

April 8, 2016

Ms. Melinda King PE
City of Greensboro
2602 S. Elm-Eugene Street
Greensboro, NC 27406

**Subject: P5821085.00, Lake Brandt Dam Gate Operations and Risk Analysis
Guilford County, North Carolina**

Dear Ms. King:

SCHNABEL ENGINEERING SOUTH, P.C. (Schnabel) is to submit this proposal for professional engineering services for the above referenced project. This proposal has been prepared in response to our recent meeting.

PROJECT DESCRIPTION

The flooding in South Carolina (Hurricane Joaquin) in early October 2015 prompted the City of Greensboro to take a closer look at their water supply dams' condition and operations. The City of Greensboro concluded that the Lake Brandt Dam's current condition, long term needs and gate operations plan are their main areas of concern. To address these concerns, Schnabel has prepared this proposal to review the current gate operations plan, perform a risk assessment of Lake Brandt Dam, and develop of recommendations for modifications to their current gate operations plan and long term recommendations for risk reduction measures.

OBJECTIVE AND SCOPE OF SERVICES

Task 1: Gate Operations Plan and Workshop

Updating the Gate Operations Plan will be performed in two parts. The first will be a 1 day workshop with City of Greensboro staff. The second will be to revise the current plan based on the discussions and outcome of the workshop. The goal of the workshop will be to review current gate operation procedures and see what the hypothetical outcomes would be during a simulated storm event similar to Hurricane Joaquin. Based on the results, a gate operations plan will be developed to provide guidance on when and how much to open gates during future storm events.

Gate Operations Workshop

The following tasks will be performed in advance of the workshop:

- We will perform a rainfall analysis of Hurricane Joaquin transposed over the City of Greensboro watershed. This will involve taking the watershed model originally developed for the Lake Townsend Dam replacement project and revising it so that it simulates a storm similar in magnitude and duration as Hurricane Joaquin.
- We will review and revise as necessary the gate capacity rating curves previously developed by Hazen and Sawyer in the previously developed gate operations plan.
- We will develop a reservoir storage and spillway hydraulic model for Lake Brandt Dam. This model will be adopted from other models previously developed by Schnabel to evaluate the Lake Townsend Dam replacement project and the Lake Brandt Dam Emergency Action Plan. We will also include analysis of the Reedy Fork USGS stream gage. This model will also include models of Lake Brandt Road and Lake Townsend.

Once the above items are prepared, Schnabel will host a workshop with the City of Greensboro staff.

During the workshop, various model simulations will be run based on the Lake Brandt water level and on when and how much to open gates. As a simulation is performed, the gate openings will be adjusted based on decisions made by City of Greensboro staff to demonstrate how gate operation decision affect spillway discharges, and water levels upstream and downstream of Lake Brandt Dam. Once a simulation is complete, we will discuss what worked well and what can be improved. Subsequent simulations will be run based on the results of the discussion. At the conclusion of the workshop and multiple simulations, the basis for the gate operations plan will be discussed. This discussion will include the following items.

- Overall goals and priorities
- Realistic response times
- Available resources
- Preferred decision making tools

Gate Operations Plan

Based on the results of the workshop, we will revise the gate operations plan for Lake Brandt Dam to assist Greensboro staff in the event of a large storm event. The plan will include guidance to be used in advance of a storms arrival and during the event. The plan will be in a format determined at the workshop by Schnabel and City of Greensboro staff.

Task 2: Potential Failure Mode Analysis and Risk Evaluation

Information Review and Gathering

Schnabel will develop a list of potential failure modes for Lake Brandt Dam. Schnabel will review available documentation and gather reference material specific to the potential failure modes being evaluated. This will include available information from Schnabel's past work, NC Dam Safety, and other documents or information the City of Greensboro has. The proposed coring of the Lake Brandt spillway and detailed gate inspections will be reviewed and considered. Details related to the Lake Brandt Bridge and roadway

alignment will be obtained and reviewed, if available. In addition, some analyses will be performed to assist with the evaluation and estimation of probability for various potential failure modes. Schnabel will use the gathered information to develop hypothetical failure modes for the individual components of the dam. Various loading conditions will be evaluated. Operational failure modes will also be considered.

