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Settlement Performance Of Test Embankments Constructed Over Sanitary Landfill (11-Sd-52-5.0/7.2)

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16. ABSTRACT

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Alignment of transportation facilities in urban areas sometimes requires construction over sanitary landfills. In general, sanitary landfills do not provide an adequate foundation material. In the past, it has been normal construction procedure to remove and replace the landfill with suitable backfill foundation material. Replacement, however, can be very costly. Thus, the design engineer must now consider the possibility of recycling or improving the sanitary landfill materials so that they are capable of withstanding the loads to be imposed by the planned facility. In order to observe behavior of the refuse under various conditions of compaction and loading, test sections are desirable prior to construction.

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DIVISION OF STRUCTURES AND ENGINEERING SERVICES

Hannon

TRANSPORTATION LABORATORY

RESEARCH REPORT

SETTLEMENT PERFORMANCE OF TEST EMBANKMENTS CONSTRUCTED OVER SANITARY LANDFILL

(II-SD-52-5.0/7.2)

APRIL 1976

76-68

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

April 1976
11-SD-52-5.0/7.2
Lab Auth. 652692

Mr. J. Dekema - 11
District Director of Transportation

Dear Sir:

Submitted for your consideration is:

Report of

SETTLEMENT PERFORMANCE OF
TEST EMBANKMENTS CONSTRUCTED
OVER SANITARY LANDFILL
11-SD-52-5.0/7.2

Study made by . . . . Geotechnical Branch
and
District 11 Materials Department

Under the General Direction of . . . . Raymond A. Forsyth
Eugene Calman

Work Supervised by . . . . Joseph B. Hannon
Jerry C. Chang
Robert Cook

Report By . . . . Preeda Sitachitta
Wilfred Yee
Jerry Chang

Very truly yours,

GEORGE A. HILL
Chief, Office of Transportation Laboratory

By Raymond A. Forsyth

Raymond A. Forsyth
Chief, Geotechnical Branch

RAF:bjs
Attachment

Introduction

This report presents the settlement performance of two highway test embankments constructed on a sanitary landfill in San Diego using prerolling with a 50 ton roller and surcharge loading. The objectives were to study the response of refuse materials subjected to different loading conditions and develop procedures to minimize long term differential settlement. These findings would assist in developing guidelines for earthwork construction on the future Route 52 alignment through this area.

A sanitary landfill may be defined as "a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, but utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary"(1).

Alignment of transportation facilities in urban areas sometimes requires construction over sanitary landfills. In general, sanitary landfills do not provide an adequate foundation material. In the past, it has been normal construction procedure to remove and replace the landfill with suitable backfill foundation material. Replacement, however, can be very costly. Thus, the design engineer must now consider the possibility of recycling or improving the sanitary landfill materials so that they are capable of withstanding the loads to be imposed by the planned facility. In order to observe behavior of the refuse under various conditions of compaction and loading, test sections are desirable prior to construction.

Engineering properties for the analysis of a sanitary landfill vary with makeup of the refuse material. The most critical concern in construction over sanitary landfill is long term settlement.

Recently, several articles by geotechnical engineers(2,3,4,5,6) have provided insight into this problem. Sowers(5) suggested that continuing settlement of sanitary landfill is analogous to secondary compression of soil. The settlement with respect to time and depth of fill was described by Sowers as follows:

$$\Delta H = \alpha \frac{H}{1 + e_o} \log \left(\frac{t_2}{t_1}\right) \qquad (1)$$

Where: ΔH = total settlement

H = fill depth

t = time

e_o = initial void ratio

α is a coefficient which depends on field condition. Sowers also suggested that $\alpha = 0.09\ e_o$ for conditions favorable to decomposition and $\alpha = 0.03 e_o$ for unfavorable conditions. Yen and Scalon(6) suggested that settlement rate can be computed by the following equation:

$$m = \frac{\alpha}{1 + e_o} \frac{H}{t-1} \log (t) \qquad (2)$$

Where m = settlement rate in feet per month

t = time elapsed in months

Other variables are the same as defined in equation 1.

The density of refuse material is usually low and variable. For this reason, it is believed that precompaction of landfill can eliminate some of the initial settlement during placement of embankment. The age of the refuse deposit, depth, composition, decomposition, rainfall, water table and method of placement are important in predicting settlements.

Evidence of undulations of roads constructed over sanitary fills may be observed in San Diego at:

Sea World Drive in the City of San Diego between Route 5 and Sea World. This Sanitary Fill was constructed by excavating and filling in the mud flats of Mission Bay. Dredge material of unknown thickness was placed on top of the Sanitary Fill.

Undulations make this facility unsuitable for speeds above 50 miles an hour. However, the A.C. pavement has not failed and no leveling has been done since constructed in 1970. Longitudinal cracks were observed in the wheel tracks during a condition survey on April 4, 1975. Undulations can also be observed where A.C. surfacing is placed on temporary haul roads over the City of San Diego sanitary fills near the test area and at the Chollas Sanitary Fill in East San Diego.

Conclusions

1. The 50 ton roller can be used to compress a foundation material consisting of dry or unsaturated sanitary landfill to reduce total primary settlement under subsequent embankment construction. However, prerolling is not beneficial in reducing settlement waiting periods. Test data indicated that one quarter of the total surcharge settlement was eliminated by prerolling. Maximum prerolling settlement was achieved after 25 passes of the 50 ton roller. Eighty-five percent of the maximum prerolling settlement developed under 10 passes of the 50 ton roller.

2. Surcharge loading is of major benefit in accelerating consolidation of sanitary landfill. The settlement rate accelerated substantially on this probject when the maximum surcharge height of 10 feet was reached. Fifty percent of the average total surcharge settlement occurred prior to completion of the surcharge embankment and 80% had occurred by 30 days after completion of the surcharge embankment.

3. Steel reinforcing bar mats appear to provide no significant advantage in reducing differential settlement. However, long term performance may be necessary to verify this conclusion.

4. Because primary settlement is still occurring, indications are an earth fill surcharge would be the most suitable method of compressing this existing sanitary landfill where embankment construction is proposed. However, leveling the undulations of the roadbed would probably be necessary every few years.

5. Since the proposed profile grade calls for excavation and unloading through the sanitary landfill areas, the longterm effects of settlement appear lessened. This study evaluated only the relative response of the refuse material under embankment construction. It is, therefore, difficult to predict the response to exposure in an excavation where oxidation is allowed to occur and entrapped gas and air can escape at the surface. If the surface is not sealed, rainfall can also penetrate the refuse elements and produce differential subsidence. The probability of the occurrence of this subsidence can be reduced by unloading by excavation and prerolling with a heavy roller.

Recommendations

The following are suggested guidelines for construction through the landfill area.

1. Excavate the existing soil cover and refuse in the sanitary landfill areas to a depth of 6 ft below finished grade and stockpile along right-of-way. Consideration could be given to possible incorporation in embankment construction.

2. Place a 6 inch lift of soil over the exposed landfill material and compact using a 50 ton roller in a dry condition with a minimum of 10 passes to accomplish partial settlement.

3. Place a 10 ft surcharge fill in any embankment areas crossing refuse and leave in place at least 60 days or until settlement platforms indicate that the primary settlement is 90 percent complete.

4. Remove the surcharge to subgrade elevation.

5. Consideration should be given to sealing the exposed refuse materials in the excavation sections by spray treatment to reduce oxidation, decay and infiltration of water.

6. If excavated refuse material can be economically incorporated in construction of embankment fills this could be accomplished in conformance with specifications similar to those used on project 07-Ora-73, P.M. 2.7/4.0. These specifications are listed along with construction guidelines in the report titled "Use of Waste Materials in Embankment Construction"(7) and are as follows:

"Those areas shown on the plans as 'Refuse Removal Area' are areas of unsuitable material. The Contractor shall excavate the refuse cover and refuse material and construct embankments within the excavated refuse area with material obtained from excavation within the project limits (except excavated refuse material) or borrow.

