PRELIMINARY REPORT

PREFABRICATED UNDERDRAINS

JHR 69-23

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INTRODUCTION

Subsurface drains have been used for many years to remove excess water from the ground, for improving crop growth, reducing pumping and frost heave under pavements, stablizing slopes and preventing wet basements. A subsurface drain consists of a filter that allows water to flow out of the soil yet prevents movement of soil grains, and an outlet for the water, commonly a gravity flow pipe. The filter often consists of a carefully graded granular soil, coarse enough to allow water flow yet fine enough to prevent intrusion of the soil to be drained.

Thirty years ago the filtering requirements of underdrains were unknown, and engineers used rule of thumb designs that resulted in a high percentage of malfunctions (1)* Filter criteria first advanced by Terzaghi and later proved by extensive tests at the Waterways Experiment Station, Vicksburg, Mississippi, established the scientific approach to underdrain design by defining the required relation between grain sizes in the protective filter and in the native soil (2). These filter criteria must be observed for successful underdrains.

An adequate underdrain system requires both proper design and construction. Even today some systems that are properly designed are improperly built and become clogged with the native soil in a matter of months.

* Numbers in brackets refer to technical papers listed at the end of the text.

CURRENT UNDERDRAIN SYSTEMS

When an underdrain system is designed and constructed properly, it fulfills the following objectives:

1. Removes water from the surrounding soil
2. Prevents the movement of soil particles in both the native soil and the sand filter

Two typical highway cross-sections are shown in Figure 1. The cross-section of Figure 1(a) with a layer of uniformly graded stone sandwiched between protective filters quickly removes water from beneath a roadway (5). In regions of frost penetration, the drain pipe must be placed sufficiently deep to lower the water table below the elevation at which capillary action feeds water to a zone of potential frost heave and to keep the drain line from freezing. To meet these requirements a section as shown in Figure 1(b) is frequently employed. The cost of burying a pipe 3 to 5 ft. becomes prohibitive if a flat sloped V-shaped trench is used. Therefore, to place a pipe at this depth beneath the highway a trench with vertical sides is commonly used. The vertical sides make it difficult, if not impossible, to use a sandwiched graded filter in the trench, so the trench is normally filled with a material like concrete sand. The permeability of concrete sand is not great and the water may require several hours to reach the drain pipe. Nevertheless, this type of underdrain when properly designed and constructed works fairly well. The pipe is usually metal and water enters the pipe either through joints purposely left open during construction or through holes in the pipes provided for this purpose. The openings, which generally comprise less than 1% of the peripheral pipe area, must be surrounded by a very permeable material to permit free water flow.

This material should also prevent intrusion of sand into the pipe.

Typical designs place crushed stone around the pipe and concrete sand filling up the rest of the trench. A variation of this design uses gap graded gravel throughout the trench, but since size distribution of the gravel is difficult to control, the drainage characteristics of this type of system are often uneven. Porous concrete pipe is sometimes used as an alternative to metal pipe. While eliminating the requirement for crushed stone, it has other shortcomings. First of all, it is expensive. Second, it lacks strength and must be handled in short sections. Third, proportionately more sand is placed in the trench decreasing still further the overall permeability of the drainage system.

THE PREFABRICATED UNDERDRAIN

A.) Basic Concepts of the System

To overcome some of the uncertainties in underdrain design and construction, a prefabricated system was developed. Two possible designs are shown in Figures 2 and 3. In each design the filter is a permeable fine mesh cloth instead of granular soil. The cloth is a filtering element that is not susceptable to piping or clogging. The thinness of the cloth insures an adequate permeability at small mesh sizes. The fine mesh cloth, having no stiffness of its own, requires support. The support must provide a passage for the flow of water. In the design shown in Figure 2(a), support comes from a foamed plastic core. The sides of this core have vertical grooves that allow the water to fall toward the plastic pipe in the bottom of the assembly. The material is wrapped around the outside of the foamed plastic core and the plastic pipe. Figure 2(b) shows a cut away of the side portion of the foamed plastic core exposing the vertical grooves. An alternate design using metals is shown in Figure 3. The metal underdrain is made from a single sheet with narrow corrugations. The bottom of the sheet is bent to form a pipe. The vertical portion provides support for the fine mesh material, the corrugations serve the same function as the grooves in the foamed plastic core.

B.) Materials

The key to this design is the fine mesh cloth. The mesh must be sufficiently fine to retain the backfilled soil but highly permeable to water. A fine mesh polyester cloth having openings of about 75 microns was selected. This cloth is resistant to tearing and to micro-organisms two additional requirements of the fine mesh cloth. In selecting this cloth, we tried its soil retaining properties against a silt in a falling head permeameter. Since a negligible quantity of silt passed through the cloth, it was accepted as suitable for filtering the majority of local soils. The water transmissibility of the cloth was 1 ft/sec under a head of 1 ft.

Use of foamed plastic for the core lends flexibility to the design. The strength of the core can be increased by using more plastic to form the section. A strength of 25 psi can be obtained which is sufficient for most installations. Two materials that show promise for use in foamed plastic cores are expanded polystyrene and styrofoam. Because the material is formed in a mold, the grooves can be cast rather than cut in the plastic. Another possibility is to cast the pipe as a section of the core rather than attaching it to the bottom.

A section of this underdrain ten feet long can be easily carried by one man and placed and connected in the trench while standing on the surface of the ground. Since there is no requirement for the workman to get into the trench, the excavation can be narrower; thereby reducing both the cost of excavation and backfill material.

C.) Model and Full Sized Tests

To determine the soundness of this design, model tests were run in the laboratory. Flow lines in the backfill were traced with potassium permanganate. All flow lines were drawn directly toward the pipe section in the bottom of the model. To check the effectiveness of the filter more closely, piezometer tubes were buried in the model backfill directly behind the drain. The piezometers showed no head, indicating that the water is removed quickly from the soil adjacent to the underdrains. Several soils were used as backfill; one was coarse to medium sand and one was medium to fine sand. A full size section was also made in the laboratory and tested against a medium to fine sand. This section also performed satisfactorily but the size of the model precluded the use of glass sides and therefore no flow net could be traced with potassium permanganate. With the encouragement of the model tests, a full sized underdrain was made for placement in a wet slope. A slope on the University of Connecticut Campus that showed landslide scars was selected. Twenty feet of underdrain is placed in the slope as shown in Figure 4. Ten observation wells were installed above the underdrain and along the slope. The three standpipes above the center of the underdrain are shown in Figure 4. The outflow from the underdrain was measured periodically and the discharge plotted in Figure 5. The plotted points of these figures represent discharges of water measured at the times indicated. The straight lines connecting the points do not represent the variation of discharge between measured points but are drawn simply to illustrate trends. The discharge from the underdrains is sensitive to rainfall. See Figure 5. Following rainstorms the flow from the underdrains increases for a time and then begins to decrease as the water in the soil diminishes. This behavior is also reflected in the standpipes shown in Figure 4. During periods of high flow illustrated in Figure 5, the water level in the standpipes rises to the level shown by the curved line in Figure 4. As flow diminishes the standpipes become dry.

