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DEPARTMENT OF TRANSPORTATION
Bureau of Materials and Physical Research

EVALUATION OF DIFFERENT TYPES OF SAND DRAINS
(Project IHD-13)

By

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A Product Evaluation Project by
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16. Abstract

This report describes a field investigation of methods of installing vertical sand drains to accelerate the consolidation of clay strata beneath a highway embankment. Three different methods of sand drain construction with drain wells at two different spacings were evaluated.

After twenty seven months of monitoring field instruments, the findings indicate that the auger and jetted drain well areas attained 90 percent primary consolidation 3 to 23 times faster than the mandrel driven well areas.

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INTRODUCTION

Purpose

The development of vertical sand drains to accelerate the consolidation of highway embankments has been rapid since World War II. There have been instances of successful performances as well as failures in rapid soil consolidation by vertical sand drains. Such variability performance tends to indicate the need of a more basic and practical approach to the theory of consolidation. A highway embankment may be safe against failures and at the same time be entirely inadequate because of possible future consolidation or volume reduction of the underlying soil mass.

Sand drains are vertical wells filled with sand that extend through a permeable sand blanket to the base of a saturated compressible soil layer. The sand blanket is placed on the top of the drains to allow escaping pore water out of the top of the drains to flow laterally from under the embankment and surcharge.

This report is concerned with the relative effectiveness of vertical sand drains installed by three commonly used methods; i.e. the 18-inch auger, the 18-inch mandrel, and the 12-inch jetted wells at spacing intervals of 6 and 10 feet.

Preliminary Evaluation

In 1971, the Illinois Division of Highways became interested in the evaluation of the three sand drain installation methods for future use in an estimated one million feet of sand drains on FAI Route 255 in St. Clair County.

The field study is located in the Mississippi River flood plain in an area known as the American Bottoms. The location overlies 17 to 31 feet of saturated compressible clayey alluvium which is little more than normally loaded. A thick sand layer underlies the compressible clay and is probably in hydrologic continuity with the granular valley train materials which constitute the aquifer underlying the American Bottoms.

Soil surveys conducted in the area of the proposed FAI Route 255 and Ill. Route 3 interchange near Dupo indicated that embankment loads would result in long term settlements of considerable magnitude. Several possible methods of remedial treatment were analyzed and judged with due consideration to their economic and engineering advantages. Of the various methods, sand drains appeared to be the most logical treatment.

The experimental sand drain installation provided a basis for evaluating the different methods of constructing sand drain. Six test areas were provided to permit the use of three different methods and two different spacings of sand drains. Figure 1 shows the plan view of the experimental sand drain project.

Scope

The experimental embankment included a four-foot layer of sand which was placed over the existing ground surface without removing the vegetation. After the sand drains were installed during the months of October to December of 1971 and January of 1972, the sand layer was overlaid with four feet of embankment soil and a five-foot surcharge.

Since the rates of settlement achieved by the three methods were of prime importance, the initial comparison consisted of determining the rate of primary consolidation of the compressible strata in each test section.

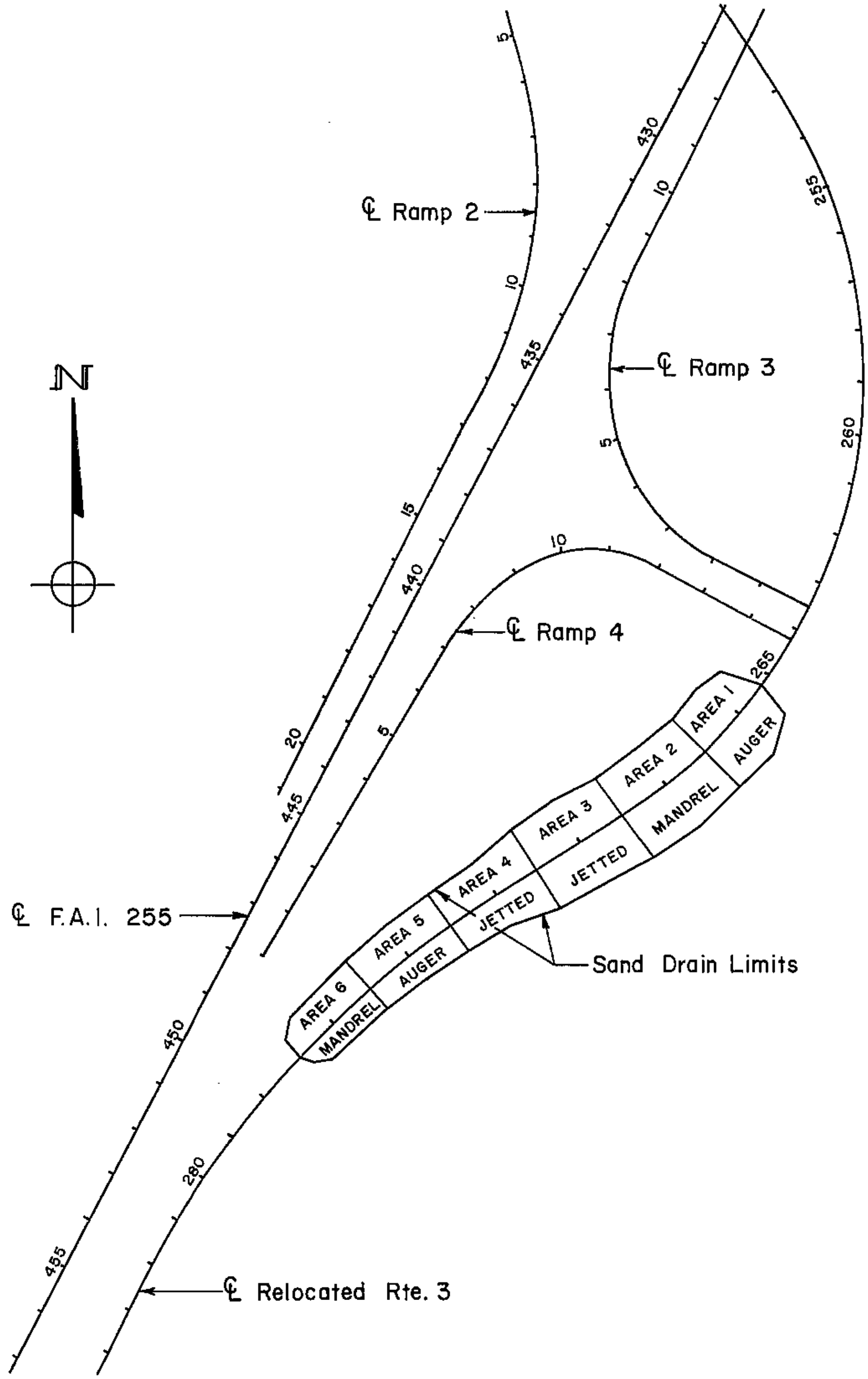

Figure 1. Plan View Of Experimental Sand Drain

Determination of the progress of primary consolidation was accomplished by installing 18 settlement platforms and 44 alignment stakes at specified locations, to periodically observe the settlement and the horizontal and vertical ground displacements, respectively. Piezometers were also installed to determine the pore water pressure in the test areas. The typical cross sections of the experimental project are shown in Figure 2 and 3.

The sand drain installation was completed in January 1972. Field data collected during 27 months of observation and recording were analyzed and reviewed.

Conclusions

After over two years of observation and monitoring field data to determine the relative effectiveness of three methods of installation of vertical sand drains at two spacing intervals, the following conclusions are presented:

1. The vertical sand drain experimental project did accomplish its objective. It provided data on the relative efficiency of sand drains installed by the auger, mandrel, and jetted methods.

2. The auger and jetted drain well areas attained 90 percent primary consolidation 3 to 23 times faster than the mandrel driven well areas.

3. The long time required by the mandrel driven drains to attain the same degree of consolidation as the other two sand drain methods is attributable to smear and soil remolding as the mandrel displaced the soil within the area of the well.

