ADDENDUM #2

SEE ATTACHED THREE INVESTIGATIONS THAT INCLUDE SUBSURFACE DATA

THEY INCLUDE:

- A 2001 REPORT BY USACOE TO INVESTIGATE SINKHOLES SOUTH OF THE TUSCARORA RD AREA
- REMEDIAL DAM REPAIR INVESTIGATION BY S&ME IN 1988, AND
- EXPLORATION IN CONNECTION WITH THE PROPOSED NEW SPILLWAY BY ECS, CONDUCTED IN 2007

NOTE THAT DURING THE STUDY PHASE THE SELECTED FIRM WILL BE ABLE TO REQUEST AND DISCUSS WITH MOTSU ANY SUBSURFACE WORK PERFROMED IN CONNECTION WITH THE LAND RAIL BRIDGE SUPPORTED ON A DEEP FOUNDATION SYSTEM.

REPORT
OF
ACCESS RAILROAD SINKHOLE INVESTIGATION
BOILING SPRING LAKES, NC

TABLE OF CONTENTS

LIST OF PHOTOS

LIST OF FIGURES

1.0 INTRODUCTION

This report covers the recent field investigation of a small sinkhole that appeared underneath the track of the Sunny Point Military Ocean Terminal (MOTSU) access railroad.

1.1 Site Description

The site is located approximately 20 miles southwest of Wilmington, North Carolina in the town of Boiling Spring Lakes (Figure 1). The railroad track serving MOTSU passes through one of the most active karst area in North Carolina. Sinkholes under or adjacent to the track in this area have caused the interruption of rail service several times in the last 30 years.

The site is characterized by an undulating sandy topography, covered by pine and oak, and sparse grass cover. Allen Creek flows out of Boiling Spring Lake near the site. Numerous paleo-karst depressions and small circular ponds exist in the area. In addition, numerous active sinkhole collapses exist near the railroad, in adjacent wooded areas. Linear trends in the karst features are generally in a northwest to southeast direction.

Boiling Springs Lake is located approximately 200 feet upstream of the railroad and is impounded by an earthen dam. Due to the increase in elevation of impounded water behind the dam, sinkhole activity has increased along about 4,000 feet of the existing track. In years past, several larger collapses caused closure of the track and resulted in the ultimate construction of a dry span concrete trestle (land bridge) on caissons set in rock.

1.2 Site History

In 1962, construction of Boiling Springs Lake adjacent to the MOTSU access railroad track significantly raised the ground-water level in the area. Later in the year, a sinkhole caused by the rising lake level developed approximately 10 feet from the railroad track. In 1964, a concrete land bridge was built over the cavity area (track stations 812+00 to 813+69) found in 1962.

In December 1976, two flowing springs and a sinkhole developed downstream of Boiling Springs Lake dam near the railroad right-of-way. Later in the year, a subsurface investigation was carried out by the Corps of Engineers in the areas north and south of Allen Creek.

In the following year (1977), a hydrogeologic investigation of the Boiling Spring Lakes area was conducted by Harry LeGrand. In 1978, the Corps of Engineers issued a Technical Report on the sinkhole development along the Sunny Point access railroad near the Boiling Spring Lake

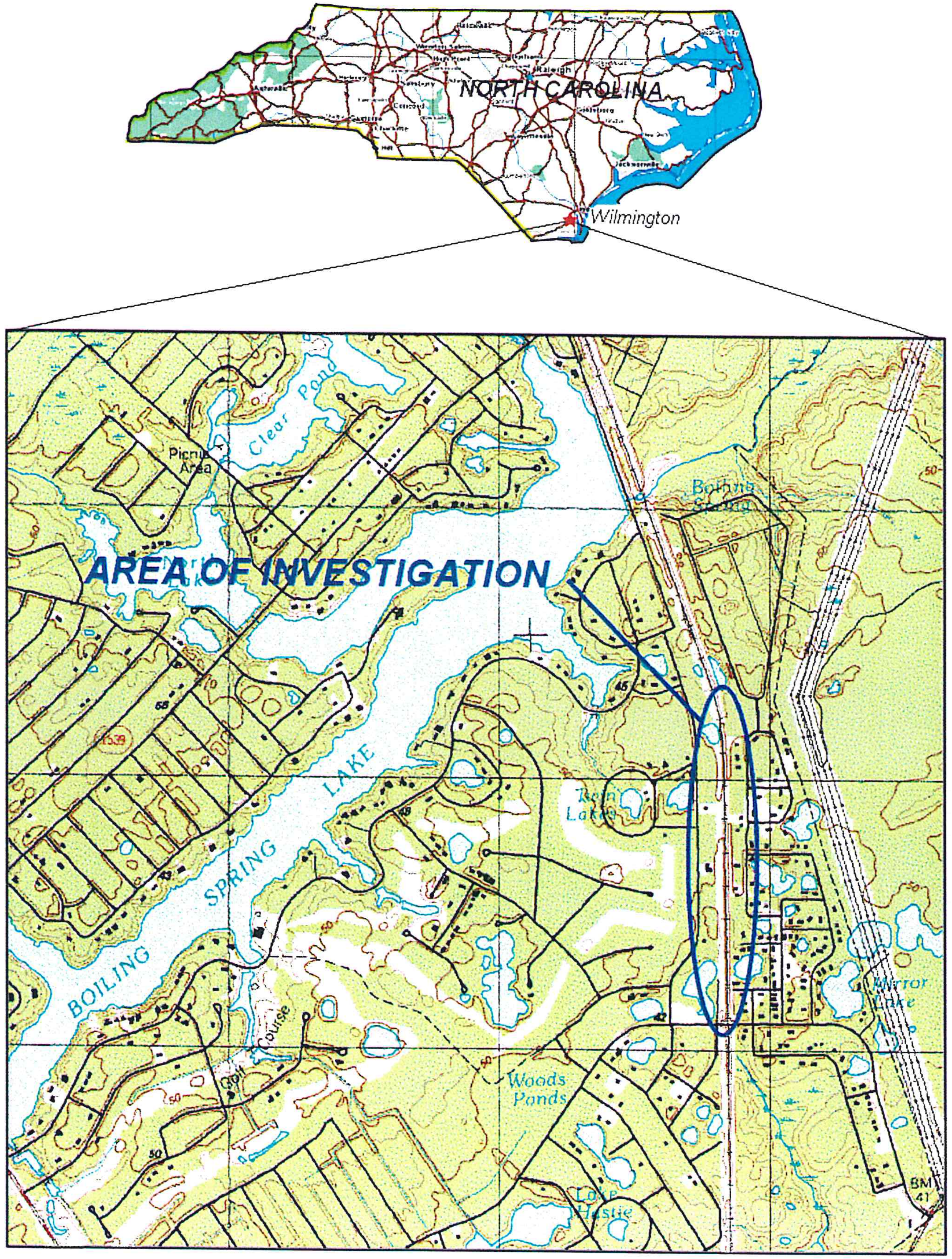


FIGURE 1
SITE LOCATION MAP

Dam.

In October 1984, a collapse near track station 823+00 resulted in closure of the railroad for three weeks. This prompted an investigation with extensive drilling by the Corps of Engineers. At this time, a reconnaissance ground penetrating radar survey was also performed in a localized area.

In 1985, a Concept Design Data Foundation Investigation by the Corps of Engineers was written based upon an extensive drilling program at the site. Later in the year, Technos, Inc. was contracted to perform an investigation using ground-penetrating radar (GPR), seismic refraction, and micro gravity along the railroad track between stations 792+00 and 833+00. GPR proved to be a very useful tool in determining the location of soil disturbances related to sinkhole activity. The repeatability of GPR also proved its worth in recognizing changes in soil structure with time. Examples of data (with interpretations) collected by Technos at the site can be found in Appendix A.

In 1986-87 a concrete land bridge founded on drilled caissons was constructed along the area of the railroad tracks between stations 792+00 and 832+55. The intent of the land bridge was to alleviate the need for emergency track repairs that had been required intermittently for the previous thirty years in the Boiling Spring area. The earlier smaller land bridge was abandoned after the construction of the new longer land bridge.

1.3 Area and Site Specific Geology and Hydrogeology

The area is mantled by Recent to Plio-Pleistocene surficial sands and the Socastee Formation, composed of interbedded quartz sand and some clay. The general thickness of these deposits is about 9 to 25 feet. Underlying these surficial units is the Canepatch Formation, which consists of cross-bedded sand, clay, silt, and occasional peat. The underlying Waccamaw and Bear Bluff Formations of Plio-Pleistocene age are made up of calcareous sandstone, sandy limestone, sand, and silt. The Canepatch, Waccamaw, and Bear Bluff Formations can account for approximately 30 to 50 feet of the upper local deposits. The Eocene Castle Hayne Formation, a fossiliferous limestone and phosphatic pebbly conglomerate, is approximately 75 to 80 feet thick in the area.

The section of the Sunny Point Access Railroad track near Boiling Springs Lake is situated over limestone that is middle-Eocene in age and is covered by non-cemented sands, silts, and clays with varying amounts of shell that are late Pleistocene to Miocene in age. A generalized geologic column is shown in Figure 2. Figure 3 shows an idealized geologic section of the site and the general nature of subsidence cavities in the Castle Hayne limestone that ultimately lead to sinkholes.

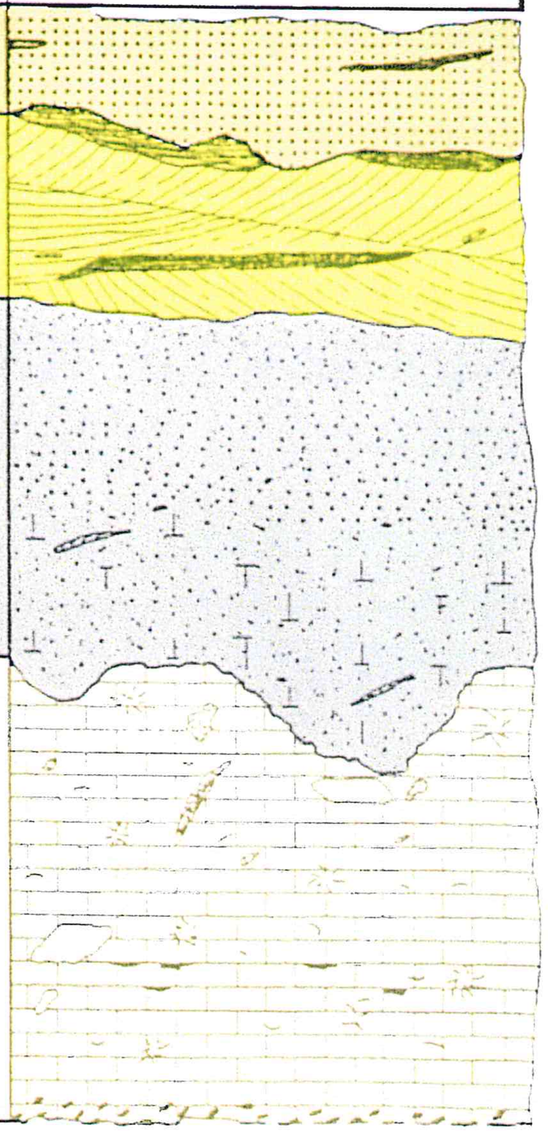
SERIES	FORMATION	DESCRIPTION	STRATAGRAPHIC COLUMN
RECENT	SURFICIAL SANDS & SOCASTEE FM	Interbeds of quartz sand and some clay	
PLIO - PLEISTOCENE	CANEPATCH FM	Deposits of sand, clay, silt and peat (THICKNESS : 30' - 50')	
	WACCAMAW FM BEAR BLUFF FM	Calcareous sandstone, sandy fossiliferous limestone, sand and silt	
EOCENE	CASTLE HAYNE FM	Fossiliferous limestone and phosphate pebbly conglomerate. (Thickness 75' to 80')	

FIGURE 2
GENERALIZED GEOLOGIC COLUMN

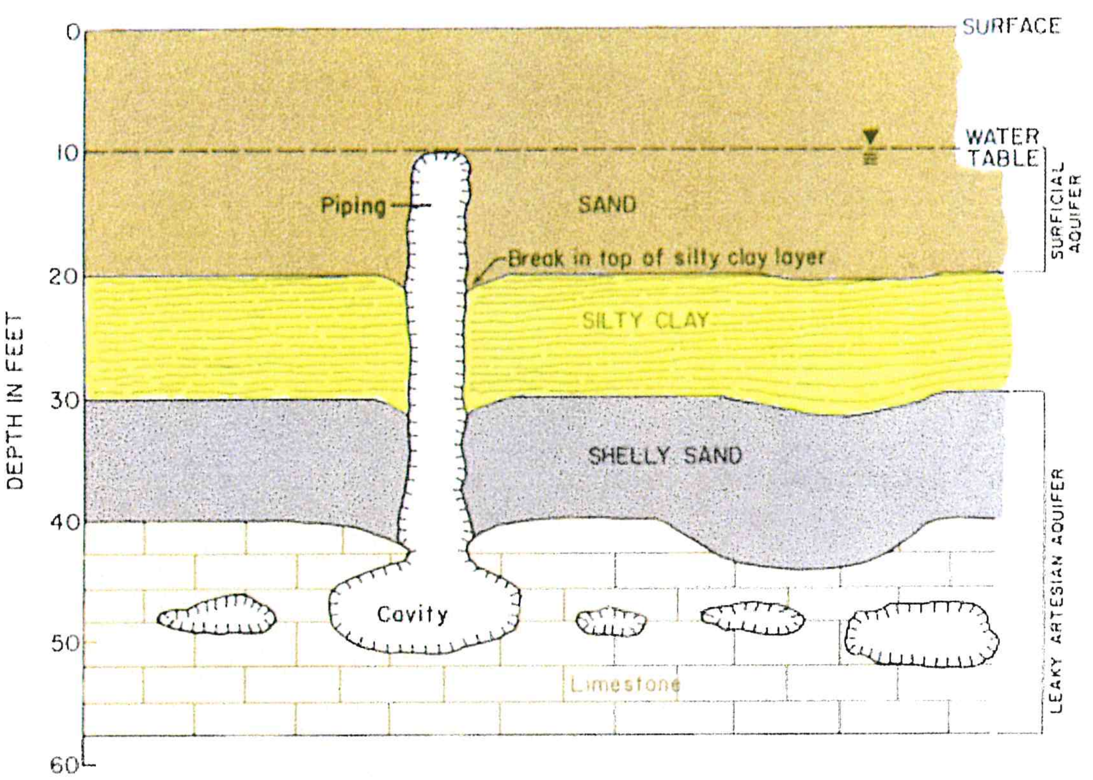


FIGURE 3
IDEALIZED GEOLOGIC SECTION

Ground water in the area occurs in two distinct hydrogeologic units. The upper unit is located in the surficial Pleistocene sands and may be perched when underlain by clay. The underlying Castle Hayne limestone is the major aquifer, which is a leaky artesian system.

Karst development is caused by variations in the piezometric head of the Castle Hayne limestone, increased flow due to the artificially higher water levels from Boiling Springs Lake, and the general solubility of the limestone.

The depth to rock varies from about 12 feet below grade in the valley at Allen Creek to about 45 feet at track station 826+00. Top-of-rock elevation is known to vary as much as 20 feet vertically in a 2-foot horizontal distance due to solutioning and pinnacle formation in the Castle Hayne limestone.

Cavities in the limestone generally occur within the upper unit of the Castle Hayne limestone. The cavities appear to be narrow in most cases, although a few have been identified which have a lateral extent of several feet and a vertical height in excess of 10 feet. The openings through the top of the rock are thought to be relatively small, probably less than 5 feet in diameter. The sinkholes develop by the movement of the loose, non-cemented, overlying soils through the openings in the rock. The process continues upward as a small diameter "pipe" until it reaches the point of sudden collapse near the surface. Most of the piping is relatively small (3 to 6 feet in diameter), even when it breaks through at the surface. Subsequently, the diameter at the surface can enlarge substantially to 50 or more feet in diameter.

2.0 PRESENT INVESTIGATION

2.1 Initial Assessment

On 8 January, 2001, a sinkhole approximately 8 feet in diameter appeared underneath the access railroad track at approximate station 837+77 (about 522 feet south of the south end of the land bridge constructed in 1987), in the vicinity of an existing paleo-sink pond that was apparently partially filled in during construction of the railroad embankment (Photo 1, and Figure 4). MOTSU railroad crews discovered the sinkhole. As a result of the sinkhole, the access track was temporarily closed to traffic. On 9 January, the MOTSU Public Works Office requested that the Savannah District Geology, Hydrogeology and HTRW Design section mobilize to the site to determine the cause and extent of the problem.

Photo 1. New Sinkhole Under Track at Station 837+77.

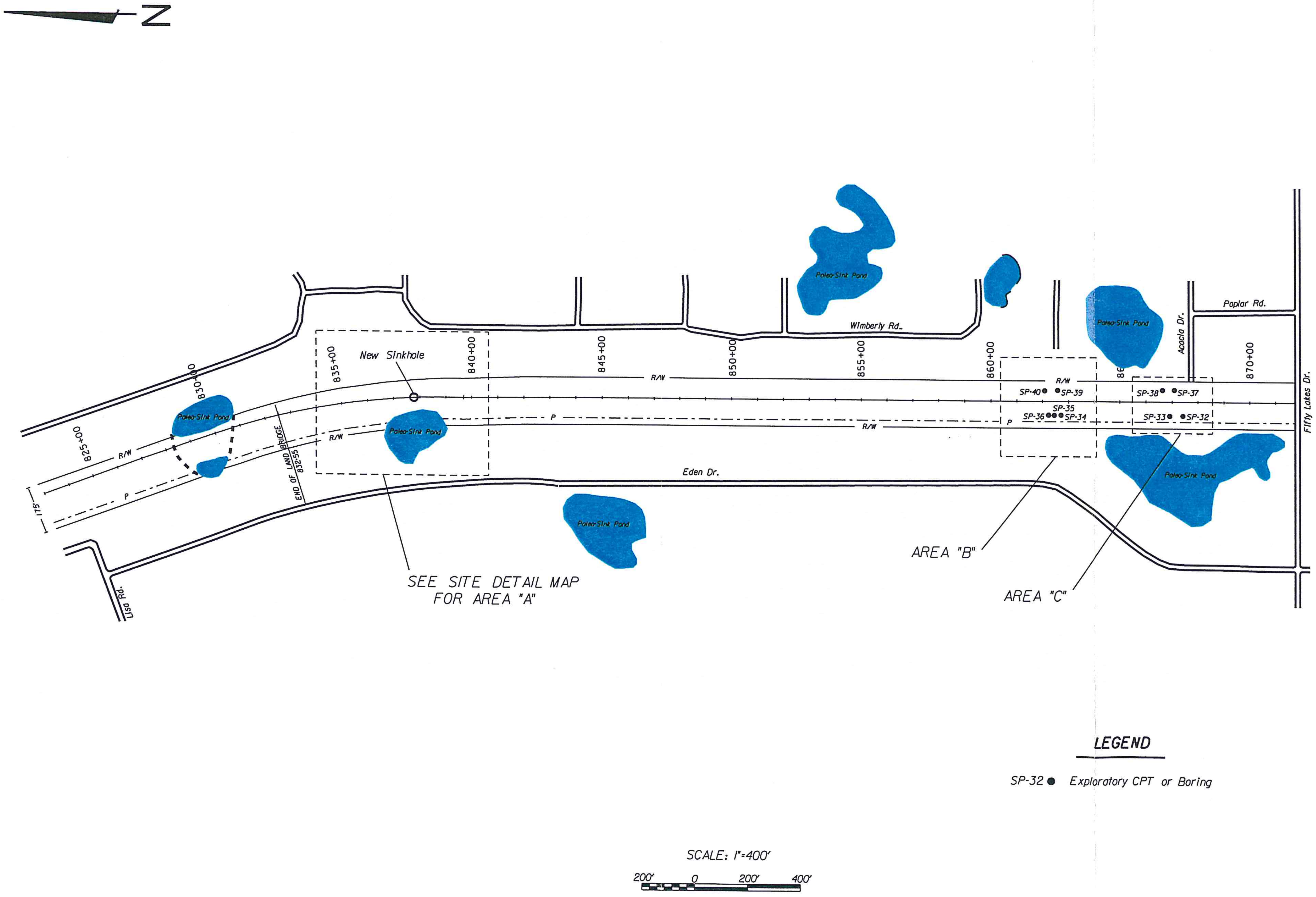


FIGURE 4
SITE MAP

On 11 January 2001, a model 66DT Geoprobe® direct push rig and a geophysical services contractor, Geophex Services Ltd., were mobilized to the site to obtain an initial assessment of damage to the track.

Six probes were performed in the immediate area of the sinkhole (Figure 5), to an average depth of about fifty feet below ground surface (BGS). These probes, including one in the approximate center of the sinkhole below the track, indicated a zone of exceptionally weak soil from about 30 to 40 feet in depth. This zone was indicated by the requirement of only light pushing with the Geoprobe® hydraulics, without hammering. In several of the probes closest to the sinkhole, the probe could be advanced by pushing down by hand.

During investigations conducted for the nearby land bridge construction, ground-penetrating radar (GPR) had been shown to give good results in locating potential sink areas before they manifested at the ground surface. Geophex Services performed a detailed GPR survey along a 350 x 60-foot area of the railroad near the new sinkhole (Photo 2).

Photo 2. GPR Survey with Geoprobe in Background.

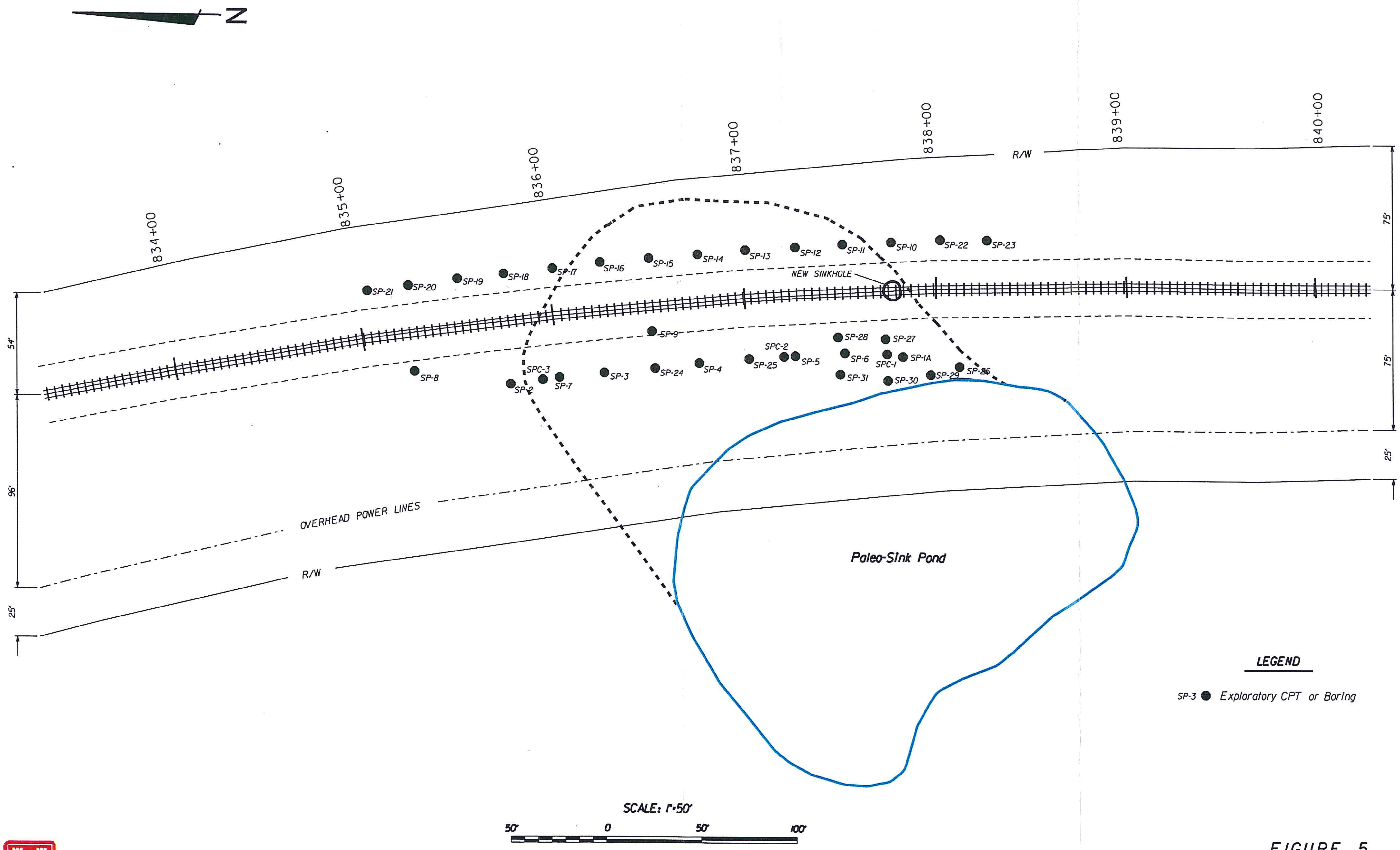


FIGURE 5
AREA "A" SITE DETAIL

2.2 Initial Assessment Results

Based on the Geoprobe® work and the GPR survey, the general soil profile along the track (Figure 6) consisted of about 15 feet of silty sand (SM) fill material comprising the track embankment, underlain by about 25 feet of sand to silty sand (SM-SP). About 8 to 10 feet of soft fat clay (CH) was found below the SM-SP. Below the CH was about 10 to 15 feet of clayey, silty fine sand (SC) with numerous shells and shell fragments. One outlying probe about 150 feet north of the sinkhole encountered limestone at about 65 feet BGS.

The GPR survey indicated distinctive down warping of sediments above the paleo-sink, and an apparent vertically oriented disturbed zone (or pipe) in the immediate area of the new sinkhole. Another vertically oriented disturbed zone was indicated near the track, about 170 feet north of the new sinkhole. Since the maximum effective depth of the GPR was about 45 feet BGS, the top of the limestone along the survey could not be determined.

Although this soil/rock profile is very characteristic of the karst terrain in the Boiling Springs area, previous experience has shown that the paleo-sink areas have been considerably altered due to down warping of soils into collapsed cavities or solution channels within the limestone. The new sinkhole under the track appeared to be located along the approximate southern edge of the portion of the old paleo-sink that had been filled to construct the railroad embankment.

Based on these initial findings, the Savannah District recommended a temporary repair. On 12 January 2001, a MOTSU rail crew backfilled the sinkhole with railroad ballast stone and tamped it. After the repair, the section of track was tested by driving a locomotive back and forth across the area.

At the same time, MOTSU issued a temporary restriction on rail traffic that directed all MOTSU trains to move through the affected area at a reduced speed of five miles-per-hour. Additionally, railway maintenance personnel were directed to inspect the affected area of the track prior to all rail movement and observe the affected track during any rail movement.

2.3 Follow-up Assessment

The results of the initial assessment led to the conclusion that direct push cone penetration testing (CPT), in combination with GPR, would be a good choice to rapidly determine the extent of the area underneath the track that would require treatment.

