A Brief Update of FHWA Highway Geohazards Program and a Case History for Stabilizing 20-Acres of Sliding Material

Khalid T. Mohamed, P.E., PMP
Senior Geotechnical Engineer
Federal Highway Adminisration
HIF / HIBS-20
Washington, DC

Geohazards Forum
Huntington, WV
August 2015

U.S. Department of Transportation
Federal Highway Administration

- Introduction
- Geohazards & Risk Definition
- MAP-21Transportation Bill
- The DRIVE Act
- FHWA Geohazards Program Relations
- Study Plan
- Example Environment Cooperation
- Landslide Case History

SR 530 Oso, Snohomish County, Washington
41 life losses

FHWA Highway Geohazards Program Overview

U.S. Department of Transportation
Federal Highway Administration

Highway Geohazards Program Introduction

Program Name: Transportation, highway, or Geohazards Program etc…

Highway Geohazards Program: involves *identification* and *evaluation* of geohazards; their *severity*, *frequency*, and *intensity*; their *interrelationship* with *extreme events* and *climate change*; and provides *mitigation* strategies to *avoid* or *reduce* negative impacts to highway transportation infrastructure assets.

U.S. 89, AZ (20 miles Detour)

U.S. Department of Transportatio
Federal Highway Administration

Geohazard Definition

Geohazard: ***geological*** or earth-material state and ***environmental*** conditions that may lead to widespread damage or risk.

- Geohazards involve short-term or long-term geological processes.
- Geohazards can be relatively small features, but also attain large dimensions.
- Geohazards may affect local and regional socio-economy to a large extent.

I-70 Glenwood Springs, CO
17 miles closed, detour up to 200 miles

U.S. Department of Transportation
Federal Highway Administration

Risk – Exposure to the chance of loss or injury.

Future phenomenon; may or may not occur; has direct impact on a project or system

Risk = Probability x Impact

Route 248
Palmerton, PA
$4.8 m Risk Mitigation Work

Risk & Risk Management

U.S. Department of Transportatio
Federal Highway Administration

- **Establishes system performance requirements**
- **State Highway Agencies to develop asset management plan toward achieving national highway performance goals**
  - *Risk-based* plan to improve and preserve assets and performance of the system
  - Must include pavement and bridges
  - Encourages inclusion of all assets within the corridor right-of-way

Source: TDOT
I-75 in TN
Repair Cost: $9.2 - $12.6m

MAP-21 – Transportation Bill July 2012

U.S. Department of Transportation
Federal Highway Administration

- **Safety** – reduce fatalities and injuries;
- **Infrastructure Condition** – maintain the highway infrastructure asset system in a state of good repair;
- **Congestion Reduction** – reduce congestion on NHS;
- **System Reliability** – improve efficiency;
- **Freight Movement and Economic Vitality** – improve the freight network, strengthen ability of rural communities to access national and international trademarks, support regional economic development
- **Reduce Project Delivery Delays**

Highway 530, Oso, WA

MAP-21 National Performance Goals

U.S. Department of Transportatio
Federal Highway Administration

DRIVE Act

- **DRIVE** – Developing a Reliable and Innovative Vision for the Economy Act
- 6-year highway reauthorization proposal covering FYs 2016-2021
- Total highway funding – $280 billion

Highway 530, Oso, WA

U.S. Department of Transportation
Federal Highway Administration

Initial Funding Sources

- FY 2014 Strategic Initiatives ($20.5 m)
  - R&T Leadership Identified 8 Areas of Interest:

1) ***Climate Change – Adaption and Resilience***
2) *Transition to Performance-Based Programs*
3) *Public Engagement*
4) *Workforce of the Future*
5) *Better Understanding of Travel Behavior*
6) *New Vehicle Technologies*
7) *Building and Retrofitting Bicycle and Pedestrian Networks in Urban Areas*
8) *Safety*

Alaska Permafrost TEACR Project

Initial Funding Sources

- FY 2014 Strategic Initiatives ($20.5 m)
  - ***Climate Change – Adaption and Resilience***
  - ✓ *Proposal was submitted and funded under name* ***"Geohazards, Extreme Events and Climate Change"***

Alaska Permafrost TEACR Project

External Links

- ***National:***
- USGS Landslides
- USGS Earthquakes
- GEER
- FEMA
- Other USA
- ***International:***
  - Int. Centre for GeoHazards
  - Safeland
  - Others

FHWA Highway Geohazards Program Relations

U.S. Department of Transportatio
Federal Highway Administration

Geohazards, Extreme Events and Climate Change Study Plan

- The Work Plan for the Project Consists of Three Phases:
  - *Phase I – Literature Review*
  - *Phase II – Peer Exchange*
  - *Phase III – Comprehensive Study*

Contract was Awarded to Parsons Brinkerhoff

Alaska Permafrost TEACR Project

U.S. Department of Transportation
Federal Highway Administration

Geohazards, Extreme Events and Climate Change Study Plan

- **Phases I & II Contract:**
  - ***Technical Panel Members:***
    - *Ben Rivers (Geotechnical)*
    - *Khalid Mohamed (Geotechnical)*
    - *Brian Beucler (Hydraulics)*
    - *Robert Kafalenos (Environment*

Alaska Permafrost Study

- **Contractors Team:**
  - *Brian Zelenko (Task Manager) (PB)*
  - *Edward Kavazanjian –PI (AZ State University)*
  - *Erik Loehr – CO-PI (University of Missouri)*

FHWA Transportation Engineering Approaches for Climate Resilience (TEACR)

- **Study Lead by:** Environment Office with Support from HIF Hydraulics Team
- Geotechnical Involvement is for certain Projects

- **Study Purpose:** Develop recommendations on ways to incorporate climate change as part of engineering practice
- Engineering analyses of a diverse set of transportation assets around the country will be performed in order to identify best practices for improving the resiliency of the transportation system to extreme weather and climate change.

