Lake Houston Dam
Comprehensive Evaluation of an Ambursen Dam

ASDSO
September 10, 2008

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Lake Houston Dam

- Designed by Ambursen, completed in 1954
  - Flat slab and buttress spillway
  - Maximum height 66 feet
  - 12,100’ long
  - Uncontrolled spillway of 3,077’
  - Four gates – two radial (18 x 20) and two flashboards (18 x 5)
  - Two earthen embankments

- San Jacinto River northeast of Houston, Texas

- Owned By City of Houston, operated by Coastal Water Authority (CWA)
Typical Buttress Section

- 158 Spillway buttresses
- 20’ on centers
- 3 rows of sheetpiles
Comprehensive Evaluation

- Review of Documents
- Site Inspection
- Update of Probable Maximum Flood
- Alignment Survey
- Identification of Dam Safety Issues
- Analysis/Resolution of Dam Safety Issues
Update of PMF

- Update was performed to include:
  - New Texas Design Storm Guidelines
  - Update methodology to new hydraulic unsteady flow model (HEC-RAS) to improve accuracy
Calibration

Lake Houston, October 1994

Date

Stage (feet msl)


- Observed
- Calculated
PMF Results

- Elev. 55.3 vs. 57.9 in previous report
  - Of 2.6’ difference, 0.5’ due to new TCEQ Guidelines
  - Of 2.6’ difference, 2.1’ due to unsteady HEC-RAS
- Peak Discharge of 578,500 cfs vs. 700,000 cfs
- Compares to 50.8 in 1994
  - 400 yr event
  - > 50% of the PMF
32 potential dam safety issues
- Identified in document research and site investigation

13 routine maintenance items

Reviewed and analyzed each issue
- Develop a resolution, or
- Develop a plan to resolve in future phases
32 Dam Safety Issues

- 2 Issues resolved with no action needed
- 13 Issues and 13 Maintenance Items Resolved with remedial action needed by CWA:
- 17 Issues addressed in second phase
Issue Resolution
Remaining 17 Issues

- One Primary Issue
  - Sliding Stability of Spillway Structures

- Nine Secondary Issues
  - Dependent on results of Stability Analysis

- Seven Other Issues
  - Unrelated to Stability
  - Attempted to resolve in second phase
Sliding Stability

No visual evidence of stability concerns. However:

- History of Ambursen Dams
- Did not know actual uplift forces acting on hearth slab
  - No existing instrumentation
- Design was based on undrained shear strengths
  - Would likely show tendency for reduced strength over time
  - Current practice would be to use drained strengths
- Drained shear strengths data available from previous analyses was limited
- Did not have soil strength tests from samples directly under slabs
Sliding Stability

- **Factors of Safety from Previous Estimates**
  - Original Ambursen Design (1951) – 1.48
  - 1994 Study – 1.90 Used original design strength parameters.
  - 2001 – 1.60 (1.35 when duplicated)

- **Recommended Values**
  - 2.0 for new construction
  - Probably 1.5 for existing structure with good knowledge of foundation
Field Exploration

- 15 Borings and 20 piezometers in spillway area
  - 5 borings, 10 piezometers in hearth
    - “shallow” and “deep” piezometers
  - 6 borings and piezometers under spillway
  - 4 borings and piezometers downstream from gates
- Samples taken from borings
- Piezometric data tracked from August 2007
Plan of Borings
Piezometric Data – Buttress 36
Nov. 18 – Dec. 20, 2007

Adjusted Tailwater Elevation (feet msl)

Lake Level (feet msl)

Tailwater in Hearth
Uplift
Lake Level
Stability Analysis

Typical Buttress Section:

- 158 Spillway buttresses
- 20’ on centers
- 3 rows of sheetpiles
## Normal Pool Stability Assumptions

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Cohesion</th>
<th>Friction Angle</th>
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</thead>
<tbody>
<tr>
<td>Ambursen (1951)</td>
<td>1370 psf</td>
<td>0 deg</td>
</tr>
<tr>
<td>1994</td>
<td>1370 psf</td>
<td>0 deg</td>
</tr>
<tr>
<td>2001</td>
<td>670 psf</td>
<td>22 deg</td>
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<tr>
<td>Freese and Nichols / Fugro</td>
<td>400 psf</td>
<td>18 deg</td>
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</table>
## Normal Pool Stability Results

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Headwater/Tailwater</th>
<th>Uplift (msl)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambursen (1951)</td>
<td>42.5/10.6</td>
<td>25</td>
<td>1.48</td>
</tr>
<tr>
<td>1994</td>
<td>42.5/10.6</td>
<td>25</td>
<td>1.90</td>
</tr>
<tr>
<td>2001</td>
<td>42.5/10.6</td>
<td>25</td>
<td>1.35</td>
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<td>Freese and Nichols / Fugro</td>
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</tr>
<tr>
<td></td>
<td>42.5/10.6</td>
<td>14</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>42.5/10.6</td>
<td>20</td>
<td>1.03</td>
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<tr>
<td></td>
<td>42.5/-0.6</td>
<td>14</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Maximum Uplift – To be tested whether feasible
Drained Hearth Conditions – Not recommended
Needed Improvements

- Increase sliding resistance of both spillways to:
  - 1.50 for normal conditions
  - 1.25 for drained hearth conditions
- Improve drainage and pressure relief systems
- Address excessive uplift under slab downstream from gated spillway
- Focus of next phase should be to focus on tailwater and uplift relationship to confirm or reduce the maximum uplift assumption.
Potential Alternatives

- Uncontrolled Spillway: (Gated similar)
  - Anchors not viable
  - Concrete Overlay
    - 2’ in spillway, 5’ on hearth
  - Improved Drainage – Reduce Uplift Pressures
    - Have to keep uplift below elevation 9.0
  - Permanently Increase Tailwater
    - Increase to elevation 19.1
    - Will not help with drained conditions
Potential Alternatives

- Combination Example: (Gated similar)
  - Concrete Overlay - 1’ in spillway, 2’ on hearth
  - Improved Drainage – Reduce max. uplift to elev. 15.5
  - Permanently Increase Tailwater to elev. 14.0
  - Will have Factor of Safety of 1.5
  - Reduce uplift to 9.5 to keep Factor of Safety to 1.25 for a fully drained hearth.
  - Combination not optimized – to be done as part of next phase
  - $8 to $12 Million
Final Design of Improvements

- **Design of Stability Improvements**
  - Likely a combination of concrete overlay, permanently increased tailwater, and improved drainage system
  - Overlay and drains installed in sections as hearth is drained
  - While drained:
    - Clear debris
    - Visual inspection
    - Geophysical testing for voids - Repair
    - Improve protection for existing piezometers

- **Design Repairs to slab downstream from gated spillway**
Questions?