One Corps, One Regiment, One Team

Geohazards in Transportation in the Appalachian Region

Rock Cut-Slope Design and Construction

Auxiliary Spillway and Relocation of SR 3051 & 302 Dewey Lake, KY

Michael Nield - Geologist
Four Main Topics of Discussion

1. Project Description
2. Site Geology
3. Rock Cut-Slope Design
4. Construction Challenges
Located in Eastern Kentucky

Dam completed in 1949

Rolled earth embankment dam with a tunnel type outlet works in the left abutment.
Hydrologic Deficiencies at Dewey Dam

Dam Safety Assurance Program identified deficiencies with the existing spillway during predicted floods, resulting in a high risk of dam failure with catastrophic consequences downstream.

Correction:

- Raise the Dam crest (future work)
- Raise crest of Brandy Keg Dike (this contract)
- Restrict flows to the Existing Spillway (this contract)
- Construct 129’ wide Auxiliary Spillway (this contract)
- Relocate State Routes 302 and 3051 (this contract)
Auxiliary Spillway – Dewey Dam, KY

Project Description

Project Features Impacted by Hydrologic Deficiencies

- Existing Spillway
- Auxiliary Spillway & St. Rt. 3051 & 302
- Relocation of St. Rt. 302
- Brandy Keg Dike
- Dam
Existing spillway was not designed to withstand predicted flows.

Constructed horizontal restrictors, which reduced the spillway width from 60 feet to 43 feet.

Rock excavation by mechanical (non-explosive) methods.
Brandy Keg Dike

Raised Brandy Keg Dike approximately 3 feet.
Relocation of State Route 302

State Route 302 was relocated as a result of the construction for the Auxiliary Spillway.

Design was performed by Fuller Mossbarger Scott & May Engineers with close cooperation by the Kentucky Department of Transportation and the Corps of Engineers.
• Constructed a 129-foot wide Auxiliary Spillway through bedrock.
• Relocate State Route 3051 and a portion of State Route 302.
• SUBJECT OF THIS PRESENTATION
Four Main Topics of Discussion

1. Project Description
2. Site Geology
3. Rock Cut-Slope Design
4. Construction Challenges
Existing and Field Data

Geologic Quadrangle Map

Joint Measurements from Outcrops

Coal Mine Adit

Auxiliary Spillway

Dewey Dam, KY

Site Geology

Auxiliary Spillway – Dewey Dam, KY

Coal Mine Adits

Original SR 3051
Exploratory Drilling

• Total of 17 Borings (15 2-inch diameter borings)
• 2 Angled Borings to Obtain Discontinuity Orientations
• 2 4-inch Diameter Core Borings, Pressure Tested at Sill Location
• 4 Borings for Highway Relocation

Boring Location Plan

Proposed Spillway Floor & Center Line

Small Coal Mine Adits
Lithology

WEATHERED SHALE AND CLAYSTONE: reddish brown to dark gray, soft, clayey, occasionally broken or weathered.

Low percentage of core recovery (30 -90).

Low RQD (30 – 75).
Lithology

SHALE with interbedded siltstone: gray to dark gray, soft to moderately hard.

High percentage of core recovery (90–100).

Medium range RQD (65 – 85)
Lithology

SANDSTONE: light gray, moderately hard, fine to medium grained, micaceous.

High percentage of core recovery (95 - 100).

Good RQD (95 - 100)
Lithology

COAL SEAMS: black, moderately hard, slightly to severely broken.
0.8’ to 2.7’ thick.
Core loss common.
Poor RQD
Geologic Cross Sections

Sill Location
Station 15+33

Proposed Spillway
Floor & Center Line

Downstream of Sill
Station 19+00

Upstream of Sill
Station 13+00

Flow
Geologic Cross Section

Station 15+33 – Spillway Crest
One Corps, One Regiment, One Team

Auxiliary Spillway – Dewey Dam, KY

Geologic Cross Section

Station 13+00 (Upstream of Sill)
Geologic Cross Section

Geologic Section - Station 19+00 (Downstream of Sill)
Four Main Topics of Discussion

1. Project Description
2. Site Geology
3. Rock Cut-Slope Design
4. Construction Challenges
Rock Cut Slope Design Topics

1. Bench and Slope Design
2. Wedge/Block Analysis
3. Rock Fall Analysis
4. Spillway Sill Design
Relatively flat-lying sedimentary rock, with interbedded lithologies that have varying resistance to weathering and high angled joints.

