Construction Risks

Best Practices in Dam and Levee Risk Analysis
Part H – Other Risks
Chapter H-3
Last modified June 2018, presented July 2019
Outline

- Objectives and Key Concepts
- Background and History
- General Conditions and Critical Considerations
- Spillway modifications
- Cofferdams
Objectives

- Understand conditions that could lead to increased risk during construction
- Understand how to construct an event tree to represent those construction risks
Key Concepts

• Construction “risk” can have different meanings, such as cost risk or schedule risk to construction. For Best Practices, construction risk refers to the failure probability, annualized life loss, individual risk or societal risk that exists during the construction of risk reduction measures.

• Can be used to evaluate non-construction activities.

• Perhaps most important concept is for decision makers to understand construction risks and cost trade-offs.

• Do no harm.
Outline

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• Background and History
• General Conditions and Critical Considerations
• Spillway modifications
• Cofferdams
Example
More Examples
Outline

• Objectives and Key Concepts
• Background and History
• General Conditions and Critical Considerations
• Spillway modifications
• Cofferdams
General Conditions – Excavation

- Open excavations near the downstream or landside toe of the structure or within the structure can:
  - Reduce stability for normal conditions
  - Change the internal erosion potential
  - Reduce seismic stability potential
- The temporary risks can be much higher than the existing risks
General Conditions – Gates, Structures, and Cofferdams

- Modifications to appurtenant structures that change the risks associated with a dam include:
  - Spillway and spillway wall modifications
  - Gate modifications
  - Outlet works modifications
- In some cases, we construct cofferdams to reduce risk during construction
  - Cofferdam stability is important
  - Cofferdam height is important
Critical Considerations

- Duration of Critical Construction Activities
- Magnitude of Impacts to the Existing Structure
- Overall Duration and Timing
- Evaluating Risks to the Structure

- Dewatering Reliability
- Construction Changes on Stability Factors
- Contingency Plans
- Warning Time
- Reservoir Restriction
Downstream Foundation Excavation Example

[Diagram showing layers of foundation types including Upstream Berm, Upstream Shell, Alluvial Foundation, Downstream Shell, Alluvial Foundation, and Bedrock Foundation, with an image of a construction site featuring workers and equipment.]
Downstream Foundation Excavation – Alternatives Considered

Alternatives
• Open Excavation (4 variants)
• Double Wall Excavation (3 variants)
• Cellular Excavation (2 variants)
• Lattice Cells (2 variants)
• Drilled Shafts (2 variants)
• Drilled Hexagonal Cells (2 variants)
• No Action

Considerations
• Field Construction Cost
• Ability to Meet Long Term Risk Reduction Objectives
• Risk During Construction
• Cost Uncertainty
• Schedule Delay Potential
• Technical Concerns or Lack of Concern
Downstream Foundation Excavation – Event Tree

- Loading (reservoir rises)
  - Dewatering System Works
    - Slope Becomes Unstable
    - Detection is Unsuccessful
    - Embankment Breaches
  - Consequences

- Loading (reservoir rises)
  - Dewatering System Fails
    - Slope Becomes Unstable
    - Detection is Unsuccessful
    - Embankment Breaches
  - Consequences
## Downstream Foundation Excavation – Summary of Risks

<table>
<thead>
<tr>
<th></th>
<th>Duration</th>
<th>Field Cost ($ Million)</th>
<th>Additional Risk During Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Open Excavation</td>
<td>8 Months</td>
<td>$36-43</td>
<td>5.0 – 16.0</td>
</tr>
<tr>
<td>2 – Double Wall</td>
<td>12-17 Months</td>
<td>$65-70</td>
<td>3.0 – 5.0</td>
</tr>
<tr>
<td>3 – Cellular</td>
<td>23-42 Months</td>
<td>$70</td>
<td>1.0 – 4.0</td>
</tr>
<tr>
<td>4 – Lattice Structure</td>
<td>N/A</td>
<td>$58-61</td>
<td>1.0</td>
</tr>
<tr>
<td>5 – Drilled Shafts</td>
<td>N/A</td>
<td>$104</td>
<td>1.0</td>
</tr>
<tr>
<td>6 – Hexagonal Cells</td>
<td>24-30 Months</td>
<td>$66-77</td>
<td>1.0 - 4.0</td>
</tr>
<tr>
<td>7 – No Construction</td>
<td>0 Months*</td>
<td>$0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The duration of increased risk (compared to the baseline) is a key consideration.
# Toe Foundation Excavation – Other Considerations

