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16. ABSTRACT

Introduction

Large earth-moving equipment has made it economically feasible to construct high earth fills to span our mountainous terrain upon which our highways run. In many of these fills metal culverts must be installed in the bottom of the fill to provide surface to provide surface water to flow through them. The present culvert design formulas were developed for culverts to be buried in moderate fill heights. Concern has arisen regarding the validity of extrapolating these formulas to the design of culverts in high fills. In order to acquire a more rational culvert design formula under high fills, the California Division of Highways Bridge Department set up a research program to gather factual experimental data on the structural behavior of culverts buried underneath high earth fills and the structural behavior of the fill interior itself.

This report covers the work performed by the Materials and Research Department in instrumenting and acquiring the test data for a 114-inch diameter steel structural plate test culvert installation at Chadd Creek under an overfill height of about 90 feet. Analysis of the test data will be made by the Bridge Department.

A report entitled "Instrumentation for the Apple Canyon Culvert" was issued by this department in December 1966. The instrumentation work performed on Chadd Creek culvert was very similar to the work performed and reported on the Apple Canyon culvert installation. To avoid repetitious reporting, reference will be made to the Apple Canyon report where appropriate.

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STATE OF CALIFORNIA
HIGHWAY TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

INSTRUMENTATION REPORT

for

CHADD CREEK CULVERT

MARCH 1967

Prepared in Cooperation
with
The U S Department of Commerce
Bureau of Public Roads

67-42 DND

State of California
Department of Public Works
Division of Highways
Materials and Research Department

March 1967

19605-762500-36352

Mr. J. E. McMahon
Assistant State Highway Engineer, Bridges
California Division of Highways
Sacramento, California

Attention: Mr. J. G. Standley, Jr.

Dear Sir:

Submitted for your consideration is a report of:

INSTRUMENTATION

FOR THE

CHADD CREEK CULVERT

Instrumentation performed by . . . . . Foundation and Structural Materials Sections

Under direction of . . . . . E. F. Nordlin and T. W. Smith

Work supervised by . . . . . J. E. Barton and W. Weber

Report prepared by . . . . . W. Chow and W. Weber

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

WC:mw
Attach.
cc: Dist. 01

INTRODUCTION

Large earth-moving equipment has made it economically feasible to construct high earth fills to span our mountainous terrain upon which our highways run. In many of these fills metal culverts must be installed in the bottom of the fill to provide surface water to flow through them. The present culvert design formulas were developed for culverts to be buried in moderate fill heights. Concern has arisen regarding the validity of extrapolating these formulas to the design of culverts in high fills. In order to acquire a more rational culvert design formula under high fills, the California Division of Highways Bridge Department set up a research program to gather factual experimental data on the structural behavior of culverts buried underneath high earth fills and the structural behavior of the fill interior itself.

This report covers the work performed by the Materials and Research Department in instrumenting and acquiring the test data for a 114-inch diameter steel structural plate test culvert installation at Chadd Creek under an overfill height of about 90 feet. Analysis of the test data will be made by the Bridge Department.

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

THE CULVERT

This culvert installation is located at Chadd Creek in District I-Hum-101-39.2/47.3 near the little hamlet of Red Crest. The installation of the culvert and fill was performed as a part of a construction contract to relocate and improve this portion of U. S. Highway 101. A view of the Chadd Creek culvert and site, Figure 1, is shown prior to the fill construction.

The culvert installation is a galvanized steel structural plate pipe furnished by American Bridge Division of United States Steel Corporation. Figure 2 is a sketch showing a plan and elevation view of the installation. The culvert was 598 feet in length and 5% elliptical in shape to provide an inside major vertical axis of 114 inches and a minor horizontal axis of 103 inches (see Figure 3).

The culvert plates each were approximately 60 inches wide by 96 inches long and with corrugations of 6-inch pitch and 2-inch radii. Six steel plates were required to form each section of the culvert ring. The steel plates were No. 1 gage copper bearing steel, galvanized and conformed to AASHO M167. The ring sections were bolted together with ASTM A-325/AASHO 164 3/4" steel bolts.

The culvert was installed with a 3.8% grade and with one 10^{o} horizontal elbow at Sta. 1 + 16.

The Chadd Creek culvert was installed using method B backfill which consists of baled straw on top of 1'-2' of backfill layer over the culvert crown. This method is commonly known as the imperfect trench method. Figure 5 shows the baled straw in place over the culvert crown prior to the fill construction. Figure 2 gives the depth and limits of the straw over the culvert.

Apple Canyon culvert was installed without the baled straw so that a comparison of culvert structural action, with and without the baled straw, could be analyzed.

MEASUREMENT REQUIREMENTS

The instrumentation requirements at Chadd Creek were similar to the Apple Canyon installation. The installation procedures and methods of data acquisition at Chadd Creek were the same as at the Apple Canyon installation and fully described in that report.

Three test stations were completely instrumented at Chadd Creek culvert: Stations 0-96, 0+44, and 1+00 as shown on Figures 2 and 4.

The culvert strains were measured with Baldwin SR-4 FABX-50-350-S9 strain gages shown on Figure 6. The location and identity of these gages are shown on Figure 7.

Culvert distortions in the vertical plane (chord lengths) were measured with an inside micrometer and also by a photographic method. The chord length identity are shown on Figure 8. Culvert longitudinal changes were measured with an outside micrometer and their identity and locations are also shown in Figure 8.

Soil pressures around the outside periphery of the culvert and in the fill body were measured with soil pressure meters. Figure 4 shows the location of the eleven meters and their identity at each of the three test stations.

Pressure meter leadout cable was shielded in flexible metal conduit. The conduit was connected to electrical junction boxes, which were mounted over holes in the culvert near the crown. In addition, electrical knockout boxes were installed near the midpoint of each of the conduits. The leadout cables were coiled several times in these boxes so that movement in the fill would not produce tension on them. The conduits were then connected to a common junction box, mounted with a 20 inch slip joint on a vertical pipe leading into the culvert. Typical results of soil pressure meter study may be seen in Figures 9 through 11.

Sealed fluid level type settlement platforms, Figure 12, and inverted riser pipe settlement platforms, Figure 13, were installed at Chadd Creek. The former were used to measure the fill settlement and the latter to measure the straw compression.

The initial group of settlement platforms was installed on original ground with plastic air and water lines. These lines were shielded in flexible metal conduit throughout

the entire distance to the outside of the fill. These conduits, along with the drain lines, were buried in the structure backfill next to the culvert. Additionally, the lines were run in ditches from about 10 feet inside the fill to the base of the indicator box post. Platforms were hand dug into the bottom of the ditch, hand backfilled and compacted by wheel rolling. Subsequent installations of settlement platforms were placed entirely in ditches prepared by the contractor.

The instrumentation plan provided for eleven fluid type settlement platforms at each station installed in four layers at twenty foot intervals (see Figures 14 - 16). The first group was inadvertently installed normal to the culvert rather than parallel to the centerline of the road, which resulted in unequal heights of fill over individual locations at the same station. To compensate for this, two additional settlement platforms were placed at each station, parallel to road centerline as shown in Figure 17.

Detailed explanation of the theory, construction, installation and readout of the above-mentioned instruments are fully described in the report, "Instrumentation for the Apple Canyon Culvert" by the Materials and Research Department dated December 1966 and are not repeated here.

As previously mentioned, baled straw was placed on top of the culvert crown. In order to measure the baled straw compression versus advancing fill height, inverted settlement platforms of the type shown on Figure 13 were installed. One each of these platforms was placed at each test station so that they extended from the upper, soil-straw interface down through holes drilled in the crown of the culvert. Readings of the three steel plate inverted settlement platforms were obtained by leveling on the bottom of the steel rod to determine the absolute straw compression. The distance to the bottom of the rod that protruded below the culvert wall was also measured to determine the relative settlement.

Time-settlement graphs for the three inverted settlement platforms are shown on Figures 18, 19, and 20.

INSTALLATION HISTORY

The culvert plates arrived on the job site Thursday, September 16, 1965. Instrumentation installation was started on this date. Because of the imminent beginning of the seasonal rains, the contractor was most desirous of constructing the culvert and backfilling it as quickly as possible. The laboratory crew cooperated fully in this respect by working 12 hour days and also on Saturday and Sunday for two weekends.

Contractor's erection of the culvert and the laboratory's instrument installation proceeded concurrently. Figure 21 is a view of the partially erected culvert with instrumentation being installed in the bottom of the invert. Because of the prediction of early winter rains, the contractor backfilled sections of the culvert as soon as partial culvert sections were completed. A view of this is shown in Figure 22. The laboratory crew concentrated on installing the strain gages on the outside of the culvert at Sta. 0-96 first so that the contractor could backfill the culvert in that vicinity immediately. By Sunday, October 3, the strain gage installations at all 3 test stations, both inside and outside, were completely finished and the contractor could backfill at will. On October 9, 150-200 feet of pipe on the upstream end had been backfilled. Figure 23 is an over-all view of the backfill operation. The soil meters around the outside of the culvert were installed concurrently as the backfill was put in. Note in Figure 23 the 4 soil meters on the culvert. These were placed in their assigned locations as the backfill was brought up around the culvert.

On October 12 all planned instrumentation for the culvert was finished and completed except the soil pressure meters and settlement platforms which were to be installed in the fill body. Naturally these would be installed in their assigned locations as the fill was brought up to height.

The first rain of the season arrived on October 14, and it was heavy. Backfilling operation to the top of the culvert crown was finished by November 8. Baled straw placement was started on this date. A view of the straw placement is shown on Figure 5. On November 19 all of the baled straw was in place over the culvert crown and with 2 feet of fill over the straw.

With the arrival of the rainy season on October 14, construction of the fill was delayed until the following spring.

The laboratory crew took many sets of readings of the strain gages, settlement platforms, soil meters, and chord lengths to verify correct instrument operation during the

installation period. After the first rain it was necessary to dam the upstream end of the culvert to stop the water flow through the culvert in order that the instrumentation data could be taken. Figure 24 is a view of the pond formed by damming the culvert. Culvert discharge is shown in Figure 25 when the dam was released.

