PRIORITIZATION OF AGING ROCK SLOPES ON I-77

Ryan Tinsley, PG
Larry Artman, PG
David Lee, PE
Wade Pence, PG
Travis Higgs, PE
PRIORITIZATION OF AGING ROCK SLOPES ON I-77

PRESENTATION OUTLINE

- Corridor Challenges
- I-77 Rock Slope Management Program
- RHRS
- Geologic Evaluations
- Preliminary Design
- Slope Remediation
- Conclusions and a Look Ahead
CORRIDOR CHALLENGES

► High AADT
► Steep Grades
► Foggy Conditions
► Unfavorable Geology
I-77 CORRIDOR CHALLENGES: FOGGY CONDITIONS
VDOT CHALLENGE: PRIORITIZATION OF AGING SLOPES

► Where are the problematic slopes along 32 Lane Miles

► What are the primary causes of the rockfall activity?

► What are feasible options?

► What are the probable construction cost estimates?

► Study Challenges
  – Significant slope height and length variability
  – No Existing Slope Inventory
  – No Survey
  – Limited Budget

Rock Slope Management Program
PRIORITIZATION OF AGING ROCK SLOPES ON I-77
GEOLOGY

► Alligator Back Formation – Proterozoic Z – Cambrian
► Complexly Deformed With at Least 2 Periods of Ductile Deformation with Isoclinal Folding
► Well-Developed Cleavage Dominates
► Rock Types:
  □ Biotite Gneiss (Metagraywacke)
  □ Mica-Biotite Schist and Amphibolite
GEOLOGY
Rockfall Hazard Rating System
Participant's Manual

FINAL REPORT
IMPLEMENTATION OF THE ROCK SLOPE MANAGEMENT PROJECT
AT THE VIRGINIA DEPARTMENT OF TRANSPORTATION

Edward J. Hoppe, Ph.D., P.E.
Senior Research Scientist
Derek H. Whitehouse, C.P.G.
Chief Transportation Geologist

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)
Charlottesville, Virginia
June 2006
VTRC 06-R23
2012 RHRS STUDY FOR — CUT SLOPE INVENTORY

- Initial Slope Inventory Using Plans and Aerial Photography
- Develop Sequential List of Cut Slopes in Each Lane Direction from South to North
- Field Verification of Cut Slopes Based on Preliminary RHRS Classes A, B, and C
  - Some Slopes Eliminated from Further Consideration and Rating
- Field Location of Class A, B, and C Slopes Using Hand-held Garmin and MP Designations

What is a Class A, B, or C Slope?

- **Class A** — High Potential for Rockfall on Roadway
- **Class B** — Moderate Potential for Rockfall on Roadway
- **Class C** — Low Potential for Rockfall on Roadway (Class C Slopes Not Rated)

Ultimately, Preliminary Class Designations are Subjective Based on Experience of Rater, But Provide a Means for Prioritizing Slopes!
### 2012 RHRS STUDY FOR

#### Cut 10-NB(M)

<table>
<thead>
<tr>
<th>Marker</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB/SB MP Marker</td>
<td>NB/SB Median Slope Begin</td>
</tr>
<tr>
<td>RHRS Preliminary Rating A</td>
<td>NB/SB Median Slope End</td>
</tr>
<tr>
<td>RHRS Preliminary Rating B</td>
<td>NB/SB Outside Slope Begin</td>
</tr>
<tr>
<td>RHRS Preliminary Rating C</td>
<td>NB/SB Outside Slope End</td>
</tr>
<tr>
<td>Historical Rockfall</td>
<td>NB/SB Begin/End Median Slope</td>
</tr>
<tr>
<td>Slope Length</td>
<td>NB/SB Begin/End Outside Slope</td>
</tr>
<tr>
<td>SB MP Baseline</td>
<td>2012 RHRS Detailed Rating Score</td>
</tr>
<tr>
<td>NB MP Baseline</td>
<td>[364]</td>
</tr>
</tbody>
</table>