On 24 January 2001, the Savannah District Site Characterization and Analysis Penetrometer System (SCAPS) rig was mobilized to the site to begin CPT work. At the same time, Geophex Services was re-mobilized to perform additional GPR surveying for an additional 3310 feet of track south of the new sinkhole, towards MOTSU. A Failing 1500 drill rig was also mobilized to obtain standard penetration test (SPT) data to correlate with CPT data, and to core the

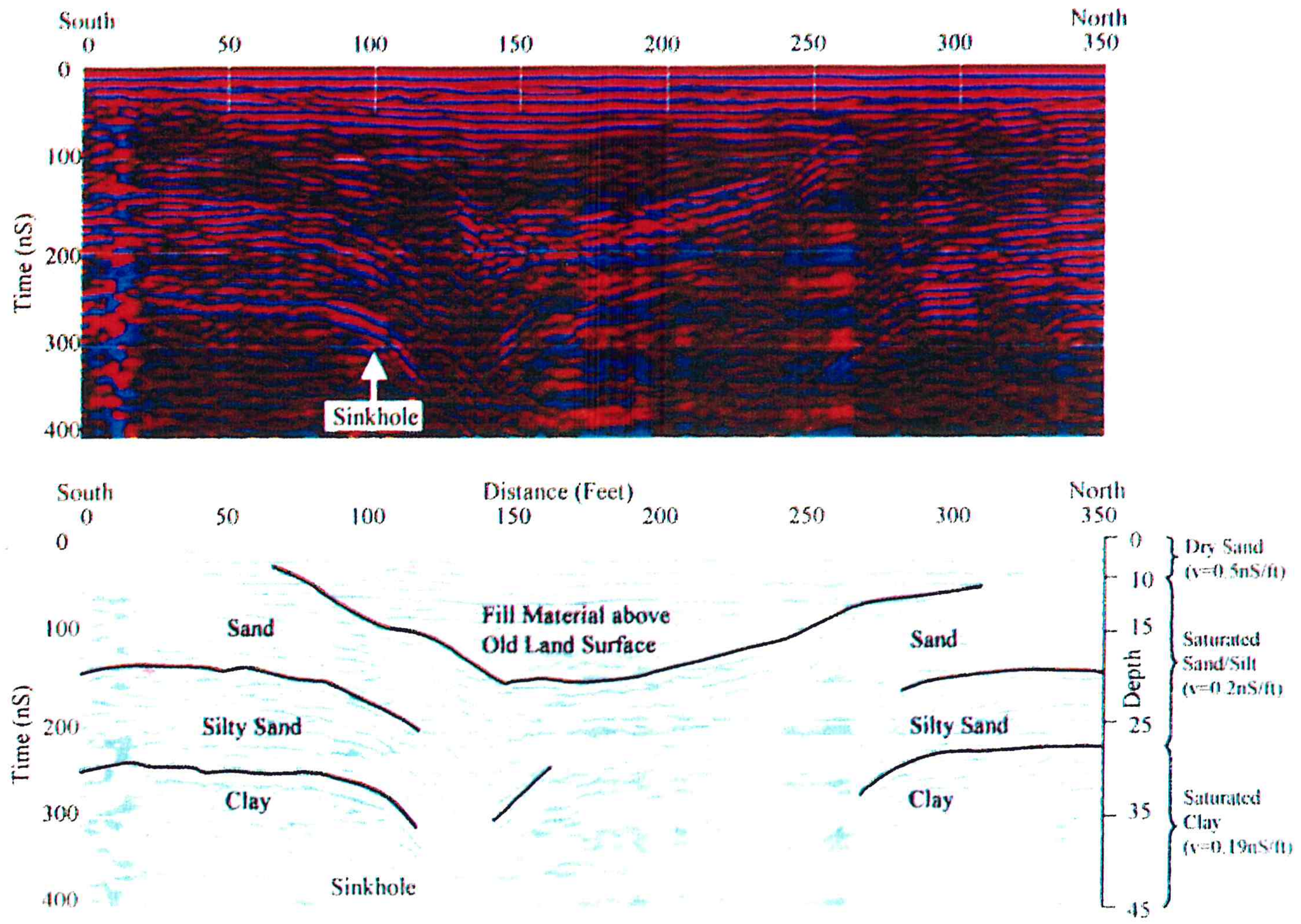


FIGURE 6
AREA "A"
GPR SURVEY DATA

limestone in selected areas.

Standard cone penetrometer soil classification is derived from the electric-mechanical response to the leading portion of a standard probe being pushed through soil. The force acting against the tip of the probe and the friction against its side are translated into a simplified classification system, which is displayed in real time as the push progresses. A CPT log is produced showing the cone tip resistance (Q_c) in tons/ft^2, sleeve (side) friction (f_s) in tons/ft^2, and soil classification, versus depth. The soil classification is derived from a ratio of Q_c and f_s, and although the classification does not directly correlate to the Unified Soil Classification System (USCS), it is extremely repeatable and useful. The main shortcoming of CPT is that it will not penetrate very dense soils.

2.4 Follow-up Assessment Results

It was discovered early on that SCAPS would generally not be able to push within about 20 feet of the track, due to very dense soils in that area. These dense soils may be the result of either compaction due to constant load and vibration from passing trains, or original compaction during construction, or both.

The SCAPS CPT work was started on the west side of the railroad track near the new sinkhole and progressed northward on roughly 50-foot centers (Figure 5 and Photo3). As the work progressed to the east side of the track, the distance between pushes was reduced to roughly 25 feet. Additional pushes on the west side were done to generally fill in between 50-foot pushes. The intent of the CPT work was to try to correlate the GPR data with CPT, determine the strength of the underlying soils, and determine the depth to the top of the limestone. A total of 40 CPT pushes were completed in about 4 days.

CPT proved to be an excellent means of confirming the GPR data, obtaining soil strength data, and determining the depth to limestone. CPT cone (tip) resistance proved to be the most useful data to correlate with GPR data. Stratigraphic sections were constructed using cone resistance to group (or classify) soils of relative strength (Figures 7, 8, and 9). The excellent correlation can be seen in an overlay of the cone data (with inferred stratigraphy) by GPR data (Figure 10). Logs of the SCAPS CPT pushes can be found in Appendix B.

The Failing 1500 drill rig was used to drill three other borings (SPC-1, SPC-2 and SPC-3) on the west side of the track (Figure 5). The intent of these borings was to collect SPT data to correlate with CPT data, and to obtain core samples of the underlying limestone. Drilling logs of these borings can be found in Appendix B.

SPC-1 was drilled about 35 west of the new sinkhole, and near several SCAPS CPT pushes. Continuous SPT data was collected in this boring down to a depth of 49.5 feet BGS. At 49.5

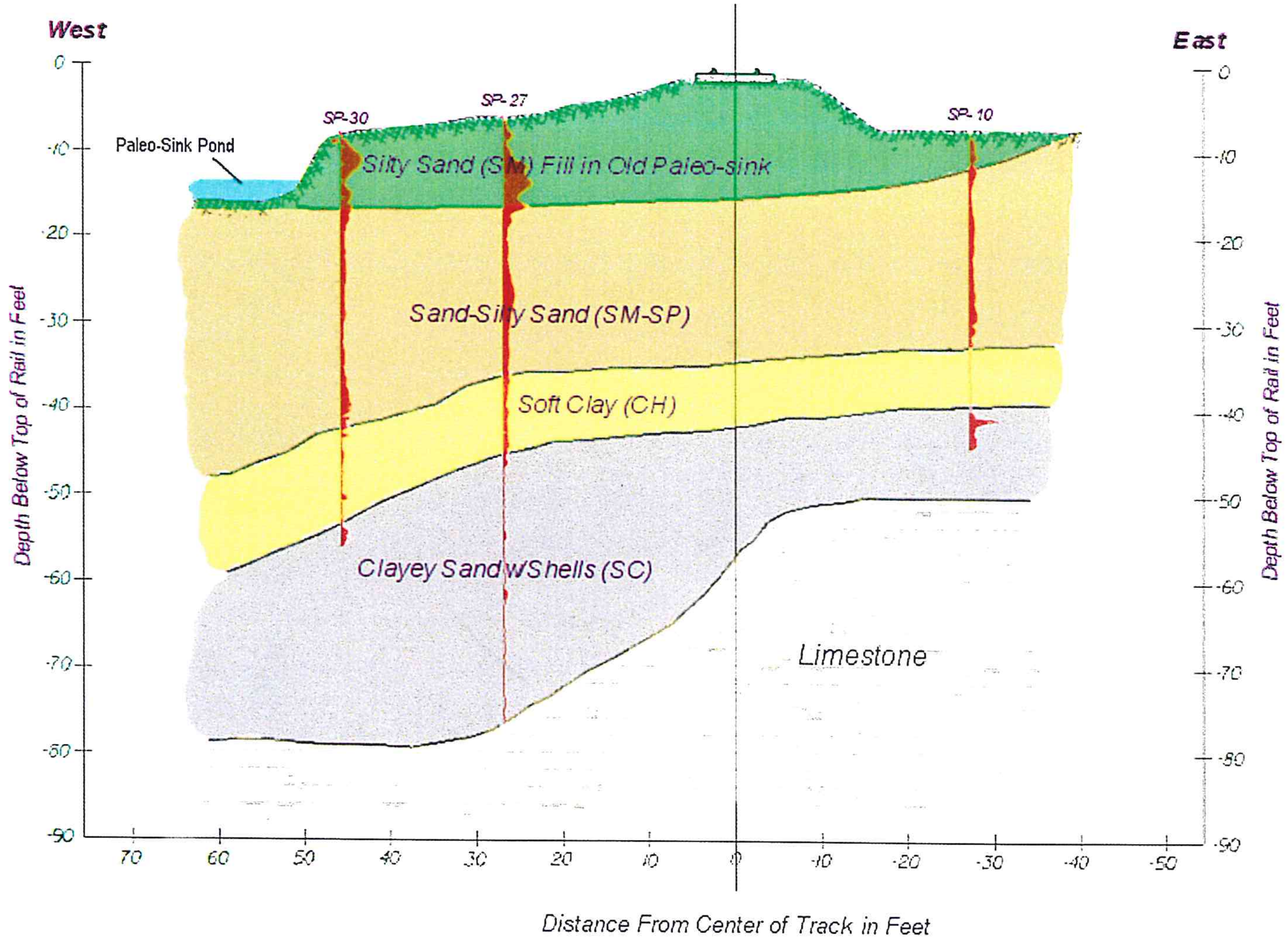
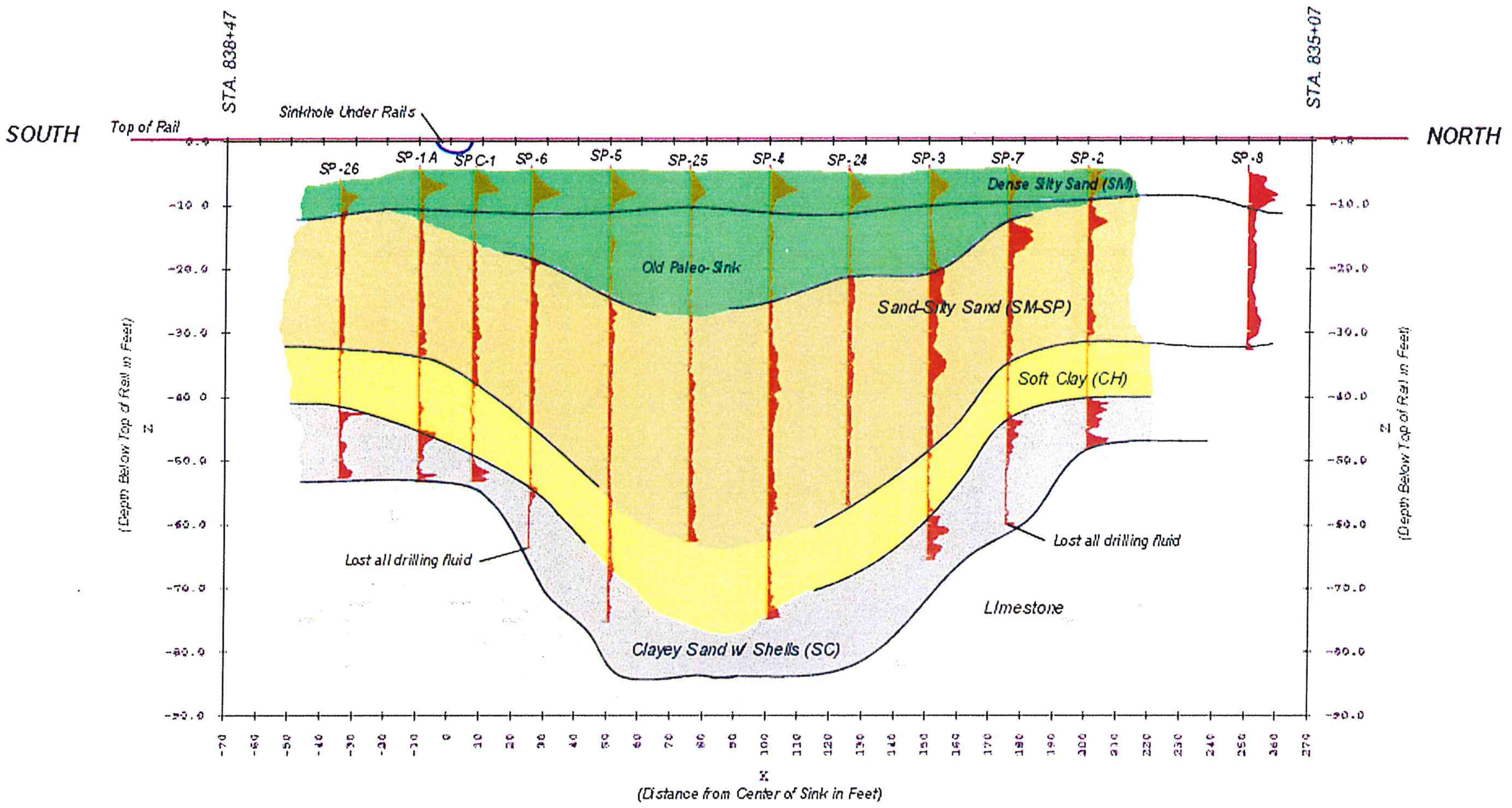
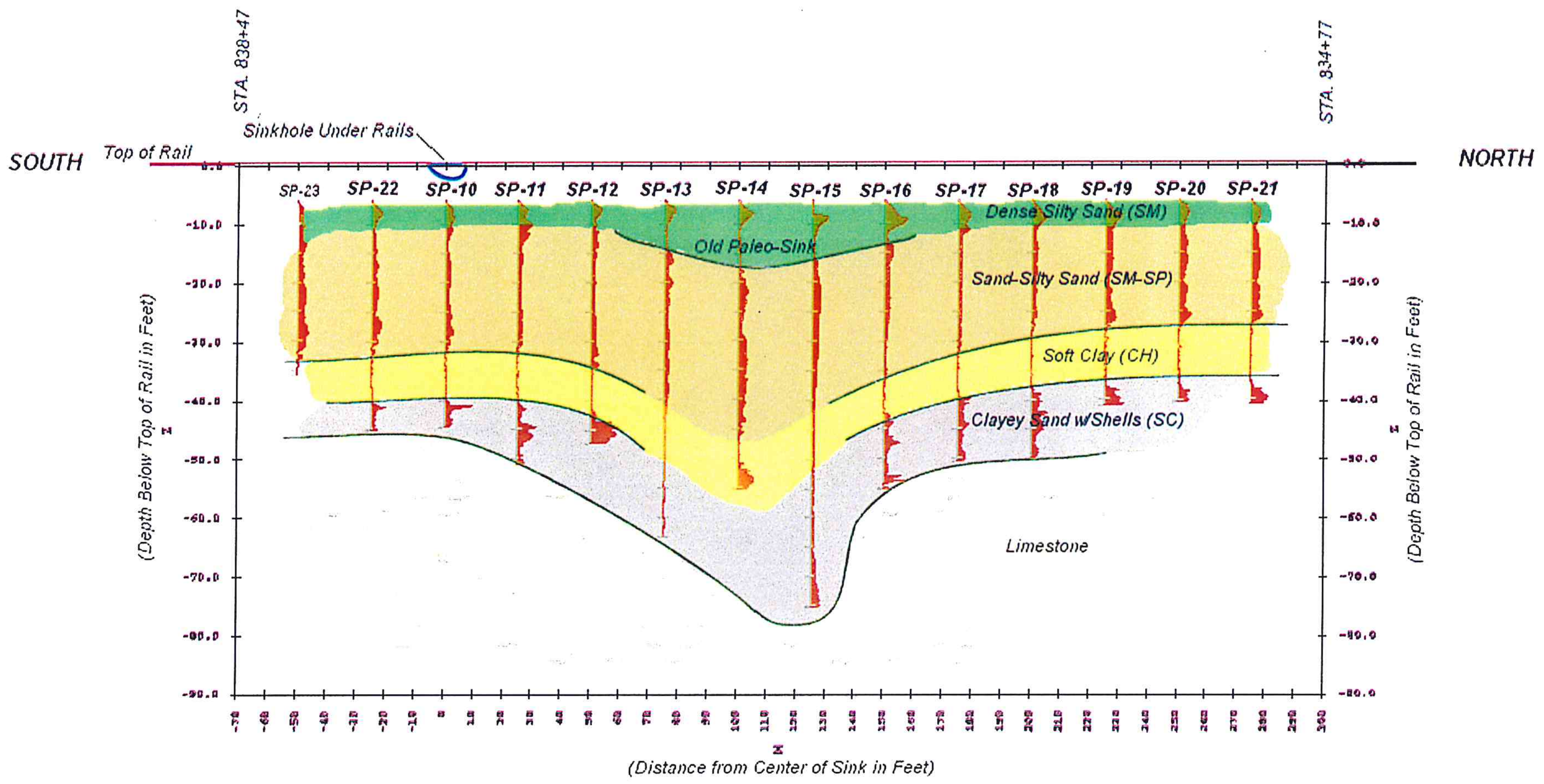


FIGURE 7
GEOLOGIC SECTION
AT TRACK STATION 837+78



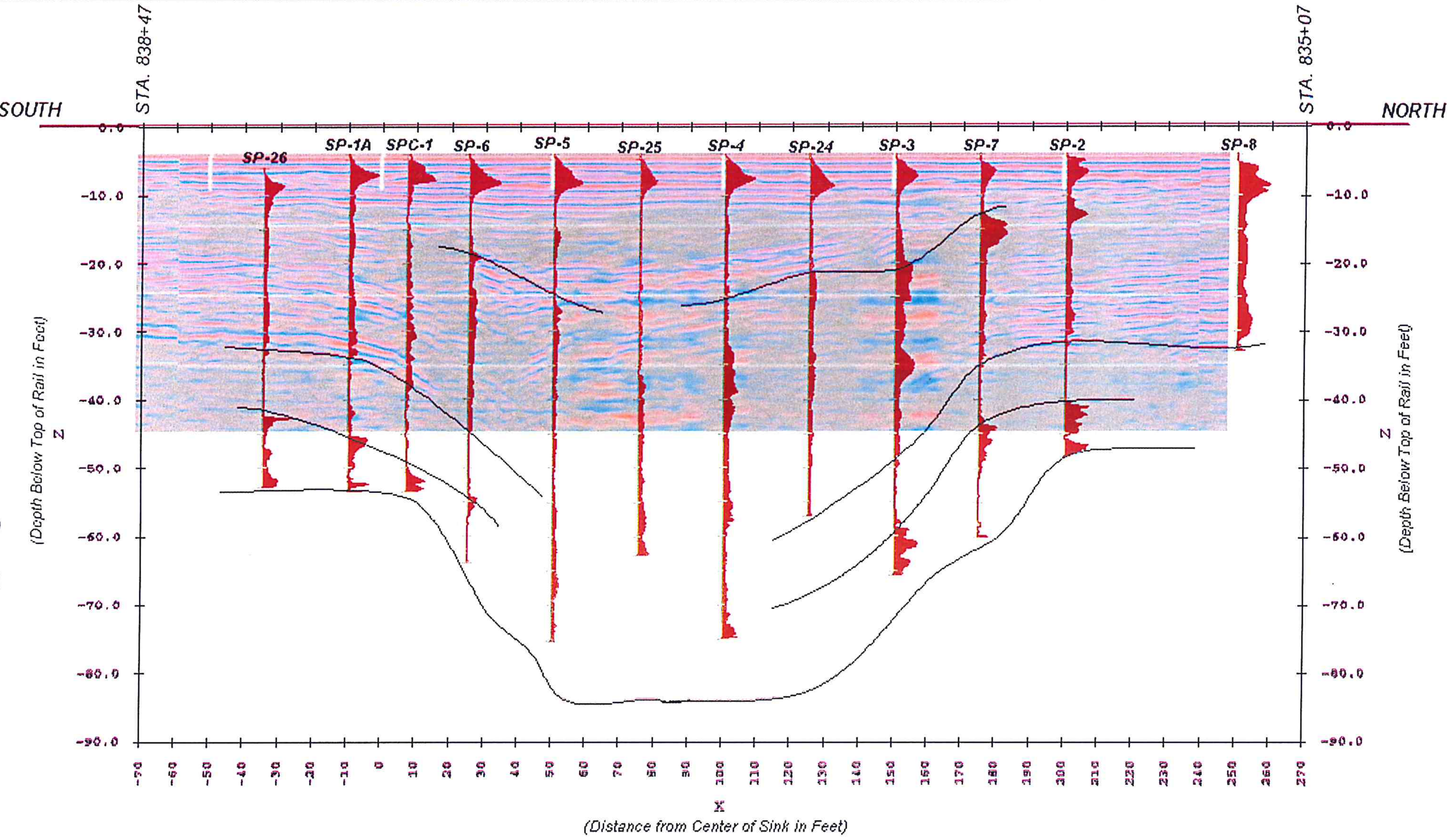
NOTES: 1. CPT curves represent only cone (qc) data in tons per square foot (TSF), see push logs for details.
2. SPC-1 represents blow counts from SPT boring used to correlate CPT data.
3. Section is approximately 30 feet west of centerline of track.

FIGURE 8
AREA "A"
SECTION ALONG WEST SIDE OF TRACK



NOTES: 1. CPT curves represent only cone (qc) data in tons per square foot (TSF), see push logs for details.
2. Section is approximately 25 feet east of centerline of track.

FIGURE 9
AREA "A"
SECTION ALONG EAST SIDE OF TRACK



Note: CPT curves rpresent only cone (Qc) dara in tons per square foot (TSF).

FIGURE 10
AREA "A"
CPT DATA WITH GPR DATA OVERLAY

feet, all drilling fluid in the borehole was lost and soil from above this zone could be heard caving into the uncased hole. Shortly thereafter an approximately 20-foot diameter area underneath the rear end of the drill rig began to slump down about one-half foot. Since the boring was about 4.5 feet into the shelly SC zone when fluid was lost, it is apparent that a void exists within or below this zone. When this zone is breached, loose, sandy soil from above and just below a shallow dense soil zone flows down into the void, causing the bridged-over dense sand to collapse up to the ground surface due to lack of support below.

SPC-2 was drilled about 60 feet north of SPC-1 and about 35 feet west of the track, near CPT push SP-5. This boring was drilled to the top of rock, at 80.5 feet BGS, with no samples taken. The limestone below 80.5 feet was then cored with a 4x5 ½ -inch core barrel. Only about 8 feet of limestone was found in this boring. The limestone indicated no apparent solution channels or voids. Only minor fluid losses were noted in this boring.

SPC-3 was drilled about 125 feet north of SPC-2 and about 35 feet west of the track, in the area of the GPR anomaly on the suspected northern edge of the old paleo-sink under the railroad embankment. The boring was drilled to a depth of 47.5 feet BGS, with no samples taken. At 47.5 feet, all drilling fluid was lost and an approximately 10-foot diameter area under the rear of the rig collapsed to a depth of about 5 feet (Photo 4).

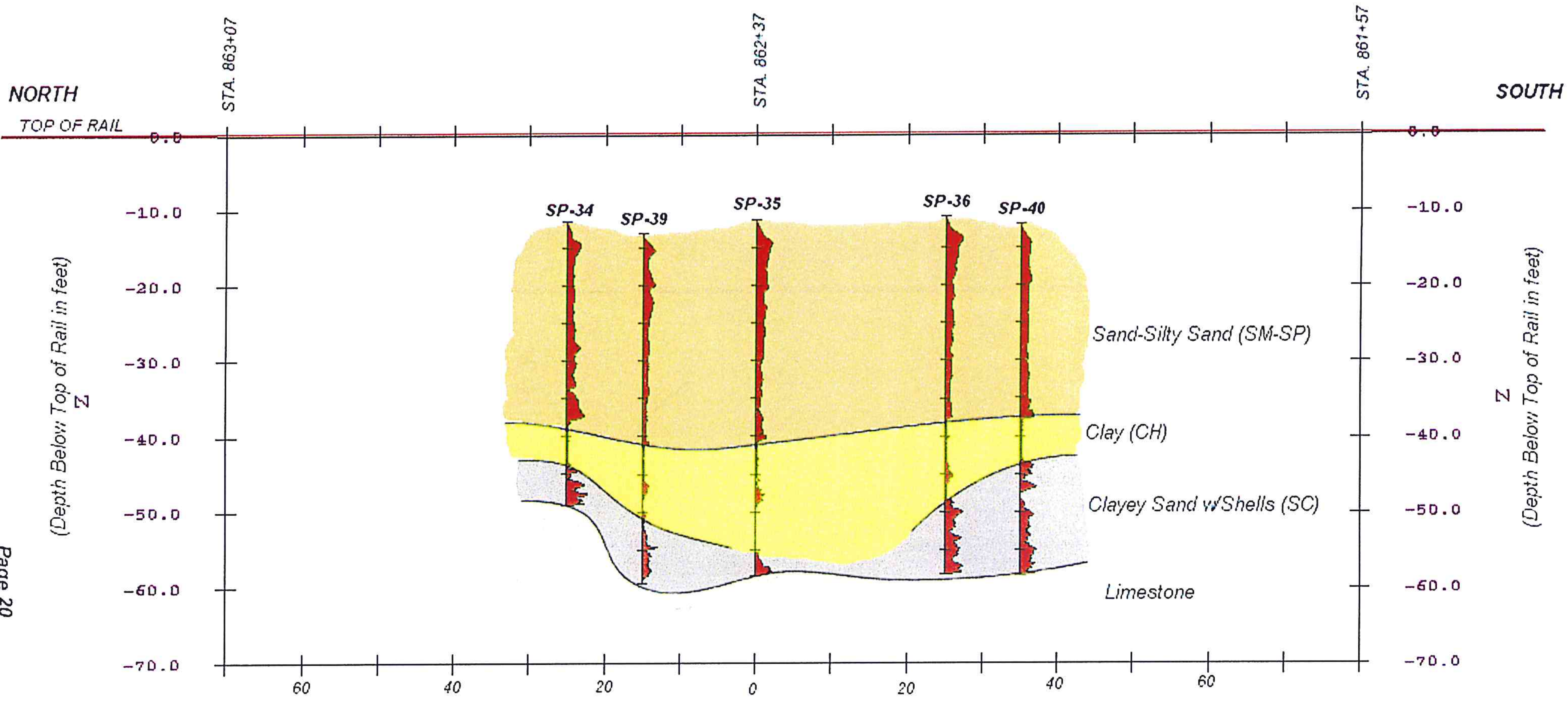
As can be seen from the geologic sections, the CPT pushes and drill holes appear to define an approximately 200 feet long area of down-warped soils, which apparently were dragged down in the collapse of the old paleo-sink. As would be expected, due to the orientation of the existing paleo-sink pond, the west side of the track exhibits the more pronounced down-warped soils, which are likely closer to the center of the old paleo-sink. The difference in depth to the top of limestone, from outside the paleo-sink to the inside of the paleo-sink, of more than 50-feet is indicative of the amount of displacement of overlying soils due to collapse of the limestone. The greatly reduced thickness of limestone within the paleo-sink is further evidence that a large solution cavity was likely the cause of the collapse.

The additional GPR survey along the railroad track south of the new sinkhole, conducted by Geophex Services, revealed a small anomaly underneath the track in an area about 2,400 feet south (towards MOTSU) of the new sinkhole (Geophex Services, Ltd. report in Appendix C). Five SCAPS CPT pushes were made in the area of this anomaly; SP-34, SP-35 and SP-36 on the west side of the track and SP-39 and SP-40 on the east side (Area "B" on Figure 4). Interpreted sections constructed along these pushes (Figures 11 and 12) reveal a zone of disturbed (down-warped) soil from about 40 to 55 feet below the top of the track. The top of limestone in this area appears to be about 60 feet below the top of the track. This zone of disturbed soil is apparently related to a feature in the limestone, which is allowing the soil structure to be gradually weakened and slumped.

Four SCAPS CPT pushes were made in another area along the track about 3,000 feet south of the new sink hole (about 500 feet north of Fifty Lakes Dr.) where MOTSU rail crews had noted what appeared to be small depressions in the ballast stone between cross-ties (Figure 4). CPT

Photo 3. SCAPS Rig Between Paleo-Sink Pond and Railroad Track.

Photo 4. Sink Which Occurred Under Drill Rig at SPC-3.



Notes:
1. CPT curves represent only cone (qc) data in tons per square foot (TSF), see push logs for details.
2. Section represents borings on both east and west sides of track.
3. This section is located in the area of a GPR anomaly.

