Construction Risks at Stampede Dam
Third Workshop on Case Histories in Dam Safety Risk-Informed Decision Making
3 May 2018
“For the strength of the Pack is the Wolf, and strength of Wolf is the Pack”  – Rudyard Kipling

The Law of the Jungle – The Jungle Book
ACKNOWLEDGEMENTS

• Steve Dominic
• Frank Dworak
• Kathleen Holman
• Kyle Hughes
• Jeanne Major
• Elizabeth Ouellette
• Miguel Rocha
• Scott Schoenfeld
• Chris Slaven
PRESENTATION OVERVIEW

1. Purpose, Context and Scope
2. Baseline Risk Assessment
3. Risk Reduction Assessment
4. Limitations, Decisions, Risk Communication and Lessons Learned
1. Purpose, Context and Scope
1.1 PURPOSE OF THE RISK ASSESSMENT
1.1 PURPOSE OF THE RISK ASSESSMENT

**Snotel (Snowpack Telemetry)**

<table>
<thead>
<tr>
<th>Elevation 6436 feet</th>
<th>Independence Creek</th>
<th>Water Year</th>
<th>Max March SWE</th>
<th>Elevation 6980 feet</th>
<th>Independence Camp</th>
<th>Water Year</th>
<th>Max March SWE</th>
<th>Elevation 8338 feet</th>
<th>Independence Lake</th>
<th>Water Year</th>
<th>Max March SWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>30</td>
<td>1983</td>
<td>45.3</td>
<td>2017</td>
<td>74.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>25.6</td>
<td>1995</td>
<td>36.9</td>
<td>1995</td>
<td>70.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1983</strong></td>
<td><strong>25.5</strong></td>
<td><strong>2011</strong></td>
<td><strong>35</strong></td>
<td><strong>2011</strong></td>
<td><strong>68</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>24.4</td>
<td>1993</td>
<td>34.8</td>
<td><strong>1983</strong></td>
<td><strong>66.3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>23.5</td>
<td>1986</td>
<td>30</td>
<td>1982</td>
<td>60.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>22.4</td>
<td>1998</td>
<td>29.3</td>
<td>1999</td>
<td>59.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>21.9</td>
<td>1999</td>
<td>27.2</td>
<td>1993</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>21.3</td>
<td>1982</td>
<td>25.7</td>
<td>1986</td>
<td>54.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2017</strong></td>
<td><strong>20.7</strong></td>
<td><strong>1980</strong></td>
<td><strong>25.1</strong></td>
<td><strong>1997</strong></td>
<td><strong>54.7</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>19.8</td>
<td><strong>2017</strong></td>
<td><strong>25.1</strong></td>
<td>1998</td>
<td>53.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

88.73% Basin

5.63% Basin

Elev. < 6000 ft – d 5.64% Basin
1.1 PURPOSE OF THE RISK ASSESSMENT

- **2004**: Risk Assessment: Increasing Justification to Reduce Risks
- **2010**: Corrective Action Study
- **2012**: Final Design for Dam Safety Modifications
- **2016/2017**: Record Snowpack
- **2017**: Decision
1.2 Context for the Risk Assessment

- Reclamation Dam Safety Triad
  - Dam Safety Office
  - Region Office
  - Area Office
- Reclamation Public Protection Guidelines
  - Annualized Failure Probability: 1E-04
  - Annualized Life Loss: 1E-03
- Dam safety case claim
1.2 Context for the Risk Assessment

Simplified Dam Safety Process

Comprehensive Review: Screening-Level RA

Corrective Action Study: Alternative Evaluation

Issue Evaluation: Refinement of Risks

Final Designs of Dam Safety Modification

Design Specifications

Construction RA

Construction EAP Countermeasures
1.2 CONTEXT FOR THE RISK ASSESSMENT

- Temporarily increased risks result from the construction activities; however, construction activities are necessary to achieve long term risk reduction
  - We will accept the temporary increase in risks
1.3 Scope of the Risk Analysis

