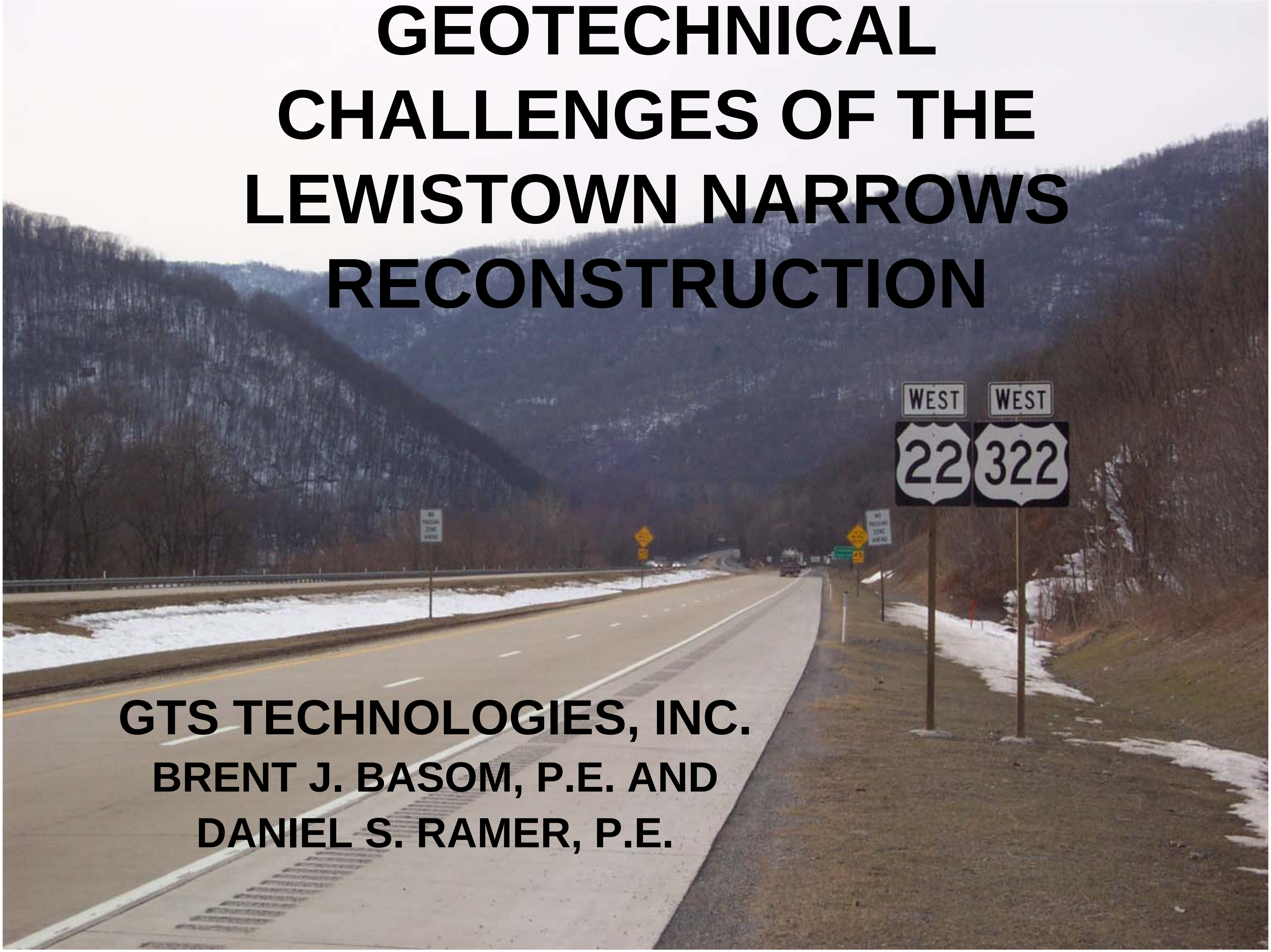
GEOTECHNICAL CHALLENGES OF THE LEWISTOWN NARROWS RECONSTRUCTION



GTS TECHNOLOGIES, INC.

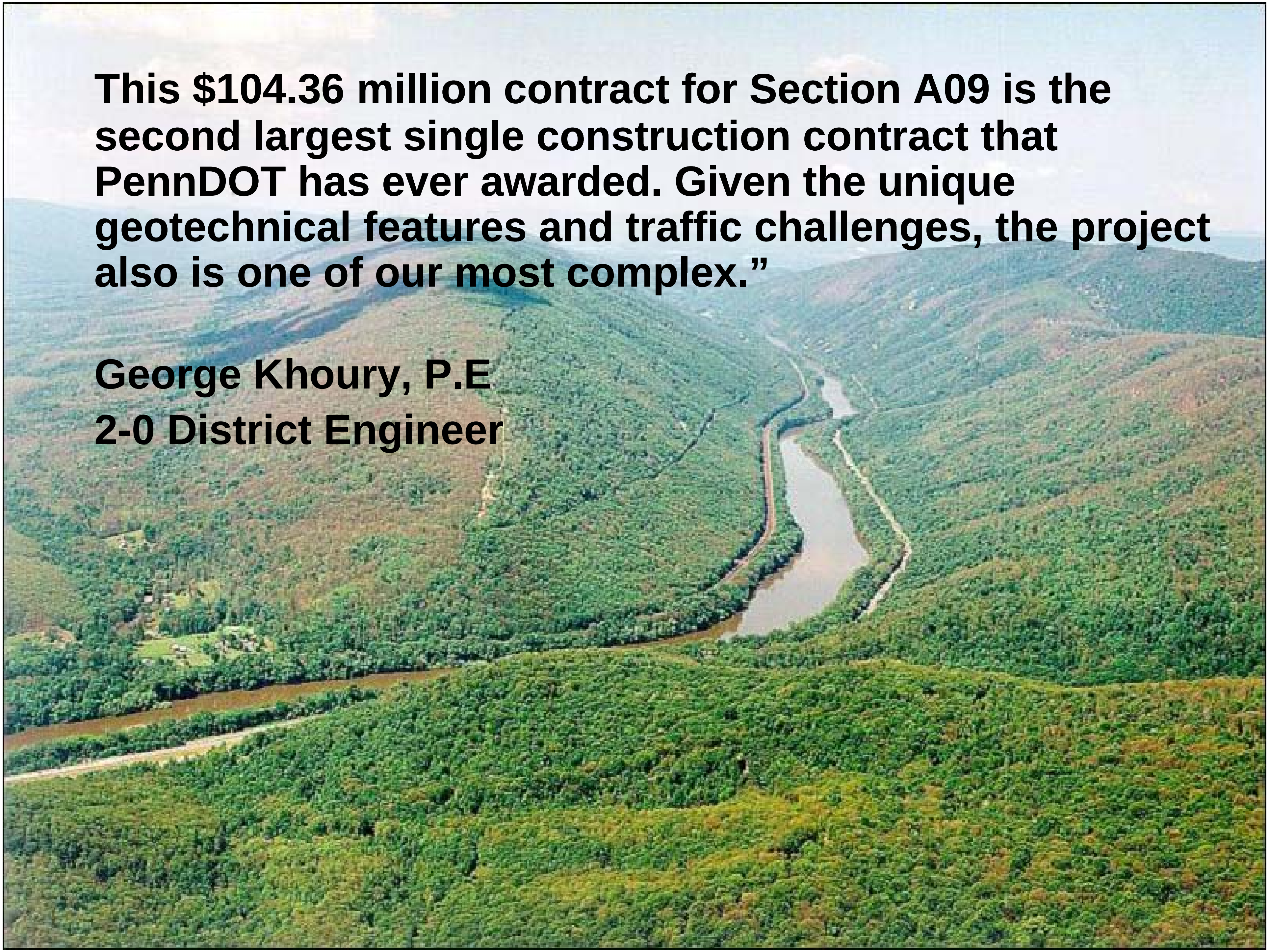
BRENT J. BASOM, P.E. AND

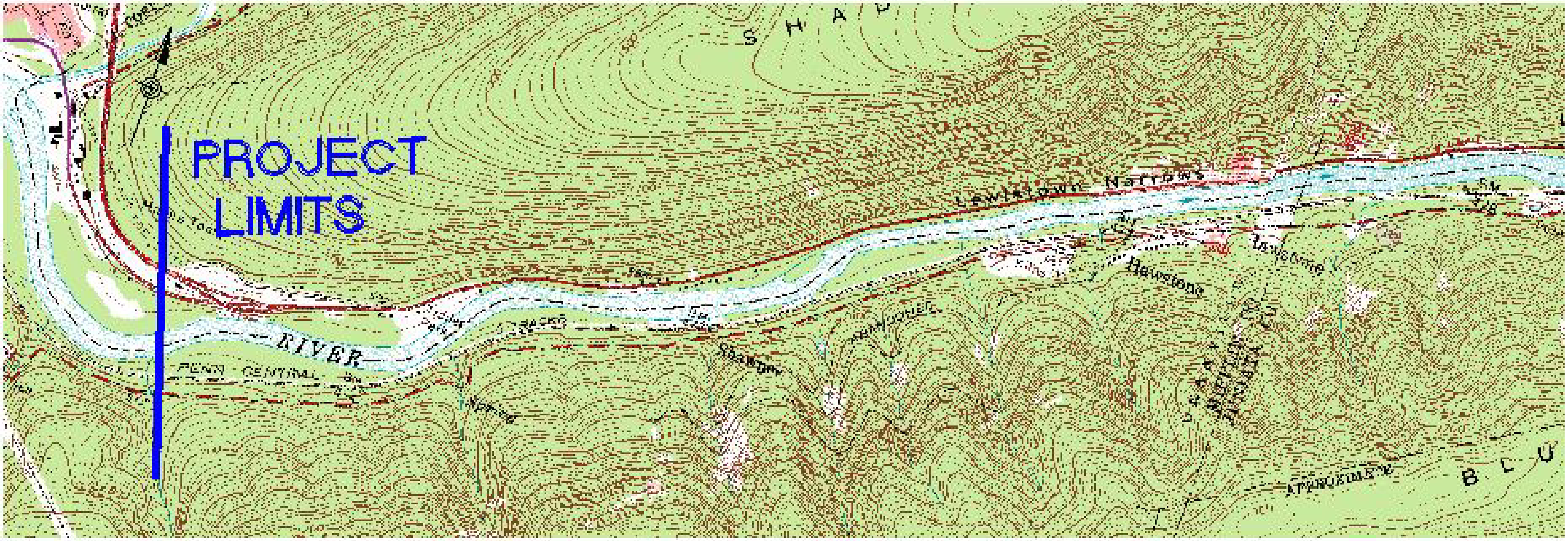
DANIEL S. RAMER, P.E.

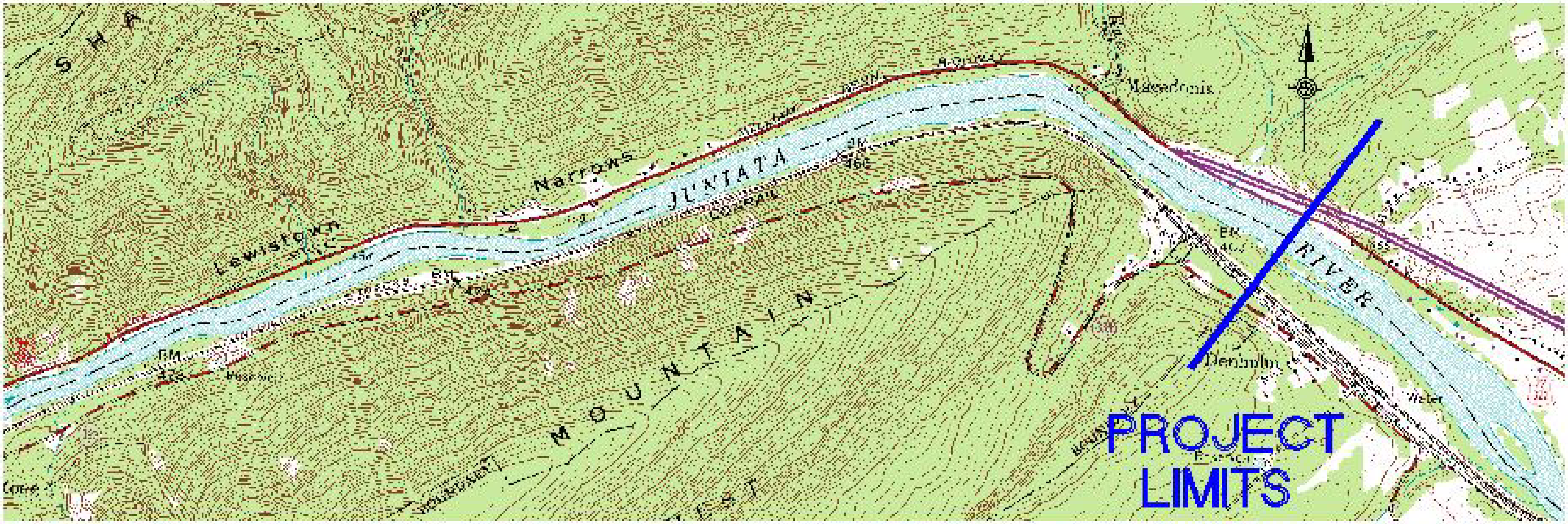
This $104.36 million contract for Section A09 is the second largest single construction contract that PennDOT has ever awarded. Given the unique geotechnical features and traffic challenges, the project also is one of our most complex."