FIGURE 11
AREA "B"
SECTION AT TRACK STATION 862+50

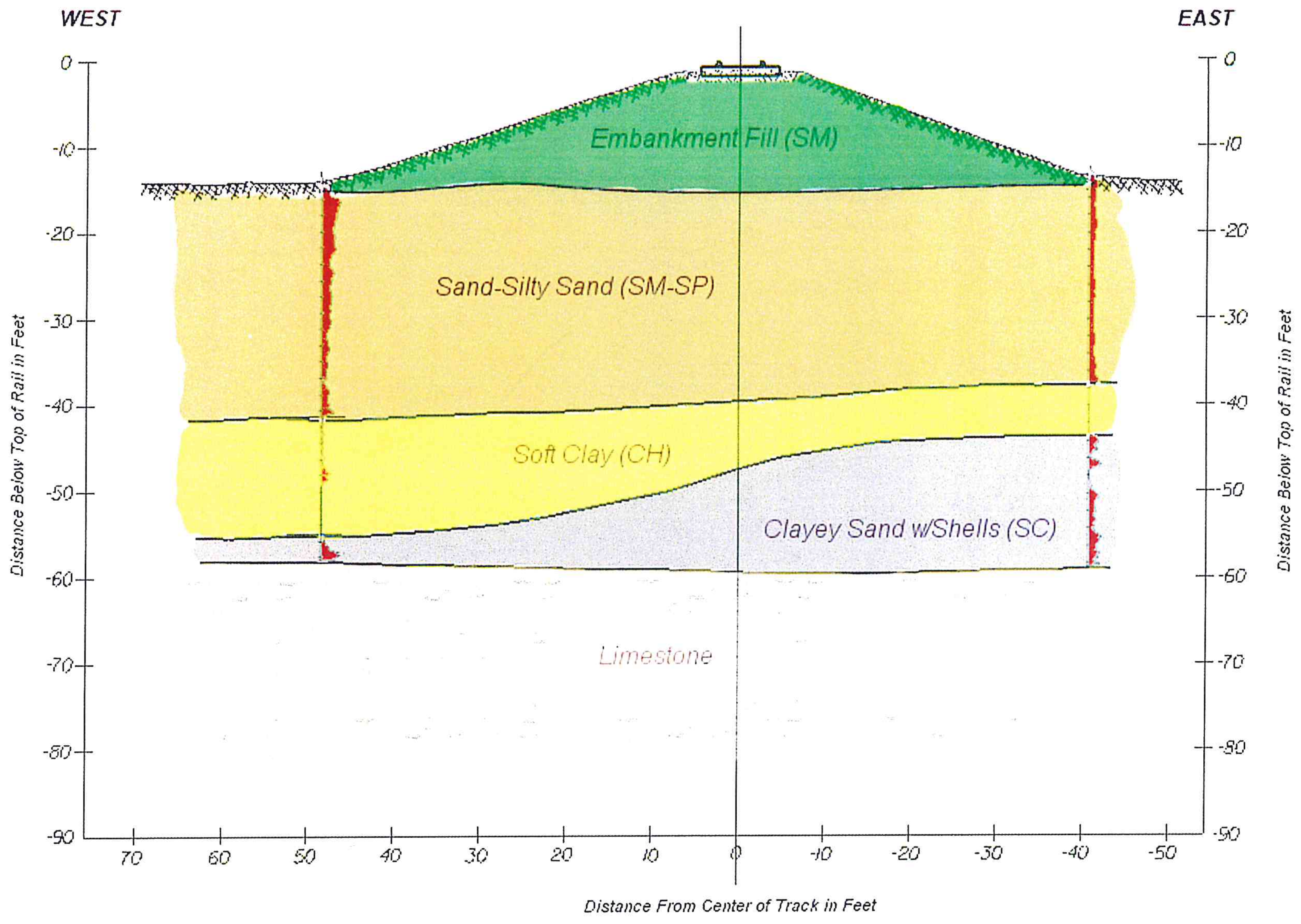
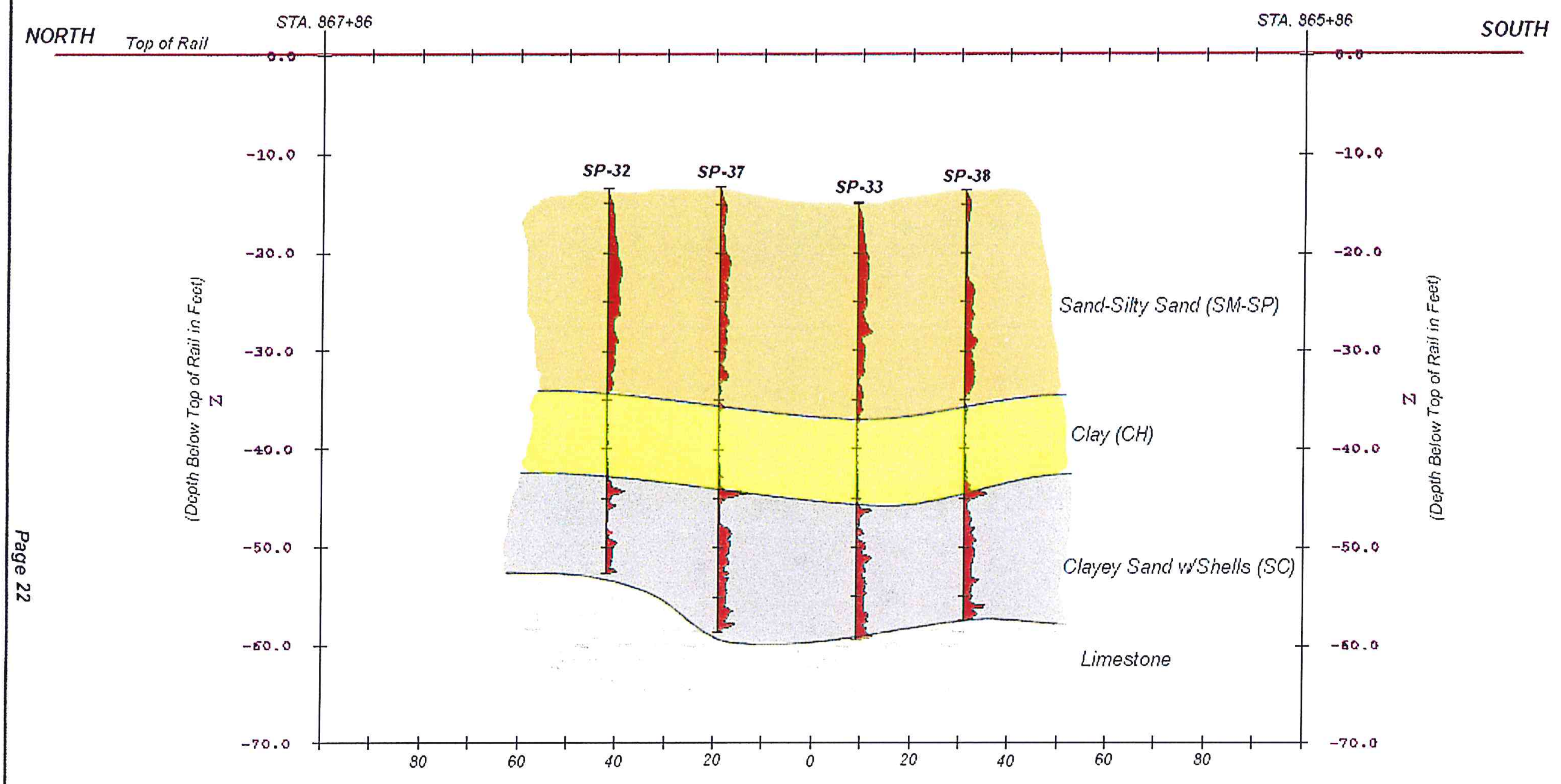


FIGURE 12
AREA "B"
SECTION AT TRACK STATION 862+25



Notes: 1. CPT curves represent only cone (qc) data in tons per square foot (TSF), see push logs for details.
2. Section represents borings on both east and west sides of track.

FIGURE 13
AREA "C"
SECTION AT TRACK STATION 867+00

pushes SP-32 and SP-33 were made on the west side of the track, and SP-37 and SP-38 on the east side. An interpreted section along these pushes is shown in Figure 13. These pushes revealed no disturbed or weakened soil zones. GPR results in this area also revealed no anomalies.

2.5 Conclusions

The occurrence of sinkholes is a very complex process. The formation of sinkholes involves a complex interaction of soil, rock and ground water. In general, the formation of a sinkhole begins with the progressive dissolving of limestone and the eventual collapse of the weakened rock or by the downward erosion of soil carried by water flowing through a pervious zone or erosion pipe to a cavity or void in underlying limestone. Solution activity within the limestone is enhanced along localized fractures, joints or bedding planes, since these features represent preferential flow paths that concentrate the flow of water in the formation. Solution activity is accelerated where the volume or velocity of flow increases.

The relationship of the new access railroad sinkhole, the GPR anomalies, and the fluid losses in two borings with the apparent edges of the old paleo-sink are not believed to be coincidental. All are believed to be due to the removal or piping of soil into remnant solution channels or voids along the edges of the old paleo-sink. These voids or channels may possibly be extensions of a larger cavity or void whose collapse was the cause of the paleo-sink.

The extreme ground-water conditions in the Boiling Spring Lakes area, caused by heavy rains in the winter of 1999 and drought in the summer of 2000 probably exacerbated soil piping along the edges of the old paleo-sink. Enough soil was removed to cause a vertical pipe to progress upward through weakened soils, and eventually manifest itself as a sinkhole beneath the railroad track. The vibration and loading from passing trains also probably contributed to the sinkhole formation.

The effect of the artificially higher hydraulic head, due to the impoundment of water in Boiling Spring Lake, undoubtedly exacerbates the sinkhole problems along the access railroad by way of increased ground-water heads and velocities. This would particularly be the case if extensions of the same solutioned joints or fractures happen to pass below both the lake and railroad.

This investigation has shown that the prediction of the location of limestone cavities and future sinkholes along the MOTSU access railroad can be greatly enhanced by the use of a combination of GPR and CPT. The use of GPR to screen extensive lengths of track for soil anomalies and the use of CPT to confirm the structure and strength of soils above the limestone can be rapidly accomplished with a minimum of effort.

Recently enhanced seismic methods such as multichannel analysis of surface waves (MASW) may also offer better resolution of the limestone surface and to some extent voids or cavities within the limestone.

2.6 Recommendations

Based on the results of this investigation and previous experience with sinkhole problems along the access railroad, it is felt that the best option to affect a fast repair with some likelihood of endurance for this recent sinkhole would be to use compaction grouting. Compaction grouting of the limestone and the soil above would help deter the further weakening of the soil/rock structure, as well as strengthen and stabilize already weakened zones. The intent would not be to attempt to fill every void within the limestone beneath the problem area, but rather to place enough grout within any larger limestone voids to support the heavily grouted soil above, and to stop any further downward movement, or piping, of soil into voids in the limestone. The longevity of a compaction-grouting repair would likely be dependent upon the occurrence of extreme rainfall conditions in the area. If conditions of the past several years are repeated in the future, the longevity of the repair may be reduced. Extreme conditions in the future may also cause sinkholes to appear in other areas.

If compaction grouting does not stabilize the new sinkhole area for the long-term, a more permanent solution such as an extension of the existing land bridge may be necessary.

It is also recommended that additional GPR surveying be performed from the end of the latest survey at Fifty Lakes Drive southward towards MOTSU for several more miles. The relatively low cost of the additional surveying would make it a very cost-effective method of "early warning" for potential sinks.

It also goes without saying that safety considerations would dictate the continued use of MOTSU's policy of reduced speed and vigilant inspection of the access railroad in the Boiling Springs Lake area.

3.0 REFERENCES

Brill, G.T. and Hussin, J. D., 1992, The Use of Compaction Grouting To Remediate A Railroad Embankment in A Karst Environment, Proceedings of the Twenty-Third Ohio River Valley Soils Seminar,

Technos, Inc., 1986, Results of Test and Production Phases of A Geophysical Investigation of Potential Sinkhole Collapse at Military Ocean Terminal Sunny Point Access Railroad, Boiling Spring Lakes, N.C.

U.S. Army Corps of Engineers, Savannah District, 1978, Technical Report on Sinkhole Development Along the Sunny Point Access Railroad at Boiling Spring Lakes, NC.

Zisman, E.D., 2001, A Standard Method for Sinkhole Detection in the Tampa, Florida, Area: Journal of Environmental & Engineering Geoscience, Vol. VII, No. 1, p. 31-50.

APPENDIX A

TECHNOS, INC. GPR DATA (1985)

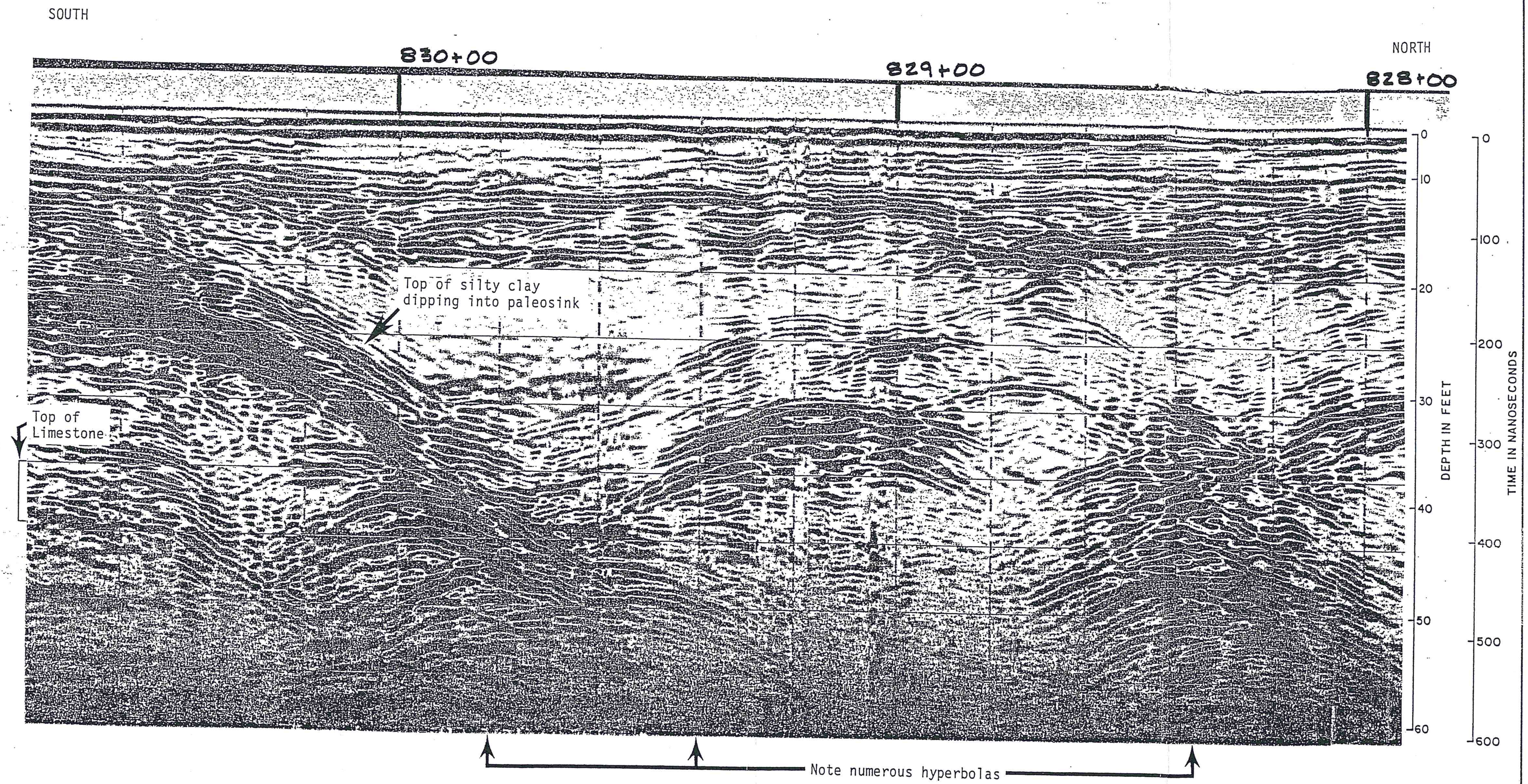
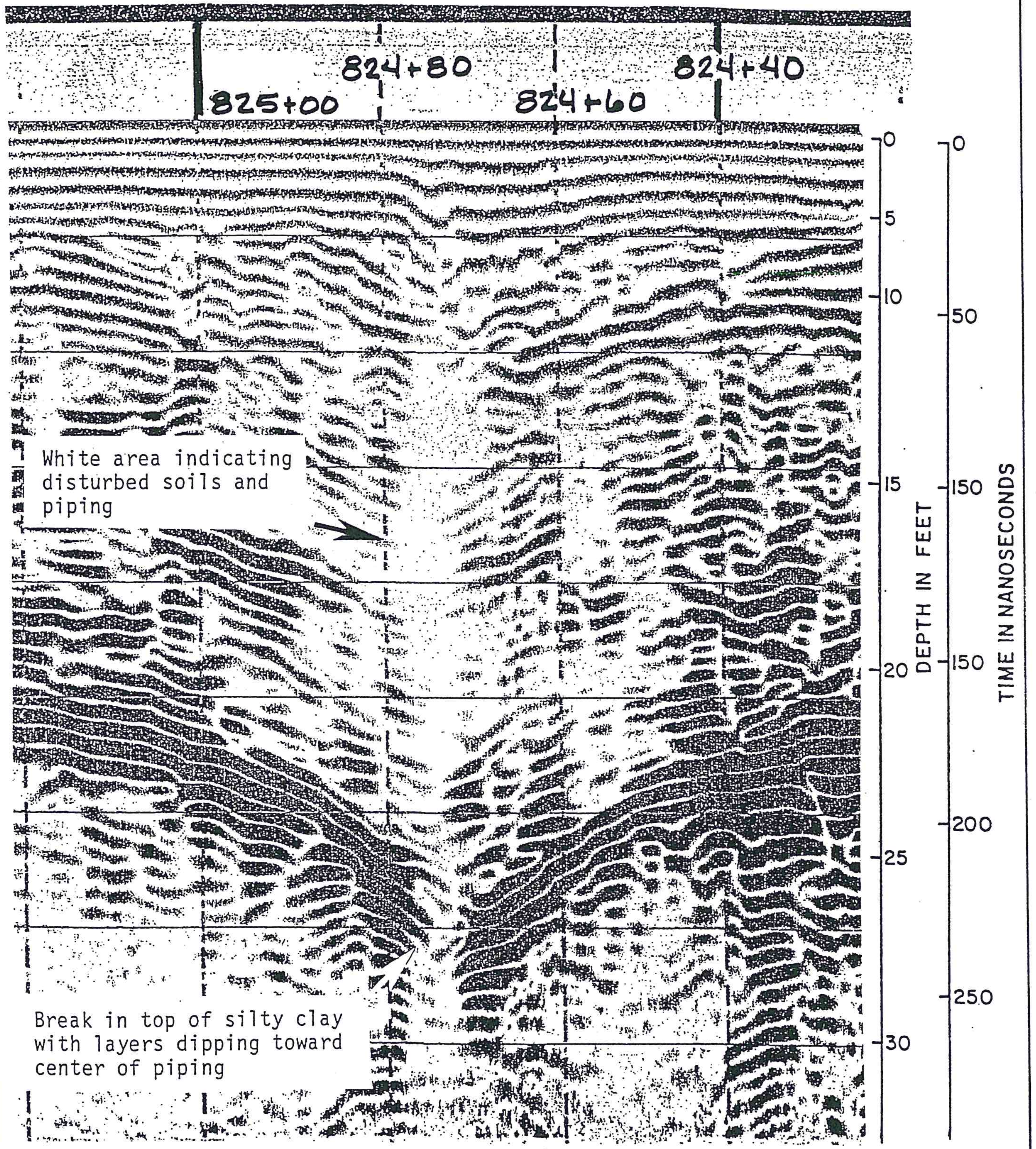


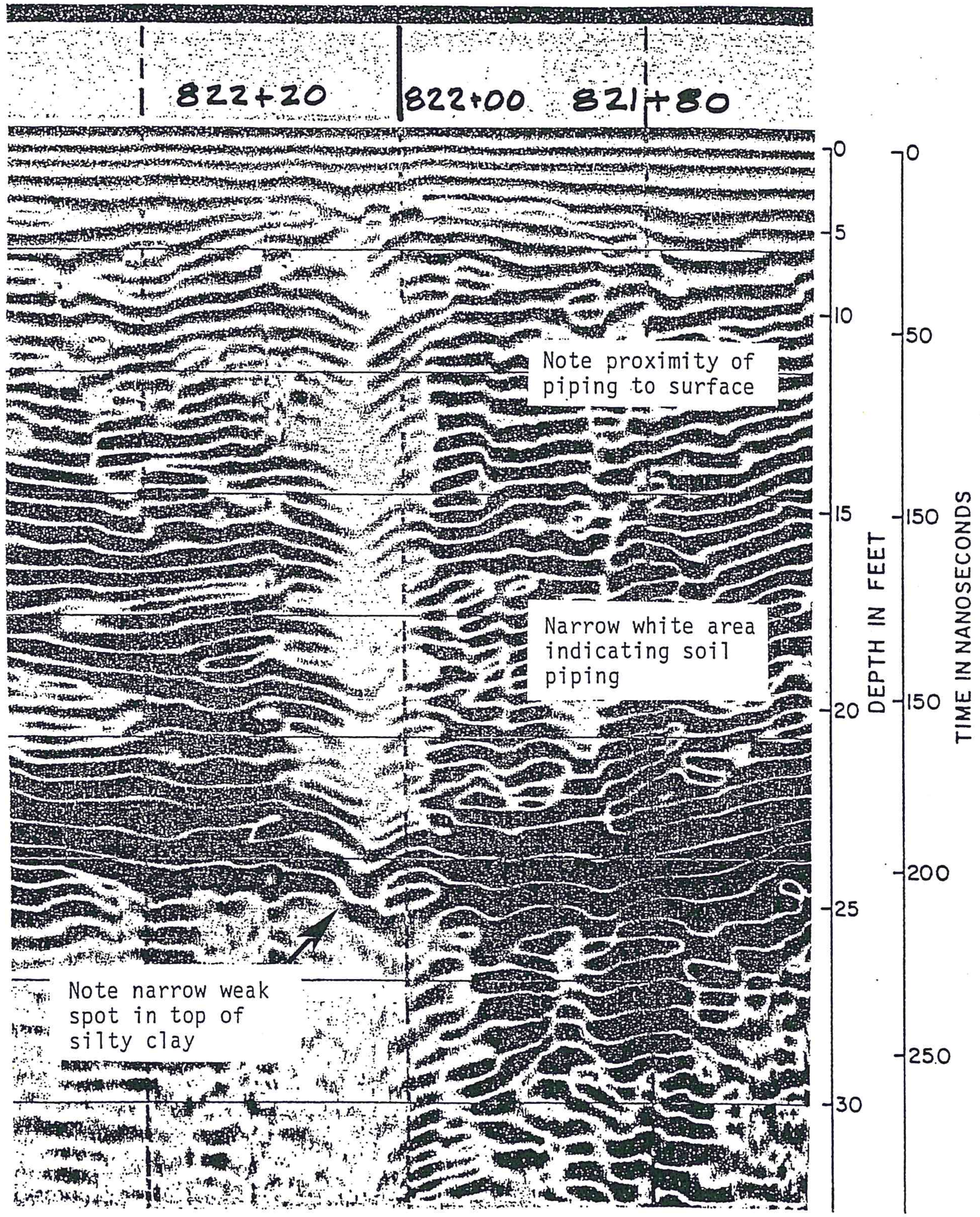
Figure 7. Deep Radar Data Showing a Paleosink.



White area indicating disturbed soils and piping

Break in top of silty clay with layers dipping toward center of piping

Figure 8. Shallow Radar Data Showing a Break in the Silty Clay Layer.



Note proximity of piping to surface

Narrow white area indicating soil piping

Note narrow weak spot in top of silty clay

Figure 10. Shallow Radar Data Showing a Narrow Piping Feature.

APPENDIX B

CPT AND BORING LOGS

Hole No. SPC-1

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SUNNY POINT M.O.T.	SHEET 1 OF 2 SHEET

1. PROJECT MOTSU RAILROAD SINKHOLE	10. SIZE AND TYPE OF BIT 1⅜" SPLITSPOON, 8" FISHTAIL
2. LOCATION *(Coordinates or Station)* SEE PLAN	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MSL
3. DRILLING AGENCY SAVANNAH DISTRICT	12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
4. HOLE NO. *(As shown on drawing title and file number)* : SPC-1	13. TOTAL NO. OF SOIL SAMPLES TAKEN : DISTURBED : : UNDISTURBED :
5. NAME OF DRILLER P. ROUNTREE	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.	15. GROUND WATER ELEVATION •35.1
	16. DATE HOLE : STARTED 30 JAN 01 : COMPLETED 31 JAN 01
7. THICKNESS OF OVERBURDEN 49.5'	17. ELEVATION TOP OF HOLE 48.0' MSL
8. DEPTH DRILLED INTO ROCK 0.0	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 49.5'	19. SIGNATURE OF INSPECTOR C. SMITH, C. MOORES - GEOLOGISTS

MSL ELEVATION 48.0'	DEPTH 0	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	JAR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g	
			(SM) Tan-brown med. grained silty sand.				8
							32
							50
	5		Tan-brown, fine to med.				10
			No Recovery				8
							2
	10						0
						Losing some fluid	3
							8
			(SM-SP) Dark brown, fine, silty sand. Saturated.				7
	15						8
			Gray-brown, fine to med.				8
			Tan-gray				10
	20		(SP) Tan-gray, fine to med. sand w/some silt, poorly graded				10
							11
							10
							13
	25		Tan, very fine, poorly graded				18
							9
							12
	30					Still losing some fluid	10
			Silt seams				10
			Gray, very fine				10
	35		Continued on Sheet #2			NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.	

DRILLING LOG (Cont Sheet)

ELEVATION TOP OF HOLE 48.0' MLW

Hole No. SPC-1

PROJECT MOTSU RAILROAD SINKHOLE

INSTALLATION SUNNY POINT M.O.T.

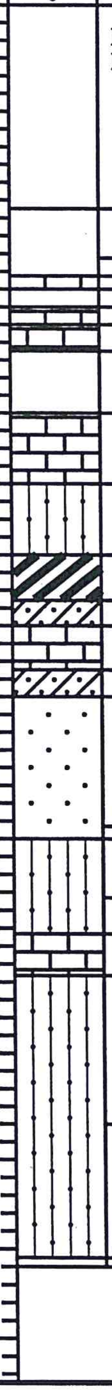
SHEET 2 OF 2 SHEETS

MSL ELEVATION 13.0' a	DEPTH 35 b	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	JAR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			No Recovery			6
		▨	(CH) Gray, silty, fat clay. Soft, sticky, saturated.			4 4
	40	▨				5 2
		▨	w/some fine sand, more stiff			3 2
	45	▨	(SC) Gray clayey fine sand w/silty clay.			6
		▨	w/shell hash			29 Lost all drilling fluid at 49.5' 27
	50		BOTTOM OF BORING AT 49.5'			10' diamter area around boring caved in about 2', approx. 10 min. after water loss.

Hole No. SPC-2

DRILLING LOG	DIVISION SOUTH ATLANTIC	INSTALLATION SUNNY POINT M.O.T.	SHEET 1 OF 1 SHEET

1. PROJECT MOTSU RAILROAD SINKHOLE	10. SIZE AND TYPE OF BIT 8" FISHTAIL
2. LOCATION (Coordinates or Station) SEE PLAN	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY SAVANNAH DISTRICT	12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
4. HOLE NO. (As shown on drawing title and file number) : SPC-2	13. TOTAL NO. OF SOIL SAMPLES TAKEN :DISTURBED : :UNDISTURBED :
5. NAME OF DRILLER P. ROUNTREE	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.	15. GROUND WATER ELEVATION
	16. DATE HOLE :STARTED : 30 JAN 01 :COMPLETED : 06 FEB 01
7. THICKNESS OF OVERBURDEN 80.5'	17. ELEVATION TOP OF HOLE 48.7' MSL
8. DEPTH DRILLED INTO ROCK 30.0'	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 110.5'	19. SIGNATURE OF INSPECTOR C. SMITH, C. MOORES - GEOLOGISTS



MSL ELEVATION -32.7	DEPTH b 0	SYMBOLS c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	JAR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			Fish-tailed w/mud to 80.5 No samples taken.			
			Began 4x5 coring at 80.5.			
-37.7	80		SANDSTONE - Gray calcareous, hard, well cemented.			
			friable, poorly cemented, fine to med. grained	83.3% 2.5/ 3.0		PULL 1
			Limestone - Gray, broken Limestone fragments.			
			No Recovery	43.3% 1.3/ 3.0		PULL 2
-37.7	85		Limestone - Gray, broken Limestone frag.; shells.			
			Limestone - Gray, broken Limestone fragments in fat silty matrix MH.	113% 4.5/ 4.0		PULL 3
			No Recovery			
-42.7	90		Limestone - Rock with shell hash. Light gray.			
			(SM) - Gray silty sand fine to med. grained with shell hash.	100% 4.0/ 4.0		PULL 4
			(CH) - Gray fat clay.			
			(SC) - Gray sandy clay, fine sand w\shell hash.			
-47.7	95		Limestone - Rock with shell hash.	100% 4.0/ 4.0		PULL 5
			(SC) - Gray sandy clay, fine sand with shell hash.			
-52.7	100		(SP) Gray sand fine to med grained with trace. inc.,silt content w\depth No cohesion	92.5% 3.7/ 4.0		PULL 6
			(SM) - Gray silty sand fine to med. grained with shell framents.	107.5% 4.3/ 4.0		PULL 7
-57.7	105		Tan silty sand fine to to med grained with shell fragments.			
			LIMSTONE - Gray sandy limestone frag. with shell hash.	92.5% 3.7/ 4.0		PULL 8
			(SM) - Tan silty sand fine to med. grained with shell partially cemented.			
-62.7	110		Gray silty sand fine to med. grained.			
			No Recovery			
			BOTTOM OF BORING AT 110.5'			

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

Hole No. SPC-3

DRILLING LOG
DIVISION SOUTH ATLANTIC
INSTALLATION SUNNY POINT M.O.T.
SHEET 1 OF 1 SHEET

1. PROJECT MOTSU RAILROAD SINKHOLE
2. LOCATION *(Coordinates or Station)* SEE PLAN
3. DRILLING AGENCY SAVANNAH DISTRICT
4. HOLE NO. *(As shown on drawing title and file number)* : SPC-3
5. NAME OF DRILLER WESLEY HERMAN
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 47.5'
8. DEPTH DRILLED INTO ROCK 0.0
9. TOTAL DEPTH OF HOLE 47.5'
10. SIZE AND TYPE OF BIT FISHTAIL
11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)* MSL
12. MANUFACTURER'S DESIGNATION OF DRILL FAILING 1500
13. TOTAL NO. OF SOIL SAMPLES TAKEN :DISTURBED : :UNDISTURBED :
14. TOTAL NUMBER CORE BOXES
15. GROUND WATER ELEVATION
16. DATE HOLE :STARTED : 07 FEB 01 :COMPLETED : 07 FEB 01
17. ELEVATION TOP OF HOLE 48.86' MSL
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR C. MOORES - GEOLOGISTS

MSL ELEVATION a	DEPTH b 0	SYMBOLS c	CLASSIFICATION OF MATERIALS *(Description)* d	% CORE RECOVERY e	JAR SAMPLE NO. f	REMARKS *(Drilling time, water loss, depth of weathering, etc., if significant)* g
43.9'	5		Fishtailed with mud 47.5' where all drilling fluid was lost.			
38.9	10					
33.9	15					
28.9	20					
23.9	25					
18.9	30					
13.9	35					
8.9	40					
3.9	45					
-1.1	50					

BOTTOM OF BORING AT 47.5'

NOTE: SOILS VISUALLY FIELD CLASSIFIED IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

Remedial Dam Repair Investigation
and Design Report
Boiling Springs Lake Dam
Boiling Springs Lake, North Carolina
S&ME Job No. 1051-87-291

S&ME
(A partnership in North Carolina)

May 10, 1988

City Commissioners
City of Boiling Spring Lakes
Post Office Box 10
Southport, North Carolina 28461

Attention: Mr. Glenn Long

Reference: Remedial Dam Repair Investigation
and Design Report
Boiling Spring Lake Dam
Boiling Spring Lake, North Carolina
S&ME Job No. 1051-87-291

Commissioners:

S&ME has completed the authorized dam safety inspections, subsurface explorations, hydrologic and hydraulic analyses, and geotechnical engineering evaluations of subsurface conditions associated with remedial repairs to the spillway structure and spillway embankment section at the Boiling Spring Lake Dam in Boiling Spring Lakes, North Carolina. This investigation and remedial dam repair design was authorized by acceptance of the S&ME Proposal dated June 24, 1987.