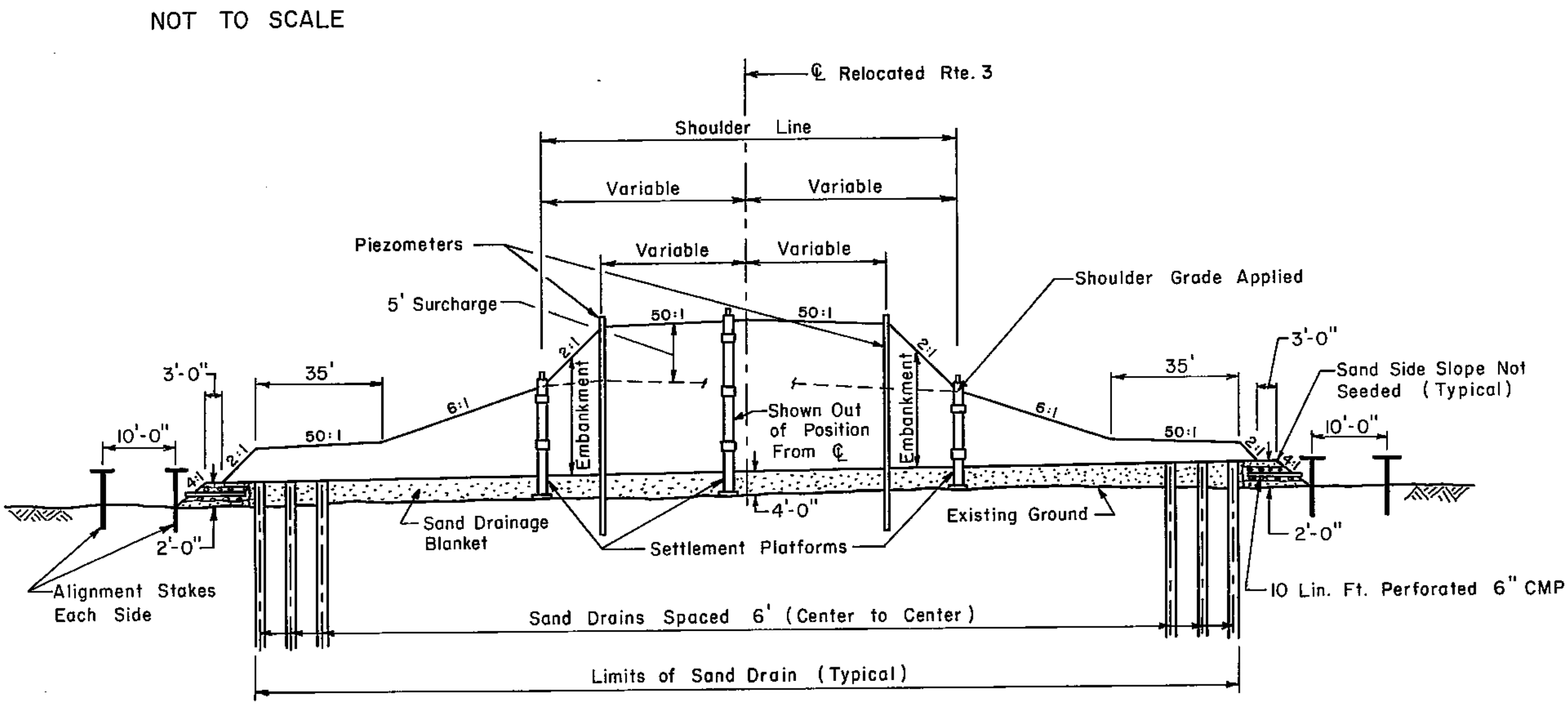

Figure 2. Typical Cross Section Of Experimental Sand Drain
Sta. 266 + 20 To Sta. 271 + 00

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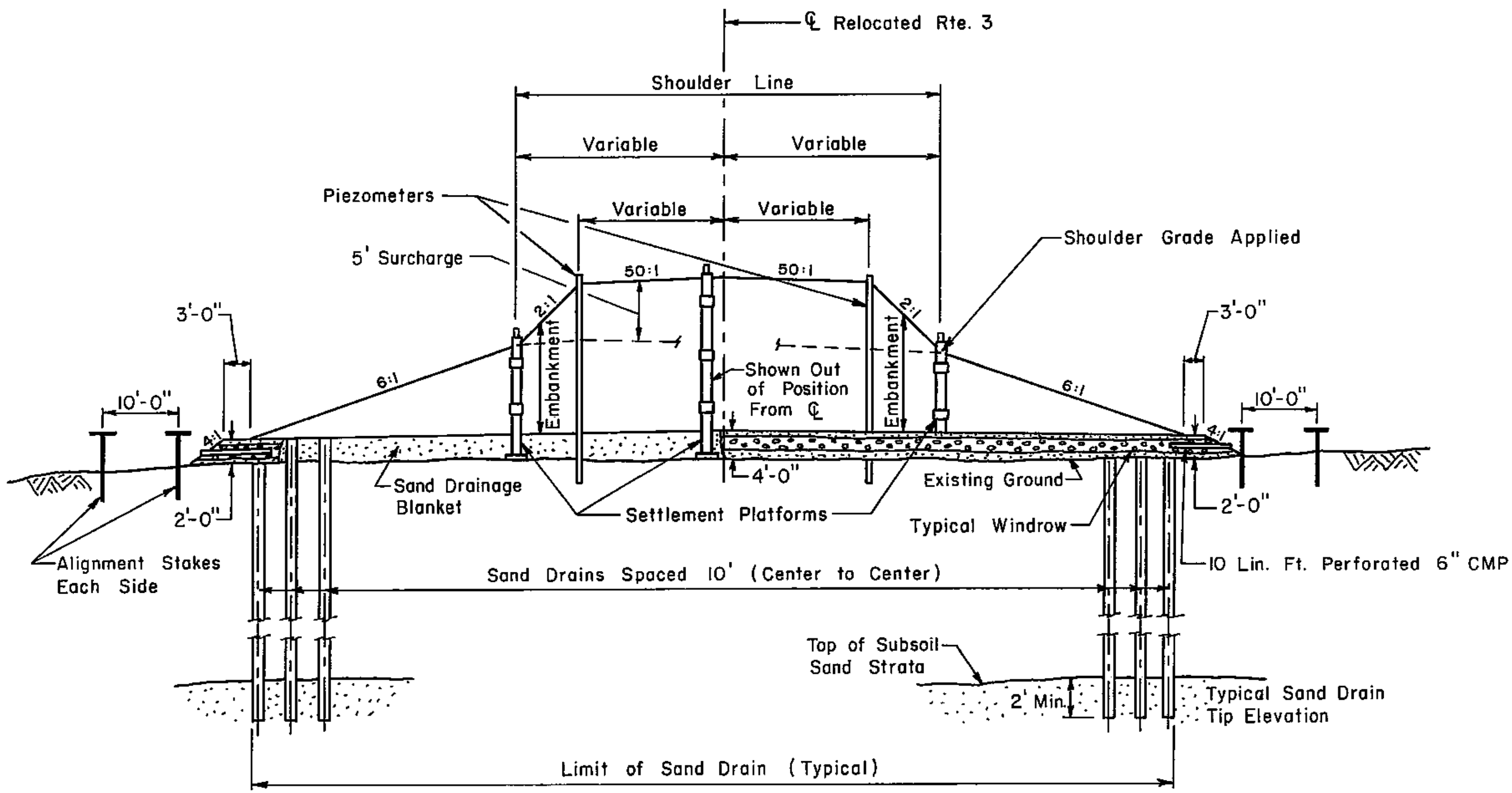

Figure 3. Typical Cross Section Of Experimental Sand Drain Sta. 271+50 To Sta. 276+52

Recommendations

Based on the results of this experimental study, it is recommended that the auger or the jetted method of installing sand drains be used for the treatment of soft foundation areas with due consideration of the economics and the desired rate of consolidation. The use of the mandrel driven drain wells is not recommended for sand drain installation in Illinois.

FIELD TEST PROGRAM

The experimental feature of this study consists of six test areas along the construction section identified as Project I-255-8(23)4, C-98-003-68 Sand Drain Test Section on relocated SBI 3, St. Clair County. Each of the test areas is 200 feet in length by 110 to 192 feet in width, requiring from 6,480 to 40,861 feet of drain well each.

Instrumentation

The experimental project was fully instrumented with piezometers, settlement platforms, and alignment stakes to record the necessary field data for the evaluation. Figure 4 shows the locations of the instrumentation.

Piezometers were used to regulate the rate of embankment placement. The contractor was not allowed to place any embankment on the sand blanket after the sand drains were installed until the initial piezometer readings had stabilized. The piezometers are manufactured by Laucks Laboratories, Inc., identified as "Terra Tec," Model 1040 with leads to the console Model C-1000. The piezometer used is shown in Figure 5.

Settlement platforms were installed at designated locations in the plan. They were placed on natural soil where practical prior to the

