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CONSTRUCTION TECHNIQUES AND CONSIDERATIONS FOR MITIGATING UNSTABLE ROCK SLOPES

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WHY DO WE NEED TO MITIGATE ROCK SLOPES?

- **Similar to Structures and Pavements Slopes have a Design Life!**
- **Where Humans Interact with Slopes There is a Need to Monitor, Evaluate & Mitigate**
- **Prior to Interstate Construction**
  - General Design Consideration was to Cut It Steep, Take Minimal Right-Of-Way
  - Slopes Perform for Limited Time
  - Slopes Will Reach Equilibrium Through Weathering and Gravity

WHY DO WE NEED TO MITIGATE ROCK SLOPES?

- **Interstate Construction Allowed for Larger Right-Of-Way Takes and Adequate Catchment Areas (In Most Cases)**

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DEFINING THE NEED

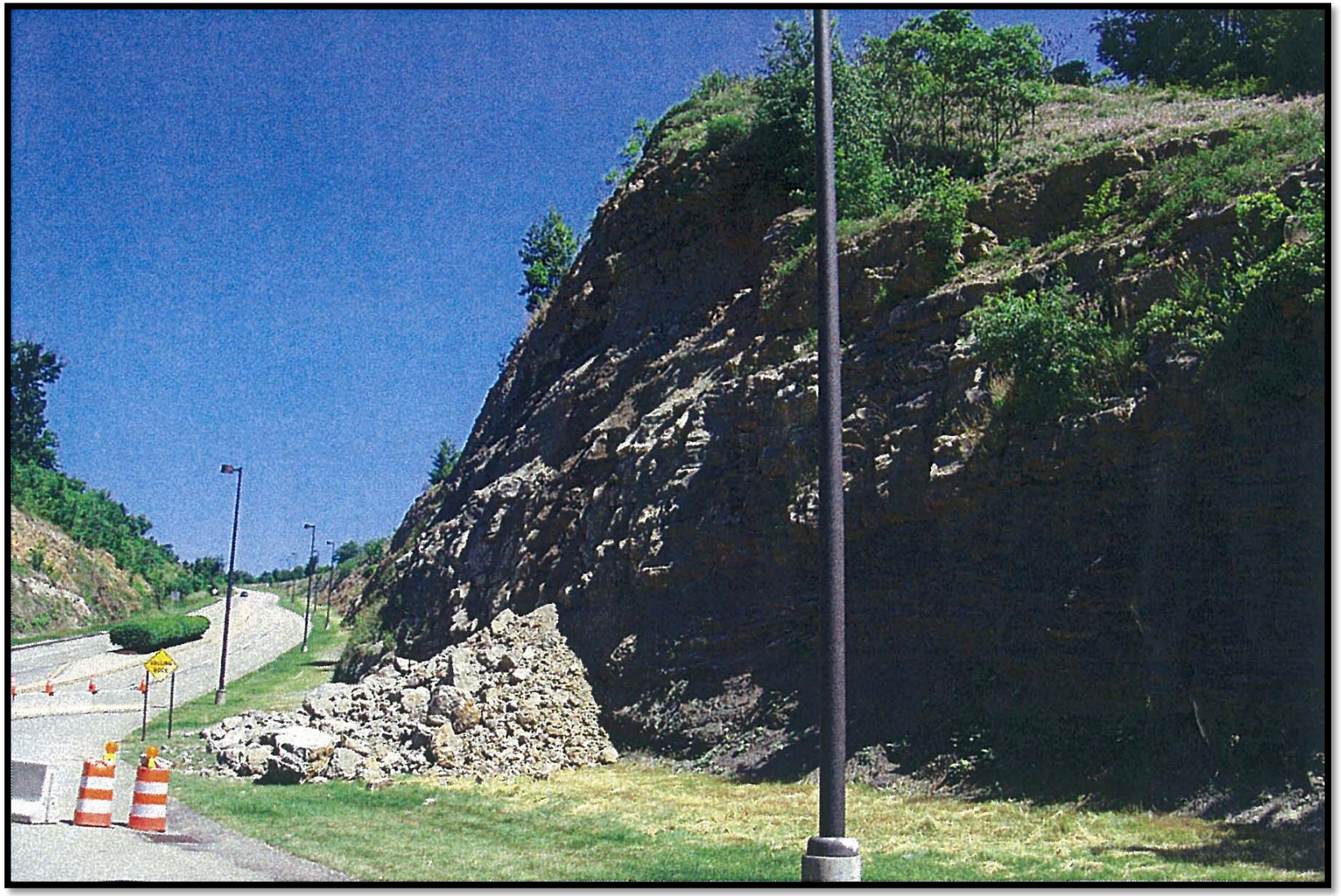
- S.R. 271, Cambria County, PA
  - Numerous Rockfall Events Dating to Original Construction 1950's
  - Rockfall Fence and Slope Mesh- 1990
  - Large Rockfall in 2007
    - Ripped Through Slope Mesh, Destroyed Fence
  - Initiated Long Term Stabilization Design in 2010

