Railroad Embankment Slope Stabilization with Tiebacks and Micropiles

Gary Brill, PE (Schnabel Engineering),

Schnabel ENGINEERING

Presentation Outline

- Background
- Existing Conditions
- Subsurface Investigation
- Global Slope Stability Analyses (Existing and Proposed)
- Structural Design of Stabilization System
- Load Testing
- Construction
- Conclusions

Problem Statement and Challenges

- **Problem Statement**

  - Site has long history of ground movement and repair attempts.

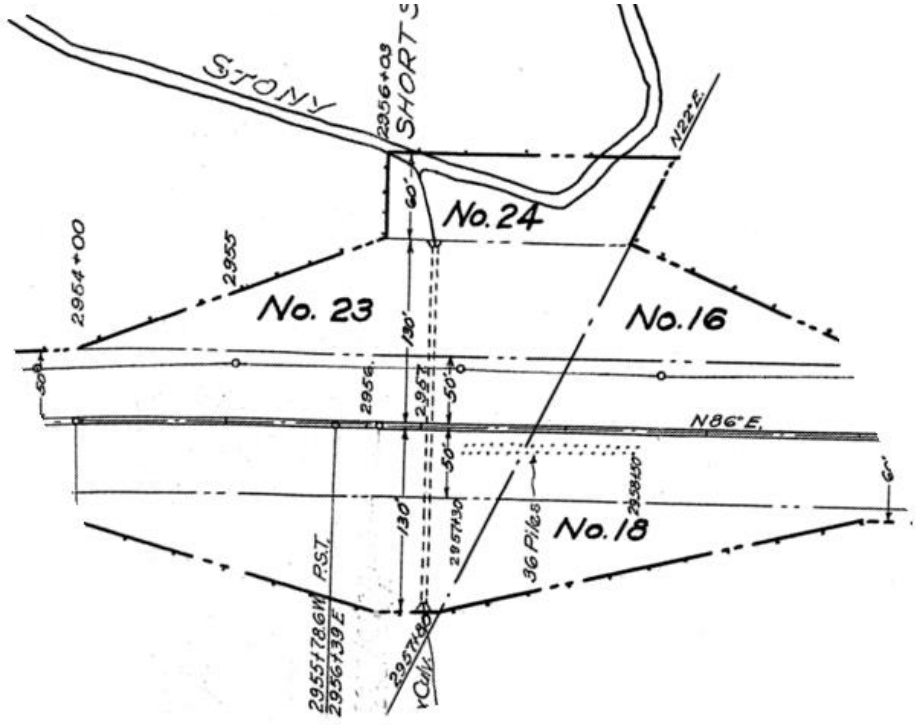
  - Ground movement has resulted in repetitive maintenance.

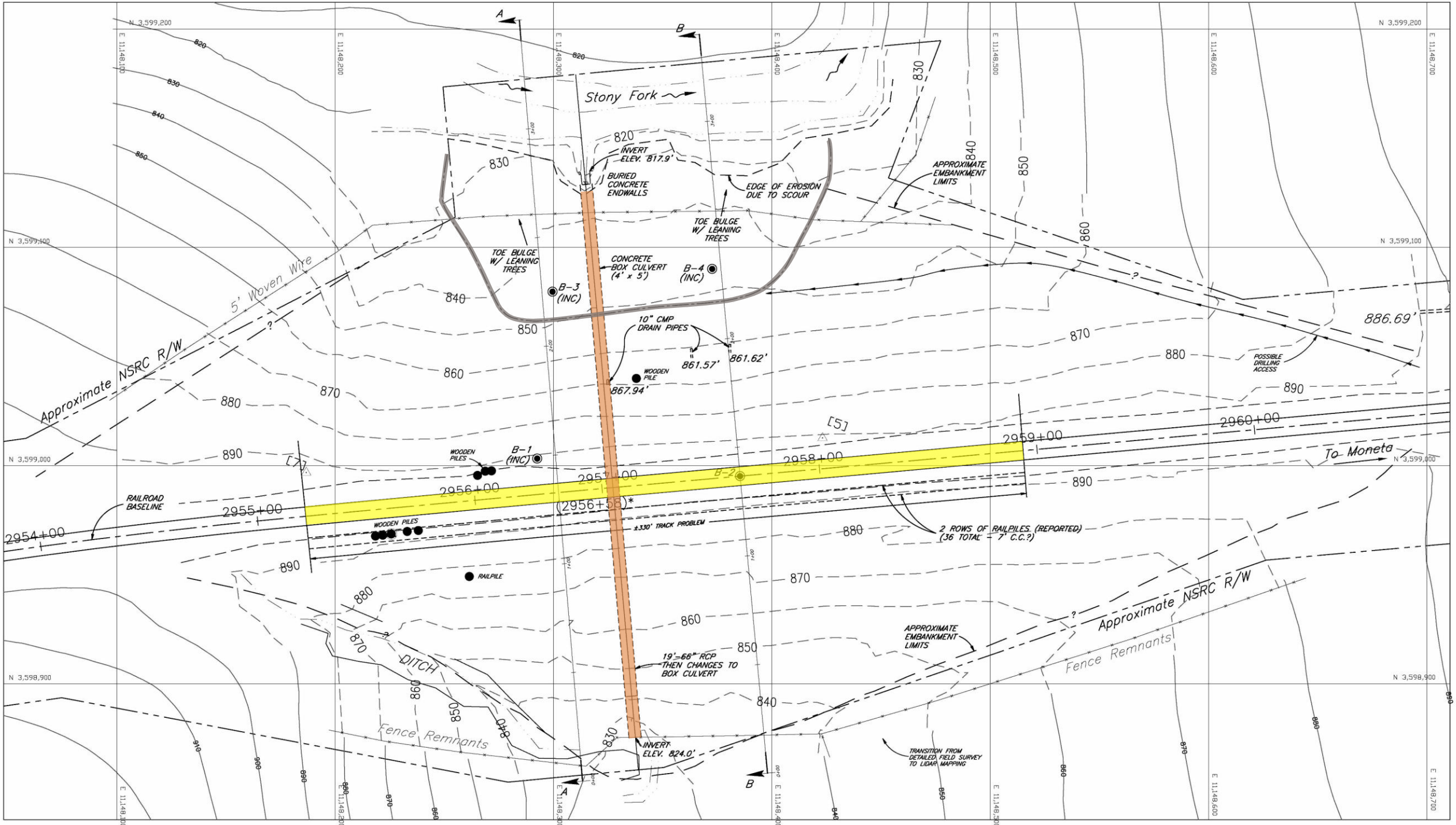
  - Recent increase in track movements prompted further stabilization measures to avoid an unsafe situation for trains.

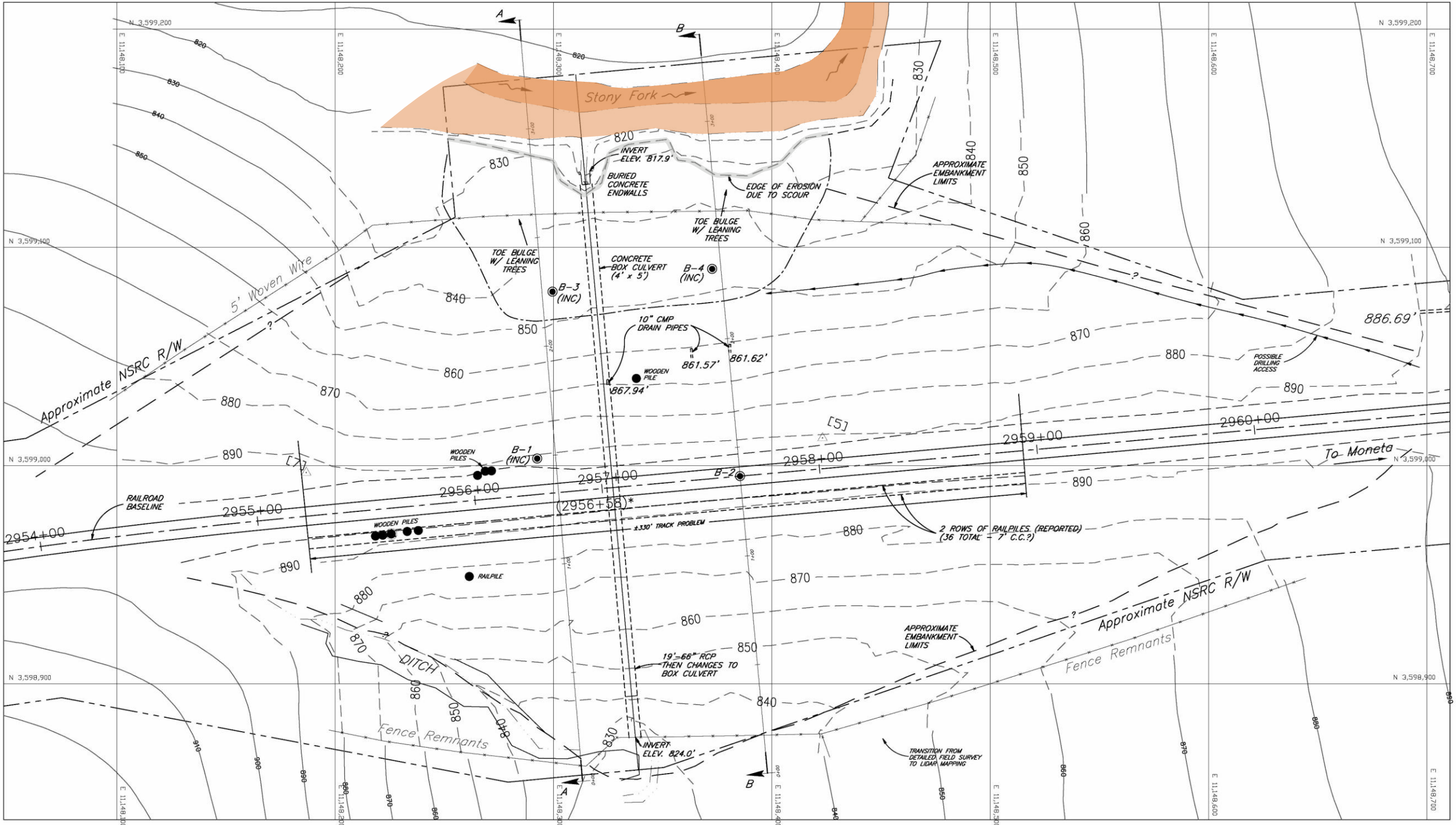
- **Challenges**

  - Client desire to minimize railway disruptions.

