CONSTRUCTION OF EXPERIMENTAL APPROACH EMBANKMENTS AT SALT FORK RIVER BRIDGES ON US 177 AND THEIR INITIAL PERFORMANCE

By

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Thesis Approved:

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CHAPTER 1

INTRODUCTION

A smooth highway is a desire shared by engineers and travelers alike. One common problem encountered throughout the United States is rough transitions between the highway pavement and the bridge deck. This "bump at the end of the bridge" is typically a result of differential settlement between the bridge and the approach embankment. Serious motorist safety problems can arise from this bump if the difference is two inches or more. Other complications from differential settlement can be driver discomfort, structural damage from dynamic impact loads, damage to the vehicles driving over the bump, and increased maintenance. This problem is common throughout the country (1).

A report by the Colorado Department of Highways cites five main reasons for approach settlement which contributes to the "bump at the end of the bridge" (1). One is the poor compaction of abutment backfill. Two others are the time dependent consolidation of the embankment foundation and time dependent consolidation of the approach embankment itself. Also, erosion of soil at the abutment face and poor drainage

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of the embankment and abutment backfill are reasons listed causing differential settlement.

The University of Oklahoma conducted research in 1990 (2) that attempted to apply statistical theory to the likelihood of and degree of deformation of the abutment backfill. Different input parameters, including settlement, were measured at several bridges in Oklahoma. Links were made associating features like traffic, depth of foundation soil, age of embankment, embankment height, SPT (Standard Penetration Test) blow count for the embankment and foundation soil, friction ratio from the CPT (Cone Penetration Test), CPT tip resistance, and skewness of the bridge approach to total measured settlement. In Schwidder's work (1), these methods were compared to conventional soil mechanics settlement calculations and found to give inconsistent data.

Research Project Description

This study is an evaluation of experimental approach embankments. The research site is a bridge replacement project on US highway 177 over the Salt Fork of the Arkansas River mostly in Noble county (with the northern tip extending into Kay county) Oklahoma. One main bridge crosses the river and two overflow bridges lie to the north. The project is surveyed from south to north so that the main bridge on the south end is bridge "A" and the two overflow bridges are bridge "B" and bridge "C". The southern abutments of the bridges are referred to as "1" and the northern end as "2" (the south and

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north ends of bridge A are known as "A1" and "A2," respectively). The focus of the research is four trial approach embankments and one control section. The bridge replacement includes a total of six abutment backfills, but the southern embankment of bridge A is twice as high as the others and was not used in the backfill comparisons. However, the south abutment of bridge A was instrumented and data from it are presented in the appendices. Since the five remaining abutments have heights between 13 and 17 feet, their similarity allows comparison. The trial backfills are a geotextile reinforced granular material at B1, controlled low strength material at B2, dynamically compacted granular material at C1, and flooded and vibrated granular material at C2.

Purpose of Thesis

This thesis documents the construction of four experimental and one control approach embankment/abutment wall backfills used at the bridge replacement project on US 177 in Kay and Noble counties in Oklahoma. Along with actual construction, this documentation includes site characterization, instrumentation installation, and materials testing for the project. Presentation of initial data and preliminary findings are presented.

The information was gathered in several steps. Site characterization came from frequent visits and the study of aerial photographs combined with the principles of terrain analysis. Backfill construction information was gathered on site during the construction of the trial backfills. Installation of the instrumentation started in February 1995, when the forms for the instruments were constructed and was mostly completed in June 1995,

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after construction of the trial backfills had been completed. Instrumentation installed thus far includes the total pressure cells, amplified liquid settlement gages, telescoping inclinometer casings, and piezometers. Surface settlement points are the only remaining items to be installed, which will be done after paving. Daily trips by OSU research staff were made during the construction phase to monitor and verify the construction techniques of the experimental backfills. Firsthand experiences along with field notes from OSU research staff and Mike Bier, ODOT construction inspector, videotapes, and photographs were utilized to document the construction. Instrumentation installation was also documented using photographs, OSU field notes, and first hand experiences. Data from the instrumentation have been continually collected on 3-4 week intervals since the installation of the instruments. The original scope of this research was to collect data for two years after installation. Although this time has not fully elapsed, preliminary suggestions will be made based on cost, time of installation, and measured performance.

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CHAPTER 2

SITE CHARACTERIZATION

Site characterization for a project is essential to develop adequate and appropriate construction plans to fit the need of a particular project. For this bridge replacement project, as with any large civil project, thorough investigation of the foundation materials was needed to characterize the soil and set parameters for design. This chapter discusses the general topography of the site, tests performed for site characterization, and concludes with construction technique recommendations from the geotechnical investigation.

Topography

General topographic description of the site is an alluvial valley surrounded by low rolling hills with moderate slopes. Aerial photography reveals mottled phototones and land uses for grain crops and grazing. Fine grained soils are the predominant surface soil type in this area.

Site description is based on the 1970 Soil Conservation Service Noble County Soil Survey(3) and the 1974 Kay County Survey(4). The southern-most portion of the

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project is classified as Miller clay with 0-1% slopes. It is characterized as a compressible and unstable soil that floods because of slow percolation (low permeability). At the south of bridge A (A1) Yahola silt loam (SM, SC, ML, CL) with 0-1% slopes is encountered. It is poor as roadfill because of low strength, but does drain favorably. The Yahola group also lies on the north bank of the Salt Fork River and continues northward approximately to the south abutment of bridge B. From there, the Port silt loam formation (classified as ML, CL) with 0-1% slopes extends northward past the north embankment of bridge C. This material has favorable drainage and is fair as roadfill. It is compressible and deemed unstable for use as embankment material. Near the south of bridge C, a band of Port silty clay loam lies within the Port silt loam formation. It has low strength and shrink swell behavior, making it fair as roadfill material. As an embankment material it is unstable and compressible. North of the Port silt loam and extending to the northern end of the project lies a Dougherty-Eufaula complex soil (SM, CL) that is characterized with moderate seepage and susceptibility to wind erosion.

Test Descriptions

Three primary in-situ tests were run for the geotechnical investigation for the US 177 project: the Standard Penetration Test, the Cone Penetration Test, and the Dilatometer Test.

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Standard Penetration Test

The Standard Penetration Test (SPT) is a widely used test that correlates results to determine soil type. A split spoon sampler (or split barrel) with a sample length capacity of 1.5 ft (0.5 m) is driven into a soil deposit. To maintain uniformity, the sampler dimensions are kept constant with a 2 in. (51 mm) outside diameter and a 1 3/8 in. (35 mm) inside diameter. A 140 lb. (64 kg) weight drives the sampler with 30 in. (75 cm) drops so the energy is known. The number of blows to drive the sampler 18 in. (45.7 cm) into the ground is recorded and the blow count, N, is the number of blows for the last one foot of the drive.

The blow count along with visual identification and laboratory results were used to describe the density of cohesionless soils and the consistency of cohesive soils. Density and consistency descriptions were used to help delineate soil strata or confirm uniformity. Other correlations with N values used were, for cohesionless soils, relative density and bearing capacity, and for cohesive soils, shear strength.

Cone Penetration Test

The Electric Cone Penetration Test (CPT) was used to define the soil profile and soil properties. As the cone penetrates, a strain gage near the tip measures strain which allows tip resistance to be calculated and then subtracted from the total applied force to obtain the sleeve friction. Sleeve friction is a function of grain size for granular soils and

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cohesion for fine-grained soils. Sleeve friction and tip resistance values were used to describe the soil type based on empirical correlation.

Dilatometer Test

The Dilatometer Test (DMT) is an in situ test used to define soil strata. The device attaches to the end of the same type of extension rods used for the CPT. It is a flat plate 96 mm (3.78 in.) wide, 240 mm (9.45 in.) long, and 15 mm (0.59 in.) thick. The penetrating end of the plate is pointed. One side of the plate contains a stainless steel membrane 0.2 mm (0.0079 in.) thick and 60 mm (2.36 in.) in diameter. Pneumatic pressure from a source on the ground surface is applied through a tube to the membrane. When the membrane expands outward 0.05 mm (0.00197 in.) and then 1.10 mm (0.433 in.) total (so an additional 1.05 mm), the applied pressure values are recorded. With these pressure values various indexes were calculated, which correlate with other empirical data. From this, estimates of the soil type, density, Ko values (earth pressure ratio), and the overconsolidation ratio were made.

Test Configuration

The original geotechnical investigation plan for the bridge replacement project called for subsurface exploration and in situ testing of the pier and abutment foundation material. The pier foundation investigation involved primarily SPT and split spoon

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sampling. Investigation for the foundation originally included 8 CPT soundings, one DMT sounding, one SPT boring, and one continuous pushtube boring. The configuration of these tests at each abutment is shown in Figure 1. During the actual investigation, changes were made. CPT number eight as shown in the figure was dropped and replaced with another DMT run near CPT number seven. A triangle represents a pressuremeter test location that was originally planned but omitted during the investigation. This configuration ensured that accurate profiles were estimated, which was especially important when attempting to reduce differential settlement between the bridge and approach embankment.

In-Situ Test Comparisons and Conclusions

Dr. Jim Nevels, Jr., ODOT geotechnical engineer, prepared the foundation report for the US 177 project site. The following information is taken from his report (5).

Comparisons

With the SPT, CPT, and DMT performed in such close proximity at this particular project site, profile comparison can confirm the relative accuracy of these procedures. CPT-5 (from Figure 1) test results and DMT data from near CPT-5 were chosen from each of the trial embankments for comparison. For bridges A and B, boring logs (including SPT N values and lab test results) were chosen from stations within 1 ft

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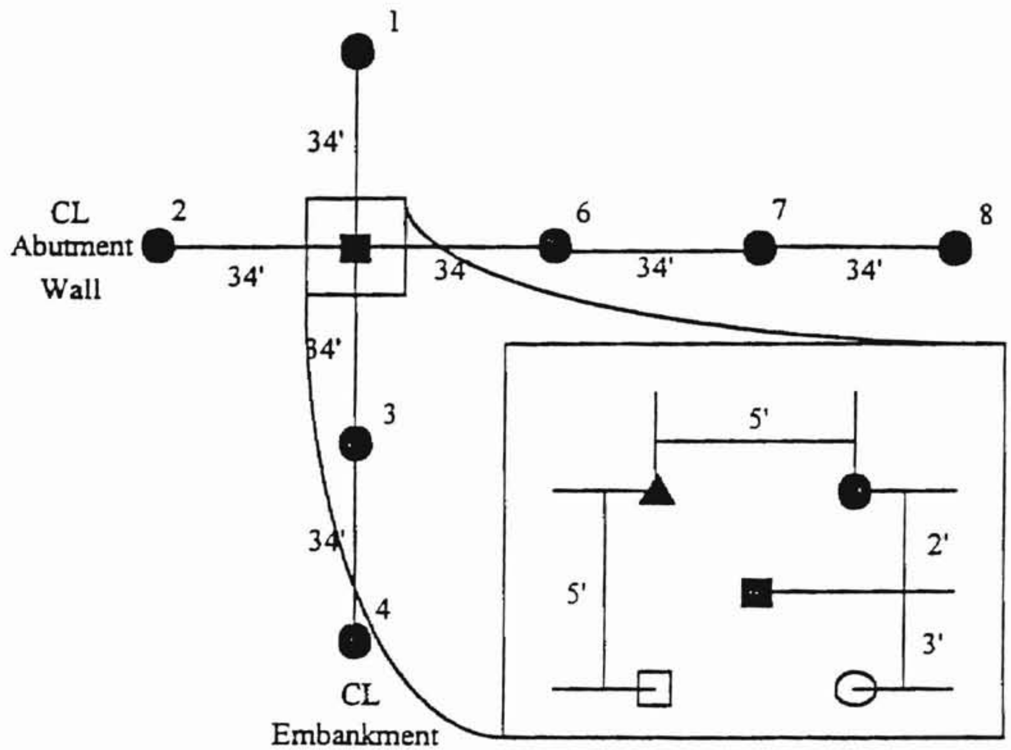

■ SPT Test
● CPT Test
▲ Pressuremeter Test
□ Dilatometer Test
○ Continuous Pushtube Boring

Figure 1. In-Situ Test Configuration for Salt River Site (1)

(0.3 m) of the north abutment wall station. Bridge C investigation sites did not correlate as closely to the abutment locations, but tests from stations nearest the abutment walls were chosen.

Soil types within a profile are determined differently for each in-situ test. The SPT boring log gives soil descriptions straight from visual inspection that are substantiated with laboratory data. With the DMT, a series of steps is required to be able to estimate soil type. After following procedures to get the material index and dilatometer modulus, soil descriptions and unit weights can be estimated. The DMT device used by the Oklahoma Department of Transportation (ODOT) has software that automatically calculates values and gives a soil description, as seen on the DMT data sheets in Appendix A.

Profile estimation from the CPT is not automated. First, major differences in soil strata were determined by visually assessing pattern changes in the friction ratio (sleeve friction / tip resistance) versus depth plot. Once these basic strata were established, average friction ratio values and tip resistance values for each strata were graphically determined. Third, plots of friction ratio versus tip resistance were used to estimate a soil description. For this particular exercise, plots from Robertson and Campanella (6) were used.

Comparison of abutments A2, B1, B2, C1, and C2 are shown in Tables 1, 2, 3, 4, and 5, respectively. Since the SPT boring involves direct observation and testing, it is considered the control for a comparison basis. Detail improved when going from the CPT to the DMT. This comparison helps verify the legitimacy and relative accuracy of the

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Table 1 In-Situ Test Profile Comparison at A2

SPT

Depth (ft)	Description
0	
	Lean Clay with Sand
2	
	Silt with Sand
4.5	Clay and Silt with Sand
5.3	Silty Clay with Sand
5.7	Silt
6	Clay with Sand
7	
	Low Plastic Silt/Clay with Sand
9.9	
	Silty Sand and Poorly Graded Sand
16.5	Sandy Lean Clay
16.8	Silty Sand
18	
	Poorly-Graded Sand with Silt
22.9	Silty and Clayey Sand
24.4	
	Poorly-Graded Sand with Silt
25.5	
	Silty Sand
28.5	Lean Clay with Sand
28.8	Poorly-Graded Sand with Silt
29.1	Lean Clay
31.2	Poorly-Graded Sand with Silt
31.5	Shale Bedrock

DMT

Depth (ft)	Description
0	
	Sand
1.6	Silty Sand
3.3	
	Sandy Silt
4.9	
	Silty Sand
23	
	Sand
24.6	Silt
26.2	
	Silty Sand
34.4	
	Clayey Silt
36	Silt
37	End of Sounding

CPT

Depth (ft)	Description
0	
	Silty Sand
10	
	Sand
28	End of Sounding

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Table 2. In-Situ Test Profile Comparison at B1

SPT

Depth (ft)	Description
0	
	Low Plasticity Silt and Sandy Silt
9 6	Silty Sand
11	
	Poorly-Graded Sand with Silt and Silty Sand
23	Low Plasticiy Clay with Sand
24	Clayey Sand
24 5	Poorly-Graded Sand
25 5	High Plasticity Clay with Sand
26 2	Clayey Sand
27	Low Plasticiy Clay with Sand
27.5	
	Poorly-Graded Sand
30.5	
	Poorly-Graded Sand withSilt and Poorly-Graded Sand
36.6	Silty Sand
37	Shale

DMT

Depth (ft)	Description
0	
	Silty Sand
3 3	
	Low Plasticity Silt with Sand
4.9	
	Silty Sand
21 3	
	Sand
23	
	Silt with Clay
24 6	
	Silty Sand
30 9	
	Low Plasticity Silt with Sand
29 53	
	Silty Sand
34 5	Sand
36 1	
	Clay with Silt
37 7	Silty Sand
39 4	
	Silt
41	End of Sounding

CPT

Depth (ft)	Description
0	
	Silty Sand
6	
	Sand
22	
	Silty Sand
29	
	Sand
36	Shale

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Table 3 In-Situ Test Profile Comparison at B2

SPT

Depth (ft)	Description
0	
	Silty Sand and Sandy Silt
6	
	Silt
8.5	
	Silty Sand and Sandy Silt
13.9	
	Poorly-Graded Sand with Silt
17	Poorly-Graded Sand
18	Low Plasticity Clay with Sand
19.5	Poorly-Graded Sand with Silt
19.9	Silty Sand
21	
	Sandy Clay
23.4	High Plasticity Clay
24	Sandy Clay
24.2	Clayey Sand
25.2	Silty Sand
25.5	Clayey Sand
27	
	Poorly-Graded Sand and Poorly-Graded Sand with Silt
31.5	Silty Sand
32	Poorly-Graded Sand
32.5	Shale Bedrock

DMT

Depth (ft)	Description
0	
	Silty Sand
3.3	
	Sand
4.9	
	Silty Sand
8.2	
	Sand
9.8	
	Silty Sand
16.4	
	Sand
18	
	Silty Clay
19.6	
	Silty Sand
24.6	
	Sand
27.9	
	Sandy Silt
29.5	Silty Sand
31.2	
	Silty Clay
32.8	Sand
34.4	
	Silty Sand
36.1	End of Sounding

CPT

Depth (ft)	Description
0	
	Sand
18.2	
	Silty Sand
28.2	
	Sand
33	End of Sounding

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Table 4. In-Situ Test Profile Comparison at C1

SPT

Depth (ft)	Description
0	
	Low Plasticity Clay
2	
	Low Plasticity Silt and Low Plasticity Silt with Sand
10	Silty Sand
11	Poorly-Graded Sand with Silt
12.5	Silty Sand
12.9	Poorly-Graded Sand with Silt
15.5	Silty Sand
15.9	High Plasticity Clay
16.3	Poorly-Graded Sand with Silt
17.5	Poorly-Graded Sand
19.3	Poorly-Graded Sand with Silt
20	
	Silty Sand
24.9	Poorly-Graded Sand with Silt
25.2	Clayey Sand
25.7	Poorly-Graded Sand
27.7	Clayey Sand
28.2	Poorly-Graded Sand with Silt
30.5	
	Poorly-Graded Sand with Silt and Clay Lenses
35.5	
	Poorly-Graded Sand
42.4	Shale

DMT

Depth (ft)	Description
0	
	Silty Sand
6.6	Sand
9.8	
	Silty Sand
14.8	Silt withClay
16.4	
	Sand
18	
	Silty Sand
19.7	
	Sand
23	
	Sand and Silty Sand
50.9	Silt with Clay
52.5	Low Plasticity Silt with Sand
54.1	End of Sounding

CPT

Depth (ft)	Description
0	
	Silty Sand
9	
	Sand
39	End of Sounding

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Table 5 In-Situ Test Profile Comparison at C2

SPT

Depth (ft)	Description
0	
	Low Plasticity Silt and Low Plasticity Clay
6.5	
	Silty Sand
7	
	Low Plasticity Clay
7.5	
	Low Plasticity Silt and Clay
11.4	
	Silty Sand and Silt
12.5	
	Poorly-Graded Sand
13	
	Silty Sand
14.5	
	Low Plasticity Silt
15.5	
	Poorly-Graded Sand with Silt and Silty Sand
20.3	
	Well-Graded Sand
23	
	Poorly-Graded Sand with Silt
24.9	
	High Plasticity Clay with Sand
26.8	
	Poorly-Graded Sand with Silt and Poorly-Graded Sand
34	
	Poorly and Well-Graded Sand
36	
	Poorly-Graded Sand with Silt and Poorly-Graded Sand
40.6	
	Shale

DMT

Depth (ft)	Description
0	
	Low Plasticity Silt with Sand
1.6	Low Plasticity Silt and Clay
3.3	
	Low Plasticity Silt with Sand
4.9	
	Low Plasticity Silt with Clay
6.6	Clay with Silt
8.2	
	Silty Sand
9.8	
	Low Plasticity Silt with Sand
11.5	
	Silty Sand
21.3	
	Sand
23	
	Silty Sand
26.2	
	Sand
31.2	
	Silty Sand
34.4	
	Sand
41	Silty Sand and Silt
51.5	End of Sounding

CPT

Depth (ft)	Description
0	
	Silty Sand
9	
	Sand
24.5	
	Silty Sand
29	
	Sand
41	End of Sounding

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CPT and DMT in situ tools if the right correlations are made. However, variations in the descriptions demonstrate the variability inherent in empirical methods. Complete details of the CPT, DMT, and SPT soil data are provided in Appendix A.

Ten-year settlement was calculated for all the abutments except for the south abutment of bridge A. Two sets of calculations were made, one based on CPT data and the other based on DMT data. For CPT based settlement calculations, the Schmertmann method (7) for ten-year settlement was calculated by converting electric cone resistance (q_c) to an equivalent elastic modulus. The DMT settlement was calculated by applying the appropriate modulus from the dilatometer with elastic theory (5). The calculations were similar at the north abutment of bridge A with both methods effectively predicting 0.8 in (2.0 cm). North abutment of bridge C gave the most variation with the CPT method predicting 0.7 in (1.8 cm) and DMT predicting 1.9 in (4.8 cm). Complete settlement estimates, as published in the foundation report, can be seen in Table 6.

Soils

Generally, the soils are Quartenary Period Alluvium deposits from the Salt Fork of the Arkansas River. This material varies from gravel and sand to silt and clay.

Bridge A. Soils at bridge A are predominantly clays and silts. Plasticity indexes (PI) from the 20s to the 30s are common. One 2.5 ft (0.8 m) thick layer of highly plastic (or "fat" in the Geo Log documentation) clays with PI values ranging from 37 to 46 and SPT N values of zero were located just south of the south abutment wall. Clay

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Table 6. Settlement Estimates from US 177 Geotechnical Investigation (5)

Bridge Abutment		Settlement (in)
A2		
	CPT-2	0.958
	CPT-5	1.135
	CPT-6	0.794
	DMT-1	0.840
B1		
	CPT-2	0.289
	CPT-5	0.340
	CPT-6	0.359
	DMT-1	0.732
B2		
	CPT-2	1.306
	CPT-5	0.728
	CPT-6	0.849
	DMT-1	1.024
C1		
	CPT-2	0.860
	CPT-5	0.837
	CPT-6	0.757
	DMT-1	1.365
C2		
	CPT-2	1.053
	CPT-5	0.937
	CPT-6	0.737
	DMT-1	1.859

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areas were abundant on the south end of the project. The Noble County Soils Report by the Soil Conservation Service (SCS) (4) reported consistent trends of more clayey soils in the southern portion of the project. Moving north, the soils became less plastic and more silty, consistent with the SCS maps. At the northern end of bridge A, PI values decreased to the teens and low 20s. SPT N values generally ranged from four to seven in these silty and silty sand regions.

Bridge B. Soil types at bridge B were coarser than those at bridge A. Most soils were silt and sand combinations with significant strata of sand. Silts and sandy silts had SPT N values ranging from five to seven. Most of these soils were non-plastic, but a few had PI values as high as 15. Soils with more sand and silty sands had higher SPT N values of 20. Locations with poorly graded sands had SPT N values of 11-20, both of which were classified as loose to medium dense, based on SPT correlations (8).

Bridge C. Bridge C soils were combinations of silt, poorly -graded sand, and clay. The material descriptions commonly changed in 6 in. (15.2 cm) intervals. Overall, the SPT N values were low and plasticity was either non-existent or low. All but one clay was classified as lean. This only "fat" clay was at the north end of bridge C. This 9 ft (2.7 m) thick layer at station 194+98, right of centerline, was not lab tested and is only documented with material description. Typical silts had SPT N values between 3 and 11 and were non-plastic. Sands appeared to be loose with SPT N values of 1 to 7. Combinations of silt and sand were common that had low SPT N values and low to zero PI values.

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Bedrock

The bedrock at the US 177 project site was shale with isolated lenses of limestone. Permian Aged shale of the Wellington Formation made up the top 10 to 15 ft (3.0 to 4.6 m) of the bedrock and was described as reddish-gray in color, soft and weathered. Depth to shale varied among the bridges with the foundation report showing depth to bedrock at bridges A, B, and C is 25, 36, and 40 ft (7.6, 11.0, 12.2 m), respectively. This upper portion had lower Rock Quality Designation (RQD) values than the underlying material. RQD's for the Wellington formation varied from 48.6 to 62 and then 83 at bridges A, B, and C, respectively. Unconfined compressive strengths (UCS) for this top formation ranged from 540 tsf (540 kg/cm^2) at bridge A to values below 10 tsf (10 kg/cm^2) at bridge C.

Beneath the Wellington Formation lies the Oscar Group, also known as the Wellington-Admire Unit. This structure was characterized as mainly shale with layers of limestone and fine-grained Arkosic sandstone. Borings showed the shale as dark gray to grayish red shale that was silty to clayey. RQD values were in the 90s for bridge A and bridge B, but in the upper 50s for bridge C. UCS values were much higher in the Oscar Group with values up to 1063 tsf (1063 kg/cm^2) at bridge A , but mostly averaging 530 tsf (530 kg/cm^2), and 22.8 tsf (22.8 kg/cm^2) and lower at bridge C. No UCS data for any bridge B borings were reported. Bridges A and B showed limestone generally 50 ft (15.2 m) below the surface with limestone interbedded in the shale at about 45 ft (13.7 m). The limestone bed was about 10 ft (3.0 m) thick and varied between bridge A and bridge B.

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Geologic mapping (6) showed the Herrington limestone unit at the project site, so the foundation report suggested the possibility of this limestone from the Herrington Formation. Bridge C borings showed no limestone present.

Crews drilled 93 ft (28.3 m) near the north end of bridge A to determine if any other limestone units existed. One 0.15 ft (4.6 cm) thick layer was encountered at 82.3 ft (25.1 m) below the ground surface. Shale was the only other bedrock material encountered.

Water levels in the borings were at depths of 2 to12 ft (0.6 to 3.7 m). Isolated gravel pits may exist within the valley that may bear significant water. Nearby wells yield 20 to 150 gallons (75.7 to 567.8 L) per hour from the alluvium. Visual investigation of the bedrock cores suggested that no significant water bearing zones existed in the bedrock formations.

Conclusions

This investigation report concluded that drilled shafts should be used for the bridge foundations and driven piles be used for the abutment foundations. The slurry displacement method was recommended for the drilled shafts due to the loose granular material and its depth below the water table. These recommendations were followed with the installation of drilled shaft bridge piers and driven piles for the abutments.

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CHAPTER 3

INSTRUMENTATION INSTALLATION AND BACKFILL CONSTRUCTION

This chapter discusses the construction and instrumentation installation at each experimental approach embankment. The objective of the experimental backfills was to reduce or eliminate the "bump at the end of the bridge" by decreasing the vertical settlement of each backfill and lateral stress exerted on abutment and wing walls. This was done by constructing backfills that were well-drained and self-supportive to act as an incompressible single mass. For quantitative monitoring, instrumentation was necessary. Instrumentation for each of the abutment walls and backfills was chosen to monitor lateral movement of the abutment wall and the backfill, lateral stresses exerted upon the abutment wall, settlement, and pore water pressure.

Instrumentation

Each abutment was instrumented with: total pressure cells, amplified liquid settlement gages, piezometer, inclinometer casings with telescoping couplings, and surface settlement points.

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Total Pressure Cells

Lateral stresses exerted onto the abutment wall were measured using total pressure cells embedded at the centerline of the abutment wall adjacent to the fill. Three cells were spaced 3 ft (0.91 m) apart vertically. The cells used were 9 in. (22.9 cm) in diameter, stainless steel covered rubber membranes (Figure 2) that measure total lateral earth pressure. A transducer converted the lateral pressure to a pneumatic pressure that was measured by the Pressure Indicator in psi (pounds per square in.) units. For reading, the Pressure Indicator applied air pressure through the input tube so that eventually, the built-up pressure was greater than the pressure exerted by the backfill. An equilibrium state for the membrane was achieved by reducing the applied pressure and that pressure was measured and recorded.

The pressure cells were installed on the face of the abutment wall so that they were flush with the wall surface. When the forms for the abutment wall were constructed, blockouts for the pressure cells and the tubing that leads up to them from the control box were included, as can be seen in Figure 3. For installation, the cells and tubing were connected and grouted in place. The pressure cells were cleaned and backfilling was begun.

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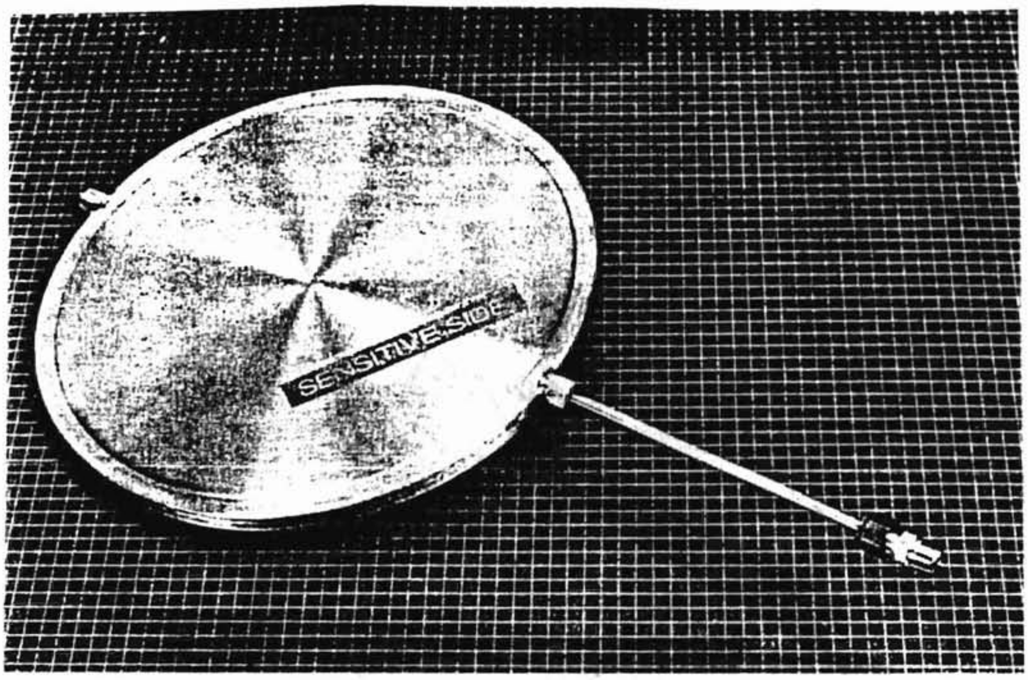

Figure 2. Total Pressure Cell (9)

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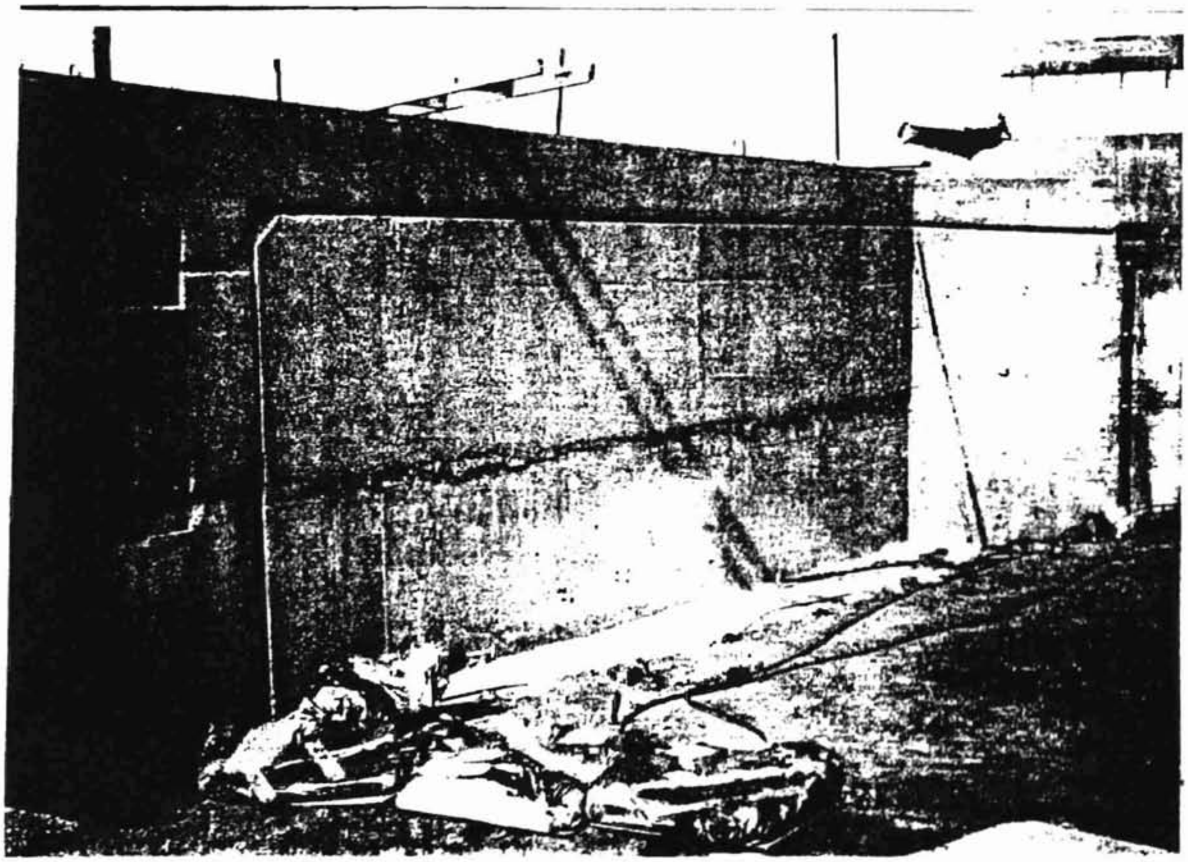

Figure 3. Blockouts for Total Pressure Cells and Tubing

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Amplified Liquid Settlement Gages

Settlement was measured using the amplified liquid settlement gages. One gage was placed on the centerline and one 10 ft west of centerline, both 2 ft (0.61 m) below the base of the abutment wall and 6 ft (1.8 m) behind the abutment wall. The gages were fixed on 18 in. by 18 in. (45.7 cm by 45.7 cm) metal plates. When settlement occurred, the buried gage moved and the head relative to a reference reservoir located on the west wingwall was measured.

The settlement gage is composed of three main parts- the transducer, the reservoir, and the tubing. The transducer is a sensing unit designed to provide continuous reading and be installed at the point of settlement measurement. The reservoir is at a fixed location on the wingwall at a higher elevation than the transducer. The tubing supplies fluid and air needed to read the transducer using the Pressure Indicator. Settlement is measured when a balance of the hydraulic head of the ethylene-glycol and regulated pneumatic pressure from the pressure indicator is achieved. Readings are in units of psi head that can be converted to a linear vertical distance.

The settlement gages were placed in 2 ft by 2 ft (0.61 m by 0.61m) holes (Figure 4) and covered with sand. Excess tubing was laid in the hole to provide extra length during settlement. Inside the backfill area, the tubing was placed in a plastic conduit that ran from the centerline settlement gage to the offset gage, to the west wingwall, and then up to the junction box.

On the outside of the west wingwall, locking steel security boxes cover a terminal

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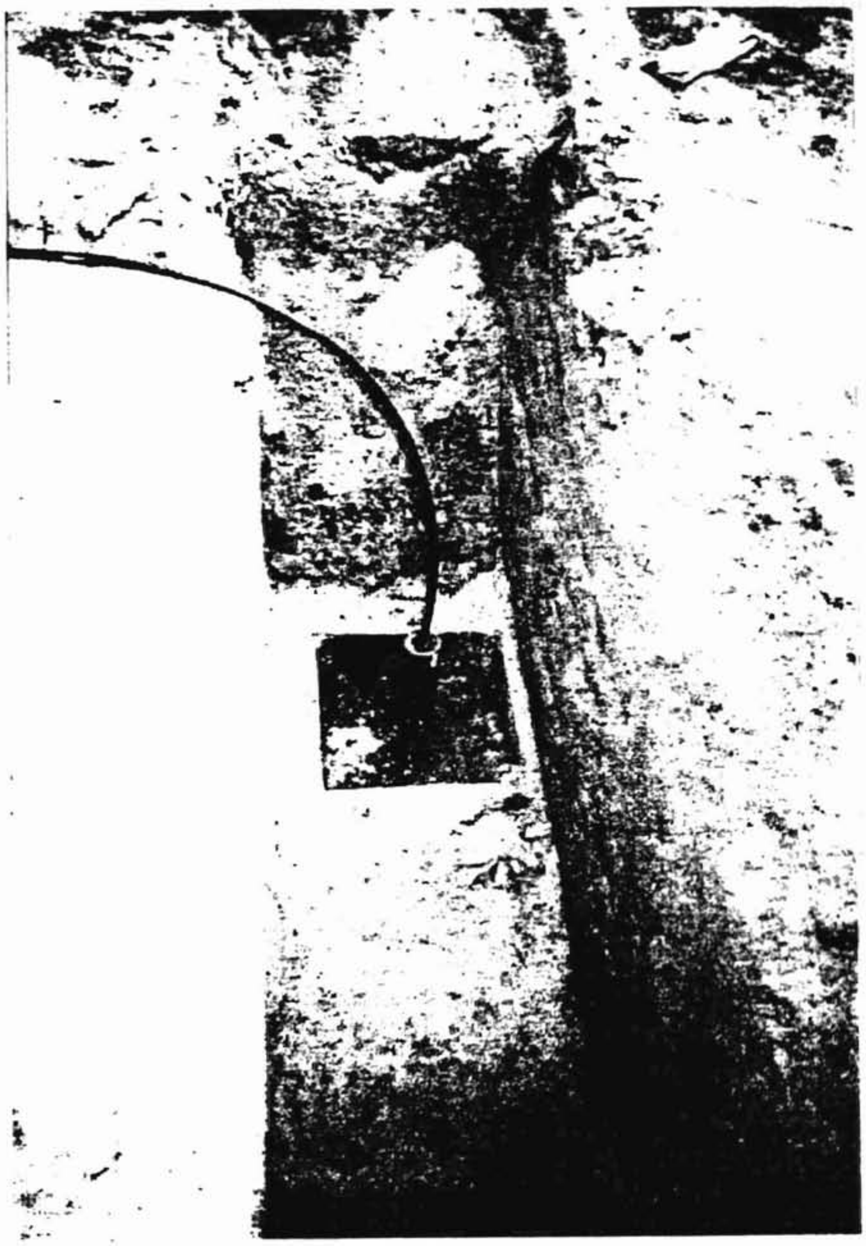

Figure 4. Amplified Liquid Settlement Gage (ALSG)

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box and tubing from the settlement gages and pressure cells. The terminal box houses labeled connections to the instrument tubing for access with the Pressure Indicator. This terminal box was placed directly above a plastic conduit that leads to the inside of the wingwall to the junction box. From there, the tubing for the amplified liquid settlement gages and total pressure cells splits to reach its respective instrument.

The Pressure Indicator is a portable device the size of a small suitcase used to measure settlement from the amplified liquid settlement gages and total lateral earth pressure from the total pressure cells. It contains a supply of nitrogen used as the controlled air pressure source for the input connections of the settlement gages and pressure cells. All readings are taken when the flow meter in the Pressure Indicator reads 0.1 SCFH (standard cubic ft per hour). A flow meter is also used for hookup to the outlet side of the instrument being read to confirm a continuous flow of air from the Pressure Indicator to the measuring device and back to the Pressure Indicator. This ensures proper air flow for accurate readings. A digital liquid crystal display pressure gage measures applied pressure which is then recorded onto data sheets. Figure 5 is a photograph of the Pressure Indicator.

Piezometers

While settlement gages and pressure cells were installed before backfill placement, instrumentation for the water pressure, lateral movement, and additional settlement were installed after each backfill was completed. One open-tube piezometer

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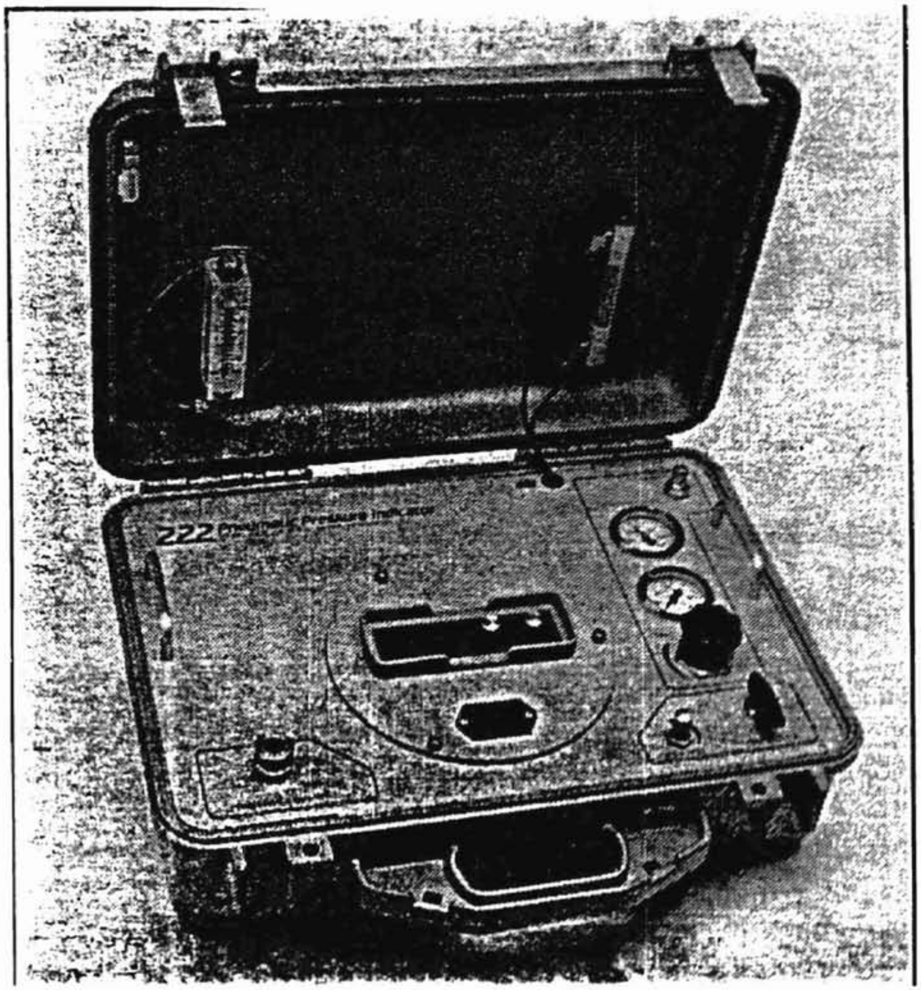

Figure 5. Pressure Indicator (9)

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was installed on the centerline in each experimental backfill 12 ft (3.7 m) from the abutment wall to depths of 40 ft (12.2 m). PVC pipe with 1.5 in. (3.8 cm) diameter was used for the riser. Groundwater depth was measured by placing a water level indicatordown the tube attached to a calibrated cord. When the tip of the indicator reached water, a simple electrical circuit was formed that triggered an alarm to sound. Using the alarm, the depth of the ground water was measured by the calibrated cord and recorded.

Inclinometer Casing with Telescoping Couplings

To measure lateral movement, three inclinometer casings were installed at the end of each bridge. One, in the abutment wall itself on centerline, was installed before the wall was poured. The other two inclinometers were installed on the centerline and 10 ft (3.05 m) west of centerline 9 ft (2.7 m) from the back of the abutment wall in the backfill after construction. Figure 6 shows the installed inclinometers and piezometer. The blue inclinometer casings are 2.75 in. (7.0 cm) diameter tubes that extend to depths ranging from 50 ft to 58 ft (15.2 m to 17.7 m) as noted in Appendix B.

Both lateral movement and settlement data were obtained from these inclinometer installations. For lateral movement, the casing is designed for an inclinometer probe with four grooves spaced 90° apart on the inside of the casing. The inclinometer probe is a stainless steel cylinder 1 in. (2.54 cm) in diameter and 2 ft (0.61 m) in length housing two accelerometers. The accelerometers were positioned at right angles of one another

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Figure 6. Installed Inclinometer Casings and Open Tube Piezometer

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and measured tilt in degrees with reference to the vertical. To take a reading, a pulley assembly was attached to the top of the inclinometer casing to facilitate the lowering and raising of the inclinometer attached to a control cable. Figure 7 shows the inclinometer with the control cable and pulley assembly. Spring loaded wheels on the outside of the inclinometer guided the device as it was pulled by hand upward through the tubing and stopped every 2 ft (0.61 m) for a reading. The probe was next rotated 180° to measure movement in the other two directions so that movement in two perpendicular planes was measured, one perpendicular to the abutment wall (plane A) and one parallel to the abutment wall (plane B). When readings were taken, data were recorded by a DataMate, an electronic memory device attached to the inclinometer.

The data were analyzed using the DataMate Manager and Digi-Pro software on a personal computer. For analysis, movement within the two planes was detected by comparison of any data set with the initial readings taken at the time of installation. Ao and Bo are designations for the positive direction for planes A and B, respectively. The Ao direction always is toward the plane formed by the back side of the abutment wall while Bo is always 90° to the right of Ao. Figure 8 shows the orientation. So when standing over the backfill inclinometer casing, Ao direction is facing the abutment wall. When standing over the abutment wall inclinometer casing, Ao is toward the backfill. The backfill Ao direction for abutments A2, B2, and C2 is south, while the backfill Ao direction for B1 and C1 is north. Referenced from the bridge or abutment wall, the Ao direction at A2, B2, and C2 is north, while the Ao direction for B1 and C1 is south.