3-7-2011: MP 3.75 NB Median Slope

---

**Note:** Slope Limits and Mile Posts are Approximate Only

**Created by R. Rao**  
**Checked by R. Tinsley**

---

Virginia Department of Transportation - Salem District  
Interstate 77, MP 0.0 to MP 8.0 (Fancy Gap)  
Slope Inventory and RHRS Slope Rating

**Prepared by:**

June 2012  
Page 7 of 15
2012 RHRS STUDY FOR

RHRS Key Rating Criteria:

- Slope Height
- Ditch Effectiveness
- AVR – Average Vehicle Risk
- % Site Distance
- Roadway Width
- Geologic Characteristics
- Block Size or Volume of Rockfall
- Rockfall History (Historical and Observed)

<table>
<thead>
<tr>
<th>TABLE 4.1: SUMMARY SHEET OF THE ROCKFALL HAZARD RATING SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CATEGORY</strong></td>
</tr>
<tr>
<td>SLOPE HEIGHT</td>
</tr>
<tr>
<td>DITCH EFFECTIVENESS</td>
</tr>
<tr>
<td>AVERAGE VEHICLE RISK</td>
</tr>
<tr>
<td>PERCENT OF BLOCKS DROPPED</td>
</tr>
<tr>
<td>ROADWAY WIDTH</td>
</tr>
<tr>
<td>GROUND CONDITION</td>
</tr>
<tr>
<td>CASE 1 ROCK FALL</td>
</tr>
<tr>
<td>GROUND CONDITION</td>
</tr>
<tr>
<td>CASE 2 DIFFERENCE IN EROSION RATES</td>
</tr>
<tr>
<td>BLOCK SIZE</td>
</tr>
<tr>
<td>VOLUME OF ROCKFALL/UNIT</td>
</tr>
<tr>
<td>CLIMATE AND PRESENCE OF WATER ON SLOPE</td>
</tr>
<tr>
<td>ROCKFALL HISTORY</td>
</tr>
</tbody>
</table>
### 2012 RHRS STUDY FOR Slope Heights: 25 to > 250 ft

<table>
<thead>
<tr>
<th>Slope Height (ft)</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category Score</td>
<td>3</td>
<td>9</td>
<td>27</td>
<td>81</td>
</tr>
</tbody>
</table>

#### Slope Height and Category Score

- **Slope Height**: 25 to > 250 ft
- **Category Score**: 3, 9, 27, 81

#### Additional Data

- **Date**: 5-10-12
- **Rating**: A/B
- **County/City**: CAPA
- **Route No.**: I-77
- **Nearest Int.**: Exit 106
- **Speed Limit**: 70
- **Left Handing**: N/S/W/E

#### Geologic Characteristics

- **Category**: Slope Geometry
  - **Remarks**: Slope Height
  - **Category Score**: 81

#### Other Information

- **Ditch Effectiveness**: G, M, N
- **Average Vehicle Risk**: 105, 5
- **Sight Distance**: 460, 50
- **Roadway Width**: 32, 8
- **Structural Condition**: D, F, R

#### Additional Notes

- **Comments**: For detailed ratings and analysis.
## 2012 RHRS STUDY FOR

### Average Vehicle Risk:

- **AADT = 18,000**
- **Slope Length = 1280 feet**
- **Typical AVR Score : 81-100**

---

**RHRS Detailed Rating Field Data Sheet**

<table>
<thead>
<tr>
<th>Category</th>
<th>Remarks</th>
<th>Category Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Geometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope Height</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Ditch Erosion Control</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Average Vehicle Risk</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Sight Distance</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Geologic Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block Size/Volume</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Rockfall History</td>
<td></td>
<td>81</td>
</tr>
<tr>
<td>Comments</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Date:** 5-18-12
- **Rating:** 81
- **AADT:** 18,000
- **Slope Length:** 1280 feet
- **Typical AVR Score:** 81-100
### 2012 RHRS STUDY FOR INTERSTATE 77

#### RHRS Detailed Rating Field Sheet

<table>
<thead>
<tr>
<th>Category</th>
<th>Remarks</th>
<th>Category Score</th>
<th>Slope Geometry</th>
<th>Slope Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Height</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ditch Effectiveness</td>
<td>G M (N)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Vehicle Risk</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sight Distance</td>
<td>% Decision S. D.</td>
<td>Sight Present</td>
<td>Yes (X)</td>
<td>Sight Distance</td>
</tr>
<tr>
<td>Roadway Width</td>
<td>% B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Geologic Characteristics**

