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16. ABSTRACT

The construction of highway embankments over marshy or so-called "swampy" lands presents several serious problems. The soils normally associated with this type of terrain are heavy in silt and clay content, often high in organic and saturated with water. When these soils exist in poorly consolidated layers, they are weak and highly compressible. As a consequence embankments built over marshes, without special treatment or control, can result in costly slipout failures during construction and/or settlements which are destructive to the structural section after paving.

There are a number of methods which can be utilized in the design and construction of fills to obviate these difficulties. Such items as the use of fill struts, sand drains, controlled rate of raising the fill, waiting periods, surcharge, etc., are very effective in overcoming the detrimental characteristics of marshy soils. It must be realized, however, that these methods of treatment are rather costly and will only be used judiciously. Therefore, it follows that the success of a method or combination of methods, used in a given situation, is heavily dependent upon the correctness of many assumptions made on the basis of preliminary foundation investigations.

This leads to the need for the measurement of the effects of the fill loading upon the foundation soil, during construction, to assure that the design assumptions are valid and provide a means of anticipating trouble. The following discussion will cover the details of the construction control methods used by the Materials and Research Department to accomplish this purpose.

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

CONSTRUCTION CONTROL OF EMBANKMENTS PLACED OVER MARSH AREAS

65-52

March 1965

65-52

CONSTRUCTION CONTROL OF EMBANKMENTS PLACED OVER MARSH AREAS

Introduction

The construction of highway embankments over marshy or so-called "swampy" lands presents several serious problems. The soils normally associated with this type of terrain are heavy in silt and clay content, often high in organics and saturated with water. When these soils exist in poorly consolidated layers, they are weak and highly compressible. As a consequence embankments built over marshes, without special treatment or control, can result in costly slipout failures during construction and/or settlements which are destructive to the structural section after paving.

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This leads to the need for the measurement of the effects of the fill loading upon the foundation soil, during construction, to assure that the design assumptions are valid and provide a means of anticipating trouble. The following discussion will cover the details of the construction control methods used by the Materials and Research Department to accomplish this purpose.

Construction Control

There are four primary instruments utilized in monitoring the settlement and stability of embankments. They are (1) settlement platforms (2) piezometers (3) heave stakes and (4) Inclinometers. The Materials and Research (M & R) Department undertakes the installation of these devices at the start of construction, utilizing specially trained and equipped personnel. The installations are made on either a written or verbal request from the district or as specified by the contract special provisions.

Reading of the instrumentation is normally performed by the resident engineer's forces, at regular intervals, with the data being recorded on special manifold forms which are furnished by the M & R Department. All necessary calculations are completed on the project and copies are sent to the Foundation Section of the M & R Department. Plotting of the data is essential to effective "up-to-date" analysis. The analysis of data is normally undertaken by the Foundation Section, however, the resident engineer may make any plots or studies he feels advisable.

A discussion of each of the devices, taken individually, will now be made with emphasis being placed upon description, principle of operation, method of reading, calculations and analysis. No attempt will be made here to detail the techniques of installation since this is the responsibility of the M & R Department and serves no purpose in this course.

SETTLEMENT PLATFORMS

There are two types of settlement platforms currently used for routine construction control purposes. They are the "sealed fluid level" and the "riser type" devices.

The schematic diagram shown in Figure 1 illustrates a typical installation of a fluid level settlement platform. The device basically consists of a standpipe attached to a 18" x 18" wood or metal platform which is placed on either the original ground or the "working table" at or near the centerline of the fill. The standpipe is connected by 3/8" plastic tubing to a transparent sight tube mounted vertically in a protective box outside the limits of the fill. A fluid, usually water*, fills the standpipe, connecting tube and sight tube.

Operation of the system is based upon the principle that a liquid seeks its own level. When the ground upon which the platform is resting, settles, the standpipe overflows and the level in the sight tube lowers correspondingly. With the graduated scale attached to the sight tube, a measurement of the amount of settlement of the platform relative to the indicating unit, can be made.

If the indicating unit remains at constant elevation then the measurement reflects the absolute settlement of the fill. On the other hand, if the indicating unit also settles or, as sometimes happens, raises because of heave, then a correction must be applied to the fluid scale reading in order to determine absolute settlement of the fill. The correction is made from elevation changes of the indicating unit as determined by performing differential levels at periodic intervals.

*Under severe freezing conditions, a light oil or kerosene may be used.

It is noted in Figure 1 that the standpipe is enclosed in a 1" galvanized pipe equipped with an "air vent" at the top and an overflow "drain" connection at the bottom. Plastic tubing is run from these two connections to the indicating unit where the ends are sheltered to keep them open and free. This completes the "sealing" of the standpipe unit to prevent flooding in the event of a rising ground water table and minimize "air locking" of the device which could prevent the standpipe from overflowing properly.

The procedure for reading the fluid level device, during construction, is given as follows:

(1) Unlock and open door to indicator box and remove cover cap. Combination of standard lock used for this purpose is as follows: Right to 24 - Left past 24 to 30 - Right to 4.

(2) Read and note (but do not record) the bottom of the water level menicus from the graduated scale to the nearest .01 ft.

(3) Add a small quantity of water (normally a paper cup full will suffice) to the filler pipe and observe the lowering of the water level until it stabilizes. Note scale reading. (Note: if water level does not lower in sight tube, insufficient liquid has been used and more must be added). Repeat the operation a second time.

(4) When these two readings check the final fluid level value is recorded on Chart T-2005 (mounted on the inside of the door of the indicator box) and in column 2 of the manifold Form T-2006 (see example in Fig. 2).

(5) Replace cover cap loosely by engaging only two or three threads. Excessive tightening tends to "freeze" the cap as rust develops. On the other hand, failure to replace the cover cap permits insects and debris to fall into the fluid column and plug the system. Close the indicator box door and lock to discourage tampering by unauthorized persons.

An example of fluid level type settlement platform data and calculations is illustrated on Form T-2006 in Figure 2. The "reference nail elevation" shown in Column 3 refers the elevation of the bottom sill of the indicator box (see Fig. 1). Addition of the "water tube reading" (Col. 2) to this elevation gives the elevation of the overflow point on the standpipe (Col. 4). The length of the standpipe (Col. 5), above the platform, is measured during installation and is obtained from the original installation log. Subtraction of standpipe length (Col. 5) from the pipe top elevation (Col. 4) gives the present elevation of the settlement platform (Col. 7). The "original elevation" (Col. 6) of the settlement platform is obtained from the installation log. Subtraction of the present (Col. 7) from the original (Col. 6) elevation gives the settlement (Col. 8) which has taken place to date. The "fill height" (Cols. 9 & 10) is important for the analysis of data and must be determined at the time the reading is taken and at the location of the settlement platform standpipe unit. An accuracy of ± 1 foot is sufficient. The starting time, from which the "elapsed time" (Col. 11) is calculated, is established by the M & R Dept.

The fluid level type of installation is very effective at locations where it is possible to establish the indicator boxes in readily accessible places at the toe of the fill. However, in areas where the fill is being built on land which is covered by water or the "mud displacement" type of construction is being used, then it is necessary to utilize the "riser type" of settlement platform.

The riser type of settlement platform consists simply of an 18" x 18" wooden or metal platform which has 3/4" galvanized pipe attached to the center by a pipe flange as shown in Figure 3. When fill heights in excess of 10' are involved, a 1½-inch pipe sleeve is placed around the 3/4" riser to prevent "pull down" of the fill on the riser. The platform is set on either the natural ground or a working table. As the fill is constructed over the platform, the 3/4" riser pipe (and 1½" sleeve) is extended and maintained above the surface of the embankment. On divided roads the settlement platform is normally placed near centerline so that the riser extends through the median. In the case of two-lane roads the platform is arranged so that the riser coincides with the shoulder.

Measurement of settlement with the riser type device is accomplished by normal survey leveling methods. Case must be exercised that suitable bench marks are accurately established and adequately referenced for this purpose. Figure 4 illustrates the use of Form T-2006 for recording and calculating data obtained from this type device.

Plotting of the data is usually performed on 3 or 4 cycle x 20 to the inch semilogrithmic paper. Figure 5 (b) illustrates the typical manner in which this is undertaken.