This report presents a brief description of the dam and spillway structure, findings of the dam safety inspections and subsurface explorations, results of the hydrologic and hydraulic analyses, and recommendations for remedial dam repairs. Enclosed herewith are the construction plans and details for remedial repair of the dam.

PROJECT DESCRIPTION

Boiling Spring Lake Dam is an earthfilled structure, having a length of about 1400 feet and a structural height of about 31 feet, located on Allen Creek as indicated on the Vicinity Map presented as Figure 1 of this report. The dam has a crest width of about 30 feet which supports a 24-foot two-lane asphaltic concrete surface roadway with paved curbs. Top of dam elevation is approximately 38 feet with tailwater at normal flow being

S&ME, Inc.
3109 Spring Forest Rd., P.O. Box 58069
Raleigh, NC 27658-8069 (919) 872-2660

about elevation 7 feet.

The normal pool elevation of 30 feet is maintained by a concrete box inlet spillway structure which serves as a riser for four 54-inch diameter corrugated metal pipe (CMP) spillway barrels. The invert elevation of the spillway barrels is approximately 7 feet. This spillway structure functions as both the primary and emergency spillway systems. Regulation and operation of the reservoir pool elevation is provided by 4 sluice gates which are aligned with the 4 barrels of the spillway structure.

According to remedial dam repair plans prepared by Henry Von Oesen & Associates in October, 1977, some remedial repairs were made at the first joint of the CMP barrels of the spillway structure during other remedial dam repair activities. These remedial repairs were deemed necessary during a more extensive grouting program to repair a sinkhole feature which developed within the lake near the left (facing downstream) abutment of the dam. Repairs to the spillway structure, located near the right abutment, involved the excavation of the first joint of the spillway barrels which had undergone settlement which resulted in separation of the joint system at the junction of the first and second segment of pipe. New joint collars were placed on the CMP barrels at the first joint and a aggregate filter system was installed around the pipes prior to backfilling the spillway embankment section.

DAM SAFETY INSPECTIONS

S&ME conducted the initial dam safety inspection of this investigation at Boiling Spring Lake Dam on May 26, 1987. This dam safety inspection was conducted as a result of findings made by the Land Quality Section, North Carolina Department of Natural Resources and Community Development (NRCD) on March 17, 1987 during a routine dam safety inspection. Results of the dam inspection was reported to the City of Boiling Spring Lakes on March 26, 1987 and May 4, 1987. Findings of the initial dam safety inspection conducted by S&ME were reported to the City of Boiling Spring Lakes with a copy to NRCD on June 24, 1987. Subsequent dam safety inspections were conducted on June 25, 1987, and in September, 1987 during subsurface exploration programs.

According to verbal information gathered during the initial dam safety inspection of May 26, 1987, a significant "drop-out" or loss of embankment soil occurred along the shoulder of the roadway on the crest of the dam during late summer or early fall of 1986. The "drop-out" appeared on the upstream slope at about the center of the alignment of the spillway barrels extending through the embankment section beneath the paved roadway. The "drop-out" was identified by a tractor-mounted roadside mower during routine maintenance mowing operations. The "drop-out" was apparently 3 to 4 feet in diameter and 2 to 3 feet in depth. Subsequent to identification or location of the "drop-out", the area was excavated to below the depth of the "drop-out" and backfilled with reportedly compacted sandy soil. Loss of embankment soils or "drop-outs" in embankments above pipes or conduits are often the visual evidence of internal erosion or piping of soils along the pipes or conduits or through separated joints in the pipes or conduits. During the dam safety inspection on May 26, 1987 and during subsequent site inspection, the asphaltic concrete pavement and paved curb in the spillway area (particularly adjacent to the previously described "drop-out") were observed to exhibit a significant amount of subsidence which was estimated to be on the order of 3 to 4 inches. The dam safety inspection did not reveal the presence of seepage at the downstream toe of the embankment or at the headwall of the CMP barrels of the spillway system. As such, soil loss as a result of internal erosion or piping along the CMP barrels through the embankment is not considered to be the cause of the previously described "drop-out". However, there is evidence that soil loss likely has occurred through the joints of the CMP barrels of the spillway.

The CMP barrels of the spillway structure have been reported to be 52-inch diameter in both NRCD and S&ME dam safety inspection reports. However, subsequent reviews of plans dated October 26, 1977 by Henry Von Oesen & Associates indicate that the CMP barrels of the spillway were originally 54-inch diameter conduits.

During the dam safety inspection on May 26, 1987, the concrete box inlet structure which forms the riser for the four 54-inch diameter CMP barrels of the spillway system was observed to be in very good condition with the exception of some seepage through the contact joint between the front wall (wier section) and the right wall of the riser system. Seepage through this joint was estimated to be about 1 to 2 gallons per minute (gpm) by NRCD on March 17, 1987. Seepage through this joint was estimated to be 1 gpm or less on May 26, 1987 with the lake level at about elevation 29.5 feet which was 6 inches below normal pool elevation. All of the sluice gates opening into the spillway gallery were observed to be leaking slightly; however, Gates No. 2 and No. 3 (interior) which are most often used to regulate the lake level were observed to be leaking more than Gates No. 1 and No. 4 (exterior). As such, the leaks around the gates are considered to be more closely associated with improper or inadequate seating of the gates than deterioration of the sluice gate bottom drain systems. It should be noted that the gates are referenced in number from south (right abutment) to north as Gates No. 1 through No. 4.

All four of the 54-inch diameter CMP barrels of the spillway system are significantly deformed, out-of-round, and mis-aligned. Deformation of sections of the CMP barrels appears to be as much as 8 to 10 inches in some areas. Vertical movement and/or settlement of sections of the CMP barrels has caused mis-alignment of the invert of the conduits such that "steps" or vertical drops exist between sections of the conduits. Deformation and mis-alignment of the CMP barrels has caused failure of the interior joint bands at most joint locations.

Spillway Barrel No. 1 (south or right abutment side) exhibits evidence of significant inflow of seepage. On May 26, 1987, inflow into the upstream end of the barrel was estimated to be 2 to 3 gpm with outflow at the downstream end estimated to be 5 to 6 gpm. The sound of seepage and flowing water as readily audible along about one-third to one-half of the upstream end of Barrel No. 1. Seepage into Barrels No. 2 and No. 3 was not as evident as seepage into Barrels No. 1 and No. 4 as a result of the higher flow rate resulting from leakage beneath Gates No. 2 and No. 3. The most obvious seepage flow was observed in Barrel No. 4 where a significant flow of water was occurring through the first joint of the CMP barrel.

SUBSURFACE CONDITIONS

As a result of the occurrence of a "drop-out" within the spillway embankment section of the dam and observed severe deformation, settlement, and general mis-alignment of the CMP barrels of the spillway system, a subsurface exploration program was deemed necessary to evaluate the stability and potential piping or internal erosion of soils around the barrels of the spillway structure. The subsurface exploration program was conducted in two phases in an attempt to develop a maximum of subsurface information by use of different exploration procedures.

The initial phase of the subsurface exploration program was conducted with a portable Dinastar Cone Penetrometer capable of developing both static and dynamic cone penetration data. Subsequently, soil test borings were conducted utilizing hollow stem augering techniques and standard penetration tests (ASTM D-1586) at selected intervals to determine the consistency and density of in-place embankment soils. Dinastar Cone Penetrometer test locations and soil test boring locations were located as indicated on the Boring Location Plan presented as Figure 2 of this report. Boring and test locations were established by taping distances from existing features such as the roadway and spillway structure and should be considered as approximate locations.

The Dinastar Cone Penetrometer testing was conducted as an equipment demonstration project. Two Dinastar Cone Penetrometer tests were conducted adjacent to the roadway on the upstream side of the spillway embankment section with the third test location approximately 100 feet north of the spillway embankment section to establish a comparative reference for embankment soil conditions within the spillway embankment section and within a typical dam embankment section.

The first Dinastar Cone Penetrometer test was a dynamic cone penetration test probe located between Barrels No. 1 and No. 2 in the vicinity of the previously described "drop-out" feature which was subsequently backfilled. This cone penetrometer test indicates the presence of very loose sands to a depth of about 4 feet where the sandy embankment fill soils become increasingly more dense to a depth of about 6 feet. Below a depth of 6 feet to a depth of about 9 feet, the embankment fill soils become increasingly less dense to a very loose condition. Below about 9 feet and extending to a depth of about 20 feet the sandy embankment fill soils are typically loose with a very loose stratum at about 12.5 feet. At the termination depth of 21 feet, the embankment fill soils are medium dense to firm in consistency. The second Dinastar Cone Penetrometer test location was on the upstream shoulder of the roadway between Barrels No. 3 and No. 4. This test was a dynamic cone sleeve test extended to a termination depth of about 9.5 feet. This cone penetration test indicates the presence of very loose embankment fill sands to the termination depth of a about 9.5 feet. These fills soils are classified texturally as loose gravels and sands as a result of the typically high friction ratio which is the ratio of skin friction on the sleeve to cone penetation resistance. This condition is indicative of a very angular sand and/or gravel soil which typically derives most of its shear strength from internal friction as opposed to apparent or true cohesion. The third Dinastar Cone Penetrometer test was conducted approximately 100 feet north of the spillway embankment section with testing continued to a depth of about 16 feet. This test location indicates the presence of stratification within the dam embankment. The embankment fill sands increase in consistency from a loose condition at the surface to a very dense consistency at 3 to 4 feet where the consistency decreases to a loose condition between about 6 and 8 feet. Between depths of about 9 to 10 feet the embankment fill soils are medium dense and again decrease to a very loose consistency at about 14 feet. Below 14 feet to the termination depth of 16 feet, the embankment soils increase in consistency to a very dense condition. This profile is indicative of potential inadequate quality control during fill placement. Logs from the Dinastar Penetrometer testing are presented in Appendix I of this report.

Soil test borings B-1 through B-3 indicate the presence of a vertical stratification of embankment fill soils relative to in-place density and consistency of the embankment materials. Soil test borings indicate that embankment fill soils increase in consistency from a loose condition at the surface as indicated by standard penetration resistance values of 10 to 13 blows per foot (bpf) to medium dense conditions at about 6 to 8 feet as indicated by standard penetration resistance values of 18 to 31 bpf. At a depth of 10 feet, the embankment fill soils are loose as indicated by standard penetration resistance values of 10 to 12 bpf, but again become medium dense to dense with increasing depth to about 16 to 18 feet where standard penetration resistance values are 41 to 53 bpf with typical values of 41 to 43 bpf. Below depths of 16 to 18 feet, the embankment fill soils become significantly looser to depths of 27 to 32 feet where standard penetration resistance values are 7 to 9 bpf. Beneath the sandy embankment fill soils at depths of about 27 to 32 feet there exist sandy clay soils exhibiting standard penetration resistance values of 7 to 9 bpf. Soil test borings terminate in natural fine sands containing shell fragments below a depth of about 37 feet. These natural sands exhibit standard penetration resistance values of 8 to 11 bpf.

Soil test borings were observed for the presence of ground water at the termination of drilling and again after periods of at least 24 hours. In addition, temporary piezometers were installed in borings B-1 and B-3 to allow long-term monitoring of ground water. Based upon these ground water observations, ground water levels were found to vary in depth from about 18.5 feet in boring B-1 to about 24.5 feet at borings B-2 and B-3. These ground water levels represent a depressed phreatic surface or seepage line through the spillway embankment section of the dam and indicate the affect of seepage loose into the CMP barrels of the spillway system.

Soil test boring data has been utilized to develop a generalized subsurface profile presented as Figure 3 of this report to graphically illustrate subsurface conditions existing at this site. More detailed descriptions of conditions encountered at individual boring locations are presented in the Test Boring Records enclosed in Appendix I of this report.

DAM AND SPILLWAY CLASSIFICATION

Boiling Spring Lake Dam has a structural height of approximately 31 feet and is located immediately upstream (west) of the primary access railroad line into the U.S. Army Sunny Point Depot Facility. Based upon current criteria for classification of dams by the North Carolina Dam Safety Law of 1967, Boiling Spring Lake Dam is classified as a small size structure since the structural height is less than 35 feet. However, because of its proximity to the primary access railroad line to Sunny Point, which is a strategic military depot facility, the structure has been classified as a high hazard dam by NRCD.

According to current criteria of the North Carolina Dam Safety Law of 1967, the spillway design flood (SDF) to be used in analysis and design of spillway system capacity is a function of both the size and hazard classification of the structure. Based upon these criteria, the SDF for Boiling Spring Lake Dam is the 0.33 probable maximum precipitation (PMP) return frequency storm event. As such, the spillway system of the Boiling Spring Lake Dam must be capable of safely passing the 0.33 PMP storm event without overtopping.

HYDROLOGIC AND HYDRAULIC ANALYSES

The contributory drainage area of Boiling Spring Lake Dam is approximately 9 square miles as determined by planimeter measurements from the Funston, North Carolina U.S.G.S. quadrangle map. The U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number Method, as outlined in "Section 4-Hydrology" N.E.H., SCS, was utilized to evaluate runoff characteristics of the contributory watershed. Soil types within the watershed were determined from the Brunswick County SCS Soil Survey. Soils within the watershed consist of both upland and wetland soil associations. The upland soils consist of the Kureb, Mandarin, and Leon Associations. The Croatan and Murville Associations comprise the wetland soils. Aerial photographs from recent soil surveys were used to evaluate current land use patterns within the watershed. Based upon the hydrologic analysis for the watershed, a weighted Curve Number of 61 was determined to represent runoff characteristics. Calculations for determination of runoff characteristics are presented in Appendix II of this report.

The probable maximum precipitation (PMP) storm event from the watershed was determined by use of the Hydrometerological Report No. 51 with more frequent returns period storm events (25-year, 50-year, and 100-year) being determined from Technical Paper No. 40. A 24-hour storm duration period was utilized in establishment of rainfall for the various return frequency storm events. Results of these rainfall analyses are tabulated below.

Storm Event	Rainfall, inches
25-year	8.0
50-year	9.0
100-year	10.0
0.33 PMP	14.2
1.0 PMP	43.0

The existing spillway structure consist of a concrete drop inlet with a 48-foot weir length which forms a riser for four 54-inch diameter CMP barrels to carry flow through the spillway embankment section of the dam. One feasible alternative for remedial repair of the existing spillway system is to provide inserts in the existing barrels of the spillway. The insert barrels will be polyethelene pipe grouted into place within the existing barrels of the spillway. In order to evaluate the minimum size inserts that could be utilizied in remedial repair of the spillway, flood routings were conducted to evaluate the proposed remedial repair scheme.

Flood routings for evaluation of the remedial repair scheme were conducted using the U.S. Army Corps of Engineers HEC-1 computer program. As a result of the very flat slope of Allen Creek downstream of Boiling Spring Lake Dam and the effect of storm events on area flooding of the Allen Creek drainage basin, the spillway system of Boiling Spring Lake Dam is considered to be outlet controlled. The tailwater elevation caused by flooding of Allen Creek downstream of the Boiling Spring Lake Dam was estimated to be elevation 20 feet which is about 13 feet above the normal flow elevation of 7 feet. Results of the flood routing analyses are summarized below. Computer print-outs of the flood routing analyses and hydraulic evaluations are presented in Appendix II of this report.

Storm Event	Maximum Inflow, cfs	Maximum Outflow, cfs	Maximum Pool Elevation
25-year	1810	611	32.6
50-year	2240	626	33.3
100-year	2680	643	34.0
0.33 PMP	5010	723	37.5

With a normal pool elevation of about 30 feet and top of dam elevation of 38 feet, the proposed remedial dam repair scheme will result in a spillway capacity that will provide 4 feet of freeboard during the estimated 100-year return frequency storm event and 0.5 foot of freeboard for the SDF which is the 0.33 PMP return frequency storm event. As such, the proposed remedial repairs which involve grouting 40-inch diameter insert pipes into the existing barrels of the spillway system appear to be a viable remedial repair scheme.

RECOMMENDATIONS

Recommendations presented herein are based upon observations during dam safety inspections, evaluations of subsurface conditions as represented by subsurface exploration data contained in this report, hydrologic and hydraulic analyses, and previous experience with similar projects and needed remedial dam repairs. Recommendations for remedial repair of the existing spillway system and spillway embankment section of the dam include the grouting of insert pipes within the barrels of the spillway system and pressure injection grouting of the spillway embankment section of the dam to stabilize embankment fill soils in the area of the spillway barrels.

Spillway Barrel Inserts - Remedial repair of the deformed and mis-aligned barrels of the spillway system should consist of the insertion of 40-inch inside diameter polyethelene pipes into the existing 54-inch diameter CMP barrels. The anular space around the polyethelene pipe inserts will be grouted with a neat cement grout having a minimum 28-day strength of 3000 pounds per square foot. The upstream invert elevation of the insert pipes will be the same as the bottom elevation of the spillway gallery. The polyethelene pipe inserts should be continuous with no joint couplings. All joints in the insert pipes should be formed by making chemical or heat welds which bond the polyethelene pipe into a continuous conduit. Construction details for the spillway barrel inserts are presented in Figure 4 of this report.

Pressure Injection Grouting - Pressure injection grouting should be utilized to stabilize fill soils within the spillway embankment section of the dam as indicated in Figure 5 of this report. The intrusion grout for pressure injection should consist of a mixture of Type 1 Portland cement and water, together with such admixtures, necessary to produce a cementitious material that can be injected under pressure into soil voids and intersticies. The split-spacing method of grouting shall be utilized with primary grout holes located at 5-foot spacings in each direction. Primary grout injection holes should extend through embankment materials and to the barrels of the spillway system. Typical primary grout injection holes along the top of dam will extend about 32 to 34 feet below existing top of dam elevation. Grout injection should start at the maximum depth and continue as the grout injection point is withdrawn to a minimum depth necessary to prevent excessive grout flow from the top of the grout injection hole. Grout proportions, grout injection pressures, and grout injection hole locations may be adjusted by the engineer to optimize grout take at minimum injection pressures.

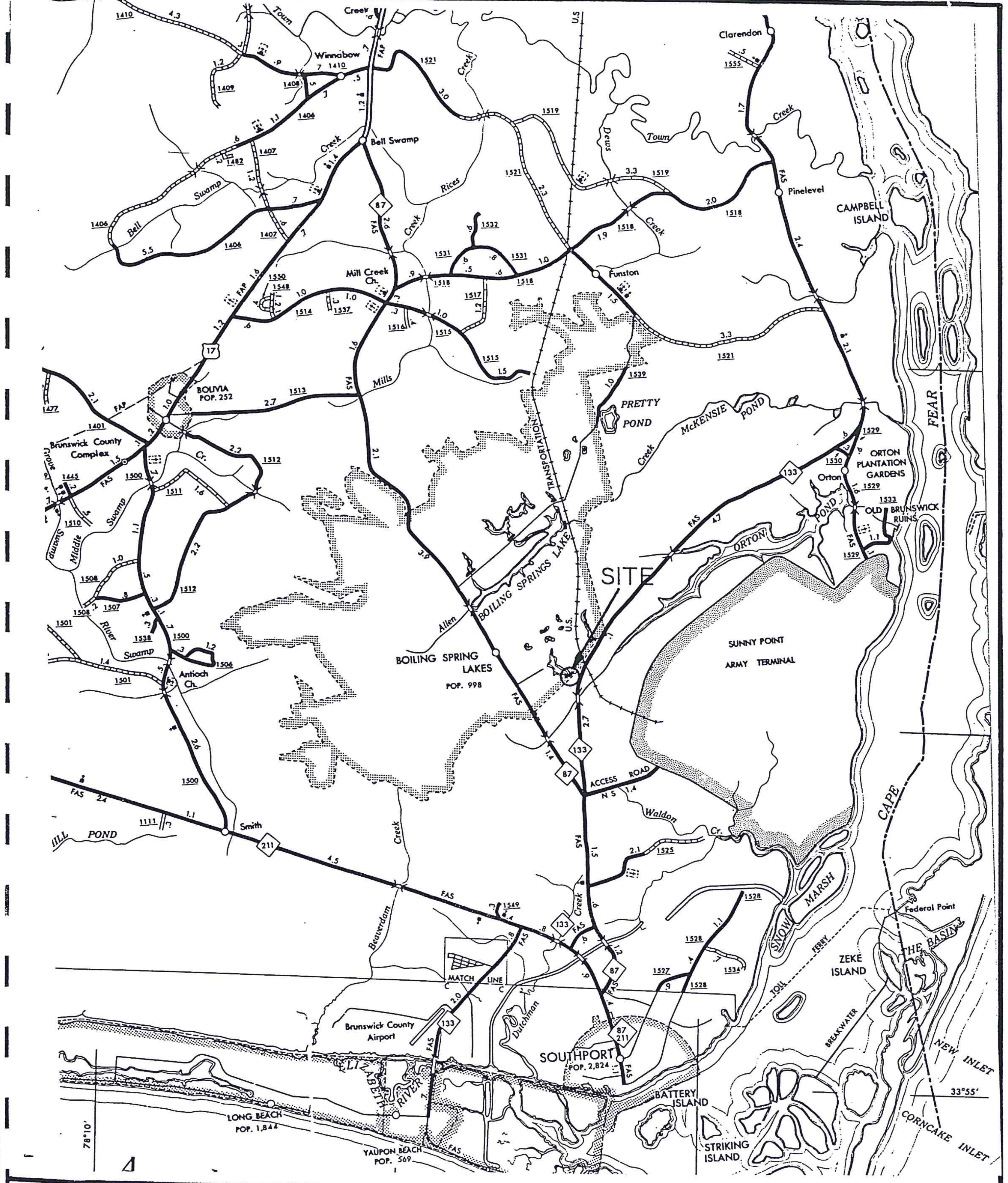
S&ME appreciates the opportunity to be of professional service on this project. If there are questions concerning this report, or if we can provide additional information, please contact us at your convenience.

Very truly yours,
S&ME

B. Dan Marks, Ph.D., P.E.
N.C. Registration No. 9631

John R. Browning, P.E.
Raleigh Branch Manager

BDM/JRB/ss

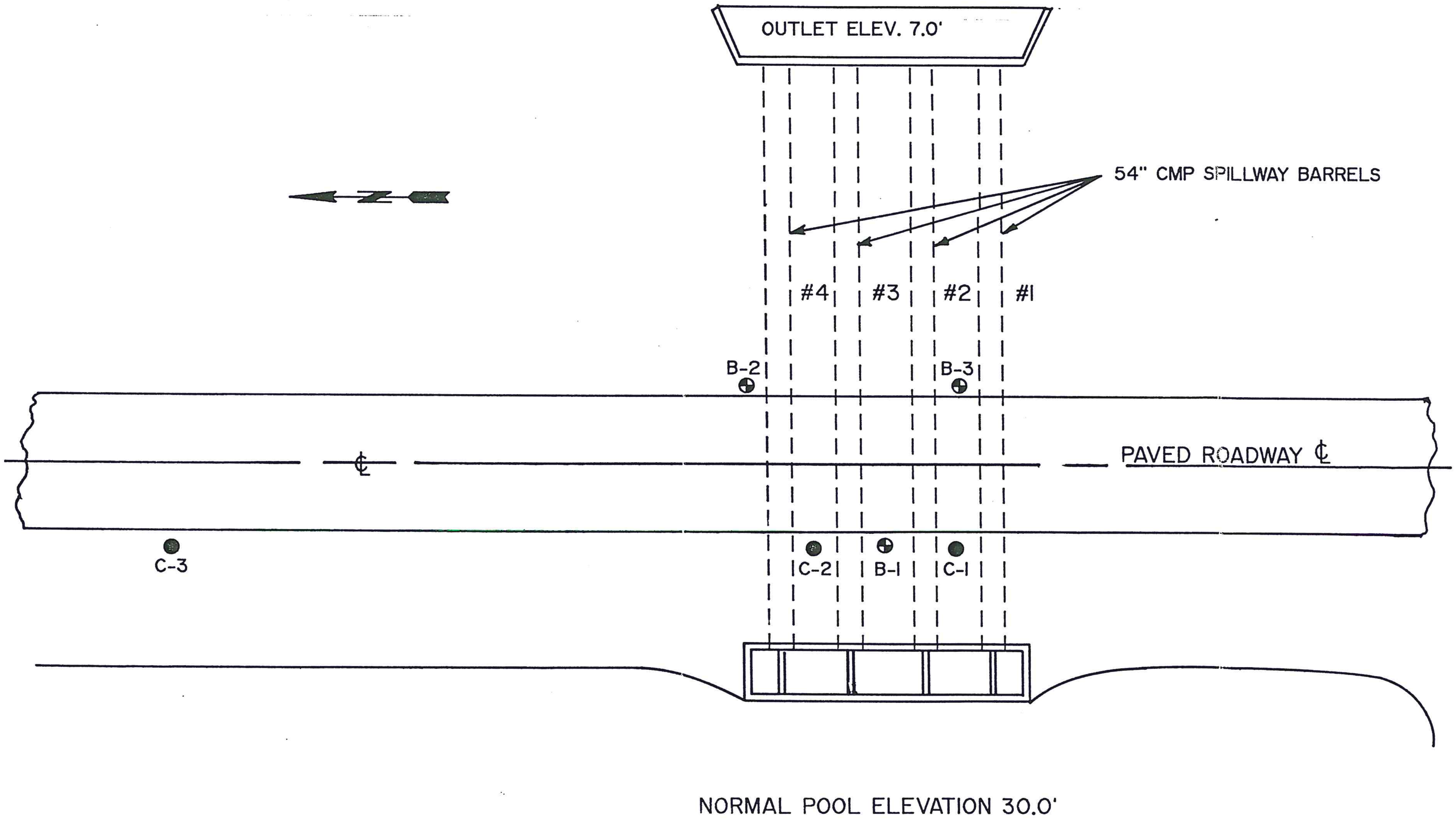


DUNCAN-PARNELL, INC., CHARLOTTE 787 800-432-6022

PROJECT
BOILING SPRING LAKE DAM
BOILING SPRING LAKE, N.C.

