WANAPUM DAM Spillway Incident

Update on Monolith 4 Repairs

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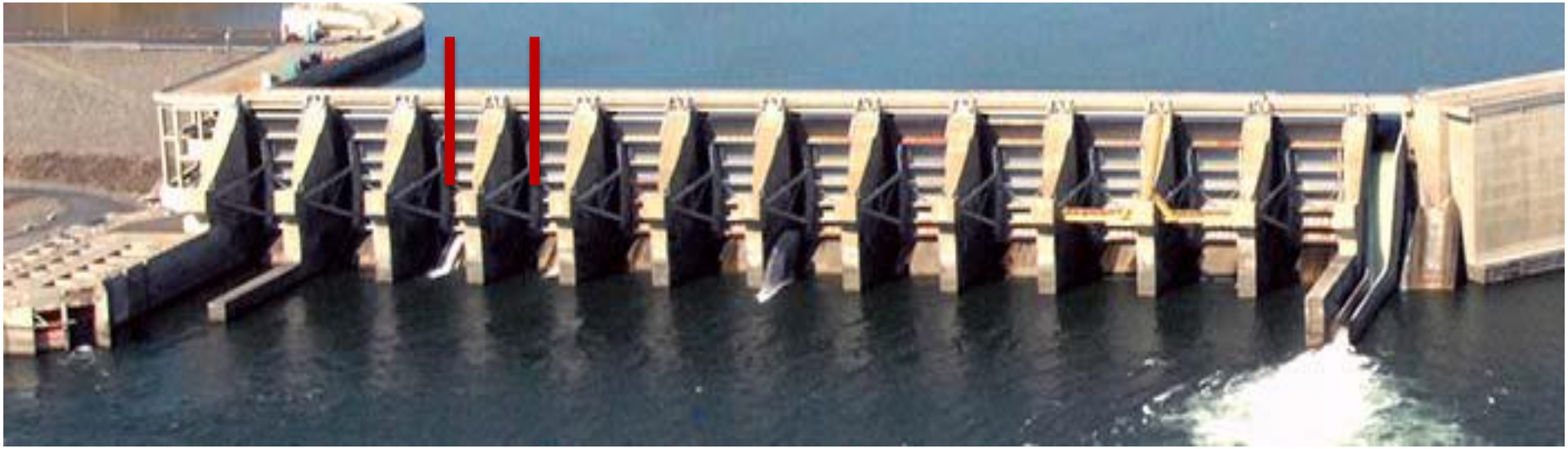
May 19, 2015

Presentation Overview

- Short Background
- Root Cause Results
- Design Challenges
- The Repairs
- Lessons Learned

Wanapum Dam Spillway

Monolith 4



- 13 monoliths
  - Each monolith approximately 65 feet
- 12 spillway gates
- Approximately 820 feet in total length
- Maximum flow capacity: 1.4 million cfs (normal operations)

