A Scaled and Efficient Semi-Quantitative Risk Analysis for an Inventory of 23 High Hazard Dams

Daniel W. Osmun, PE
Elena Soskenkina, PE
Cris Parker, PE
Sunit Deo, PE
Kelley Rich, PE
1. Purpose, Context and Scope
1.1 PURPOSE OF THE RISK ASSESSMENT

- Suburbs north of Austin, Texas
- Dams built by NRCS (SCS) in 1950s
- Upper Brushy Creek Water Control and Improvement District is the watershed sponsor – responsible for operation and maintenance of the dams
- NRCS no longer has responsibility, but can provide grant funding
1.1 Purpose of the Risk Assessment

- Hazard Creep – Low to High

2002

2018
1.1 PURPOSE OF THE RISK ASSESSMENT

- Extensive suburban sprawl development has occurred around the dams (Austin)
- District recognized the need for ongoing significant remediation and maintenance work
1.1 Purpose of the Risk Assessment

- District desired a systematic risk-informed approach to prioritize future work and funding
- 10-year CIP approach
1.2 **CONTEXT FOR THE RISK ASSESSMENT**

- District obtained a taxing authority in 2002 to begin work on the dams to “buy down” risk
- Standards based approach – State regulated
- “Modernization” program completed on all dams
1.2 CONTEXT FOR THE RISK ASSESSMENT

- Dams continue to age
- Consequences continue to increase
  - District cannot regulate development, only communicate risk to Cities and Counties within the watershed
1.3 Scope of the Risk Assessment

- Start with the end in mind:
  - A risk-informed prioritized listing of dam safety projects and O&M activities

- Process to get there:
  - Semi-quantitative risk assessments of PFM
  - PFM “converted” to projects and activities
  - Develop a relative ranking
1.3 Scope of the Risk Assessment

- Mostly making use of extensive engineering studies already available
- Loading conditions / initiating events
  - Normal (static) loading
  - Hydrologic loadings
- Update hydrologic loading – new Texas PMP data
1.3 **SCOPE OF THE RISK ASSESSMENT**

- New breach analysis with HEC-RAS 2D
- Consequence – empirical life loss estimate using Reclamation RCEM
1.3 **Scope of the Risk Assessment**

- **Schedule goal**: 1 year
- **23 dams**
- **PFMA workshop covering 3 dams every 6 weeks**
- **2 day workshops**
  - ½ day site visit
  - ½ day PFMA session per dam
2. Baseline Risk Assessment
### 2.1 Potential Failure Modes Identification