Defining the Need

- Pennsylvania S.R. 28, Allegheny County, PA
  - Major Rockfall Events
  - Slope Cut in 1970's
  - Large Rockfall During Roadway Reconstruction in 2007
    - Crossed 4 Lanes of Traffic @ Approx 4:00 a.m.
  - Construction Contract Amended to Include Slope Reconstruction/Rockfall Fence

Defining the Need

- **FedEx Drive, Allegheny County, PA**
  - **Major Rockfall Events**
  - **Slope Cut in 1990's**
  - **Construction Contract Amended to Include Slope Reconstruction/Rockfall Fence**



WHEN DO WE FIX?

Slope is Reconstructed as Part of:

- **Major Roadway Alignment Projects**
- **Bridge Replacement Projects**

Based on Hazard to Traveling Public:

- **Rockfall Hazard Rating Systems – Used by Owners to Categorize Rock Slopes into Hazard Categories (i.e. High, Medium, Low) Based on Variety of Factors (Failure Frequency, ADT, Sight Distance)**

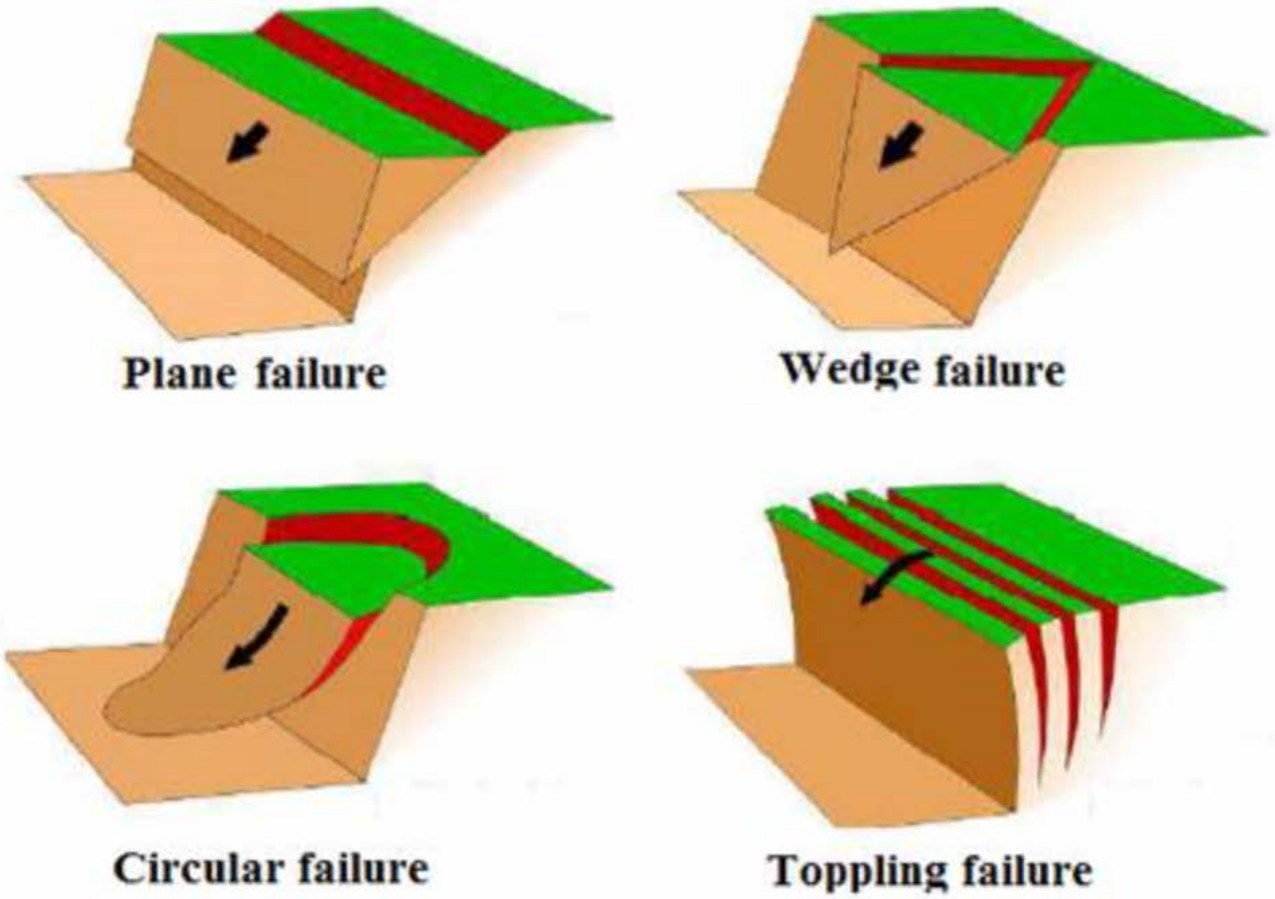
HOW DO WE FIX?