"At the option of the Contractor, excavated refuse material may be used in embankment construction in the areas shown on the plans as 'Refuse Embankment Areas'.

"In addition to the requirements in Section 19-5, 'Compaction', and Section 19-6, 'Embankment Construction', of the Standard Specifications, the placement of excavated refuse material in embankments shall conform to the following:

a. Excavated refuse material shall be thoroughly mixed with suitable embankment material at a rate not to exceed 50% of the mixture.

b. Each layer of the refuse material mixture shall be covered with at least 2 layers of suitable embankment material.

c. No layer of the refuse material mixture shall be placed within 4 feet of finished grade.

d. Rock, portland cement concrete, asphalt concrete, ferrous and nonferrous metals shall not exceed one foot in the vertical dimension when placed in embankments.

e. All other material including biodegradable material shall not exceed one-half foot in greatest dimension.

"Suitable embankment material referred to herein shall be considered as material excavated from within the limits of this project (except refuse material) or borrow.

"During the operations of excavating and depositing refuse material, the Contractor shall take precautions to prevent offensive odors within the surrounding area. Such precautions may consist of the use of earth cover or the application of commercial odor masking compound as directed by the Engineer. Precautions to prevent offensive odors will be paid for as extra work as provided in Section 4-1.03 of the Standard Specifications." In case combustible gases are discovered, the installation of a landfill gas control system should be considered. Engineering Science, Inc. at Arcadia, California, has successfully developed such gas control systems for several landfill projects(8).

7. Place a structural section utilzing stage construction with asphalt concrete surfacing. Allow for a leveling blanket and the final asphalt concrete surfacing course in 2-5 years.

8. Instrument all approach embankment foundations and surcharge areas with settlement platforms.

Site Location and Description

The sanitary landfill test site for this study is located on proposed Route 52 in San Diego County between Stations 334± and 336± (Figure 1). This is within the City of San Diego's Sanitary Fill accessible from Mercury Street north of Clairemont Mesa Boulevard. The Sanitary Landfill within the project limits consists of two separate fills located between Stations 329± and 344± and between Stations 355± and 380±. Refuse materials, including glass, wood, kitchen garbage, paper, rags, metal, etc., were dumped in this area between 1964 and 1967, and covered with a thin earth layer.

November, 1973 soil borings indicate that the refuse depth in the test location is about 18 to 20 feet (Figure 2). The native soils underlying the fill vary from clayey sands to gravelly clayey sands. The soil borings extended down to Elevation 358± (42 feet below existing ground surface) beyond the test area and no free water was encountered. However, there is surface water in the deep gulley near Station 344±. The area receives only about 10 inches rainfall yearly and little decomposition has taken place, except for food or vegetation waste. Old paper in the refuse is easily read. Photo 1 shows a typical view of the general contents of the refuse layer. The proposed highway profile grade in the sanitary landfill area will generally be in excess of 10 feet below ground surface and require excavation up to 16 feet through the refuse material.

Instrumentation

Two test areas, 46 feet wide by 59 feet long, separated by a 54 foot strip were selected for this study (Figures 3 and 4). The construction sequence began in September 1974 under the direction of the District 11 Materials Department assisted by the Transportation Laboratory. Initially, the existing 3 ft ± soil layer above the sanitary landfill was removed to expose the trash level. Several layers of soil were then placed and compacted to form a 2 foot thick working table above the trash level prior to installation of settlement platforms. Figure 3 shows the layout and placement of the settlement platforms and the locations of the instrumentation readout. The cross-sectional views are presented in figure 4. Twelve settlement platforms were placed in each test area by District personnel. The settlement platform gauge readout for Test Area 1 is shown in Photo 2.

Test Area 2 was constructed with two layers of No. 4 reinforcing steel mats in an effort to reduce post construction differential settlement. Test Area 1 served as the control and was unreinforced. The performance of these test areas were monitored by settlement platforms supplemented by elevation points, surface profiles and visual observations.

Construction Procedures

It was originally proposed to perform all rolling with a 50 ton roller. It was assumed that this operation would serve to compress and preconsolidate the underlying refuse material and thereby shorten the settlement waiting period and reduce post construction differential settlement. This procedure has previously been used in New York State(9,10).

Prerolling was performed successfully on Test Area 1 without the aid of water. No prerolling was done on Test Area 2. Both areas were then saturated with water to increase compaction. However, after saturating with water and covering with 6 to 12 inches of compacted fill, the roller became stuck due to excessive penetration (Photo 3). It was determined that 3 feet of compacted fill would be necessary to bridge over the refuse material prior to the application of the 50 ton roller if the underlying material is saturated. The 3 foot working table was placed with a scraper and sheepsfoot roller.

The following is the sequence of events as performed in the field during construction of the test areas:

Test Area 1

About three feet of soil were removed down to the trash level and 6 inches of fill material were placed. The area was then rolled 25 passes with a 50 ton roller (one pass equals one complete rolling of the test area). Settlement was determined after each 5 passes by measuring changes in cross-section profiles.

Six inches of material were then removed and the area was scarified. Water in the amount of 50,000 gallons was applied to the landfill. Two 6 inch soil layers were placed and compacted with a sheepfoot roller. Heavy rains occurred following this operation and mud and water were removed down to the trash level and 2 feet of new fill material were then placed and compacted in two lifts with a sheepfoot roller and a drill rig. Settlement platforms were then installed. Two 8 inch compacted layers of fill material were placed and compacted on top of the settlement platforms using 1 pass of the loaded scraper per layer. The second layer was also rolled with 10 passes of the 50 ton roller and settlement platforms were read after each sequence.

A series of 30 passes each was then made by the loaded scraper and the 50 ton roller. The settlement platforms were again read after this sequence.

Upon completion of the above sequence, an attempt was made to develop shearing failure in the 3 foot working table over the saturated refuse fill by overrolling. This test indicated that the 3 foot thickness was adequate to support the heavy rolling equipment. Area 1 was then rolled a total of 60 passes with a loaded 20 cubic yard self loading scaper and 40 passes with a 50 ton roller.

Thereafter, the sequence consisted of placing 10 inches of uncompacted material and compacting with one pass of the loaded scraper. This operation was repeated until a fill height of about 10 feet was reached. Settlement platforms and cross section profiles were read at various intervals to determine changes in grade and cross section.

Test Area 2

About three feet of soil were removed down to the trash level and 6 inches of fill material were placed. No precompaction of this dry layer was performed.

Heavy rains occurred during early stages of fill placement subsequent to saturation of the trash layer by the contractor. Difficulty developed with the rolling operation as evidenced by Photo 5 since the area was too soft for the 50 ton roller. Mud and water were then removed down to the trash level and 2 feet of fill material were placed in two lifts and compacted with the sheep-foot roller and a watertruck. Settlement platforms were then installed.

The first layer of the reinforcing steel mat (No. 4 bars with 1 ft sq mesh) was then placed. Two 8 inch compacted layers of fill material were placed over the mat and compacted with a loaded scraper. Numerous passes were then made with a 50 ton roller. Settlement platforms and surface profiles were read after each series.

The second layer of reinforcing steel mat was then placed followed by 8 inches of compacted fill (Photo 5). The area was then rolled 30 passes each with a loaded scraper and the 50 ton roller. Thereafter, the sequence consisted of placing 10 inches of material and compacting with a loaded scraper. This operation was repeated until a fill height of about 10 feet was reached in November, 1974 (Photo 6). Settlement platforms were read and surface profiles plotted at various intervals.

<u>Test Results</u>

The benefits of prerolling with a 50 ton roller are shown graphically in Figure 5 where the compression of the refuse is plotted against various passes of the 50 ton roller over Test Area 1 using dry compaction. Three tenths foot of the average precompression was developed during the first 10 passes of the 50 ton roller. The maximum recorded average precompression of 0.35 feet was achieved after 15 additional passes or a total of 25 roller passes.