- Description of facilities

<table>
<thead>
<tr>
<th>No.</th>
<th>Length of Dam (ft)</th>
<th>Height of Dam (ft)</th>
<th>Normal Storage Volume (ac-ft)</th>
<th>100-yr Storage Volume (ac-ft)</th>
<th>Max Storage Volume (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4,250</td>
<td>120</td>
<td>2070</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>2</td>
<td>2,500</td>
<td>55</td>
<td>150</td>
<td>3,000</td>
<td>6,000</td>
</tr>
<tr>
<td>3</td>
<td>3,120</td>
<td>75</td>
<td>190</td>
<td>3,800</td>
<td>7,600</td>
</tr>
<tr>
<td>4</td>
<td>1,650</td>
<td>40</td>
<td>100</td>
<td>2,000</td>
<td>4,000</td>
</tr>
<tr>
<td>5</td>
<td>1,000</td>
<td>40</td>
<td>50</td>
<td>1,000</td>
<td>2,000</td>
</tr>
<tr>
<td>6</td>
<td>1,650</td>
<td>45</td>
<td>170</td>
<td>3,500</td>
<td>7,000</td>
</tr>
<tr>
<td>7</td>
<td>2,300</td>
<td>54</td>
<td>270</td>
<td>5,400</td>
<td>10,800</td>
</tr>
<tr>
<td>8</td>
<td>2,250</td>
<td>45</td>
<td>300</td>
<td>6,000</td>
<td>12,000</td>
</tr>
<tr>
<td>9</td>
<td>3,300</td>
<td>40</td>
<td>160</td>
<td>3,200</td>
<td>6,400</td>
</tr>
<tr>
<td>10A</td>
<td>1,500</td>
<td>40</td>
<td>100</td>
<td>2,000</td>
<td>4,000</td>
</tr>
<tr>
<td>10B</td>
<td>1,800</td>
<td>40</td>
<td>160</td>
<td>3,200</td>
<td>6,400</td>
</tr>
<tr>
<td>11</td>
<td>2,450</td>
<td>41</td>
<td>200</td>
<td>4,000</td>
<td>8,000</td>
</tr>
<tr>
<td>12</td>
<td>5,000</td>
<td>40</td>
<td>160</td>
<td>3,200</td>
<td>6,400</td>
</tr>
<tr>
<td>13</td>
<td>5,000</td>
<td>40</td>
<td>110</td>
<td>2,200</td>
<td>4,400</td>
</tr>
<tr>
<td>14</td>
<td>1,725</td>
<td>37</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>2,775</td>
<td>38</td>
<td>210</td>
<td>4,200</td>
<td>8,400</td>
</tr>
<tr>
<td>16</td>
<td>2,500</td>
<td>46</td>
<td>170</td>
<td>3,400</td>
<td>6,800</td>
</tr>
<tr>
<td>17</td>
<td>1,175</td>
<td>33</td>
<td>120</td>
<td>2,400</td>
<td>4,800</td>
</tr>
<tr>
<td>18</td>
<td>2,400</td>
<td>29</td>
<td>170</td>
<td>3,400</td>
<td>6,800</td>
</tr>
<tr>
<td>19</td>
<td>1,450</td>
<td>35</td>
<td>70</td>
<td>1,400</td>
<td>2,800</td>
</tr>
<tr>
<td>20</td>
<td>1,050</td>
<td>30</td>
<td>90</td>
<td>1,800</td>
<td>3,600</td>
</tr>
<tr>
<td>21</td>
<td>446</td>
<td>30</td>
<td>90</td>
<td>2,200</td>
<td>4,400</td>
</tr>
<tr>
<td>22</td>
<td>130</td>
<td>30</td>
<td>70</td>
<td>1,400</td>
<td>2,800</td>
</tr>
</tbody>
</table>

---

Third Workshop on Case Histories in Dam Safety Risk-Informed Decision Making
2018 Annual Conference Workshop
2.1 Potential failure modes identification

- Description of facilities
  - 27 to 54 feet high
  - Max storage ~ 600-6,000 ac-ft
  - Homogeneous embankment dams
  - Conduit through the embankment serves as primary spillway with low level outlet valve
  - Earth emergency spillways