PIEZOMETERS

The piezometer is a device for measuring the water pressure within a soil mass at a given point. It consists of a hollow cylindrical porous stone, normally one foot long and 1½" O.D. by 1" I.D., which is connected to a plastic tube. The stone is embedded in the soft mud layer, where pressure determinations are desired, and the plastic tube extends above ground.

There are two types of systems used in measuring hydrostatic pressure. They are the "open" and "closed" systems. In the open system the plastic tubing is brought straight up directly above the porous stone to the ground surface and the elevation of the water level inside the tubing is determined. In the closed system a pressure gage (capable of reading both positive pressure and vacuum) is connected to the plastic tubing and the entire system filled with water. Figures 6(a) and (b) illustrate the basic details of both systems.

In order to amplify the meaning of pore pressure and its relation to fill construction, consider a typical soft, marshy soil in its natural condition. The soil is both saturated and highly impermeable (i.e. resists passage of water). In this state the soil particles are rather loosely contacting each other. When an external load is applied, such as in the construction of a fill, part of the stress is transmitted through the water and registers as pore pressure. Since water has no shear strength (for all practical purposes), the soil is initially relatively weak. An increase in strength is attainable through the process of consolidation which brings the soil particles into more intimate contact and consequently transfers more of the load from the water to the soil particles. This in turn reduces the pore pressure. However, for consolidation to take place, water must be squeezed from the pores and out the drainage path. Since most marshy soils are highly resistant to the movement of water, the transfer of pressure from water to soil does not take place readily. Pore pressures remain relatively high until water passes from the soil over a period of time. It, therefore, may be considered that the factors of strength gain and settlement are time dependent functions of pore pressure.

It is seen from this that piezometer measurements of pore pressure may be used for monitoring both settlement and stability. For settlement studies, the piezometers are normally placed near centerline and near the settlement platforms. These installations are especially useful for determining when primary settlement is nearly complete so that paving may be undertaken. It is possible to do some stability analysis from centerline piezometers. However, this is highly theoretical and since many assumptions must be made, the accuracy of this method is sometimes debatable.

A more direct method for monitoring stability is to place several piezometers at the toe of the fill. Under normal circumstances a small amount of pressure will be registered on these devices during construction. Any sharp and sudden change in pressure, either in the positive or negative direction, foretells of a shear failure occurring in the foundation soil.

The procedure for reading the "closed system" type piezometers is given as follows:

(1) Read and record water table elevation from water table tube in vicinity using either a weighted tape or M-scope.

(2) Unlock and open door to gage box. Lock combination same as for settlement platforms.

(3) Lightly tap gages with finger and read to nearest 0.1 psi.

Record on Form T-2004.

Caution do not open valves attached to gage or bleeder line unless specially instructed to do so by the M & R Dept. De-gassing and maintenance of devices is normally undertaken by M & R Dept. personnel.

(4) Shut and lock gage box.

(5) Note and record fill height over piezometer. Accuracy to ± 1 ft. is adequate.

An example of piezometer data and calculations on Form T-2004 is illustrated in Figure 7 for a "closed" system. The "Water Table Elevation" shown in Column 1, is determined from measurement in a water table tube which is normally placed near the installation. The "elevation piezometric level" (Col. 2) is the elevation of the center of the pressure gage and is determined by survey levels. Check levels should be run on all gages about once a month during construction. Column 3 is determined by subtracting Column 1 from Column 2. The "pressure of water col." (Col. 4) is determined by multiplying Column 3 by .031. The "gage reading" (Col. 5) is recorded as + if pressure and - if vacuum. To convert the gage reading to tons/square foot in Column 6, multiply by .072 if gage registers pressure (+) or .035 if gage reads Vacuum (-). When calculating the value for Column 7, Columns 4 and 6 are added algebraically.

The procedure for reading the "open type system" piezometers is given as follows:

(1) Read and record water table elevation from water table tube.

(2) Determine elevation of piezometric level in piezometer tube with an M-Scope. An M-Scope consists of a coil of insulated wire connected to a battery and a milliammeter. The wire is pushed gently into the piezometer tube and when the bare ends of the wire contacts the water surface, the milliammeter pointer is deflected. The wire is marked with tape every five feet. When contact is established with the water surface, the distance to the nearest

mark is measured and the depth to the water surface is determined. Since the elevation of the tube end is established by survey levels, the elevation of the water surface may be easily calculated.

An example of Piezometer data and calculations on Form T-2004 is illustrated in Figure 8 for an "open system" installation.

A typical example demonstrating the plotting of piezometer data is shown in Figure 5 (c).

HEAVE STAKES

Heave stakes are surface movement indicating devices which are used when the stability of the fill foundation is considered to be a problem. A row of stakes, usually consisting of 2" x 2" x 18" hubs (or larger) are placed from 10 to 25 ft. outside of and generally parallel to the toe of the fill slope. The hubs may be spaced on centers ranging from 10 to 100 ft., depending on circumstances, however, the most common spacing is 50 ft. It is not advisable to extend heave line points much beyond a distance of about 1000 ft. as sight distance begins to affect the accuracy of measurements.

Survey tacks are set on each hub in line using a transit. Sight targets for line are placed on some solid support (e.g., tree, power pole, building, etc.) at each end of the line. It is advisable, wherever possible to "double" target each end of the line on independent supports for reference.

Differential levels are run on the hubs for elevations. It is desirable to have a bench mark (B.M.) located on solid ground near each end of the line so that levels can start at one B.M. and close on the other. However, for lines under 500 ft. in length, one good bench mark may be used for both starting and closing. Error of closure should never exceed 0.10 ft. Errors between 0.05 and 0.10 ft. should be redistributed among heave points.

Figure 9 shows an example of heave stake data recorded on Form T-2081. Figure 10 illustrates the manner in which both vertical and horizontal movement are plotted for each individual heave stake.

In analyzing the heave stake data, it must be borne in mind that, it is not the total magnitude of movement but rather the rate of change which is important. The faster the horizontal and vertical displacement moves, the more critical the stability situation becomes.

INCLINOMETER

The Inclinometer is a device for sensing subsurface movement of soil masses. It consists of 10 ft. lengths of 3/4" I.D. plastic tubing joined together to form a suitable length. The tubing is installed vertically through the soft mud layer to firmer material at a distance of from 5 to 15 feet outside the toe of fill. Extreme care is exercised to insure that the tubing is initially installed straight.

When an unstable condition begins to develop and the mud flows outwardly away from the fill, the inclinometer tube will be bent or deflected in a manner similar to that demonstrated in Figure 11. Detection of this bending is accomplished by lowering a .675" diameter test rod into the 3/4" tubing, on the end of a line, until the rod binds in the bend as shown in Figure 12. This procedure is performed with three rods having lengths of 3 ft., 1 ft. and ½ ft. respectively, and depths to refusal are determined in each case. If on the first trial, the 3-ft. rod goes to the bottom of the tube then it is not necessary to try the 1-ft. and ½-ft. rods. Inclinometer data is recorded on Form T-2078 as shown in Figure 13 and plotted in the manner illustrated in Figure 14.