This information was developed from a series of cross section profiles taken at 5 pass intervals during the prerolling operation. Figure 5 shows that 85% of the initial compression is accomplished with 10 passes of the 50 ton roller. Plots of the relationship between the loading time and the average settlement for Test Areas 1 and 2 are shown on Figure 6. The settlements due to prerolling in Test Area 1 is excluded in the total settlement plotted in Figure 6. Settlement is still continuing after 476 days after the start of embankment construction. These plots suggest that prerolling is beneficial in reducing the total primary settlement, but the time rate of settlement (slope of plotted curve in Figure 6) remains the same. It is evident that Test Area 1 developed less settlement from surcharge due to prerolling. Figure 6 shows also that 50% of the average total surcharge settlement occurred at completion of the surcharge fill and 80% of the average total settlement developed at 30 days after completion of the surcharge fill.

The underlying 18 to 20 foot landfill continues to settle under the 10 foot surcharge. Contours of the total settlements recorded in the 476 days following the start of construction are presented in Figures 7 and 8. Figure 7 shows also the contours in dash lines for the prerolling settlements which are the basic data for developing the average prerolling settlement in Figure 5. Cross-sections along centerline of Test Area 1 and 2 together with surcharge settlements are shown in Figures 9 and 10 respectively. These plots were developed to evaluate the performance of the steel mats in reducing differential settlement. Inspection of these data suggest that no significant benefit was achieved with steel mat reinforcement at this location.

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9. Moore, Lyndon H. and McGrath, Maurice E., "Highway Construction on Refuse Landfills", Bureau of Soil Mechanics, New York State Department of Transportation.

10. Sinacori, M. W., "Compaction of Unstable Material with Heavy Pneumatic Tired Roller", HRB Bulletin No. 42, 1951.

PHOTO 1: Refuse excavated from test pit dug by bulldozer. Refuse is 5 to 10 years old.

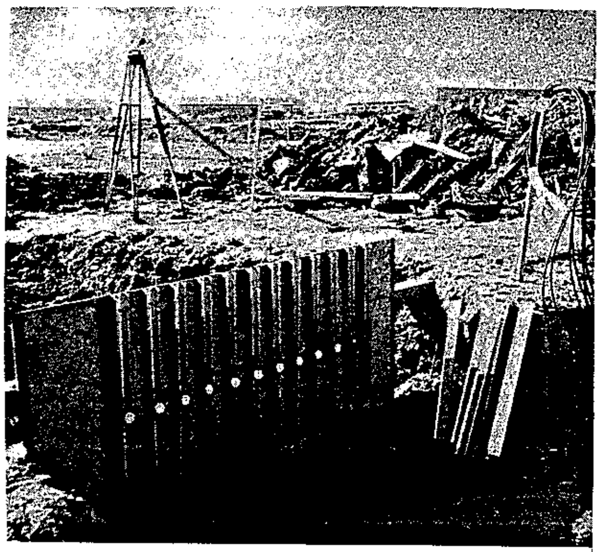


PHOTO 2: Settlement platform gauges for Test Area 1. Note excavated refuse in background

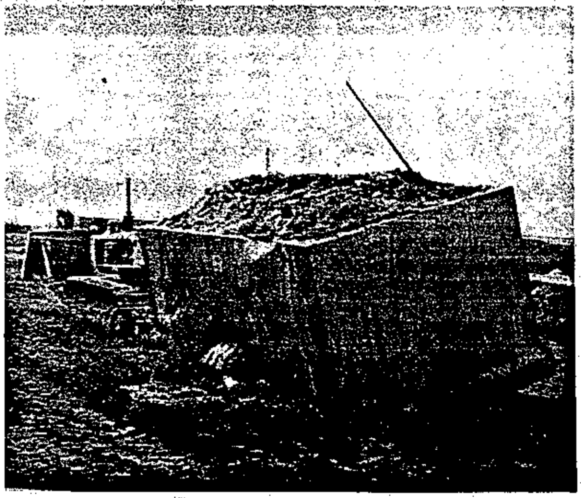


PHOTO 3: 50 Ton Roller stuck on first pass with 6 inches of earth over saturated sanitary fill in Test Area 2.

PHOTO 4: Exposed sanitary landfill saturated with about 2500 gallons of water in Test Area 2.

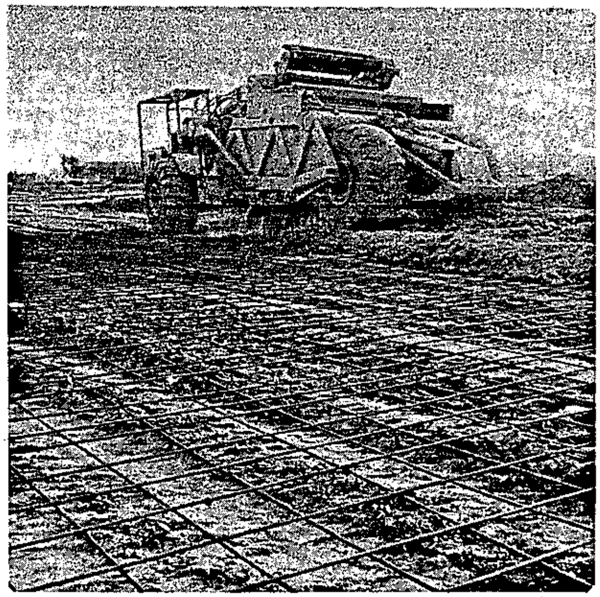
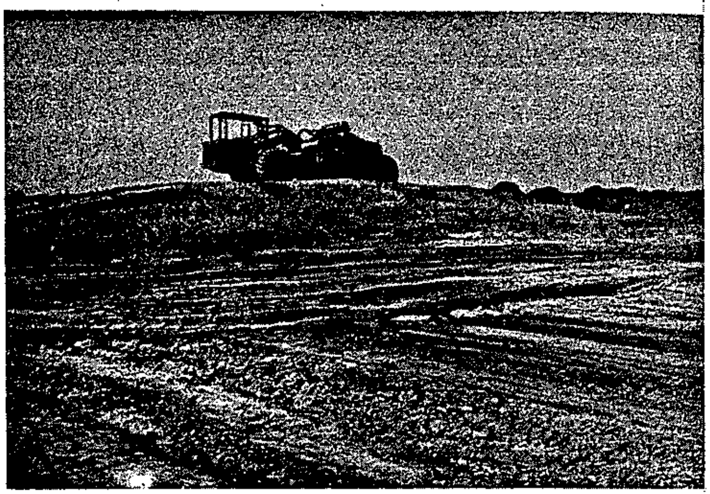
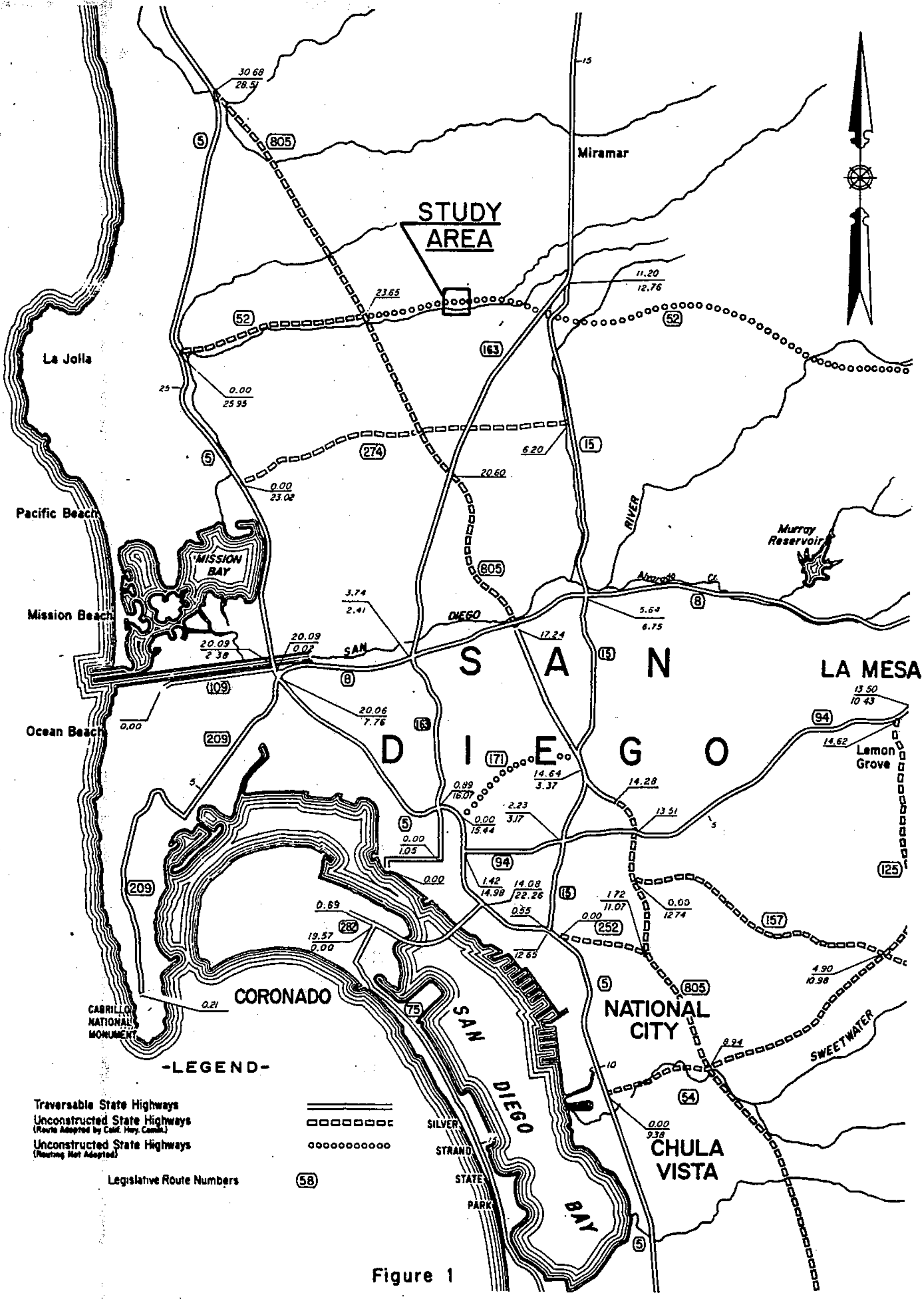