<table>
<thead>
<tr>
<th>No.</th>
<th>Length of Dam (ft)</th>
<th>Max Height of Dam (ft)</th>
<th>Normal Storage Volume (ac-ft)</th>
<th>100-yr Storage Volume (ac-ft)</th>
<th>Max Storage Volume (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4,350</td>
<td>35</td>
<td>210</td>
<td>2010</td>
<td>4,030</td>
</tr>
<tr>
<td>2</td>
<td>2,500</td>
<td>31</td>
<td>110</td>
<td>1130</td>
<td>2,210</td>
</tr>
<tr>
<td>3</td>
<td>4,075</td>
<td>49</td>
<td>180</td>
<td>3340</td>
<td>6,650</td>
</tr>
<tr>
<td>4</td>
<td>1,960</td>
<td>51</td>
<td>170</td>
<td>1750</td>
<td>3,300</td>
</tr>
<tr>
<td>5</td>
<td>1,080</td>
<td>31</td>
<td>40</td>
<td>380</td>
<td>760</td>
</tr>
<tr>
<td>6</td>
<td>1,650</td>
<td>45</td>
<td>170</td>
<td>1970</td>
<td>4,350</td>
</tr>
<tr>
<td>7</td>
<td>2,300</td>
<td>54</td>
<td>270</td>
<td>3830</td>
<td>5,590</td>
</tr>
<tr>
<td>8</td>
<td>2,290</td>
<td>45</td>
<td>50</td>
<td>3070</td>
<td>4,260</td>
</tr>
<tr>
<td>9</td>
<td>3,350</td>
<td>36</td>
<td>180</td>
<td>1970</td>
<td>3,200</td>
</tr>
<tr>
<td>10A</td>
<td>1,560</td>
<td>42</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10B</td>
<td>1,480</td>
<td>37</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>2,480</td>
<td>41</td>
<td>200</td>
<td>2340</td>
<td>5,520</td>
</tr>
<tr>
<td>12</td>
<td>5,000</td>
<td>32</td>
<td>80</td>
<td>1600</td>
<td>2,880</td>
</tr>
<tr>
<td>13</td>
<td>5,000</td>
<td>32</td>
<td>80</td>
<td>1160</td>
<td>2,840</td>
</tr>
<tr>
<td>14</td>
<td>1,725</td>
<td>27</td>
<td>120</td>
<td>980</td>
<td>2,520</td>
</tr>
<tr>
<td>15</td>
<td>2,770</td>
<td>28</td>
<td>110</td>
<td>500</td>
<td>1,180</td>
</tr>
<tr>
<td>16</td>
<td>2,550</td>
<td>46</td>
<td>170</td>
<td>2060</td>
<td>4,870</td>
</tr>
<tr>
<td>17</td>
<td>1,765</td>
<td>33</td>
<td>120</td>
<td>450</td>
<td>740</td>
</tr>
<tr>
<td>18</td>
<td>2,400</td>
<td>29</td>
<td>170</td>
<td>790</td>
<td>1,750</td>
</tr>
<tr>
<td>19</td>
<td>1,450</td>
<td>35</td>
<td>70</td>
<td>570</td>
<td>970</td>
</tr>
<tr>
<td>20</td>
<td>1,020</td>
<td>36</td>
<td>90</td>
<td>300</td>
<td>690</td>
</tr>
<tr>
<td>21</td>
<td>746</td>
<td>35</td>
<td>90</td>
<td>270</td>
<td>590</td>
</tr>
<tr>
<td>22</td>
<td>910</td>
<td>30</td>
<td>70</td>
<td>260</td>
<td>560</td>
</tr>
</tbody>
</table>
2.1 Potential failure modes identification
2.1 Potential failure modes identification

- Extensive use of existing information and studies
  - Inspections
  - Geotechnical studies
  - Past Performance
  - Upgrades/modification designs
2.1 Potential failure modes identification

- New Inspections/Studies to Support PFM:
  - Breach inundation study (2D)
  - Life loss estimation (empirical)
  - Spillway conduit camera inspections
2.1 POTENTIAL FAILURE MODES IDENTIFICATION

- PFM Development
  - Dams are very similar; site specific differences
  - Developed standardized naming convention
  - Scaling – to take advantage of the similarities
2.1 Potential failure modes identification

- Pre-Screening and info packet sent to team
- Pre-PFMA input from team

<table>
<thead>
<tr>
<th>PFM</th>
<th>Description</th>
<th>Notes</th>
<th>Failure Likelihood (Preliminary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-1</td>
<td>A large storm event results in dam overtopping</td>
<td>Updated hydrologic and hydraulic analysis indicates that Dam 18 is able to contain the Probable Maximum Flood water surface elevation without overtopping the parapet wall. The failure likelihood of PFM H-1 is negligible.</td>
<td>X</td>
</tr>
<tr>
<td>H-2</td>
<td>A large storm event results in parapet wall failure leading to dam overtopping</td>
<td>Structural integrity of parapet compromised due to factors including but not limited to seepage through joint cracks, sliding and overturning. Many of expansion joints are significantly cracked with broken pieces of parapet wall missing. Holes adjacent to footing of parapet wall. In one area, reinforcing steel was visible. Parapet wall is able to contain PMF without overtopping.</td>
<td>X</td>
</tr>
</tbody>
</table>
2.1 POTENTIAL FAILURE MODES IDENTIFICATION

