Foundation Investigation at Hickory Log Creek Dam, Canton, Georgia

Gary D. Rogers, P.G.[1], Chuck Kahler, P.E.[2], and Scott Deaton[3]

[1]Schnabel Engineering, 11-A Parkway Dr., Greensboro, NC 27407, 336-274-9456, grogers@schnabel-eng.com
[2]Schnabel Engineering, 5975 Shiloh Rd., Suite 114, Alpharetta, GA 30005, ckahler@schnabel-eng.com
[3]dataforensics, 3730 Chamblee Tucker Rd., Atlanta, GA 30341, 678-406-0106, sdeaton@dataforensics.net

Abstract

Hickory Log Creek Dam is a proposed 55 meter high roller compacted concrete dam located on a tributary of the Etowah River near Canton, Georgia. The site characterization involved several approaches that facilitated the rapid foundation investigation schedule. These included identification of critical data needs, design of the program to collect these data, and selection of preferred data acquisition and evaluation. The foundation area of the dam is composed of fresh relatively unfractured mica schist in the stream valley and a mantle of residual soil and partially weathered rock on the abutment hillslopes.

Introduction

The Cobb County-Marietta Water Authority (CCMWA) and the City of Canton are planning a new water supply reservoir on Hickory Log Creek in Cherokee County. The reservoir and dam will be located about 4 kilometers northeast of downtown Canton. The reservoir is a pumped-storage project where the natural flow from Hickory Log Creek will be augmented by water pumped from the Etowah River during high flow times for later use in low flow periods. The 55 meter high dam will be approximately 305 meters long and span Hickory Log Creek, which is a tributary of the Etowah River. The reservoir will cover 150 hectares, feature 24 kilometers of shoreline, and hold 19,000 cubic meters of water with a normal pool elevation of 323 meters above mean sea level. The Georgia Safe Dams Program has classified the proposed dam as a Category I structure.

The site characterization involved several approaches that facilitated the rapid schedule. First, an evaluation of the data needed for all geotechnical and design analyses was made and both the data type and method of obtaining the data was defined. Second, scheduling of all activities was reviewed to identify those activities which could be performed concurrently and thus maintain the overall schedule. Third, data acquisition and evaluation methods were reviewed and preferred methods selected.

Figure 1. Project Location

The field program included 40 borings with over 274 meters of soil drilling and sampling, 349 meters of rock coring, 158 meters of angle rock coring, and 50 rock permeability tests. Critical to the logging of the borings and evaluation of the data was the use of PLog, a program for Palm PDAs that allowed digital logging of soil and rock samples and drilling information in the field. Use of this method allowed for draft logs to be printed at the end of the day and reviewed and finalized shortly after completion of each boring. The completed boring logs could then be used to develop geologic cross sections and profiles to assist in evaluating field data and real-time evaluation of project deliverables.

Foundation Investigation Approach

The primary purpose of all field and laboratory investigations is to obtain the data needed for analysis and design. The most challenging part of these investigations is to collect only those data needed with the least amount of money and in the least amount of time. This must be accomplished in a carefully planned program so that all critical data are collected in an efficient manner that minimizes field costs.

Our approach to planning the field investigation began with conceptualizing the potential final design products. Because the data was being used to select a type of dam from a number of potential alternatives, the data that might be needed for the final design varied. The footprint of the two primary alternatives, earthfill dam and roller compacted concrete (RCC) dam, are shown on Figure 2. The data needs for each dam alternative were developed by considering the data input parameters required for the types of analyses required for design and summarized on a project data flow chart.