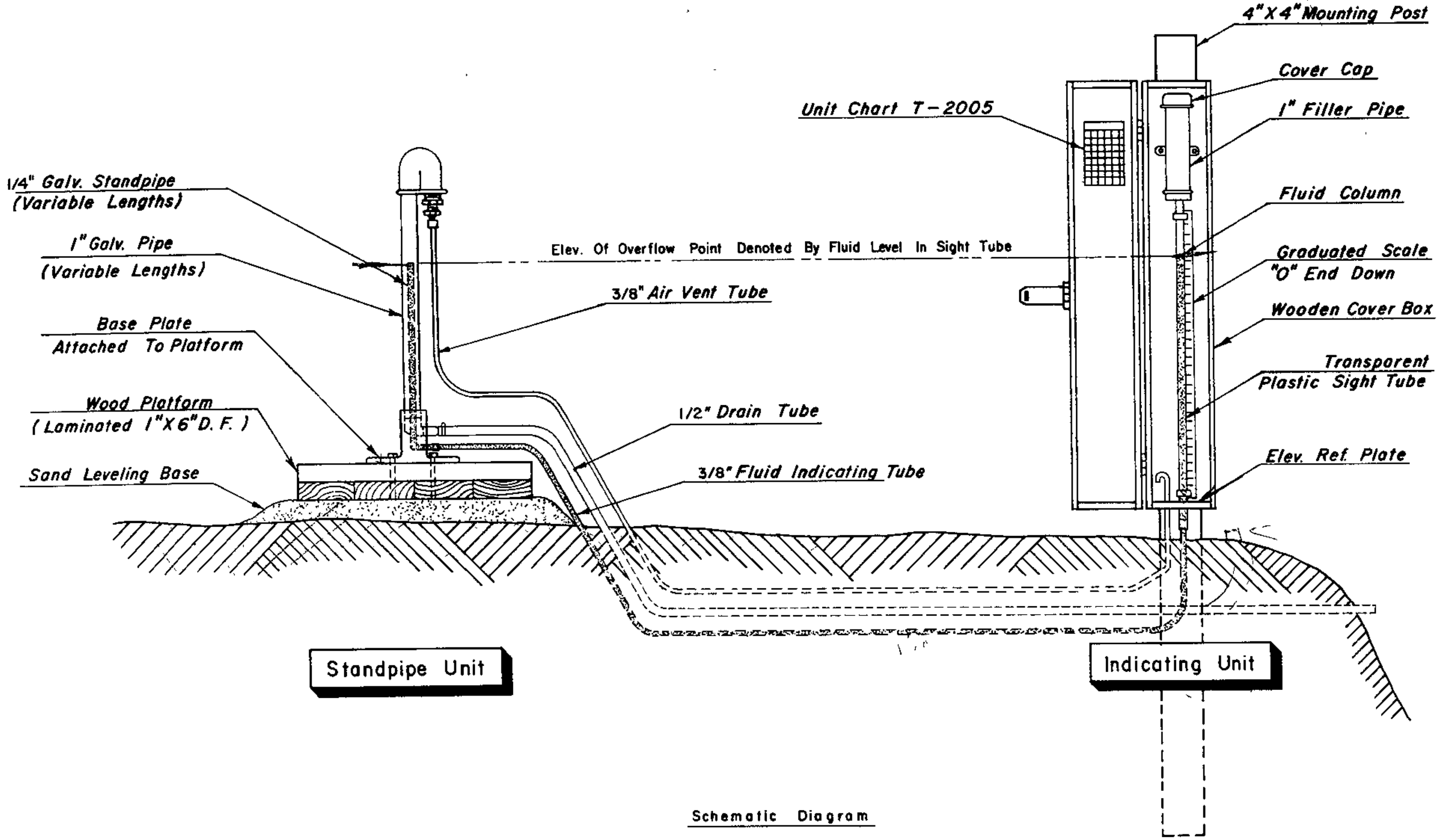
The Inclinometer will provide only a very general concept of the measurement of the magnitude of underground movement, but it can give a fair indication of the depth at which displacement is occurring. The significance of this field test, with regard to stability, is not only how much the refusal points change, for the various rods, but also how rapidly they change. The faster the positions change the more critical stability becomes.

Summary

The two principle items of concern, when building embankments over marshes, are (1) the stability of the fill and (2) the magnitude and rate of settlement. The location of the control devices in or on the fill foundation is dependent upon the type of problem involved. When only settlement is of concern, a settlement platform and several piezometers, at various depths, are installed on or near centerline. On the other hand, where stability is a problem, piezometers are installed at the toe of the fill along with an inclinometer (5' to 15" out from toe) and heave lines (10' to 25' ft. out from toe). Figure 15 illustrates the instrument positioning for both stability and settlement.

The frequency of reading the devices will vary according to circumstances involved in individual projects. In general, readings will range from one to three times a week during the fill loading period. If stability is critical, readings may be taken two or three times a week. On the other hand, if the problem only involves settlement then once a week will usually suffice. After the embankment is completed, and during a waiting period before paving, the frequency of readings may be tapered off to once or twice a month. The number of readings will not only depend upon the criticalness of stability, but also the rate of settlement. If the rate of settlement is relatively large then more frequent readings are in order. This will aid in making predictions as to when settlement will be nearly complete so that surcharges may be removed and/or the construction of the structural section may be satisfactorily undertaken.

In summarizing field control operations, it may be said that the effectiveness of the instrumentation is no better than the care and conscientiousness with which the measurements are made. Effective use of construction control methods, when dealing with difficult marshlands, will lead to less expensive and better riding highways for tomorrow's traffic.



Schematic Diagram

SETTLEMENT INDICATING DEVICE
SEALED FLUID LEVEL TYPE

Division of Highways
Materials and Research Dept.

FIGURE 1

TO HEADQUARTERS LABORATORY

STATE OF CALIFORNIA - DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
Materials & Research Department
SETTLEMENT DATA
FORM T-2006 (REV. 3-57)

Water Level Type
Settlement Platforms

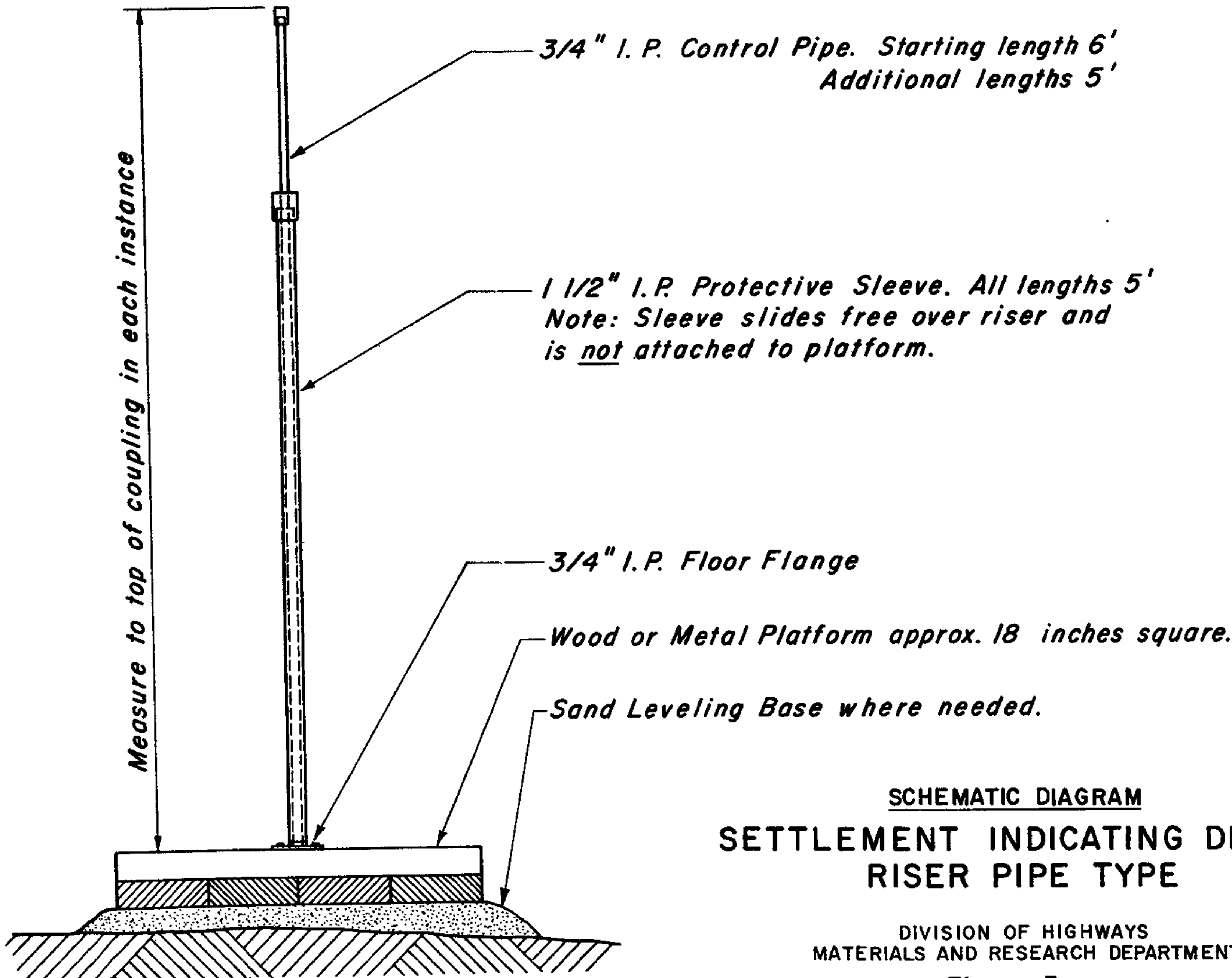
JOB NO.	DATE 1-24-64	PAGE 2
DIST. IV	CO. Mon	RTE. 56 / SEC. J
CONTRACT	LOCATION Watsonville Bypass	

UNIT WEIGHT OF FILL LB/CU. FT.