George Khoury, P.E

2-0 District Engineer



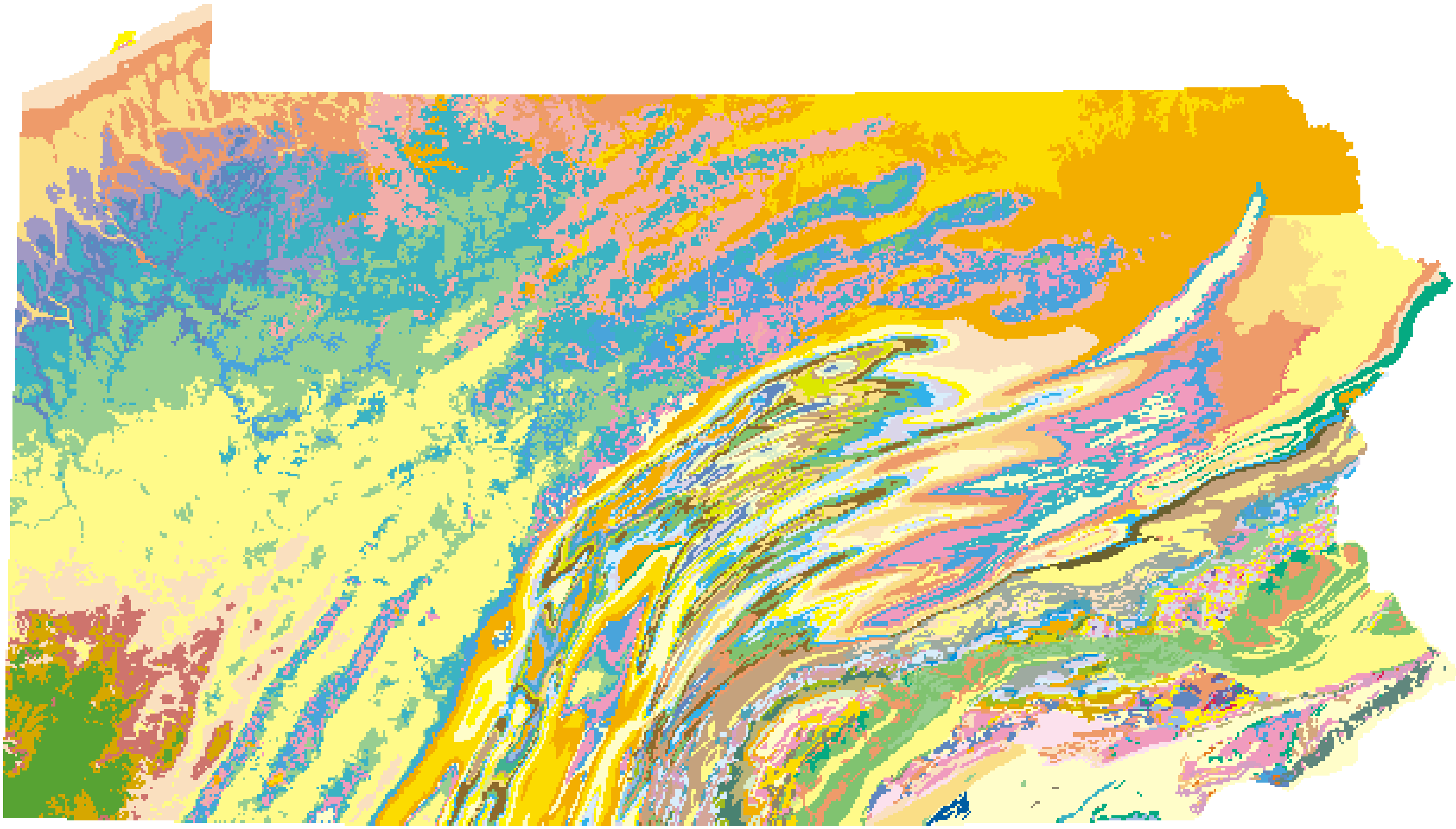

PROJECT
LIMITS
Lewistown Narrows
RIVER
PENN CENTRAL


Lewistown
Narrows
JUNIATA
RIVER
MOUNTAIN
PROJECT
LIMITS

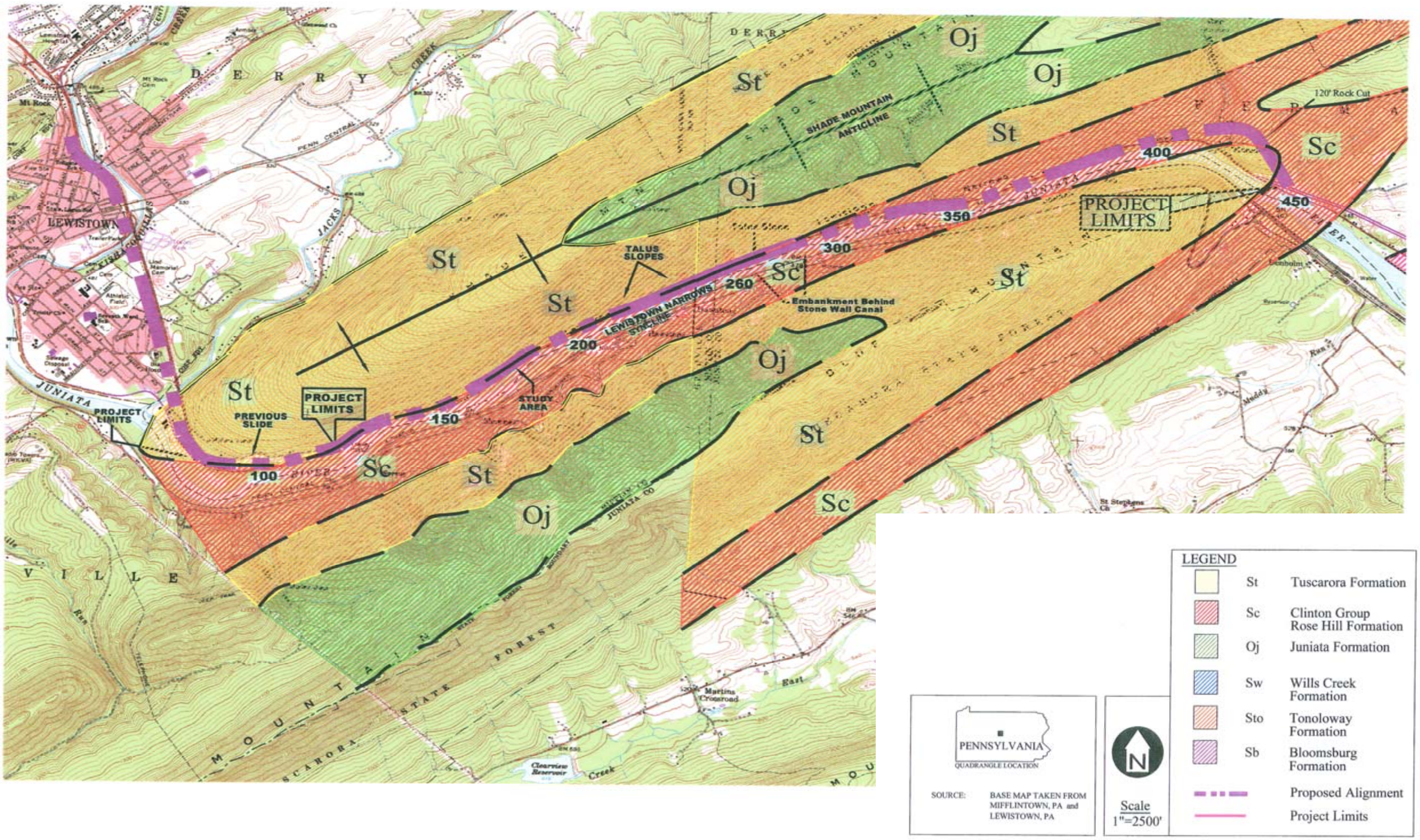

Lewistown 8
State College 38

PROJECT OVERVIEW

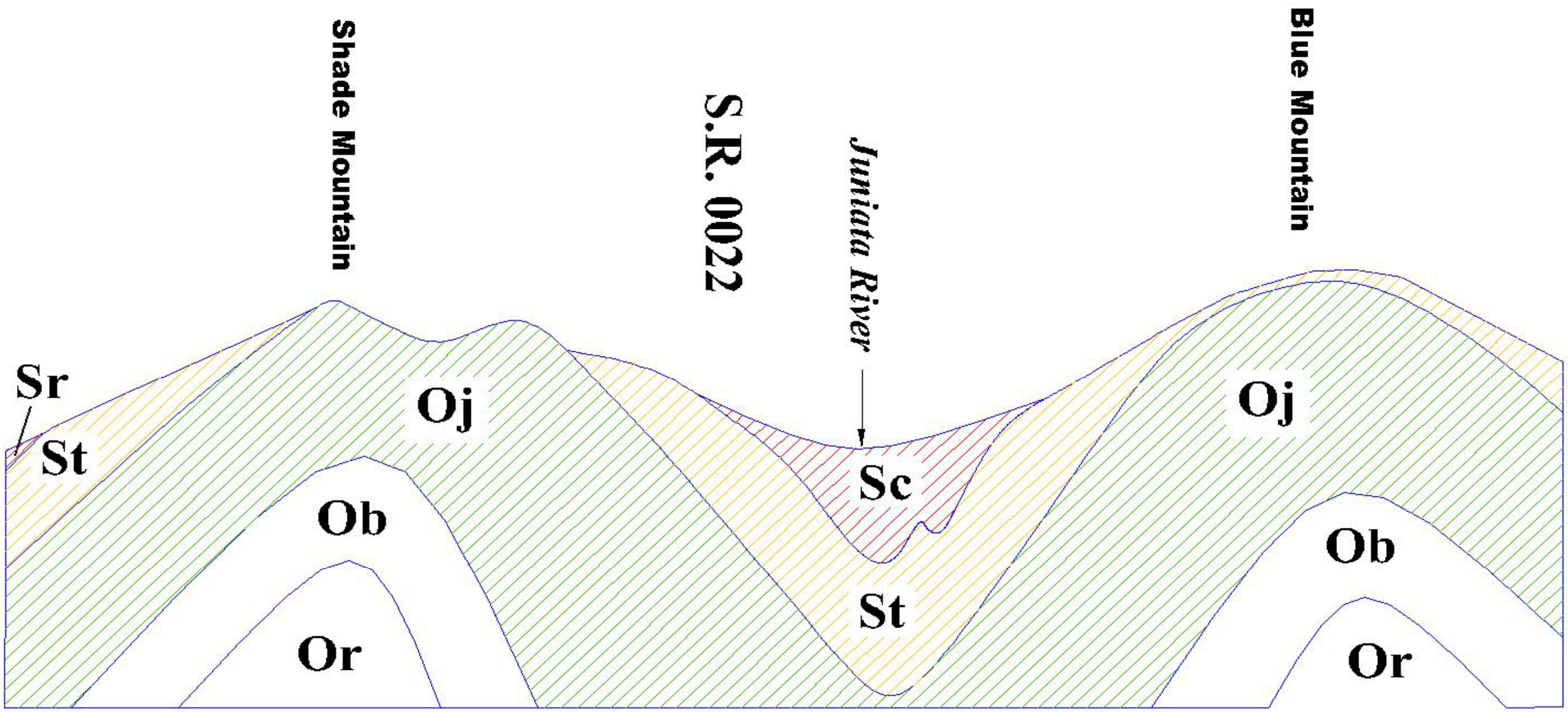
- 3 Construction Sections
  - A09 - $104.4m Narrows Reconstruction
    - » 6.5 miles
    - » 2 bridges, 3 culverts
    - » 2 MSE walls (15,000 lf), 9 CIP walls (7500 lf)
    - » 2.8m CY of earthwork
  - A10 – $12.7m Arch Rock Interchange Reconstruction
    - » Full diamond construction
    - » 3 bridges, 2 culverts
  - A11 – $17.7m SR 22/SR 322 Interchange
    - » 1 bridge, 2 MSE walls
    - » 360 rock anchors
    - » 380,000 CY earthwork



GEOLOGIC MAP



GEOLOGIC CROSS SECTION
through the Lewistown Narrows
(looking east)