  - Limited available documentation on embankment construction




Stony Fork
INVERT ELEV. 817.9'
BURIED CONCRETE ENDWALLS
EDGE OF EROSION DUE TO SCOUR
APPROXIMATE EMBANKMENT LIMITS
TOE BULGE W/ LEANING TREES
TOE BULGE W/ LEANING TREES
CONCRETE BOX CULVERT (4' x 5')
B-3 (INC)
B-4 (INC)
10" CMP DRAIN PIPES
861.57'
861.62'
WOODEN PILE
867.94'
886.69'
POSSIBLE DRILLING ACCESS
5' Woven Wire
Approximate NSRC R/W
WOODEN PILES
B-1 (INC)
B-2
[5]
[7]
RAILROAD BASELINE
2956+00
2955+00
2954+00
2957+00
2958+00
2959+00
2960+00
(2956+58)*
±330' TRACK PROBLEM
2 ROWS OF RAILPILES (REPORTED) (36 TOTAL - 7' C.C.?)
WOODEN PILES
RAILPILE
To Moneta
DITCH
Fence Remnants
19'-66" RCP THEN CHANGES TO BOX CULVERT
INVERT ELEV. 824.0'
APPROXIMATE EMBANKMENT LIMITS
TRANSITION FROM DETAILED FIELD SURVEY TO LIDAR MAPPING
N 3,599,200
N 3,599,100
N 3,599,000
N 3,598,900
E 11,148,100
E 11,148,200
E 11,148,300
E 11,148,400
E 11,148,500
E 11,148,600
E 11,148,700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E 11,148,700
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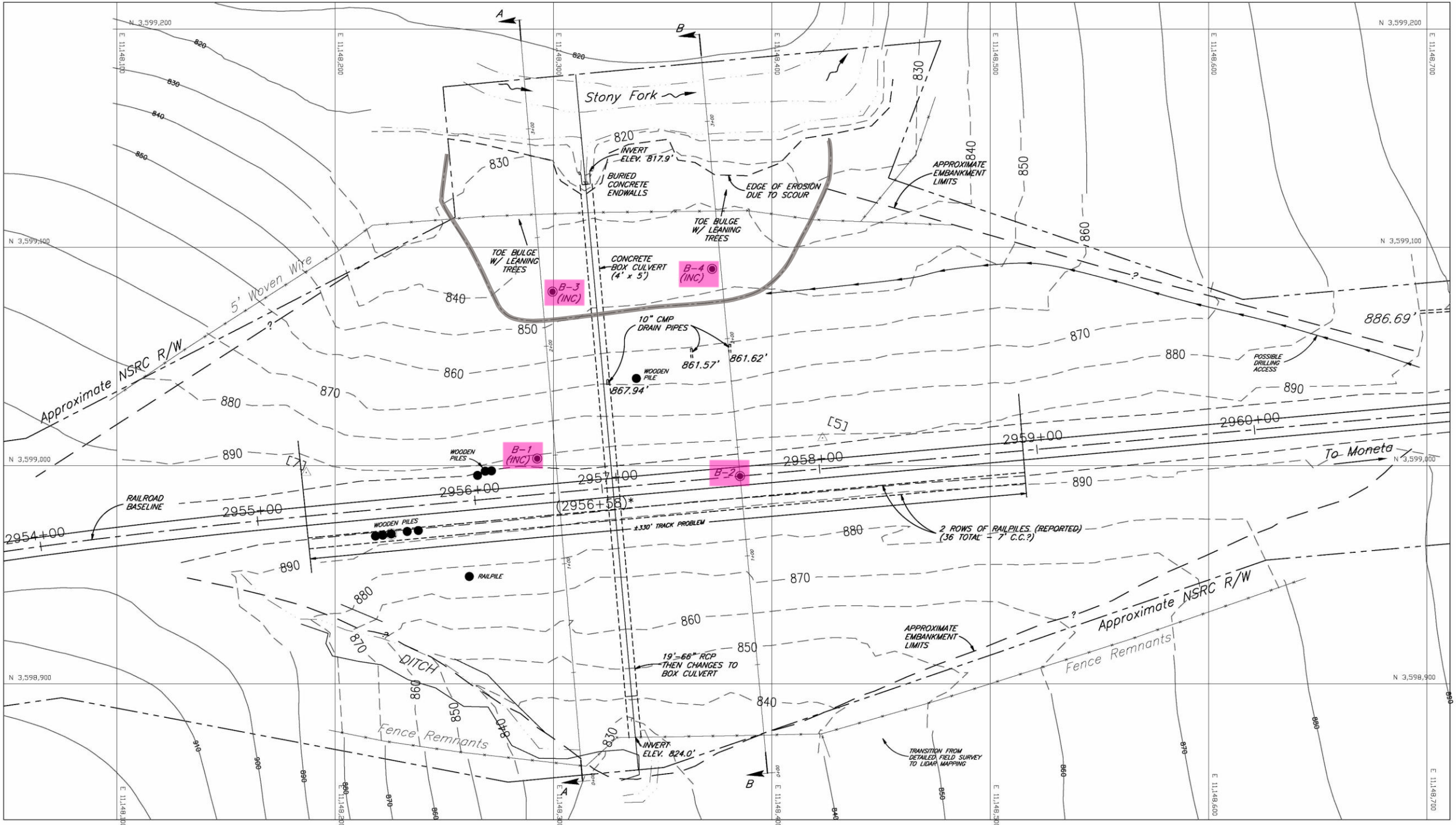
2956+00
2957+00
2958+00
2959+00
2960+00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BURIED CONCRETE ENDWALLS
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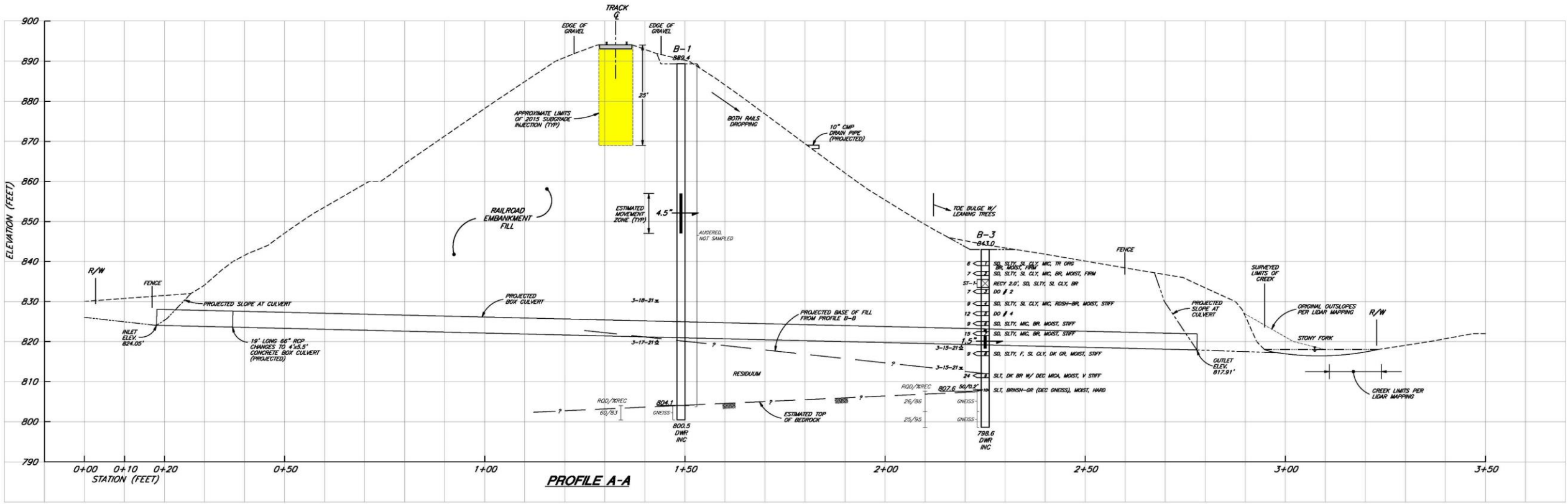
A
B
N 3,599,200
N 3,599,100
N 3,599,000
N 3,598,900
E 11,148,100
E 11,148,200
E 11,148,300
E 11,148,400
E 11,148,500
E 11,148,600
E 11,148,700