PHOTO 5: Placement of 1st lift over 2nd steel reinforcing mat in Test Area 2.

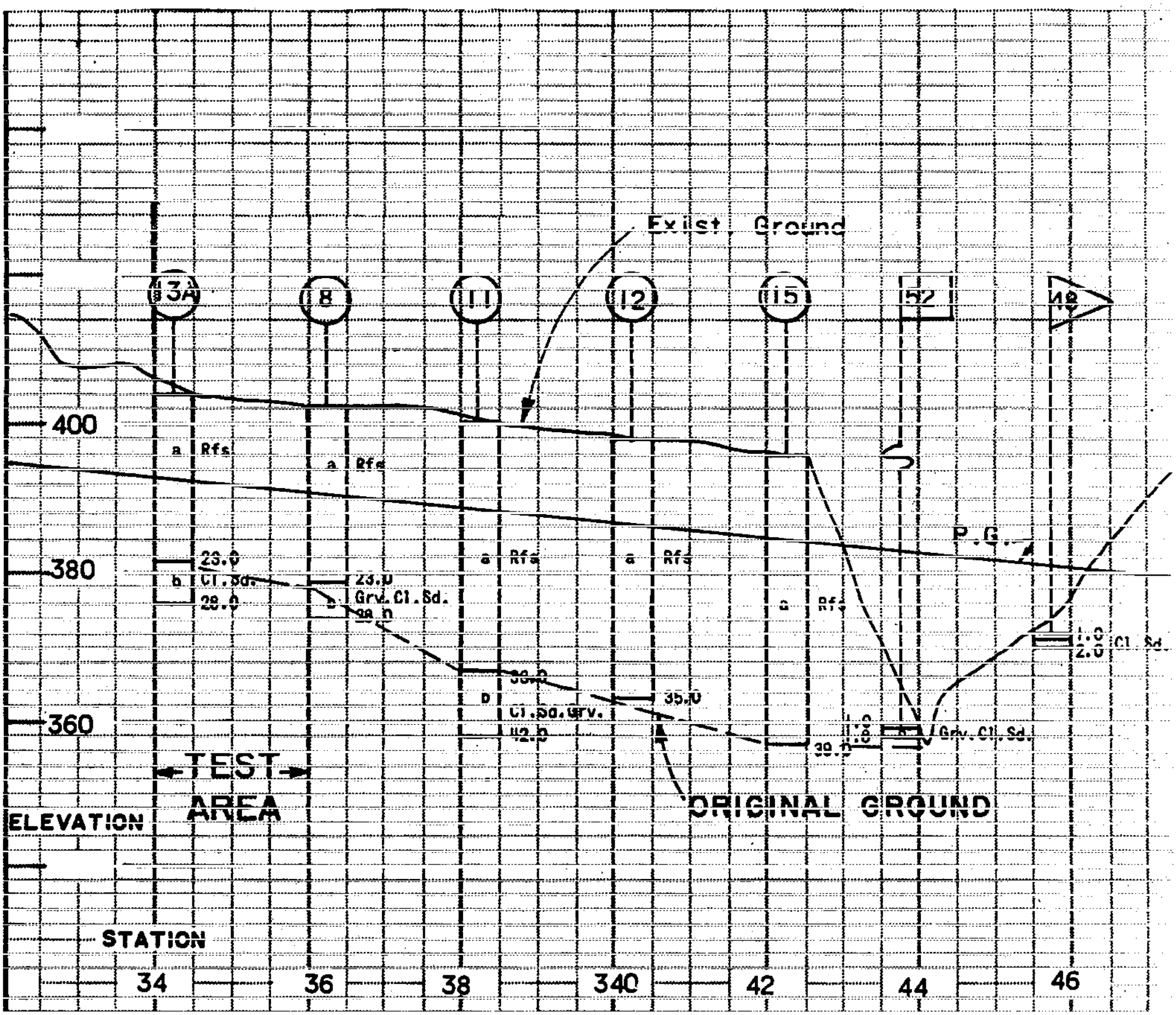
PHOTO 6: Finish grade of embankment about 10' above refuse level. (Test Area 2)





STUDY AREA
Miramar
La Jolla
Pacific Beach
MISSION BAY
Mission Beach
Ocean Beach
SAN DIEGO
LA MESA
Lemon Grove
Murray Reservoir
RIVER
NATIONAL CITY
CHULA VISTA
CORONADO
CABRILLO NATIONAL MONUMENT
SILVER STRAND STATE PARK
SAN DIEGO BAY
SWEETWATER
-LEGEND-
Traversable State Highways
Unconstructed State Highways (Route Adopted by Calif. Hwy. Comm.)
Unconstructed State Highways (Routing Not Adopted)
Legislative Route Numbers
58
5
805
52
163
274
15
8
109
209
94
171
125
157
252
282
75
54