<table>
<thead>
<tr>
<th>Case</th>
<th>Structural Condition</th>
<th>Rock Friction</th>
<th>Differential Erosion Features</th>
<th>Difference in Erosion Rates</th>
<th>Rockfall Characteristics</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>D (G) F R (A)</td>
<td>R I C D G-S</td>
<td>P O N M</td>
<td>S M L E</td>
<td>P O M</td>
<td>805</td>
</tr>
<tr>
<td>Case 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**
- High potential for rockfall.
- High potential for washouts.
- High potential for road failure.
- High potential for structural failure.

% Decision Sight Distance: Worst Case: 420 ft
% Decision S. D. Score = 81
Continuous and Adverse Orientation

Slopes Showing Their Age

2012 RHRS STUDY FOR

### RHRS Detailed Rating Field Data Sheet

**Date:** 5-18-12

**Rating:** A/B

**County/City:** [Redacted]

**Start Latitude:** 36.6033

**Start Longitude:** 80.1492

**End Latitude:** 36.6045

**End Longitude:** 80.1496

**Nearest Inter:** 241.6 (mi)

**Start MP (ea):** 3.75

**End MP (ea):** 3.75

**ADT:** 16,000 (ca)

**Speed Limit:** 45

**Left / Right:** Heading N N E W

**H L:** (Redacted)

**Category** | **Remarks** | **Category Score** | **Slope Geometry**
---|---|---|---
Slope Height | | | Slope Height
Ditch Effectiveness | | | Ditch Effect
Average Vehicle Risk | | | Average Vehicle Risk
Sight Distance | | | Sight Distance
Sign Present | | | Sign Present
Roadway Width | | | Roadway Width

**Geologic Characteristics**

**Structural Condition** | **Rock Friction** | **Total Score**
---|---|---
D | R | 565

**Continuous and Adverse Orientation**

**Slopes Showing Their Age**
64 Slopes Inventoried
28 Slopes – High Hazard (RHRS Score >300)
MP: 2.9 to 6.3
RHRS Scores: 319 to 565
How to prioritize beyond the RHRS Ratings?
### 2012 RHRS STUDY FOR - CUT SLOPE PRIORITIZATION LIST

<table>
<thead>
<tr>
<th>Cut Slope Priority for Detail Evaluation</th>
<th>Cut Slope Designation</th>
<th>Begin MP</th>
<th>End MP</th>
<th>RHRS Detail Rating [2012]</th>
<th>Relevant Comments /Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8-SB</td>
<td>2.95</td>
<td>3.15</td>
<td>565</td>
<td>- Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)</td>
</tr>
<tr>
<td>2</td>
<td>14-SB</td>
<td>3.75</td>
<td>3.9</td>
<td>565</td>
<td>- Documented Rockfall History (Early 1990s)</td>
</tr>
<tr>
<td>3</td>
<td>19b-SB</td>
<td>4.9</td>
<td>5</td>
<td>565</td>
<td>- Existing Rockfall Barrier Fence</td>
</tr>
<tr>
<td>9</td>
<td>23-SB</td>
<td>5.45</td>
<td>5.65</td>
<td>565</td>
<td>- Documented Rockfall History (3/7/2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Slope Remediation Completed (8/29/2012)</td>
</tr>
<tr>
<td>10</td>
<td>10-NB(M)</td>
<td>3.6</td>
<td>3.9</td>
<td>560</td>
<td>- Sister slope to 14-SB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)</td>
</tr>
<tr>
<td>2a</td>
<td>9-NB</td>
<td>3.7</td>
<td>3.85</td>
<td>506</td>
<td>- Initial evaluation completed during I-77 Phase 1 Work (12/11/2011)</td>
</tr>
<tr>
<td>4a</td>
<td>15d-NB(M)</td>
<td>5.05</td>
<td>5.15</td>
<td>506</td>
<td>- Documented Rockfall History (4/29/2008)</td>
</tr>
<tr>
<td>5</td>
<td>21-NB(M)</td>
<td>5.4</td>
<td>5.65</td>
<td>506</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>16-SB</td>
<td>4.45</td>
<td>4.65</td>
<td>487</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Existing Rockfall Barrier Fence</td>
</tr>
<tr>
<td>7</td>
<td>13-NB(M)</td>
<td>4.45</td>
<td>4.65</td>
<td>482</td>
<td>- Documented Rockfall History (7/13/2011)</td>
</tr>
<tr>
<td>8</td>
<td>14-NB</td>
<td>4.45</td>
<td>4.65</td>
<td>482</td>
<td>- Documented Rockfall History (4/29/2008)</td>
</tr>
<tr>
<td>4b</td>
<td>15b-NB(M)</td>
<td>4.85</td>
<td>5</td>
<td>452</td>
<td></td>
</tr>
<tr>
<td>4c</td>
<td>15a-NB(M)</td>
<td>4.75</td>
<td>4.85</td>
<td>362</td>
<td></td>
</tr>
</tbody>
</table>