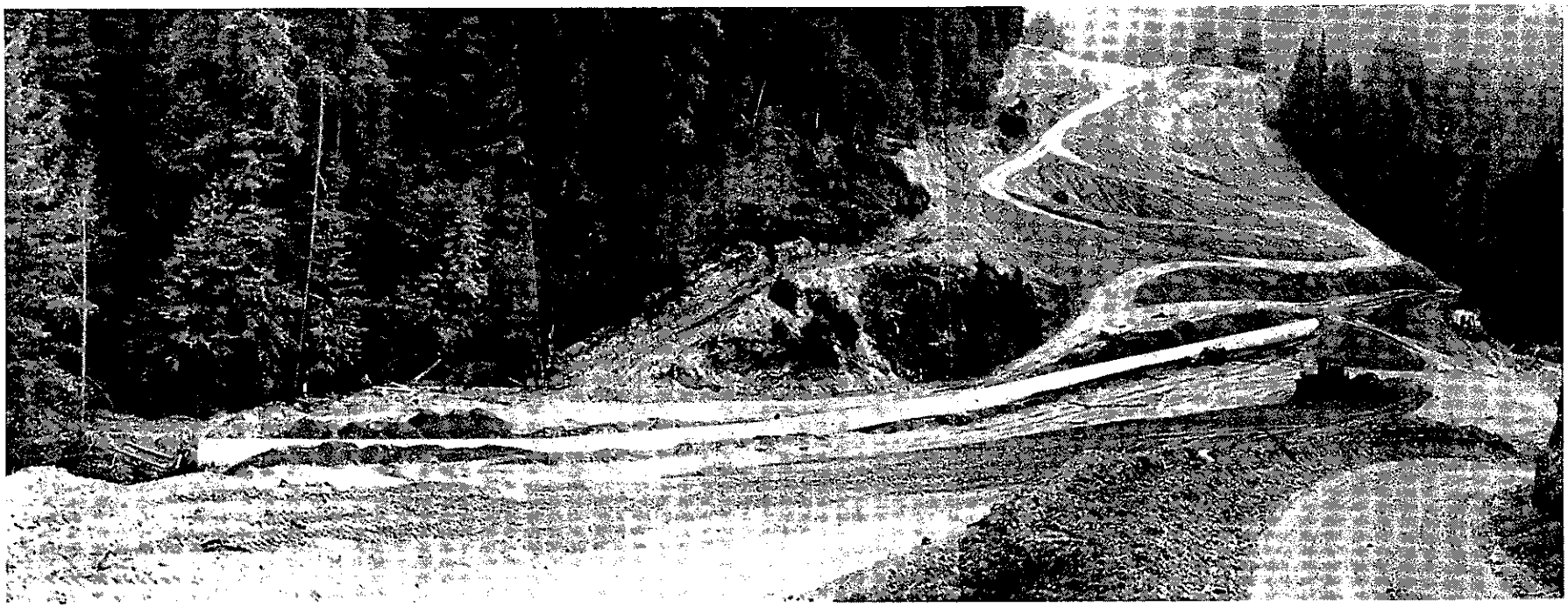
A final set of instrumentation readings was taken on November 19, 1965, and completed at 10:00 P.M. that night. When the crew emerged from the culvert, a heavy downpour was in progress.

On November 19 the contractor shut down all operations for the winter and the laboratory crew left and did not return until next spring.

Severe storm damage occurred during the winter of 1965-66, resulting in the failure of five settlement platforms placed on original ground (Settlement Platforms 1, 2, 4, 5, and 6). Additionally, Settlement Platform 33 became inoperative shortly after installation due to a leak in the water line.

Spring construction started again on this project in late April 1966. The laboratory crew returned to Chadd Creek in April. Storm damages were confined to the settlement platforms with no damage to the other instrumentation. All strain gages and soil pressure meters were operative and with high insulation resistance.

Fill construction started in early May and was finished in September 1966. Ten sets of instrumentation data were taken during the construction of the fill and are listed on Figure 26. Instrumentation data will be taken at 6, 9, 12, 18, and 24 months after fill completion as set forth in the Bridge Department plans.



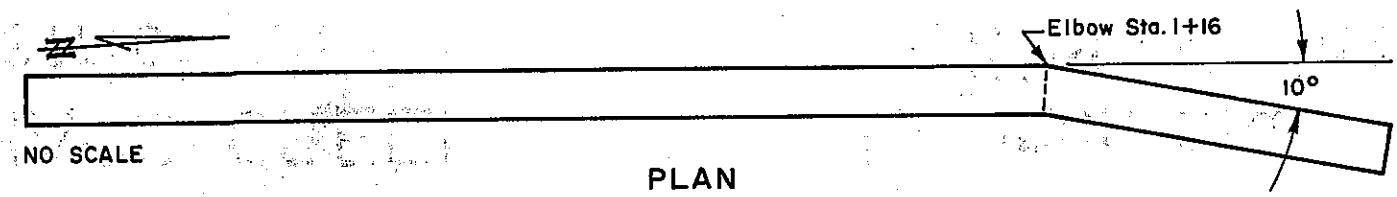
CHADD CREEK
District 01
Hum-101

114 inch dia.
multiplate steel
culvert.

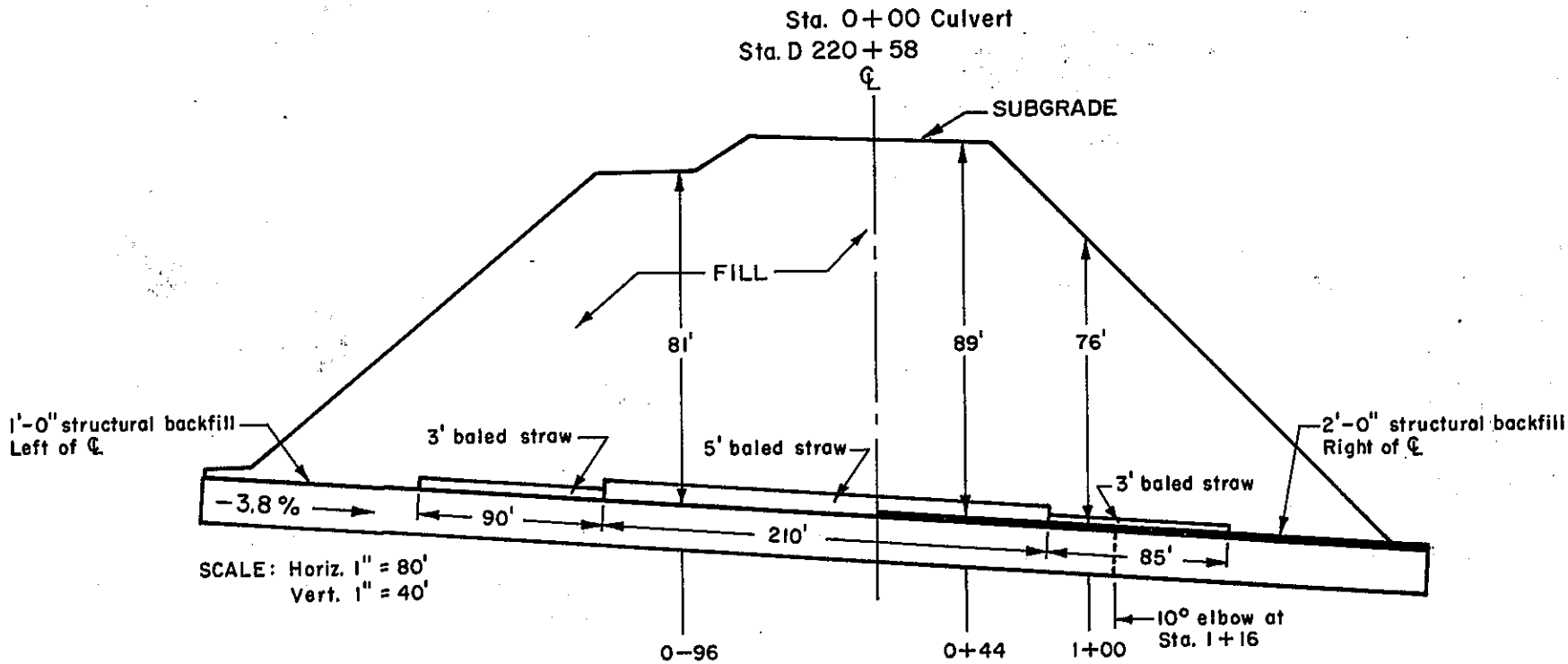
Figure 1

INSTALLATION AT CHADD CREEK OF 114" x 598' PIPE CULVERT

01-HUM-101 39.2/47.3

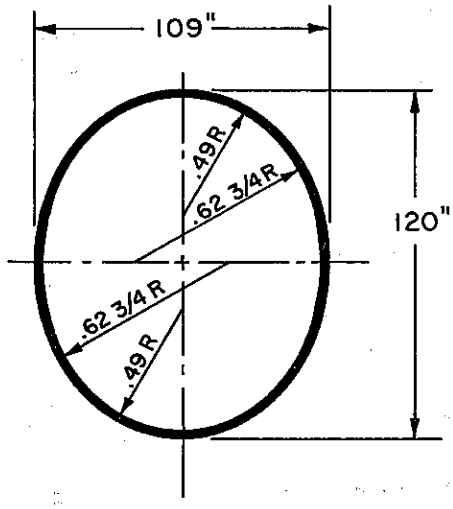


PLAN



ELEVATION

CHADD CREEK PIPE CULVERT
VERTICAL SHAPE



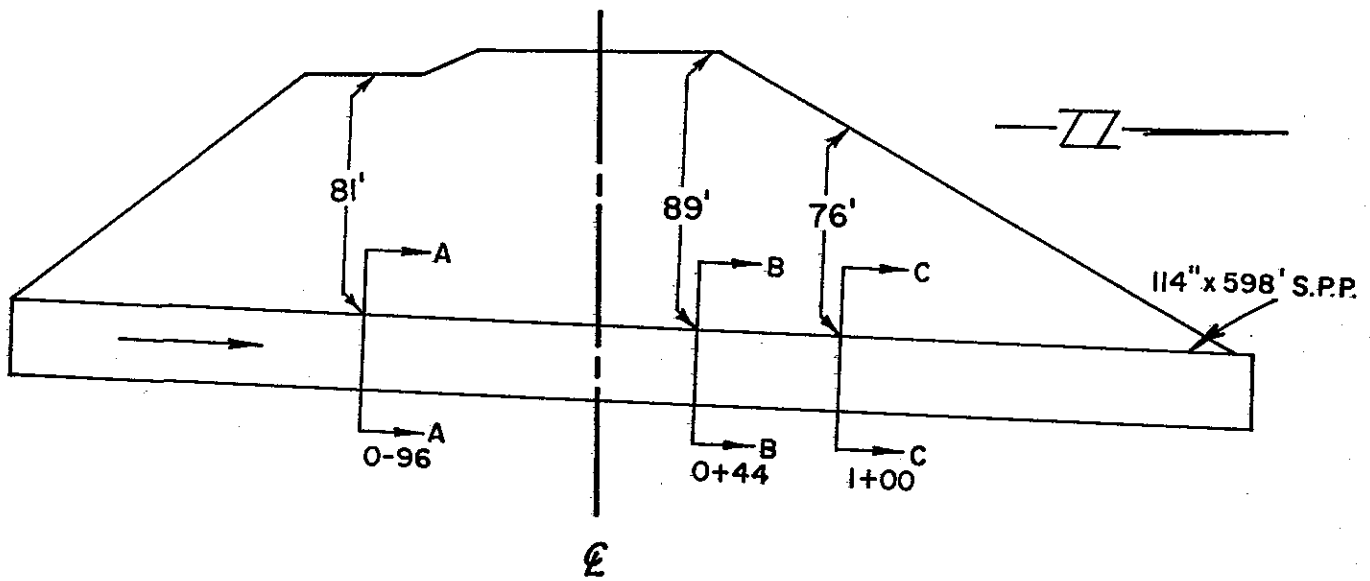
ELLIPTICAL PIPE

PIPE CULVERT DIMENSIONS	
	Nominal - Inches
Inside Horizontal	103"
Outside Horizontal	109"
Inside Vertical	114"
Outside Vertical	120"