We will meet with City of Greensboro personnel (maintenance, operators, supervisors, decision makers, etc) to discuss operations and performance of the dam.

We will review the dam breach inundation study previously prepared by Schnabel to evaluate the consequences of failure for select dam failure scenarios. Breach analyses and inundation maps. Analyses have been performed for a sunny day failure (static and seismic) and for a SDF failure of the dam. The Emergency Action Plan (EAP) currently in use will be reviewed. Consequences include loss of life, loss of water supply, property damage, and environmental damages. Additional dam breach analyses may be performed for storms identified in the PFMA to consider storms smaller than the SDF, if needed. We will not develop inundation maps for these scenarios.

Population at Risk (PAR) estimates will be developed using the existing inundation study, GIS mapping tools, and census data as available. Potential Life Loss (PLL) will be estimated using the PAR estimates and fatality rates, considering warning time and flood severity, based on Bureau of Reclamation (Reclamation) procedures (DSO-99-06). An appropriate confidence level will be assigned for each estimate.

Property and environmental damage will be estimated on a qualitative basis. We will discuss the consequence of lost water supply storage for the various potential failure modes with the City of Greensboro. It is anticipated that we will prepare a simple event tree to evaluate the effect of various return period droughts on the consequences. The loss of storage may not be significant if it occurred during a very wet year. However, if the loss of storage occurred during a drought, the consequences to water supply could be devastating.

Potential Failure Model Analysis Meeting and Risk Workshop

A PFMA review meeting will be held with representatives from the City of Greensboro, and Schnabel. The purpose of this meeting will be to review the various potential failure modes that were developed, the factors that make these potential failure modes more likely or less likely, and the risk reduction measures that were identified. We will develop factors that make the failure more likely and less likely, discuss possible interventions that would prevent failure, and the ability to perform surveillance and monitoring to detect developing failure modes. Likely consequences of each potential failure mode will be discussed. Photographs, plans, maps, and previous reports and analyses will be available to aid in the discussion, as needed.

A Risk Workshop will be held following the PFMA review meeting. During the Risk Workshop, simple event trees will be developed by the risk evaluation team for each of the selected PFMs. The event trees will include various nodes in the following general sequence:

Loading Condition → Initiation → Continuation → Progression → Release of Reservoir

Each node of the event tree will be discussed by Schnabel and City of Greensboro staff to provide a better understanding of the likelihood (probability) of the event occurring, including the identification of more likely and less likely factors. The workshop will focus on Lake Brandt Dam; however some consideration will be given to failure modes for Lake Higgins as they may affect Lake Brandt. Potential intervention actions that could prevent or delay an uncontrolled reservoir release will also be discussed.

The proposed approach will use Failure Likelihood Descriptions (very high, high, moderate, low, very low, and remote) to evaluate each of the identified PFMs. Common probability estimates for each of these categories have been developed and are presented in guidelines by the Bureau of Reclamation (2013) and in RIDM Training Workshops by FERC. The group will assign a probability to each node of the event tree to estimate the probability of failure. The computer program @RISK will be used to perform this exercise.

To aid participants in assigning appropriate loading probabilities, Schnabel will review available flood frequency and probabilistic seismic hazard information for the project, and develop a reservoir exceedance curve. The probability of these triggering events will be a key factor for the determination of the Annualized Failure Probability (AFP) and Annualized Life Loss (ALL) for each PFM. The initiation of static failure modes, such as internal erosion through the embankment or foundation at various locations, may be more difficult to estimate and will require more discussion from the technical experts. For each PFM, the key factors will be discussed with the technical experts and other team members. Once consensus is obtained by the risk evaluation team, the results will be recorded along with an estimate of the confidence (Low, Medium or High) for each PFM evaluated.

The mean estimates for AFP and for life loss for each PFM will be plotted on a risk decision matrix. The confidence of the estimates will be graphically shown. These graphs will be summarized in our report, which will also include a written description of the risk assessment process, justification for the decisions made, summary of the results, and recommendations for additional analyses or for risk reduction measures.