The Discovery - February 24, 2014

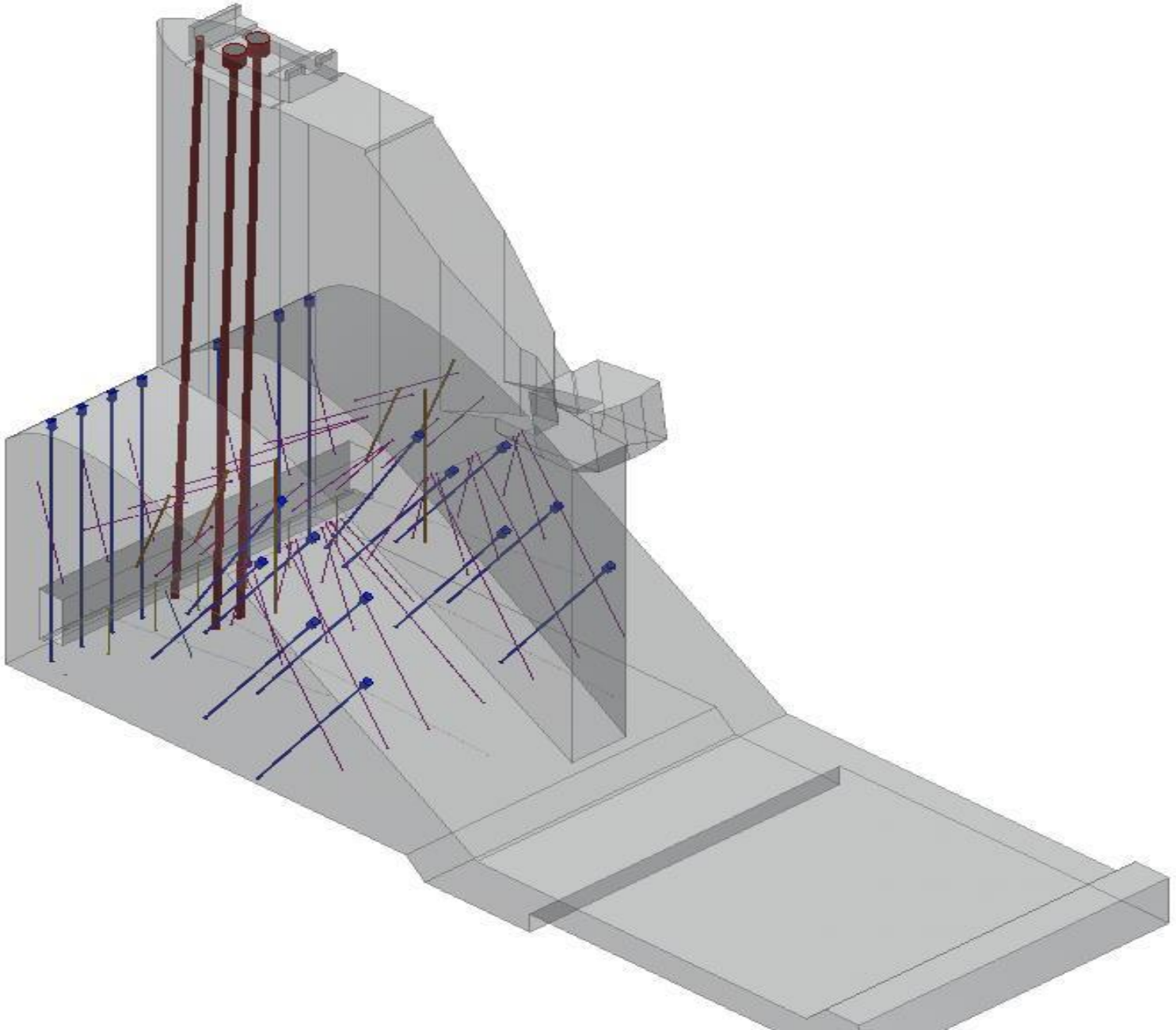
Determining the Root Cause – Data Collection

Determining the Root Cause – Data Collection

Determining the Root Cause – The Results

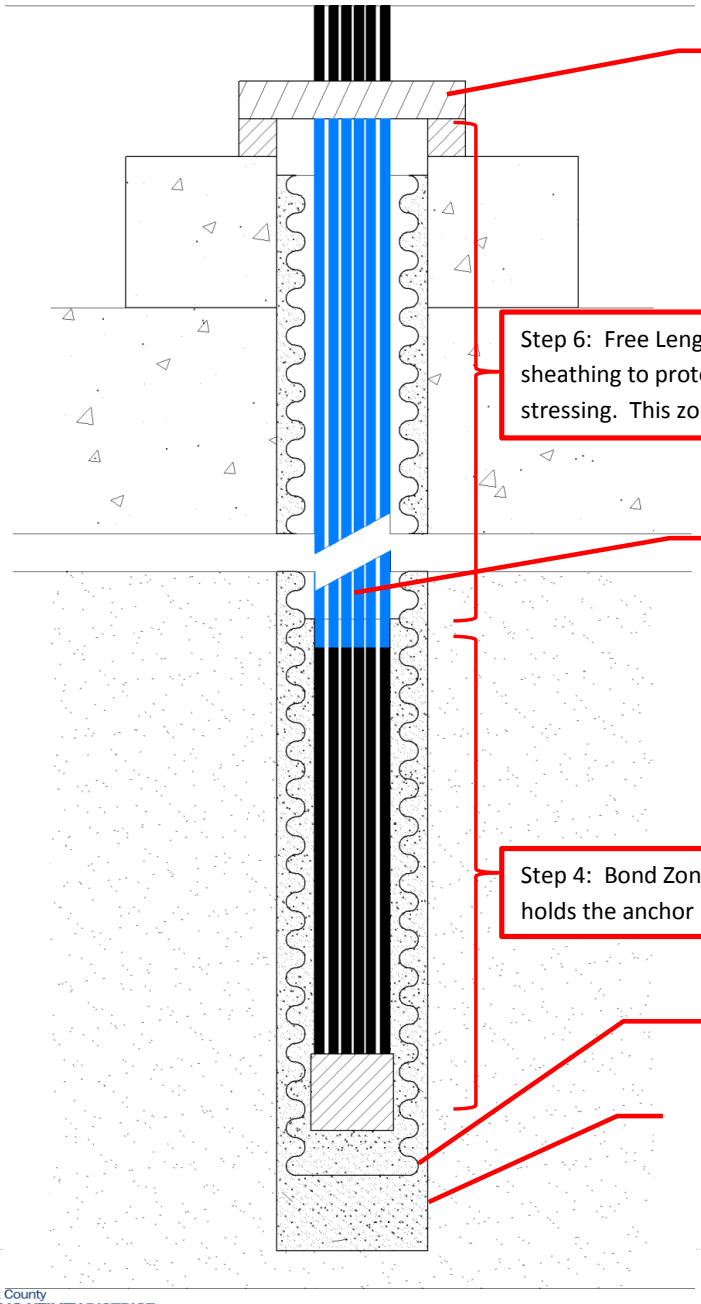
- Mathematical error in the original design
  - Tension verses compression (at upstream face)
- Seasonal thermal exchange impacts
- The termination of rebar in the concrete (at the fracture elevation)
- Hot temperatures during construction of the location of the fracture
- Bulkhead in place in the winter of 2006-2007