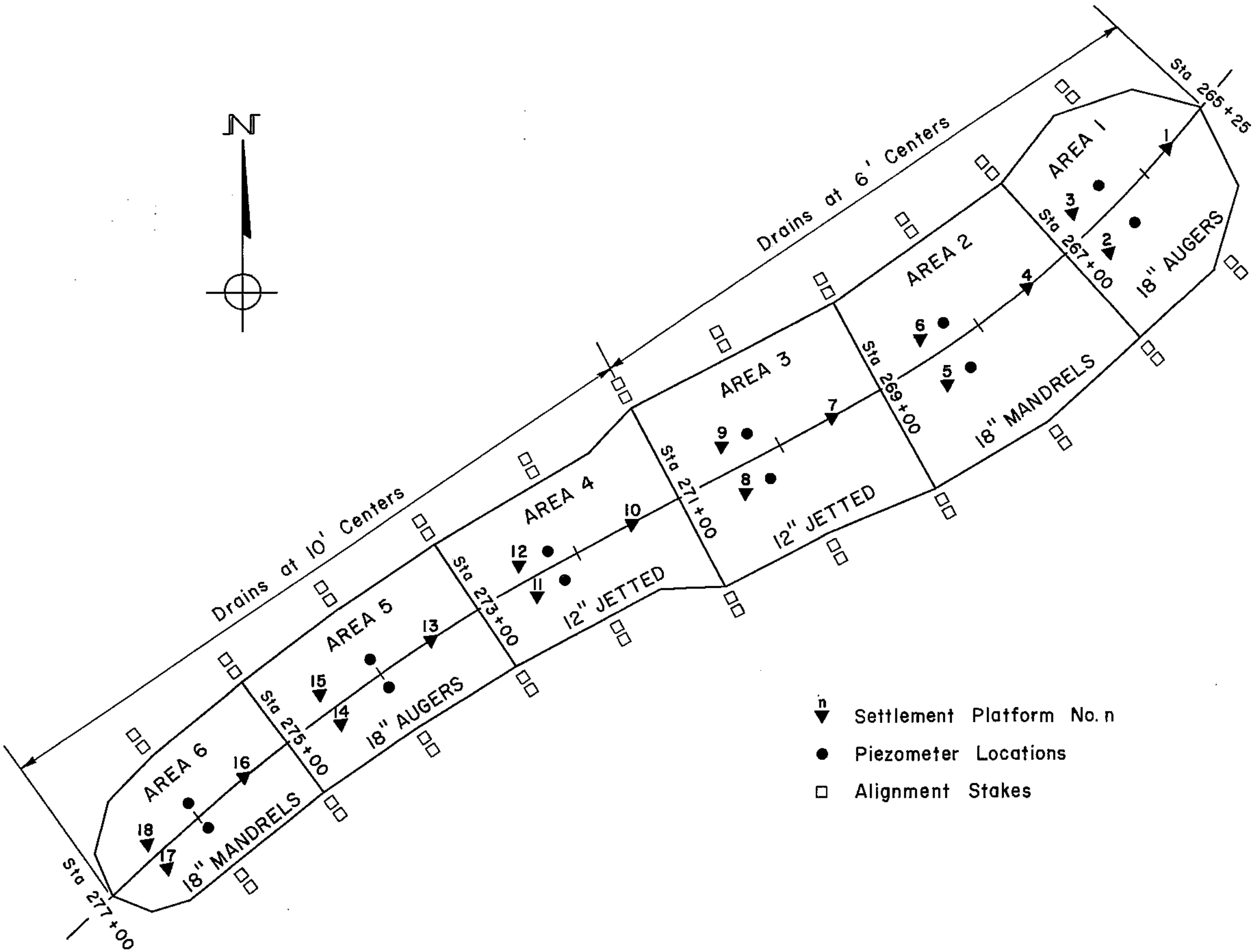

Figure 4. Instrumentation Locations

Figure 5. Piezometer Instrument

construction of the sand blanket. In marshy areas, it was necessary to place about 6 inches of granular bedding material to properly seat the platform. The platform consists of a 3/4 inch steel pipe attached to a 1/4 inch thick by four-foot square steel plate with a threaded malleable iron floor flange welded to the plate. Four-foot lengths of 3/4 inch pipe were added as the height of the embankment and surcharge was increased. It was specified that the top of the grade pipe should at no time extend more than 4.5 feet or less than 0.5 foot above the height of the embankment or surcharge as shown in the settlement platform detail in Figure 6.

Alignment stakes were provided for the purpose of observing any vertical or horizontal ground displacements. The stakes were constructed in a T-shape configuration projecting four feet above the ground or sand blanket and driven approximately six feet into the ground with the cross-arm in the direction perpendicular to the centerline of the embankment. One side of the cross-arm and one side of the upper four feet of the vertical leg was painted with white and black graduations in tenths and hundredths of a foot. The stakes were made of sound 2" x 4" redwood lumber with a minimum length of ten feet for the vertical leg and two feet for the cross-arm as shown in Figure 7.

Sand Drain Methods

The installation of vertical sand drains was accomplished by three different methods after placement of the sand blanket and prior to construction of the embankment. They include the mandrel method, the auger method, and the jetted method of sand drains spaced at 6 and 10 feet center to center. The sand drain tip elevations are estimated, and adjustments to the estimated lengths of drain were made in the field. The drain wells extend a minimum of 2 feet into the sand stratum beneath the compressible material.

