Project No. G-35-642
Project Director: L. T. Long
School/Lab: Geo. Sci.
Sponsor: Department of Army, Wilmington, N.C.; Corp of Engineers

Type Agreement: P.O. #DACW54-82-F-0039 under contract #NH00014-80-H-0008
Award Period: From 1/1/82 To 12/31/82
Sponsor Amount: $9,678
Contracted through: GTRIMPF
Title: Micro Earthquake Monitoring

1) Sponsor Technical Contact:
OCA Contact: Linda H. Bowman x4820
2) Sponsor Admin/Contractual Matters:
Sherrel Henderson
Procurement & Supply Division
Wilmington District, Corps of Engineers
Box 1890
Wilmington, N.C. 28402
919-343-4866

Defense Priority Rating: none
Security Classification: none

RESTRICTIONS
See Attached N/A Supplemental Information Sheet for Additional Requirements.
Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.
Equipment: Title vests with N/A

COMMENTS:

COPIES TO:
Administrative Coordinator
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services (OCA)
Library
EES Public Relations (2)
Computer Input
Project File
Other
SPONSORED PROJECT TERMINATION SHEET

Date 3/17/83

Project Title: Microearthquake Monitoring, B. Everett Jordan Lake, North Carolina

Project No: G-35-642

Project Director: Dr. L. T. Long

Sponsor: Dept. of Army; Corps of Engineers

Effective Termination Date: 12/31/82

Clearance of Accounting Charges: Fixed price

Grant/Contract Closeout Actions Remaining:

- [ ] Final Invoice and Closing Documents
  - Accounting Document for Fixed Price
  - Final Fiscal Report
  - Final Report of Inventions
  - Govt. Property Inventory & Related Certificate
  - Classified Material Certificate
  - Other

Assigned to: Geo Sci (School/Laboratory)

COPIES TO:

- Administrative Coordinator
- Research Property Management
- Accounting
- Procurement/EES Supply Services
- Research Security Services
- Reports Coordinator (OCA)
- Legal Services (OCA)
- EES Public Relations (2)
- Computer Input
- Project File
- Other

FORM OCA 10:781
Mr. R. L. Siesen  
U.S. Army Corps of Engineers  
P.O. Box 1890  
Wilmington, NC 28401

Subject: Quarterly Letter Report No. 1, Covering the Period  
1 January 1982 - 31 March 1982  
Re: Contract No. DACW 54-82-F-0039, Microearthquake  
Monitoring, B. Everett Jordan Lake, North Carolina

Dear Sirs:

The B. Everett Jordan seismograph operated continuously during the  
period with a 26.8% loss of recording time. Most of this can be  
attributed to recording-instrument breakdown from 12 March to 31 March,  
which is due to a short in the lightning arrester box. The short was  
across the seismic input into the recorder. Also, no records were found  
from 28 January to 31 January.

During January there was a loss of 20.2% of the total possible  
coverage time. There was a loss of 6.8% due to instrument failure,  
6.59% due to a lack of records, and of the remaining data 6.7% were lost  
due to noise. During February there was a loss of 7.8% of coverage time  
with 1.8% due to instrument breakdown. Of the remaining data 6.11% was  
lost due to noise.

The coverage during March was the least complete. There was a loss  
of 50.4% of the total possible coverage time with 40.0% of this  
attributed to instrument failure and 10.4% to noise.

Several regional blasts or events were recorded by the seismograph  
during this period, some of which are listed below:

<table>
<thead>
<tr>
<th>Date</th>
<th>P-Arrival</th>
<th>S-P (sec)</th>
<th>Distance from BEJ (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Jan 82</td>
<td>16:43:35.2</td>
<td>-</td>
<td>Telesism</td>
</tr>
<tr>
<td>11 Jan 82</td>
<td>21:44:49.0</td>
<td>-</td>
<td>Telesism</td>
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<tr>
<td>12 Jan 82</td>
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<tr>
<td>18 Jan 82</td>
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<td>7.2</td>
<td>58</td>
</tr>
<tr>
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<td>Telesism</td>
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<tr>
<td>25 Jan 82</td>
<td>05:39:55.0</td>
<td>-</td>
<td>Telesism</td>
</tr>
<tr>
<td>10 Feb 82</td>
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<td>-</td>
<td>Telesism</td>
</tr>
<tr>
<td>4 Mar 82</td>
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<td>-</td>
<td>Telesism</td>
</tr>
<tr>
<td>11 Mar 82</td>
<td>10:52:22.1</td>
<td>-</td>
<td>Telesism</td>
</tr>
</tbody>
</table>
The seismograph continued to record quarry blasts from Haywood, Sharon Harris, Farrington, Bragtown, and Mountain Vernon Springs.