Figure 1



SOIL PROFILE TAKEN IN NOVEMBER, 1973

Figure 2

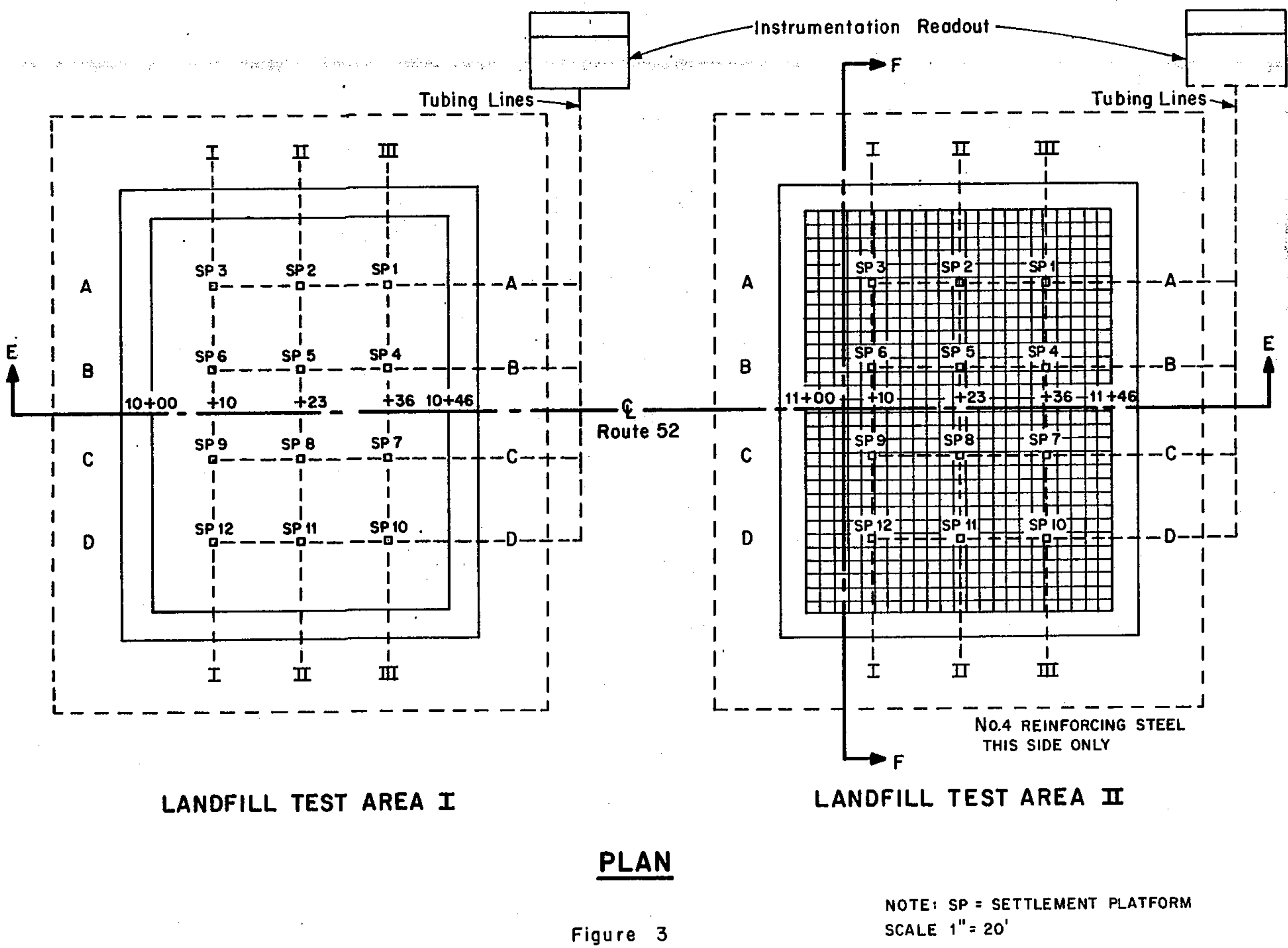
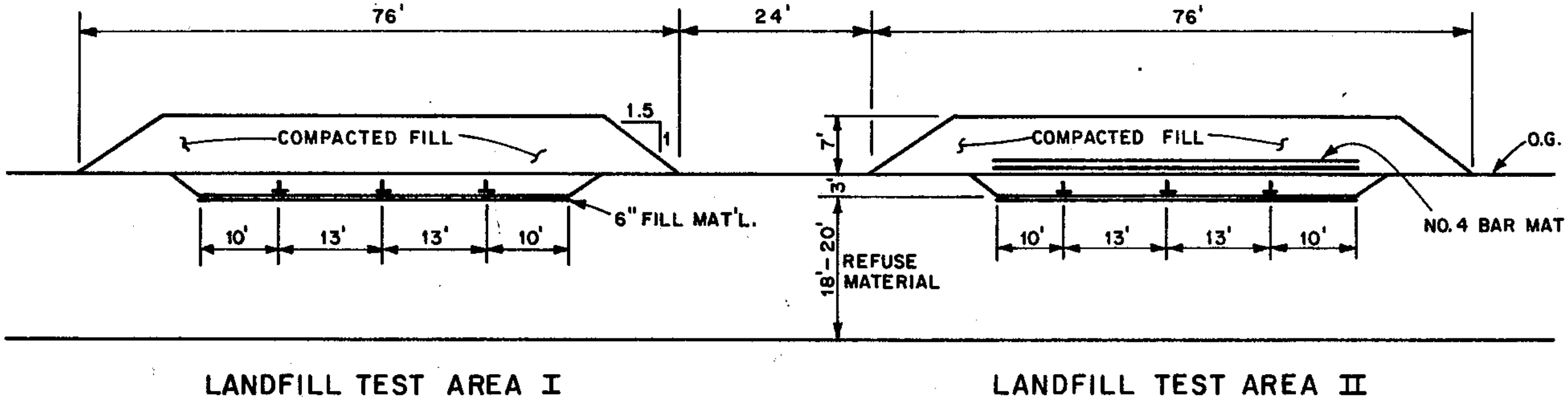
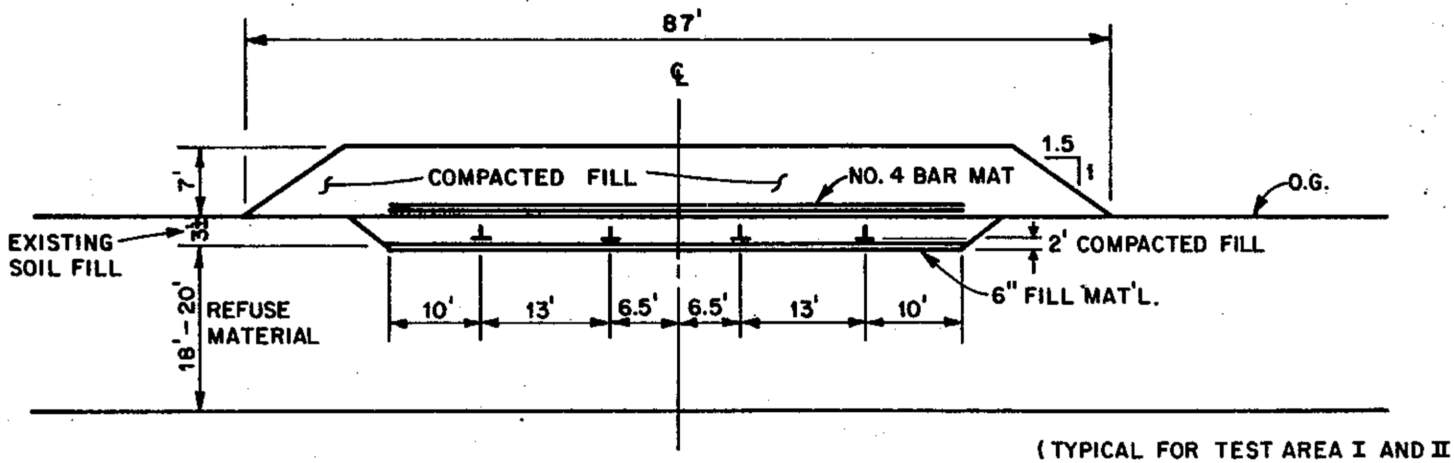

Instrumentation Readout
Tubing Lines
Tubing Lines
I
II
III
A
B
C
D
SP 1
SP 2
SP 3
SP 4
SP 5
SP 6
SP 7
SP 8
SP 9
SP 10
SP 11
SP 12
10+00
+10
+23
+36
10+46
11+00
11+46
E
F
℄ Route 52
No.4 REINFORCING STEEL
THIS SIDE ONLY
LANDFILL TEST AREA I
LANDFILL TEST AREA II
PLAN
NOTE: SP = SETTLEMENT PLATFORM
SCALE 1" = 20'

