



**Schnabel**  
ENGINEERING

**Landslide Stabilization  
Blue Ridge Parkway MP 400.8**

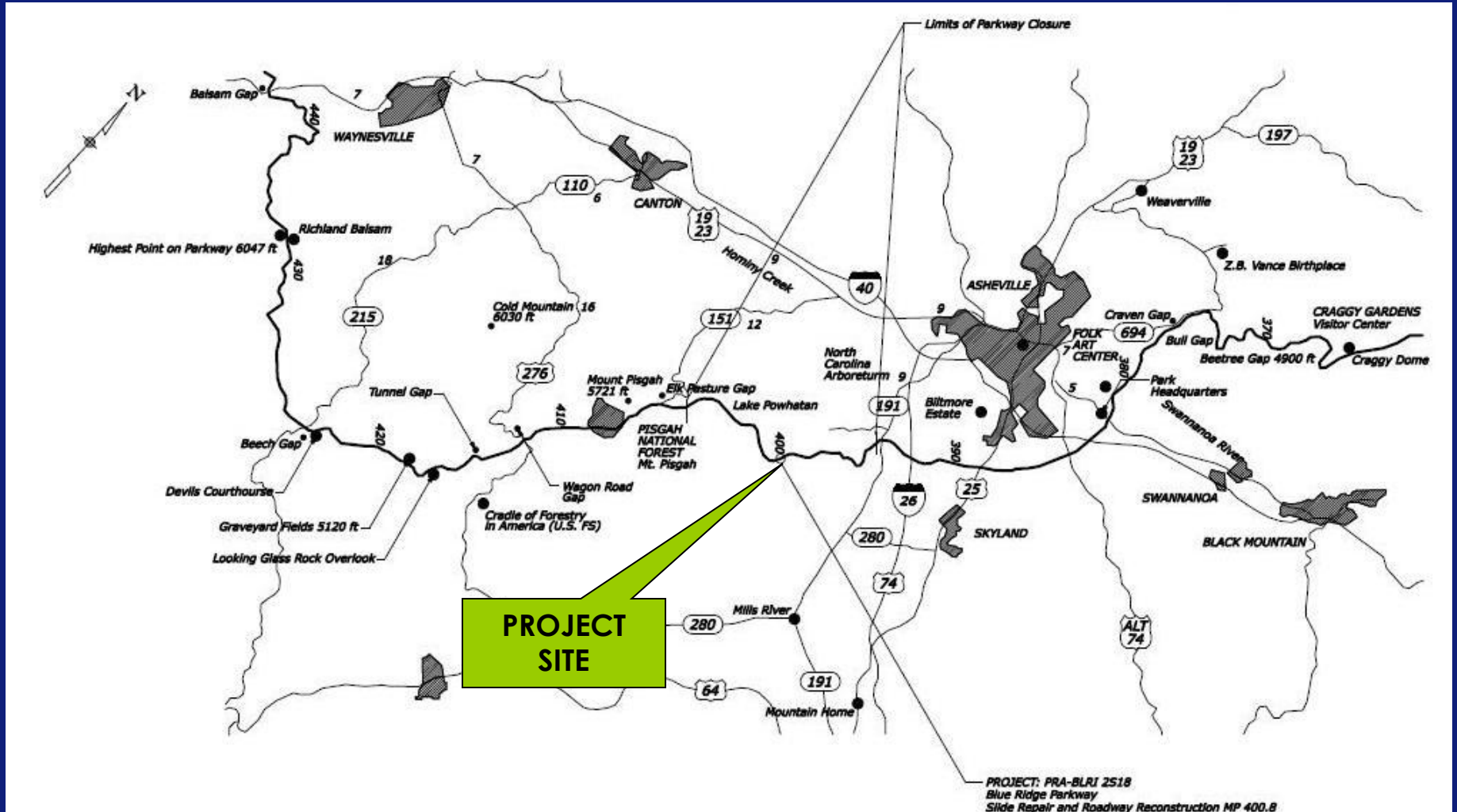
**Brian K. Banks, PG  
Pamela Patrick, PE**

**STGEC  
October 5, 2010**

# Outline

- Landslide history
- Field mapping data
- Slope stability analyses
- Landslide failure mechanism
- Remediation concepts
- “Final” design
- Construction progress