- RHRS Rating >500
- Actively Producing Rockfall
- Maintenance Records/Rockfall Clean-up
PRIORITIZATION OF AGING ROCK SLOPES ON I-77
GEOLOGIC EVALUATIONS

► 3 Priority Slopes
► 4,500 LF of Slope
► MP: 2.9 to 5.7
► Goal:
  – Feasible Options
  – Probable Construction Cost Estimates
TEAM APPROACH

Key Factors:

- Client Input (Throughout Project)
- Understanding of Geologic Conditions
- Site Constraints
- Slope Access/ Construction Feasibility
- Product Applicability
Priority Slope Approach

- Establish Baseline
- Document Cut Slope Conditions
- Discontinuity Measurements
- Develop Slope Profiles for CRSP
- Identify Priority Slope Sections (AOI)
- Preliminary Kinematic Analysis
GEOLOGIC EVALUATIONS: STAGE 2 – ROPES ON THE SLOPE

► AOI Investigation

– Geologic Investigation – potential failure mode(s)
– Obscured slope sections
– Stabilization requirements and option feasibility
– Slope access
GEOLOGIC EVALUATIONS:

I-77 NB – Median Slope

- Well defined NW shear plane
- Mobilized/Separated blocks
- Exposed NE joint and NE stress relief joint
- Mobilized blocks
- Location of previous rockslide on March 7, 2011
- Remove Mobilized Wedge
- Remove Well-developed overhangs
- Similar system of joints as previous rockslide at Station 10+80: NW back-plane and NE joint
- Area of further investigation

I-77 NB Project Stationing (APPROXIMATE, NOT TO SCALE)

- Remove Potential Wedge
- Remove Well-developed overhangs
- Scale and remove loose block
- Differential weathering and blast damage of rock face
- Remove Wedge and mobilized block
- Remove loose rock
- Remove wedge

Remove Loose Material – to be completed with an excavator and/or by scaling based on location on slope.
Scaling – to be completed by Ameritech

Virginia Department of Transportation - Salem District
Interstate 77, Approximate MP 3.8, Carroll County
Investigation of Existing Rock Cut Slopes

Prepared by HDR
November 2011  Figure: NB-M-2
TECHNOLOGIES VS. SLOPE CONDITION

► Applicability
- Maintain Existing Ditch
- Scaling
- Excavation
- Rock Slope Drape
- Attenuator Drape
- Concrete Barrier
- Flexible Rockfall Barrier
- High Energy Barrier
- Pinned Mesh
- Rock Bolting
PRIORITIZATION OF AGING ROCK SLOPES ON I-77

Corridor Challenges

I-77 Rock Slope Management Program

RHRS

Geologic Evaluations

Preliminary Design

Preliminary Design
PRELIMINARY DESIGN: CONSIDERATIONS FOR FEASIBLE OPTIONS

Subglobal Condition (Rockfall)

- Height of Rockfall Generator
- Maximum Bounce Height
- Maximum Energy (kJ)

Global Conditions (Planar, Wedge, Rock Mass)

- Height of Block Generator
- Slope Access/Site Constraints
FEASIBLE SUBGLOBAL OPTIONS FOR SLOPE CONDITIONS

Sub-Global Stability (Rockfall)

Slope height of rockfall generator < 70 ft.