- Condensed PFMA
  - Review of PFMs (both plausible and negligible)
  - Quickly discuss
  - Make efficient use of previously developed PFMs for other similar dams; adjust descriptions as appropriate
2.1 Potential failure modes identification

- Condensed PFMA
  - Work through more likely – less likely factors
  - Take advantage of previous similar work
  - Team rating of PFMs (later)

<table>
<thead>
<tr>
<th>PFM:</th>
<th>N-1</th>
<th>Failure Mode:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiator:</td>
<td>Embankment cracks or high permeability zone exists at or below the normal reservoir level</td>
<td></td>
</tr>
<tr>
<td>Step-by-Step Description:</td>
<td>Reservoir water flows through the crack and slowly scours embankment material. The crack remains open and does not swell shut or collapse. Materials continue to erode, widening and deepening erosion pathway. The flow and erosion goes unnoticed, and when it is noticed intervention efforts fail</td>
<td></td>
</tr>
<tr>
<td>Breach:</td>
<td>The dam fails by gross enlargement of the erosion pathway and the reservoir is released</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>More Likely Factors</th>
<th>Less Likely Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seep observed at the base of the dam collected by toe drain pipe at auxiliary spillway.</td>
<td>There has been no evidence of any concentrated seepage through the embankment dam.</td>
</tr>
<tr>
<td>Vegetation at toe near plunge pool could make it difficult to observe adverse behavior or material transport with excessive or unusual seepage.</td>
<td>Cracks on embankment would be visible with little vegetation.</td>
</tr>
<tr>
<td>Plastic clays could experience cracking.</td>
<td>No evidence of material transport in seepage areas.</td>
</tr>
<tr>
<td>Hot dry temperature creates desiccation cracking that could exacerbate existing cracking or could worsen if left untreated.</td>
<td>No evidence of animal burrows.</td>
</tr>
<tr>
<td>Rodent burrows could lead to defects and increased gradients.</td>
<td>No observations of sinkholes or depressions that may be indicative of subsurface cracking or erosion.</td>
</tr>
<tr>
<td>Alluvial materials (silty sand?) in the drainage channel may have been used as embankment fill, creating a permeable unsaturated zone.</td>
<td>There is some vegetation at the toe of the dam but no large trees or extensive root systems that could create seepage pathways.</td>
</tr>
<tr>
<td>Small cracks could widen if they dry out due to nature of the clays.</td>
<td>Construction — lift thickness (8-10 inches with well documented construction would be less likely factor).</td>
</tr>
<tr>
<td>If a concentrated leak developed and began eroding soils, there is no designed filter to prevent erosion</td>
<td>Flaw — dam was well built by SCS. Engineers were experienced in dam construction, lower risk of built-in flaw, design flaw or construction flaw</td>
</tr>
</tbody>
</table>
2.2 EVALUATION AGAINST DAM SAFETY STANDARDS

- State (TCEQ) Hydrologic Criteria for Dams
  - Hazard Creep -> Low to High Hazard

2002

2018
### 2.2 Evaluation Against Dam Safety Standards

- State (TCEQ) Hydrologic Criteria for Dams
  - Hazard Creep -> Low to High Hazard

<table>
<thead>
<tr>
<th>Classification</th>
<th>Size, as defined in §299.13 of this title (relating to Size Classification Criteria)</th>
<th>Minimum Design Flood Hydrograph (expressed as a percentage of the probable maximum flood (PMF)).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Small 25% PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermediate 25% PMF to 50% PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large 50% to 75% PMF</td>
<td></td>
</tr>
<tr>
<td>Significant</td>
<td>Small 50% PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermediate 50% PMF to 75% PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large 75% to PMF</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Small 75% PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermediate 75% to PMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large PMF</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Evaluation against Dam Safety Standards

- State Hydrologic Criteria for Dams
  - District opted for modernization designs to pass 100% of PMF – though TCEQ only required 75%
  - With new hydrology and routings, some dams are overtopped for PMF
2.2 Evaluation Against Dam Safety Standards

- Modernization for 100% PMF
  - 2006-2018
  - Most of 23 dams modernized
2.2 Evaluation Against Dam Safety Standards

System of USGS Gages
2.2 EVALUATION AGAINST DAM SAFETY STANDARDS

- **Slope Stability**
  - Geotechnical explorations and stability studies performed Part of Modernization
- Previous shallow slides on 13 A and 22
2.3 Risk Model Form

- PFMA / SQRA – semi quantitative risk analysis
  - What is our level of risk analysis?
  - What decisions are we trying to make?