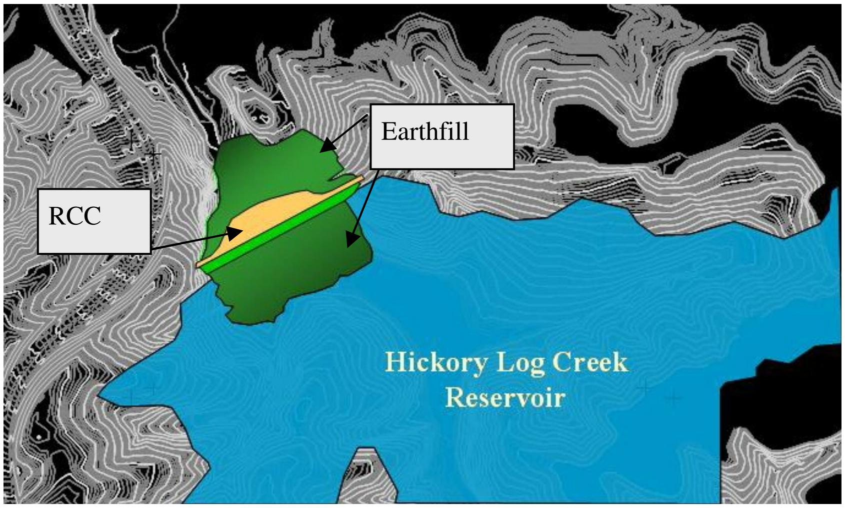

Figure 2. Earthfill versus RCC Dam Footprints

The project data flow chart included headings for field observations, field testing and sampling, lab testing, analysis/design, and constructability. The later phases of the project (analysis/design and constructibility) included lists of the analyses and data needed to efficiently plan for or complete these phases. We started with these data needs, then created lists of the field observations, field testing and sampling, and lab testing that would be required to develop the data appropriate to this project. The foundation investigation plan was written as the logistical plan for collection of these data.

An integral part of the planning was a Round 1 field investigation tailored to collect baseline data to be used for development of design alternatives. After completion of Round 1 a number of design alternatives were evaluated and a preferred alternative was selected by the client. The Round 2 field investigation then concentrated on collecting data for a specific conceptual design. The more complex geotechnical testing was scheduled for Round 2 where it could be performed at specific locations based on the selected design alternative.

The advantages of this data-driven project investigation approach are:

- Highly experienced engineers define the potential design alternatives
- The potential design alternatives determine the analyses needed
- Each analyses require specific input data parameters
- The required data determine the field investigation methods and tools
- The field investigation is planned to collect the required data
- The Foundation Investigation reports can clearly identify the data in a format that is easy to find and use during analysis and design

In the end, communication is enhanced because the purpose of the foundation investigation is very clearly defined. This is especially important in projects involving multiple disciplines. We have found that emphasis needs to be placed on communications between disciplines because of the different backgrounds, experience, and training of the various project team members.

Overview of Field Exploration Program

The field program consisted of drilling, sampling of soil and rock, permeability testing in rock, pressuremeter testing, geologic mapping, and geophysical seismic surveys. The field program was on a tight schedule, with preliminary results needed as the field program progressed.

Two rounds of drilling were performed. The first Round extended from November to December, 2004 using two rubber tired ATV-mounted drill rigs. A second round of drilling was performed from January to March, 2005 and included two rubber tired ATV drill rigs and one track-mounted drill rig for areas of very difficult access. This two round approach allowed for preliminary data to be compiled and evaluated and used to develop several alternatives.

Sampling of soil was performed with standard split spoon samplers as part of the standard penetration tests, and a Pitcher Barrel sampler for undisturbed sampling. Sampling of rock core was performed with N size core barrels including NQ double barrel, NQ triple barrel, and NQ2 double barrel. Bulk samples were obtained from the test pits. Permeability testing in rock was performed with double packer assemblies. Pressuremeter testing was performed on two borings to obtain in-situ values of undrained shear strength and elastic properties of selected site soils. Geophysical refraction surveys were also performed.

Streamlined Data Collection

One of the primary products of foundation investigations are the boring logs. The logs provide the fundamental data report on which much of the design is based. Of critical importance on a fast–track project with multiple drill rigs is consistency and speed of product delivery. On the Hickory Log project we had five geologists and engineers logging soil and rock, each with different levels of experience and training. Schnabel has specific methodologies for soil and rock description, but typically hand-written logs from different personnel can vary substantially in details thus requiring review, editing, and associated delays. For this project we utilized handheld personal digital assistants (PDAs) housed in weatherproof cases (Figure 3) with the program PLog. The program presents the user with a series of input screens for entry of related field data (Figure 4). The data is typically selected from a "pick list" of terms. These terms are pre-loaded on each PDA and can be customized for a specific project or utilize the organization's standard description terminology.