# Site Location

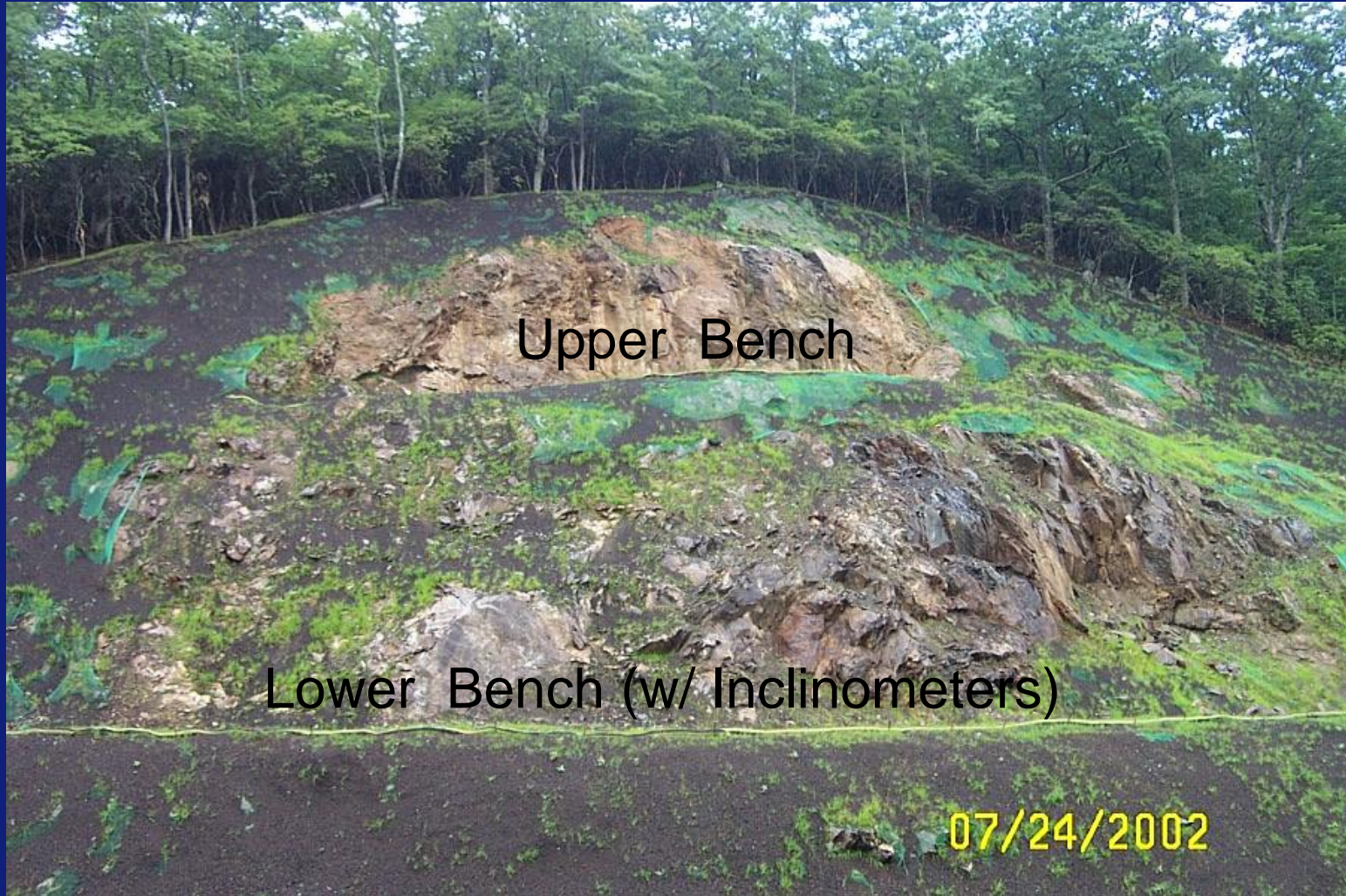


# Landslide History



March 2002

# Initial Slope Repair



# Continued Movement



Pavement Patch

Slope Bulge

January 2009

# Bulging Pavement



January 2009

# Localized Rockfall



January 2009



# Tension Cracks



January 2009