Settlement was the other parameter measured with the inclinometer casings set in

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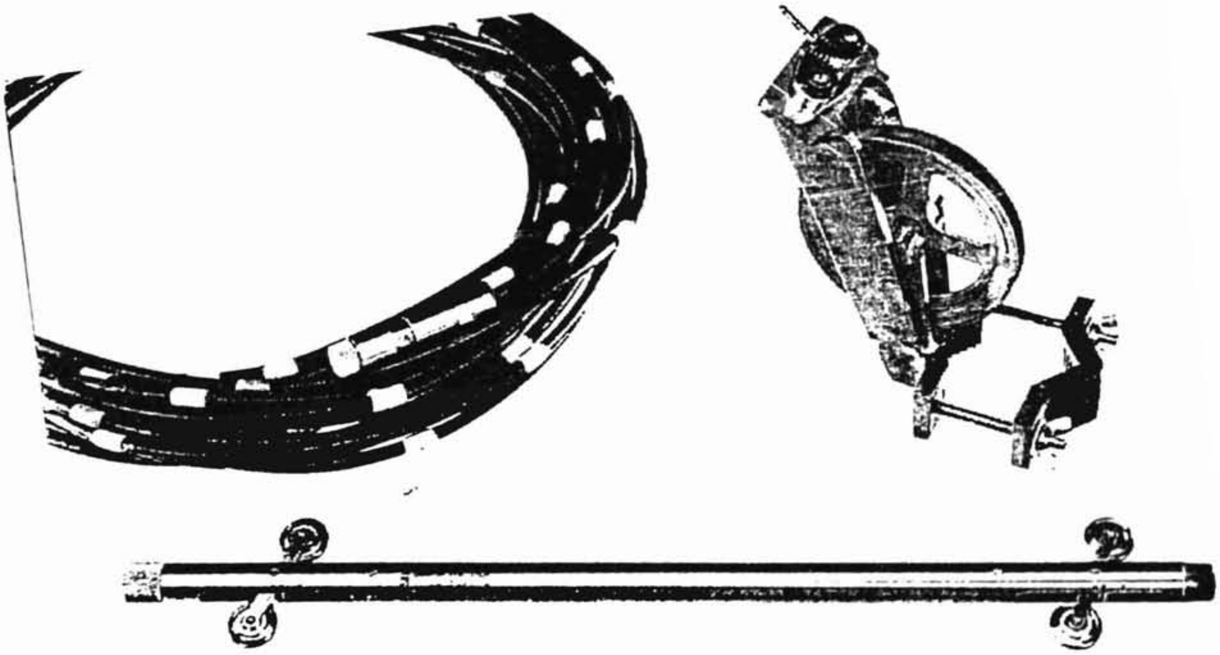

Figure 7. Inclinometer, Pulley Assembly, and Control Cable (9)

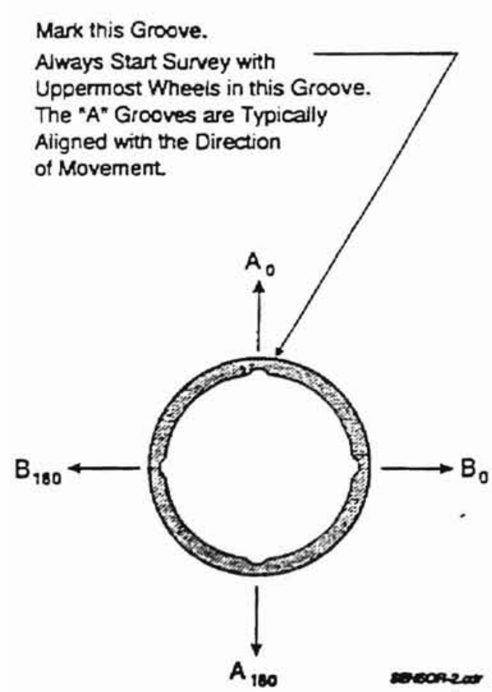

Figure 8. Ao and Bo Orientation (9)

the backfill (the casing in the abutment wall was read for lateral measurement only). As can be seen in Appendix B, telescoping joints were installed at different depths along the backfill inclinometer casings. A specially designed hook was lowered down the casing and pulled upward. As it was pulled up, it caught the bottom lip of the top piece of casing in the telescoping coupling. The hook was attached to a measuring tape that allows depth readings with reference from the top of the casing. As distances from one joint to the other changed, isolated strata of settlement were delineated.

Surface Settlement Points

Settlement is measured yet another way with the surface settlement points. These points will be installed on the surface of the asphalt once paving is completed. Elevations at the time of installation will be recorded and then compared to subsequent elevations measured when readings for all the instruments are taken. The configuration of the surface settlement points will be a 4 point by 4 point grid with 5 ft (1.5 m) spacing. The configuration will run from the west wingwall to the centerline, and from the abutment wall 20 ft (6.1 m) away from the bridge.

Appendix B contains plan and profile drawings of as-built instrumentation of each backfill. Table 7 is a summary of the approach embankments and instrumentation.

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Table 7. Backfill and Instrumentation Summary

South of Bridge A, A1- unclassified borrow (not considered in this study)

North of Bridge A, A2 - unclassified borrow (control section)

South of Bridge B, B1 - geotextile reinforced granular backfill

North of Bridge B, B2 - controlled low strength backfill

South of Bridge C, C1 - dynamically compacted granular backfill

North of Bridge C, C2 - flooded and vibrated granular backfill

		A1	**A2**	**B1**	**B2**	**C1**	**C2**
Total Pressure Cells in Centerline Abutment Walls		3	3	3	3	3	3
Amplified Liquid Settlement Gages beneath approach embankment	Centerline	1	1	1	1	1	1
	Offset	0	1	1	1	1	1
Inclinometer casing in abutment wall		1	1	1	1	1	1
Inclinometer casing with telescoping couplings thru approach embankment	Centerline	1	1	1	1	1	1
	Offset	0	1	1	1	1	1
Open Tube Piezometer thru embankment centerline		1	1	1	1	1	1
Surface Settlement Points		16	16	16	16	16	16

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Backfills

The primary aim of this research project was to monitor the performance of the four experimental backfills and compare their performance to one another and an identically instrumented control section. The following is a discussion of the Spring 1995 construction of the five backfills involved in this research.

Drainage

Drainage construction for each of the backfills followed standard ODOT specifications. Consistent drainage system construction should eliminate drainage as a factor in the cause of "the bump at the end of the bridge" and maintain the validity of the data. A perforated PVC pipe was buried along the inside base of the abutment wall and covered with granular material. A solid PVC pipe connected the east end of each perforated drain pipe and ran through the base of the east wingwall and down the embankment where it drained beneath the bridge. For A2 and B2, the pipe was covered with coarse pipe underdrain material which was covered with filter sand. Since the other trial sections used granular material, the PVC pipe cover was all coarse pipe underdrain material, with no filter sand material.

North of Bridge A, A2

The backfill north of bridge A was used as a control section for this research. The

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method of construction was not specified to represent a typically constructed backfill. The contractor was to use unclassified borrow and achieve the specified densities.

On Thursday, April 27, backfilling began. The initial method of compaction the contractor used was inadequate. At first, a cube of concrete with side dimensions of approximately 4 ft (1.2 m) was dropped from heights of 5 ft (1.5 m) as a sort of dynamic compaction. Density requirements were not met. The next day, compaction was successful using a Case 1150C tracked front end loader with a full scoop and simply driving over the 1 ft (0.3 m) lifts as shown in Figure 9. The loader passed over the backfill twice, once in a direction parallel to the abutment wall and once parallel to the centerline. The area approximately 2 ft (0.6 m) away from the walls was compacted using a walk behind pad vibrator. The following Monday was a rain day and work resumed on Tuesday, May 2. Because of a series of rain days, the backfill compaction was finally completed on Wednesday, May 10, with a construction time of 4 days and a cost of $1500.

South of Bridge B, B1

Behind the south abutment of Bridge B a geotextile reinforced wall was constructed. This technique was chosen because of its ability to support its own weight. Tension on the folded portion was resisted by the pressure of the overlying lift, creating essentially a free standing structure supported by its own weight. Theoretically this would keep all lateral stress from the abutment walls and both wingwalls. Settlement

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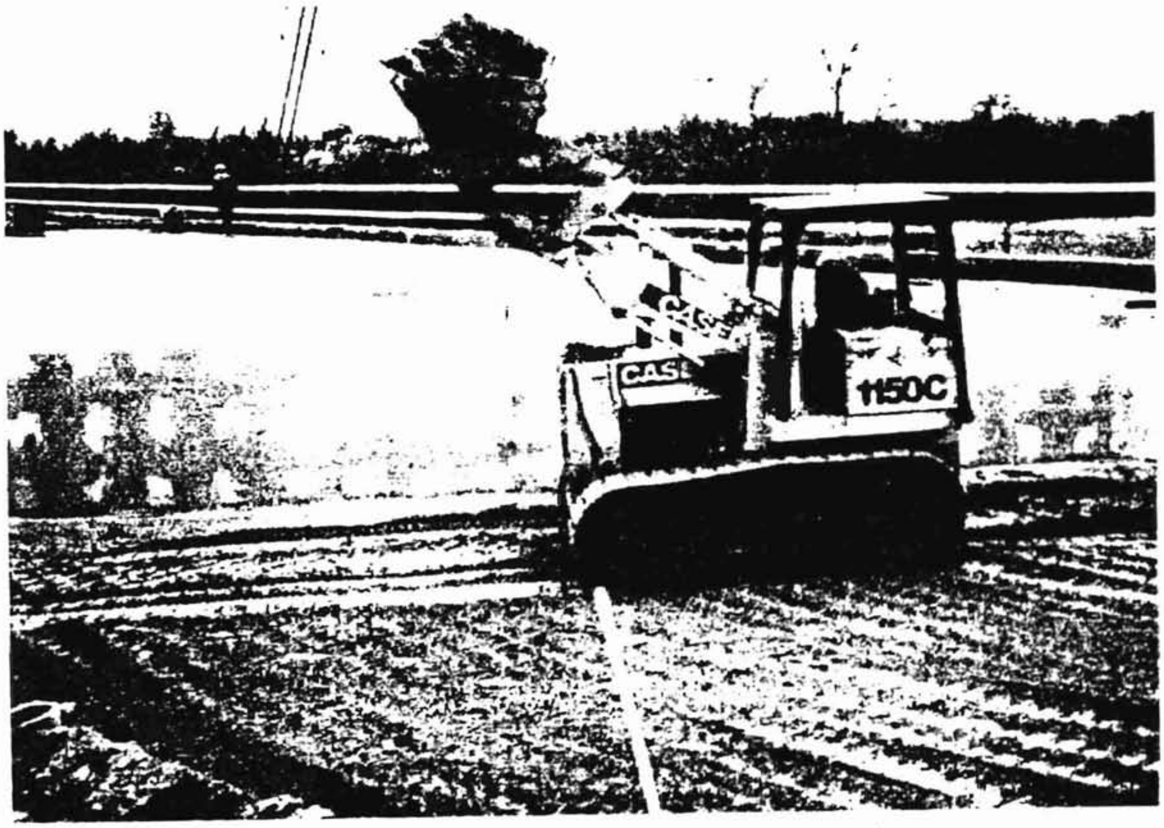

Figure 9. Compaction of Control Section, A1

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was minimized by densification of each lift assuring a well-compacted backfill.

Preliminary steps were required before the non-woven geotextile could be laid. First, the excavation had to be level and the 5:1 incline towards the south had to be defined. A base lift of granular material was placed to be a level and densified base for the geotextile wall. Then, as shown in Figure 10, 4 ft X 8 ft X 2 in. (1.2 m X 2.4 m X 5.1 cm) panels of collapsible honeycomb cardboard were wrapped with plastic to be longitudinally attached to the abutment and wing walls. Steel rods used for the reinforcement of concrete ("rebars") were stuck into the ground at the base of the panels used to keep them against the wall. These bars were removed as the backfill was placed. At first, only the bottom row of spacers was set with the second row to be set as construction of the geotextile wall progressed upward. The panels were left in place and will be collapsed prior to paving by wetting the cardboard. When collapsed, space between the walls and the face of the geotextile structure will allow tension to further develop and improve the free-standing characteristics of the structure. Once the excavation was detailed, the base layer placed, and the first row of wrapped honeycomb cardboard spacers were set, construction could begin.

Construction of the south of bridge B geotextile reinforced granular backfill began on Monday, May 22, and consisted basically of repeating five steps for each of the eight lifts: lay the textile, place and spread the sand, water, compact, and fold over the flaps. Figure 11 shows the placement. Laying the geotextile was similar to laying carpet. Rolls of textile 12 ft (3.7 m) wide were rolled in the direction perpendicular to the face of the wall (north to south). Excess fabric (approximately 6 ft (1.8 m)) was temporarily

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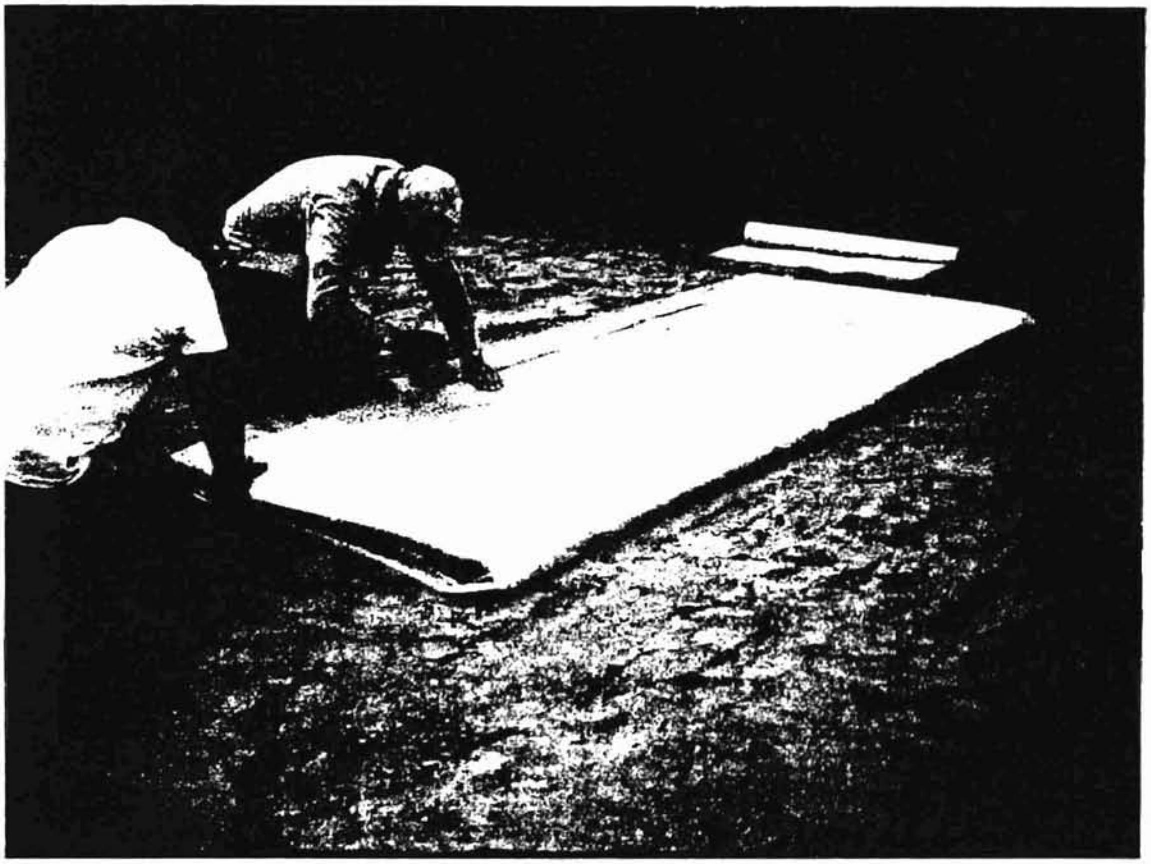

Figure 10. Wrapping of Cardboard Spacing for Geotextile Reinforced Backfill, B1

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Figure 11. Layout of Geotextile at B1

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attached to the abutment and wing walls to later be folded back onto the granular material. This proved to be somewhat of a challenge. At first, duct tape was used but would be inadequate by not sticking to the cool, damp concrete abutment wall for more than 15 minutes. By the fifth lift, wires were used along with the tape by sticking through the fabric and attaching to rebar or other available anchors. The width of the backfill along with the excess required for construction of the wall required that a total of four strips of textile had to be placed. Overlap seams were chosen instead of sewn ones. These 3 ft to 6 ft (0.91 m to 1.8 m) overlaps helped to create a strong seam through friction. Since the backfill area was about 40 ft wide (39 ft 8 in. or 12.1 m), the fourth strip overlapped much more than the 2 ft (0.61 m) minimum. Shovelfuls of granular backfill were placed near the edge of the fabric to help keep the honeycomb cardboard and the fabric from blowing in the wind.

Next, the sand was placed using a tracked front end loader and a bulldozer occasionally. The front end loader dumped sand from the south to the north to avoid direct contact to the geotextile by the machinery. While the loader was operating, five men with concrete spreaders and shovels spread the material. Once all the material was placed, a total of six men distributed the material to create a 12 in. (30.5 cm) thick lift.

Compaction with a walk behind vibrator followed. The weather had been rainy during the week and the sand was already somewhat moist, but to reach saturation extra moisture was applied using a water truck. A five horsepower walk behind pad vibrator achieved adequate densities with one, or sometimes two, passes. Density readings were taken with a Troxler nuclear density/moisture gage. After density was achieved, a small

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mound descending away from the wall was pushed up using concrete spreaders around the perimeter of the three walls. The flaps were then brought down from hanging on the walls and laid on top of this grade as seen in Figure 12.

This process continued until eight lifts were completed on Thursday, June 1. With an average of four men for spreading and the equipment mentioned, completion took 104 man-hours. The time for each lift gradually increased since the area of the lift increased with the slope of the backfill volume. The estimated cost was approximately $25,000 for installation over a 5 day period.

North of Bridge B, B2

Controlled low strength material (CLSM) backfill was placed behind the north abutment wall of bridge C. This backfill supports itself since the fill acts like a single unit upon curing. Self -support theoretically eliminates lateral wall stress and the relatively high strength of 300 psi (21.6 kg/cm^2) for base materials will help reduce settlement.

Construction of the CLSM approach embankment was simple and fast. First, the excavation was cleaned out and the faces of the two exposed pressure cells covered with plastic for protection (the lowest pressure cell was covered with the granular drainage material as was the case with all four test sections). Then forms were built on the north side of the fill area. The contractor built the forms so that the outside corners of the fill

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Figure 12. Folding Over the Geotextile to Form the Face of the Wall at B1

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were deeper than the rest at the edge for strengthening. Excavation and form work construction took 8 man-hours total.

Pouring the backfill involved ready-mix concrete trucks backing up to the forms and releasing the backfill material down the chute directly into the excavated volume. Two trucks were able to simultaneously unload. Twenty-three loads of nine cubic yards each were dumped for a total of 207 cubic yards (158.3 m^3) in 4.5 hours on Friday, May 12. Figure 13 shows the filling taking place. Besides pouring, the only labor involved was using a vibrator near the abutment wall and magnesium concrete leveler attached to extension rods. Total time for this construction was 2 days at a cost of $14,560.

South of Bridge C, C1

Dynamically compacted granular backfill was placed at the south abutment of bridge C. Dense and confined sand will have high shear strength and will approach behavior of single, solid mass. With effective densification, both settlement and lateral earth pressures were minimized.

The construction began on Friday, May 12, and finished on Thursday, May 18. Lifts of granular backfill 2 ft (0.6 m) thick were spread and then sprayed with water. Then a tracked crane dropped a 4 ft (1.2 m) cube of concrete as seen in Figure 14. The weight of the cube was estimated at 4 tons (3629 kg). It was dropped from heights of 8 ft (2.4 m). The drop configuration was from the edge of the wing wall to the center and from the abutment wall back. Impact areas overlapped half of the previous impact. This

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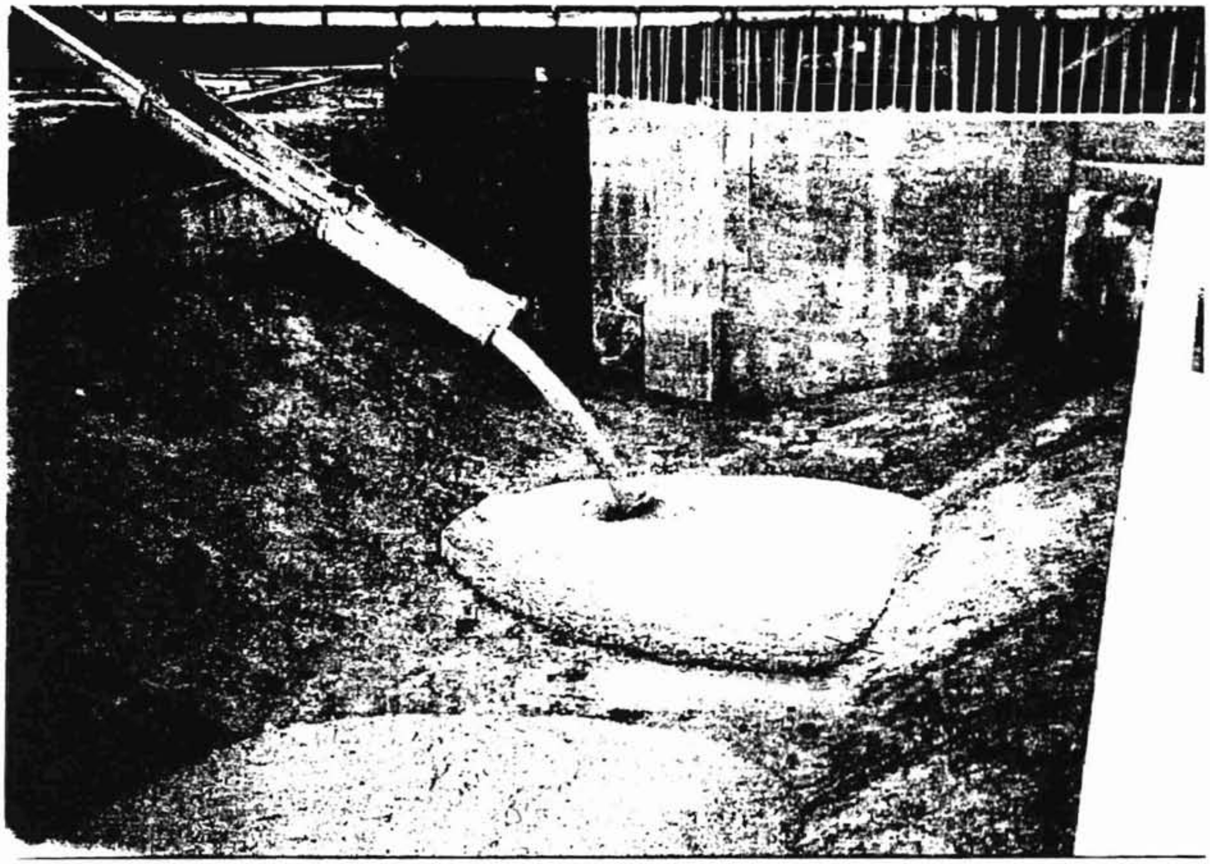

Figure 13. Pouring of Controlled Low Strength Backfill at B2

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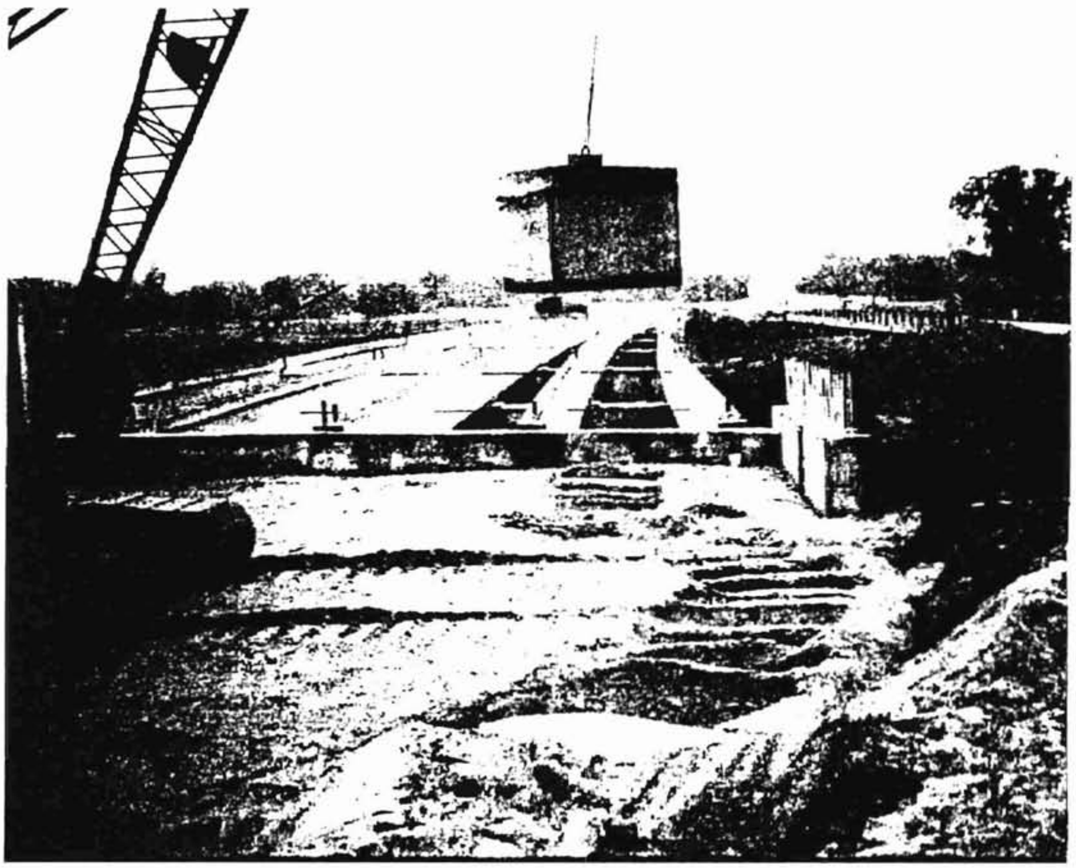

Figure 14. Dynamic Compaction of C1

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procedure followed through the next three lifts. Control of the drop height and pattern improved after the first lift was completed which resulted in more consistent heights closer to the specifications and efficient overlapping. A walk behind pad vibrator densified the perimeter and then densities were taken. If density was sufficient, material for the next lift was brought in with a front-end loader.

One main concern with this method was the movement of the abutment and wing walls, so there were no drops closer than 2 ft (0.61 m) from the walls. Transits set up about 100 ft (30.5 m) from the backfill focused on wall marking to detect lateral movement. None occurred until the second lift while movement was greatest during compaction of the third and fourth lifts. Total movement of the abutment wall was 0.01 ft (0.305 cm) away from the backfill (north), while the west wingwall moved 0.01 ft (0.305 cm) west and the east wingwall moved 0.02 ft (0.610 cm) east.

Cost for south backfill of bridge C dynamic compaction was $15,000 over a 5 day period. Workers included a crane operator and a spotter. Equipment used was a crane, front end loader, walk behind pad vibrator, and three transits.

North of Bridge C, C2

The north abutment of bridge C was backfilled with granular material, then flooded and vibrated. The same reasoning was used here as with the south side of bridge C in that as sand density increases, so will its shear strength and bearing capacity.

Figure 15 shows the construction that began on Friday, May 12, with the

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Figure 15. Flooding and Vibration at C2

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placement of the first 4 ft (1.2 m) lift. First, the granular material was placed and spread with a front end loader. Then the lift was flooded with water from a water truck. A hand held concrete vibrator was inserted to the approximate depth of the lift at approximate 1 ft (0.6 m) spacing over the whole backfill area to create a 1 ft (0.6 m) grid pattern. Densities were then checked using a Troxler density/moisture gage. The first round of testing after completion of the first lift revealed that the densities were too low. On the following Monday, vibration of the first lift was repeated and all subsequent densities were sufficient. The second 4 ft (1.2 m) lift was placed and the backfill was completed on Tuesday, May 16.

Equipment used was one loader, one vibrator, and a water truck. The construction time was 2 days and the cost was estimated at $16,000.

Summary

Table 8 shows a summary of the cost and time of construction for each of the backfills. Construction times are approximate due to the variation in the rate of productivity of the workforce and a "learning curve" for the new and different techniques. This unfamiliarity with certain construction methods was to be expected and was most prevalent on B2, the geotextile reinforced granular backfill, since it was definitely the most unique and labor intensive. Construction time could have been reduced at C2, the flooded and vibrated backfill, by eliminating the second vibration of the first lift.

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Table 8. Cost and Time of Construction Summary

	Quantities	Estimated Cost	Construction Days	Equipment
A2	300 yd^3	\$1,500	4	Loader, walk-behind pad vibrator
B1	375.2 yd^3 fill 2227 yd^2 textile	\$25,000	5	Loader, walk-behind pad vibrator, concrete spreaders, water truck
B2	182 yd^3	\$14,560	2	Concrete trucks, concrete vibrator
C1	305.9 yd^3	\$15,000	5	Crane, concrete block, walk-behind pad vibrator, water truck
C2	305.9 yd^3	\$16,000	2	Water truck, concrete vibrator

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CHAPTER 4

MATERIALS TESTING

This chapter discusses the materials testing conducted for the Salt Fork River bridge replacement project on US 177 in Noble and Payne counties in Oklahoma. Three categories of testing took place: on-site quality control/quality assurance (QC/QA) testing, laboratory testing, and the in-situ Cone Penetration Testing following construction.

On-Site QC/QA

During construction, QC/QA testing was performed by both ODOT inspectors and OSU research staff. A Troxler nuclear density gage was used to measure density, ensuring adequate compaction of the lifts for all backfills except for B2, where controlled low strength material backfill was placed.

The granular backfills (B1, C1, and C2) were all tested during construction using the nuclear density/moisture gage and obtaining percent Proctor compaction values based on Standard Proctor tests conducted by ODOT. Proctor dry density values inherently do

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not appropriately describe the in-place density of granular backfill. For approaches C1 and C2, the density was reaffirmed using the electric cone penetration test (CPT), to be discussed later in this chapter. But in approach B1, only a nuclear gage was used, and tests were run just as they would be run in fine-grained materials, with a percentage Proctor specification.

Test specifications should not be the same for coarse-grained and fine-grained materials. To measure density of granular materials, the Relative Density was used. Maximum and minimum index density values were obtained in the OSU soils laboratory and then used in the Relative Density formula (10):

$$D_R = \frac{(\gamma_{field} - \gamma_{min})}{(\gamma_{max} - \gamma_{min})} * \frac{\gamma_{max}}{\gamma_{field}} * 100 \qquad (1)$$

where:

D_R = *Relative Density,%*

γ_{field} = *Field Density*

γ_{min} = *Minimum Index Density*

γ_{max} = *Maximum Index Density*

to compute percentage relative density. Values between 0 and 33% indicate "loose" soils, 34% to 67% indicate "medium dense" soils, and values greater than 67% indicate "dense" soils (10). CPT soundings were conducted through the backfill materials on both ends of bridge C and confirmed adequate densities. The Proctor test performed by ODOT for the south of bridge B gave a maximum dry density value of 115.6 pcf (18.2 kN/m^3). The measured index densities gave a relative density of 42%, the lower end of

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the "medium dense" range. Since this is the maximum value used in the Proctor density specification, lifts obtaining 95% or more of the 115.6 pcf (18.2 kN/m^3) density would meet specifications. This specification allows a density of 109.8 pcf (17.3 kN/m^3), which yields a relative density value of 2%, a very loose value. The base layer was placed with a relative density of 1% and the eight lifts had relative density values from 19% to 32%. All measured density values yield relative density values below 33%, classifying them as "loose".

The depth of compaction is also a limit for the common nuclear gage. The probe of the nuclear gage was inserted to depths of 6 in. (15.2 cm), giving accurate data for depths short of the lift thickness of backfills in C1 and C2. The cone penetration test overcame this limit as it continuously tested to depths greater than 25 ft (7.6 m).

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OSU Soils Laboratory Testing

Laboratory soil tests were performed at OSU to ensure consistency with ODOT data and compliance with the project specifications. Both the south and north of bridge A approach embankment materials underwent Standard Proctor (ASTM D-698) and Atterberg Limit (ASTM D-4318) tests. These materials were low plasticity with the south abutment backfill classified as CL, low plasticity clay, and the north abutment backfill as SM, silty sand. South of bridge B, eight lifts of SP material were placed. OSU performed relative density tests (ASTM D-2049) to determine maximum and minimum index densities so that relative densities in the field could be determined. No soils tests were conducted north of B, where the CLSM was placed. Lab tests for both ends of bridge C were performed. Maximum and minimum index density tests were performed as well as classification testing of the backfill material. Each end of bridge C is backfilled with SP material, poorly-graded sand. Appendix C contains laboratory test results.

ODOT CPT Testing

To ensure final construction quality, ODOT performed electric cone penetration tests on both approach embankments of bridge C. On each approach embankment three CPT's were run- east, center, and west. The east and west soundings extended through the approach embankment while the center sounding extended to the bedrock. C1 tests gave relative density results of 90% or greater for the depth of the experimental backfill (the only exception being the surface of the backfill which had relative density values of 70%). At C2, the tests showed relative density values of above 70% to depths of the trial backfill.

The CPT test also gave phi angle, ϕ (angle of internal friction), estimates for the material. This allowed quantification of the shear strength of the soil which could be used to estimate total lateral earth pressure exerted upon the wall. For C1, ϕ of the backfill ranged from 46° to 48° for the bottom 2 ft (0.6 m) of the fill, and greater than 48° for the rest. C2 had lower ϕ results. The top 2 ft (0.6 m) gave readings greater than 48°

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and the middle of the fill had values of 46° to 48°. Toward the bottom, ϕ values of 40° to 42° were determined.

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CHAPTER 5

DISCUSSION OF RESULTS

All instrumentation but surface settlement points were installed and readings are continually taken. Cost, time of construction, and performance are the criteria for making a final recommendation about performance and can only be accurately done with at least two years worth of data. Preliminary observations and comments will be made based on the performance data from the first 7 months. Preliminary findings are discussed and the conclusion presents a case for continued data collection.

Performance To Date

Performance of the approach backfills through December 1995 was evaluated. Parameters measured were lateral earth pressure against the abutment wall, lateral movement of the backfill and abutment wall, settlement, and pore water pressure. These parameters are discussed in the following paragraphs.

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Lateral Earth Pressure

The pressure exerted against the abutment walls was measured by the total pressure cells in units of pounds per square inch. For comparison with measured values, theoretical Rankine values were computed for approaches A2, B1, C1, and C2. The Rankine formula for lateral stress against a retaining structure is (11)

$$\sigma_a = K_a * \gamma * H \qquad (2)$$

where:

σ_a = *active lateral earth pressure against a retaining structure at depth H*

K_a = *Rankine coefficient for active earth pressure*

$= tan^2\left(45 - \frac{\phi}{2}\right)$

ϕ = *internal angle of friction*

γ = *dry density*

H = *depth of interest.*

Lateral earth pressure at rest was also calculated using the same formula as above, but replacing K_a with K_o and, according to Jaky, is equal to 1-sin ϕ (11). Table 9 shows measured total pressure cell values and theoretical values using the Rankine formulas for active and at rest conditions. For A2, the ϕ angle of internal friction is estimated at 39°, taken from Schwidder's initial approximation (1). Total pressure cell readings vary from a maximum at the center cell with a pressure of 1.6 psi (0.115 kg/cm^2) to a minimum at the top pressure cell 0.4 psi (0.029 kg/ cm^2). B1 values are included to show the data collected. With higher readings for the bottom TPC, it appears the bottom cardboard

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Table 9. Theoretical and Measured Total Lateral Earth Pressures

	A2	B1	B2	C1	C2
ϕ, in degrees	39[a]	<30		48.5[b]	46.7[b]
K_a	0.2275	0.3610[c]		0.1435	0.1576
K_0	0.3707	0.5305		0.2510	0.2722
γ, in pcf	103.3[d]	111.3		123.6[e]	122.8[e]
H1, feet	2.19	1.86	1.55	0.96	0.96
$\sigma_a 1$, psi	0.4	0.5		0.1	0.1
$\sigma_o 1$, psi	0.6	0.8		0.2	0.2
$\sigma 1$ measured, psi	0.5	0.2	0.5	0.5	0
H2, feet	5.19	4.86	4.55	3.96	3.96
$\sigma_a 2$, psi	0.8	1.4		0.5	0.5
$\sigma_o 2$, psi	1.4	2.0		0.9	0.9
$\sigma 2$ measured, psi	1.6	0.4	0	1.0	1.0
H3, feet	7.66	7.86	7.55	6.96	6.96
$\sigma_a 3$, psi	1.3	2.2		0.9	0.9
$\sigma_o 3$, psi	2.0	3.2		1.5	1.6
$\sigma 3$ measured, psi	1.5	6.0	0.7	2.5	2.7

a- from Schwidder (1)
b- weighted average from 0 to 8 feet depths from ODOT CPT tests
c- ϕ assumed at 28°, from Bowles (7)
d- 95% of 108.7 pcf dry density from OSU Standard Proctor Test
e- average of field densities taken by OSU
σ_a- theoretical Rankine active lateral earth pressure
σ_o- theoretical Rankine lateral earth pressure at rest
H1- distance from top of subgrade to the center of the top TPC
H2- distance from top of subgrade to the center of the middle TPC
H3- distance from top of subgrade to the center of the bottom TPC

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spacers are still intact. The column for B2 is incomplete because of the lack of ϕ values for the CLSM. The middle total pressure cell at B2 shows no lateral pressure exerted while the top and bottom cells register pressure values. For C1 and C2, the ϕ angle used is an average of the top 8 ft (2.4 m) from the cone penetration test. Middle TPC measured values are close to the at rest conditions. Time plots of total lateral earth pressure are shown in Appendix D.

Possible reasons for total lateral pressure differences between the measured and theoretical values are numerous. Speculation can include the working condition of the cells and the readout equipment. At B1 the bottom cell value can be ignored until the cardboard is collapsed. As more data are collected, perhaps more understanding of differences like these could be understood.

Active total force was calculated for approach embankments A2, C1, and C2. Quantities for the abutments are the same as used in the lateral pressure calculations. The total force per running foot of wall was calculated using the formula (11)

$$P_o = \frac{1}{2} * K_a * \gamma * H^2 \qquad (3)$$

where:

P_o = force, pound per running foot of wall

K_a = Rankine coefficient of active earth pressure

γ = unit weight of the soil, pcf

H = height of wall, ft.

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At A2, using the same values for density and ϕ angle as used for the lateral earth pressure calculations, P_0 is 881 lb./ft (1311 kg/m). At C1 and C2, the same set of values was also used from the lateral pressure calculations giving of 562 lb./ft (836 kg/m) at C1 and 613 lb./ft (912 kg/m) at C2.

Lateral Earth Movement

Lateral earth movement was detected by using inclinometer readings through September 1995 and analyzing the data with the Digi-Pro software. Plots of data from each abutment are shown in Appendix D. At A2 both backfill casings indicate positive movement in the A plane (southward in this case) while the abutment wall also shows positive movement. When comparing the abutment wall, offset, and centerline plots a match can be made between at least two of the plots showing similar magnitudes in the same direction. The three plots for B2, C1, and C2 show the most consistent movements regarding direction. Magnitudes are low with typical values of 0.05 in. (1.27 mm).

Settlement

Settlement was measured by the amplified liquid settlement gages and the telescoping couplings of the inclinometer casings. Table 10 summarizes the data for both as of December 1995. The complete data are shown in appendix D.

Concerning the settlement gages, the centerline gage indicates more settlement

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than the offset. Centerline settlement is greatest at A2 and least at C2. The backfills with the greatest differential settlement between the centerline and the offset are B2 and C2, with differences of .16 ft. (4.8 cm) and .115 ft. (3.5 cm) respectively. These values show trends of greater settlement along the centerline and are consistent with conventional vertical stress theory. Stresses are greatest in the center of a trapezoidal loading configuration, directly attributing to the increased deformation.

Table 10. Summary of Settlement

Liquid Settlement Gages

ΔH in feet

	A2	**B1**	**B2**	**C1**	**C2**
Centerline	.275	.202	.260	.250	.175
Offset	.180	.140	.100	.250	.060

Telescoping Couplings

Δin Length (L) in feet

	A2		**B1**		**B2**		**C1**		**C2**	
	Centerline	Offset	Centerline	Offset	Centerline	Offset	Centerline	Offset	Centerline	Offset
ΔL_2	-0.04	0.001	0.036	-0.01	-0.10	0.01	0	0.035	0	0.01
ΔL_3	0	0	0	0.01	0	0	0	-0.005	-0.085	-0.01
ΔL_4	0.09	0.001	0.002	0	0	-0.06	-0.05	0.075	0.005	-0.015

where:

ΔL_4= R4-R3= Settlement of Foundation Strata

ΔL_3= R4-R2-ΔL_4= Settlement of Embankment Strata

ΔL_2= R4-R1-ΔL_3- ΔL_4= Settlement of Experimental Backfill Strata

R1, R2, R3, R4= depth readings to telescoping couplings, 1 as the top coupling and 4 as the bottom coupling

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The telescoping couplings provided a good indication of movement, but the hook method was not as reliable and accurate as the settlement gages. So, when analyzing the hook data, movements of thousandths of a foot cannot be reliable. Although the precision of the hook method may be doubtful, trends can certainly be detected. The largest deformation occurred in the foundation of A2 centerline, again consistent with vertical stress distribution theory. C1 offset shows the most total movement, with settlement in the trial backfill and foundation. One clear trend detected is the general lack of settlement in the embankment material below the experimental approach embankments. Abutment backfills B2 and C2 show cumulative negative movement (upward), raising questions about that particular set of data. Of the backfills with cumulative positive magnitude, B1 showed the least settlement and A2 showed the most.

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Pore Water Pressure

The elevation of the water table corresponded to river depth fluctuations which were a function of rainfall amounts. Points in mid-June and the beginning of August 1995 reflect the large rainfalls recorded at those times, with the August rainfall attributed to the northward scour of the river just to the west of bridge A. Groundwater table elevations over time are shown in Appendix D.

Pore water pressure has played little role in the performance of the backfills. During flood stage, the water table reached elevations near the original ground surface.

But, with the sandy foundation and embankment soils, deformation was primarily elastic, which was not effectively influenced by the pore water pressure.

Preliminary Findings

Evaluation of the experimental approach embankments was based on a simple ranking system. Cost, time of construction, and measured performance were the ranking categories. The backfill with the highest cost was B1, the geotextile reinforced granular backfill, at $25,000. The rest of the experimental backfills were all between $14,000 and $16,000, while the control section cost the least at $1500. For time of construction, B1 and C1 ranked last in this category with 5 days required; B2 and C2 were the fastest with 2 days.

Evaluation of performance was more complicated, but was still a ranking process. A ranking system assigned the value 1 to the best performing backfill (the least amount of pressure, movement, or settlement) and 5 assigned as the worst performance. This system adequately reflects the relative performance of each backfill. Each experimental backfill received a ranking in the following performance sub-categories: total pressure cells, amplified liquid settlement gages, inclinometer plots, and telescoping couplings. These different instrumentation rankings were summed, which indicated the best overall performer with the lowest sum. For B2 and C2, the telescoping couplings have cumulative negative values, so these sub-categories were removed from performance consideration. These final rankings and qualitative consideration of relative magnitudes

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indicate B2, the controlled low strength material backfill, as the best performing trial abutment backfill/approach embankment to date.

Abutment C2, the flooded and vibrated backfill, achieved rankings close to B2. It showed the least telescoping coupling settlement among the backfills, but high movements in the inclinometer and a ranking of third in the total pressure cell readings kept it ranked overall below B2. Abutment B1, the geotextile reinforced granular backfill, showed good performance (an equal overall ranking to C2), but is by far the most costly and time consuming. All trial backfills performed better than the control section A2. Although abutment A2 did not always rank last in the categories, it was consistently ranked in the bottom half of the individual instrumentation rankings.

In the performance and time of construction categories, B2 achieved the highest ranking. In the cost category, qualitative judgment must be used. Although B2 shows the second to lowest cost, it is still almost ten times the cost of the control section at A2. Only an economical analysis involving research on the cost of the damage from differential settlement betweent the bridge and approach embankment could quantitatively determine the cost effectiveness of spending this extra amount during construction.

Conclusion

In order for these preliminary findings to be confirmed, more observation is required. Data collection through years of use is desirable to allow full consideration of

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performance over time, including sustained traffic loading. As the Oklahoma University study (2) points out, generally the older the structure, the more likely differential settlement will occur. Although the "bump at the end of the bridge" is a problem among highway departments throughout the United States, practical studies to this extent are rare if not non-existent. The final results of this study will help Oklahoma, its highways, and taxpayers. Also, recognition will be gained by ODOT, OSU, and the entire state of Oklahoma upon completion and publication of this innovative and practical research. The continued collection of data over at least the next two years is imperative and will help to maximize the potential of this important study.

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APPENDIX A

SPT, CPT, AND DMT SOUNDINGS FROM

GEOTECHNICAL INVESTIGATION

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Oklahoma Department of Transportation
Materials Division–Soils & Foundations Branch
Bridge Sounding

JECT NO.- BRF-319(104) BORING NO 4

COUNTY Noble DATE 10/7/92
STATION 14+28, 4' Rt. of C.L. SURVEYED BY: Webb & Party
ELEVATION 905.8 EQUIPMENT CME-75, mud rotary, 3 1/2" drag bit, SPT, TCP
TOTAL DEPTH 56.0
WATER TABLE-AT END OF BORING: ______ AT 24 HRS. ______

REMARKS: Bridge 'A'. Hollow stem augers set to 19.5 ft.