The native soil in this slope has a permeability of $3 \times 10^{-6 ft/min}$ indicating the presence of a substantial amount of silt. The size distribution of the soil is shown in Figure 6. This soil as seen from the graph has 15% passing the 200 mesh sieve. Also plotted in Figure 6 are the Terzaghi-Vicksburg criteria for graded filters and the size distribution of the sand used to backfill. This plot indicates that the sand possess too many fines for optimum permeability. It was used, however, because of its availability. Because of its size distribution, there is no danger of the backfill sand becoming clogged with fines from the native material. Despite these unfavorable conditions, the underdrain continues to function properly and helps lower the level of the water table and stablize the slope. A second field installation of an underdrain in a flatter but longer slope is shown in Figure 7.

This second underdrain was 10 feet long, and the measured discharges from it are as shown in Figure 8. This soil is granular and stratified, having very permeable layers sandwiched between less permeable layers. The same phenomena described before are evident in Figure 8.. After rainstorms the flow increases; during dry periods the flow decreases. The increases are more pronounced in this underdrain because it is buried in sandy soil.

These field installations show that prefabricated underdrains effectively remove water from the soil. The underdrain also has the advantage of removing water from beneath such facilities as a highway pavement more quickly than any method developed to date. Consider the removal of water from a highway base course in the cross-section shown in Figure 1(b). Sometimes a backfill of gravel is used, but more often it is a well graded concrete sand having a permeability of about 7×10^{-3} ft/min. Trenches for laying pipe are normally at least 3 feet deep. Water requires, therefore, about 7 hours to flow from the sand in the top of the trench into the pipe. Figure 9 shows an ideal installation of the prefabricated underdrain. The underdrain protrudes slightly above the top of the trench. The base course is open graded aggregate surrounded by protective filters. Water entering the underdrain at the top of the trench will flow into the pipe at the bottom in seconds. With the installation shown in Figure 9 open graded aggregate can be used as base course to advantage. The use of open graded aggregate as subbases when the trench is filled with material of lower permeability will cause the base course to be saturated for long period of time, causing harmful effects to the pavement.

Another installation under a highway is shown in Figure 10(a). In this cross-section open graded aggregate is not used but the trench and base course are backfilled with the same material. Figure 10(b) shows a longitudinal view of the underdrains. The use of prefabricated underdrains is not limited to highways. Figure 11(a) shows the underdrain as it might be placed behind a retaining wall and Figure 11(b) shows one way of using it to keep a basement of a building dry.

D.) Slope Stabilization Project

Prefabricated underdrains are presently being installed on a slope that has been unstable since it was cut two years ago. The instability is due to seepage of groundwater from the hill above. The drains will be installed on the slope as shown in Figure 12. The upper drain will be 250 feet long; the lower 300 feet long. These drains will be placed with no granular backfill, allowing rapid installation. Conventional trench section curtain-drains would require considerably more hand labor for installation in this situation.

To place the prefabricated underdrains on the slope a shelf will be cut with a bulldozer at the proposed elevation of the drain as shown in Figure 13. The drain is then placed against the vertical face of the shelf and backfilled with native soil. The estimated total time for placement of the 250' upper drain and slope dressing will be 8 - 10 hours.

E.) Acknowledgement

The research and development of this underdrain system is being sponsored by the Connecticut Highway Department, the Connecticut

Department of Public Works, and the University of Connecticut Physical Plant.

The prefabricated underdrain system is being patented through the University of Connecticut and the Research Foundation.

SUMMARY

A new underdrain system is presented. This system may be prefabricated from plastics or metals with a fine mesh plastic cloth to keep soil from entering byt allowing water to pass. The soundness of this design is verified by model and field tests. The advantages of this underdrain and its use in highway, building and retaining wall construction are illustrated.

REFERENCES

1. Turnbull, W. J., Discussion of Seepage Requirements of Filters and Pervious Bases", by H. R. Cedergren, ASCE J. of Soil Mechanics and Foundations Engineering, Vol. 87, No. SM1, February 1961.

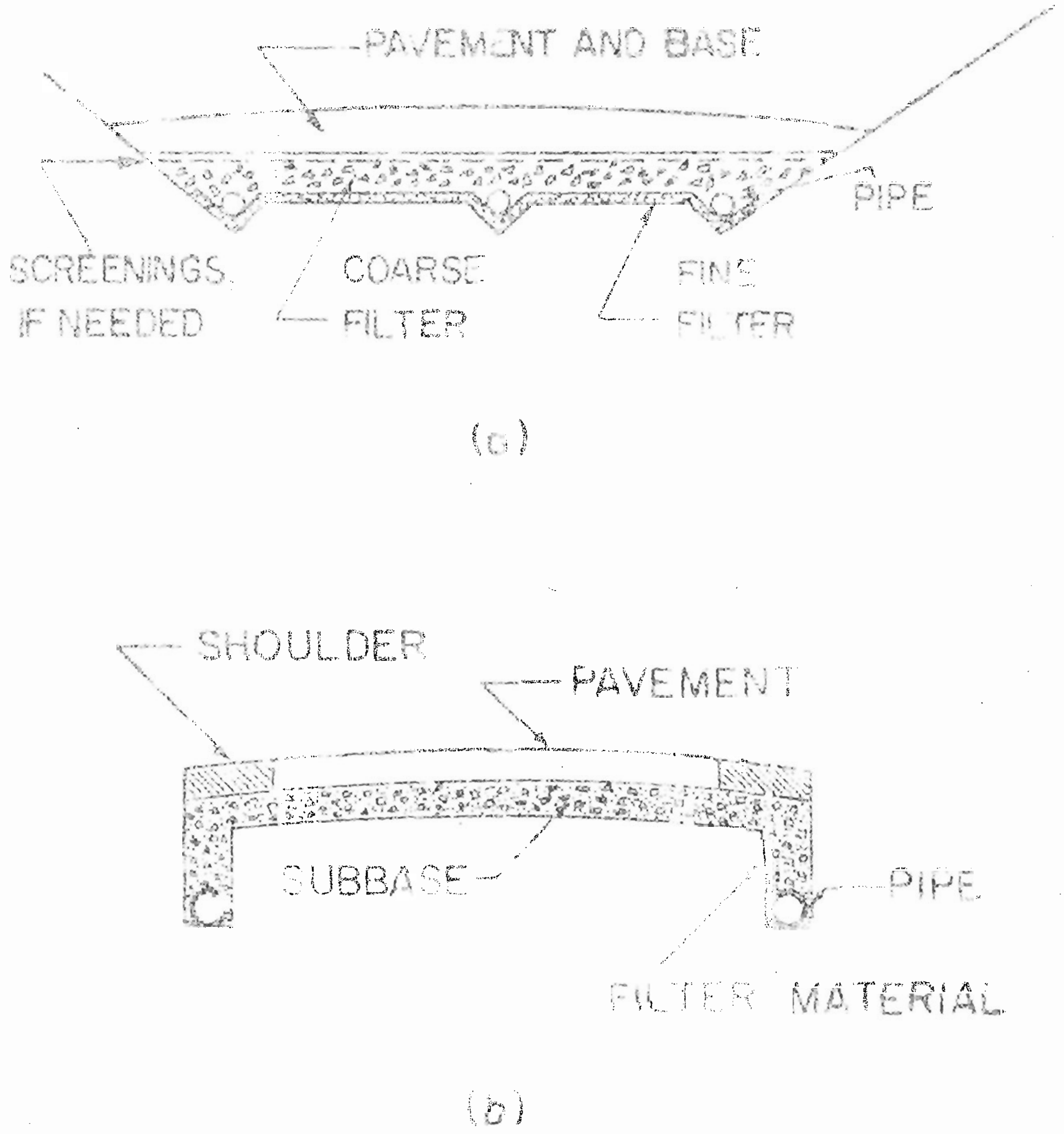
2. Taylor, D. W., "Fundamentals of Soil Mechanics", PP 134-35, J. Wiley and Sons, New York, 1948.