# Tension Cracks



January 2009

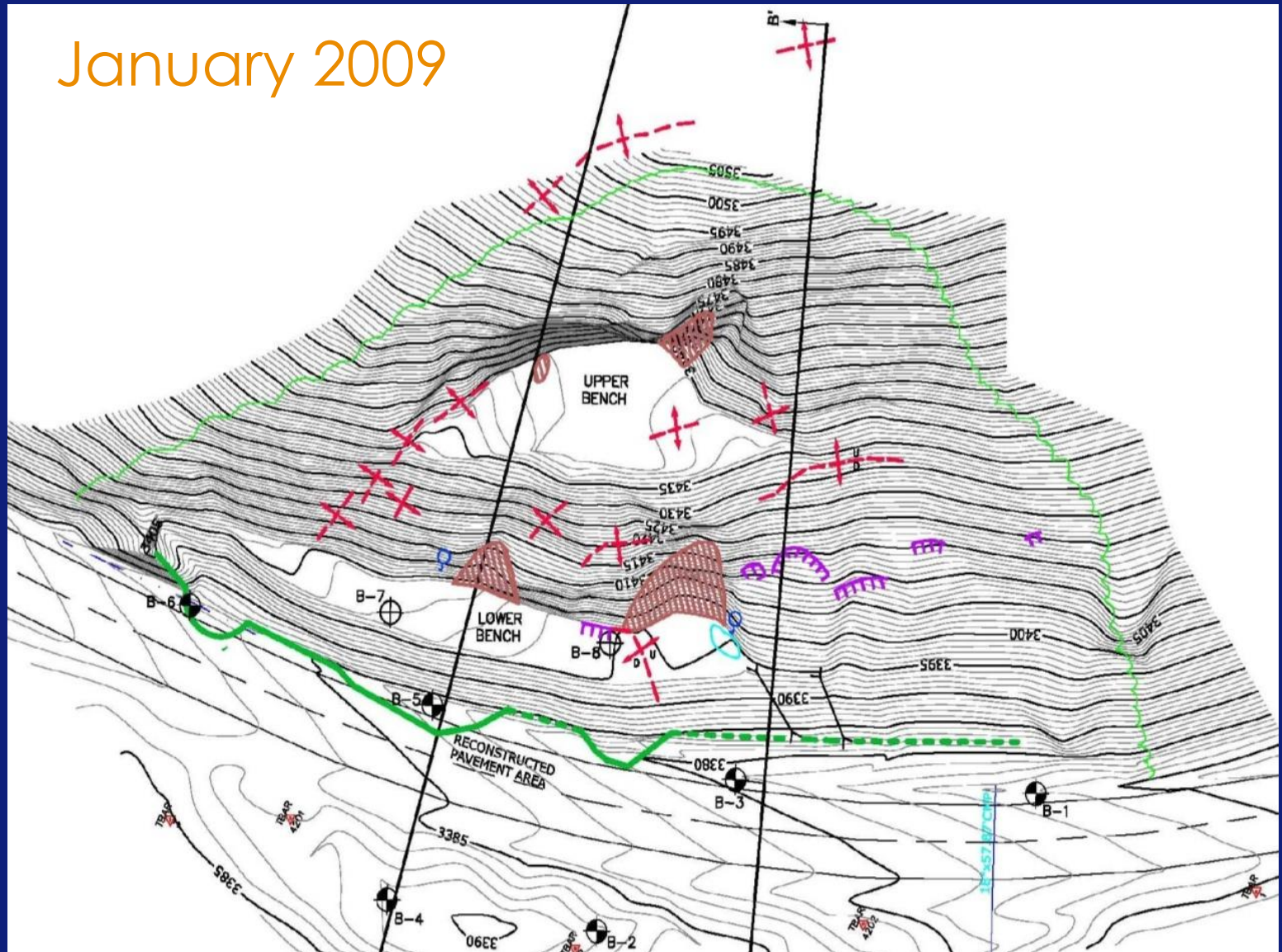
# Tension Cracks



January 2009

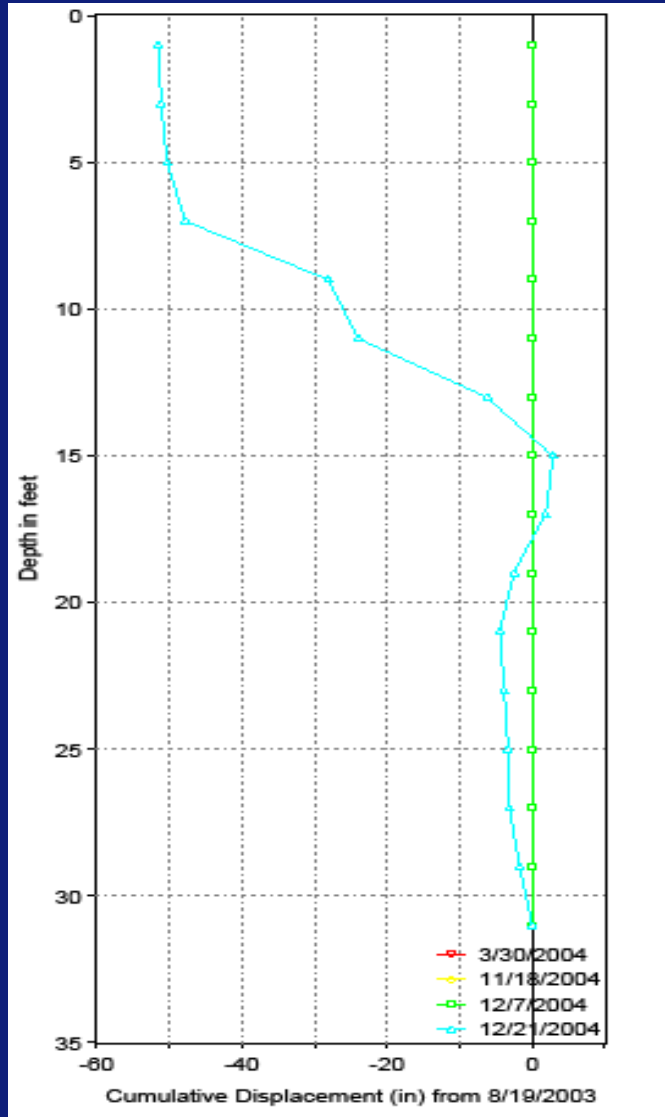
# Field Mapping

January 2009



# Inclinometer Data

15 ft →



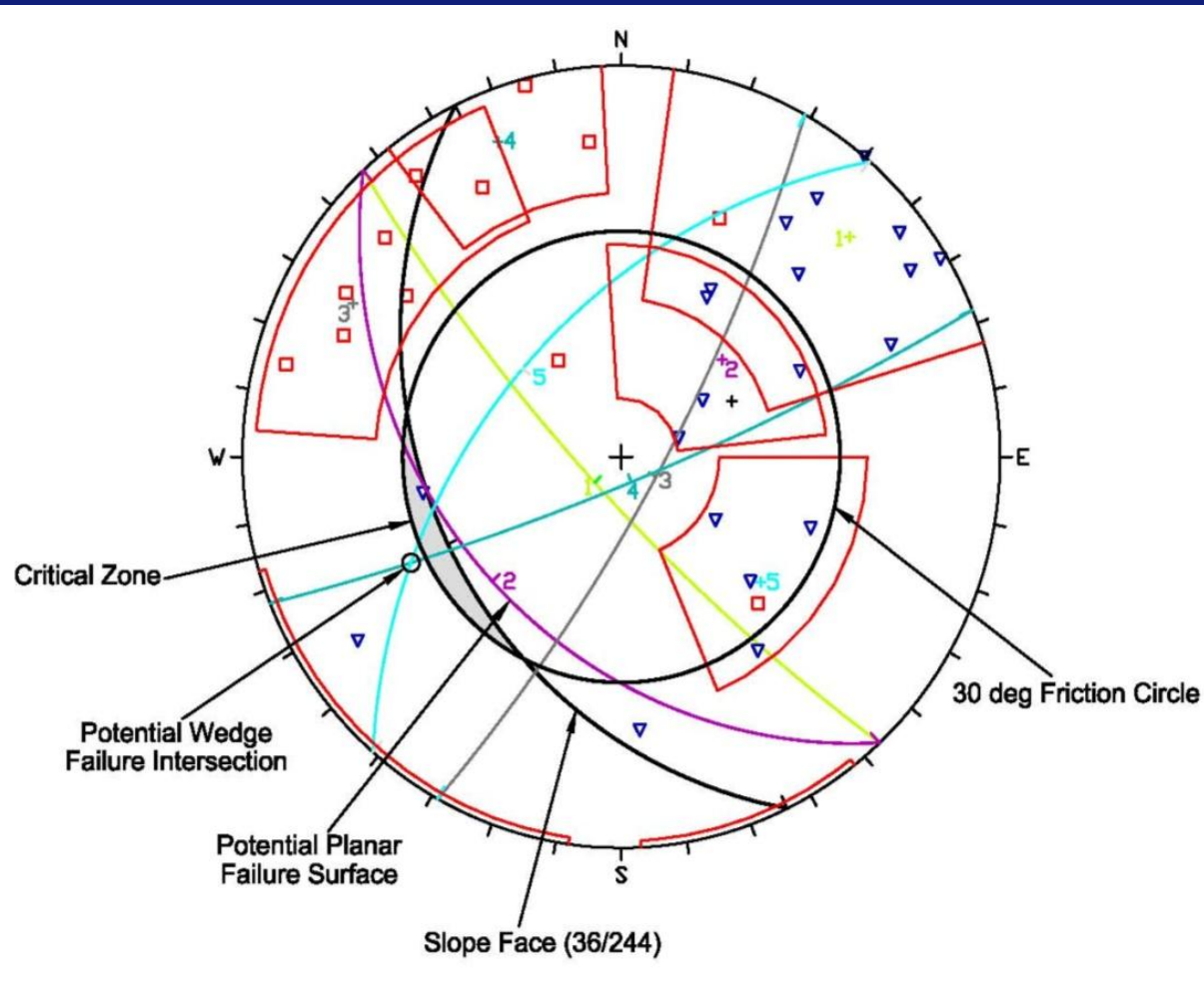
Weathered  
Rock

Competent  
Rock

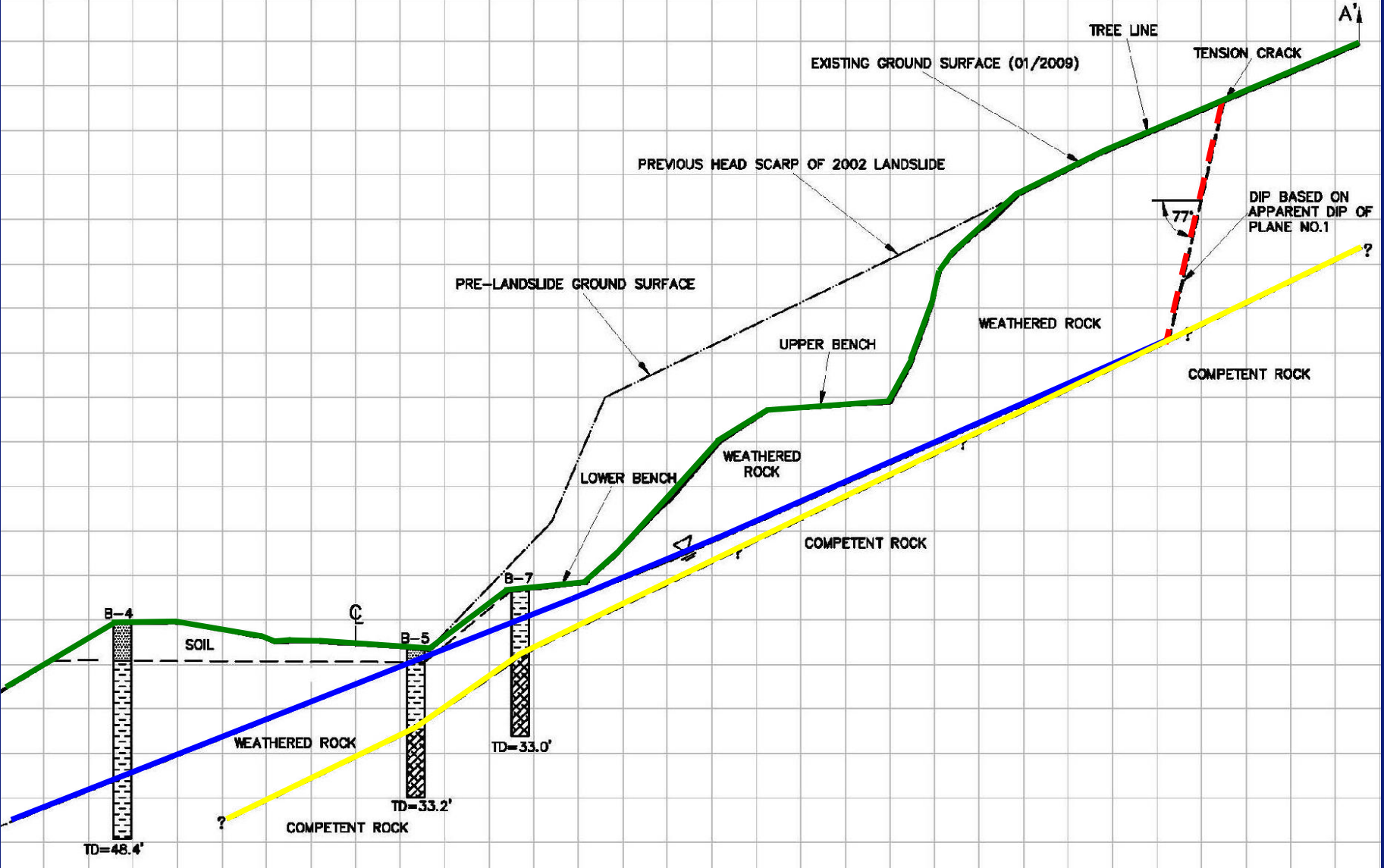