Figure 3



SECTION E-E

SCALE 1" = 20'



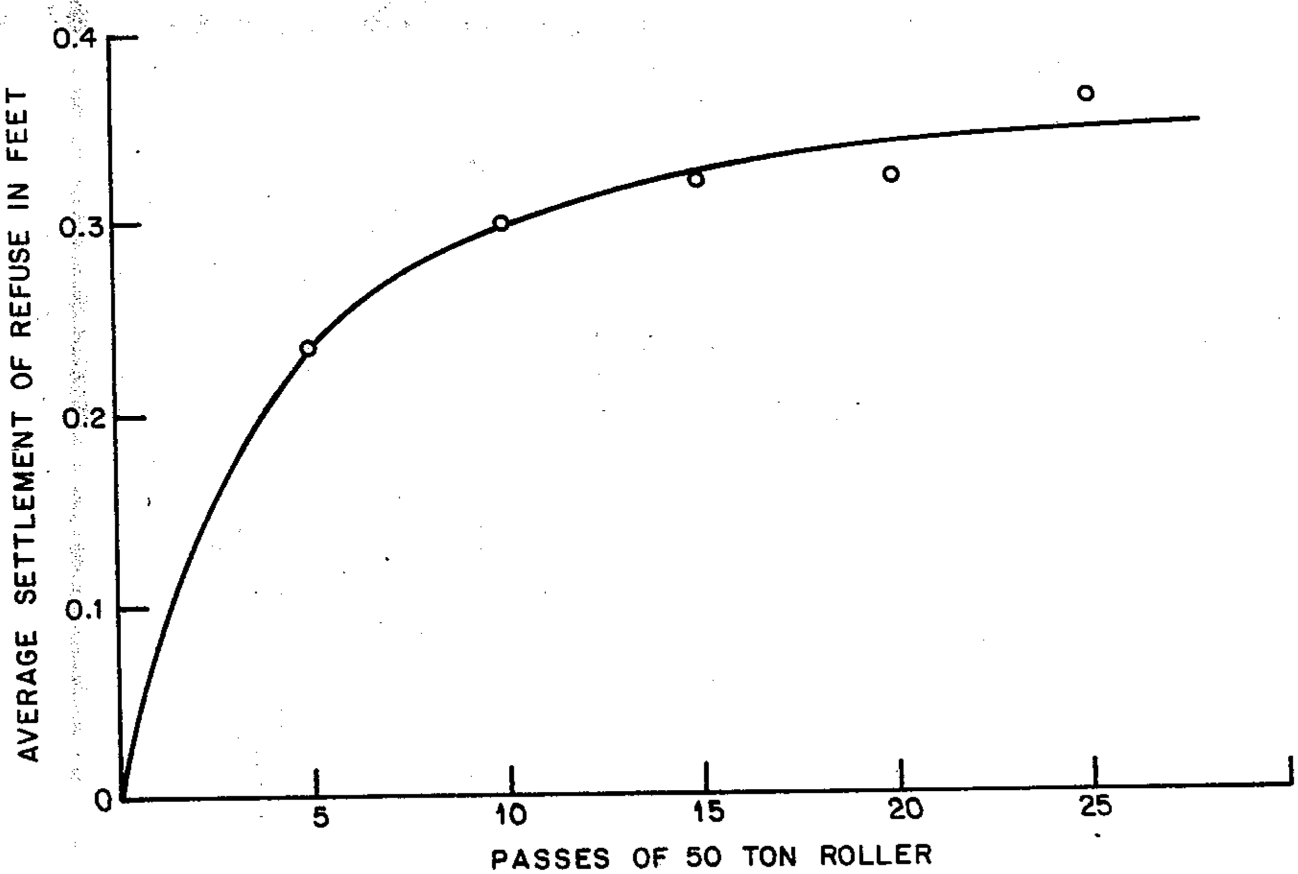
SECTION F-F

SCALE 1" = 20'

(TYPICAL FOR TEST AREA I AND II EXCEPT BAR MAT)