The Repairs - Conceptual diagram



The Repairs

- Approximately 400 drilled holes in the Wanapum spillway to complete the project
  - 35 pier tendons
  - Remaining holes:
    - Post tensioned bar anchors
    - Lift joint drains
    - Lift joint drain efficiency holes
    - Grout holes
    - Piezometers
    - Crack exploratory holes
    - Geotechnical exploratory holes
    - Temporary post tensioned bar anchors



Step 5: Anchor Head and Wedge Plate – Tendon is stressed/tensioned and strands are clamped/wedge to hold tension (see photos)

Step 6: Free Length – Wire strands are encapsulated with plastic sheathing to protect from corrosion and allow for stretching during stressing. This zone is grouted after tendon is stressed.

Step 3: 61-Strand Tendon Anchor – Install 250 foot long (approximate) tendon into corrugated sheath (see photo)

Step 4: Bond Zone – Bare wires grouted into sheath prior to stressing. This holds the anchor into the rock formation.

Step 2: 10” Diameter Corrugated Sheath – Grouted into hole

Step 1: 16” Diameter Bore Hole – Drilled through spillway structure and into bedrock (see photo)

Post Tensioned Bar Anchor Installation Process

- Drill pilot hole
- Drill 8.5” diameter hole
- Grout water tight
- Re-drill as needed
- Drill out 20” recess
- Mill the bearing surface
- Install the anchor and grout
- Tension

Construction Photos

Tendon Hole Drilling

Sheath Installation

Tendon Installation – Off Coiler

Tendon Installation - Crane

Post Tensioned Anchor Bars

Post Tensioned Anchor Bars

Construction Status

- Construction completed
  - All 35 tendons installed
  - 40 post tensioned bar anchors installed in monolith 4
  - 29 post tensioned bar anchors installed in the other monoliths
  - The crack has been grouted
  - All Structural work is complete
  - All deck restoration work to be completed by June 30th

