Structural Inspection and Evaluation of Lake Delhi Dam

Lake Delhi Recreation Association (LDRA)
Delhi, Iowa

Final
October 2010

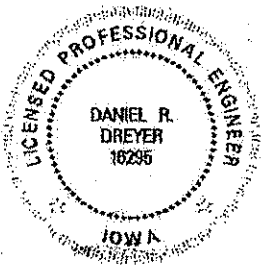
I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Iowa.

Daniel R. Dreyer 10/14/2010

Daniel R. Dreyer, P.E. 10/14/2010

My license renewal date is December 31, 2011.

Pages or sheets covered by this seal: Entire Report



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APPENDICES

Lake Delhi Dam Inspection/Evaluation

General

The Lake Delhi Recreation Association (LDRA) requested that Stanley Consultants, Inc. complete a structural inspection/evaluation of the existing Portland Cement Concrete Dam Structure at Lake Delhi near the Town of Delhi, Iowa. During the flood event of July 23-24, 2010, approximately 240 lineal feet of earthen dam located at the southern end of the Portland Cement Concrete Dam Structure was breached and eroded by the flood. Flood water also infiltrated and seeped through approximately 75 feet of earthen dam located at the north end of the Portland Cement Dam Structure. This section of embankment was not breached during the flood event.

Stanley Consultants performed visual inspections of accessible portions of the concrete dam.

Engineer's Inspection

The structural inspection/evaluation of the Lake Delhi Dam was performed on September 23, 2010 by the following personnel:

William E. Holman, P.E., Stanley Consultants, Inc.

Daniel R. Dreyer, P.E., Stanley Consultants, Inc.

Weather conditions during the inspection/evaluation were overcast with scattered showers and temperatures in the 60s. The use of left and right directions are referred in the text as one faces

downstream. The inspection/evaluation was conducted in the presence of Dave Fink (LDRA project manager) and Roger Mohn, P.E. The above water portions of the following dam components (from north to south) were observed:

- Approach roadway and retaining walls (North Embankment)
- Powerhouse Structure
- Gated Spillways
- Inspection Tunnel

Each of these major components was inspected for signs of settlement, movement, seepage, leakage, cracking, erosion, and general signs of deterioration. A detailed photographic log of the major dam components is included in Appendix A.

Approach Roadway and Retaining Walls (North Embankment)

The approach to the north end of the dam consists of earthen embankment with retaining walls supporting a concrete roadway. The original approach roadway curved to the east from the north end of the Powerhouse Structure. The original design drawings indicate that a concrete retaining wall was constructed on each side of this roadway. Sometime in the past, the road was straightened and a precast concrete "bin-type" retaining wall was constructed roughly parallel to the upstream side of the dam (Photo 1.1). The original upstream retaining wall was covered in fill beneath the new road.

A later project installed a storm water intake in the approach roadway (Photo 1.2). This intake discharges via a concrete pipe routed through the retaining wall on the upstream side of the dam. When the drainage pipe was installed, a portion of the original retaining wall on the upstream side of the dam was removed to make room for the pipe. Based on observations made during the inspection, the wall was not patched after pipe was placed.

The upstream retaining wall generally appeared to be stable and in good condition, with a localized area of deterioration below the outlet of the storm pipe (Photo 1.3). The grade along the base of the upstream retaining wall shows signs of significant erosion. The eroded area has been partially filled with concrete rubble and/or large riprap (Photo 1.1)

The approach roadway appears to have been damaged, presumably during the July flood, due to the presence of slab cracking and settlement (Photo 1.4). The cracking and settlement appear to be the result of the loss of material adjacent to and underneath the roadway in the

vicinity of the storm drainage pipe. Presumably, the material loss resulted from the seepage of water from the upstream side of the embankment, along the concrete pipe and through the retaining wall on the downstream side of the dam.

The retaining wall on the downstream side of the approach roadway appears to be original construction. The wall is of reinforced concrete construction (Photos 1.5 to 1.7). The wall generally appeared to be stable and in fair condition with no conclusive indications of tipping or differential movement. Efflorescence was observed around multiple cracks in the downstream retaining wall. The efflorescence appeared to be concentrated around a rectangular area near the center of the wall (Photo 1.8). The rectangular portion of concrete appears to have been poured at a different time than the surrounding concrete wall. The efflorescence appears to be result of water behind the wall seeping through the joint around the rectangular area and through cracks that have formed in this area. It was reported that during the July flood event, multiple leaks were observed though cracks in this area of the wall. Water was seen spraying several feet beyond the face of the wall.