Boring B-2, Top of the Embankment

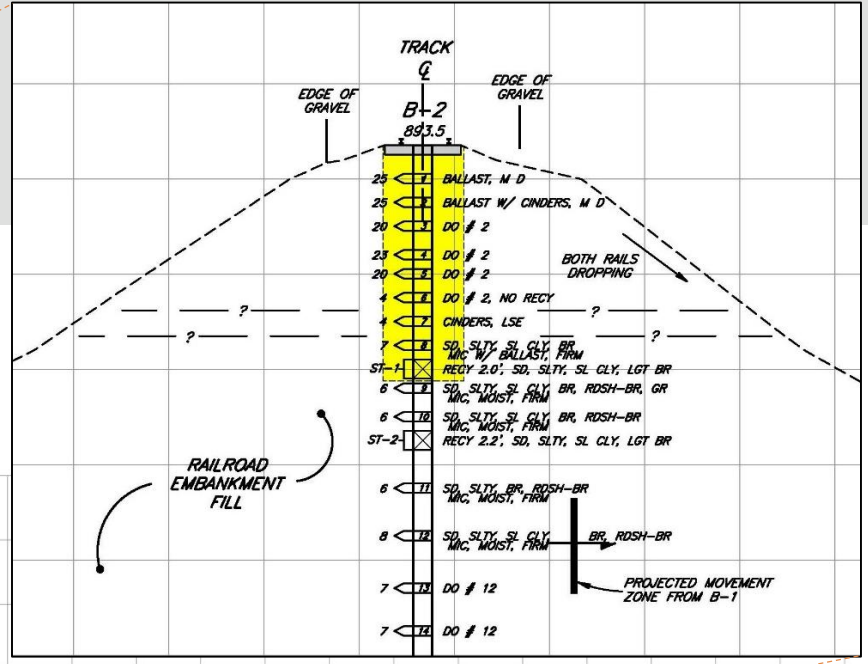
Boring B-3, Top of Embankment

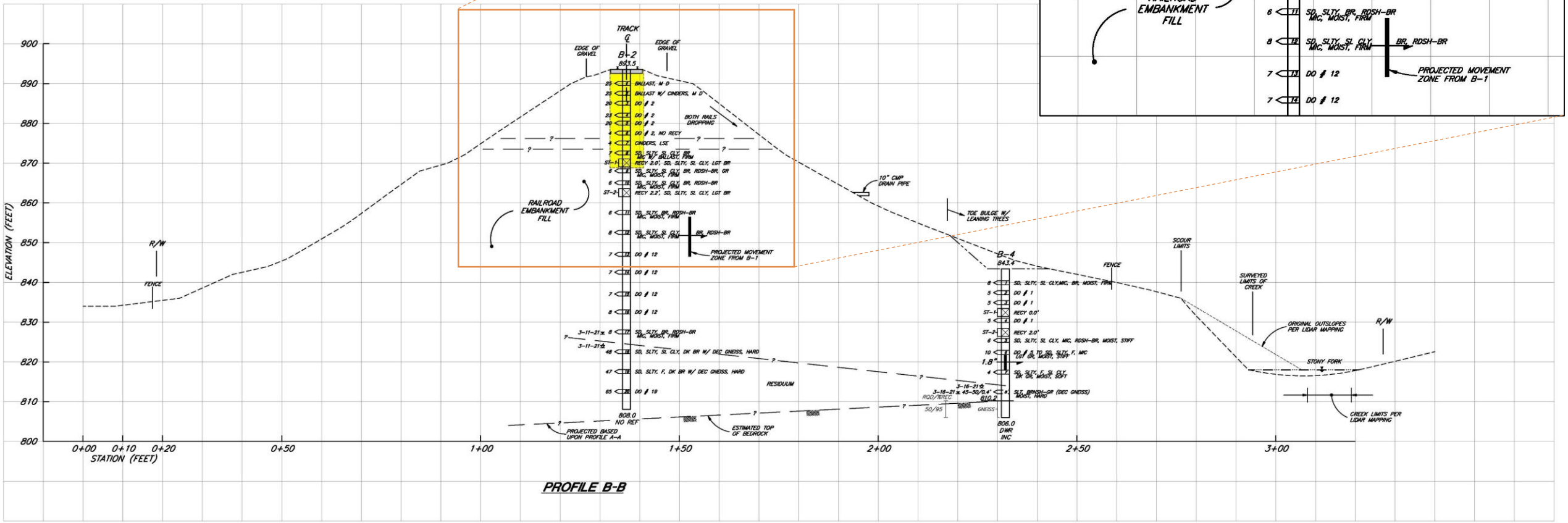
Boring near Toe of Embankment

Profile A-A

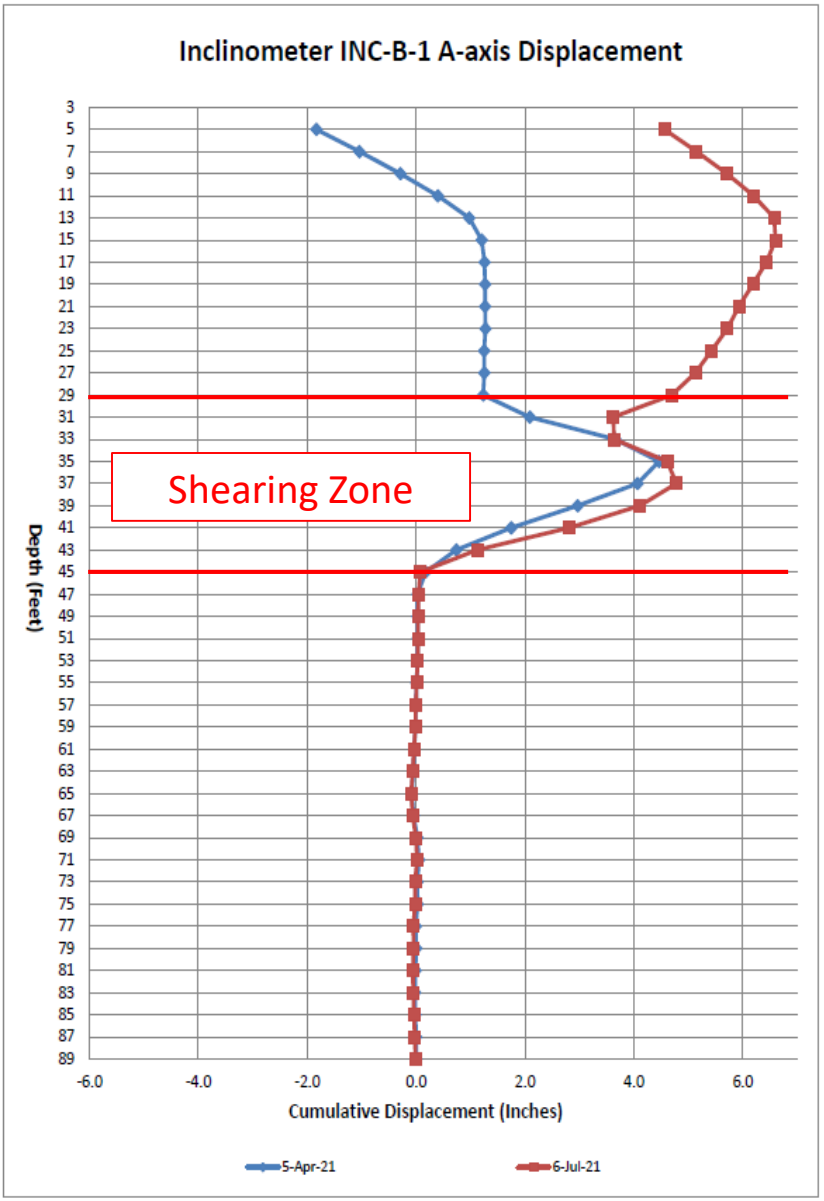

TRACK ℄
EDGE OF GRAVEL
EDGE OF GRAVEL
B-1
889.4
25'
APPROXIMATE LIMITS OF 2015 SUBGRADE INJECTION (TYP)
BOTH RAILS DROPPING
10" CMP DRAIN PIPE (PROJECTED)
RAILROAD EMBANKMENT FILL
ESTIMATED MOVEMENT ZONE (TYP)
4.5"
AUGERED, NOT SAMPLED
TOE BULGE W/ LEANING TREES
B-3
843.0
FENCE
R/W
FENCE
PROJECTED SLOPE AT CULVERT
INLET ELEV. 824.05'
19' LONG 66" RCP CHANGES TO 4'x5.5' CONCRETE BOX CULVERT (PROJECTED)
PROJECTED BOX CULVERT
3-18-21±
3-17-21±
PROJECTED BASE OF FILL FROM PROFILE B-B
3-15-21±
1.5"
3-15-21±
RESIDUUM
ROD/%REC
60/83
804.1
GNEISS
800.5
DWR
INC
ESTIMATED TOP OF BEDROCK
ROD/%REC
807.6
50/0.2"
26/86
GNEISS
25/95
GNEISS
798.6
DWR
INC
SURVEYED LIMITS OF CREEK
PROJECTED SLOPE AT CULVERT
ORIGINAL OUTSLOPES PER LIDAR MAPPING
R/W
STONY FORK
OUTLET ELEV. 817.91'
CREEK LIMITS PER LIDAR MAPPING
ELEVATION (FEET)
900
890
880
870
860
850
840
830
820
810
800
790
0+00
0+10
0+20
0+50
1+00
1+50
2+00
2+50
3+00
3+50
STATION (FEET)
PROFILE A-A

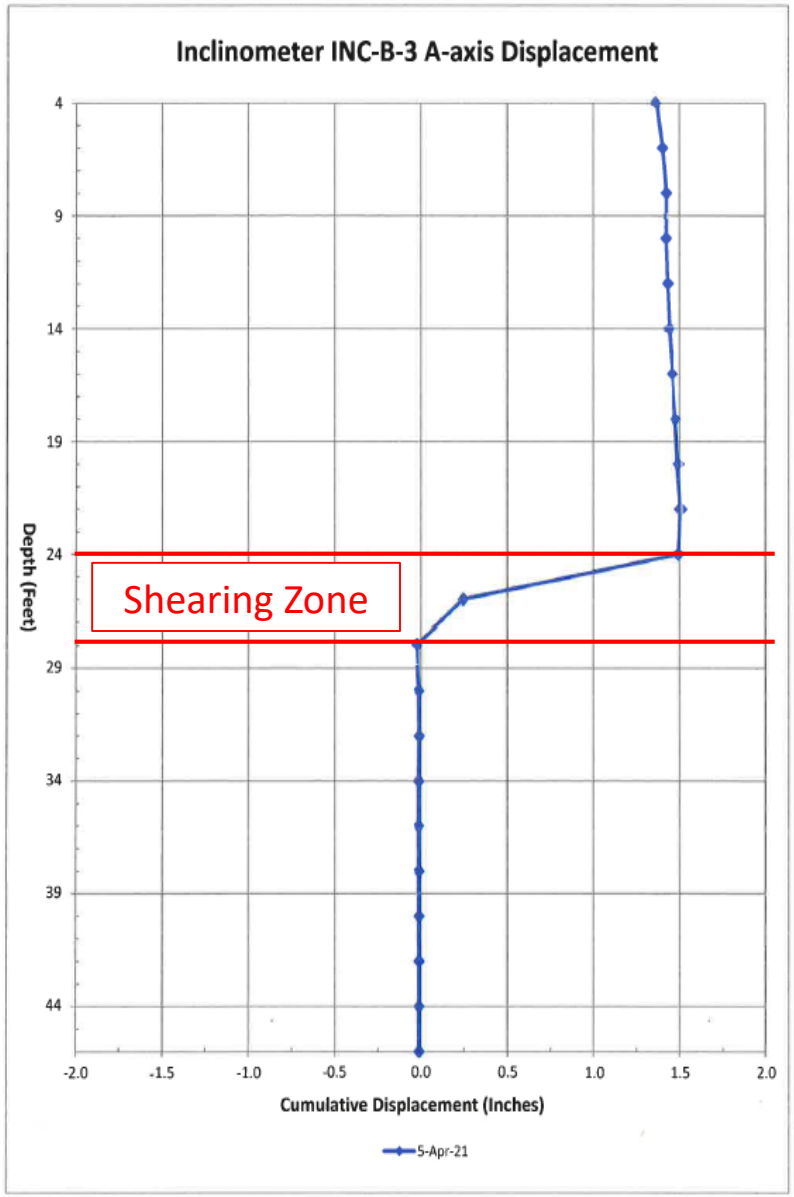
Profile B-B

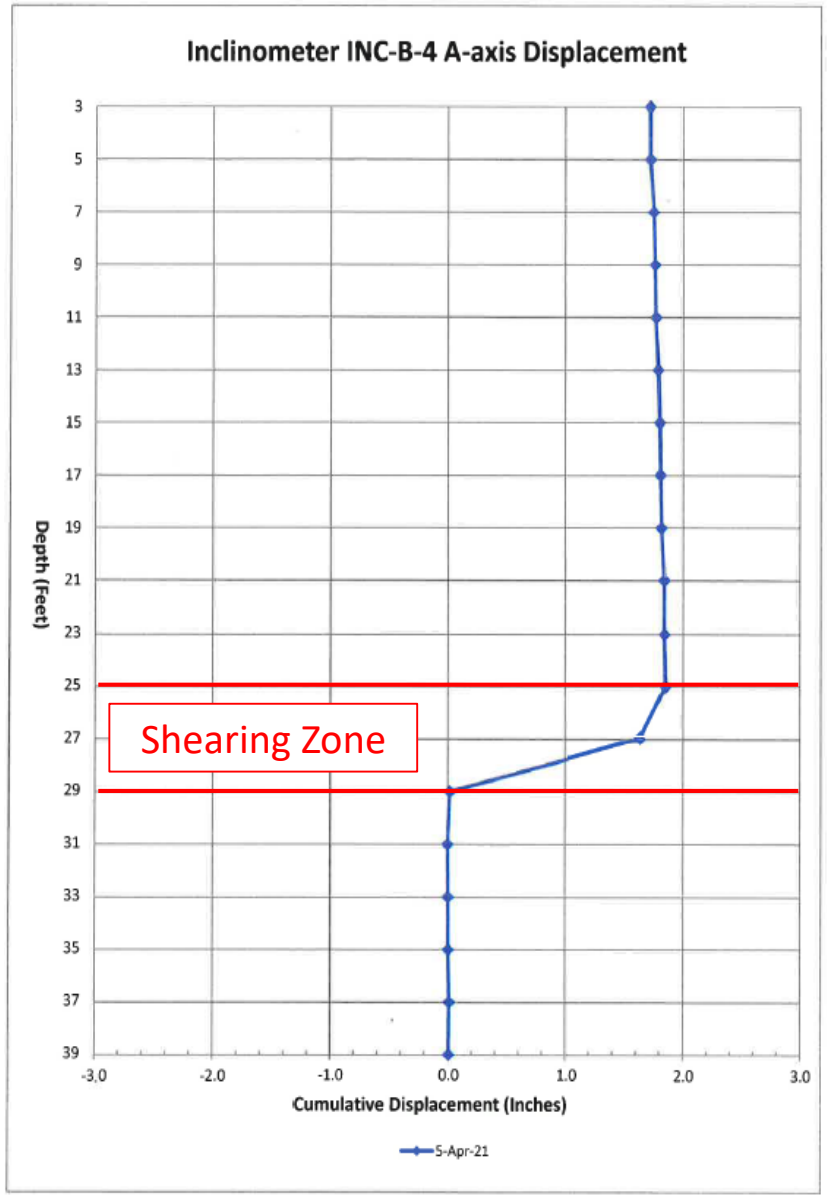

TRACK ℄
EDGE OF GRAVEL
EDGE OF GRAVEL
B-2
893.5
BOTH RAILS DROPPING
RAILROAD EMBANKMENT FILL
PROJECTED MOVEMENT ZONE FROM B-1


