GeoSyntec Consultants

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18 September 1998

Mr. Dallon Thomas Woosley, P.E.
Environmental Engineer
Safe Dams Program
Environmental Protection Division
Georgia Department of Natural Resources
Atlanta Tradeport, Suite 110
4244 International Parkway
Atlanta, Georgia 30354

RECEIVED
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DAM SAFETY

Subject: Scope of Work
Lake Petit Dam

Dear Mr. Woosley:

Pursuant to your request at the 10 September 1998 meeting for the Lake Petit Dam project, GeoSyntec Consultants (GeoSyntec) is pleased to present the Georgia Safe Dams Program with this letter summarizing the scope of work that we intend to undertake to further evaluate the slope stability conditions of the dam and potential rehabilitation measures to increase dam stability. The remainder of this letter addresses the following scope of work items:

- additional field investigation;
- embankment fill shear strength evaluation;
- steady-state seepage evaluation;
- static slope stability evaluation;
- seismic slope stability and deformation evaluation;
- evaluation of dam rehabilitation alternatives; and
- preliminary schedule for dam rehabilitation program.

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ADDITIONAL FIELD INVESTIGATION

GeoSyntec will perform an additional field investigation of the Lake Petit Dam embankment structure for purposes of developing additional data for the steady-state seepage and static and seismic slope stability analyses described subsequently. GeoSyntec plans to consult with Mr. Karl Myers of Piedmont Geotechnical Consultants during development of the detailed field investigation plan. The investigation program will involve advancing four to five soil borings on the crest and downstream face of the dam. Standard penetration tests (SPTs) performed in accordance with ASTM D 1586 will be obtained in each borehole at approximate 5 ft (1.5 m) vertical intervals. In each borehole, thin-walled ("Shelby") tube samples will be attempted (in accordance with ASTM D 1587) at approximately 10 ft (3.3 m) vertical intervals.

Standpipe piezometers will be installed in three of the boreholes. Each of these boreholes will contain two to three PVC standpipes screened at select elevations within the embankment fill and foundation.

In addition to the foregoing, the field investigation will include evaluation of other pertinent features. At a minimum, this will include:

- examination of all visible drainage features, and estimation of flow rates;
- visual examination of the downstream dam slope, noting any areas of sloughing, varying vegetation types (used as an indirect indication of differing surficial moisture content); and
- examination of the creek bed immediately downstream of the dam to identify any visual signs of upward flow due to vertical pressure gradients.

EMBANKMENT FILL SHEAR STRENGTH EVALUATION

Previous slope stability analyses for Lake Petit Dam characterized the shear strength of the embankment fill material using an effective stress friction angle, ϕ', of

30°. This value of ϕ' was identified in the Piedmont Geotechnical Consultants, Inc. report of 3 February 1998 as a conservative shear strength parameter to use in the absence of project-specific testing.

GeoSyntec plans to perform a project-specific material evaluation to further assess the above value of ϕ'. The evaluation will have two components: (i) laboratory shear strength testing; and (ii) correlation to SPT blow counts (N values). Each of these is described in more detail below. GeoSyntec plans to consult with Mr. Myers during development of the detailed laboratory testing plan and evaluation of test results.

Up to six consolidated-undrained triaxial compression test series with pore pressure measurement (ICU triaxial tests) will be performed in accordance with ASTM D 4767. The tests will be performed at GeoSyntec's Geomechanics and Environmental Laboratory in Alpharetta, Georgia. For each test, an attempt will be made to extrude the thin-walled tube samples to obtain undisturbed soil specimens for testing. A geotechnical engineer from GeoSyntec will observe the extrusion process and make a determination as to whether a sample will be tested using undisturbed specimens from the sample, or instead, whether the sample is considered to be disturbed. In the latter case, the entire thin-walled tube sample will be reworked and recompacted and test specimens will be trimmed from the recompacted material for testing. The moisture and density conditions for any such recompaction will be selected based on the original construction specifications for soil compaction in the dam shell and core, standard Proctor compaction test results for original soil borrow areas, and, potentially, additional standard Proctor compaction tests performed by GeoSyntec.

