

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS
PHASE II 2017 DAM SAFETY INSPECTION REPORT
Lake Lure Dam and Appurtenances
Town of Lake Lure, North Carolina
Project No. ME – 16 – 006

Prepared for:

**Mayor Kevin Cooley and Town Council of Lake Lure;
Mr. Ron Nalley, Town Manager;
and Town Department Directors**

Prepared by:

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February 12, 2018

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Introduction

Leaders in the discipline of Civil Engineering; associated sub-disciplines; and businesses of dam design, construction, operation, maintenance, and safety have reached general agreement on loading conditions that should be used to determine factors of safety of dams and the numerical values of factors of safety that are acceptable for various loading conditions.

The currently accepted loading conditions for determination of factors of safety of dams include, but are not limited to, the following:

- **Normal Loading** – Often referred to as “Sunny Day”- Loading
Conditions: Normal Water Surface Elevation (NWSE); No Storm Conditions; No Maintenance or Construction Activities; and No Earthquake or Geological Conditions.
- **Unusual Loading** - Generally associated with a pre-determined Flood event based upon the Hazard Classification of the dam [Spillway Design Flood (SDF); or Inflow Design Flood (IDF); etc.]
- **Extreme Loading** - Pre-Determined Design Magnitude Earthquake

The currently accepted minimum values for factors of safety for each of the loading conditions are as follows:

- Normal Loading Condition - Minimum Factor of Safety = 3.0
- Unusual Loading Condition - Minimum Factor of Safety = 2.0
- Extreme Loading Condition - Minimum Factor of Safety = 1.0

Consideration must also be given to anticipated modes of failure for various types of dams. Quite obviously, a concrete gravity dam is not going to fail as a result of a slope failure in the downstream slope because there is no earthen downstream slope. Conversely, an earthen dam is not likely to fail by overturning since the dam embankment does not exhibit sufficient internal strength to act as structural component. But, concrete slab and buttress dams such as Lake Lure Dam may be subject to failure by sliding along the contact of the foundation and foundation bearing material. Likewise, a concrete dam of any type may be subject to failure as a result of inadequate strength or quality of the concrete, reinforcement steel, or configuration of a structural element. Furthermore, both a concrete dam and an earthen dam may be subject to failure as a result of inadequate spillway capacity to safely pass the Design Spillway Flood (DSF). As such, the dam engineer must assess the dam in question to determine conditions that must be evaluated in the dam safety analyses of a particular dam. These evaluation considerations fall into at least three (3) categories of dam behavior. These categories include, but may not be limited to, the following categories depending upon the type or composition of the dam:

a) component considerations (overturning, sliding, slope failure, etc.);

b) integrity considerations (internal strength and quality of materials);

and; c) performance and operation (erosion, leakage, seepage & aging).

The primary categories of dam safety evaluations used for Lake Lure Dam consisted of stability or component evaluations associated with overloading of the slab-and-buttress systems thus resulting in overturning of specific buttresses or sliding of particular buttresses as a result of overloading, loss of strength of foundation bedrock with age, or build-up of excess hydrostatic uplift pressure as a result of joint and fraction system deterioration with age. Stability analyses and evaluations of safety factors are presented in tabular form in the following section of this report. Factors of safety are presented in the order of Normal, Unusual, and Extreme where multiple factors of safety are presented for a given location.

The presentation of analytical evaluations will begin at the left abutment (facing downstream) and continue to the right abutment. There are a few; but not many, dam components and/or locations that require no maintenance or remediation construction; however, these areas will be included with a minor comment so that there will be less likelihood that other locations that do require some upgrade construction are not left out of the presentation progression.

The ratings for priority of remediation or construction are High, Medium, Low, and Long-Term. A High priority rating means that remediation construction work shall be initiated within the next year (2019). Medium priority work shall be completed within the next two (2) years (2020). Low priority work shall be completed within the next three (3) years (2021), and Long-Term priority work shall be initiated within the next four (4) years (2022). In no case shall a lower priority activity be scheduled ahead of a higher priority rated activity.

<u>Location/Component</u>	<u>Factors of Safety</u>	<u>Priority</u>
• Left Abutment Wingwalls	3.06; 3.05; & 1.35	Medium
• Ogee Spillways/Flood Gates	3.0; 3.0; & 2.0	Long-Term
• Left Abutment Access Road	N/A	High
• Spillway Channel Realignment	N/A	Medium
• NCDOT Buffalo Shoals Bridge	N/A	High

Dam and its appurtenances (Buffalo Shoals Road Bridge) cannot withstand another major storm event such as either Hurricane Francis or Hurricane Ivan in 2004, or an earthquake event having a Richter Magnitude of approximately 5.0 that would be about two (2) points higher than the 2007 Magnitude 3.1 earthquake event.