<table>
<thead>
<tr>
<th>Technical Concerns</th>
<th>Long Term Risk Reduction</th>
<th>Risk of Construction Delays</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Open Excavation</td>
<td>Significant</td>
<td>Yes</td>
</tr>
<tr>
<td>2 – Double Wall</td>
<td>Some to Significant</td>
<td>Yes</td>
</tr>
<tr>
<td>3 – Cellular</td>
<td>Some</td>
<td>Yes</td>
</tr>
<tr>
<td>4 – Lattice Structure</td>
<td>Very Significant</td>
<td>No</td>
</tr>
<tr>
<td>5 – Drilled Shafts</td>
<td>Significant</td>
<td>No</td>
</tr>
<tr>
<td>6 – Hexagonal Cells</td>
<td>Some</td>
<td>Yes</td>
</tr>
<tr>
<td>7 – No Construction</td>
<td>None</td>
<td>No</td>
</tr>
</tbody>
</table>

The duration of increased risk (compared to the baseline) is a key consideration.
During Construction

Picture during construction with reservoir up
Outline

- Objectives and Key Concepts
- Background and History
- General Conditions and Critical Considerations
- Spillway modifications
- Cofferdams
Spillway Modification Construction
Spillway Mod. Construction – Alternatives Considered

Key Considerations
• Level of protection for the cofferdam
• Operational changes required during construction
• Construction duration

Alternatives Considered
• Replace Spillway Chute
• Replace Spillway Chute (Behind Cofferdam)
• Permanent Reservoir Restriction
• No Action
Spillway Modification – Example Event Tree

- Starting Reservoir Pool (reservoir restrictions are common)
  - Flood Loading
  - Cofferdam Overtops
  - Detection and Intervention Unsuccessful
  - Cofferdam Breaches
  - Consequences

There are many potential scenarios that would need custom event trees.
Spillway Modification – Summary of Risks

- Reducing spillway capacity or lowering dam crest may increase risk of dam overtopping during large floods
- Construction risks can be minimized by:
  - Schedule or stage work to reduce risk (minimize exposure during flood season)
  - Temporarily restrict reservoir during critical phases of work
- Costs of alternative construction schedules need to be identified and portrayed
Spillway Construction – Summary of Risks

• Seasonal floods and starting reservoir water surface elevations may need to be considered if construction activities are limited to certain months or periods

• May need to consider more remote floods if dam overtopping is an issue

• For construction only risks – need to portray potential for more frequent floods
Outline

• Objectives and Key Concepts
• Background and History
• General Conditions and Critical Considerations
• Risk Duration
• Cofferdams
Cofferdams

Historical Practice
• Cofferdams were constructed to protect the construction site from flooding for the duration of construction
• Typical historical practice has been ?? year level of protection for risks that impact construction (not dam failure.)
• Contractors are typically interested in reducing cofferdam costs – they are usually lump sum items in bid schedules

Key Concepts
• Cofferdam height should be commensurate with the risk and consequences
• Robustness should be explicitly considered
• For dams with high consequences, cofferdams will likely require the same level of design and attention as the dam itself
Cofferdams
Cofferdams – Alternatives Considered

Some Key Considerations
• Level of Protection
• Flood Frequency, Duration, and Warning Time
• Construction Site Safety
• Redundancy
• Contingency Plans
• Reservoir Restriction

Potential Alternatives
• Partial Height Cofferdam
• Full Height Cofferdam
• Earthen Cofferdam with Cutoff Wall (concrete, steel)
• Cellular cofferdam
• Concrete Cofferdam
Cofferdam Failure – Event Tree

These are typical failure modes for cofferdams:

- Overtopping
- Instability
  - Scour can lead to instability
- Internal erosion through embankment or foundation
- Failure at the contact with existing structures or slopes

Typical event trees have been provided earlier in presentation or in other presentations. Customization will be needed.
Cofferdams – Summary of Risks

• Event tree will need to address if the cofferdam failure could lead to more severe event such as loss of additional pool due to down cutting during cofferdam breach discharge.

• Typically the consequences of cofferdam failure vary throughout the construction duration as the protected structure gets built.
Take Away

• There are many ways to deal with the increase in risk during construction, some of which involve additional funding to offset risk.
• Construction timing and schedule adjustments are evaluated for a given alternative.
• The duration of increased risk (compared to the baseline) is a key consideration
• Matrices are often used to evaluate the key information.
• A risk informed decision on construction risk can be made if all of the key information is considered and made available to the decision makers in a timely fashion.
• Do no harm.