SPT N Value Correlation

SPT N values were recently obtained at four locations along the crest and downstream face of the dam by Piedmont Geotechnical Consultants, Inc. GeoSyntec will supplement this existing database by obtaining additional SPT N values as described in the previous section of this letter.

As part of the evaluation of the shear strength of the embankment fill, GeoSyntec will use empirical correlations to relate ϕ' to the measured SPT N values. Based on experience, GeoSyntec proposes to use two independent correlations, both applicable to residual silty sands. The first correlation, developed by Professor J.H. Schmertmann at the University of Florida, is given by the equation:

$$\phi' = \tan^{-1}[N/(12.2 + 20.3\sigma'_{vo}/P_{atm})^{0.34}$$

where ϕ' is the friction angle of the soil, N is the measured SPT N value, σ'_{vo} is the vertical effective stress in the ground, and P_{atm} is atmospheric pressure (=2,117 psf). The second correlation, developed by Japanese researchers, is given by the equation:

$$\phi' = \sqrt{15.4(N_1)_{60}} + 20°$$

where $(N_1)_{60}$ is the SPT blowcount value, N, adjusted to account for in-situ stress level and SPT hammer efficiency.

STEADY-STATE SEEPAGE EVALUATION

Steady-state seepage analyses (i.e., flow net analyses) will be performed using the PC-based computer program SEEP/W. SEEP/W is based on the finite element method of analysis and can be used to model water movement (seepage and porewater pressure distribution) within porous materials such as soil and rock. Both saturated and unsaturated flow problems can be analyzed. SEEP/W is well-suited for modeling unconfined flow such as the case of flow through an earth dam.

Issues related to the analysis of the Lake Petit Dam that can be evaluated using SEEP/W include: (i) variations in horizontal and vertical permeability of compacted soils; (ii) geometry of the core/shell and soil/rock interface; (iii) differing permeabilities of the core, shell, and foundation layers; (iv) position of the phreatic (zero pore pressure) line; and (v) influence of drains on pore pressures within the dam. SEEP/W permits rapid interpretation of results through various forms of graphical output.

Actual pore pressure data is presently available for the twelve discrete piezometers installed at existing instrumentation locations (P-2, P-4, P-6, and P-7). Additional data obtained through the previously described field investigation program will be used to supplement the existing database. The SEEP/W program will be used to develop a site-specific model of the existing, pre-rehabilitation seepage regime. Existing and new data will be used for model refinement and validation purposes.

Once the model has been validated as providing a reasonable representation of present conditions, it will be used to develop a pore pressure distribution grid for use in both the static and seismic slope stability evaluations. The benefits in using this approach include:

- pore pressure distributions within the dam can be accurately simulated; this is important since it allows appropriate use of the slope stability software (XSTABL) in identifying the critical potential slip surface (note: the user manual provides specific guidance with respect to the preferred use of pressure grids as opposed to discrete piezometric surfaces when using the software to search for critical potential slip surfaces); and
- the validated model can also be used for the evaluation of various rehabilitation measures.

STATIC SLOPE STABILITY EVALUATION

GeoSyntec will perform static (steady-state) stability analyses of Lake Petit Dam to determine the factor of safety for the dam in both its current state and after rehabilitation.

Steady-state stability analyses will be performed using the PC-based computer program XSTABL. XSTABL is a widely-used, fully-integrated version of the slope stability analysis program STABL originally developed at Purdue University. XSTABL can be used to perform two-dimensional limit equilibrium analyses to compute the factor of safety for a layered soil slope, dam, or embankment using either the simplified Bishop, simplified Janbu, generalized Janbu, or Spencer method of analysis. The program incorporates a search routine to identify the most critical potential slip surface.

Input parameters to the slope stability analyses will include dam geometry, soil unit weights, soil shear strength, and pore pressure distribution in the dam. Dam geometry will be obtained from available maps and survey information. Soil unit weights will be estimated from previous and proposed laboratory test results and experience. Soil shear strengths will be conservatively estimated from SPT N values and ICU triaxial test results as previously described in this letter. The pore pressure distribution in the dam will be estimated using the results of the steady-state seepage analyses described previously.