Number or Station	Water Tube Reading	Reference Nail Elevation	Riser Pipe: Elevation Top of Pipe	Riser Pipe: Length of Pipe	Settlement Platform: Original Elevation	Settlement Platform: Present Elevation	Settlement in Feet	Fill Height: Surface Elevation	Fill Height: Fill Above Original Ground	Elapsed Time Days	Remarks
SP 7	1.77	20.29	22.06	5.53	16.79	16.53	.26		5	9	
SP 8	1.53	17.61	19.14	5.55	13.89	13.59	.30		5		
SP 9	1.63	22.48	24.11	5.65	18.96	18.46	.50		6		
SP 11	1.80	22.73	24.53	5.25	19.55	19.28	.27		6		
SP 13	1.35	19.90	21.25	5.35	16.09	15.90	.19		2		
(Col. 1)	(Col. 2)	(Col. 3)	(Col. 4)	(Col. 5)	(Col. 6)	(Col. 7)	(Col. 8)	(Col. 9)	(Col. 10)	(Col. 11)	

Plotted
1-28-64
BTS

FIGURE 2



SCHEMATIC DIAGRAM

SETTLEMENT INDICATING DEVICE
RISER PIPE TYPE

DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

Figure 3

TO HEADQUARTERS LABORATORY

STATE OF CALIFORNIA - DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
Materials & Research Department
SETTLEMENT DATA
FORM T-2006 (REV. 3-57)

Riser Type
Settlement Platforms

JOB NO. 29	DATE 12-18-64	PAGE 18
DIST. 10 / CO. Sol	RTE. 21	SEC.
CONTRACT 65-10MAC049004	LOCATION Benecia to Cordelia	

Number or Station	Water Tube Reading	Reference Nail Elevation	Riser Pipe: Elevation Top of Pipe	Riser Pipe: Length of Pipe	Settlement Platform: Original Elevation	Settlement Platform: Present Elevation	Settlement in Feet	Fill Height: Surface Elevation	Fill Height: Fill Above Original Ground	Elapsed Time Days	Unit Weight of Fill Lb/Cu. Ft. / Remarks
SP-17	(Riser Type S.P.)		30.29	21.20	9.75	9.09	0.66	22.3	20.5	122	197~± Ult. ℄
-18	"	"	26.38	16.09	11.01	10.29	0.72	20.6	18.2	"	199~± " "
-19	"	"	26.27	15.94	10.50	10.33	0.17	18.0	13.5	"	201+50± " "
-20	"	"	11.40	5.37	6.15	6.03	0.12	6.4	7.1	"	201+50 Rt Fr Rd.
-21	"	"	11.63	5.38	6.63	6.25	0.38	6.6	4.7	"	199~ " " "
-22	"	"	11.80	5.37	6.61	6.43	0.18	7.2	5.2	"	197~ " " "
-23	"	"	13.99	10.60	3.98	3.39	0.59	11.6	8.3	147	310~ Ult ℄
-24	"	"	13.82	10.59	3.82	3.23	0.59	13.1	8.4	"	312~ " "
-25	"	"	14.99	10.64	4.54	4.35	0.19	13.7	8.5	"	314~ " "
-39	"	"	9.01	5.35	4.40	3.66	0.74	6.8	4.8	"	310+25 Rt Fr Rd
-40	"	"	9.35	5.37	4.50	3.98	0.52	6.3	4.4	"	312~ " " "
-41	"	"	9.67	5.36	4.52	4.31	0.21	6.1	3.9	"	314~ " " "
-42B	"	"	20.15	15.86	4.44	4.29	0.15	15.9	14.0	57	321~ Ult ℄
-44	"	"	18.97	10.67	8.51	8.30	0.21	15.0	13.4	65	323+50 " "
-45B	"	"	19.60	15.89	3.78	3.71	0.07	14.8	13.0	57	326~ " "
-72	"	"	13.79	10.66	3.20	3.13	0.07	10.7	6.9	65	328~ " "
-65	"	"	11.25	5.35	6.02	5.90	0.12	8.5	1.0	47	372+90± Rt Fr Rd
-62	"	"	11.74	5.35	6.42	6.39	0.03	7.8	5.0	47	374+75± " " "
-46	"	"	18.02	16.00	2.86	2.02	0.84	11.4	7.4	107	394+95 Ult ℄
-47A	"	"	20.04	1588	-0.51			17.5	7.4	57	400+40± " "
										189	

Plotted 12-29-64

FIGURE 4

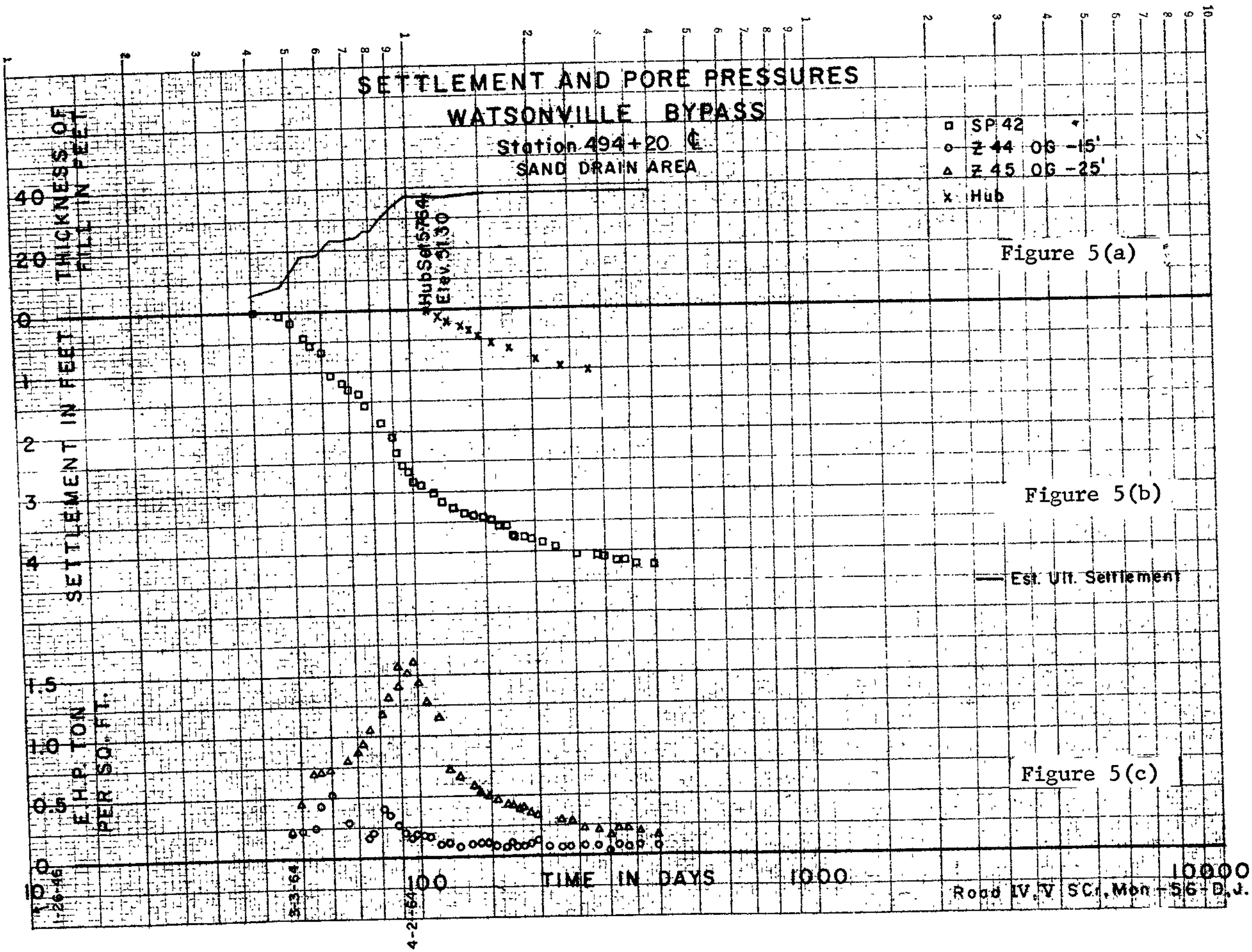


Figure 5(a)