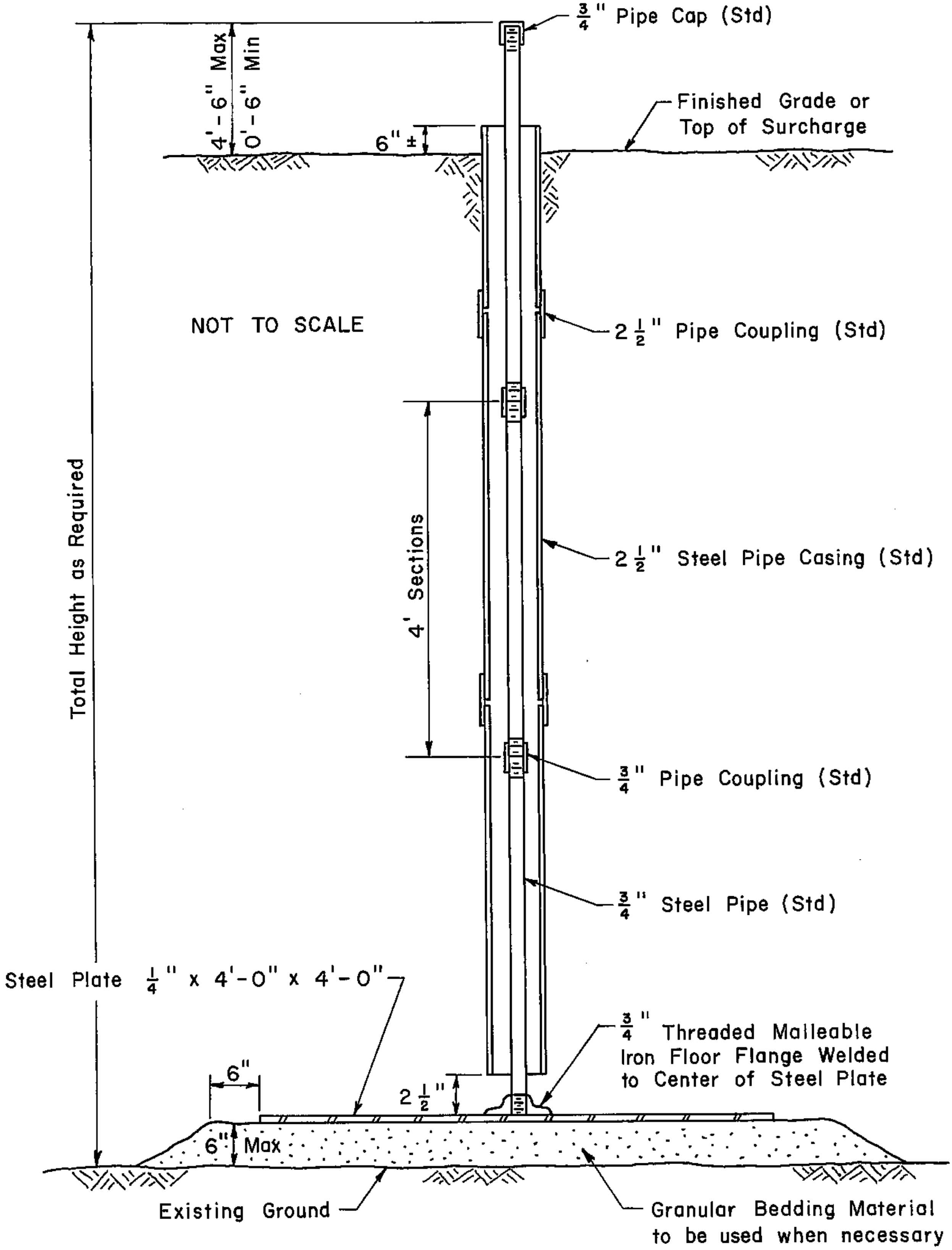

Figure 6. Settlement Platform Detail

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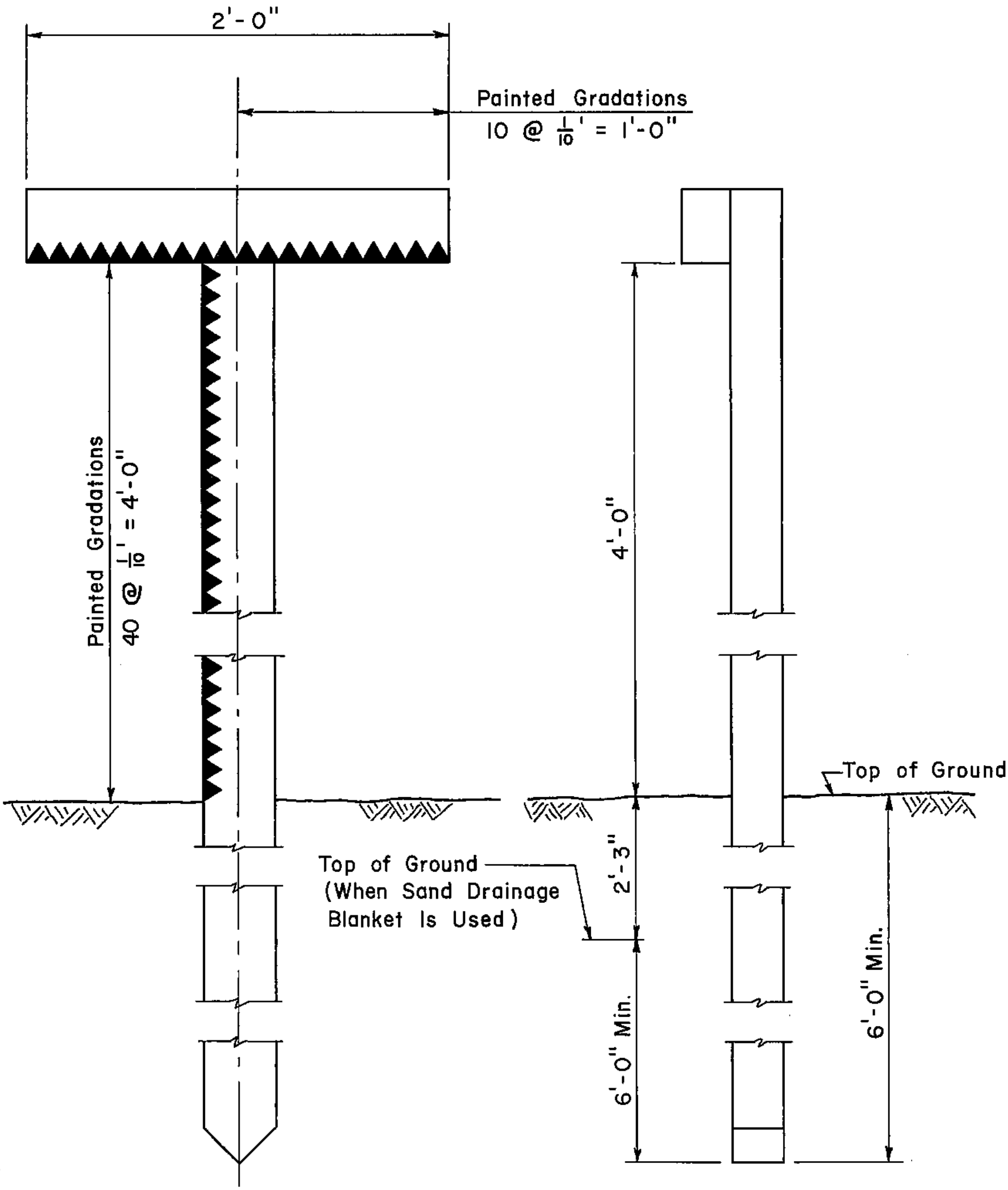

Figure 7. Alignment Stake Detail

The Special Provisions for the Project describes the three methods, materials and construction requirements, as well as the basis of payment. The minimum outside diameter of the drain wells was specified not less than 18 inches for the mandrel and auger methods, and not less than 12 inches for the jetted method. The Special Provisions are presented in Appendix A and the typical pattern of installing the sand drains is shown in Figure 8.

FIELD TEST RESULTS

The rate of settlement achieved by the three methods was the prime concern of this study. Comparisons of plots of the settlement records were used to indicate the relative rates of settlement achieved by the three methods. In each case, only data from settlement platforms that were in close proximity to each other with similar soil conditions were compared. Figures 9 through 13 shows the plots for settlement platforms (SP) 2 through 16.

Graphical Analysis

Analysis of the settlement data clearly indicates that settlement is achieved faster with either the auger or jetted methods of sand drain than with the mandrel method. In the analysis by Messrs. Benson and Brownfield,[1/] it was assumed that 700 days represents the boundary between primary and secondary settlement for the more rapid settling curve in each comparison. Extending the slope of portion of the curve (600 to 700 days) of slower settlement platforms to its intercept with the same level of settlement attained by the faster platforms at 700 days, closely represents the settlement performance of these platforms. Figures 9 thru 13 are discussed below:

[1/] DuPo Sand Drain Test Section, FAI Route 255, Section 82-81, St. Clair County, Illinois, Bureau of Design, Illinois Dept. of Trans., July, 1974

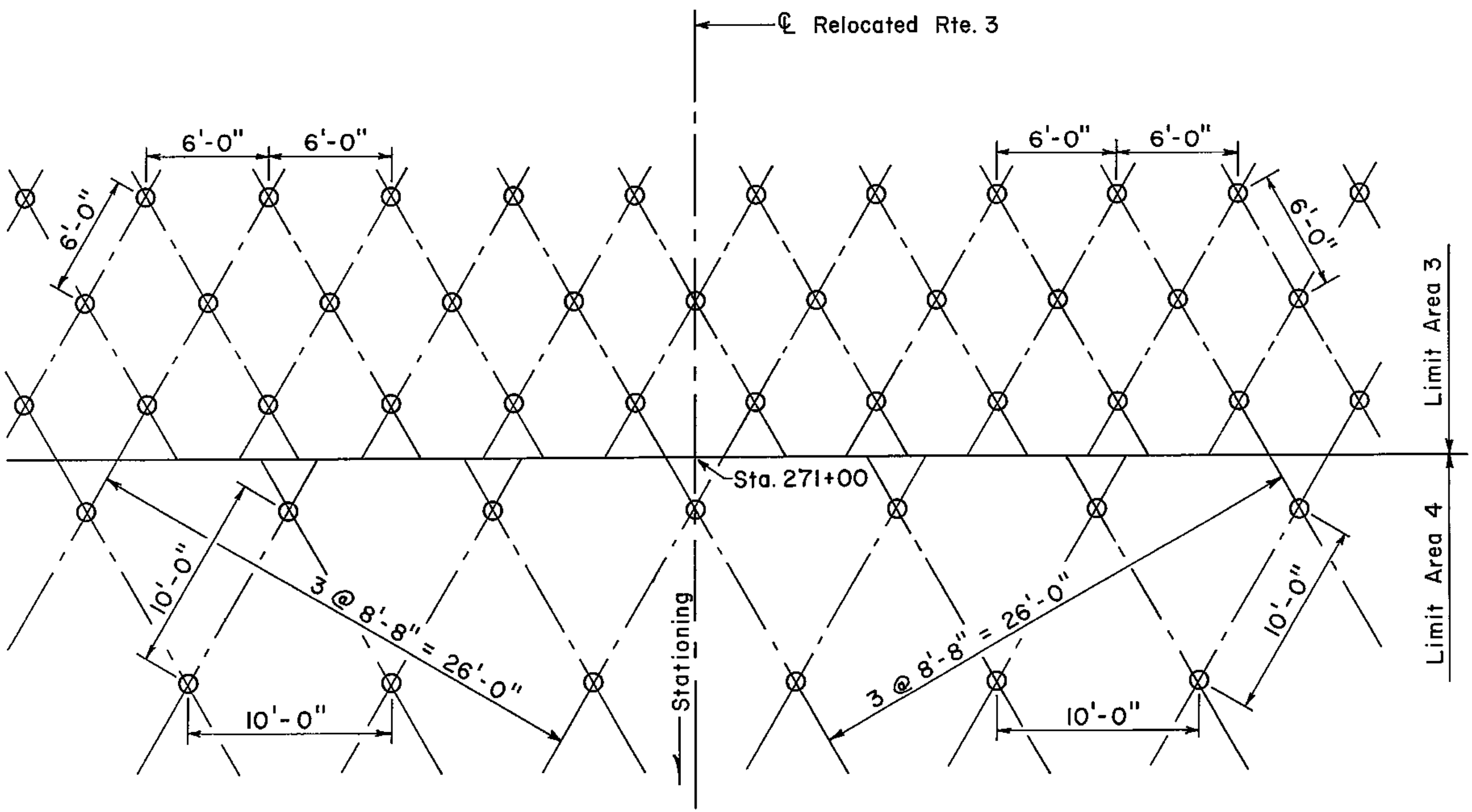

Figure 8. Typical Plan Of Sand Drain Pattern

Figure 9 shows a comparison between Auger area 1, SP2 and SP3, and Mandrel area 2, SP4, both with 18-inch diameter drain wells at 6-foot spacings. The slope of the Mandrel area curve for the 100 days (600 to 700 days) amounts to a rate of settlement of 0.10 feet per 100 days. The difference in settlement at 700 days between the two methods of sand drains is 1.82 feet. Straight line extrapolation indicates that SP4 will achieve the same level of settlement as at SP2 and SP3 in 1820 more days. This suggests a performance ratio of $\frac{1820 + 700}{700} = 3.6$, indicating the auger method is about 3.6 times more effective than the mandrel method.

Figure 10 shows a comparison between Mandrel area 2, SP5 and SP6, and Jetted area 3, SP7, with 18- and 12-inch diameter drain wells, respectively, at 6-foot spacings. The slope of the Mandrel area curve for the 100 days (600 to 700) amounts to a rate of settlement of 0.08 ft. per 100 days. With 1.72 feet of differential settlement between SP5 and SP7, the curve suggests that 2150 additional days will be required of SP5 to achieve the same settlement which SP7 attained in 700 days. Thus $\frac{2150 + 700}{700} = 4.1$, indicating that the jetted drain wells was 4.1 times more effective than the mandrel method wells. It may be worthwhile mentioning that the 12-inch jetted drains have the same spacing as the 18-inch mandrel drains, thus giving the mandrel drains an advantage due to a greater surface wall area in the well. This means that the calculated 4.1 times advantage for the jetted drains may be somewhat low.