- **Ideal Mitigation**
  - Cut Slope Back
  - Eliminate the Hazard

- **Why This Is Rarely Feasible?**
  - Right-Of-Way Availability = Expense
  - Equipment and Labor = Expense
    - Traffic Control/Excavating/Hauling
  - Environmental Permitting = Expense & Time
    - Erosion and Sedimentation Control
    - Point Source Discharge
    - Waste Site Permitting
  - Public Impact = Expense & Time
    - Road Closures/Business Impacts

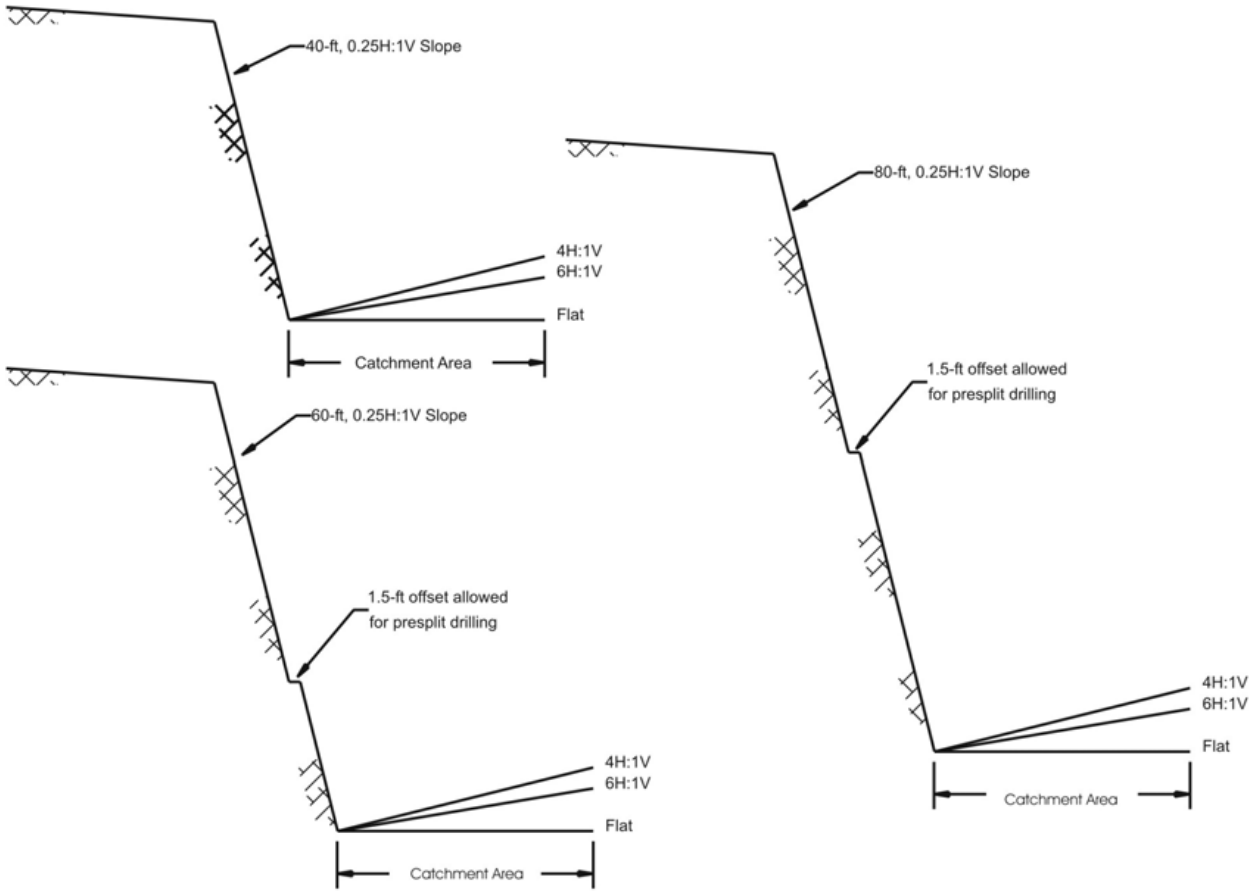
MITIGATION PROCESS

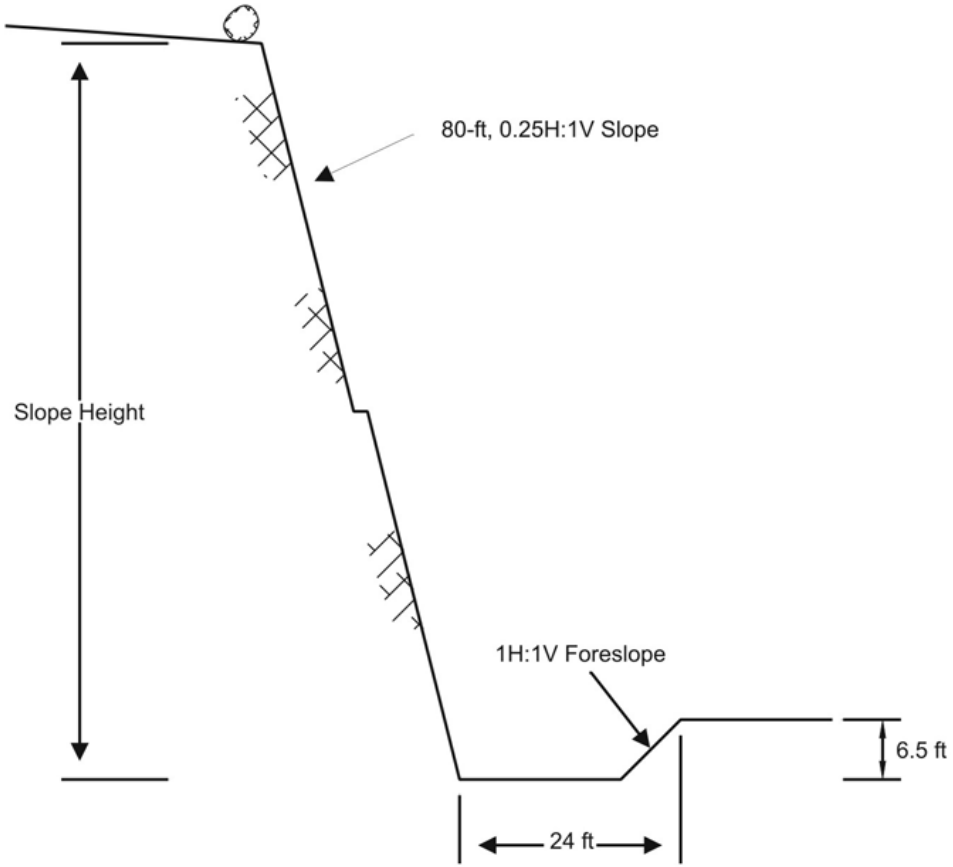
- **Field Reconnaissance**
  - Determine Failure Mode(s)
- **Determine Failure Frequency**
  - Maintenance Records
- **Define Project Constraints (Right-Of-Way, Maintenance of Traffic)**
- **Establish Conceptual Mitigation Plan**
- **Adjust Plan Based on Project Team Input**
- **Prepare Plans/Specifications or Design/Build Specifications**
- **Construction**
- **Follow Up Inspection of Mitigation Elements**



METHODS OF MITIGATION

- **Let it Fall and Catch It at the Bottom**
  - If Possible Establish Catchment Area
  - Rockfall Barriers