S&ME

SCALE: 1" = 2miles
JOB NO: 1051-87-291
FIG. NO: 1



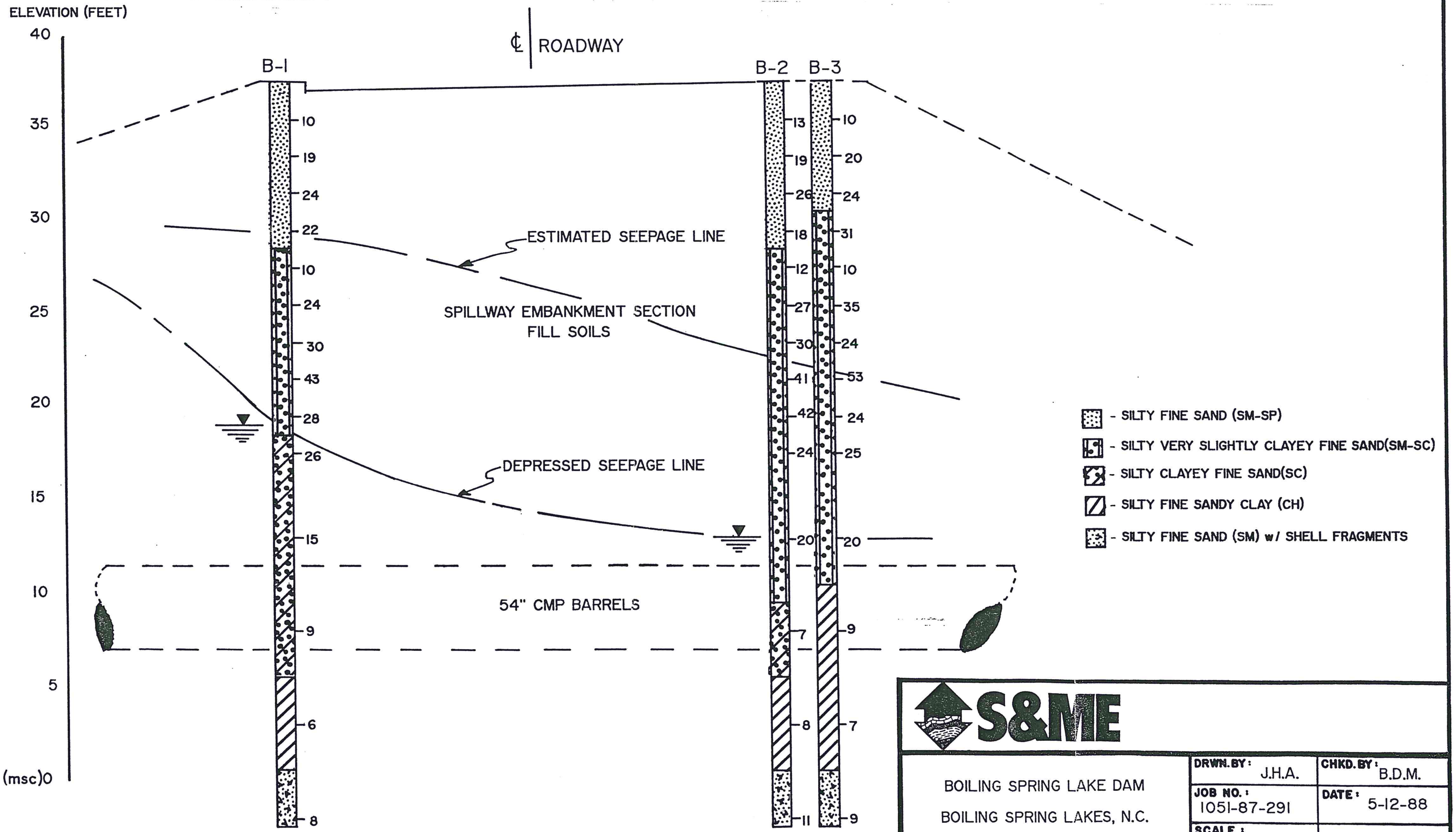
S&ME

BORING LOCATION PLAN

BOILING SPRING LAKE DAM
BOILING SPRING LAKES, N.C.

DRWN. BY: J.H.A.
CHKD. BY: B.D.M.
JOB NO.: 1051-87-291
DATE: 5-12-88
SCALE: 1" = 20'
FIGURE 2

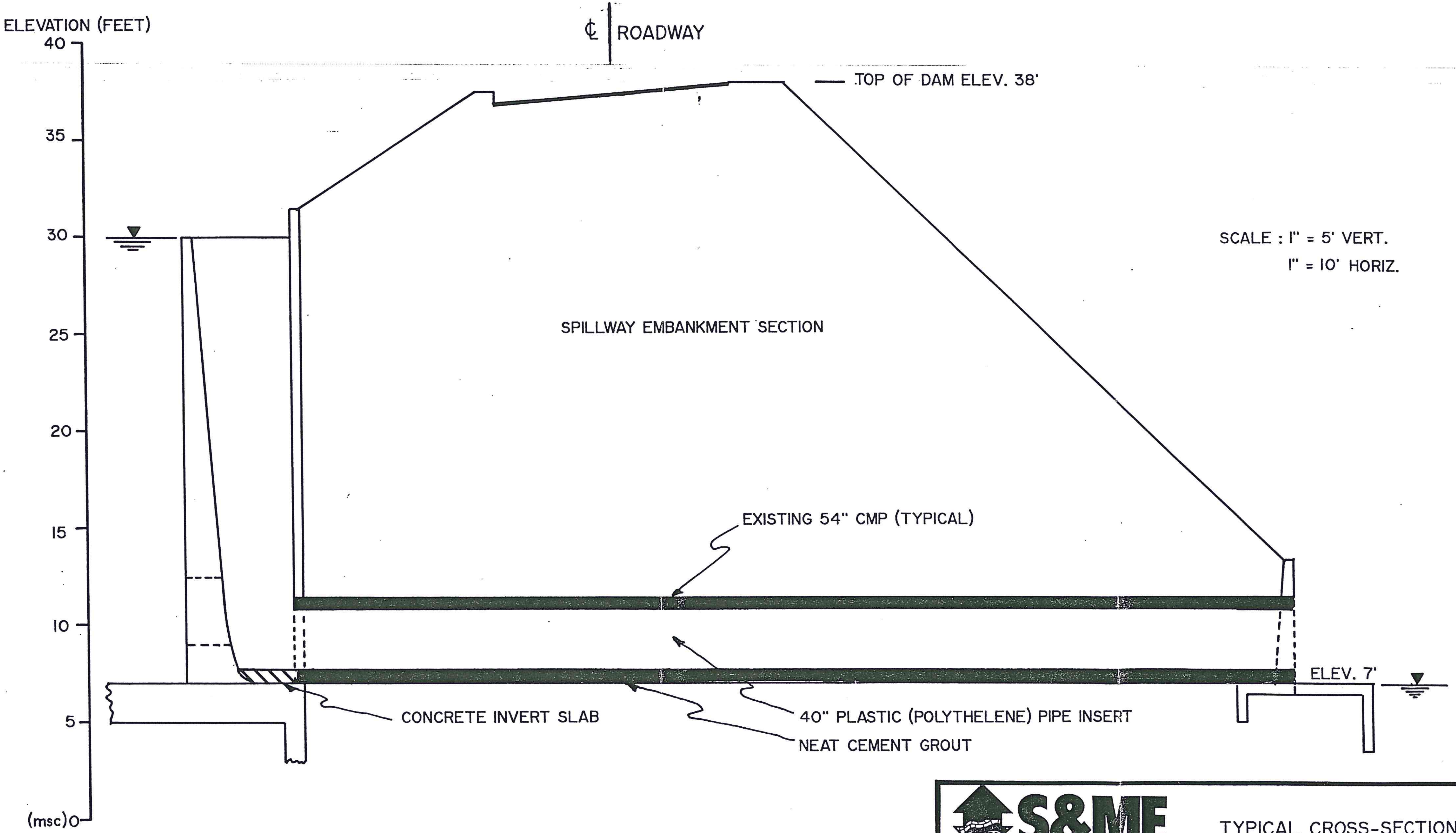
GENERALIZED SUBSURFACE PROFILE



S&ME

BOILING SPRING LAKE DAM
BOILING SPRING LAKES, N.C.

DRWN. BY: J.H.A.	CHKD. BY: B.D.M.
JOB NO.: 1051-87-291	DATE: 5-12-88
SCALE: 1" = 5'	FIGURE 3



S&ME

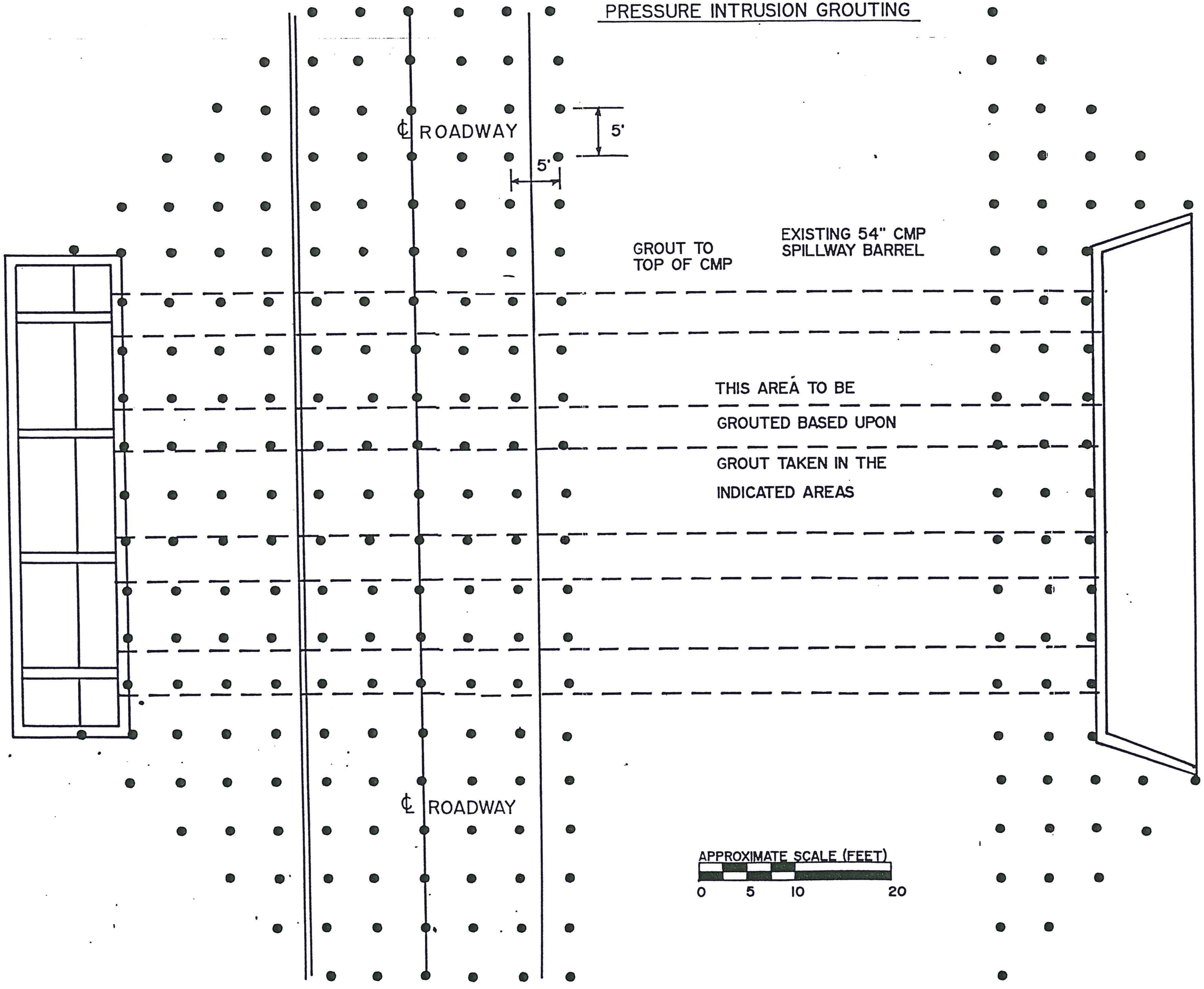
TYPICAL CROSS-SECTION
REMEDIAL DAM REPAIR

BOILING SPRING LAKE DAM
BOILING SPRING LAKES, N.C.

DRWN.BY: J.H.A.	**CHKD.BY:** B.D.M.
JOB NO.: 1051-87-291	**DATE:** 5-12-88
SCALE: AS SHOWN	FIGURE 4

DUNCAN-PARNELL, INC., RALEIGH 1287 919-833-4877

PLAN VIEW
PRESSURE INTRUSION GROUTING



S&ME

BOILING SPRING LAKE DAM
BOILING SPRING LAKES, N.C.

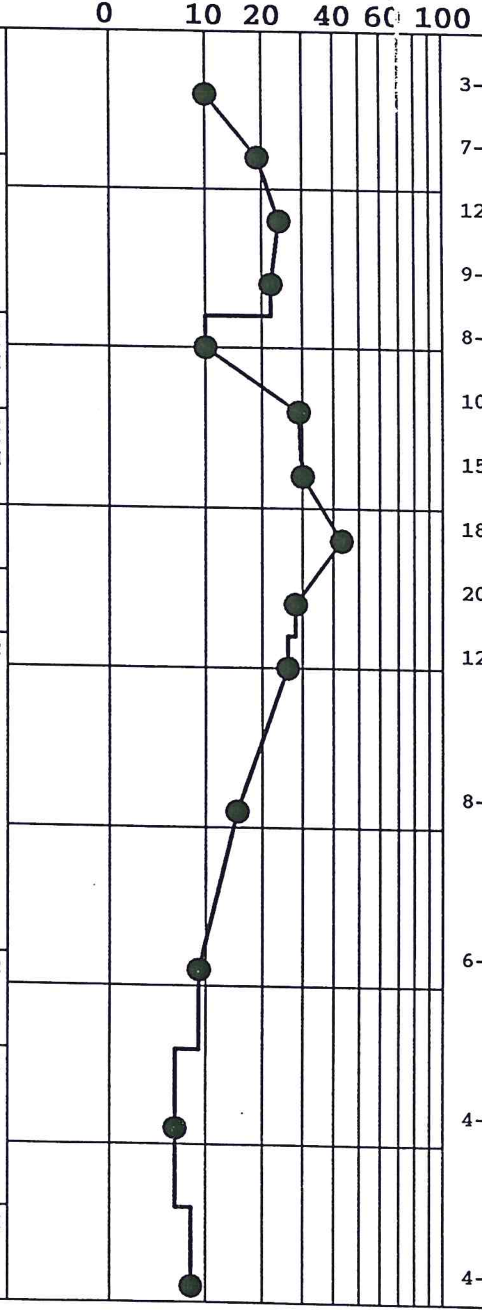
DRWN.BY: J.H.A.	CHKD.BY: B.D.M.
JOB NO.: 1051-87-291	DATE: 5-12-88
SCALE: AS SHOWN	FIGURE 5

TEST BORING RECORD

DEPTH (FT.)	DESCRIPTION	
0.0	Loose Brown, Tan and Gray Silty Fine SAND	SM
4.0	Medium Dense Brown, Tan and Gray Silty Fine SAND	SM
9.0	Loose Gray Slightly Clayey Silty Fine SAND	SC SM
12.0	Medium Dense Gray Slightly Clayey Silty Fine SAND	SC SM
15.0	Dense Gray Slightly Clayey Silty Fine SAND	SC/SM
17.0	Medium Dense Gray Slightly Clayey Silty Fine SAND	SC/SM
19.0	Medium Dense Dark Brown and Gray Clayey Fine SAND with Wood Fragments at 23.5 - 25.0 Feet	SC
29.0	Loose Dark Brown and Gray Clayey Fine SAND	SC
32.0	Firm Black and Gray Fine Sandy Silty CLAY with Organics	CH
37.0	Loose Gray Silty Fine SAND with Shell Fragments	SM
40.0	Boring Terminated at 40.0'	

ELEVATION (FT.)

PENETRATION (BLOWS/FT.)



BLOWS PER SIX IN.

3-4-6
7-9-10
12-12-12
9-10-12
8-6-4
10-15-14
15-15-15
18-20-23
20-16-12
12-14-12
8-8-7
6-5-4
4-3-3
4-4-4

18.5 ▽

REFER TO ATTACHED SHEET FOR EXPLANATIONS AND SYMBOLS

JOB NUMBER 051-87-291
BORING NUMBER B-1
DATE 09-04-87

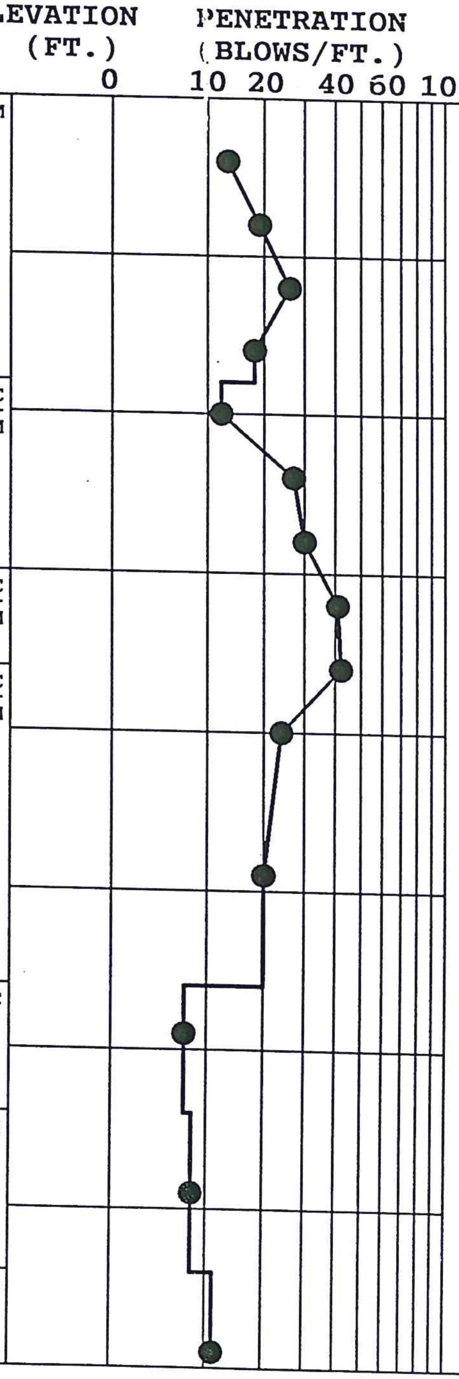
PAGE 1 OF 1

S&ME

TEST BORING RECORD

DEPTH (FT.)	DESCRIPTION	
0.0	Medium Dense Brown and Gray Silty Fine SAND	SM
9.0	Medium Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC SM
15.0	Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC SM
18.0	Medium Dense Brown and Gray Slightly Clayey Silty Fine SAND with Wood Fragments at 23.5 - 25.0 Feet	SC SM
28.0	Loose Gray Silty Clayey Fine SAND	SC
32.0	Firm Black Fine Sandy Silty CLAY with Organics	CH
37.0	Medium Dense Brown Silty Fine SAND with Shell Fragments	SM
40.0	Boring Terminated at 40.0'	

ELEVATION (FT.)



BLOWS PER SIX IN.
4-7-6
7-10-9
10-12-14
14-10-8
8-6-6
6-8-19
15-15-15
17-20-21
21-22-20
18-16-8
8-12-8
6-4-3
4-3-5
5-6-5

24.5

REFER TO ATTACHED SHEET FOR EXPLANATIONS AND SYMBOLS

JOB NUMBER 051-87-291
BORING NUMBER B-2
DATE 09-05-87

PAGE 1 OF 1

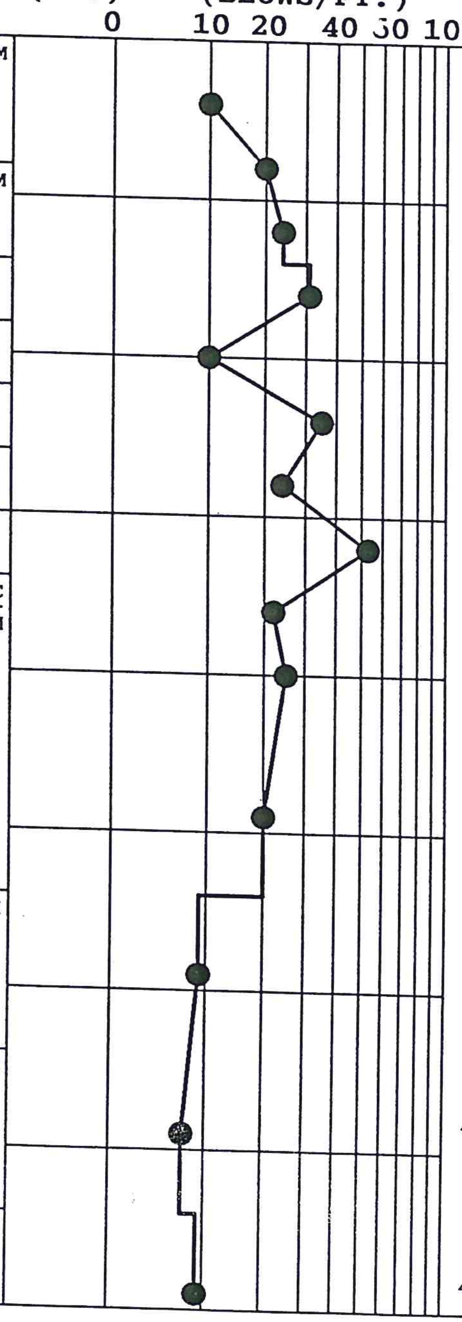
S&ME

TEST BORING RECORD

DEPTH (FT.)	DESCRIPTION	
0.0	Loose Brown and Gray Silty Fine SAND	SM
4.0	Medium Dense Brown and Gray Silty Fine SAND	SM
7.0	Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
9.0	Loose Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
11.0	Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
13.0	Medium Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
15.0	Very Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
17.0	Medium Dense Brown and Gray Slightly Clayey Silty Fine SAND	SC/SM
27.0	Stiff Black and Gray Fine Sandy Silty CLAY	CH
32.0	Firm Black and Gray Fine Sandy Silty CLAY	CH
37.0	Loose Gray Silty Fine SAND with Shell Fragments	SM
40.0	Boring Terminated at 40.0'	

ELEVATION (FT.)

PENETRATION (BLOWS/FT.)



BLOWS PER SIX IN.
3-3-7
7-12-8
12-14-10
14-15-16
12-5-5
15-20-15
15-10-14
14-20-33
12-10-12
12-13-12
12-10-10
10-5-4
4-3-4
4-5-4

24.5 ▽

REFER TO ATTACHED SHEET FOR EXPLANATIONS AND SYMBOLS

JOB NUMBER	051-87-291
BORING NUMBER	B-3
DATE	09-04-87

PAGE 1 OF 1

S&ME

```
                DINASTAR DYNAMIC CONE LOG :  TEST No. B1888...

         PROJECT              : BOILING SPRING LAKES DAM
         PROJECT No.          : 1051-87-291
         OWNER                : BOILING SPRING LAKES
         LOCATION             : SPILLWAY
         TEST DATE            : 6/25/87
         SURFACE ELEVATION    : ROADWAY
         CREW                 : FT/MB/BM/DM
         NAME OF DATA FILE    : SME1
         SLURRY FILLED
         HAMMER Wt. 30 kgf;  DROP 20 cm;  CONE AREA 10 sq cm
=========================================================================
DEPTH      BLOWS      DYNAMIC CONE    CONE RESISTANCE, MPa   TESTED CONSISTENCY
ft   m   per 10 cm  RESISTANCE, MPa   0        5         10   SAND   SILT   CLAY
------   ---------  ---------------   --------------------   --------------------

    0.1      3            0.9         . *
    0.2      3            0.9         . *                    VLoose VLoose Soft
 1  0.3      3            0.9         . *                    VLoose VLoose Soft
    0.4      3            0.9         . *                    VLoose VLoose Soft
    0.5      3            0.9         . *                    VLoose VLoose Soft
 2  0.6      2            0.6         .*                     VLoose VLoose Soft
    0.7      2            0.6         .*                     VLoose VLoose Soft
    0.8      2            0.6         .*                     VLoose VLoose Soft
 3  0.9      3            0.9         . *                    VLoose VLoose Soft
    1.0      3            0.9         . *                    VLoose VLoose Soft
    1.1      6            1.7         .  *                   VLoose VLoose Soft
 4  1.2      7            2.0         .   *                  Loose  Loose  Medium
    1.3     10            2.8         .     *                Loose  Loose  Medium
    1.4     11            3.1         .     *                Loose  Loose  Medium
 5  1.5     10            2.8         .     *                Loose  Loose  Stiff
    1.6      9            2.5         .    *                 Loose  Loose  Medium
    1.7     13            3.6         .      *               Loose  Loose  Medium
 6  1.8     16            4.5         .        *             Loose  Loose  Stiff
    1.9     13            3.6         .      *               Firm   Loose  Stiff
    2.0     10            2.8         .     *                Loose  Loose  Stiff
 7  2.1      8            2.1         .   *                  Loose  Loose  Medium
    2.2      7            1.8         .   *                  Loose  Loose  Medium
    2.3      6            1.6         .  *                   Loose  Loose  Medium
 8  2.4      4            1.1         . *                    Loose  Loose  Medium
    2.5      5            1.3         .  *                   Loose  Loose  Soft
    2.6      4            1.1         . *                    Loose  Loose  Soft
 9  2.7      3            0.8         . *                    Loose  Loose  Soft
    2.8      3            0.8         . *                    VLoose VLoose Soft
    2.9      4            1.1         . *                    VLoose VLoose Soft
10  3.0      6            1.6         .  *                   Loose  Loose  Soft.
    3.1      5            1.3         .  *                   Loose  Loose  Medium
    3.2      7            1.8         .   *                  Loose  Loose  Soft
    3.3      8            2.0         .   *                  Loose  Loose  Medium
11  3.4     10            2.5         .    *                 Loose  Loose  Medium
    3.5     10            2.5         .    *                 Loose  Loose  Medium
    3.6     10            2.5         .    *                 Loose  Loose  Medium
12  3.7      6            1.5         .  *                   Loose  Loose  Medium
    3.8      3            0.8         . *                    Loose  Loose  Medium
    3.9      5            1.3         .  *                   VLoose VLoose Soft
 3  4.0      9            2.3         .    *                 Loose  Loose  Soft
    4.1      9            2.1         .   *                  Loose  Loose  Medium
    4.2      8            1.9         .   *                  Loose  Loose  Medium
14  4.3      7            1.7         .  *                   Loose  Loose  Medium
    4.4      6            1.4         .  *                   Loose  Loose  Medium
    4.5      5            1.2         . *                    Loose  Loose  Soft
 5  4.6      6            1.4         .  *                   Loose  Loose  Soft
    4.7     10            2.4         .    *                 Loose  Loose  Soft
    4.8     10            2.4         .    *                 Loose  Loose  Medium
16  4.9     10            2.4         .    *                 Loose  Loose  Medium
    5.0     10            2.4         .    *                 Loose  Loose  Medium
    5.1      8            1.8         .   *                  Loose  Loose  Medium
 7  5.2      8            1.8         .   *                  Loose  Loose  Medium
    5.3      8            1.8         .   *                  Loose  Loose  Medium
    5.4      7            1.6         .  *                   Loose  Loose  Medium
18  5.5      7            1.6         .  *                   Loose  Loose  Medium
    5.6      5            1.1         . *                    Loose  Loose  Medium
    5.7      5            1.1         . *                    Loose  Loose  Soft
19  5.8      6            1.4         .  *                   Loose  Loose  Soft
    5.9      7            1.6         .  *                   Loose  Loose  Soft
    6.0      7            1.6         .  *                   Loose  Loose  Medium
 0  6.1      5            1.1         . *                    Loose  Loose  Medium
    6.2      7            1.5         .  *                   Loose  Loose  Soft
    6.3      7            1.5         .  *                   Loose  Loose  Medium
21  6.4     14            3.0         .     *                Loose  Loose  Medium
                                                             Loose  Loose  Stiff
```

```
          DINASTAR STATIC CONE - DYNAMIC SLEEVE TEST :  LOG No. BC-1


          PROJECT                  : BOILING SPRING LAKES DAM
          PROJECT No.              : 1051-87-291
          OWNER                    : BOILING SPRING LAKES
          LOCATION                 : SPILLWAY
          TEST DATE                : 6/25/87
          SURFACE ELEVATION        : ROADWAY
          CREW                     : FT/MB/BM/DM
          NAME OF DATA FILE        : SME2
          SLEEVE AREA              : 900 sq. cm
          HAMMER Wt. 30 kgf;  DROP 20 cm;  CONE AREA 10 sq cm
================================================================================
                CONE   SKIN  FRICT
 DEPTH    BLOW  RES.   FRICT RATIO    CONE RESISTANCE, MPa    TESTED CONSISTENCY
ft    m   COUNT MPa     MPa    %      0         5         10
 ------ ----- -----  ----- -----    ---------------------   --------------------
     0.1   -     -      -     -
     0.2   -     -      -     -
 1   0.3   -     -    0.007   -
     0.4   -     -    0.005   -
     0.5   0     -    0.008   -
 2   0.6   0     -    0.008   -
     0.7   0     -    0.012   -
     0.8   4    1.0   0.008  0.78    .  *                     Loose GRAVEL
 3   0.9   3    1.1   0.009  0.85    .  *                     Loose GRAVEL
     1.0   5    1.1     -     -      .  *
     1.1   5    1.4     -     -      .   *
 4   1.2   8    1.2     -     -      .  *
     1.3   5    1.2   0.014  1.21    .  *                     Loose SAND&GRAVEL
     1.4   6    1.2   0.011  0.90    .  *                     Loose GRAVEL
 5   1.5   7    1.7+  0.009   -      .   +
     1.6  12    1.5+  0.010   -      .   +
     1.7  12    1.4+  0.010   -      .   +
 6   1.8   9    1.2   0.012  0.98    .  *                     Loose GRAVEL
     1.9   7    1.4   0.010  0.73    .   *                    Loose GRAVEL
     2.0   6    1.6   0.007  0.46    .   *                    Loose GRAVEL
 7   2.1   7    1.7   0.006  0.36    .   *                    Loose GRAVEL
     2.2   7    1.5   0.006  0.40    .   *                    Loose GRAVEL
     2.3   8    1.2     -     -      .  *
 8   2.4   7    0.9     -     -      .  *
     2.5   5    1.2     -     -      .  *
     2.6   4    0.7     -     -      .*
 9   2.7   4    0.6     -     -      .*
     2.8   0    0.5     -     -      .*
```

```
           DINASTAR DYNAMIC CONE LOG :  TEST No. B-2

      PROJECT              : BOILING SPRING LAKES DAM
      PROJECT No.          : 1051-87-291
      OWNER                : BOILING SPRING LAKES
      LOCATION             : AWAY FROM SPILLWAY
      TEST DATE            : 6/25/87
      SURFACE ELEVATION    : ROADWAY
      CREW                 : FT/MB/BM/DM
      NAME OF DATA FILE    : SME3
      SLURRY FILLED
      HAMMER Wt. 30 kgf;  DROP 20 cm;  CONE AREA 10 sq cm
==========================================================================
DEPTH     BLOWS    DYNAMIC CONE   CONE RESISTANCE, MPa   TESTED CONSISTENCY
ft   m  per 10 cm RESISTANCE, MPa 0         5        10  SAND   SILT   CLAY
------  --------- --------------- ---------------------  --------------------

    0.1     6         1.8   .   *                 Loose  Loose  Medium
    0.2     8         2.4   .    *                Loose  Loose  Medium
 1  0.3    16         4.7   .        *            Firm   Loose  Stiff
    0.4    20         5.9   .           *         Firm   Medium VStiff
    0.5    24         7.1   .             *       Firm   Medium VStiff
 2  0.6    30         8.9   .                 *   Firm   Dense  Hard
    0.7    30         8.9   .                 *   Firm   Dense  Hard
    0.8    28         8.3   .                *    Firm   Dense  Hard
 3  0.9    33         9.8   .                   * Comp.  Dense  Hard
    1.0    35        10.4   .                   + Comp.  Dense  Hard
    1.1    33         9.2   .                 *   Comp.  Dense  Hard
 4  1.2    35         9.8   .                   * Comp.  Dense  Hard
    1.3    29         8.1   .               *     Firm   Dense  Hard
    1.4    25         7.0   .             *       Firm   Medium VStiff
 5  1.5    20         5.6   .          *          Firm   Medium VStiff
    1.6    15         4.2   .       *             Firm   Loose  Stiff
    1.7     8         2.2   .   *                 Loose  Loose  Medium
 6  1.8     7         2.0   .   *                 Loose  Loose  Medium
    1.9     8         2.2   .   *                 Loose  Loose  Medium
    2.0    11         3.1   .     *               Loose  Loose  Stiff
 7  2.1     6         1.6   .  *                  Loose  Loose  Medium
    2.2     9         2.4   .    *                Loose  Loose  Medium
    2.3    15         4.0   .       *             Loose  Loose  Stiff
 8  2.4    15         4.0   .       *             Loose  Loose  Stiff
    2.5    10         2.6   .    *                Loose  Loose  Medium
    2.6     8         2.1   .   *                 Loose  Loose  Medium
 9  2.7    13         3.4   .      *              Loose  Loose  Stiff
    2.8    34         9.0   .                 *   Firm   Dense  Hard
    2.9    18         4.8   .         *           Firm   Loose  Stiff
10  3.0    18         4.8   .         *           Firm   Loose  Stiff
    3.1    28         7.0   .             *       Firm   Medium VStiff
    3.2    28         7.0   .             *       Firm   Medium VStiff
    3.3    14         3.5   .      *              Loose  Loose  Stiff
11  3.4    10         2.5   .    *                Loose  Loose  Medium
    3.5     7         1.8   .   *                 Loose  Loose  Medium
    3.6    10         2.5   .    *                Loose  Loose  Medium
 2  3.7    11         2.8   .     *               Loose  Loose  Medium
    3.8     9         2.3   .    *                Loose  Loose  Medium
    3.9     6         1.5   .  *                  Loose  Loose  Medium
13  4.0     6         1.5   .  *                  Loose  Loose  Medium
    4.1     6         1.4   .  *                  Loose  Loose  Soft
    4.2     5         1.2   . *                   Loose  Loose  Soft
14  4.3     3         0.7   .*                    VLoose VLoose Soft
    4.4     4         1.0   . *                   VLoose VLoose Soft
    4.5    18         4.3   .        *            Firm   Loose  Stiff
 5  4.6    20         4.8   .         *           Firm   Loose  Stiff
    4.7    42        10.0   .                   * Comp.  Dense  Hard
    4.8    68        16.2   .                   + Comp.  Dense  Hard
```