Figure 11 shows a comparison between Jetted area 3, SP8 and SP9, and Jetted area 4, SP10, both 12-inch diameter drain wells and spaced 6 feet and 10 feet, respectively. The slope of the 600 to 700 day portion of the curve for SP10 suggests that approximately an additional 200 days is required to attain the same settlement as at SP9. Thus, $\frac{200 + 700}{700} = 1.3$; SP8 and SP9 appears to have a time advantage of 1.3 to 1 over SP10.

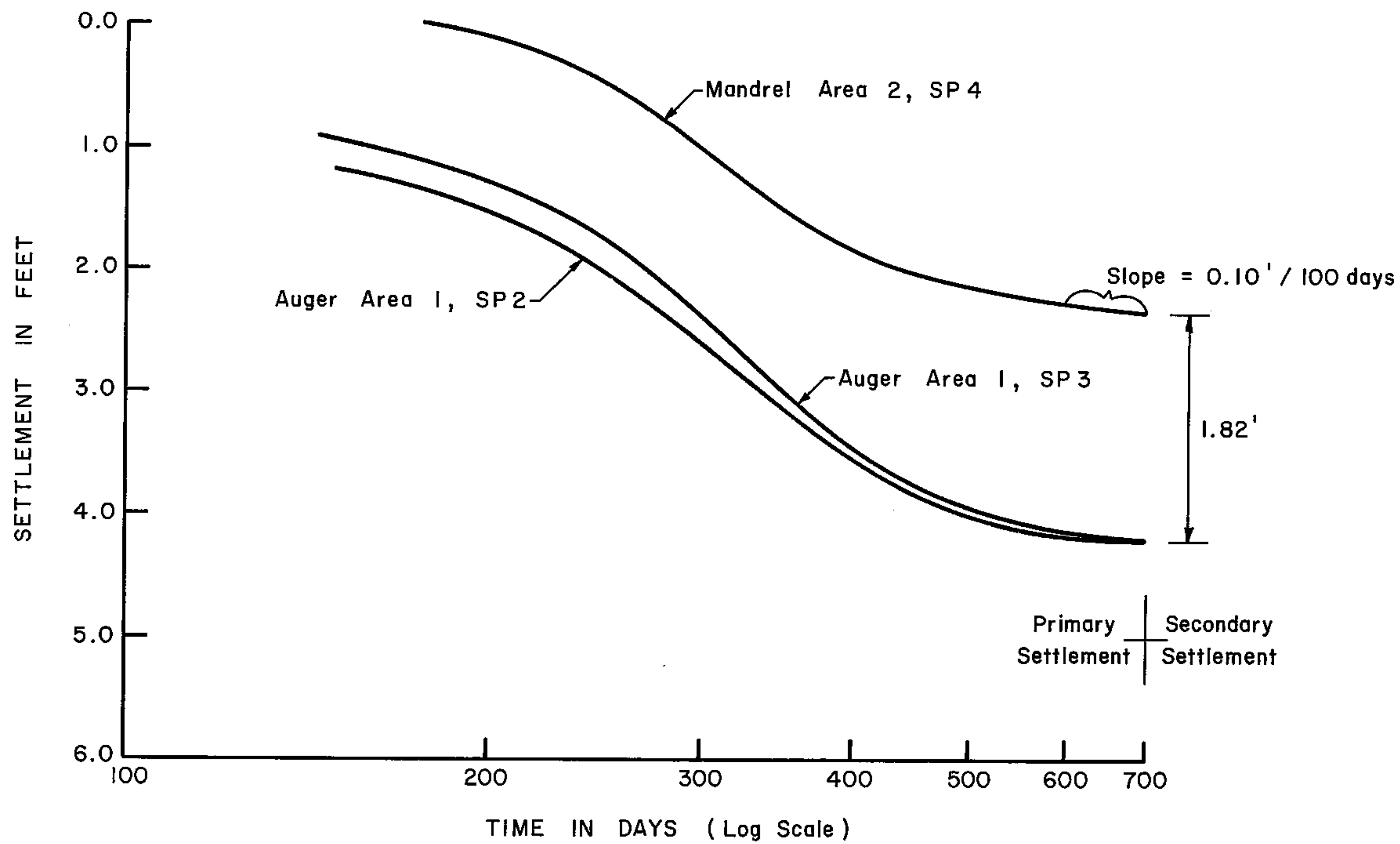

Figure 9. Time - Settlement Curve (Areas 1 & 2)

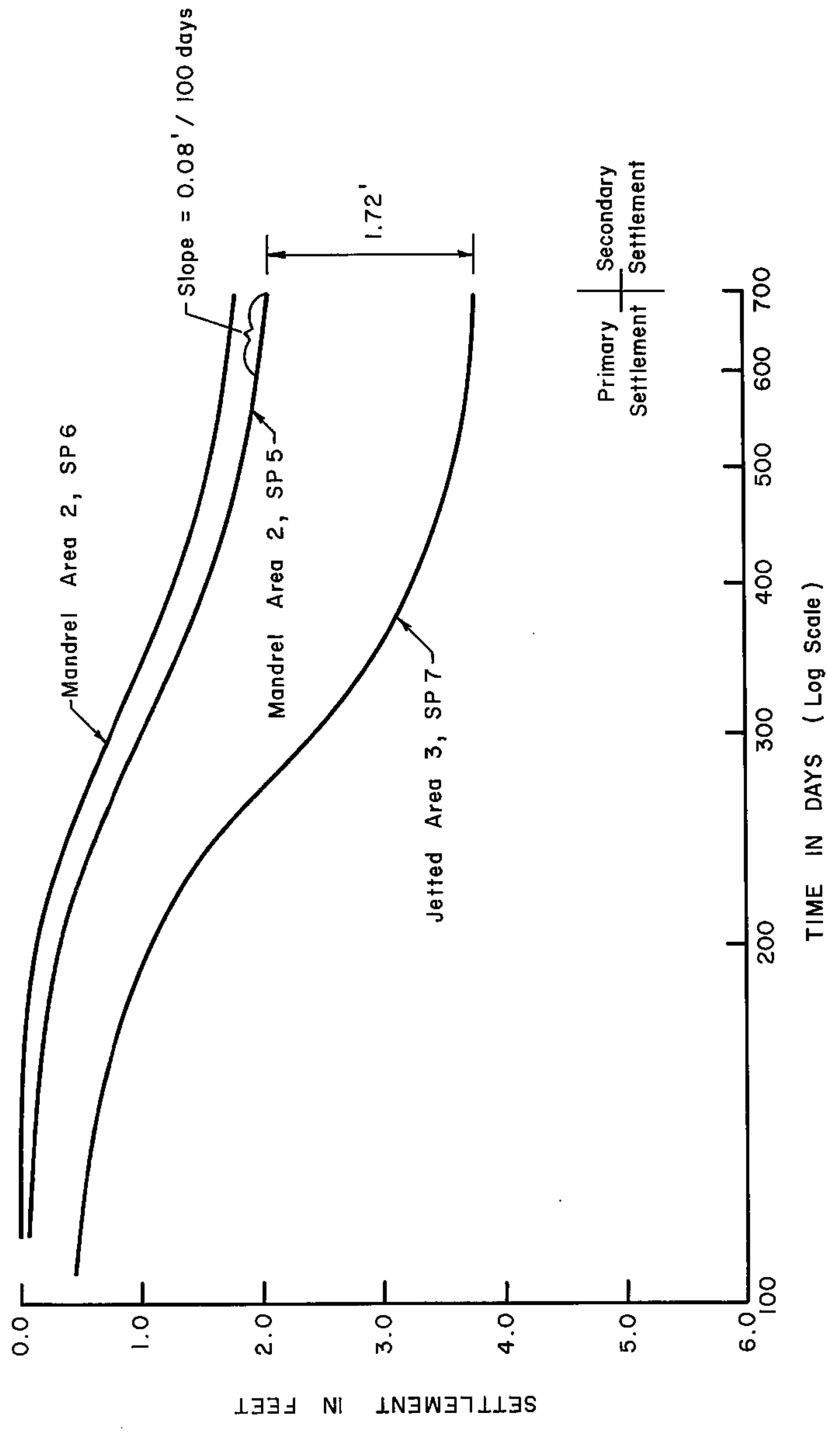

Figure 10. Time - Settlement Curve (Areas 2 & 3)