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	MC (%)
0.0			CLAY, dark brown								
			SILTY SAND, light reddish brown								
5.0			SANDY CLAY, reddish brown								
			CLAY, dark grayish brown and reddish brown								
		CL	LEAN CLAY, dark grayish brown and reddish brown	0	46	26	100	99	97	33 2	
15.0			CLAY, with wood, dark grayish brown and reddish brown								
			SAND, medium to coarse, with GRAVEL								
			WEATHERED SHALE, reddish brown								
		CL	WEATHERED SHALE with one hard SANDSTONE lense, 0.1' thick (LEAN CLAY with GRAVEL)	63	43	21	100	83	79	76 7	
20.0											

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DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	SPT(N)	LL	PI	% PASSING			
							#4	#10	#40	#200
[illegible]			WEATHERED SHALE, reddish brown							
		CL	WEATHERED SHALE (LEAN CLAY), reddish brown	51	46	19	100	98	98	96.4
			WEATHERED SHALE, reddish brown							
25										
		CL	WEATHERED SHALE (LEAN CLAY), reddish brown	50R(4 7/8")	41	20	100	99	98	97.9
			SHALE, reddish brown							
30			SHALE, grayish brown							
			SHALE, reddish brown and brownish gray TCP - 50(5 11/16"), 50(5 11/16") @ 31.0 ft.							
35			SHALE with thin SANDSTONE and LIMESTONE lenses							
			SHALE, reddish brown and gray TCP - 50(6"), 50(5 1/4") @ 36.0 ft.							
40										
			TCP - 50(4 7/8"), 50(2 1/8") @ 41.0 ft.							
45										

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DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
			SHALE with SANDSTONE lenses, light gray							
			SHALE, reddish brown and gray TCP - 50(5/8"), 50(5/16") @ 46.0 ft.							
50.0			SHALE with LIMESTONE lenses, dark gray and light gray							
			INTERBEDDED SHALE and LIMESTONE, dark gray and light gray TCP - 50(1/4"), 50(1/8") @ 51.0 ft.							
5.0										
5.0			LIMESTONE, hard, gray TCP - 50(3/16"), 50(1/16") @ 56.0 ft.							

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Oklahoma Department of Transportation

Materials Division—Soils & Foundations Branch
Bridge Sounding

:CT NO.- BRF-319(104) BORING NO. 8

COUNTY: Noble
DATE: 10/28/93
STATION: 153+01, C.L.
SURVEYED BY: Nevels, Arnold, Sessums & Party
ELEVATION: 908.26
EQUIPMENT: CME-75, mud rotary, 3 1/2" S.D. bit [illegible]
TOTAL DEPTH: 54.1
WATER TABLE—AT END OF BORING: ______ AT 24 HRS. 12.5

REMARKS: Bridge 'A', N. Abut.

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200	MC (%)
		CL	SANDY LEAN CLAY	0.0		26	8	100	100	99	53.7	10.1
		CL	LEAN CLAY with SAND	0.4		36	21	100	100	99	74.5	11.5
		CL	SANDY LEAN CLAY	0.8		27	11	100	100	99	66.6	9.4
				1.2		25	8	100	100	99	65.2	9.5
		CL-[illegible]	LEAN CLAY	1.5	7	26	7	100	100	100	85.4	11.5
		ML	SANDY SILT	2.0		NP	NP	100	100	99	58.1	8.5
				2.5		NP	NP	100	100	97	51.8	6.2
		CL-[illegible]	LEAN CLAY with SAND	3.0	6	26	7	100	100	100	76.3	12.5
		ML	SANDY SILT	3.5		NP	NP	100	100	100	59.8	15.7
		ML	SILT with SAND	4.0		NP	NP	100	100	100	70.5	15.5
		CL	LEAN CLAY with SAND	4.5	6	44	21	100	100	100	78.7	13.3
		ML	SILT with SAND	4.9		NP	NP	100	100	100	72.7	11.0
		CL-ML	SILTY CLAY with SAND	5.3		24	4	100	100	99	76.7	20.2
		ML	SILT	5.7		NP	NP	100	100	100	87.0	
		CL	LEAN CLAY with SAND	6.0	6	26	9	100	100	100	77.1	23.7
				6.5		24	6	100	100	100	73.3	16.1
		ML	SILT with SAND	7.0		NP	NP	100	100	100	77.1	
				7.3		23	1	100	100	100	75.8	
		CL	LEAN CLAY with SAND	7.5	5	42	19	100	100	100	79.4	20.7

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DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200	
8.0		ML	SILT	8.0		NP	NP	100	100	100	86.2	
		CL	LEAN CLAY	8.5		30	9	100	100	100	95.0	22.3
		ML	SILT with SAND	8.7		NP	NP	100	100	100	82.9	
				9.0	5	24	3	100	100	99	83.4	
		CL-ML	SILTY CLAY with SAND	9.5		25	6	100	100	91	72.5	
		SP	POORLY-GRADED SAND with SILT	9.9		NP	NP	100	92	40	9.4	
				10.3		NP	NP	100	96	48	8.6	
		SM	SILTY SAND	10.5	8	NP	NP	100	100	91	22.2	
		SP	POORLY-GRADED SAND with SILT	11.0		NP	NP	100	98	73	8.7	
		SP	POORLY-GRADED SAND	11.6		NP	NP	99	99	91	1.6	
		SP	POORLY-GRADED SAND with SILT	12.0	12	NP	NP	92	86	60	6.1	
		▼		12.5		NP	NP	99	96	62	9.1	
13.0		SP	POORLY-GRADED SAND	12.9		NP	NP	93	84	63	4.2	
		SP	POORLY-GRADED SAND with SILT	13.5	7	NP	NP	97	91	56	9.3	
				14.0		NP	NP	99	94	53	10.6	
		SM	SILTY SAND	14.5		NP	NP	99	86	70	22.9	
				15.0	5	NP	NP	98	94	79	22.9	
				15.5		NP	NP	99	96	62	14.7	
				16.0								
		CL	SANDY LEAN CLAY	16.5	6	33	16	97	92	86	65.5	
		SM	SILTY SAND	16.8		NP	NP	100	99	92	15.6	
				17.2		NP	NP	100	99	68	12.6	
				17.7								
18.0												

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USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200
SP	POORLY-GRADED SAND	18.0	10	NP	NP	96	90	36	4.5
		18.3		NP	NP	100	98	44	8.3
SP	POORLY-GRADED SAND with SILT	18.9							
		19.5	12	NP	NP	98	93	38	7.1
SP	POORLY-GRADED SAND	19.9		NP	NP	100	99	51	4.4
		20.5							
SP	POORLY-GRADED SAND with SILT	21.0	8	NP	NP	99	93	29	5.7
		21.6		NP	NP	97	89	17	6.4
		22.1							
		22.5	8	NP	NP	89	85	29	8.3
SM-SC	SILTY CLAYEY SAND	22.9		20	6	100	98	49	19.8
		23.5							
SC	CLAYEY SAND	24.0	6	21	8	98	94	32	15.3
SP	POORLY-GRADED SAND with SILT	24.4		NP	NP	98	93	28	9.3
		25.0							
SM	SILTY SAND	25.5	9	NP	NP	100	99	66	15.3
		26.0		NP	NP	100	100	68	14.9
		26.6							
		27.0	22	NP	NP	100	99	72	14.6
		27.4		NP	NP	100	99	62	13.3
		27.8							

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DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	
		CL	LEAN CLAY with SAND	28.5	10	39	24	96	89	78	70.1	26.1
		SP	POORLY-GRADED SAND with SILT	28.8		NP	NP	100	96	43	10.7	
		CL	LEAN CLAY	29.1		37	20	100	100	99	96.7	31.4
				29.8								
				30.0	5	39	22	100	100	97	92.4	40.2
				30.4		35	18	100	100	99	93.8	32.8
				30.9		34	17	100	100	97	92.2	23.6
		SP	POORLY-GRADED SAND with SILT	31.2		NP	NP	100	99	39	6.4	
		CL	SHALE (LEAN CLAY with SAND)	31.4 31.5	6	43 43	18 24	88 99	83 98	72 96	72.7 94.6	[illegible]
		CL	SHALE (LEAN CLAY)	32.1		45	21	100	100	99	98.1	18.4
				32.7								
		CL	SHALE (LEAN CLAY with SAND)	33.0	40	43	18	99	97	89	79.9	23.6
		CL-[illegible]	SHALE (LEAN CLAY)	33.5		25	7	100	100	100	98.4	20.3
				34.0		42	18	98	96	94	91.6	17.1
			SHALE, red		83							
			Core 1, 34.5-79.5 ft, RQD=90.2									

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LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
		SHALE, red Core 2, 39.5-44.1 ft, RQD=89.0								
		SHALE, red Core 3, 44.1-49.1 ft, RQD=36.6								

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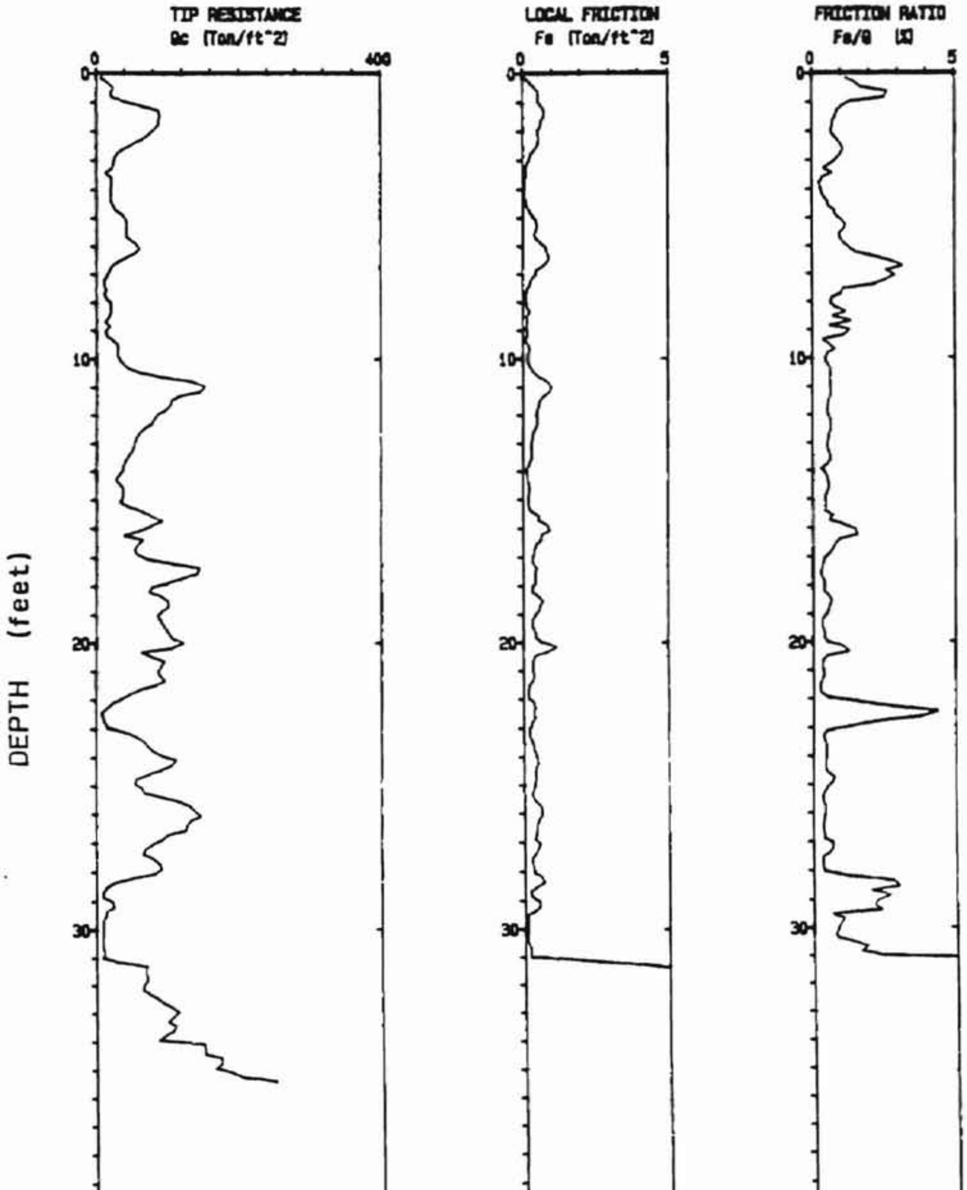
DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
								# 4	# 10	# 40	# 200
			SHALE, red								
			Core 4, 49.1-54.1 ft, RQD=61.0								

OKLAHOMA STATE UNIVERSITY

Oklahoma DOT

Operator : DEAN
Sounding : 158 Pg 1 / 1
Cone Used : 252

CPT Date : 8/11/93 7:43
Location : US177 NORTH A
Job No. : CPT-5



Depth Increment : .05 m

Max Depth : 35.43 ft

OKLAHOMA STATE UNIVERSITY

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. DMT-1
DDT PAGE 1
JOB FILE: NOBLE CO. US 177 FILE NO. : BRIDGE A - NORTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY SNDG.DATE: 11/9/93
ANAL.BY : DEAN ANAL.DATE: 12/16/93

ANALYSIS PARAMETERS: LO RANGE =10.00 BARS ROD DIAM. = 3.60 CM BL.THICK. = 14.5 MM SU FACTOR = 1.00
SURF.ELEV. =276.80 M LO GAGE 0 = 0.02 BARS FR.RED.DIA. = 4.70 CM BL.WIDTH = 95.6 MM PHI FACTOR = 1.00
WATER DEPTH = 4.63 M HI GAGE 0 = 0.21 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.27 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.000 CAL GAGE 0 = 0.02 BARS DELTA/PHI = 0.50 DELTA-B = 0.48 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI KO FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
*****	******	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	******	******	******
0.50	3059.	4.31	18.10		0.27	0.48	10.00	0.02	0.21	0.02	3.94	17.43		0.000	2.00	0.082
1.00	1264.	1.61	5.57		0.27	0.48	10.00	0.02	0.21	0.02	1.72	5.09		0.000	1.80	0.176
1.50	1244.	3.51	9.90		0.27	0.48	10.00	0.02	0.21	0.02	3.50	9.42		0.000	1.80	0.264
2.00	887.	1.63	5.42		0.27	0.48	10.00	0.02	0.21	0.02	1.75	4.94		0.000	1.80	0.352
2.50	958.	1.71	5.89		0.27	0.48	10.00	0.02	0.21	0.02	1.81	5.41		0.000	1.90	0.441
3.00	3467.	3.77	14.95		0.27	0.48	10.00	0.02	0.21	0.02	3.53	14.28		0.000	1.90	0.531
3.50	4741.	7.55	22.90		0.27	0.48	10.00	0.02	0.21	0.02	7.10	22.23		0.000	2.00	0.627
4.00	3314.	4.29	14.90		0.27	0.48	10.00	0.02	0.21	0.02	4.08	14.23		0.000	1.90	0.723
4.50	3926.	5.49	17.85		0.27	0.48	10.00	0.02	0.21	0.02	5.19	17.18		0.000	2.00	0.818
5.00	4130.	6.52	21.50		0.27	0.48	10.00	0.02	0.21	0.02	6.09	20.83		0.036	2.00	0.881
5.50	2355.	3.28	13.30		0.27	0.48	10.00	0.02	0.21	0.02	3.10	12.63		0.085	1.70	0.927
6.00	2753.	3.50	13.25		0.27	0.48	10.00	0.02	0.21	0.02	3.33	12.58		0.134	1.70	0.971
6.50	3926.	5.03	18.40		0.27	0.48	10.00	0.02	0.21	0.02	4.68	17.73		0.183	2.00	1.018
7.00	1081.	4.02	13.30		0.27	0.48	10.00	0.02	0.21	0.02	3.37	12.63		0.232	1.70	1.065
7.50	1468.	2.51	11.90		0.27	0.48	10.00	0.02	0.21	0.02	2.36	11.23		0.281	1.70	1.109
8.00	2804.	4.35	9.45		0.27	0.48	10.00	0.02	0.21	0.02	4.40	8.97		0.330	1.80	1.150
8.50	6526.	6.61	21.80		0.27	0.48	10.00	0.02	0.21	0.02	6.17	21.13		0.379	2.00	1.195
9.00	4130.	5.13	16.30		0.27	0.48	10.00	0.02	0.21	0.02	4.89	15.63		0.429	2.00	1.244
9.50	4843.	6.77	20.30		0.27	0.48	10.00	0.02	0.21	0.02	6.41	19.63		0.478	2.00	1.293
10.00	4333.	6.48	20.80		0.27	0.48	10.00	0.02	0.21	0.02	6.08	20.13		0.527	2.00	1.342
10.50	4945.	6.29	21.95		0.27	0.48	10.00	0.02	0.21	0.02	5.82	21.28		0.576	2.00	1.391
[illegible]00	4435.	22.30	36.50		0.27	0.48	10.00	0.02	0.21	0.02	21.71	35.83		0.625	2.10	1.442
[illegible]50	6475.	19.20	36.25		0.27	0.48	10.00	0.02	0.21	0.02	18.47	35.58		0.674	2.10	1.496

END OF SOUNDING (INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. DMT-1
DDT PAGE 2
JOB FILE: NOBLE CO. US 177 FILE NO. : BRIDGE A - NORTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY SNDG.DATE: 11/9/93
ANAL.BY : DEAN ANAL.DATE: 12/16/93

ANALYSIS PARAMETERS: LO RANGE =10.00 BARS ROD DIAM. = 3.60 CM BL.THICK. = 14.5 MM SU FACTOR = 1.00
SURF.ELEV. =276.80 M LO GAGE 0 = 0.02 BARS FR.RED.DIA. = 4.70 CM BL.WIDTH = 95.6 MM PHI FACTOR = 1.00
WATER DEPTH = 4.63 M HI GAGE 0 = 0.21 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.27 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.000 CAL GAGE 0 = 0.02 BARS DELTA/PHI = 0.50 DELTA-B = 0.48 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI KO FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	KD	ID	UD	ED (BAR)	KO	SU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHIO (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
*****	*****	*****	*****	******	*****	*****	*****	*****	******	*****	*****	*****	******	************
0.50	47.77	3.43	0.00	468.									1864.	SAND
1.00	9.79	1.76	0.00	117.	1.13		41.5	44.1	0.30	40.9	1.66	9.4	290.	SILTY SAND
1.50	13.25	1.69	0.00	205.	1.75		32.9	39.1	0.43	36.1	5.68	21.5	568.	SANDY SILT
2.00	4.96	1.83	0.00	111.	0.77		27.9	38.4	0.57	35.8	1.35	3.8	204.	SILTY SAND
2.50	4.10	1.99	0.00	125.	0.68		30.7	37.8	0.71	35.6	1.28	2.9	208.	SILTY SAND
3.00	5.64	3.05	0.00	373.	0.73		119.8	44.4	0.90	42.9	2.18	4.1	800.	SILTY SAND
3.50	11.32	2.13	0.00	525.	1.36		151.2	43.2	1.06	41.9	8.34	13.3	1374.	SILTY SAND
4.00	5.64	2.49	0.00	352.	0.71		111.9	42.4	1.21	41.2	2.64	3.6	699.	SILTY SAND
4.50	6.34	2.31	0.00	416.	0.80		130.4	42.3	1.37	41.3	3.76	4.6	867.	SILTY SAND
5.00	6.87	2.44	0.00	512.	0.68		134.3	41.8	1.47	40.9	4.87	5.5	1105.	SILTY SAND
5.50	3.25	3.17	0.00	331.	0.48		100.4	41.1	1.54	40.2	1.45	[illegible]	504.	SILTY SAND
6.00	3.29	2.89	0.00	321.	0.51		95.7	40.4	1.60	39.6	1.66	1.7	490.	SILTY SAND
6.50	4.42	2.90	0.00	453.	0.59		135.0	41.9	1.70	41.2	2.48	2.4	508.	SILTY SAND
7.00	3.42	2.41	0.00	304.	0.74		30.7	31.7	1.62	30.7	3.10	2.9	464.	SILTY SAND
7.50	1.37	4.27	0.00	308.	0.47		51.7	35.7	1.76	35.0	1.31	1.2	322.	SAND
8.00	3.54	1.12	0.00	158.	0.90						2.80	2.4	233.	SILT
8.50	4.85	2.59	0.00	519.	0.53		230.9	44.1	2.03	43.7	2.63	2.2	961.	SILTY SAND
9.00	3.59	2.41	0.00	373.	0.51		144.3	41.3	2.07	40.9	2.22	1.9	585.	SILTY SAND
9.50	4.59	2.23	0.00	459.	0.62		164.9	41.5	2.15	41.2	3.49	2.7	619.	SILTY SAND
10.00	4.14	2.53	0.00	488.	0.60		147.2	40.7	2.22	40.4	3.25	2.4	832.	SILTY SAND
10.50	3.77	2.94	0.00	536.	0.52		172.8	41.7	2.32	41.5	2.61	1.9	685.	SILTY SAND
[illegible].00	14.62	0.67	0.00	490.	2.32						32.11	22.3	1401.	CLAYEY SILT
[illegible]1.50	11.89	0.96	0.00	594.	2.05						24.14	16.1	1582.	SILT

END OF SOUNDING

OKLAHOMA STATE UNIVERSITY

Oklahoma Department of Transportation

Materials Division—Soils & Foundations Branch
Bridge Sounding

PROJECT NO.- BRF-319(104) BORING NO. 3

COUNTY: Noble DATE: [illegible]
STATION: [illegible] SURVEYED BY: [illegible]
ELEVATION: 910.02 EQUIPMENT: CME-75 [illegible]
TOTAL DEPTH: 58.0
WATER TABLE-AT END OF BORING: ______ AT 24 HRS. 14?

REMARKS: Bridge B, S. Abut.

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200	MC (%)
ML	SANDY SILT	0.0		NP	NP	100	100	99	76.2	
		0.4		NP	NP	100	100	100	73.1	
		0.9		NP	NP	100	100	100	71.9	
		1.3		NP	NP	100	100	100	77.8	
		1.5	5	NP	NP	100	100	100	70.0	
		2.0		NP	NP	100	100	100	67.4	
		2.5		NP	NP	100	100	100	64.1	
		3.0	6	NP	NP	100	100	100	74.5	
ML	SILT	3.5		NP	NP	100	100	100	92.2	
ML	SANDY SILT	2.9		NP	NP	100	100	100	79.2	
		4.3		NP	NP	100	100	100	72.5	
ML	SILT	4.5	7	NP	NP	100	100	100	88.8	
		5.0		NP	NP	100	100	100	95.9	
		5.6		NP	NP	100	100	100	91.9	
		6.0	5	25	4	100	100	100	86.3	
		6.5		28	11	100	100	100	87.3	
		7.0		32	15	100	100	100	96.1	
ML	SANDY SILT	7.5	7	25	6	100	100	99	78.3	
		7.9		NP	NP	100	100	100	89.0	

OKLAHOMA STATE UNIVERSITY

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
						#4	#10	#40	#200
ML	SILT								
ML	SANDY SILT	8.4		NP	NP	100	100	100	77.6
		8.8		NP	NP	100	100	100	75.2
ML	SILT	9.0	9	NP	NP	100	100	100	90.5
SM	SILTY SAND	9.6		NP	NP	100	99	73	16.3
		10.1		NP	NP	100	100	94	13.3
		10.5	7	NP	NP	100	99	81	15.3
SP	POORLY-GRADED SAND with SILT	11.0		NP	NP	100	100	98	9.7
		11.6		NP	NP	100	100	97	11.2
SM	SILTY SAND	12.0	17	NP	NP	100	100	93	16.0
		12.5		NP	NP	99	99	80	19.5
		13.1		NP	NP	100	100	98	22.6
SP	POORLY-GRADED SAND with SILT	13.5	20	NP	NP	91	90	71	12.0
SM	SILTY SAND	14.0		NP	NP	100	100	97	18.3
		14.6							
SP	POORLY-GRADED SAND with SILT	15.0	15	NP	NP	92	92	69	6.3
		15.5		NP	NP	100	100	79	10.3
		16.1							
		16.5	14	NP	NP	100	99	66	9.6
		16.9		NP	NP	100	100	81	6.6
		17.4							

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DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
				18.0	7	NP	NP	100	100	91	10.2
				18.5		NP	NP	100	100	55	6.1
				19.0							
				19.5	8	NP	NP	100	97	52	7.5
		SP	POORLY-GRADED SAND	20.0		NP	NP	98	91	29	4.4
				20.5							
				21.0	11	NP	NP	99	95	32	5.0
				21.5		NP	NP	99	91	21	4.5
				22.0							
		SP	POORLY-GRADED SAND with SILT	22.5	9	NP	NP	97	86	36	5.5
21.0		CL	SANDY LEAN CLAY	23.0		31	14	99	98	79	69.9
				23.5							
		SC	CLAYEY SAND	24.0	5	26	10	88	77	33	22.0
		SP	POORLY-GRADED SAND with SILT	24.5		NP	NP	95	79	25	11.3
				25.0							
		SC	CLAYEY SAND	25.5	10	38	22	66	64	18	13.7
		CH	FAT CLAY with SAND	25.9		55	33	99	96	80	77.3
		SC	CLAYEY SAND	26.2		43	26	94	98	35	25.4
				26.6							
		CL	LEAN CLAY with SAND	27.0	7	34	13	99	91	85	81.9
		SP	POORLY-GRADED SAND	27.5		NP	NP	99	97	17	4.1
30.0											

OKLAHOMA STATE UNIVERSITY

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
		28.1							
		28.5	12	NP	NP	100	97	16	2.9
		29.0		NP	NP	98	93	15	2.9
		29.5							
		30.0	13	NP	NP	97	93	22	3.0
SP	POORLY-GRADED SAND with SILT	30.5		NP	NP	99	95	27	5.6
		31.0							
SP	POORLY-GRADED SAND	31.5	13	NP	NP	93	90	23	3.3
SP	POORLY-GRADED SAND with SILT	32.0		NP	NP	95	79	26	5.8
		32.5							
SP	POORLY-GRADED SAND	33.0	20	NP	NP	99	91	31	2.0
SP	POORLY-GRADED SAND with SILT	33.4		NP	NP	100	100	92	5.8
		34.1							
SP	POORLY-GRADED SAND	34.5	18	NP	NP	97	88	24	3.6
		35.0		NP	NP	93	91	26	4.1
		35.5							
SP	POORLY-GRADED SAND with SILT	36.0	13	NP	NP	65	75	19	6.5
SM	SILTY SAND	36.4		NP	NP	93	96	68	44.1
		36.6		35	14	100	98	90	84.7
CL	SHALE (LEAN CLAY with SAND)								
		37.0		41	18	100	100	99	95.3
CL	SHALE (LEAN CLAY)								
		37.3							
		37.5	46	42	20	100	100	97	95.4

OKLAHOMA STATE UNIVERSITY

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
				30.2		40	20	96	95	91	88.8
			SHALE		50 (2.38")						
			Core 1, 31.0-44.0 ft, RQD=98.8								
			Core 2, 44.0-48.0 ft, RQD=65.8								

OKLAHOMA STATE UNIVERSITY

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING				
							# 4	# 10	# 40	# 200	
		Core 3, 48.0-53.0 ft, RQD=71.2									
		Core 4, 53.0-58.0 ft, RQD=86.8									

OKLAHOMA STATE UNIVERSITY

Oklahoma DOT

Operator : DEAN

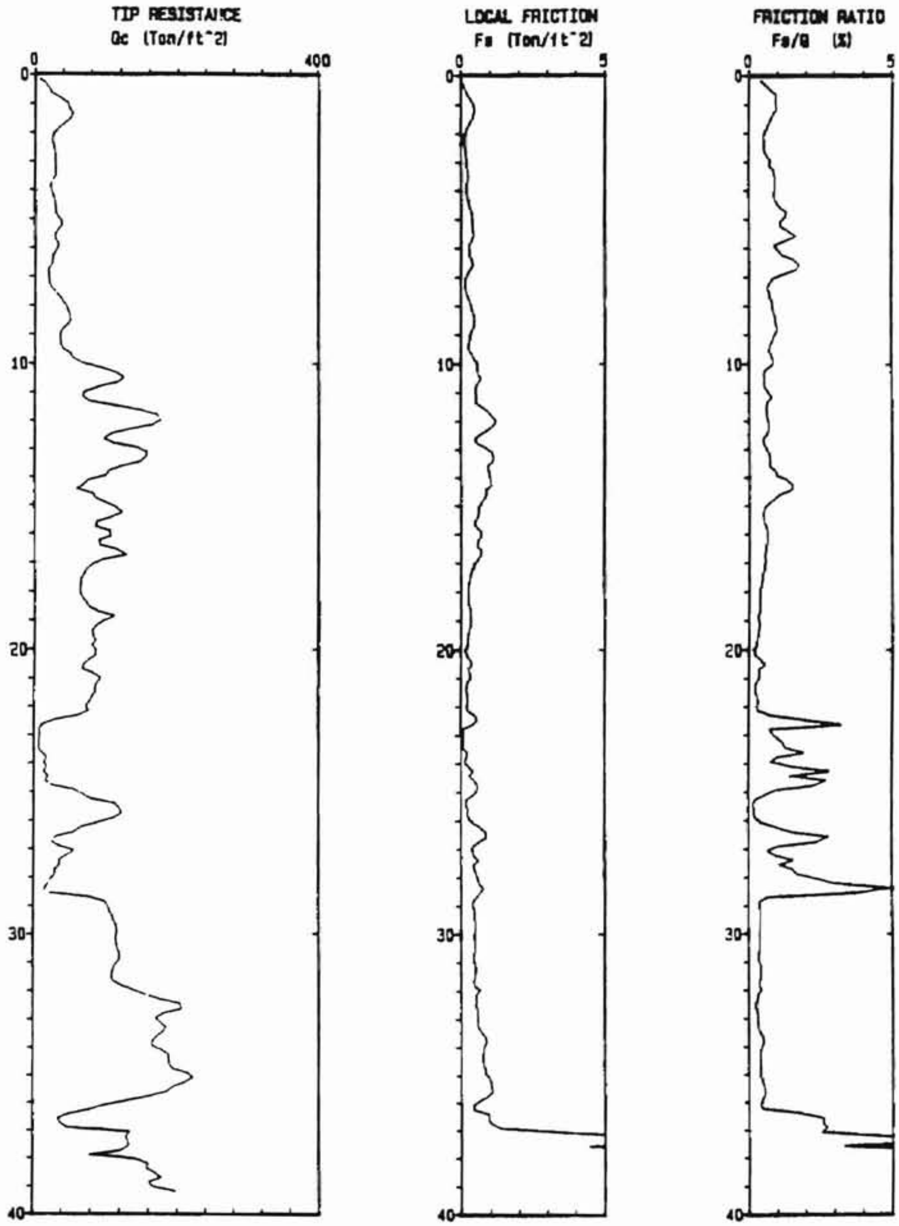
Sounding : 92 Pg 1 / 1

Cone Used : 252

CPT Date : 8/11/93 9:17

Location : US177 SOUTH B

Job No. : CPT-5



Depth Increment : .05 m

Max Depth : 39.21 ft

OKLAHOMA STATE UNIVERSITY

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. DMT-1
J00I PAGE 1
JOB FILE: NOBLE CO. US 177 FILE NO. : BRIDGE B - SOUTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY SNDG.DATE: 11/9/93
ANAL.BY : DEAN ANAL.DATE: 12/16/93

ANALYSIS PARAMETERS: LO RANGE =10.00 BARS ROD DIAM. = 3.60 CM BL.THICK. = 14.5 MM SU FACTOR = 1.00
SURF.ELEV. =277.36 M LO GAGE 0 = 0.04 BARS FR.RED.DIA. = 4.70 CM BL.WIDTH = 95.6 MM PHI FACTOR = 1.00
WATER DEPTH = 4.42 M HI GAGE 0 = 0.35 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.27 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.000 CAL GAGE 0 = 0.04 BARS DELTA/PHI = 0.50 DELTA-B = 0.44 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI KO FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
0.50	779.	1.86	6.35		0.27	0.44	10.00	0.04	0.35	0.04	1.94	5.91		0.000	1.80	0.082
1.00	728.	1.63	5.51		0.27	0.44	10.00	0.04	0.35	0.04	1.74	5.07		0.000	1.80	0.171
1.50	1438.	2.48	7.34		0.27	0.44	10.00	0.04	0.35	0.04	2.54	6.70		0.000	1.80	0.259
2.00	1356.	2.39	7.48		0.27	0.44	10.00	0.04	0.35	0.04	2.43	7.04		0.000	1.90	0.350
2.50	1193.	1.86	6.42		0.27	0.44	10.00	0.04	0.35	0.04	1.94	5.98		0.000	1.80	0.441
3.00	1784.	2.77	8.77		0.27	0.44	10.00	0.04	0.35	0.04	2.77	8.35		0.000	1.90	0.531
3.50	3459.	4.41	14.65		0.27	0.44	10.00	0.04	0.35	0.04	4.22	13.90		0.000	2.00	0.627
4.00	4020.	7.32	21.35		0.27	0.44	10.00	0.04	0.35	0.04	7.00	20.60		0.000	2.00	0.725
4.50	3365.	5.11	15.45		0.27	0.44	10.00	0.04	0.35	0.04	4.91	14.70		0.008	2.00	0.816
5.00	3314.	4.13	14.50		0.27	0.44	10.00	0.04	0.35	0.04	3.93	13.75		0.057	1.70	0.862
5.50	2294.	2.73	10.10		0.27	0.44	10.00	0.04	0.35	0.04	2.70	9.35		0.106	1.70	0.906
6.00	2706.	3.42	12.60		0.27	0.44	10.00	0.04	0.35	0.04	3.28	11.85		0.155	1.70	0.950
6.50	2906.	3.07	12.55		0.27	0.44	10.00	0.04	0.35	0.04	2.94	11.59		0.204	1.70	0.995
7.00	1540.	2.83	13.10		0.27	0.44	10.00	0.04	0.35	0.04	2.64	12.35		0.253	1.90	1.039
7.50	724.	1.98	3.89		0.27	0.44	10.00	0.04	0.35	0.04	2.19	3.45		0.302	1.70	1.078
8.00	3416.	5.57	17.30		0.27	0.44	10.00	0.04	0.35	0.04	5.30	16.55		0.351	2.00	1.120
8.50	2355.	4.65	14.45		0.27	0.44	10.00	0.04	0.35	0.04	4.48	13.70		0.400	1.70	1.166
9.00	2141.	5.84	14.05		0.27	0.44	10.00	0.04	0.35	0.04	5.75	13.30		0.449	1.95	1.212
9.50	3777.	4.89	16.60		0.27	0.44	10.00	0.04	0.35	0.04	4.61	15.85		0.499	2.00	1.260
10.00	3110.	3.79	14.75		0.27	0.44	10.00	0.04	0.35	0.04	3.68	14.00		0.548	1.70	1.306
10.50	5455.	5.85	21.05		0.27	0.44	10.00	0.04	0.35	0.04	5.41	20.30		0.597	2.00	1.353
11.00	3110.	2.39	13.75		0.27	0.44	10.00	0.04	0.35	0.04	2.34	13.00		0.646	1.90	1.399
11.50	3620.	4.71	6.69		0.27	0.44	10.00	0.04	0.35	0.04	4.71	5.45		0.695	1.70	1.439
12.00	5912.	7.43	22.75		0.27	0.44	10.00	0.04	0.35	0.04	6.78	22.00		0.744	2.00	1.480
12.50	5734.	22.60	41.30		0.27	0.44	10.00	0.04	0.35	0.04	21.66	40.55		0.793	2.10	1.532

END OF SOUNDING (INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. DMT-1
J00T PAGE 2
JOB FILE: NOBLE CO. US 177 FILE NO. : BRIDGE B - SOUTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY SNDG.DATE: 11/9/93
ANAL.BY : DEAN ANAL.DATE: 12/16/93

ANALYSIS PARAMETERS: LO RANGE =10.00 BARS ROD DIAM. = 3.60 CM BL.THICK. = 14.5 MM SU FACTOR = 1.00
SURF.ELEV. =277.36 M LO GAGE 0 = 0.04 BARS FR.RED.DIA. = 4.70 CM BL.WIDTH = 95.6 MM PHI FACTOR = 1.00
WATER DEPTH = 4.42 M HI GAGE 0 = 0.35 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.27 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.000 CAL GAGE 0 = 0.04 BARS DELTA/PHI = 0.50 DELTA-B = 0.44 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI KO FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	KD	ID	UD	ED (BAR)	KO	SU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHID (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
0.50	23.55	2.04	0.00	138.	2.76		29.3	44.5	0.14	40.3	4.39	53.2	456.	SILTY SAND
1.00	10.20	1.71	0.00	115.	1.29		28.4	41.8	0.28	38.3	2.00	11.7	291.	SILTY SAND
1.50	9.81	1.71	0.00	151.	1.24		44.6	41.9	0.43	39.1	2.81	10.8	375.	SANDY SILT
2.00	6.75	1.70	0.00	160.	0.94		42.5	40.5	0.58	38.1	2.14	6.1	345.	SILTY SAND
2.50	4.40	2.09	0.00	140.	0.67		39.1	39.3	0.72	37.2	1.31	3.0	244.	SILTY SAND
3.00	5.22	2.01	0.00	193.	0.74		58.2	40.4	0.88	38.6	1.97	3.7	366.	SILTY SAND
3.50	6.73	2.29	0.00	336.	0.85		100.8	42.3	1.05	40.9	3.24	5.2	718.	SILTY SAND
4.00	7.65	1.94	0.00	472.	1.22		124.7	41.7	1.21	40.5	7.67	10.6	1164.	SILTY SAND
4.50	6.02	1.79	0.00	340.	0.80		110.1	41.4	1.35	40.4	3.64	4.5	588.	SILTY SAND
5.00	4.50	2.53	0.00	341.	0.60		113.6	41.8	1.44	40.9	2.18	2.5	507.	SILTY SAND
5.50	2.37	2.56	0.00	231.	0.47		90.5	37.9	1.49	38.9	1.32	1.5	318.	SILTY SAND
6.00	3.27	2.74	0.00	277.	0.49		101.9	41.0	1.57	40.1	1.53	1.6	451.	SILTY SAND
6.50	2.75	3.24	0.00	309.	0.42		104.2	41.0	1.65	40.3	1.19	1.2	424.	SILTY SAND
7.00	2.39	4.07	0.00	337.	0.51		52.8	35.2	1.65	35.3	1.30	1.4	412.	SAND
7.50	1.75	0.67	0.00	44.	0.48						0.88	6.8	37.	CLAYEY SILT
8.00	4.42	2.27	0.00	390.	0.65		113.5	40.1	1.84	37.5	3.19	2.8	584.	SILTY SAND
8.50	3.50	2.26	0.00	320.	0.57		96.3	39.1	1.90	38.5	2.45	2.1	492.	SILTY SAND
9.00	4.37	1.42	0.00	252.	0.77		63.9	35.8	1.92	35.2	4.29	3.5	445.	SANDY SILT
9.50	3.27	2.73	0.00	390.	0.48		140.2	41.2	2.09	40.8	1.95	1.6	588.	SILTY SAND
10.00	2.40	3.30	0.00	358.	0.42		111.5	39.8	2.14	39.4	1.48	1.1	451.	SILTY SAND
10.50	3.56	3.39	0.00	517.	0.45		195.0	42.8	2.27	42.5	1.97	1.5	928.	SILTY SAND
11.00	1.21	5.28	0.00	370.	0.26		119.2	40.3	2.31	40.1	0.60	0.4	314.	SAND
11.50	2.73	0.37	0.00	54.	0.77	0.51					2.61	1.9	66.	SILTY CLAY
12.00	4.22	2.41	0.00	521.	0.55		202.2	42.1	2.47	42.0	3.23	2.2	574.	SILTY SAND
12.50	13.62	0.71	0.00	655.	2.22						30.55	19.9	1930.	SILT

END OF SOUNDING

Oklahoma Department of Transportation

Materials Division—Soils & Foundations Branch
Bridge Sounding

PROJECT NO.- BRF-319(104) BORING NO. 5

COUNTY Noble DATE 12/1/93
STATION 168+61 C.L. SURVEYED BY: Swearing & Parry
ELEVATION 907.35 EQUIPMENT CME-75, air rotary, 3 1/2" bit
TOTAL DEPTH 54.5
WATER TABLE-AT END OF BORING: ______ AT 24 HRS. 7.4

REMARKS: Bridge 'B', N. Abut.