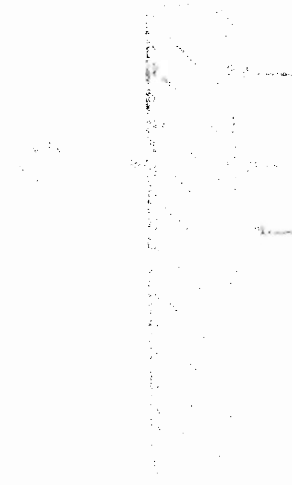
3. Cedergren, H. R., Grain Size vs. Dollars for Drainage Aggregates, Civil Engineering, PP 62-63, Vol. 37, No. 11, November 1967.

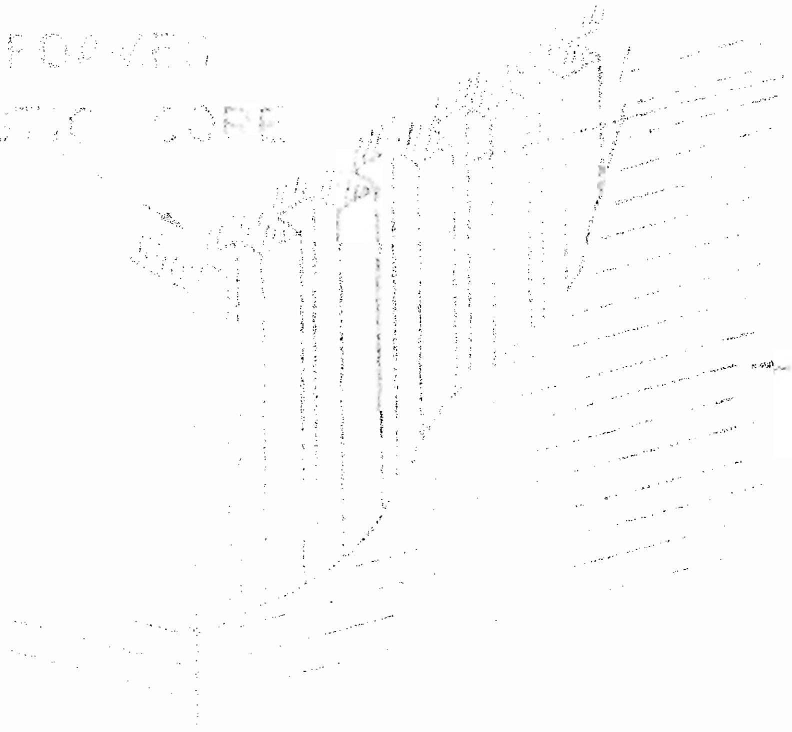
4. Cedergren, H. R., "Seepage Requirements of Filters and Pervious Bases", ASCE J. of Soil Mechanics and Foundations Engineering", Vol. 86, No. SM5, October 1960.

5. Cedergren, H. R., "The Economocs and Practicability of Layered Drains for Roadbeds", Highway Research Record No. 215, PP 1-8, HRB-NRC 1968.

FIG 1


PAVEMENT AND BASE
PIPE
SCREENINGS IF NEEDED
COARSE FILTER
FINE FILTER
(a)
SHOULDER
PAVEMENT
SUBBASE
PIPE
FILTER MATERIAL
(b)