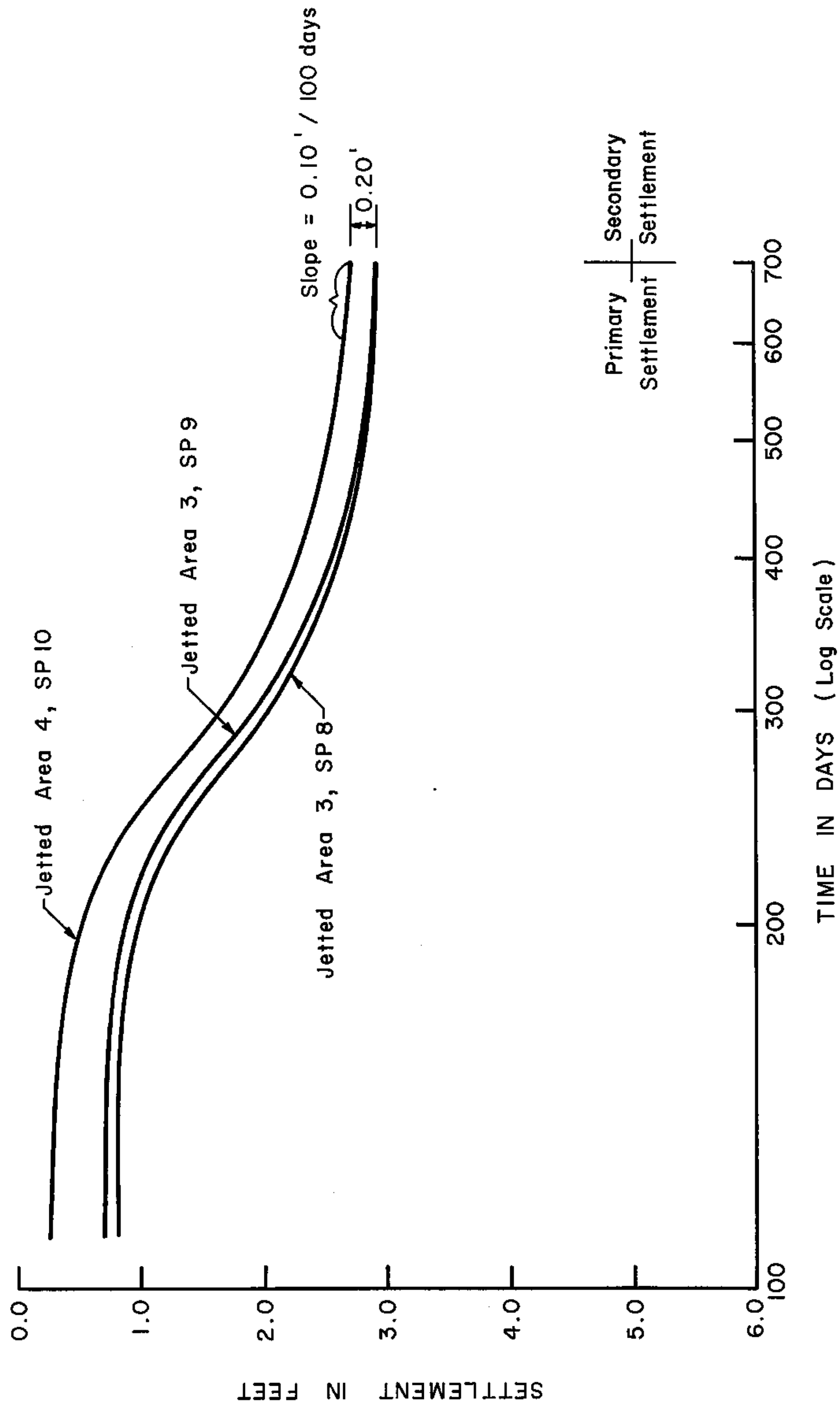

Figure 11. Time - Settlement Curve
(Areas 3 & 4)

Figure 12 shows a comparison between Jetted area 4, SP11 and SP12, and Auger area 5, SP13, with 12-inch and 18-inch diameter drain wells, respectively, both spaced 10 feet apart. The slope of the 600 to 700 day portion of the curve for SP13 suggests that approximately an additional 500 days is required to attain the same settlement as at SP12. Thus, $\frac{500 + 700}{700} = 1.7$; that is SP12 has a time advantage of 1.7 to 1 over SP13.

Figure 13 shows a comparison between Mandrel area 6, SP16, and Auger area 5, SP14 and SP15, both areas with 18-inch diameter drain wells at 10-foot spacing. The curve indicates that SP16 will attain the same settlement as at SP14 in about 500 additional days; suggesting a performance ratio of $\frac{500 + 700}{700} = 1.7$. In this case, the auger method appears to be about 1.7 times faster than the mandrel method.

The above comparative evaluation, while logical and valid, is rather over-simplified. The fact that predictions were made on the basis of a straight line extrapolation, results in a smaller performance differential than might be encountered in actual jobs. Accordingly, a somewhat more detailed geotechnical analysis was performed by Messrs. Benson and Brownfield.

<u>Geotechnical Analysis</u>

The geotechnical analysis initially recognized that at 700 days most of the pore water pressure had been dissipated (according to piezometer readings) except for Area 2. It also assumes that at 700 days, the test area is in secondary settlement.

The results of the study are summarized in Table 1. The upper section shows the time required from the placing of the surcharge at design grade to the attainment of 90% primary consolidation. The middle section shows the coefficients of consolidation without sand drains and with sand drains. The lower section contrasts the time requirements with and without sand drains.

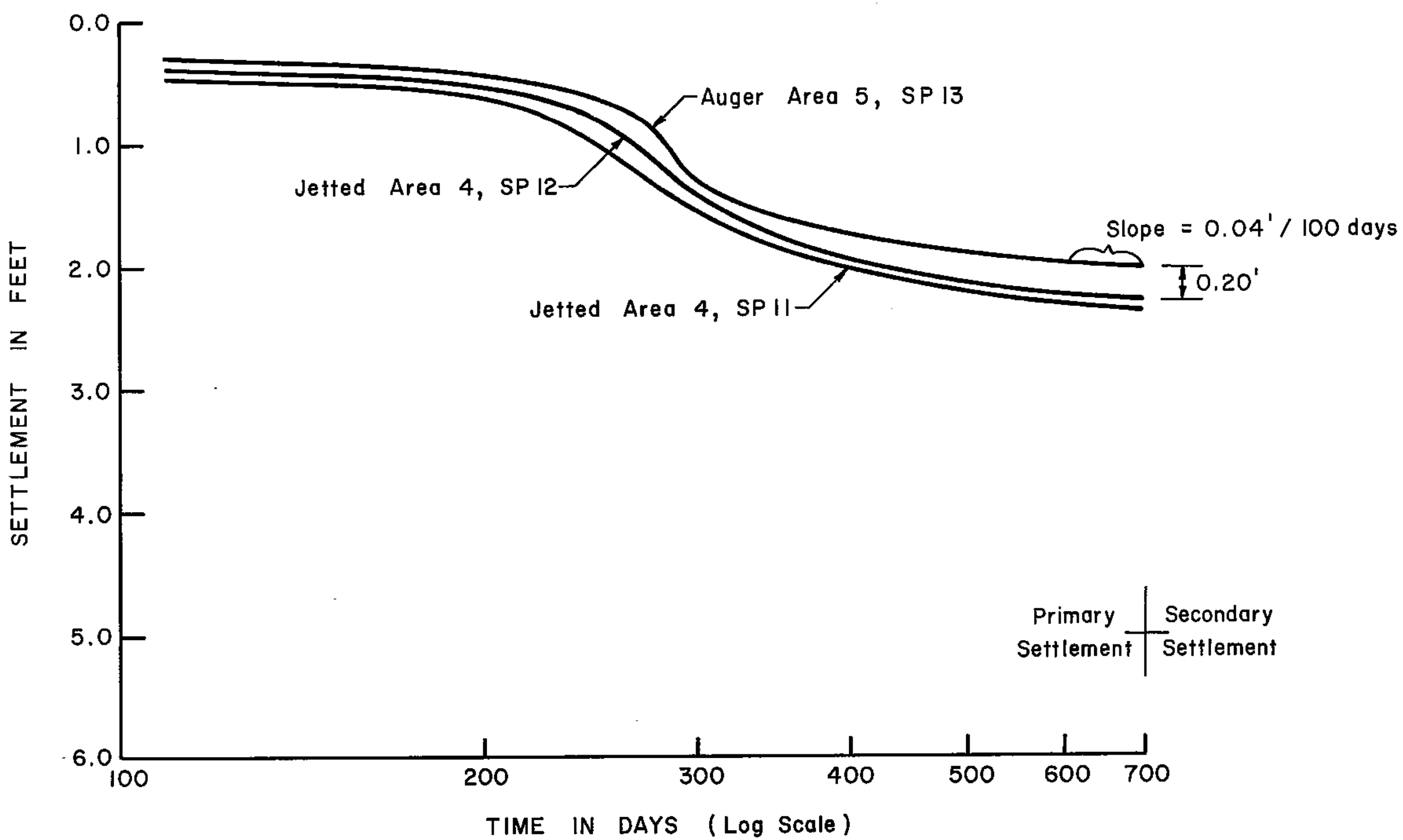

Figure 12. Time - Settlement Curve
(Areas 4 & 5)