ELEVATION (FEET)
900
890
880
870
860
850
840
830
820
810
800
STATION (FEET)
0+00
0+10
0+20
0+50
1+00
1+50
2+00
2+50
3+00
R/W
FENCE
RAILROAD EMBANKMENT FILL
10" CMP DRAIN PIPE
TOE BULGE W/ LEANING TREES
B-4
843.4
SCOUR LIMITS
SURVEYED LIMITS OF CREEK
ORIGINAL OUTSLOPES PER LIDAR MAPPING
STONY FORK
CREEK LIMITS PER LIDAR MAPPING
RESIDUUM
PROJECTED BASED UPON PROFILE A-A
ESTIMATED TOP OF BEDROCK
808.0 NO REF
806.0 DWR INC
PROFILE B-B

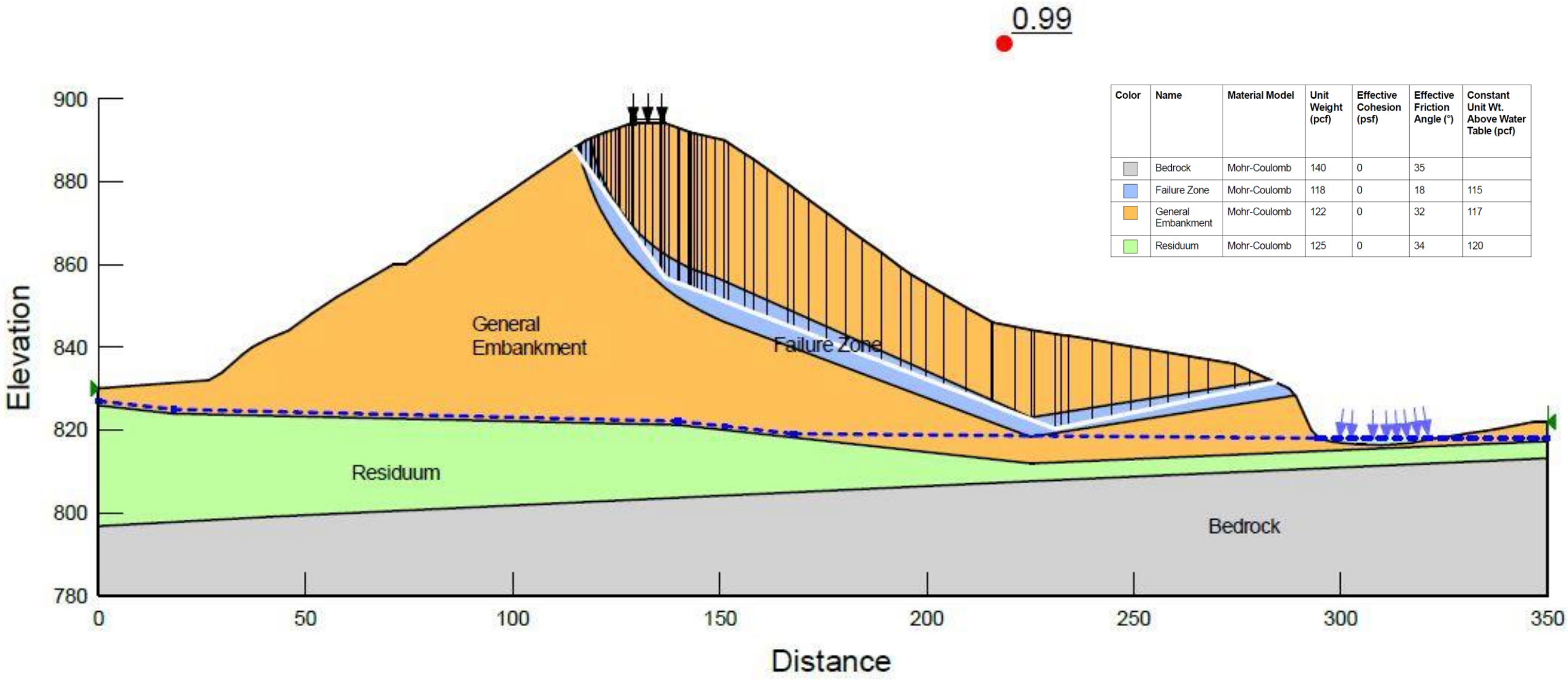
Inclinometer Data, Cumulative Displacement vs Depth