Figure 3. Digital and Paper Logging

Deposition Env.: ▼ Alluvium

Secondary Major: ▼ silty
Major: ▼ clay
Structure: ▼ mottled
Plasticity: ▼ medium

Soil Description
SILTY CLAY (CL) - medium plasticity, dark brownish red, moist to wet, medium stiff to stiff, mottled, trace

Figure 4. Example PLog Input

At the end of each field day the PDAs were synchronized on a laptop computer, imported into gINT, and printed. This draft log was then checked by the field personnel within 24 hours while the information was still fresh in their minds. Final logs could easily be generated within hours of the completion of a boring and typically only required minor editing. Geologic profiles and cross sections could also be plotted directly from this data using gINT.

Foundation Conditions

The foundation conditions were observed and evaluated using the methods described in the first part of this paper. This second part of the paper describes the encountered conditions.

Regional Geology

The project site is located within the Blue Ridge geologic province. The mica schist rock beneath the site is part of the Murphy Belt, a regionally continuous belt of rocks extending from Nantahala, North Carolina to southwestern Cherokee County. Rock units beneath the site are part of the Nantahala-Brasstown Formation, which is a subdivision of the Hiawassee River Group. The Nanatahala-Brasstown Formation was deposited as sedimentary material during the Lower Cambrian (about 540 Million years ago (Mya)) and later metamorphosed and deformed during the Appalachian mountain building event (~460 Mya to 300 Mya).

Mapped geologic units in the area show the general northeast-southwest trend of the rock units in the Murphy belt, with repetition of the rock units in a northwest-southeast direction. This repetition is caused by the folding of the Murphy belt rocks into several large synclines and anticlines. These structures are very large tight trough-shaped ductile folds. In the immediate area of the proposed Hickory Log Dam the rock layers are likely overturned by the folding, but no direct evidence of this was observed.

Engineering Geologic Units

Several geologic units with characteristic engineering properties were encountered during the field exploration program. These strata were defined based on their geologic and engineering properties into an alluvial unit, two residual soil units, a partially weathered rock unit, and two rock units, as described below.

Stratum A - Alluvium – Poorly Graded Gravel with Silt and Sand (GP-GM) to Gravelly Silt with Sand (ML), reddish brown, wet. The N-values ranged from 6 to 50/4", with some zones of very difficult drilling due to gravel, cobble or boulders. These are stream deposited sediments consisting of silt, sand, gravel, cobbles and boulders which become coarser with depth. This is the surface unit where present, with an observed thickness up to 10 ft thick. It occurs only in and adjacent to the existing stream and a former stream bed and has a sharp lower contact.

Stratum B1 – Residual Soil - Sandy Silt (ML), reddish brown, moist, homogenous soil structure, low plasticity, trace of mica. The N-values ranged from 7 to 37. This is a residual soil formed by in-situ chemical weathering of rock. It is the surface unit where Stratum A is absent, has an observed thickness of 1.5 to 18.5 ft thick, with the thickest sequence on the lower hillslope of the right abutment. This unit is not present in rock outcrop areas. It has a gradational to sharp contact with the underlying Stratum B2 or C.

Stratum B2 – Residual Soil with Relic Rock Texture - Sandy Silt to Silty Sand (ML to SM), reddish to yellowish brown, dry, weathered with highly fractured quartz veins, relic schist rock texture, and highly micaceous. The N-values ranged from 12 to 100. This is a residual soil formed by in-situ chemical weathering of rock. The observed thickness ranged from 2.5 to 15 ft. It has a gradational contact with the underlying Stratum C and is not present in rock outcrop areas.