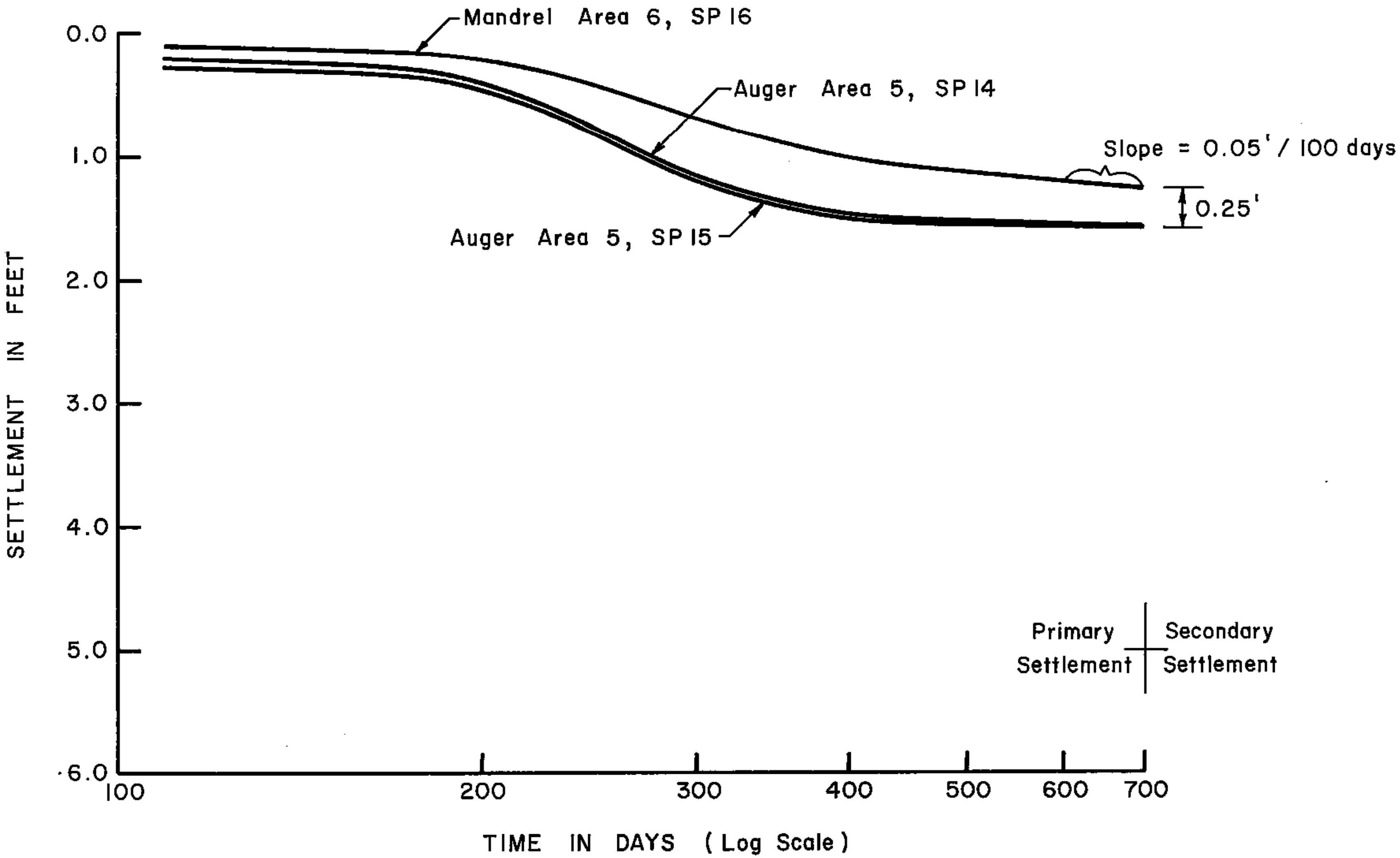

Figure 13. Time - Settlement Curve
(Areas 5 & 6)

TABLE 1

COMPARISON OF SETTLEMENT DATA

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
SAND DRAIN INSTALLATION	Auger	Mandrel	Jetted	Jetted	Auger	Mandrel
Diameter (Inch)	18	18	12	12	18	18
Spacing (Foot)	6	6	6	10	10	10
TIME REQUIRED FROM SURCHARGE PLACEMENT TO 90% Consolidation (Days)	70	1474	64	87	54	158
COEFFICIENT OF CONSOLIDATION ($Ft.^2/d$)						
Without Sand Drains	.0265	.0153	.0160	.0131	.0096	.0107
With Sand Drains	.0740	.0054	.1139	.2734	.3032	.1389
Consolidation Gain	.0475	-.0099	.0979	.2603	.2936	.1282
TIME FROM THEORICAL ZERO TO 90% PRIMARY CONSOLIDATION						
Without Sand Drains (Days)	5660	7171	7340	7481	7640	7707
With Sand Drains (Days)	121	1666	116	194	130	285
Time gained by Sand Drains (Yrs)	15.2	15.1	19.8	20.0	20.6	20.3
Time req'd. by Sand Drains (% of time req'd. without Sand Drains)	2.1	23.2	1.6	2.6	1.7	3.7

From Table 1, the results indicate that the auger drain areas required 54 and 70 days to attain 90% primary consolidation; the jetted areas, 64 and 87 days; and the mandrel areas 158 and 1474 days. The auger and jetted drain well areas attained 90% primary consolidation 3 to 23 times faster than the mandrel driven well areas. The fact that the 6-foot spaced mandrels required more time than the 10-foot spaced mandrels, is attributable to smear and soil remolding as the mandrel displaced the soil within the area of the well.

The coefficient of consolidation without sand drains was computed on the assumption that the drainage was entirely vertical, while that with sand drains was entirely radial. Neither assumption is entirely true, but the error is probably minor.

Alignment Stakes Measurement

Periodic measurement of alignment stakes installed along the boundary limits of the sand drain installation indicated no significant vertical or horizontal ground displacements. This may be attributable to the shallow depths of installation or the lack of surface area on the vertical leg to create enough uplift or side pressure to affect the alignment of the stakes. Also, the wooden stakes may have been too rigid to detect any significant lateral movement of the embankment. Had sections of flexible tubing been used instead of the rigid stakes, it may have been possible to measure minute lateral movements by a pendulum-type device inside the tube.

IMPLEMENTATION STATEMENT

The auger or the jetted method of installing vertical sand drains is very effective in attaining the desired 90% primary consolidation in the shortest possible time. Proper design considerations as to the diameter and spacing of drain wells could provide the most economical installation.

The mandrel method would require a much greater time to attain the same degree of consolidation as the other two methods. In certain cases this could extend the time required to construct the embankment by reducing the rate at which the embankment height can be extended safely, and would greatly extend the time required between completion of the embankment and placement of the pavement structure to obtain settlement. The mandrel method of sand drains should not be used in embankment construction over soft soils.

APPENDIX A

SPECIAL PROVISIONS FOR SAND DRAIN METHODS

SAND DRAINS (MANDREL METHOD): DESCRIPTION: The work under this item shall include furnishing equipment and materials necessary to install vertical sand drains not less than 18 in. in diameter at the locations shown on the plans or as ordered by the Engineer and as specified herein.

MATERIALS: Materials for use in backfilling the sand drains shall consist of clean natural sand meeting the following gradation requirements:

Sieve	3/8"	#4	#16	#50	#100
Per cent Passing	100	85-100	50-85	0-25	0-4

The only quality requirement for the sand is that it shall be relatively free from deleterious material to be determined at the judgement of the Engineer.

CONSTRUCTION REQUIREMENTS: Installation of the vertical sand drains shall be accomplished by driving or jetting a closed-end mandrel with a minimum outside diameter of 18 in. The sand drains shall be installed after placement of the sand blanket and prior to construction of the embankment. The sand drain <u>tip elevations</u>, as indicated on the plans, are estimated and adjustments to the estimated lengths of drain will be made by the Engineer in the field. The sand drains shall be constructed a minimum of 2 ft. into the sand stratum beneath the compressible material.

The closed-end mandrel shall be equipped with a suitable hinged door on the tip to prevent soil from entering the mandrel during driving and for opening to permit filling the hole with sand upon withdrawl. The sand shall be placed in the madrel, with the door locked in place, under an air pressure of 100 psi after the tip elevation of the drain is reached. This pressure shall be held for at least 5 sec. and the hinged door shall then be opened to permit discharge of the sand.

Air pressure shall be maintained on the sand in the mandrel as the mandrel is slowly and evenly withdrawn. The air pressure should be reduced as the tip of the mandrel nears the surface to prevent a "blowout" of the sand when it reaches the surface. The withdrawl shall be regulated in such a manner as to assure that a continuous column of sand is deposited in the hole. The sides of the hole shall be supported at all times either by the walls of the mandrel or the sand column.

Where obstructions are encountered that cannot be penetrated by the mandrel, the holes shall be formed by spudding with a steel spud.

The Engineer reserves the right to increase or decrease sand drain spacing and/or length of the drains at the Contractor's unit price for this work. The Engineer reserves the right to add or delete drains at the unit price for this work.

The Contractor shall identify in a suitable manner the center of each sand drain after completion of its installation.

METHOD OF MEASUREMENT: Vertical sand drains shall be measured as lineal feet in place by measuring the depth of penetration of the mandrel at each location from the top of the sand blanket.