# Rock Structure Mapping



# Stereonet

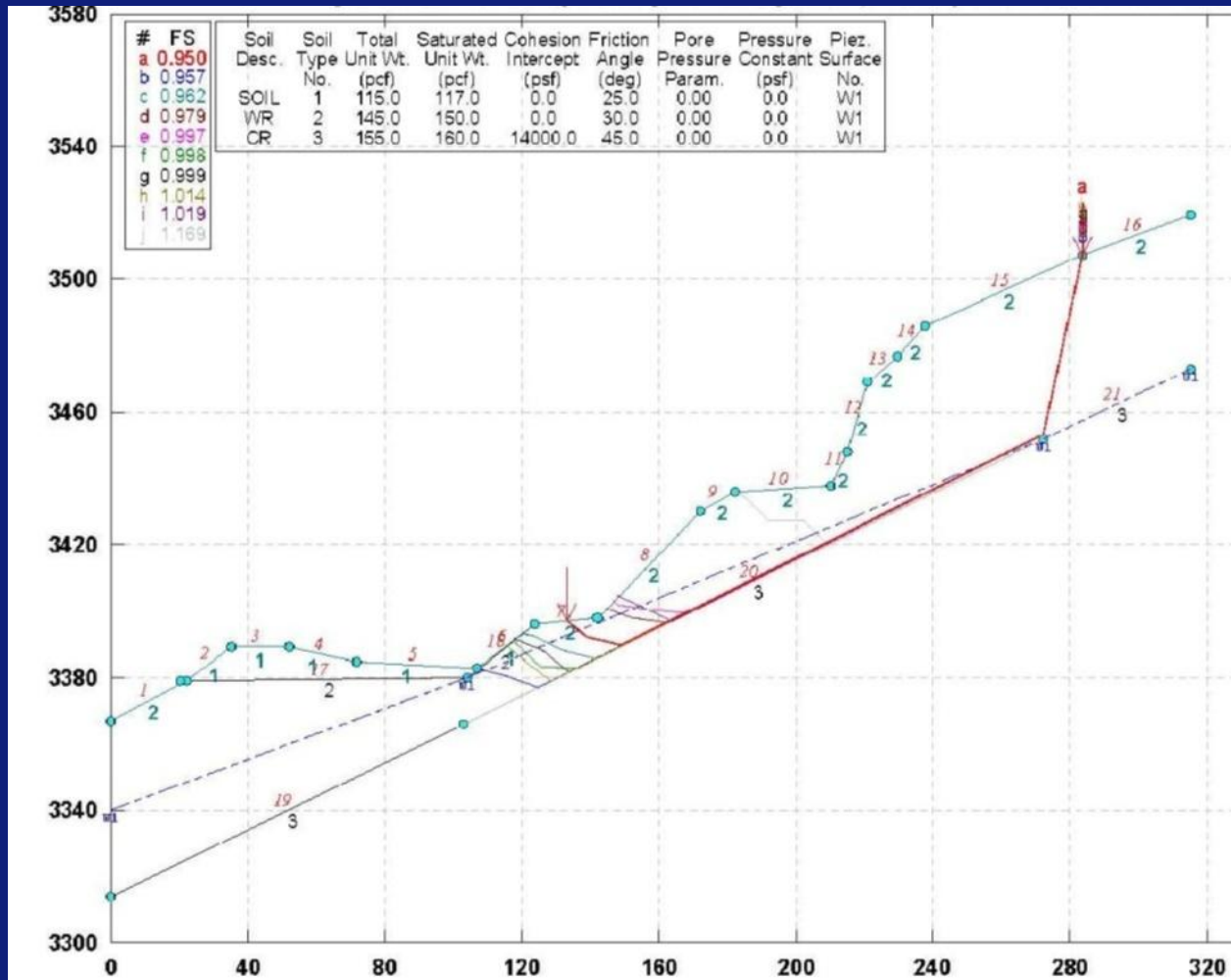


# Failure Model

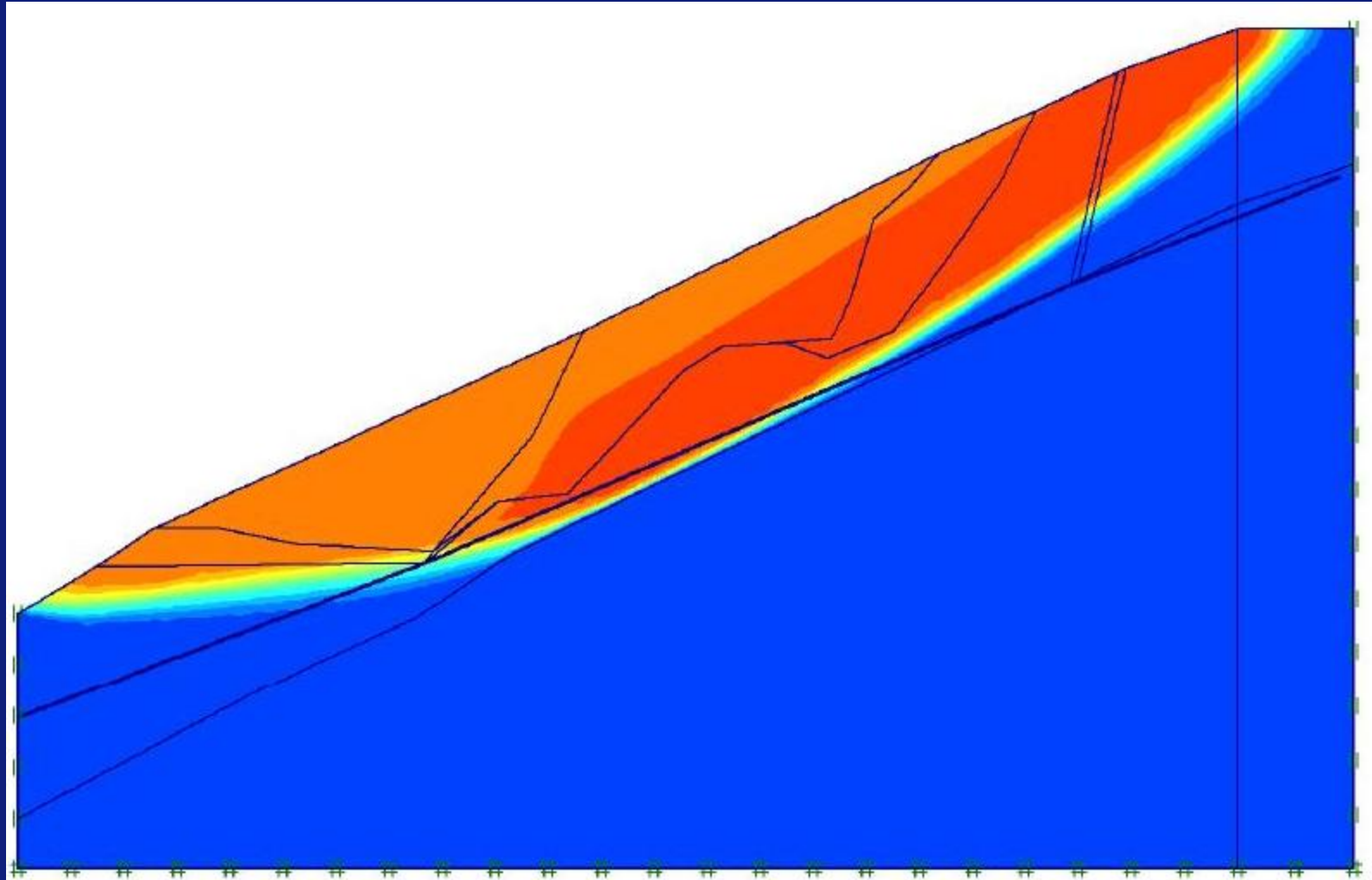




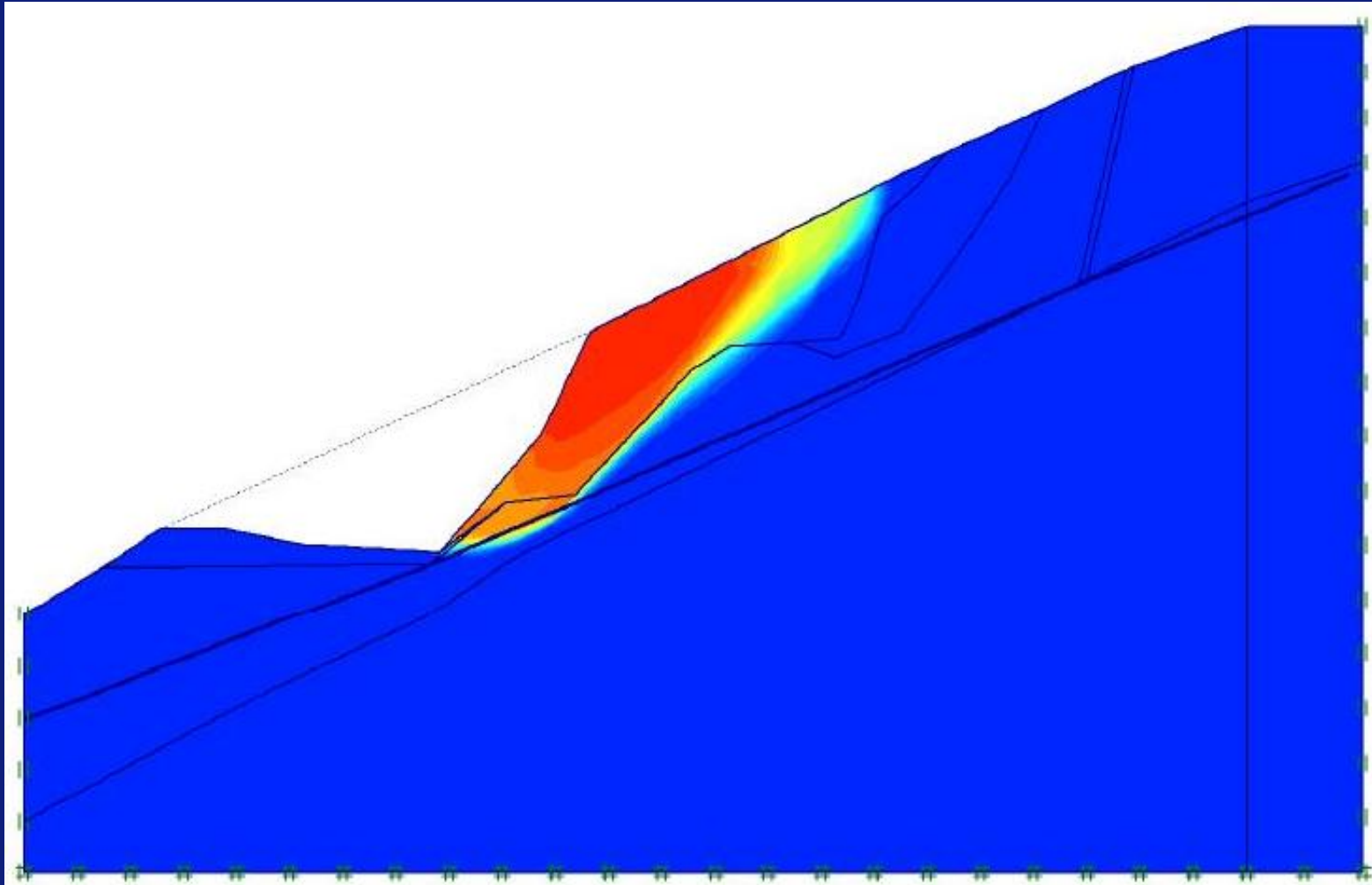
# GSTABL7 Stability Analysis



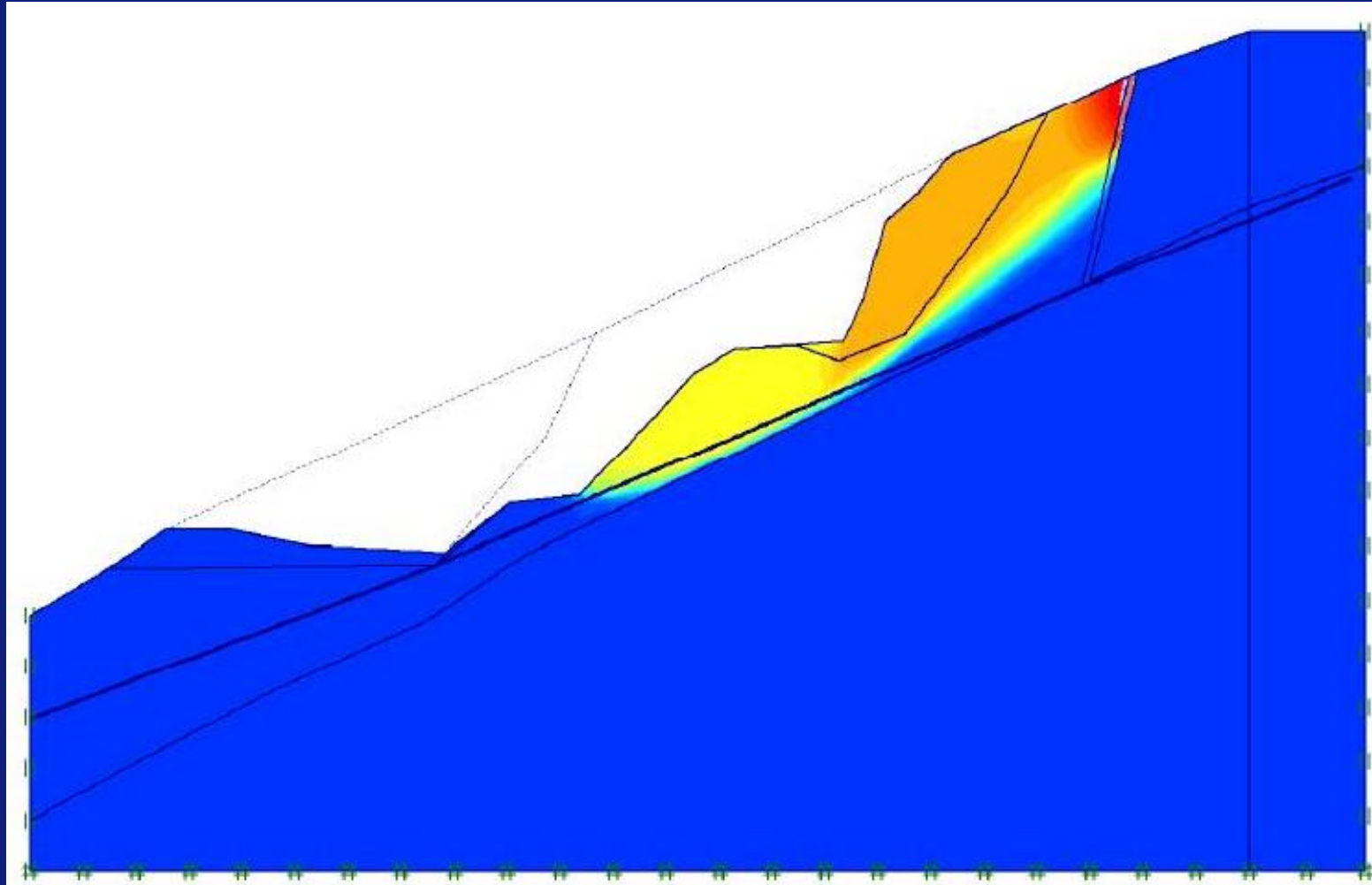