- Outcome desired: approval from the Triad
- Potential Failure Mode: Overtopping during a flood event
- Initiating event: Large floods caused by atmospheric Rivers under construction conditions
  - Uncertainty: relationship between large floods and seasonal floods
1.3 **Scope of the Risk Analysis**

100-year events  
Final Design
1.3 Scope of the Risk Analysis

• Purpose: Reduce risks associated with hydrologic overtopping PFM

• Modification components:
  • Embankment raises to increase flood storage capacity
    • Dam
    • Dike
    • Construction of freeboard dikes
  • Spillway crest structure modification
2. Baseline Risk Assessment
2.1 Potential failure modes identification

• Single PFM impacted by construction activities: increased risks of overtopping temporarily.
2.1 Potential failure modes identification

- Constructing dam and dike crest raise by mechanically stabilized earth (MSE) constr. methods.
2.1 POTENTIAL FAILURE MODES IDENTIFICATION

- Replacing spillway crest structure; headwall to limit peak spillway discharges during the IDF to 3,000 ft³/s.
2.2 Evaluation Against Dam Safety Standards

• It is difficult to evaluate construction risks within the standard annualized framework
  • Conditions are temporary
  • Loading ranges can vary
    • Atmospheric river season is not construction season

• Tracking risk with construction schedule
2.3 RISK MODEL FORM

- Event trees to estimate annual failure probability
  - 2012 trees used full range of starting RWS elevations
  - 2017 trees needed to account for the forecast RWS elevations
- Impacts to downstream reservoirs were assessed
  - System flood routings
2.4 Estimation of Load Probabilities

- Overtopping by more frequent floods
  - No spillway operation during 2017 construction season
  - Crest Excavation to an elevation 5 feet below existing
2.5 Estimation of System Response Probabilities

• Flood hydrographs and routings accounted for the reservoir downstream and the intervening area
  • Risk estimates were not made for the downstream reservoir
  • Designers considered flood routing results to guard against overtopping
2.6 Estimation of Consequences

- Consequences: life loss
- Factors taken into account
  - Breach outflow
  - Inundation area
  - Flood severity
  - Warning times
2.7 EXISTING DAM RISK ESTIMATES AND TOLERABLE RISK EVALUATION

• Time history of risk with construction schedules
  • 2012: Strict Annualized Life Loss
  • 2017: Updated annualized life loss accounting for anticipated reservoir operations
2.7 EXISTING DAM RISK ESTIMATES AND TOLERABLE RISK EVALUATION
2.7 EXISTING DAM RISK ESTIMATES AND TOLERABLE RISK EVALUATION

Stampede Reservoir Level and Construction Schedule

- Pre Project Crest El.
- Projected RWS El.
- Actual RWS El.
- Cofferdam Construction

Min Crest El.
Required Ex.
Projected Max.
2,000-yr.

Cofferdam
Spillway Crest
Remove Cofferdam
Embankment Section Lowered

Timeline:
- August '16
- September '16
- October '16
- November '16
- December '16
- January '17
- February '17
- March '17
- April '17
- May '17
- June '17
- July '17
- August '17
- September '17
- October '17
2.7 Existing Dam Risk Estimates and Tolerable Risk Evaluation

Stampede Dam Modification
Construction Risk (ALL) Time History Comparison

- 2012 Construction Risk Estimates
- MSE Dike - Excavated
- MSE Dike - Res. Exist.
- Winter Shutdown
- MSE Dam - Excavated
- MSE Dam - Res. Exist.
- MSE Dam - Completed

Annualized Life Loss

Construction Time (days)
baseline flood protection? 2012 flood protection? no need to plot, but discuss.
Huggins, Jennifer E, 4/5/2018
2.7 EXISTING DAM RISK ESTIMATES AND TOLERABLE RISK EVALUATION
work through this, talking thru black, then blue, then red.