Legend

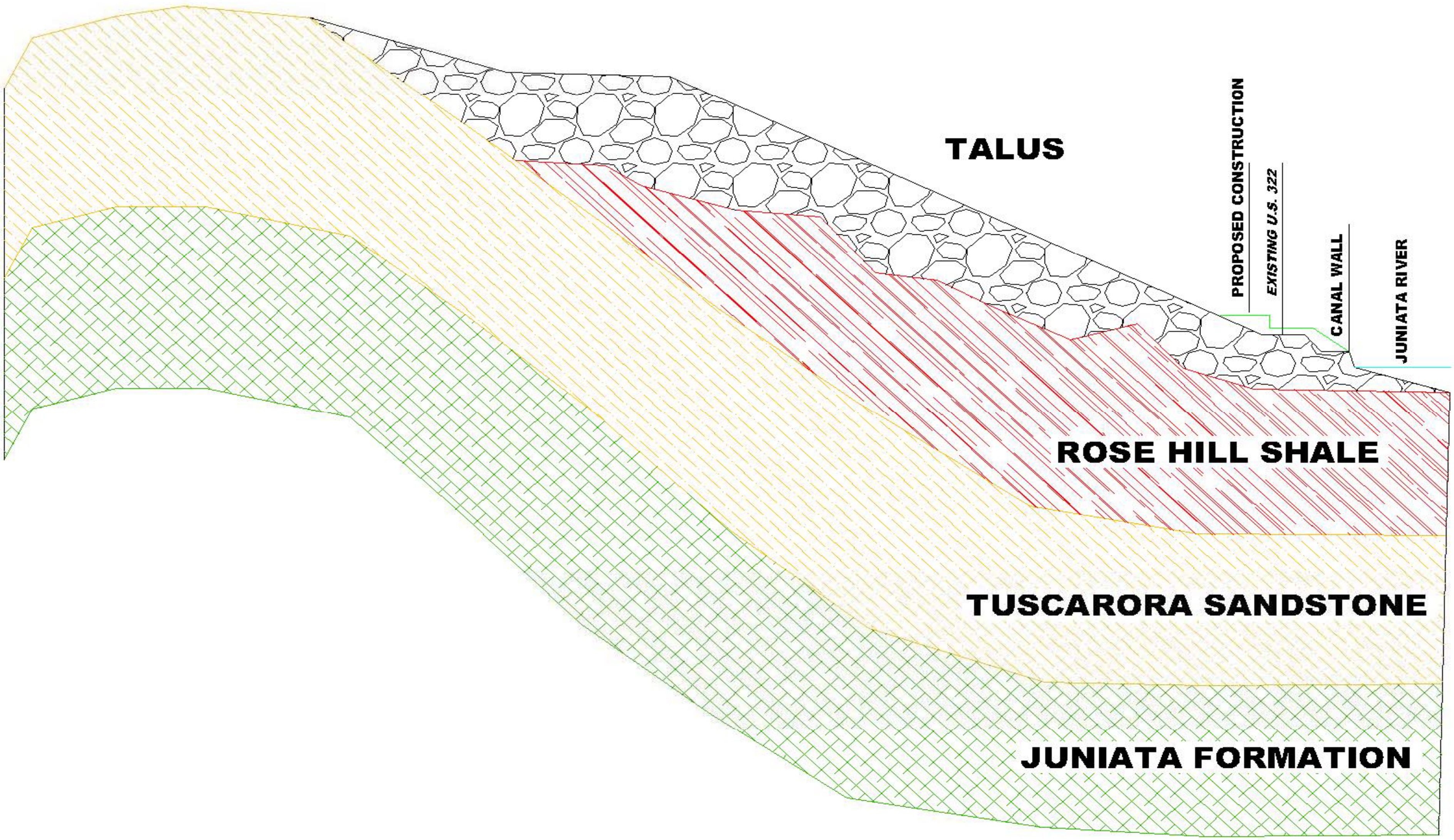
St - Tuscarora Formation

Sc - Rose Hill Formation

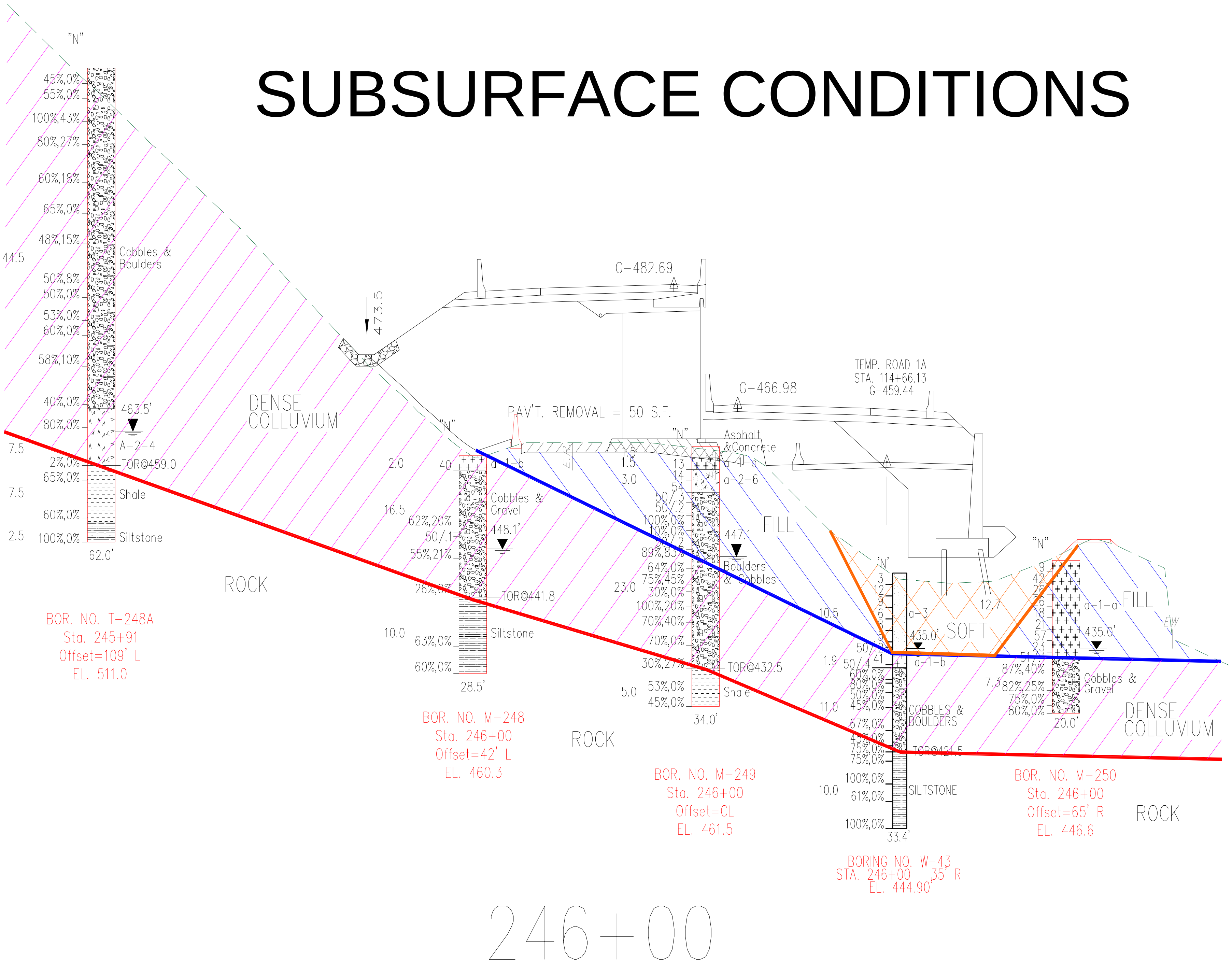
Oj - Juniata Formation

Ob - Beekmantown Group

Or - Reedsville Formation


TALUS
PROPOSED CONSTRUCTION
EXISTING U.S. 322
CANAL WALL
JUNIATA RIVER
ROSE HILL SHALE
TUSCARORA SANDSTONE
JUNIATA FORMATION

SUBSURFACE CONDITIONS



SUBSURFACE INVESTIGATIONS

- 850+ borings
- 35+ piezometers
- 8 inclinometers
- Geophysical investigations
  - VLF Resistivity
  - Seismic Refraction
  - Ground Penetrating Radar
- Utilized borings from previous design

SUBSURFACE INVESTIGATIONS

SUBSURFACE INVESTIGATIONS

SUBSURFACE INVESTIGATIONS

SUBSURFACE INVESTIGATIONS

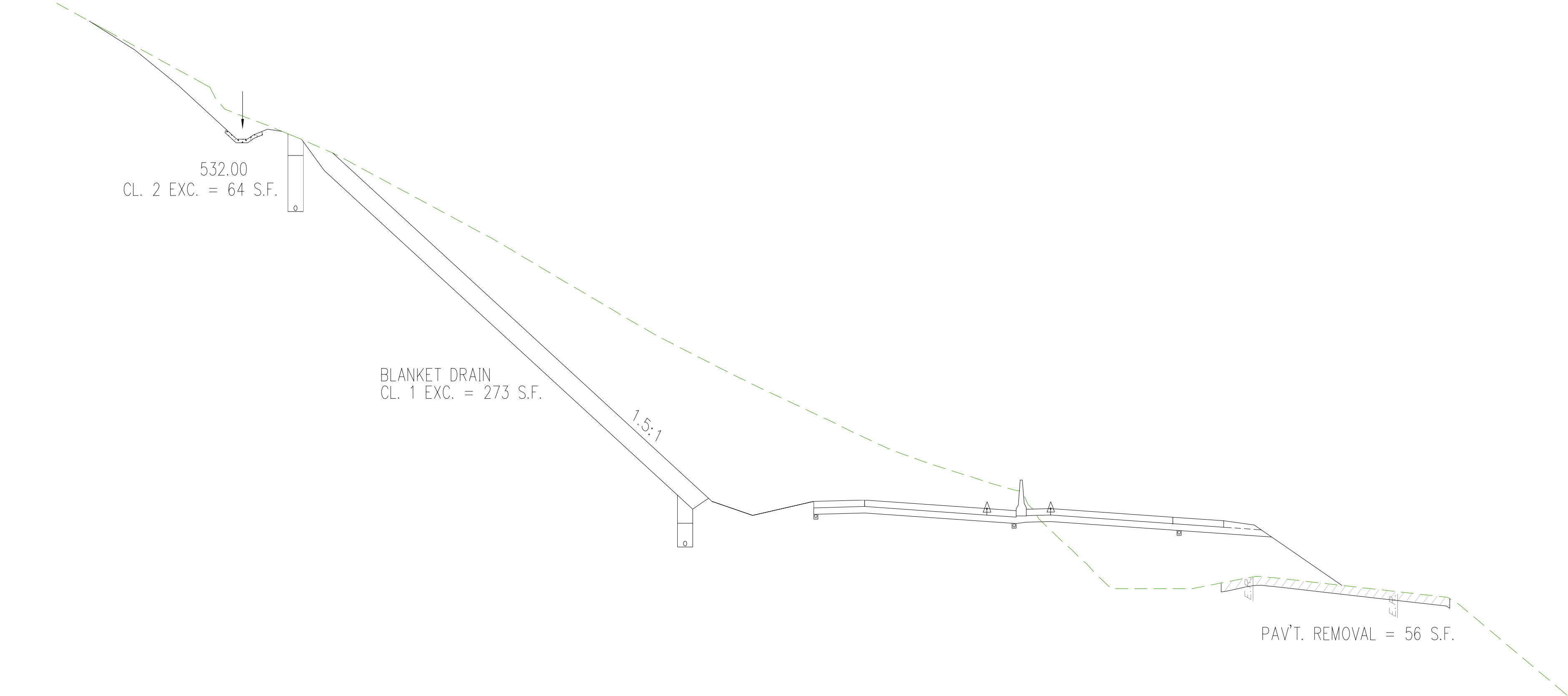
SUBSURFACE INVESTIGATIONS

GEOTECHNICAL CHALLENGES

- Stability of talus slopes
- Stability of bifurcation construction
- Talus rockfall and construction
- Reinforced soil slope design
- Instrumentation program
- Rock anchor design