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	MC (%)
SM	SILTY SAND	0.0		NP	NP	99	98	77	41.3	
		0.5		NP	NP	100	99	83	31.7	
		1.0		NP	NP	98	90	59	25.8	
		1.5	12	NP	NP	99	96	69	32.5	
		2.0		NP	NP	100	96	59	23.2	
ML	SANDY SILT	2.5		NP	NP	100	99	87	51.2	
SM	SILTY SAND	3.0	9	NP	NP	99	96	62	25.8	
		3.5		NP	NP	100	98	65	31.5	
		4.0		NP	NP	99	97	71	36.0	
ML	SANDY SILT	4.5	6	NP	NP	100	100	93	51.9	
SM	SILTY SAND	5.0		NP	NP	100	99	83	49.1	
ML	SANDY SILT	5.5		NP	NP	100	98	94	58.6	
ML	SILT	6.0	6	NP	NP	100	100	99	94.2	
		6.5		NP	NP	100	100	100	97.4	
		7.0		NP	NP	100	100	99	90.3	
		7.5	5	NP	NP	100	100	99	89.4	

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							# 4	# 10	# 40	# 200
			8.0		NP	NP	100	100	100	87.5
	ML	SANDY SILT	8.5		NP	NP	100	100	99	80.8
			9.0	4	NP	NP	100	100	95	50.0
			9.5		NP	NP	100	100	99	51.1
	SM	SILTY SAND	10.0		NP	NP	100	100	93	37.3
			10.5	5	NP	NP	100	100	96	44.1
			11.0		NP	NP	100	100	97	44.7
			11.5							
			12.0	7	NP	NP	100	94	75	26.4
	ML	SANDY SILT	12.5		NP	NP	100	100	98	54.2
			13.1							
	SM	SILTY SAND	13.5	8	NP	NP	100	96	71	42.6
	SP	POORLY-GRADED SAND with SILT	13.9		NP	NP	100	98	49	9.8
			14.4							
			15.0	7	NP	NP	99	97	49	6.6
			15.5		NP	NP	99	95	24	5.2
			16.0							
			16.5	8	NP	NP	100	99	60	5.4
	SP	POORLY-GRADED SAND	17.0		NP	NP	100	99	47	4.8
			17.5							

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USCS	DESCRIPTION OF MATERIAL	DEPTH	SPTDN	LL	PI	% PASSING #4	#10	#40	#200	
CH	FAT CLAY with SAND	18.0	11	53	30	97	93	80	71.6	36.3
CL	LEAN CLAY with SAND	18.5		47	26	99	96	83	76.0	30.5
		19.1								
SP	POORLY-GRADED SAND with SILT	19.5	4	NP	NP	99	93	47	9.1	
SM	SILTY SAND	19.9		NP	NP	100	96	58	22.9	
		20.3								
CL	SANDY LEAN CLAY	21.0	7	30	16	96	93	82	58.8	19.3
		21.4		36	21	100	93	79	65.1	24.3
		21.8		29	12	99	96	76	62.4	27.0
		22.2								
		22.5	4	38	21	98	90	71	58.5	19.4
		22.9		48	31	96	82	57	50.2	18.7
CH	FAT CLAY	23.4		81	51	100	100	96	94.8	36.5
CL	SANDY LEAN CLAY	24.0	3	41	24	92	83	66	56.4	34.0
SC	CLAYEY SAND	24.2		35	21	88	67	26	18.9	
		24.7		35	20	98	88	61	49.9	21.1
SM	SILTY SAND	25.2 / 25.3		NP	NP	99	81	32	15.5	
SC	CLAYEY SAND	25.5	5	24	8	89	72	26	17.3	25.0
		26.0		37	21	89	74	54	42.7	
		26.5								
SP	POORLY-GRADED SAND with SILT	27.0	3	NP	NP	85	66	17	8.3	
SP	POORLY-GRADED SAND	27.5		NP	NP	98	90	22	2.8	

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LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING				
							#4	#10	#40	#200	
	SP	POORLY-GRADED SAND with SILT	28.0		NP	NP	99	90	32	6.6	
			28.3								
	SP	POORLY-GRADED SAND	28.5	22	NP	NP	94	82	17	2.4	
			29.0		NP	NP	99	88	24	3.2	
			29.5								
			30.0	12	NP	NP	100	93	30	3.5	
			30.5		NP	NP	100	95	28	4.3	
			31.0								
	SM	SILTY SAND	31.5	16	NP	NP	97	30	31	12.4	
	SP	POORLY-GRADED SAND	32.0		NP	NP	99	94	34	3.8	
	CL	SHALE (LEAN CLAY)	32.5		38	15	100	100	99	97.3	17.7
			32.8								
	CL	SHALE (LEAN CLAY with SAND)	33.0	15	40	16	100	77	76	74.9	19.3
	CL	SHALE (LEAN CLAY)	33.5		40	17	100	100	97	95.9	17.1
		SHALE									
				50/8 (2")							
		Core 1, 34.5-39.5 ft, RQD=78.8									

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							# 4	# 10	# 40	# 200
		Core 2, 39.5-44.5 ft, RQD=75.0								
		Core 3, 44.5-49.5 ft, RQD=94.1								

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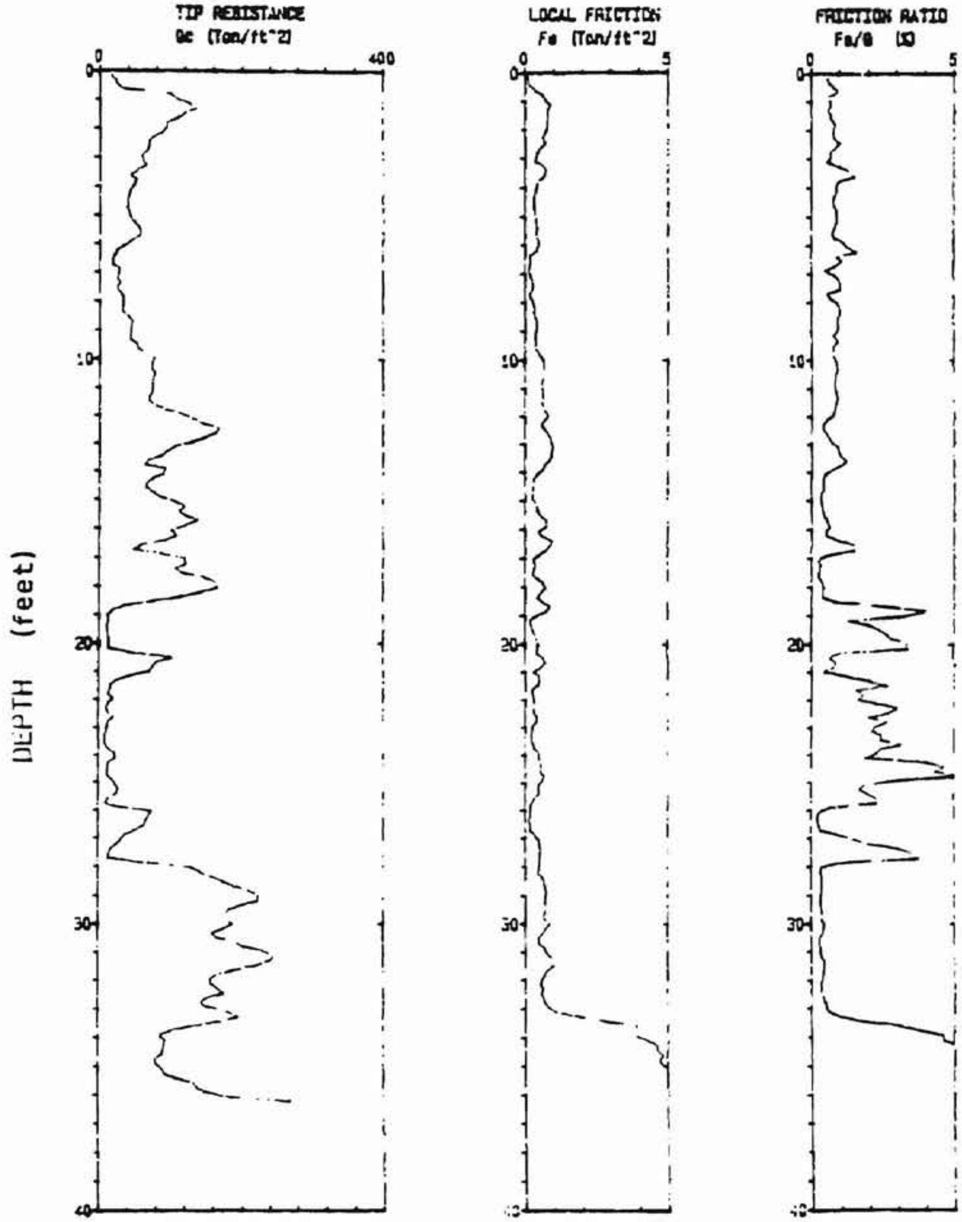
LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							# 4	# 10	# 40	# 200
		Core 4, 49.5-54.5 ft. RQD=62.6								

OKLAHOMA STATE UNIVERSITY

Oklahoma DOT

Operator : DEAN
Sounding : 13 Pg 1 / 1
Cone Used : 252

CPT Date : 10/07/93 13:42
Location : US177 NORTH B
Job No. : CPT-9



Depth Increment : .05 m   Max Depth : 36.25 ft

OKLAHOMA STATE UNIVERSITY

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL)
ODOT
JOB FILE: NOBLE CO. US 177
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY
ANAL.BY : DEAN

SNDG. NO. DMT-1
PAGE 1
FILE NO. : BRIDGE B - NORTH

SNDG.DATE: 10/27/93
ANAL.DATE: 11/5/93

ANALYSIS PARAMETERS:
SURF.ELEV. =276.56 M
WATER DEPTH = 4.08 M
SP.GR.WATER = 1.000
MAI SU ID = 0.60
UNIT CONVERSIONS:

LO RANGE =10.00 BARS
LO GAGE 0 = 0.04 BARS
HI GAGE 0 = 0.25 BARS
CAL GAGE 0 = 0.04 BARS
SU OPTION = MARCHETTI
1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI

ROD DIAM. = 3.60 CM
FR.RED.DIA. = 4.70 CM
LIN.ROD WT. = 6.50 KGF/M
DELTA/PHI = 0.50
MIN PHI ID = 1.20

BL.THICK. = 14.5 MM
BL.WIDTH = 95.6 MM
DELTA-A = 0.23 BARS
DELTA-B = 0.44 BARS
OCR OPTION= MARCHETTI
1 M = 3.2808 FT

SU FACTOR = 1.00
PHI FACTOR = 1.00
OCR FACTOR = 1.00
M FACTOR = 1.00
KO FACTOR = 1.00

Z (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
*****	******	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	******	******	******
0.50	3671.	5.37	20.45		0.23	0.44	10.00	0.04	0.25	0.04	4.89	19.80		0.000	2.00	0.082
1.00	2447.	2.72	9.80		0.23	0.44	10.00	0.04	0.25	0.04	2.63	9.36		0.000	1.70	0.178
1.50	1784.	2.12	9.65		0.23	0.44	10.00	0.04	0.25	0.04	2.01	9.21		0.000	1.70	0.271
2.00	1326.	1.71	6.35		0.23	0.44	10.00	0.04	0.25	0.04	1.74	5.91		0.000	1.80	0.362
2.50	1682.	2.49	10.20		0.23	0.44	10.00	0.04	0.25	0.04	2.38	9.55		0.000	1.70	0.453
3.00	2192.	3.27	14.85		0.23	0.44	10.00	0.04	0.25	0.04	2.96	14.20		0.000	1.90	0.546
3.50	2468.	3.57	13.50		0.23	0.44	10.00	0.04	0.25	0.04	3.35	12.85		0.000	1.70	0.639
4.00	2651.	3.67	13.10		0.23	0.44	10.00	0.04	0.25	0.04	3.47	12.45		0.000	1.90	0.733
4.50	3263.	5.08	18.30		0.23	0.44	10.00	0.04	0.25	0.04	4.69	17.65		0.041	2.00	0.787
5.00	1988.	3.78	13.50		0.23	0.44	10.00	0.04	0.25	0.04	3.57	12.85		0.090	1.90	0.834
5.50	2702.	3.22	13.50		0.23	0.44	10.00	0.04	0.25	0.04	2.98	12.85		0.139	1.90	0.878
6.00	551.	3.81	6.52		0.23	0.44	10.00	0.04	0.25	0.04	3.94	6.08		0.188	1.80	0.920
6.50	1835.	4.91	14.25		0.23	0.44	10.00	0.04	0.25	0.04	4.72	13.60		0.237	2.00	0.964
7.00	806.	2.41	6.81		0.23	0.44	10.00	0.04	0.25	0.04	2.45	6.37		0.286	1.80	1.008
7.50	1468.	3.56	10.45		0.23	0.44	10.00	0.04	0.25	0.04	3.49	9.80		0.335	1.90	1.050
8.00	1285.	2.41	9.95		0.23	0.44	10.00	0.04	0.25	0.04	2.30	9.51		0.384	1.90	1.094
8.50	2192.	2.58	6.16		0.23	0.44	10.00	0.04	0.25	0.04	2.66	5.72		0.433	1.70	1.133
9.00	5557.	7.19	24.80		0.23	0.44	10.00	0.04	0.25	0.04	6.58	24.15		0.482	2.00	1.175
9.50	938.	5.03	8.04		0.23	0.44	10.00	0.04	0.25	0.04	5.14	7.50		0.532	1.80	1.219
10.00	3875.	4.69	18.40		0.23	0.44	10.00	0.04	0.25	0.04	4.28	17.75		0.581	2.00	1.263
10.30	7443.	7.58	27.05		0.23	0.44	10.00	0.04	0.25	0.04	6.88	26.40		0.610	2.00	1.293

— END OF SOUNDING (INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL)
ODOT
JOB FILE: NOBLE CO. US 177
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY
ANAL.BY : DEAN

SNDG. NO. DMT-1
PAGE 2
FILE NO. : BRIDGE B - NORTH

SNDG.DATE: 10/27/93
ANAL.DATE: 11/5/93

ANALYSIS PARAMETERS:
SURF.ELEV. =276.56 M
WATER DEPTH = 4.08 M
SP.GR.WATER = 1.000
MAI SU ID = 0.60
UNIT CONVERSIONS:

LO RANGE =10.00 BARS
LO GAGE 0 = 0.04 BARS
HI GAGE 0 = 0.25 BARS
CAL GAGE 0 = 0.04 BARS
SU OPTION = MARCHETTI
1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI

ROD DIAM. = 3.60 CM
FR.RED.DIA. = 4.70 CM
LIN.ROD WT. = 6.50 KGF/M
DELTA/PHI = 0.50
MIN PHI ID = 1.20

BL.THICK. = 14.5 MM
BL.WIDTH = 95.6 MM
DELTA-A = 0.23 BARS
DELTA-B = 0.44 BARS
OCR OPTION= MARCHETTI
1 M = 3.2808 FT

SU FACTOR = 1.00
PHI FACTOR = 1.00
OCR FACTOR = 1.00
M FACTOR = 1.00
KO FACTOR = 1.00

Z (M)	KD	ID	UD	ED (BAR)	KO	SU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHIO (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
*****	*****	*****	*****	******	*****	*****	*****	*****	******	*****	*****	*****	******	************
0.50	59.32	3.05	0.00	517.									2166.	SILTY SAND
1.00	14.76	2.56	0.00	234.	1.54		82.7	46.7	0.31	43.9	3.15	17.7	670.	SILTY SAND
1.50	7.40	3.59	0.00	250.	0.83		60.8	44.3	0.46	41.8	1.41	5.2	559.	SAND
2.00	4.81	2.39	0.00	145.	0.65		44.8	41.4	0.60	39.1	1.08	3.0	265.	SILTY SAND
2.50	5.25	3.02	0.00	249.	0.71		55.8	41.2	0.75	39.2	1.60	3.5	483.	SILTY SAND
3.00	5.43	3.79	0.00	390.	0.72		73.1	41.6	0.91	40.0	1.99	3.6	768.	SAND
3.50	5.24	2.84	0.00	330.	0.70		82.3	41.4	1.06	40.0	2.21	3.5	637.	SILTY SAND
4.00	4.74	2.59	0.00	312.	0.65		89.2	41.2	1.22	40.0	2.15	2.9	571.	SILTY SAND
4.50	5.91	2.79	0.00	450.	0.78		107.3	41.5	1.31	40.4	3.37	4.3	915.	SILTY SAND
5.00	4.17	2.67	0.00	322.	0.67		64.1	38.4	1.35	37.3	2.41	2.9	554.	SILTY SAND
5.50	3.24	3.47	0.00	342.	0.48		75.1	41.1	1.46	40.1	1.36	1.6	520.	SAND
6.00	4.08	0.57	0.00	74.	1.00	0.49					2.79	3.0	117.	SILTY CLAY
6.50	4.65	1.98	0.00	308.	0.79		54.6	36.2	1.53	35.2	3.68	3.8	550.	SILTY SAND
7.00	2.15	1.81	0.00	136.	0.61		25.8	31.1	1.53	30.0	1.76	1.7	142.	SILTY SAND
7.50	3.00	2.00	0.00	219.	0.62		46.9	35.0	1.65	34.1	2.26	2.2	302.	SILTY SAND
8.00	1.75	3.77	0.00	250.	0.47		45.4	34.9	1.72	34.1	1.27	1.2	247.	SAND
8.50	1.97	1.37	0.00	106.	0.40		79.4	38.6	1.84	38.0	1.12	1.0	97.	SANDY SILT
9.00	5.19	2.88	0.00	610.	0.64		191.4	42.8	1.97	42.4	3.51	3.0	1174.	SILTY SAND
9.50	3.78	0.53	0.00	85.	0.94	0.59					3.29	2.7	128.	SILTY CLAY
10.00	2.93	3.64	0.00	467.	0.43		138.5	41.3	2.10	40.9	1.62	1.3	670.	SAND
10.30	4.85	3.11	0.00	677.	0.51		265.1	44.5	2.20	44.2	2.68	2.1	1268.	SILTY SAND

END OF SOUNDING

Oklahoma Department of Transportation
Materials Division–Soils & Foundations Branch
Bridge Sounding

PROJECT NO.- BRF-319(104) BORING NO: 6

COUNTY: Noble DATE: 10/5/93
STATION: 159+00 CL SURVEYED BY: Dean Sorrum & Party
ELEVATION: 936.67 EQUIPMENT:
TOTAL DEPTH: 7.5
WATER TABLE–AT END OF BORING: ____ AT 24 HRS. 3.3

REMARKS: Bridge C, S. Abut.

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	MC (%)
		CL	LEAN CLAY, dark reddish brown, roots	0.0		33	13	100	100	100	95.1	
				0.5		33	13	100	100	100	96.2	
				1.0		31	9	100	100	100	96.7	
				1.5	0	30	8	100	100	100	93.4	
		ML	SILT, yellowish red, saturated	2.0		NP	NP	100	100	100	89.7	
				2.5		NP	NP	100	100	100	90.5	
				2.8 / 3.0	4	NP / NP	NP / NP	100 / 100	100 / 100	100 / 100	95.3 / 93.9	
				3.5		NP	NP	100	100	100	95.7	
				4.0		NP	NP	100	100	100	92.9	
				4.5	0	NP	NP	100	100	100	91.5	
				5.0		NP	NP	100	100	100	98.4	
				5.5		NP	NP	100	100	100	98.5	
				5.7		NP	NP	100	100	100	98.3	
		ML	SILT with SAND, yellowish red, saturated	6.0	2	NP	NP	100	100	99	83.8	
		ML	SILT, yellowish red, saturated	6.5		NP	NP	100	100	100	94.5	
				7.0		NP	NP	100	100	100	98.0	
				7.5		NP	NP	100	100	100	98.1	

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200
		8.0	2	NP	NP	100	100	100	99.0
		8.5		NP	NP	100	100	100	82.7
ML	SILT with SAND, yellowish red	9.0		NP	NP	100	100	100	97.7
SM	SILTY SAND, yellowish red with reddish brown lenses	9.5	7	NP	NP	100	100	87	27.8
SP	POORLY-GRADED SAND with SILT, yellowish red with reddish brown lenses	10.0		NP	NP	100	100	82	12
		10.5							
SP	POORLY-GRADED SAND with SILT, reddish brown with yellowish red lenses	11.0	11	NP	NP	99	99	78	7.3
		11.5		NP	NP	100	100	83	8.3
SM	SILTY SAND, reddish brown with yellowish red lenses	12.0		NP	NP	100	100	93	21.2
SP	POORLY-GRADED SAND with SILT, light brown	12.5	16	NP	NP	100	99	72	8.0
SM	SILTY SAND, light brown with brown to strong brown lenses	12.9		NP	NP	99	99	96	21
		13.4							
		14.0	9	NP	NP	99	99	96	33.7
		14.5		NP	NP	100	100	98	29.7
		14.9 15.1		NP NP	NP	100	99	93	35.5
CH	FAT CLAY, dark reddish brown	15.5	9	50	29	100	99	97	98.9
SP	POORLY-GRADED SAND with SILT, brown	15.9		NP	NP	99	97	67	11.3
SW	WELL-GRADED SAND with SILT, brown, with dark brown CLAY lenses	16.2		NP	NP	99	95	42	10.1
		16.6							
SP	POORLY-GRADED SAND, brown	17.0	5	NP	NP	97	88	23	4.2
SP	POORLY-GRADED SAND with SILT, brown	17.5		NP	NP	91	80	27	5.2

USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200
		18.0							
		18.5	5	NP	NP	81	76	66	8.1
		18.8		NP	NP	100	98	67	8.4
SM	SILTY SAND, brown	19.3		NP	NP	99	94	69	10.5
		19.6							
SP	POORLY-GRADED SAND with SILT, brown	20.0	11	NP	NP	95	91	55	9.5
		20.5		NP	NP	99	91	27	7.0
		21.1							
		21.5	7	NP	NP	97	91	25	7.4
		22.0		NP	NP	97	88	22	7.5
		22.5							
		23.0	6	NP	NP	88	74	21	5.4
		23.5		NP	NP	100	95	25	5.5
		24.0							
		24.5	9	28	10	87	69	14	6.4
SC	CLAYEY SAND, gray	24.9		40	23	96	87	58	46.9
SP	POORLY-GRADED SAND, brown to grayish brown	25.2		NP	NP	99	95	45	4.0
SP	POORLY-GRADED SAND, grayish brown	25.7							
		26.0	14	NP	NP	88	74	15	5.3
		26.5		NP	NP	100	96	18	4.2
		27.1							
SC	CLAYEY SAND, dark grayish brown	27.5	15	30	16	92	88	72	49.1
		27.7		NP	NP	99	89	33	5.2

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
								#4	#10	#40	#200
		SP	POORLY-GRADED SAND with SILT, dark grayish brown	28.2							
		SP	POORLY-GRADED SAND with SILT, grayish brown								
		SP	POORLY-GRADED SAND, grayish brown	29.0	12	NP	NP	95	84	24	3.5
				29.5		NP	NP	99	93	28	2.7
				30.1							
		SP	POORLY-GRADED SAND, grayish brown, with CLAY lenses	30.5	14	NP	NP	69	61	15	3.9
		SP	POORLY-GRADED SAND with SILT, grayish brown	31.0		NP	NP	99	97	41	5.8
				31.5		NP	NP	93	89	32	5.7
		SP	POORLY-GRADED SAND, grayish brown with traces of yellowish red	31.9 32.0	22	NP	NP	92	74	12	2.9
				32.5		NP	NP	99	96	40	3.6
				33.0		NP	NP	98	85	22	4.1
		SP	POORLY-GRADED SAND with SILT, grayish brown	33.4 33.5	13	NP	NP	96	79	19	5.8
				34.0		NP	NP	97	76	15	4.9
				34.5							
		SP	POORLY-GRADED SAND, grayish brown	35.0	8	NP	NP	95	82	16	3.5
		SP	POORLY-GRADED SAND with SILT, grayish brown, with CLAY lense	35.5		NP	NP	95	83	13	5.5
		SP	POORLY-GRADED SAND with SILT, grayish brown	36.0		NP	NP	93	95	15	4.3
		SP	POORLY-GRADED SAND, grayish brown	36.3 36.5	8	NP	NP	87	72	12	4.1
		SP	POORLY-GRADED SAND with SILT, grayish brown	37.0		NP	NP	92	74	15	5.6
				37.5							

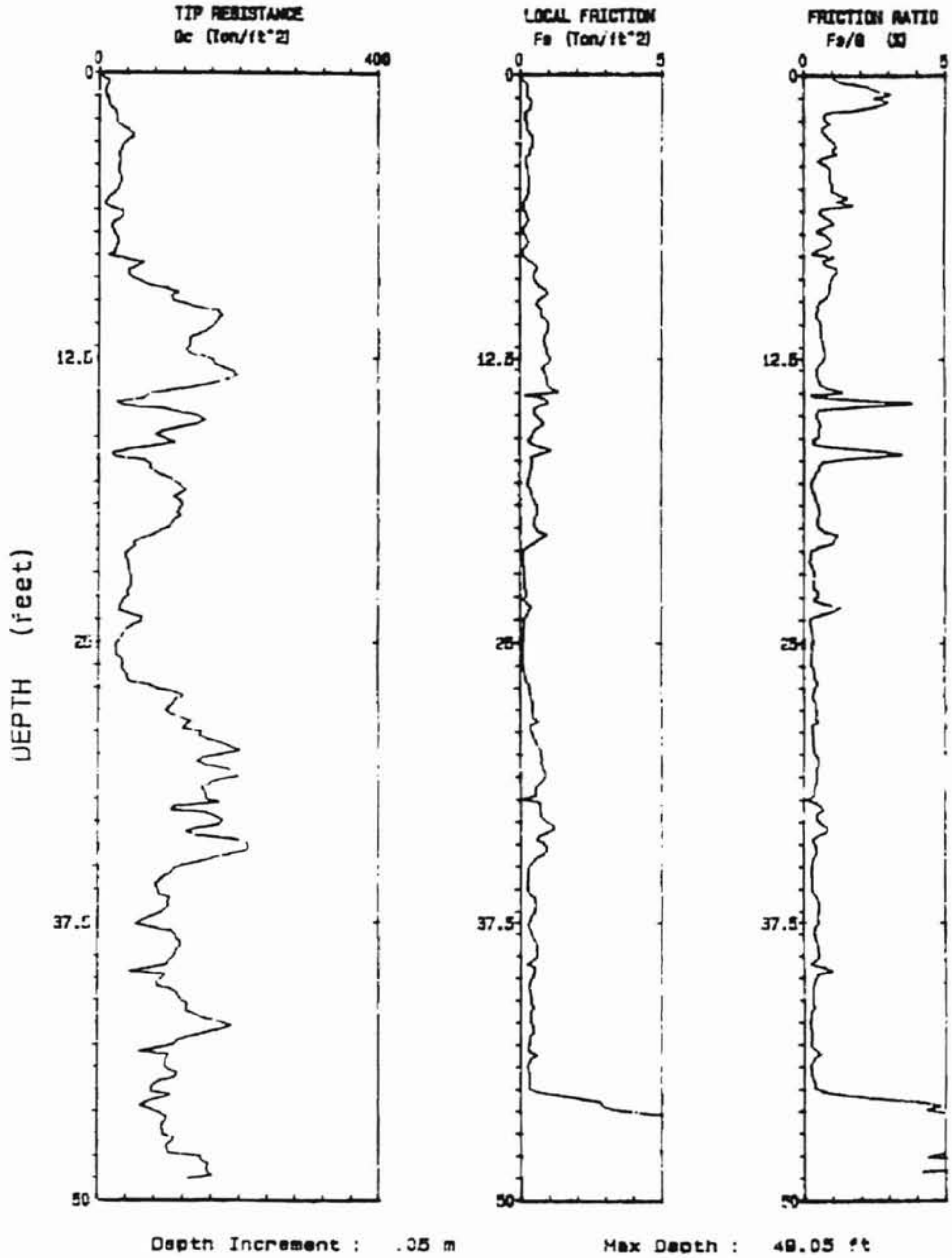
USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	#10	#40	#200
SP	POORLY-GRADED SAND, grayish brown	38.0	6	22	8	88	64	10	4.6
		38.5		NP	NP	94	75	11	3.8
SP	POORLY-GRADED SAND, brown	39.0							
		39.5	7	NP	NP	92	80	22	4.1
		40.0		NP	NP	87	68	17	4.1
		40.5		NP	NP	95	87	29	4.8
		40.8 41.0	6	NP	NP	77	68	16	3.6
SP	POORLY-GRADED SAND with SILT, brown	41.5		NP	NP	83	66	17	6.4
CL	LEAN CLAY, blocky, dark reddish brown with light and pinkish gray seams	42.0		40	22	100	99	96	95.2
CL	SHALE (LEAN CLAY), blocky, dark reddish brown with light and pinkish gray seams	42.4 42.5	4	44	19	99	95	90	88.2
		43.0		42	18	100	98	95	93.0
		43.5		41	17	100	97	95	93.6
CL	SHALE (LEAN CLAY with SAND)	44.0	59	42	32	66	88	76	73.4
		44.5		41	18	100	100	99	97.8
	Core 1 42.5-47.5, RQD=96.0	45.0		44	21	100	100	99	97.9
SC	CLAYEY SANDSTONE (CLAYEY SAND), dark reddish brown	45.5	73	42	21	56	55	48	44.6
CL	SHALE (LEAN CLAY), dark reddish brown	46.0		43	20	100	99	98	96.5
		46.5		42	21	100	100	99	98.1
	SHALE	46.9	25, 452 (17/8")						

	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING				
							# 4	# 10	# 40	# 200	
		Core 2, 47.5-52.5, RQD=30.2 Core 3, 52.5-57.5, RQD=76.4									

Oklahoma DOT

Operator : DEAN
Sounding : 3 Pg 1 / 1
Cone Used : 252

CPT Date : 08/29/93 16:10
Location : US177 SOUTH C
Job No. : CPT-5



Depth Increment : .05 m   Max Depth : 49.05 ft

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DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL)      SNDG. NO. DMT-1
FDOT                                                                                 PAGE 1
JOB FILE: NOBLE, US 1?7                                                              FILE NO. : BRIDGE C-SOUTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY                                                    SNDG.DATE: 10/13/93
ANAL.BY : DEAN                                                                       ANAL.DATE: 10/23/93

ANALYSIS PARAMETERS:    LO RANGE     =10.00 BARS    ROD DIAM.     = 3.60 CM       BL.THICK. = 14.5 MM    SU  FACTOR = 1.00
 SURF.ELEV.  =276.36 M  LO  GAGE 0 = 0.03 BARS     FR.RED.DIA. = 4.70 CM       BL.WIDTH  = 95.6 MM    PHI FACTOR = 1.00
 WATER DEPTH =  2.00 M  HI  GAGE 0 = 0.25 BARS     LIN.ROD WT. = 6.50 KGF/M    DELTA-A   = 0.18 BARS OCR FACTOR = 1.00
 SP.GR.WATER = 1.000    CAL GAGE 0 = 0.03 BARS     DELTA/PHI   = 0.50          DELTA-B   = 0.56 BARS M   FACTOR = 1.00
 MAX SU ID   = 1.20     SU OPTION  = MARCHETTI     MIN PHI ID  = 0.10          OCR OPTION= MARCHETTI  K0  FACTOR = 1.00
UNIT CONVERSIONS:       1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI     1 M = 3.2808 FT
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Z (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
0.50	734.	0.88	3.65		0.18	0.56	10.00	0.03	0.25	0.03	0.96	3.09		0.000	1.70	0.082
1.00	967.	1.12	4.62		0.18	0.56	10.00	0.03	0.25	0.03	1.16	4.95		0.000	1.80	0.168
1.50	755.	1.01	3.92		0.18	0.56	10.00	0.03	0.25	0.03	1.08	3.36		0.000	1.70	0.254
2.00	1142.	1.91	6.99		0.18	0.56	10.00	0.03	0.25	0.03	1.77	6.43		0.000	1.80	0.340
2.50	1387.	1.72	8.70		0.18	0.56	10.00	0.03	0.25	0.03	1.59	8.14		0.049	1.80	0.379
3.00	2519.	3.66	15.50		0.18	0.56	10.00	0.03	0.25	0.03	3.32	14.72		0.098	1.90	0.421
3.50	5333.	7.35	24.50		0.18	0.56	10.00	0.03	0.25	0.03	6.70	23.72		0.147	2.00	0.468
4.00	5947.	8.22	23.40		0.18	0.56	10.00	0.03	0.25	0.03	7.69	22.62		0.196	2.00	0.517
4.50	3059.	5.95	16.20		0.18	0.56	10.00	0.03	0.25	0.03	5.57	15.62		0.245	2.00	0.566
5.00	1193.	2.33	4.47		0.18	0.56	10.00	0.03	0.25	0.03	2.44	3.71		0.294	1.70	0.607
5.50	2090.	2.71	11.10		0.18	0.56	10.00	0.03	0.25	0.03	2.52	10.32		0.343	1.70	0.647
6.00	1388.	3.12	10.60		0.18	0.56	10.00	0.03	0.25	0.03	2.97	9.62		0.393	1.70	0.691
6.50	2243.	2.25	12.25		0.18	0.56	10.00	0.03	0.25	0.03	1.78	11.47		0.442	1.70	0.735
7.00	1550.	2.64	11.75		0.18	0.56	10.00	0.03	0.25	0.03	2.40	11.17		0.491	1.70	0.779
7.50	1509.	4.45	14.10		0.18	0.56	10.00	0.03	0.25	0.03	4.17	13.32		0.540	1.90	0.823
8.00	1191.	2.83	10.10		0.18	0.56	10.00	0.03	0.25	0.03	2.69	9.32		0.589	1.90	0.868
8.50	4486.	6.16	19.40		0.18	0.56	10.00	0.03	0.25	0.03	5.75	18.62		0.638	2.00	0.914
9.00	5200.	6.21	21.60		0.18	0.56	10.00	0.03	0.25	0.03	5.67	20.82		0.687	2.00	0.963
9.50	6016.	6.52	20.90		0.18	0.56	10.00	0.03	0.25	0.03	6.03	20.12		0.736	2.00	1.012
10.00	4496.	6.58	20.30		0.18	0.56	10.00	0.03	0.25	0.03	6.12	19.52		0.785	2.00	1.061
10.50	5914.	7.37	22.80		0.18	0.56	10.00	0.03	0.25	0.03	6.85	22.02		0.834	2.00	1.110
11.00	4792.	5.71	19.95		0.18	0.56	10.00	0.03	0.25	0.03	5.28	19.17		0.883	2.00	1.159
11.50	2090.	4.30	13.20		0.18	0.56	10.00	0.03	0.25	0.03	4.08	12.42		0.932	1.70	1.206
12.00	3263.	5.05	15.60		0.18	0.56	10.00	0.03	0.25	0.03	4.75	14.82		0.981	1.90	1.250
12.50	3726.	6.05	16.50		0.18	0.56	10.00	0.03	0.25	0.03	5.76	15.72		1.030	2.00	1.297
13.00	2355.	4.28	13.95		0.18	0.56	10.00	0.03	0.25	0.03	4.02	13.17		1.079	1.90	1.343
13.50	1622.	4.38	12.10		0.18	0.56	10.00	0.03	0.25	0.03	4.22	11.32		1.128	1.70	1.388
14.00	2345.	4.31	15.05		0.19	0.56	10.00	0.03	0.25	0.03	4.00	14.27		1.176	1.90	1.432
14.50	4396.	5.91	17.30		0.19	0.56	10.00	0.03	0.25	0.03	5.52	16.52		1.227	2.00	1.478
15.00	4191.	6.08	19.00		0.18	0.56	10.00	0.03	0.25	0.03	5.50	18.22		1.276	2.00	1.527
15.50	4434.	5.47	19.40		0.19	0.56	10.00	0.03	0.25	0.03	5.05	18.62		1.325	2.00	1.577
16.00	4588.	[illegible]	30.90		0.18	0.56	10.00	0.03	0.25	0.03	17.55	30.12		1.374	2.10	1.628
16.50	5730.	19.10	43.20		0.19	0.56	10.00	0.03	0.25	0.03	17.97	42.42		1.423	2.10	1.682

END OF SOUNDING (INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

Z (M)	KD	ID	UD	ED (BAR)	K0	CU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHIO (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
0.50	11.65	2.22	0.00	74.	1.22		24.2	46.1	0.14	42.2	0.93	11.2	195.	SILTY SAND
1.00	5.90	2.49	0.00	101.	1.84		29.0	43.0	0.28	39.7	0.86	5.1	218.	SILTY SAND
1.50	4.26	2.11	0.00	79.	1.63		25.5	40.3	0.42	37.3	0.67	2.6	135.	SILTY SAND
2.00	5.20	2.64	0.00	162.	1.73		37.5	40.5	0.56	38.0	1.24	3.7	310.	SILTY SAND
2.50	4.06	4.26	0.00	227.	1.54		48.4	41.9	0.63	39.7	0.79	2.1	390.	SAND
3.00	7.65	3.54	0.00	396.	2.31		34.0	43.3	0.71	41.3	2.57	5.1	597.	SAND
3.50	14.01	2.60	0.00	591.	3.58		176.4	45.0	0.80	43.4	8.55	18.3	1665.	SILTY SAND
4.00	14.50	1.79	0.00	518.	3.71		160.6	43.8	0.87	42.2	10.86	21.0	1478.	SILTY SAND
4.50	7.42	1.96	0.00	363.	2.20		95.1	41.7	0.94	40.1	5.74	10.1	336.	SILTY SAND
5.00	3.53	0.67	0.00	51.	1.63	0.27	35.7	37.4	0.98	35.6	1.45	2.4	73.	CLAYEY SILT
5.50	3.36	3.37	0.00	271.	1.48		74.0	41.4	1.07	40.0	1.03	1.6	421.	SAND
6.00	3.74	2.65	0.00	235.	1.57		68.2	40.2	1.14	38.9	1.48	2.1	385.	SILTY SAND
6.50	3.09	4.18	0.00	327.	1.39		83.7	42.0	1.23	40.8	0.48	0.7	376.	SAND
7.00	2.45	4.59	0.00	304.	1.47		54.8	38.4	1.26	37.2	1.04	1.3	389.	SAND
7.50	4.41	2.52	0.00	317.	1.76		45.7	36.1	1.31	34.8	2.91	3.5	550.	SILTY SAND
8.00	2.13	3.15	0.00	230.	1.35		37.0	34.9	1.36	33.6	1.44	1.7	292.	SILTY SAND
8.50	5.59	2.52	0.00	447.	1.68		153.7	42.9	1.54	42.1	3.13	3.4	593.	SILTY SAND
9.00	5.17	3.04	0.00	526.	1.59		182.6	43.8	1.63	43.1	2.53	2.6	1013.	SILTY SAND
9.50	5.23	2.66	0.00	489.	1.56		213.2	44.4	1.72	43.8	2.47	2.4	940.	SILTY SAND
10.00	5.03	2.51	0.00	455.	1.65		153.4	42.2	1.77	41.5	3.20	3.0	874.	SILTY SAND
10.50	5.42	2.52	0.00	526.	1.53		205.7	43.5	1.88	43.0	3.32	3.0	1026.	SILTY SAND
11.00	4.65	2.39	0.00	447.	1.60		165.5	42.2	1.94	41.7	3.00	2.5	907.	SILTY SAND
11.50	2.61	2.65	0.00	289.	1.52		71.8	37.2	1.94	36.6	1.92	1.6	377.	SILTY SAND
12.00	3.01	2.67	0.00	349.	1.49		114.5	40.0	2.05	37.6	1.94	1.6	501.	SILTY SAND
12.50	3.64	2.11	0.00	346.	1.54		135.8	40.6	2.14	40.3	2.56	2.0	541.	SILTY SAND
13.00	2.19	3.11	0.00	317.	1.42		103.1	37.1	2.19	39.8	1.44	1.1	375.	SILTY SAND
13.50	3.23	2.29	0.00	246.	1.54		57.2	34.7	2.18	34.3	2.12	1.5	378.	SILTY SAND
14.00	1.77	3.64	0.00	356.	1.44		34.2	37.4	2.30	37.1	1.59	1.1	328.	SAND
14.50	3.56	2.27	0.00	416.	1.50		175.6	41.5	2.46	41.3	2.59	1.3	549.	SILTY SAND
15.00	3.42	2.24	0.00	407.	1.53		144.4	40.0	2.51	39.9	2.88	[illegible]	[illegible]	SILTY SAND
15.50	[illegible]	2.66	0.00	436.	1.44		175.0	41.3	2.62	41.2	3.09	1.3	[illegible]	SILTY SAND
16.00	[illegible]	[illegible]	0.00	435.	1.43	[illegible]	112.9	36.0	2.59	35.7	22.73	19.0	97.	CLAYEY SILT
16.50	[illegible]	[illegible]	0.00	851.	1.23		189.6	37.1	2.74	37.1	20.50	12.2	[illegible]	SANDY SILT

END OF SOUNDING

Oklahoma Department of Transportation
Materials Division–Soils & Foundations Branch
Bridge Sounding

...ECT NO.- BRF-319(104) BORING NO: 3

COUNTY: Noble DATE: 8/19/93
STATION: 194+40 C.L. SURVEYED BY: Sooner & Party
ELEVATION: 905.52 EQUIPMENT: CME-75, mud rotary, 3 1/2" S.D. bit
TOTAL DEPTH: 53.0
WATER TABLE - AT END OF BORING: ____ AT 24 HRS. 2.8

REMARKS: Bridge 'C'

DEPTH	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	MC (%)
0.0	CL	LEAN CLAY	0.0		31	9	100	100	99	91.1	
	ML	SILT	0.4		NP	NP	100	100	100	94.8	
			0.9		NP	NP	100	100	100	94.3	
			1.3		NP	NP	100	100	100	97.5	
			1.5	11	NP	NP	100	100	100	90.2	
			2.0		NP	NP	100	100	100	94.4	
			2.5		NP	NP	100	100	100	87.6	25.1
			2.7		NP	NP	100	100	100	92.4	
	CL	LEAN CLAY	3.0	5	30	8	100	100	100	97.8	
	ML	SILT	3.5		NP	NP	100	100	100	97.5	
			4.0		NP	NP	100	99	99	97.6	
			4.2		NP	NP	100	100	100	98.8	
			4.5	4	NP	NP	100	100	100	98.5	
5.0			5.0		NP	NP	100	100	100	88.3	
			5.5		NP	NP	100	100	100	91.7	
	CL	LEAN CLAY	6.0	5	29	10	100	100	99	98.8	
	SM	SILTY SAND	6.5		NP	NP	99	99	99	46.4	
	CL	LEAN CLAY	7.0		46	28	100	100	100	99.4	32.3
	ML	SILT	7.5	4	NP	NP	100	100	100	98.2	
8.0											

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							#4	#10	#40	#200
			8.0		NP	NP	100	100	100	99.1
			9.0	5	NP	NP	100	100	100	97.8
	ML	SILT with SAND	9.5		NP	NP	100	100	100	74.7
	ML	SILT	10.0		NP	NP	100	100	100	98.5
			10.5	0	NP	NP	100	100	99	92.3
			10.7		NP	NP	100	100	99	95.9
	ML	SILT with SAND	11.4		NP	NP	100	100	99	81.0
	SM	SILTY SAND	11.9		NP	NP	100	100	90	12.9
	SP	POORLY-GRADED SAND with SILT	12.5	7	NP	NP	100	100	95	10.2
	SM	SILTY SAND	13.0		NP	NP	100	100	88	21.9
			14.0	3	NP	NP	100	99	75	36.8
	ML	SANDY SILT	14.5		NP	NP	100	100	94	65.6
	SP	POORLY-GRADED SAND with SILT	15.5	1	NP	NP	100	100	55	9.9
			16.0		NP	NP	100	100	72	5.3
			16.5		NP	NP	100	100	75	7.3
			17.0	6	NP	NP	100	100	97	10.9
	SM	SILTY SAND	17.5		NP	NP	100	100	100	12.6

DEPTH	LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING #4	% PASSING #10	% PASSING #40	% PASSING #200	
		SP	POORLY-GRADED SAND with SILT	18.5	9	NP	NP	100	100	99	9.8	
				19.0		NP	NP	100	100	100	12.0	
		SM	SILTY SAND	19.5		NP	NP	100	99	95	14.0	
				20.0	7	NP	NP	95	81	47	13.8	
		SW	WELL-GRADED SAND	20.3		NP	NP	99	90	36	7.2	
		SP	POORLY-GRADED SAND	21.5	6	NP	NP	99	91	23	4.2	
				22.0		NP	NP	97	89	25	3.3	
		SW	WELL-GRADED SAND with SILT	23.0	4	NP	NP	100	95	34	11.6	
		SP	POORLY-GRADED SAND with SILT	23.4		NP	NP	99	94	27	8.9	
				24.5	9	NP	NP	100	99	27	5.2	
		CH	SANDY FAT CLAY	24.9		55	39	98	92	62	57.5	32.0
		CL	SANDY LEAN CLAY	25.3		43	25	100	94	78	69.9	22.5
		CH	FAT CLAY	26.0	0	70	42	100	99	91	90.0	51.4
		CH	SANDY FAT CLAY	26.4		61	36	99	99	70	51.0	47.1
		SP	POORLY-GRADED SAND	26.8		NP	NP	93	85	30	2.7	
				27.5	9	NP	NP	96	86	21	0.6	
				27.9		NP	NP	98	90	28	4.8	

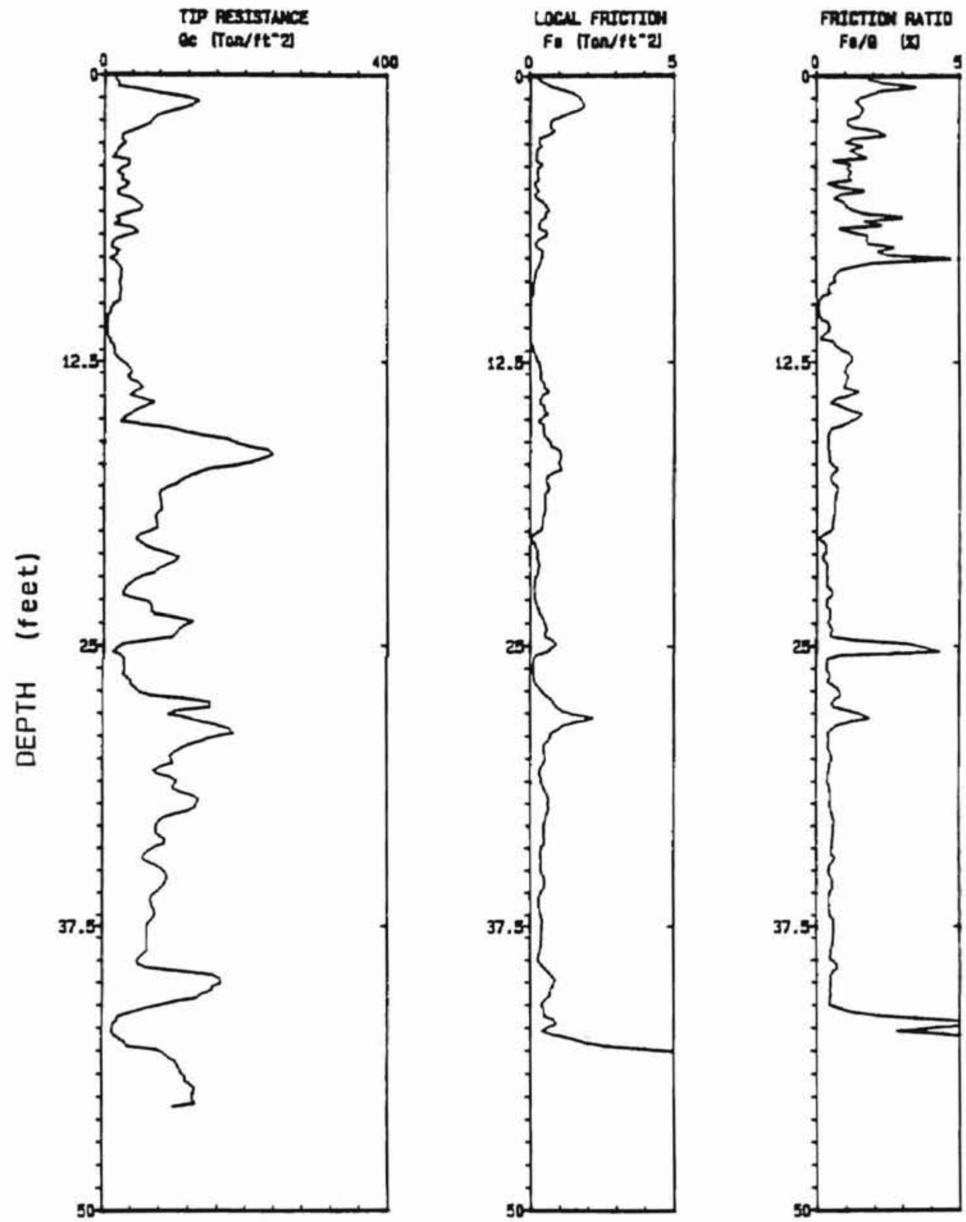
LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							#4	#10	#40	#200
			28.4		NP	NP	100	93	26	3.5
			29.0	12	NP	NP	100	99	31	5.5
			29.4		NP	NP	94	91	15	3.3
			30.5	12	NP	NP	98	96	20	3.6
			31.0		NP	NP	97	87	14	3.3
			32.0	12	NP	NP	89	82	16	3.2
			32.5		NP	NP	94	86	15	4.0
	SP	POORLY-GRADED SAND with SILT	33.5	11	NP	NP	96	77	16	5.8
	SP	POORLY-GRADED SAND	34.0		NP	NP	87	62	8	3.5
			35.0	7	NP	NP	98	90	22	2.5
	SW	WELL-GRADED SAND	35.5		NP	NP	69	53	14	3.9
	SP	POORLY-GRADED SAND with SILT	36.0		NP	NP	99	92	17	5.3
			36.5	5	NP	NP	96	86	18	5.7
	SP	POORLY-GRADED SAND	37.0		NP	NP	94	66	11	4.2
	SP	POORLY-GRADED SAND with SILT	37.5		NP	NP	97	81	13	5.1