SOIL & MATERIAL ENGINEERS, INC.

JOB NO. 1051-87-291
SHEET NO. 1 of 4
DATE 12-9-87

JOB NAME Boiling Springs Dam
COMPUTED BY SCV
SUBJECT H & H
CHECKED BY BDM

Hydrology

DRAINAGE AREA - by planimetor USGS Quad

$$\begin{array}{r} 66.13 \\ \underline{35.97} \\ 30.16 \end{array} \qquad \begin{array}{r} 135.97 \\ \underline{105.84} \\ 30.13 \end{array}$$

$$\begin{array}{r} 56.11 \\ \underline{23.98} \\ 32.13 \end{array} \qquad \cancel{\begin{array}{r} 123.98 \\ \underline{91.44} \\ 32.54 \end{array}} \qquad \begin{array}{r} 91.44 \\ \underline{59.40} \\ 32.04 \end{array}$$

$$(30.15 + 32.08) \times \frac{2000^2}{43560} = 5710 \text{ acres} = 8.93 \text{ mi.}^2$$

LAKE SURFACE AREA (ELEV. 30)

$$\begin{array}{r} 94.78 \\ \underline{90.98} \\ 3.80 \end{array} \qquad \begin{array}{r} 90.98 \\ \underline{87.12} \\ 3.86 \end{array} \qquad 3.83 \times \qquad = 352 \text{ Acres}$$

ELEV. 40

$$\begin{array}{r} 71.03 \\ \underline{64.60} \\ 6.43 \end{array} \qquad \begin{array}{r} 64.60 \\ \underline{58.78} \\ 5.82 \end{array} \qquad \begin{array}{r} 58.78 \\ \underline{52.57} \\ 6.21 \end{array} \qquad 6.15 \times \qquad = 565 \text{ Acres}$$

HYDRAULIC LENGTH

$l = 10000.$ ft

SLOPE

$$\frac{20}{6000} = 0.3 \qquad \frac{14}{4000} = 0.35 \qquad \frac{10}{7500} = 0.13$$

$$\frac{16}{3000} = 0.53 \qquad \frac{20}{3500} = 0.57 \qquad \bar{y} = 0.33\,\%$$

JOB NO. 1051-87-291
SHEET NO. 2 of 4
DATE 12-9-87

JOB NAME BOILING SPRINGS
COMPUTED BY SCV
SUBJECT
CHECKED BY BDM

SOIL TYPE

CROATAN MURVILLE	D	WOODS	40 %
LEON MANDARIN KUREB	A	WOODS, 1 AC. RES.	60 %

LAND USE & CN

USE		%	CN
WOODS, GOOD	D	35	77
LAKE	—	10	100
WOODS, FAIR	A	25	35
1 AC. RES.	A	30	51

CN = 61.

CN = 61

LAG TIME

$$LAG = \frac{10000^{.8}\ (7.39)^{1.7}}{1900\ \sqrt{.33}}$$

$= 5.89$ HRS.

$\frac{1000}{61} - 10 = 6.39$

$T_c = 9.8$ HRS

FLOW RATE ESTIMATES 100 YR

USGS $Q = 610\,(8.93)^{.52} = 1900$ cfs

SCS CN TR 55

$P_{100} = 10''$ 24 HR.
RUNOFF = 5.03
CMS/INCH = 60 FIG. 5-2
$Q_{100} = (60)(5.03)(8.73) = 2700$ cfs

JOB NO. 1051-87-291

SHEET NO. 3 of 4

DATE 12-9-87

JOB NAME Boiling Springs Dam

COMPUTED BY SCV

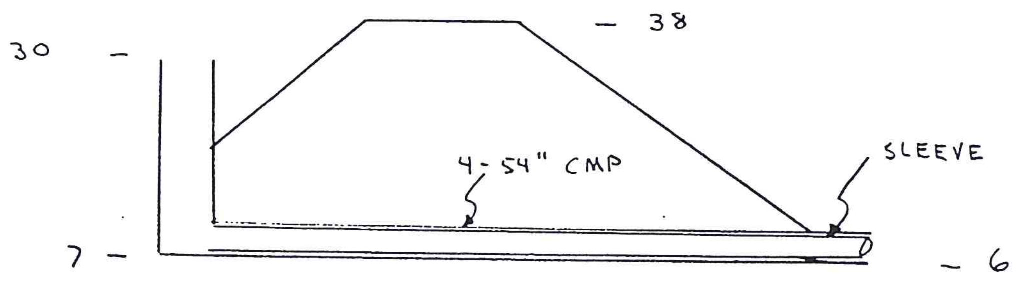
SUBJECT

CHECKED BY BDM

PRECIPITATION

	30 min	1 HR	2 HR	3 HR	6 HR	12 HR	24 HR.
P_{100}	3.2	4.1	5.1	5.7	7	8.4	10.0
P_{50}							9.0
P_{25}							8.0
PMP					30.5	36.5	43

HYDRAULICS



RISER - MODEL AS WEIR

$Q = C_w L H^{1.5}$

$C_w = 3.1$
$L = 48'$
$H = (ELEV - 30)$

$Q = 149 (ELEV - 30)^{1.5}$

BARREL - TRY 40" PVC SLEEVE

INLET CONTROL

$Q = 4 \cdot C_d A \sqrt{2gH}$

$C_d = .6$
$A = \pi d^2/4 = 8.72 \text{ ft}^2$
$H = (ELEV - 9)$

$Q = 168 (ELEV - 9)^{0.5}$

BARREL CONTROL

$Q = 4 \cdot A \sqrt{\frac{2gH}{1 + K_e + K_p L}}$

$= 174 (ELEV - 20)^{0.5}$

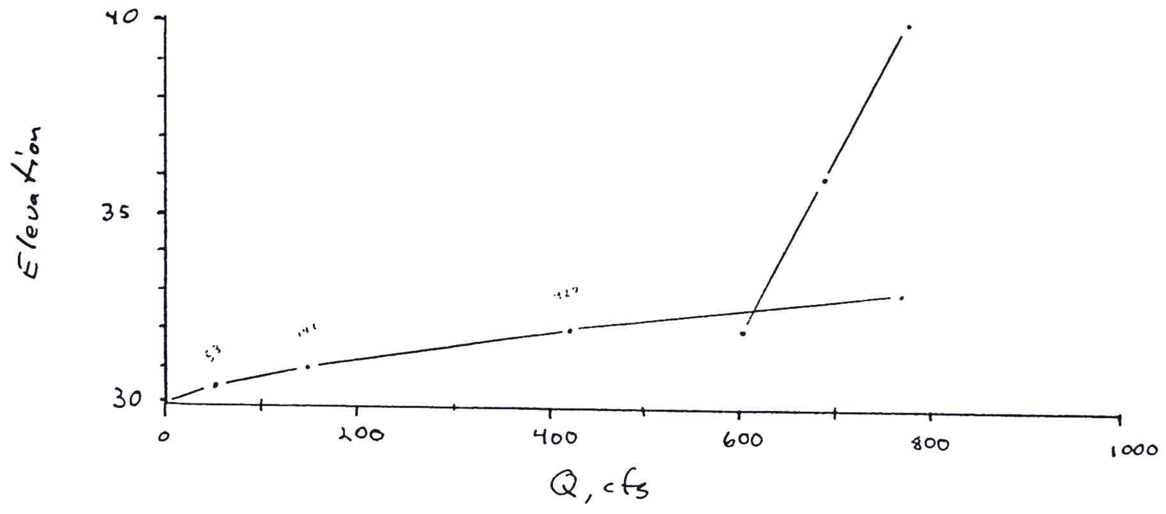
$A = 8.72$
$K_e = 1$
$K_p = .0054$: [illegible]
$L = 110'$
$H = ELEV - \overset{TW}{TAILWATi}$

LET TW = 20
CONSERVATIVE

SOIL & MATERIAL ENGINEERS, INC.

JOB NO. 1051-87-291
SHEET NO. 4 of 4
DATE 12-9-87

JOB NAME Boiling Springs Dam
COMPUTED BY SCV
SUBJECT
CHECKED BY BDM



HEC-1 RESULTS

STORM	Q_{IN} (CFS)	Q_{OUT} (CFS)	MAX. WSEL
25 YR.	1810	611	32.6
50 YR.	2240	626	33.3
100 YR.	2680	643	34.0
1/3 PMP	5010	723	37.5

```
1
                                              ****
                          FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
              U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                              ****




             THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3


1
                                        HEC-1 INPUT                                      PAGE  1

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1          ID       BOILING SPRINGS DAM
           2          ID       S&ME 1051-87-291
           3          ID       4-40" SLEAVES
*** FREE ***
           4          IT      15       0       0     300
           5          IO       5
           6          JR    PREC      .8      .9     1.0

           7          KK  INFLOW
           8          BA    8.93
           9          PH       0       0       0     2.3     4.1     5.1     5.7     7.0     8.4      10
          10          LS       0      61
          11          UD    5.89

          12          KK     DAM
          13          RS       1    ELEV      30
          14          SA     352     565
          15          SE      30      40
          16          SQ       0      53     149     420     610     690     780
          17          SE      30    30.5      31      32    32.6      36      40
          18          ST      38     800     2.9     1.5
          19          ZZ
                                              ****
                          FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
              U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                              ****



                        BOILING SPRINGS DAM
                        S&ME 1051-87-291
                        4-40" SLEAVES

  5 IO        OUTPUT CONTROL VARIABLES
 -                  IPRNT          5  PRINT CONTROL
                    IPLOT          0  PLOT CONTROL
                    QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT         HYDROGRAPH TIME DATA
                     NMIN         15  MINUTES IN COMPUTATION INTERVAL
                    IDATE      1   0  STARTING DATE
                    ITIME       0000  STARTING TIME
                       NO        300  NUMBER OF HYDROGRAPH ORDINATES
```

```
              COMPUTATION INTERVAL     .25 HOURS
                  TOTAL TIME BASE   74.75 HOURS

         ENGLISH UNITS

     JP         MULTI-PLAN OPTION
                     NPLAN           1  NUMBER OF PLANS

     JR         MULTI-RATIO OPTION
                   RATIOS OF PRECIPITATION
                    .80       .90
                   1.00
1

              PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                              FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                           TIME TO PEAK IN HOURS


                                                  RATIOS APPLIED TO PRECIPITATION
OPERATION       STATION     AREA    PLAN           RATIO 1  RATIO 2  RATIO 3
                                                       .80      .90     1.00

HYDROGRAPH AT
                 INFLOW      8.93     1   FLOW       1810.    2239.    2684.
                                          TIME       18.75    18.75    18.75

ROUTED TO
                    DAM      8.93     1   FLOW        611.     626.     643.
                                          TIME       27.75    28.50    29.25

                                   ** PEAK STAGES IN FEET **
                                   1  STAGE      32.63    33.27    33.99
                                      TIME       27.75    28.50    29.25
                             SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION      DAM


     PLAN  1 ...............              INITIAL VALUE     SPILLWAY CREST     TOP OF DAM
                           ELEVATION         30.00             38.00            38.00
                           STORAGE              0.             3460.            3460.
                           OUTFLOW              0.              735.             735.


                   RATIO     MAXIMUM    MAXIMUM    MAXIMUM    MAXIMUM   DURATION    TIME OF     TIME OF
                     OF     RESERVOIR    DEPTH     STORAGE    OUTFLOW   OVER TOP  MAX OUTFLOW   FAILURE
                    PMF      W.S.ELEV  OVER DAM     AC-FT       CFS      HOURS      HOURS        HOURS

          25 YR    .80        32.63      .00        993.       611.       .00       27.75         .00
          50 YR    .90        33.27      .00       1255.       626.       .00       28.50         .00
         100 YR   1.00        33.99      .00       1558.       643.       .00       29.25         .00


*** NORMAL END OF HEC-1 ***
```

```
1                                                        ****
                             FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
              U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                                         ****




              THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3


1                                             HEC-1 INPUT                                          PAGE  1

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1          ID       BOILING SPRINGS DAM
           2          ID       S&ME 1051-87-291
           3          ID       4-40" SLEAVES
 *** FREE ***
           4          IT      15       0       0     300
           5          IO       5
           6          JR    PREC      1.

           7          KK  INFLOW
           8          BA    8.93
           9          PM    14.3       1       0       0      71      85     100
          10          LS       0      61
          11          UD    5.89

          12          KK     DAM
          13          RS       1    ELEV      30
          14          SA     352     565
          15          SE      30      40
          16          SQ       0      53     149     420     610     690     780
          17          SE      30    30.5      31      32    32.6      36      40
          18          ST      38     800     2.9     1.5
          19          ZZ
                                                         ****
                             FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
              U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                                         ****




                         BOILING SPRINGS DAM
                         S&ME 1051-87-291
                         4-40" SLEAVES

   5 IO          OUTPUT CONTROL VARIABLES
                      IPRNT          5  PRINT CONTROL
                      IPLOT          0  PLOT CONTROL
                      QSCAL         0.  HYDROGRAPH PLOT SCALE

    IT           HYDROGRAPH TIME DATA
                       NMIN         15  MINUTES IN COMPUTATION INTERVAL
                      IDATE      1   0  STARTING DATE
                      ITIME       0000  STARTING TIME
                         NQ        300  NUMBER OF HYDROGRAPH ORDINATES
```

```
               COMPUTATION INTERVAL     .25 HOURS
                   TOTAL TIME BASE   74.75 HOURS

          ENGLISH UNITS

      JP         MULTI-PLAN OPTION
                     NPLAN            1  NUMBER OF PLANS

      JR         MULTI-RATIO OPTION
                    RATIOS OF PRECIPITATION
                   1.00
1

             PEAK FLOW AND STAGE (END-OF-PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
                          FLOWS IN CUBIC FEET PER SECOND,  AREA IN SQUARE MILES
                                     TIME TO PEAK IN HOURS


                                                  RATIOS APPLIED TO PRECIPITATION
OPERATION       STATION     AREA    PLAN             RATIO 1
                                                       1.00

HYDROGRAPH AT
+                INFLOW      8.93     1   FLOW        5012.
                                          TIME        21.75

ROUTED TO
+                  DAM       8.93     1   FLOW         723.
                                          TIME        32.25

                                   ** PEAK STAGES IN FEET **
                                   1  STAGE         37.46
                                      TIME          32.25
1                          SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION       DAM


      PLAN  1 ..............                INITIAL VALUE    SPILLWAY CREST    TOP OF DAM
                          ELEVATION            30.00            38.00           38.00
                          STORAGE                 0.             3460.           3460.
                          OUTFLOW                 0.              735.            735.


                 RATIO    MAXIMUM    MAXIMUM   MAXIMUM   MAXIMUM   DURATION    TIME OF    TIME OF
                  OF     RESERVOIR    DEPTH    STORAGE   OUTFLOW   OVER TOP  MAX OUTFLOW  FAILURE
                  PMF     W.S.ELEV  OVER DAM    AC-FT      CFS      HOURS      HOURS       HOURS

           1/3 PMP ~~1.00~~   37.46       .00      3182.      723.       .00      32.25        .00

*** NORMAL END OF HEC-1 ***
```

ECS LLP
CAROLINAS

REPORT OF SUBSURFACE EXPLORATION AND GEOTECHNICAL ENGINEERING ANALYSIS

BOILING SPRING LAKES - SPILLWAY
BOILING SPRING LAKES, NORTH CAROLINA

ECS, LTD. PROJECT NUMBER 09.13750

PREPARED FOR
CITY OF BOILING SPRING LAKES
BOILING SPRING LAKES, NORTH CAROLINA

APRIL 4, 2007

ECS CAROLINAS, LLP
Geotechnical • Construction Materials • Environmental

April 4, 2007

Mr. Howard Resnik, P.E.
Coastal Site Design
3805 Cherry Avenue
Wilmington, North Carolina 28406

ECS Project No. 09.13750

Reference: Report of Subsurface Exploration and Geotechnical Engineering Analysis
Boiling Spring Lakes - Spillway
Boiling Spring Lakes, North Carolina

Dear Mr. Resnik:

ECS Carolinas, LLP (ECS) has completed a subsurface exploration for the subject site as authorized by acceptance of our Proposal, dated January 26, 2007. The purposes of this exploration were to explore the soil, rock, and groundwater conditions at the site and to develop geotechnical recommendations to guide design and construction of the project. This report presents our evaluations and recommendations, the results of our exploration, our scope of work, and our understanding of the project information. ECS appreciates the opportunity to provide our professional services during this phase of your project. Please do not hesitate to contact us if you have any questions concerning the following report.

Respectfully,

ECS CAROLINAS, LLP

SEAL
024430
4/4/07
RUSSELL A. BENDEL

Russell A. Bendel, P.E.
Senior Engineer
Licensed NC 24430

Stephen L. Neas

Reviewed By: Stephen L. Neas, P.E.
Principal Engineer
Licensed NC16085

Attachments

4811 Koger Boulevard • Greensboro, NC 27407 • (336) 856-7150 • Fax (336) 856-7160

DESIGN RECOMMENDATIONS

Spillway Foundation Conditions and Settlement

The existing embankment associated with the dam has been in place for several years. The foundation conditions below the roadway and in the area of the new spillway are suitable for support of the dam. Settlement of the fill materials beneath the proposed spillway box culverts are not expected to be excessive. Settlements will typically occur as the spillway culverts are placed such that almost all settlement will occur during construction of the new spillway.

Some scarifying, drying, and recompaction of materials should be planned for soils beneath the proposed location of the spillway culvert.

Slope Stability

Slope stability analysis was not performed as part of this project. Observations of the slopes made during a site visit indicated no sloughs, slides, or erosion present on the upstream or downstream slopes of the dam embankment. Based on the existing slope configuration, and condition of the slopes observed on site, the slopes appear stable, and no modifications are required.

Seepage Analysis and Drainage

A seepage analysis was not performed as part of this project. We did not observe seepage on the downslope side of the dam of the dam made during our site visit.

We recommend the spillway be designed with a filter/drainage diaphragm to collect seepage and convey it safely out of the dam. The filter/drainage diaphragm will control seepage along the new spillway to prevent breakout at the face of the downstream slope and to improve the factor of safety against piping of embankment material. The filter/drainage diaphragm should consist of NCDOT 14M stone at least 2 feet thick. The filter/drainage diaphragm should extend a minimum of 2 feet into the existing ground of the spillway foundation and extend 5 feet into the temporary excavation slopes to intercept seepage.

We recommend the subgrade at the interface between temporary slopes in the excavation of the spillway construction and new controlled backfill be adequately scarified prior to placement and compaction of new fill to create a good bond and prevent a path for uncontrolled seepage.

In addition, the spillway should have a concrete bedding placed beneath and between the concrete culverts to minimize the potential for seepage and to fill voids created by excavation for construction of the spillway. A seepage collar should be designed around the box culverts near the upstream end to prevent seepage along the new spillway.

Embankment Fill

The existing embankment soils encountered at the site can be used as controlled fill for use as backfill for the new spillway construction. Controlled fill should be compacted to at least 95 percent of the maximum dry density obtained in accordance with ASTM Specification D-698, Standard Proctor Method. We recommend a shrinkage factor of 10 to 15 percent when calculating earthwork quantities using on-site soils for fill.

The existing embankment soils removed for construction of the spillway may be too wet for reuse as compacted structural fill. Some consideration should be given to drying these soils prior to reuse or disposing the wet soils in a suitable disposal area.

CONSTRUCTION RECOMMENDATIONS

Subgrade Preparation and Earthwork Operations

Site preparation should begin with removal of asphalt and subbase, and stripping all vegetation, root-zone, and all other soft or unsuitable material. We anticipate a stripping depth of at least 3 to 6 inches.

Following stripping and excavation, but prior to construction of the spillway, the exposed subgrades should be proofrolled. Unstable areas identified by proofrolling should be scarified and recompacted. If sufficient stability to allow compaction of the embankment fill cannot be achieved by drying, the unstable soils should be undercut to facilitate compaction.

After preparation and approval of the subgrades and excavation bottoms, fill can be placed and compacted to construct the spillway and spillway closure section. Dam fill should consist of an approved material, free of organic matter and debris. It appears that the majority of the soils at the project site will be suitable for use in the dam modifications. Moisture conditioning of some of the on-site soils may be necessary to adjust the soil moisture to within the acceptable range for compaction.

Prior to the commencement of fill operations, the contractor should provide representative samples of the proposed fill soils to the geotechnical engineer. The geotechnical engineer can determine the material's suitability for use as an engineered fill within the appropriate zones of the dam and develop moisture-density relationships in accordance with the recommendations provided herein. Samples should be provided to the geotechnical engineer at least 3 days prior to their use in the field to allow for the appropriate laboratory testing to be performed.

All fill materials placed within the dam embankment and pavement areas should be placed in lifts not exceeding 8 inches in loose lift thickness and moisture conditioned to within their working range of optimum moisture content. The typical working range of optimum moisture for the natural Coastal Plain soils at the site is expected to be within approximately 3 percent of the optimum moisture content. The fills should then be compacted to a minimum of 95 percent of the soil's standard Proctor (ASTM D 698) maximum dry density. Compaction equipment suitable to the soil type should be selected to compact the fill. Care should also be taken to provide a smooth, gently sloping ground surface at the end of each day's earthwork activities to help reduce the potential for ponding and absorption of surface water.

Grade controls should also be maintained throughout the filling operations. All filling operations should be observed on a full-time basis by a representative of ECS to determine that the required compaction is being achieved. We recommend that a minimum of one compaction test per 2,000-square-foot area be performed for each lift of controlled fill. Areas which fail to achieve the required degree of compaction should be re-worked until the specified degree of compaction is achieved. Failing test areas may require moisture adjustments or other suitable remedial activities in order to achieve the required compaction.

Fill materials should not be placed on frozen, frost-heaved, and/or soils which have been recently subjected to precipitation. All wet or frozen soils should be removed prior to the continuation of site grading and fill placement. Borrow fill materials should not contain excessively wet or frozen materials at the time of placement. Additionally, if grading operations occur during the winter months, all frost-heaved soils should be removed prior to placement of engineered fill, granular sub-base materials, foundation or slab concrete, and asphalt pavement materials.

If problems are encountered during the site grading operations, or if the actual site conditions differ from those encountered during our subsurface exploration, the geotechnical engineer should be notified immediately.

Excavation Conditions

Areas of excavation should meet the requirements of the most current Occupational Safety and Health Administration (OSHA) 29 CFR Part 1926, "Occupational Safety and Health Standards – Excavations". Regardless, site safety shall be the responsibility of the contractor and his subcontractors. The stability of temporary excavations slopes can be enhanced by lowering the level of the reservoir in the lake prior to excavation.

The site soils are OSHA Type C soils for the purpose of excavation support. Excavations should be constructed in compliance with current OSHA standards for excavation and trenching safety. Excavations should be observed by a "competent person", as defined by OSHA, who should evaluate the specific soil type and other conditions, which may control the excavation side slopes or the need for shoring or bracing.

Temporary Groundwater Control

Temporary groundwater control may be necessary during construction even though groundwater was not encountered within the borings. Although we do not expect significant excavation below grades in the areas of dam construction, groundwater may likely be present due to the presence of the existing dam and lake. We recommend lowering the existing lake as early as possible during construction to reduce the impact of the water associated with the lake.

Groundwater control measures such as gravity ditches or pumping from gravel lined and cased sumps should be sufficient to provide temporary groundwater control where necessary.

SPECIFICATION RECOMMENDATIONS

Proofrolling

Exposed subgrades shall be proofrolled using appropriate equipment to identify areas of unstable subgrade. Appropriate equipment shall be a dump truck having a single rear axle with axle weight of at least 10 tons, or a dump truck having a tandem rear axle with axle weight of at least 20 tons. Alternate equipment, such as a fully loaded pan scraper, may be utilized with approval of the geotechnical engineer responsible for evaluating the subgrade during construction.

Proofrolling shall consist of driving the appropriate equipment over the subgrade at a walking pace. The proofrolling equipment shall make overlapping passes across the subgrade in the same direction, with the overlap not exceeding ½ the width of the equipment. A second set of overlapping passes shall then be made in a direction perpendicular to the first set of passes.