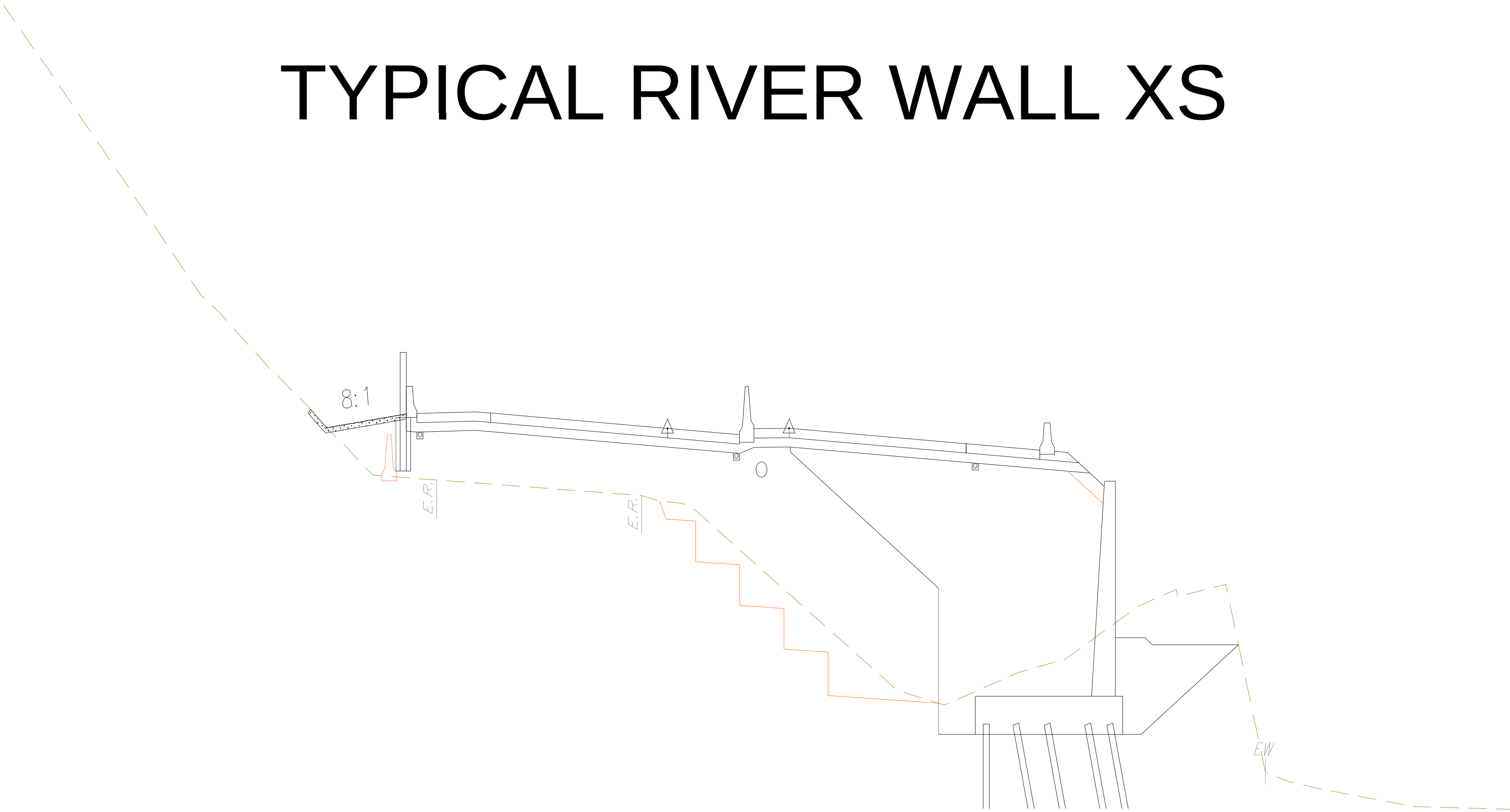
TYPICAL ROCK CUT XS

TYPICAL SOIL CUT XS



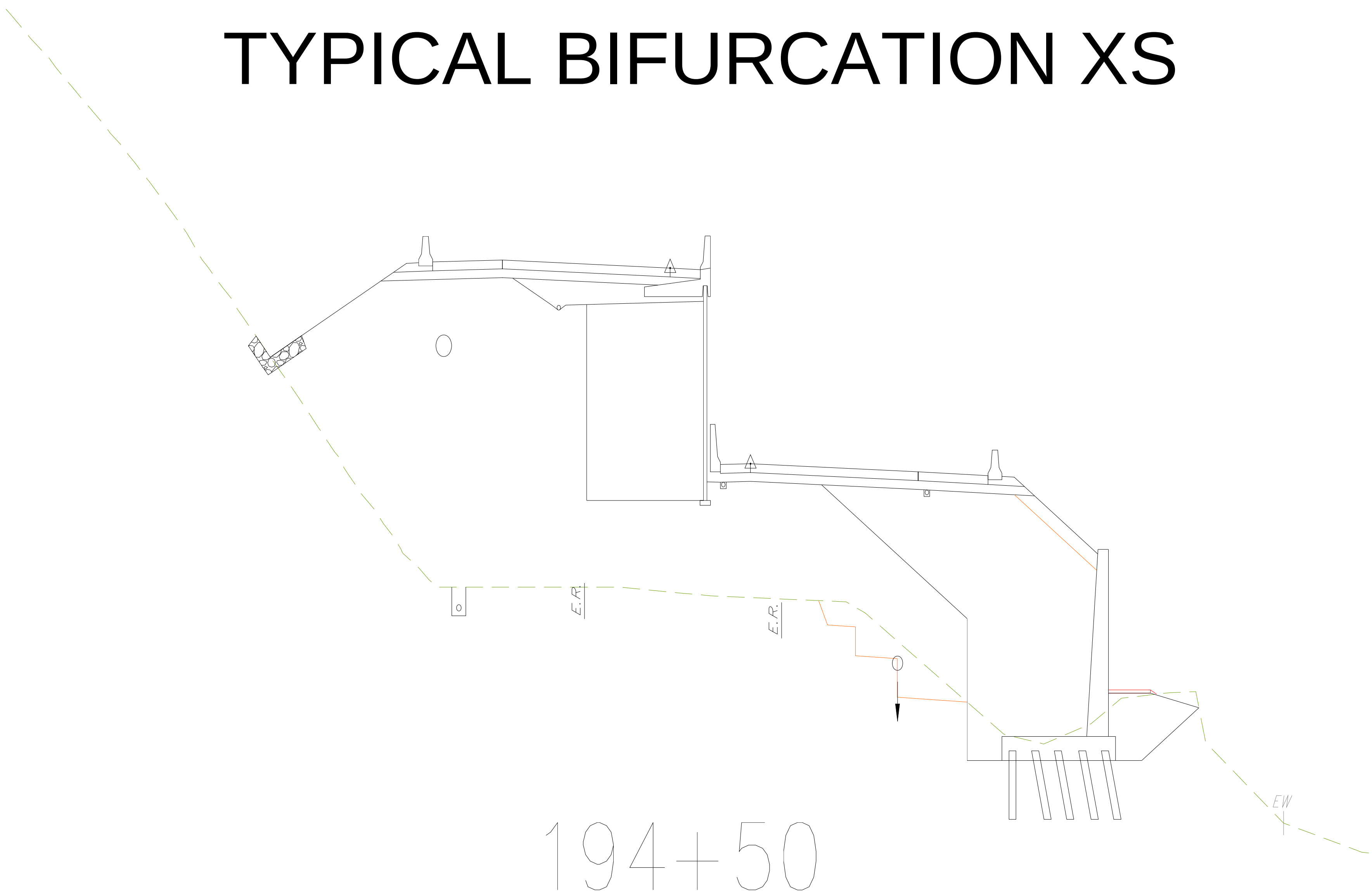
414+50

TYPICAL RIVER WALL XS

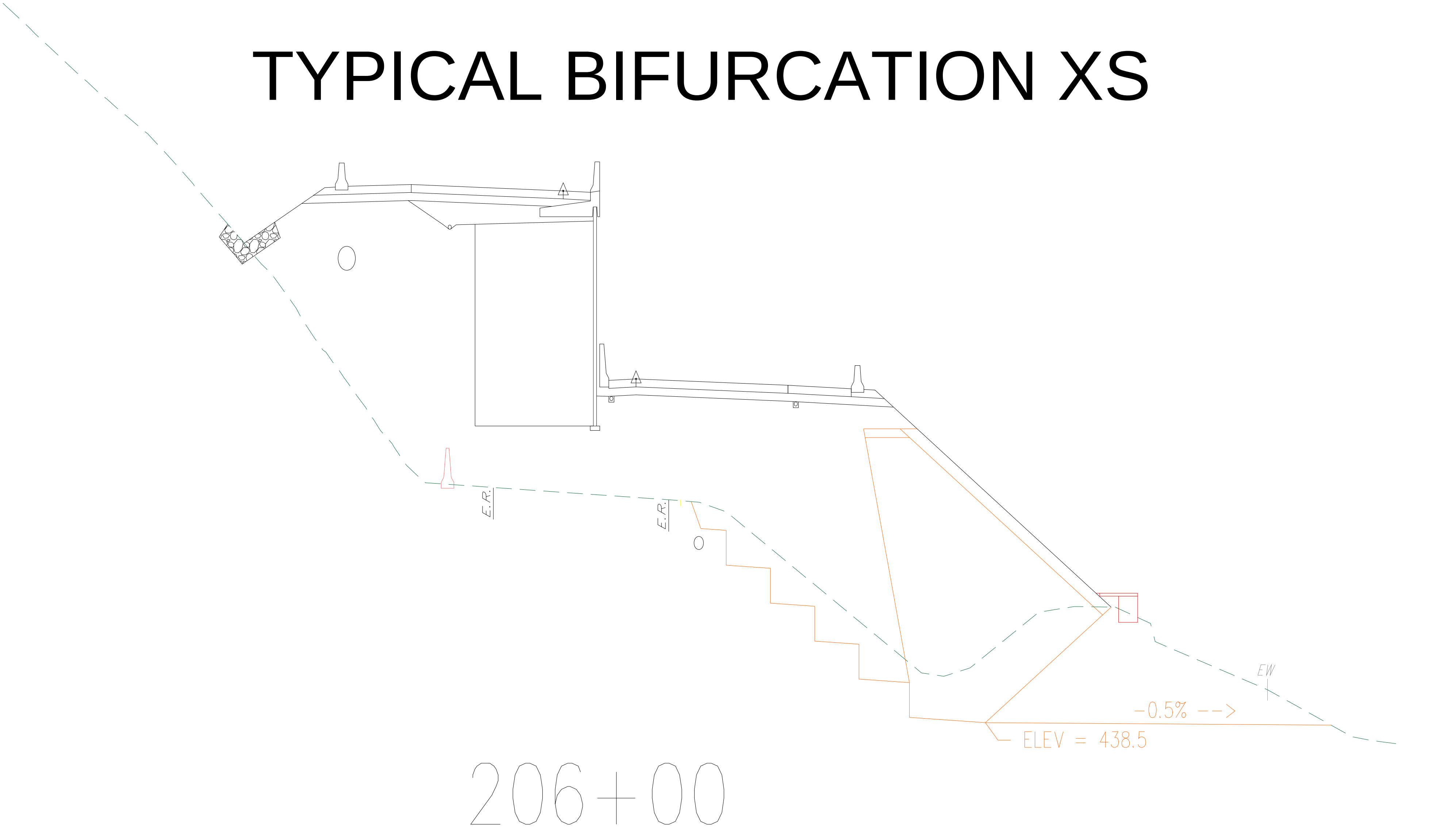


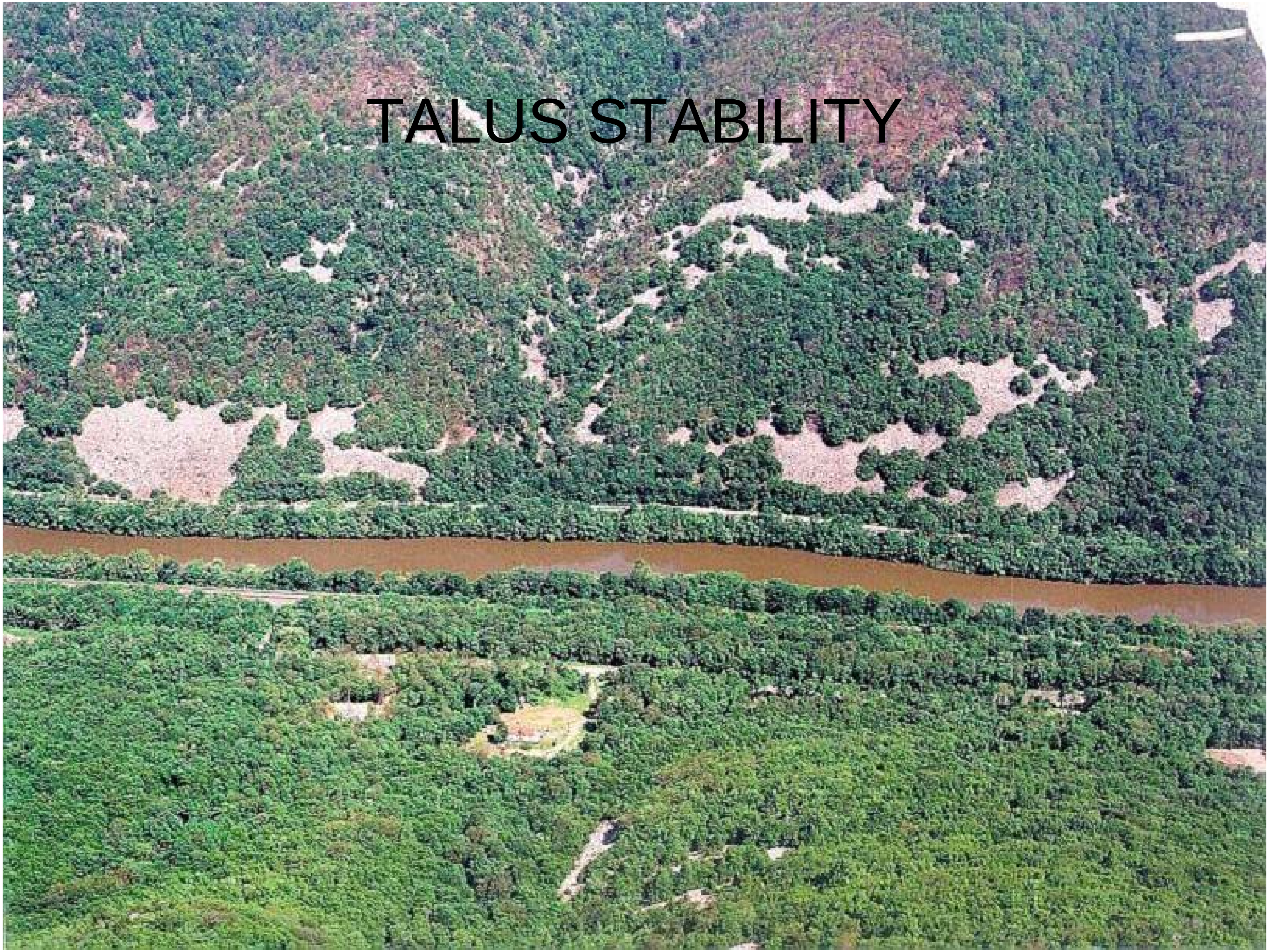
152+50

TYPICAL BIFURCATION XS



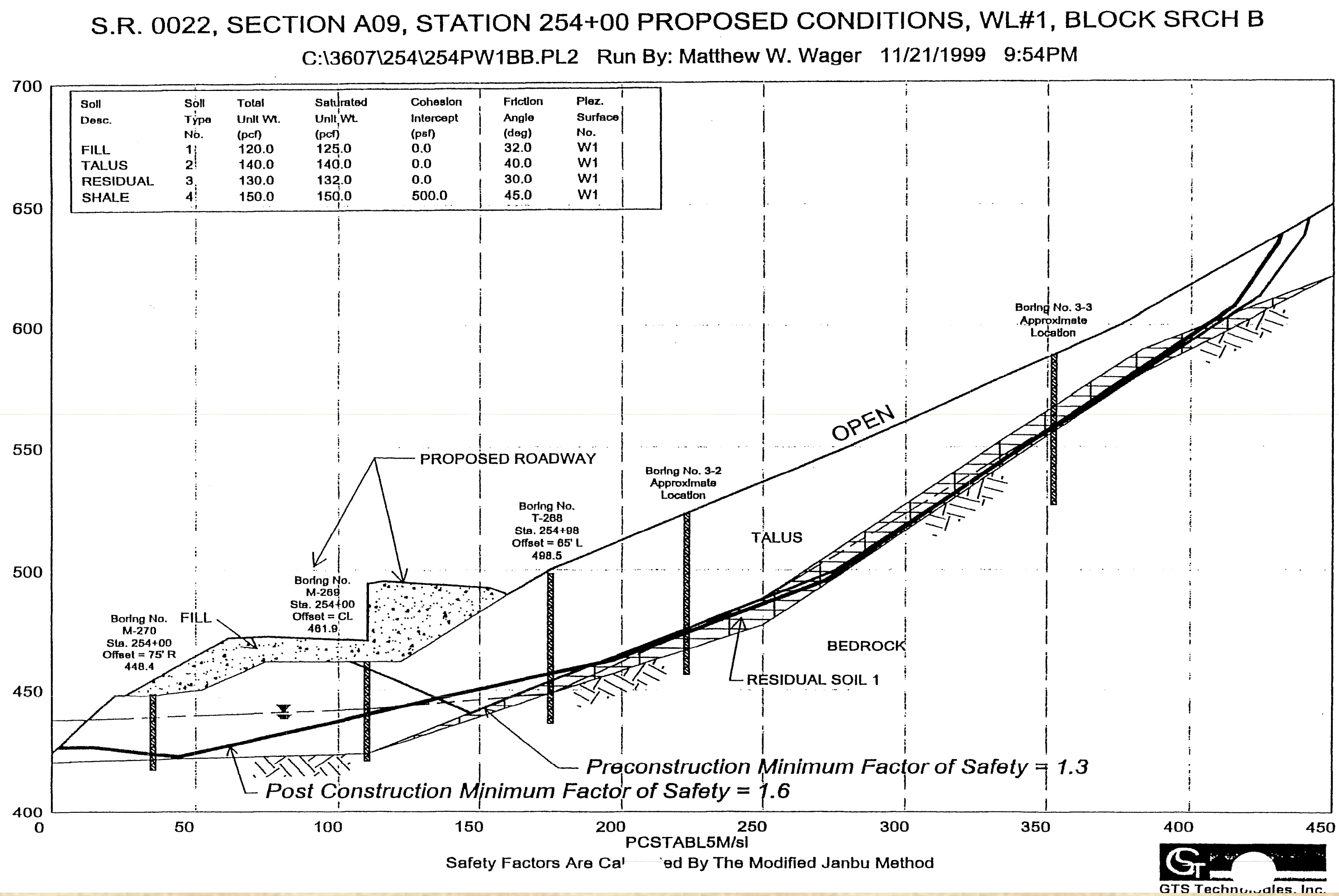
TYPICAL BIFURCATION XS




TALUS STABILITY


TALUS STABILITY

TALUS STABILITY



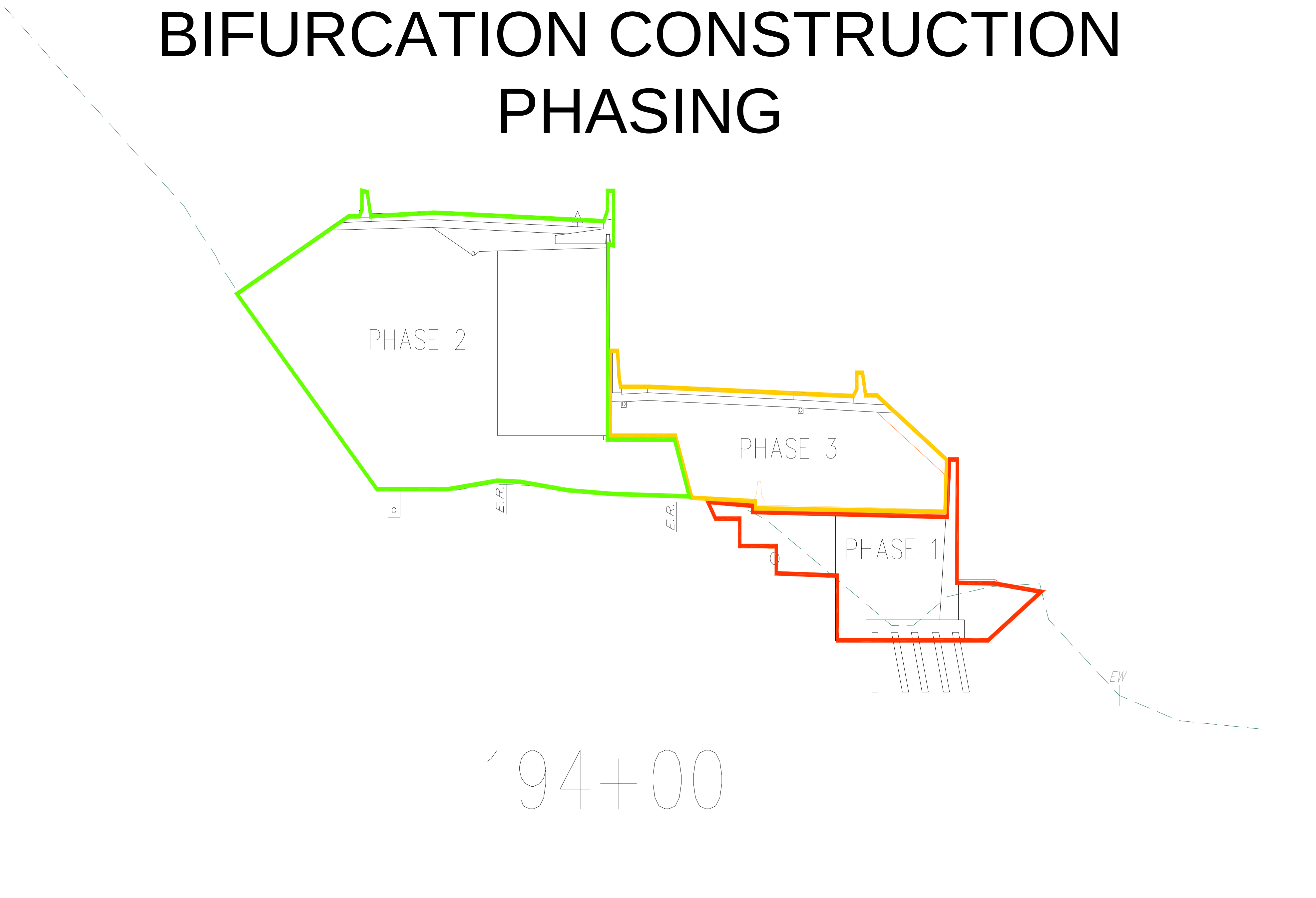
TALUS STABILITY ANALYSES

Station	$SF_{existing}$	$SF_{proposed}$
188+00	1.2	1.4
192+00	1.1	1.7
196+00	1.3	1.6
212+00	1.8	1.9
238+00	1.2	1.3
254+00	1.3	1.6
274+00	1.3	1.7

TALUS STABILITY CONCLUSIONS

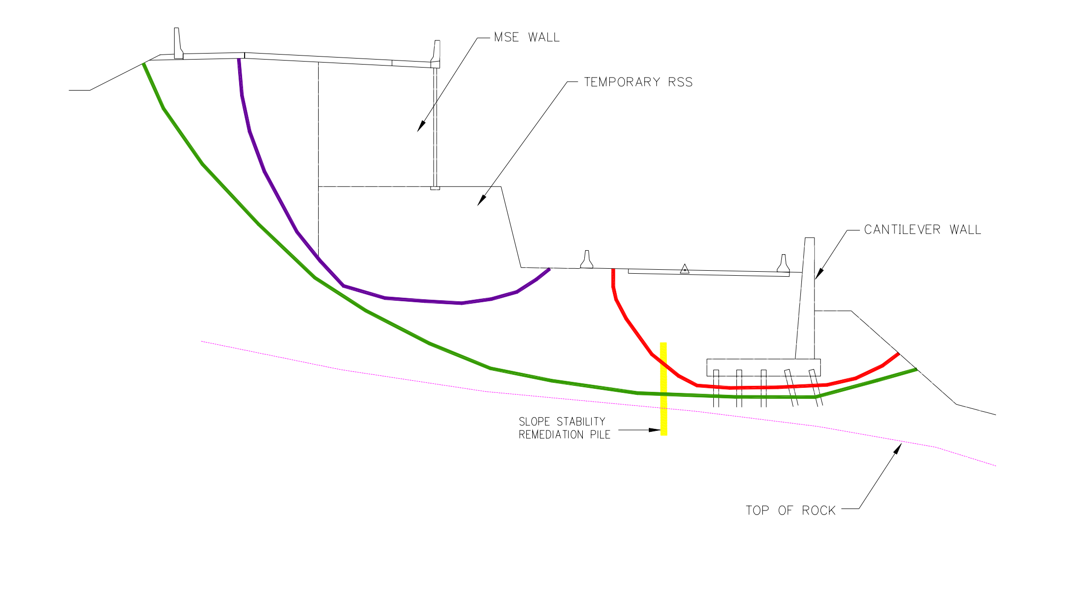
- Proposed construction increases SF, with overall SF>1.3.
- No recorded slides or slope movement, through flood events and excavations into talus.
- Based on recent history the talus is in a state of equilibrium.
- No economically feasible methods exist to stabilize the mountain slopes. Therefore SF = 1.3 is acceptable.
- Do not allow excavations into talus slopes.

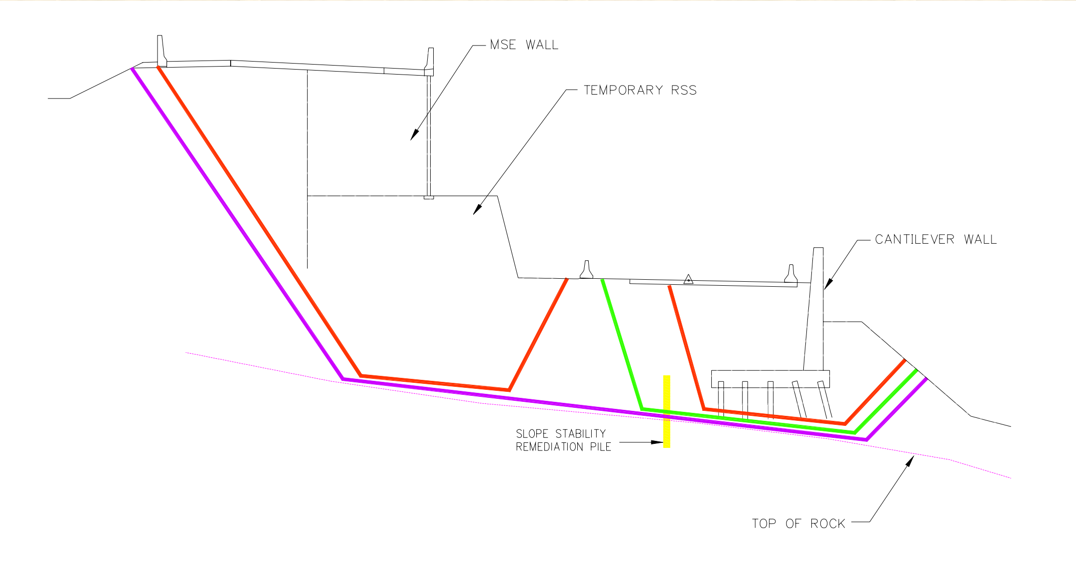
BIFURCATION CONSTRUCTION PHASING



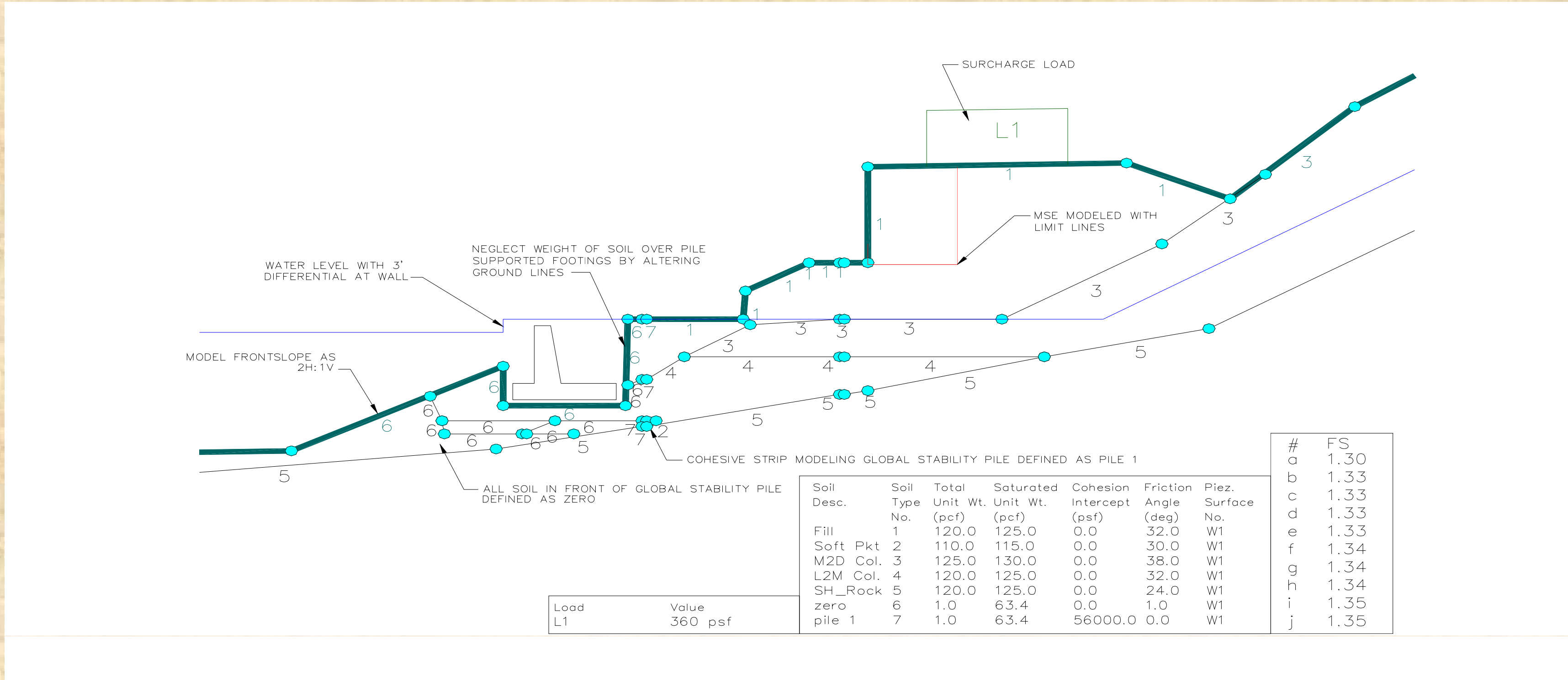
BIFURCATION FAILURE MODES

- Shallow Circle
- MSE Circle
- Deep Circle
- Eastbound Block
- Sliver Block
- MSE Block
- Full Block





BIFURCATION ANALYSES



- Target safety factor
  - Phase 1 and 2, SF = 1.3
  - Phase 3 SF = 1.5
- Water Levels – No water and critical flood elevation