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING				
							# 4	# 10	# 40	# 200	
		Core 2, 47.0-52.0 ft, RQD=83.2									
		Core 2, 52.0-57.0 ft, RQD=57.6									

LEGEND	USCS	DESCRIPTION OF MATERIAL	DEPTH	SPT(N)	LL	PI	% PASSING			
							# 4	# 10	# 40	# 200
		Core 4, 57.0-62.0 ft, RQD=46.0								

Oklahoma DOT

Operator : DEAN | CPT Date : 10/12/93 13:28
Sounding : 21 Pg 1 / 1 | Location : US 177 NORTH C
Cone Used : 399 | Job No. : CPT-5



Depth Increment : .05 m | Max Depth : 45.44 ft

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. DMT-1
ODOT PAGE 2
JOB FILE: NOBLE CO. US 177 FILE NO. : BRIDGE C - NORTH
LOCATION: NEAR CPT-5
SNDG.BY : DEAN, SESSIONS, & PARTY SNDG.DATE: 10/27/93
ANAL.BY : DEAN ANAL.DATE: 11/5/93

ANALYSIS PARAMETERS:			
SURF.ELEV. = 0.00 M	LO RANGE =10.00 BARS	ROD DIAM. = 3.60 CM	BL.THICK. = 14.5 MM	SU FACTOR = 1.00
WATER DEPTH = 1.00 M	LO GAGE 0 = 0.04 BARS	FR.RED.DIA. = 4.70 CM	BL.WIDTH = 95.6 MM	PHI FACTOR = 1.00
SP.GR.WATER = 1.000	HI GAGE 0 = 0.25 BARS	LIN.ROD WT. = 6.50 KGF/M	DELTA-A = 0.27 BARS	OCR FACTOR = 1.00
MAX SU ID = 1.20	CAL GAGE 0 = 0.04 BARS	DELTA/PHI = 0.50	DELTA-B = 0.38 BARS	M FACTOR = 1.00
	SU OPTION = MARCHETTI	MIN PHI ID = 0.10	OCR OPTION= MARCHETTI	KO FACTOR = 1.00

UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	KD	ID	UD	ED (BAR)	KO	SU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHID (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
0.50	33.64	2.45	0.00	234.									855.	SILTY SAND
1.00	14.54	0.63	0.00	54.	1.85	0.45	27.7	40.6	0.28	37.0	4.15	24.4	154.	CLAYEY SILT
1.50	10.91	1.57	0.00	122.	1.40		31.8	41.0	0.34	37.7	2.83	13.8	314.	SANDY SILT
2.00	6.53	0.65	0.00	35.	0.95	0.23	21.0	38.7	0.38	35.4	1.42	6.0	72.	CLAYEY SILT
2.50	6.16	0.46	0.00	26.	0.87	0.24	27.8	39.8	0.44	36.8	1.36	5.1	52.	SILTY CLAY
3.00	4.67	2.39	0.00	117.	0.60		42.9	42.3	0.50	39.8	0.78	2.6	211.	SILTY SAND
3.50	2.86	1.25	0.00	42.	0.61		14.2	34.7	0.53	31.7	0.69	2.1	53.	SANDY SILT
4.00	3.44	3.60	0.00	158.	0.49		42.9	41.5	0.61	39.2	0.60	1.6	249.	SAND
4.50	7.11	3.06	0.00	310.	0.87		75.1	42.9	0.69	40.9	2.25	5.5	684.	SILTY SAND
5.00	14.08	2.99	0.00	669.	1.69		126.5	43.3	0.77	41.4	9.34	20.4	1889.	SILTY SAND
5.50	7.56	2.30	0.00	304.	0.93		90.9	42.6	0.85	40.9	3.17	6.3	682.	SILTY SAND
6.00	6.20	2.24	0.00	265.	0.86		63.7	40.4	0.90	38.7	2.75	5.0	545.	SILTY SAND
6.50	4.69	2.73	0.00	263.	0.64		74.9	41.5	0.98	39.9	1.68	2.6	482.	SILTY SAND
7.00	3.30	3.60	0.00	263.	0.58		45.3	36.2	1.03	35.6	1.31	2.1	404.	SAND
7.50	5.62	2.84	0.00	376.	0.73		99.8	42.0	1.14	40.7	2.55	3.7	750.	SILTY SAND
8.00	3.73	2.10	0.00	197.	0.69		37.2	35.8	1.15	34.3	2.03	2.8	313.	SILTY SAND
8.50	4.58	3.99	0.00	489.	0.49		149.7	44.2	1.31	43.2	1.47	1.9	891.	SAND
9.00	4.98	3.63	0.00	515.	0.52		175.0	44.6	1.40	43.7	1.74	2.1	976.	SAND
9.50	2.95	5.02	0.00	445.	0.31		143.5	44.1	1.47	43.2	0.65	0.8	640.	SAND
10.00	5.12	3.09	0.00	501.	0.61		160.3	43.3	1.54	42.5	2.51	2.7	962.	SILTY SAND
10.50	3.11	3.25	0.00	336.	0.47		101.5	40.9	1.59	40.1	1.42	1.5	500.	SILTY SAND
11.00	2.19	3.78	0.00	289.	0.42		73.7	38.8	1.63	38.0	1.11	1.1	341.	SAND
11.50	1.86	4.30	0.00	291.	0.35		89.2	40.0	1.72	39.3	0.81	0.8	302.	SAND
12.00	3.08	3.35	0.00	391.	0.47		112.2	40.7	1.81	40.1	1.62	1.5	577.	SAND
12.50	2.15	3.41	0.00	289.	0.35		113.1	41.0	1.88	40.4	0.94	0.8	337.	SAND
13.00	3.58	2.62	0.00	385.	0.54		120.2	40.5	1.95	39.9	2.31	1.9	509.	SILTY SAND
13.50	3.47	3.23	0.00	479.	0.42		188.1	43.2	2.08	42.8	1.59	1.3	757.	SILTY SAND
14.00	8.51	2.50	0.00	947.	1.21		113.1	37.9	2.08	37.5	12.67	9.9	2230.	SILTY SAND
14.50	2.45	1.03	0.00	116.	0.62	0.38	27.8	31.8	2.04	31.2	2.57	1.9	128.	SILT
15.00	13.20	1.24	0.00	785.	1.76		153.9	38.3	2.23	38.0	30.36	22.0	2169.	SANDY SILT
15.50	13.14	1.55	0.00	1015.	1.75		168.4	38.6	2.33	38.3	30.97	21.6	2799.	SANDY SILT
15.70	12.16	1.44	0.00	884.	1.59		207.9	39.9	2.39	39.7	35.85	17.8	2373.	SANDY SILT

END OF SOUNDING

Z (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
0.50	2090.	2.81	10.10		0.27	0.38	10.00	0.04	0.25	0.04	2.76	9.51		0.000	1.90	0.082
1.00	999.	2.28	4.41		0.27	0.38	10.00	0.04	0.25	0.04	2.48	4.03		0.000	1.70	0.170
1.50	1071.	2.18	6.17		0.27	0.38	10.00	0.04	0.25	0.04	2.28	5.77		0.049	1.70	0.205
2.00	693.	1.42	3.03		0.27	0.38	10.00	0.04	0.25	0.04	1.64	2.65		0.098	1.60	0.237
2.50	877.	1.55	2.91		0.27	0.38	10.00	0.04	0.25	0.04	1.78	2.53		0.147	1.60	0.266
3.00	1234.	1.49	5.34		0.27	0.38	10.00	0.04	0.25	0.04	1.60	4.96		0.196	1.80	0.300
3.50	428.	0.99	2.78		0.27	0.38	10.00	0.04	0.25	0.04	1.20	2.40		0.245	1.60	0.335
4.00	1293.	1.51	6.51		0.27	0.38	10.00	0.04	0.25	0.04	1.56	6.13		0.294	1.80	0.369
4.50	2243.	3.42	12.80		0.27	0.38	10.00	0.04	0.25	0.04	3.26	12.21		0.343	1.90	0.411
5.00	4028.	7.48	26.70		0.27	0.38	10.00	0.04	0.25	0.04	6.83	26.11		0.393	2.00	0.457
5.50	2753.	4.40	13.60		0.27	0.38	10.00	0.04	0.25	0.04	4.25	13.01		0.442	1.90	0.504
6.00	1988.	3.98	12.10		0.27	0.38	10.00	0.04	0.25	0.04	3.89	11.51		0.491	1.90	0.548
6.50	2192.	3.41	11.50		0.27	0.38	10.00	0.04	0.25	0.04	3.32	10.91		0.540	1.90	0.592
7.00	1336.	2.78	10.85		0.27	0.38	10.00	0.04	0.25	0.04	2.69	10.26		0.589	1.90	0.636
7.50	2957.	4.71	15.90		0.27	0.38	10.00	0.04	0.25	0.04	4.46	15.31		0.638	1.90	0.681
8.00	1183.	3.39	9.45		0.27	0.38	10.00	0.04	0.25	0.04	3.39	9.07		0.687	1.90	0.725
8.50	4181.	4.67	18.95		0.27	0.38	10.00	0.04	0.25	0.04	4.27	18.36		0.736	2.00	0.771
9.00	4894.	5.31	20.30		0.27	0.38	10.00	0.04	0.25	0.04	4.87	19.71		0.785	2.00	0.820
9.50	3875.	3.73	16.80		0.27	0.38	10.00	0.04	0.25	0.04	3.39	16.21		0.834	1.90	0.867
10.00	4588.	5.98	20.60		0.27	0.38	10.00	0.04	0.25	0.04	5.56	20.01		0.883	2.00	0.914
10.50	2855.	4.11	14.20		0.27	0.38	10.00	0.04	0.25	0.04	3.92	13.61		0.932	1.90	0.960
11.00	2039.	3.31	12.10		0.27	0.38	10.00	0.04	0.25	0.04	3.18	11.51		0.981	1.90	1.004
11.50	2396.	3.11	11.95		0.27	0.38	10.00	0.04	0.25	0.04	2.98	11.36		1.030	1.90	1.049
12.00	3161.	4.71	16.30		0.27	0.38	10.00	0.04	0.25	0.04	4.44	15.71		1.079	1.90	1.093
12.50	3059.	3.70	12.50		0.27	0.38	10.00	0.04	0.25	0.04	3.57	11.91		1.129	1.90	1.137
13.00	3467.	5.67	17.10		0.27	0.38	10.00	0.04	0.25	0.04	5.41	16.51		1.178	2.00	1.184
13.50	5200.	5.89	19.90		0.27	0.38	10.00	0.04	0.25	0.04	5.50	19.31		1.227	2.00	1.233
14.00	4079.	13.45	40.10		0.27	0.38	10.00	0.04	0.25	0.04	12.21	39.51		1.276	2.15	1.285
14.50	1183.	4.48	8.32		0.27	0.38	10.00	0.04	0.25	0.04	4.59	7.74		1.325	1.90	1.333
15.00	6016.	20.60	42.80		0.27	0.38	10.00	0.04	0.25	0.04	19.58	42.21		1.374	2.10	1.380
15.50	5475.	21.60	50.10		0.27	0.38	10.00	0.04	0.25	0.04	20.27	49.51		1.423	2.10	1.434
15.70	7392.	20.30	45.20		0.27	0.38	10.00	0.04	0.25	0.04	19.15	44.61		1.443	2.10	1.455

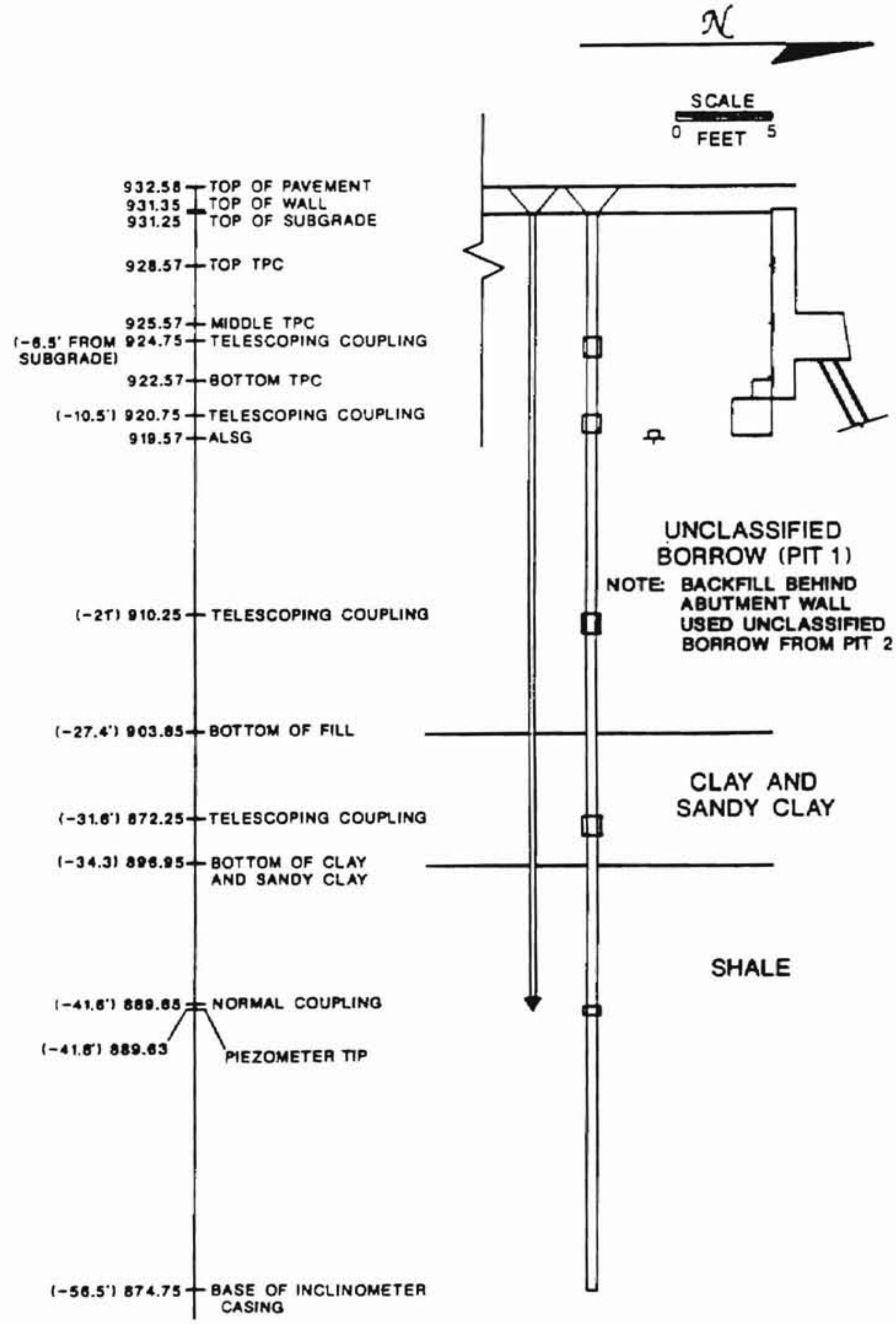
END OF SOUNDING

(INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

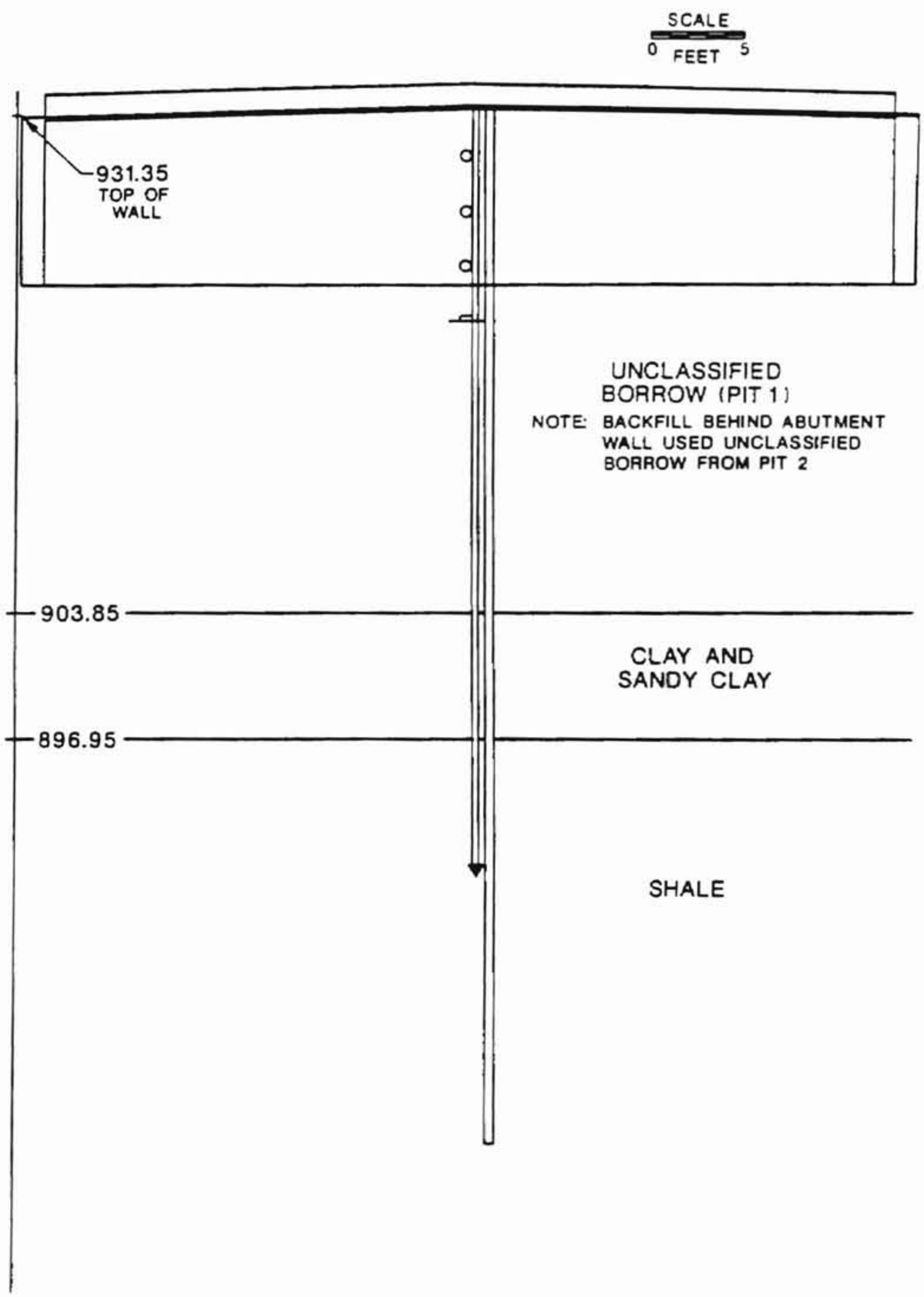
APPENDIX B

INSTRUMENTATION LOCATIONS

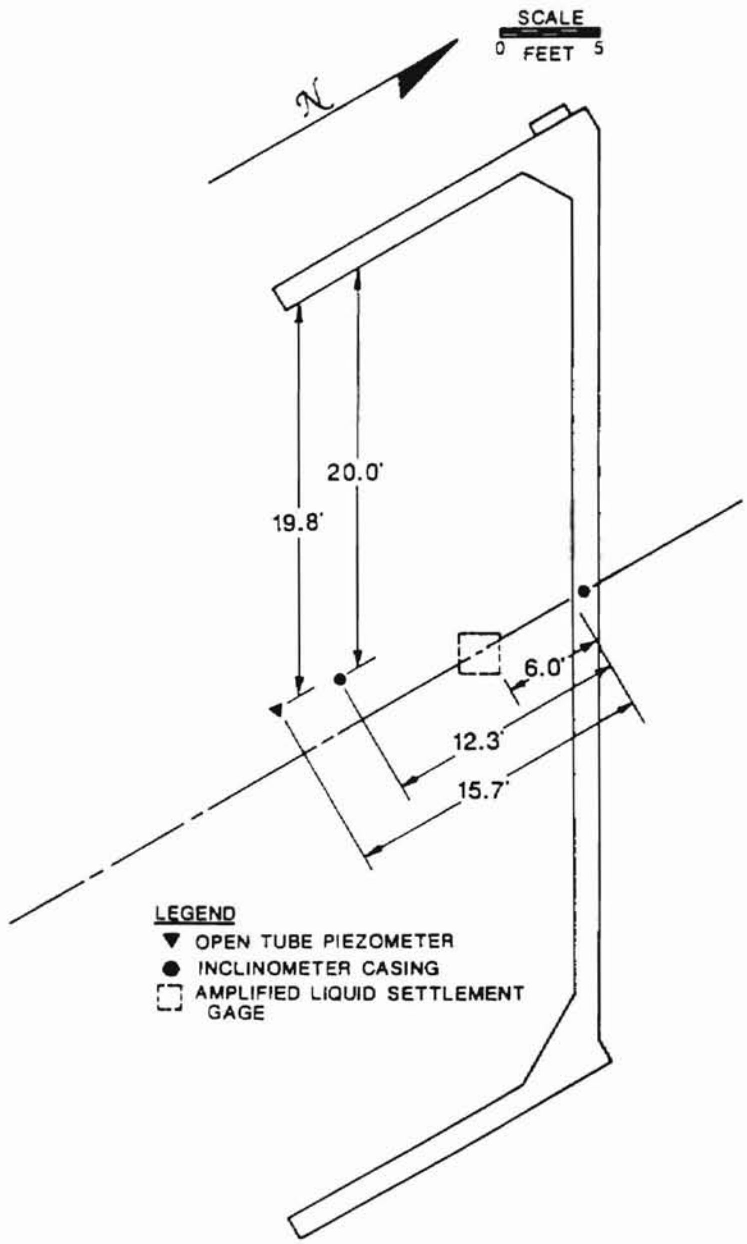
AS-BUILT



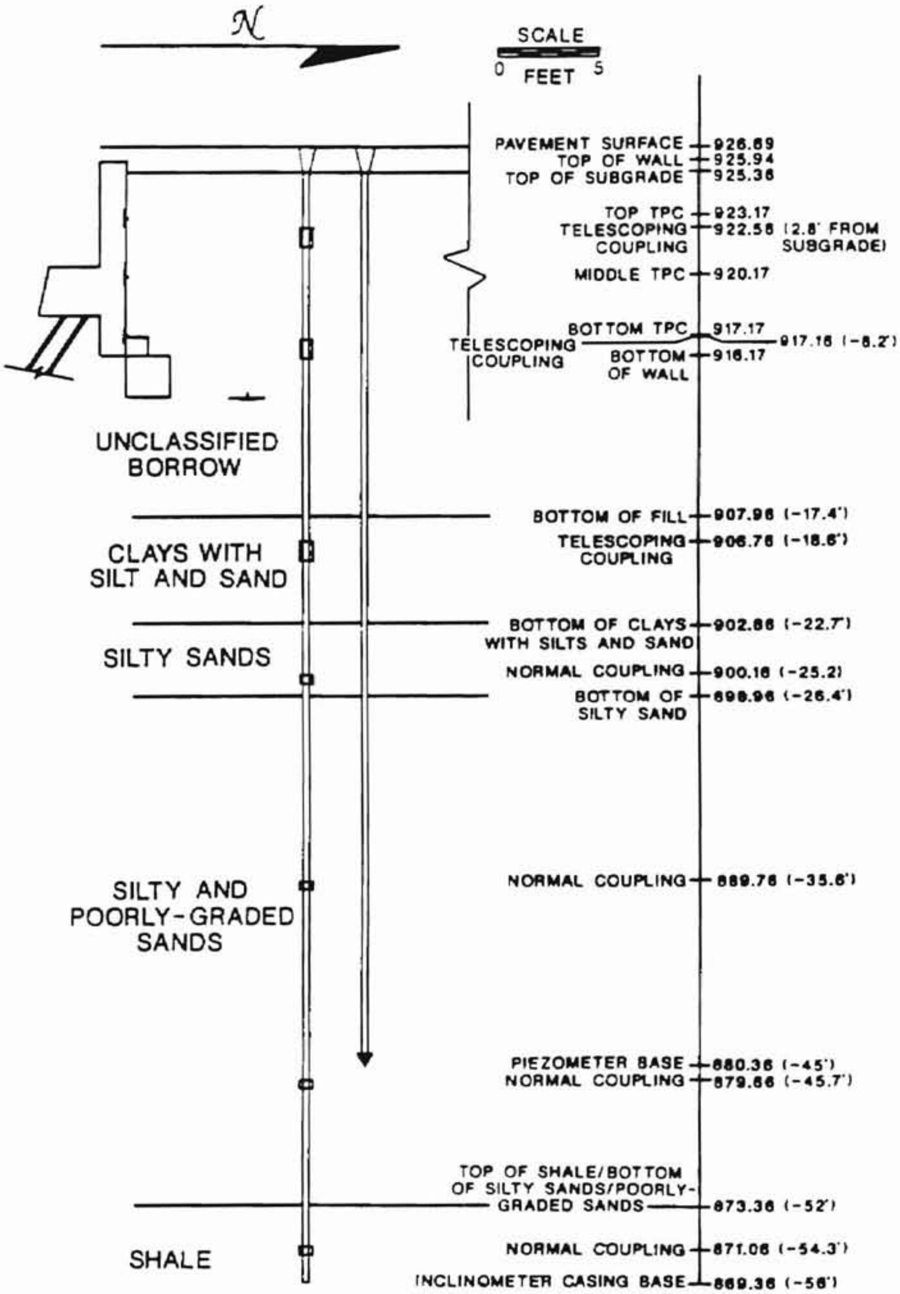
℄ CROSS SECTION, SOUTH ABUTMENT WALL,
BRIDGE A, AS-BUILT CONDITIONS



BACK OF WALL SECTION, SOUTH ABUTMENT WALL, BRIDGE A, AS-BUILT CONDITIONS



PLAN SECTION, SOUTH ABUTMENT WALL,
BRIDGE A, AS-BUILT CONDITIONS



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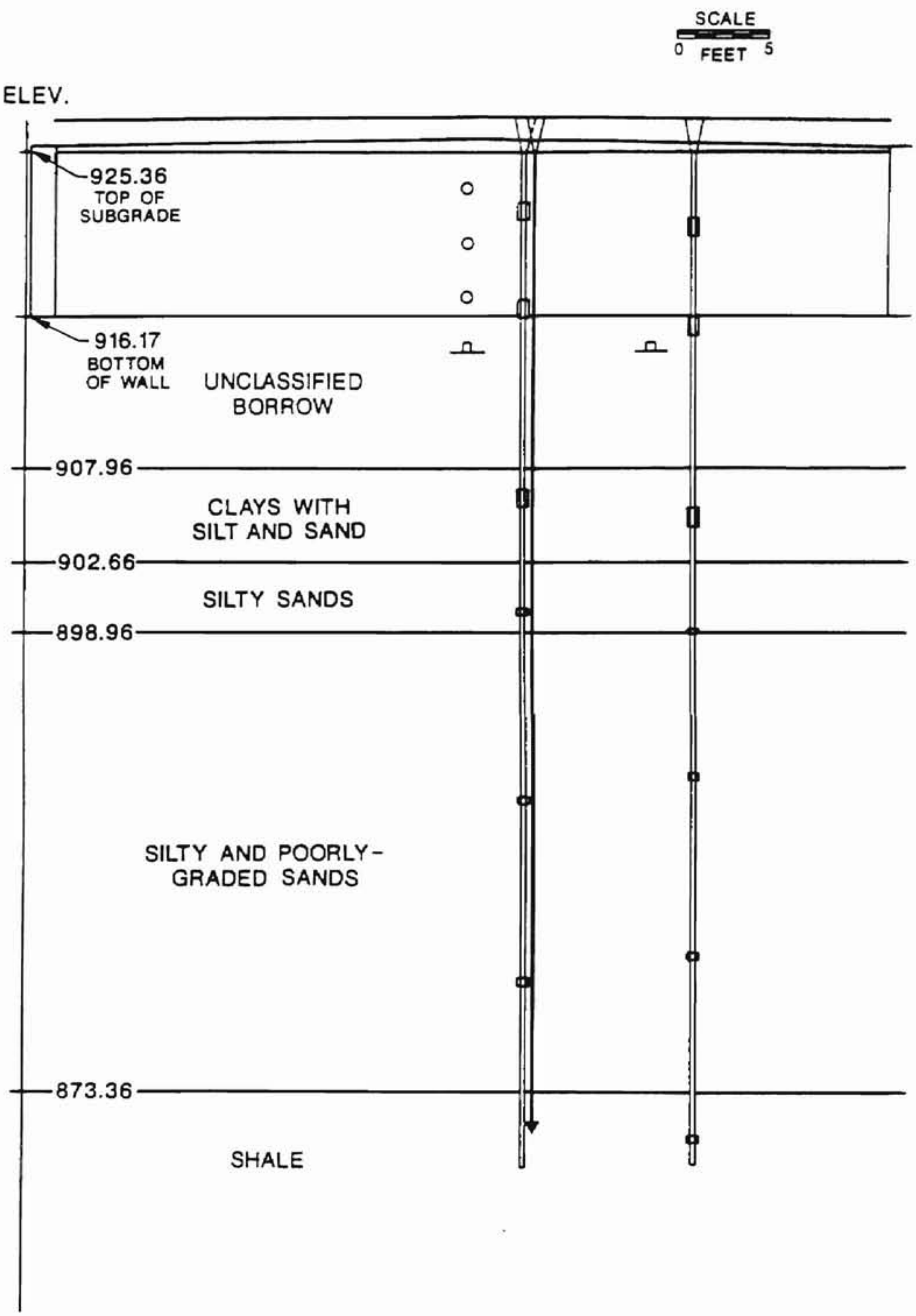
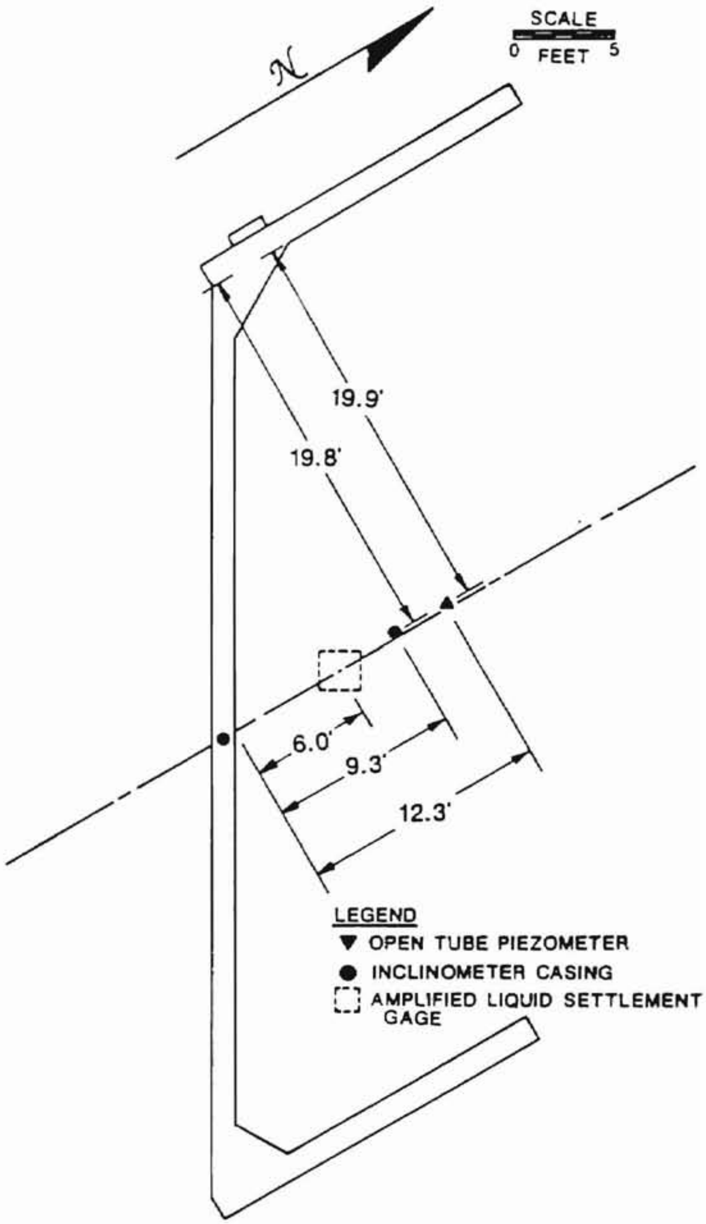
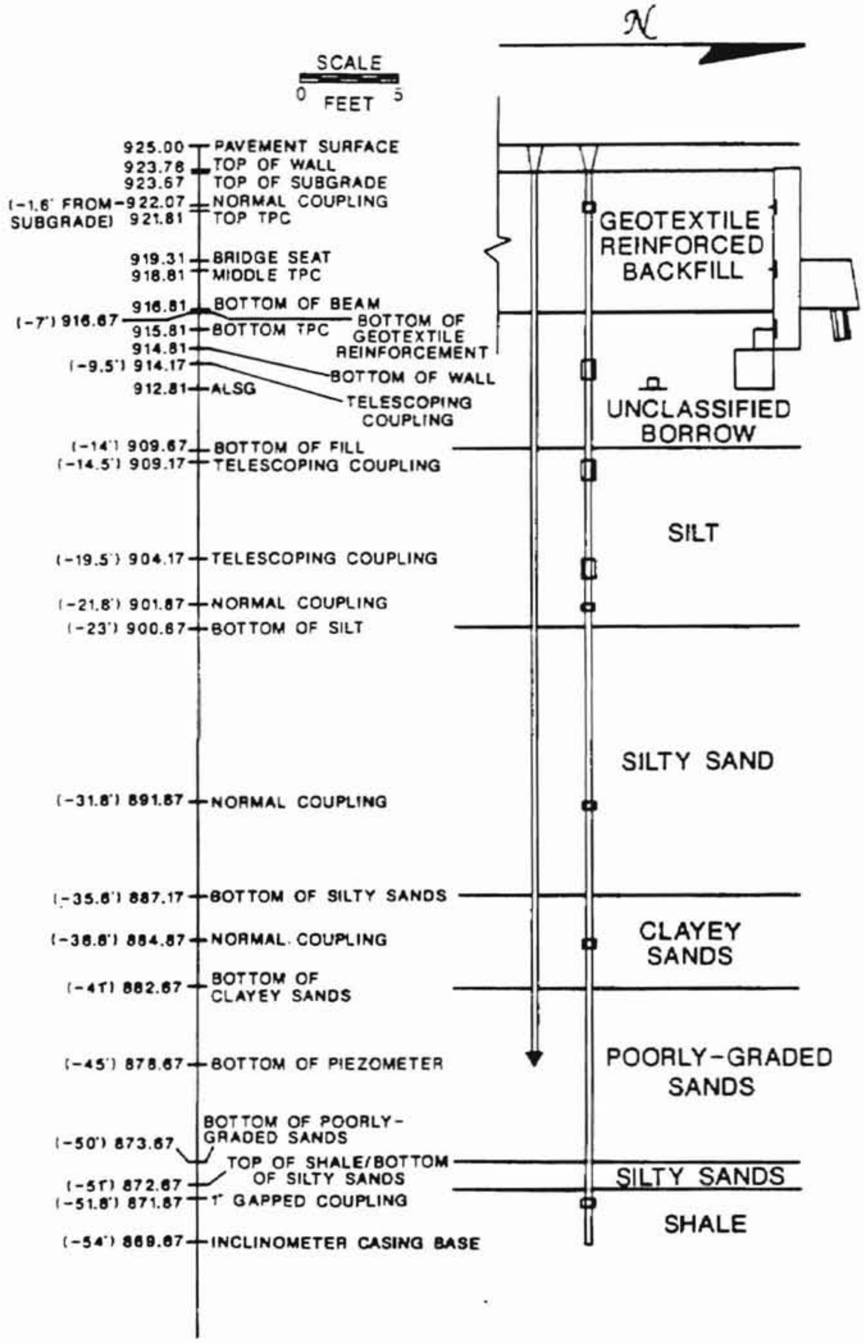


