HYDRAULIC ROUGHNESS OF CORRUGATED, UNPERFORATED PLASTIC DRAINAGE TUBING

Thesis for the Degree of M. S.

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GUROL DINC

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ABSTRACT

HYDRAULIC ROUGHNESS OF CORRUGATED,
UNPERFORATED PLASTIC
DRAINAGE TUBING

By

Gurol Dinc

Manning's formula has long been used in the design of drainage systems for clay and concrete tiles. The more extensive use in recent years of corrugated plastics has developed the need for an investigation on the hydraulic properties of corrugated plastic tubing. This study was made to investigate the effect of corrugation spacings and types, variation of diameters, and the slope of the tile lines with respect to the hydraulic characteristics of plastic tubing.

Two experimental tubing lines were set up, one for small diameters and the other for large diameters. The hydraulic properties of the tubing were investigated under full-flow conditions.

Experimental data showed that fluctuations of Manning's n resulted from a) corrugation spacings and b) types of corrugations.

For slopes less than .008 ft/ft coefficient n of Manning formula became a function of slope. For slopes greater than .008 ft/ft the coefficient n was close to being constant.

Approved

E H Kidder

Major Professor

B A Stout

Department Chairman

HYDRAULIC ROUGHNESS OF CORRUGATED, UNPERFORATED PLASTIC DRAINAGE TUBING

By

Gurol Dinc

A THESIS

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Michigan Vitrified Tile Co., Springfield Plastics, Inc. and Canada Dominion Sugar Co., Ltd. for donating the tubing used in the experiment.

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INTRODUCTION

It is believed that the drainage of irrigated lands began as early as irrigation took place in agriculture. Although it is not known whether Sumerians or Egyptians were the first masters of irrigation and drainage, it is fact that during the Roman Empire era drainage of lands was in practice.

The middle ages, which one can identify as the dark centuries of human history, did not bring any striking innovation to the field of irrigation and drainage. This situation prevailed until the beginning of the 19th century when subsurface drain tiles were initiated in England.

The mechanization of many agricultural practices, as a result of the industrial revolution, included the installation of drain tiles. The machines were built to facilitate the tiresome job of tile embedding. Advancements in technology brought automated tile installing machines and equipment to decrease the higher overall cost of the subsurface drainage systems.

However, these developments have not satisfied the demand for low cost. Especially, the cost of draining agricultural lands has been relatively higher in slowly permeable soils and in soils with shallow impervious layers demanding narrow drain spacings.

Reducing the high cost of installation of subsurface drains could be achieved through the development of new techniques in the handling of modern equipment and by lowering the amount of labor involved in placing drains. Through the invention of the polyethylene plastics in the 1940's researchers in the field of drainage considered the possibility of using plastics as a raw material for tiles. Since then there has been extensive research carried on concerning the use of plastic tubing in subsurface drainage systems.

Recent researches have shown that using 200 feet long corrugated polyethylene plastic drains provided sufficient and promising results toward lowering the cost of subsurface drainage of Agricultural lands, even though their prices are comparatively higher than concrete and clay tiles.

Despite all of the developments in the use of plastic drain tiles, there was little known about hydraulic characteristics, particularly the tubing of large diameters. It was necessary to conduct a hydraulic investigation of these tubing, especially to determine the friction factors. Information on the values and variation of "n" was collected for use in the design of subsurface drainage systems.

Experiments were conducted on eight different sets of corrugated plastic tubing. The effects of diameter, slope, styles, patterns, shapes, and spacings of corrugations were the critical items taken into consideration in the experiments. These factors were evaluated at several flow rates.

REVIEW OF LITERATURE

Although there has been much research done on flow conditions and the determination of roughness on closed conduits, very little has been done on corrugated plastic tubing used in drainage systems. Information initially used for roughness of plastic tubing were based on extrapolations from previous research done on clay and concrete tiles. The information from clay and concrete tiles could only provide approximate values for the plastic tubing and uncertainty existed about their validity.

I. Development of Plastics in the Use of Drainage Systems

Schwab (1955) succeeded in installing smooth plastic tubes into mole drains, and studied the feasibility of perforated plastic tubes as a method of subsurface drainage. After four years of observation, he concluded that pipe diameter, wall thickness and depth of installation had an effect on the deformation of plastic tubes. Contrarily, the size of the mole channel and the type of soil had no effect on the deformation of plastic pipes.