- Traffic surcharge iterations
- Soil vertically supported by wall footing does not contribute to driving or resistance of failure mass

REJECTED REMEDIATION OPTIONS

REDUCE DRIVING FORCES

Construct median northbound lanes of bifurcation with lightweight fill.	Rejected due to cost of fill and also stability concerns still existed.
Lower westbound grades to improve stability.	Performed to the extent possible.
Support westbound lanes on viaduct.	Rejected due to cost, schedule and also stability concerns still existed to some extent.

REJECTED REMEDIATION OPTIONS

INCREASE RESISITING FORCES

Construct MSE river wall to increase resisting force.	Rejected due to scour and erosion concerns of wall adjacent to river.
Utilize tiebacks to provide resisting forces.	Rejected as tiebacks will extend though and be bonded in questionable material. Concerns with longevity.
Use rear row of retaining wall piles to provide resistance.	Would need to predrill and socket all piles. Could only provide 30 k/lf resistance. Don’t allow global stability loads to reach walls.

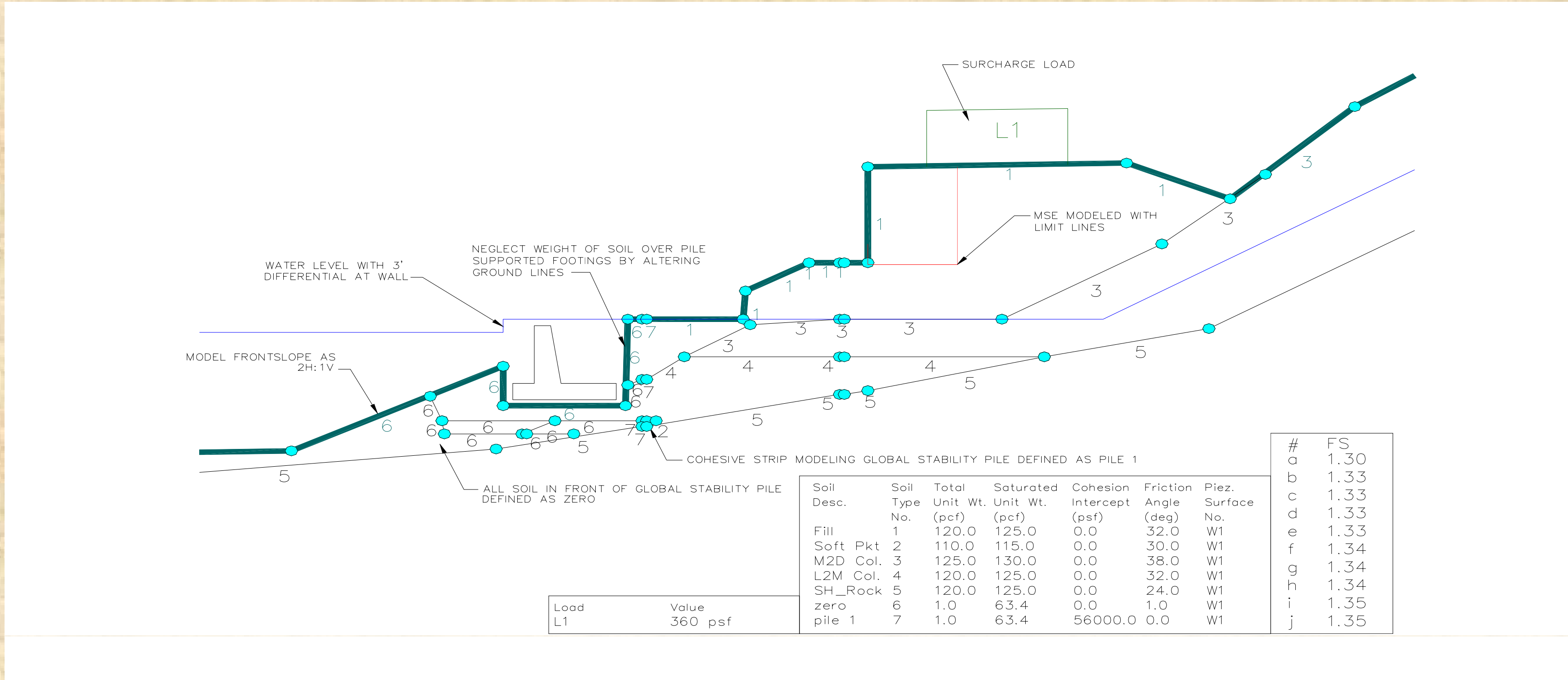
REMEDIATION TS&L

- System of discrete vertical elements designed to resist the driving forces through bending and shear of the element.
  - Steel H-piles socketed into bedrock
  - Micro-piles drilled into bedrock
  - Drilled Shafts socketed into bedrock
- Piles located 5 feet behind the heel of the retaining wall. Will not allow loads to transfer to wall.