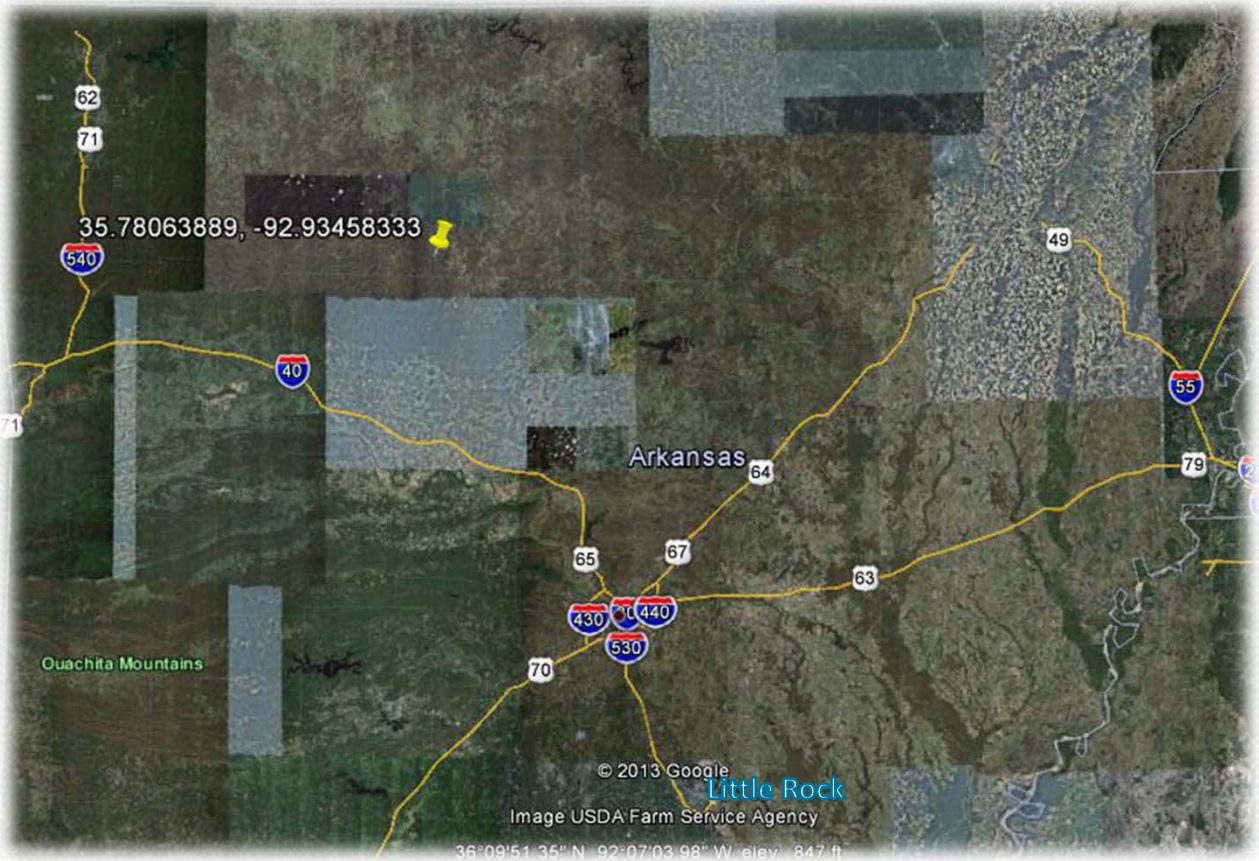
Alaska Permafrost TEACR Project

U.S. Department of Transportation
Federal Highway Administration

Case History

U.S. Department of Transportation
