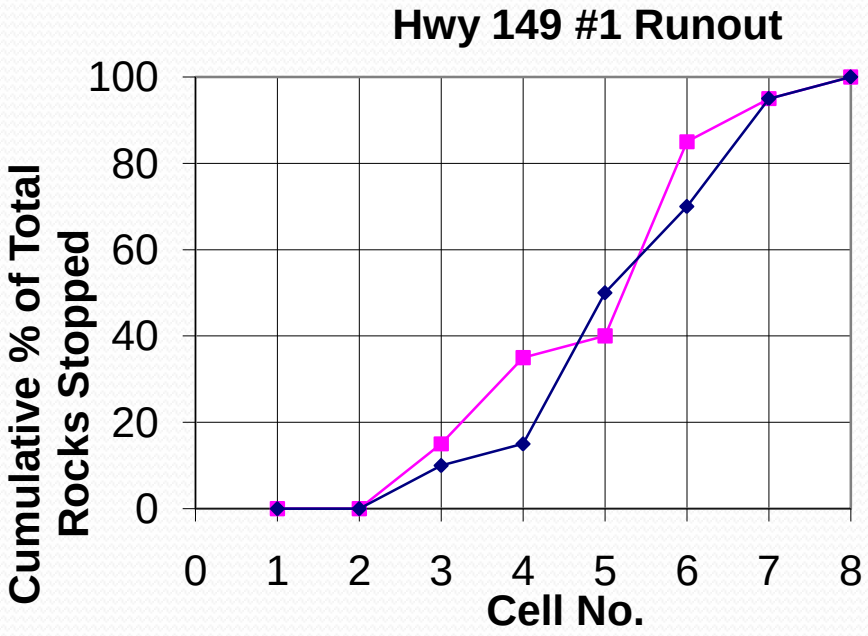
2 to 6 ft rocks
Hardness: 0.85
Boulder Talus = 0.70
Soft Organic Soil = .30