Controlled Fill

After preparation and approval of the subgrades and excavation bottoms, fill can be placed and compacted to construct the embankment modifications and spillway closure section. Dam fill should consist of an approved material, free of organic matter and debris. It appears that the majority of the soils at the project site will be suitable for use in the dam modifications. Moisture conditioning of some of the on-site soils may be necessary to adjust the soil moisture to within the acceptable range for compaction.

Prior to the commencement of fill operations, the contractor should provide representative samples of the proposed fill soils to the geotechnical engineer. The geotechnical engineer can determine the material's suitability for use as an engineered fill within the appropriate zones of the dam and develop moisture-density relationships in accordance with the recommendations provided herein. Samples should be provided to the geotechnical engineer at least 3 days prior to their use in the field to allow for the appropriate laboratory testing to be performed.

All fill materials placed within the dam embankment and pavement areas should be placed in lifts not exceeding 8 inches in loose lift thickness and moisture conditioned to within their working range of optimum moisture content. The typical working range of optimum moisture for the natural Coastal Plain soils at the site is expected to be within approximately 3 percent of the optimum moisture content. The fills should then be compacted to a minimum of 95 percent of the soil's standard Proctor (ASTM D 698) maximum dry density. Compaction equipment suitable to the soil type should be selected to compact the fill. Care should also be taken to provide a smooth, gently sloping ground surface at the end of each day's earthwork activities to help reduce the potential for ponding and absorption of surface water.

Grade controls should also be maintained throughout the filling operations. All filling operations should be observed on a full-time basis by a representative of ECS to determine that the required compaction is being achieved. We recommend that a minimum of one compaction test per 2,000-square-foot area be performed for each lift of controlled fill. Areas which fail to achieve the required degree of compaction should be re-worked until the specified degree of compaction is achieved. Failing test areas may require moisture adjustments or other suitable remedial activities in order to achieve the required compaction.

Fill materials should not be placed on frozen, frost-heaved, and/or soils which have been recently subjected to precipitation. All wet or frozen soils should be removed prior to the continuation of site grading and fill placement. Borrow fill materials should not contain excessively wet or frozen materials at the time of placement. Additionally, if grading operations occur during the winter months, all frost-heaved soils should be removed prior to placement of engineered fill, granular sub-base materials, foundation or slab concrete, and asphalt pavement materials.

If problems are encountered during the site grading operations, or if the actual site conditions differ from those encountered during our subsurface exploration, the geotechnical engineer should be notified immediately.

The maximum loose lift thickness depends upon the type of compaction equipment used:

EQUIPMENT	MAXIMUM LOOSE LIFT THICKNESS, IN.
Large, Self-Propelled Equipment (CAT 815, etc.)	8
Small, Self-Propelled or Remote Controlled (Rammax, etc.)	6
Hand Operated (Plate Tamps, Jumping Jacks, Wacker-Packers)	4

The moisture content at the time of compaction should be near the optimum moisture content determined by ASTM D698. If possible, it is desirable to achieve compaction of soils wet of the optimum moisture content of the soils but within the compactable range. A soil compacted wet of optimum tends to be less permeable than the same soil compacted dry of optimum. The goal for dam embankments is to compact wet of optimum, yet maintain sufficient stability as to allow compaction of overlying fill layers.

Controlled fill shall be soil that has less than 5% fibrous organic content. Controlled fill for embankment construction should have at least 12 percent fines (material passing the No. 200 standard sieve) by weight. Soils with Unified Soil Classification System group symbols of SM, SC, and ML are suitable for use as controlled fill. Soils with USCS group symbol of CL may be suitable for use as controlled fill if tested and accepted by the geotechnical engineer.

Compaction Testing

We recommend that all fill operations be observed and tested by an engineering technician to determine if compaction requirements are being met. We recommend at least one field density test be performed for every 2,000 square feet of fill placed per lift. We recommend at least one test per lift of fill for every 50 linear feet of trench backfill.

APPENDICES

Appendix A – Exploration Results

Appendix B – Exploration Procedures

Appendix C – Project Description

Appendix D – Report Qualifications

Appendix E – Illustrations

Site Location Map
Boring Location Plan
Legend Sheet and Unified Soil Classification System
Soil Test Boring Logs

Appendix F – Laboratory Test Results

Moisture Density Relationship Curve (From Previous Exploration)
Grain Size Distribution

APPENDIX A -EXPLORATION RESULTS

Site Conditions

The site is developed with an existing embankment that serves as a roadway and dam. The existing earthfill dam is approximately 25 feet tall and 700 feet long, with approximate side slopes of 2.5H:1V.

Regional Geology

The site is located in the Coastal Plain Physiographic Province of North Carolina. The Coastal Plain is composed of seven terraces, each representing a former level of the Atlantic Ocean. Soils in this area generally consist of sedimentary materials transported from other areas by the ocean or rivers. These deposits vary in thickness from a thin veneer along the western edge of the region to more than 10,000 feet near the coast. The sedimentary deposits of the Coastal Plain rest upon consolidated rocks similar to those underlying the Piedmont and Mountain Physiographic Provinces. In general, shallow unconfined groundwater movement within the overlying soils is largely controlled by topographic gradients. Recharge occurs primarily by infiltration along higher elevations and typically discharges into streams or other surface water bodies. The elevation of the shallow water table is transient and can vary greatly with seasonal fluctuations in precipitation.

Soil Conditions

The borings performed on top of the embankment in the roadway encountered fill. Beneath the asphalt surface to depths of 25 feet, the test borings typically encountered layers of medium dense to dense silty sands and clean sands (SM, SP). Standard penetration test resistances (N-values) in these soils generally ranged from 18 to 46 blows per foot (bpf). From depths of 25 feet to termination depths of 35 feet, the test borings typically encountered layers of loose to dense clean sands (SP). Standard penetration test resistances (N-values) in these soils generally ranged from 9 to 37 (bpf).

The borings performed just beyond the downstream toe of the dam embankment encountered layers of loose to medium dense silty sands and clean sands (SM, SP) and limestone. Standard penetration test resistances (N-values) in these soils generally ranged from 4 to 18 blows per foot (bpf).

Auger refusal materials were not encountered in any of the borings.

The descriptions provided in this section are a general summary of the subsurface conditions encountered within the test borings. The Test Boring Records in Appendix E contain detailed information recorded at each of the boring locations and represent the geotechnical engineer's interpretation of the data based on visual examination of the soil samples obtained during the field exploration. The stratification lines on the Test Boring Records represent approximate boundaries between material types and the actual transitions between strata are expected to be gradual.

Groundwater Conditions

Groundwater was not encountered within the soil borings. The borings remained open and did not cave-in.

In general, shallow unconfined groundwater movement within the soils overlying bedrock is controlled largely by topographic gradients. Movement in this water table is generally from higher to lower elevations. Recharge occurs primarily by infiltration along higher elevations and typically discharges into streams or other surface water bodies. The elevation of the shallow water table is transient and can vary greatly with seasonal fluctuations in precipitation, surface water runoff, and other factors. Normally, the highest groundwater levels occur in the late winter and spring and the lowest groundwater levels occur in the late summer and fall.

APPENDIX B - EXPLORATION PROCEDURES

Soil Test Borings

The four soil test borings drilled on the site were performed using a CME 45 drill rig utilizing various cutting bits to advance the boreholes. Mud rotary drilling was utilized to advance the borings. Representative soil samples were obtained by means of the split-barrel sampling procedure in general conformance with ASTM D-1586. In this procedure, a 2-inch O.D., split-barrel sampler is driven into the soil a distance of 18 inches by a 140-pound hammer falling 30 inches. The number of blows required to drive the sampler through a 12-inch interval is termed the Standard Penetration Test (SPT) value and is indicated for each sample on the boring logs in Appendix E.

The SPT value can be used as a qualitative indication of the in-place relative density of cohesionless soils. In a less reliable way, it also indicates the consistency of cohesive soils. This indication is qualitative, since many factors can affect the standard penetration resistance value (i.e., differences between drill crews, drill rigs, drilling procedures, and hammer-rod-sampler assemblies) and prevent a direct correlation between SPT resistance value, or N-Value, and the consistency or relative density of the tested soil. Split-spoon samples were obtained at approximately 2.5-foot intervals within the upper 10 feet and at approximately 5-foot intervals thereafter. The approximate locations of the soil test borings are indicated on the Boring Location Plan in Appendix E of this report.

The drilling crew maintained a field log of the soils encountered in the borings. After recovery, each sample was removed from the sampler and visually classified. Representative portions of each soil sample were then sealed in air-tight containers and brought to our laboratory in Greensboro, North Carolina for visual examination and formal classification by a geotechnical engineer. The soil samples were visually classified in general accordance with the Unified Soil Classification System (USCS). The basic elements of the USCS are described on a legend sheet attached with this report and in ASTM D2487. Additional information from each soil boring is provided on the individual soil test boring logs in the Appendix. We will retain the soil samples at our laboratory for sixty days before discarding them, unless other storage arrangements are made.

Laboratory Testing Program

Ten samples were tested for natural moisture content in accordance with ASTM D2216. One sample was tested for grain size distribution in accordance with ASTM D422. These samples are representative of typical conditions for the earthfill embankment, and coastal plain soils. In addition, laboratory testing for the bulk sample was tested for standard Proctor compaction in accordance with ASTM D-698. Results of the laboratory tests are presented in Appendix F, and on the boring logs.

APPENDIX C - PROJECT DESCRIPTION

The project consists of the construction of a new spillway for the dam. The dam is classified as a High Hazard dam according to the Dam Safety Act of North Carolina. The dam is approximately 700 feet long and approximately 25 feet high. Preliminary plans for the dam rehabilitation indicate the new spillway will consist of four, 4-foot x 12-foot box culverts laid side by side. The subgrade of the box culvert will be approximately 7 to 12 feet below existing top of dam. The box culverts will outlet on the downstream slope and a concrete chute and energy dissipater will be constructed along the downstream slope to convey the water to the outlet stream. The crest of the dam is at approximate elevation 39 feet.

Project information was obtained from Mr. Howard Resnik, P.E. of Coastal Site Design. We have received a copy of a preliminary site plan that shows existing embankment dam and spillway and proposed new spillway at the dam site.

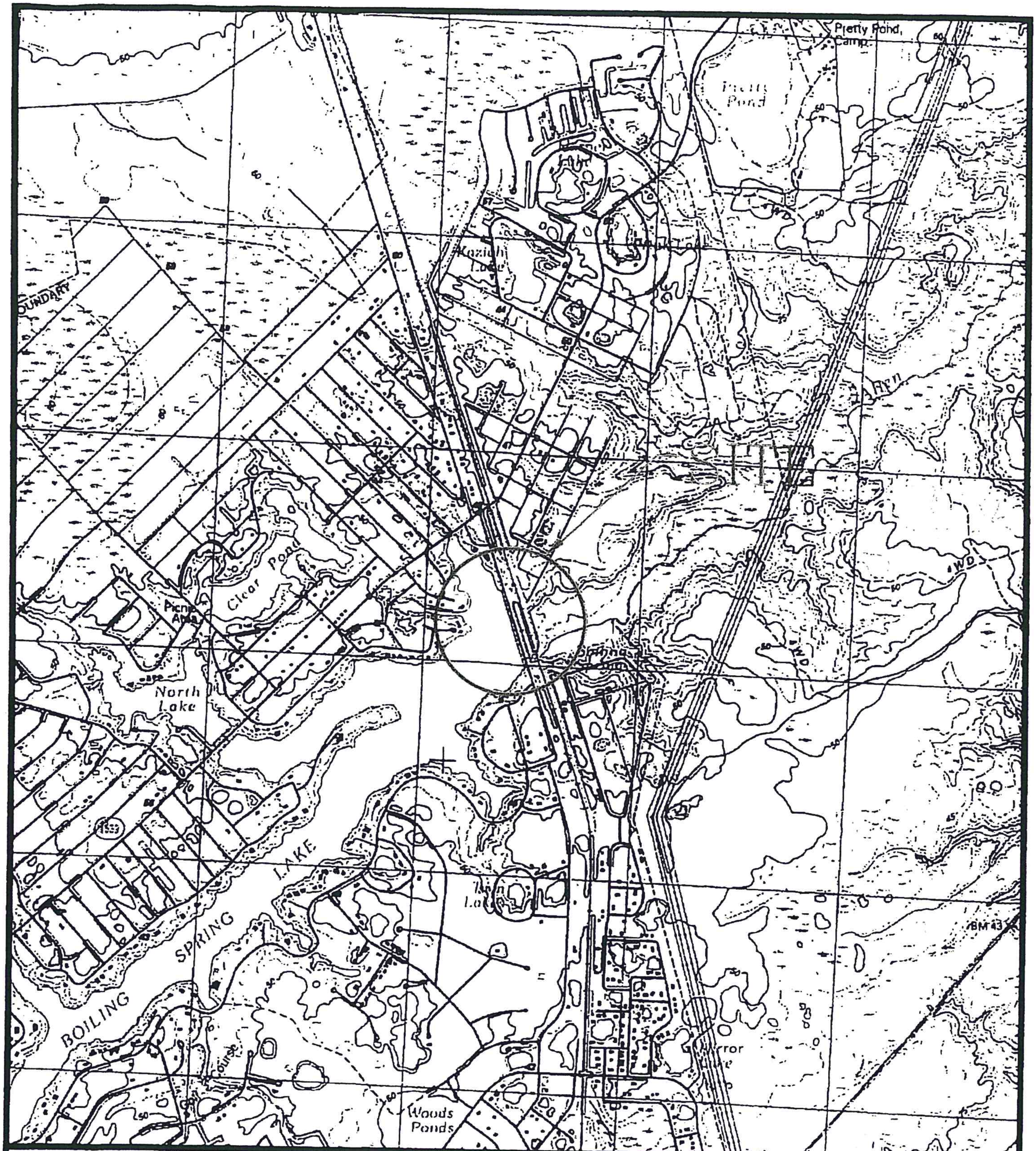
APPENDIX D - REPORT QUALIFICATIONS

This report has been prepared in order to aid in the evaluation of this site and to assist the Owner and Engineer in the feasibility study of the project. The report scope is limited to the specific project and location described, and the project description represents our understanding of the significant aspects relevant to soil and foundation characteristics.

The recommendations in this report have been developed using generalized subsurface conditions based on the soil test borings performed. Subsurface conditions can vary laterally and with depth, and significantly different conditions may exist at locations between the borings. Conditions different from those encountered by the borings and described in this report may require modifications to the geotechnical recommendations for the project.

We recommend that the construction activities be monitored by a qualified geotechnical engineering firm to provide the necessary overview and to check the suitability of the subgrade soils for support of slabs, pavements, and footings. We would be pleased to provide these services.

APPENDIX E – ILLUSTRATIONS



SCALE (IN FEET)
1000 2000
2000 0

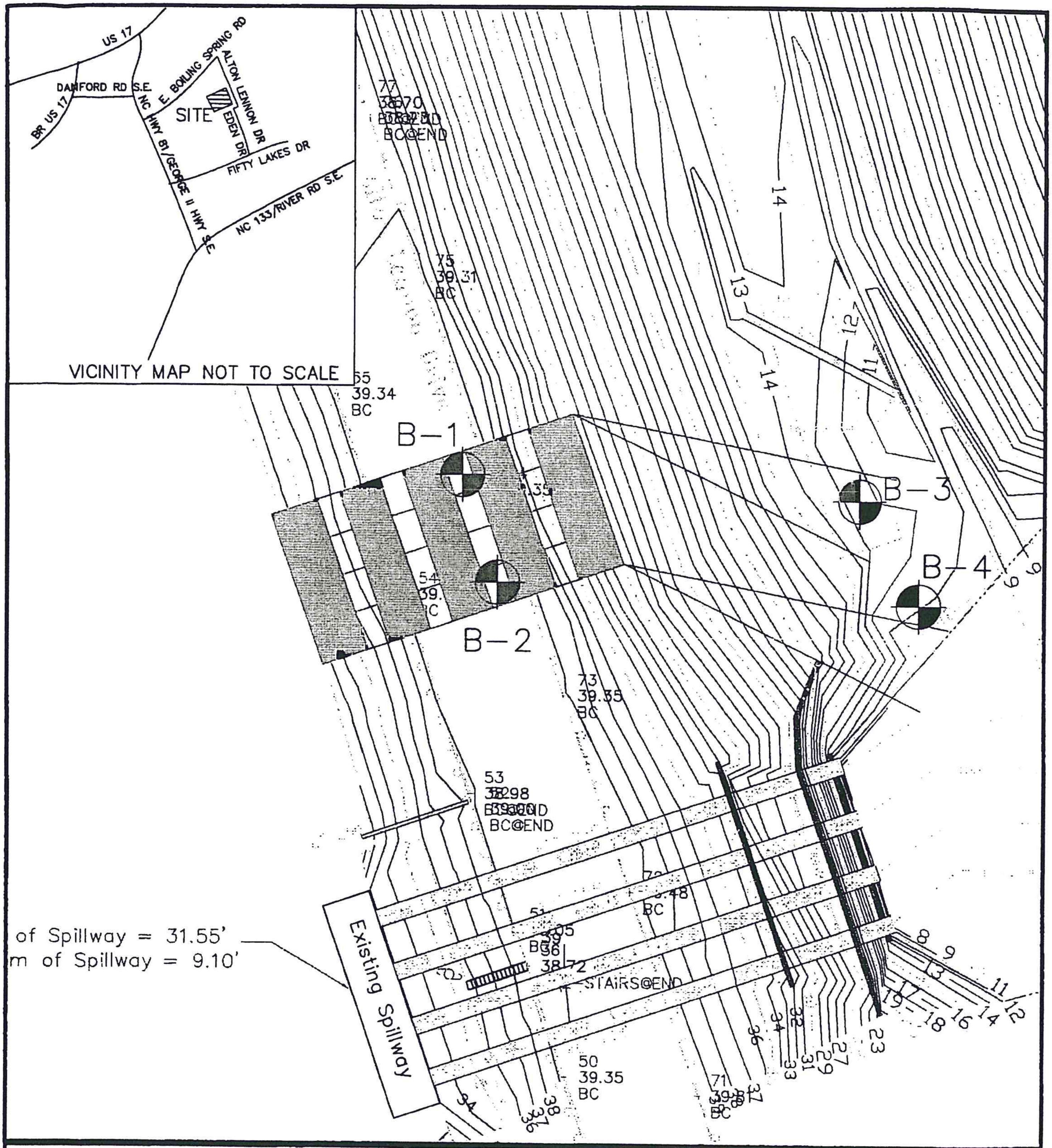
REFERENCE:
USGS TOPOGRAPHIC MAP
FUNSTON, NC QUADRANGLE
DATED 1990

ECS LLP
CAROLINAS

FIGURE 1
SITE LOCATION MAP

BOILING SPRING LAKES – SPILLWAY
BOILING SPRING LAKES, NORTH CAROLINA

ECS PROJECT 09.13750



SCALE (IN FEET)

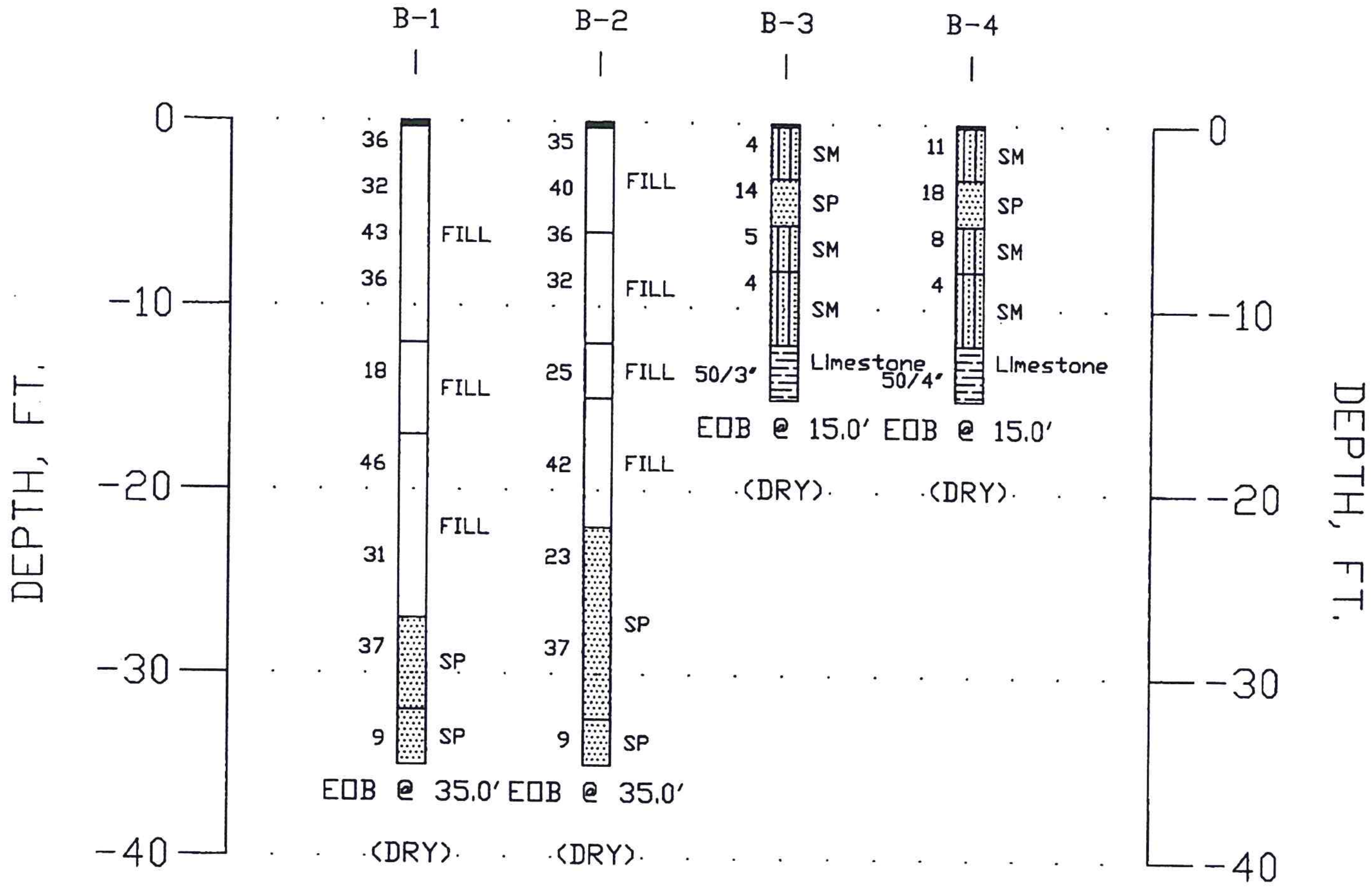
40 20 0 40

REFERENCE:
SITE PLAN PROVIDED BY COASTAL SITE DESIGN IN ELECTRONIC FORMAT

ECS LLP
CAROLINAS

FIGURE 2
BORING LOCATION PLAN
BOILING SPRING LAKES – SPILLWAY
BOILING SPRING LAKES, NORTH CAROLINA

ECS PROJECT 09.13750



NOTES:
1. NUMBERS NEXT TO BORINGS REPRESENT STANDARD PENETRATION TEST RESISTANCE IN BLOWS PER FOOT (ASTM D1586)
2. HORIZONTAL DISTANCES NOT TO SCALE
3. VERTICAL DISTANCES ARE 1" = 10'

SOIL CLASSIFICATION LEGEND

☐ FILL – FILL (POSS/PROB) OF ALL TYPES.
▩ GW – WELL GRADED GRAVEL
▩ GM – SILTY GRAVEL
▩ GP – POORLY GRADED GRAVEL
▩ GC – CLAYEY GRAVEL
▩ SW – WELL GRADED SAND
▦ SM – SILTY SAND
▤ SP – POORLY GRADED SAND
▨ SC – CLAYEY SAND
▥ ML – LOW PLASTICITY SILT
▧ CL – LOW PLASTICITY CLAY
▥ MH – HIGH PLASTICITY SILT
▨ CH – HIGH PLASTICITY CLAY
▒ ALLUV – ALLUVIUM
▒ RC – ROCK CORE
▤ PWR – PARTIALLY WEATHERED ROCK
EOB – END OF BORING
–C– CAVE IN DEPTH
▽ TIME OF BORING WATER LEVEL
▼ END OF BORING WATER LEVEL
▽ STABILIZED WATER LEVEL

ECS LLP
CAROLINAS

FIGURE 3
GENERALIZED
SUBSURFACE PROFILE
BOILING SPRING LAKES –
SPILLWAY
BOILING SPRING LAKES, NORTH
CAROLINA

DRAWN BY/DATE NRR/03-19-07
CHECKED BY/DATE
PROJECT NO. 09.13750

REFERENCE NOTES FOR BORING LOGS

I. Drilling and Sampling Symbols:

SS	Split Spoon Sampler	RB	Rock Bit Drilling
ST	Shelby Tube Sampler	BS	Bulk Sample of Cuttings
RC	Rock Core: NX, BX, AX	PA	Power Auger (no sample)
PM	Pressuremeter	HSA	Hollow Stem Auger
DC	Dutch Cone Penetrometer	WS	Wash Sample

Standard Penetration Test Blow Count (Blows/Ft) refers to the blows per foot of a 140 lb. hammer falling 30 inches on a 2 inch O.D. split spoon sampler, as specified in ASTM D-1586. The blow count is commonly referred to as the N-value.

II. Correlation of Penetration Resistance to Soil Consistency:

Sands		Cohesive Soils – Silts and Clays		
SPT N value	Consistency	SPT N value	Consistency	Unconfined Compressive Strength, Qp, tsf
0 - 3	Very Loose	0 - 2	Very Soft	0 - 0.25
4 - 9	Loose	3 - 4	Soft	0.25 - 0.5
10 - 29	Medium Dense	5 - 8	Medium Stiff	0.5 – 1.0
30 - 49	Dense	9 - 16	Stiff	1.0 – 2.0
50 - 100	Very Dense	17 - 29	Very Stiff	2.0 – 4.0
100+	Partially Weathered Rock	30 - 50	Hard	4.0 - 8.0
		50 - 100	Very Hard	> 8.0
		100+	Partially Weathered Rock	

III. Unified Soil Classification Symbols:

GP	Poorly Graded Gravel	ML	Low Plasticity Silt
GW	Well Graded Gravel	MH	High Plasticity Silt
GM	Silty Gravel	CL	Low Plasticity Clay
GC	Clayey Gravel	CH	High Plasticity Clay
SP	Poorly Graded Sand	OL	Low Plasticity Organics
SW	Well Graded Sand	OH	High Plasticity Organics
SM	Silty Sand	CL-ML	Dual Classification (Typical)
SC	Clayey Sand		

IV. Water Level Measurement Symbols:

WL	Water Level	AB	After Boring
WS	While Sampling	AC	After Coring
WD	While Drilling		

The water levels are those water levels actually measured in the borehole at the times indicated by the symbol. The measurements are relatively reliable when augering, without adding fluids, in a granular soil. In clays and plastic silts, the accurate determination of water levels may require several days for the water level to stabilize. In such cases, additional methods of measurement are generally applied.