Federal Highway Administration

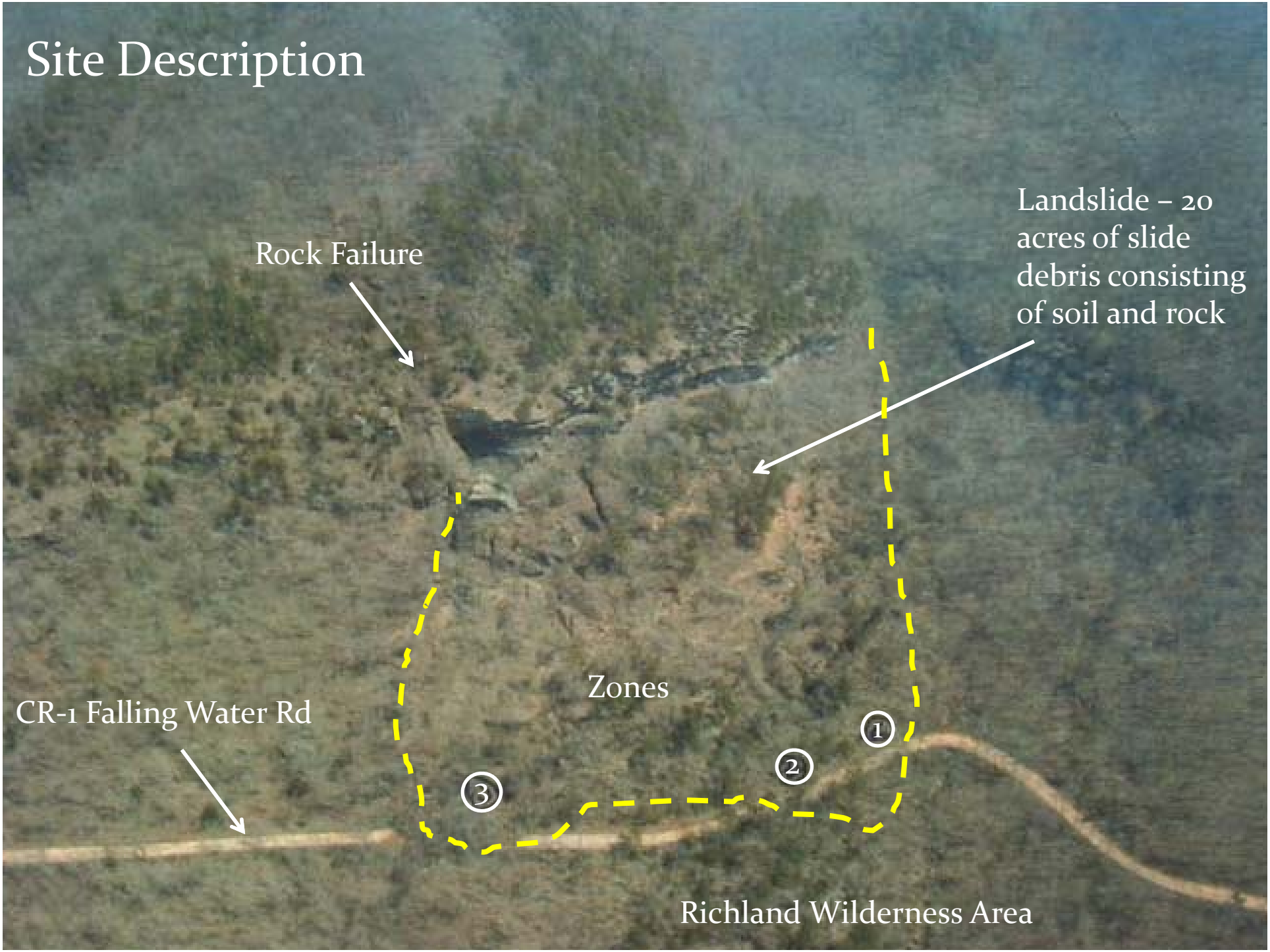
Project Location



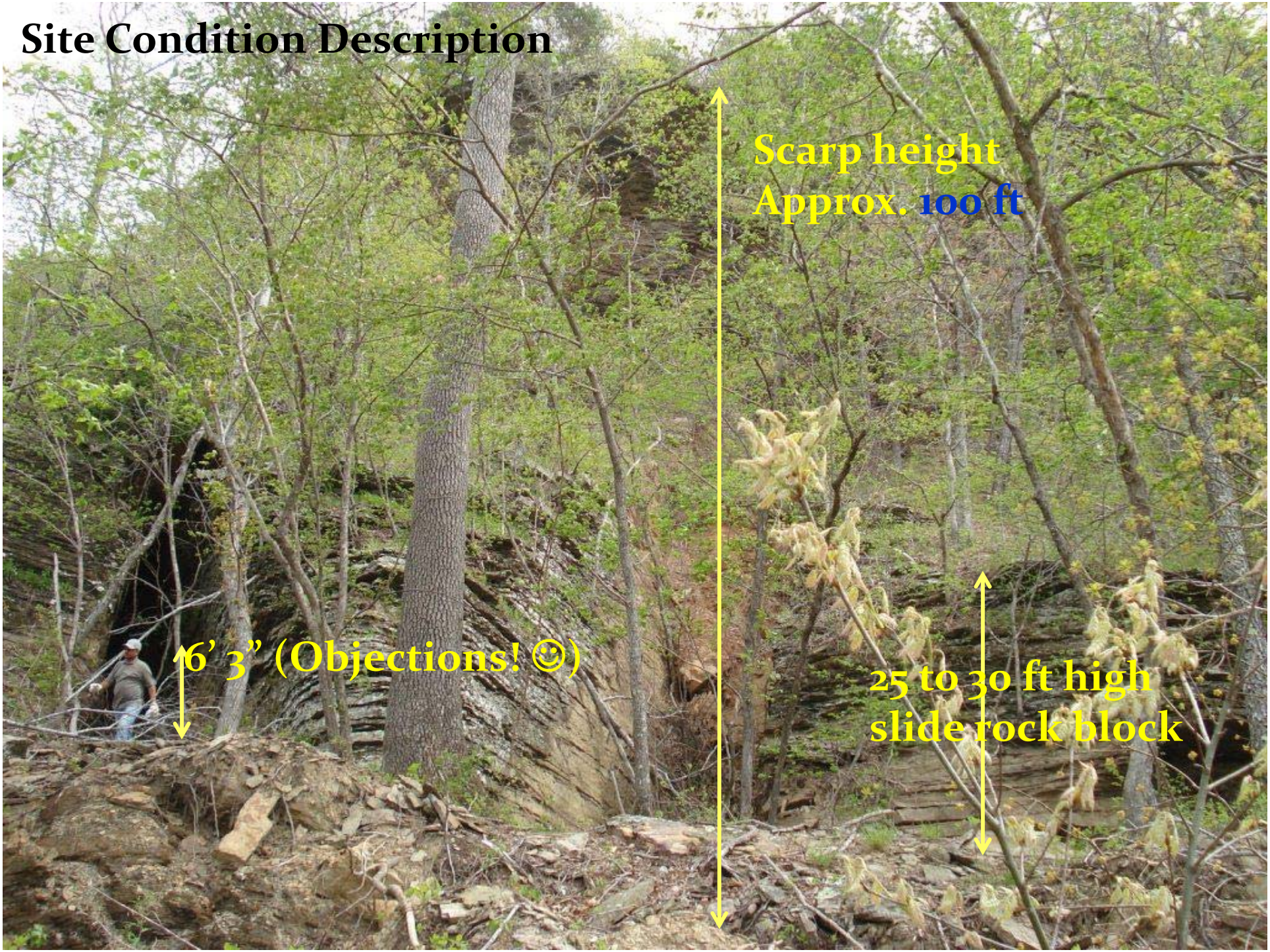
- Searcy County, Arkansas
- Ozark National Forest
- 80 miles NW of Little Rock