GROOVED CORE
SYNTHETIC FILTER FABRIC AROUND PIPE AND CORE
4" PLASTIC PIPE WITH HOLES OR SLOTS IN UPPER 180°


GROOVED PLASTIC CORE
MOULDED OR CUT GROOVES
FILTER CLOTH OF SYNTHETIC FABRIC

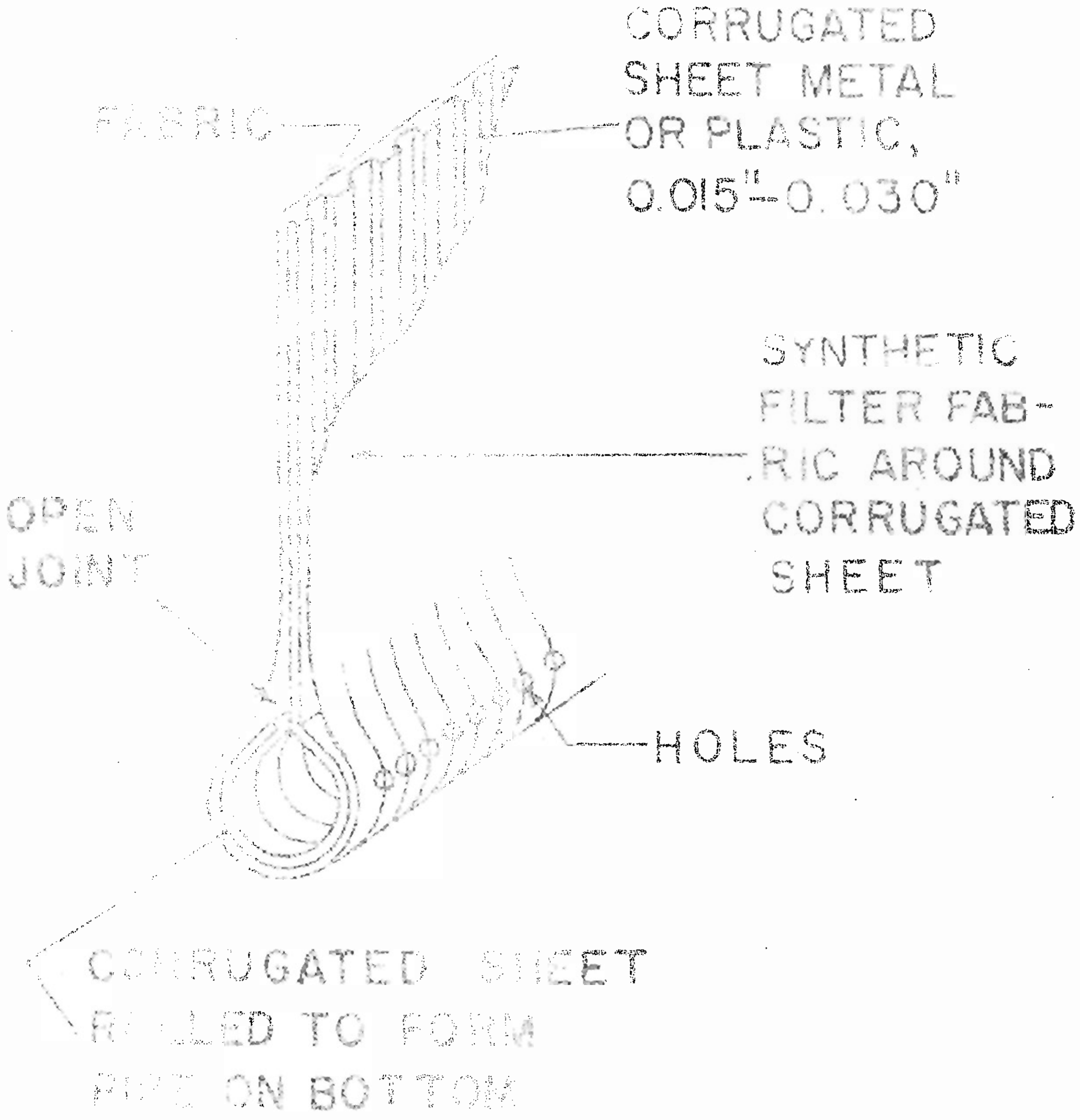
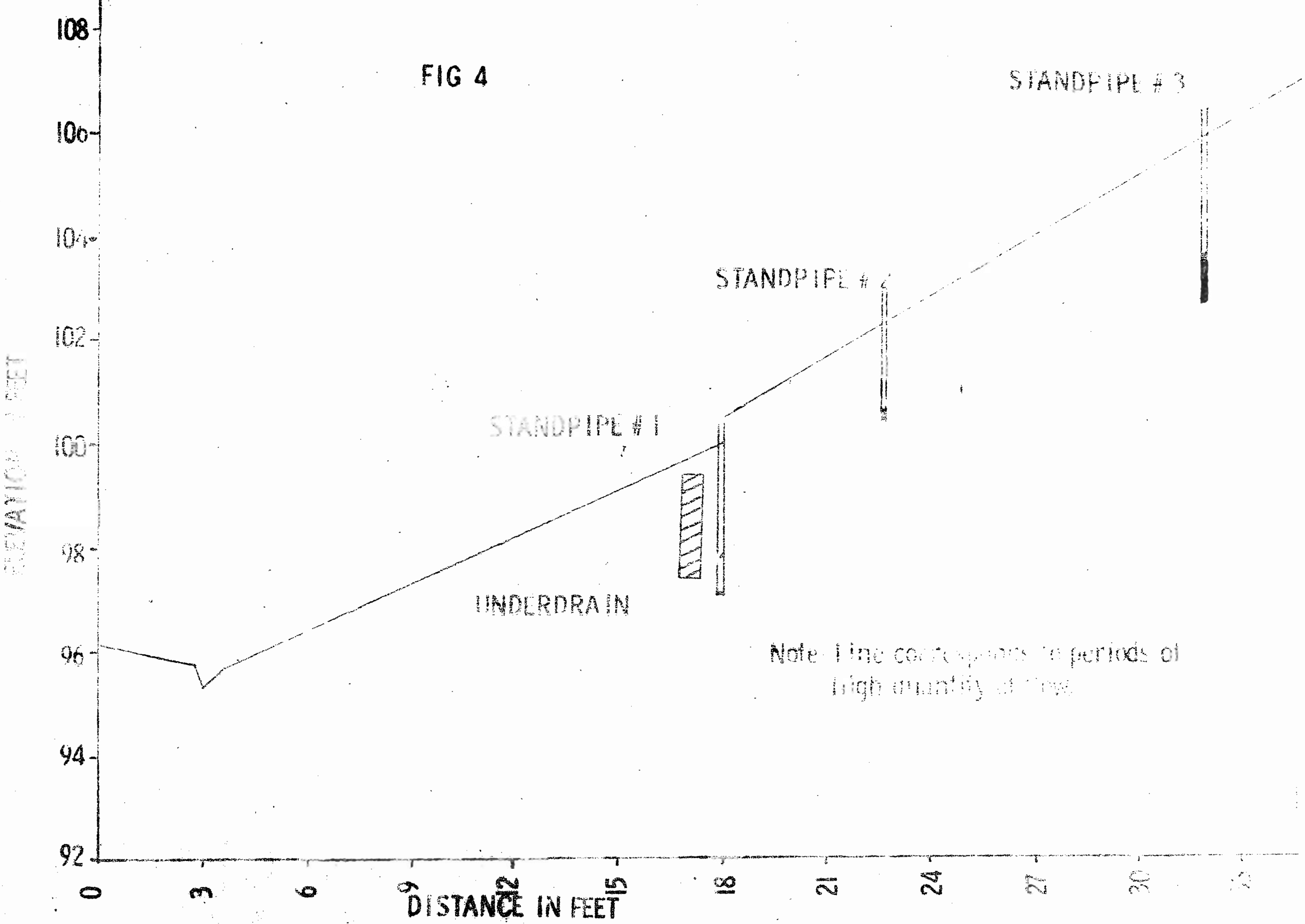

CORRUGATED
SHEET METAL
OR PLASTIC,
0.015"-0.030"
FABRIC
SYNTHETIC
FILTER FAB-
RIC AROUND
CORRUGATED
SHEET
OPEN
JOINT
HOLES
CORRUGATED SHEET
ROLLED TO FORM
PIPE ON BOTTOM