SEISMIC SLOPE STABILITY EVALUATION

GeoSyntec will perform seismic stability and deformation analyses of Lake Petit Dam to determine the factor of safety for the dam in its current state and after rehabilitation. The proposed Georgia Safe Dam rules call for a minimum factor of safety of 1.1 for the steady-state seepage with seismic loading condition. The proposed rules provide the following additional requirements and flexibility.

> *"All dams and appurtenant structures shall be capable of withstanding seismic accelerations defined in the most current "Map for Peak Acceleration with a 2% exceedance in 50 years" for the contiguous United States published by United State Geological Survey (a.k.a. NEHRP maps). The minimum seismic acceleration shall be 0.05g. The seismic accelerations may be reduced or seismic evaluation eliminated if the applicant's engineer can successfully demonstrate to the Director by engineering analyses or judgment that smaller seismic accelerations are appropriate or no seismic evaluation is needed."*

GeoSyntec will utilize the rule flexibility cited above in the evaluation of seismic stability. The approach that will be used involves four steps as discussed below: (i) establish peak (horizontal) bedrock acceleration at the dam site; (ii) perform seismic response analysis of dam and calculate the peak average accelerations along potentially-critical slope stability slip surfaces; (iii) calculate yield acceleration for each potentially critical slip surface and compare to the previously-calculated peak average accelerations; and (iv) if needed based on the results of the pervious step perform seismic deformation analyses of the dam. Each of these steps is described in more detail below.

The peak bedrock acceleration at the project site will be obtained from the most recent version of the seismic hazard probability maps prepared by the United States Geological Survey for the National Earthquake Hazard Reduction Program. The peak bedrock acceleration will be selected using the map for "Peak Acceleration (% g) with 2% Probability of Exceedence in 50 Years". The peak bedrock acceleration for the Lake Petit Dam site (34° 27' 45" N latitude, 84° 17' 25" W longitude) based on this map is 0.183 g.

Seismic response analyses of Lake Petit Dam will be performed using the PC-based computer program SHAKE. SHAKE was originally developed in the 1970s by Professor H.B. Seed and his coworkers at the University of California, Berkeley and updated in the early 1990s by professor I.H. Idriss at the University of California, Davis. SHAKE is the most widely used computer program for one-dimensional seismic response analysis of earth dams and other soil structures. The SHAKE model is used to idealize a dam-foundation system as a series of homogeneous, visco-elastic, horizontal sublayers. The response of this system is calculated considering vertically propagating shear waves. An equivalent linear procedure is used to account for the nonlinearity of soil shear modulus and damping ratio using an iterative procedure to obtain values that are compatible with the equivalent uniform strain induced in each sublayer. At the outset, a set of properties (shear modulus, damping, and total unit weight) is assigned to each sublayer of the dam and foundation. The analysis is conducted using these properties and the shear strain induced in each sublayer is calculated. The shear modulus and the damping ratio for each sublayer are then modified based on the applicable relationship relating these two properties to shear strain. Basic input to SHAKE includes the dam and foundation profile, soil properties, and earthquake acceleration-time histories. Embankment fill and foundation soil parameters will be defined using published empirical relationships between the various parameters and soil index properties, such as grain size distribution and Atterberg limits. Soil index properties will be obtained from site-specific laboratory test results.

The acceleration time histories used for the SHAKE analyses will be selected using a two-step process. First, the range of expected characteristics of an earthquake having a 2% probability of exceedance in a 50-year period will be defined. The characteristics to be considered will include earthquake source mechanism, peak bedrock acceleration, distance from earthquake source to the site, and earthquake magnitude. These characteristics will be defined based on published geology and seismology literature relevant to north Georgia. The second step is to select several previously recorded earthquake acceleration time histories which represent the defined range of earthquake characteristics as closely as possible. Approximately three different acceleration time histories will be selected to account for the inherent variability of earthquake motions. Libraries of previously recorded acceleration time histories are available from the National Center for Earthquake Engineering Research (NCEER) and other organizations.