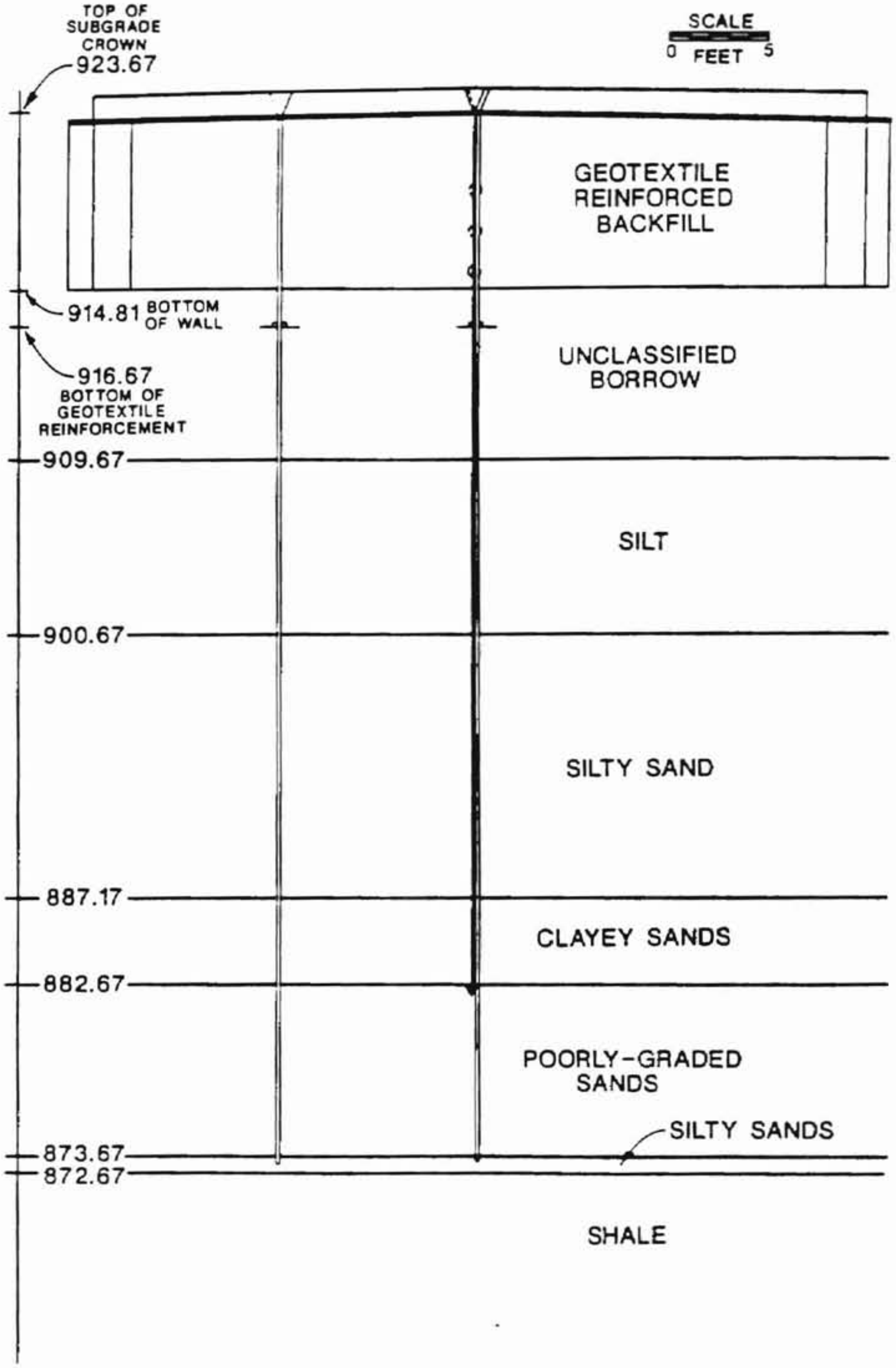
BACK OF WALL SECTION, NORTH ABUTMENT WALL, BRIDGE A, AS-BUILT CONDITIONS



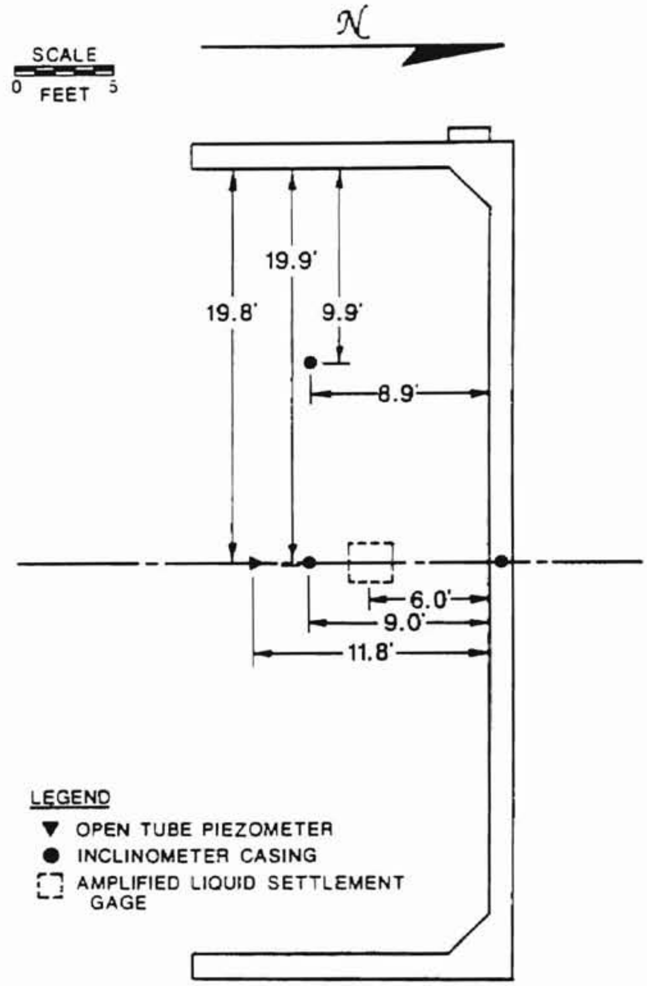
PLAN SECTION, NORTH ABUTMENT WALL, BRIDGE A, AS-BUILT CONDITIONS



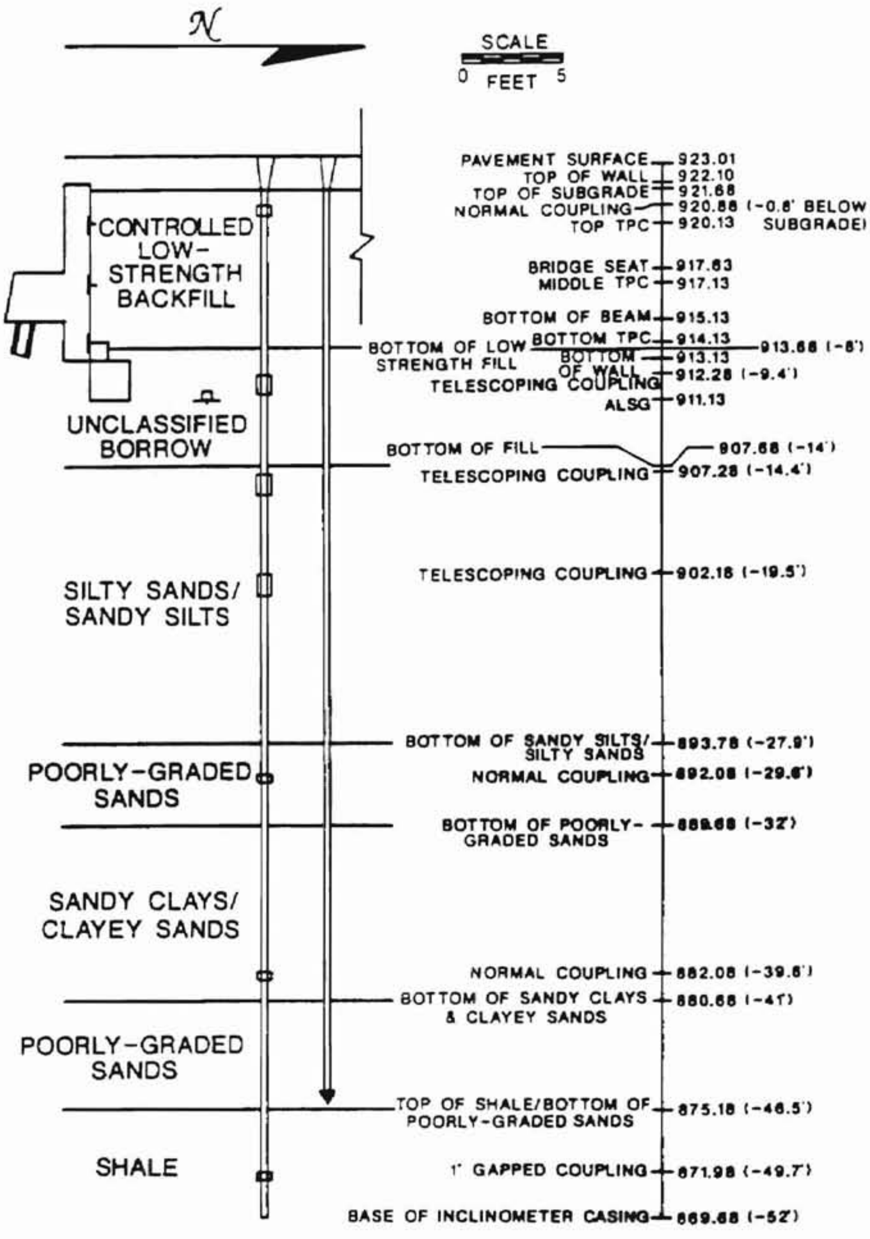
℄ CROSS SECTION, SOUTH ABUTMENT WALL, BRIDGE B, AS-BUILT CONDITIONS



BACK OF WALL SECTION, SOUTH ABUTMENT
WALL, BRIDGE B, AS-BUILT CONDITIONS



PLAN SECTION, SOUTH ABUTMENT WALL, BRIDGE B, AS-BUILT CONDITIONS



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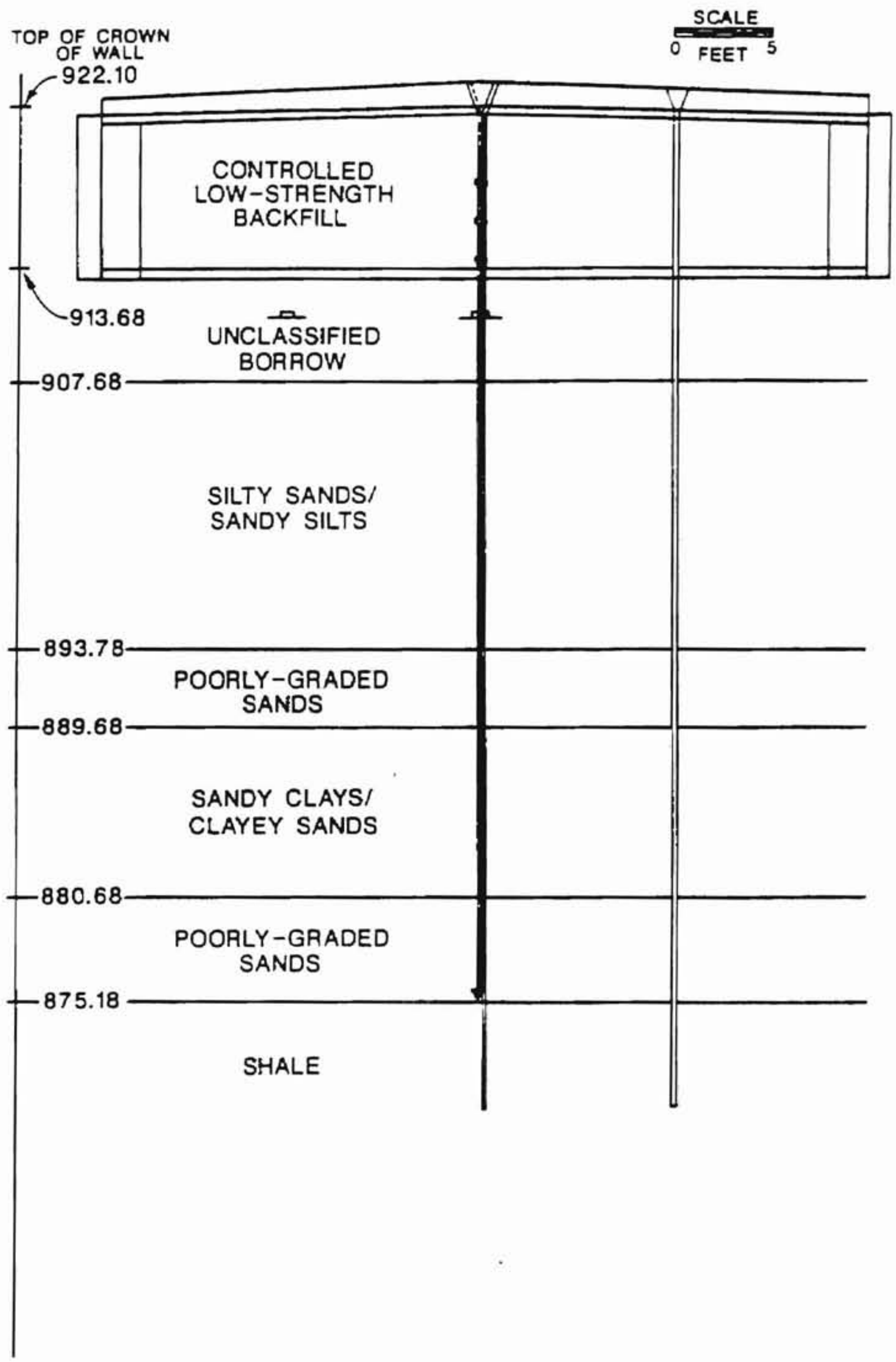
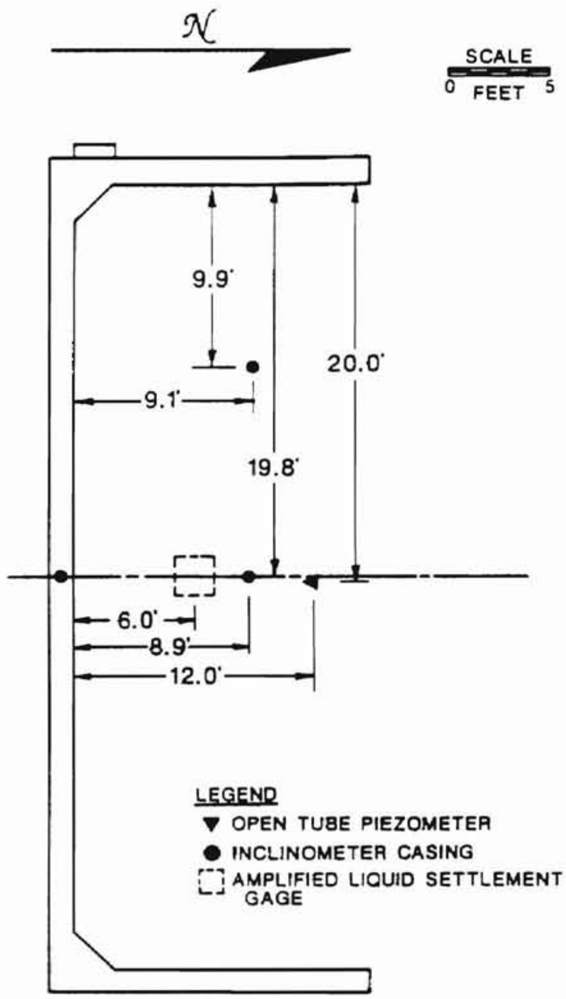
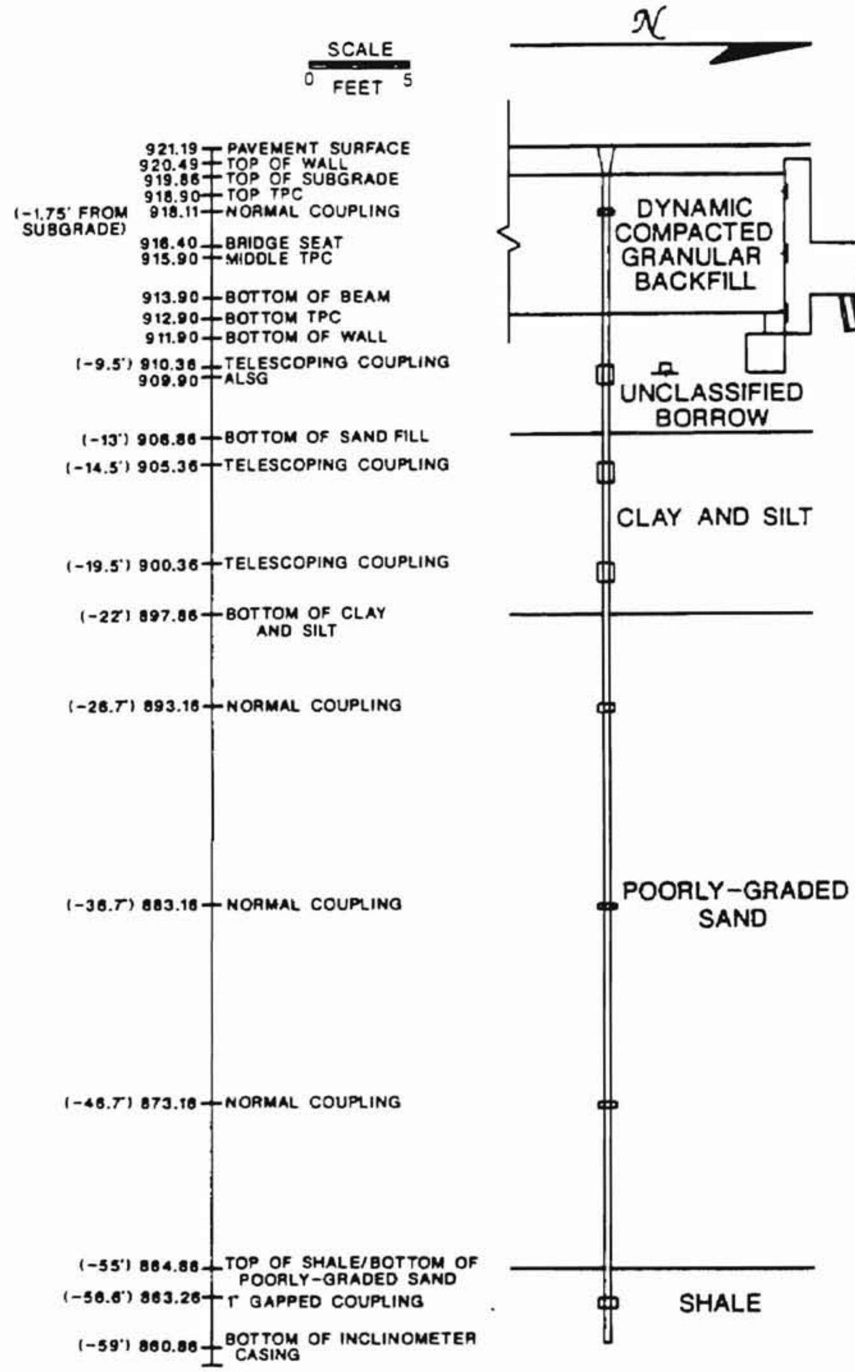


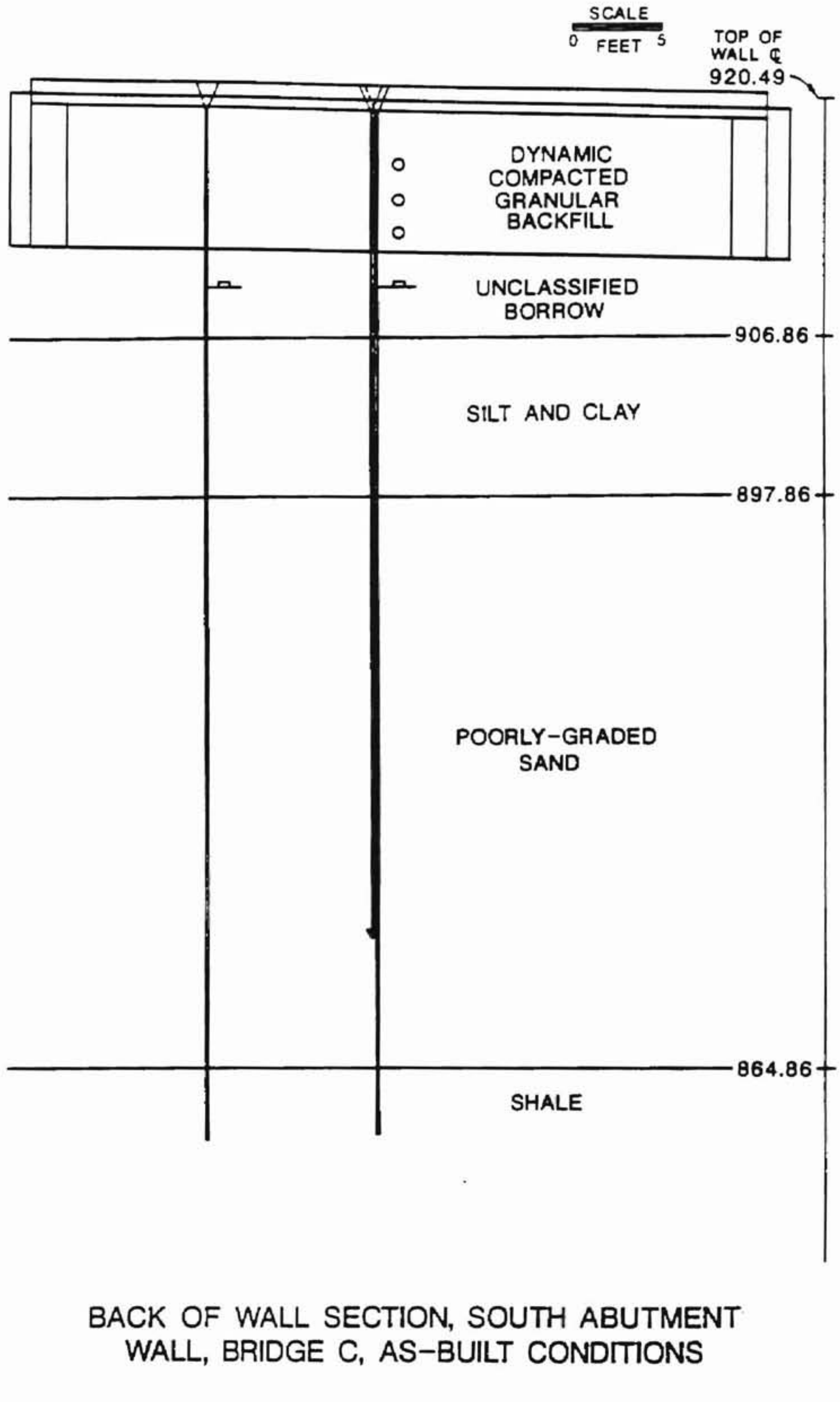
BACK OF WALL SECTION, NORTH ABUTMENT WALL, BRIDGE B, AS-BUILT CONDITIONS



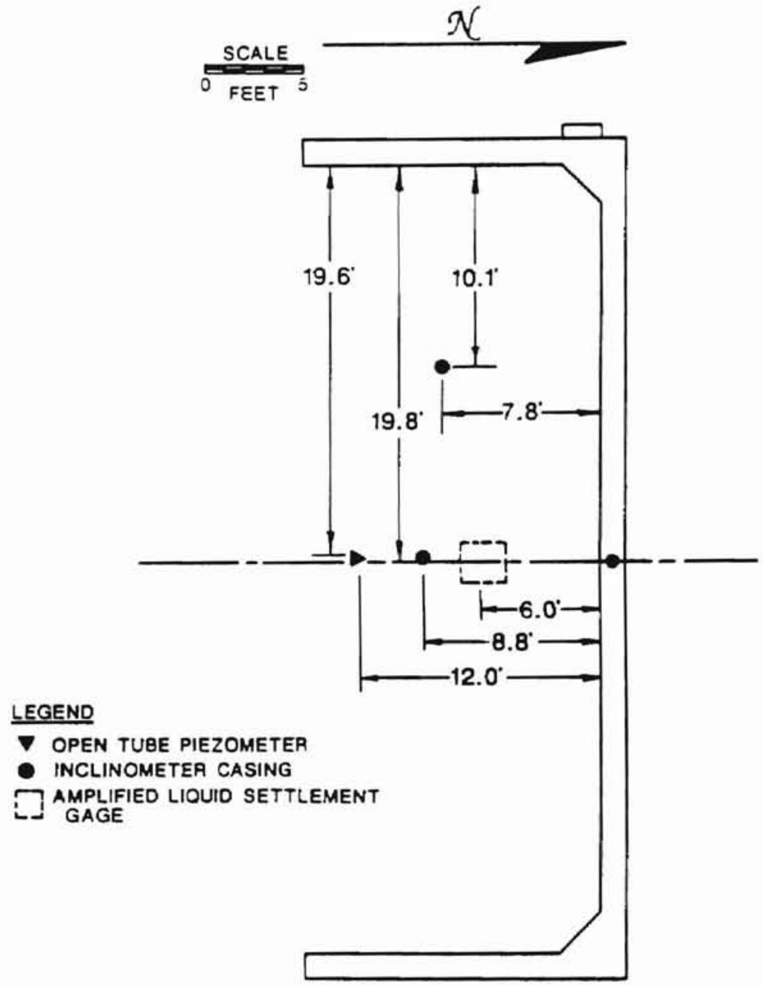
PLAN SECTION, NORTH ABUTMENT WALL, BRIDGE B, AS-BUILT CONDITIONS



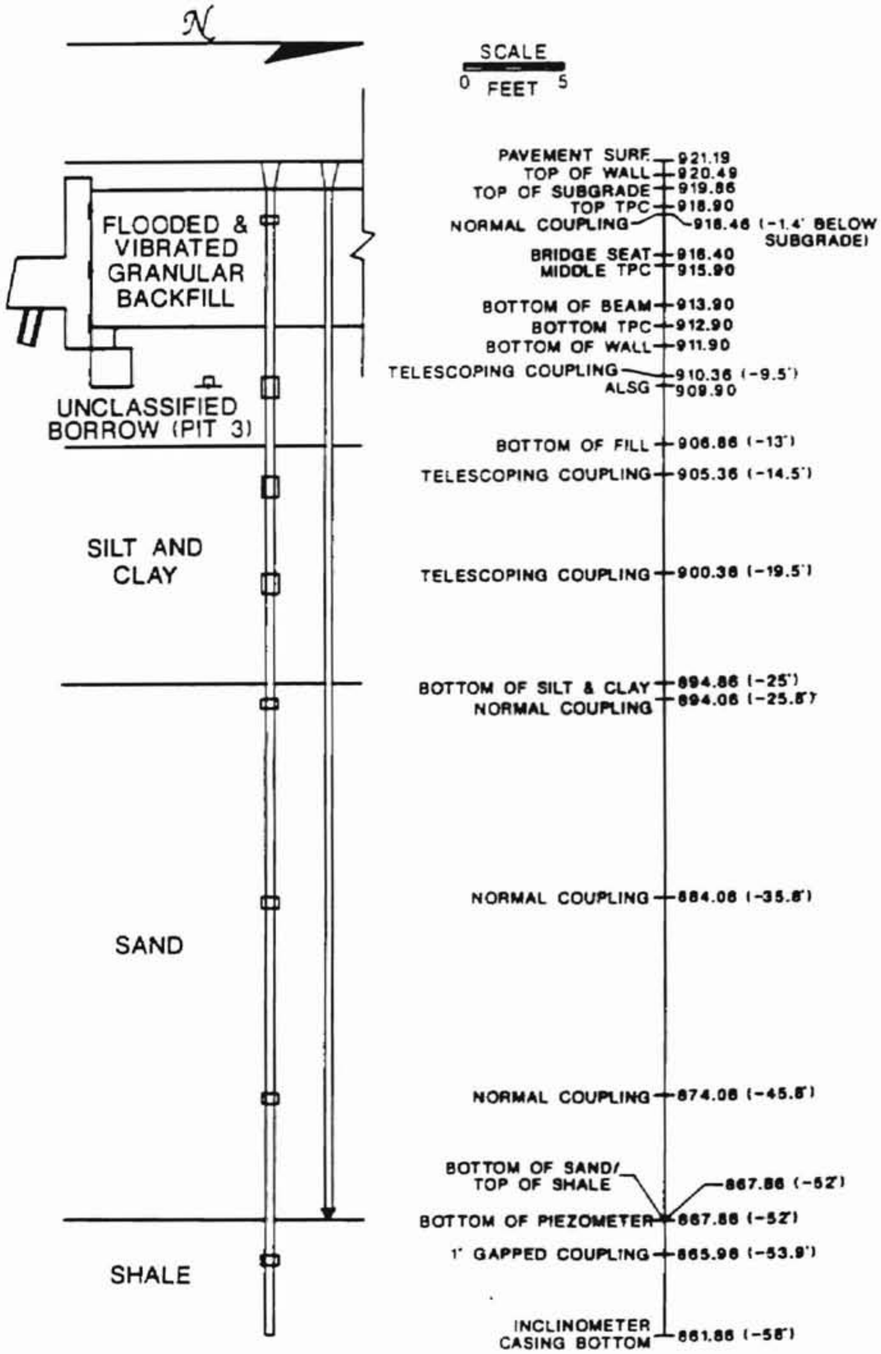
℄ CROSS SECTION, SOUTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS



BACK OF WALL SECTION, SOUTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS



PLAN SECTION, SOUTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS



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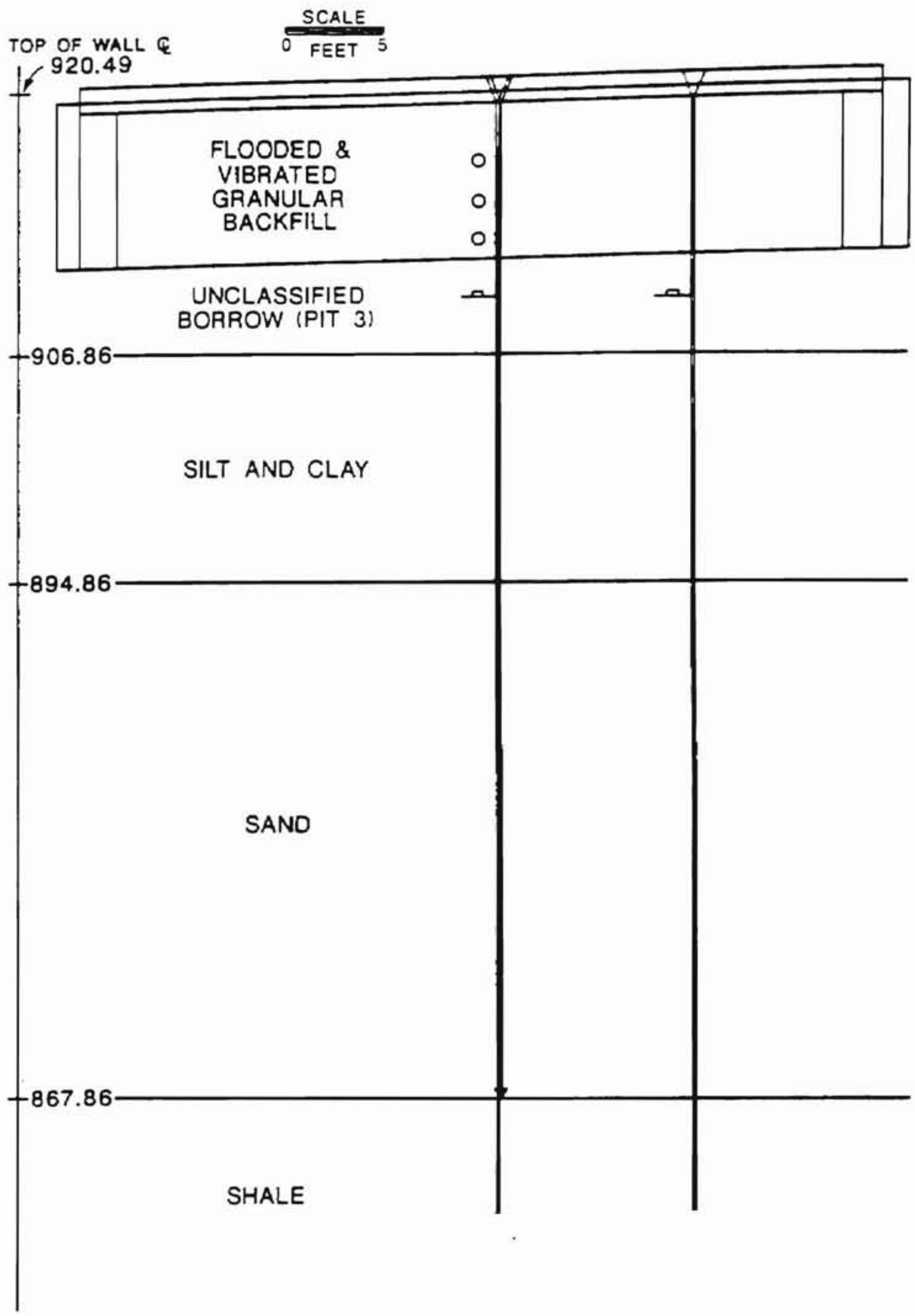
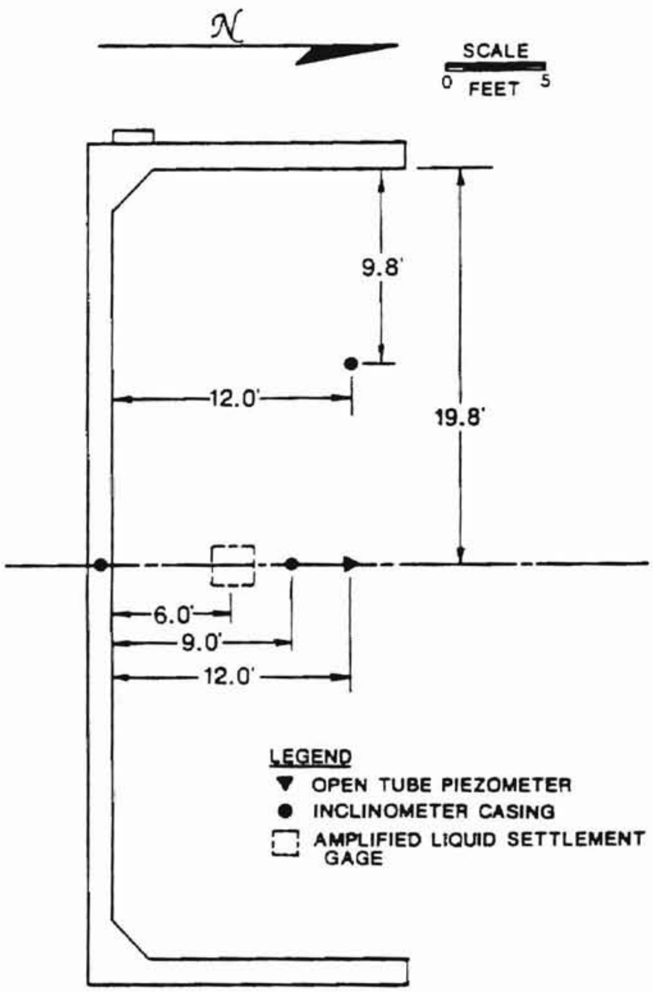


BACK OF WALL SECTION, NORTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS



PLAN SECTION, NORTH ABUTMENT WALL, BRIDGE C, AS-BUILT CONDITIONS

APPENDIX C

OSU SOILS LABORATORY TEST RESULTS AND

B1 RELATIVE DENSITIES

Soils Laboratory Results

Bridge A

South Approach Embankment, Unclassified Borrow, Pit 1

Liquid Limit	29.7%
Plastic Limit	19.7%
Plasticity Index	10.0
% - #200 Sieve	85%
Max. Dry Density	114.4 pcf
Optimum Moisture Content	14.4%
Classification	CL, A-6

North Approach Embankment, Unclassified Borrow, Pit 2

Liquid Limit	20.67%
Plastic Limit	17.9%
Plasticity Index	2.7
% - #200 Sieve	24%
Max. Dry Density	108.7 pcf
Optimum Moisture Content	13.6%
Classification	SM, A-2-4

Bridge B

South Approach Embankment, Granular Backfill

Plastic Limit	Non-Plastic
% - #200 Sieve	0.2%
Min. Ave. Index Density	109.6 pcf
Max. Ave. Index Density	125.1 pcf
Classification	SP, A-1-b

North Approach Embankment, Controlled Low Strength Backfill

No Soils Tests Conducted

Bridge C

South Approach Embankment, Granular Backfill

Plastic Limit	Non-Plastic
% - #200 Sieve	0.3%
Min. Ave. Index Density	109.7 pcf
Max. Ave. Index Density	125.2 pcf
Classification	SP, A-1-b

North Approach Embankment, Granular Backfill

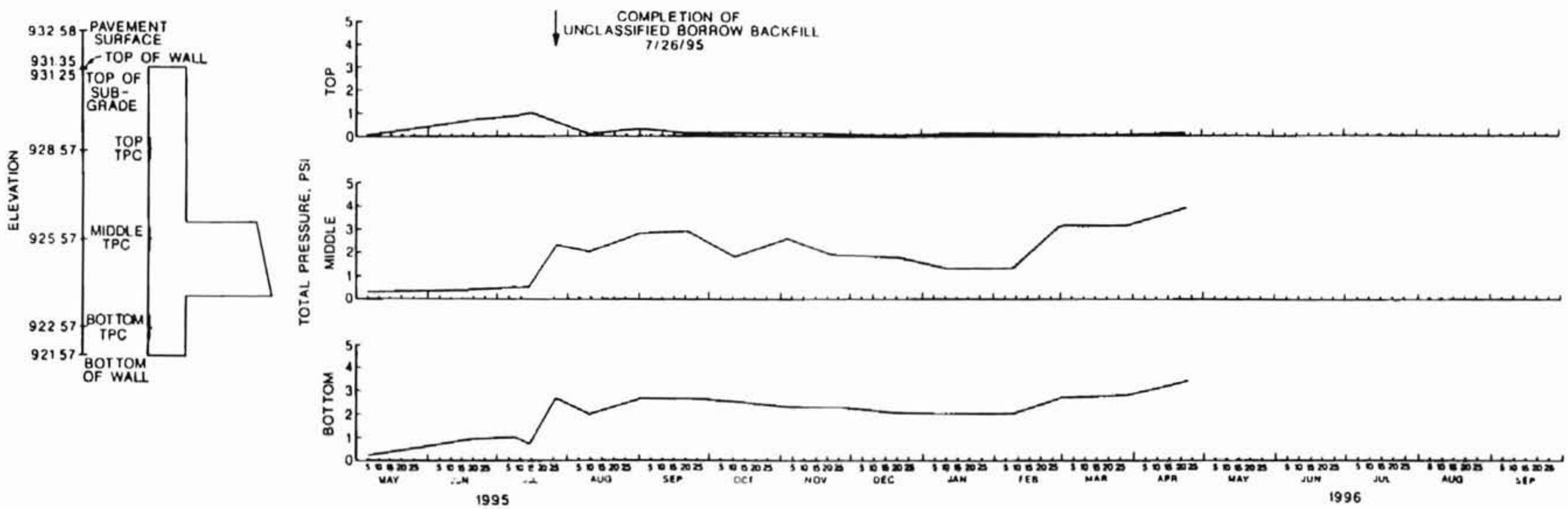
Plastic Limit	Non-Plastic
% - #200 Sieve	0.4%
Min. Ave. Index Density	109.9 pcf
Max. Ave. Index Density	125.6 pcf
Classification	SP, A-1-b

Relative Densities at B1

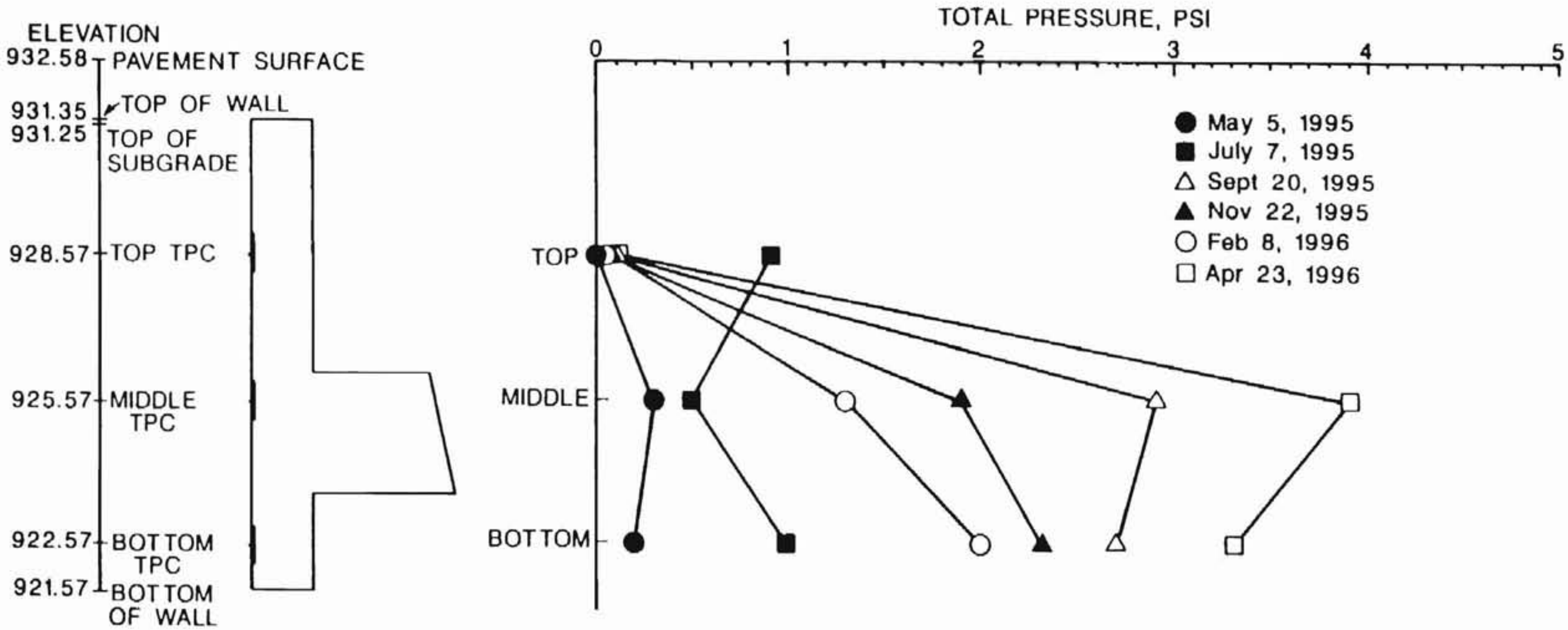
Lift	Base	1	2	3	4	5	6	7	8
D_R(%)	0.7	23	30	28	22	19	32	23	30

APPENDIX D

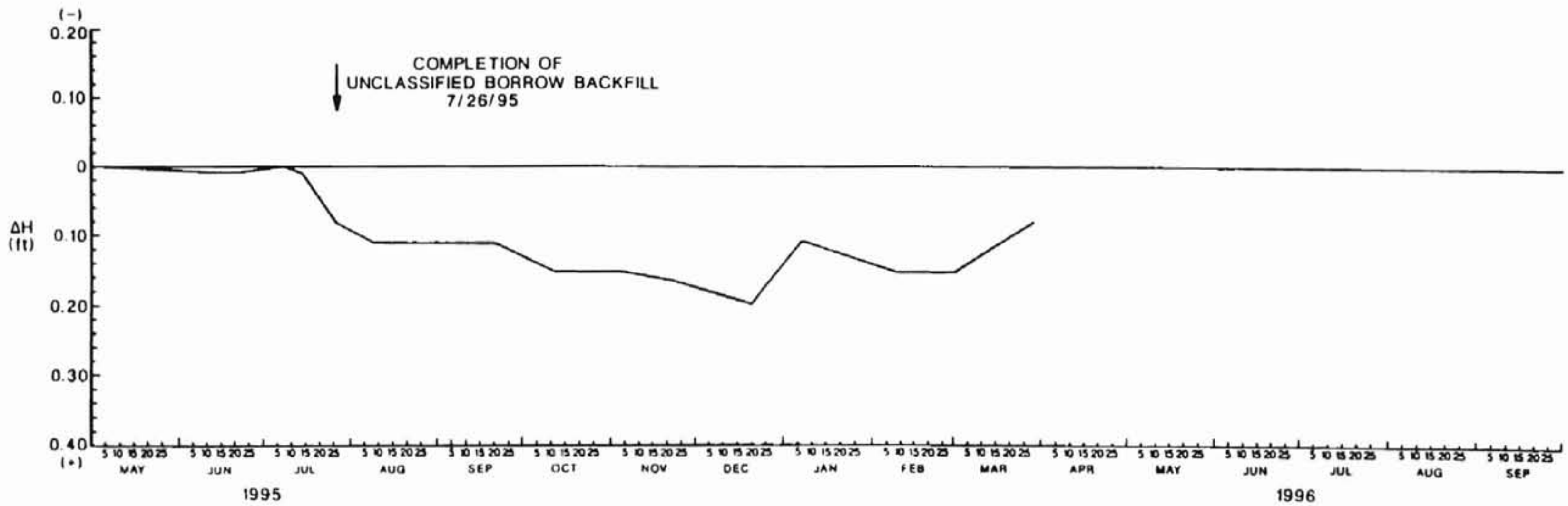
INSTRUMENTATION DATA



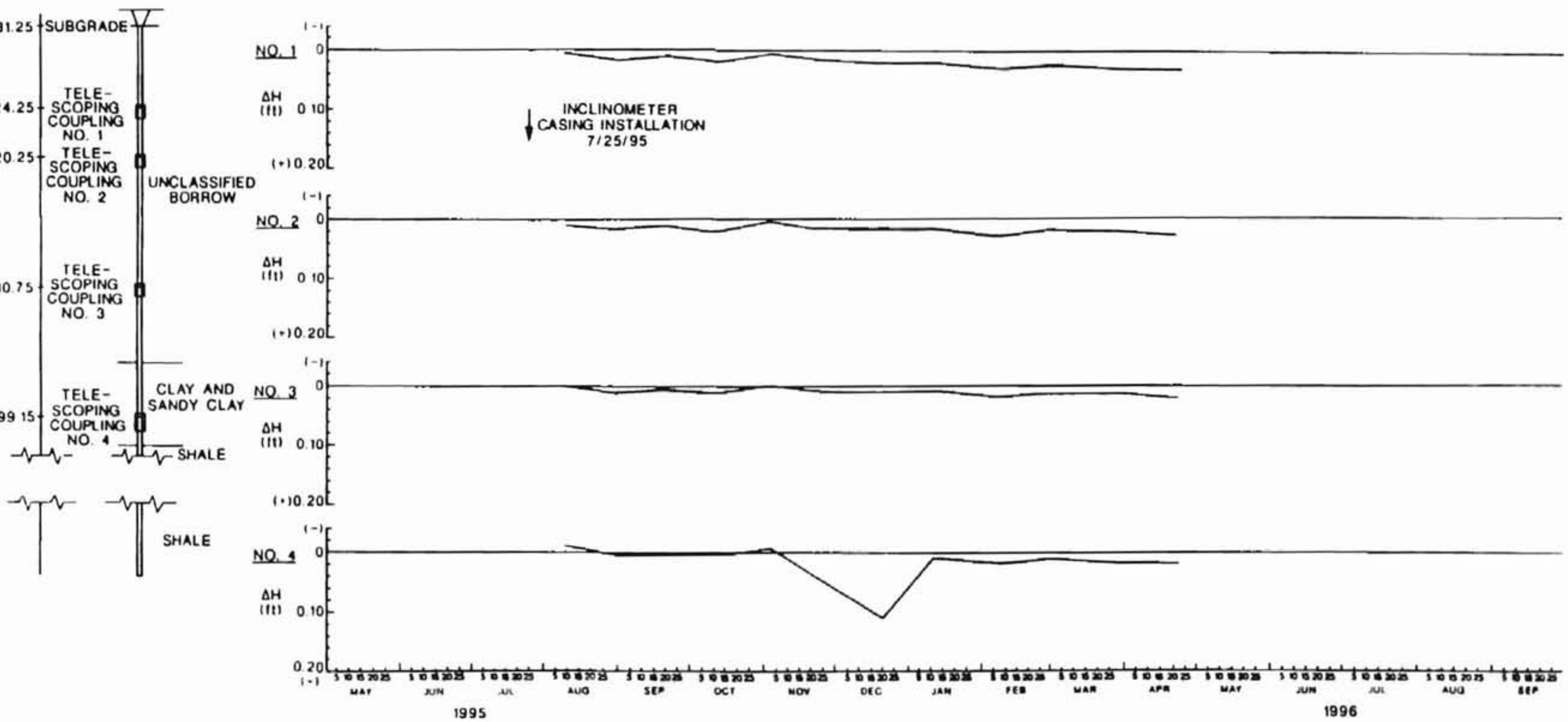
TOTAL PRESSURE CELL DATA (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A



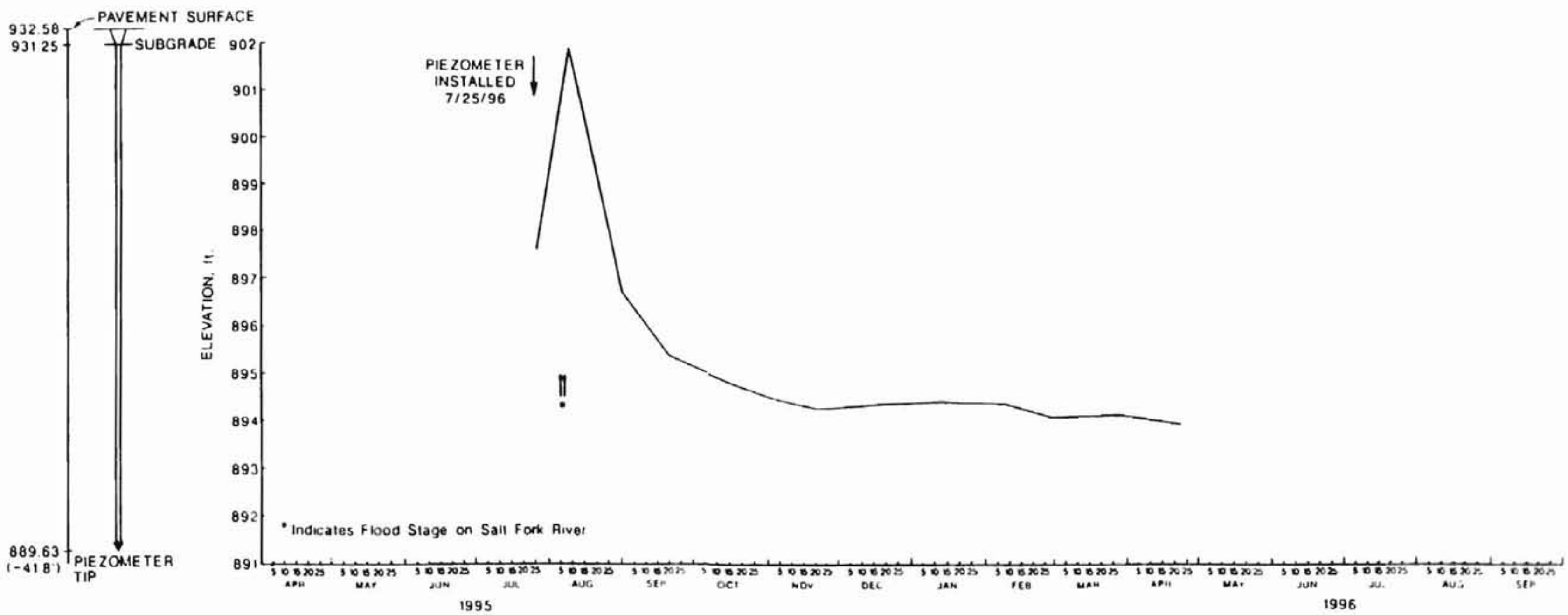
TOTAL PRESSURE CELL DATA (PROFILE) SOUTH ABUTMENT WALL, BRIDGE A



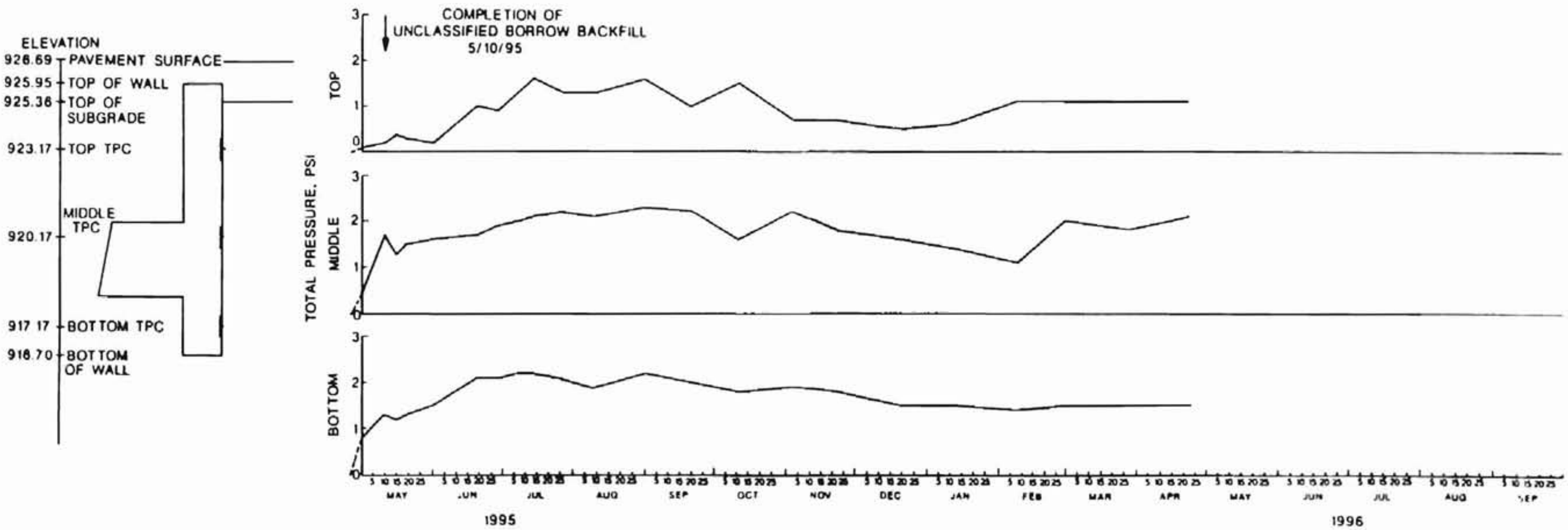
SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES (℄) SOUTH ABUTMENT WALL, BRIDGE A