# PLAXIS Stability Analysis



# Stability of Initial Cut Slope



# Stability of Benched Configuration



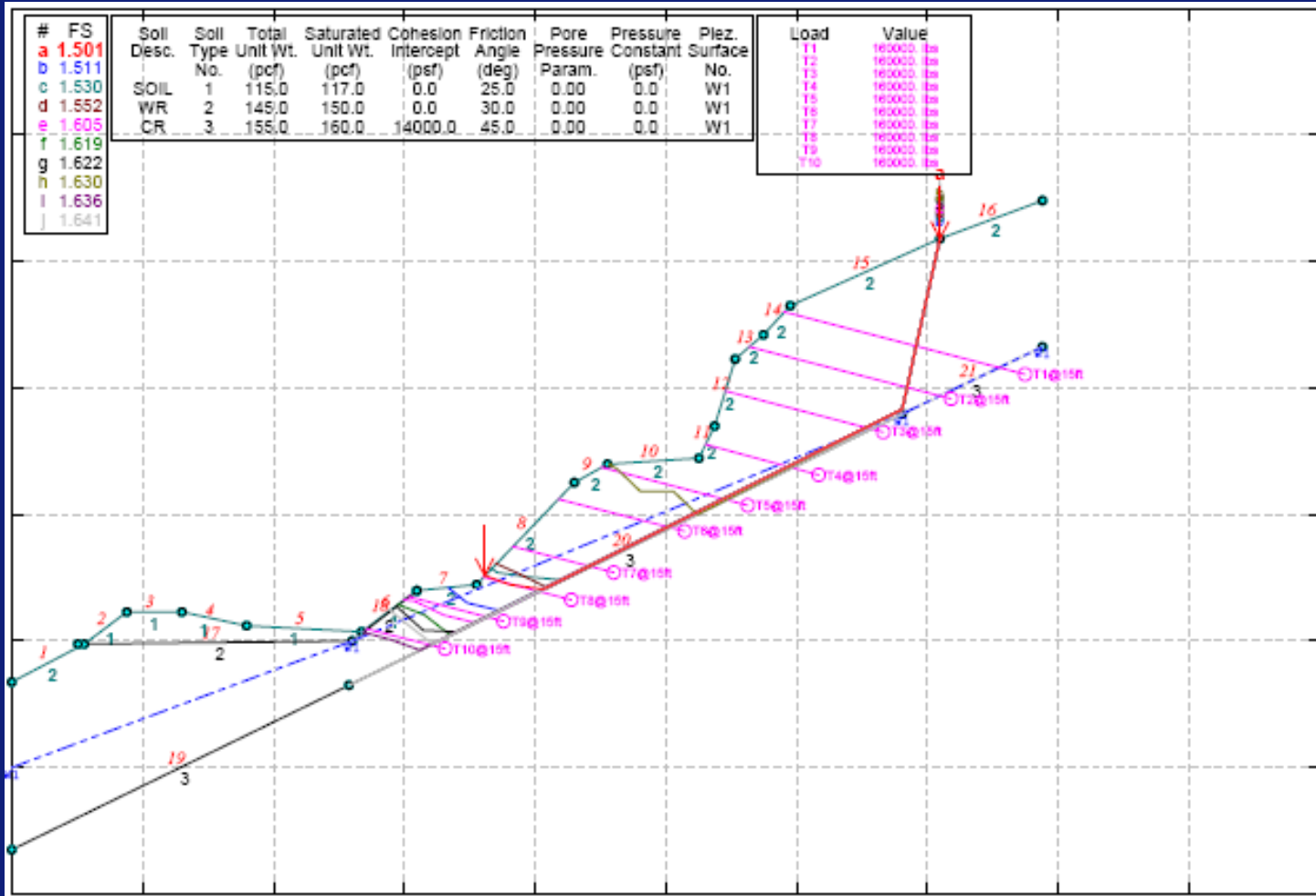
# Possible Stabilization Measures

- Mass grading – cut
- Mass grading – fill
- Rock anchors
- Rock gluing
- Retaining wall on drilled piles
- Rock-anchored retaining wall
- Rock Shed
- Hybrid Methods