Provisions shall be made for durable markings of one foot intervals on the outside of the mandrel for the purpose of making said measurements. No extra measurement will be allowed, and no allowance will be made for vertical sand drains placed outside the specified locations or as ordered by the Engineer.

BASIS OF PAYMENT: Vertical sand drains (mandrel method) shall be paid for at the contract unit price per lineal foot for SAND DRAINS (MANDREL METHOD) measured as specified herein which price shall include furnishing all materials and equipment, and constructing the vertical sand drains at locations as shown on the plans and as specified herein.

SAND DRAINS (AUGER METHOD): DESCRIPTION: The work under this item shall consist of furnishing equipment and materials for the construction of vertical sand drains prior to embankment construction within the areas as shown on the plans or as ordered by the Engineer and herein specified and satisfactory disposal of unsuitable material removed during installation of the vertical sand drains (auger method).

MATERIALS: Material for use in backfilling the sand drains shall consist of clean natural sand and shall meet the following gradations:

Sieve	3/8"	#4	#16	#50	#100
Per cent Passing	100	85-100	50-85	0-25	0-4

The only quality requirement for the sand is that it shall be relatively free from deleterious material to be determined at the judgement of the Engineer.

A hollow stem helical auger shall be used for the installation with the auger having a minimum helix outside diameter of 18 in. and a maximum hollow stem outside diameter of 11 in. The auger shall be of constant diameter and shall be straight to within one inch of axial deviation when suspended in a vertical position.

CONSTRUCTION REQUIREMENTS: The rate of advance of the auger shall not be greater than one pitch length per revolution and shall be adjusted so that the volume of soil removed by the helix at any depth is equal to the volume displaced by the hollow shaft at that depth. Suitable means shall be provided such that soil does not enter the bottom of the shaft during the advancement of the auger.

The sand drain tip elevations, as indicated on the plans, are estimated and adjustments to the estimated lengths of drain will be made by the Engineer in the field. The sand drains shall be constructed a minimum of 2 ft. into the sand stratum beneath the compressible material.

At the end of the auger advance for each sand drain, the auger shall be held stationary and rotated at least one revolution. Backfilling of the drain with sand shall then be accomplished in one of the following procedures:

Alterante #1: Air Pressure Method

The sand shall then be placed in the hollow shaft with the check valve at the tip locked in place under an air pressure of 100 psi and held for at least 5 seconds. The check valve shall be released while the air pressure is maintained and the auger withdrawn in such a manner that a continuous column of sand having a minimum diameter of 18 in. extends from the bottom of the drain to the surface of the sand blanket or working platform.

The withdrawl of the auger shall be vertical and the rate of the withdrawl shall be regulated so that the sides of the hole are supported at all times, either by the sand backfill or the soil in the auger helix. The auger shall not be rotated upon extraction without permission of the Engineer. The air pressure shall be decreased as the tip of the auger nears the surface so as to prevent a "blow-out" at the surface.

Alternate #2: Inner Auger Method

In lieu of the previously stated method, an auger may be used inside the hollow stem to backfill the drain with sand. The diameter of the inner auger shall be of such size as to be compatible with the inside diameter of the 18 in. outer auger. The inside auger shall be utilized to convey sand to the tip of the sand drain in the following manner:

At the end of the auger advance and after one stationary revolution of the auger for each sand drain, sand shall be placed inside the outer auger. The outer auger shall then be raised approximately 6 in. with the interior auger remaining at or near the tip elevation. The interior auger shall be rotated to feed sand down into the void as both augers are slowly withdrawn. The inner auger shall protrude outside the outer auger approximately 6 in. to 12 in. during withdrawl. The rate of rotation of the inner auger shall be properly correlated with the rate of withdrawl to insure a continuous column of sand having a minimum diameter of 18 in. extending from the tip elevation to the surface of the sand blanket or working platform.

The Engineer reserves the right to increase or decrease sand drain spacing and/or length of the drains at the Contractor's unit price for this work. The Engineer reserves the right to add or delete drains at the unit price for this work.

The Contractor shall identify in a suitable manner the center of each sand drain after completion of the drain. The compressible material removed from the hole shall be disposed of outside the embankment area.

The surplus excavated unsuitable material removed during installation of the vertical sand drains (auger method) shall be disposed of outside the limits of the Right of Entry in accordance with Article 202.03 of the Standard Specifications.

METHOD OF MEASUREMENT: Vertical sand drains shall be measured as lineal feet in place to be determined by measuring in a suitable manner the depth of penetration of the auger at each location from the top of the sand blanket. No extra or customary measurement of any kind will be allowed, and no allowance will be made for vertical sand drains placed outside the specified locations or as ordered by the Engineer.

BASIS OF PAYMENT: Vertical sand drains (auger method) shall be paid for at the contract unit price per lineal foot for SAND DRAINS (AUGER METHOD) measured as specified herein which price shall include furnishing all materials and equipment and constructing the vertical sand drains at locations as shown on the plans and as specified herein. No additional compensation will be allowed for satisfactorily disposing of the unsuitable material removed during installation of the vertical sand drains by the auger method.

SAND DRAINS (EXTERNAL JETTED METHOD): DESCRIPTION: The work under this item shall include furnishing equipment and materials necessary to install vertical sand drains not less than 12 in. in diameter at the locations shown on the plans or as ordered by the Engineer and as specified herein.

MATERIALS: Materials for use in backfilling the sand drains shall consist of clean natural sand meeting the following gradation requirements:

Sieve	3/8"	#4	#16	#50	#100
Per cent Passing	100	85-100	50-85	0-25	0-4

The only quality requirement for the sand is that it shall be relatively free from deleterious material to be determined at the judgement of the Engineer.

CONSTRUCTION REQUIREMENTS: Installation of the vertical sand drains shall be accomplished by jetting uncased holes with a minimum diameter of 12 in. The sand drains shall be installed after placement of the sand blanket and prior to construction of the embankment. The sand drain tip elevations, as indicated on the plans, are estimated and adjustments to the estimated lengths of drain will be made by the Engineer in the field.

The sand drain shall be constructed a minimum of 2 ft. into the sand stratum beneath the compressible material.

The method of jetting the hole and backfilling with sand shall meet the following requirements:

1) If a jetting pipe is used, all wash & jet water must return between the pipe and soil, and the inside of the pipe must remain clean for its entire length during washing and jetting.

2) The water pressure and volume of water must be such to guarantee satisfactory progress of sand drain installation. When the hole has reached the required tip elevation, the hole shall be washed out for a period of time to be determined experimentally at the commencement of work.

3) During washing and jetting operation, no water shall be permitted to discharge from any completed drains.

4) During installation of the hole the Contractor shall provide a suitable method of determining the depth of the hole at any given time.

5) Each hole shall be inspected and approved by the Engineer before the sand is placed therein. The Contractor shall provide a suitable device for checking the diameter of the hole for its entire depth. Holes shall be checked for diameter at the discretion of the Engineer with a minimum of four (4) checks to be made daily.

6) Uncased holes must at all times be filled with water prior to and during placement of the sand backfill.

7) The backfill material shall be placed by a method that will produce a continuous column of clean sand for the full diameter and depth of vertical sand drain.

When the Contractor begins installation of the jetted drains, the first thirty (30) drains to be installed shall be used for an in-place experimental determination of a wash period for the remainder of the drains. Five holes shall be jetted and washed prior to backfilling for each of the following time intervals:

No. Holes	Washing Period
5	0
5	1 min.
5	2 min.
5	3 min.
5	4 min.
5	5 min.

Subsequent to the jetting and washing period for each of the first thirty (30) drains, the wash water shall be sampled to determine the amount by weight of the minus #200 soil particles within the water. The washing period to be selected shall be selected as the minimum time required to maintain the amount of minus #200 soil particles within the wash water below 10% by weight. There may be a time delay of one day after completion of the thirty test holes prior to resumption of the installation of the remainder of the drains.

The sand blanket has been designed with a gradient of approximately two (2) percent from the centerline of roadway to the outside edges. It is the intent to allow the wash water from the jetting process to drain over the surface of the sand blanket. It is the Contractor's responsibility to clean up the surface of the blanket after installation of the sand drains by blading off and wasting the major portion of the large pieces of clay which have been jetted out. It is not necessary to remove the upper portion of blanket which will be contaminated by fines carried in the wash water.

If it is deemed necessary by the Engineer or other State or County officials, the Contractor may be required to build a collection system for removing the sediment from the wash water prior to discharging the wash water into any local streams. This work shall be incidental to the contract and done at the Contractor's expense without additional compensation.

METHOD OF MEASUREMENT: Vertical sand drains shall be measured as lineal feet in place by measuring the depth of penetration of the jet at each location from the top of the sand blanket. Provisions shall be made for durable markings of one foot intervals on the outside of the jet and hose for the purpose of making depth measurements. No extra measurement will be allowed, and no allowance will be made for vertical sand drains placed outside the specified locations or as ordered by the Engineer.

BASIS OF PAYMENT: Vertical sand drains (jetted method) shall be paid for at the contract unit price per lineal foot for SAND DRAINS (JETTED METHOD) measured as specified herein which price shall include furnishing all materials and equipment, and constructing the vertical sand drains at locations as shown on the plans and as specified herein.