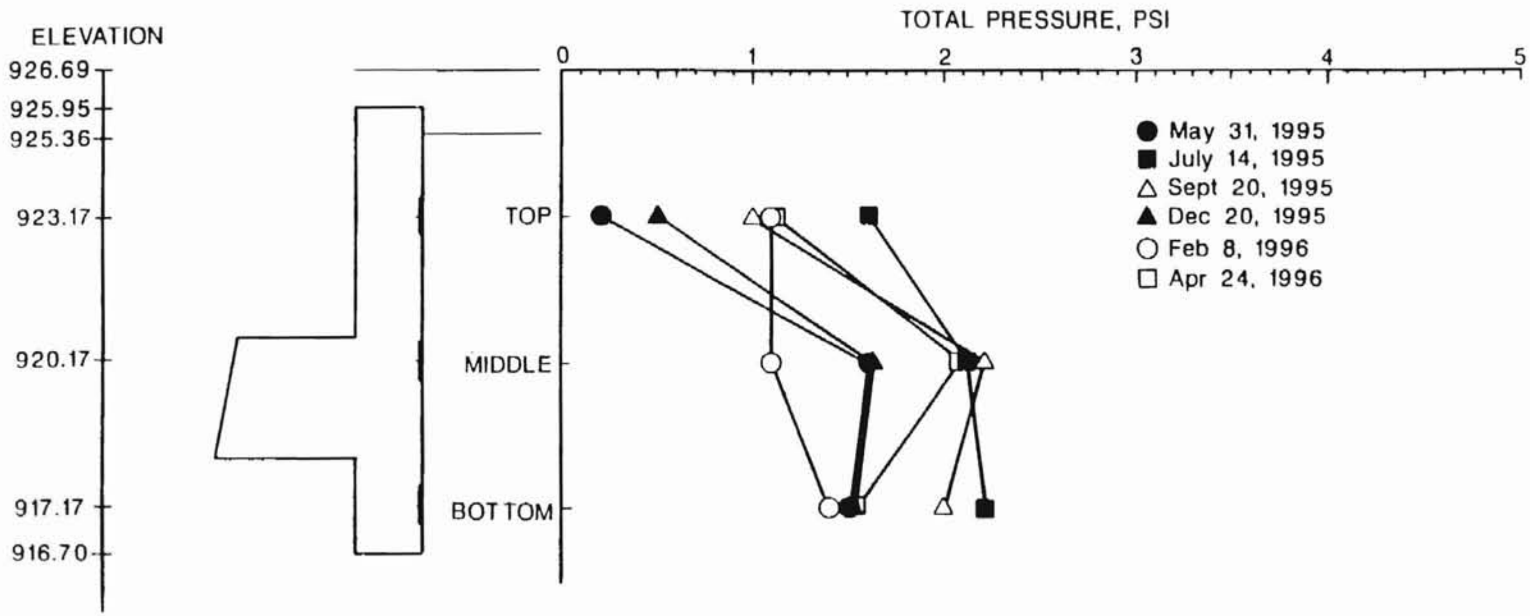
SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A



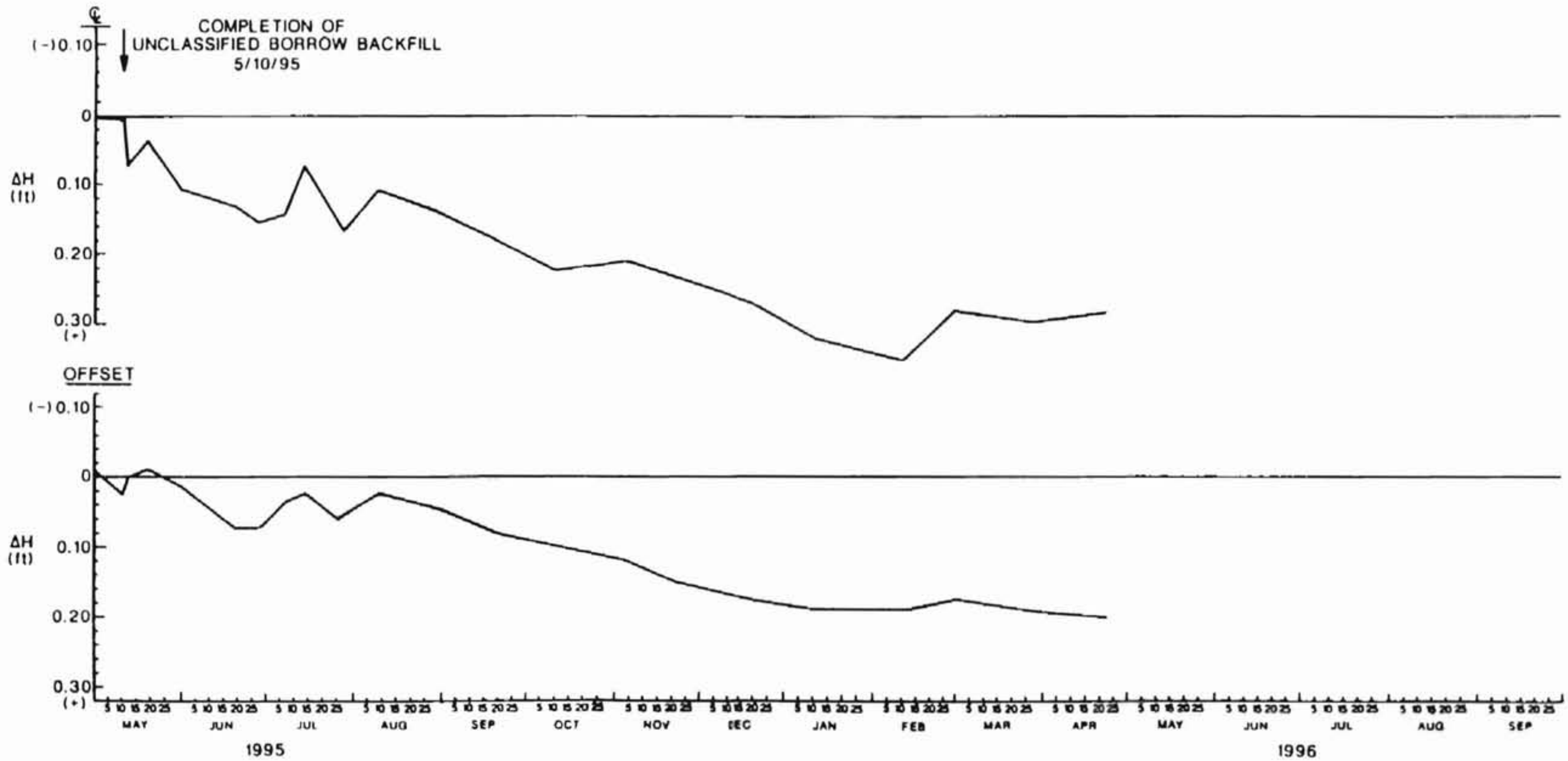
GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE A



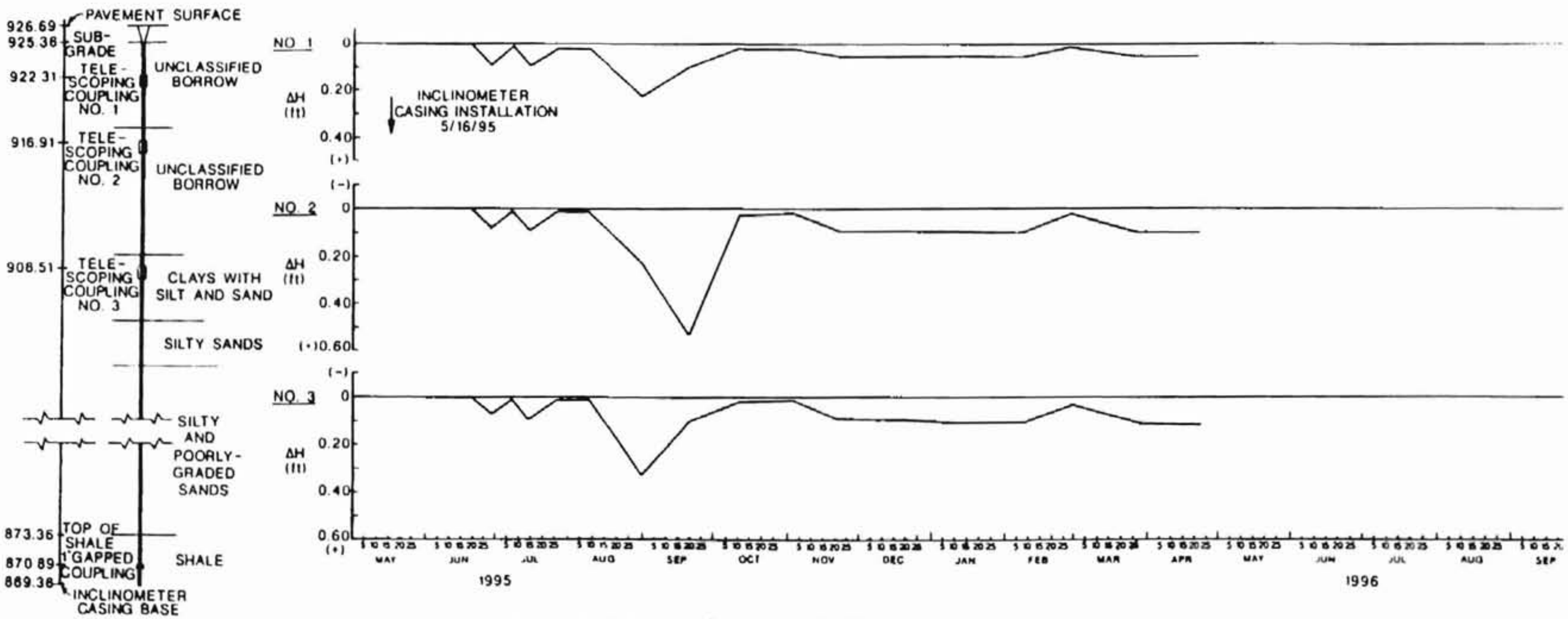
TOTAL PRESSURE CELL DATA (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE A



TOTAL PRESSURE CELL DATA (PROFILE) NORTH ABUTMENT WALL, BRIDGE A



SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT GAGES (CL) NORTH ABUTMENT WALL, BRIDGE A



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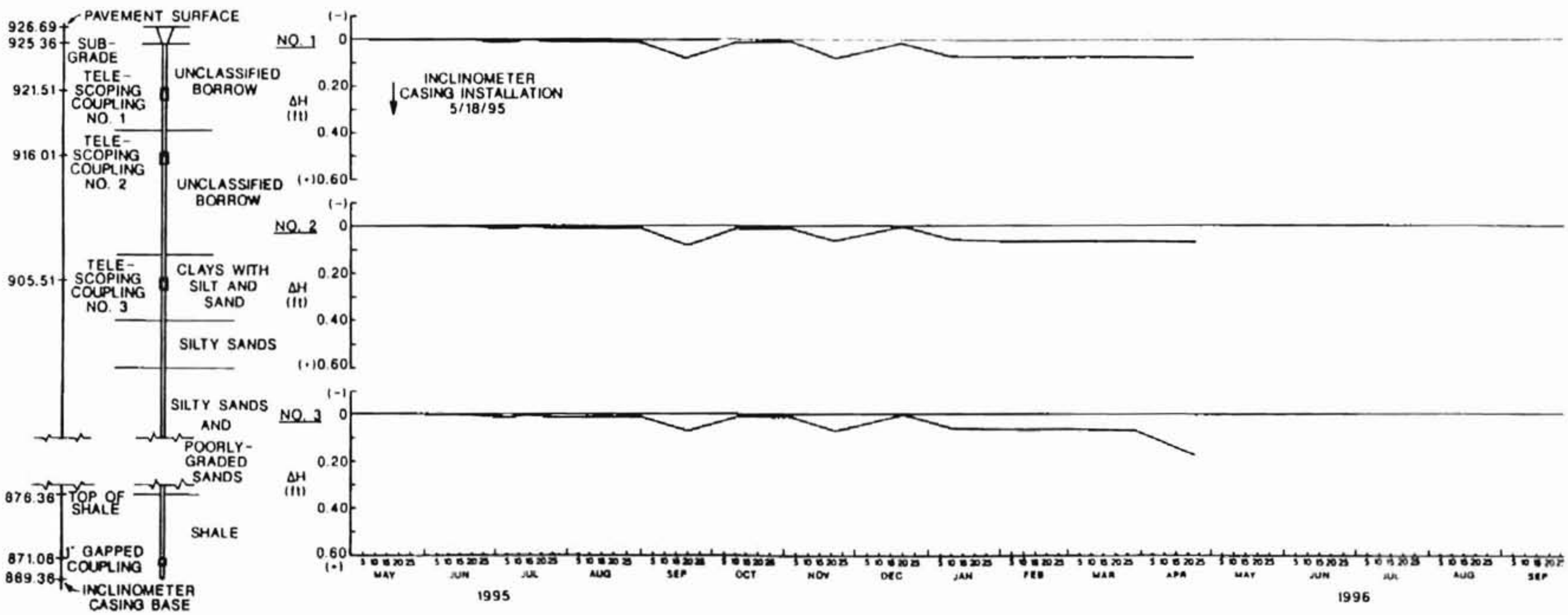
(TIME PLOT) CENTERLINE, NORTH ABUTMENT WALL, BRIDGE A



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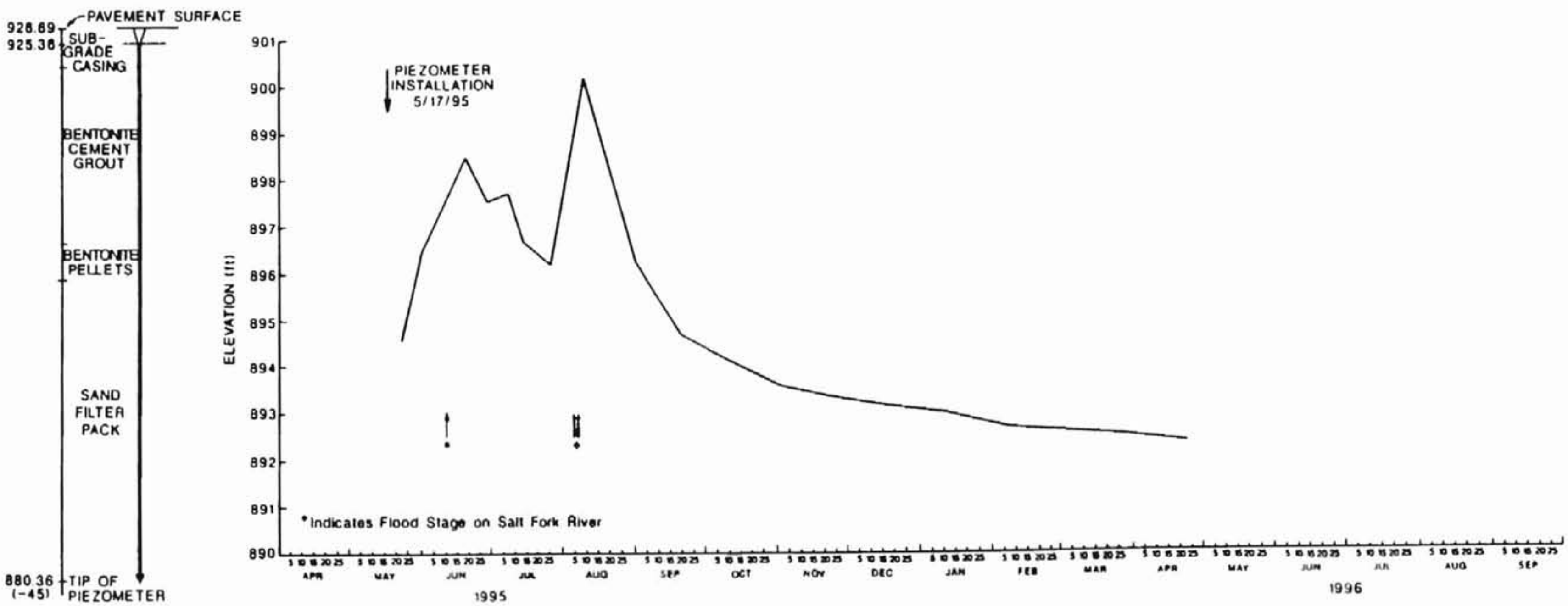
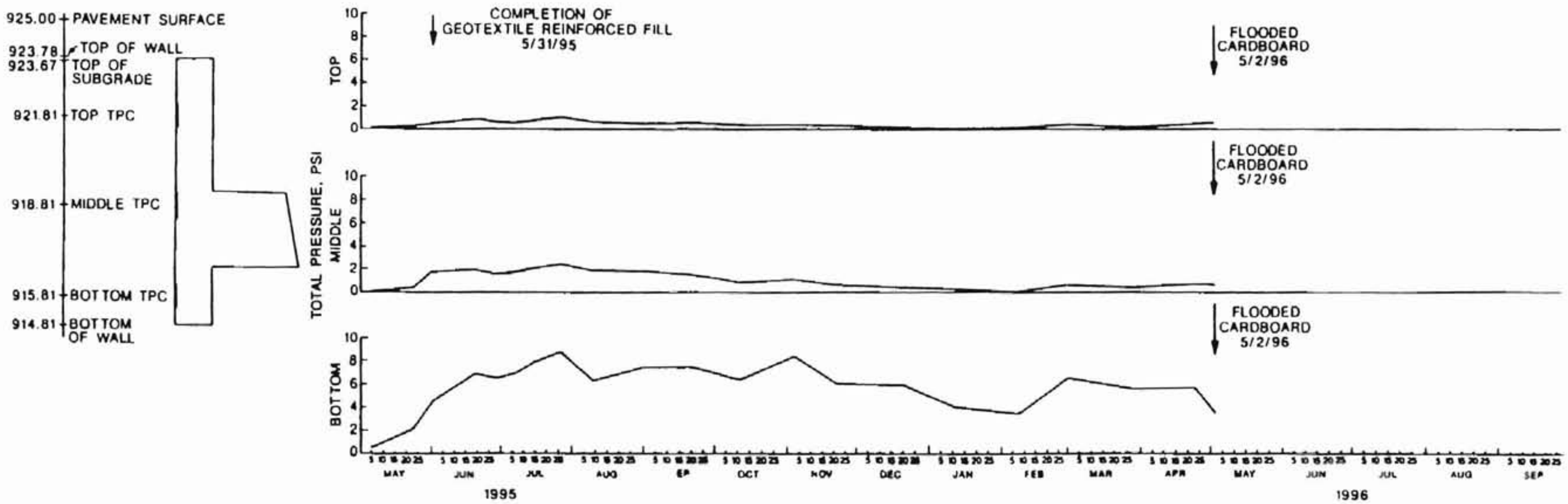
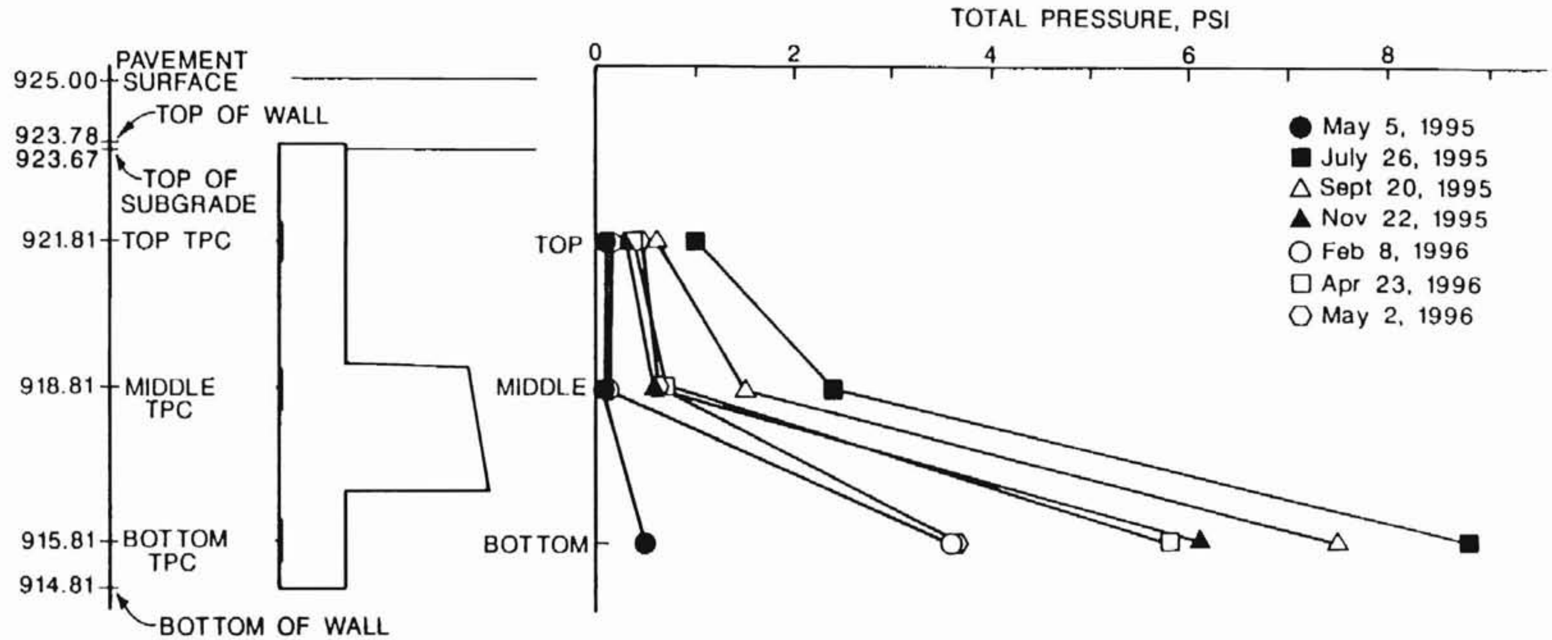


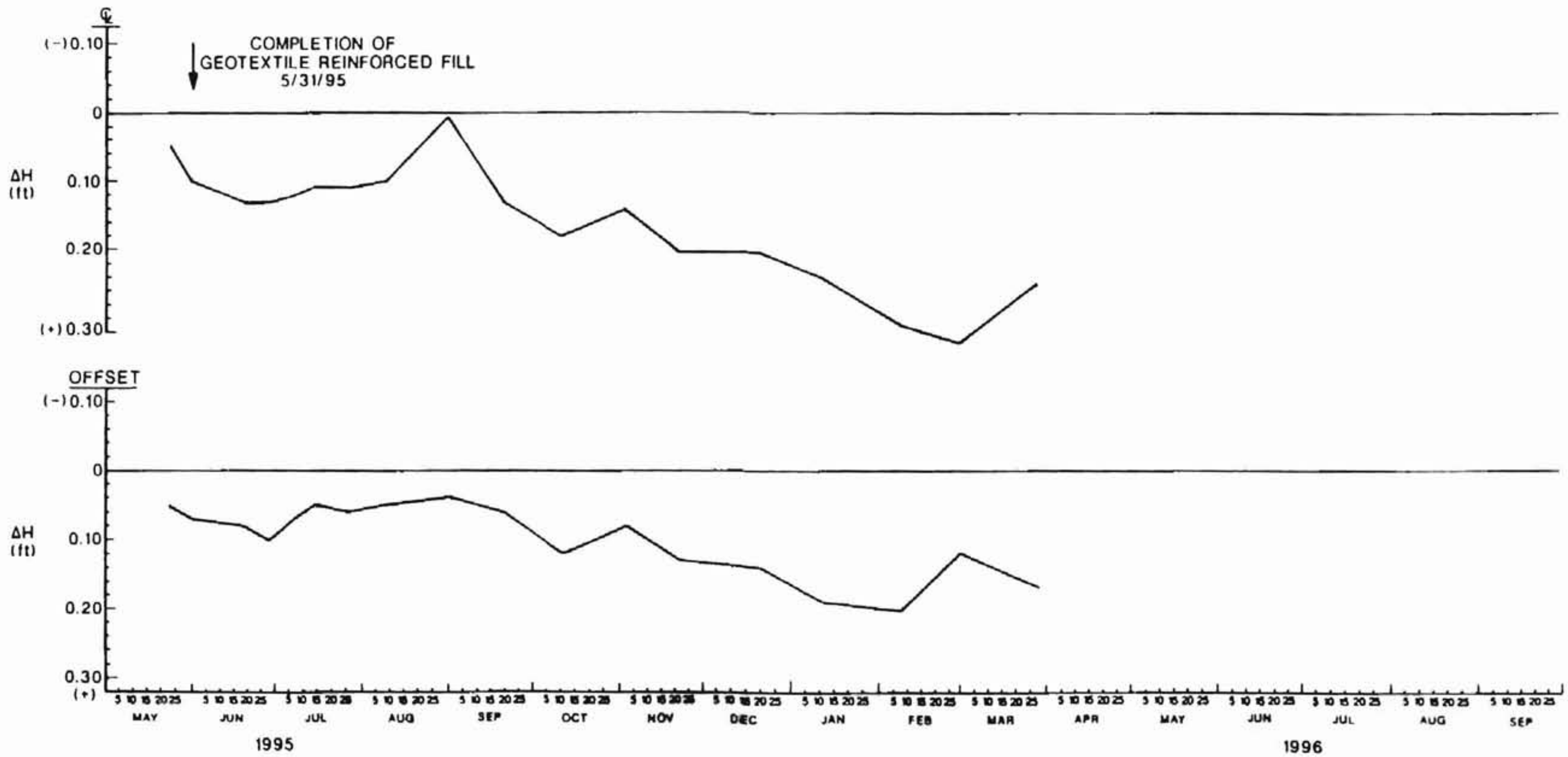
GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE A



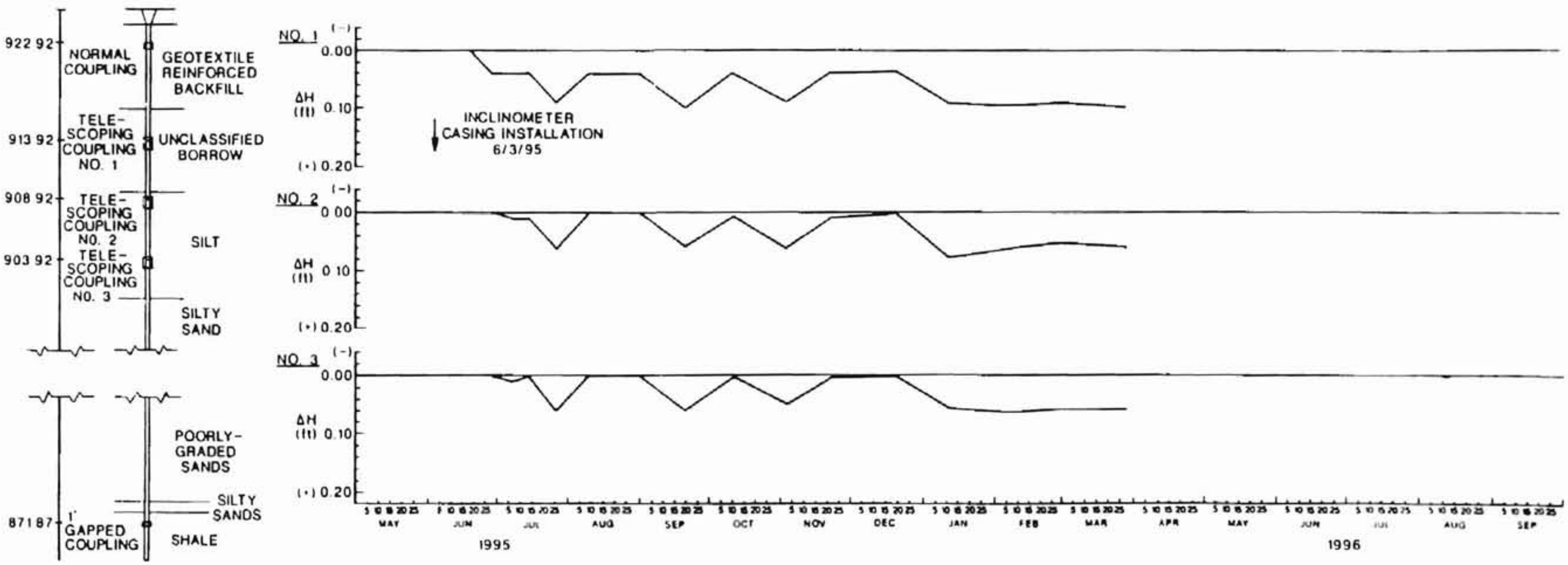
TOTAL PRESSURE CELL DATA (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE B



TOTAL PRESSURE CELL DATA (PROFILE) SOUTH ABUTMENT WALL, BRIDGE B



SETTLEMENT FROM AMPLIFIED LIQUID SETTLEMENT
GAGES SOUTH ABUTMENT WALL, BRIDGE B



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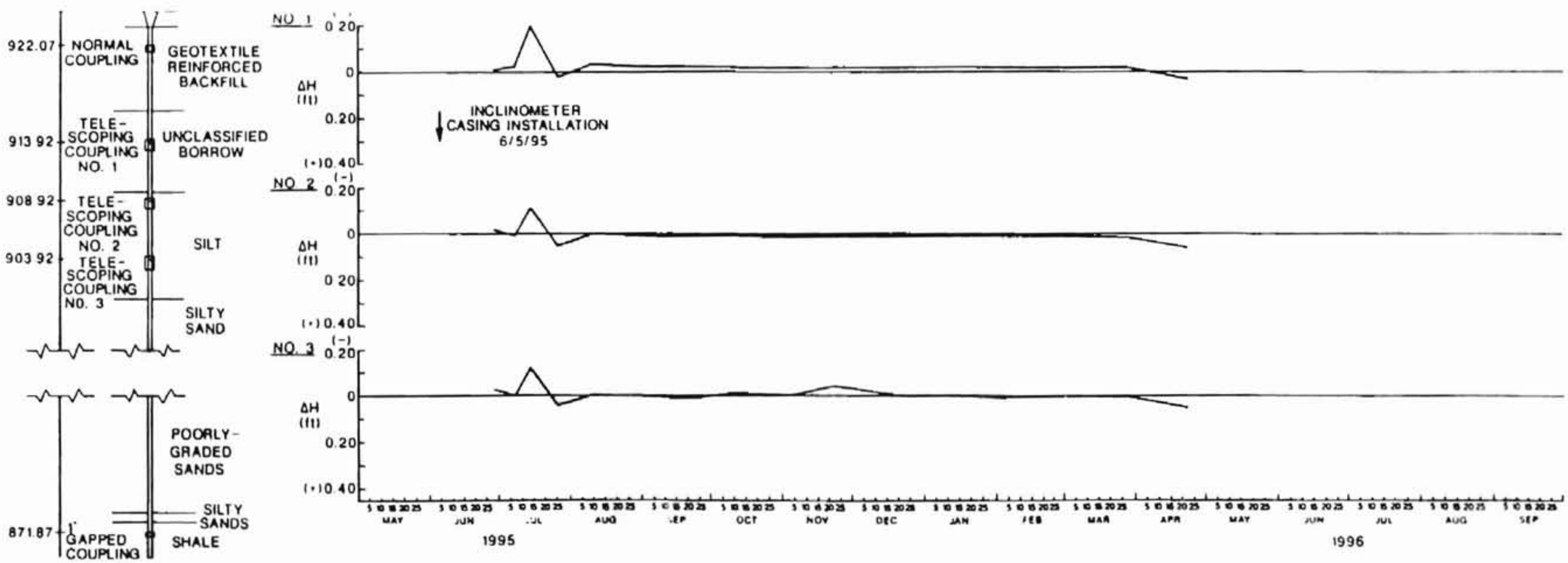
(TIME PLOT) CENTERLINE, SOUTH ABUTMENT WALL, BRIDGE B



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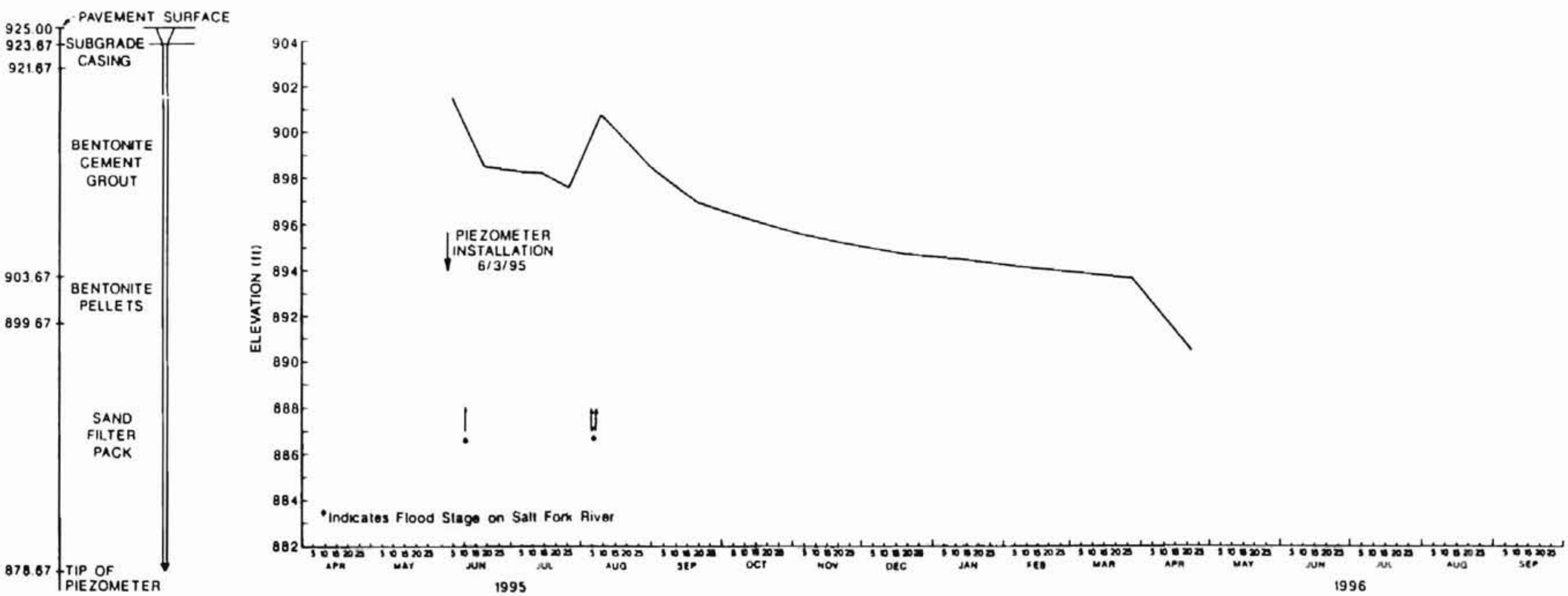
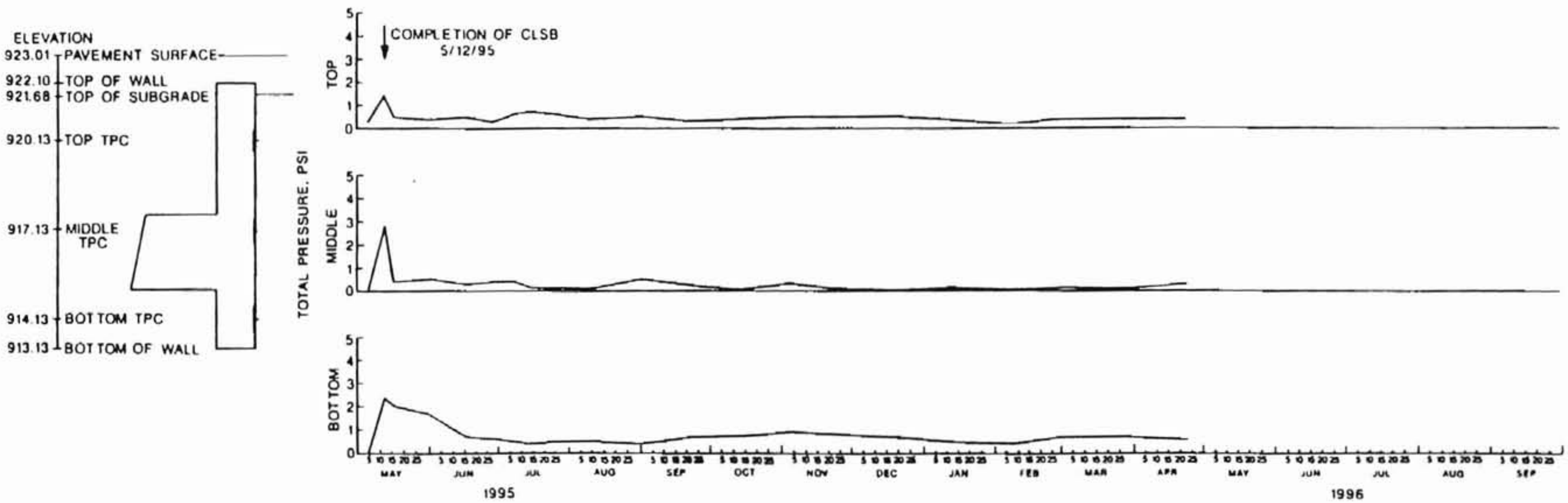


GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE B



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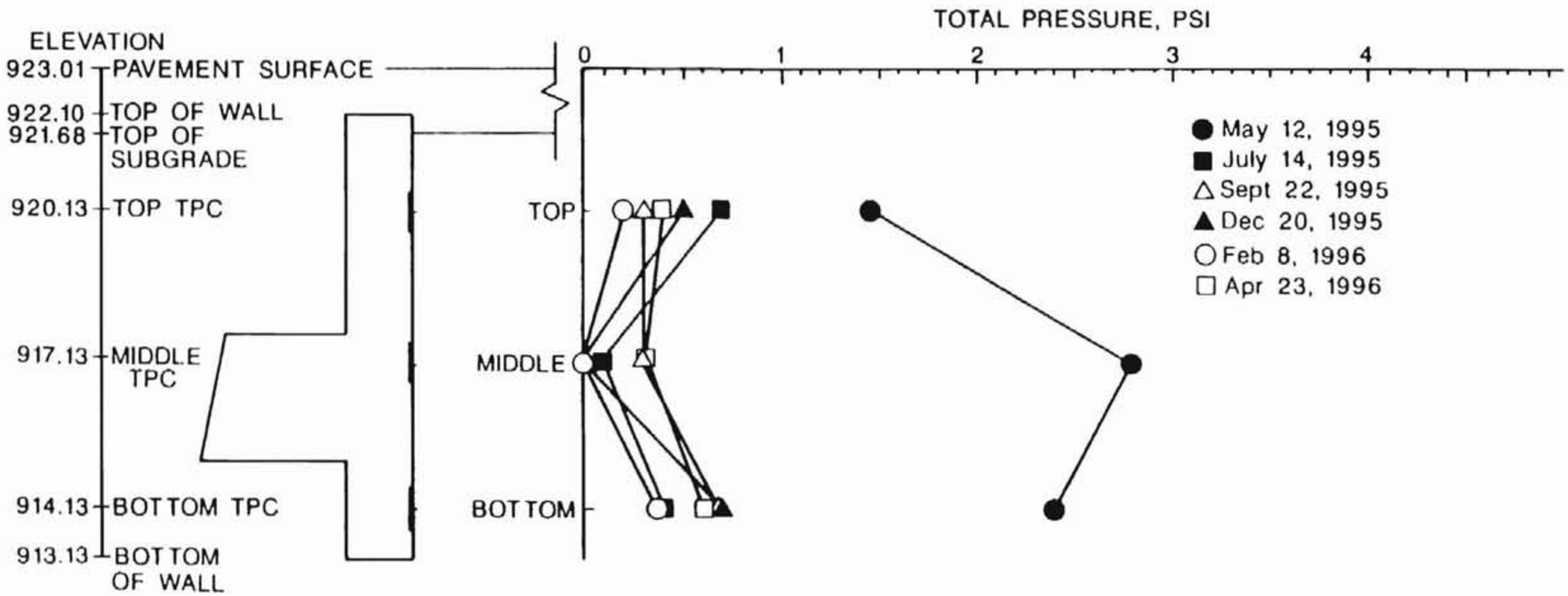

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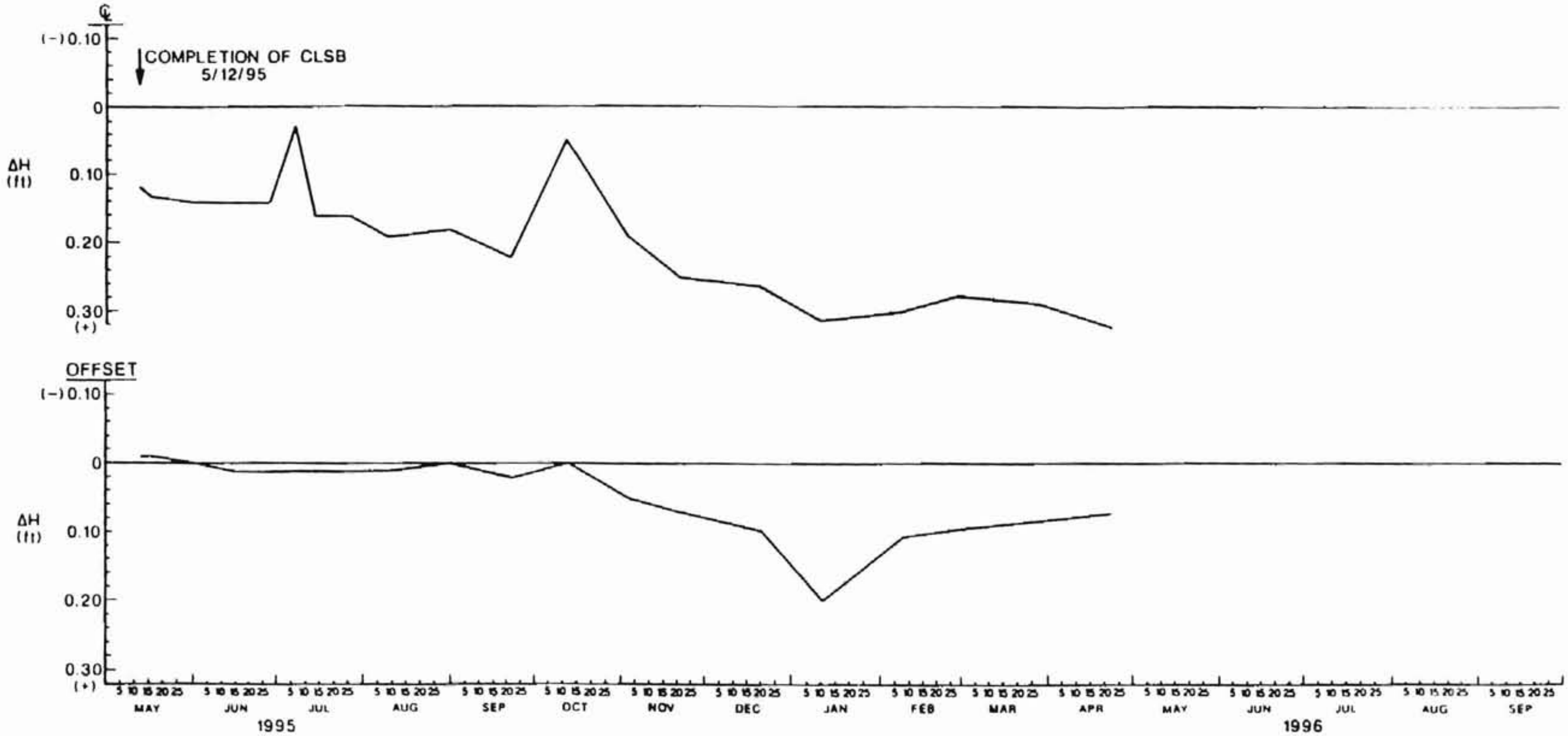

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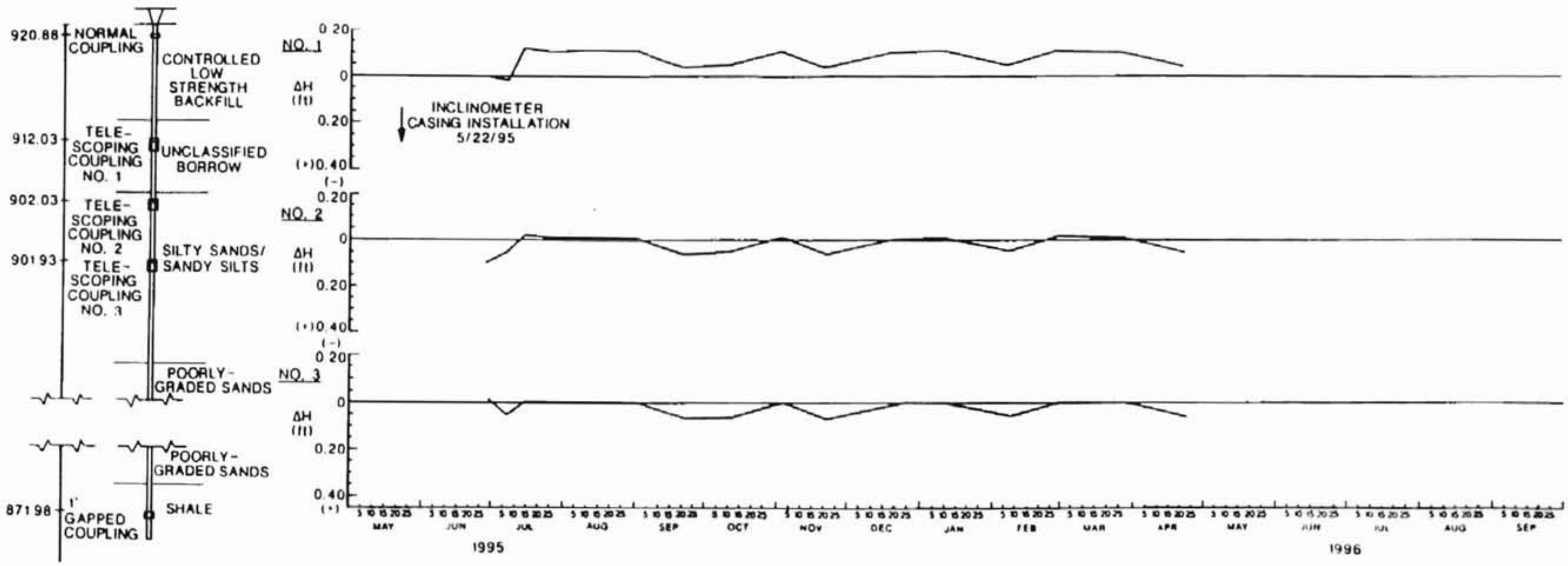
GAGES NORTH ABUTMENT WALL, BRIDGE B