CLIENT	JOB #	BORING #	SHEET
CITY OF BOILING SPRING LAKES	09.13750	B-1	1 OF 2

ECS LLP CAROLINAS

PROJECT NAME: BOILING SPRING LAKES - SPILLWAY

ARCHITECT-ENGINEER:

SITE LOCATION: BOILING SPRING LAKES, NORTH CAROLINA

-O- CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% —— 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

DESCRIPTION OF MATERIAL ENGLISH UNITS

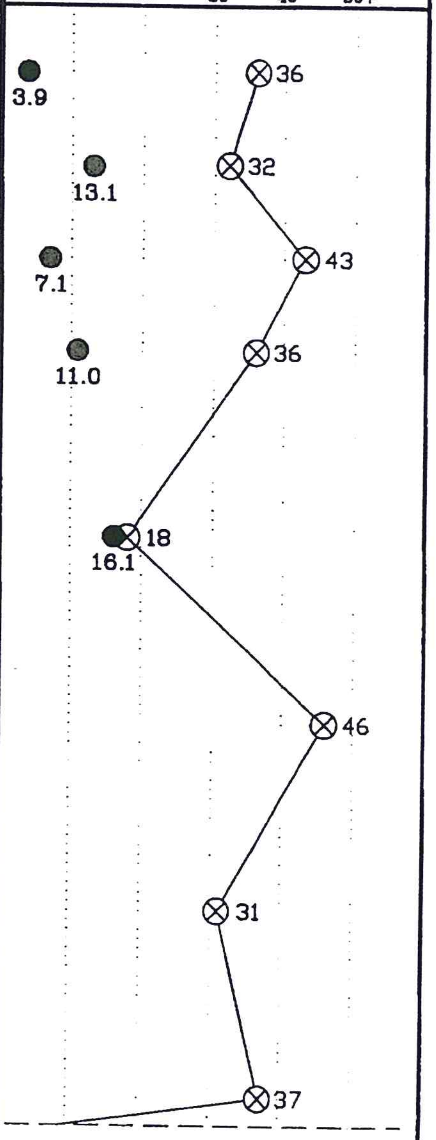
BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%

SURFACE ELEVATION

WATER LEVELS | ELEVATION (FT)

SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL
				Asphalt Depth 4"
1	SS	18	14	FILL: Grayish Brown, Fine SAND, Moist, Dense, (FILL)
2	SS	18	14	
3	SS	18	14	
4	SS	18	14	
				Gray, Fine Sandy With Clay, Moist, Medium Dense, (FILL)
5	SS	18	14	
				Grayish Brown, Fine SAND, Moist, Dense, (FILL)
6	SS	18	14	
7	SS	18	14	
				COASTAL PLAIN: Grayish Brown, Silty Fine SAND, Moist, Dense, (SP)
8	SS	18	14	

DEPTH (FT): 0 5 10 15 20 25 30



CONTINUED ON NEXT PAGE.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽ WL	WS OR (D)	BORING STARTED	02-26-07	
▼ WL(BCR)	▼ WL(ACR)	BORING COMPLETED	02-26-07	CAVE IN DEPTH ●
▽ WL		RIG CME 45	FOREMAN MID-ATLANTIC	DRILLING METHOD HSA

NRR (03-19-07) NRR (03-19-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07) NRR (03-29-07)

rbendel(03/13/2007)

CLIENT CITY OF BOILING SPRING LAKES	JOB # 09.13750	BORING # B-1	SHEET 2 OF 2	ECS LLP CAROLINAS
PROJECT NAME BOILING SPRING LAKES - SPILLWAY	ARCHITECT-ENGINEER			
SITE LOCATION BOILING SPRING LAKES, NORTH CAROLINA				

-○- CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

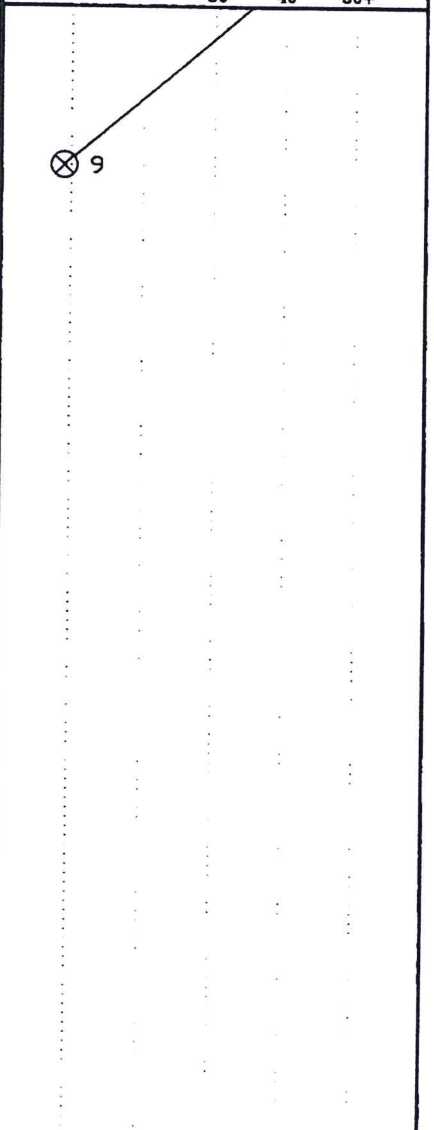
PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY
RQD% — — — REC.% ———
20% — 40% — 60% — 80% — 100%

⊗ STANDARD PENETRATION BLOWS/FT.
10 20 30 40 50+

DESCRIPTION OF MATERIAL — ENGLISH UNITS
BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%
SURFACE ELEVATION

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)
30					COASTAL PLAIN: Grayish Brown, Silty Fine SAND, Moist, Dense, (SP)		
	9	SS	18	14	Dark Brown, Silty Fine SAND, With Wood Fragments, Wet, Loose, (SP)		
35					END OF BORING @ 35.0'		
40							
45							
50							
55							
60							



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽ WL	WS OR (WD)	BORING STARTED 02-26-07	
▼ WL(BCR)	▼ WL(ACR)	BORING COMPLETED 02-26-07	CAVE IN DEPTH ●
▽ WL		RIG CME 45 FOREMAN MID-ATLANTIC	DRILLING METHOD HSA

NRR (03-19-07) NRR (03-19-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07) NRR (03-29-07)

rbendel(03/13/2007)

CLIENT	JOB #	BORING #	SHEET
CITY OF BOILING SPRING LAKES	09.13750	B-2	1 OF 2

ECS LLP CAROLINAS

PROJECT NAME
BOILING SPRING LAKES - SPILLWAY

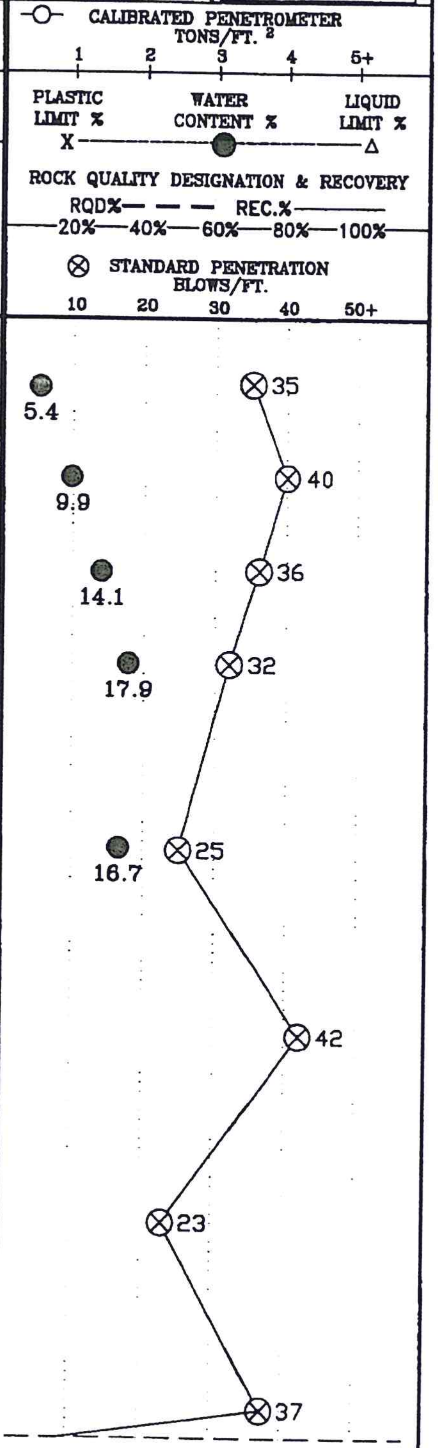
ARCHITECT-ENGINEER

SITE LOCATION
BOILING SPRING LAKES, NORTH CAROLINA

DESCRIPTION OF MATERIAL ENGLISH UNITS
BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%
SURFACE ELEVATION

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL
0					Asphalt Depth 4"
	1	SS	18	14	FILL: Brown, Silty Fine SAND, Moist, Dense, (FILL)
5	2	SS	18	14	
	3	SS	18	14	Grayish Brown, Medium SAND, Wet, Dense, (FILL)
10	4	SS	18	14	
					Grayish Brown, Silty Fine SAND With Clay, Wet, Medium Dense, (FILL)
15	5	SS	18	14	
					Grayish Brown, Silty Fine SAND, Trace Rock Fragments and Wood Fragments, Wet, Dense, (FILL)
20	6	SS	18	14	
					COASTAL PLAIN: Grayish Brown, Silty Fine SAND, Wet, Medium Dense to Dense, (SP)
25	7	SS	18	14	
30	8	SS	18	14	

WATER LEVELS
ELEVATION (FT)



CONTINUED ON NEXT PAGE.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽ WL	WS OR [✓ WD]	BORING STARTED 02-26-07	
▼ WL(BCR)	▼ WL(ACR)	BORING COMPLETED 02-26-07	CAVE IN DEPTH ●
▽ WL		RIG CME 45 FOREMAN MID-ATLANTIC	DRILLING METHOD HSA

CLIENT	JOB #	BORING #	SHEET
CITY OF BOILING SPRING LAKES	09.13750	B-2	2 OF 2

ECS LLP CAROLINAS

PROJECT NAME
BOILING SPRING LAKES - SPILLWAY

ARCHITECT-ENGINEER

SITE LOCATION
BOILING SPRING LAKES, NORTH CAROLINA

-O- CALIBRATED PENETROMETER TONS/FT.^{2}
1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % Δ

ROCK QUALITY DESIGNATION & RECOVERY
RQD% — — — REC.% ———
20% — 40% — 60% — 80% — 100%

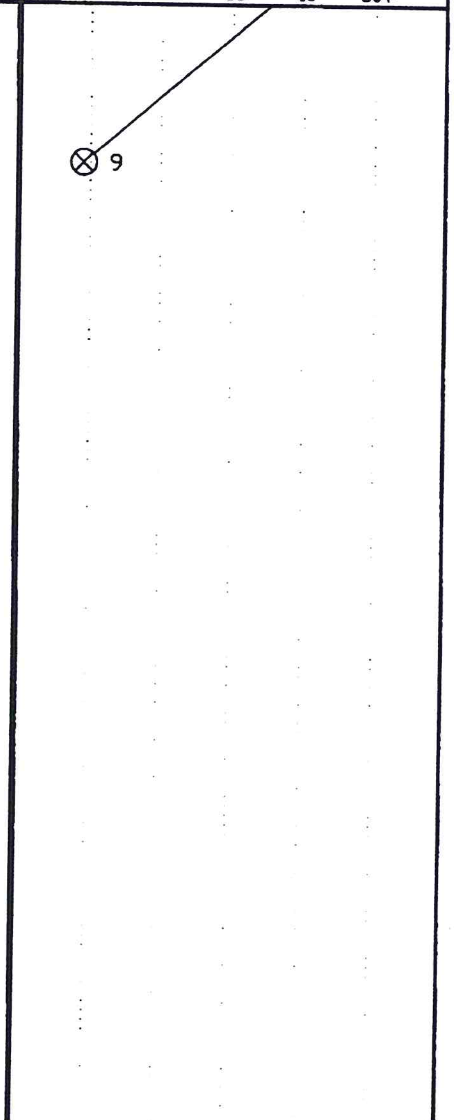
⊗ STANDARD PENETRATION BLOWS/FT.
10 20 30 40 50+

DESCRIPTION OF MATERIAL ENGLISH UNITS

BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%

SURFACE ELEVATION

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)
30					COASTAL PLAIN: Grayish Brown, Silty Fine SAND, Wet, Medium Dense to Dense, (SP)		
	9	SS	18	14	Dark Brown, Silty Medium SAND, Trace Wood Fragments and Roots, Wet, Loose, (SP)		
35					END OF BORING @ 35.0'		
40							
45							
50							
55							
60							



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

∇ WL WS OR WD	BORING STARTED	02-26-07	
▼ WL(BCR) ▼ WL(ACR)	BORING COMPLETED	02-26-07	CAVE IN DEPTH ●
∇ WL	RIG CME 45 FOREMAN MID-ATLANTIC		DRILLING METHOD HSA

NRR (03-19-07) NRR (03-19-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07) NRR (03-29-07)

rbende(03/13/2007)

CLIENT
CITY OF BOILING SPRING LAKES

JOB #
09.13750

BORING #
B-3

SHEET
1 OF 1

ECS LLP CAROLINAS

PROJECT NAME
BOILING SPRING LAKES - SPILLWAY

ARCHITECT-ENGINEER

SITE LOCATION
BOILING SPRING LAKES, NORTH CAROLINA

-O- CALIBRATED PENETROMETER TONS/FT.^{2}
1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY
RQD% — — — REC.% ———
20% — 40% — 60% — 80% — 100%

⊗ STANDARD PENETRATION BLOWS/FT.
10 20 30 40 50+

DESCRIPTION OF MATERIAL — ENGLISH UNITS

BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%

SURFACE ELEVATION

SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)
1	SS	18	14
2	SS	18	14
3	SS	18	14
4	SS	18	14
5	SS	9	9

DEPTH (FT): 0, 5, 10, 15, 20, 25, 30

Topsoil Depth 2"

COASTAL PLAIN: Tannish Brown, Silty Fine SAND, Trace Clay and Black Inclusions and Rock Fragments, Moist, Loose, (SM)

Grayish Brown, Medium SAND, Trace Roots and Black Inclusions, Wet, Medium Dense, (SP)

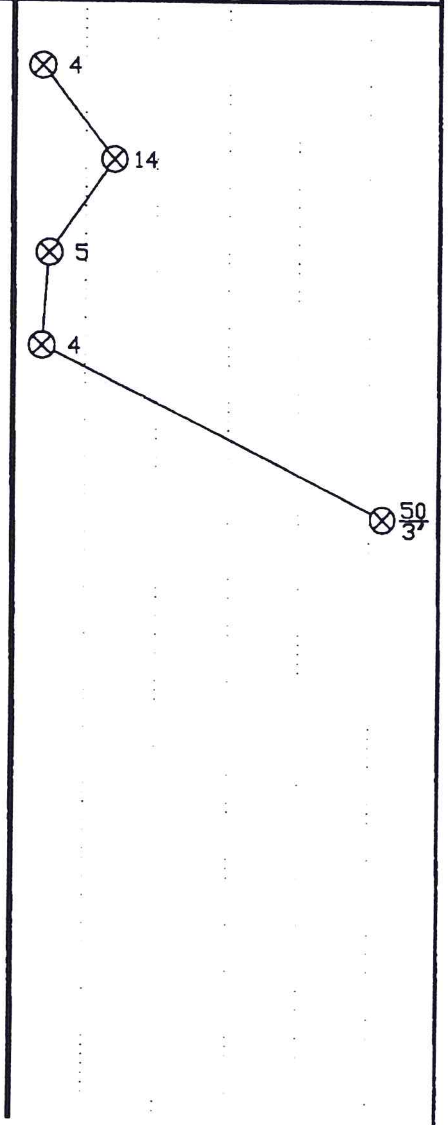
Brown, Silty Fine SAND, With Black Inclusions, Trace Clay and Wood Fragments, Wet, Loose, (SM)

Dark Brown, Silty Fine SAND, With Roots and Wood Fragments, Wet, Loose, (SM)

LIMESTONE: Gray, Medium SAND, With Weathered Limestone, Saturated, (Limestone)

END OF BORING @ 15.0'

WATER LEVELS — ELEVATION (FT)



THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽ WL	WS OR WD	BORING STARTED	02-26-07	
▼ WL(BCR)	▼ WL(ACR)	BORING COMPLETED	02-26-07	CAVE IN DEPTH ●
▽ WL		RIG CME 45 FOREMAN MID-ATLANTIC		DRILLING METHOD HSA

NRR (03-19-07) NRR (03-19-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07)

rbendel(03/13/2007)

CLIENT CITY OF BOILING SPRING LAKES	JOB # 09.13750	BORING # B-4	SHEET 1 OF 1
PROJECT NAME BOILING SPRING LAKES - SPILLWAY	ARCHITECT-ENGINEER		
SITE LOCATION BOILING SPRING LAKES, NORTH CAROLINA			

ECS LLP CAROLINAS

DESCRIPTION OF MATERIAL ENGLISH UNITS

BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%

SURFACE ELEVATION

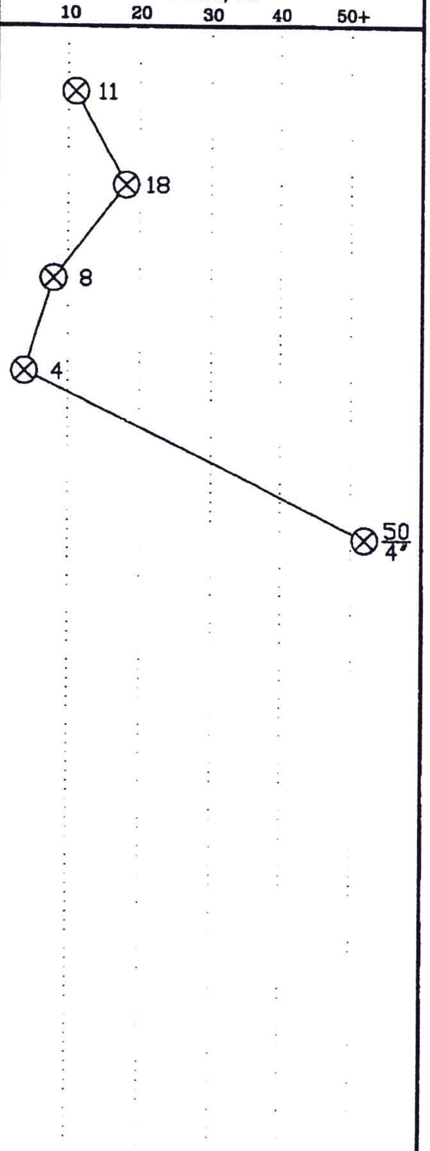
–O– CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% —— 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)
0					Topsoil Depth 2"		
	1	SS	18	14	COASTAL PLAIN: Dark Brown, Silty Fine SAND, With Roots and Wood Fragments, Moist, Medium Dense, (SM)		
	2	SS	18	14			
5					Light Gray, Medium SAND, Wet, Medium Dense, (SP)		
	3	SS	18	14	Medium Gray, Silty Medium SAND, With Rock Fragments and Black Inclusions, Moist, Loose, (SM)		
	4	SS	18	14			
10					Dark Brown, Silty Medium to Coarse SAND, With Wood Fragments, Wet, Loose, (SM)		
					LIMESTONE: Light Gray, Fine Sandy SILT, With Rock Fragments, Saturated, (Limestone)		
	5	SS	4	4			
15					END OF BORING @ 15.0'		
20							
25							
30							



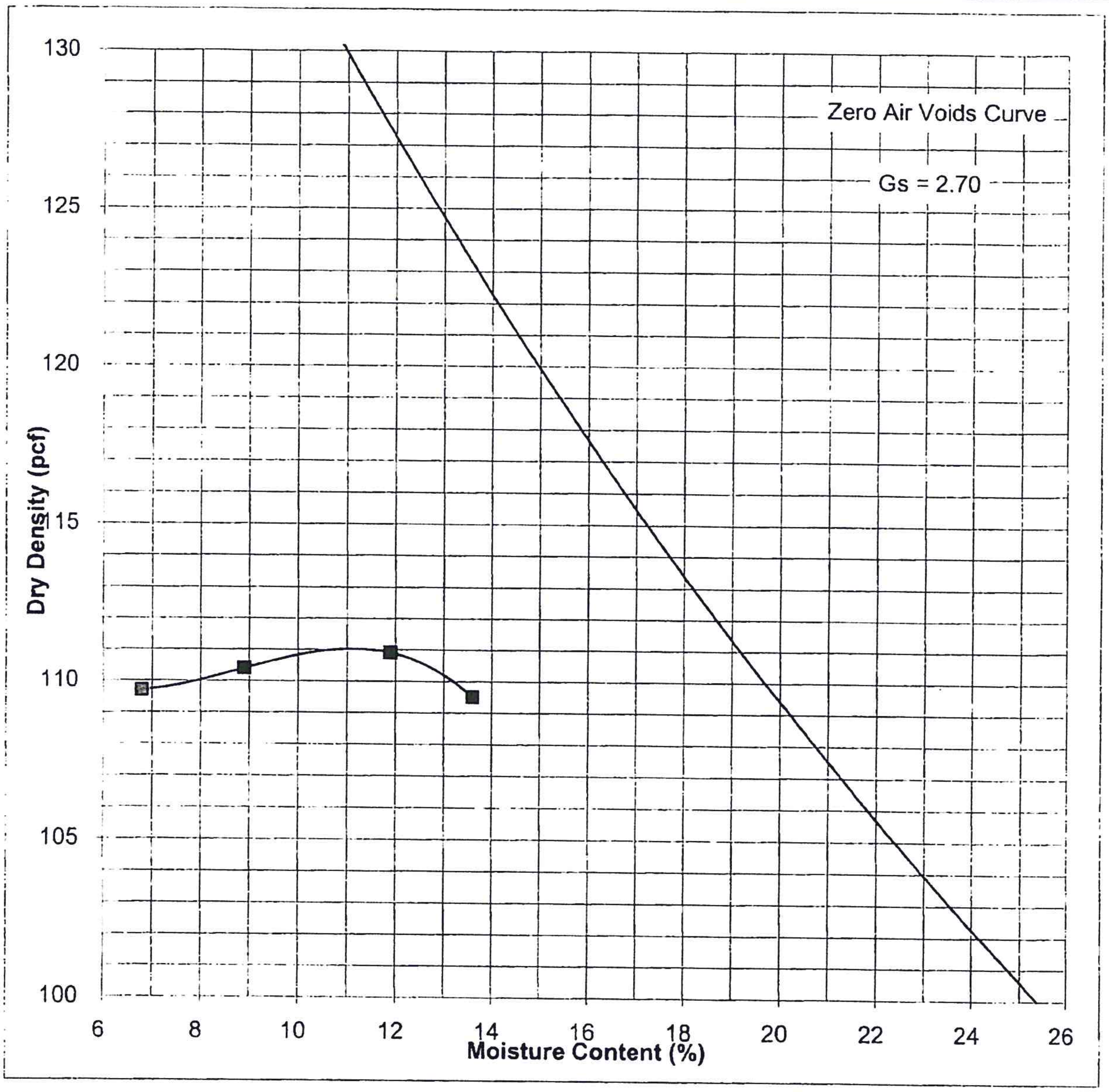
THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽ WL WS OR (D)	BORING STARTED 02-26-07	
▼ WL(BCR) ▼ WL(ACR)	BORING COMPLETED 02-26-07	CAVE IN DEPTH ●
▽ WL	RIG CME 45 FOREMAN MID-ATLANTIC	DRILLING METHOD HSA

NRR (03-19-07) NRR (03-19-07) NRR (03-27-07) NRR (03-27-07) NRR (03-27-07)

rbende(03/13/2007)

APPENDIX F – LABORATORY RESULTS



Sample No.	6059	Natural Moisture Content	
Boring	Bulk	Percent Passing No. 200 Sieve	
Depth		Percent Retained on No. 4 Sieve	0.0
Liquid Limit (LL)		Percent Retained on 3/4" Sieve	0.0
Plastic Limit (PL)		Maximum Dry Density (pcf)	111.0
Plasticity Index (PI)		Optimum Moisture Content (%)	11.0
Liquidity Index (LI)		Corr. Maximum Dry Density (pcf)	111.0
Description	Tan Silty Fine SAND	Corr. Optimum Moisture Content (%)	11.0
Classification		Percent (%) Gravel as Tested	0.0
Specific Gravity	2.70 (Assumed)	Percent (%) Gravel Total	
Test Standard	ASTM D-698	Test Method	B

Project: Boiling Springs Lake-Spillwa
Project No.: **G-13750**
Date: **3-14-07**

ECS Carolinas, LLP
Greensboro, North Carolina
Moisture Density Relationship Curve

Natural Moisture

Job Name: **Boiling Springs Lake-Spillway** Date: **03/13/2007**
Job Number: **09:13750** By: **CC**

Boring	Depth	Pan Wt. (g)	Wet Wt. (g)	Dry Wt. (g)	Dry Wt. Soil (g)	Water Wt. (g)	Moisture Content
1	1-2.5	13.46	53.72	52.22	38.76	1.5	3.9%
	3.5-5	13.64	58.54	53.35	39.71	5.19	13.1%
	6-7.5	13.44	61.27	58.08	44.64	3.19	7.1%
	8.5-10	13.56	69.45	63.89	50.33	5.56	11.0%
	13.5-15	13.51	56.17	50.25	36.74	5.92	16.1%
2	1-2.5	11.26	53.03	50.88	39.62	2.15	5.4%
	3.5-5	16.89	59.94	56.07	39.18	3.87	9.9%
	6-7.5	13.6	64.05	57.83	44.23	6.22	14.1%
	8.5-10	17.11	68.94	61.07	43.96	7.87	17.9%
	13.5-15	13.53	65.02	57.64	44.11	7.38	16.7%

AASHTO Accredited Lab

Jeffrey P. White, Lab Manager

Engineering Consulting Services, Ltd.
Greensboro, North Carolina

Particle Size Analysis ASTM D-422

Date: 03/15/2007

Job No.: 13750

Project Name: Boiling Springs

Boring #:

Sample #: Lab # 6059

Depth:

Street:

Station:

Description: Tan Silty Fine SAND

MC:

LL:

PL:

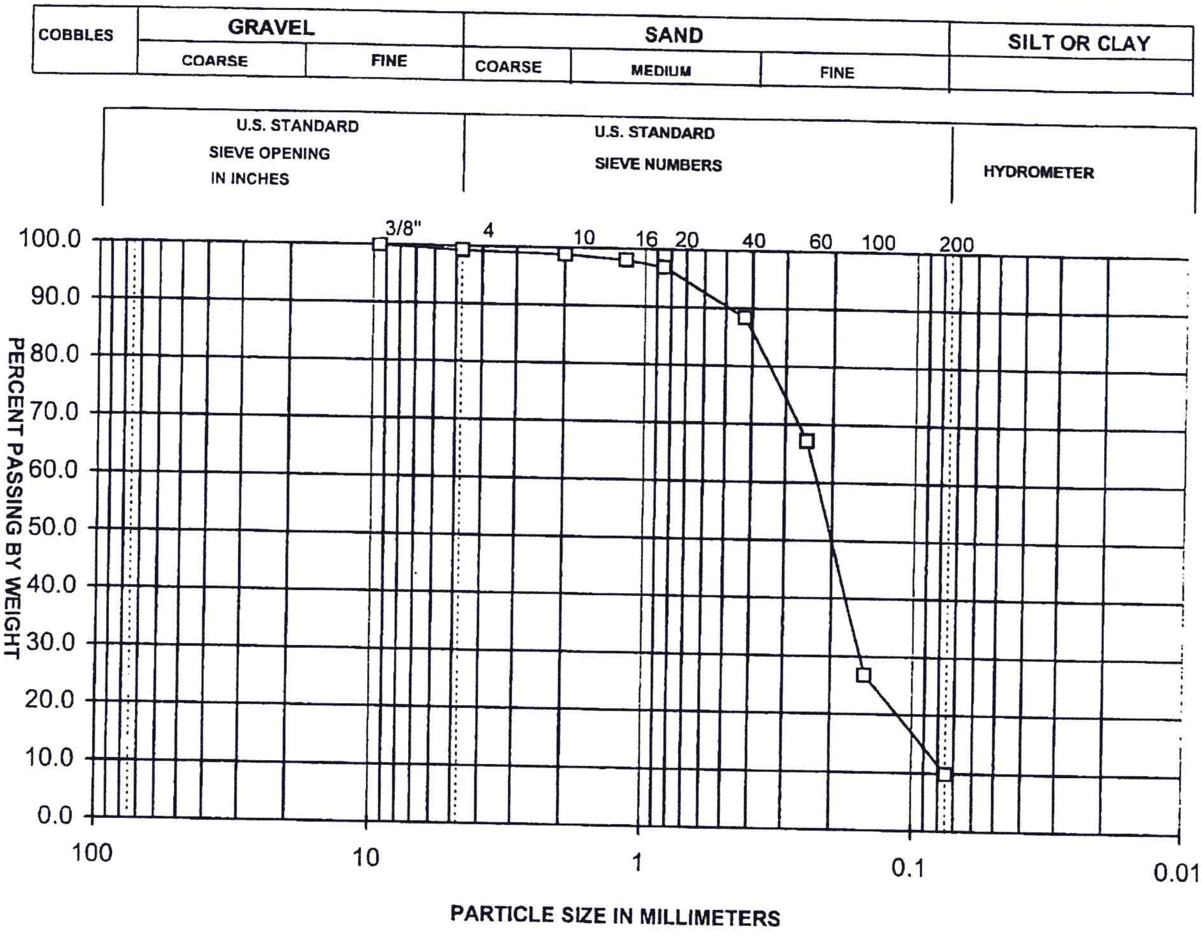
PI:

Wash Sample	Initial	Final
Dry Wt. of Sample + Tare (g)	139.14	
Wt of Tare (g)	0.00	0.00
Dry Wt. of Sample (g)	139.14	

Sieve No.	(mm)	Weight Retained	Percent Retained	Percent Passed
1/2	12.70	0.00	0.0	
3/8	9.50	0.00	0.0	100.0
4	4.75	0.94	0.7	99.3
10	2.00	1.65	1.2	98.8
16	1.18	2.81	2.0	98.0
20	0.85	4.27	3.1	96.9
40	0.43	16.15	11.6	88.4
60	0.25	45.64	32.8	67.2
100	0.15	101.83	73.2	26.8
200	0.08	125.40	90.1	9.9

(V) = Visual Classification

(B) = Based on Lab Results



Boring/ Sample No.	Depth (feet)	Svmbol	LL	PI	Description
Lab 6059		□		NP	Tan Silty Fine SAND
/		■			
/		△			
/		▲			

Project: Boiling Springs
Project No.: 13750

Date: 3/15/07

ECS Carolinas, LLP
Greensboro, North Carolina
Particle Size Distribution Curves