Figure 5(b)

Figure 5(c)

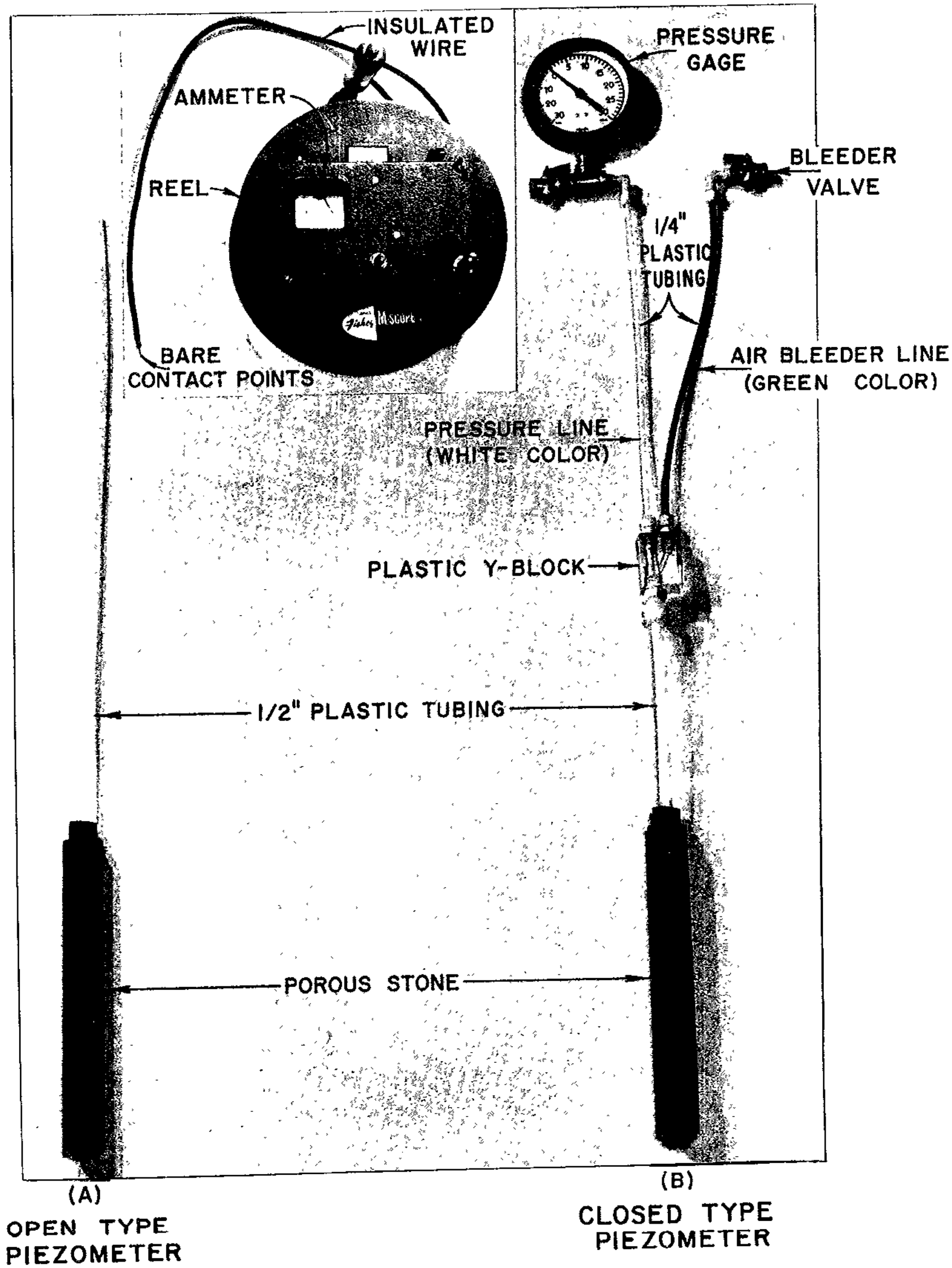

INSULATED WIRE
AMMETER
REEL
BARE CONTACT POINTS
PRESSURE GAGE
BLEEDER VALVE
1/4" PLASTIC TUBING
AIR BLEEDER LINE (GREEN COLOR)
PRESSURE LINE (WHITE COLOR)
PLASTIC Y-BLOCK
1/2" PLASTIC TUBING
POROUS STONE
(A) OPEN TYPE PIEZOMETER
(B) CLOSED TYPE PIEZOMETER

FIGURE 6

TO HEADQUARTERS LABORATORY

STATE OF CALIFORNIA - DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
Materials & Research Department

EXCESS HYDROSTATIC PRESSURE DATA

FORM T-2004 (REV. 3-57)

Closed Type System

Job No.	Date	Page
2 Q	12-11-64	

Dist.	Co.	Rte.	Sec.
04	Mon-SCr	56-67	J-D-Wats-A

Contract	Location
64-4TT3C32F	Watsonville Bypass

Piezometer Number	1 Water Table Elevation	2 Elevation Piezometric Level	3 Distance From Water Table-Feet	4 Pressure of Water Col. (3 X .091)	5 Gauge Reading	6 Reading T/S.F. (5 X .072)	7 Pore Press. T/S.F. (4+6)	8 Height of Fill Placed Feet	9 Loading Due to Fill T/S.F.	Elapsed Time Days	Unit Weight of Fill Lb/Cu. Ft. Remarks
✓Z-46	10.1'	17.3	9.2	0.22	-3.0	-0.11	0.11	38 ft	✓	331	
Z-38	↓	16.8	6.7	0.21	-2.0	-0.07	0.14	18 ft	✓	↓	
✓Z-44		17.4	7.3	0.23	-4.5	-0.16	0.07	✓ ✓	✓		
✓Z-45		17.8	7.7	0.24	0.0	0	0.24	✓ ✓	✓		
✓Z-39		16.8	6.7	0.21	-2.2	-0.08	0.13	✓ ✓	✓		
✓Z-29		17.4	7.3	0.23	-2.1	-0.08	0.16	47 ft	✓		
✓Z-40		16.6	6.5	0.20	5.0	+0.36	0.56	18 ft	✓		
✓Z-12		19.9	9.8	0.30	-2.2	-0.08	0.22	✓ ✓	✓		
✓Z-14		18.4	8.3	0.26	-4.8	-0.17	0.09	26 ft	✓		
✓Z-10		19.5	9.4	0.29	-1.0	-0.04	0.25	16 ft	✓		
✓Z-53	12.2	18.2	8.0	0.19	-1.5	-0.05	0.14	32 ft	✓		
✓Z-54	↓	19.0	6.8	0.21	-1.1	-0.04	0.17	✓ ✓	✓		
✓Z-55		19.0	6.8	0.21	-2.8	-0.10	0.11	✓ ✓	✓		
✓Z-56		18.4	6.2	0.19	-2.9	-0.10	0.09	✓ ✓	✓		
✓Z-58	11.2	20.3	9.1	0.28	-0.5	-0.02	0.26	✓ ✓	✓		
✓Z-59	↓	19.5	8.3	0.26	0.5	-0.02	0.24	✓ ✓	✓		
✓Z-60		21.3	10.1	0.30	-4.1	-0.15	0.15	34 ft			
✓Z-61		19.5	8.3	0.26	-4.0	-0.14	0.12	✓ ✓		↓	Plotted 12-18-64 JZ

FIGURE 7

TO HEADQUARTERS LABORATORY

STATE OF CALIFORNIA - DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
Materials & Research Department

EXCESS HYDROSTATIC PRESSURE DATA

FORM T-2004 (REV. 3-57)

Open Type System

JOB NO.	DATE	PAGE
2464-21-5	8-27-62	26

DIST.	CO.	RTE.	SEC.
XI	SD	2	Nat, C

CONTRACT	LOCATION
62-11V13C17-I	National City

UNIT WEIGHT OF FILL 120 LB/CU. FT.

