S.R. 11/15 Rock Slope Safety Improvement Project

Marysville, Pennsylvania

Project Team

Owner:

pennsylvania
DEPARTMENT OF TRANSPORTATION

District 8-0

Municipalities

EAST PENNSBORO TOWNSHIP · CUMBERLAND COUNTY, PA · EST. 1736 · INC. 1952

MARYSVILLE PA SESQUICENTENNIAL · 1866 · 2016 · 150 YEARS ALONG THE SUSQUEHANNA

Engineer

AEG
American Engineers Group

Contractor

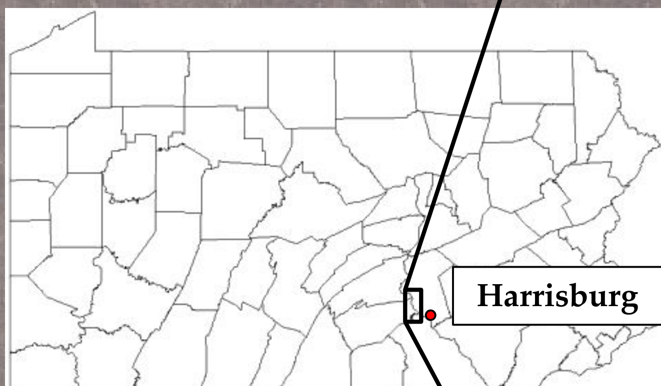
J.D. ECKMAN INC.
CONSTRUCTION
J.D.E.
BRIDGE HIGHWAY
EST. 1945

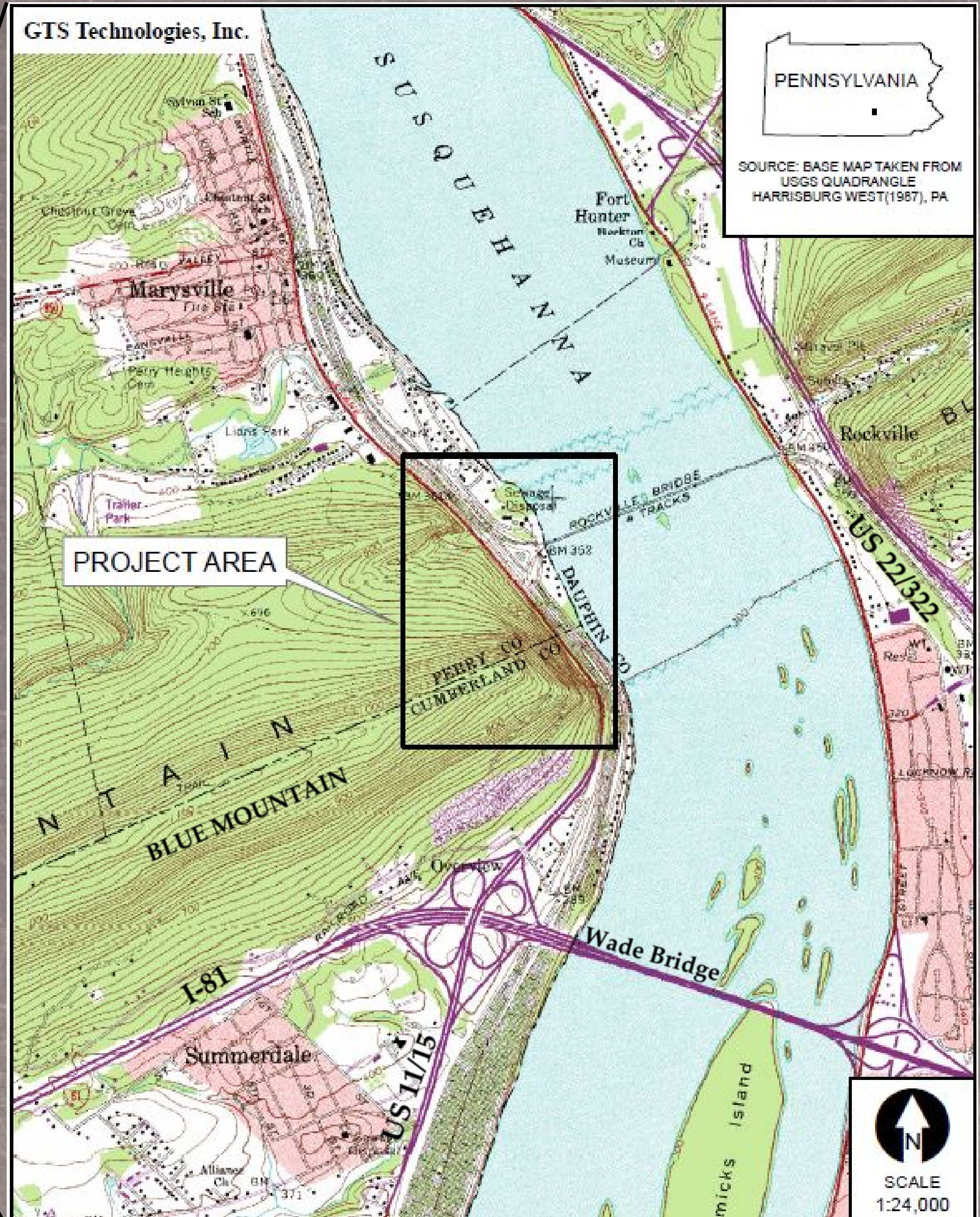
McCormick Taylor, Inc.
AWK Consulting Engineering, Inc.
ASC Group, Inc.

Outline

1. **Location and Description**
2. **Geologic Setting**
3. **Purpose and Need**
4. **Alternatives Analysis**
5. **Detour**
6. **Slope Access**
7. **Rock Slope Stabilization & Rockfall Protection Methods**

Project Location





Original Construction: 1938

Pre-Construction (2016)

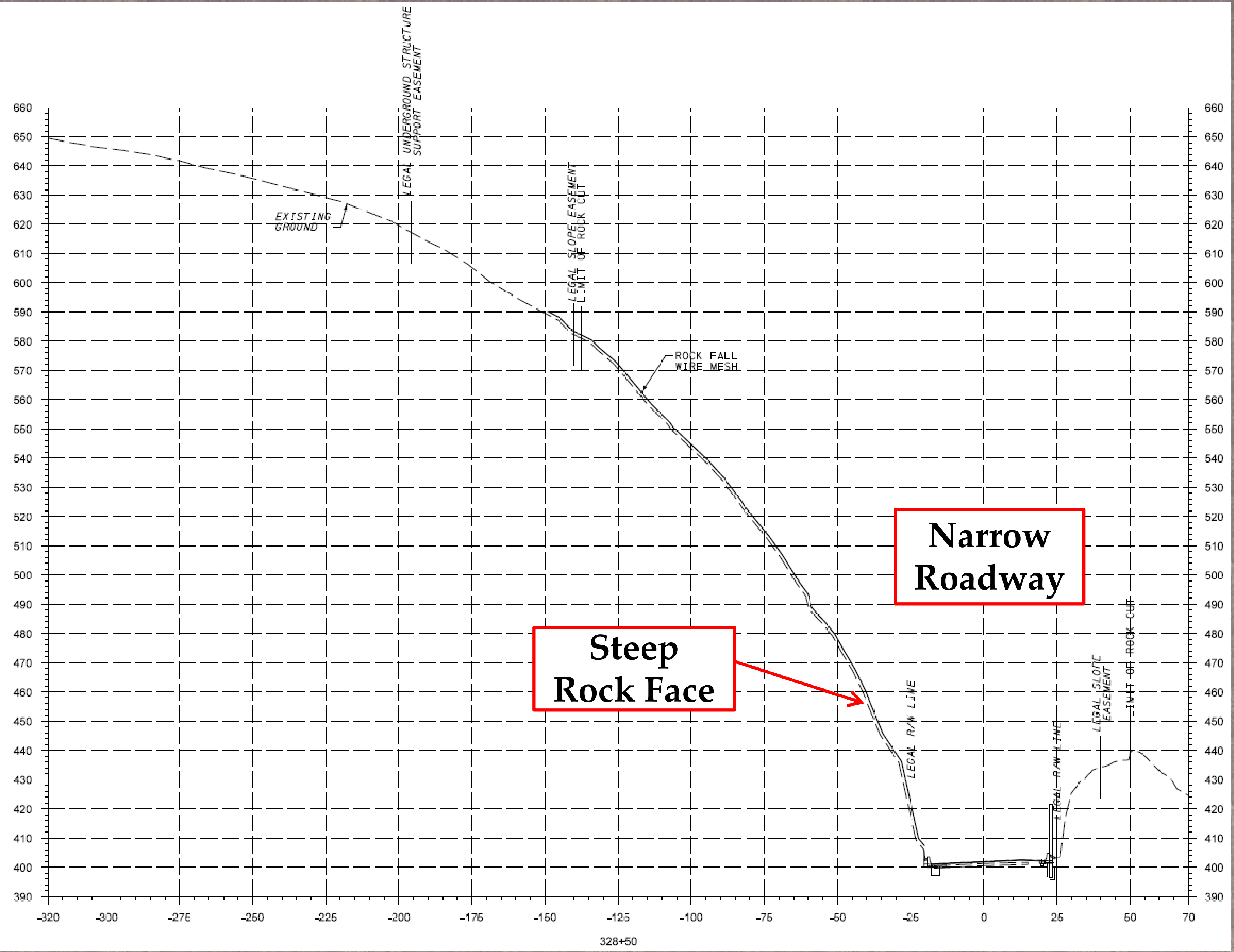
Original Construction: 1938

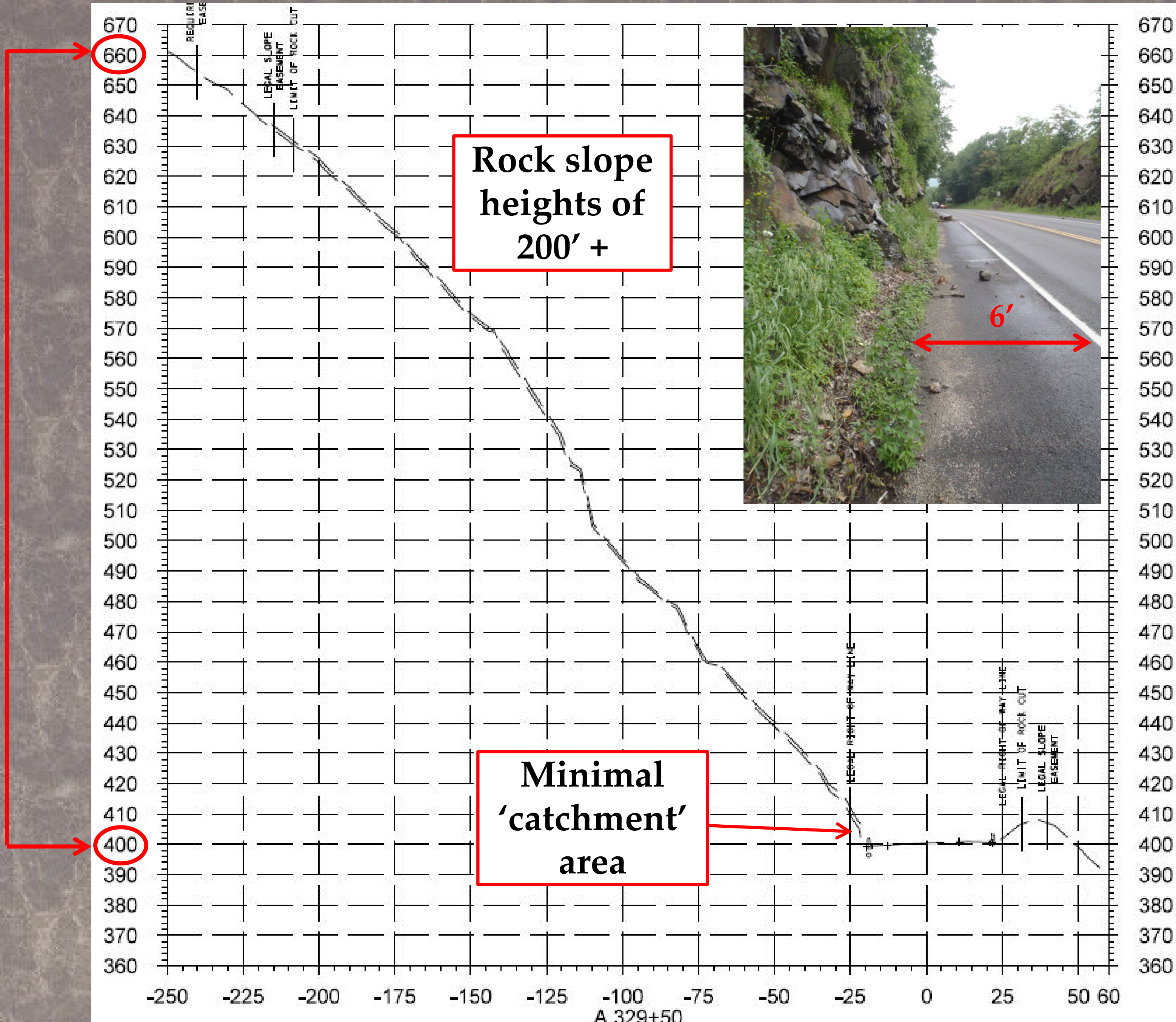
MOUNTAIN SLICED AWAY TO PROVIDE SAFER ROAD BETWEEN WORMLEYSBURG AND MARYSVILLE

This unusual photograph taken by a staff photographer of THE PATRIOT shows how the new West Shore road is being improved b through the end of a mountain. The Rockville Bridge over the Susquehanna can be seen at the extreme right, with the Blue Ridge Mo a background.