Simple Screening

Moderate

Thorough / Complex
2.3 Risk Model Form

Simple Screening (PFMA)

Moderate (SQRA)

Thorough / Complex (full QRA)
2.3 **RISK MODEL FORM**

Do we have a dam safety issue?

Which dam presents the highest risk?

How serious is the issue?

What other actions should we take?

What effort (cost, time) is needed to reduce risk? What actions should we take? How quickly is action required?
2.3 Risk Model Form

Do we have a dam safety issue?
Which dam presents the highest risk?

How serious is the issue?
What other actions should we take?
2.3 Risk Model Form

- Screening Level
- Moderate
- Thorough & Complex

Increasing information, data, time and cost
2.3 Risk Model Form

- **Screening Level**
- **Moderate**
- **Thorough & Complex**

Increasing information, data, time and cost

Decreasing uncertainty (range of risk)
2.4 Estimation of Load Probabilities

- Hydrologic PFMs
- Used and extrapolated data from 10%, 1%, and 0.2% Storm Frequencies (10 yr, 100 yr, & 500 yr)
- Plotted PMF
- Recognize significant uncertainty!!
2.4 Estimation of Load Probabilities

- Other critical non-breach “events”
  - Spillway flow
  - Upstream flooding
  - Low area discharge (flanking flows)
2.4 ESTIMATION OF LOAD PROBABILITIES

- Important for understanding residual risk (risk that remains)
- Non-breach plus incremental
2.5 Estimation of System Response Probabilities

- Extremely simplified
- Normal operation PFM - SQRA
  - Judgments based on past performance, understanding of the deficiencies, engineering analysis, case histories of similar dams, and verbal mapping

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Assigned Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtually Certain</td>
<td>0.999</td>
</tr>
<tr>
<td>Very Likely</td>
<td>0.99</td>
</tr>
<tr>
<td>Likely</td>
<td>0.9</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.5</td>
</tr>
<tr>
<td>Unlikely</td>
<td>0.1</td>
</tr>
<tr>
<td>Very Unlikely</td>
<td>0.01</td>
</tr>
<tr>
<td>Virtually Impossible</td>
<td>0.001</td>
</tr>
</tbody>
</table>
2.6 Estimation of Consequences

- Inundation scenarios
  - PMF, Sunny Day with Breach and PMF with Breach
  - 2D Model Depth-Velocity Results
2.6 ESTIMATION OF CONSEQUENCES

- Reclamation Consequence Estimating Methodology (RCEM)
  - Fatality Rate Selection
  - Incremental Life Loss
2.7 Existing Dam Risk Estimates and Tolerable Risk Evaluation

- SQRA Tolerable Risk Matrix

![Risk Matrix Diagram](image)

- Federal Guidelines for Dam Safety Risk Management (FEMA, 2015)
- FERC RIDM (2016)
2.8 INSIGHTS AND RECOMMENDATIONS
3. Risk Reduction Assessment
3.1 Identification of Risk Reduction Alternatives

- Inventory prioritization
  - 23 dams
  - Operation and maintenance
  - Low areas around reservoir rim
  - Dam safety modifications
- Risk communication with public
- Alternatives and costs
3.2 REPRESENTATION OF RISK REDUCTION ALTERNATIVES IN RISK MODEL

- Make use of SQRA matrix
- Could consider packaging similar O&M and/or risk reduction alternatives at multiple dams
3.3 Risk estimates and tolerable risk evaluation for alternatives

- Follow up work – after 23 dams have SQRA
4. LIMITATIONS, DECISIONS, RISK COMMUNICATION AND LESSONS LEARNED
### 4.1 LIMITATIONS