The induced activity noted on the December 1981 records has not continued. We detected only six in the three-month reporting period, and these were so small as to be questionable. The location still appears to be within two kilometers of the recording sites. No other natural activity has been detected within 15 km of the recording site during this recording period.

Respectfully submitted,

Leland Timothy Long
Professor

LTL:pr
22 September 1982

Mr. R. L. Siesen
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, NC 28401

Subject: Quarterly Letter Report No. 2, Covering the Period 1 April 1982 - 30 June 1982

Re: Contract No. DACW 54-82-F-0039, Microearthquake Monitoring, R. Everett Jordan Lake, North Carolina

Dear Sirs:

The R. Everett Jordan seismograph operated intermittently for an average coverage of 14.3% of the available recording time. Most of the lost time is due to recording-instrument problems. The loss of coverage for the month of April and the first 21 days of May was due to a lightning strike on 21 March 1982. Another lightning strike caused the loss of seismic coverage for the period 4 June to 30 June 1982.

The monthly coverage percentage is 0% for the month of April, 33% for the month of May, and 9.8% for the month of June 1982.

Few regional blasts were recorded by the seismograph during this period. Nearby quarry blasts were also recorded during the operation period.

Several impulse-like recordings were observed. However, these recordings were so small as to be questionable. No other natural activity has been detected within 15 km of the recording site during this recording period.

Respectfully submitted,

Leland Timothy Long
Professor

LWL:LM:pr
Mr. Porter Morgan  
U.S. Army Corps of Engineers  
P.O. Box 1890  
Wilmington, N.C. 28401  


Dear Sirs:

The seismograph did not operate during the third quarter. The causes of the instrument failure were lightning strikes on 3 June and 10 June, 1982. Additional damage was inflicted by lightning on 19 June, 1982. No seismic coverage is available for the third quarter.

The damage to the instrument was more extensive than initially assumed. The following repairs were performed:

1. The geophone preamplifier I.C., op-amp was replaced and recalibrated.  
2. Entire lightning protection unit was replaced.  
3. The voltage regulators in the A.C. power supply were replaced and a minor design flaw was corrected. This design flaw affected the time pulse when the clock display was on.  
4. Clock was returned to factory for repair. Upon its return, in December, 1982 it was reinstalled.  
5. Pen motor drive transistors required replacement.  
6. Two filter capacitors on the amplifier were probably destroyed by lightning and were replaced.  
7. The filter/amplifier in the MEQ 800 required a new op-amp.  
8. The geophone should be cleaned and resealed before any extended period of operation. It is, however, working.

The recording system has been repaired and is in working condition. It will be returned under separate cover.

Respectfully submitted,

L. Tim Long  
Professor

LTL:ps
February 28, 1983

Mr. Porter Morgan
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, N.C. 28401

Subject: Final Report, Covering the period 1 January, 1982 to 31 December, 1982.

RE: Contract No. DACW 54-82-F-0039 Microearthquake Monitoring, B. Everett Jordan Lake, North Carolina

Dear Sirs:

Seismic coverage for Microearthquake Monitoring near B. Everett Jordan Lake, North Carolina was limited to the spring quarter. The induced seismicity noted in December, 1981, did not appear to continue into winter or spring.

A summary of our study of the B. Everett Jordan Lake induced seismicity was presented at the Spring Meeting, American Geophysical Union, 1982. A copy of the transcript and abstract for the talk is attached. The monitoring of B. Everett Jordan Lake was essential for the detection of the minor seismicity that was induced.