Busch (1958) modified a mole installing unit and mounted it on the tool bar of a model D-4 tractor of the

Caterpillar Company to install plastic lining into mole channels to prevent future channel clogging by the soil. He concluded that the mole drainage with a plastic lining was feasible and was of low cost compared to the conventional subsurface drainage.

In the Netherland, De Jager (1960) examined the deformation, sand infiltration, and the discharge of corrugated plastic pipes in a one meter sand tank. He used Hooghaudt's (5*) assumption that the flow of water in the vicinity of the drain can be divided into radial flow and entry flow. For calculating the discharge of perforated plastic pipes, he used Ernst (6*7*) equations which included the radial and entry flow:

$$\Delta h_r = \frac{Q}{\Pi k} \ln \frac{D}{U} \qquad \text{and} \qquad \Delta h_x = \alpha \frac{Q}{k}$$

where,

Δh_r = hydraulic head for radial flow

Δh_x = hydraulic head for entry flow

k = permeability (m/day)

Q = drain discharge per m. drain (m^2/day)

D = height of installation above underlying impermeable layer (m)

U = wet surface (m)

α = coefficient

He installed the perforated plastic pipes into different types of soil and compared them with clay tile

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*See the author's paper.

drains under the same field conditions. He concluded that there were no reliable differences in drainage performance between plastic pipes and clay tiles.

Fouss and Donnan (1962) investigated the stability and deformation of zipper-type plastic lining in mole channels. It was observed that zipper-type plastic lining was more stable than arc-type or overlapping-types of plastic lining. The zipper-type gave an especially better performance in sandy soil than the other types.

Myers, Rektorik, and Wolfe's (1967) work included the deflection of polyethylene drain tiles. Laboratory studies showed that plastic drains fail by deflection rather than by rupture of the walls. To provide lateral support for the polyethylene tiles they recommended that a 5-inch diameter cradle should be installed to support 160 degrees of the pipe's circumference.

Rektorik and Myers (1967) developed a wheel-type trencher to install continuous perforated polyethylene tubing to depths of 9 feet in a trench only 10 inches wide. This made the cost of an installed plastic subsurface drainage system 10 to 15 per cent lower than other equivalent systems. They also studied the deflecting characteristics of the polyethylene tubing under various envelope materials.

II. Hydraulic Properties of Flow in Drainage Tiles

The flow of fluids through pipes has long been computed by the Darcy-Weisbach equation. However, the hydraulic designs of drainage systems are based on the well-known Manning (1889) formula,

$$Q = \frac{1.489}{n} R^{2/3} S^{1/2} A$$

where,

Q = discharge from the tile lining (cfs)

A = cross-section of tile (ft^2)

R = hydraulic radius of flow (ft)

S = slope of the hydraulic grade line (ft/ft)

n = the coefficient of roughness (dimensionless)

This formula was developed by Manning from seven different formulas, based on Basin's experimental data, and further verified by 170 observations.

Yarnell and Woodward (1920) worked intensively on the flow in drain tiles. Full-scale models for experimental investigation under uniform flow assumptions were used. They checked the validity of the Chezy's flow formula and determined the Manning's roughness coefficient as 0.0108 for concrete and clay tiles. This value was based on tests of tiles up to 12 inches in diameter. They also found that the roughness coefficient may be increased to as much as 0.02 for tile in poor alignment.

Wesseling and Homma (1967) studied extensively the hydraulic resistance measurements of full flowing drainage pipes under pressure. A straight line relationship between log λ and log Re, was found in which,

λ = dimensionless friction factor

Re = Reynold's number

From this relationship they concluded that the R and S exponents in the Manning's formula are higher than the ones normally used. The research showed that for corrugated polyethylene tubing, this relationship did not hold. Therefore they determined the resistance of corrugated plastic pipes with small diameters from the Manning's formula as n = 0.0142.

