TSAILE DAM MODIFICATION PROJECT
Unearthing a Safer Dam

Bureau of Indian Affairs
Navajo Regional Safety of Dams Program

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Tsaile Dam, Navajo Reservation, AZ

- Constructed 1964
- Height = 52 feet (maximum section)
- Crest Length = 1,950 feet
- Crest El. 7037.3 feet
- Reservoir Capacity = 5,500 acre-feet
- 24” Dia. CMP Outlet
- Conduit Capacity = 40 cfs
- Emergency Spillway Passes the PMF
Existing Plan & Topo
Canyon de Chelly – Navajo Culture
Anasazi Ruins in Canyon de Chelly
Downstream - Consequences

- Town of Chinle
- Residents in the Canyon
- Tourists in the Canyon
- PAR= 450
Potential Failure Modes

- **Static**
  - Seepage through embankment
  - Seepage into/out of outlet conduit
  - Seepage along outside of conduit
  - Collapse of outlet conduit (CMP)

- **Seismic**
  - Liquefaction of alluvium in foundation
  - Transverse cracking of embankment

- **Hydrologic**
  - Erosion of the embankment along the left side of the spillway
Rocks in the outlet conduit

Sediment in the toe drain
Rehab Design Goals

- Resolve the Deficiencies to Address PFM
  - Fix the outlet works by remove and replace
  - Fix the foundation alluvium by remove dam and replace

- Quantity of embankment is not large; limits the construction cost

- Control costs by planning construction in one season
Downstream Embankment Shift

- Downstream Limits – Wetlands & Cultural Features
- Remnant of Dam to Serve as Cofferdam
- Full Excavation Enables Foundation Treatment
- Exposing Middle Rock Bench Provides Location for Outlet Conduit in Rock Trench
KEY ELEMENTS

- Construct ‘New’ Dam from Bottom Up
  - Existing Dam Removal
  - Foundation Preparation
  - Filter-compatible Internal Drainage System
  - Zoned Embankment with Central Core
  - Concrete Outlet Tower
  - Concrete-Encased Outlet Conduit
  - Durable Riprap
  - Improved and Safer Alignment for BIA Road 8077
EXISTING DAM REMOVAL

- Excavate the Existing Dam
- Re-use Exc. Material to Construct the New Dam
EXISTING DAM REMOVAL

- Segregate and Stockpile Excavated Material
- Needed to Re-Use All of it – Available Borrow is Lesser Quality!
EXISTING DAM REMOVAL

- Internal Erosion Hole In-Progress
- In-line with CMP Outlet Conduit and beneath d/s stability berm
- 8 to 10 feet diameter
- 8 feet deep
- Small amount of water in bottom
EXISTING DAM REMOVAL

Exposed in the Foundation:

- Embankment Packed Beneath Rock Overhangs
EXISTING DAM REMOVAL

- Exposed in the Foundation:
  - Rock Overhangs – More Extensive than Anticipated
  - Alluvial Deposits – Present Beneath Downstream Shell
EXISTING DAM REMOVAL

- Remove Rock Overhangs – Drill and Excavate to 1H:4V Slope
- Used Rock Excavation Bid Item
EXISTING DAM REMOVAL

- Rock Overhangs Removed
- Lower, Middle, and Upper Foundation Benches
FOUNDATION PREPARATION

- Limited Grout *Exploration* Program (Foundation Seepage is Not a PFM)
- Single Line, Targeted Steeply Dipping Joints
- Only two holes had substantial grout take!
FOUNDATION PREPARATION

- Paleo-Stream Channel in Joints
- Treated 2 Joints with Dental Concrete
FOUNDATION PREPARATION

- Clean Foundation Rock
  - Shovels, Brooms, Pressurized Air Wands
FOUNDATION PREPARATION

- Treat a Former Stream Bed Channel with Dental Concrete
- Address Shallow Seepage and ‘Steps’ in Rock
FOUNDATION PREPARATION

- Key Trench
KEY TRENCH

Zone 1 Core Placed in Key Trench
DRAINAGE SYSTEM

- Zone 1 Core, Chimney Drain and Blanket Drain
- Blanket 1 ft Sand, 2 ft Gravel, 1 ft Sand – Imported
DRAINAGE SYSTEM

Toe Drain – Lower Foundation
DRAINAGE SYSTEM

- Middle Foundation Blanket Drain
ZONE EMBANKMENT

- Zone 1 – Clay with Silt
- Zone 2 – Sandy Silt with Clay
ZONED EMBANKMENT

- Contractor Informs Us Zone 2 Will Run Out!
- Additional Material Needed to Complete Upper Portion of Downstream Shell
- Proposal - Use the Zone 2 Contaminated with Sandstone Cobbles – Zone “2B”
- Pre-spooling Operation using Dozer to Break Down Oversize and Raking
ZONE 2B EMBANKMENT

○ Test Fill to Demonstrate Means and Methods
○ Prescribed Number of Compactor Passes
ZONE EMBANKMENT

- Zone 2B, Chimney, Zone 1, Zone 2
OUTLET CONDUIT

- DIP Encased in Concrete in Rock Trench
Intake Tower

- Rock 14 feet Low at Tower Location – Critical Path Task
- Excavated and Placed 14 ft Concrete Pedestal Foundation
RIP RAP

- On-Site Borrow Sandstone Not Durable
- Design Change Notice to Import Basalt
- $D_{50} = 14''$
- $T = 2.8'$
FINDINGS DURING CONSTRUCTION

- Outlet Conduit CMP in Failed Condition – Severe Internal Erosion
- Overhanging Rock - Additional Rock Excavation
- Foundation Grouting – No Major Issues
- Intake Tower Foundation Lower than Anticipated – Build Concrete Pedestal
- Able to Use all Stockpiled Material – No Need to Open Borrow
- On-Site Sandstone Riprap was Poor Quality – Import Basalt
PROJECT SUCCESSES

- Eliminated Static and Seismic PFM's
- Close CM coordination with Contractor and BIA
- Ability to adjust the work to the conditions
- Maintained construction schedule
- After many years of planning – A Completed Project!
- New dam will serve the Navajo Nation and community for many decades
- Construction Cost $8.5M