Respectfully submitted,

L. Tim Long
Professor

LTL:ps
Minor Seismicity Near Reservoirs in the Piedmont Province of the Southeastern United States

LELAND TIMOTHY LONG (School of Geophysical Sciences, Georgia Institute of Technology, Atlanta, Georgia 30332)

Seismic monitoring programs carried out recently near Lake Oconee, GA and B. Everett Jordan Lake, NC were designed specifically to detect reservoir induced seismicity following impoundment. B. Everett Jordan Lake was filled in September 1981. A two-month long swarm of very small events (less than magnitude -1.0) were detected starting one month after filling of the reservoir. Five similar events were identified on records from the spring of 1979 when heavy rains caused the reservoir to fill for short periods of time. The seismic array around Lake Oconee detected only 16 events (magnitude less than 0) occurring in the spring of 1980, over one year after impoundment in the winter of 1979. However, many events were located near Lake Sinclair, GA, 25 km southwest of Lake Oconee. The Lake Sinclair earthquake epicenters located primarily over a single geologic unit, a biotite granite gneiss or amphibolite hornblende gneiss, which also intercepts Lake Oconee near the epicenters of the 16 earthquakes. We conclude, first that near-surface geologic units, in this case a biotite granite gneiss, may determine where minor induced seismicity will occur. Second, because these events would not have been detected without seismic monitoring, we conclude that many other reservoirs may have triggered similar but undetected seismic activities.
MINOR SEISMICITY NEAR RESERVOIRS IN THE PIEDMONT PROVINCE OF THE SOUTHEASTERN UNITED STATES

Leland Timothy Long
School of Geophysical Sciences
Georgia Institute of Technology, Atlanta, GA 30332

ABSTRACT

Seismic monitoring programs carried out recently near Lake Oconee, Georgia, and B. Everett Jordan Lake, North Carolina, were designed specifically to detect reservoir induced seismicity following impoundment. B. Everett Jordan Lake was filled in September 1981. A two-month long swarm of very small events (less than magnitude -1.0) were detected starting one month after filling of the reservoir. Five similar events were identified on records from the spring of 1979 when heavy rains caused the reservoir to fill for short periods of time. The seismic array around Lake Oconee detected only 19 events (magnitude less than 0) near Lake Oconee, sixteen of these occurring in the spring of 1980, over one year after impoundment in the winter of 1979. However, many additional events were located near Lake Sinclair, Georgia, 25 km southwest of Lake Oconee. The Lake Sinclair earthquake epicenters located primarily over a single geologic unit, a biotite granite gneiss or amphibolite hornblende gneiss, which also intercepts Lake Oconee near the epicenters of the 16 earthquakes. We conclude, first, that near-surface geologic units, in this case a biotite granite gneiss, may determine where minor induced seismicity will occur. Second, because these events would not have been detected without seismic monitoring, we conclude that many other reservoirs may have triggered similar but undetected seismic activities.
Two reservoirs in the Piedmont Province have been monitored by Georgia Tech for seismicity prior to, during, and after impoundment. Both reservoirs showed very minor levels of induced seismicity. The object of this talk is to present our data on, first, B. Everett Jordan Lake, North Carolina, and second, Lake Oconee, Georgia.

----- SLIDE 1 ----- 

B. Everett Jordan Lake is located 2-1/2 miles SW of Raleigh, North Carolina. The earth and rock fill dam is 0.4 km (1330 ft) long and 34 m (113 ft) high. The base is at 47 m (154 ft) above mean sea level. The reservoir at maximum pool of 73 m (240 ft) covers 130 square km (32,000 acres) and the normal pool is 58 square km (14,300 acres), with a volume of $2.9 \times 10^8$ m$^3$ (235,410 acre-feet).

----- SLIDE 2 ----- 

The dam and impoundment are located on the western margin of the Durham Triassic Basin. The western margin is defined by a series of faults with much less displacement than the 6000 to 8000 ft observed on the southeast side. The basin tilts to the southeast. Small embayments of Triassic rocks extend to the northwest over meta-volcanic Carolina Slate Belt rocks. The dam is just upstream of the fault at the Triassic-Carolina Slate belt contact. To the north, upstream, of the dam is the Deep River fault which runs parallel to the dam. The Carolina Slate Belt rocks at the dam site are meta-basalts, meta-dacites,
meta-felsites, and volcanic breccia. The joints are predominantly high-angle or vertical. The major joint set strikes N60°E, parallel to the dam. Some zones of badly broken and fractured rocks exist, and where drilled they often were associated with a large water loss.