They also derived a relationship between discharge, hydraulic head, and length of drain for a constant inflow per unit length in the form of:

$$H = 9.55 \times 10^{-4} a \left(\frac{9}{L}\right)^{1.75} \{L^{2.75} - (L-X)^{2.75}\} D^{-4.75}$$

where,

9 = discharge of the line

L = length

X = the distance from the outlet

D = diameter of tile

H = hydraulic head

a = constant

However, they found certain discrepancies between the obtained formula and field data.

Full-scale experiments were conducted by Hermsmeir and Willardson (1970) on small diameter corrugated plastic drain tubing. Manning's n and Darcy-Weishbach f were determined on six different tubing ranging from 0.37 inch to 4 inch in nominal diameter. They recommended an average design value of Manning's n of 0.016 for 2 inch through 3 inch diameter corrugated plastic tubing for grades over 0.001. For lower grades an average design value of Manning's n of 0.017 was recommended with these diameters. For corrugated plastic tubing less than 2 inch diameter an average design value of Manning's n of 0.018 was recommended. Their studies showed that humps and depressional variations up to two diameters from a uniform grade did not increase head losses in full-flowing lines.

EXPERIMENTAL SET UP AND PROCEDURE

An experimental model tile line was set up near the Agricultural Engineering Department Annex to determine the hydraulic roughness on 4 and 5 inch diameter corrugated plastic tubing. The installation was later moved into the Dairy Plant and modifications were made to handle larger diameter tubing.

I. Experimental Set Up for Tubing Up to 5 Inches Nominal Diameter

A platform was built to provide a zero grade for the tiles. This horizontal position was checked frequently during the experimental period. The platform was approximately 60 feet long, 3.5 feet high, and was supported by wooden stilts at 6 foot intervals.

The operation of the system installation is shown in Figure 1. The water flowed from the head tank through the tile line into the wooden weir flume and from there it was discharged to the collecting reservoir. It was pumped back into the head tank for recirculation.

The head tank included a stone baffle to prevent air vortex from going through the tile line. A valve was

Figure 1.--System installation under operation. Water falling into the reservoir is pumped back into the head tank for recycling.

installed to block flow until a sufficient volume of water was stored in the system.

The wooden flume consisted of a stone baffle, a 90° V-Notch weir, and two piezometers. The stone baffle was used to keep the turbulance and the approaching velocity head on the weir at a minimum. Two piezometers were placed on the side of the flume, two-feet apart from each other. The leading piezometer was 3 feet away from the weir.

The collecting reservoir was essentially a minature plastic swimming pool, having a diameter of 7 feet and a depth of 2 feet.

The pumping unit (Figure 2) included a suction line, a gasoline engine driven horizontal centrifugal pump, 2 control valves, a feedback hose and a pressure hose.

The level of the water in the head tank was maintained by the two control valves. This was accomplished by operating the valves manually.

The pressure hose consisted of a rigid plastic tube of 2½ inches nominal diameter with one and connected to the pressure control valve and the other end was attached to the head tank.

The feedback hose was a tube of 2 inch nominal diameter with a connection at the feedback control valve and an attachment to the collecting reservoir.

Four piezometers were installed at 10 feet intervals along the tile line. The first piezometer was placed

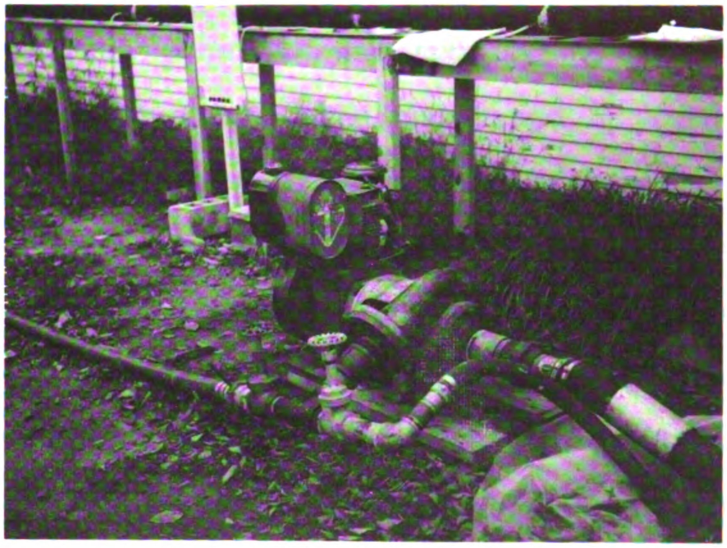


Figure 2.--Pumping unit. Pressure control valve on the left, feedback control valve on the right.