Pre-Construction (2016)

Typical Cross Sections





Rock slope heights of 200′ +
6′
Minimal ‘catchment’ area
LEGAL SLOPE EASEMENT
LIMIT OF ROCK CUT
LEGAL RIGHT OF WAY LINE
LEGAL RIGHT OF WAY LINE
LIMIT OF ROCK CUT
LEGAL SLOPE EASEMENT
670
660
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
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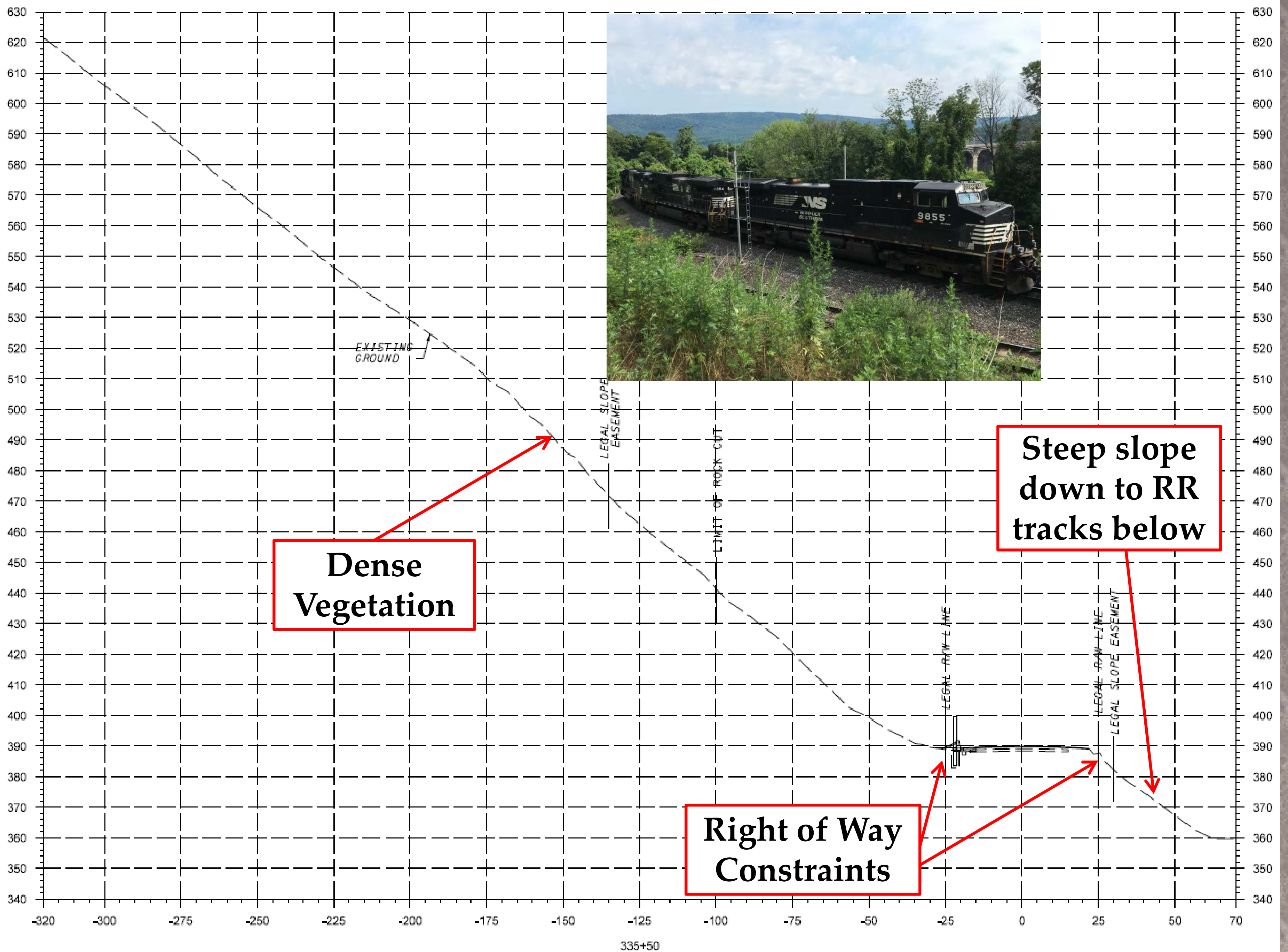
A 329+50



630
620
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470
460
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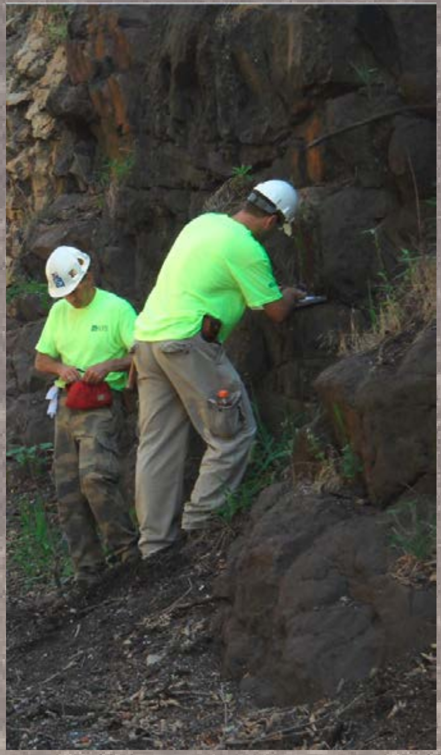
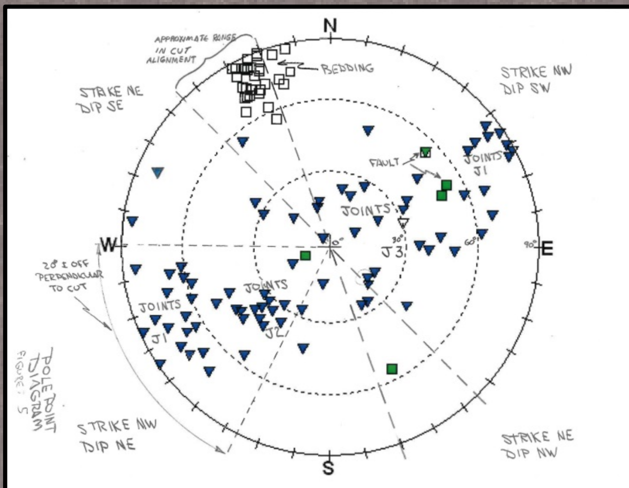
420
410
400
390
380
370
360
350
340
-320
-300
-275
-250
-225
-200
-175
-150
-125
-100
-75
-50
-25
0
25
50
70
335+50
EXISTING GROUND
LEGAL SLOPE EASEMENT
LIMIT OF ROCK CUT
LEGAL R/W LINE
LEGAL R/W LINE
LEGAL SLOPE EASEMENT
9855
Dense Vegetation
Steep slope down to RR tracks below
Right of Way Constraints

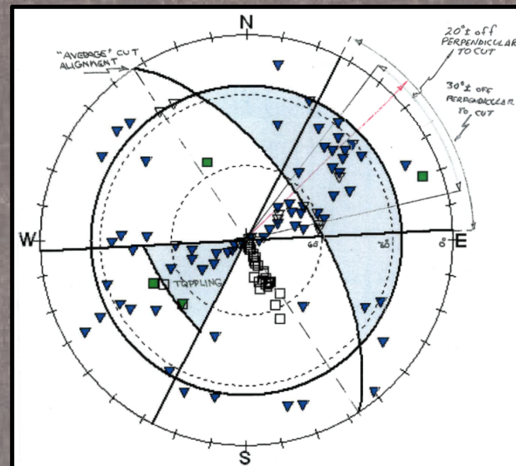
Geologic Setting

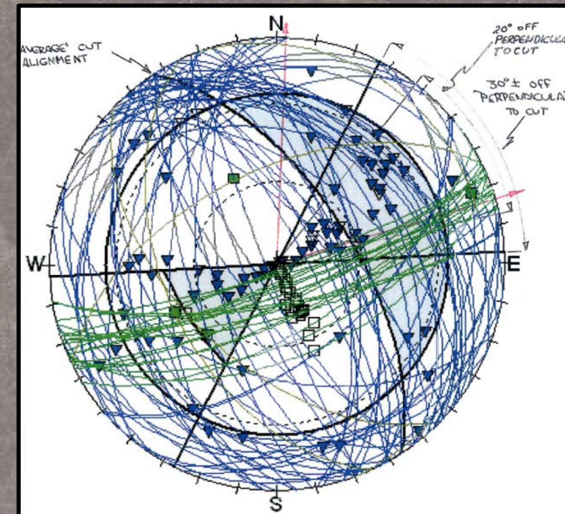
- Ridge and Valley Physiographic Province
- West-Southwest to East-Northeast fold axes
- Sandstone, Siltstone, Shale, and Conglomerate
- Bedrock strikes perpendicular to roadway
- Bedrock generally dips steeply to the Southeast, on the South limb of the Cove Syncline



Stereonet Analysis







<u>Conclusions</u>

- **Probability of rock failures along the primary joint set plane, and along the wedges formed by the intersection of the bedding planes and the joint set, for primary east-facing slopes**

- **Probability of toppling failures to occur locally**

Basically, a confirmation of what we already knew…

Rockfall Hazard

Project Purpose and Need

PROBLEM

- **Rockfall poses a safety hazard to motorists**
- **Constant maintenance to clear rockfall debris**

GOAL

- **Control or contain falling rocks to reduce safety hazard**
- **Determine the most practical design while considering cost and impacts to the public**

Alternatives Analysis

Determination of Treatment Limits

Define existing rock cut limits

- **Field mapping**
- **Topographic maps/surveys**
- **LiDAR (DCNR - PAMAP)**
- **Aerial Photography**

Limited access to slopes with live traffic below, and locally dense vegetation

Alternatives Analysis

Four rock slopes identified that needed treatment

Alternatives Analysis

WHAT ARE THE SITE CONSTRAINTS?

The existing site conditions played a significant role in evaluating what means and methods were practical.

1. Access to slopes
2. Proximity of slopes to roadway (narrow shoulders)
3. Height of slopes
4. Limited right-of-way
5. Proximity to active Norfolk Southern Railroad
6. Overhead utilities
7. Narrow work zone
8. Heavily travelled route

Alternatives Analysis

WHAT WERE THE OPTIONS?

1. ~~Do Nothing~~
2. ~~Widen the cuts on one or both sides~~
3. ~~Widen the roadway on the downslope side~~
4. Vegetation removal and rock scaling
5. Wire Mesh systems
6. Rockfall fences
7. Other slope stabilization methods
   (i.e. rock bolting, rock overhang support)

This type of work is only performed by a handful of qualified contracting teams from across the nation.

Project Detour

Several options including temporary stoppages, as well as alternating light-controlled traffic, were investigated.

However, a road closure was essential for protection of the workers and the public during completion of the hazardous work.

Project Detour

Road closure meant high impact for nearby communities and the region.

Economic and emergency management considerations were evaluated and discussed in great detail with elected officials, business leaders, school officials, and emergency response providers.