Maximum bounce height < 4 ft.

- Maximum energy < 80 KJ
  - Yes: Condition A: Options
    - A1. Existing Ditch
    - A2. Scaling
    - A3. Concrete Barrier
  - No: Condition B: Options
    - B2. Scaling
    - B4. Rock Slope Drape with Existing Ditch
    - B5. Attenuator Drape with Existing Ditch
    - B6. Flexible Rockfall Barrier

- No: Condition C: Options
  - C2. Scaling
  - C4. Rock Slope Drape with Existing Ditch
  - C5. Attenuator Drape with Existing Ditch
  - C6. Flexible Rockfall Barrier
  - C7. Two-Tiered Rockfall Barrier

Slope height of rockfall generator < 150 ft.

Maximum bounce height < 20 ft.

- Yes: Condition A: Options
- No: Condition B: Options

Condition A: Options

Condition B: Options

Condition C: Options
SLOPE CONDITIONS: A, B AND C

I-77 SB – RHRS SLOPE 8-SB: Photo Mosaic

CONDITION C SLOPE

Condition C: Options
- C2. Scaling
- C4. Rock Slope Drape with Existing Ditch
- C5. Attenuator Drape with Existing Ditch
- C6. Flexible Rockfall Barrier
- C7. Two-Tiered Rockfall Barrier

I-77 SB Project Stationing (NOT TO SCALE)
FEASIBLE GLOBAL OPTIONS FOR SLOPE CONDITIONS

**Global Stability (Rock Mass, Toppling, Planar, Wedge Failures)**

Slope height of rockfall generator < 50 ft.

*Yes*  
*No*

**Condition D: Options**
- D2. Scaling
- D8. Excavation
- D9. Rock Bolts
- D10. Anchored Mesh
- D11. High - Energy Absorbing Device/Barrier with Existing Ditch

**Condition E: Options**
- E2. Scaling
- E9. Rock Bolts
- E10. Pinned Mesh or Nets
- E11. High - Energy Absorbing Device/Barrier with Existing Ditch
1. Driver = Aspect or consideration of a feasible slope mitigation option during the selection process

2. Importance Factor = a weight assigned to each driver to determine relative importance amongst the drivers.

3. Driver Rating = relative assessment of each driver on a 1 to 5 scale

<table>
<thead>
<tr>
<th>Driver</th>
<th>Importance Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost</td>
<td>7</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>10</td>
</tr>
<tr>
<td>Construction Complexity</td>
<td>6</td>
</tr>
<tr>
<td>Traffic Impacts</td>
<td>9</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>3</td>
</tr>
<tr>
<td>Rockfall Maintenance</td>
<td>5</td>
</tr>
<tr>
<td>System Maintenance</td>
<td>8</td>
</tr>
<tr>
<td>Fog Impacts</td>
<td>7</td>
</tr>
<tr>
<td>Maintenance Experience</td>
<td>7</td>
</tr>
<tr>
<td>Environmental</td>
<td>3</td>
</tr>
</tbody>
</table>
**SCORED RELATIVE ASSESSMENT AND OPTION SHORTLIST**