SELECTED REMEDIATION OPTION

Option	Structural Resistance (k/lf)	Total Cost	Production Rate
14” H-piles	200	$20 m	2/day
7” Micro-piles	100	$14 m	8/day

ANALYSIS METHODOLOGY



- Retaining wall does not contribute to the stability of the slope (i.e. neglect all soil in front of the wall).
- Model the necessary resisting force as a 1 foot wide cohesive strip extending through bedrock.
- Adjust the cohesion of the strip to obtain the target safety factor.

ANALYSIS RESULTS

STA 266 Phase 1 - Target F.S. = 1.3

Failure Surface	Critical WSEL	Original F.S.	Pile Location from CL	Required Remediation Pile Force (klf)
Shallow Circle	Normal	1.17	N/A	N/A
	BFE	1.13		
Block	Normal	1.53		
	BFE	1.56		

STA 266 Phase 2 - Target F.S. = 1.3

Failure Surface	Critical WSEL	Original F.S.	Pile-1 Location from CL	Required Pile-1 Force (klf)
Shallow Circle	intermed.	0.91	34'R	11.3
	No Water	1.46		N/A
MSE Circle	100 YR	1.33^	N/A	N/A
	No Water	1.43		
Deep Circle	intermed.	1.22	34'R	20
	No Water	1.54		N/A
Block	intermed.	1.13	34'R	48
	No Water	1.41		N/A

STA 266 Phase 3 - Target F.S. = 1.5

Failure Surface	Critical WSEL	Original F.S.	Pile-1 Location from CL	Required Pile-1 Force (klf)
Shallow Circle	intermed.	0.84	34'R	24
	No Water	1.18		22
"Artificial" Shallow Circle[1]	intermed.	0.83	34'R	14.5
	No Water	1.18		13
MSE Circle	100 YR	1.91	N/A	N/A
	No Water	2.18		
Deep Circle	100 YR	1.33	34'R	33
	No Water	1.57		N/A
"Artificial" Deep Circle[1]	100 YR	1.32	34'R	18
	No Water	1.60		N/A
East Bound Block	intermed.	1.14	34'R	57
	No Water	1.5		N/A
Block	intermed.	1.11	34'R	57
	No Water	1.38		44

1) Artificial Shallow and Deep Circles were analyzed to force ci and/or L2M material.

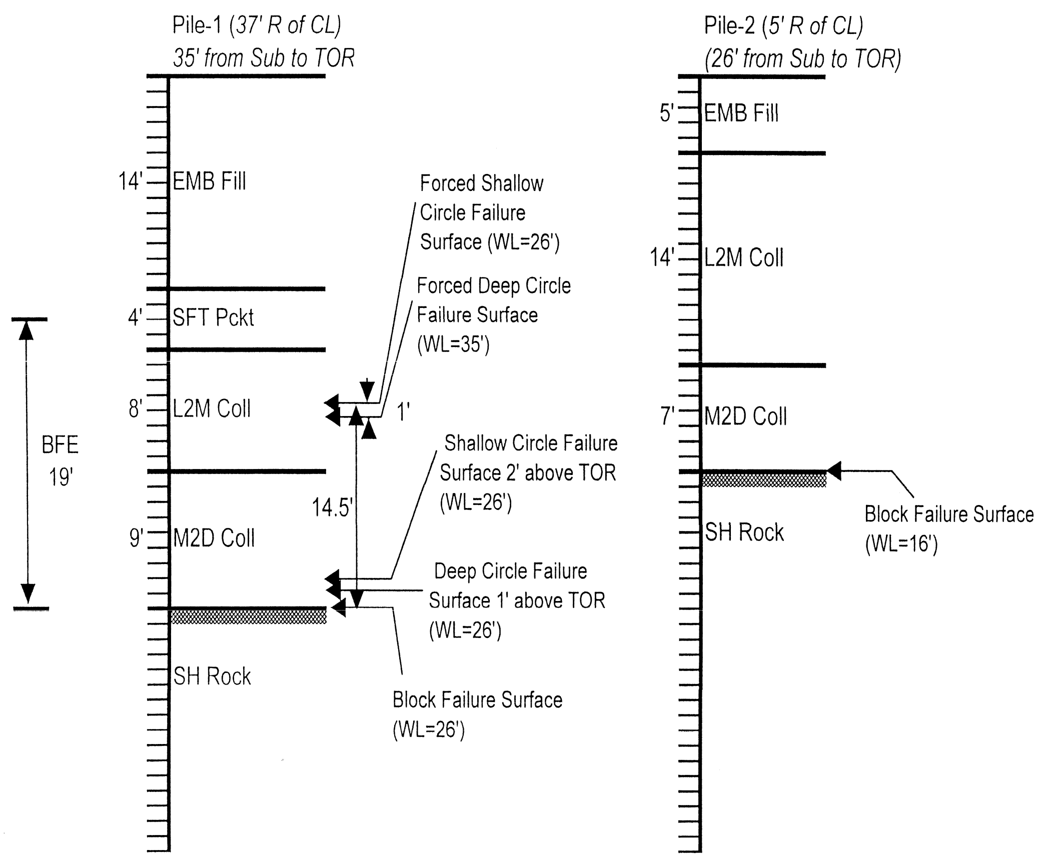
N/A- Not Applicable

^=Strap lengths were extened 2' to provide appropriate F.S.

ANALYSIS RESULTS

	Unit Weights (pcf)			Subgrade Modulus (pci)	
Soil Properties	Dry	Sat.	Friction Angle	Dry	Sat.
EMB FILL	120	125	32	130	90
SFT PCKT	110	115	26	60	40
L2M COLL	120	125	30	120	80
M2D COLL	125	130	38	275	175
SH ROCK	140	145	45	600	500

Phase No.: 3



BIFURCATION STABILITY CONCLUSIONS

- Eastbound and Full Block failures typically resulted in a load of 60 to 100 k/lf.
- Shallow circles and full circles typically resulted in a load of 20 to 40 k/lf.
- MSE circles and MSE Blocks occurred in isolated areas (10 to 20 k/lf) requiring an occasional second row of piles at the median.

MICRO-PILE DESIGN

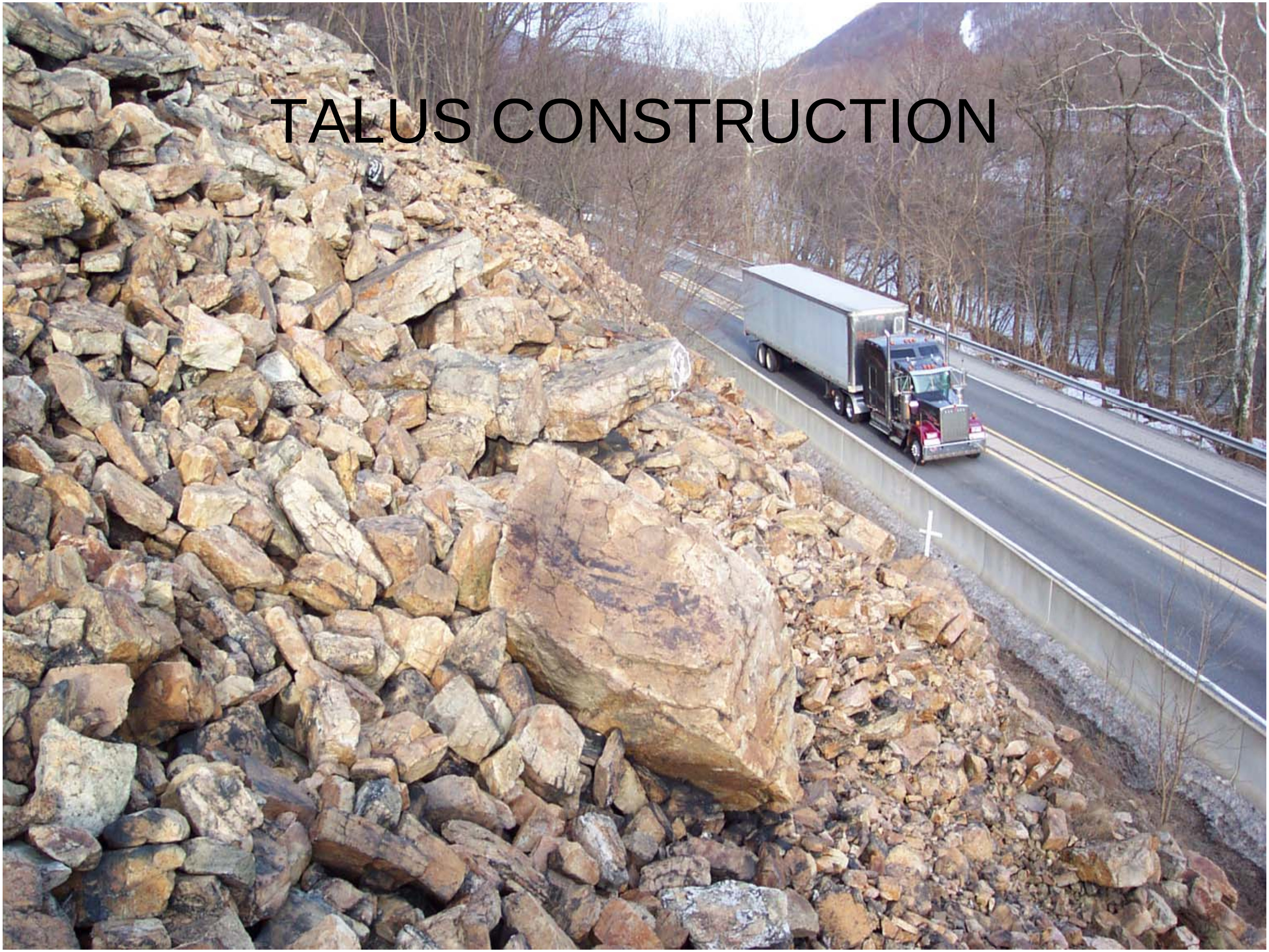
- Designed as a shear pin, holding a block on an inclined plane. Considered shear and deflection in design.
- Limited deflection to 1”.
- Used 7” pipe due to availability.
- Analyses showed a 4 foot embedment into rock was required, specified 6 feet due to variable nature of rock.
- Typical spacing of piles was 1’ to 2’, constructed in a staggered (sawtooth) pattern.
- Final plans included 230,000 lf (42 miles) of micro-piles, bid at $19,000,000 for the entire project.

STABILITY ANALYSIS FAST FACTS

- (7 failure types) x (2 phases) x (2 water levels) x (2 pile options)
  = 56 possible failure analyses per station.
- (2 failure types) x (2 water levels) x (2 pile options)
  = 8 possible phase 1 analyses per station.
- Analyzed 84 stations for walls only (100 to 200 foot intervals)
- Estimated total number of stability runs performed over the life of the project????

450,000?