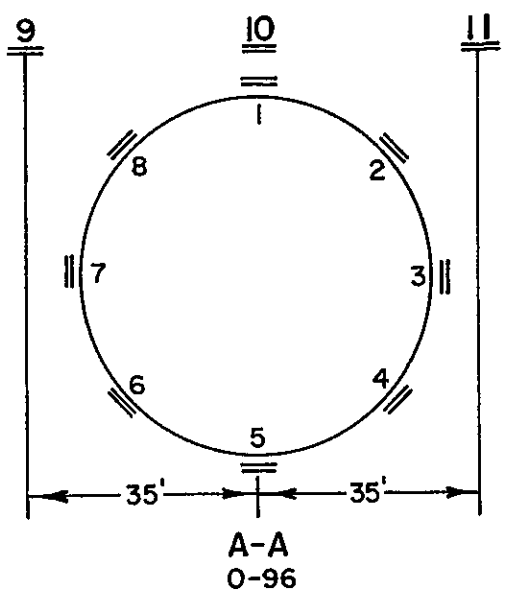
Figure 4

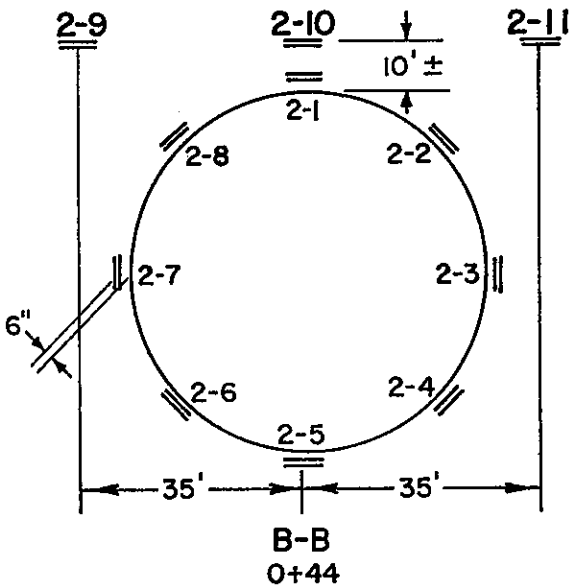
CHADD CREEK SOIL PRESSURE METER IDENTIFICATION

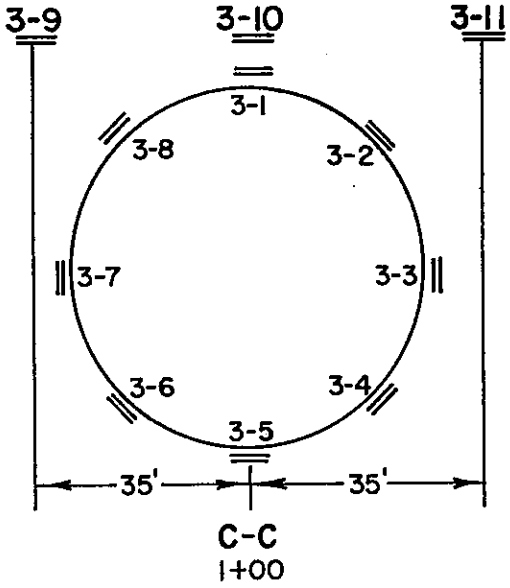
I-HUM-101 39.2/47.3



NO SCALE







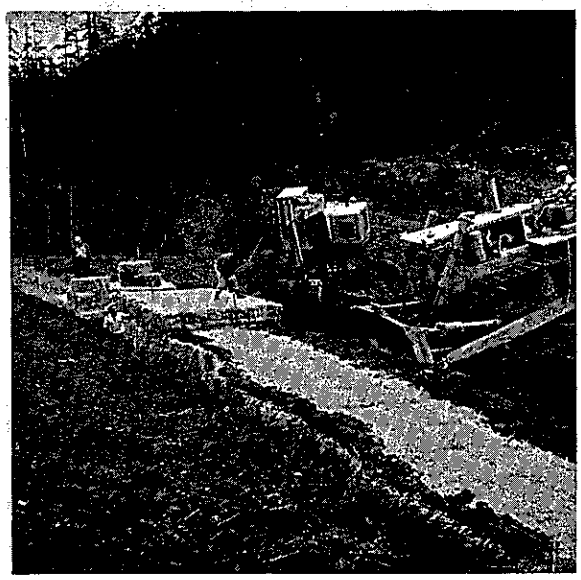


FIGURE 5

PLACEMENT OF BALED STRAW
OVER THE CULVERT

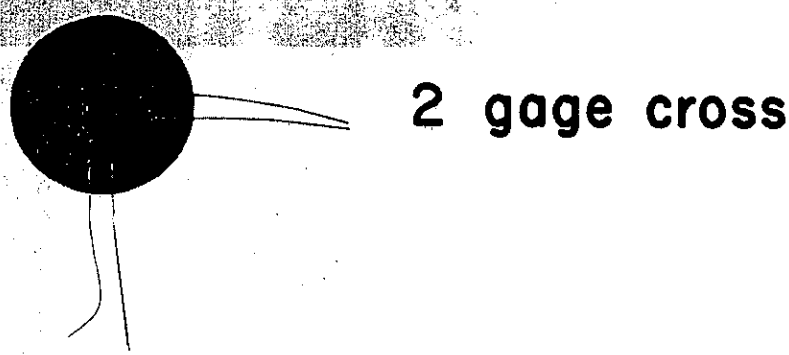


FIGURE 6

BALDWIN SR-4 STRAIN GAGE

STRAIN GAGE NUMBER SYSTEM (identical at each sta.) FOR CHADD CREEK CULVERT

GAGE STATIONS	
CHADD CREEK	0-96, 0+44, 1+00