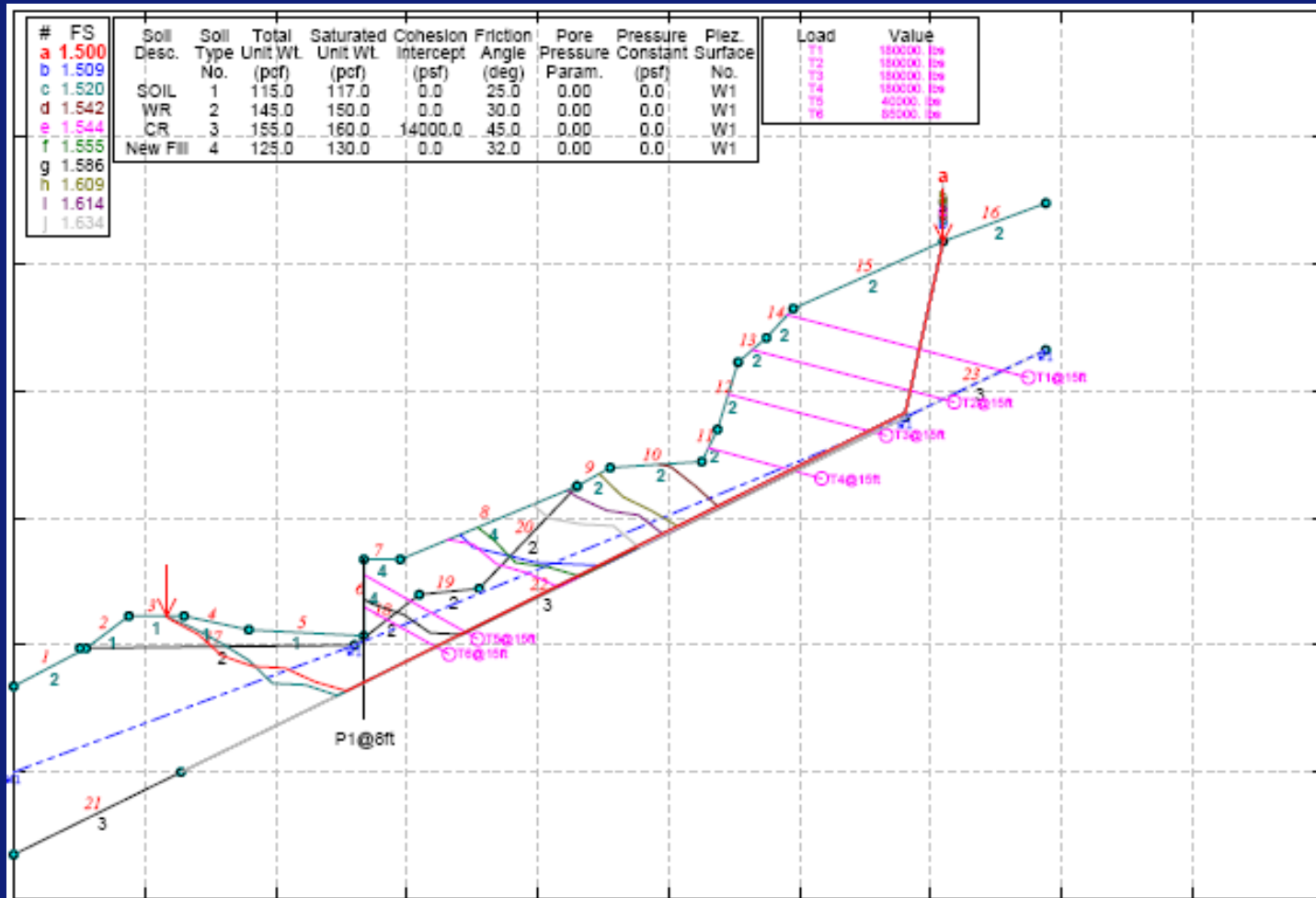
# Design Concepts

- Option 1 – Rock Anchors
- Option 2 – Anchored Retaining Wall(s)