ROCKFALL BARRIERS

- **Rockfall Barrier (Low Deflection)**

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ROCKFALL BARRIER

- **Rockfall Barrier (High Deflection)**

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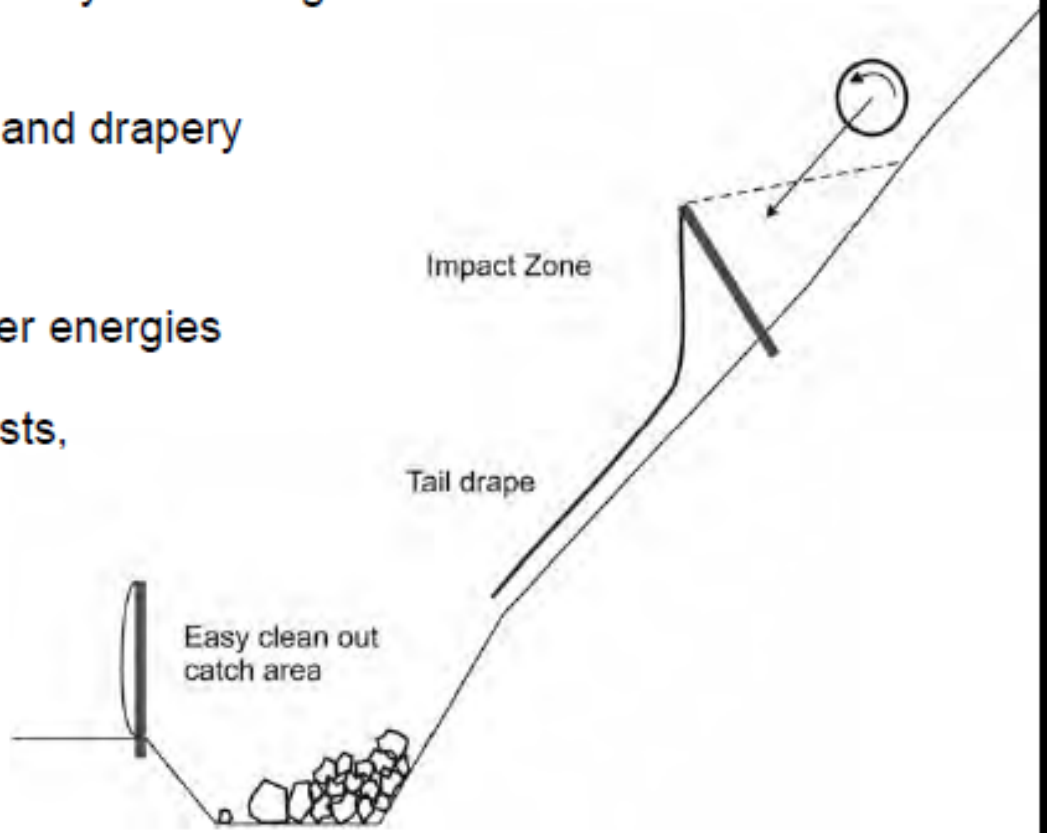
- **Hybrid Attenuator**

Rock fall Attenuators

- **Attenuation** = Loss of intensity of any flux through a medium
- **Design** = Hybrid of rock fall nets and drapery (impact & exit zone)
- **Function** = Catch & guide to lower energies
- **Construction** = Steel netting, posts, support ropes, (brake elements)



ROCKFALL BARRIER

- **Hybrid Attenuator**

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ROCKFALL BARRIER

- **Gallery Barrier**

In-Situ Methods For Rock Slope Stabilization

- **How Do We Know These Systems Work?**

METHODS OF MITIGATION

- **Rock Scaling and Removal**
  - Hand Scaling (Pry Bars/Air Bags)
  - Mechanical Scaling (Hammers/Excavators)
  - Trim Blasting

- **Requires Special Provision Specific to Rock Slope Scaling and Protection**
  - Identify Acceptable Methods
  - Identify Experience Requirements (Typically Requires Specialty Subcontractor)
  - Identify Temporary Rockfall Protection Requirements (Typically Contractor Designed Based on Means/Methods)
  - Define Measurement and Payment (Typically by the Hour for Hand Scaling)