Program Calibration

Rock Runout Distance



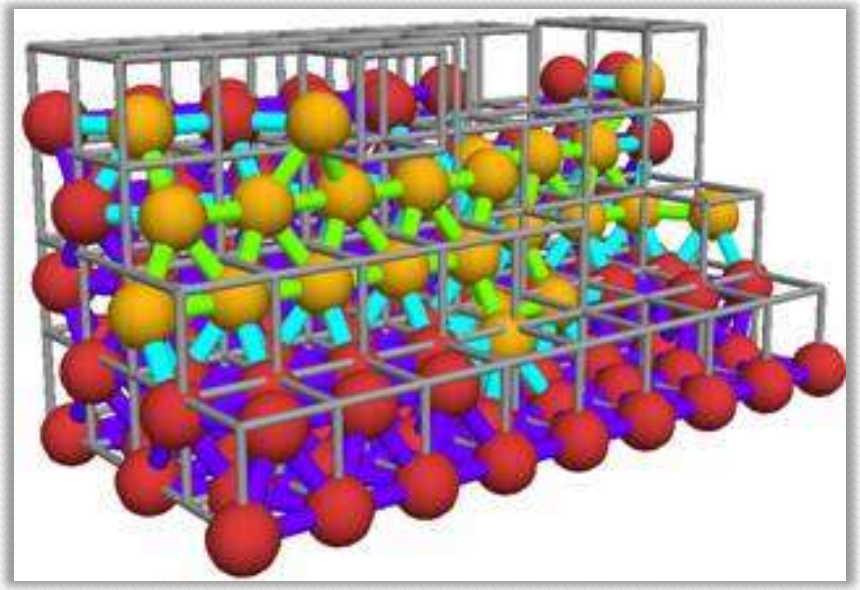
After Coe et al., 2005

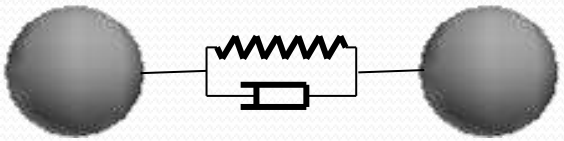


3 to 6ft rocks
Firm soil = 0.6

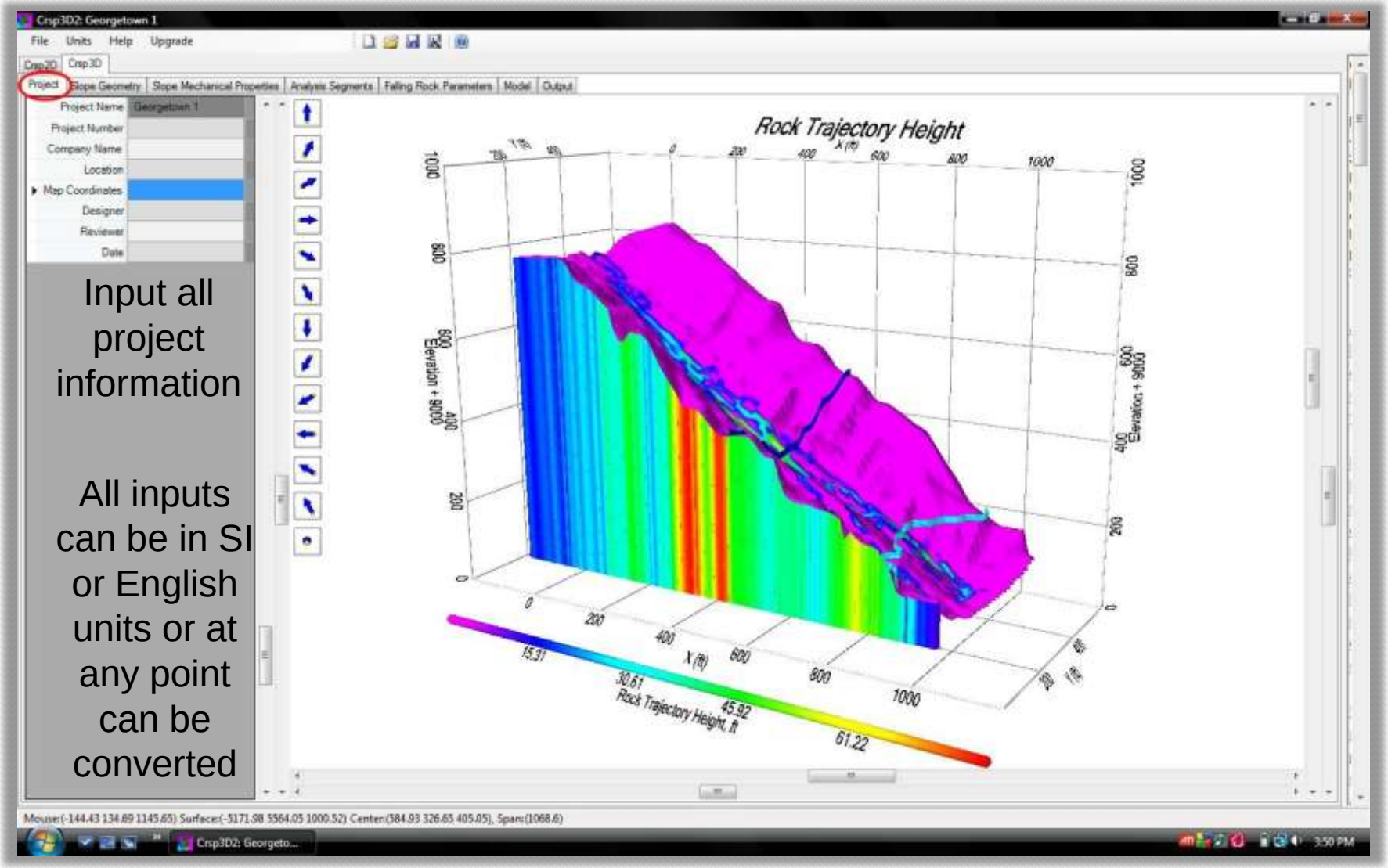
Geostructural Analysis Package

The visco-elastic contact model is the most popular constitutive contact model used a Discrete Element Model. Because of its simplicity, the calculations are very efficient. The assumption of a linear elastic contact force-displacement relationship between two impact bodies is a good approximation.