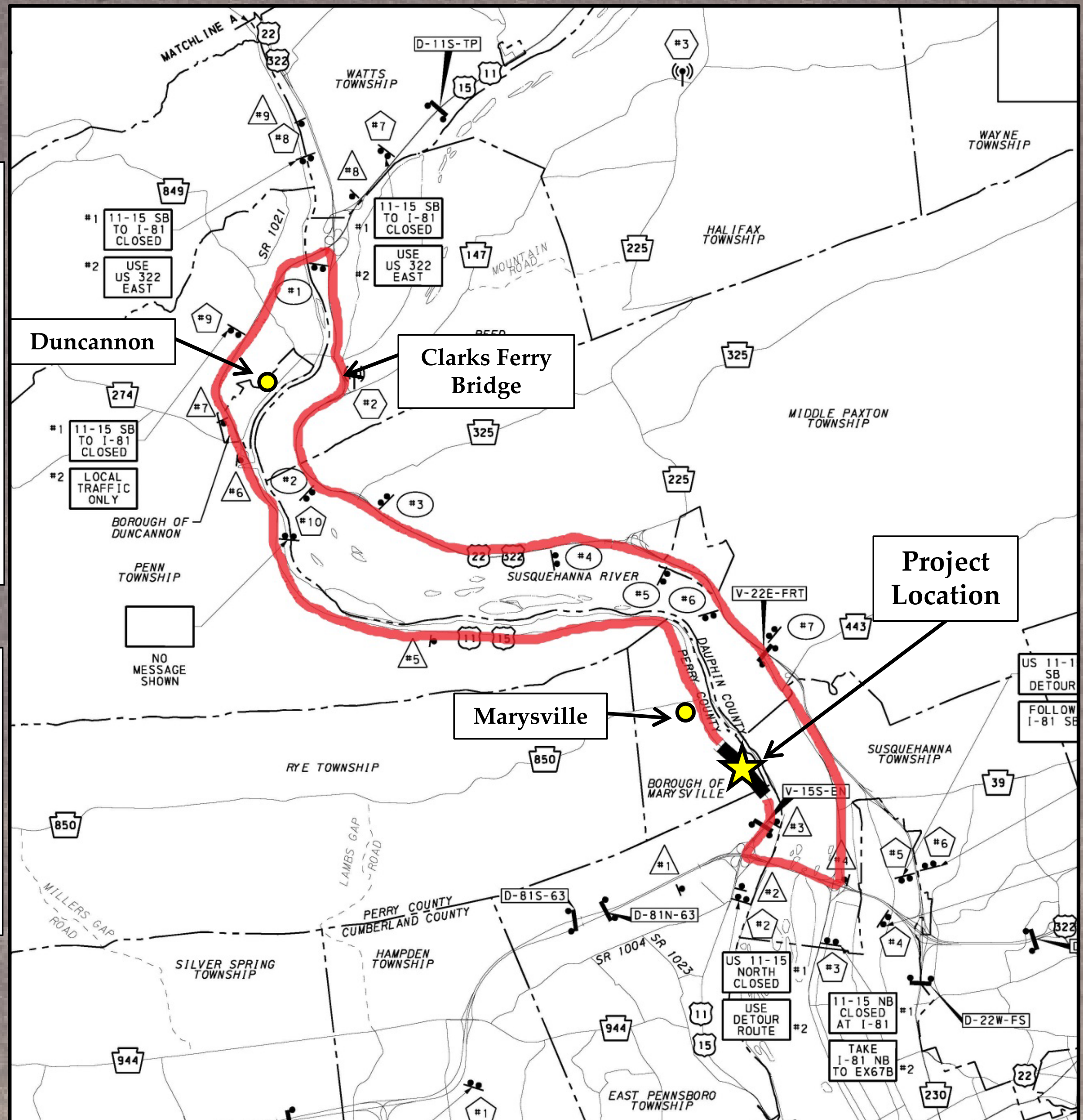
Traffic management and public outreach were critical to the project's success.

- **Media briefings**
- **511PA**
- **Social media**
- **Truck alert radios**
- **Variable message boards**

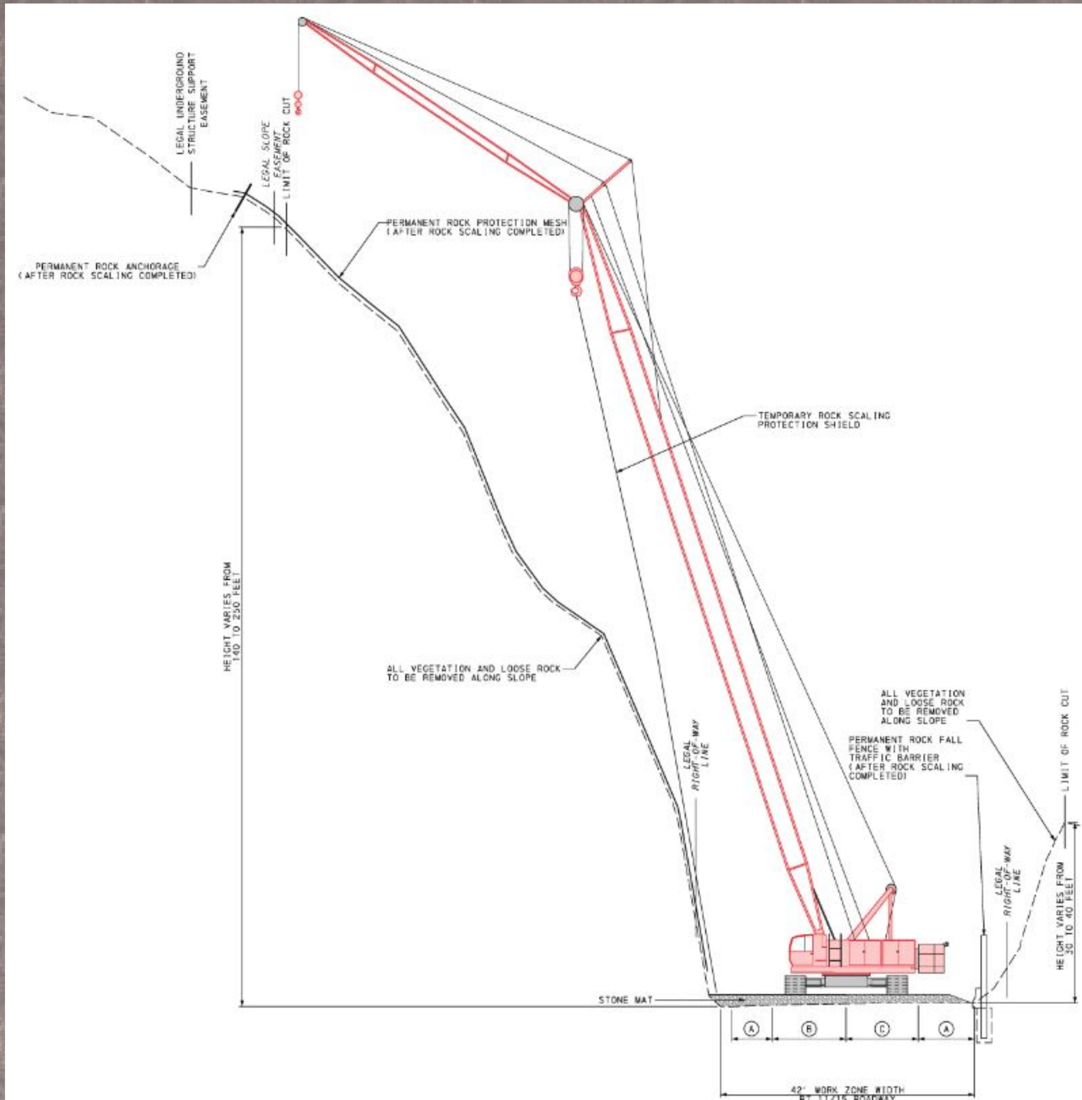
Project Detour

Numerous early action safety improvements were made to the local and regional roadway system to accommodate the primary 27-mile detour, 4 incident management routes, and a local EMS access route.

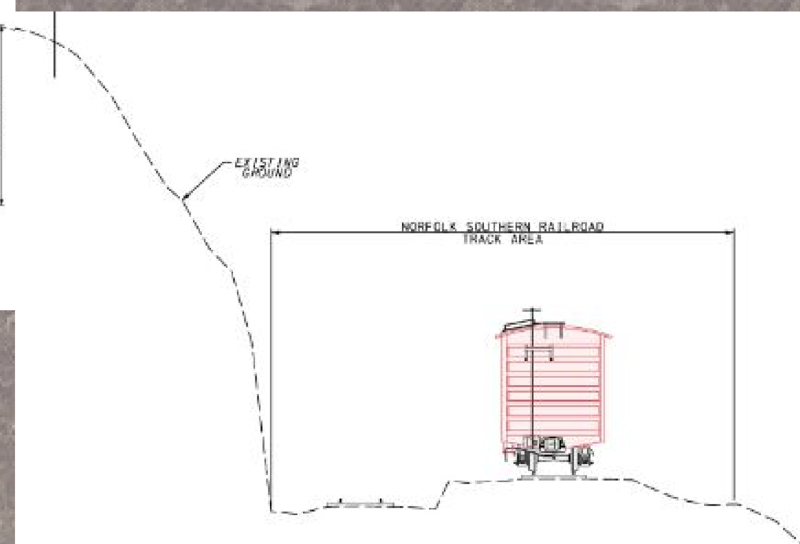
- Various road repairs
- New signs and guide rail
- Speed display signs
- Added pavement markings
- Increased police presence
- Contraflow gates on 22/322



Slope Access



Other than the primary danger of falling rocks and debris, another reason for the detour was simply that the equipment required took up almost the entire width of the roadway when in operation.



Work zone width = 42 ft.

Slope Access

A 200-ton crane was needed not only to reach 200 feet up, but also to extend a significant distance horizontally away from the roadway to reach top of slope.

The roadway was covered with a 24″ gravel mat for protection from the weight of the crane and from falling rocks and debris.

Rockfall Protection Measures

- Rock Scaling (vegetation clearing)
- Rock Overhang Support
- Anchored Wire Mesh (Active system)
- Draped Wire Mesh (Passive system)
- Rockfall Fence

For many of these activities, a temporary shielding system was required.

- Significant slope heights
- Narrow work zone
- Proximity to active railroad
- Protection of workers

Hi-Tech Rockfall Construction Inc. performed the majority of work on the slopes, including rock scaling, anchor drilling, and mesh installation. Kane GeoTech, Inc. provided design and oversight for the wire mesh systems, and provided engineering support during work on the slopes.

Temporary Shielding

Designed to contain falling rock and debris, especially during rock scaling

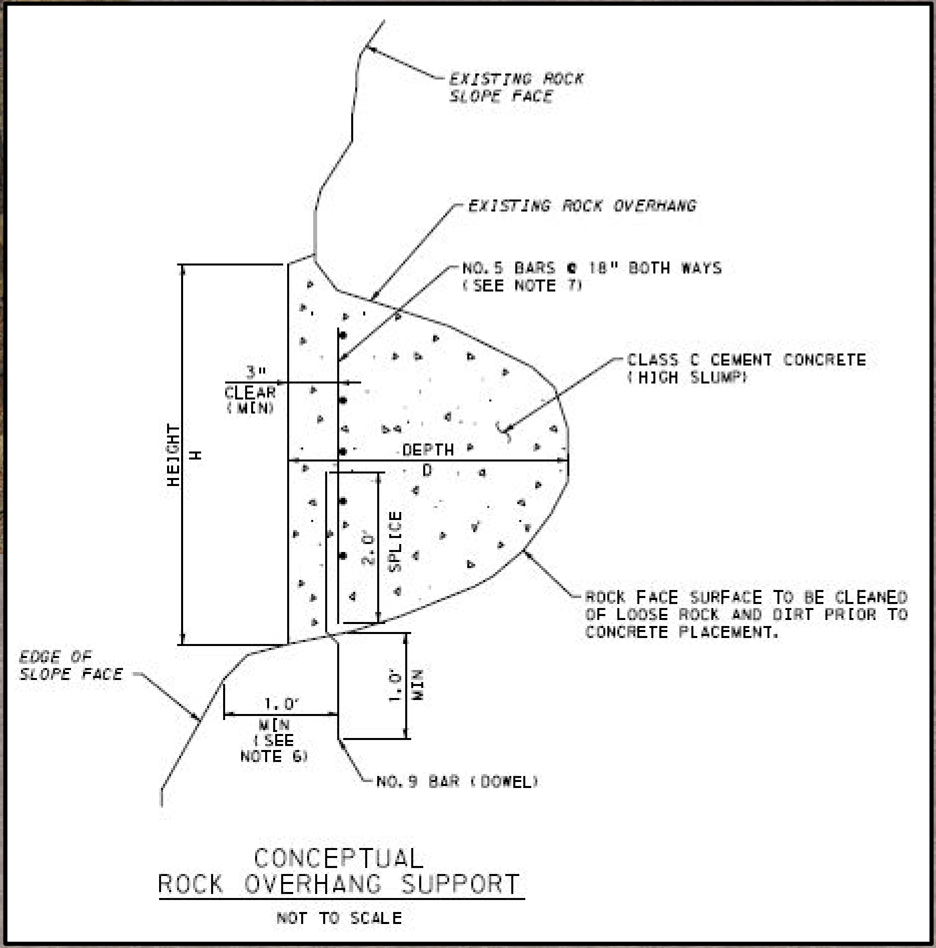
Analysis required to verify that crane and shield had capacity to withstand energy from falling rock

Rock Scaling

- The purpose of rock scaling is to remove loose or unstable rock to create a uniform surface, typically prior to the placement of wire mesh
- The removal of vegetation is usually required prior to performing effective rock scaling.