The result of the SHAKE analysis will be used to derive the peak average acceleration of potentially-critical slip surfaces within the dam. The peak average acceleration calculated using SHAKE incorporates the effects of ground motion amplification or attenuation by the dam structure and temporal and spatial variability to seismically-induced motions.

The next step in the analysis is to compare the peak average acceleration for each potentially-critical slip surface to the yield acceleration for that potential slip surface. The yield acceleration is typically defined in geotechnical earthquake engineering as that acceleration producing a factor of safety of 1.0 along the potential slip surface. To be conservative, the yield acceleration will be calculated using a factor of safety of 1.1. Calculation of the yield acceleration will be performed using the computer program XSTABL (previously described) and appropriate input parameters. If the yield acceleration for a factor of safety of 1.1 (calculated using XSTABL) exceeds the peak average acceleration (calculated using SHAKE) along each potentially-critical slip surface, the analysis is complete.

If the yield acceleration is less than the peak average acceleration, then the dam will be assumed to undergo seismically-induced deformation during the design earthquake event. In this event, a calculation will be performed to estimate the seismically-induced deformation. The PC-based computer program YSLIP will be used to perform these calculations. YSLIP is a coded version of the analysis method originally developed by Professor N.M. Newmark of the University of Illinois for evaluating permanent seismic deformation of earth structures. With this method, peak average acceleration pulses (in the earthquake acceleration-time history) exceeding the yield acceleration are double-integrated to calculate the accumulated permanent seismic deformation. If the calculated deformation is less than 6 to 12 in (150 to 300 mm), the seismic stability of the dam is acceptable. If the seismic deformation of the dam is larger than this magnitude, dam rehabilitation is needed to increase seismic stability.

EVALUATION OF REHABILITATION ALTERNATIVES

Following completion of the revised static and seismic stability evaluations for the existing pre-rehabilitation condition, the site-specific slope stability and steady-state seepage models will be used to evaluate the effects of various potential rehabilitation measures. Potentially applicable rehabilitation measures include, but may not be limited to the following:

- supplemental drainage features (e.g., toe drains, buttress drains, pressure relief wells, trench drains, and horizontal wells);
- toe buttresses (e.g., earth fill, reinforced soil or rock fill, and retaining walls with soil or rock backfill); and
- use of low permeability barriers to reduce seepage through the dam.

Combinations of the above measures may also be evaluated. The evaluation process will include consideration of the following:

- attainment of minimum acceptable factors of safety;
- constructability;
- ability to implement the rehabilitation measures within a reasonable schedule;
- ability to monitor improvements through appropriate use of instrumentation (as appropriate to the selected measures);
- capital cost; and
- operational and maintenance costs.

The goal of this evaluation will be to identify an appropriate course of rehabilitation that results in an acceptable improvement to the safety of the dam, while addressing community concerns with respect to:

- road traffic safety during construction;
- loss of amenities;
- and disturbance of the environment.

Following completion of these evaluations, GeoSyntec will prepare an interim technical memorandum for submittal to Georgia Safe Dams. This technical memorandum will include the following items at a minimum:

- results of field investigation and associated laboratory testing;
- embankment fill shear strength evaluation with recommendations for values to be used in subsequent evaluations;

- results of steady-state seepage, static stability, and seismic stability evaluations for the pre-rehabilitation condition;

- description of proposed rehabilitation measures, with associated steady-state seepage, static stability, and seismic stability evaluations;

- a listing of design criteria to be used in developing the detailed design for the rehabilitation measures; and

- conceptual drawings for the rehabilitation measures.

PRELIMINARY SCHEDULE

Figure 1 attached to this letter provides a preliminary schedule for performing the scope of work described herein. Key target dates incorporated into the schedule (consistent with the 10 September 1998 discussion between Georgia Safe Dams and GeoSyntec) include:

- submittal of an interim technical memorandum by 30 October 1998;

- receipt of Georgia Safe Dams comments on the interim technical memorandum by 20 November 1998;

- submittal of detailed drawings and specifications for rehabilitation measures by 16 December 1998;

- receipt of Georgia Safe Dams approval of rehabilitation measures by 22 January 1999; and

- commence construction during April 1999.