A diagonal wall crack was observed near the south end of the wall near the point where the wall ties into the Powerhouse Structure. The crack was visible from the ground surface in front of the wall to a horizontal construction joint approximately 10' above grade (Photos 1.9 to 1.11). The crack could be an indication of settlement of the retaining wall relative to the Powerhouse Structure. It is unknown whether this crack existed prior to the July flood event. No efflorescence was observed around this crack, possibly indicating the crack developed more recently than some of the other cracks in the wall.

Powerhouse Structure

The Powerhouse Structure is located immediately south (to the right) of the approach roadway and retaining walls (Photos 2.1 and 2.2). The Powerhouse is a multi-level reinforced concrete structure. Various improvements have been performed in recent years including concrete repair and installation of new trash rack cleaning equipment and dewatering gate hoisting equipment. Most of the improvements were to the operating deck level at the top of the dam, and generally did not extend below the upstream waterline or into the turbine room.

The concrete on the upstream face of the Powerhouse below the original waterline appears to be in generally good condition. No significant cracking, differential movement, tilting or alignment changes were observed along this portion of the structure. The concrete at or

above the original waterline appeared to be in fair condition. More cracking, spalling and evidence of past repairs were observed in these locations (Photo 2.3). Dave Fink reported that during the dewatering bulkhead hoist installation project, the concrete below the south hoist support columns had to be removed as much as six feet to reach sound concrete. Only three feet of concrete under the remaining columns was removed as needed to install anchor bolts for the new columns. The upstream sides of the turbine bays were packed with wood and other debris remaining from the July flood, and the bar screens and piers were mostly covered in marine growth (Photo 2.4).

Downstream of the structure, the east concrete wall is in fair condition (Photos 2.5, 2.6, and 2.7). No significant cracking, differential movement, tilting or alignment changes were observed along this side of the structure. A deteriorated portion of wall was observed adjacent to the existing metal panel wall near the north end of the wall (Photo 2.8). It is presumed that this deterioration is the result of cracking in the upper portions of the wall, allowing the infiltration of water and de-icing salts from the roadway above the roof of the Powerhouse.

The interior of the Powerhouse consists of three main rooms on three levels. A Control Room is located just below and upstream of the roadway. This room was originally accessed via a floor hatch and ladder (Photo 2.9). The dam operations staff has installed steel stairs enclosed by a concrete masonry block building at roadway level to improve access to this room (Photo 2.10). The concrete roof, walls and floor of this room appear to be in fair condition. Cracks were observed in the north wall of this room (Photo 2.11). These cracks do not appear to be recently formed, due to the presence of paint in the crack in some locations. Due to their random pattern, the cracks do not appear to be a sign of a significant structural defect or differential movement, and were most likely the result of concrete shrinkage. The steel stairs are functional, but are significantly corroded in several locations.

The Turbine Room floor is located approximately 24 feet below the roadway level. The roof of the Turbine Room supports the roadway above. The generators are not currently in operation. Prior to the July flood, the dam operations staff regularly operated the wicket gates to permit the flow of water through this portion of the dam. The original windows on the downstream side of the dam have been replaced with metal panels and, residential type windows and exhaust fans (Photo 2.12). These items appear to be in good condition except

for the northernmost section. The exterior door at this location is missing, and a temporary plywood barrier has been installed in its place (Photo 2.13).

The upstream wall of the Turbine Room appears to be in fair condition with no major cracking or other damage. Random cracks were observed near the floor level (Photo 2.14). These cracks do not appear to be a sign of a significant structural defect or differential movement, and were most likely caused by concrete shrinkage. Efflorescence was observed around other cracks and construction joints in this wall (Photo 2.14). The efflorescence is an indication of water seepage through the cracks. A steel stair is located along this wall to provide access between the Turbine Room and the Control Room (Photos 2.14 and 2.15). The stairs are functional, but are heavily corroded in many locations.

The north and south walls of the Turbine Room appear to be in fair condition. Water has been infiltrating through the north wall through various cracks and construction joints (Photo 2.15). The water appears to be infiltrating the wall from the saturated fill behind it, and from cracks in the roof slab adjacent to the wall. The south wall appears to be in better condition than the north wall. The cracking and water infiltration appears to be most prevalent in the upper portions of the wall near the roof slab (Photo 2.16).