Rock Scaling

Rock Overhang Support



Used in areas where rock scaling is not appropriate, but support is required.

Rock Overhang Support

Rock Overhang Support

Before

After

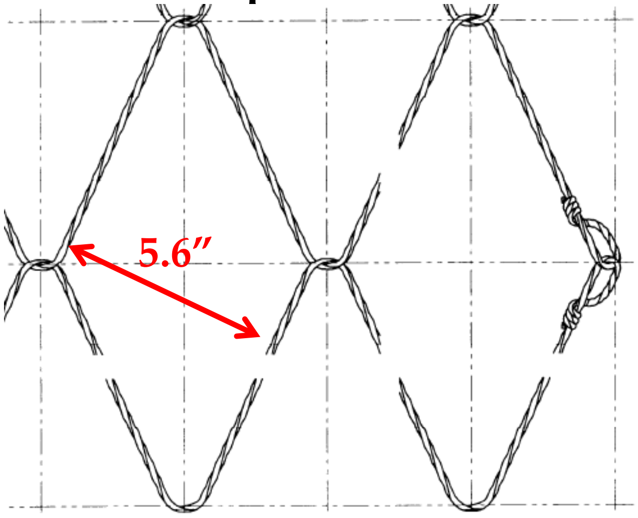
Wire Mesh

Two types of proprietary wire mesh systems were specified for use on this project based on strength and durability.

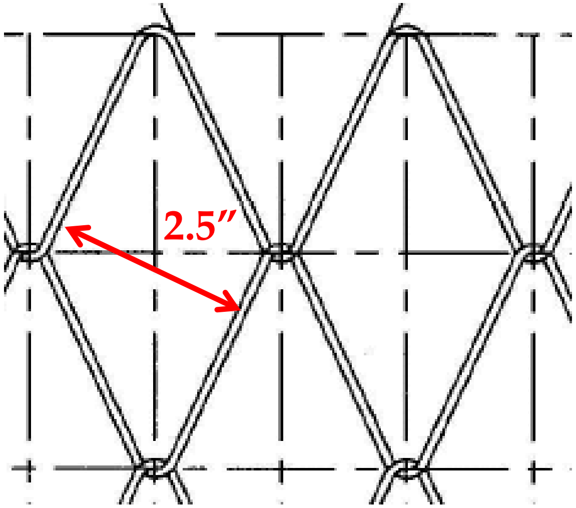
Spider®: Used to 'lock in' larger rock blocks that remain on slope

Tecco®: Used as a drape to funnel smaller rocks down slope

Spider®



Tecco®



Wire Mesh

The Tecco® mesh was used as a draped mesh, which is anchored at the top of the slope.

The draped mesh was used as the treatment option on the highest slopes and covered a large, pre-determined area.

Wire Mesh

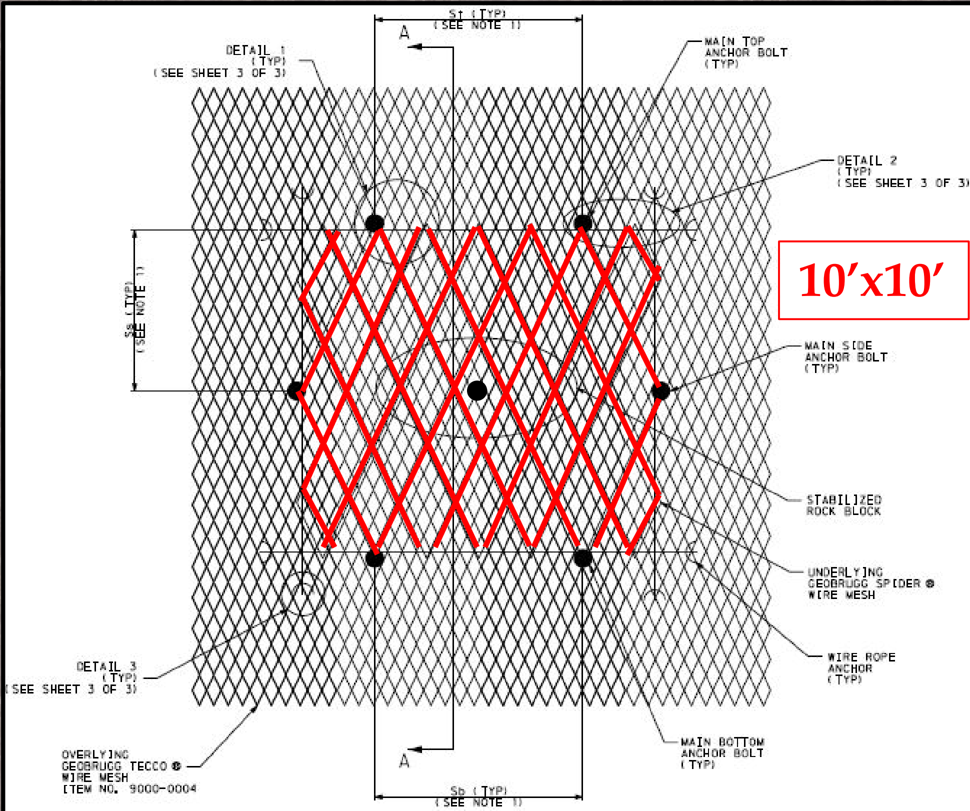
- **Prior to the placement of the draped Tecco® mesh, the slope conditions were evaluated.**

- **If 'suspect' areas were identified, the Spider® mesh system was implemented.**

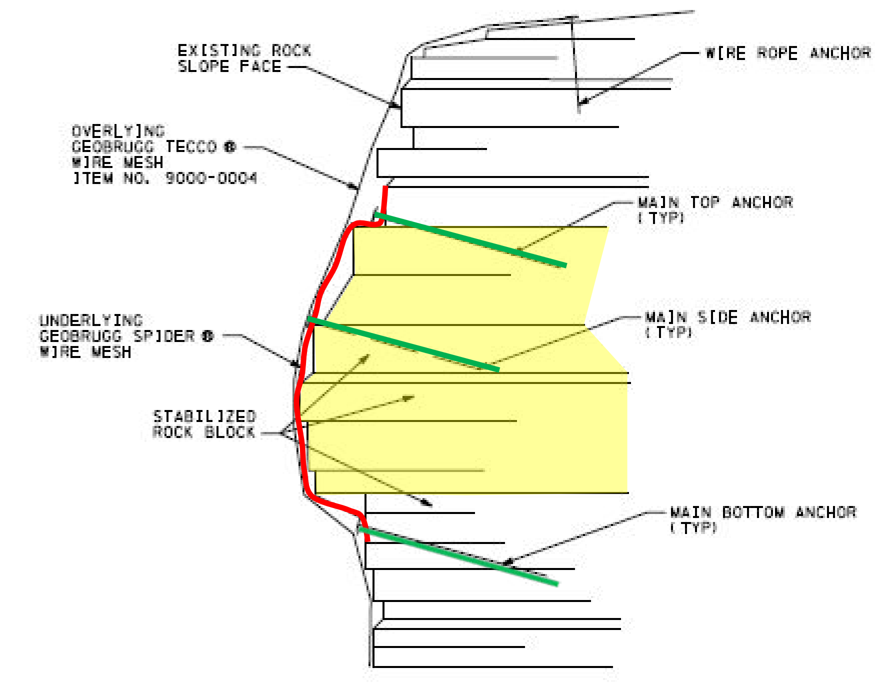
- **The Contractor and AEG agreed on locations where the Spider® mesh was appropriate.**

Spider® Mesh

The Spider® mesh is secured to the slope face by a pattern of rock anchor bolts. A program called Ruvolum was used to determine anchor bolt spacing with separate calculations to determine the anchor embedment depths.