The cut slope design needs to minimize the effects of differential weathering to reduce wedge/block failures and rock fall hazards.
Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design

Bench and Slope Design

Geologic Section - Station 15+33 – Spillway Crest

18' Bench at Elev. 800 on Coal Seam
18' Bench on Coal Seam
18' Bench at Base of Sandstone
Spillway Sill Foundation Elev. 688
SR 3051 & Spillway Crest Elev. 866
SOIL
SHALE & SILTSTONE
SANDSTONE
COAL SEAM
WEATHERED SH & CLS

South/Left
North/Right

US Army Corps of Engineers
Huntington District
Bench and Slope Design

Geologic Section - Station 13+00 (Upstream of Sill)
Bench and Slope Design

Geologic Section - Station 19+00 (Downstream of Sill)

18’ Bench at Base of Sandstone
18’ Bench on Coal Seam
SR 3051
730
701
701
1
2
4
1

SOIL
SANDSTONE
SHALE & SILTSTONE
COAL SEAM

South/Left
North/Right
Auxiliary Spillway – Dewey Dam, KY

Rock Cut Slope Design

Bench and Slope Design

- Limits of Excavation
- 2.4% Slope on Coal Seams
- 2.4% Slope at Base of Sandstone
- 3% Slope on Coal Seam

Elevation View – South/Left Spillway Wall

Elevation View – North/Right Spillway Wall
Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design

Bench and Slope Design

Plan View
Wedge/Block Analysis - Four Main Failure Modes

Circular Failure – soil-like failure, unlikely to occur at this project, will not be discussed at this time.

Planar Failure – common with joints that are parallel to cut-slope some failures may be blast induced

Wedge Failure – could be detrimental, large volume of rock.

Toppling Failure – similar results as planar failure, unlikely to occur at this project, will not be discussed at this time.

Wedge/Block Analysis - Four Main Failure Modes

Planar Failure – common with joints that are parallel to cut-slope some failures may be blast induced.

Wedge Failure – could be detrimental, large volume of rock.
Wedge/Block Analysis – Joint Analysis

Joint measurements obtained from outcrops and angled exploratory borings.

Typical joint surface has a planar shape with smooth texture, occasionally iron stained or slightly open.
Wedge/Block Analysis – Joint Analysis

Stereographic Projection of Joint Measurements – Pole Plot
Wedge/Block Analysis – Joint Analysis

Stereographic Projection of Joint Measurements – Contoured Plot of Poles
Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design

Wedge/Block Analysis – Joint Analysis

Stereographic Projection of Joint Measurements – Planes Representing Joint Sets
Wedge/Block Analysis – Wedge Failure Analysis

Sandstone
Phi Angle = 30

Wedge
Sliding Zone

1/4:1 Slope – North Wall

Joint Intersection

Stereographic Projection of Planes used for Wedge Analysis

Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design
Wedge Analysis 1/2:1 Slope
South Wall
Shale

Wedge Analysis 1/4:1 Slope
South Wall
Sandstone

Wedge Analysis 1/2:1 Slope
North Wall
Shale

Wedge Analysis 1/4:1 Slope
North Wall
Sandstone
Wedge/Block Analysis – Planar Failure

Planar Sliding Zone

Sandstone
Phi Angle = 30

Daylight Envelope

1/4:1 Slope – North Wall

Stereographic Projection of Poles used for Planar Analysis
Planar Analysis
1/2:1 Slope
South Wall
Shale

Planar Analysis
1/4:1 Slope
South Wall
Sandstone

Planar Analysis
1/2:1 Slope
North Wall
Shale

Planar Analysis
1/4:1 Slope
North Wall
Sandstone
Rock Fall Analysis – Input Parameters

Values are subjective, derived from published tables.

Computer programs included Colorado Rockfall Simulation and RocFall.