15 feet from the initial start of the tile line in order to avoid entrance turbulance effects on the monometer.

Connections were made by inserting corks, with 4-inch long glass tubes in them. The corks were mounted in the holes in such a way that the end of the monometer openings were the same level as the inside wall of the tile. An industrial cohesive was applied to seal around the corks. The glass tubes were connected by ¼ inch diameter tygon tubes to the central monometer board.

The monometer board consisted of 5 glass tubes of 0.030 inch inside diameter. Four of them were used to measure the pressure in the tile line. These were the piezometers mentioned previously. The other tube was connected to the head tank to measure the water level.

The slope of the hydraulic grade line was varied by changing the water level in the head tank. This was done by throttling down the pressure control valve and by gradually opening the feedback valve. Initially the head tank was filled to a certain level, then lowered an inch at a time. For each inch increment, a set of readings were taken from the monometer board and the weir. The water temperature was also recorded. Data for the readings are given in Appendix.

II. The Calibration of 90° V-notch Weir

The calibration of the V-notch weir was done by measuring the discharge over the weir at different heads.

In measuring the discharge, a container with a known volume was used. The time required to fill the container was recorded for each head. A fortran computer program was written to determine the coefficients of the weir by the least square method.

III. Experimental Set Up for Tubing 6 and 8 Inch in Diameter

The principals of the set up were the same as it was with the 5-inch or smaller diameters. The same monometer board and platform were used. Some modifications however, had to be made on the system due to the larger dimensions involved. The set up is shown in Figure 3.

The head tank had the dimensions of 5x5x8 feet, and the dimensions of the lower tank were 6x3x12 feet. Eight inch nipples were welded to the sides facing each other. These nipples were used to connect the tanks to the tile line (Figure 4).

On the side opposite the nipple in the lower tank, a 4-inch line was constructed. This outlet was connected to the suction line of the pump.

Two 2-inch flowmeters (as shown in Figure 5) were connected parallel to the pressure side of the pump. Each flowmeter had a capacity of 160 gallons per minute.

A valve was located on the pump side of one of the flowmeters. The valve was used to regulate the flow. At low flow rates the valve was closed and the discharge was measured by only one flowmeter.

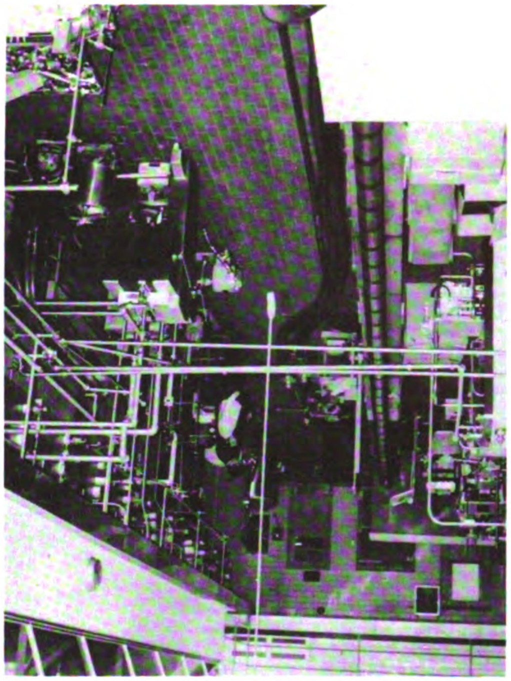


Figure 3.--Head tank in the foreground connected to the lower tank by 8 inch plastic tubing.