WIRE MESH FACING
NOT TO SCALE

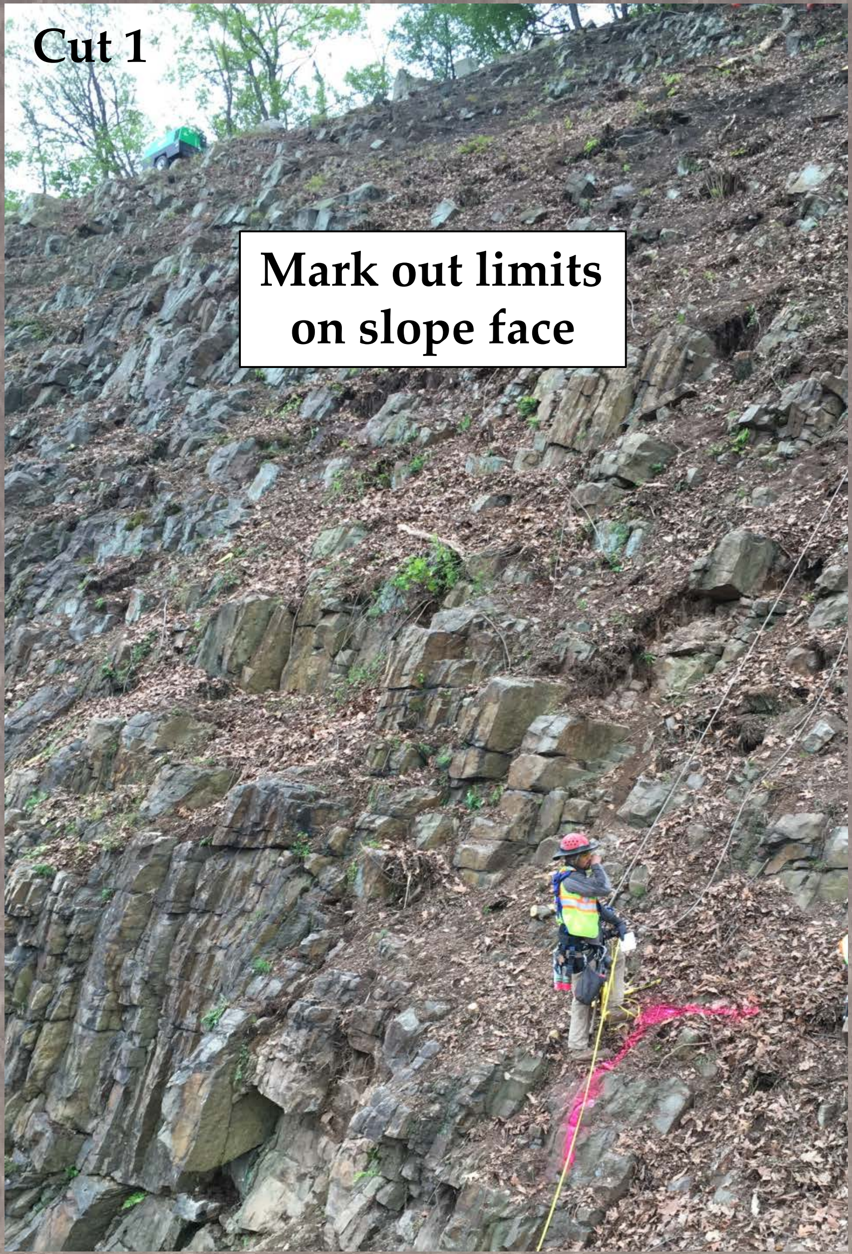


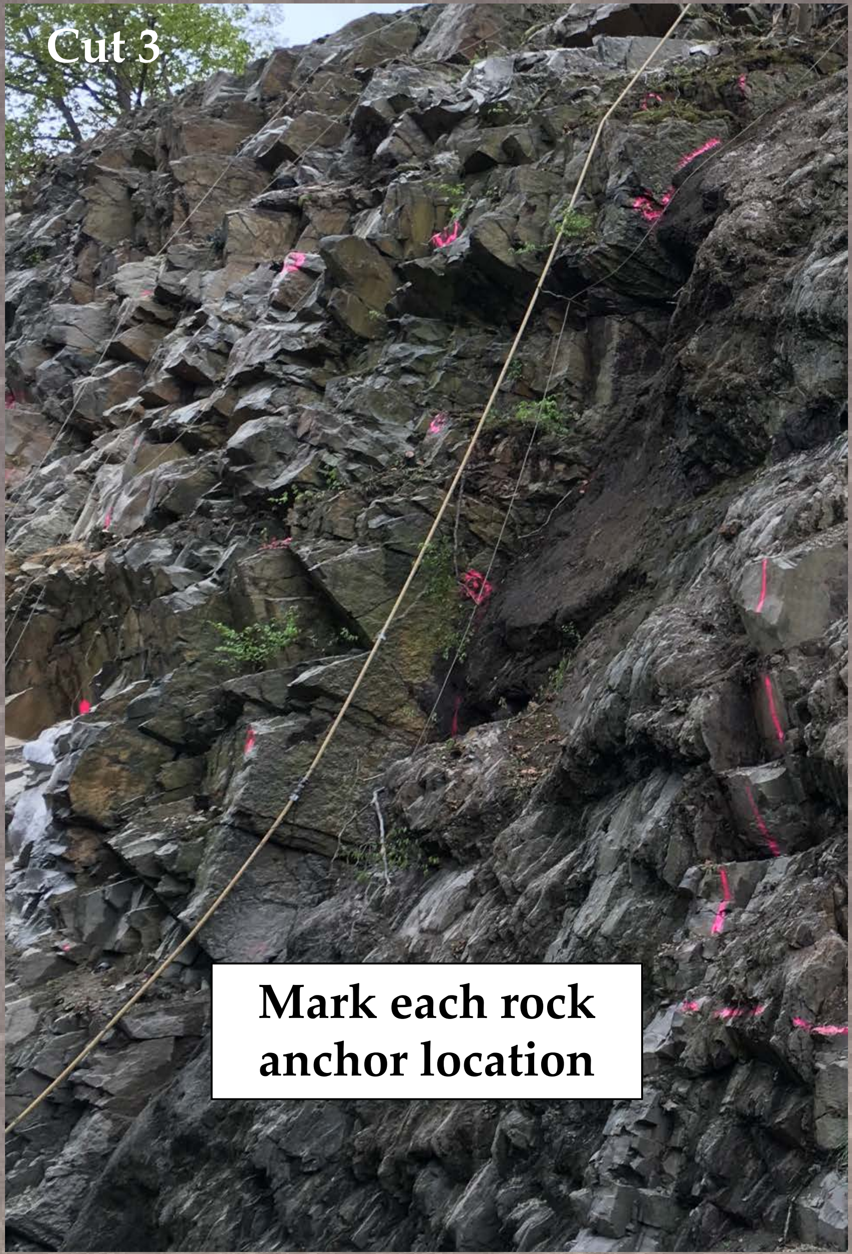
SECTION A-A

Spider® Mesh

Determination of Spider® mesh locations after rock scaling.

Spider® Mesh


Cut 1
Mark out limits on slope face

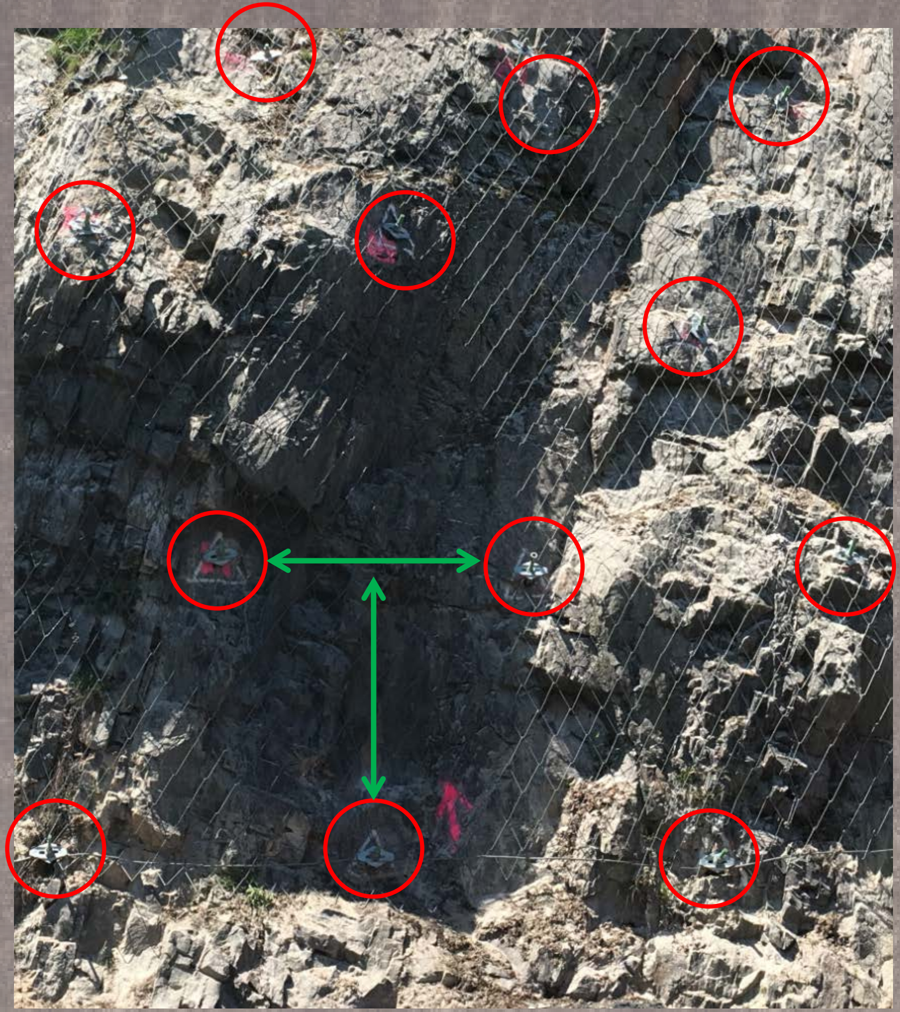

Cut 3
Mark each rock anchor location

Drilling for Spider® Mesh

Drill Rig

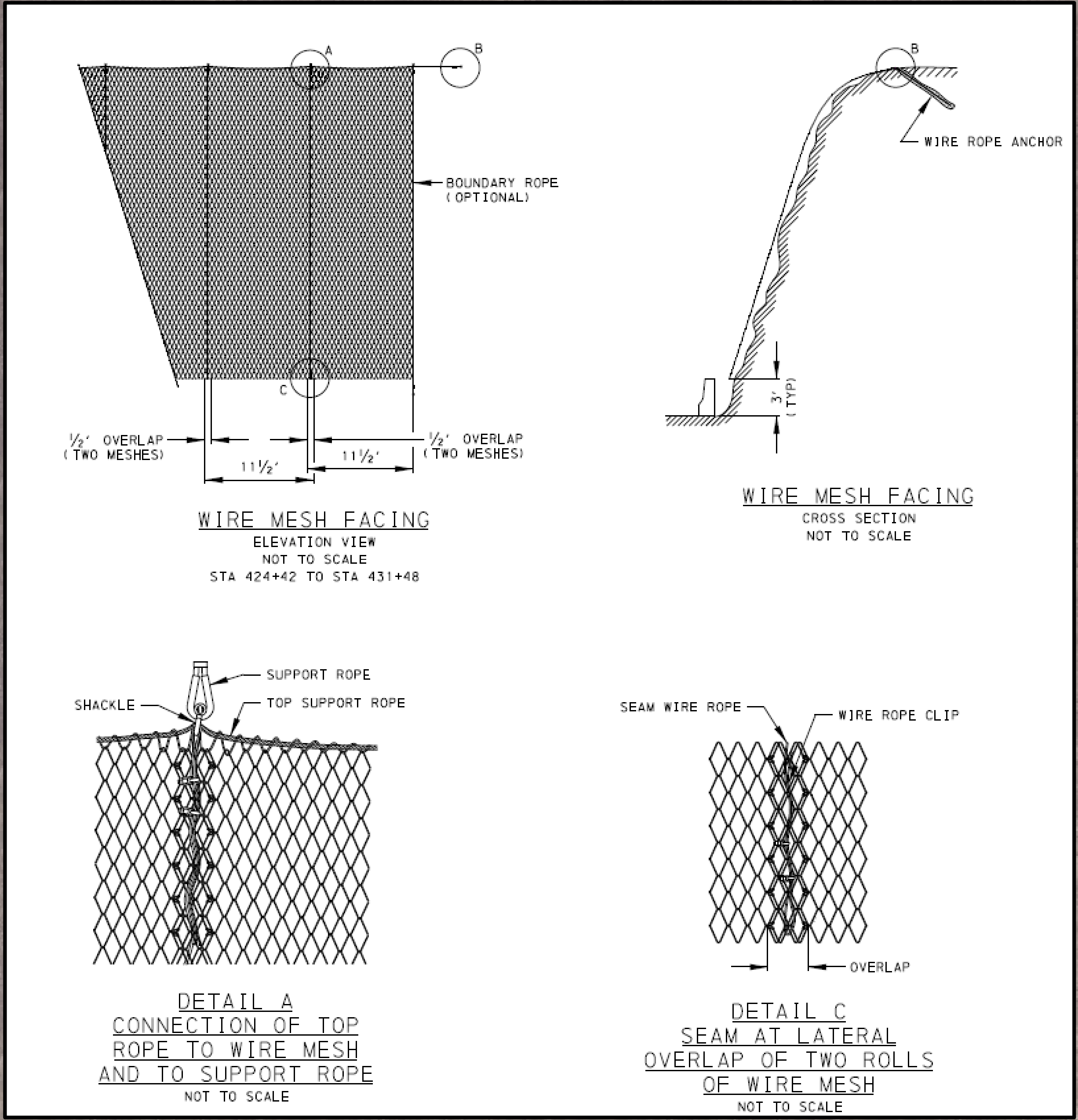
Spider® Mesh

Installed



Tecco® Mesh

Following the drilling and installation of the Spider® mesh, it was time to install the draped Tecco® mesh.



Tecco® Mesh

The Contractor decided that using a helicopter for installation was more efficient than the crane based on:

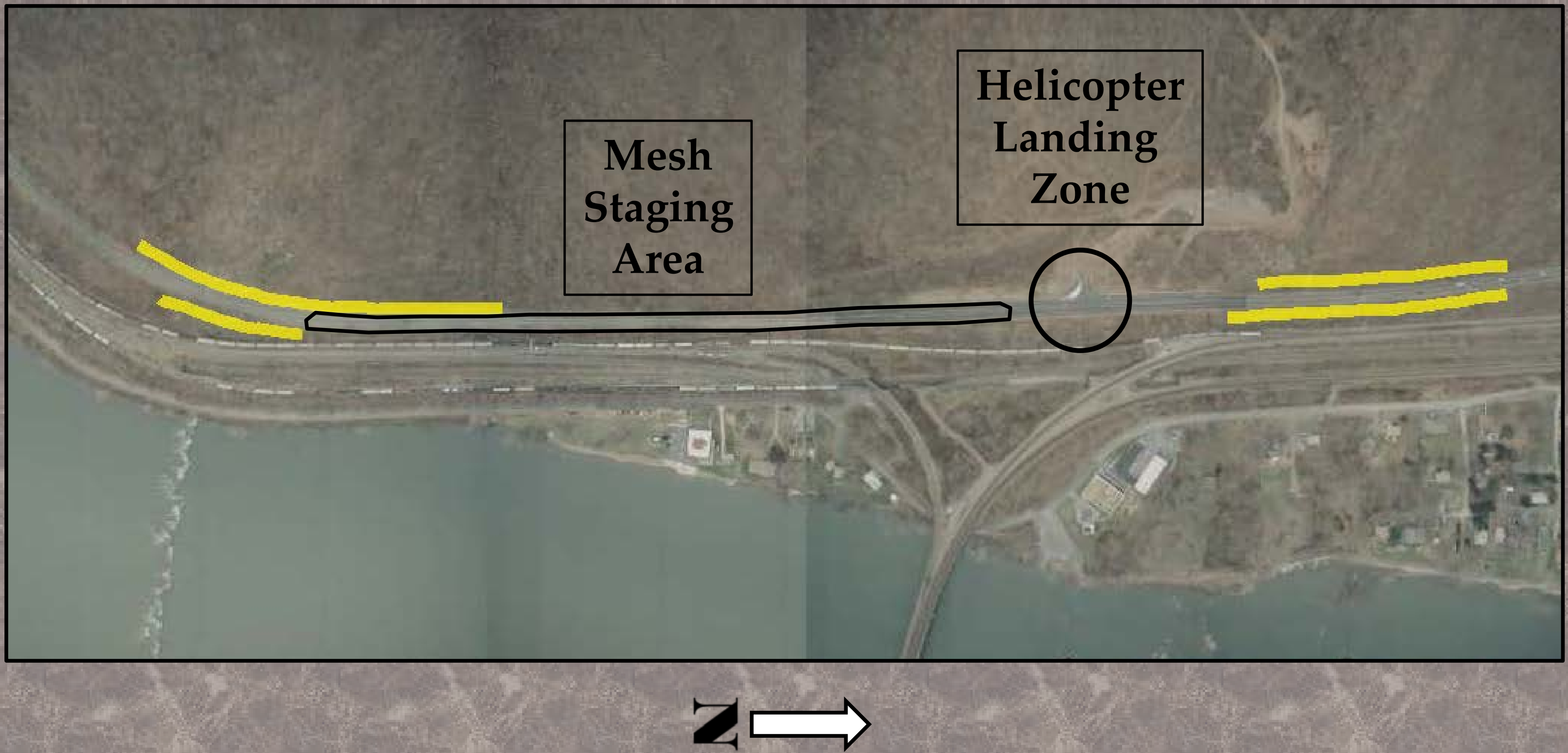
- Quantity of mesh rolls that needed to be placed
- The heights that needed to be reached

A helicopter landing zone was designated within the project area.