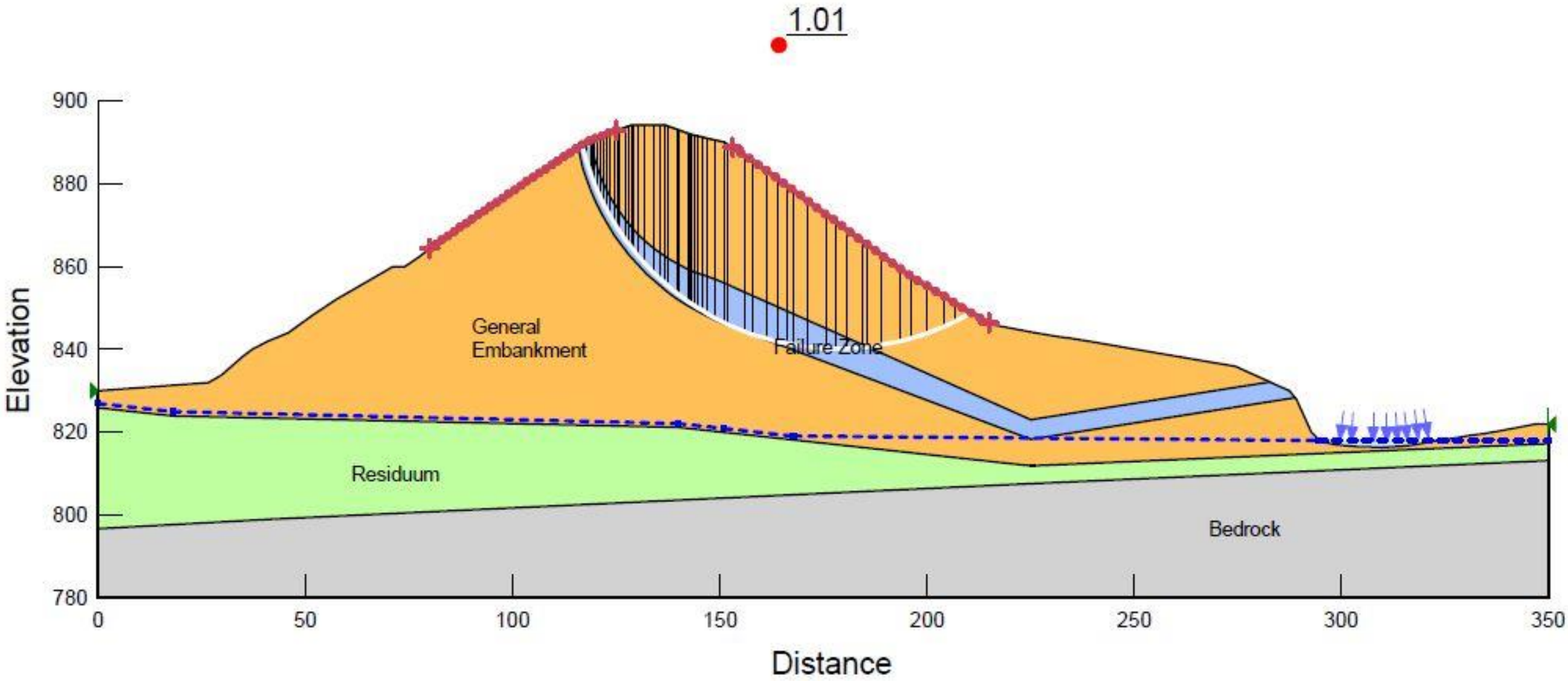


Profile A-A, Existing Conditions

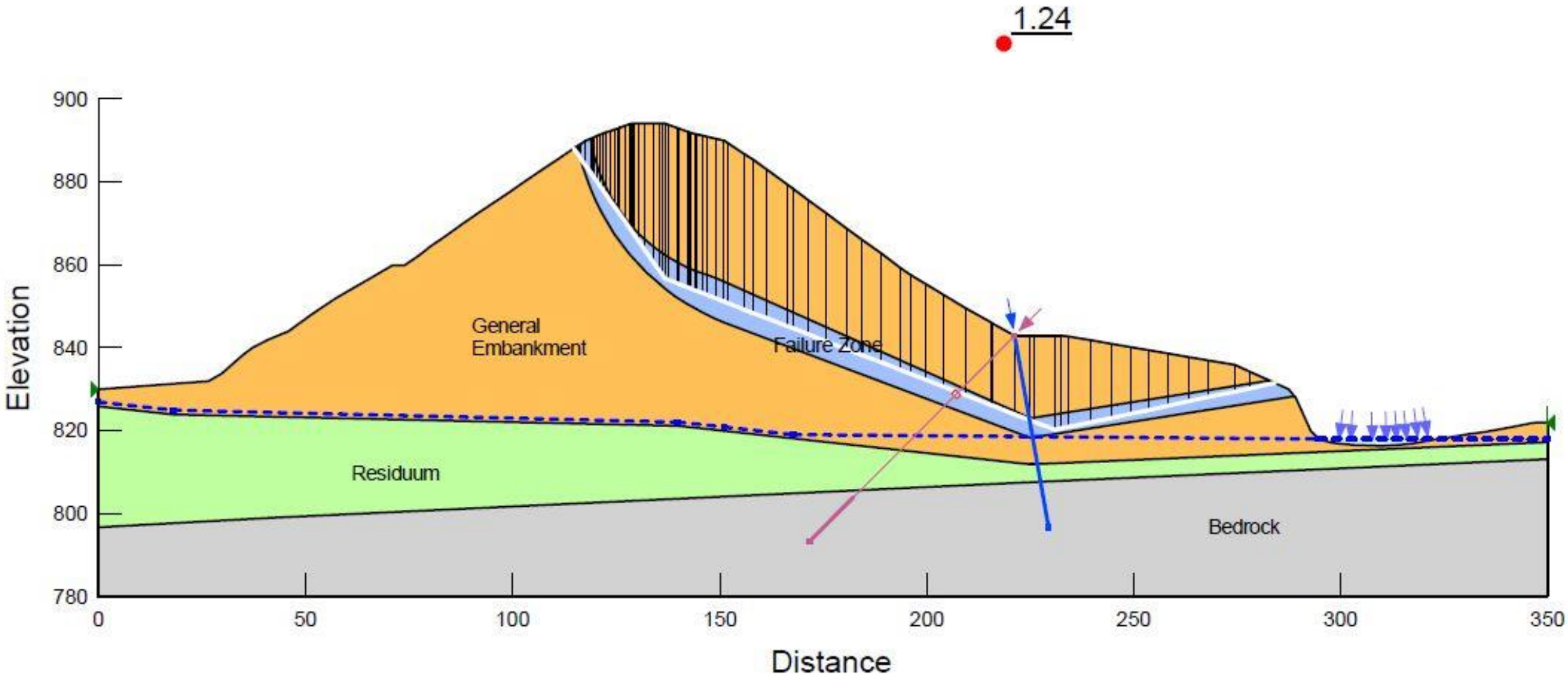


Color	Name	Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Constant Unit Wt. Above Water Table (pcf)
	Bedrock	Mohr-Coulomb	140	0	35	
	Failure Zone	Mohr-Coulomb	118	0	18	115
	General Embankment	Mohr-Coulomb	122	0	32	117
	Residuum	Mohr-Coulomb	125	0	34	120

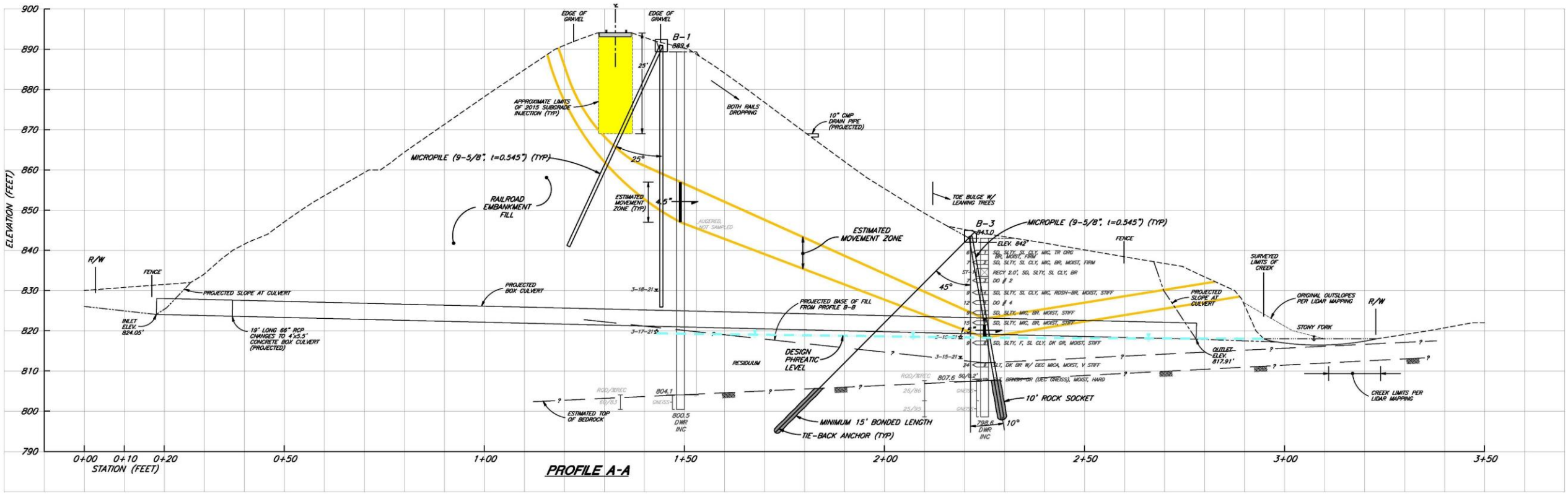
Profile A-A, Existing Conditions, Intermediate Slip Plane



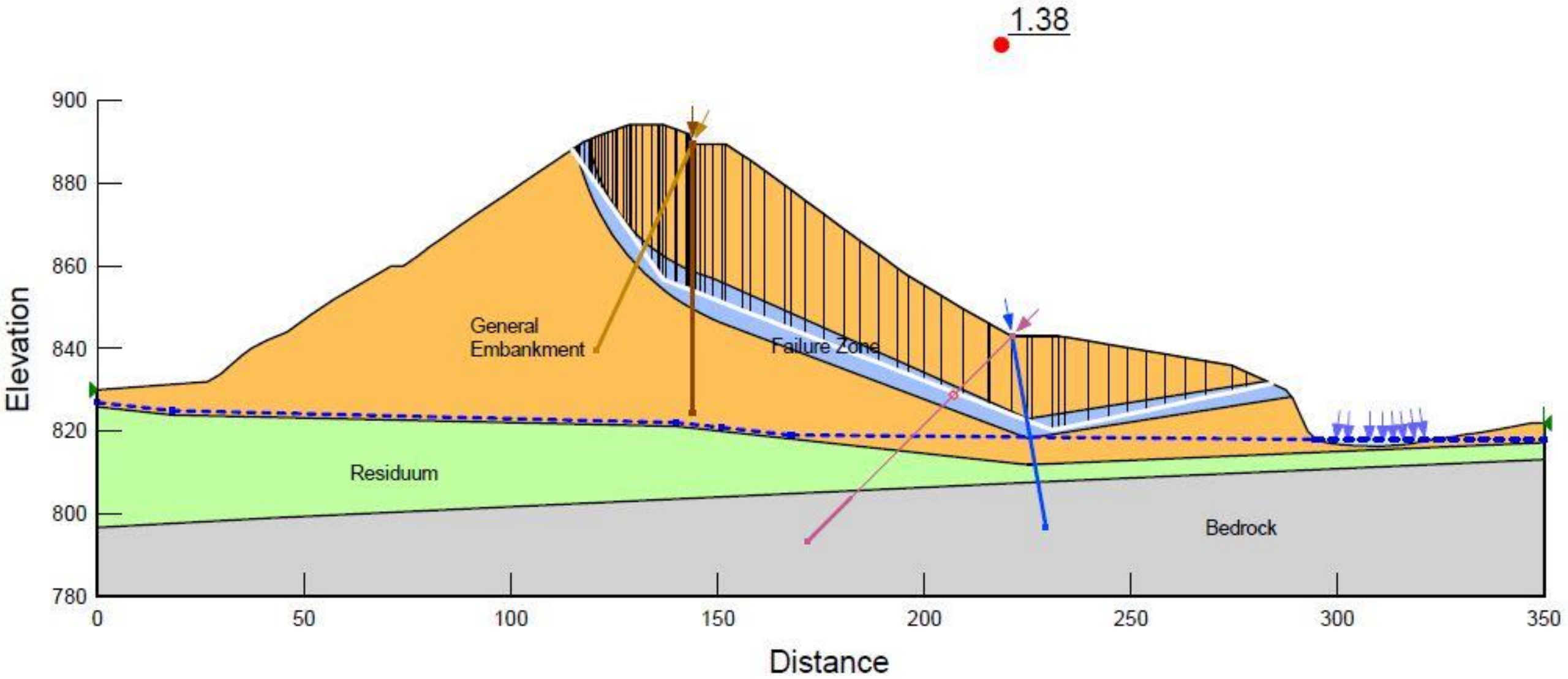
Profile A-A, Bottom Stabilization System Installed



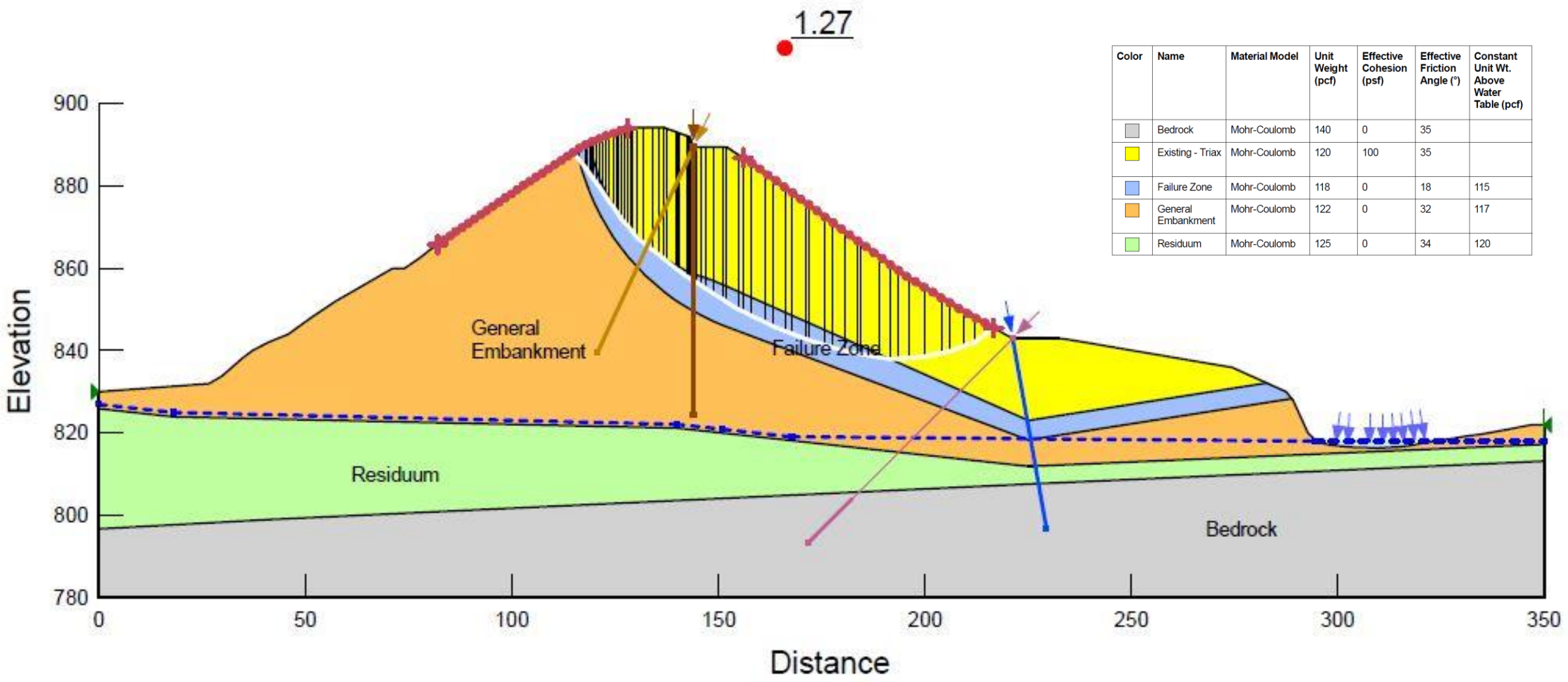
Profile A-A, Design Section



Profile A-A, Top and Bottom Stabilization System Installed



Profile A-A, Top and Bottom Stabilization System Installed, Intermediate Slip Plane,