GeoSyntec will promptly inform Georgia Safe Dams in the event of any occurrence beyond the reasonable control of GeoSyntec or Big Canoe POA that results in a need for the modification of this schedule.

CLOSING

GeoSyntec appreciates the opportunity to submit this planned scope of work for the Lake Petit Dam project. Please do not hesitate to contact either of the undersigned if you have any questions or require additional information

Sincerely,

R. Neil Davies, P.E.
Associate

Rudolph Bonaparte, Ph.D., P.E.
Principal

Copy to: Francis E. Fiegle, II, P.E.
Big Canoe POA
Jim Stokes, Alston & Bird

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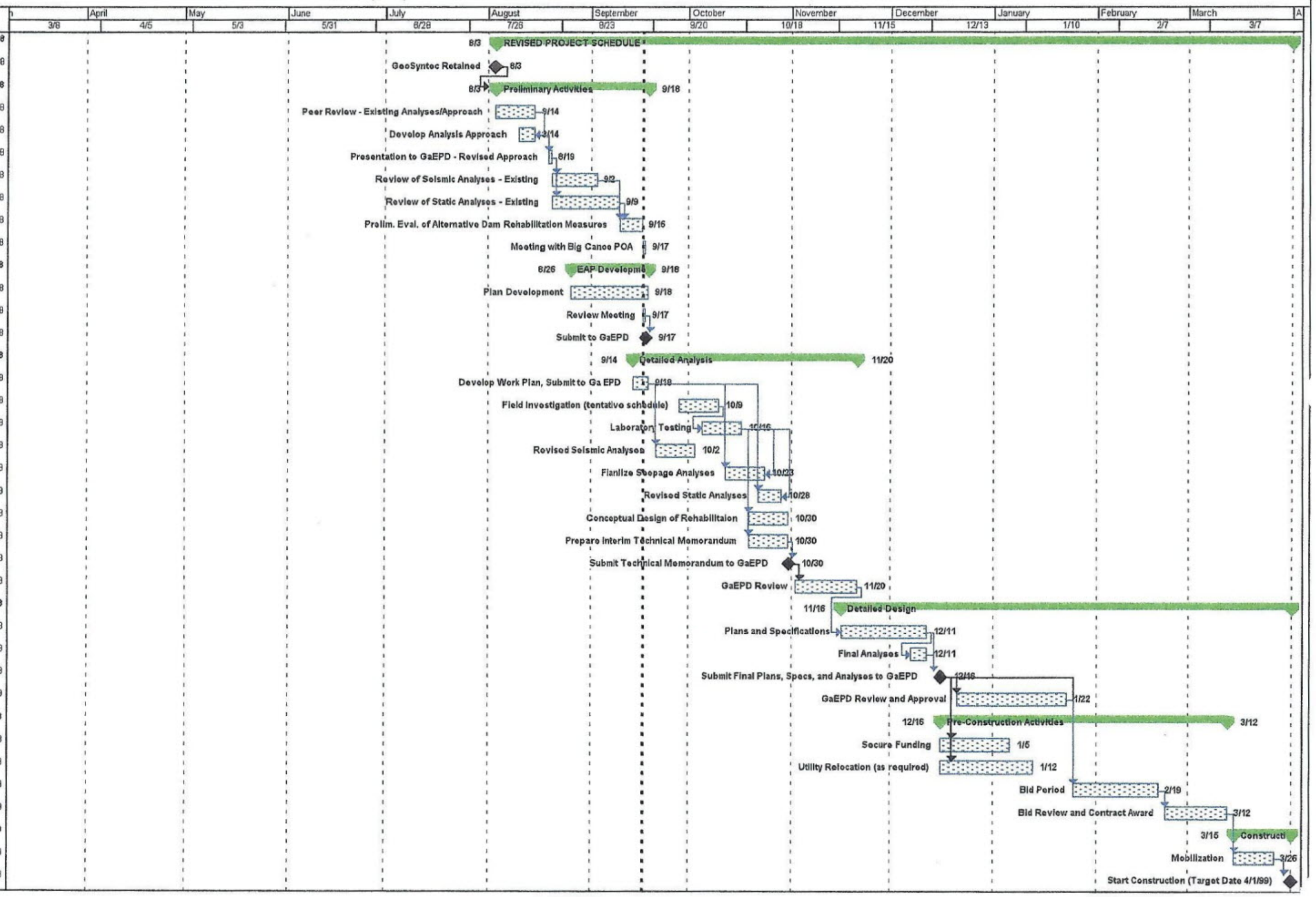
Lake Petit Dam, Big Canoe, Georgia
Figure 1
Preliminary Project Schedule