Seismic monitoring was achieved by one portable MEQ recorder. The recorder is located in the Resource Manager's office adjacent to the dam. The geophone is located about 500 ft away from the recorder. The system routinely records nearby quarry blasts and the rare regional earthquakes.

The induced events we recorded were very close and very small. The S-P time was too short to resolve with the pen and ink recording medium and we estimate less than 0.1 sec S-P time or equivalently a distance of less than 800 m. The center of the dam is approximately 500 m from the seismometers. The events were all too small to allow a magnitude estimate, but I would estimate at least smaller than -3. For comparison, this slide shows microearthquakes recorded in the Clark Hill Reservoir area at approximately 1 km distance. The Clark Hill events are very similar to the B. Everett Jordan events. When viewed in detail, the Clark Hill events look more like a typical event.

The events at the B. Everett Jordan site were not recorded at the Sharon Harris stations about 10 km away. The size and occurrence of these events are such that it is unlikely they would have been recorded at distances more than 2 km from the epicenter. We cannot rule out the occurrence of many such events throughout the reservoir.
Their rate of occurrence following impoundment was perhaps most diagnostic. The reservoir filled rapidly during the first week of September 1981. The seismic activity started 1 October first and built up to a peak 10 December 1981. Following the peak the activities decreased rapidly and no events have been detected this year.

Lake Oconee is located in central Georgia, 130 km (80 mi) east-southeast of Atlanta, 30 km (20 mi) north of Milledgeville. Wallace Dam is on the Oconee River at the headwaters of Lake Sinclair to the south. Lake Sinclair is impounded by Sinclair Dam 5 km north of Milledgeville. The Lake Oconee normal water level is 30 m above Lake Sinclair. At normal elevations, Lake Oconee covers an area of 73 km². In both length and area Lake Oconee is about 20 per cent larger than B. Everett Jordan.

Wallace Dam and Lake Oconee are underlain by rocks of the Kiokee Series and Little River Series, which have been correlated with the Carolina Slate Belt in North and South Carolina. The rocks vary from the Siloam granite to meta-gabbro and norite. Triassic dikes exist in the area, but the nearest Triassic basin is perhaps 50 km (30 mi) southeast and hidden under coastal plain sediments. A regional set of joints (N30°E, N50°W) both dip vertically. The N30°E set parallels the major fold axes. In general, the area is not well mapped for geologic structures.

Seismic monitoring was achieved by a tripartite net centered about the southern portion of the reservoir. A station was located to the southwest to assist in monitoring activity in nearby Lake
Sinclair. The stations are 13 to 18 km apart. Recording began in June 1977 and continued through August 1981. The reservoir was filled first to 120 m (16 m deep) in January 1979 and was brought up to within 10 ft of a full pool elevation of 128 m (24 m deep) by early April 1979. Seismicity in the Lake Oconee vicinity was first detected in October 1979, 10 months after filling. Earthquakes of magnitude 0.0 or less were detected through December. A swarm of about 9 events occurred in early May 1980. Nineteen events were detected and located in total. The locations cluster tightly about a point where the reservoir branches, 5 km north of the dam. No events were detected at this site from May 1980 through termination of the net in August 1981. However, a few isolated, widely scattered events were detected in the Lake Oconee vicinity but for these a non-seismic source could not be ruled out. The peak activity occurred one full year after the impoundment reached peak water level, and water level changes after impoundment are typically less than one meter. With the exception of an order of magnitude difference in the time scale, the observed sequences are very similar for Oconee and B. Everett Jordan Lakes.

Throughout the recording period, significant seismic activity was detected and located 15 to 20 km southward in the Lake Sinclair vicinity. Lake Sinclair was impounded in the 1950's. The region around Lake Sinclair has experienced activity extending back to 1872 and perhaps earlier. The largest event was an Intensity VII on March 5, 1914. The locations of the events near Lake Sinclair are scattered. Some of the scatter is undoubtedly due to the fact that the events were outside the recording array. However, the
individual clusters are representative of distinct zones of activity. Not all the reservoir showed activity during this time period. Hence, it is instructive to compare surface geology with the locations of the earthquakes and the reservoir. In particular, a unit described as a biotite granitic gneiss, feldspathic biotite amphibolite gneiss seems to be responsible for most of the activity. Admittedly, the geology from the state map is largely a reconnaissance effort, and in general the rock units are variable in properties and composition. Some others may in actuality turn out to be marginally indistinguishable from this. Nevertheless this unit as mapped seems to correlate with the seismicity, both the Sinclair activity and the Oconee induced seismicity.