FIG 3

T. J. SHARP 12/17/68

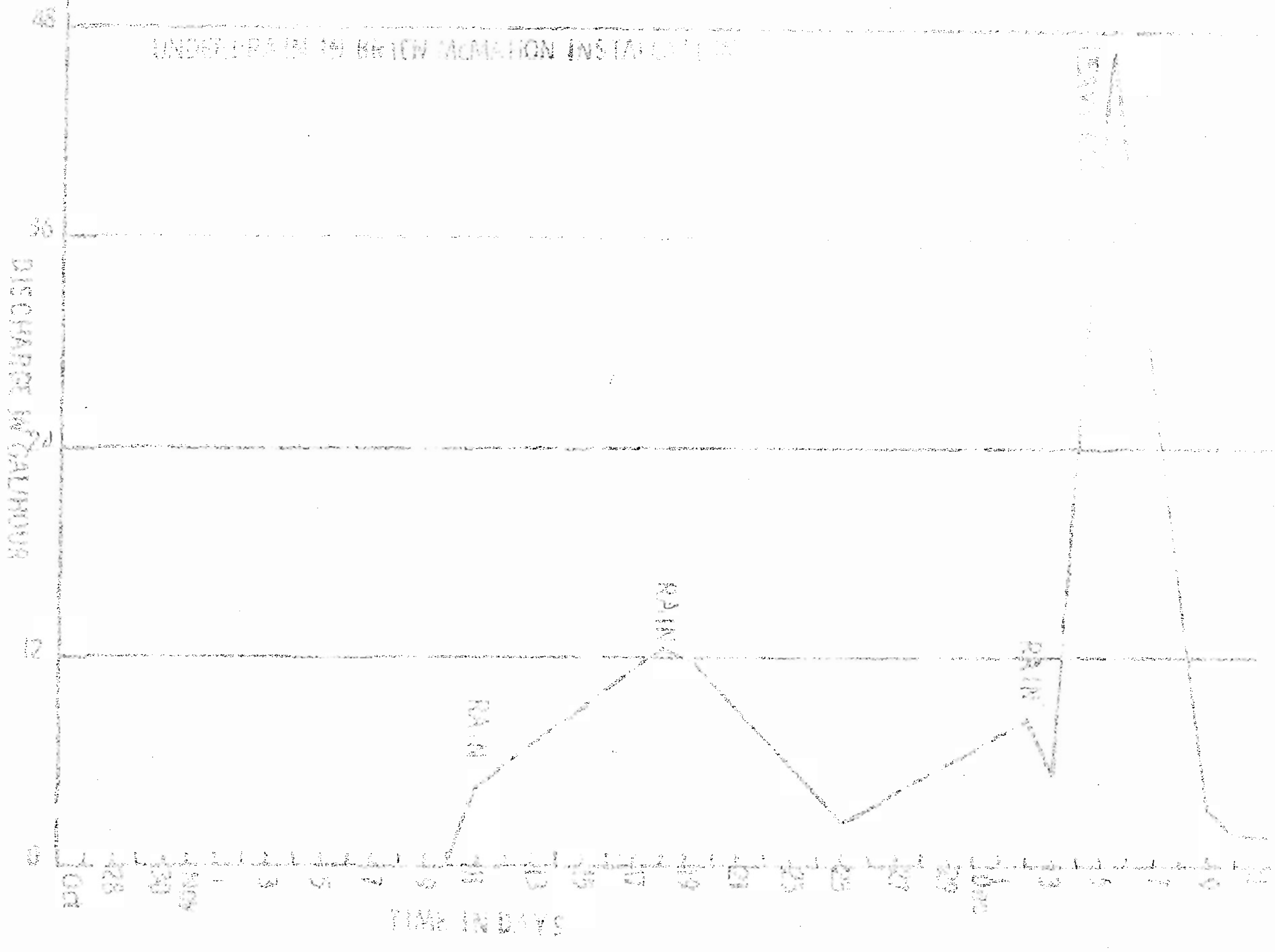
EFFECT OF DRAIN ON THE WATERTABLE AT BRIEN McMAHON INSTALLATION

FIG 4



Note: Line corresponds to periods of high quantity of flow.

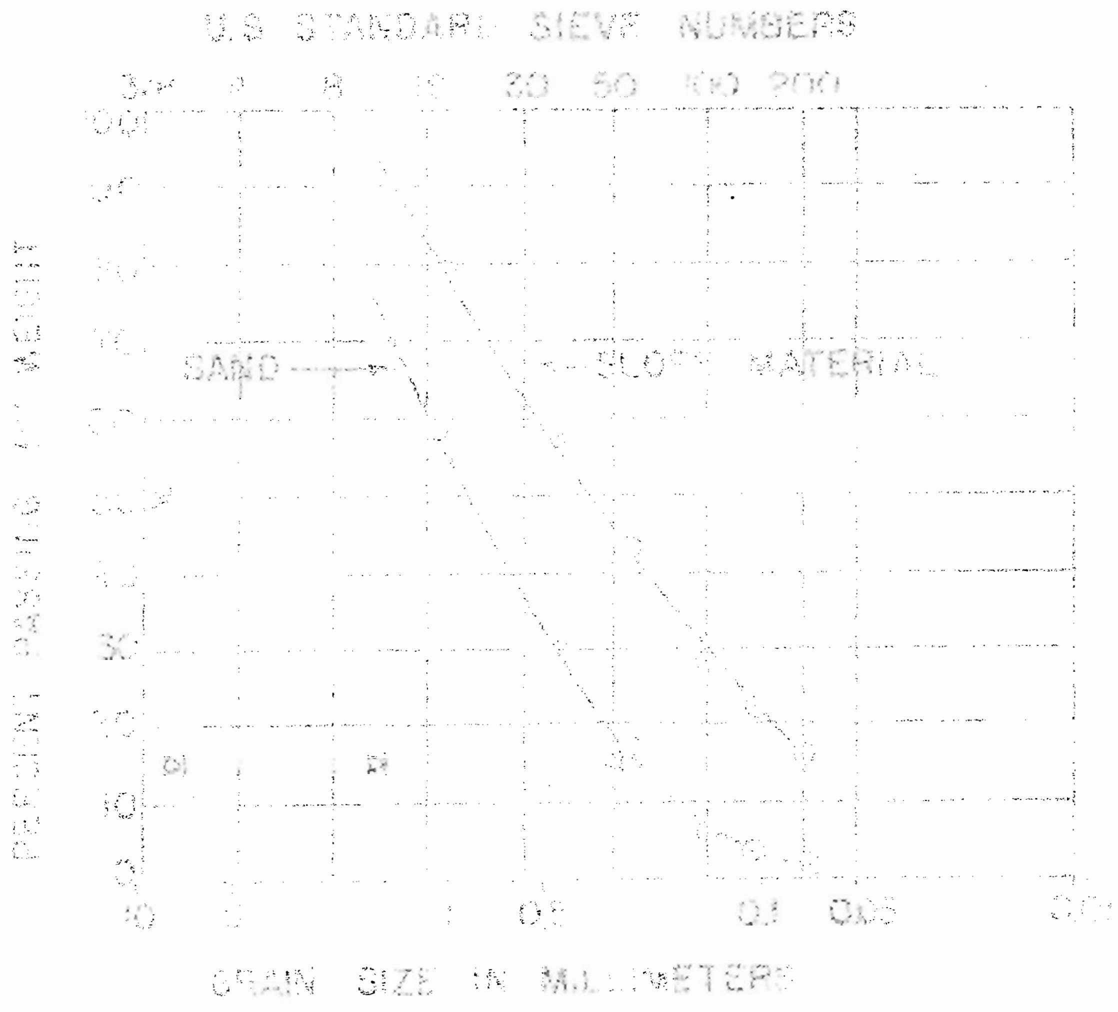
FIG. 5


UNDERDRAIN IN McMAHON INSTALLATION
DISCHARGE IN GAL/HOUR
48
36
24
12
0
RAIN
RAIN
RAIN
TIME IN DAYS
Oct
28
30
Nov
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Dec
3
5
7
9
11