SLOPE SCALING

- **Slope Scaling – Hand Scaling**

SLOPE SCALING

- **Slope Scaling – Mechanical Excavation**

SLOPE SCALING

- **Slope Scaling – Mechanical Excavation**

SLOPE SCALING

- **Trim Blasting**

IN-SITU METHODS FOR STABILIZATION

- **In-Situ Stabilization – Slope Mesh**

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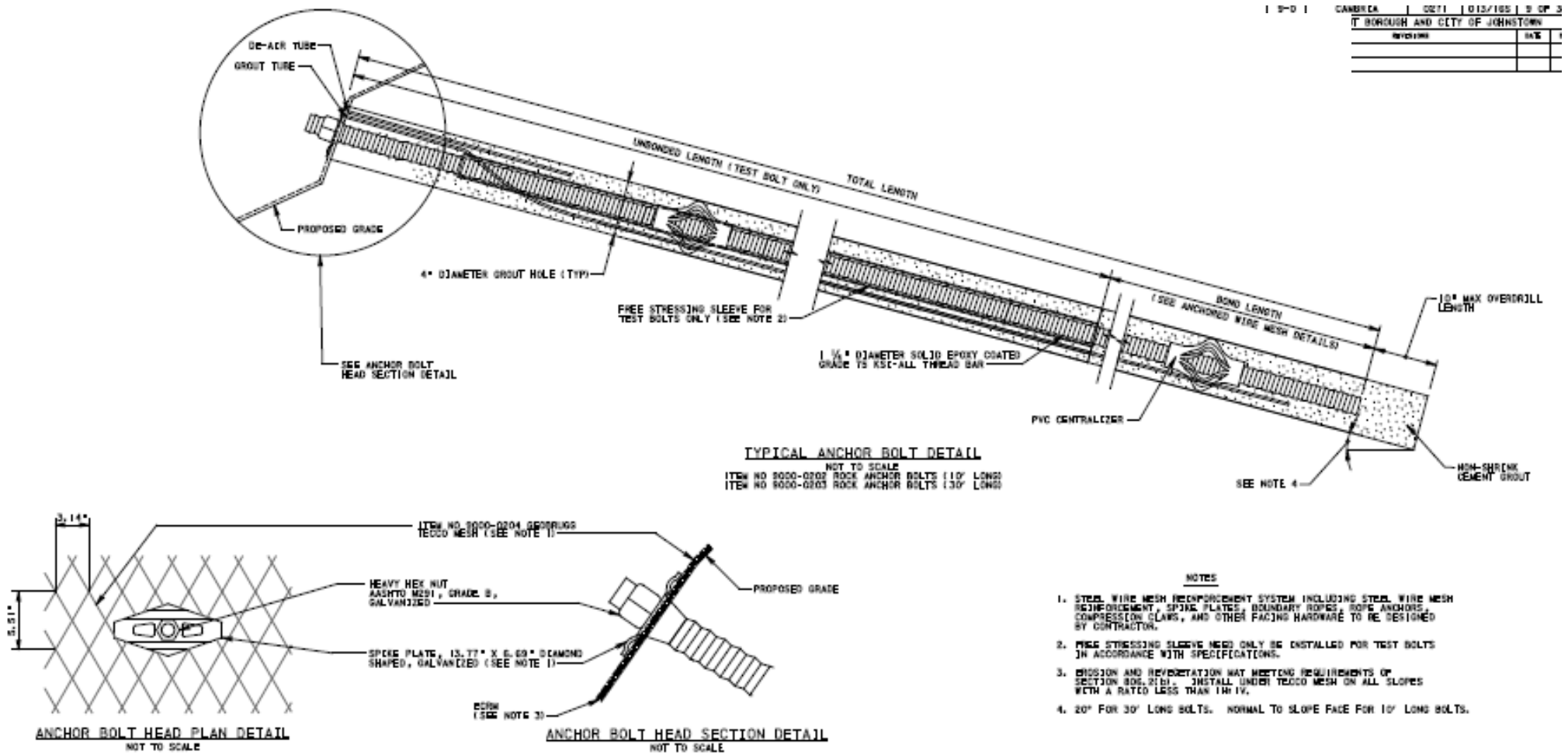
- **In-Situ Stabilization – Slope Mesh**