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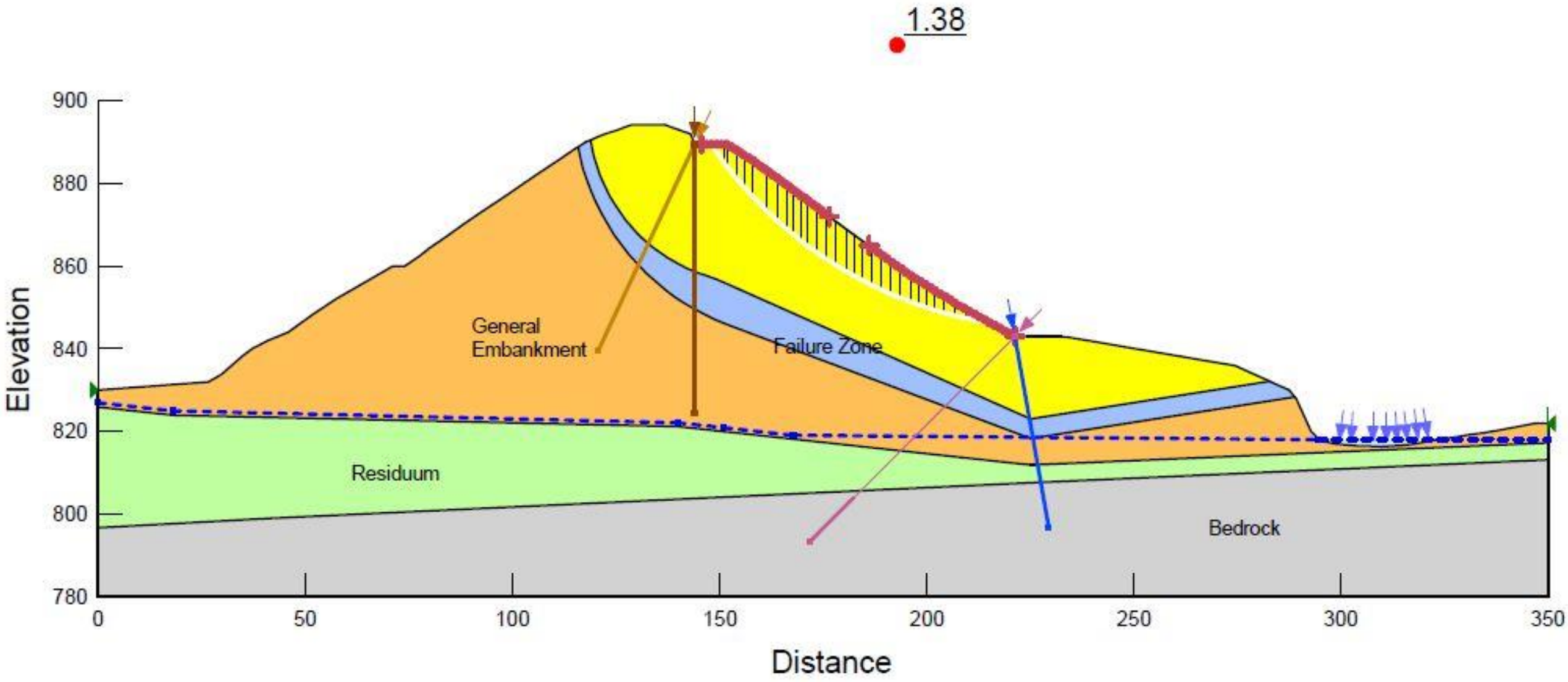
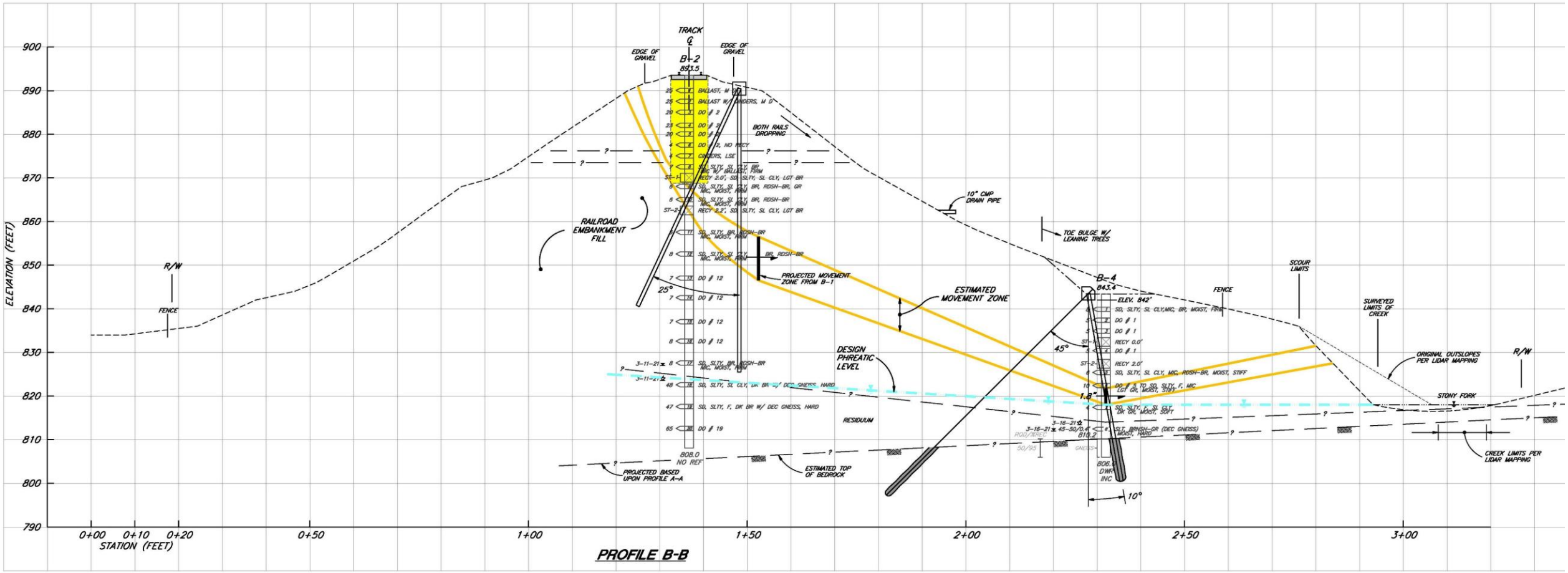
	Residuum	Mohr-Coulomb	125	0	34	120

Profile A-A, Top and Bottom Stabilization System Installed, Slip Between Systems

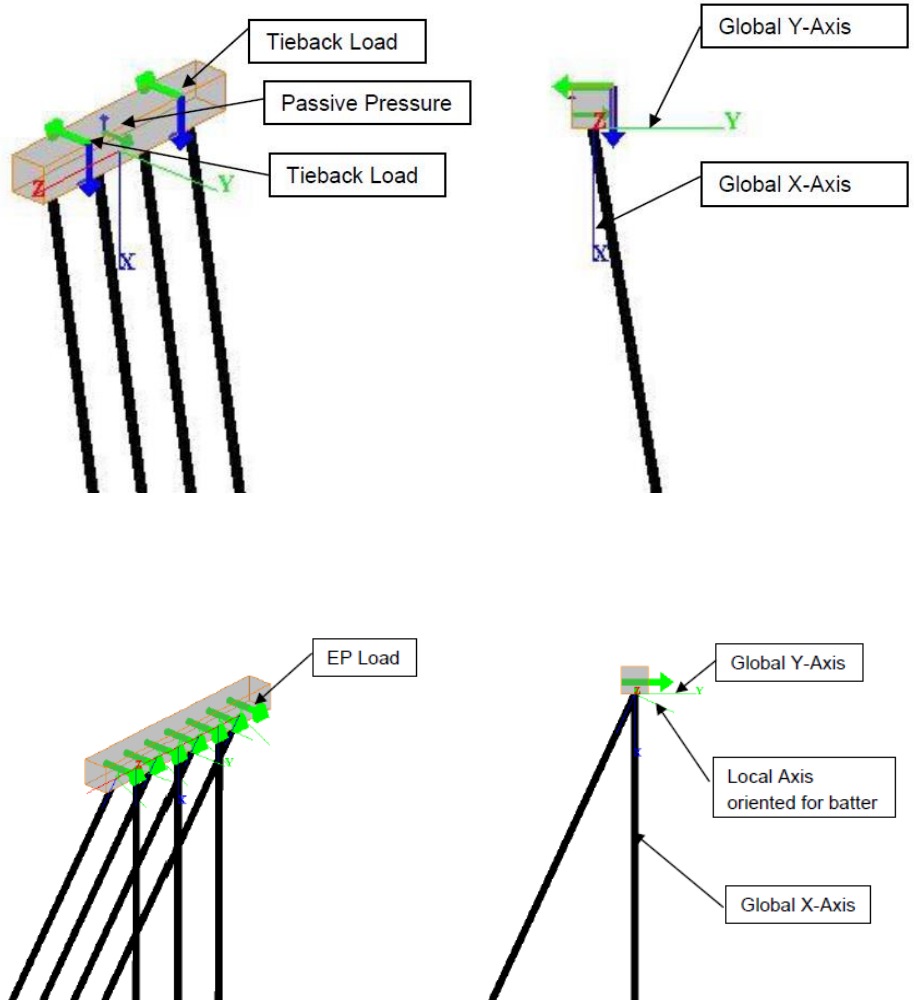


Profile B-B, Design Section



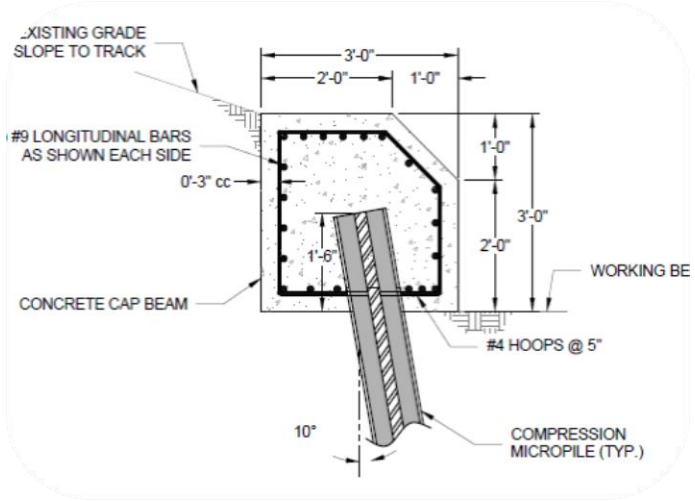
Stabilization Element Design Process

- Shear resistance from global slope stability analysis used to determine required shear resistance (per foot) of cap beams.
- Micropiles modeled in Ensoft's p-y analysis programs LPILE and GROUP. Soil movement from inclinometers as inputs for driving force on piles.
- Design checks
  - Pull out resistance
  - Shear capacity of micropiles (no shear capacity contribution from tiebacks)
  - Plastic soil flow between piles
- Assumed Ultimate Bond Strengths:
  - 12 psi in soil
  - 118 psi in rock