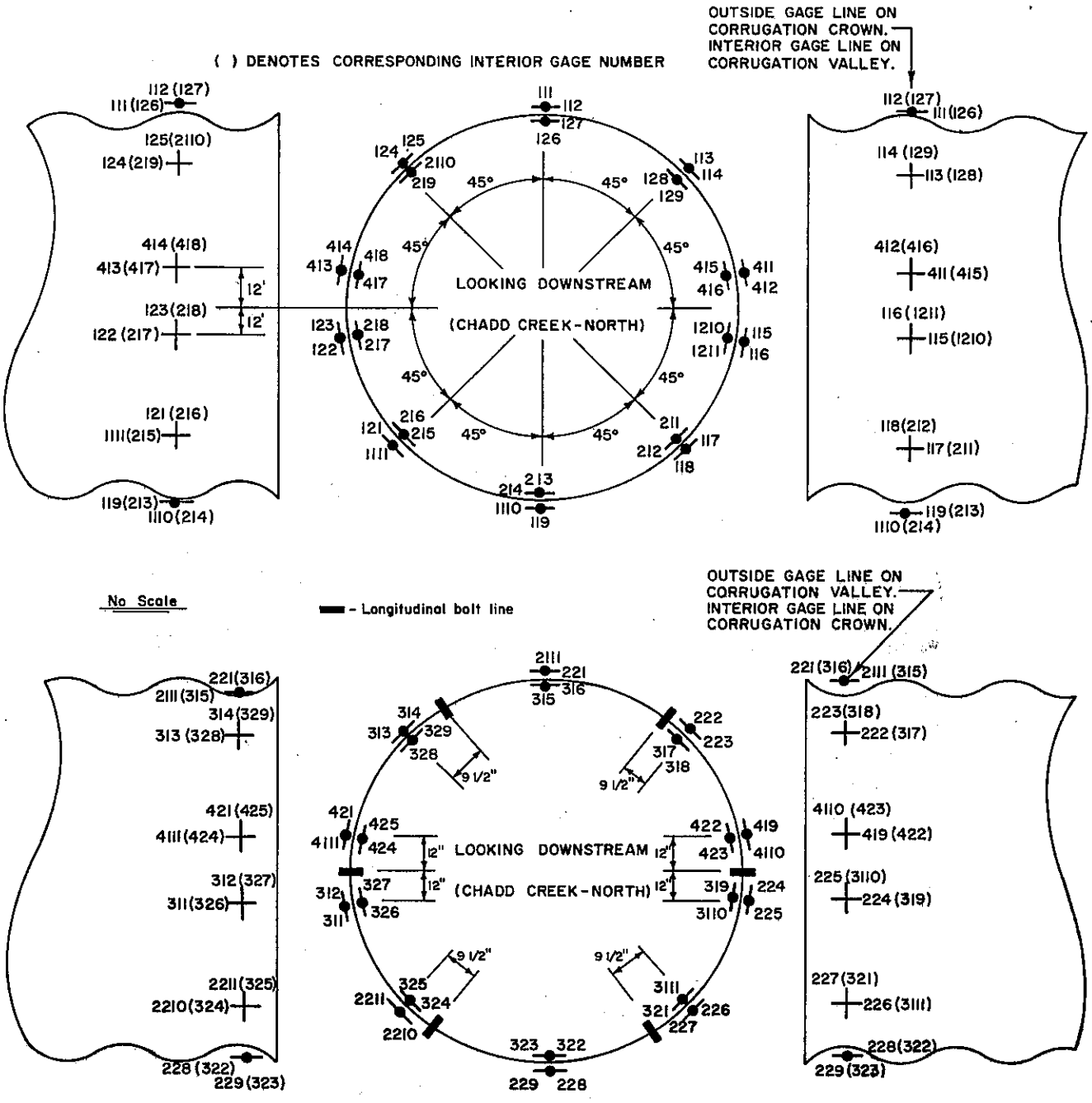


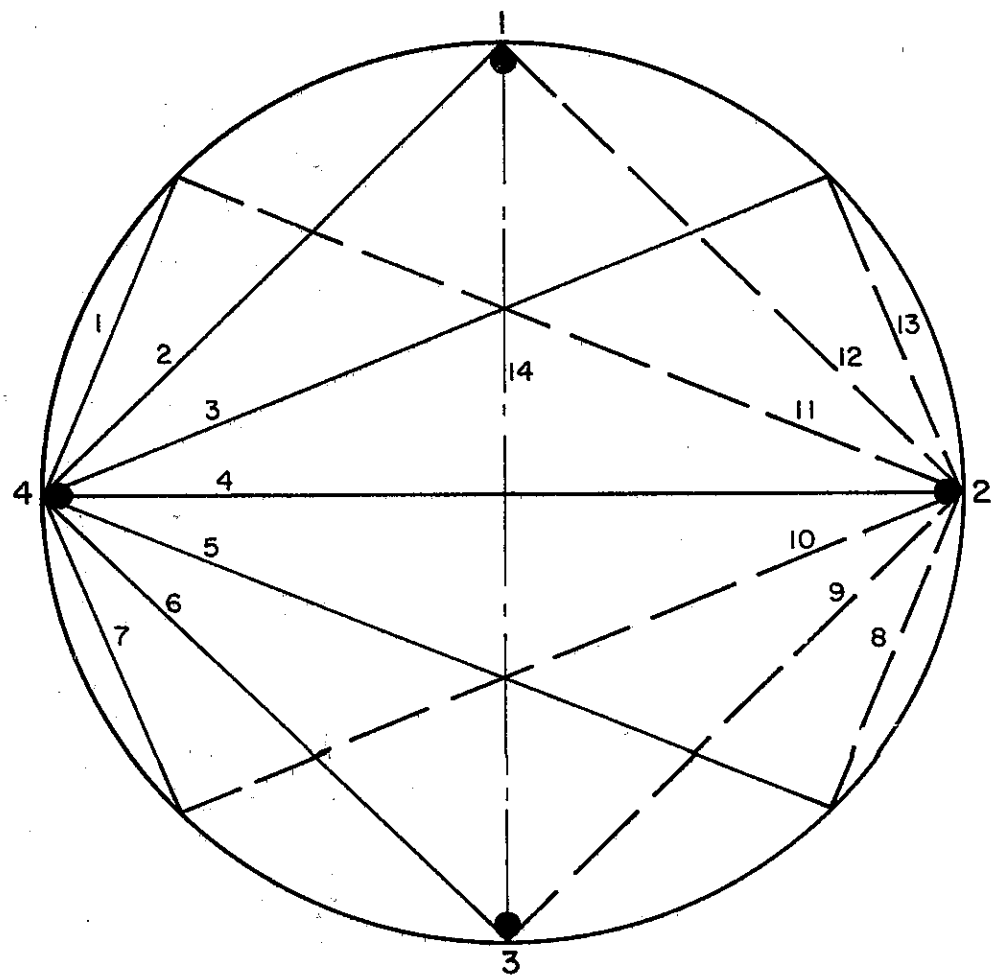
Figure 8

CULVERT DEFORMATION MEASUREMENTS
CHADD CREEK

LEGEND

Chord Length Identity — 2

Corrugation Elongation Identity ●



LOOKING DOWNSTREAM

Figure 9

VARIATION OF EFFECTIVE DENSITY
CHADD CREEK STA.A(0-96)

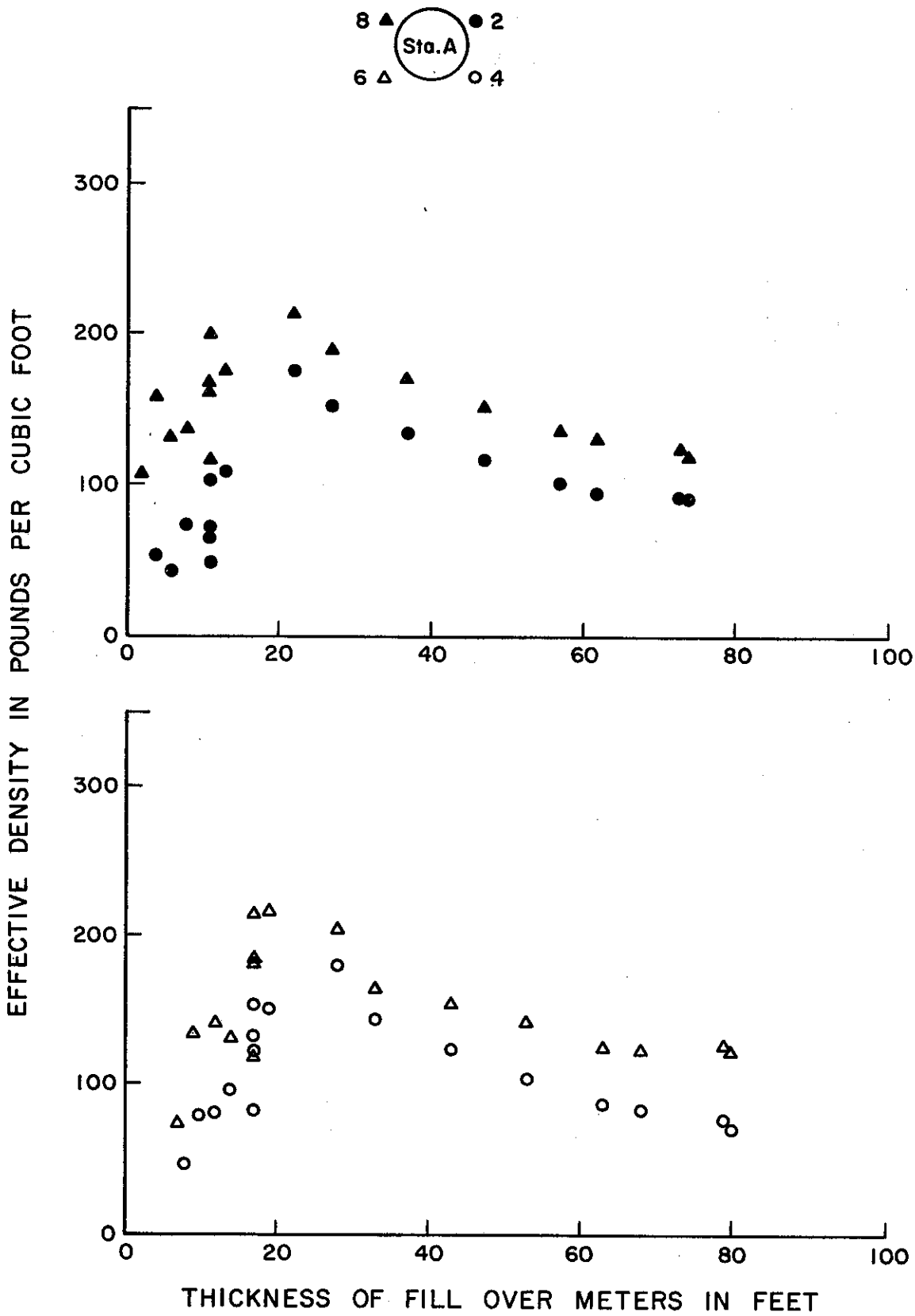


Figure 10

VARIATION OF EFFECTIVE DENSITY
CHADD CREEK STA. B (0+44)

Stress Meter Legend

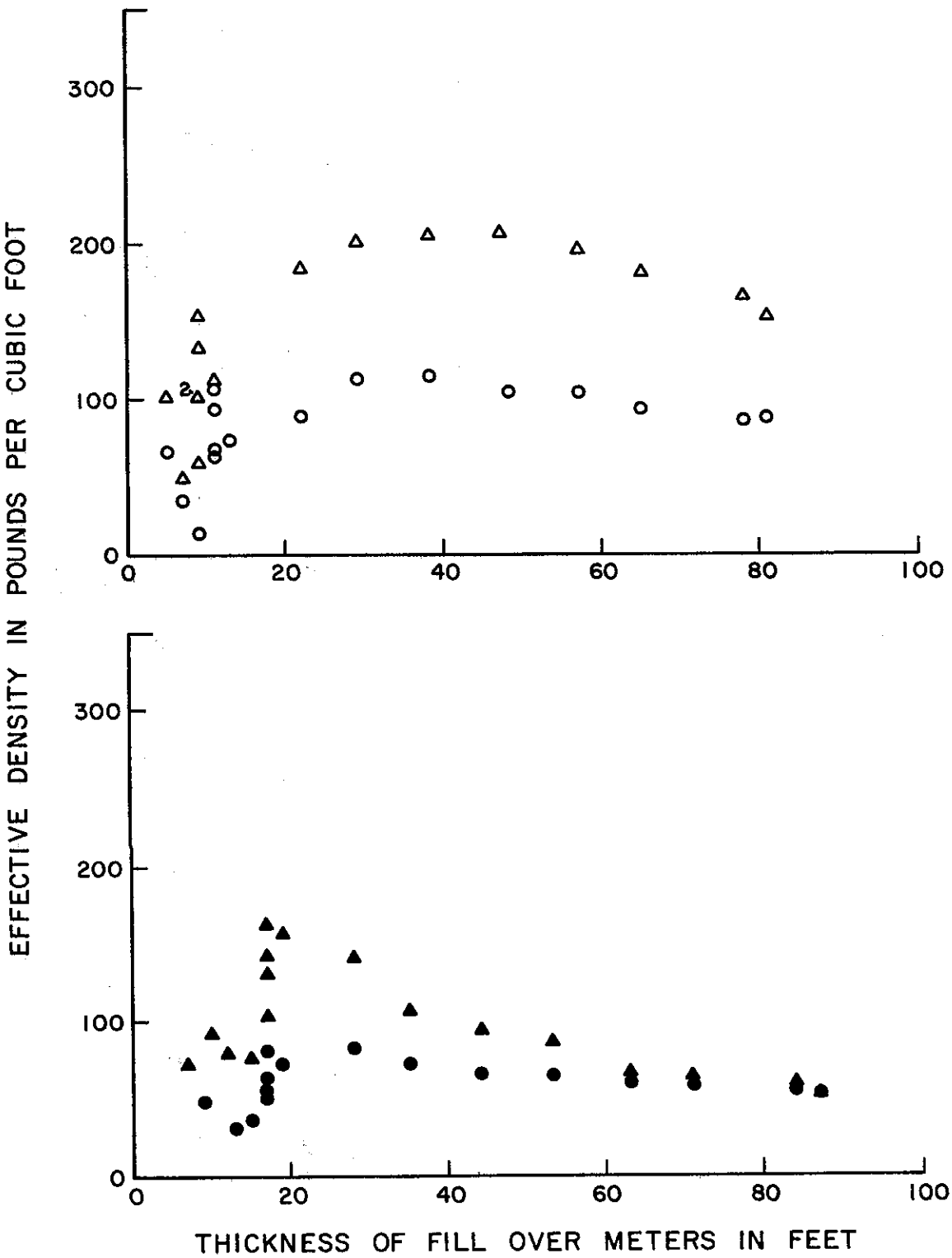


Figure 11

VARIATION OF EFFECTIVE DENSITY
CHADD CREEK STA. C (1+00)