	1	2	3	4	5	6	7	8	9		
PIEZOMETER NUMBER	WATER TABLE ELEVATION	ELEVATION PIEZOMETRIC LEVEL	DISTANCE FROM WATER TABLE-FEET	PRESSURE OF WATER COL. (3 X .031)	GAUGE READING	READING T/S.F. (5 X .072)	PORE PRESS. T/S.F. (4 + 6)	HEIGHT OF FILL PLACED FEET	LOADING DUE TO FILL T/S.F.	ELAPSED TIME DAYS	REMARKS
8	0.5	6.13	5.6	.174	—	—	.17	6.8	.41	68	
9	0.5	8.06	7.6	.236	—	—	.24	7.2	.43		
13	0.5	3.66	3.2	.099	—	—	.10	0	0		
14	0.5	1.98	1.5	.047	—	—	.05	0	0		
#38	W.T	0.51	—	—	—	—	—	—	—	68	

FIGURE 8

MATERIALS & RESEARCH DEPARTMENT

REPORT OF HEAVE STAKES

Lab. Auth. ______ Dist. 05 Co. MON Rt. [illegible] Sec. J

Location Watsonville By-pass Contract 64-04T12C32F

Date 4/17/69 Recorder Pagnini party Fill Height on ℄ ______ ft.

Line No. Rt. of "J" 490 to 497+50

Station	Vertical Movement				Horizontal Movement		Remarks
	H.I.	Rod Reading	Present Elevation	Original Elevation	Left	Right	
B.M.#9		-8.92	14.18	14.18 *			
497+50		-9.20	13.[illegible]	13.91		0.00	
497		-8.84	14.[illegible]	14.30	✓	0.05	
496+50		-9.41	13.69	13.74		0.06	
496		-9.99	13.11	13.14	✓	0.10	
495+50		-9.75	13.35	13.38	✓	0.15	
495		-10.34	12.76	12.77		0.14	
+60		-10.50	12.60	12.61	✓	0.08	
494+50		-9.58	13.52	13.53	✓	0.0[illegible]	
494+05		-9.08	14.02	14.02	✓	0.03	Mark on H.W.
+5.80 T.P.	23.10	-12.47	17.30				
+11.44 B.M.	29.77	-11.44	18.32	18.33			
493+40		-9.66	20.10	20.11	✓	0.01	
493		-10.57	19.1[illegible]	19.19	✓	0.01	
492+50		-9.55	20.21	20.21	✓	0.02	
492		-5.24	24.52	24.50	✓	0.04	Plotted 4-21-69 BTS
+80		-3.68	26.08	26.05	✓	0.03	
+0.29 +50	29.76	-13.25	29.47	29.46	✓	0.04	
491+25		-11.24	31.48	31.47	✓	0.03	
490+00		[illegible]	41.72	40.71	✓	0.01	
+0.69 B.M.#8	42.72		42.03				

"B" "A"

Form T-2081 (Orig. 10-61)

FIGURE 9

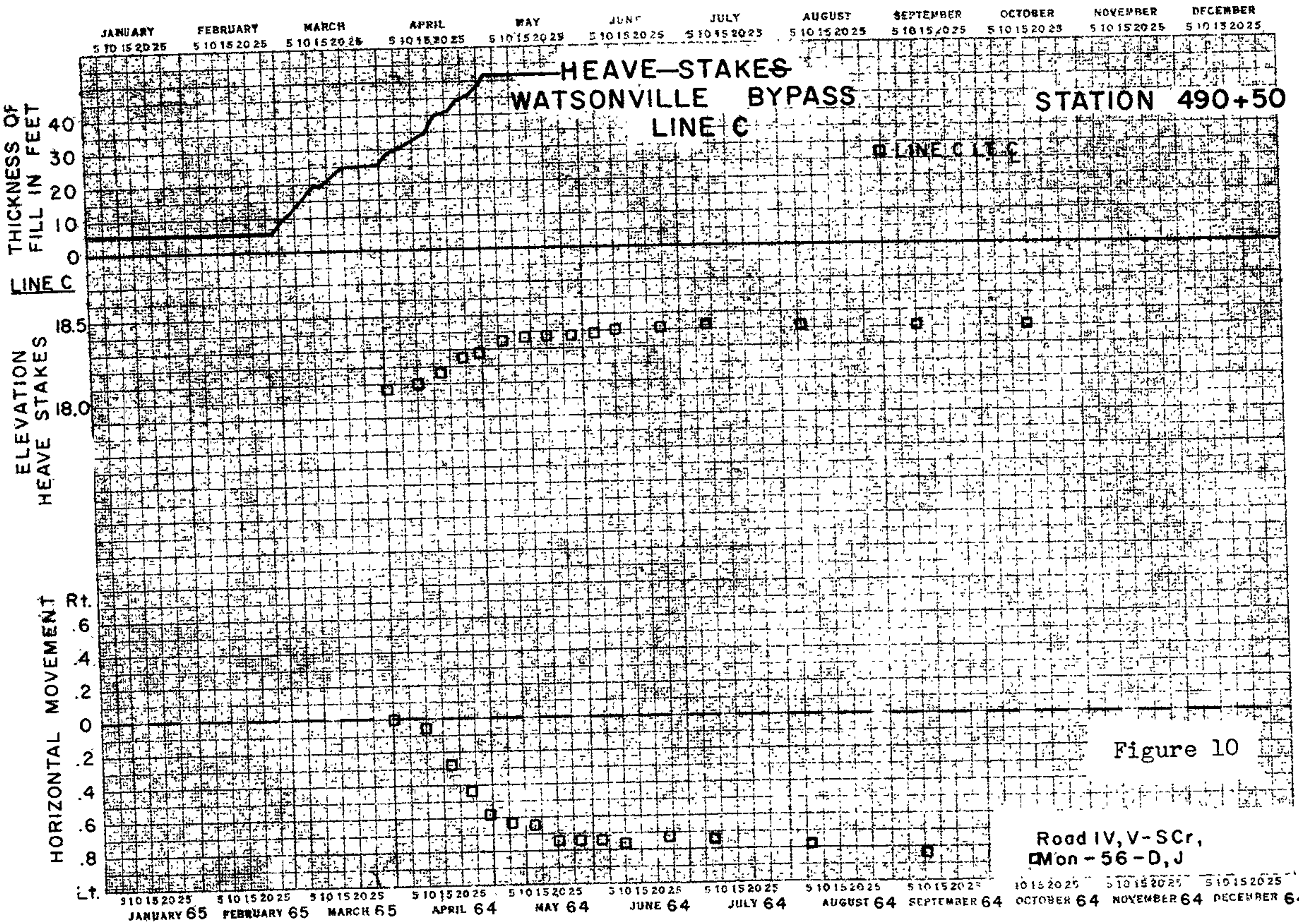

HEAVE—STAKES
WATSONVILLE BYPASS
LINE C
STATION 490+50
LINE C LT. C
THICKNESS OF FILL IN FEET
40
30
20
10
0
LINE C
ELEVATION HEAVE STAKES
18.5
18.0
HORIZONTAL MOVEMENT
Rt.
.6
.4
.2
0
.2
.4
.6
.8
Lt.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 65
FEBRUARY 65
MARCH 65
APRIL 64
MAY 64
JUNE 64
JULY 64
AUGUST 64
SEPTEMBER 64
OCTOBER 64
NOVEMBER 64
DECEMBER 64
Road IV, V-SCr,
Mon-56-D, J