[illegible] DISTRIBUTION OF SOILS IN

[illegible] EMBANKMENT SLOPE

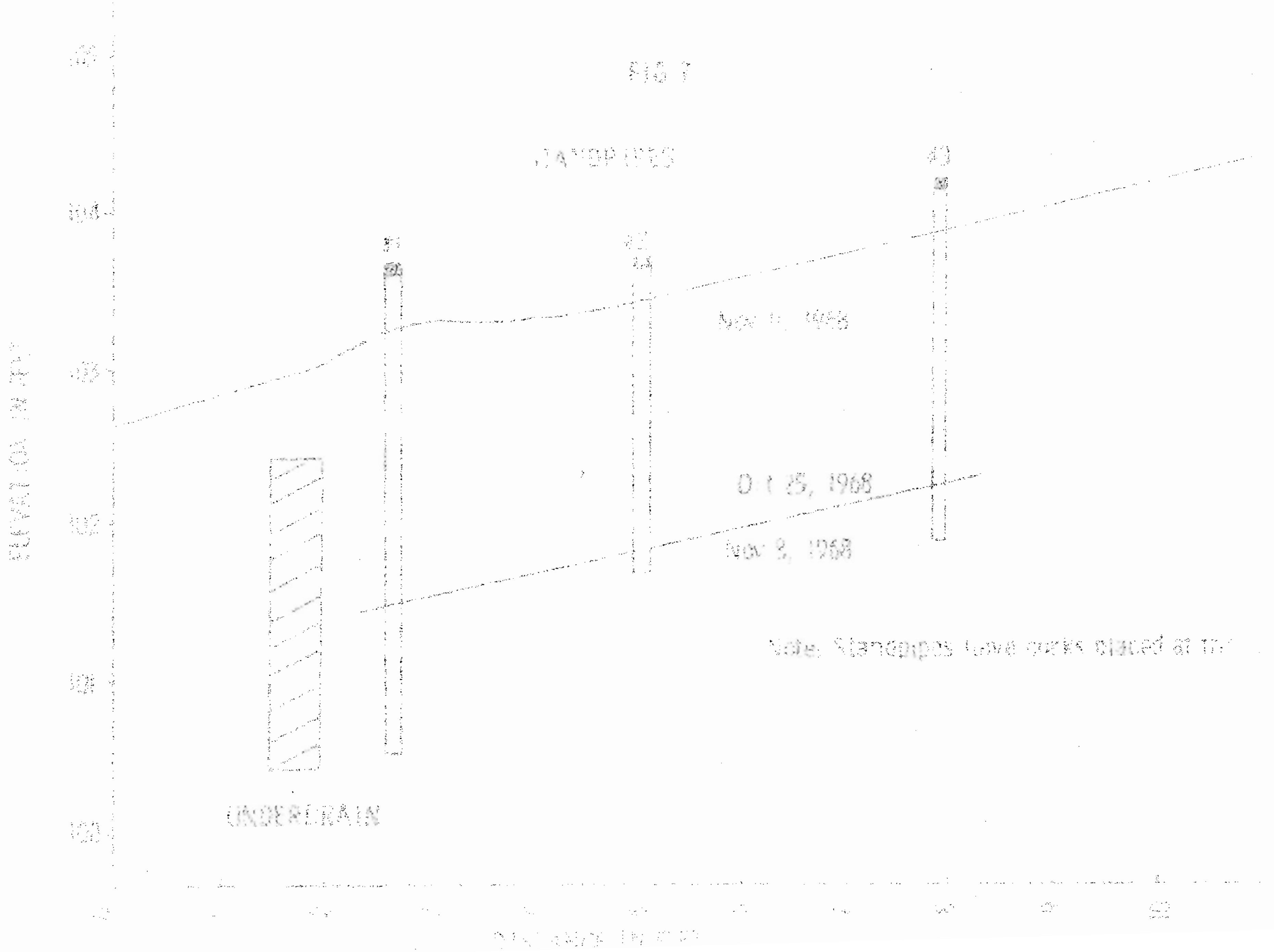
FIG. 5



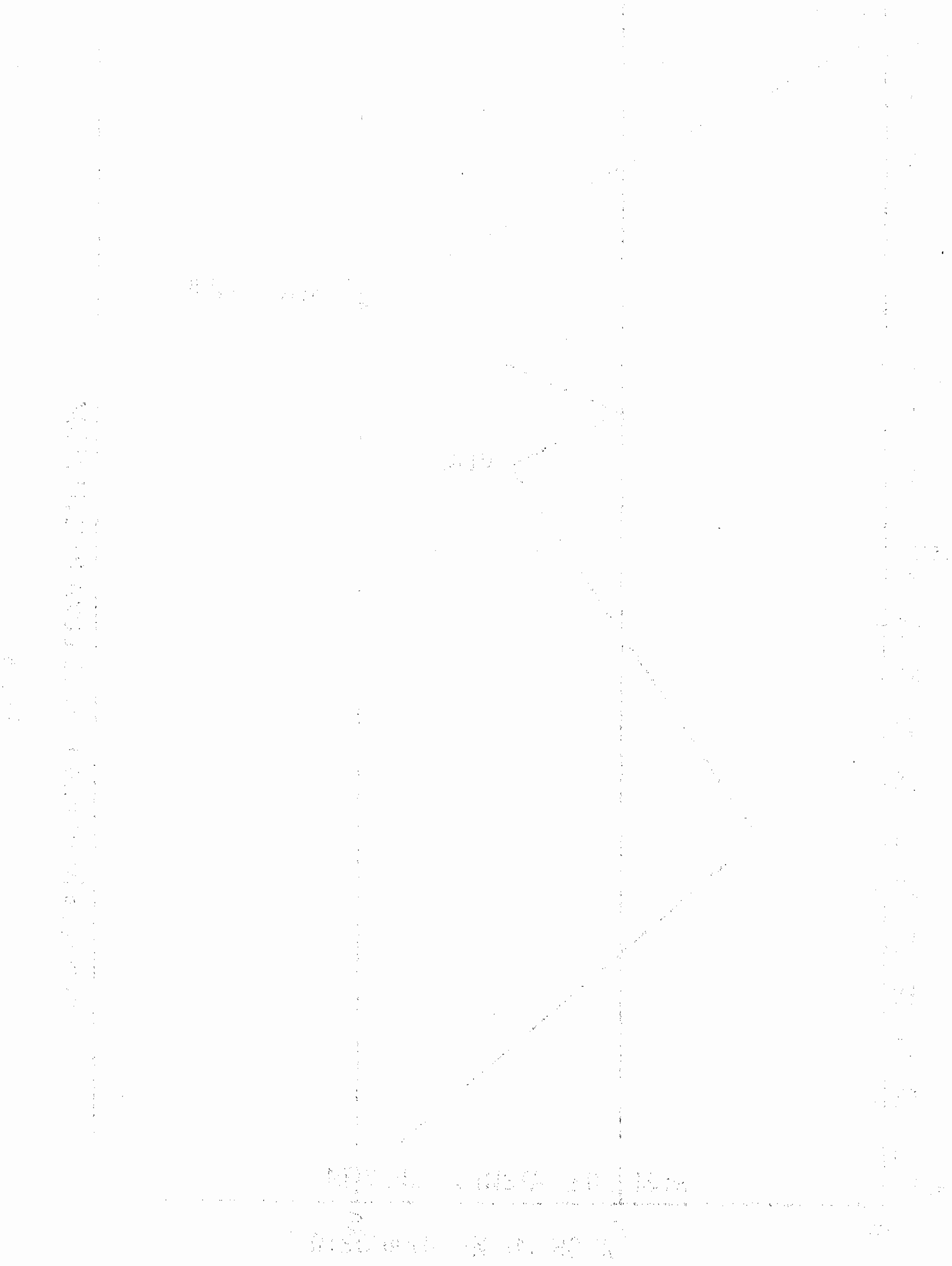