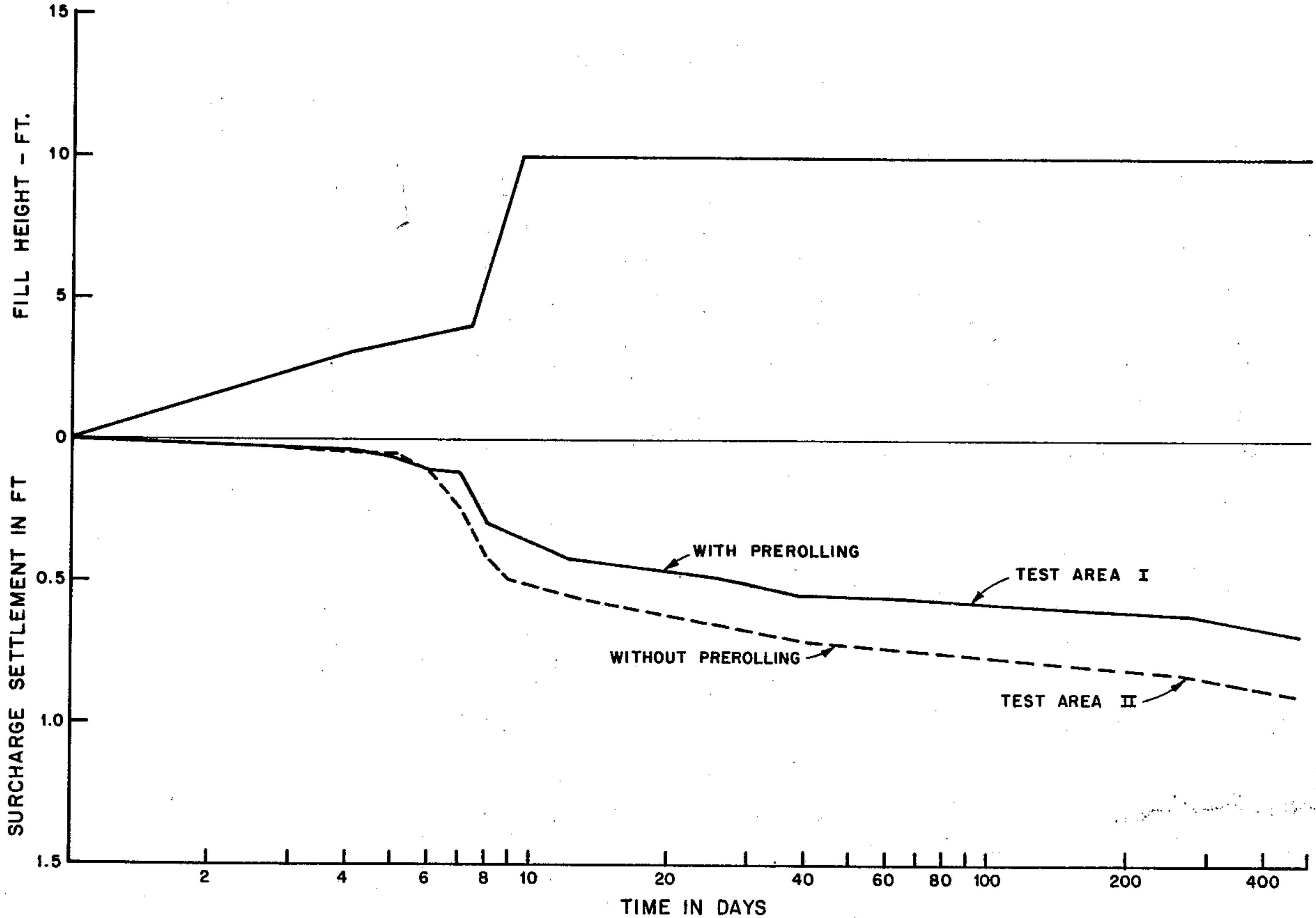
NOTE:
⊥ = SETTLEMENT PLATFORM

Figure 4



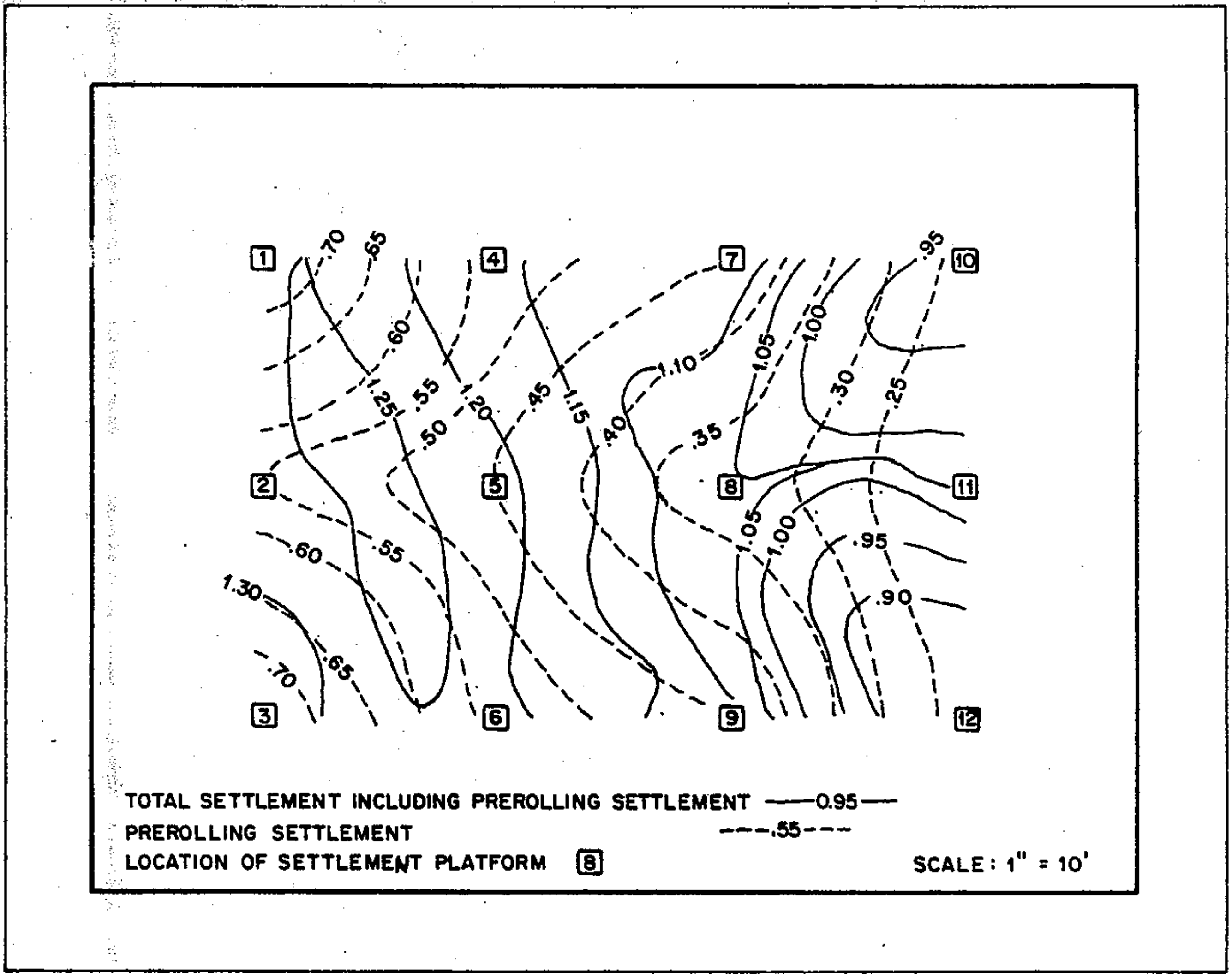
PREROLLING SETTLEMENTS — TEST AREA I (DRY)