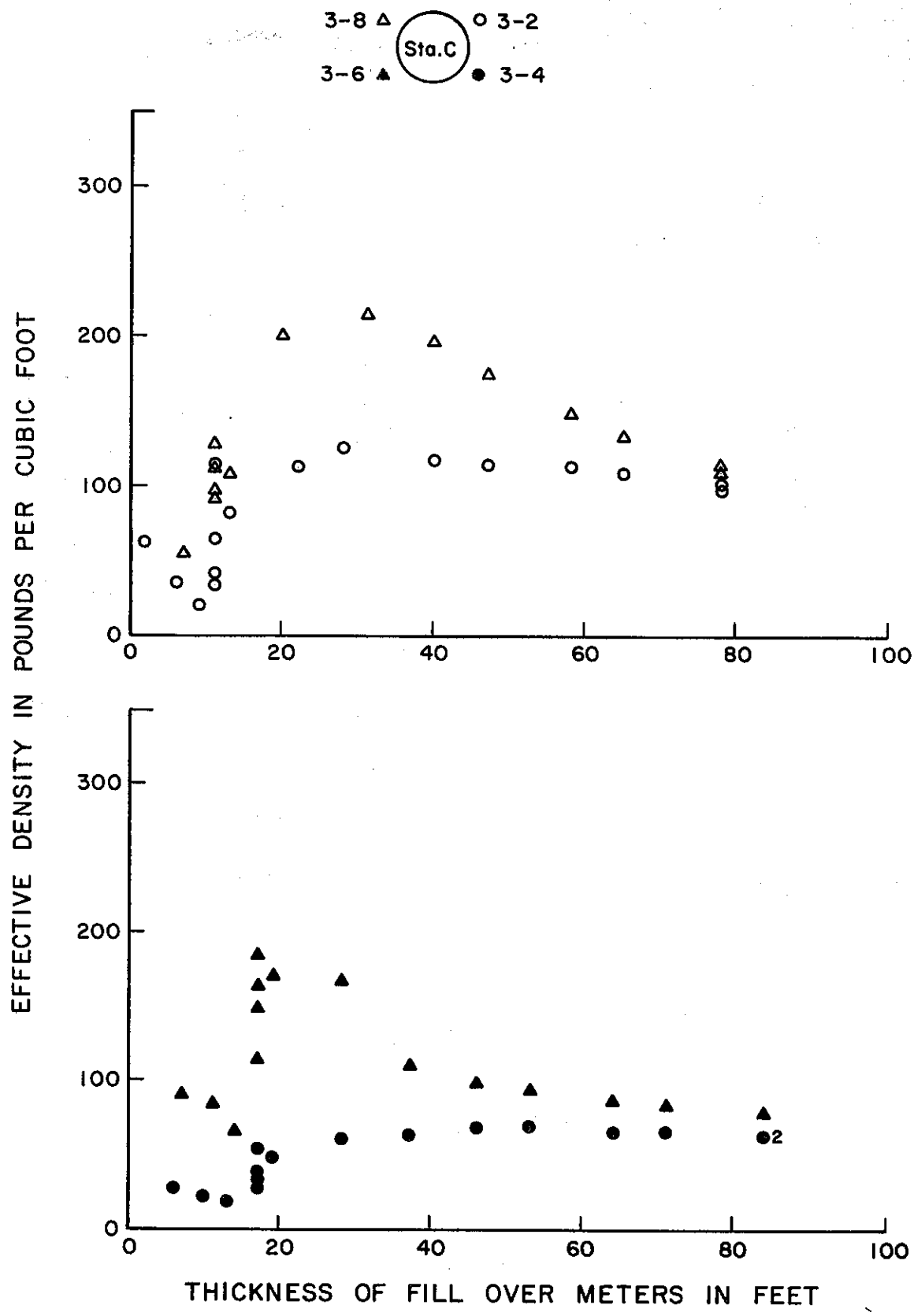
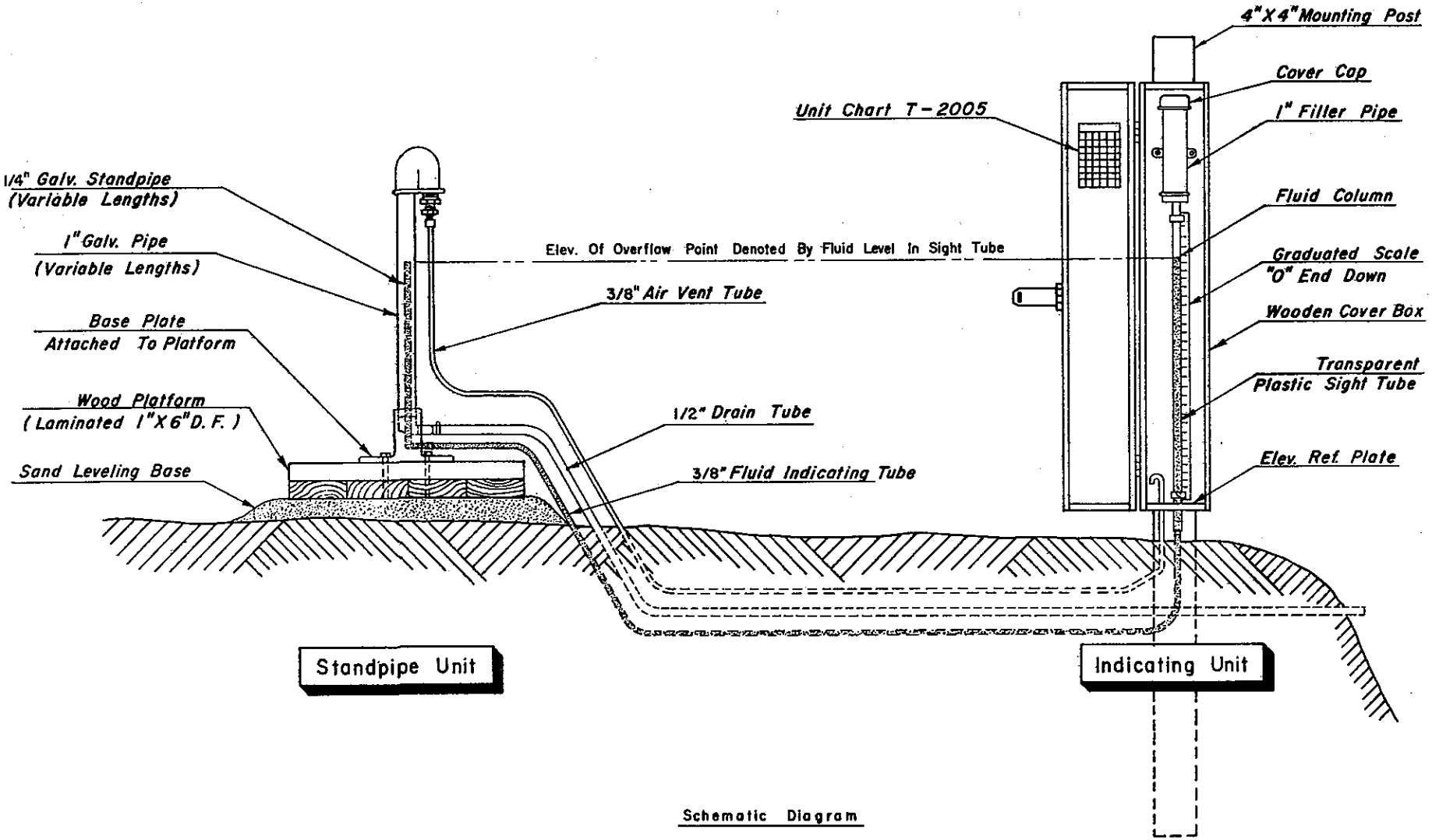


Figure 12



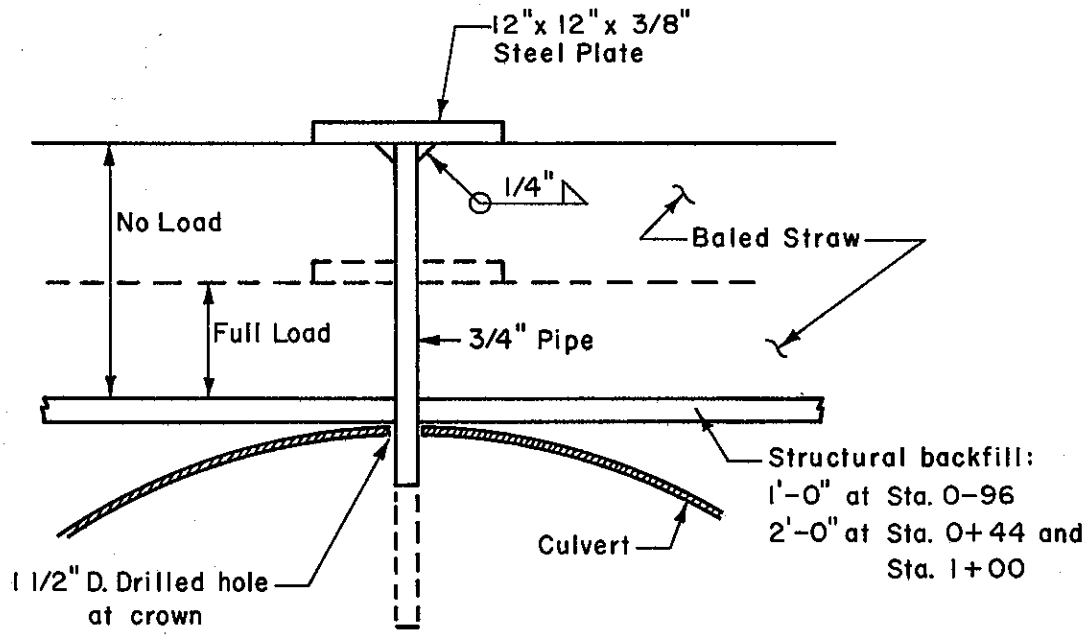
Schematic Diagram

SETTLEMENT INDICATING DEVICE
SEALED FLUID LEVEL TYPE

Division of Highways
Materials and Research Dept.