* INDICATES LIMITS OF TERZAGHI-VICKSBURG SPECIFICATIONS

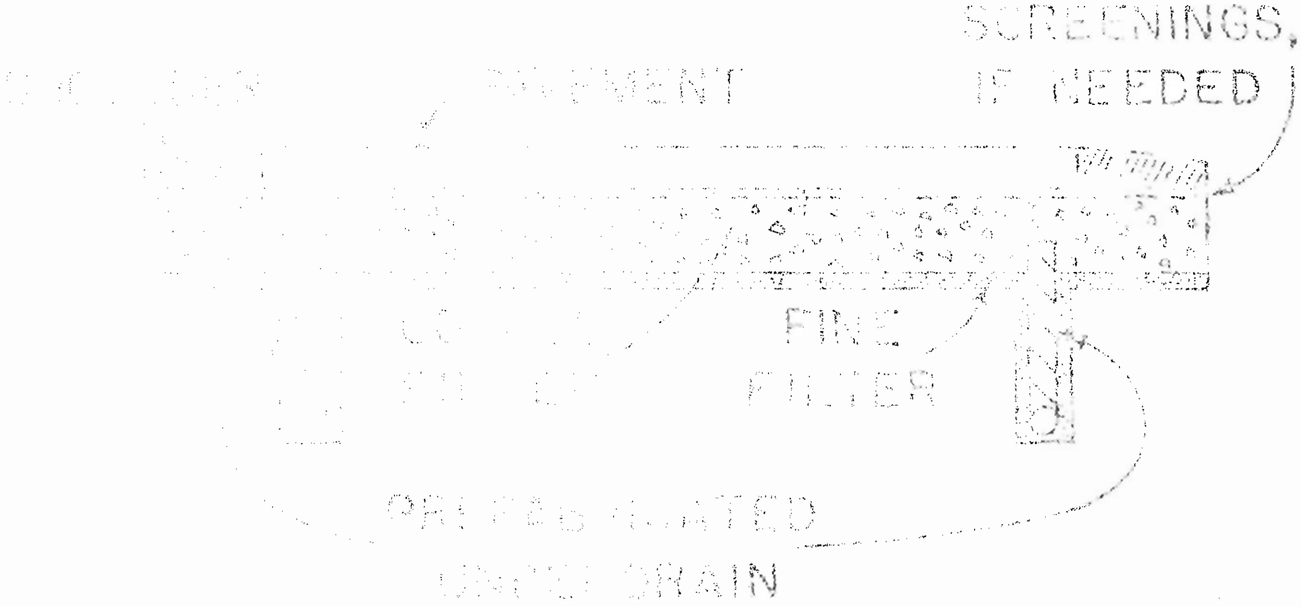
[illegible] ROAD [illegible]