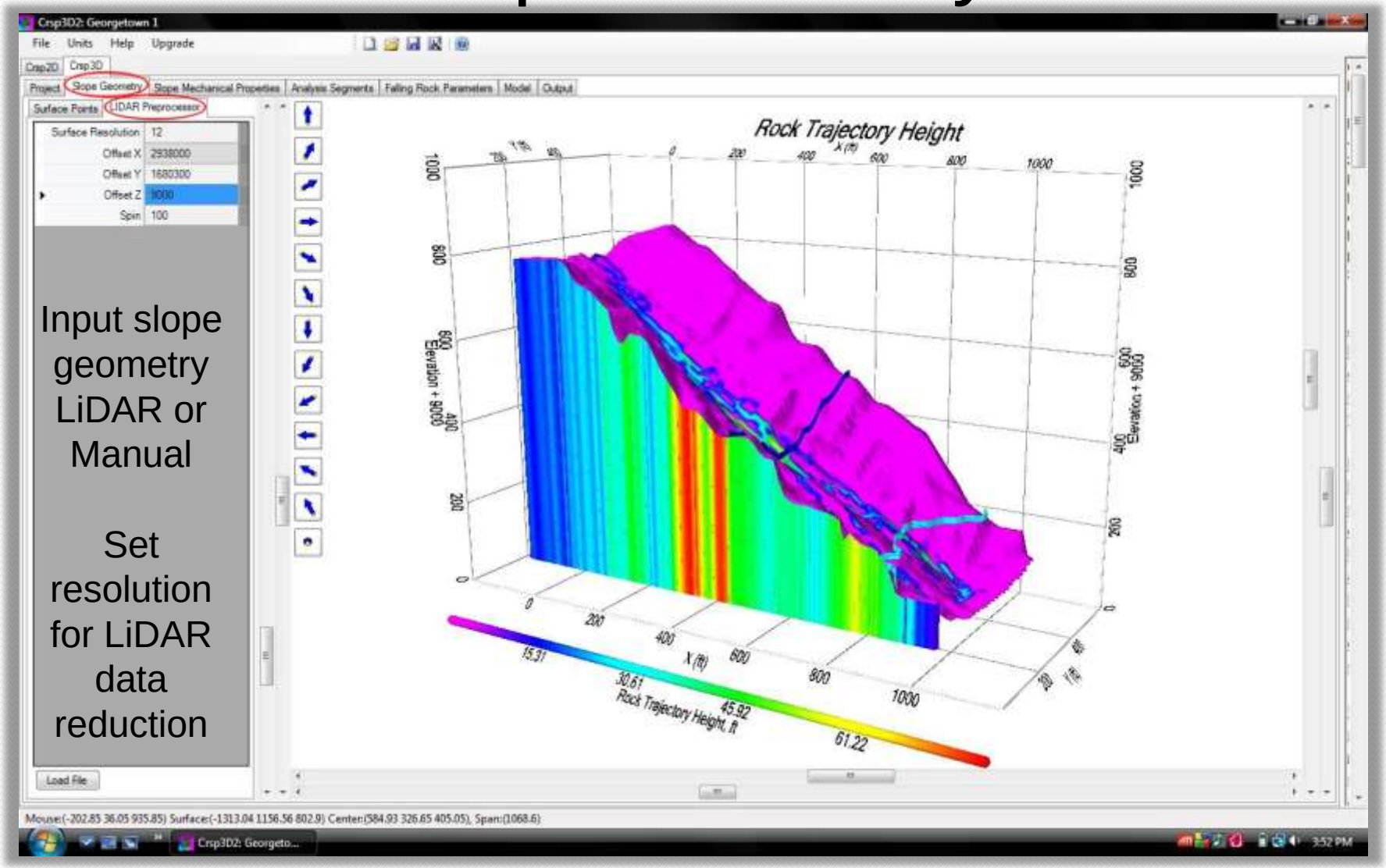
Project Information



Input all project information

All inputs can be in SI or English units or at any point can be converted

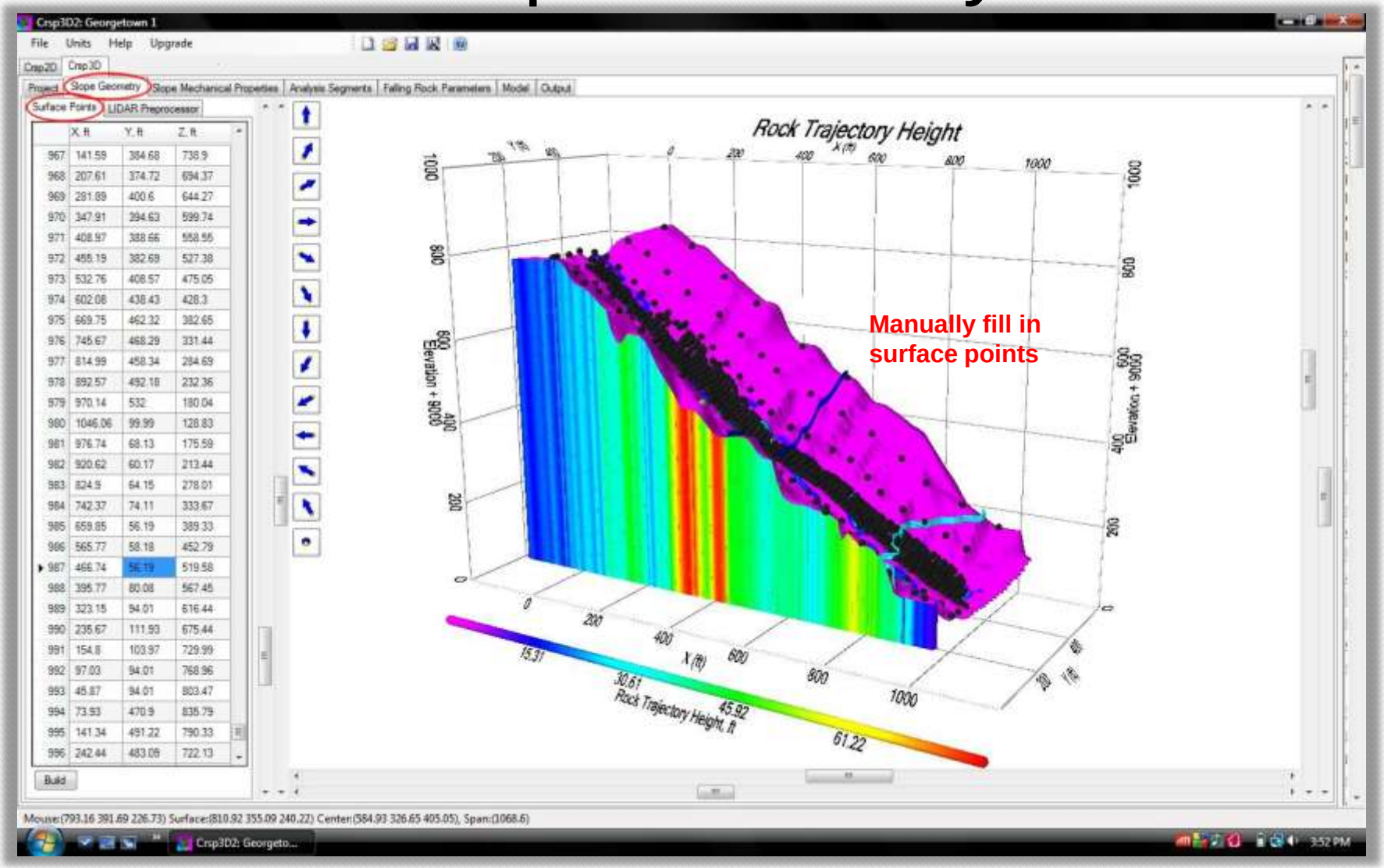
Slope Geometry



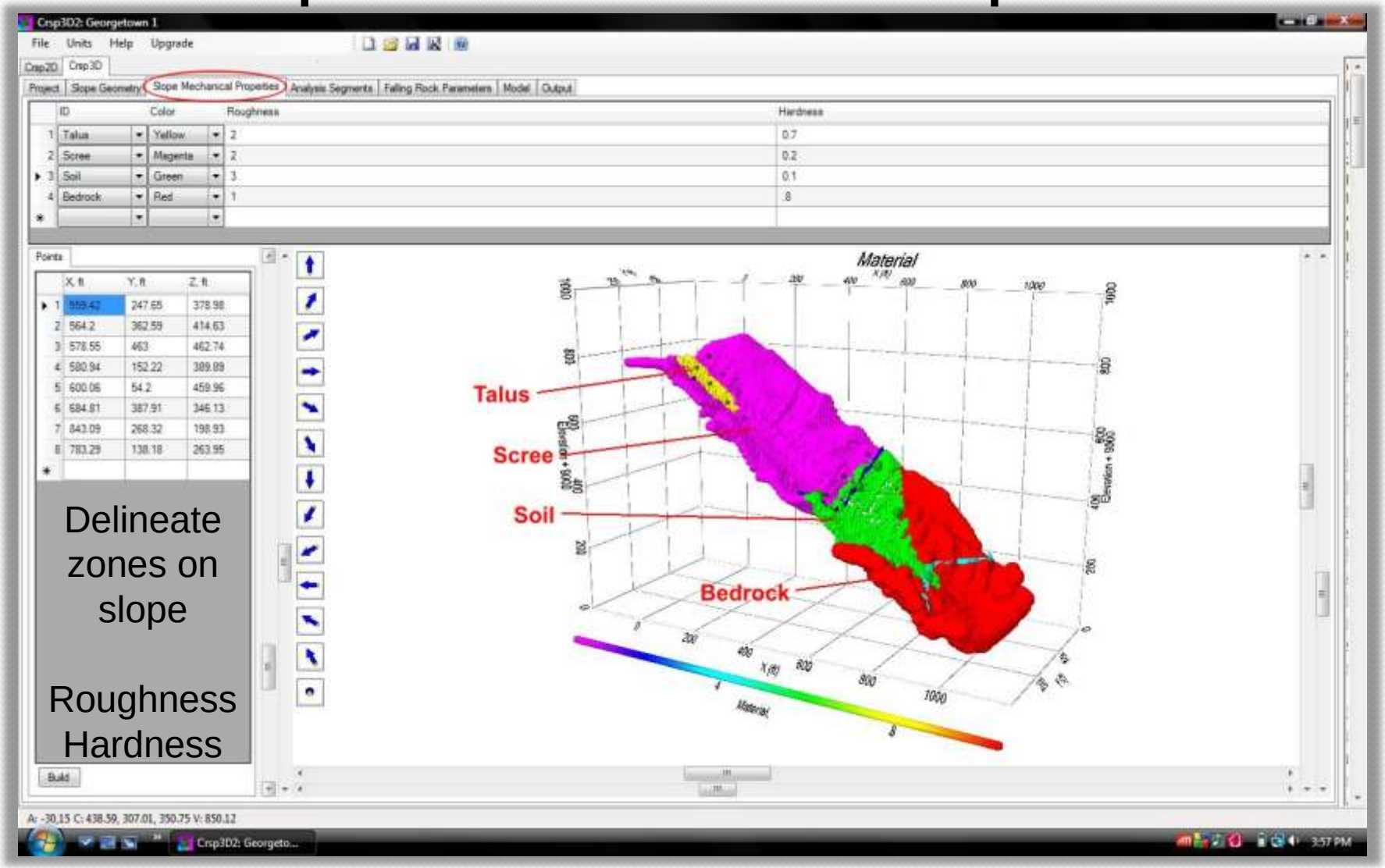