Figure 10

TYPICAL INSTALLATION SHOWING INCLINOMETER MOVEMENT DURING DISPLACEMENT

Not to Scale

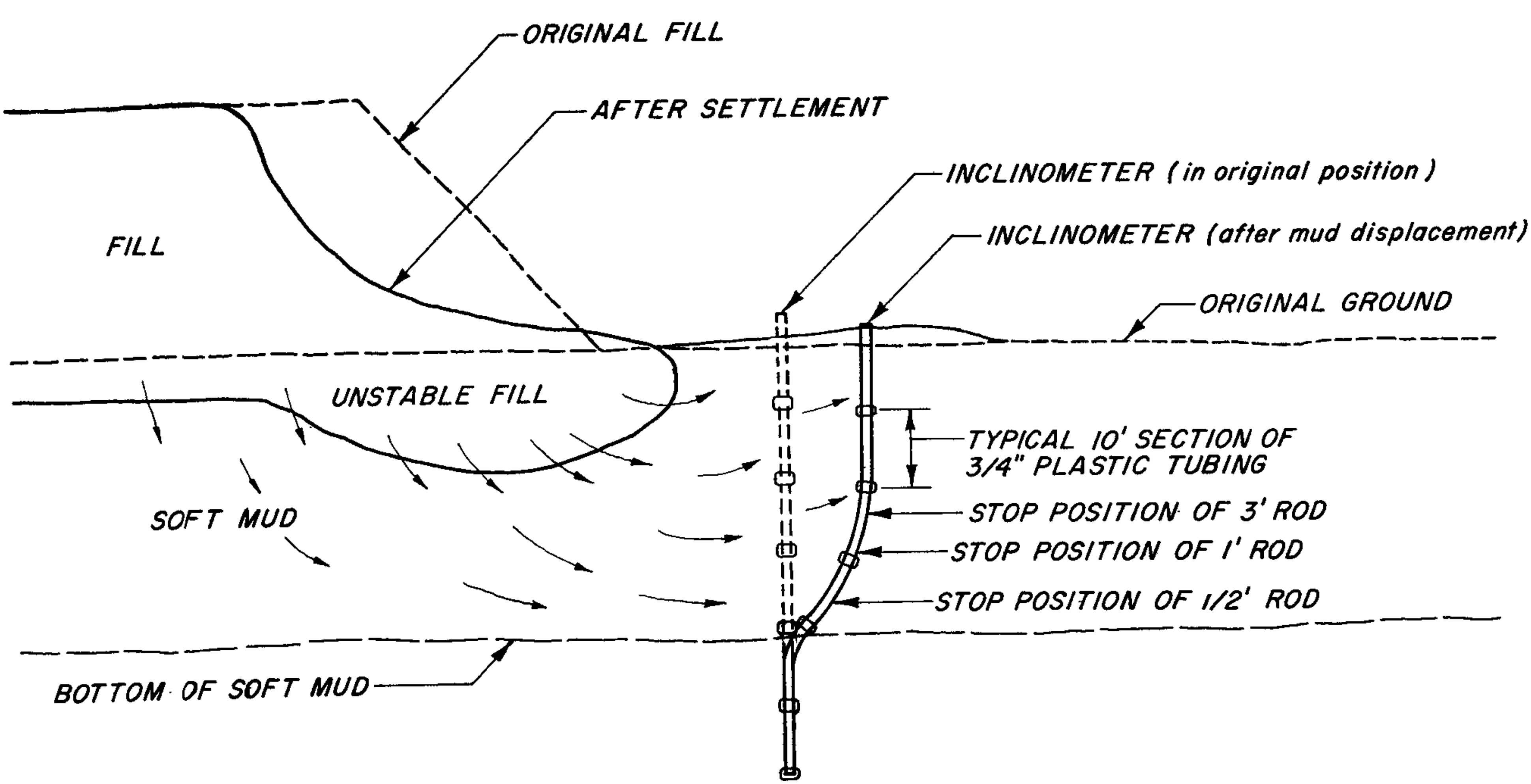


FIGURE 11

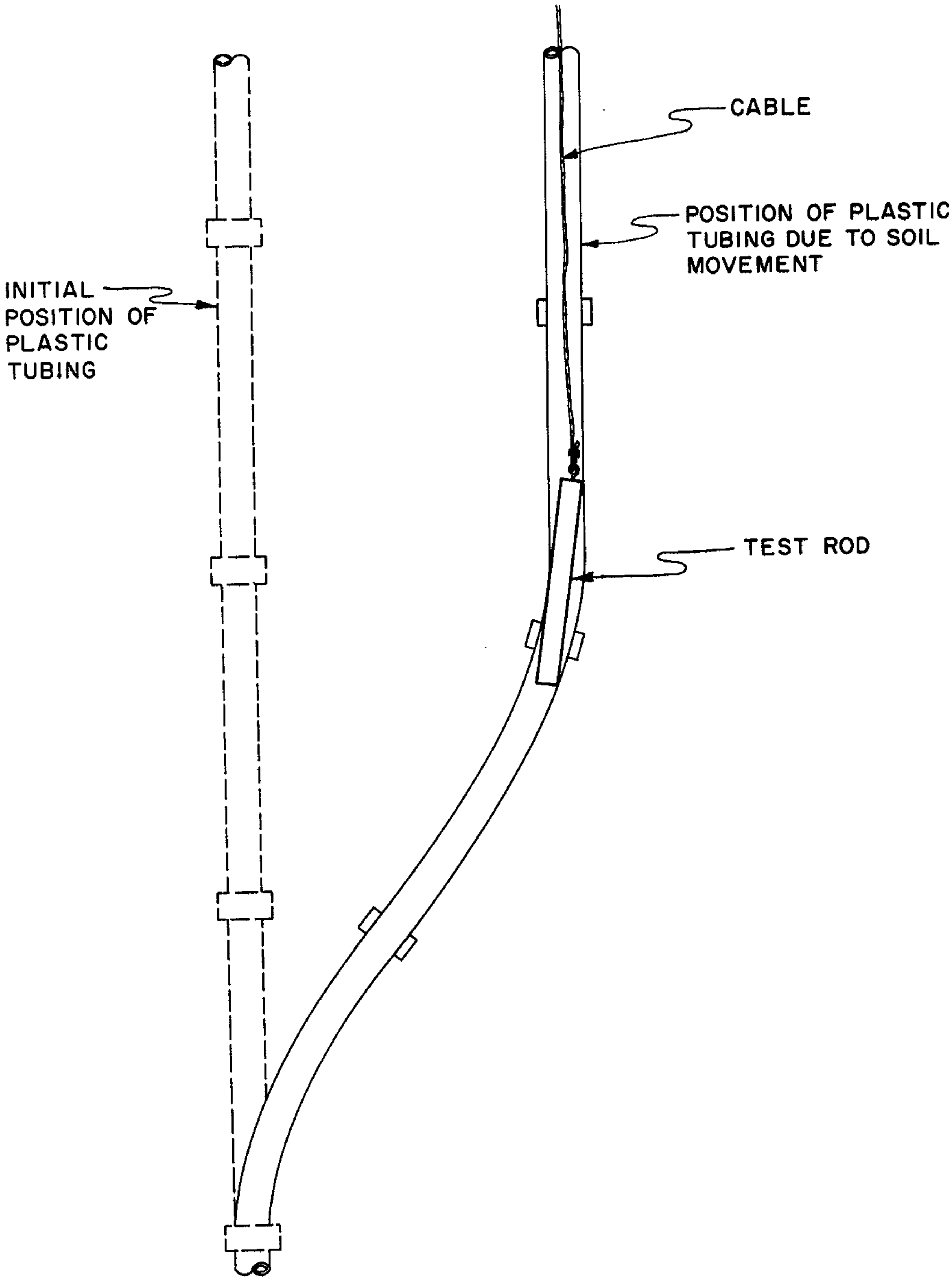

CABLE
POSITION OF PLASTIC TUBING DUE TO SOIL MOVEMENT
INITIAL POSITION OF PLASTIC TUBING
TEST ROD

FIGURE 12

MATERIALS & RESEARCH DEPARTMENT

ROOT INCLINOMETER READINGS

LAB. AUTH. 2Q DIST. 10 CO. Sol RT. 21 SEC.

LOCATION Benicia to Cordelia

DATE 1-12-65 OPERATOR Leavitt

NUMBER	DEPTH IN FEET	DEPTH PROBE DROPS TO 3 FOOT	1 FOOT	½ FOOT	REMARKS
I - 37	30.10	6.0	20.0	22.5	Mud Heave
34	30.00	11.2	16.7	16.8	" "
33	26.63	4.5	21.4	22.8	" "
32	21.35	14.2	14.4	19.8	
31	22.10	5.0	19.0	19.0	
28	21.95	6.1	14.1	18.5	
48	17.1	4.6	15.2	17.0	* See below
49	20.0	8.0	19.9	19.9	* " "
50	15.50	4.0	15.5	15.5	* " "
55	16.10	15.9	15.9	15.9	
57	20.10	10.6	19.9	19.9	* " "
74	14.70	14.7	14.7	14.7	
73	6.10	5.9	5.9	5.9	
54	9.95	4.4	9.8	9.8	
53	12.45	4.4	12.4	12.4	

* Delta caused by erosion from last storm in vicinity of settlement platforms has apparently deflected inclinometer near surface.