The first step in preparation for emergency action has already been taken without emphasis on the degree of emergency preparedness necessary. Mr. Donnie McCraw, Operator of Lake Lure Power Plant requested Mr. Charles Mierek and Dr. Marks to prepare Operation & Maintenance (O&M) Plans for both the Hydroelectric Power Generation Facilities; and Lake Lure Dam and Its Appurtenances. At the time of this request, Mr. McCraw did not know the critical state of the dam and hydroelectric power generation plant. As such, the requested O & M Plans must be elevated to include an Emergency Operation and Inspection Section of the document. This effort must be initiated immediately and implemented by April 1, 2018.

The next sequential tasks to be completed in the overall remediation of Lake Lure Dam and its appurtenances shall consist of a series of repetitive activities involving dam remediation design and dam remediation construction. This major remediation project has been divided into a minimum of four (4) approximately one-year phases. The first phase of the project design shall begin as soon as practical but no later than April 2018. This should allow sufficient time for preparation of the Phase I Construction Plans and Specifications and approval by the North Carolina Dam Safety Engineer by August 2018. This schedule should allow sufficient time for selection of a Contractor that can begin work on the Phase I Construction Project by September 2018. The Phase I Dam Remediation Construction Project would extend through August or September 2019 when the Phase II Dam Remediation Construction Project would have been approved for initiation of project work. This sequential, repetitive design/construction process will be continued through the minimum four (4) construction phases by Fall 2022, or Winter 2023.

The anticipated scope of work for each of the phases of construction is presented in the following section of this report. Changes in the scope of work for each phase of a project involving as many activities and spanning as long of a time period as anticipated for the Lake Lure Dam Remediation Construction Project are surely to occur; however, maintaining control over the number and significance of changes in scope of work will be one of the major challenges for the Project Engineer/Consultant.

Phase I Dam Remediation Construction Activities (2018-2019)

- **Modification of the Main Entrance Road at the Dam**
- **Pressure Injection Grouting of Bays No. 9, No. 10, and No. 11**
- **Install Subsurface Drainage Systems (Bays No. 9 – No. 11)**
- **Modify Surface Water Drainage in Bays No. 12 & No. 13**
- **Miscellaneous Repairs of Powerhouse Floor Slabs and Walls**
- **Construction of Restroom Facilities in Bay No. 8**
- **Reinforcement of Buttress No. 9 in Bay No. 8 (Shear Crack)**
- **Coordination with NCDOT Installation of Six (6) Safety Nets**
- **Finalize Negotiation of Bridge Transfer from NCDOT**

Phase II Dam Remediation Construction Activities (2019-2020)

- **Construction of Downstream River-Crossing of Access Road**
- **Construction of Left Abutment Access Roadway**
- **Construction of Spillway Discharge Outlet Channel**
- **Pressure Injection Grouting of Powerhouse Penstock Room**
- **NCDOT Transfer of Buffalo Shoals Bridge to Lake Lure**

Phase III Dam Remediation Construction Activities (2020-2021)

- **Stabilization of Left Abutment Wingwalls**
- **Pressure Injection Grouting of Bay No. 4**
- **Extension of Buttress No. 4 & Beginning of Spillway Channel**

- **Surface Water Drainage Improvements at Right Abutment**
- **Install Two (2) Safety Nets over Powerhouse & one (1) Net in Each of Two (2) Bays on Each side of the Powerhouse**

Phase IV Dam Remediation Construction Activities (2021-2022)

- **Pressure Washing & Injection Grouting of All Joints**
- **Pressure Injection Grouting of Bay No. 5 (Sewer Line)**
- **Installation of any Remaining Safety Nets**
- **Dredging of Tailrace (Powerhouse to River Crossing)**
- **Construct Thickened Reinforced Concrete Bridge Deck**

2022 Dam Safety Inspection and Subsequent Five (5) – Year Inspections

Completion of the Lake Lure Dam Remediation Project will mark the fifth (5th) Anniversary of the 2017 Dam Safety Inspection of Lake Lure Dam. This 5th Anniversary plus the successive five-year anniversaries for the next twenty five (25) years shall be marked by conducting an Independent Consultant Dam Safety Inspection of Lake Lure Dam. The currently recommended dam remediation construction project is anticipated to provide desirable operations and performance for about fifty (50) years (until about 2068). However, the next major action to be taken with Lake Lure Dam will likely be to replace the existing dam with a dam located downstream of the existing dam. Replacement of a dam of the magnitude and cost of Lake Lure Dam will require a significant amount of lead time to make decisions about dam type, exact location, purchase of property, and design of the dam and its appurtenances. As such, conducting detailed inspections on a five (5) year time interval is not an unusually long period of time to monitor the performance of a dam that had to be remediated from a very low level of stability and performance to gain the additional life span.