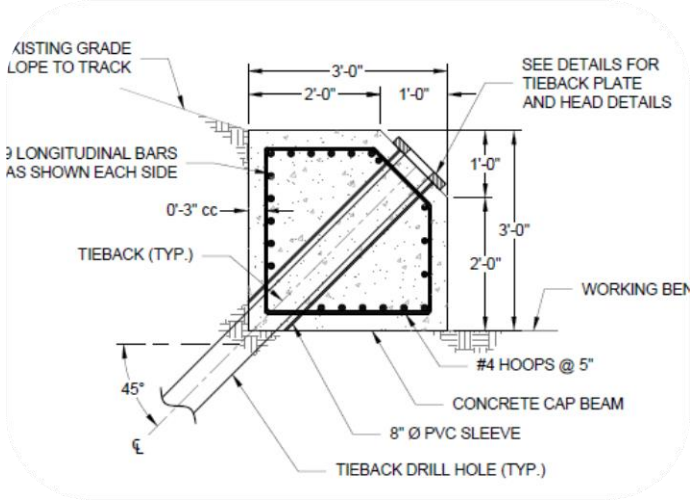


Lower System - Design Loads

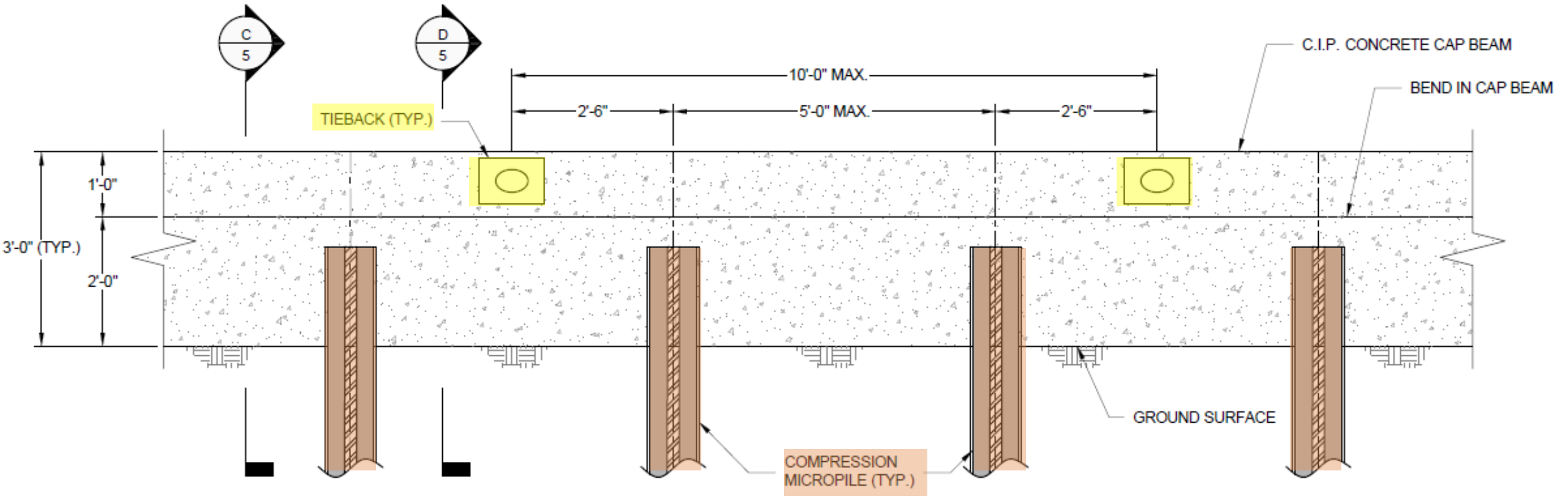
- Micropiles (Compression):
  - Compression Force: 56 kip
  - Bending Moment: 175 kip-ft
  - Lateral Shear Force: 72 kip



- Tieback Anchors
  - Tension: 176 kip
  - No shear capacity from tiebacks



Lower System – Design Results



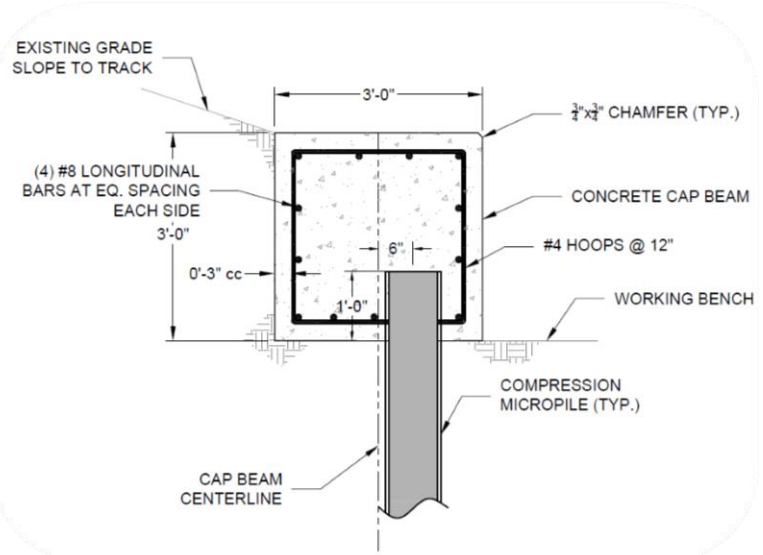
2 BOTTOM CAP BEAM DETAIL - PROFILE VIEW

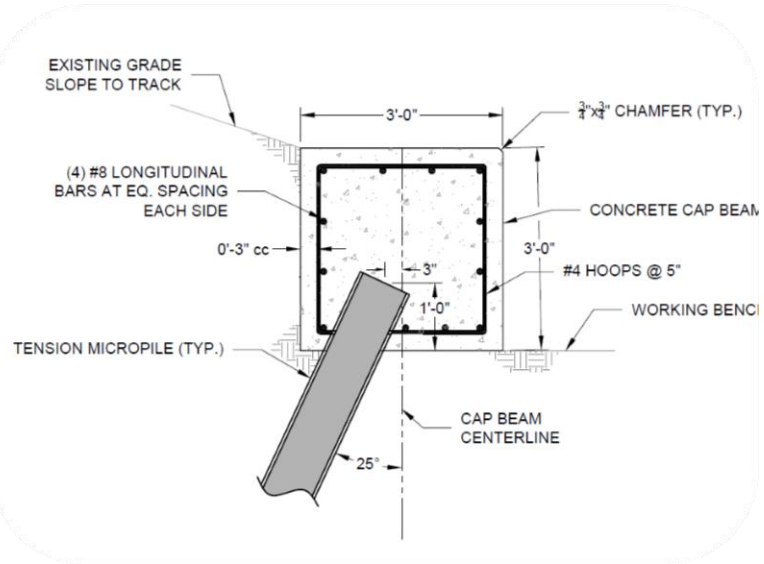
N.T.S.

Upper System – Design Loads

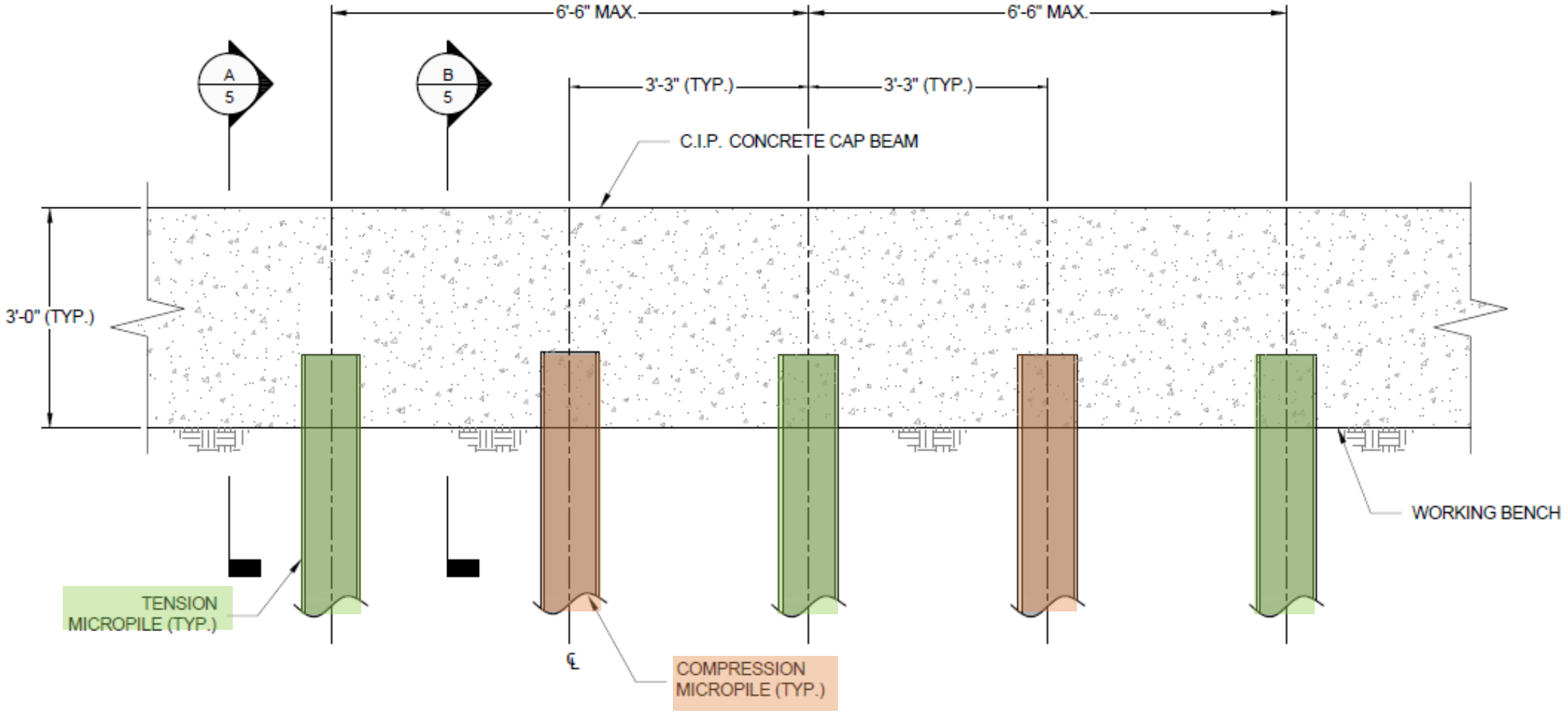
- Micropiles (Compression):
  - Compression Force: 53 kip
  - Bending Moment: 118 kip-ft
  - Lateral Shear Force : 42 kip