IN-SITU METHODS FOR STABILIZATION

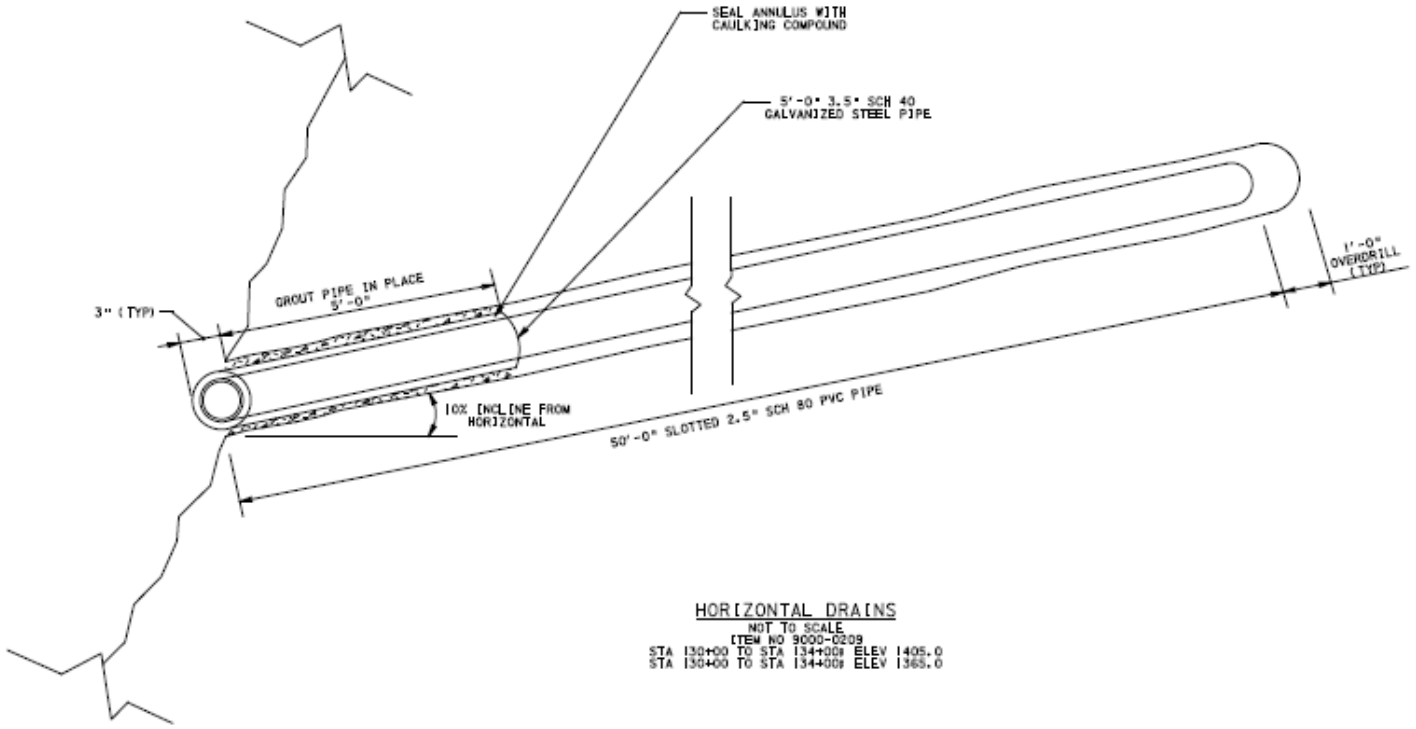
- **Typical Details for Anchored Mesh**



HORIZONTAL DRAINS

OTHER METHODS OF STABILIZATION

- **Horizontal Drains to Reduce Water Pressure**



HORIZONTAL DRAINS
NOT TO SCALE
ITEM NO 9000-0209
STA 130+00 TO STA 134+00; ELEV 1405.0
STA 130+00 TO STA 134+00; ELEV 1365.0

NOTES

1. INSTALL HORIZONTAL DRAINS IN THE SLOPE AT 20' HORIZONTAL CENTERS AT THE INDICATED STATIONS AND ELEVATIONS.

SHOTCRETE

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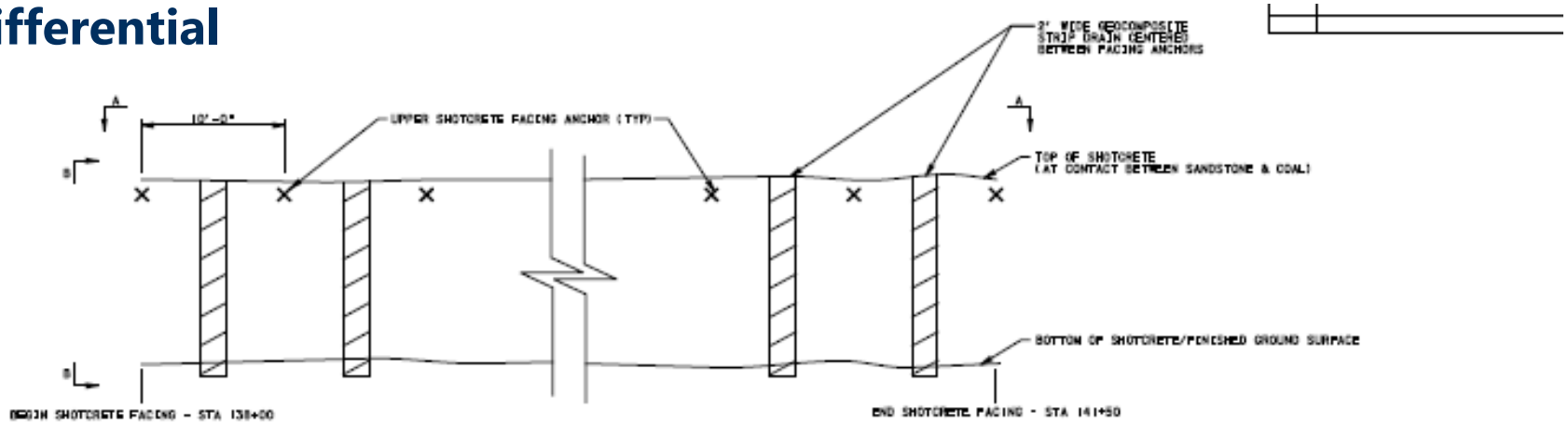
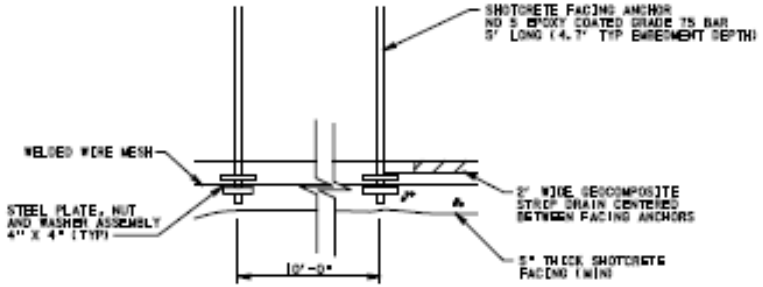
OTHER METHODS OF STABILIZATION