SETTLEMENT GAGE DETAILS AT CHADD CREEK

STA. 0-96, 0+44, 1+00



NO SCALE

Figure 14

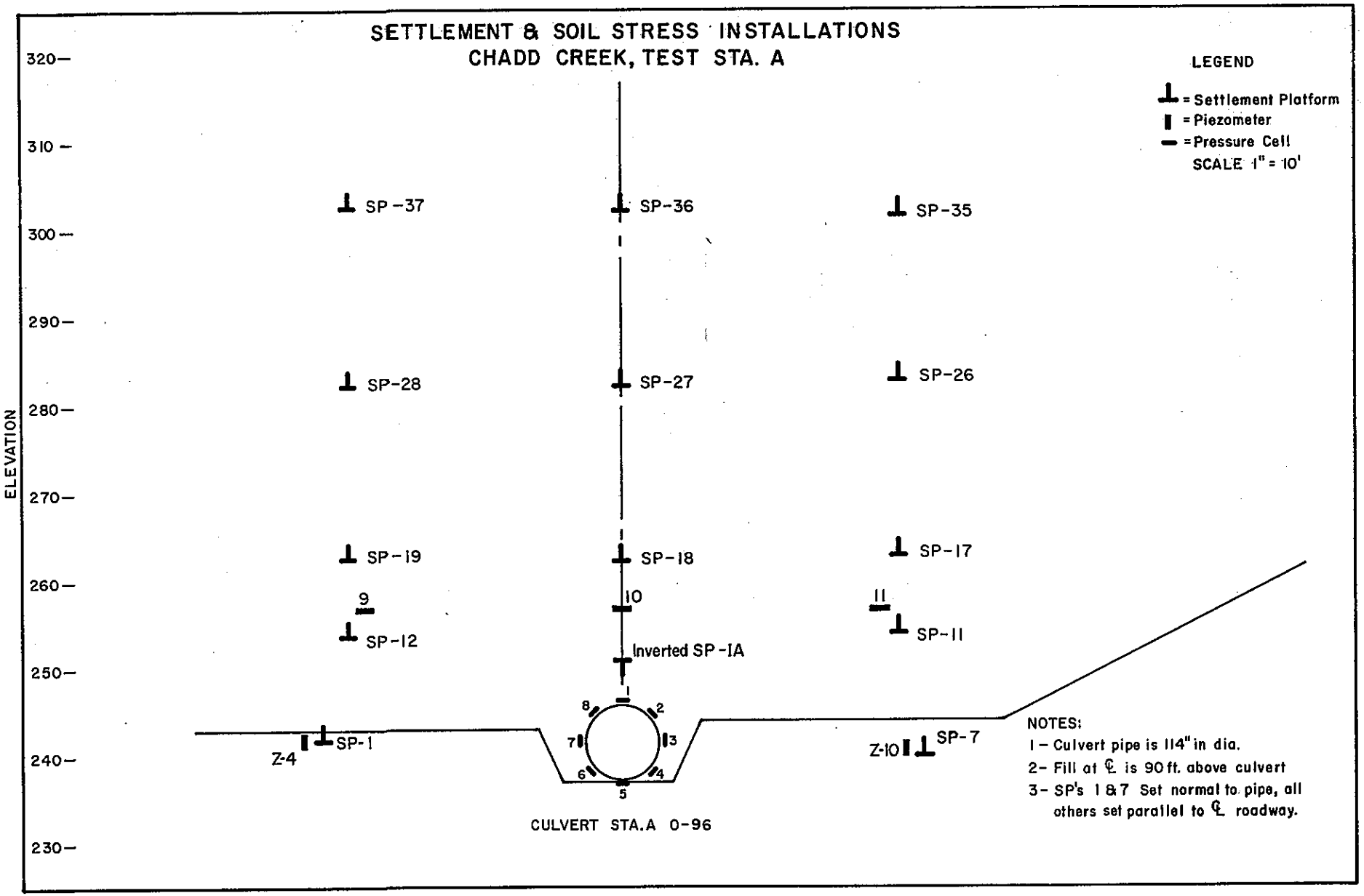


Figure 15

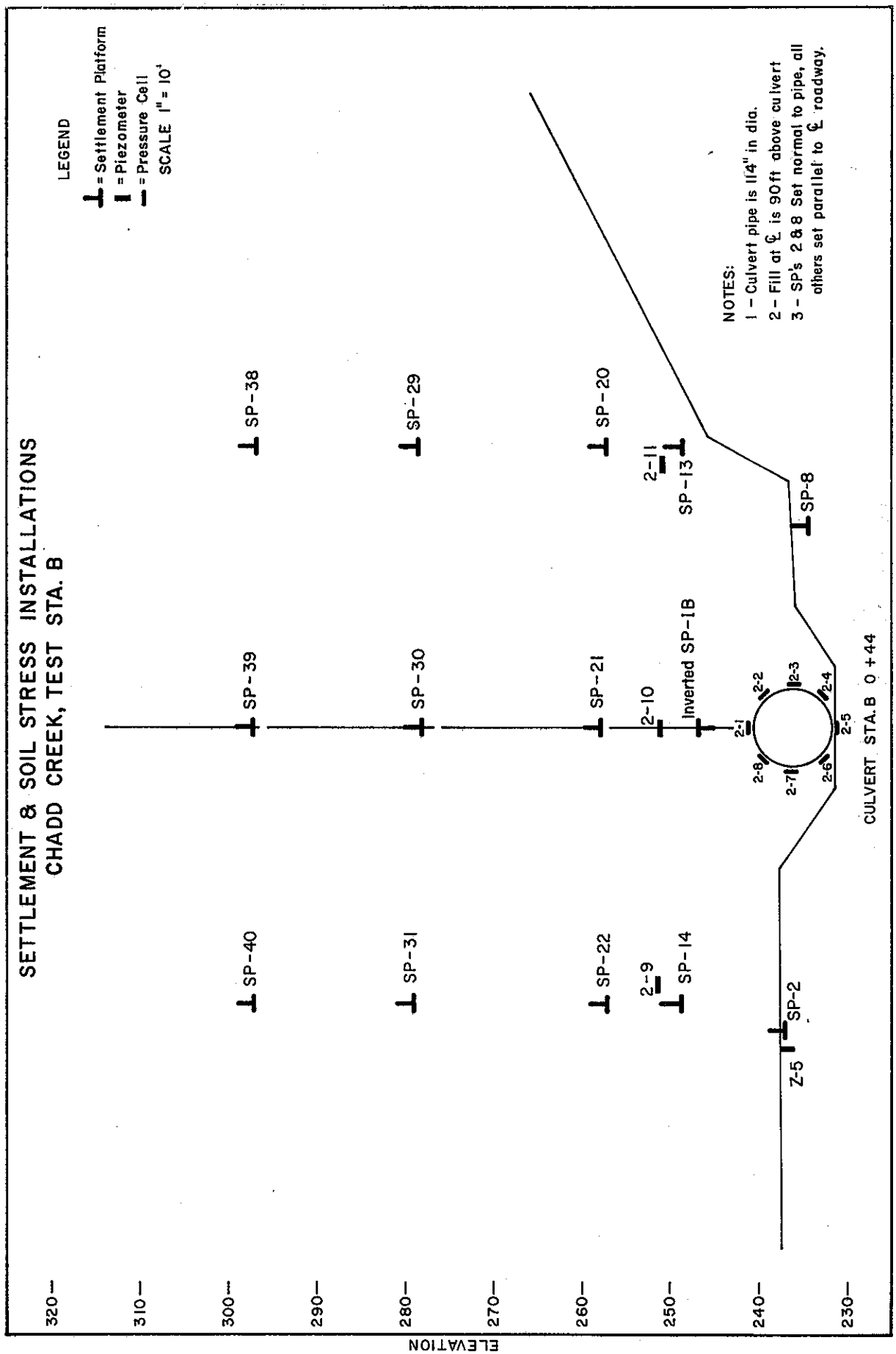
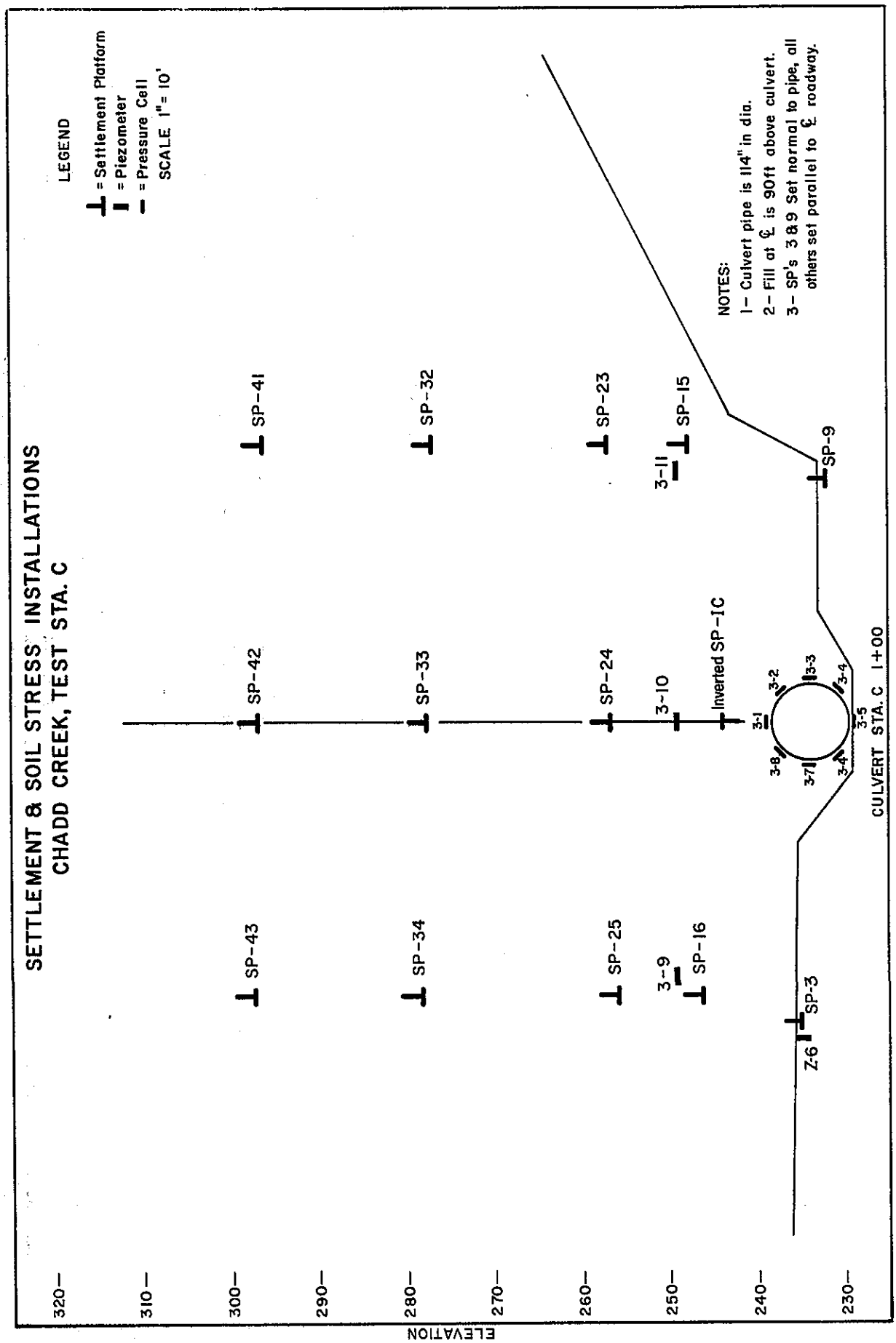
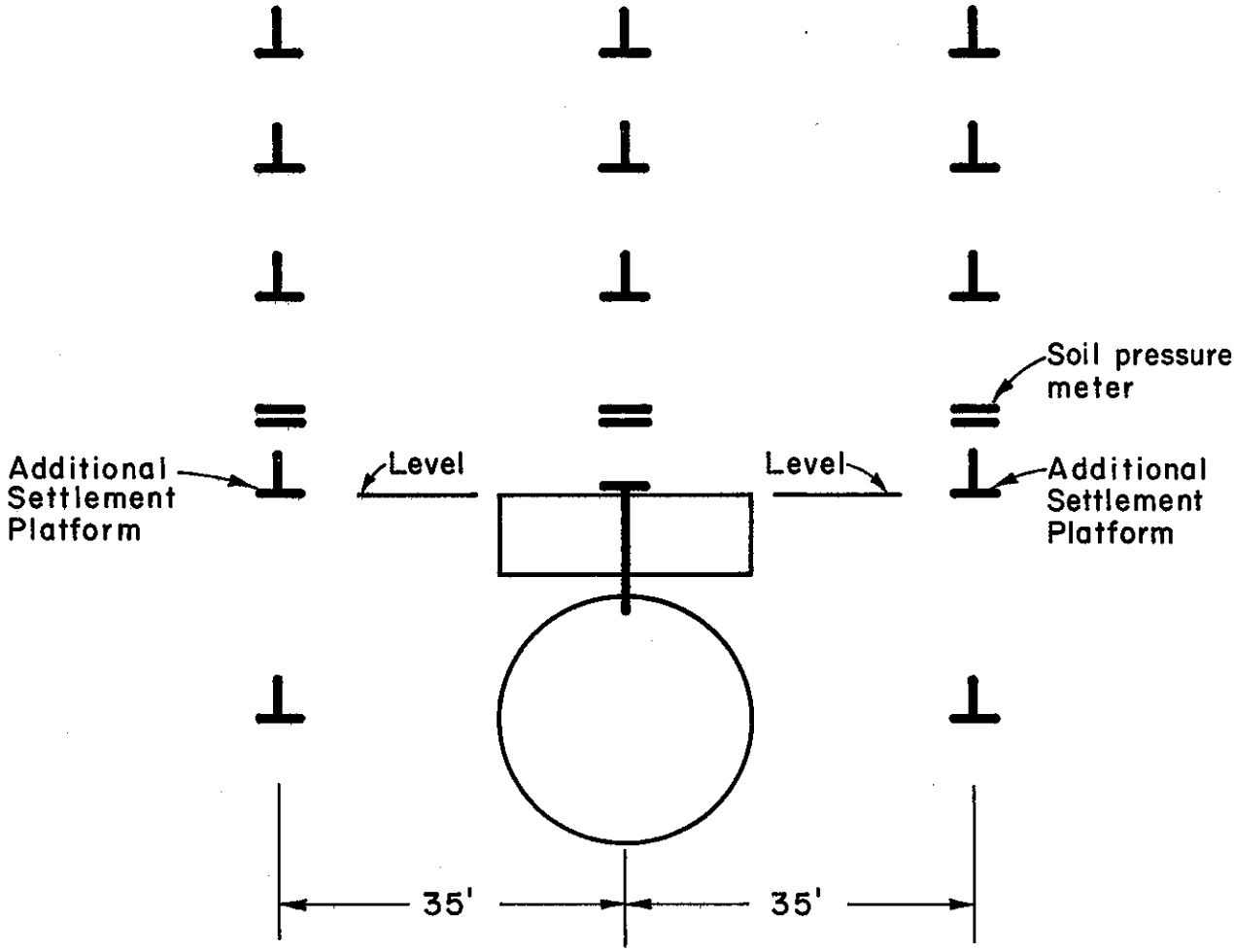