Stratum C – Partially Weathered Rock, reddish to yellowish brown to gray, dry, weathered with highly fractured quartz veins present, relic schist rock texture, and highly micaceous. The disaggregated material classifies as ML to SM. The standard penetration resistance exceeds 100 blows per foot and is less than 100 blows per 2 inches of penetration. This unit is formed by in-situ chemical weathering of rock. The observed thickness ranged from 1.8 ft thick near the stream to 55 ft on the right hillslope and abutment. It occurs as layers in D1 and D2 material in zones of low or no core recovery. The contact with D1 or D2 material is sharp to gradational over a few inches. This unit is not present in rock outcrop areas.

Stratum D1 – Schist, RQD<40%, typically reddish brown to grayish brown, moderately to highly weathered, moderately to highly fractured, soft to moderately hard, quartz veins present, may contain completely weathered (soil) zones of Stratum C or zones of less weathered rock (D2). The observed thickness ranged up to 33.8 ft, and it commonly occurred in narrow zones as fractured, weathered intervals above or within the upper parts of D2 material. The contact with D2 material is sharp to gradational over a few inches. Hydraulic conductivities were measured in intervals of D1 that contained other materials. In mixed D1 and C strata, the permeability was over 117 Lugeons (over 1.6×10^{-3} cm/sec) as measured in one test. In mixed Stratum D2, D1 and C the range of five tests was 1 to 95 Lugeons (1.8x10-5 to 9.0x10-4 cm/sec) with an average of 37 Lugeons (3.3x10-4 cm/sec). In mixed D1 and D2 Strata in 9 tests the ranges was 0 to 31 Lugeons (0 to 3.0x10-4 cm/sec) with an average of 12.4 Lugeons (1.3x10-4 cm/sec).

Stratum D2 – Schist, RQD > 40%, gray to green gray, foliation typically at about 30 degrees but locally ranged from 0 to 70 degrees, fresh to slightly weathered, moderately hard, massive to slightly fractured, quartz veins present, fractures are rare with RQDs and recovery typically above 95%. The maximum drilled thickness was 167.5 ft. This unit is composed predominantly of white mica, quartz, garnets up to 3mm in size, and quartz veins. There are minor occurrences of seams of biotite and disseminated pyrite. Hydraulic conductivities were measured in 34 packer tests, only 5 of which had measurable permeability with a maximum of 12 Lugeons (1.2×10^{-4} cm/sec).

Geologic Structures

There are no faults, shear zones, dikes, or other major structural features in the vicinity of the site shown on the geologic maps of the dam area (Groszos, 1996). The nearest mapped fault is the Allatoona Fault, a regional southeast dipping fault that is located approximately 2½ miles to the south-southeast.

The predominant geologic structure observed in rock core samples and outcrops was foliation of the mica mineral grains. Foliation is parallel to compositional layering in the metamorphic rocks encountered on the site. The dip of the foliation was typically about 30 to 50 degrees in rock cores, although the orientation ranged significantly in areas of local small scale folding.

Foliations were measured in bedrock outcrops in the dam and reservoir areas. The mean orientation was N55ºE 40ºSE. Measurements were relatively uniform, with measured strikes ranging from N28ºE to N75ºE and dips ranging from 25° to 60° SE.

Fractures were present in rock cores and rock outcrops. The predominant fracture orientation in rock cores was parallel to foliation (typically N30ºE to N50ºE), with a lesser frequency of fractures at N70ºE and N90ºE (vertical). Fracturing in cores was more common near the soil/rock contact and decreased with depth, as shown by the increasing RQD of the rock core with depth.

Fractures measured in bedrock outcrops within and adjacent to the reservoir area can be grouped into three sets: N16ºE 62ºNW, N80ºW 56ºSW, and N50ºW and vertical. A fourth set was observed during rock coring that was parallel to foliation, but this set was difficult to observe in outcrop. Observed fractures typically had tight joints with little or no weathering.

Fractures commonly transmit groundwater which leads to preferential weathering near the fracture. In some cases this weathering can produce a zone of weathered rock or soil that extends beneath fresh rock, resulting in no recovery or poor recovery of rock core in some intervals in the borings. This situation was observed in borings drilled on the hillslope and abutments.

No evidence of faults was observed in rock cores or outcrops.