Input slope geometry LiDAR or Manual

Set resolution for LiDAR data reduction

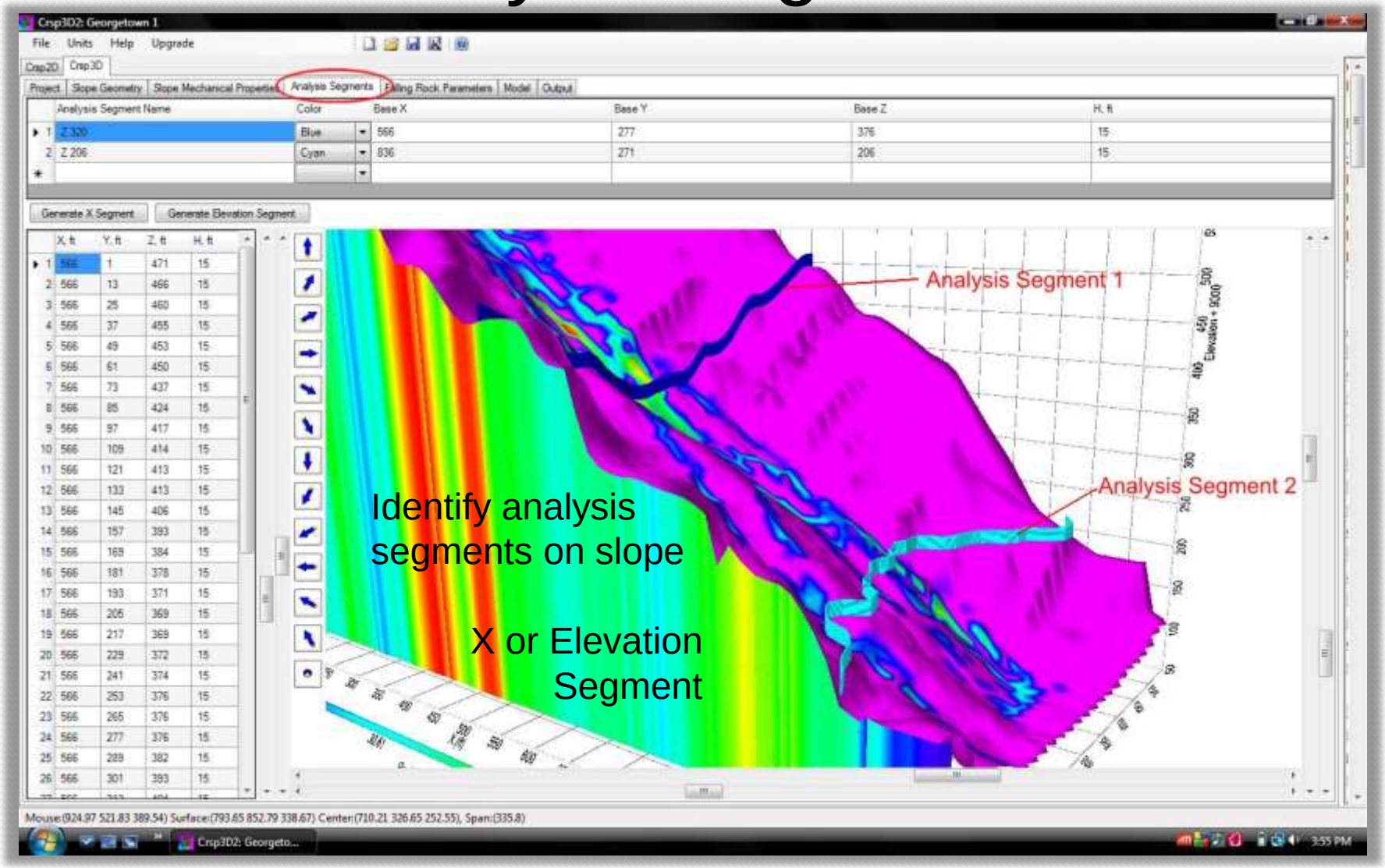
Slope Geometry



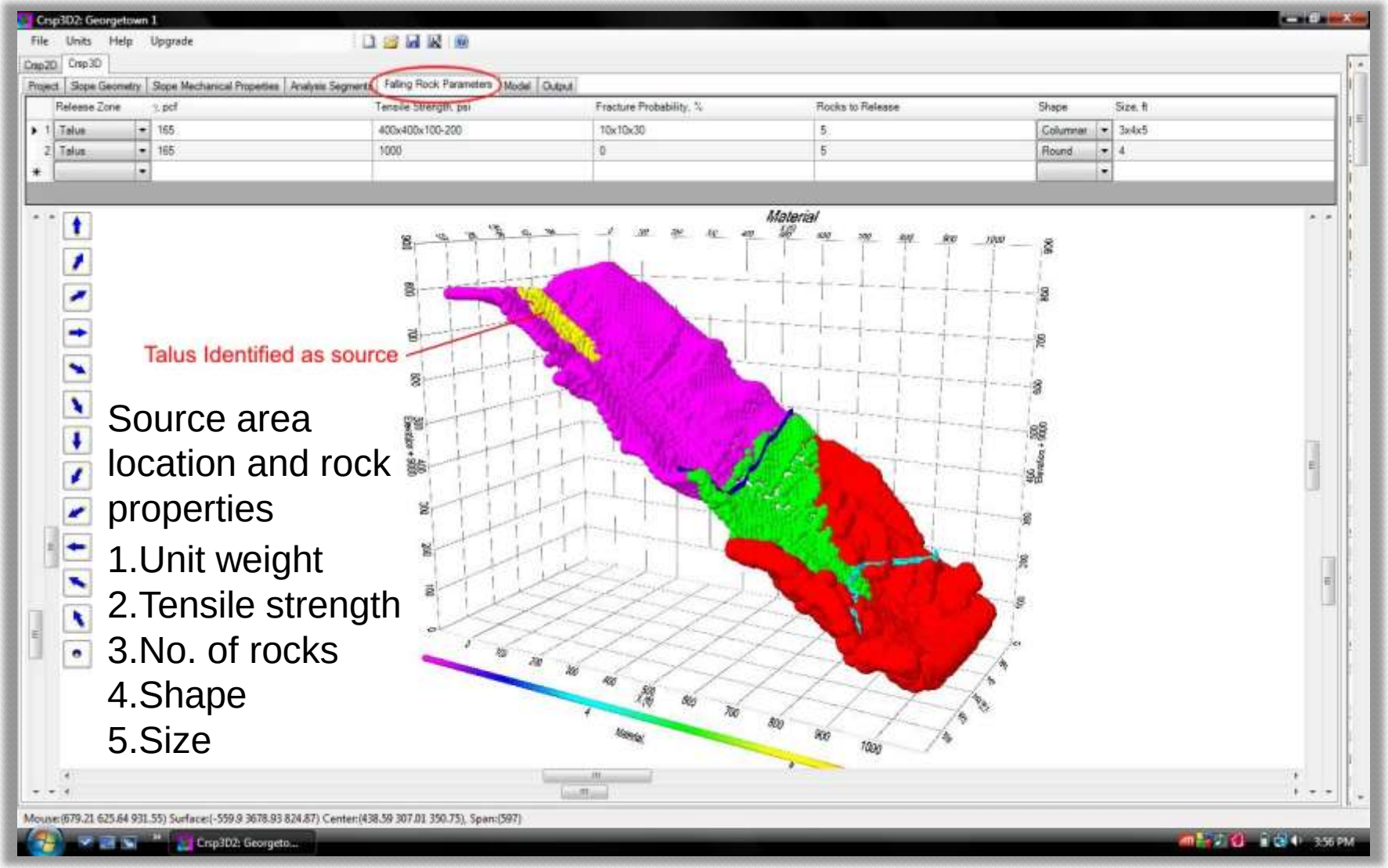
Slope Mechanical Properties



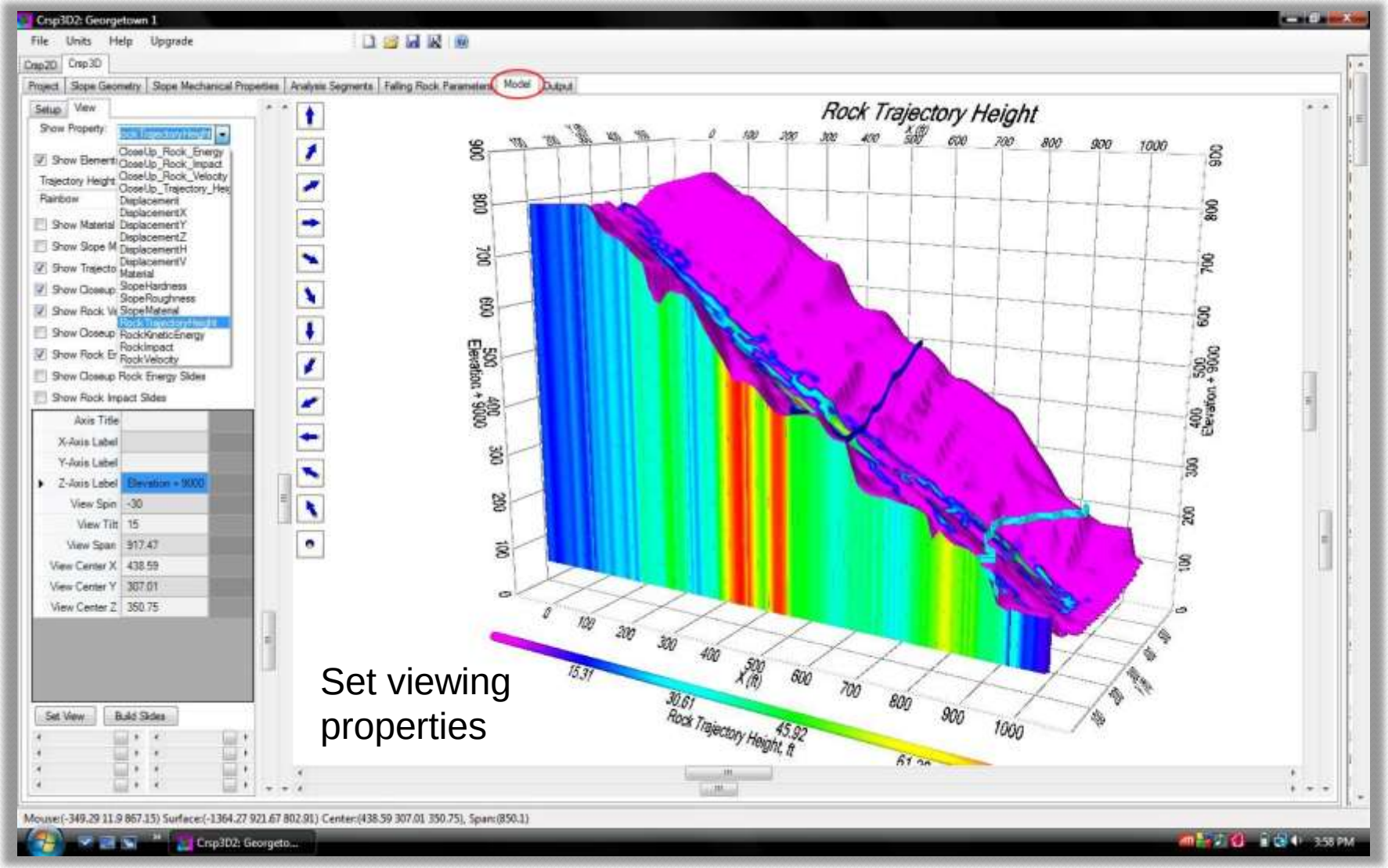
Analysis Segments