U.S. Department of Transportation
Federal Highway Administration

Site Description



Site Condition Description

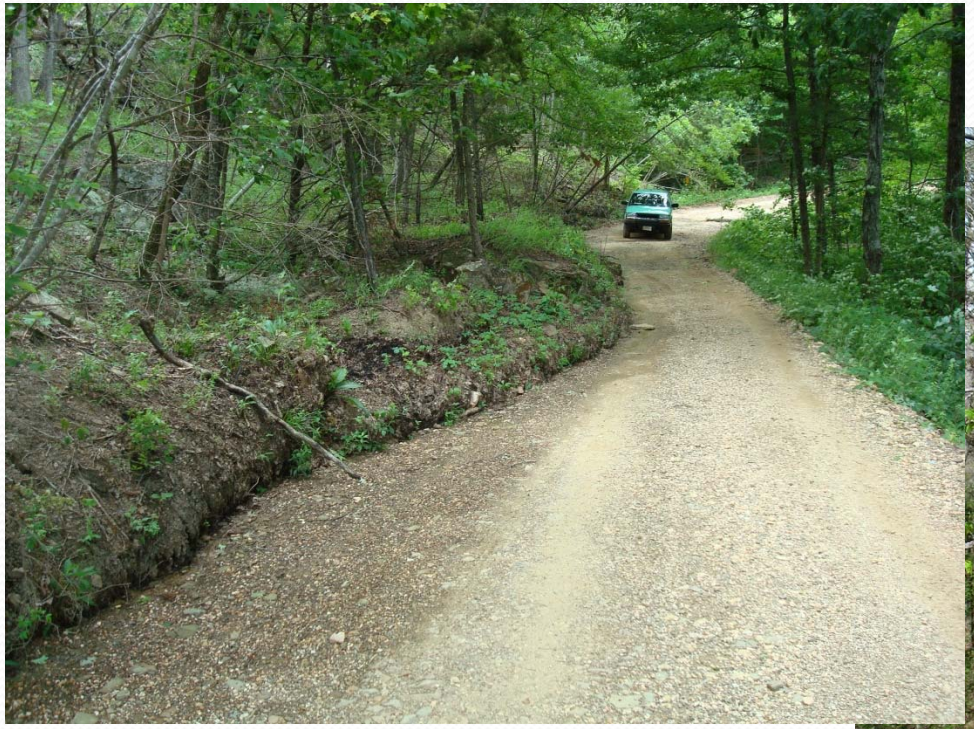


Project Challenges

- Difficult access
- Remote site (approx. *60 min. driving from paved road*)
- Environmental limitations (adjacent to wilderness area)
- Cost effective design
- Ease of construction
- Long-term performance
- Safety

Project Challenges

Slide Continued to Slowly Move Completely Blocking the Road



U.S. Department of Transportation
Federal Highway Administration

Subsurface Investigation

Legend:

I - Inclinometer

P - Piezometer

Note:

1. Instrumentation installed immediately after regrading the slope, prior to anchor installation activities.

0 50 100
SCALE IN FEET

U.S. Department of Transportation
Federal Highway Administration

Subsurface Investigation

Drilling at Toe of Slide

Performing Seismic Survey

- Seismic survey lines were performed at slide areas not accessible with drill rig

Subsurface Profile

Zone 1 South	(0-15 ft) – Very loose to medium dense weathered shale fragments little clay
Sta. 10+00 to 13+30	(15-23 ft) – Dense to very dense weathered shale fragments some clay
	(23-41.5 ft) – Shale and Sandstone RQD = 100%; UCS = 7,750 psi

Subsurface Profile (cont.)

Zone 2 Center	(0-3 ft) – Soft clay some weathered shale fragments
Sta. 13+30 to 16+67	(3-27 ft) – Stiff to hard clay some weathered shale fragments
	(27-39 ft) – Weathered Shale RQD = 21 - 66% (very poor to poor)

Subsurface Profile (cont.)

Zone 3 North	(0-4 ft) – Soft weathered shale fragments and clay
Sta. 16+67	(4-33 ft) – Stiff to hard weathered shale fragments and clay
to 19+00	(27-49 ft) – Shale and Sandstone RQD = 59 - 88% (fair); UCS = 9,730 psi – 15, 460 psi

Subsurface Profile (cont.)

- Three (3) seismic refraction survey lines were performed

Soil Type/Density	P-wave velocity (ft/s)
Soft weathered shale fragments and clay	0-1,500
Stiff to very stiff weathered shale fragments and clay	1,500 - 3,500
Hard weathered shale fragments and clay	3, 500 – 5,000
Soft to moderately hard shale and sandstone	5,000 -7,000
Competent rock (Hard shale and sandstone)	> 7,000

- The seismic refraction survey revealed a depth to competent rock between 30 and 100 ft

Repair Alternative 1

- Excavation and removal of slide rock and unstable weathered material
  - Flattening slope to 1v: 3h by removing the slide debris (soil, weathered rock and large boulders with sizes up to 25 ft in diameter)
  - Deep excavation of approximately 35 to 40 ft is expected to remove slide rocks from the top of the slope to reduce load and improve slope stability
  - ***Benefit:*** Eliminates the hazard from additional rock fall and reduce future maintenance
  - ***Cons:*** Requires a significant amount of excavation, making this option unfeasible due to high construction cost
  - **This alternative must be combined with other elements to reduce the amount of excavation**