Geologic Profiles and Cross Sections

A series of geologic profiles and cross sections were developed based on the borings drilled during the field exploration program. A profile along the dam centerline shows the interpretation of the subsurface information for the proposed dam (Figure 5).

The geologic profile along the baseline shows a gradually thickening zone of Stratum B1 and B2 (residual soil) and Stratum C (Partially Weathered Rock) on the right side of the stream. Stratum B1 and B2 are present from near the stream bank and thicken to about 5 ft thick at the base of the slope, then to 58 ft near the top of the steep portion of hillslope, and then 70 ft thick. On the left side of the stream the Stratum B1/B2 and C zone is intermittent, with areas of rock outcrop (Stratum D1) exposed on this hillslope. Stratum D1 material is very thin or not present beneath the stream valley, and thickens up each side of the valley to about 40 ft thick at the top of the right and left abutment slopes.

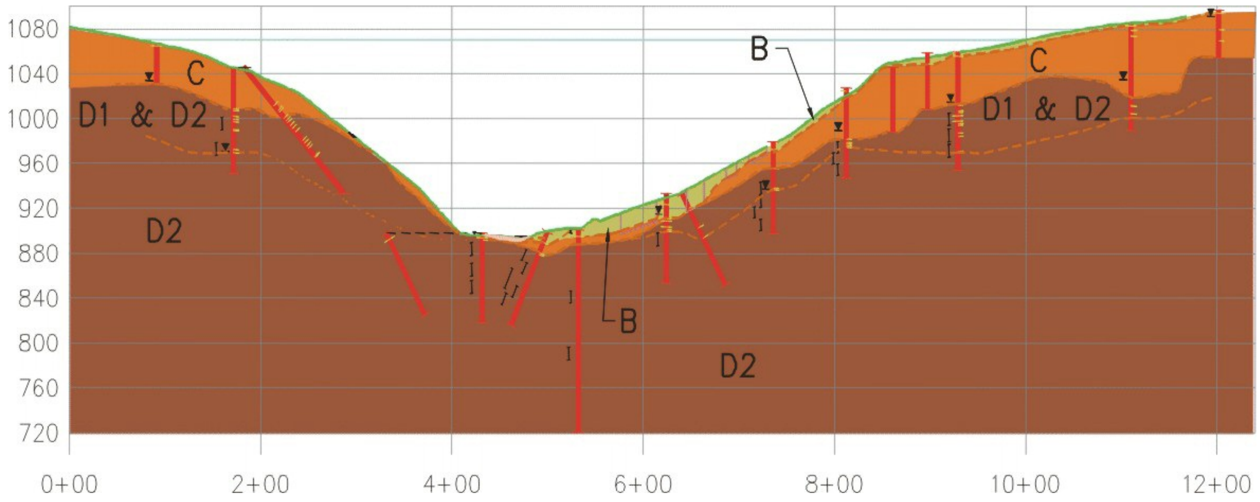

Figure 5. Geologic Profile Along Dam Centerline (looking downstream)

Conclusions

The use of carefully identified data needs and rapid turnaround of field data is a powerful combination. It provides the design engineers with critical data early in the project thus allowing them to maintain the project schedule and identify any additional data needs while the field crews are mobilized. Critical to the success of this approach is proactive planning and communication across disciplines in the project team.

The Hickory Log Dam foundation is composed of geologic materials common to the Piedmont. The material observed in the vicinity of the dam were:

- alluviual material transported by the stream and deposited in the present and former stream channel,
- residual soil formed from the chemical weathering of rock,
- partially weathered rock formed by the almost complete weathering of rock but still maintaining a relatively high density and the texture of the original rock,
- mica-quartz-garnet schist, both weathered and fresh, with occasional quartz veins.

Acknowledgements

Schnabel’s Project Manager, Randy Bass, P.E., provided invaluable support. The support of the clients, Cobb County-Marietta Water Authority and the City of Canton, and the prime contractor, Brown & Caldwell, are gratefully acknowledged.

References

Groszos, Mark, 1996, The Geology of the Murphy Belt in North Central Georgia, Ph.D. Dissertation, Florida State University