TALUS CONSTRUCTION



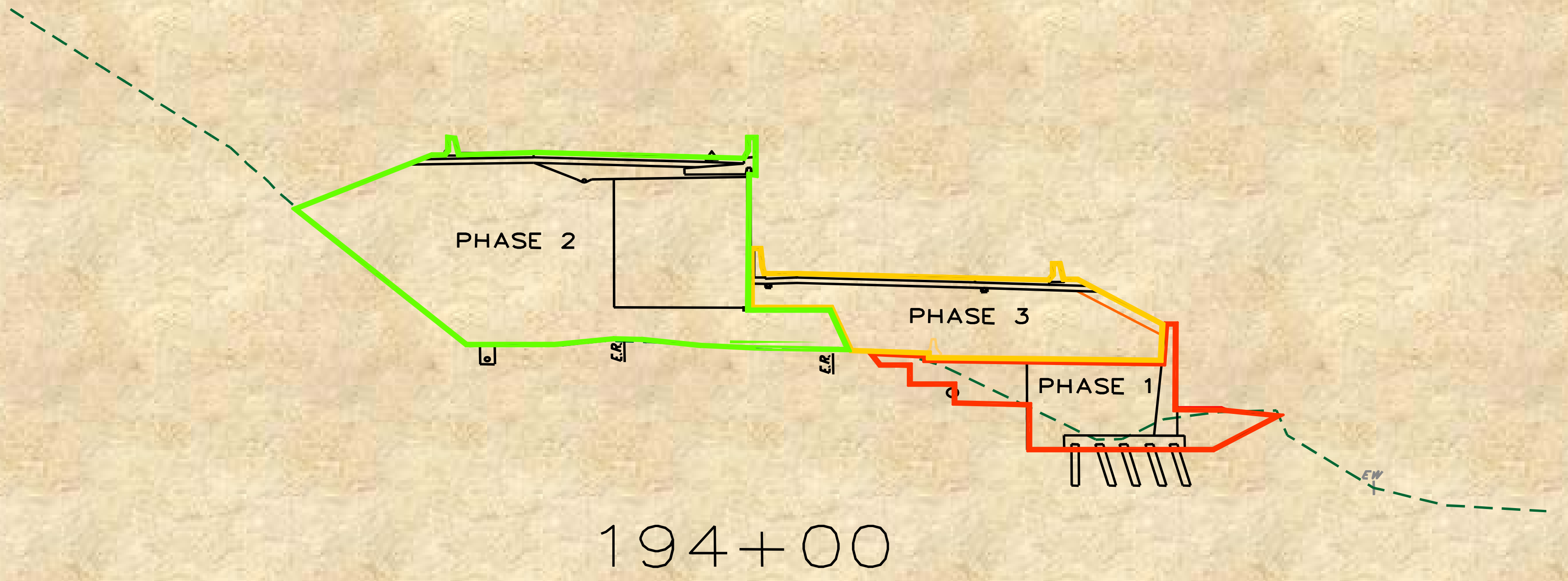
TALUS CONSTRUCTION

TALUS CONSTRUCTION


37


607L63

TALUS CONSIDERATIONS

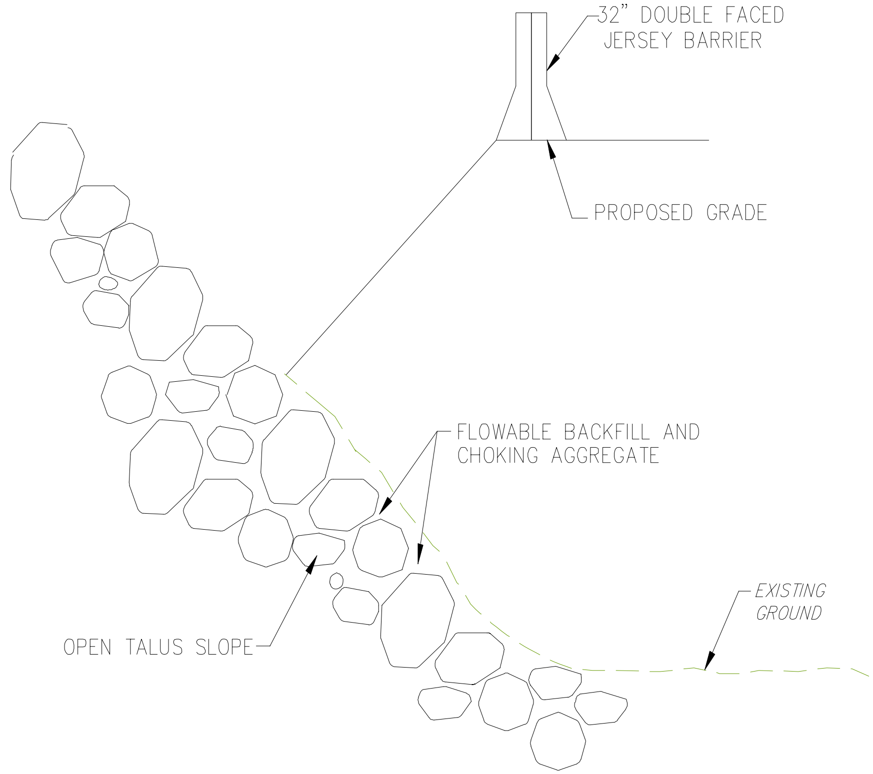


- Phase 1 - Remediation of talus rockfall during construction.
- Phase 2 - Construction of embankment over talus.
- Phase 2 and 3 - Permanent talus rockfall protection.

PHASE 1 REMEDIATION

- Pre-Construction Remediation
  - Removal
  - Buttressing
  - Flowable fill
- Phase 1 Temporary Rockfall Protection
  - Protect traffic during phase 1.
  - Fence to be designed by contractor to withstand force of 10,000 ft lbs, with a height of 10 feet.
  - Vibration monitoring to ensure no vibration induced rockfall.

EMBANKMENT OVER TALUS



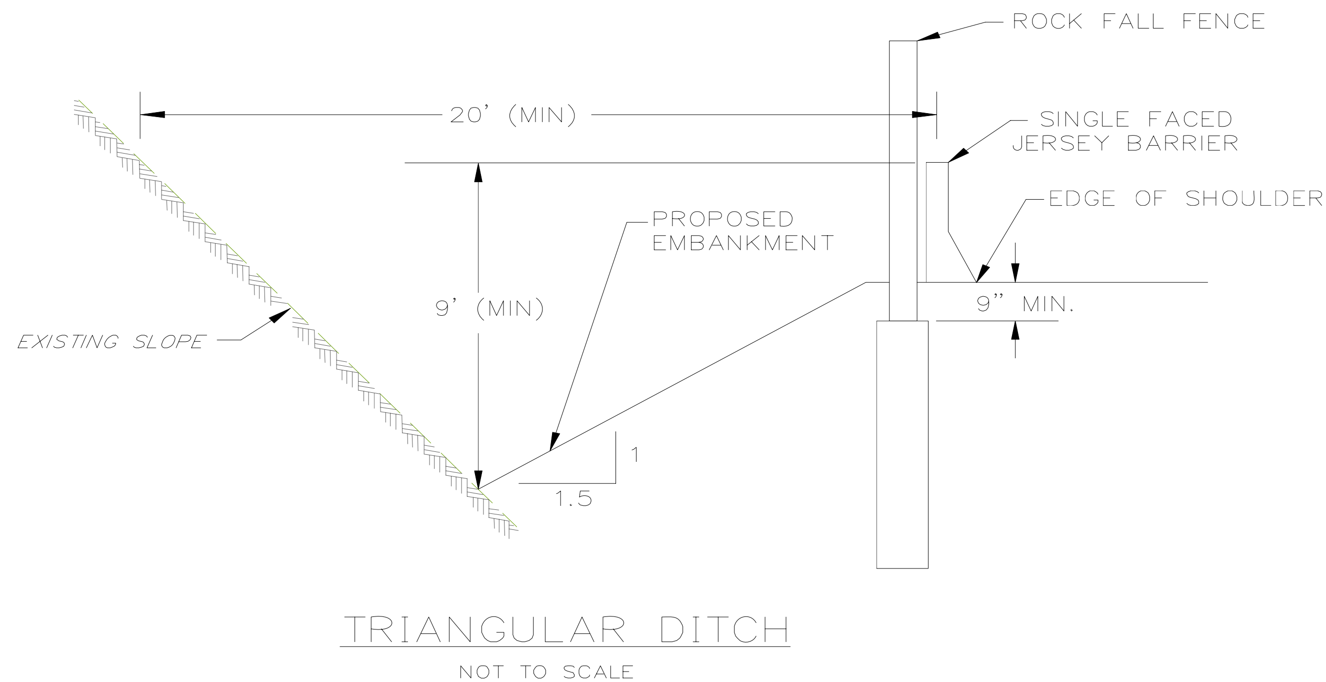
TALUS CHOKING

NOT TO SCALE

PHASE 2 REMEDIATION

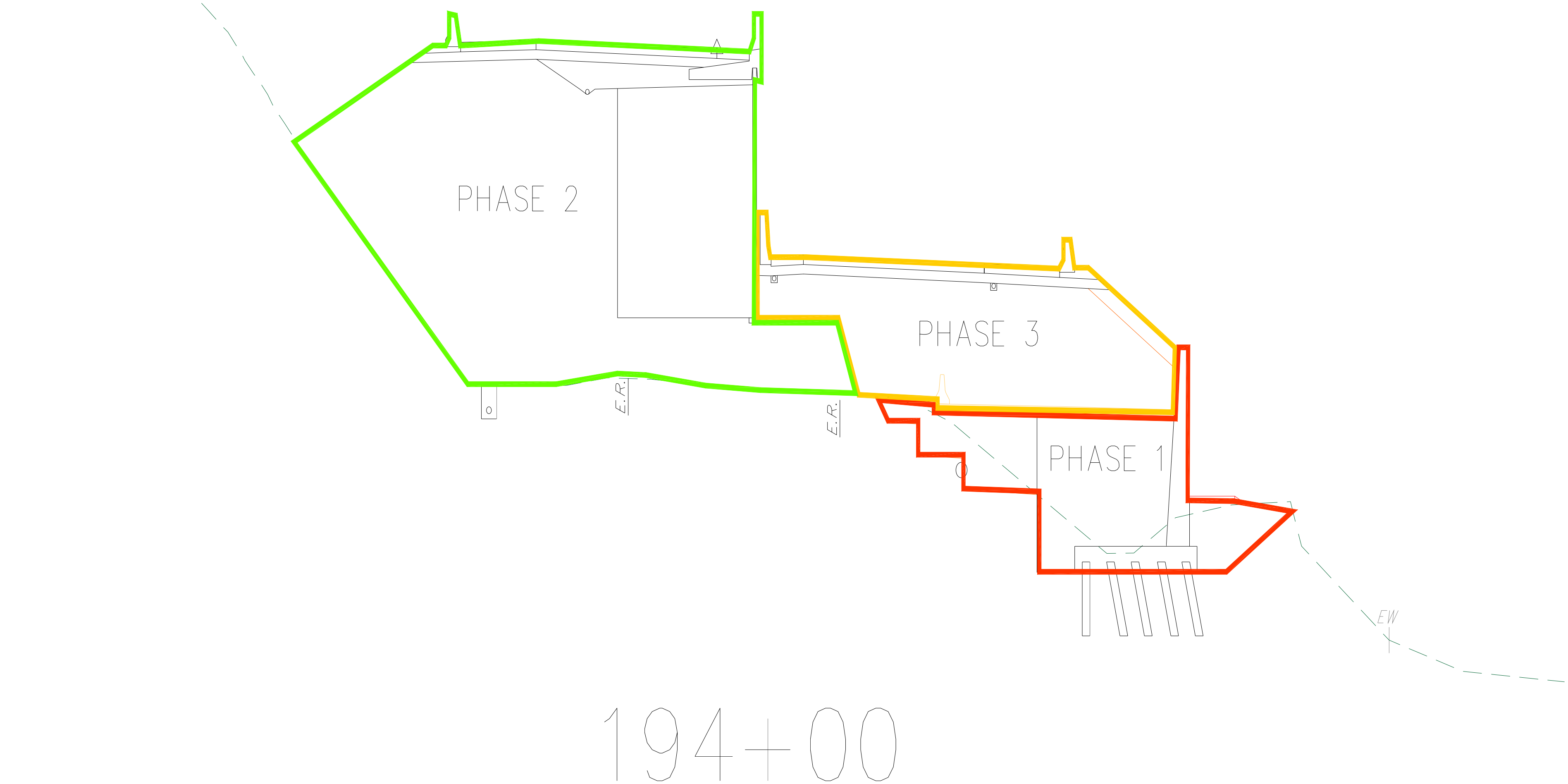
- Traffic will be protected by the buffer zone created by the WB lanes and the MSE wall.
- Permanent remediation of all talus problems.
  - Removal
  - Buttressing
  - Flowable Fill
  - Rock bolts and anchors
  - Netting and tiedowns

PERMANENT ROCKFALL PROTECTION

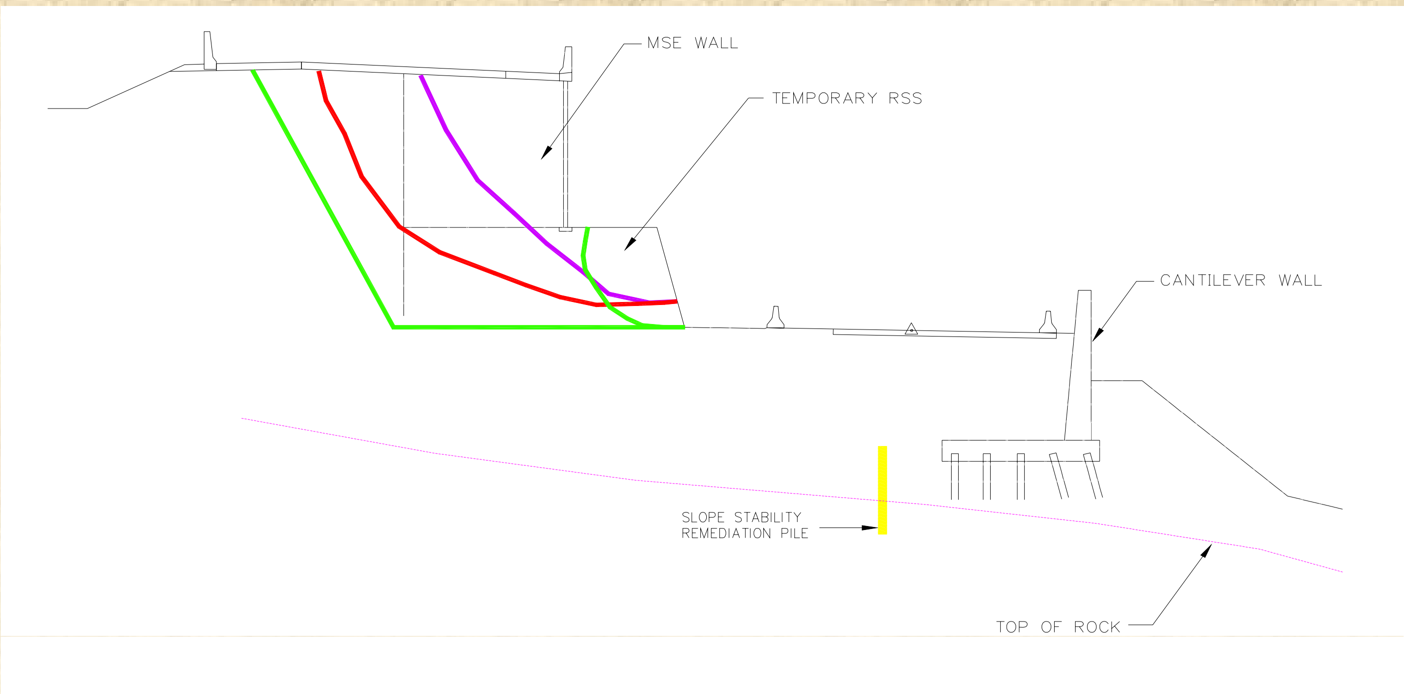


- Required for slopes steeper than 1.5:1.
- Combination design using CRSP and Ritchie ditch design.
- 9' deep by 20' wide V-ditch.
- 8' high soldier beam rockfall fence where ditch is inadequate.