Falling Rock Properties

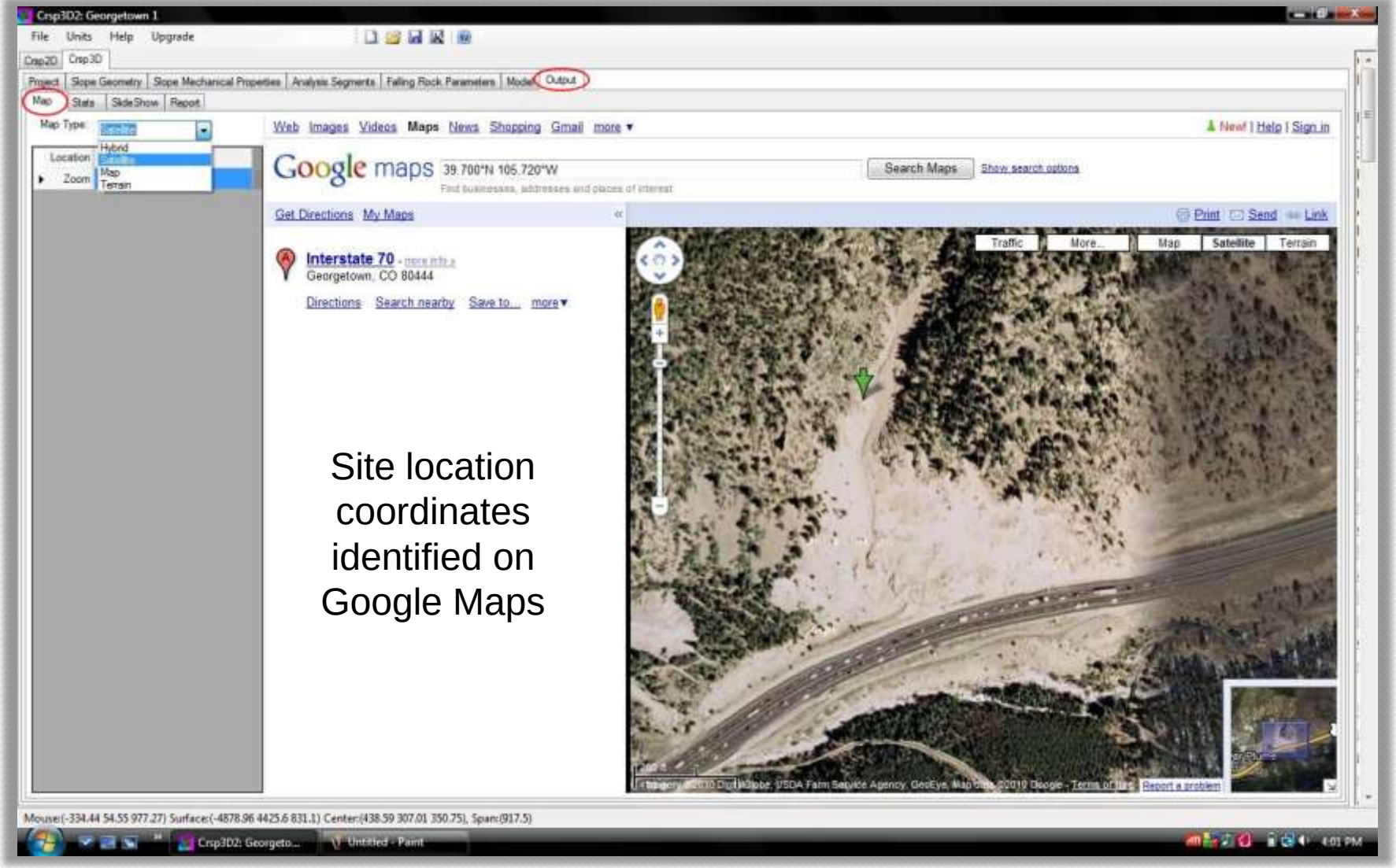


Model Settings



Set viewing properties

Model Output



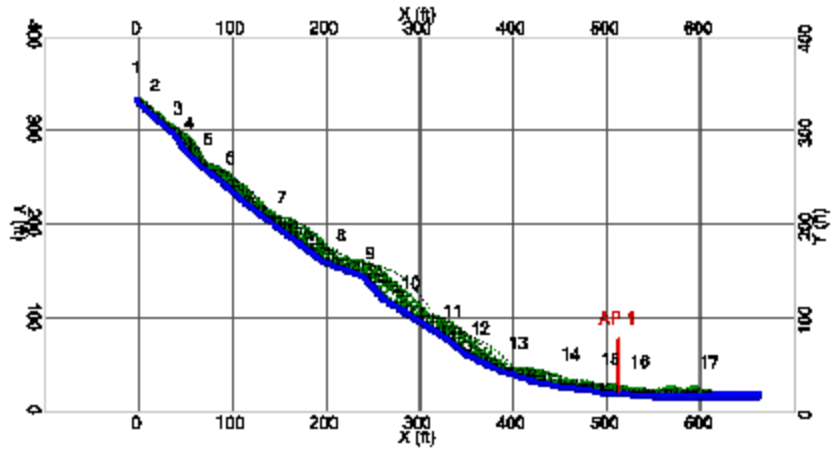
Model Output

Generate Report | Page Setup | Print Preview | Print

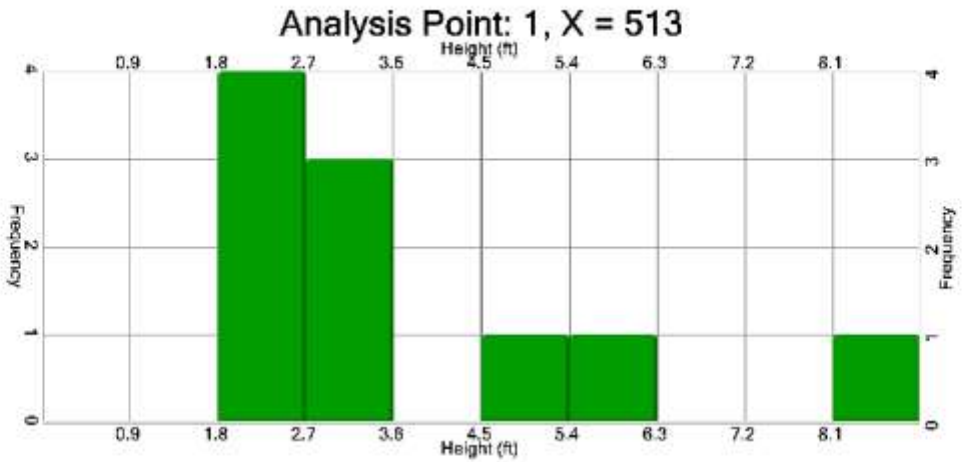
Colorado Rockfall Simulation Program--CRSP 5.0

CRSP Rockfall Analysis

CRSP was used to determine the expected kinetic energy and bouncing height of falling rocks at various points along the slope. In the analysis, it was assumed that rounded boulders with a maximum diameter of 5.0 feet would impact the rockfall retaining system. For each simulation, the model rolled 10 spherical shaped rocks from a source area at 330 - 332 feet. A slope surface roughness of 0.0 - 4.0, and hardness of 0.0 - 0.7 were used.