<table>
<thead>
<tr>
<th>SURFACE AND MATERIALS</th>
<th>Coefficient of Normal Restitution</th>
<th>Coefficient of Tangential Restitution</th>
<th>Friction Angle (Phi angle)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>std. dev.</td>
<td>mean</td>
</tr>
<tr>
<td>ALL BENCHES</td>
<td>0.35</td>
<td>0.02</td>
<td>0.85</td>
</tr>
<tr>
<td>SLOPES IN SANDSTONE</td>
<td>0.37</td>
<td>0.05</td>
<td>0.87</td>
</tr>
<tr>
<td>SLOPES IN SHALE/SILTSTONE</td>
<td>0.37</td>
<td>0.05</td>
<td>0.87</td>
</tr>
</tbody>
</table>
One Corps, One Regiment, One Team

Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design

Rock Fall Analysis

Boulder Origin at Bench Elev. 800

Boulder Origin at Top of Cut Slope

Slope was Redesign
Rock Fall Analysis

Boulder Origin at Bench Elev. 725

Boulder Origin at Bench Elev. 766
Spillway Sill Design

Plan View

SR 3051

Spillway Sill

Auxiliary Spillway – Dewey Dam, KY
Rock Cut Slope Design
# Spillway Sill – Bedrock Parameters

<table>
<thead>
<tr>
<th>LITHOLOGIC MEMBER</th>
<th>Sliding Friction Strength</th>
<th>Cross Bed Shear Strength</th>
<th>Anchor Bond Strength</th>
<th>Unit Weight</th>
<th>Allowable Bearing Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>phi (degree)</td>
<td>psi (psi)</td>
<td>phi (degree)</td>
<td>psi (psi)</td>
<td>psi</td>
</tr>
<tr>
<td>LOWER SHALE</td>
<td>25</td>
<td>0</td>
<td>30</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>LOWER SANDSTONE</td>
<td>25</td>
<td>15</td>
<td>50</td>
<td>175</td>
<td>95</td>
</tr>
</tbody>
</table>

- **Concrete Spillway Sill**: Crest EL. 688
- **Flow**: 37’ Long, 1¼” Diameter Threadbar Anchor, Tensioned to 112 kips
- **Lower Shale Member**: EL. 678
- **Lower Sandstone Member**: EL. 676
- **Cross Section – Spillway Sill – Normal Condition**: 4” Diameter Hole
Four Main Topics of Discussion

1. Project Description
2. Site Geology
3. Rock Cut-Slope Design
4. Construction Challenges
Construction Contract

• PRIME CONTRACTOR:
  Tab Construction Co. of Canton, Ohio

• DRILLING AND BLASTING SUBCONTRACTOR:
  Hilltop Energy Inc. of Mineral City, Ohio

• CONSTRUCTION DURATION:
  Approximately Two Years from August 2000 to September 2002.

• FINAL EXCAVATION QUANTITIES:
  Rock Excavation: 677,000 cubic yards
  Structural (Rock/Concrete) Excavation: 1,000 cubic yards
  Common (Soil) Excavation: 306,000 cubic yards

• FINAL CONSTRUCTION CONTRACT COST:
  $12.8 Million Dollars
Modifying Rock-Cut Slopes

Removal of Slip-Prone Soil  Initial Rock Cut
Blasting Vibration Control

Blasting for Auxiliary Spillway SR 3051 & 302

Perched Boulders

Homes

Location of Homes

Blasting Within 790 Feet of Boulders and 1,000 Feet From Homes

Restricted Peak Particle Velocity to 1.5 in/sec at 200 Feet From Blast
One Corps, One Regiment, One Team

Auxiliary Spillway – Dewey Dam, KY

Construction Challenges

Blasting Vibration Control

Large Boulders Located on Ridge Line and Perched Above Homes
Drilling And Blasting

Pre-Split Drilling
18” to 30” Center to Center

Loading Production Shot

Auxiliary Spillway – Dewey Dam, KY
Construction Challenges
One Corps, One Regiment, One Team

Auxiliary Spillway – Dewey Dam, KY
Construction Challenges

Drilling And Blasting

Production Blast

Production Blast
Excavation and Spoil Sites

Rock Excavation

Spoil Sites
Maintaining Traffic and Utilities During Excavation

View of South/Left Spillway Wall

Spillway Sill
Spillway Sill

Over Excavation of Spillway Sidewalls

Modifications to Correct for Future Erosion of Shale

Eliminated Upper Rock Anchor

Low Strength Concrete

Recessed Concrete

SR 3051
Final Product

South/Left Spillway Wall as Viewed from Upstream

North/Right Spillway Wall as Viewed from Upstream
Auxiliary Spillway – Dewey Dam, KY
Construction Challenges

Upstream of Spillway
Route 302 Transition

Relocated SR 302

Auxiliary Spillway Viewed from Downstream

Relocated SR 3051
Questions & Discussion

Contact Information:
Michael Nield
Phone: (304) 529-5056
E-mail: michael.c.nield@lrh01.usace.army.mil