Conclusions

1) At both Oconee and B. Everett Jordan Lake, the instrumentally detected seismicity would not have been detected or noted without the instrumentation. Hence, it is possible that every reservoir in the Piedmont province may have induced some activity.

2) The association of existing and induced seismic activity with a particular mapped geologic unit indicates that these units determine where seismicity will occur and indicates that induced and shallow natural seismicity in the Piedmont share a common mechanism.
B. Everett Jordan Dam & Lake
General Development Plan
The Master Plan
U.S. Army Corps of Engineers
Johnston, R.I.

Legend:
- Major Roads
- Minor Roads
- City Limits
- - - Top of Curve Control Point
- - - Top of Curve
- - - Road Bridges
- - Road Bridges, Walkways
- - - Neighborhood Development Areas
- - Relocated Railroads

5 km
THE B. EVERETT JORDAN DAM AND LAKE PROJECT
ORIGIN AND PURPOSE

A comprehensive study of the Cape Fear River Basin was begun by the Corps of
Engineers by direction of the Congress in 1947, and culminated in authorization of
the B. Everett Jordan Dam and Lake project by Congress in 1963. Project design and
coordination with state and federal environmental agencies began immediately; land
acquisition commenced in 1967.

B. Everett Jordan Dam and Lake is a multiple-purpose project for flood control,
water supply, water quality control, general outdoor recreation and fish and wildlife
conservation.

The total acreage to be acquired for the project is 47,000 acres, of which 14,300
acres will be permanently flooded to form the conservation pool at elevation 216'
above sea level. Additional capacity will be available for restraint of flood waters; the
maximum flood control pool, at elevation 240', would cover 32,000 acres. About
32,700 acres above the conservation pool limit will be permanently maintained as wild-
life habitat, recreation, and green-belt areas, exempted from private development.

Groundbreaking for the dam, spillway, and outlet works began on 7 December, 1970
and will be completed in 1974.

B. EVERETT JORDAN DAM AND LAKE PROJECT
CHATHAM, ORANGE, DURHAM AND WAKE COUNTIES
NORTH CAROLINA

THE DAM: FACTS AND FIGURES

Type: The B. Everett Jordan Dam and Lake will be a zoned earth and rock
fill structure with a side-channel, free-flowing chute spillway and a
multiple level outlet structure.

Length of Dam: 1330 Feet
Maximum height of Dam 113 Feet
Base elevation (mean sea level) 154 Feet
Top elevation (mean sea level) 266.5 Feet
Spillway elevation (mean sea level) 240.0 Feet
Length of spillway crest 800 Feet

THE LAKE:

Elevations (above mean sea level):
Bottom conservation pool 202.0 Feet
Top of conservation pool 216.0 Feet
Top of flood control pool 240.0 Feet
Lower clearing limit 197.0 Feet
Upper clearing limit 217.0 Feet
Guide acquisition line 240 feet contour, plus 300 feet
horizontally or 5 feet vertically, whichever is greater

Length of lake at elevation 216.0 feet, along:
Haw River 5 miles
New Hope Creek 17 miles
Length of shoreline of lake at 216 feet elevation 150 miles

SURFACE AREA OF LAKE

Top of flood control pool (elev. 240.0') 32,000 acres
Top of conservation pool (elev. 216.0') 14,300 acres
Bottom of conservation pool (elev. 202.0') 7,200 acres

 STORAGE VALUE

Top of flood control pool (elev. 240.0') 778,100 acre-feet
Top of conservation pool (elev. 216.0') 235,400 acre-feet
Bottom of conservation pool (elev. 202.0') 88,400 acre-feet
Figure 28. Cumulative distribution of events in both Lake Sinclair and Lake Oconee.