Task 3 –Timeline and Cost Estimate for Rehabilitation or Replacement

The condition of the various components will be analyzed or inspected as part of the preparation of the PFMA discussed in Task 2. During the development of the PFMA, the deficiencies associated with the dam will be identified. Using this information, Schnabel will prepare an estimated timeline and cost estimate for Rehabilitation or Replacement of the Lake Brandt Dam. Currently, NC Dam Safety has agreed that the Lake Brandt Dam does not need to be modified due to inadequate spillway capacity because of improvements to the Lake Townsend Dam immediately downstream. Recommendations for rehabilitation or replacement will be based on a qualitative assessment of the risk analysis performed, operational and performance concerns identified, and input from the City of Greensboro. The recommendations will also include a timeline and priority list for the recommended improvements.

A conceptual level evaluation of alternatives will be performed to address the various deficiencies identified. A typical layout and cross sections of major components (embankment, spillway, etc) will be provided of the proposed improvements. The cost estimate will be considered a Level 4 cost estimate and is expected to have accuracy on the order of -30 to plus 50 percent. It is anticipated that this estimate will be provided to serve as a place holder in the City's Capital Improvement Plan.

M/WBE EXCLUSION

In accordance with The City of Greensboro's Minority/Women Business Enterprise Program to promote the economic inclusion and full and equitable utilization and development of firms that engage in business with the City in the Greensboro marketplace, Schnabel Engineering has shown good faith efforts in the pursuit of eligible firms qualified to assist in this unique design-specific dam engineering project.

After interviewing several firms listed in the 10 county area designated by the City as eligible candidate's and further discussion with the City of Greensboro Water Resources and M/WBE staff, it was determined that none of the firms found on the list were qualified to perform the work or had the required expertise to assist in this particular project.

We have listed below the firms we met with over the past few weeks to discuss this unique project:

- Chester Engineering, Darnetta Craig
- Critek Engineering, Dawayne Crite
- Westcott, Small & Associates, Tori Small

PROJECT FEES

Our fees are summarized below and are for the specific scope of services detailed herein. The fee for work requested beyond the scope of services included herein will be based on our current unit prices at the time the work is authorized or a negotiated lump sum. Our current Schedule of Personnel Fees is included as Enclosure (1). Our Standard Contract Terms and Conditions of Enclosure (2) will apply to services to be provided under this proposed agreement.

Breakdown of Fees

Task	Fee Type	Fee
Task 1 – Gate Operations Plan and Workshop	Lump Sum	\$ 32,500
Task 2 – PFMA and Risk Evaluation	Lump Sum	\$ 83,400
Task 3 – Timeline and Cost Estimate for Rehabilitation or Replacement	Lump Sum	\$ 26,600
Total Lump Sum Fee		\$142,500

Invoices will be submitted monthly as a percentage of completion of the lump sum fee, or at intervals when considerable time charges have accrued, with a final invoice submitted after completion of the services outlined herein. Payment will be due on receipt of our invoices and will be considered past due 30 days after the invoice date. Payments will not be contingent on receipt of funds from third parties. Interest at 1.5% per month will be charged on all overdue amounts. Please note that this proposal considers the payment terms as stated will be met. Should alternative payment terms be desired, they will have an impact on the costs associated with this work.

We appreciate the opportunity to submit our proposal for these services and are looking forward to a cordial working relationship for this engagement. Please contact our office if you have any questions with

**City of Greensboro
Lake Brandt Dam Risk**

regard to this proposal. Your acceptance of this proposal by signing and returning one copy of this letter will form our agreement for these services.

Sincerely,

SCHNABEL ENGINEERING SOUTH, P.C.



Thomas J. Fitzgerald, PE
Senior Vice President

LS:TF/gcr

Attachments:

- (1) Schedule of Personnel Fees
- (2) Standard Contract Terms and Conditions (2 Sheets)

The terms and conditions of this proposal, including the attached Standard Contract Terms and Conditions are:

ACCEPTED BY: _____ **City of Greensboro**

SIGNATURE: _____

PRINTED NAME: _____

TITLE: _____ **DATE:** _____