Huggins, Jennifer E, 4/5/2018
2.7 EXISTING DAM RISK ESTIMATES AND TOLERABLE RISK EVALUATION
2.8 Insights and Recommendations

• Risks increase from 2012 to 2017: higher starting RWS elevations
• Routing results are conservative
  • Annual Rain on snow storms
  • Large events driven by atmospheric rivers
• Risk refinement: season construction hydrographs
3. Risk Reduction Assessment
3.1 Identification of Risk Reduction Alternatives

• Factors that Reduce risk
  • Increased Presence at the dam
  • Construction Emergency Action Plan (CEAP)

• Interventions
  • Emergency
    • Backfill any excavated embankments
    • Cofferdam Breach for spillway releases
  • Non-Emergency
    • Management of RWS elevation through outlet works operations
3.1 IDENTIFICATION OF RISK REDUCTION ALTERNATIVES

• Developed by team in 2012 (updated 2017)
  • Region & Area office
  • Construction office
  • TSC
  • DSO

• Identifies RWS elevations for
  • More frequent monitoring
    • Cofferdam
    • Reservoir operations
  • Notification of officials
3.2 Representation of Risk Reduction Alternatives in Risk Model

- Increase freeboard
- Increase release capacity
3.2 REPRESENTATION OF RISK REDUCTION ALTERNATIVES IN RISK MODEL

• Non-Emergency Intervention: Managing reservoir for increased storage
  • Hydraulic modeling
  • Advanced Draw-down
3.2 REPRESENTATION OF RISK REDUCTION ALTERNATIVES IN RISK MODEL

Emergency intervention to increase freeboard
SuperSacks to Backfill excavated areas

http://www.bigbagsusa.com/cofferdam/index.asp
3.2 Representation of risk reduction alternatives in risk model
3.2 Representation of Risk Reduction Alternatives in Risk Model
### 3.2 Representation of Risk Reduction Alternatives in Risk Model

**Emergency Intervention: Breach of Cofferdam for Increased release capacity**

<table>
<thead>
<tr>
<th>Field Condition</th>
<th>Factors for Consideration</th>
</tr>
</thead>
</table>
| • Cofferdam crest < des. El., Existing Spillway Functional                       | • Existing spillway discharge  
• Outflows from Stampede Dam could combine with intervening inflows to Boca and exceed Boca’s release capacity.                                                                                                           |
| • Cofferdam at des. elevation, Existing Spillway demolished                      | • Releases would not be controlled by a spillway crest  
• Flows would pass directly over the tuff breccia bedrock.                                                                                                                                                           |
| • Cofferdam at des. Elevation, New Crest Structure Partially Complete            | • Erosion of embankment or bedrock materials could Initiate  
• Release capacity at Boca could be exceeded                                                                                                         |
3.3 Risk estimates and tolerable risk evaluation for alternatives

Without any intervention, we have 2,000-year storm protection
4. LIMITATIONS, DECISIONS, RISK COMMUNICATION AND LESSONS LEARNED
4.1 LIMITATIONS

- Fruit Salad
  - Typical RIDM: Annualized
  - Construction: Seasonal
4.2 Decision and Risk Management Recommendations

• Accept temporarily increased construction risks to achieve long-term risk reduction
4.3 Risk Communication

• Within Reclamation
  • Decision makers
    • DSAT
    • DD/TROF (approval from Triad)
  • Field office ↔ Design office

• With Contractor
  • CEAP
  • COR
4.4 Lessons Learned

• Would we estimate construction risks differently in retrospect?
  • No
  • Sensitivity Studies

• Reassessing construction risks of value to Dam Safety Office
“Wash daily from nose tip to tail tip; drink deeply, but never too deep; And remember the night is for hunting and forget not the day is for sleep.” – Rudyard Kipling

*The Law of the Jungle – The Jungle Book*