The mesh was first prepped on the ground and staged in long sections.

On the day of installation, the helicopter hoisted the unfurled rolls and delivered them to the crews that awaited on the slope.

Tecco® Mesh



Tecco® Mesh

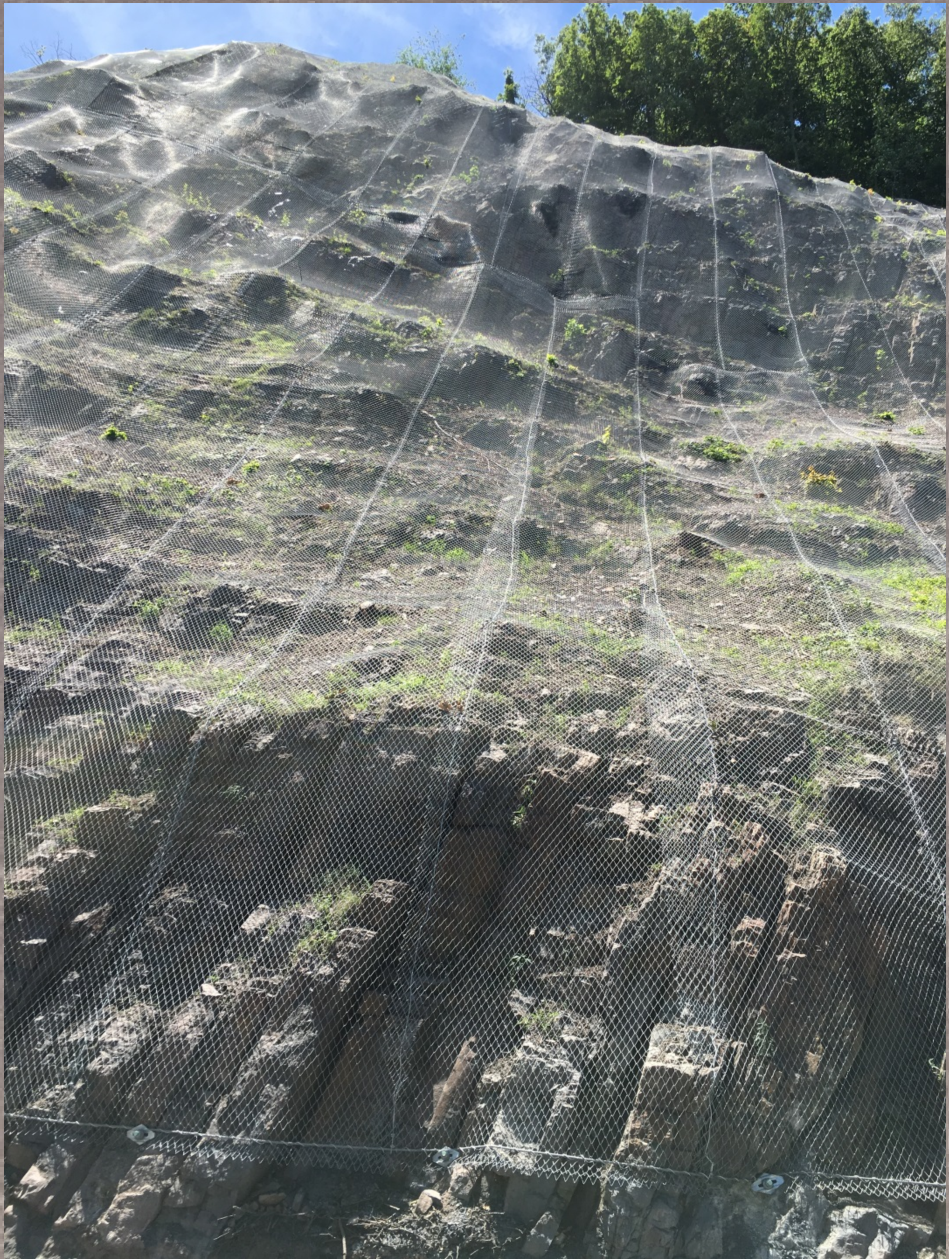
Installation

Tecco® Mesh

Installation

Tecco® Mesh

Installed



Tecco® Mesh

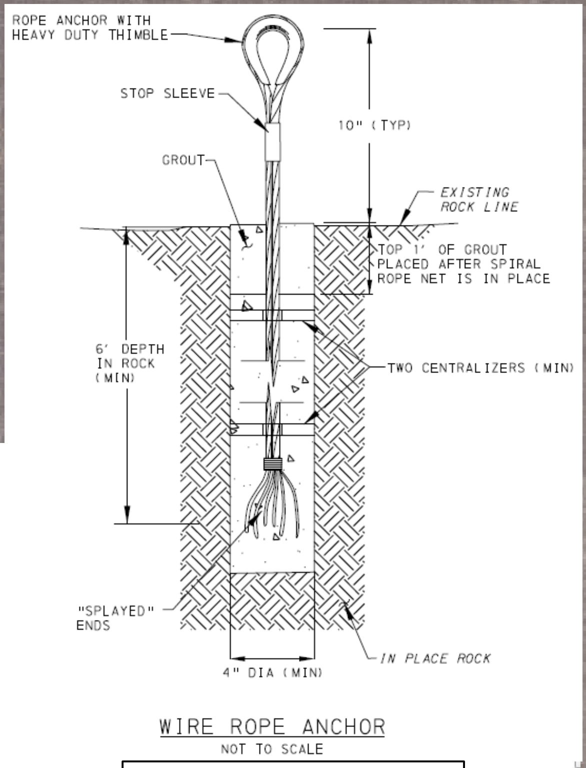
Installed

Mesh Anchors

The mesh systems utilized two types of anchors.

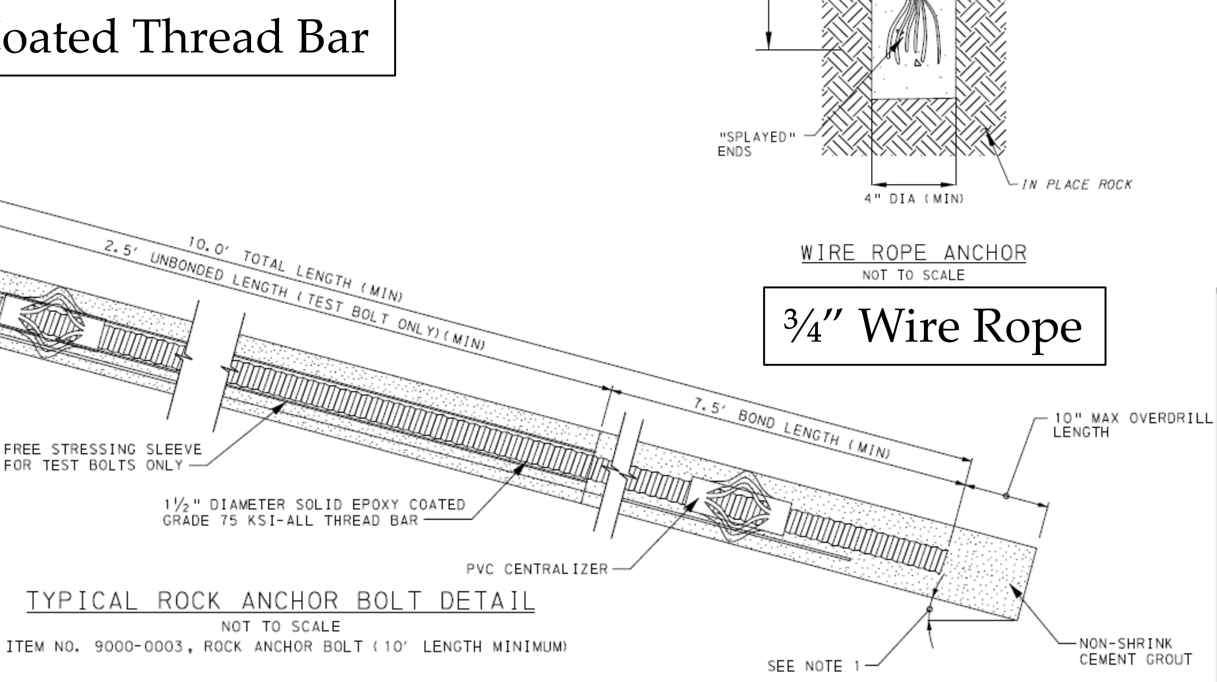
- **Wire Rope Anchors allow a support cable to be secured through a thimble**

- **Anchor Bolts are fastened with a Spike Plate to allow the mesh to be held against the slope face**



¾″ Wire Rope

1-⅜″ Epoxy Coated Thread Bar



Mesh Anchors

Wire Rope Anchor
with Support Rope

Rock Anchor Bolt
with Spike Plate

Mesh Anchors

Rock Anchor Bolts

Tecco mesh
132 rock anchor bolts ⇨ 2,230 LF

Spider mesh
391 rock anchor bolts ⇨ 3,774 LF

6,004 LF

Wire Rope Anchors

Tecco mesh
21 wire rope anchors ⇨ 210 LF

Spider mesh
56 wire rope anchors ⇨ 336 LF

546 LF

Roughly 1.25 miles of drilling into rock face!

Mesh Anchor Testing

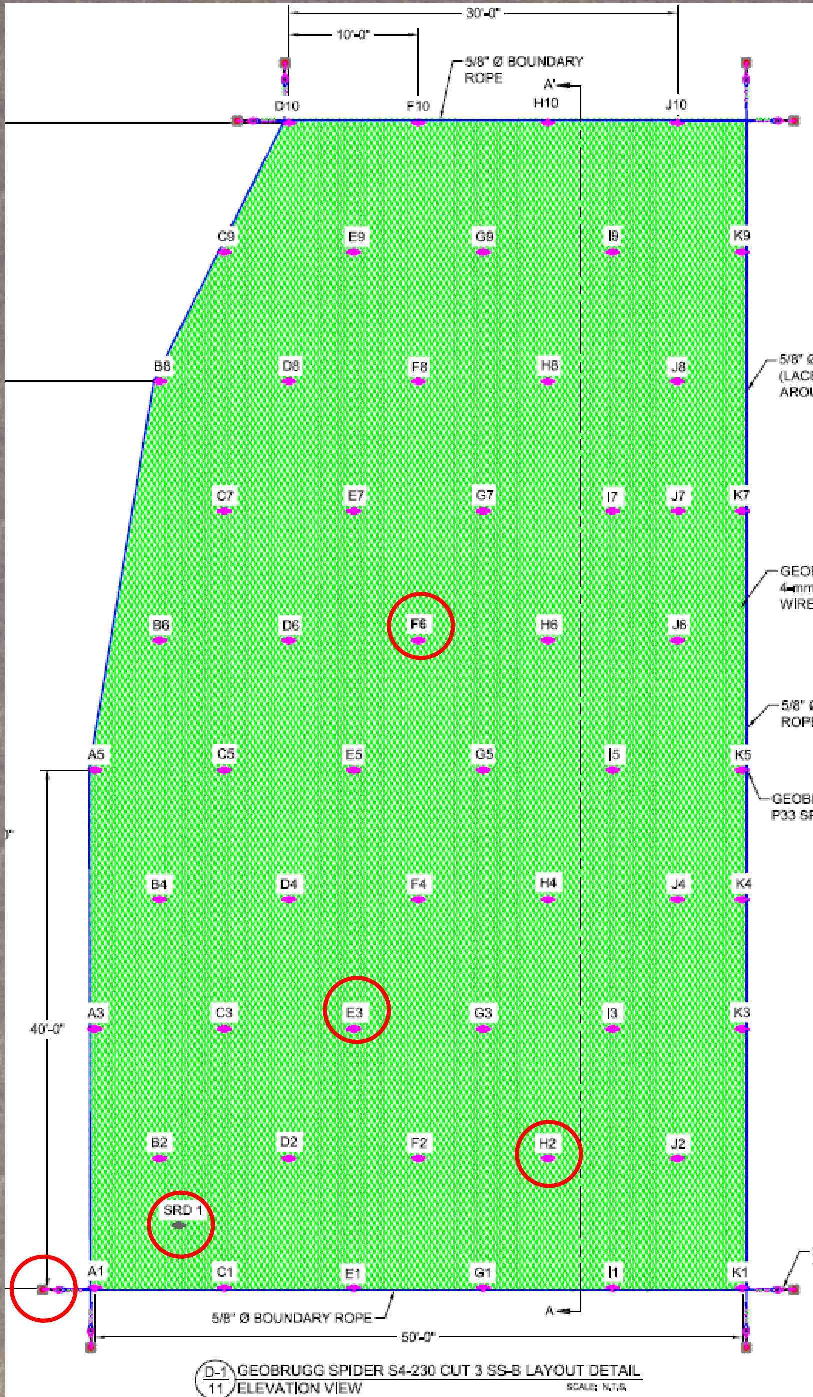
The specifications indicated that a certain number of each type of anchor must be tested to ensure that the bond strength was being attained so that the systems could support the anticipated loads.