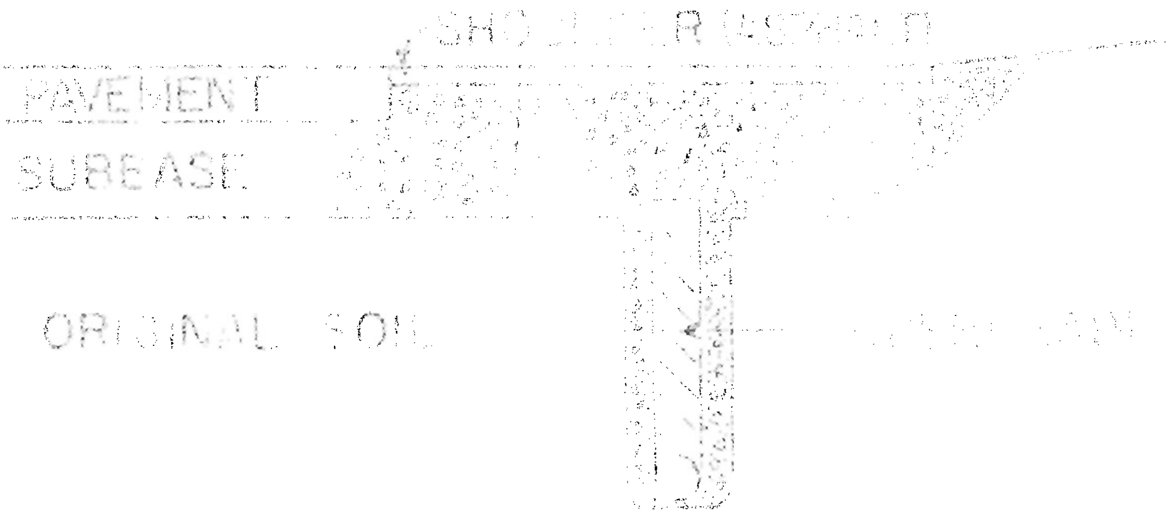
FIG 7



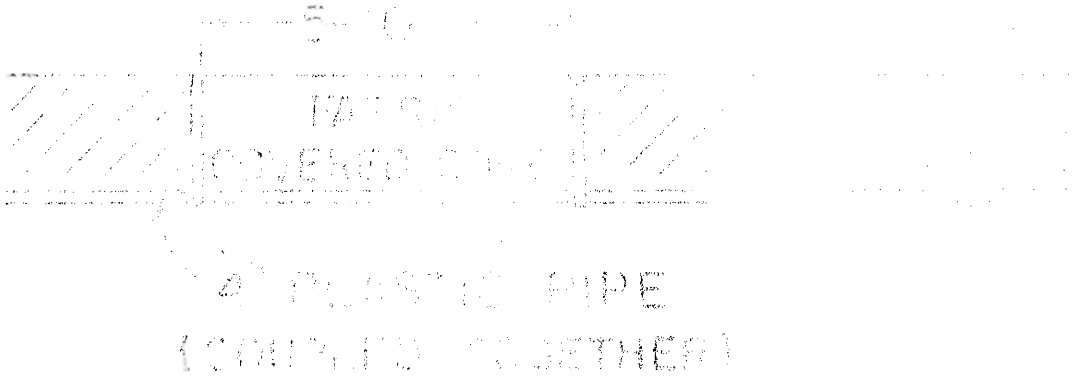
Note: Standpipes have corks placed at the




SHOULDER
PAVEMENT
SCREENINGS, IF NEEDED
COARSE FILTER
FINE FILTER
PREFABRICATED UNDERDRAIN


SHOULDER (ASPHALT)
PAVEMENT
SUBBASE
ORIGINAL SOIL

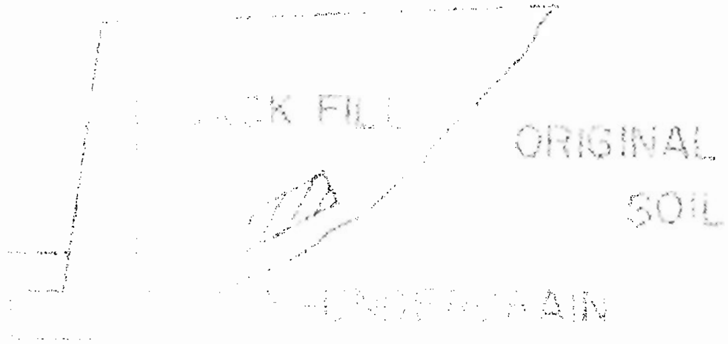
(a)


5'-0"
COVERED
4" PLASTIC PIPE
(COUPLED TOGETHER)

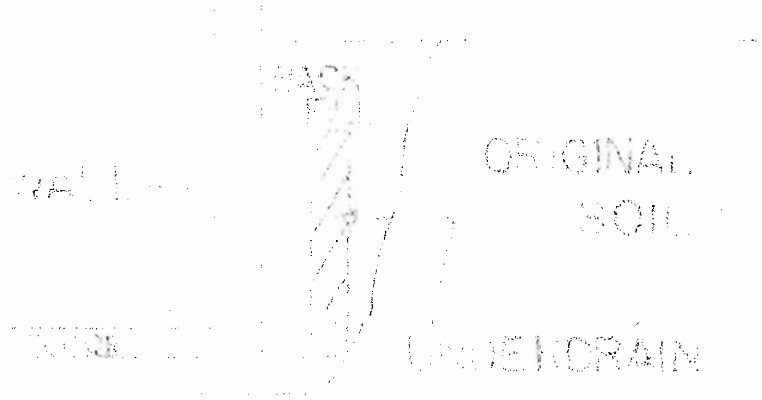
(b)

[illegible]

RETAINING WALL

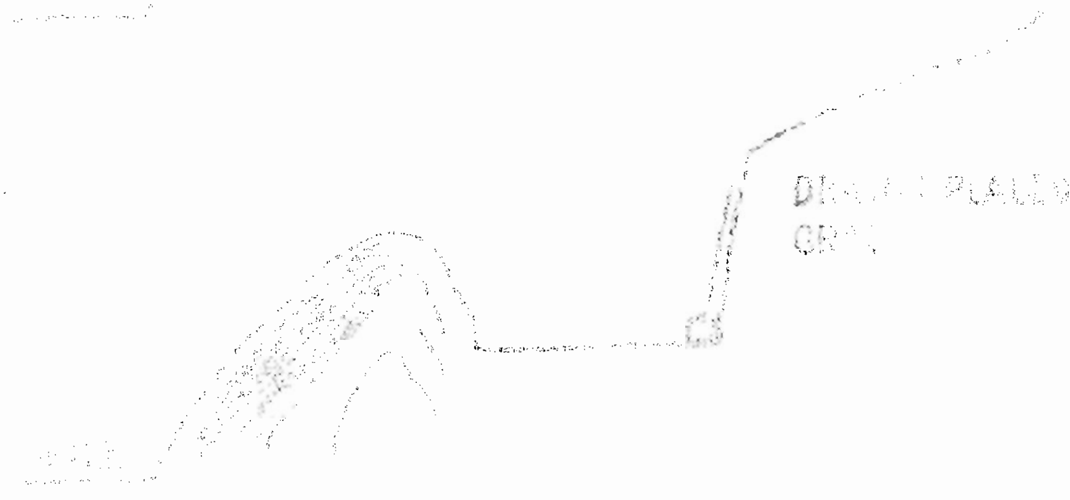


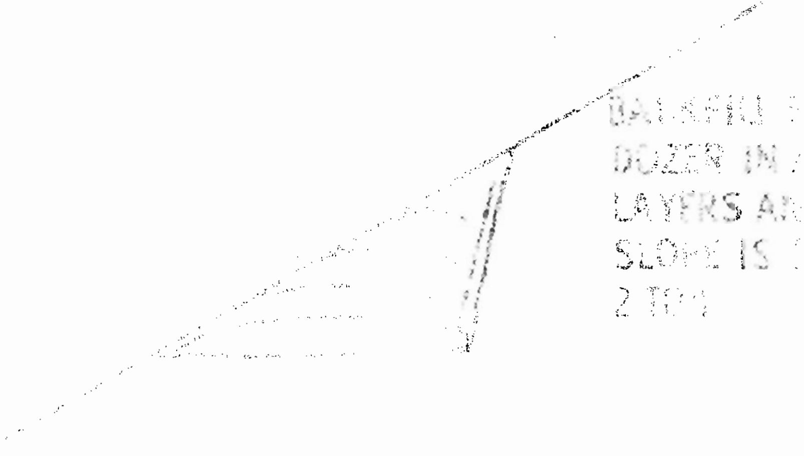
BUILDING FOUNDATION WALL




EXISTING GROUND


BENCH IS CUT IN
HARDPAN
PROPERLY TILTED
INTO SLOPE


DRAIN PLACED AT PROPER
GRADE


BACKFILL PLACED BY
DOZER IN A SERIES OF
LAYERS AND FINISHED
SLOPE IS COMPACTED
2 TIMES