Plotted 2-9-65
B

Form T-2078 (ORIG. 9-61)

FIGURE 13

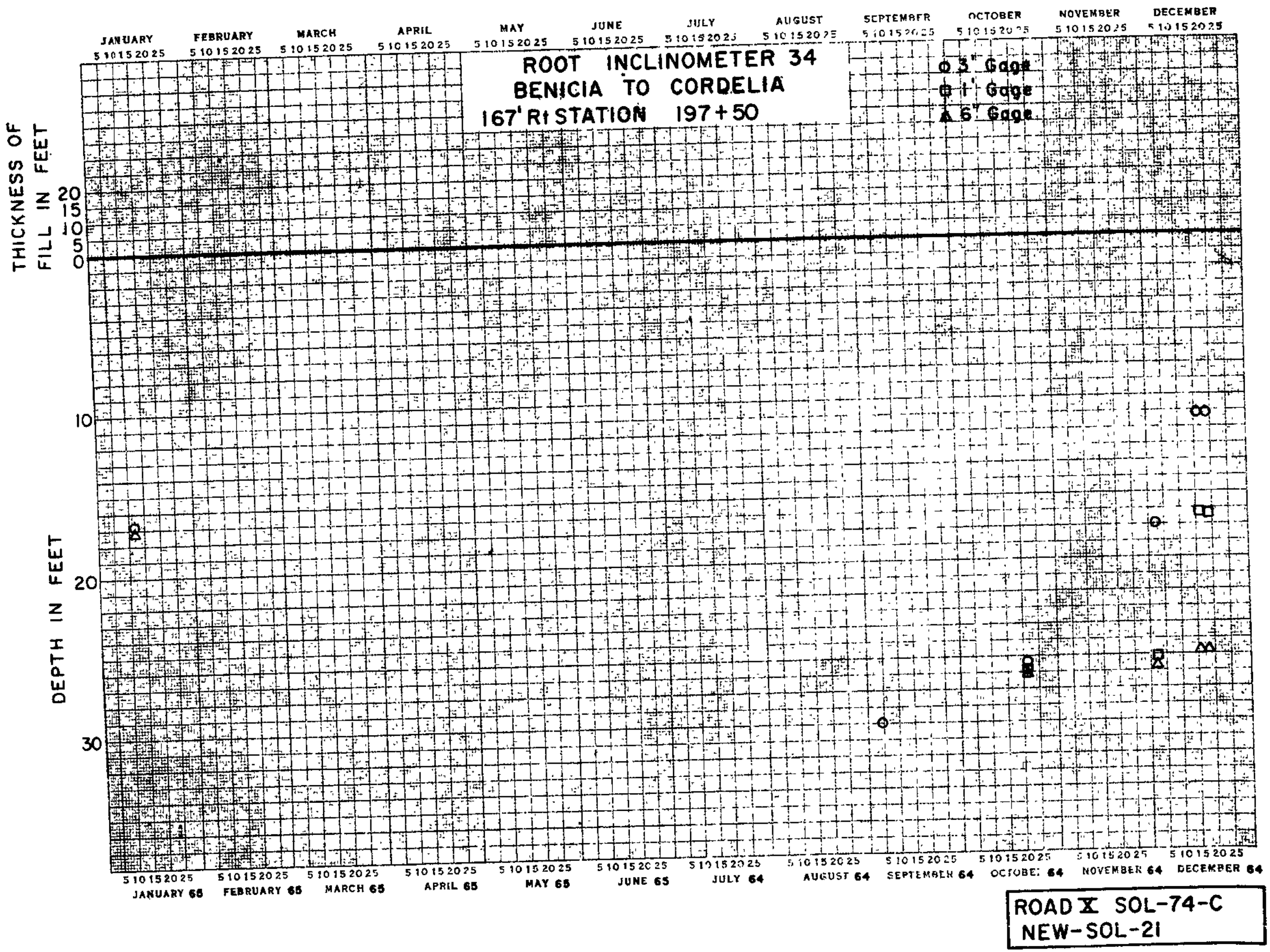
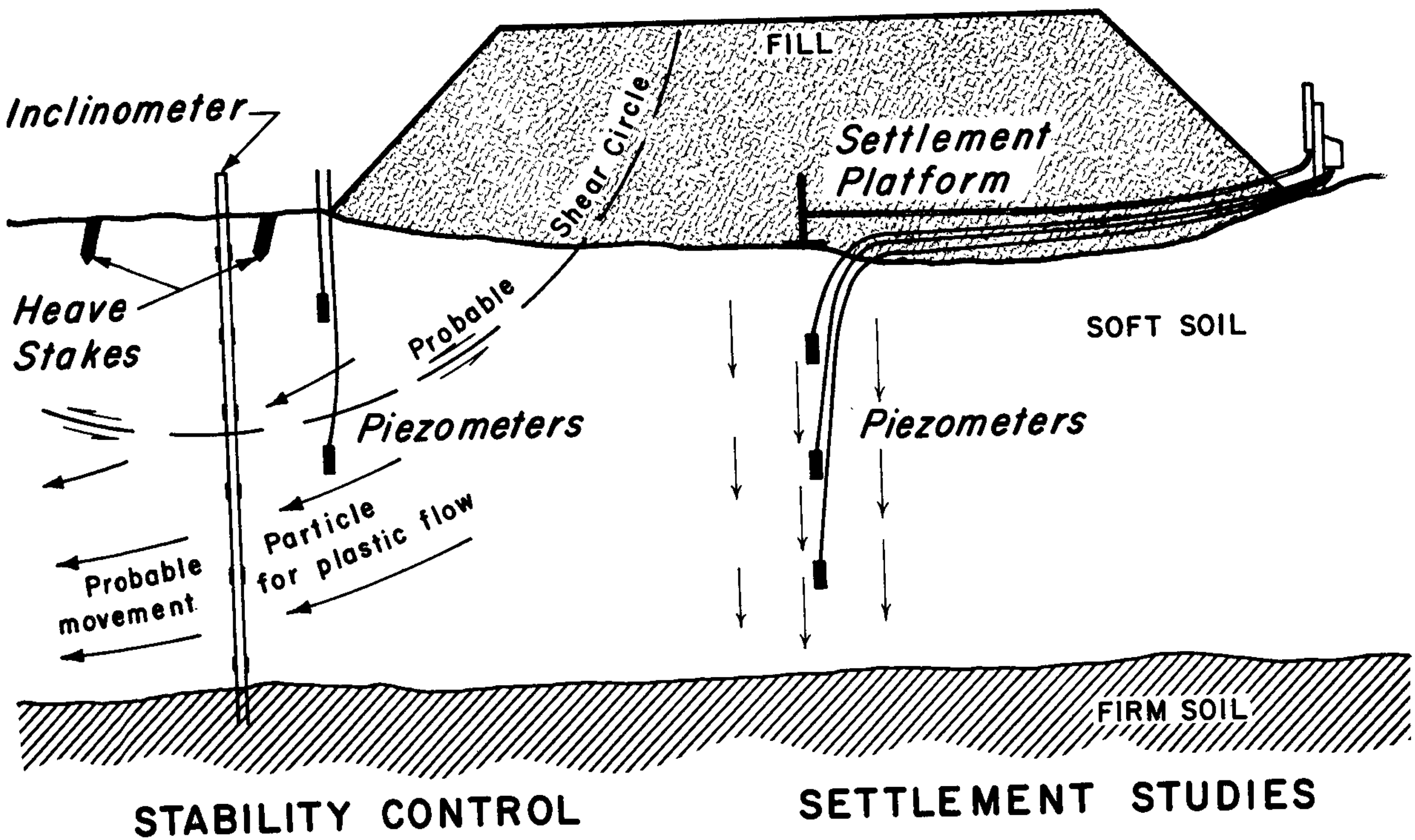

ROOT INCLINOMETER 34
BENICIA TO CORDELIA
167' Rt STATION 197+50
3" Gage
1' Gage
6" Gage
THICKNESS OF FILL IN FEET
DEPTH IN FEET
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 65
FEBRUARY 65
MARCH 65
APRIL 65
MAY 65
JUNE 65
JULY 64
AUGUST 64
SEPTEMBER 64
OCTOBER 64
NOVEMBER 64
DECEMBER 64
ROAD X SOL-74-C
NEW-SOL-21

FIGURE 14



PLACEMENT OF CONSTRUCTION CONTROL DEVICES

FIGURE 15