Photo courtesy of Scarptec, Inc.

Hydraulic Jacking System

Photo courtesy of Scarptec, Inc.

Pressure Gauge

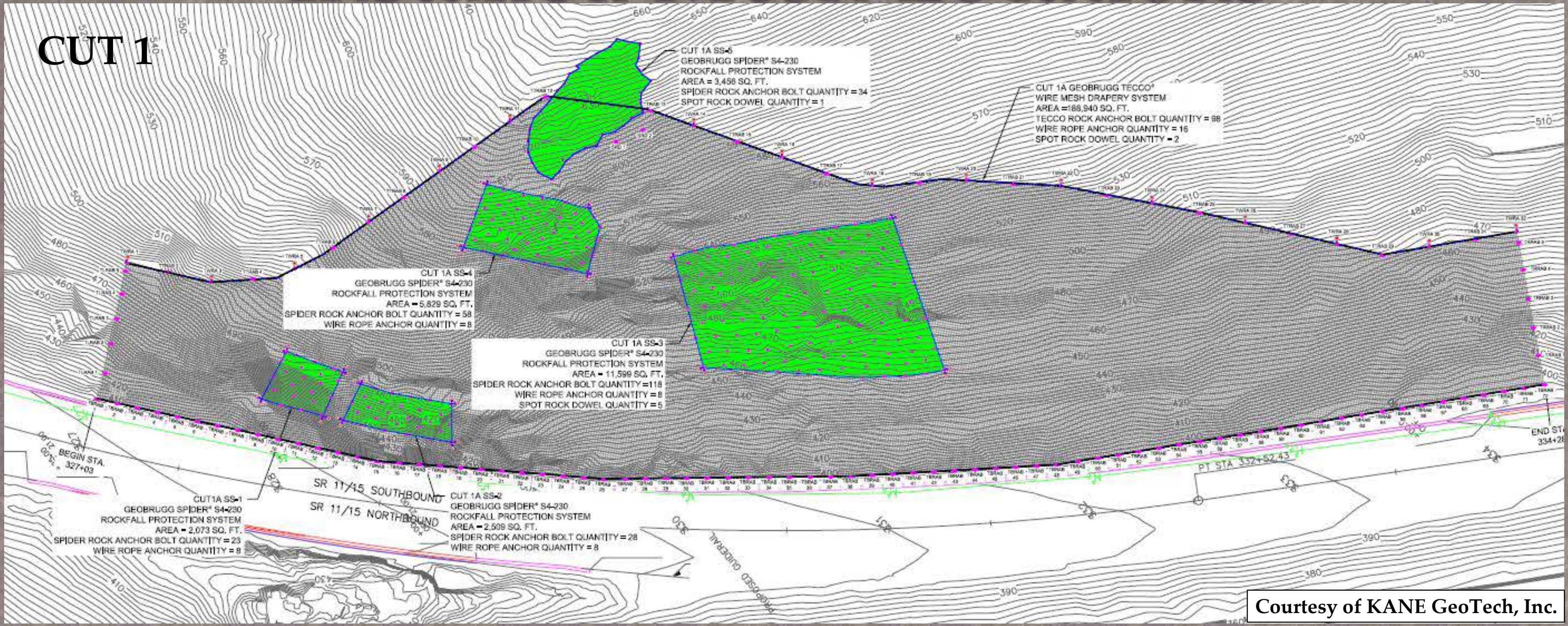


Mesh Anchor Testing

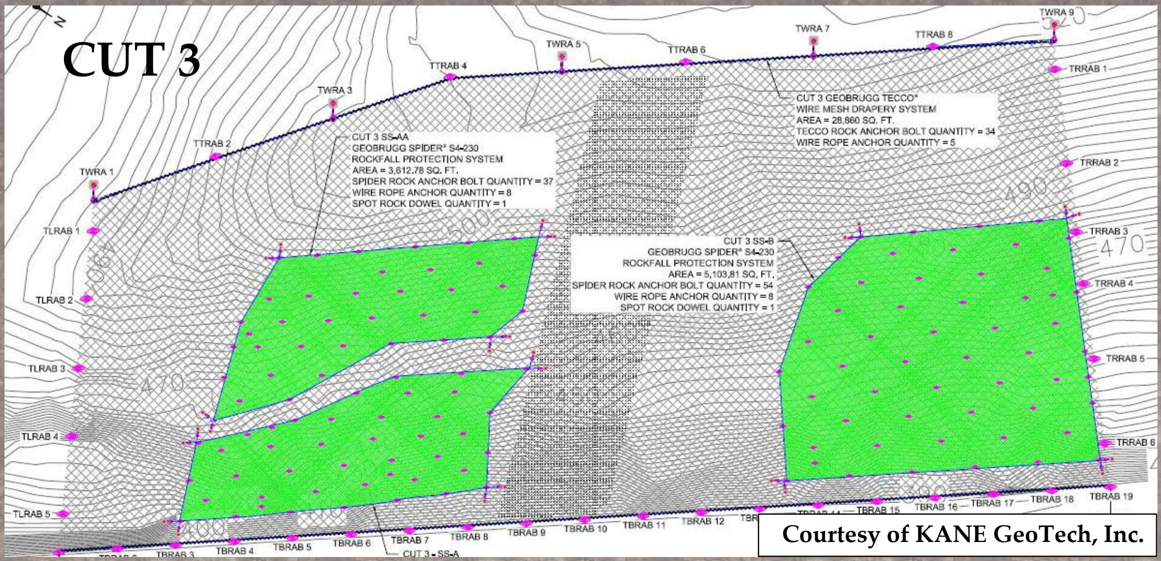
CUT 3 SS-B ANCHOR TEST SCHEDULE			
ANCHOR ID	TEST TYPE	MAXIMUM TEST LOAD (KIPS)	CREEP (INCHES)
E3	PERFORMANCE	88	0.079
F6	PROOF	88	N/A
H2	PROOF	88	0.035
SRD 1	PROOF	88	N/A
SRD 1	PERFORMANCE	88	0.036
WRA R1	PROOF	45	N/A
SACRIFICIAL*	PERFORMANCE	88	0.059
*NOTE: SACRIFICIAL ANCHOR ONLY USED FOR GROUT SOCK TESTING.			

Courtesy of KANE GeoTech, Inc.

Installed Mesh Locations



Cut 1
Spider: 25,466 ft^2
Tecco: 188,940 ft^2



Cut 3
Spider: 12,272 ft^2
Tecco: 28,860 ft^2

Rockfall Fence

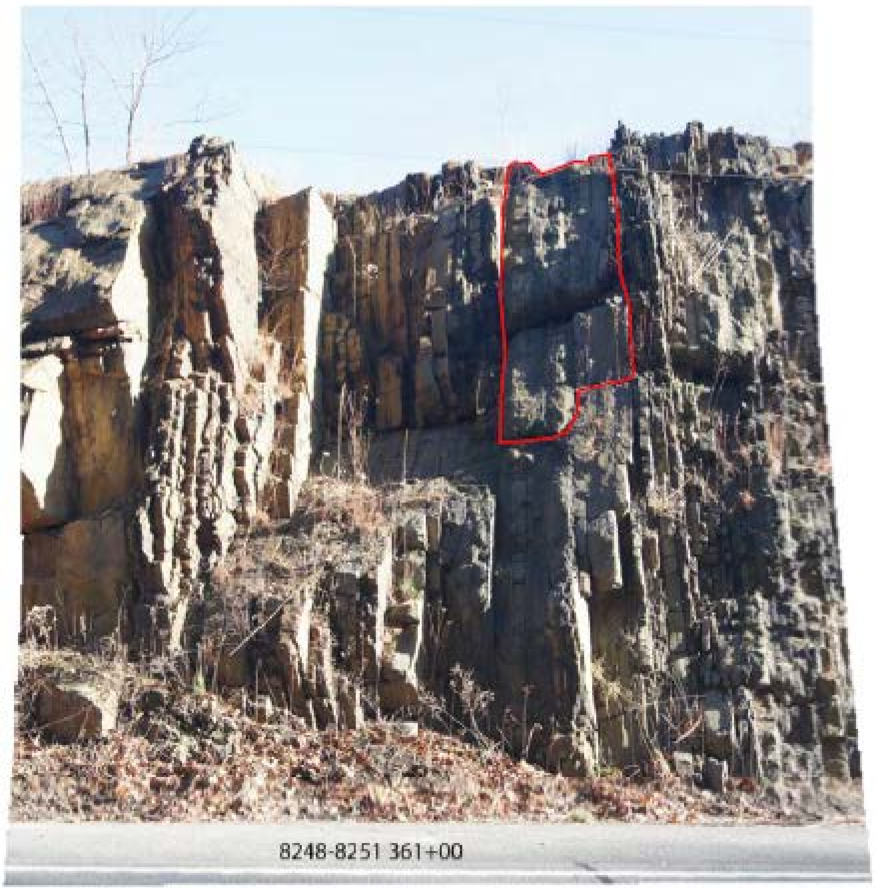
- **Rockfall fence design was based on models developed using the Colorado Rockfall Simulation Program (CRSP)**

- **Fence design had to follow three primary design criteria:**
  1. **Height (Elevation)**
  2. **Energy Rating**
  3. **Deflection**

The first two criteria were based on the typical rock sizes found at each cut location

Rockfall Fence

Rock Size Determination



STA. 361+00

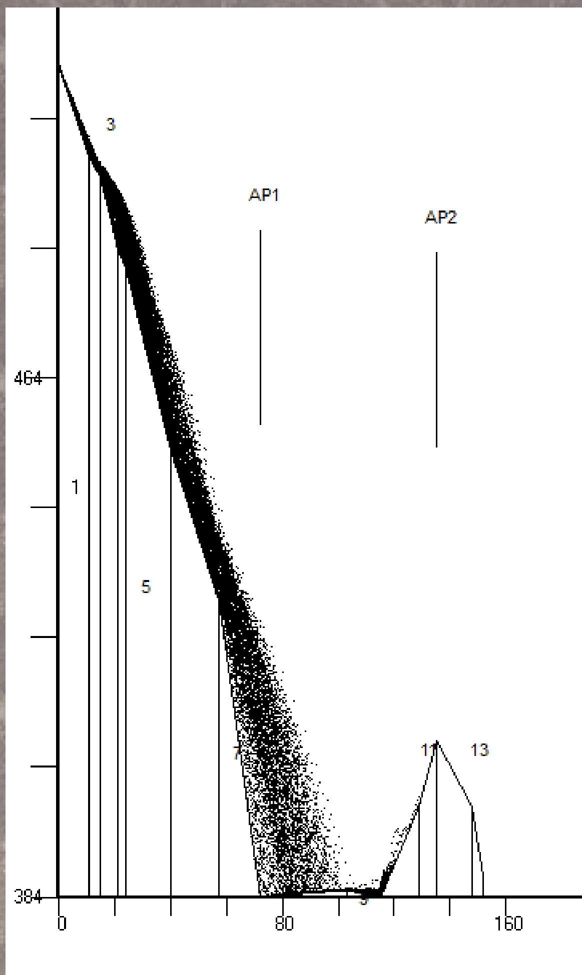
STA. 362+25

Overall: 10'H x 5.5'W x 30"D
Note: Four primary beds within, 1.5', 1',1', and 2'.
Depth based on exposure near base.

Overall: 8'H x 18'W x 2'-3'D?
a. 2.5'H x 18"W x 2'D?
b. 3.5'H x 4'W x 2'D?
c. 1'H x 8"W x 1'D?
Note: Depth uncertainty

Rockfall Fence

The rock size information collected was used in the CRSP models to determine the anticipated rock bounce heights and kinetic energies at each fence location



Analysis Point 1

Analysis Point 1: X = 24, Y = 381

Spherical Rock: 2.25-ft dia., 975-lb

Total Rocks Passing Analysis Point: 5000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Height (ft)
50%	34.68	25077	0.22
75%	40.26	32406	6.24
90%	45.28	38999	11.66
95%	48.29	42957	14.91
98%	51.67	47399	18.56

Note: Velocity and kinetic energy are analyzed assuming a normal distribution.
Bounce height is analyzed assuming a log distribution.