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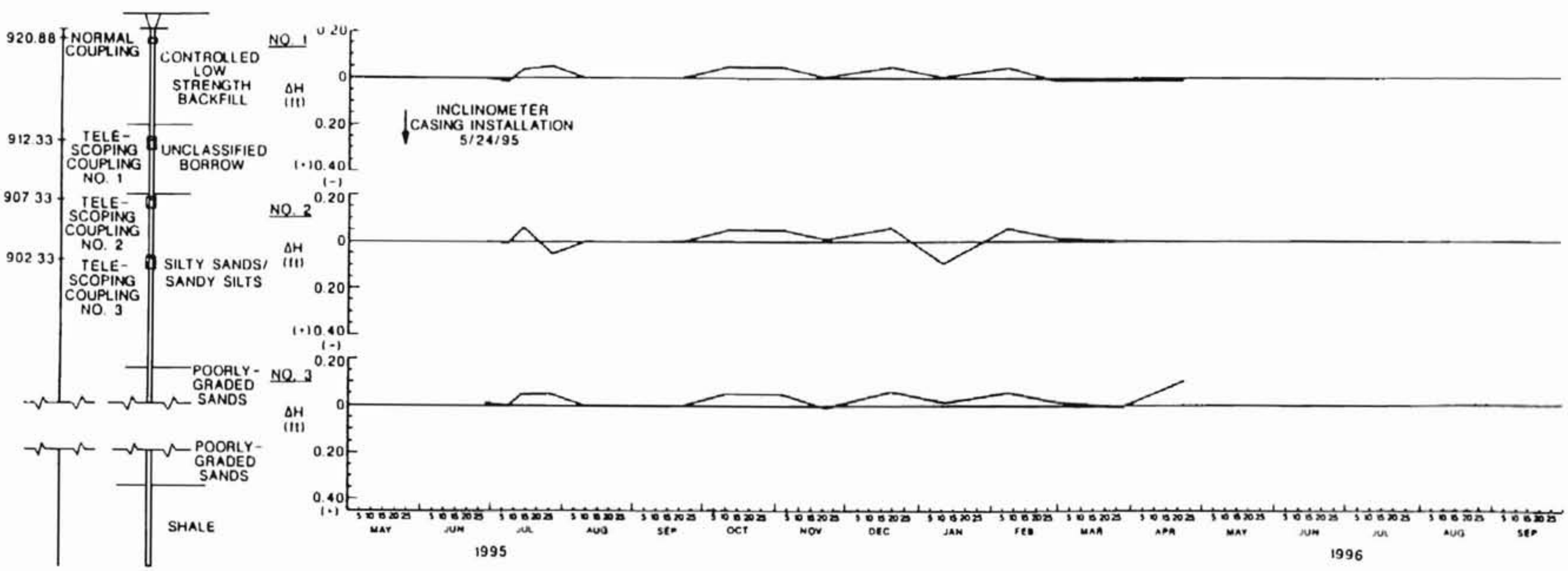

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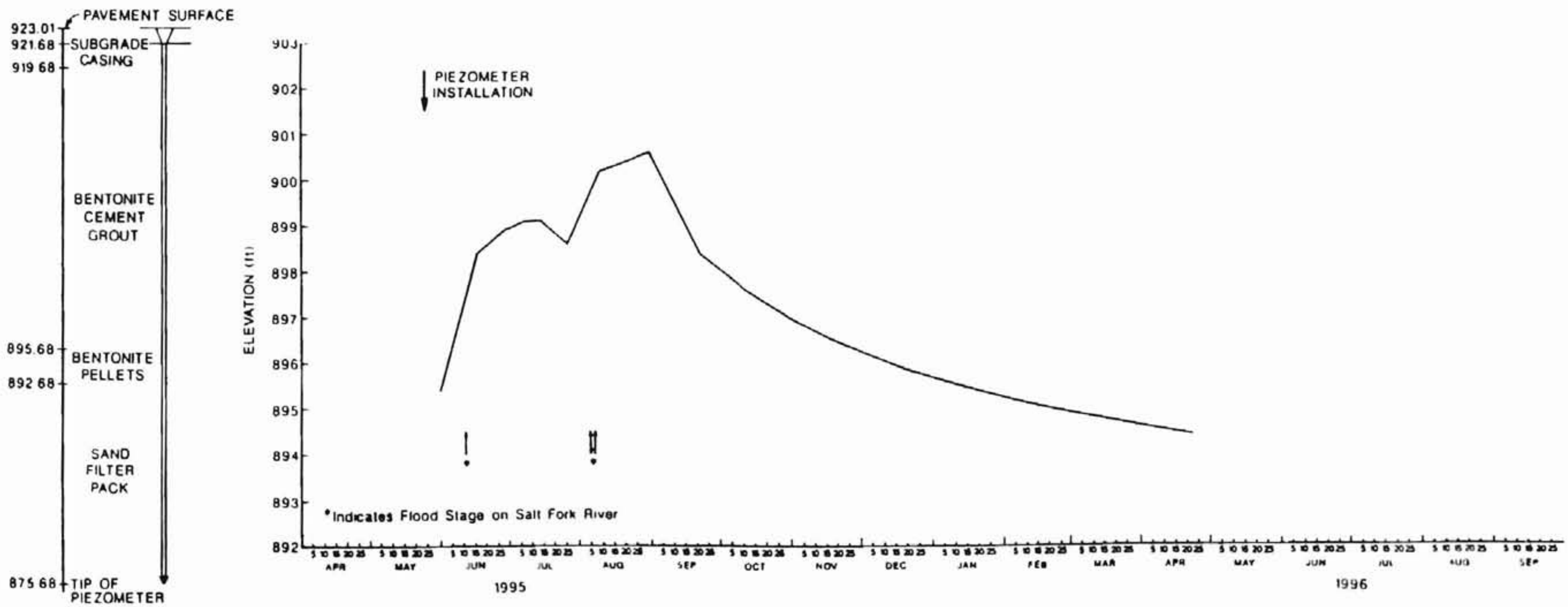
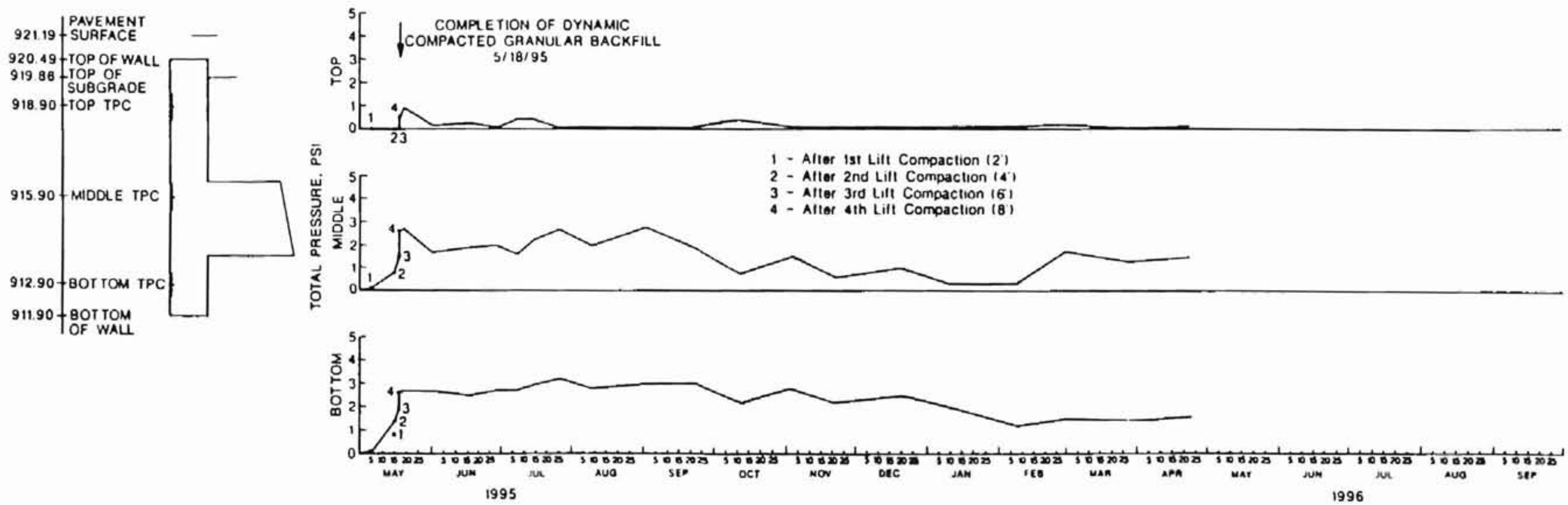


GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE B



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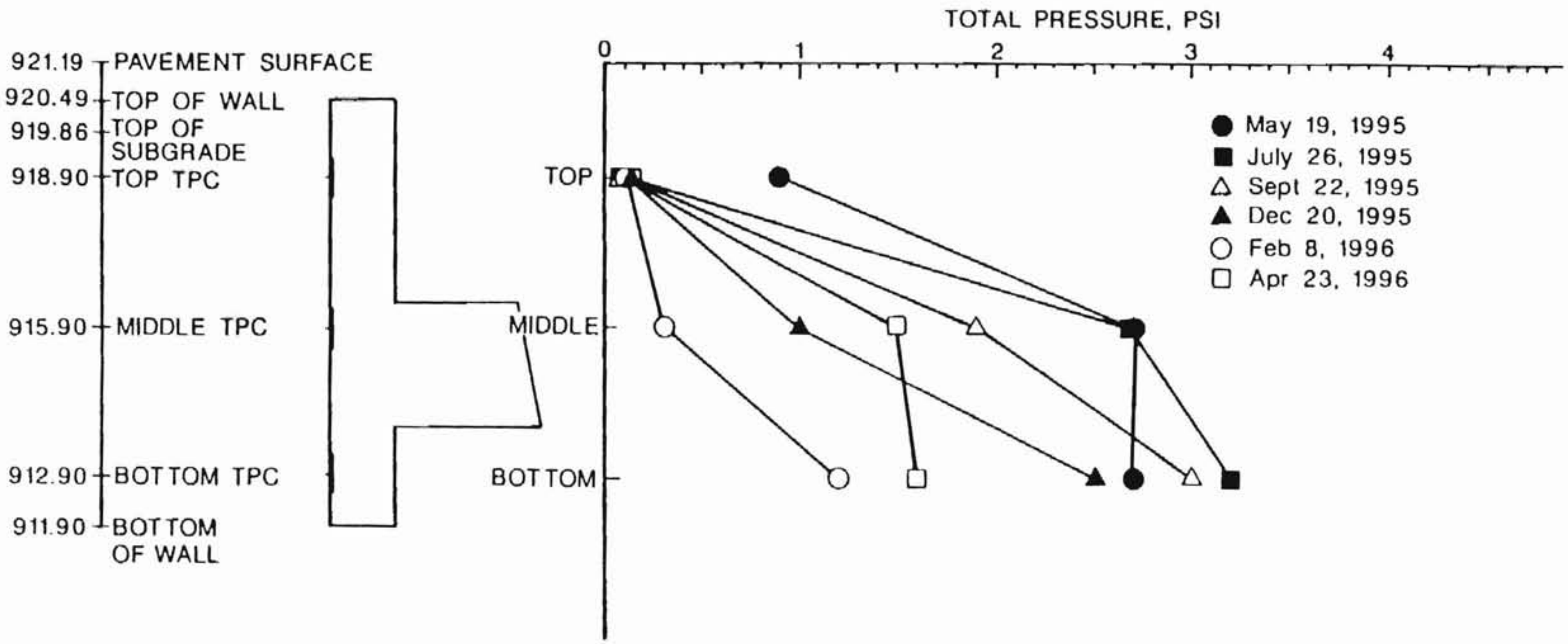

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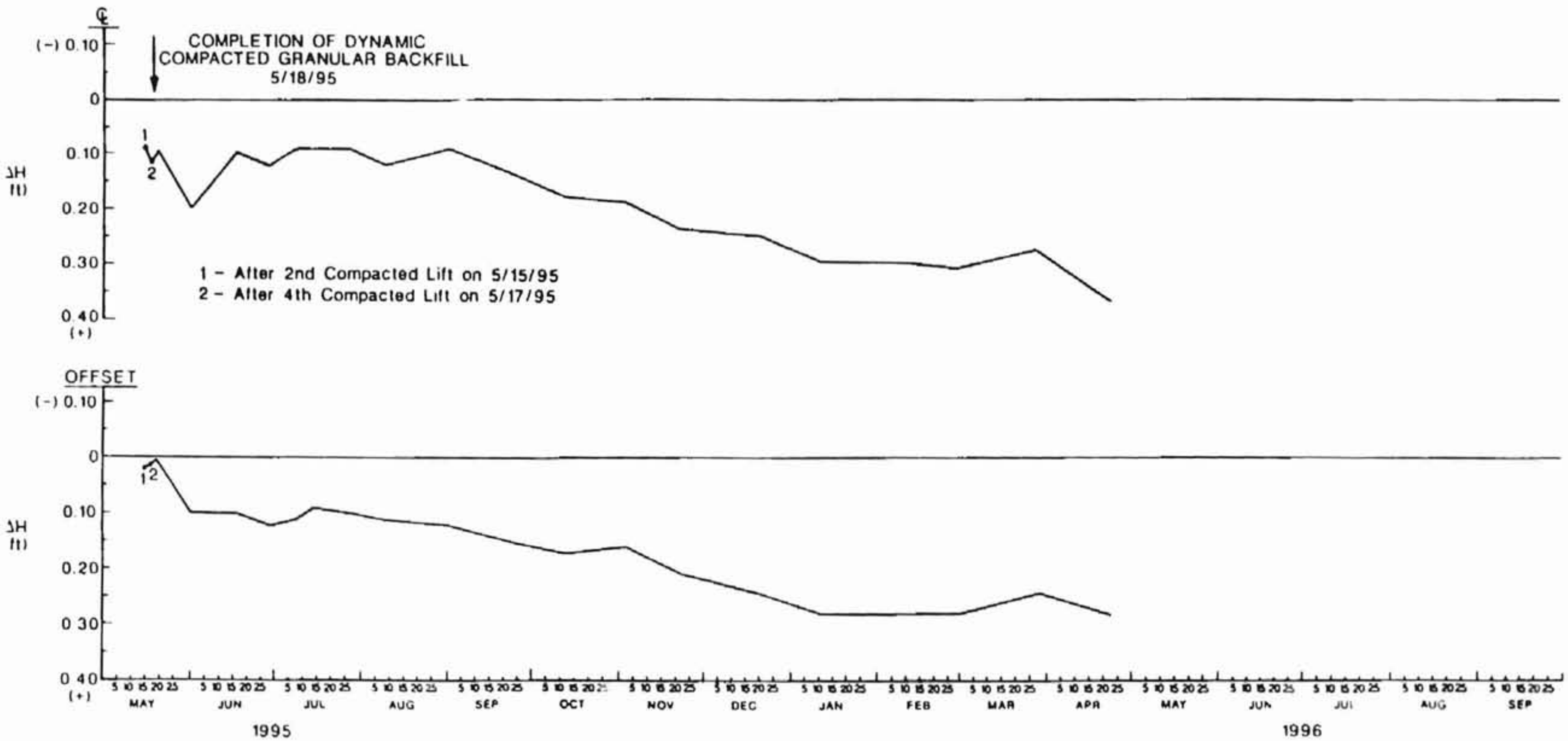

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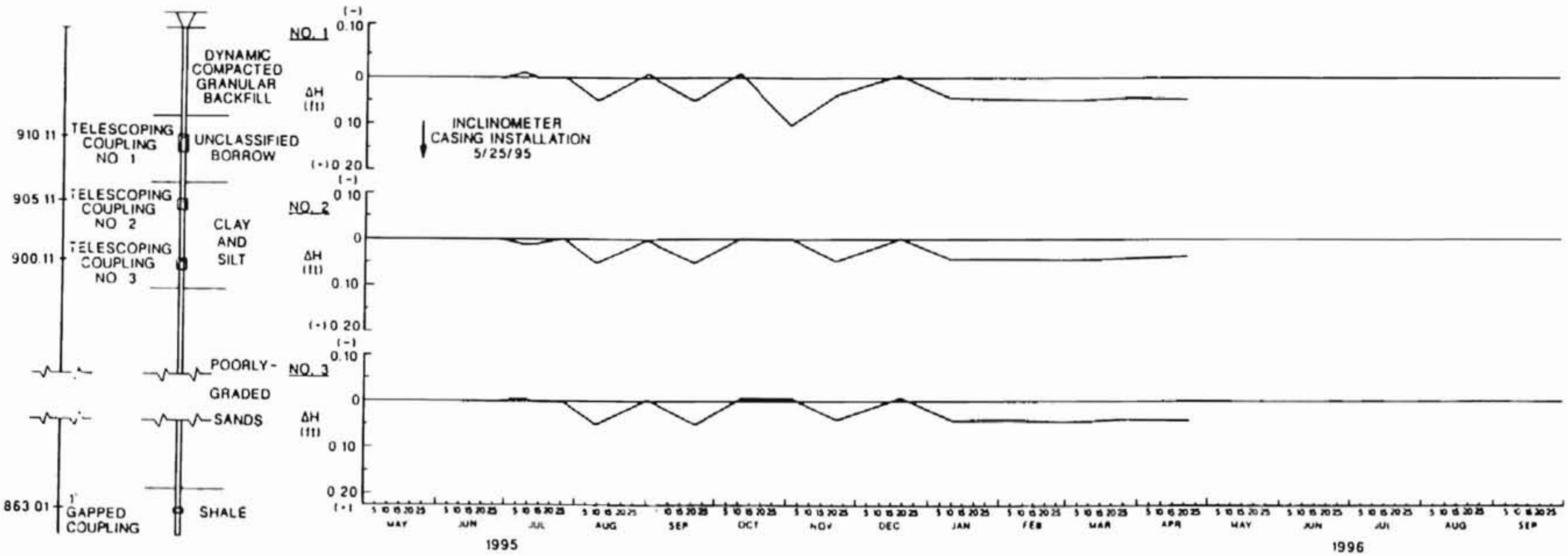
GAGES SOUTH ABUTMENT WALL, BRIDGE C



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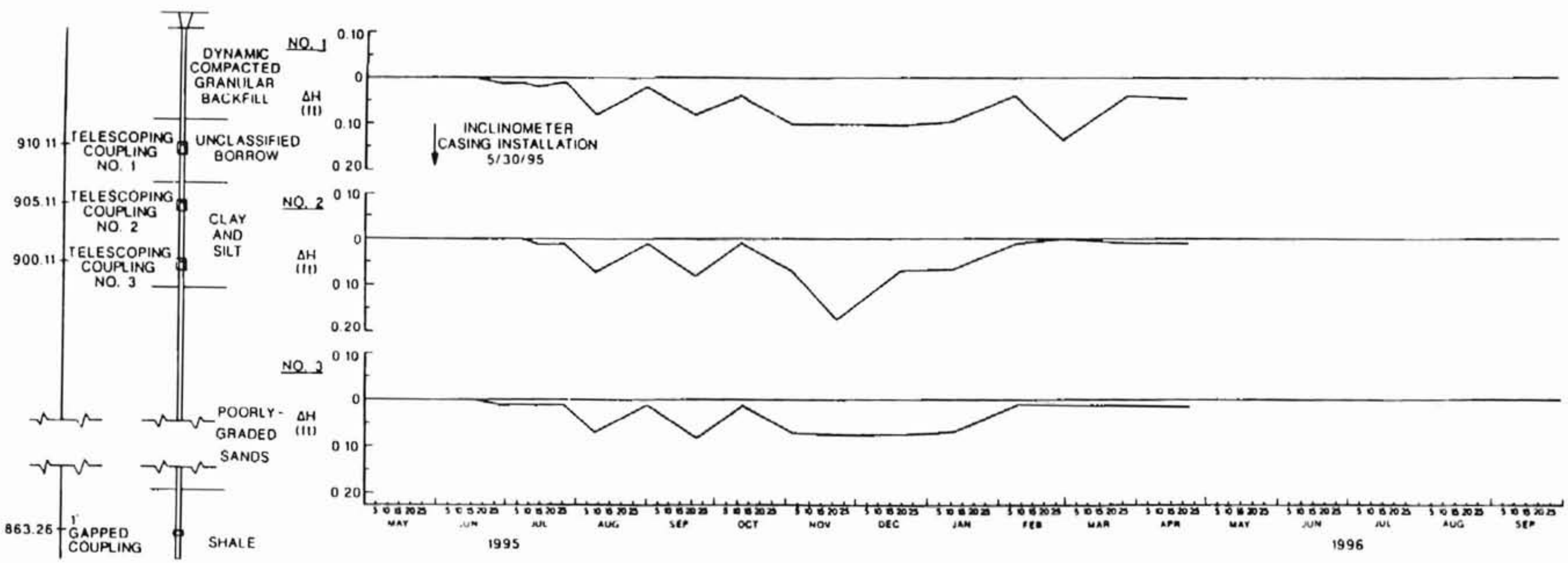

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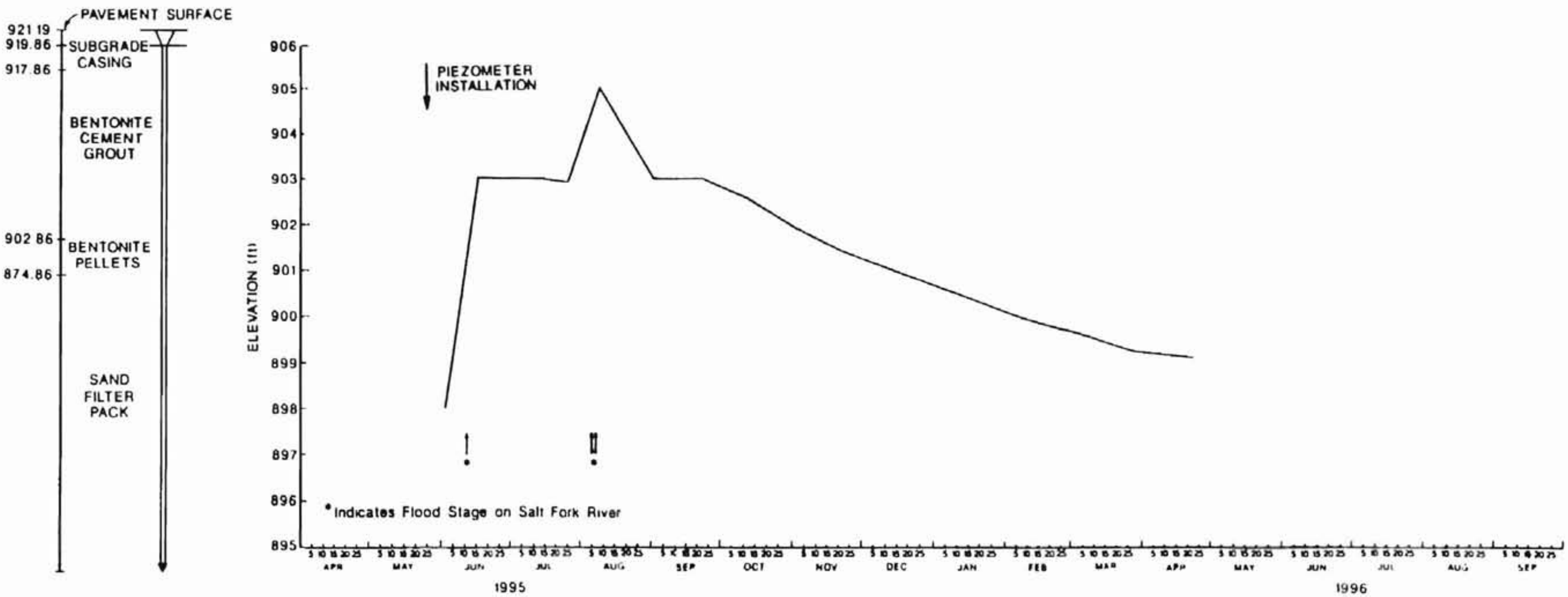
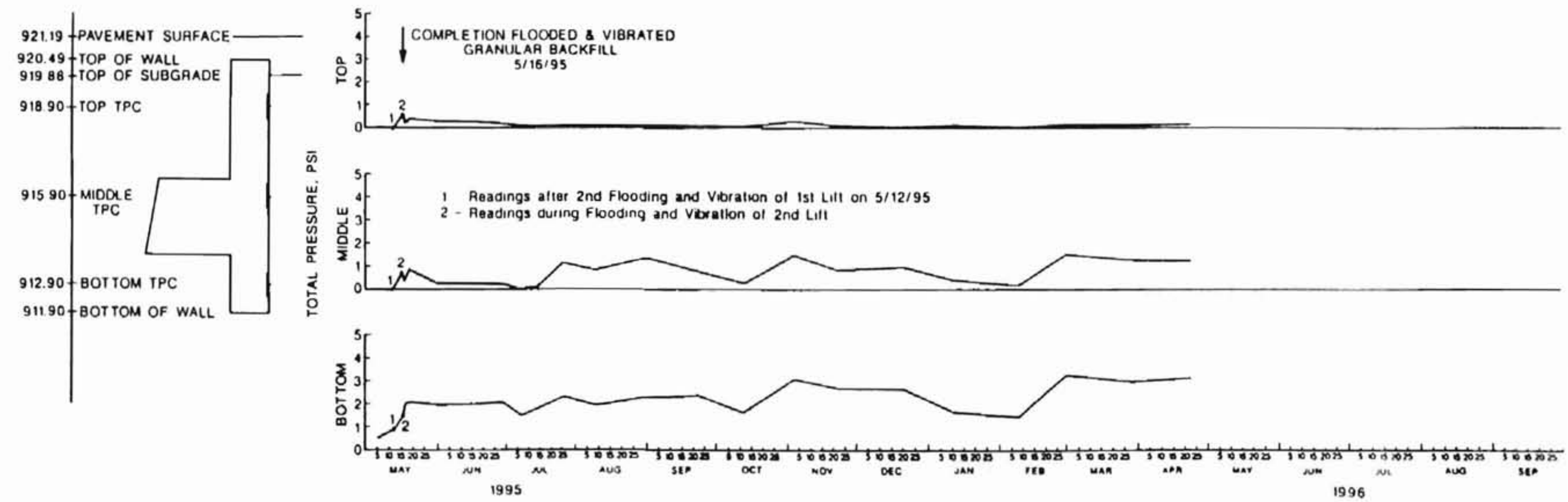
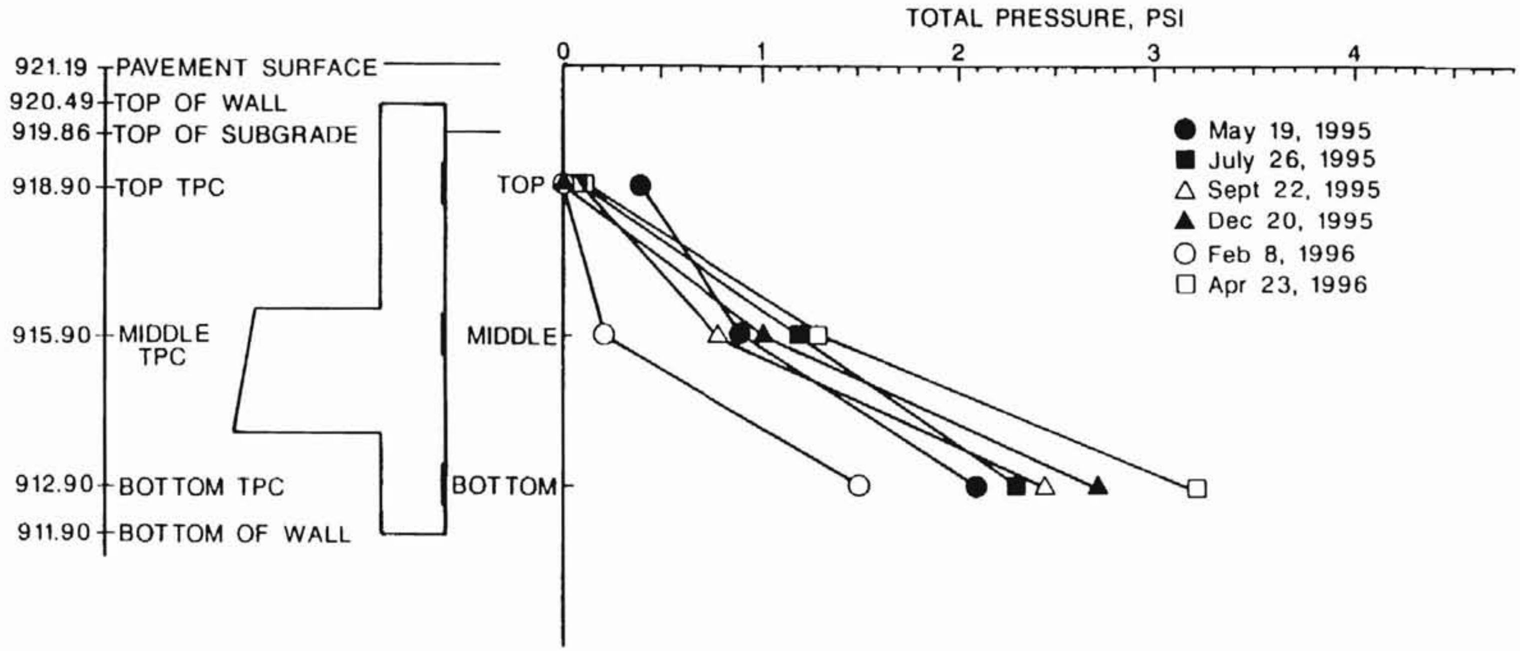


GROUNDWATER TABLE ELEVATION (TIME PLOT) SOUTH ABUTMENT WALL, BRIDGE C



TOTAL PRESSURE CELL DATA (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE C



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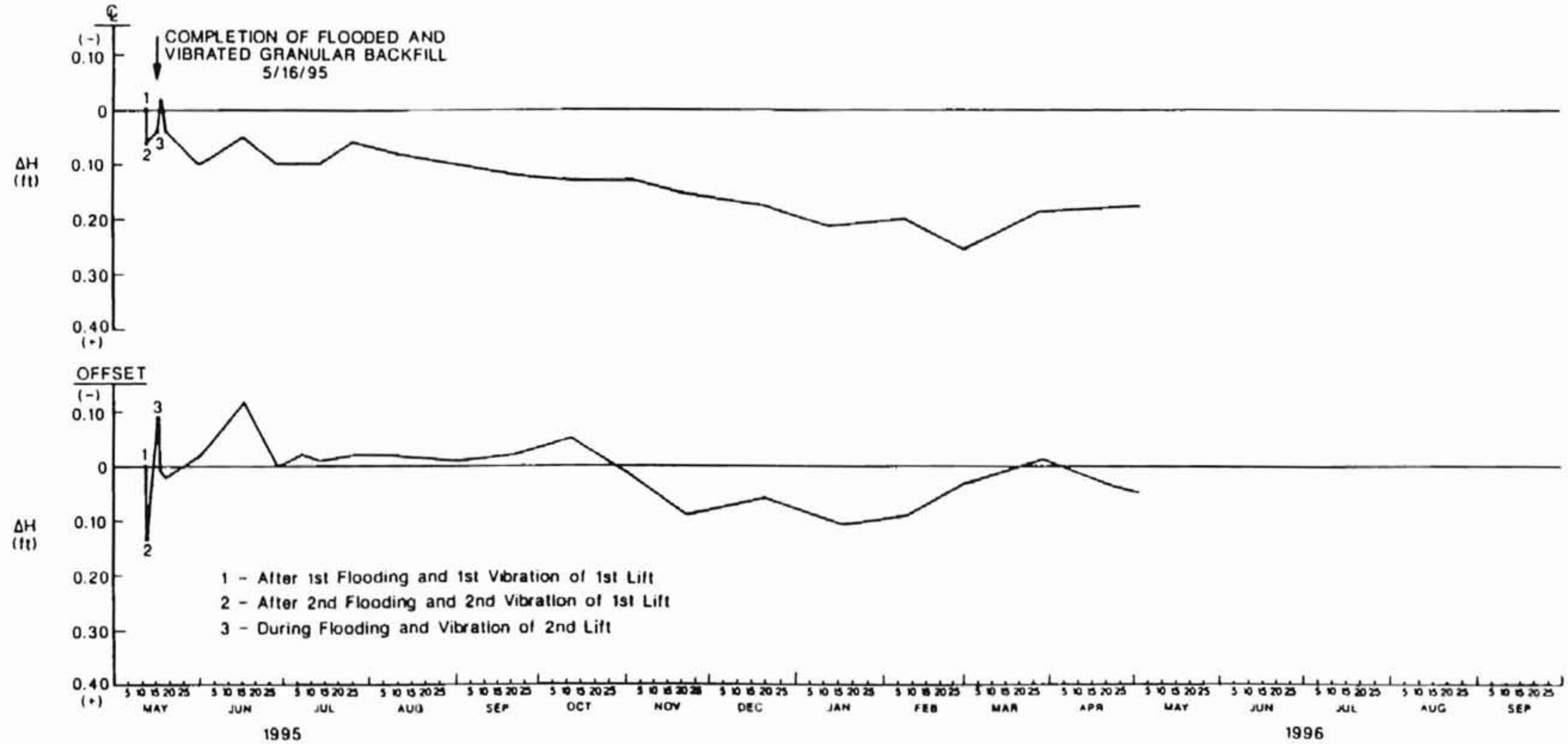

℄
(-)
0.10
0
ΔH
(ft)
0.20
0.30
0.40
(+)
COMPLETION OF FLOODED AND
VIBRATED GRANULAR BACKFILL
5/16/95
1
2
3
OFFSET
1 - After 1st Flooding and 1st Vibration of 1st Lift
2 - After 2nd Flooding and 2nd Vibration of 1st Lift
3 - During Flooding and Vibration of 2nd Lift
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
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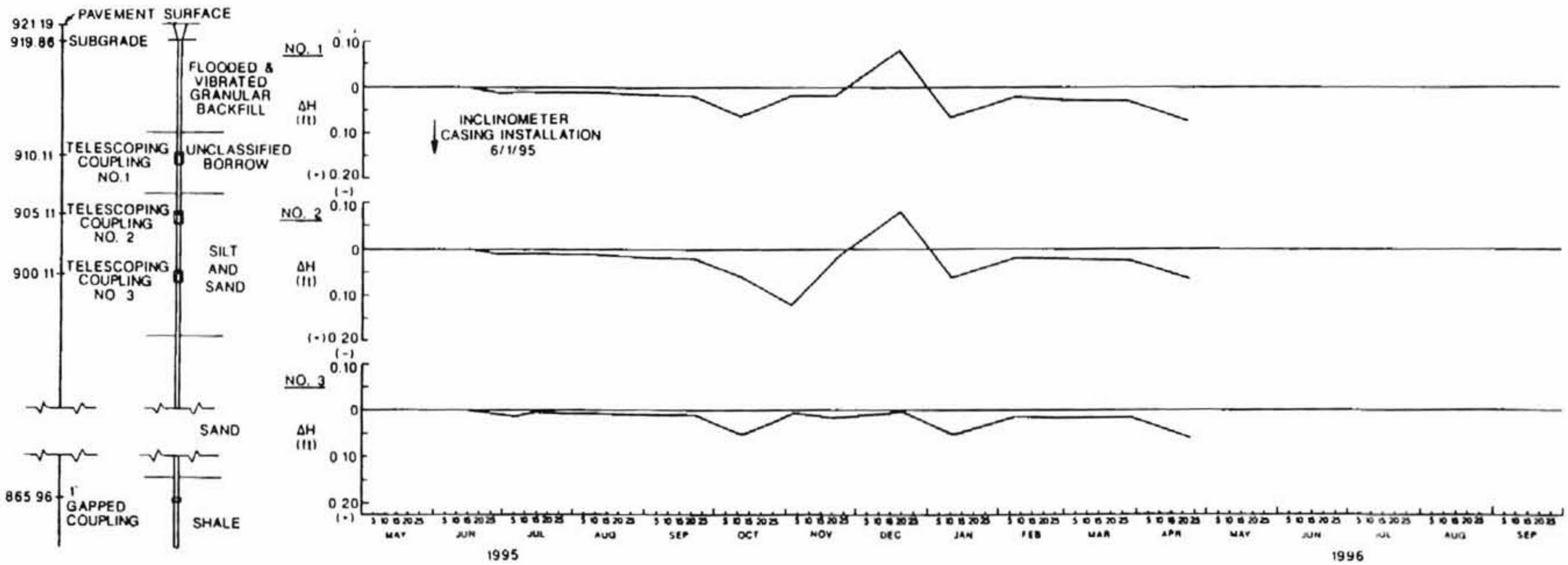
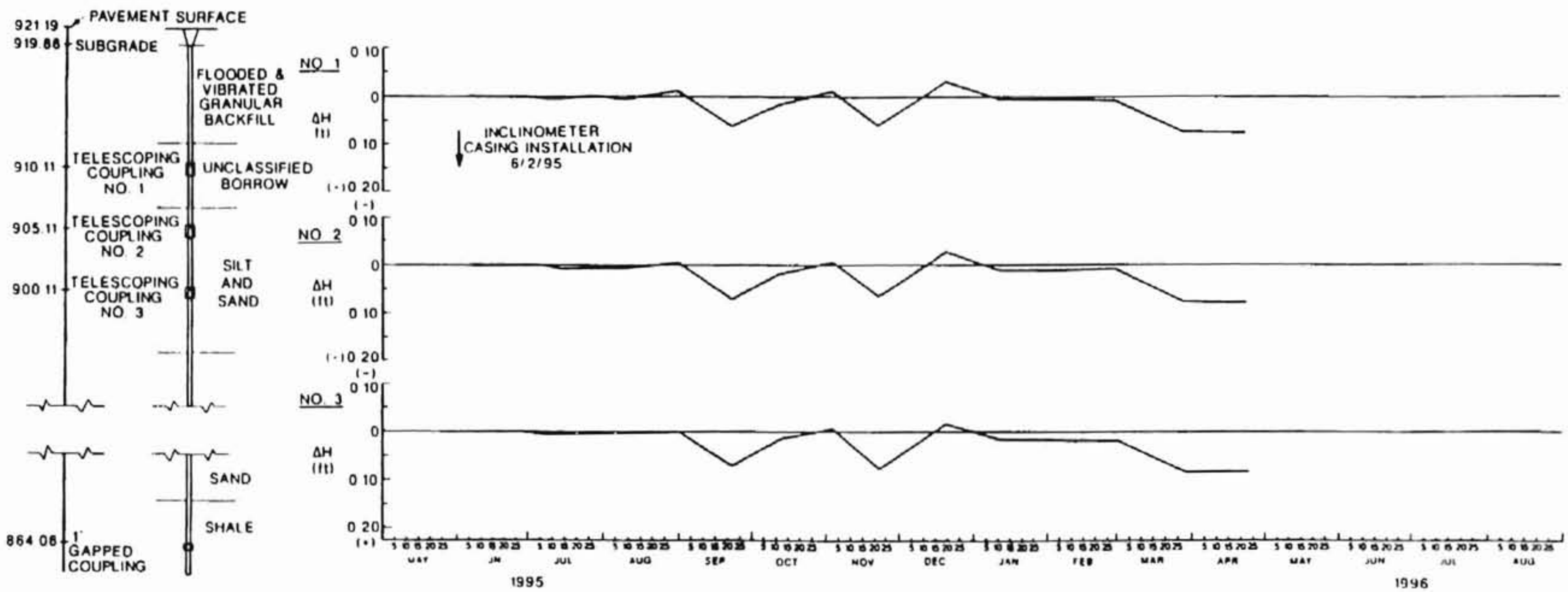
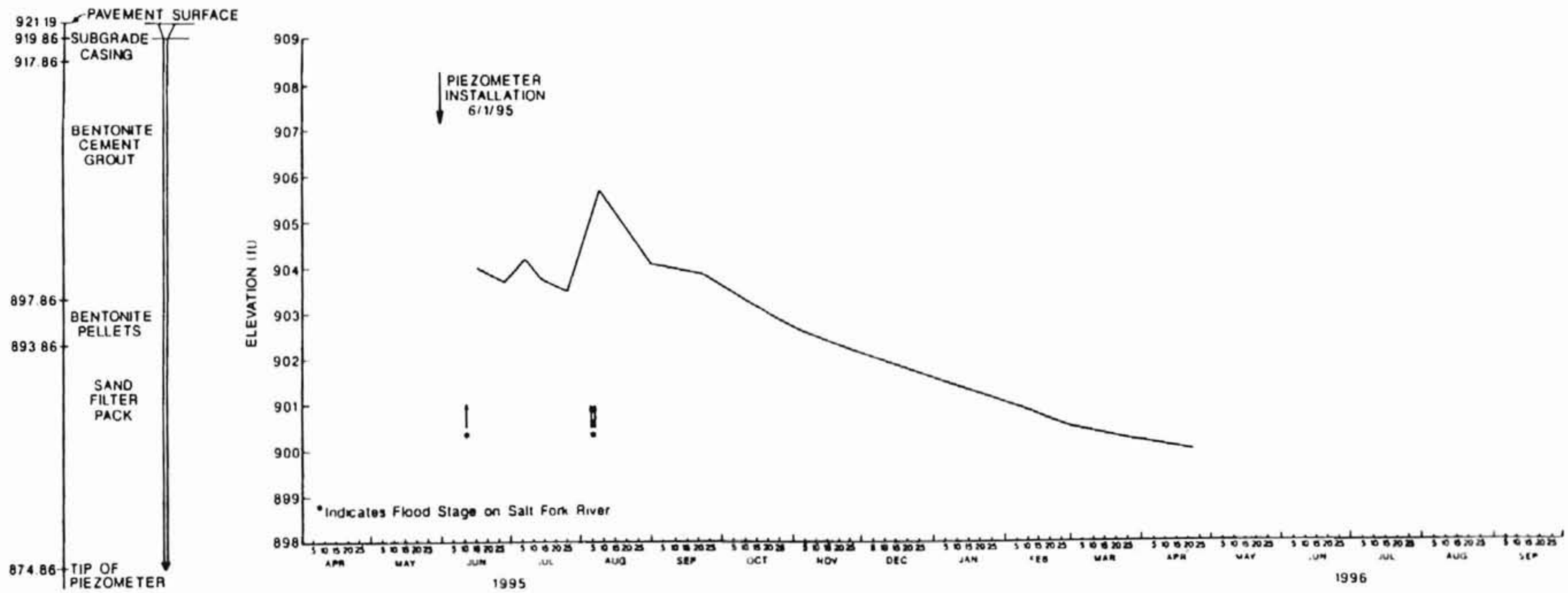
AUG
SEP
1995
1996



SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) CENTERLINE, NORTH ABUTMENT WALL, BRIDGE C



SETTLEMENT FROM INCLINOMETER TELESCOPING COUPLINGS
(TIME PLOT) OFFSET, NORTH ABUTMENT WALL, BRIDGE C



GROUNDWATER TABLE ELEVATION (TIME PLOT) NORTH ABUTMENT WALL, BRIDGE C

VITA

John M. Benson

Candidate for the Degree of

Master of Science

Thesis: CONSTRUCTION OF EXPERIMENTAL APPROACH EMBANKMENTS AT SALT FORK RIVER BRIDGES ON US 177 AND THEIR INITIAL PERFORMANCE

Major Field: Civil Engineering

Biographical:

Personal: Born in Norman, Oklahoma, on December 28, 1970, son of John and Beth Benson.

Education: Graduated from Broken Arrow Senior High School, Broken Arrow, Oklahoma, May 1989; received Associate of Science Degree from Tulsa Junior College, Tulsa, Oklahoma, July 1992; received Bachelor of Science Degree in Civil Engineering from Oklahoma State University, Stillwater, Oklahoma, May 1995; completed requirements for Master of Science Degree at Oklahoma State University, July 1996.

Experience: Employed by Western Technologies, Inc., Farmington, New Mexico, as a materials and soils testing technician, summer 1994; employed by Oklahoma State University as a graduate research assistant, 1995 to May 1996.

Professional Memberships: National Society of Professional Engineers, American Society of Civil Engineers