Repair Alternative 2

- Partial excavation of slide material, installation of anchors with concrete blocks and a toe buttress
  - Flattening the slope by excavating the unstable material to an approximate depth of 30 ft near the top of the slope
  - Install anchors with concrete blocks and a rock toe buttress at 5-ft offset from the edge of the roadway embankment
  - The anchor blocks will be covered with on-site soil and the slope will be re-vegetated
  - Improve drainage
  - ***Benefits:*** Reduces excavation, re-uses of on-site rock, and keep the material out of the roadway if a future slide occurs

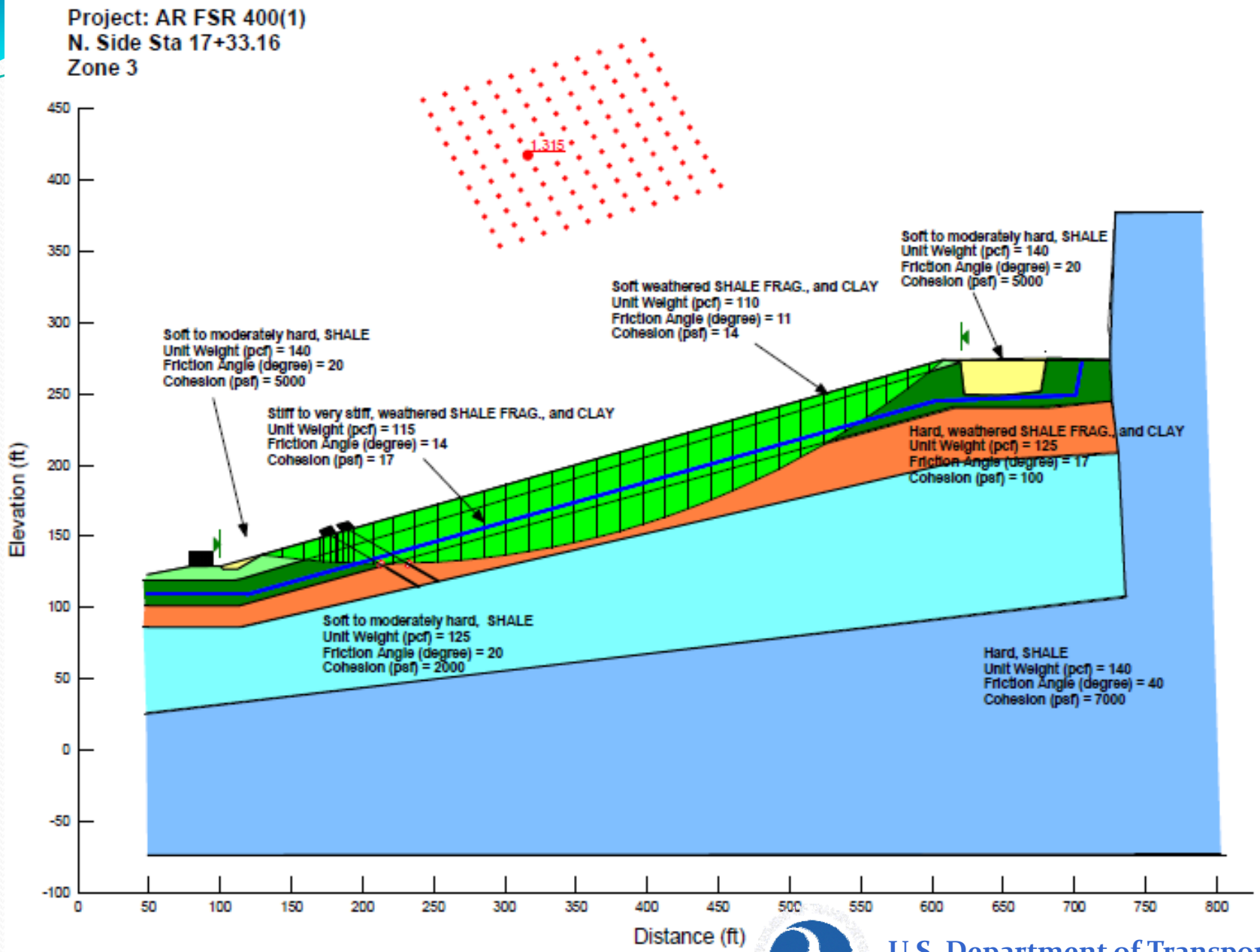
Repair Alternative 3

- Toe anchored or cantilevered soldier pile wall with drilled shafts socketed into bedrock and partial excavation
  - An anchored soldier pile wall system would be required because of the high lateral loads
  - Cons: The depth to competent rock and the size of the slide rendered this alternative inapplicable because of concerns with high cost for this low ADT road