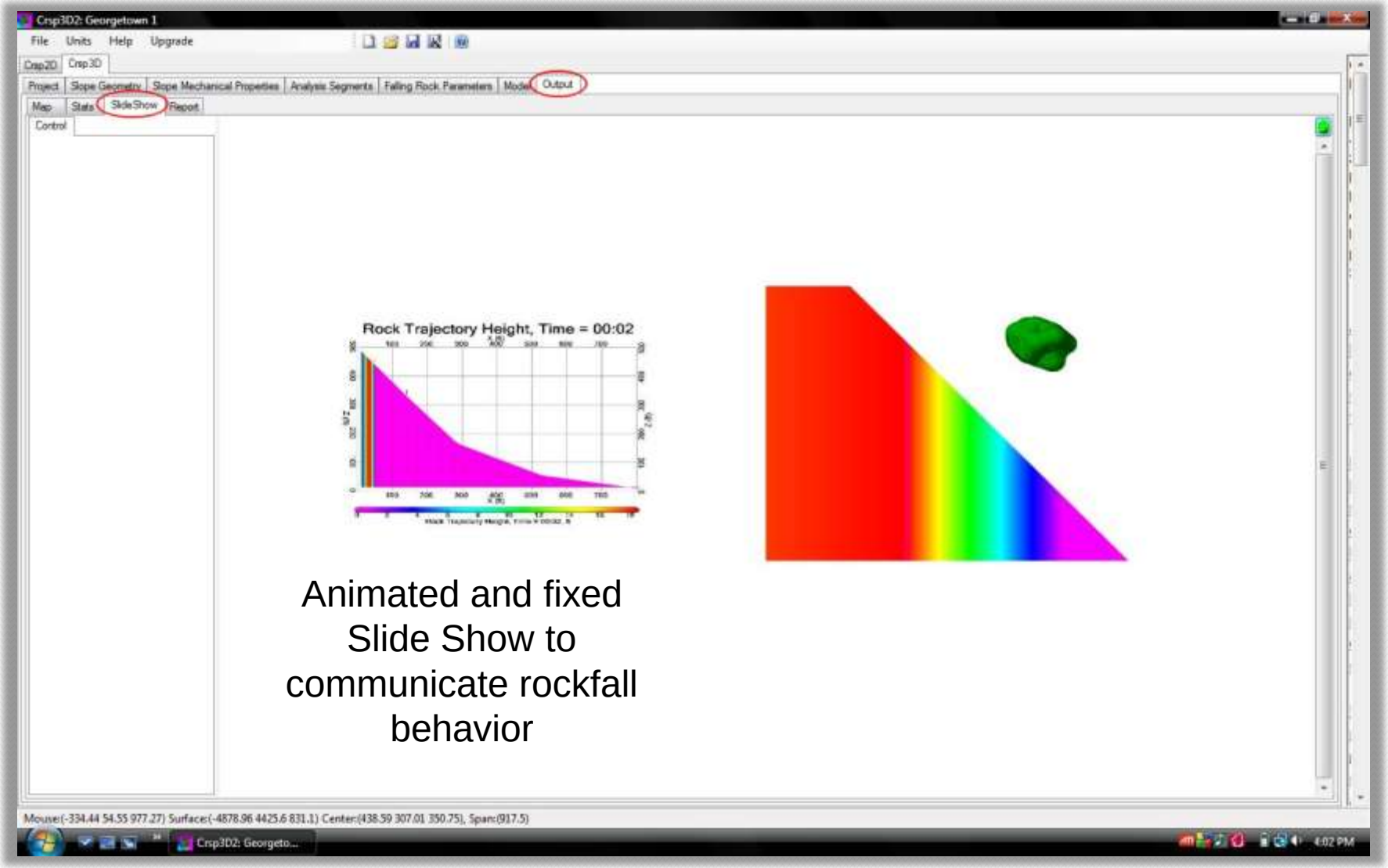


Model Output

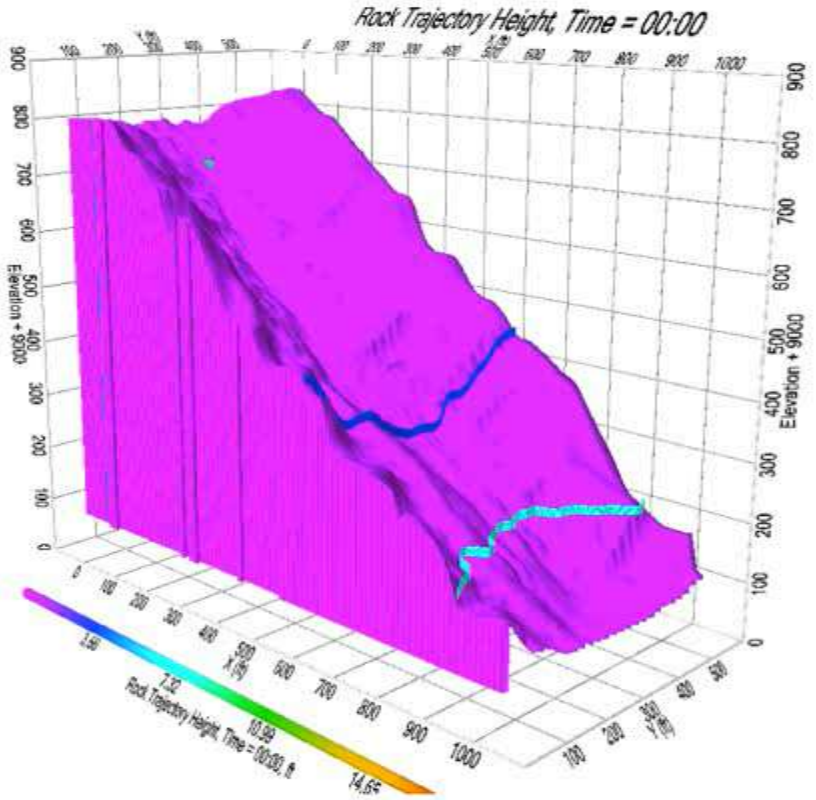


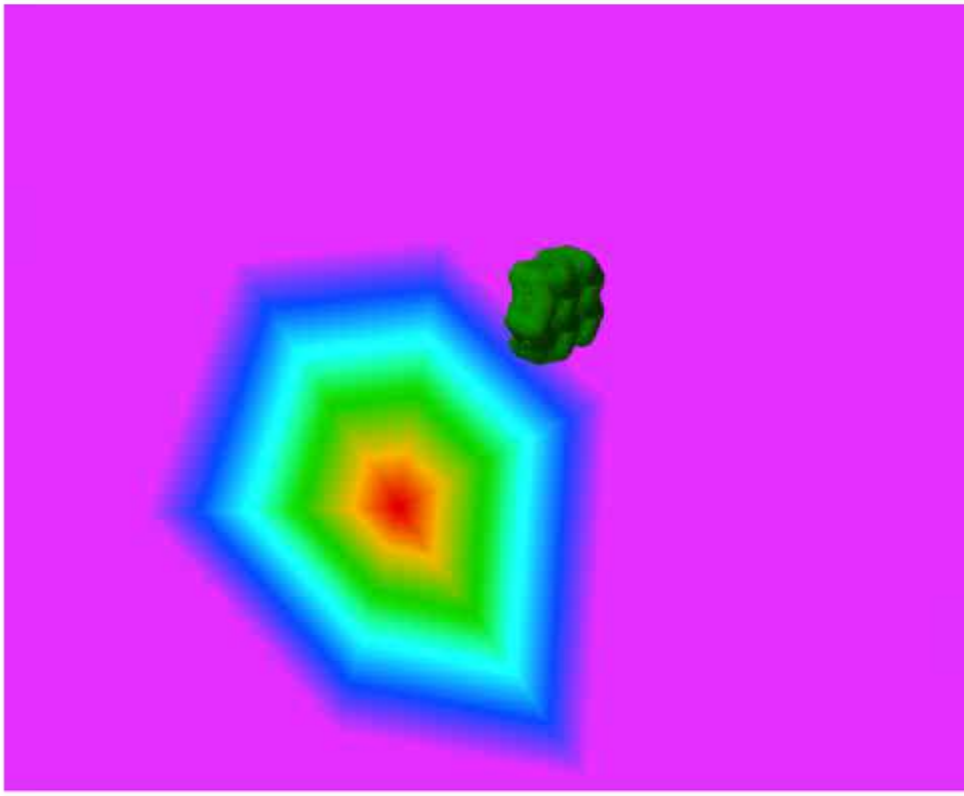
Analysis Pnt X (ft)	Diameter (ft)	Mass (lbm)	Vx (ft/s)	Vy (ft/s)	V (ft/s)	W (rad/s)	Height (ft)	KEv (ft-kips)	KEw (ft-kips)	KE (ft-kips)	Start X (ft)	Start Y (ft)	Stop X (ft)	Stop Y (ft)
513	4.6	8698	51.1	1.6	51.1	-22.1	3.3	353	140	493	3	332	577	21
513	4.2	6437	53.0	2.0	53.0	-25.6	2.4	281	114	395	2	332	601	21
513	3.4	3563	45.3	-4.4	45.5	-26.5	2.1	115	46	160	1	332	572	21
513	4.6	9110	51.7	5.0	51.9	-22.0	3.4	382	150	532	2	332	610	22
513	2.2	1000	32.5	7.2	33.3	-31.6	5.4	17	8	25	1	332	564	20
513	3.8	4854	52.6	1.2	52.6	-27.7	2.9	209	84	293	2	332	571	21
513	2.8	1819	51.9	-18.1	55.0	-38.2	2.2	85	31	116	1	332	579	20

Model Output



Animated and fixed Slide Show to communicate rockfall behavior


Rock Trajectory Height, Time = 00:00
Elevation + 90000
Elevation + 90000
Rock Trajectory Height, Time = 00:00, ft
1.46
7.32
10.99
14.65



Summary

1. CRSP 3D is nearing completion (June 2010).
2. Beta testing by rockfall panel.
3. The program should be available for free distribution once all testing is completed.