# Option 1 – Rock Anchors

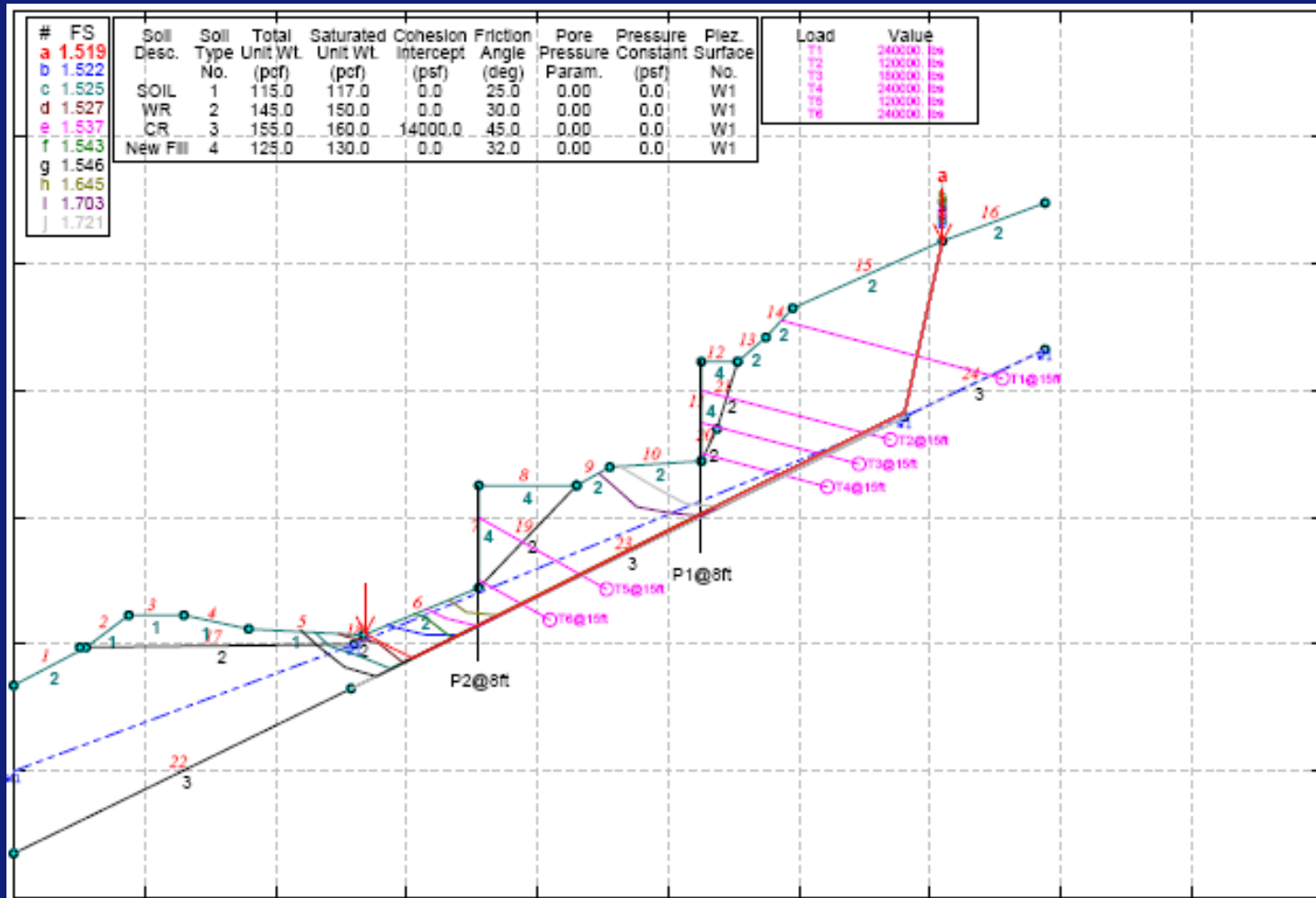


# Option 2a – Anchored Retaining Wall





# Option 2b – Anchored Retaining Walls

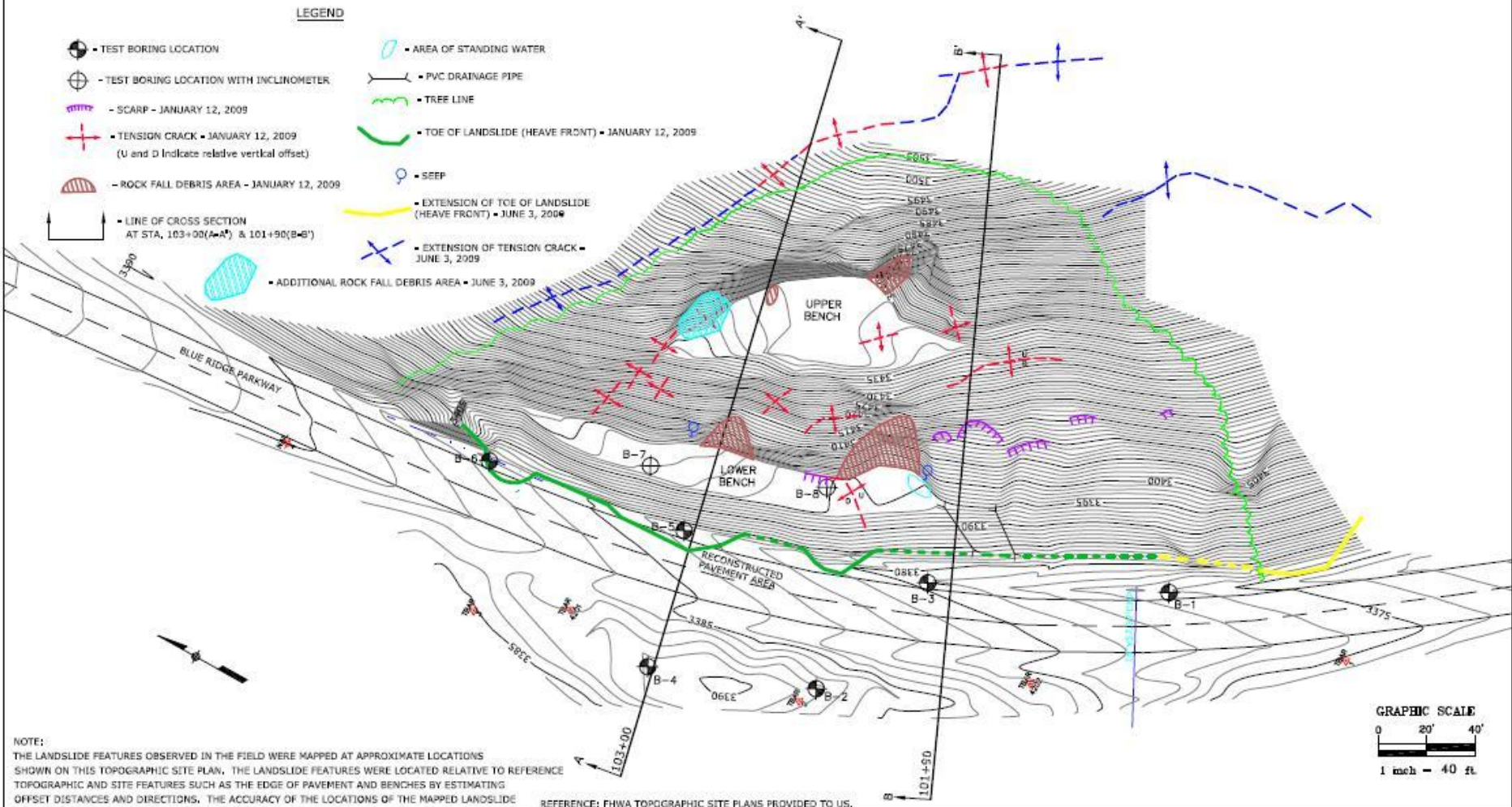


# Additional Recommendations

- Scaling
- Horizontal Drains
- Wire mesh

**LEGEND**

- TEST BORING LOCATION
- ⊕ - TEST BORING LOCATION WITH INCLINOMETER
- SCARP - JANUARY 12, 2009
- ⊕ - TENSION CRACK - JANUARY 12, 2009  
(U and D Indicate relative vertical offset)
- ROCK FALL DEBRIS AREA - JANUARY 12, 2009
- LINE OF CROSS SECTION AT STA. 103+00(A-A') & 101+90(B-B')
- AREA OF STANDING WATER
- PVC DRAINAGE PIPE
- TREE LINE
- TOE OF LANDSLIDE (HEAVE FRONT) - JANUARY 12, 2009
- SEEP
- EXTENSION OF TOE OF LANDSLIDE (HEAVE FRONT) - JUNE 3, 2009
- EXTENSION OF TENSION CRACK - JUNE 3, 2009
- ADDITIONAL ROCK FALL DEBRIS AREA - JUNE 3, 2009



NOTE: THE LANDSLIDE FEATURES OBSERVED IN THE FIELD WERE MAPPED AT APPROXIMATE LOCATIONS SHOWN ON THIS TOPOGRAPHIC SITE PLAN. THE LANDSLIDE FEATURES WERE LOCATED RELATIVE TO REFERENCE TOPOGRAPHIC AND SITE FEATURES SUCH AS THE EDGE OF PAVEMENT AND BENCHES BY ESTIMATING OFFSET DISTANCES AND DIRECTIONS. THE ACCURACY OF THE LOCATIONS OF THE MAPPED LANDSLIDE FEATURES IS BASED ON THE LOCATION METHOD USED.

REFERENCE: FHWA TOPOGRAPHIC SITE PLANS PROVIDED TO US.

REVISION	DESCRIPTION
07-09-2009	ADDED FEATURES OBSERVED ON 06-03-2009



SLOPE STABILITY INVESTIGATION  
 BLUE RIDGE PARKWAY MP 400.8  
 BUNCOMBE COUNTY, NC

DRAWN BY: NT	DATE: 03-02-2009
CHECKED BY: PP	SCALE: AS SHOWN

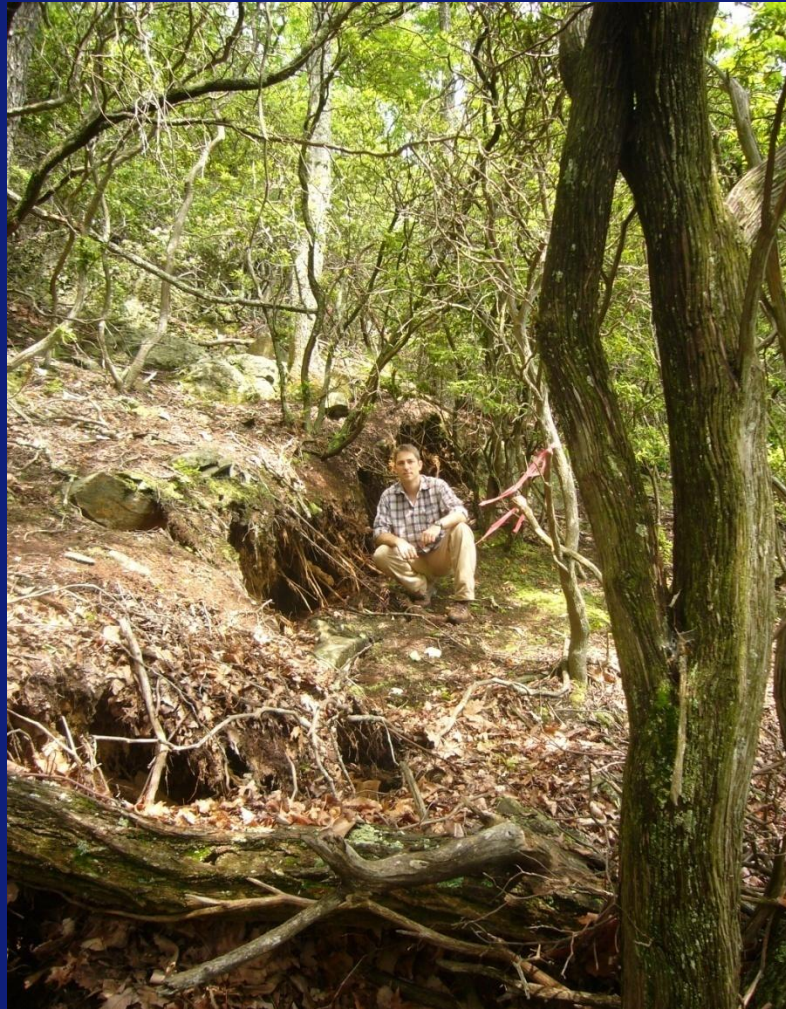
TOPOGRAPHIC SITE PLAN  
 PROJECT 05140065.05  
 FIGURE 2