Analysis Point 1

Analysis Point 1: X = 24, Y = 381

Spherical Rock: 4.1-ft dia., 5900-lb

Total Rocks Passing Analysis Point: 5000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Height (ft)
50%	33.62	143267	0.27
75%	35.82	162398	2.6
90%	37.79	179606	4.7
95%	38.98	189937	5.95
98%	40.31	201532	7.36

= 273.2 KJ

Note: Velocity and kinetic energy are analyzed assuming a normal distribution.
Bounce height is analyzed assuming a log distribution.

Rockfall Fence

- **Rockfall fence design was based on models developed using the Colorado Rockfall Simulation Program (CRSP)**

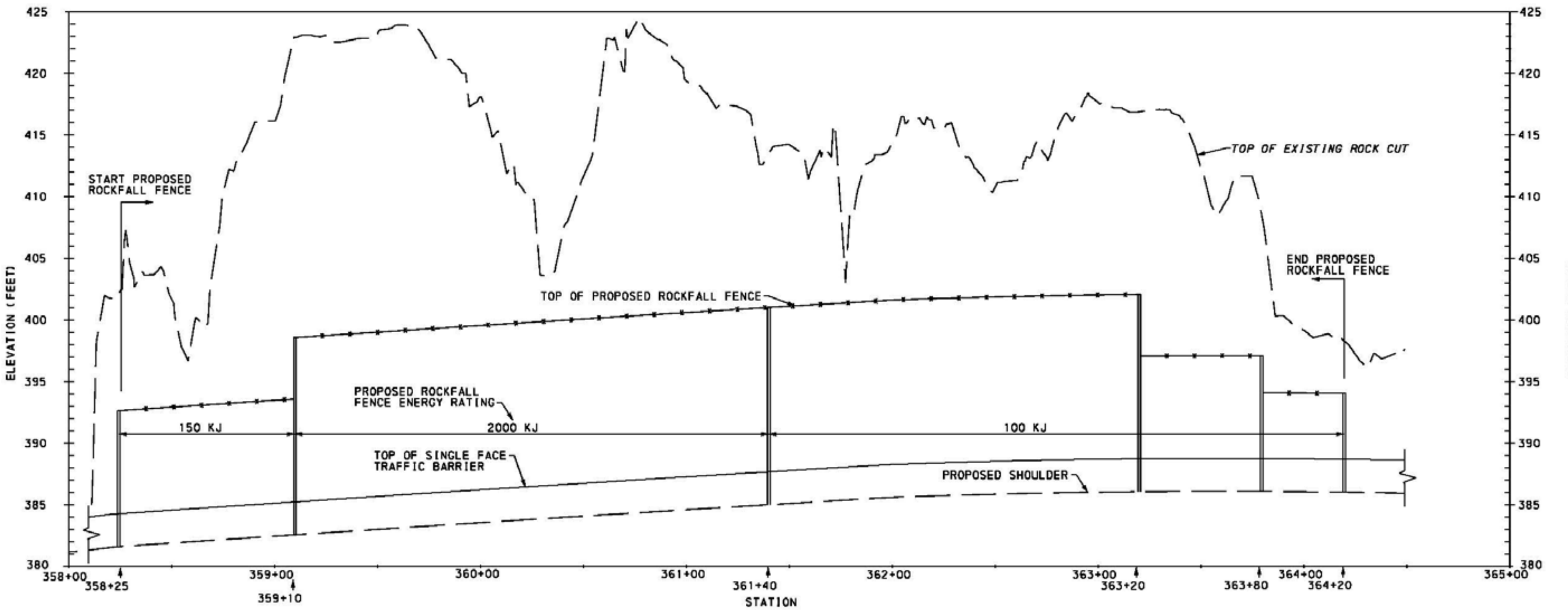
- **Fence design had to follow three primary design criteria:**
  1. **Height (Elevation)**
  2. **Energy Rating**
  3. **Deflection**

The deflection criteria was based on the available shoulder width at each fence location. Recall that there is not much space available at the edge of the roadway.

The fence was designed so that it would not deflect into the travel lanes.

Rockfall Fence

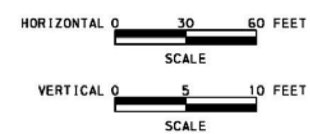
The fence heights and energy ratings were optimized along the length of each fence section.



ROCKFALL FENCE

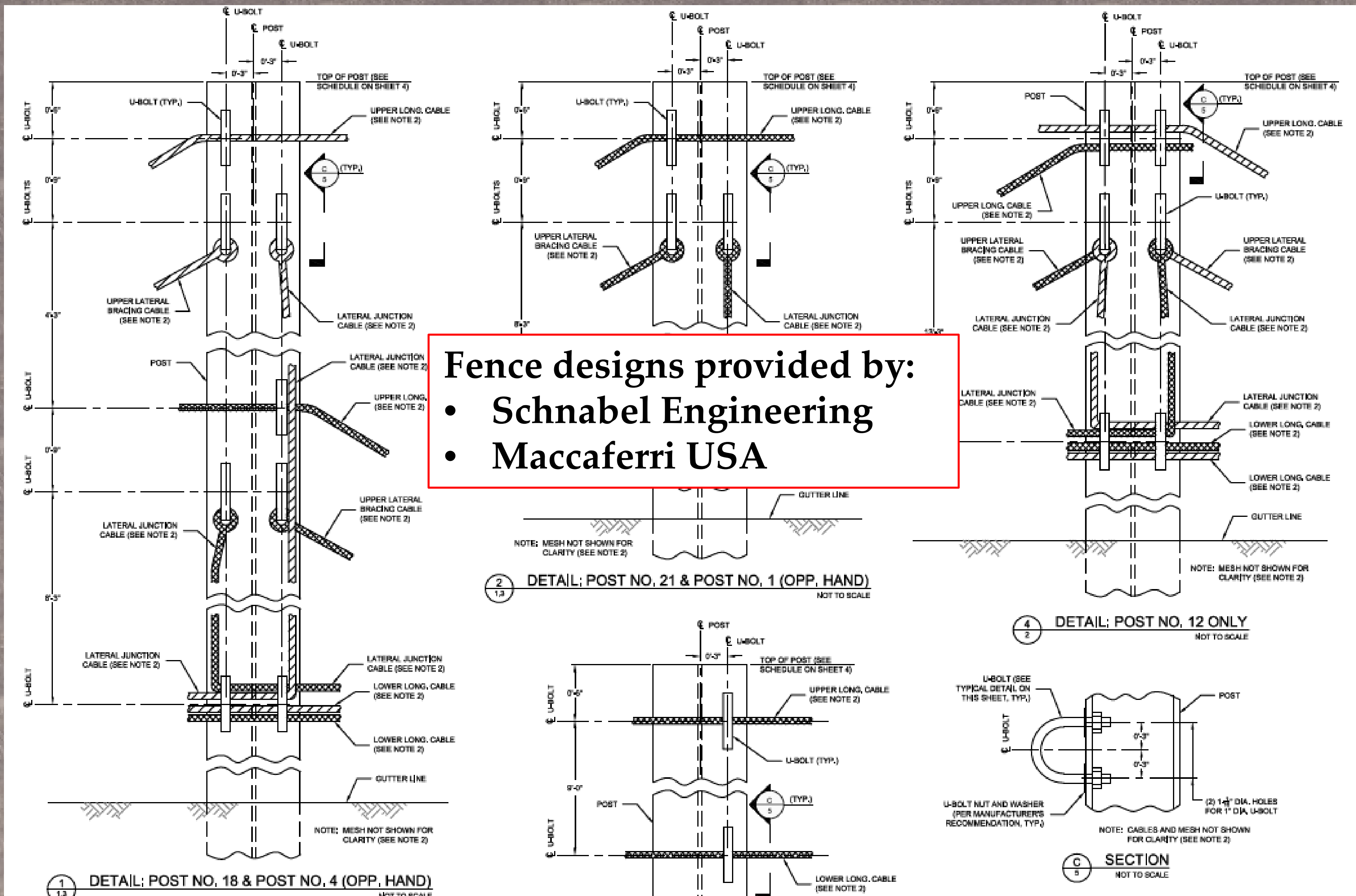
ITEM NO.	STATION	ELEVATION (FT.) MINIMUM*	ENERGY (KJ)	MAXIMUM DEFLECTION (FT.)
9624-0010	358+25 RT	393.0	150	10
	359+10 RT	393.5		
9624-0011	359+10 RT	398.5	2000	10
	361+40 RT	401.0		
9624-0012	361+40 RT	401.0	100	10
	363+20 RT	402.0		
9624-0013	363+20 RT	397.0	100	10
	363+80 RT	397.0		
9624-0014	363+80 RT	394.0	100	10
	364+20 RT	394.0		

* TOP OF FENCE



Rockfall Fence

The Contractor's fence designer provided the required fence post spacing, cabling and anchorage requirements, and mesh panel specifications.



Fence designs provided by:
- **Schnabel Engineering**
- **Maccaferri USA**

Rockfall Fence

Construction

Drilled Caisson diameter = 18″ to 30″

Rock Socket length = 5′ to 15′

Post length = 27′ to 47′

Rockfall Fence

Construction

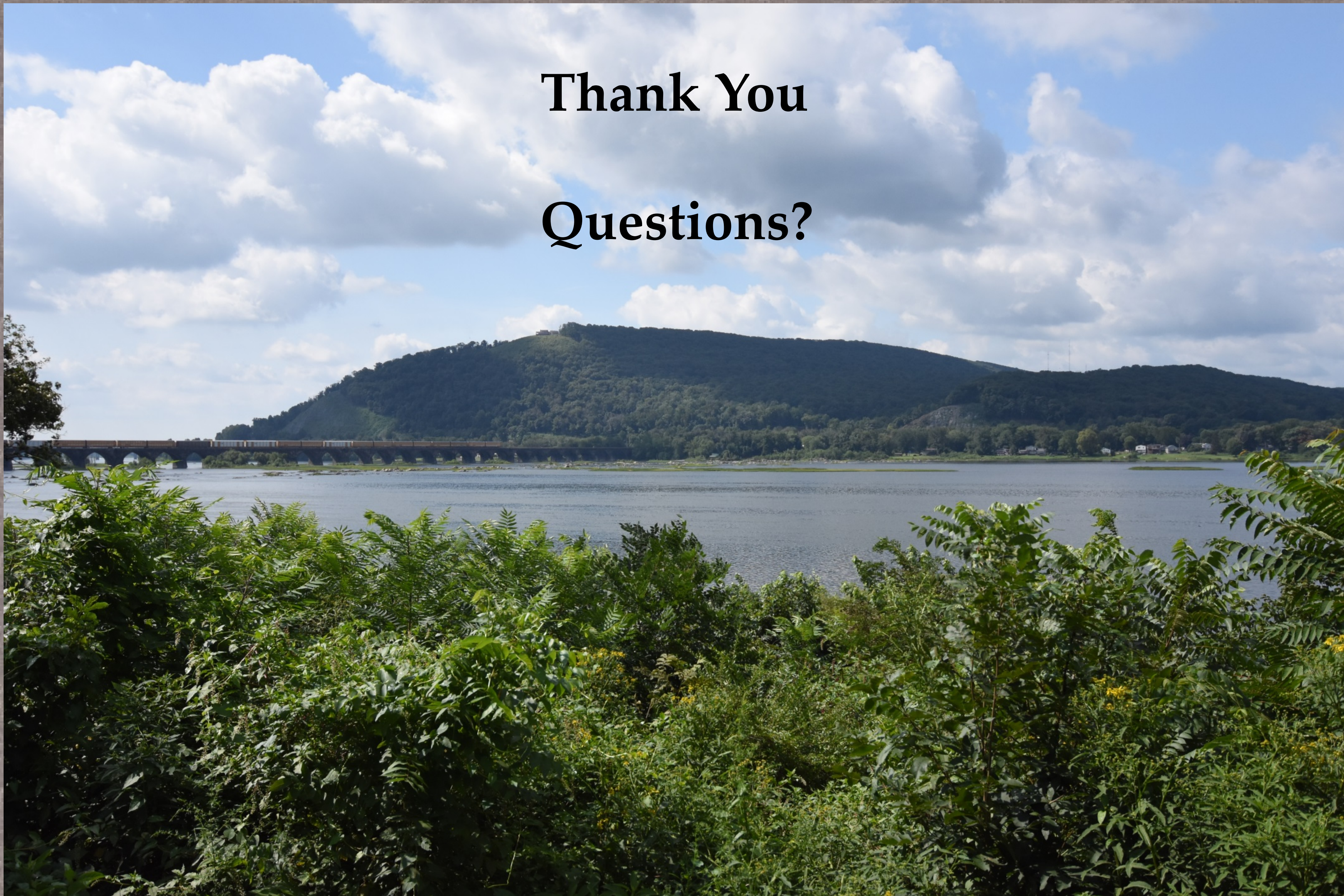
Final Product

A 90-day road closure was allowed. The Contractor successfully reopened the roadway in 55 days.

Final Product

Final Product

Rockfall Contained


Thank You
Questions?