One of the most, if not the most important concept for the Project Engineer/Consultant to be constantly cognizant of throughout both design and construction is the benefit – to – cost ratio as related to the planned and/or accomplished extended service life of the dam, its appurtenances, and supported capital facilities such as water supply, hydroelectric generation, or aquatic product markets. For example, it is not an economical benefit to utilize low quality materials and construction methodologies that are less costly but have no chance of lasting through the extended service period. These types of mistakes can put an undesirable strain on the operation and maintenance budget and the project becomes unbalanced as a result of unnecessary major variances in dam remediation construction costs. Conversely, some Project Managers, Project Engineers, and Consultants often go beyond wise expenditure of funds and purchase materials and equipment that will long outlast the predicted extension of service life. This practice has a reverse effect on the project by using construction fund beyond the actual need thus putting the long-term or ending budget in jeopardy thus forcing the utilization of cheaper low-quality products.

Dr. Marks has attempted to walk the middle ground in providing cost estimates for construction of the required dam remediations. In addition, he is confident that he has planted the right seed with the NCDOT to modify the Buffalo Shoal road bridge over Lake Lure Dam, prior to turning the bridge over to the Town of Lake Lure with a bonus of at least \$500,000.00 to assist the Town in making future repairs and maintaining the bridge as a closed-road structure. If this comes to fruition, the bridge could be closed to traffic and made into a pedestrian toll-walkway retrofitted to allow individuals and group to come and observe dam remediation construction work. This is a project that the citizens of Lake Lure could undertake during the four-year construction phase. There will be hundreds that come to watch the equipment operate. Adding a couple of telescopes or spotting scopes to each side of the bridge would likely raise the ante to \$5.00 a person per hour. Obviously, cold drinks and water in the summer would be great along with hot coffee and cocoa in the winter.

After the projects were completed, another group of citizens could convert the construction watching theme into “A Walk Through History” highlighting the dam, its construction, and the people that pulled it all together. These are some thoughts thrown in to reply to a question by Mr. Ron Nalley on February 2, 2018 paraphrased as “Can you think of some ideas that citizen groups could do to contribute to the dam remediation.” In both instances a one-way lane could remain open to allow access to the gates at the left abutment of the dam.

Estimation of construction costs prior to development of dam remediation plans is somewhat of a tough assignment. Fortunately, the dam remediation procedures and methodologies that will be used at Lake Lure Dam will likely be some of the same types of construction that are used quite frequently to remediate older dams. As such, the costs of most of the required procedures that will have to be utilized in the Lake Lure Dam remediations are known from experience on other dam remediation projects. Presented below are the ranges of construction costs anticipated for each phase of the overall project along with the average of the range of estimated costs and a running total of the average costs for each of the phases of the overall project.

Marks Enterprises is of the opinion that we can do the engineering design for a cost of about seven (7) percent of the estimated construction cost as opposed to the normal rate of ten (10) percent used by the Town Council for estimation of construction cost. Similarly, a cost of eight (8) percent of the construction costs was used for estimation of construction services fees as opposed to ten (10) percent currently used. Construction services during construction of the project will entail regular monitoring and inspection of critical construction activities, sampling and testing of materials, and providing technical review of requested field changes proposed by the Contractor during the course of construction. In addition to these activities, the Project Engineer with assistance from the Contractor, will prepare a set of Drawings-of-Record to be submitted to the Town of Lake Lure and to the Regional Office and Central Office of the State Dam Safety Program. Marks Enterprises will make every effort to maintain engineering fees within the presented limits.

Estimated Dam Remediation Construction Costs for Lake Lure Dam

- **Phase I Dam Remediation Costs (September 2018 through August 2019)**

\$ 1,350,000.00 to \$ 1,550,000.00 Average: \$ 1,450,000.00

- **Phase II Dam Remediation Costs (September 2019 through August 2020)**

\$ 1,500,000.00 to \$ 1,800,000.00 Average: \$ 1,650,000.00

Running Total Average: \$ 3,100,000.00

- **Phase III Dam Remediation Costs (September 2020 through August 2021)**

\$ 900,000.00 to \$ 950,000.00 Average: \$ 925,000.00

Running Total Average: \$4,025,000.00

- **Phase IV Dam Remediation Costs (September 2021 through August 2022)**

\$ 375,000.00 to \$ 525,000.00 Average: \$ 450,000.00

Running Total Average: \$4,475,000.00

Total Range of Entire Project: \$4,125,000.00 to \$4,825,000.00

Potential Contribution by NCDOT: \$ 500,000.00 to \$ 1,000,000.00