**Total Option Score = \( \sum (\text{Importance Factor} \times \text{Driver Rating}) \)**

**Driver Rating = 1 to 5 scale**

<table>
<thead>
<tr>
<th>Driver</th>
<th>VDOT Importance Factor (Weight)</th>
<th>C2: Scaling</th>
<th>Total Scaling Score</th>
<th>C4: Rock Slope Drape with Ditch</th>
<th>Total Rock Slope Drape with Ditch Score</th>
<th>C5: Attenuator Drape with Ditch</th>
<th>Total Attenuator Drape with Ditch Score</th>
<th>C6: Flexible Rockfall Barrier</th>
<th>Total Flexible Rockfall Barrier Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>5</td>
<td>50</td>
<td>5</td>
<td>50</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Traffic Impacts</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>18</td>
<td>2</td>
<td>18</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>System Maintenance</td>
<td>8</td>
<td>5</td>
<td>40</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Fog Impacts</td>
<td>7</td>
<td>5</td>
<td>35</td>
<td>5</td>
<td>35</td>
<td>5</td>
<td>35</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Maintenance Perception</td>
<td>7</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>35</td>
<td>5</td>
<td>35</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Construction Complexity</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>12</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Rockfall Maintenance</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>3</td>
<td>15</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>3</td>
<td>5</td>
<td>15</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Environmental Impacts</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>179</strong></td>
<td></td>
<td><strong>189</strong></td>
<td><strong>183</strong></td>
<td></td>
<td><strong>210</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PRELIMINARY DESIGN

► VDOT Design Requirements (MOI, 2012)
  – Rockfall Simulation:

<table>
<thead>
<tr>
<th>Alignment Type</th>
<th>Critical Rock Slope</th>
<th>Non-critical Rock Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>0%</td>
<td>N/A</td>
</tr>
<tr>
<td>Primary</td>
<td>0%</td>
<td>N/A</td>
</tr>
<tr>
<td>High-Volume Secondary</td>
<td>&lt;1%</td>
<td>5%</td>
</tr>
<tr>
<td>Low-Volume Secondary</td>
<td>1%</td>
<td>5%</td>
</tr>
</tbody>
</table>

I-77 Priority Rock Slopes = Critical Rock Slope

0% Design = Low Risk, but Higher $
PRELIMINARY DESIGN: ROCKFALL PROBABILITY

► Significant Variation in Slope Height/Angle
► Varying Degrees of Vegetation
► Changes in Geology/Weathering Susceptibility
► Multiple Rockfall Generators
► Multiple Launch Features
PRELIMINARY DESIGN APPROACH

Design Criteria

- Help Bracket Cost vs Rockfall Risk based on Probability of Occurrence:

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Percentage of Rockfall Entering the Travel Lane (%)</th>
<th>Probability of Rockfall Being Retained (%)</th>
<th>Rockfall Generator Location</th>
<th>Probable Construction Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (per MOI)</td>
<td>0</td>
<td>99.9</td>
<td>Highest Possible</td>
<td>Higher</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>95</td>
<td>Most Likely</td>
<td>Lower</td>
</tr>
</tbody>
</table>
PRIORITIZATION OF AGING ROCK SLOPES ON I-77

Corridor Challenges
I-77 Rock Slope Management Program
RHRS
Geologic Evaluations
Preliminary Design
Conclusions and a Look Ahead

Conclusions and A Look Ahead
CONCLUSIONS

► Establishes Baseline (RHRS), Risk Assessment

► Geologic Evaluation
  – Aids in Further Prioritization of High Hazard Slopes
  – Involves all key players for reasonable construction cost estimates
  – Supports emergency response remediation of slopes sections

► Design Approach
  – Client input is very important
  – Design criteria allows for a relative Cost vs Risk assessment
A LOOK AHEAD

► Currently Conducting Preliminary Design and Developing Probable Construction Costs for each slope

► VDOT plans to utilize these costs for budgeting purposes for future final design and slope remediation

► Development of Contract Bid Documents

► Contract Advertisements for slope remediation as funding becomes available
ACKNOWLEDGEMENTS

• Wade Pence, PG – District Engineering Geologist, Salem District
• David Lee, PE – District Materials Engineer, Salem District
• Travis Higgs, PE – District Geotechnical Engineer, Salem District

• Aaron Zdinak, PE – Geotechnical Business Class Leader
• Russ Kanith, PG – Project Geologist
• Joe Wallen, PE – Geotechnical Engineer
• Matt Schuster, PhD, PE – Geotechnical Engineer

• Jeff Boone – President of Ameritech Slope Constructors
• Bob Forbes – Vice President of Ameritech Slope Constructors
• Roger Moore, PG, PE – Partner/Geotechnical Engineer

• Frank Amend, PE – Regional Manager, Southeastern USA
QUESTIONS...........SLIP - SLIDE & ROCK-N-ROLL?