Design Process of Selected Option

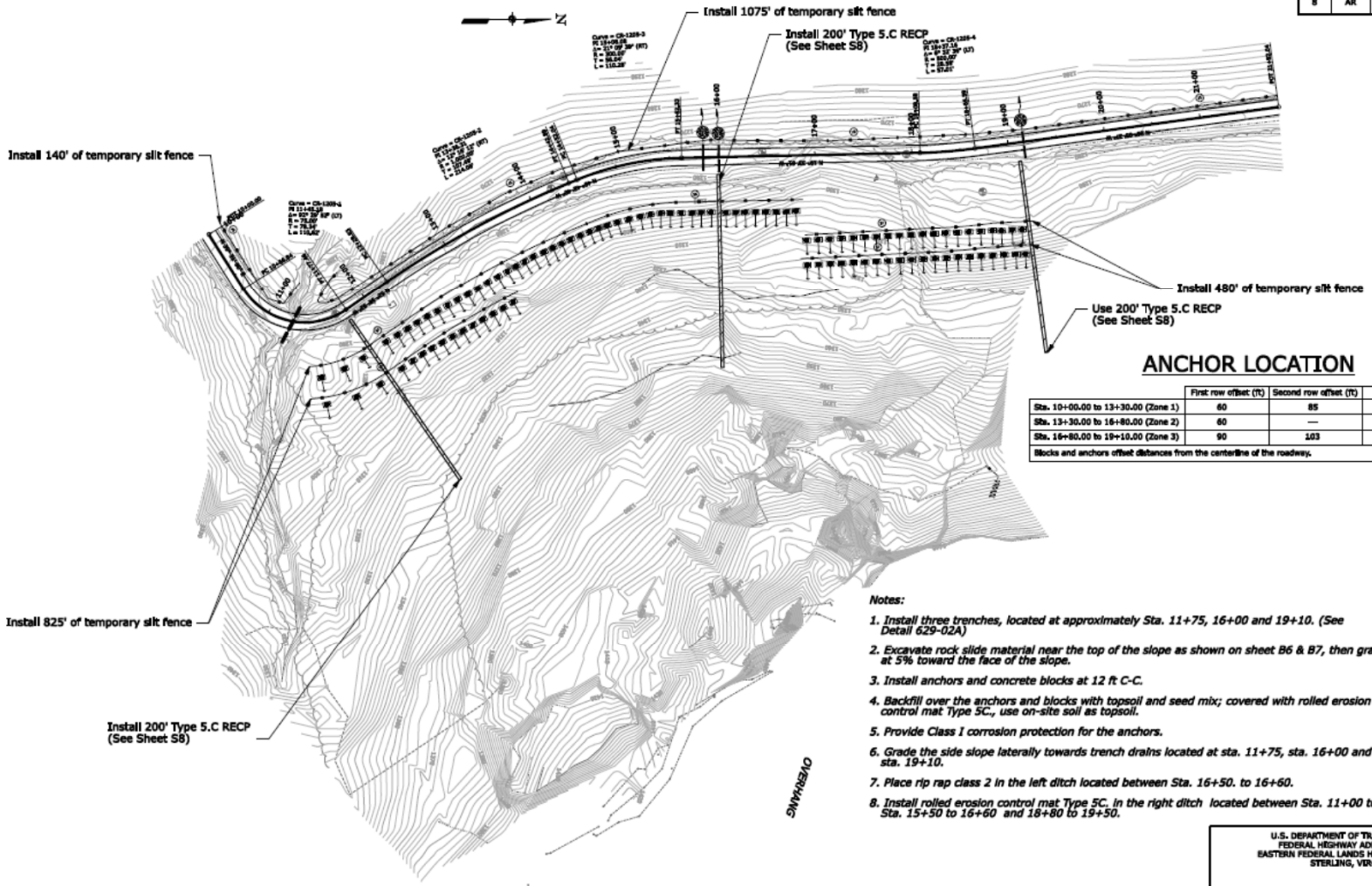
Alternative 2 - Excavation of Slide Material, Installation of Anchors with Concrete Blocks and a Toe Buttress

A GRS Embankment was Selected for Reconstruction of the Roadway Embankment for All Three Options



U.S. Department of Transportation
Federal Highway Administration

REG	STATE	PROJECT	SHEET NO.
8	AR	ERFO-FSR 400(1)	D4



ANCHOR LOCATION

	First row offset (ft)	Second row offset (ft)	Anchor Quantities
Sta. 10+00.00 to 13+30.00 (Zone 1)	60	85	30
Sta. 13+30.00 to 16+80.00 (Zone 2)	60	—	30
Sta. 16+80.00 to 19+10.00 (Zone 3)	90	103	40
Blocks and anchors offset distances from the centerline of the roadway.			

Notes:

1. *Install three trenches, located at approximately Sta. 11+75, 16+00 and 19+10. (See Detail 629-02A)*
2. *Excavate rock slide material near the top of the slope as shown on sheet B6 & B7, then grade at 5% toward the face of the slope.*
3. *Install anchors and concrete blocks at 12 ft C-C.*
4. *Backfill over the anchors and blocks with topsoil and seed mix; covered with rolled erosion control mat Type 5C., use on-site soil as topsoil.*
5. *Provide Class I corrosion protection for the anchors.*
6. *Grade the side slope laterally towards trench drains located at sta. 11+75, sta. 16+00 and sta. 19+10.*
7. *Place rip rap class 2 in the left ditch located between Sta. 16+50. to 16+60.*
8. *Install rolled erosion control mat Type 5C. in the right ditch located between Sta. 11+00 to 12+00, Sta. 15+50 to 16+60 and 18+80 to 19+50.*

0 25 50
SCALE IN FEET

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

OZARK-ST. FRANCIS NATIONAL FOREST

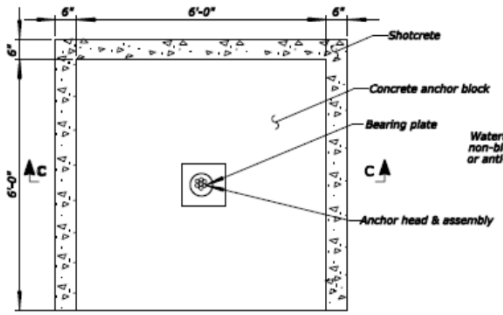
GRADING PLAN

Sta. 10+00.00 to Sta. 21+82.04

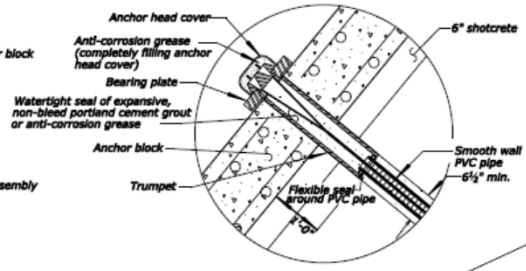
6/15/2010 2:02:25 PM M:\Projects\Fsr\400\Hard_dev\CADD\erfsr400\hard_400 50sch24.dgn