Figure 16



FLUID TYPE SETTLEMENT PLATFORM LOCATION

Exact Locations Shown on Figures 14, 15 & 16



MEASURED PARALLEL TO ROADWAY ℄

Figure 18

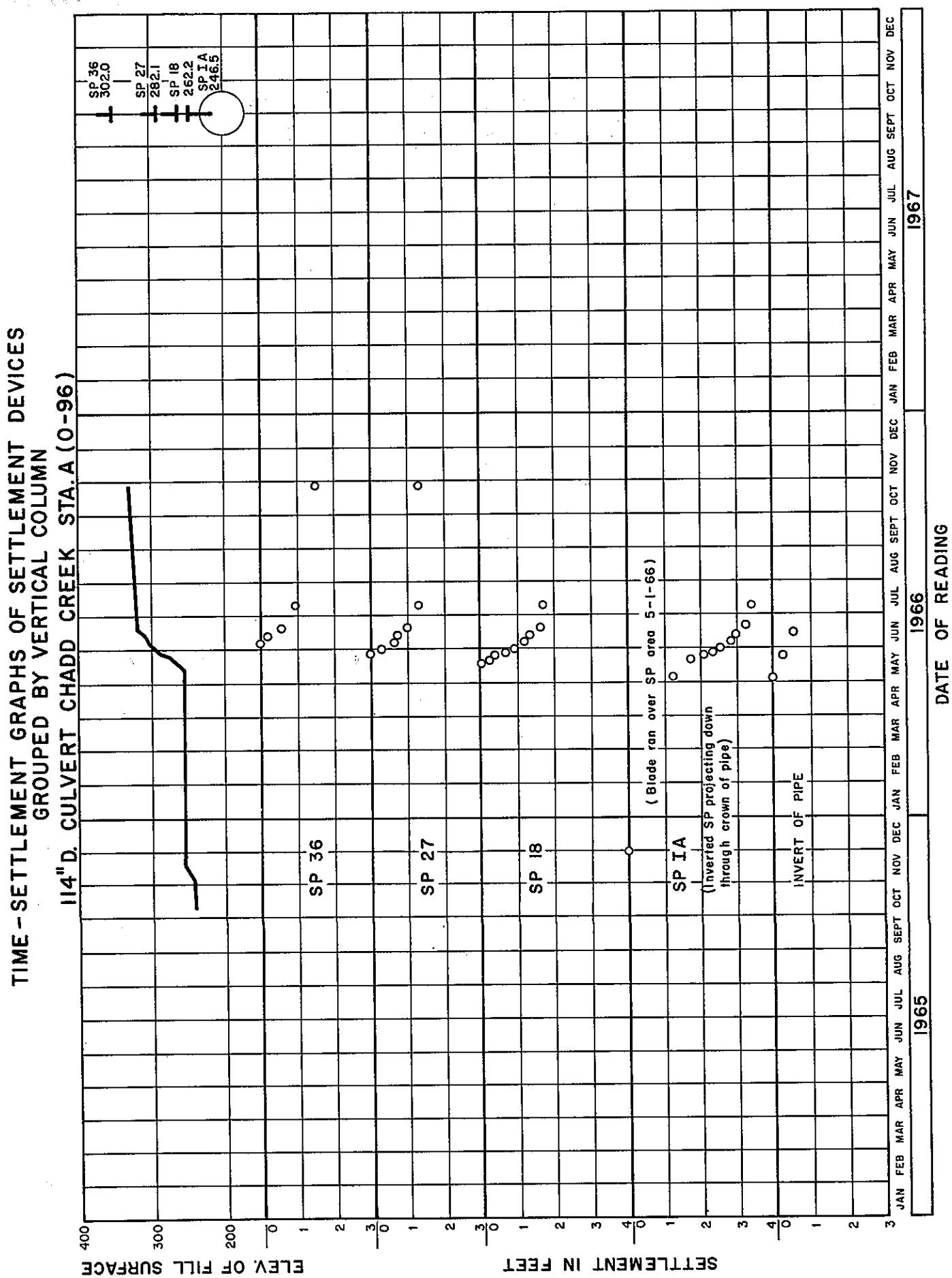


Figure 19

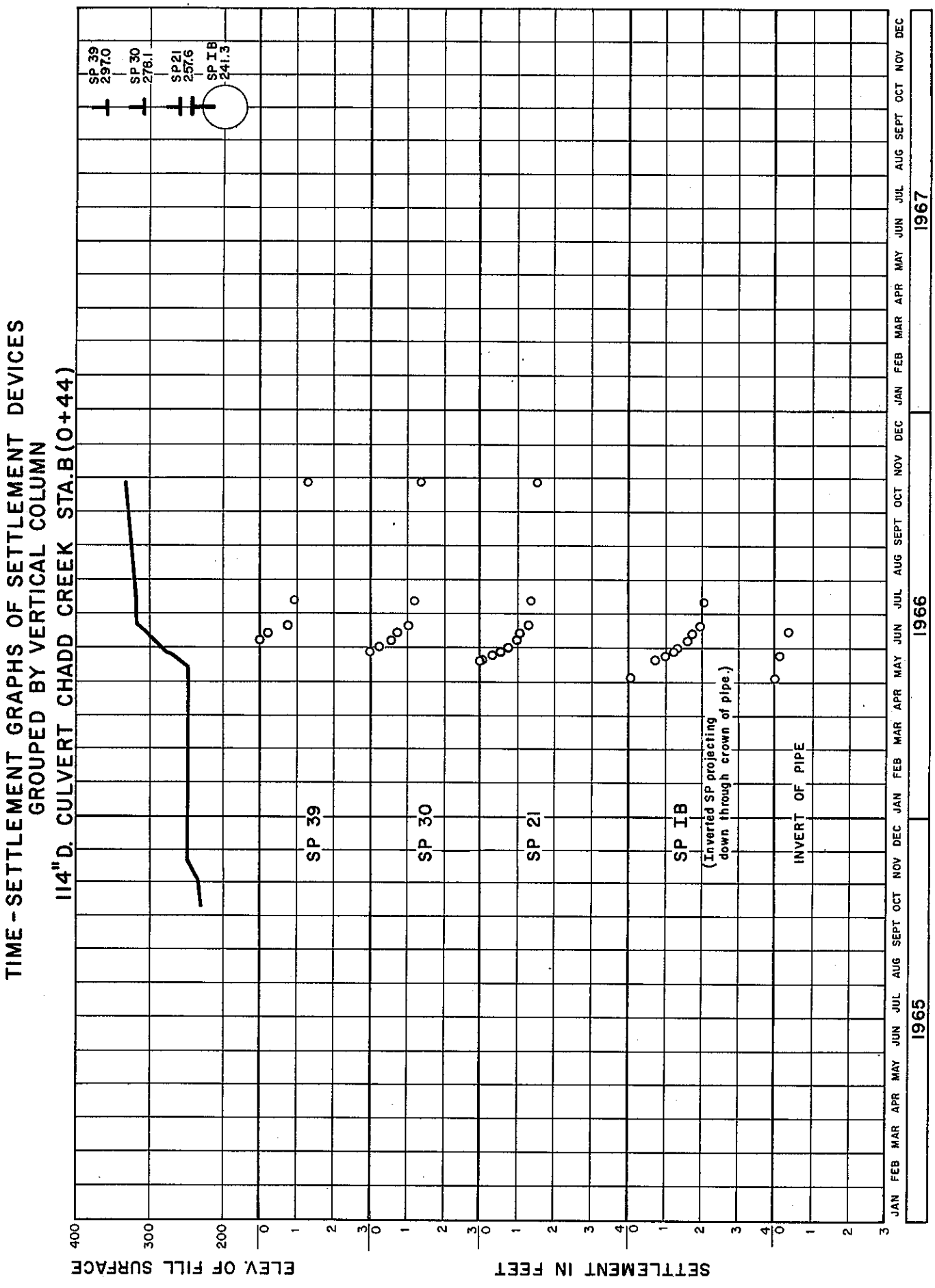
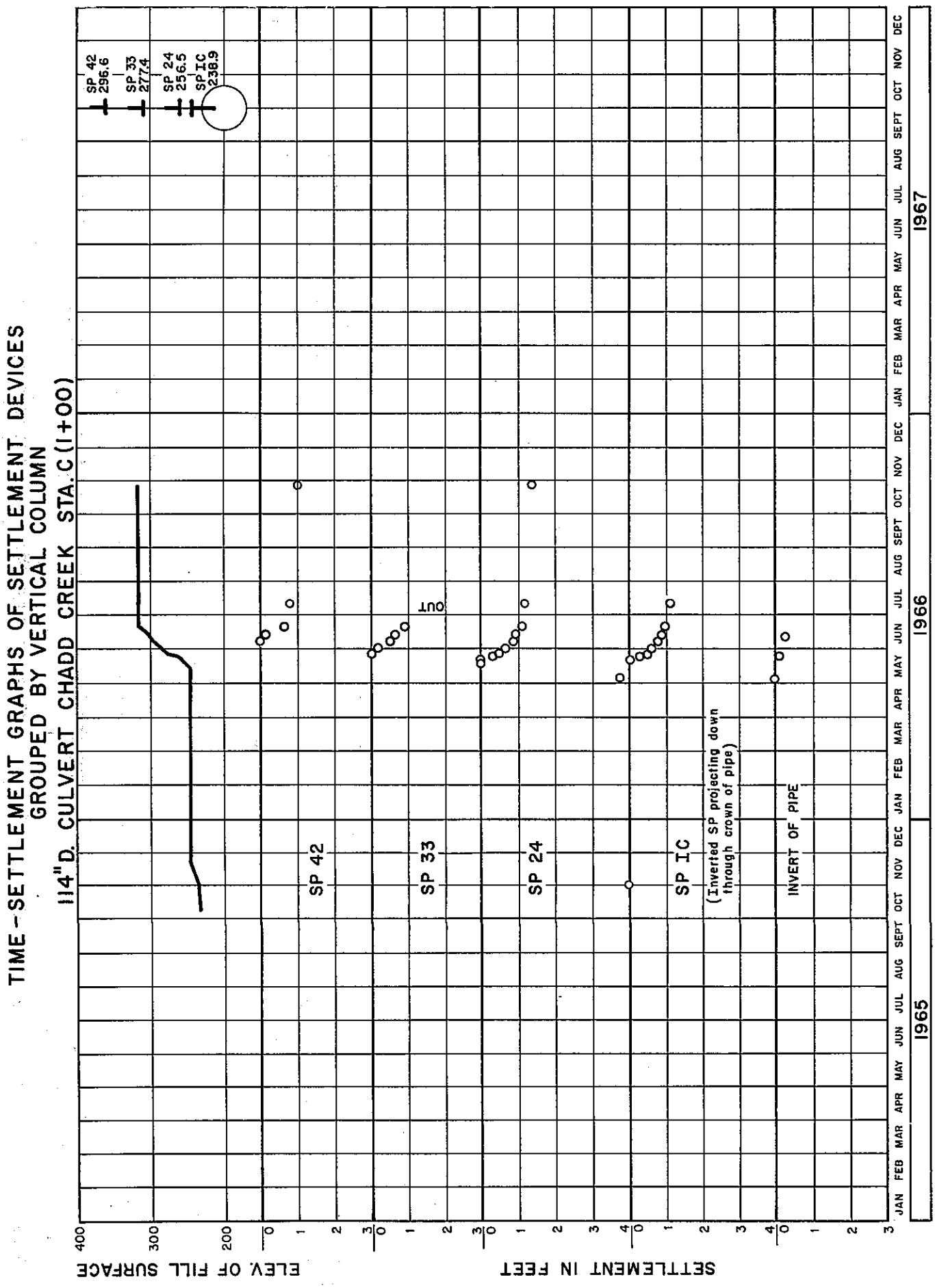


Figure 20



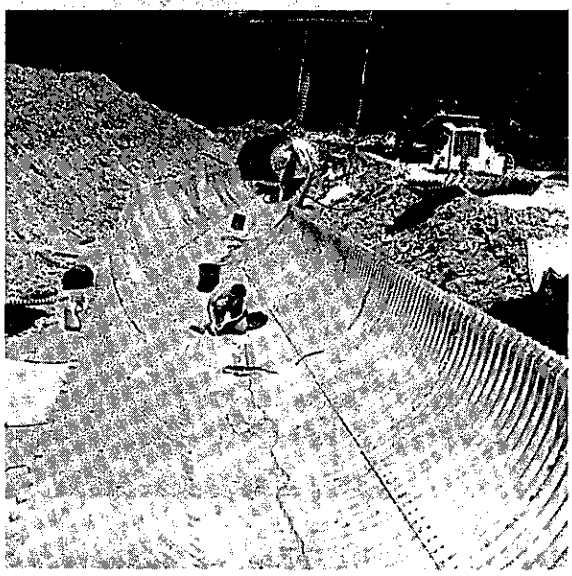


FIGURE 21

PARTIALLY ERECTED CULVERT WITH INSTRUMENTATION BEING INSTALLED IN THE BOTTOM OF THE INVERT

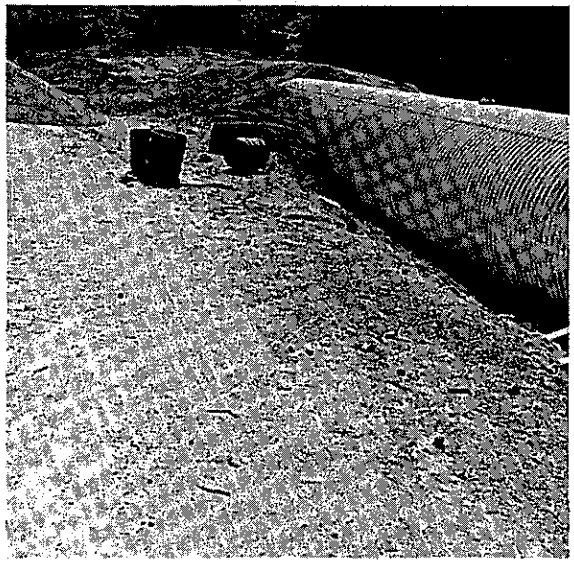


FIGURE 22

PORTION OF CULVERT BACKFILLED

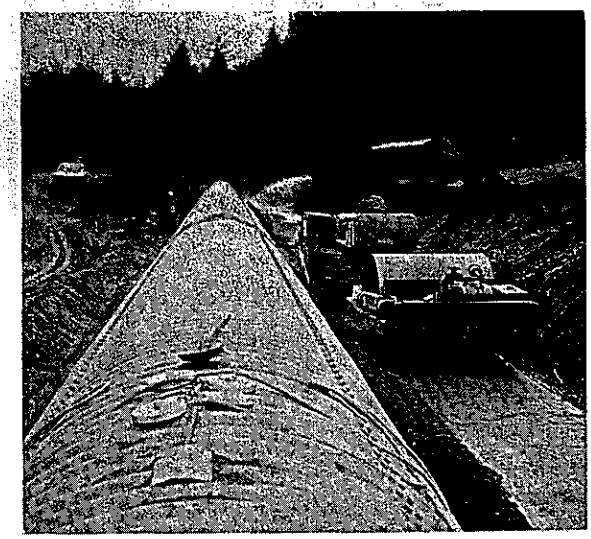


FIGURE 23

BACKFILL OPERATION

FIGURE 24

CHADD CREEK POND FORMED BY
DAMMING THE CULVERT

FIGURE 25

CULVERT DISCHARGE

FIGURE 26

CHADD CREEK

Data Acquisition vs. Fill Heights

Date	Batch	0 - 96		0 + 44		1 + 00	
		Elev.	Fill Over Crown	Elev.	Fill Over Crown	Elev.	Fill Over Crown
		247	0	242	0	240	0
5-10-66	Zero Reference	256	9	250	8	248	8
5-12-66	1	258	11	253	11	251	11
5-19-66	2	267	20	262	20	259	20
5-24-66	3	272	25	269	27	268	29
5-26-66	4	282	35	278	36	278	38
6-1-66	5	292	45	287	45	285	45
6-6-66	6	302	55	297	55	296	56
6-13-66	7	307	60	305	63	303	63
6-20-66	8	318	71	318	76	316	76
7-14-66	9	319	72	321	79	316	76
9-21-66	10	328	81	331	89	316	76
1-19-67	11	328	81	331	89	316	76