Cracks were observed in the northeast corner of Turbine Room roof (Photo 2.17). The cracks appear to extend from the roof slab into the north wall. Dave Fink reported that water regularly leaks through the roof in this location, prompting the dam operation staff to construct wood and metal sheds to keep various pieces of equipment dry (Photo 2.15). The cracks are likely the result of water infiltrating through the roadway above and into the concrete roof structure. Repeated freeze-thaw cycles have likely deteriorated the roof concrete, creating additional cracks and allowing further water infiltration. De-icing chemicals used on the roadway above could have been carried into the roof concrete with the water. These chemicals could have contributed to further deterioration of the roof and walls, by corroding the reinforcing steel. It is likely that this process contributed to the concrete cracking and deterioration observed on the downstream exterior wall (Photo 2.8). The roof leaks have contributed to heavy corrosion observed on all exposed steel in this room, including the overhead bridge crane and runway beams (Photo 2.17).

A Mechanical Room (Photos 2.18 and 2.19) is located below the north end of the Turbine Room floor. This room reportedly housed a boiler and other equipment that have since been

removed. Access to an inspection tunnel that runs the full length of the concrete portion of the dam structure is located in the northeast corner of this room. The steel stairs from the Turbine Room to the Mechanical Room are functional, but heavily corroded (Photo 2.20). Embedded steel around the perimeter of removable floor panels between the Turbine Room and the Mechanical Room are significantly corroded (Photo 2.20). The concrete walls and ceiling appear to be in good condition, with no significant cracking or deterioration observed. The majority of the floor was covered in mud and was not observed.

Gated Spillways

The above water inspection of the gated spillways included three concrete spillways, concrete spillway piers and abutment, three vertical lift steel gates (numbered starting with Gate 1 at the left to Gate 3 at the right), the operator's deck and roadway (Photos 3.1 and 3.2).

Concrete Spillways Logs, wood framing, remnants of a pontoon boat, and other debris accumulated upstream of the spillway gates during the July flood (Photo 3.1). The upstream concrete surfaces of the spillways appear to be in fair condition. No significant cracking, differential movement, tilting or alignment changes were observed along this portion of the structure. Several abrasions on the concrete surfaces in this location were observed, presumably caused by debris and other objects impacting the concrete as they passed over the spillway (Photos 3.3 and 3.4). The abrasions may be an indication of deterioration and softening of the outer concrete surface.

The downstream surfaces of the spillway crests appear to be in fair condition. No significant cracking, differential movement, tilting or alignment changes were observed along this portion of the structure. Abrasions similar to those observed on the upstream spillway surfaces were visible on the downstream surfaces, along with apparent areas of concrete surface erosion resulting from the flow of water over the spillways and freeze-thaw action (Photo 3.5). The exposed surface of the spillway concrete was easily chipped with a light hammer, indicating softening of the concrete (Photo 3.6).

Concrete Spillway Piers and Abutment Significant concrete deterioration was observed in the gate piers. Soft concrete that sounded hollow when tapped with a hammer was encountered from the crest of spillway downstream of the gate slots upward as far as could be reached at Gates 1 and 2 (Photo 3.7). This indicates significant concrete deterioration and potential delaminated concrete requiring repair.

Severe concrete deterioration and damage was observed in the piers adjacent to Gate 3 (Photos 3.8 and 3.9). The left embedded steel guide slot for Gate 3 has broken away and moved outward from the pier, spalling the adjacent concrete and exposing the underlying reinforcing. It was reported that Gate 3 seized during the flood and could not be fully opened. The out of plumb guide slots likely caused this situation.

The embedded steel guide slots and seal plates for all three gates are in generally poor condition and are heavily corroded (Photo 3.10). These conditions likely resulted in the significant leakage reported around the gates in the closed position.

The abutment wall appears to be in fair condition. Eroded concrete and exposed reinforcing was visible on the abutment downstream of the spillway (Photo 3.11). The bedrock foundation supporting the downstream end of the abutment appears to be partially eroded away (Photo 3.12). Prior to the earthen dam breach, water was reportedly observed seeping out of the embankment in this area, near the end of an abandoned concrete fish ladder structure.

Minor cracks are present in the top of the downstream abutment wall (Photo 3.13). The top of the upstream abutment wall has been damaged, presumably due to debris, boats and other items that impacted the wall after the earthen dam was breached (Photo 3.14). No excessive cracking beyond that noted above, differential movement, tilting or alignment changes were observed along this portion of the structure.