Construction Challenges/Issues

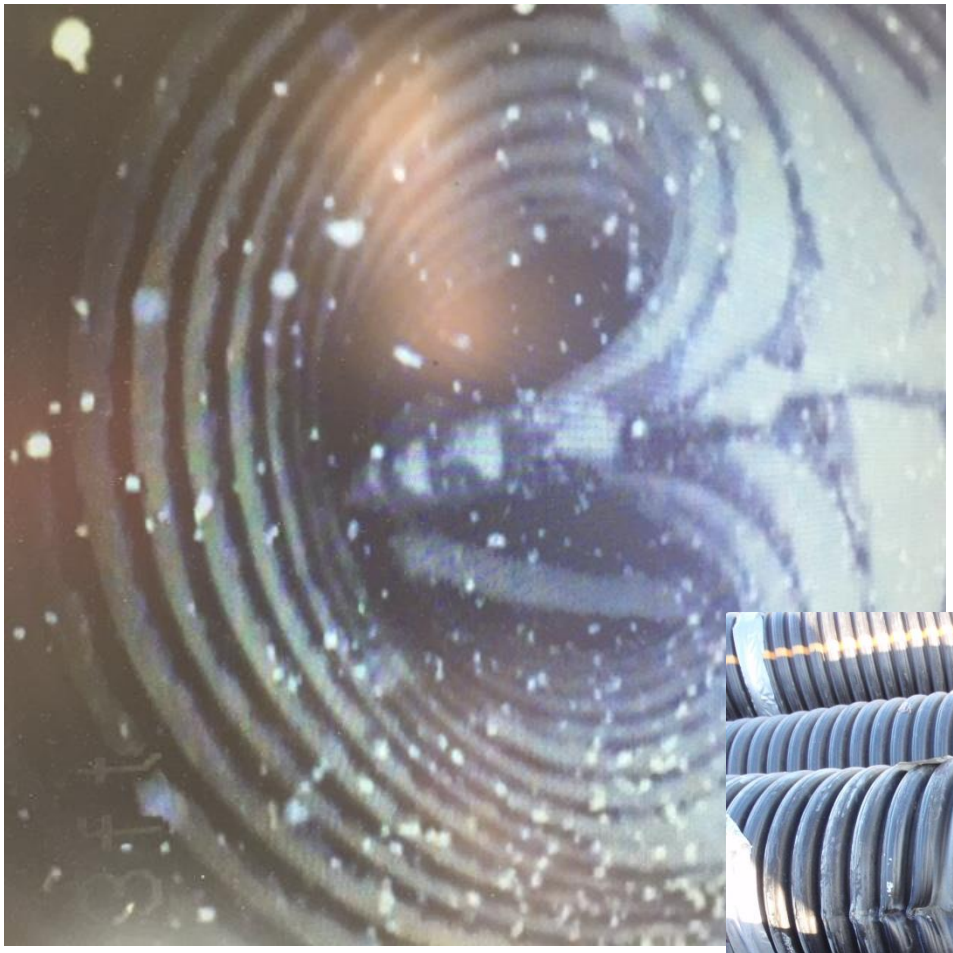
- Limited Access

Construction Challenges/Issues

- Stuck drill bit

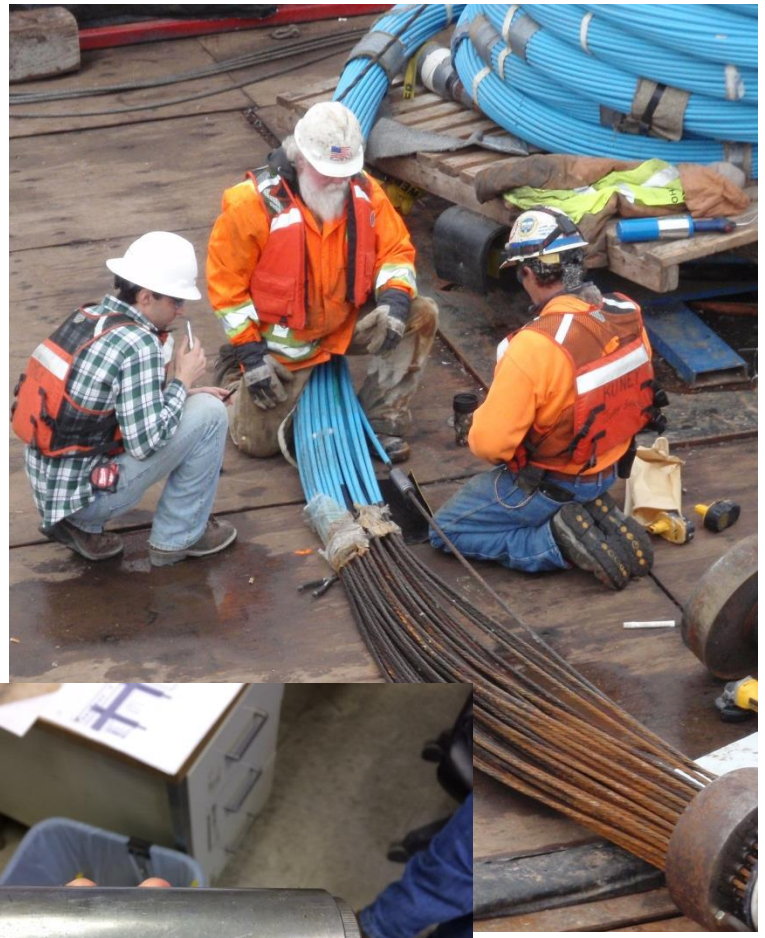
Construction Challenges/Issues

- Collapsed Sheath



Construction Challenges/Issues

- Strand Repairs



Surveillance and Monitoring

- Lift Joint Drains
- Spillway Grout Gallery Crack Monitoring
- Pier Alignment Surveys

Lessons Learned

- Established District-Wide Priorities
  - Common Decision Criteria
- Established Hydro Project Team goals
  - Ensured organization, definition of roles and focus
- Pier Reinforcement Termination Location Should be Reviewed Periodically in Static Analysis
- Communication and Coordination with a Design and Review Team in different locations is still challenging. Electronic document review helped significantly (SharePoint).

Thank you.

For information go to: grantpud.org