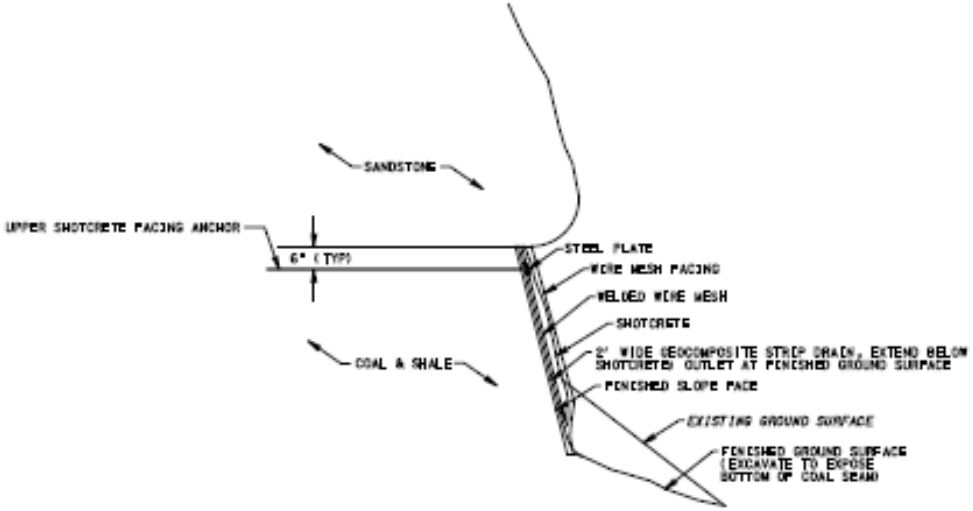
- **Shotcrete to Reduce Differential Weathering of Strata**



ELEVATION SHOTCRETE FACING DETAIL
NOT TO SCALE
ITEM NO 9000-0206 SHOTCRETE FACING
STA 138+00 TO STA 141+50



SHOTCRETE FACING DETAIL - SECTION A-A
NOT TO SCALE



SHOTCRETE FACING DETAIL - SECTION B-B
NOT TO SCALE

ROCK ANCHOR INSTALLATION

ROCK ANCHOR INSTALLATION

WIRE MESH INSTALLATION

WIRE MESH INSTALLAITON

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WIRE MESH INSTALLATION

SHOTCRETE

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FINISHED SLOPE…

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FINISHED SLOPE…

FINISHED SLOPE…

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SLOPE MESH PERFORMANCE

FINISHED SLOPE…

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FINISHED SLOPE…

CONCLUSIONS

- **Rock Slope Stabilization Projects are Dynamic – TREATMENT LIMITS & ITEM QUANTITIES WILL CHANGE**
  - Maintaining Consistent Communication Between Project Team (CM/Contractor/Designer) Through Construction Is Key in Resolving Contractor Questions in an Expedient Manner

- **Increase Quantity Contingencies for Items Such As Rock Anchors and Mesh that may Increase Based on Unpredictable or Variable Conditions Encountered During Construction**

- **Provide Clear Illustration (PLANS) and Intent (SPECIFICATIONS) for Non-Standard and Specialty Construction Items**
  - Important to have experienced designer on the team for evaluations and preparation of plans and specifications.
  - Specifications must include experience requirements for work tasks.

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Thank You!

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