The abutment wall was also observed from the south bank of the Maquoketa River (Photo 3.15). A reinforced concrete and steel sheet pile cutoff wall tied into the abutment near the upstream face of the spillway. The cutoff wall collapsed during the earthen dam breach. A section of abutment wall near the top of the cutoff wall appears to have been repaired sometime in the in past (Photo 3.16). Cracking with efflorescence and spalling in the concrete repair area was visible from the south bank of the river.

Steel Gates The dam utilizes the steel gates originally constructed with the dam. The gates appear to have multiple coats of paint that appear to be flaking and beyond their useful life. Varying amounts of corrosion are visible on all three gates, along with the degraded coatings (Photos 3.17 and 3.18). The portions of the gates visible at the time of the inspection appear to be in serviceable condition. The gates do not have side seals. The bottom seals consist of timbers attached to the bottom of each gate, which bear on

the seal plates embedded in the top of the spillway concrete. The timbers appear to be in poor condition and reportedly do not provide adequate seal at the bottom of the gates (Photo 3.19).

Operator's Deck and Roadway The operator's deck was undergoing partial rehabilitation prior to the July flood. The existing drum and cable hoists were being replaced with vertical stem lifting mechanisms. The tops of the concrete piers were demolished and reconstructed to install anchor bolts for attaching the new lifting mechanisms (Photos 3.20 and 3.21). Cracking was observed on the underside of the concrete beams on the upstream side of the operator's deck (Photo 3.22). Cracking and efflorescence was observed in the concrete beams on the downstream side of the operator's deck (Photo 3.23).

The Roadway appears to be relatively new construction that is in very good condition (Photos 3.23, 3.24 and 3.25). No significant cracking or deterioration was observed in the roadway.

Inspection Tunnel

An inspection tunnel (approximately 4' wide by 8' tall) starts at the north end of the Powerhouse and extends the full length of the concrete structure to the south abutment wall. The tunnel is located on the upstream side of the dam. The floor of the tunnel is approximately 18'-6" below the crest of the gated spillways.

The floor of the tunnel was covered with a thick layer of mud leftover from the July flood (Photo 4.1). The concrete tunnel walls were generally dry and in good condition. No significant cracking or differential movement was observed in this part of the structure.

Moisture on the walls and roof of the tunnel was observed at multiple locations. The moisture appeared to be the result of water seeping into the tunnel through construction joints in the concrete. It appears that this has been happening for an extended period of time, based on the presence of efflorescence and what appear to be lime deposits forming on the concrete adjacent to the construction joints (Photos 4.2 through 4.7).

Recommendations for Repair and Evaluation

Areas in Need of Repair and Evaluation Prior to Returning the Dam to Service

Approach Roadway and Retaining Walls

1. The eroded grade in front of the upstream retaining wall should be filled and protected with additional riprap to reduce the potential for future erosion.
2. The damaged components of the upstream concrete "bin wall" should be repaired or replaced in the dry, while access to the wall is optimal.
3. The north approach roadway between the upstream and downstream retaining walls should be removed and the embankment beneath the roadway evaluated for the presence of voids or other anomalies. Voids or other conditions that could potentially compromise the stability of the roadway and/or the retaining walls should be filled with flowable cementitious fill or compacted soil.
4. The portions of original wall construction removed for the placement of the storm drainage pipe should be patched with concrete to reduce the potential for seepage along the pipe during high water.
5. The grade in front of the downstream retaining wall should be evaluated for the presence of subsurface voids or other anomalies. Voids or other conditions that could compromise the stability of the wall should be filled with flowable cementitious fill or compacted soil.
6. The cracks and holes in the downstream retaining wall should be repaired to reduce the potential for water infiltration into and seepage through the wall.
7. Crack monitoring gauges should be installed across selected existing cracks, so that they can be monitored for differential movement during pool filling and operation.

Powerhouse Structure

1. The debris upstream of the bar screens should be removed and disposed of.
2. The marine growth on the bar screens should be removed.
3. A new, secure, exterior door on the downstream wall of the Powerhouse should be installed.

4. Consideration should be given to performing concrete repairs and repairing or replacing embedded steel items on the upstream side of the structure while the area is dry and access is optimal.

5. Install crack monitoring gauges across selected existing cracks, so that they can be monitored for differential movement during pool filling and operation.