- Micropiles (Tension)
  - Tension Froce: 40 kip
  - Bending Moment : 106 kip-ft
  - Lateral Shear Force : 37 kip



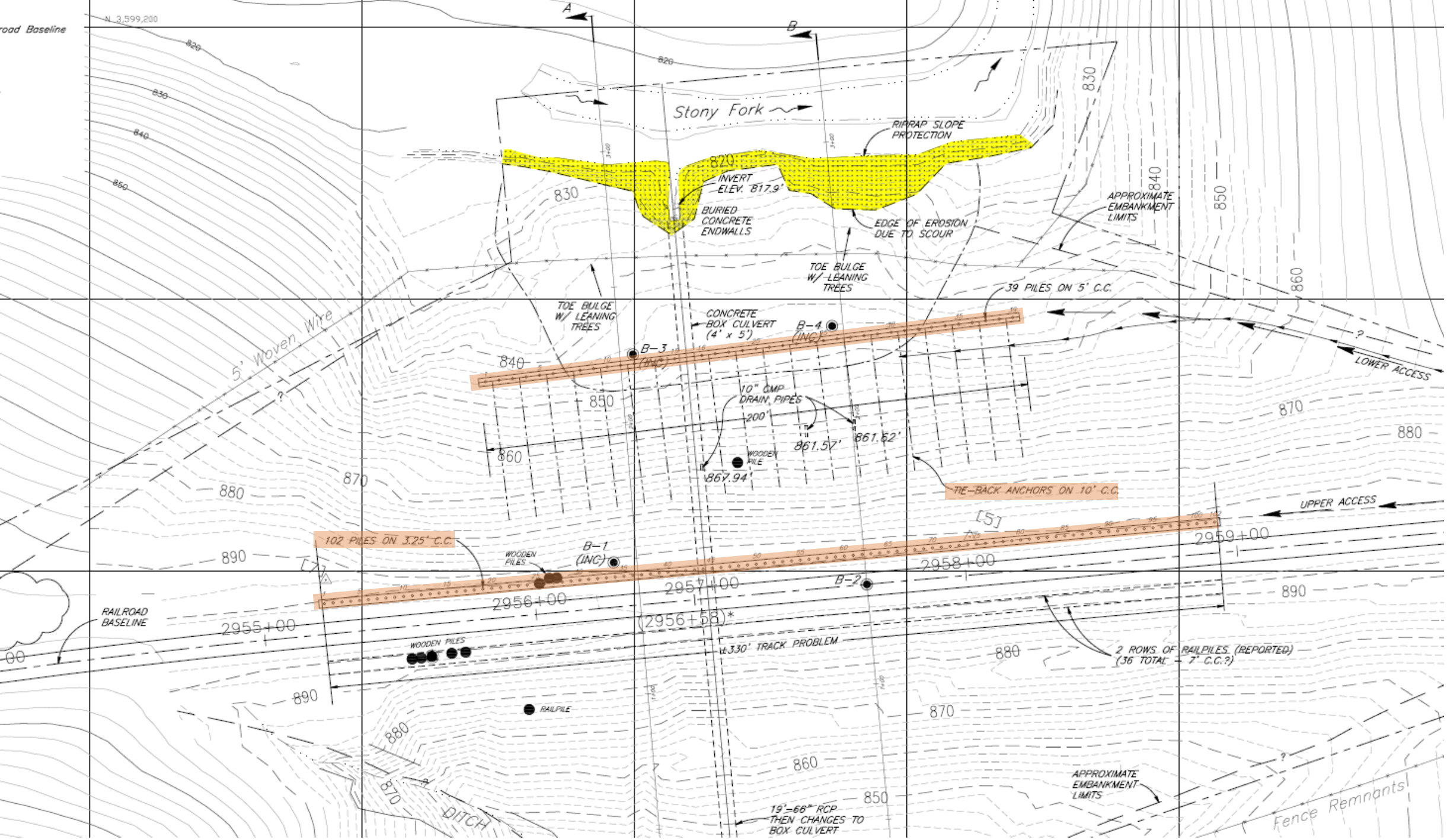


Upper System – Design Results



1 TOP CAP BEAM DETAIL - PROFILE VIEW

N.T.S.


N 3,599,200
Road Baseline
A
B
Stony Fork
RIPRAP SLOPE PROTECTION
INVERT ELEV. 817.9'
BURIED CONCRETE ENDWALLS
EDGE OF EROSION DUE TO SCOUR
APPROXIMATE EMBANKMENT LIMITS
TOE BULGE W/ LEANING TREES
TOE BULGE W/ LEANING TREES
39 PILES ON 5' C.C.
5' Woven Wire
CONCRETE BOX CULVERT (4' x 5')
B-4 (INC)
B-3 (INC)
LOWER ACCESS
10" CMP DRAIN PIPES
200'
861.57'
861.62'
867.94'
WOODEN PILE
TIE-BACK ANCHORS ON 10' C.C.
UPPER ACCESS
102 PILES ON 3.25' C.C.
WOODEN PILES
B-1 (INC)
B-2
2959+00
2958+00
2957+00
2956+00
(2956+58)*
2955+00
RAILROAD BASELINE
330' TRACK PROBLEM
2 ROWS OF RAILPILES (REPORTED) (36 TOTAL - 7' C.C.?)
WOODEN PILES
RAILPILE
DITCH
19'-66" RCP THEN CHANGES TO BOX CULVERT
APPROXIMATE EMBANKMENT LIMITS
Fence Remnants

Load Testing Requirements

- Tieback Anchors:
  - 1 Pre-production Verification Test on a Sacrificial Anchor
  - Performance Test 5 percent of Anchors
  - Proof Test all other Anchors
  - Evaluation of rock-grout bond strength also applicable to micropiles bonded in rock (Lower System)

- Micropiles Bonded in Soil
  - 1 Pre-production Verification Test on a Sacrificial Pile
  - Applicable to Upper System only

Micropile Load Testing – Verification Test

Construction Approach

Total Construction Duration – 28 Weeks

Lower Cap

Upper Cap

Lower System - Micropile Install and Cap Forming

Lower System – Cap Beam and Tieback Install

Lower Cap Finished Product

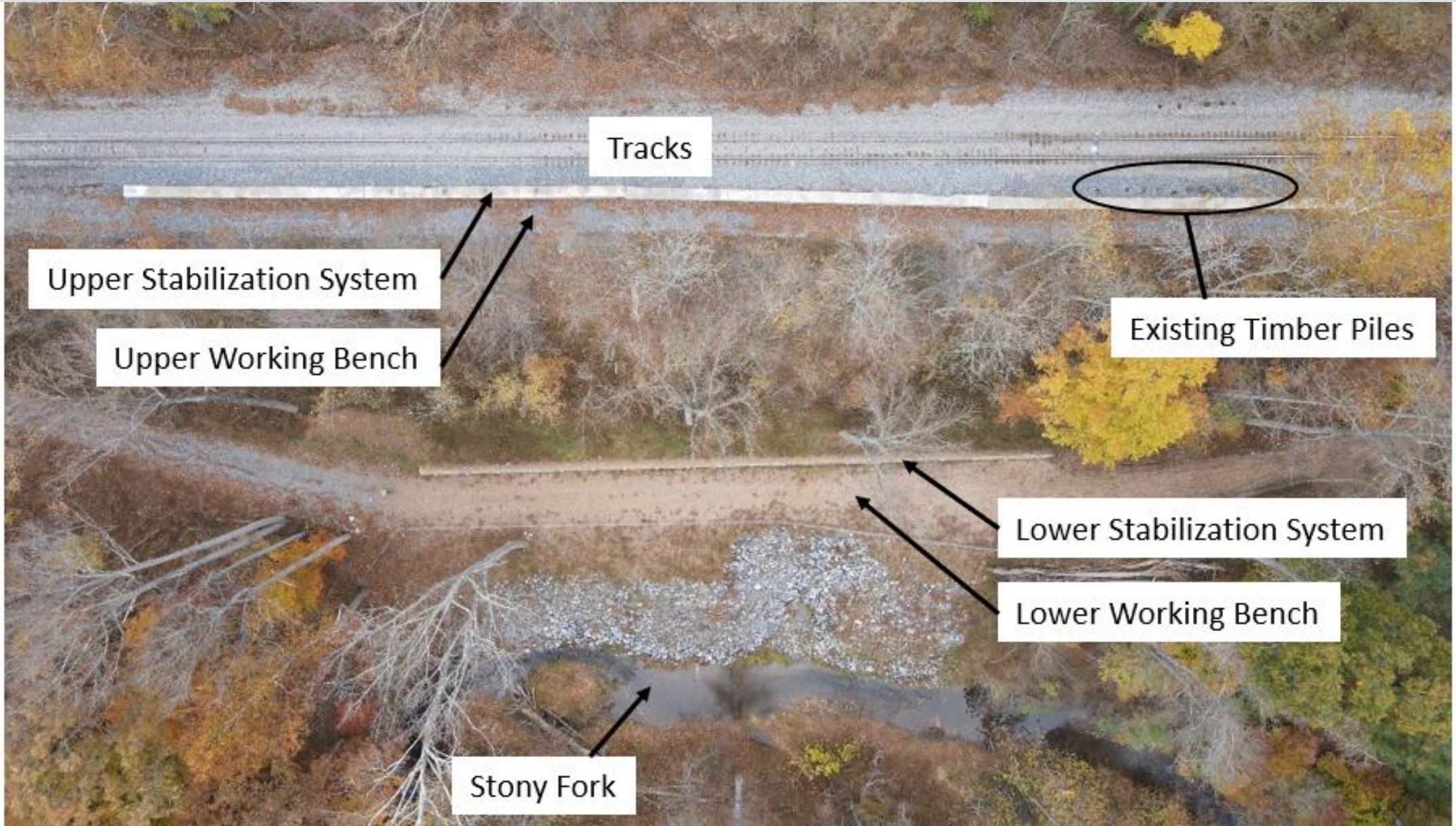
Upper System – Tension Piles

Upper System – Compression Piles

Upper System – Cap Beam and Micropile Install

Upper System Final Product

Final Site Condition



Final Site Condition

Conclusions

- LIDAR data can be a useful in understanding site conditions and planning a subsurface investigation.
- Slope inclinometers were critical to identifying slip plane and formulating repair methods.
- The selected type of stabilization elements allowed for relatively small installation equipment which was more conducive to the site conditions and limited access.
- Communication and coordination were key to fulfilling the client’s desire to keep the railroad active throughout construction and limit impacts to railroad operations.
- The A-frame stabilization system was completed in June 2022 and no signs of slope or rail movement have been reported since.