U.S. Department of Transportation
Federal Highway Administration

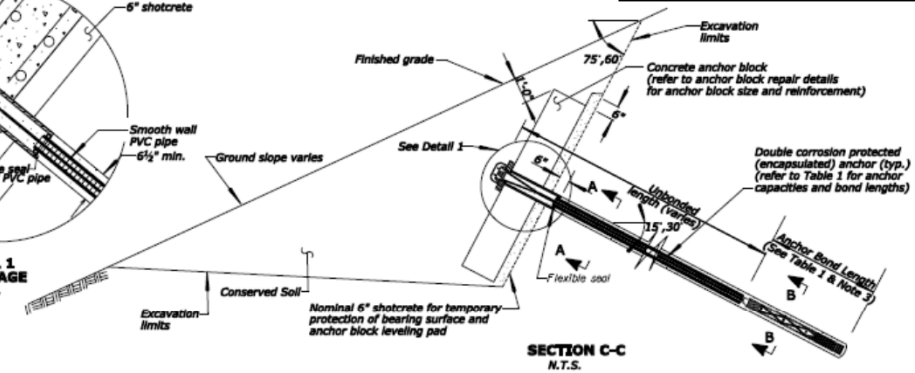
REGION	STATE	PROJECT	SHEET NO.
8	AR	AR-ERFO-FSR-400(1)	R02



ANCHOR BLOCK PLAN VIEW
N.T.S.



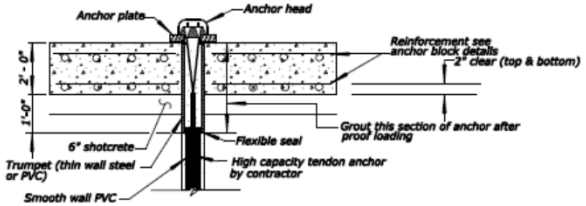
DETAIL 1
ANCHORAGE
N.T.S.



SECTION C-C
N.T.S.

TABLE 1

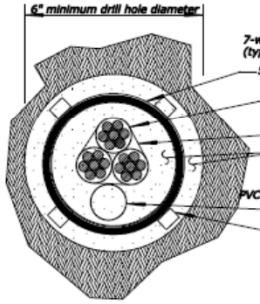
DESIGN ANCHOR CAPACITY (KIPS)	NUMBER OF 7-WIRE STRANDS (0.6"dia.) per anchor	TOTAL ANCHOR STRAND X-SECTION(IN²)	ESTIMATED[3] MINIMUM ANCHOR BOND LENGTH(FT)	MINIMUM DRILL HOLE DIAMETER	ANCHOR DIRECTION	
PRODUCTION ANCHORS						
240K	7	1.52	26	6.5"	ZONE 1	15°
					ZONE 2	30°
					ZONE 3	30°
PERFORMANCE LOAD TESTED ANCHORS						
240K	7	1.52	26	6.5"		



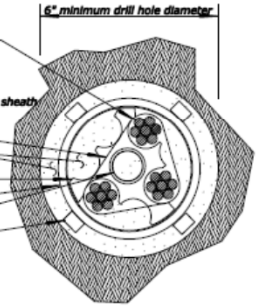
ANCHOR BLOCK SECTION
N.T.S.

NOTES:

1. Use ASTM-416 high strength steel (FPU=270 KSI, nominal As=0.22 sq in per 7-wire strand)
2. At the direction of the CO, carefully remove any soft soils, rock pinnacles, ledges, or other unsuitable material from the anchor block face to a depth of 6" behind the face and shotcrete to provide a 6" thick leveling pad for the anchor block. Replace any material disturbed beyond a depth of 6" with shotcrete at no additional cost.
3. Minimum anchor bond lengths are estimates only. Adjust anchor length in the field based on verification and proof test result and at the approval of the CO.
4. Select drilling equipment and methods that provide anchor bond zones of adequate length and diameter to meet or exceed the required anchor capacities. All equipment and methods will be subject to approval by the CO.



SECTION A-A
UNBONDED LENGTH
N.T.S.



SECTION B-B
UNBONDED LENGTH
N.T.S.

NOTE:
Typical three 7-wire strand arrangement shown above. actual number of anchor strands not shown for clarity.