Gated Spillways

1. The debris upstream of the gates should be removed and disposed of.

2. The embedded guide slots in the piers and abutment should be repaired or replaced to ensure they are plumb and adequately anchored to the surrounding concrete.

3. The deteriorated and damaged concrete on the piers, abutment and weirs should be repaired.

4. An Underwater Inspection of the submerged downstream dam apron and adjacent river bottom was reportedly performed in 2008. The July 2010 flood subjected the dam to severe conditions that could have damaged the underwater portions of the structure or eroded the riverbank immediately downstream of the dam. An additional Underwater Inspection should be conducted using a commercial diver and acoustic imaging methods. The primary purpose of this inspection would be to document the current structural condition of the downstream dam apron and to estimate the lateral extent of any apron damage discovered. In addition, the inspection would determine if scour has taken place adjacent to and under the apron, adversely impacting the structural integrity of the dam structure.

5. The embedded gate seal plates at the crest of the weir should be reconditioned or replaced.

6. The deteriorated or damaged concrete observed on the south side of the abutment wall adjacent to cutoff wall tie-in point should be repaired.

7. The wooden seals on the bottom of the gates should be replaced with rubber seals to reduce the amount of leakage under the gates at these locations.

8. Consideration should be given to retrofitting the existing gates with rubber side seals to reduce the amount of leakage past the gates in these locations.

9. Consideration should be given to sandblasting, repairing and recoating the gates while the area is dry and access is optimal.

10. Consideration should be given to repairing the concrete beams supporting the Operator's deck above the spillways while the area is dry and access is optimal.

Inspection Tunnel

1. Remove the mud from the floor of the tunnel and inspect tunnel floor for signs of cracking or differential movement.

Areas in Need of Repair and Evaluation Following Restoration of the Pool

The following items are in need of repair, but could be delayed until after the dam is returned to service. If the dam is not immediately returned to service, these items should be evaluated and performed within the next 5 years to slow the advancement of deterioration in the existing facility.

Powerhouse Structure

1. Perform concrete repairs and repair or replace embedded steel items on the upstream side of the structure.

2. Remove the roadway above the Powerhouse and repair the deteriorated concrete roof structure.

3. The Powerhouse roof should be waterproofed and sloped to drain.

4. The roadway above the Powerhouse roof could be reconstructed, or replaced with an alternative system that will allow access to the remaining structure for maintenance.

5. Cracks and other deterioration observed in the concrete walls should be repaired.

6. The corroded steel stairs and railings in the Powerhouse should be repaired and repainted, or replaced.

7. Metal items embedded in concrete that are significantly corroded should be repaired or replaced.

8. The existing overhead bridge crane should be repaired and repainted.

Gated Spillways

1. If not completed prior to retuning the dam to service, the existing gates should be retrofitted with rubber side seals to reduce the amount of leakage past the gates in these locations.
2. If not completed prior to retuning the dam to service, the existing gates should be sandblasted, repaired and recoated.
3. If not completed prior to retuning the dam to service, the concrete beams supporting the Operator's deck above the spillways should be repaired.

While above recommendations were primarily based upon safety or operational concerns and structures' integrity, other criteria such as preservation of structure, structure lifecycle, environmental, aesthetics, etc. should also be considered when monitoring/ maintenance/repair is programmed.

Conclusions

Stanley Consultants performed visual inspections of accessible portions of the concrete dam. The dam needs repair, but does not show obvious signs of significant structural defects or differential movement.

In our opinion, the remaining concrete dam structure is serviceable and could be returned to service upon completion of the recommended repairs and additional Underwater Inspections. Should the additional Underwater Inspections reveal hidden damage and/or undermining of the dam, repairs should be made prior to returning the dam to service.

The July 2010 flood subjected the dam to severe conditions that could have damaged or undermined the dam in ways that cannot be readily observed from a visual inspection. If the dam is returned to service, it should be monitored while the pool is restored to identify spreading of existing cracks, differential movement within the structure and seepage under the foundation.

A survey of the structure prior to filling the pool should be completed to serve as a reference for monitoring structure movement. Divers could be used to inspect for signs of seepage under the dam during filling.

Respectfully submitted,

Stanley Consultants, Inc.

Prepared by Daniel R. Dreyer P.E.
Daniel R. Dreyer, P.E.

Approved by William E. Holman
William E. Holman, P.E.