ID	Task Name	Duration	Start
1	**REVISED PROJECT SCHEDULE**	**173 days**	**Mon 8/3/98**
2	GeoSyntec Retained	0 days	Mon 8/3/98
3	**Preliminary Activities**	**35 days**	**Mon 8/3/98**
4	Peer Review - Existing Analyses/Approach	2 wks	Mon 8/3/98
5	Develop Analysis Approach	1 wk	Mon 8/10/98
6	Presentation to GaEPD - Revised Approach	1 day	Wed 8/19/98
7	Review of Seismic Analyses - Existing	2 wks	Thu 8/20/98
8	Review of Static Analyses - Existing	3 wks	Thu 8/20/98
9	Prelim. Eval. of Alternative Dam Rehabilitation Measure	1 wk	Thu 9/10/98
10	Meeting with Big Canoe POA	1 day	Thu 9/17/98
11	**EAP Development (JJ&G)**	**18 days**	**Wed 8/26/98**
12	Plan Development	18 days	Wed 8/26/98
13	Review Meeting	1 day	Thu 9/17/98
14	Submit to GaEPD	0 days	Thu 9/17/98
15	**Detailed Analysis**	**50 days**	**Mon 9/14/98**
16	Develop Work Plan, Submit to Ga EPD	1 wk	Mon 9/14/98
17	Field Investigation (tentative schedule)	2 wks	Mon 9/28/98
18	Laboratory Testing	2 wks	Mon 10/5/98
19	Revised Seismic Analyses	2 wks	Mon 9/21/98
20	Fianlize Seepage Analyses	2 wks	Mon 10/12/98
21	Revised Static Analyses	1 wk	Thu 10/22/98
22	Conceptual Design of Rehabilitaion	2 wks	Mon 10/19/98
23	Prepare Interim Technical Memorandum	2 wks	Mon 10/19/98
24	Submit Technical Memorandum to GaEPD	0 days	Fri 10/30/98
25	GaEPD Review	15 days	Mon 11/2/98
26	**Detailed Design**	**98 days**	**Mon 11/16/98**
27	Plans and Specifications	4 wks	Mon 11/16/98
28	Final Analyses	1 wk	Mon 12/7/98
29	Submit Final Plans, Specs, and Analyses to GaEPD	0 days	Wed 12/16/98
30	GaEPD Review and Approval	5 wks	Mon 12/21/98
31	**Pre-Construction Activities**	**63 days**	**Wed 12/16/98**
32	Secure Funding	3 wks	Wed 12/16/98
33	Utility Relocation (as required)	4 wks	Wed 12/16/98
34	Bid Period	4 wks	Mon 1/25/99
35	Bid Review and Contract Award	3 wks	Mon 2/22/99
36	**Construction**	**13 days**	**Mon 3/15/99**
37	Mobilization	2 wks	Mon 3/15/99
38	*Start Construction (Target Date 4/1/99)*	0 days	Thu 4/1/99



Project: Schedule #1
Date: Fri 9/18/98

Task		Milestone		Rolled Up Task		Rolled Up Progress	External Tasks
Progress		Summary		Rolled Up Milestone		Split	Project Summary

Fri 9/18/98
Schedule #2.mpp
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