PRELIMINARY
NOT FOR CONSTRUCTION

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

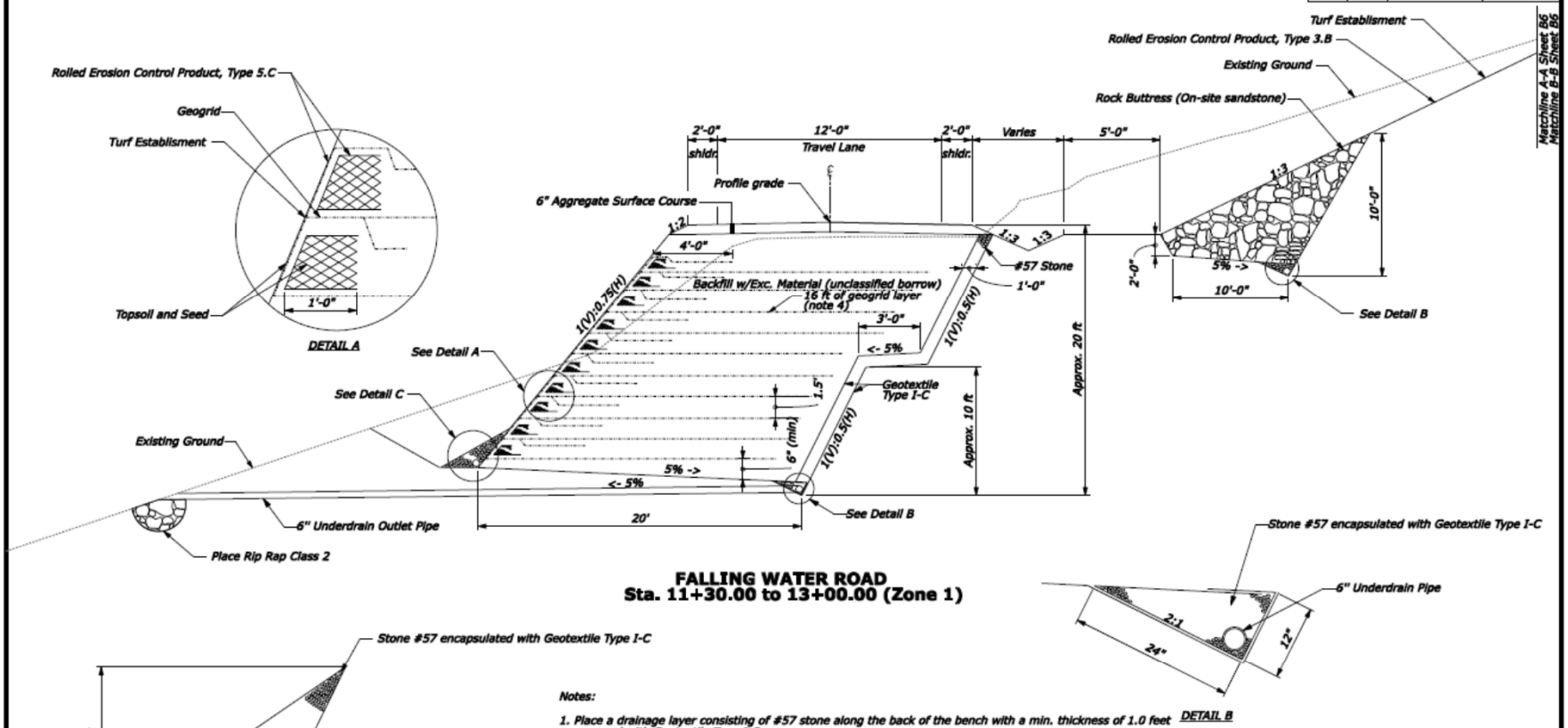
OZARK-ST. FRANCIS NATIONAL FOREST

ANCHOR BLOCK & ANCHORS DETAIL

NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
								CV	CV	QN	No scale	Quinn Nguyen	2 of 2	November 2009	E256-A

5/6/2010 6:24:54 PM M:\Projects\f's\ar\40011\proj_site\CADD\ar\40011AR 400 9\sht\DETAILS\R02_ANCHOR BLOCKS AND ANCHORS DETS.dgn

REG	STATE	PROJECT	SHEET NO.
8	AR	ERFO/AR FSR-400(1)	B3



FALLING WATER ROAD
Sta. 11+30.00 to 13+00.00 (Zone 1)

Notes:

1. Place a drainage layer consisting of #57 stone along the back of the bench with a min. thickness of 1.0 feet wrapped with Geotextile Type I-C
2. Place underdrain at the toe and along the back of the excavated bench using #57 stone and 6 inches diameter pipe wrapped in Geotextile Type I-C.
3. Provide a minimum of 2 underdrain outlets at equal spacing using a 6 inches diameter pipe, embedded in #57 stone and wrapped in Geotextile Type I-C.
4. Provide a geogrid with minimum LTDS of 2000 lb/feet. Place the first geogrid layer at 0.5 feet above the bottom of the excavation. Extend geogrid layers a minimum 16.0 feet of embedment depth at 1.5 feet vertical spacing.
5. Use excavate material consisting of unclassified borrow in accordance with Subsection 704.06.
6. Construct rock buttress using on-site sandstone in accordance with Section 252.
7. Lateral pay limits of clearing and grubbing extend two foot beyond slope stake limits; excluding roadway.
8. Place 6 inches layer of on-site topsoil and establish turf over the repaired slope according to Section 624 & 625.

NOT TO SCALE

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

OZARK-ST. FRANCIS NATIONAL FOREST

TYPICAL SECTIONS

Construction Process

Slide Debris

- 196,000 Cubic Yard of
  - Soil
  - Boulders
  - Tree Branches
  - Mud

U.S. Department of Transportation
Federal Highway Administration

Excavation of 5 to 30 ft slide debris

Good Portion of on-site Material was Reused to backfill Low Slope Areas

Prepare Benches for the Concrete Anchor Blocks

Anchors and Anchor Block Installation
Shotcrete was Used to Prepare Bench Back Cut for Block

Anchors and Anchor Block Installation – (2 rows)

Near Completion of Construction

Slope Stabilization Consisted of:

Anchors with Anchor Blocks (single and double rows)

Excavation (Reduce load)

Toe Rock Buttress

GRS Embankment

Drainage

Engineers Estimate = $5.2 millions
Low Bid = **$3.8** millions !

Thanks You!

Questions?

U.S. Department of Transportation
Federal Highway Administration