TEMPORARY REINFORCED SOIL SLOPE (RSS)

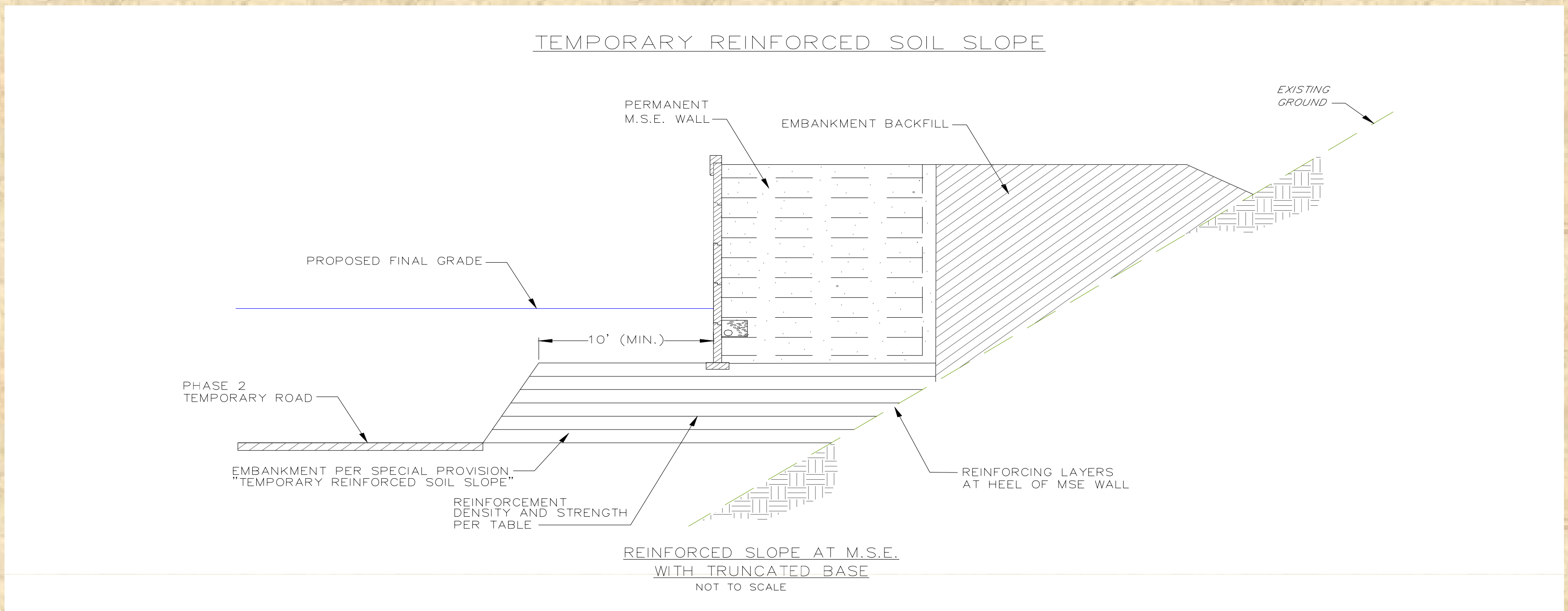


RSS DESIGN



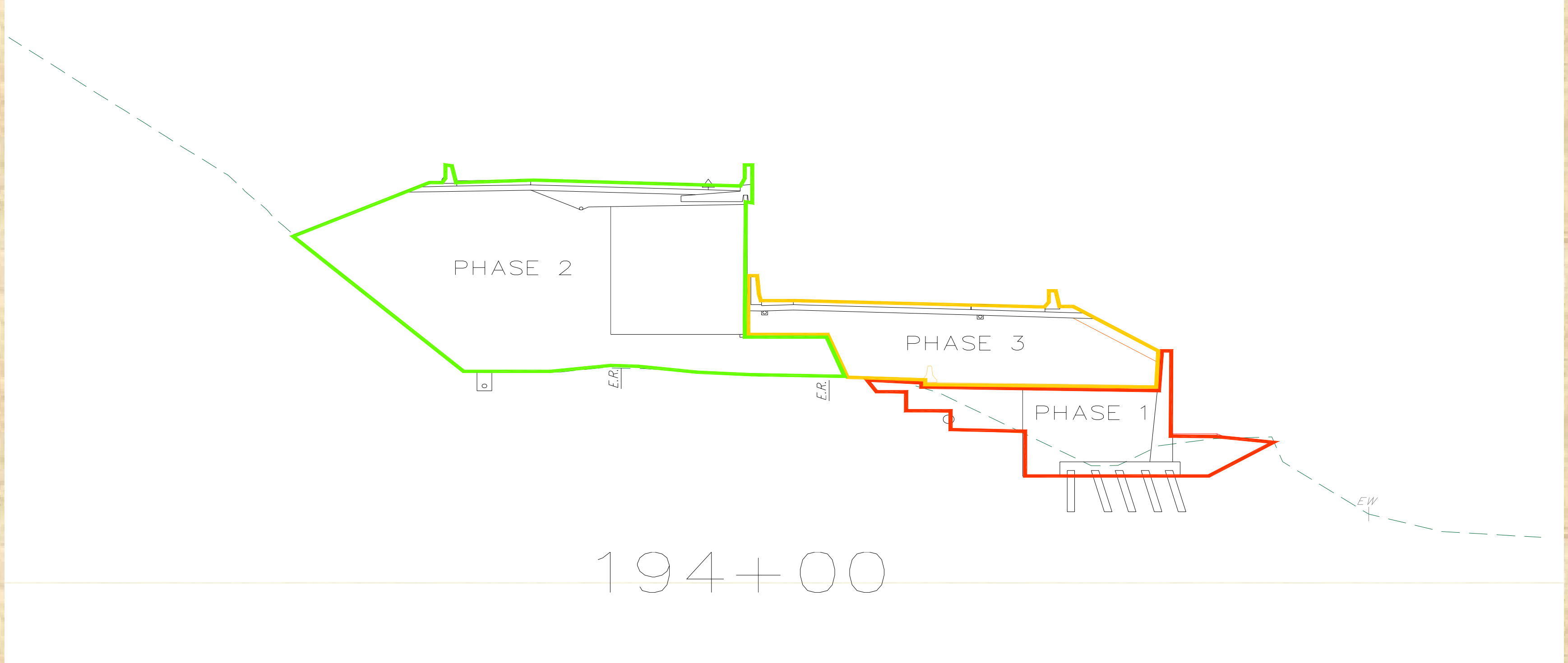
- Global Stability
  - External
  - Internal
  - Compound
- Include contribution of MSE wall as a surcharge.
- Iterate geogrid strength to achieve target safety factor.

RSS DESIGN



- Sliding stability
- Excavation stability
  - Placement length of straps.
  - Do not allow excavations.
- Remediation – extend straps or provide piles
- Construction traffic and damage

STABILITY INSTRUMENTATION

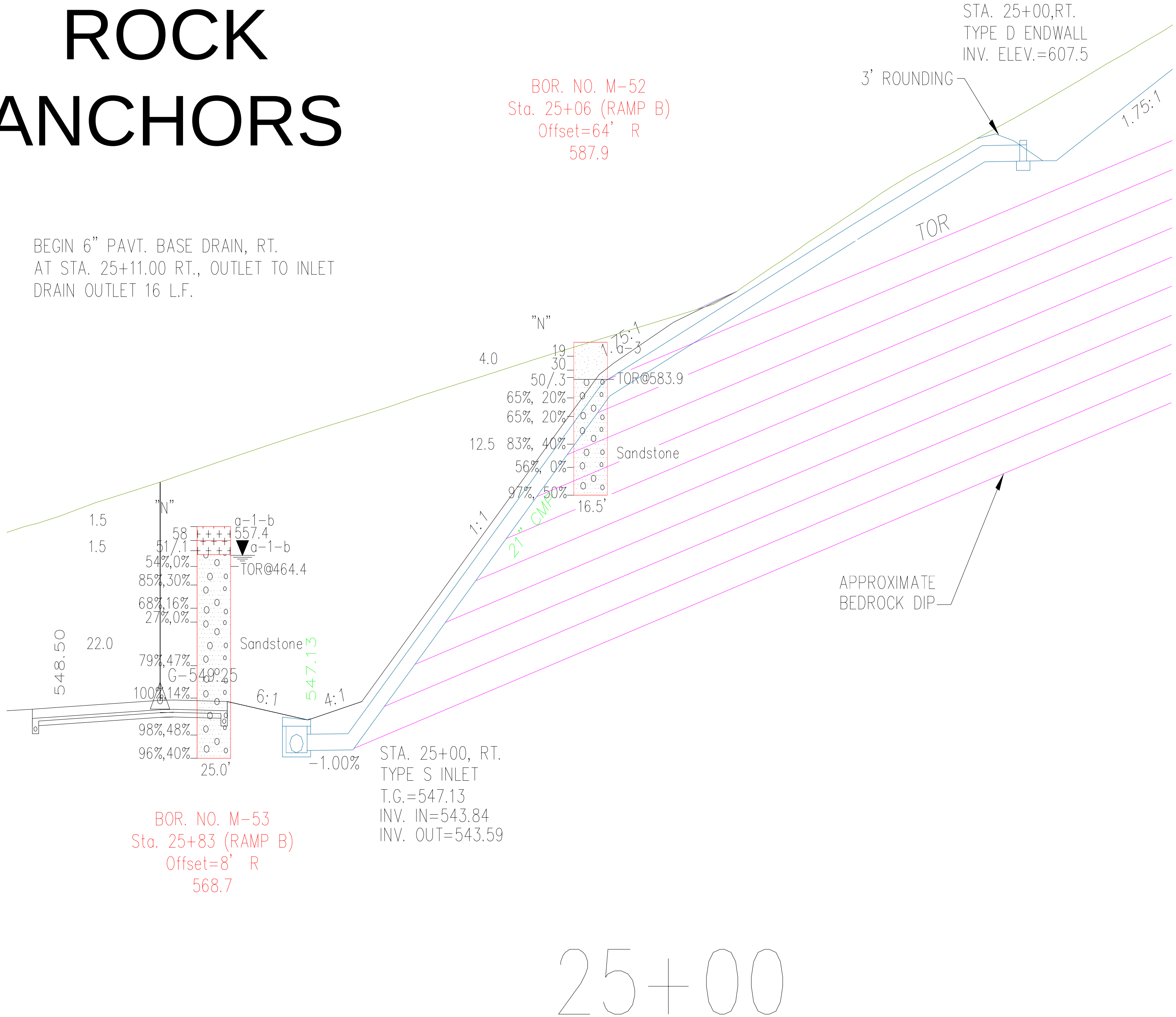


- Piezometers
- Inclinometers
  - In-Place
  - Standard
- Strain Gauges
- Real time monitoring and remote processing

VIBRATION MONITORING

- Reduce vibration induced rockfall
- Origin of vibrations
  - Micro-piles
  - H-piles and predrilling
  - Embankment placement
- Preliminary threshold
- Remedial actions

ROCK ANCHORS



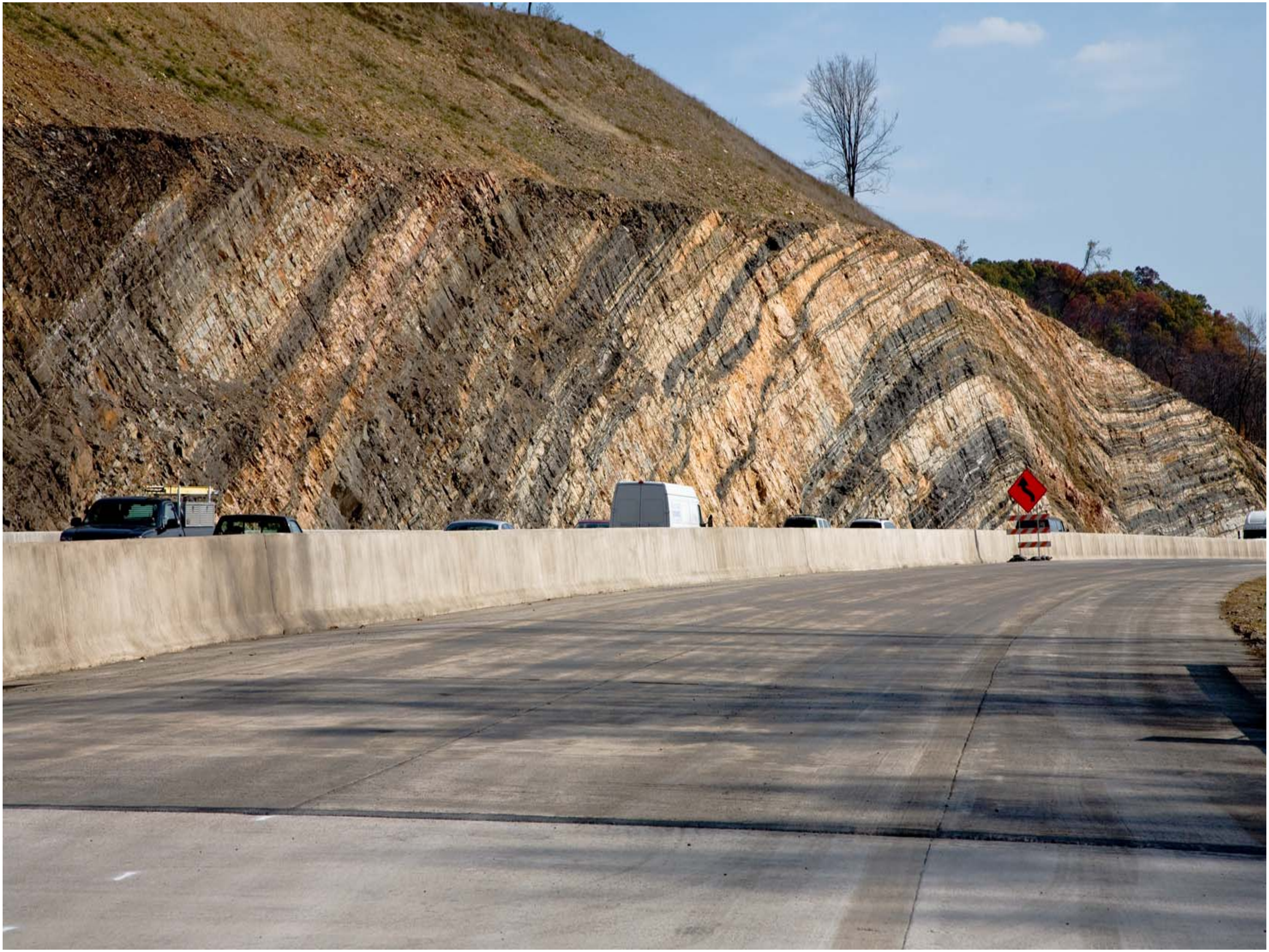
ROCK ANCHOR DESIGN

- Design cut slopes up to 1H:1V
- Design loading = 240 k
- 360 anchors
  - 10’ c/c grid pattern
  - 2 to 4 rows of anchors
- Temporary excavations in rock for abutment and temporary roadway

ROCK ANCHORS

ROCK ANCHORS


ROCK ANCHORS



QUESTIONS ?