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June 2009



# Ongoing Movement



June 2009

# Ongoing Movement



June 2009

# Ongoing Movement



June 2009

# Ongoing Movement



June 2009

# Ongoing Movement



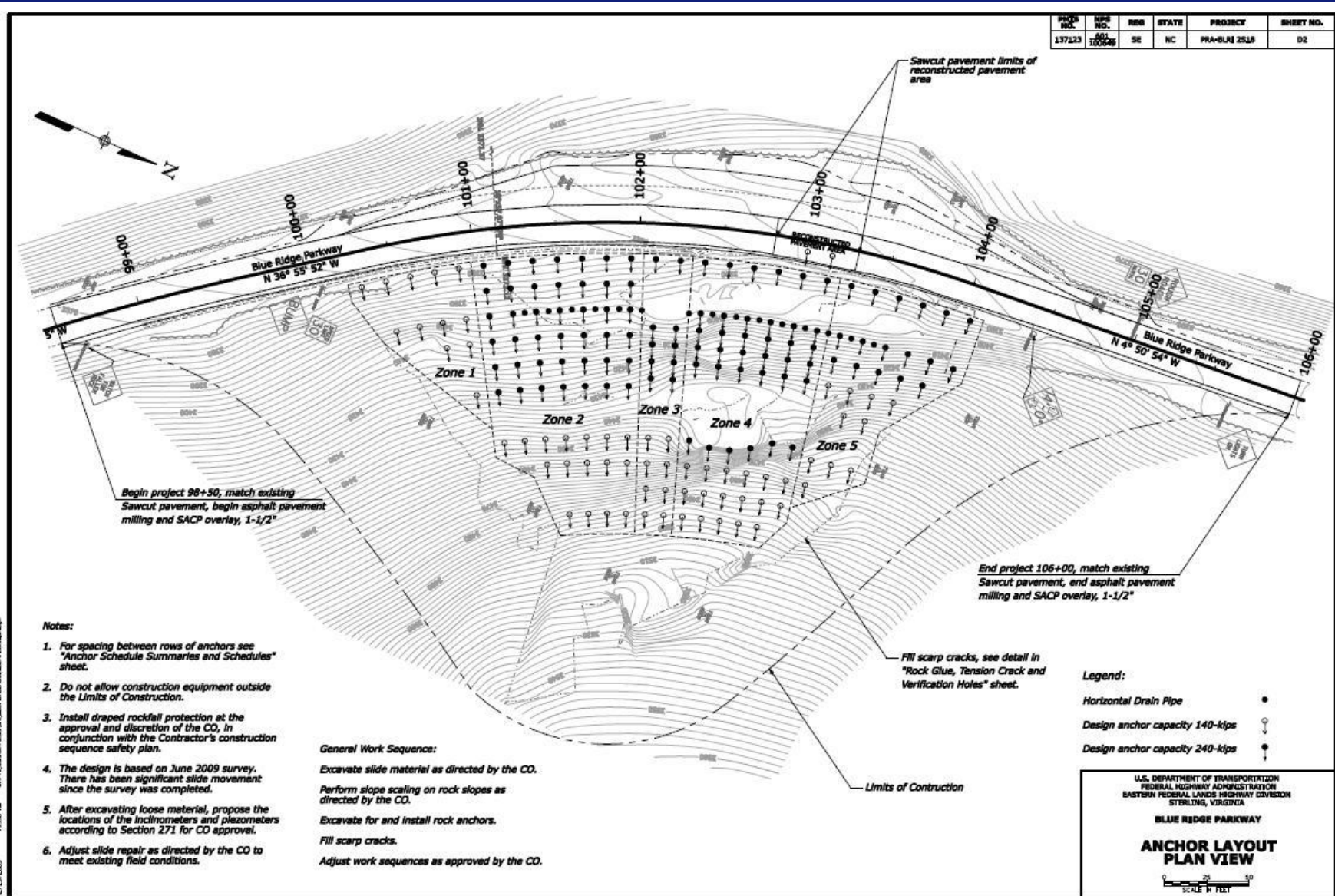
June 2009



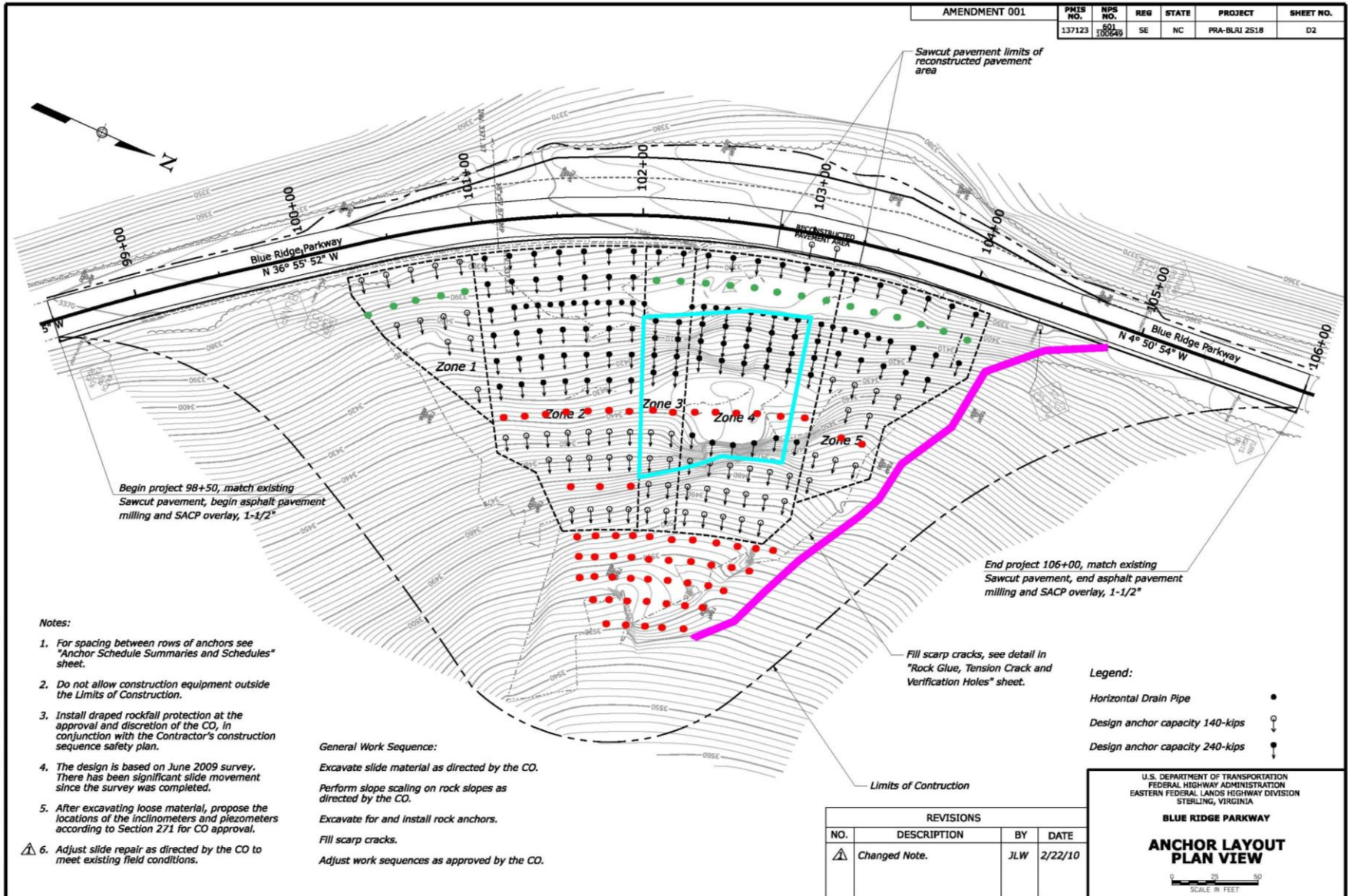
# “Final” Design

- Completed by EFLHD
- Rock anchor solution chosen due to aesthetic and cost considerations
- Treatment area was expanded
- Also included:
  - grouting of tension cracks
  - additional high-angle anchors in the road
  - temporary wire mesh

# “Final” Design



# Final Design



AMENDMENT 001	PHS NO.	NPS NO.	REG.	STATE	PROJECT	SHEET NO.
	137123	601 100649	SE	NC	PRA-BLRI 2518	D2

- Notes:**
1. For spacing between rows of anchors see "Anchor Schedule Summaries and Schedules" sheet.
  2. Do not allow construction equipment outside the Limits of Construction.
  3. Install draped rockfall protection at the approval and discretion of the CO, in conjunction with the Contractor's construction sequence safety plan.
  4. The design is based on June 2009 survey. There has been significant slide movement since the survey was completed.
  5. After excavating loose material, propose the locations of the inclinometers and piezometers according to Section 271 for CO approval.
  6. Adjust slide repair as directed by the CO to meet existing field conditions.

**General Work Sequence:**

- Excavate slide material as directed by the CO.
- Perform slope scaling on rock slopes as directed by the CO.
- Excavate for and install rock anchors.
- Fill scarp cracks.
- Adjust work sequences as approved by the CO.

REVISIONS			
NO.	DESCRIPTION	BY	DATE
1	Changed Note.	JLW	2/22/10

- Legend:**
- Horizontal Drain Pipe
  - Design anchor capacity 140-kips
  - Design anchor capacity 240-kips

U.S. DEPARTMENT OF TRANSPORTATION  
 FEDERAL HIGHWAY ADMINISTRATION  
 EASTERN FEDERAL LANDS HIGHWAY DIVISION  
 STERLING, VIRGINIA

**BLUE RIDGE PARKWAY**

**ANCHOR LAYOUT PLAN VIEW**

0 25 50  
 SCALE IN FEET

# Recessed Anchors



# Recessed Anchors



# Access Road



# Anchor Pads



# Wire Mesh





# Upper Work Bench



# Bench Failure



# Bench Failure



**Thank you!**

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October 5, 2010**