Figure 5



RELATIONSHIP BETWEEN AVERAGE ELAPSED TIME AND SETTLEMENTS

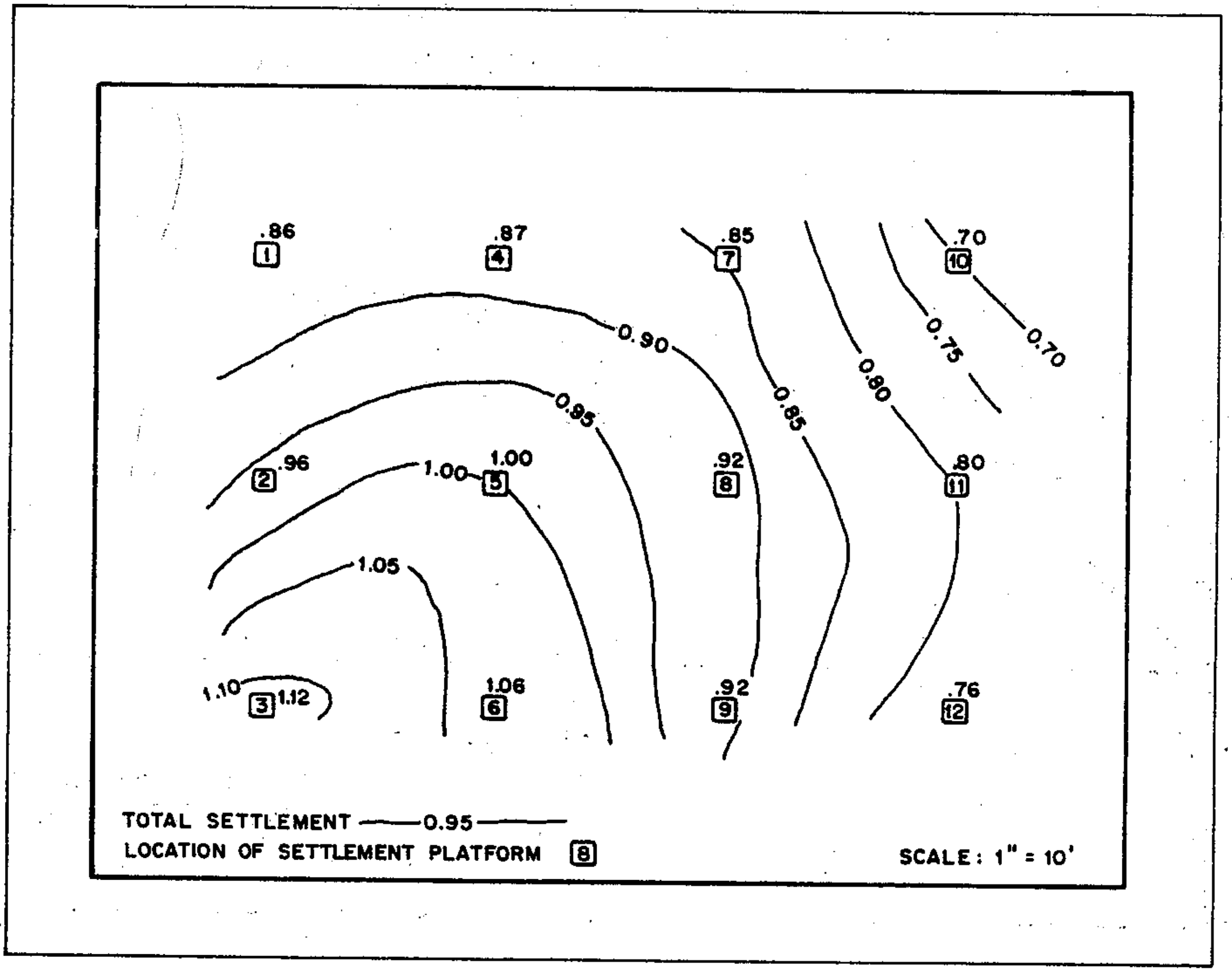
Figure 6



TEST AREA I

SETTLEMENT CONTOURS AFTER 476 DAYS OF FILL CONSTRUCTION

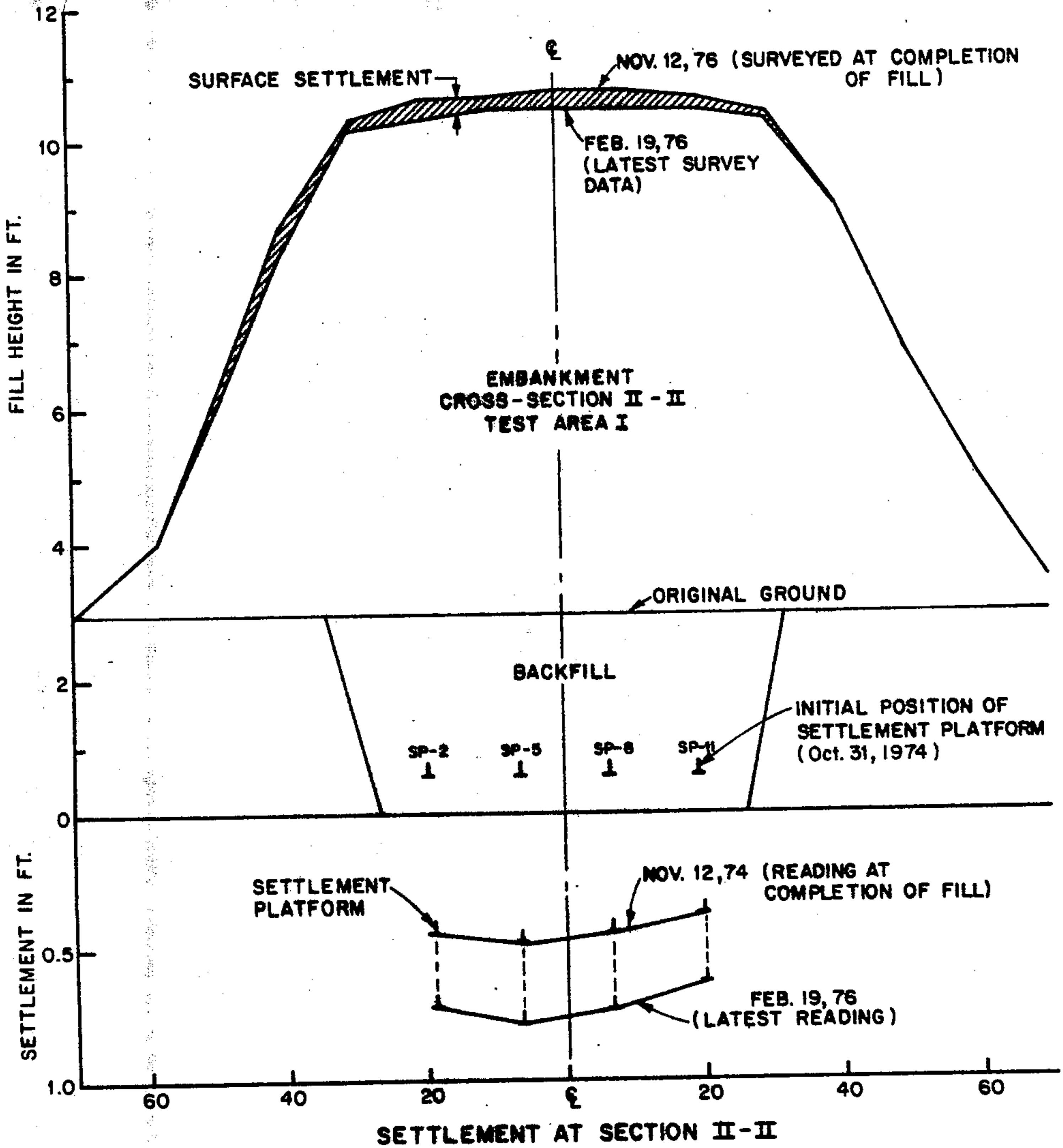
Figure 7



TEST AREA II

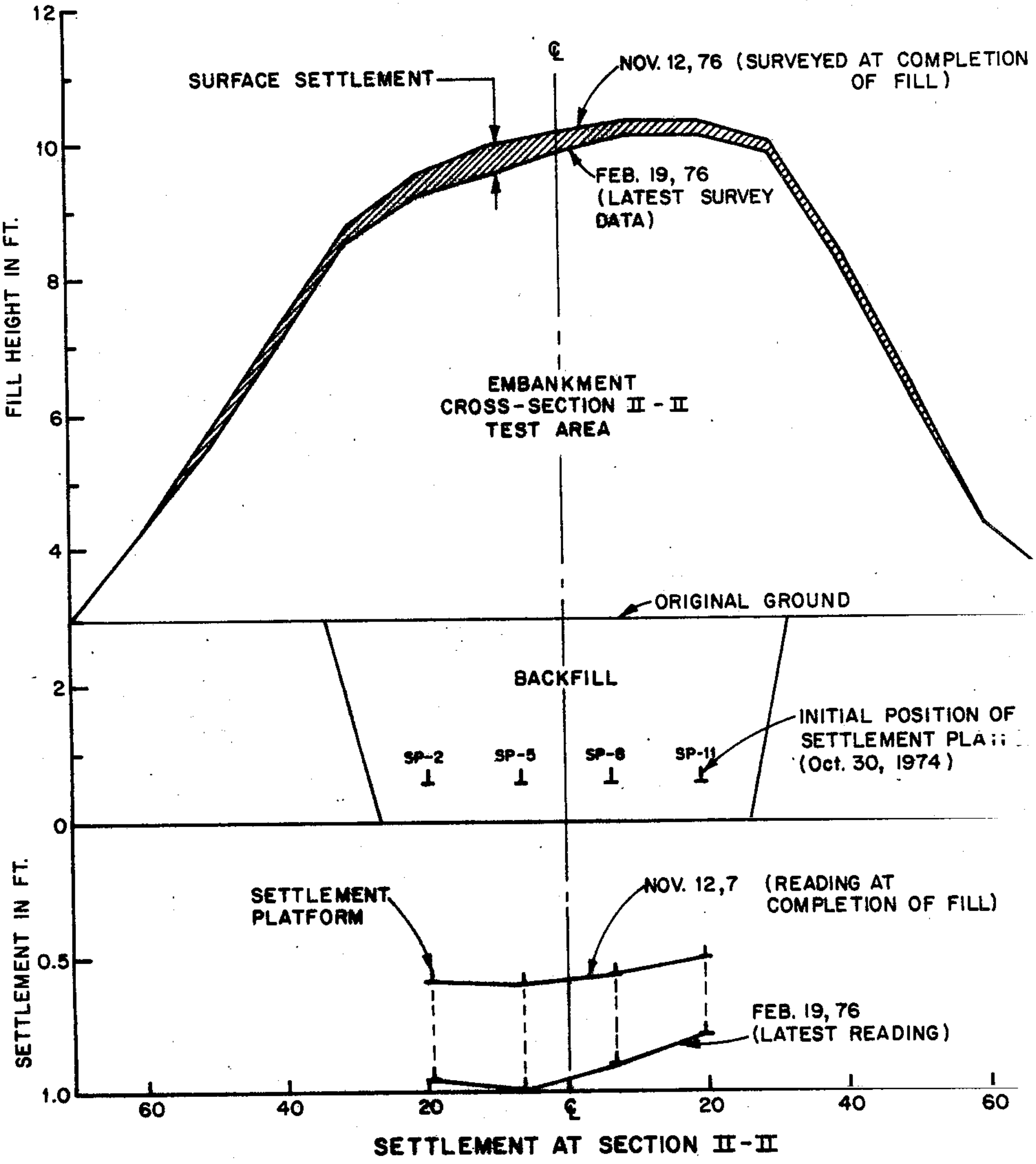
SETTLEMENT CONTOURS AFTER 476 DAYS OF FILL CONSTRUCTION

Figure 8



TEST AREA I, NO STEEL REINFORCING MATS BUT WITH PREROLLING

Figure 9



TEST AREA II, WITH STEEL REINFORCING MATS AND NO PREROLLING

Figure 10