- **Condensed PFMA / SQRA**
  - Significant uncertainty – limited understanding
    - Actions to address uncertainty will depend on the relative ranking of potential issues

- **Cost effectiveness for risk reduction measures can’t be quantified with PFMA/SQRA**
4.2 DECISION AND RISK MANAGEMENT

RECOMMENDATIONS

- Prioritization scheme
- Start with Federal Guidelines for Dam Safety Risk Management (FEMA P-1025)
- Additional engineering studies
- Potential small modifications
- Consider O&M actions

Table 1 — Joint Federal risk categories

<table>
<thead>
<tr>
<th>Urgency of action</th>
<th>Characteristics and considerations</th>
<th>Potential actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I — VERY HIGH URGENCY</td>
<td>CRITICALLY NEAR FAILURE: There is direct evidence that failure is in progress, and the dam is almost certain to fail during normal operations if action is not taken quickly. OR EXTREMELY HIGH RISK: Combination of site or economic consequences and likelihood of failure is very high with high confidence.</td>
<td>Take immediate action to avoid failure. Communicate findings to potentially affected parties. Implement IRRMs. Ensure that the emergency action plan is current and functionally tested. Conduct heightened monitoring and evaluation. Expedite investigations and actions to support long-term risk reduction. Initiate intensive management and situation reports.</td>
</tr>
<tr>
<td>II — HIGH URGENCY</td>
<td>RISK IS HIGH WITH HIGH CONFIDENCE, OR IT IS VERY HIGH WITH LOW TO MODERATE CONFIDENCE: The likelihood of failure from one of these occurrences, prior to taking some action, is too high to delay action.</td>
<td>Implement IRRMs. Ensure that the emergency action plan is current and functionally tested. Give high priority to heightened monitoring and evaluation. Expedite investigations and actions to support long-term risk reduction. Expedite confirmation of classification.</td>
</tr>
<tr>
<td>III — MODERATE URGENCY</td>
<td>MODERATE TO HIGH RISK: Confidence in the risk estimates is generally at least moderate, but can include facilities with low confidence if there is a reasonable chance that risk estimates will be confirmed or potentially increase with further study.</td>
<td>Implement IRRMs. Ensure that the emergency action plan is current and functionally tested. Conduct heightened monitoring and evaluation. Prioritize investigations and actions to support long-term risk reduction. Prioritize confirmation of classification as appropriate.</td>
</tr>
<tr>
<td>IV — LOW TO MODERATE URGENCY</td>
<td>LOW TO MODERATE RISK: The risks are low to moderate with at least moderate confidence, or the risks are low with low confidence, and there is a potential for the risks to increase with further study.</td>
<td>Ensure that routine risk management measures are in place. Determine whether action can wait until after the next periodic review. Before the next periodic review, take appropriate interim measures and schedule other actions as appropriate. Give normal priority to investigations to validate classification, but do not plan for risk reduction measures at this time.</td>
</tr>
<tr>
<td>V — NO URGENCY</td>
<td>LOW RISK: The risks are low and are unlikely to change with additional investigations or studies.</td>
<td>Continue routine dam safety risk management activities and normal operations and maintenance.</td>
</tr>
</tbody>
</table>
4.3 RISK COMMUNICATION

- Working with District to develop consistent communication approach
- Risk Communication to City and County officials, land developers, and residents
- Goal is to increase awareness of the risk posed by the dams
  - Flood operations (non-breach risk)
  - Dam failure
4.4 Lessons Learned

- In-progress
- Solid technical work with comprehensive documentation is important
- Up-front work before PFMA workshop is critical
- Consistency, consistency, consistency
  - Tracking PFMs across all dams – and asking “does this make sense?”
  - Tracking conditional failure probability (e.g. parapet wall failure; flood overtopping)
4.4 Lessons Learned

- Provides a non-subjective process for the District to use funding efficiently
- Provides a risk informed justification for continued funding of dam safety activities for these aging facilities
- Provides a rational methodology for prioritization of future projects
QUESTIONS?