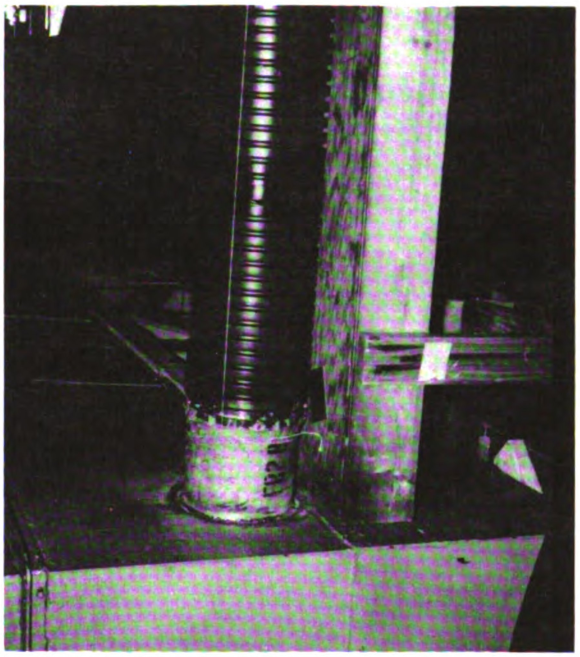


Figure 4.--Eight inch nipple is welded to the head tank for connection of the plastic tubing.

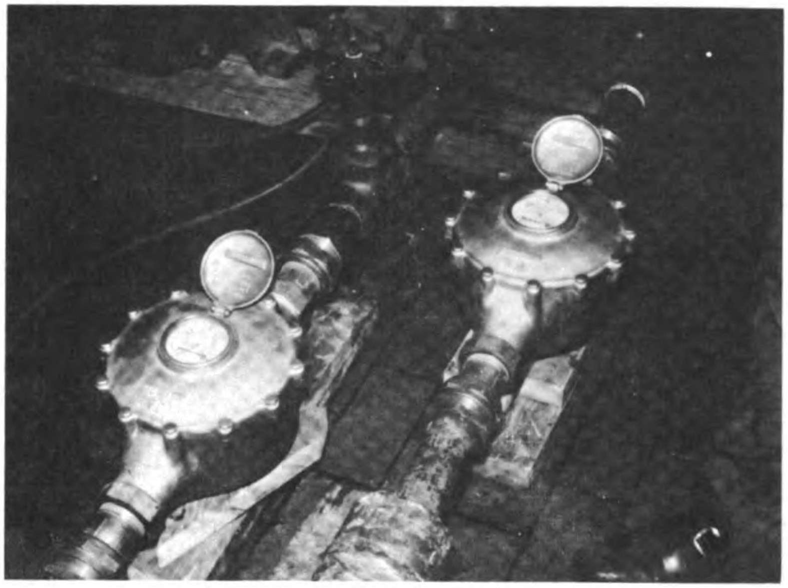


Figure 5.--Parallel connection of the flowmeters. Control valve is in background on the left.

The slope of the hydraulic grade line of the system was changed by the same method as mentioned previously for the 4 and 5 inch lines.

The calibration of the flowmeters was done by using the facilities of the City Board of Water and Light of Lansing. They were found to be exceptionally accurate to within ±0.001.

The 8-inch tiles came in lengths of approximately 18 inches. In order to obtain the length of tubing needed, tape was used to splice the pieces together and to form a water seal.

Two pumps were connected parallel to the lower tank outlet. Unlike the other systems, the pressure sides were not attached to the head tank.

The measurement of discharge was done by photographic method, using a 35 mm camera with high speed film. Initially the system was filled with water. After starting the pump, the lower tank started discharging water at a constant rate. The change of the head in the head tank and the pressure changes on the monometer were photographed at 5 second intervals, with 20 pictures for each constant rate of flow. Head drops on the head tank observed at 5 second intervals, were used to calculate the rate of flow coming out from the tubing line.

IV. Tubing

Tubing used in the experiment were obtained from companies throughout the United States and one company from Canada. The diversity of tubing were examined before the tubing were ordered to get a better representative sampling of various types. The names of the companies and their products used in the experiment are listed in Table 1.

TABLE 1.--Tubing companies and products used.

Name of Company	Nominal Diameter Inches	Corrugation Spacing (average) Inches
Michigan Vitrified Tile Co.	4.0	0.7
Canada Dominion Sugar Co., Ltd.	4.0	0.5 (Helical)
Advance Drainage Systems, Inc.	4.0	0.5
Michigan Vitrified Tile Co.	5.0	0.7
Springfield Plastics, Inc.	5.7	0.5
Advance Drainage Systems, Inc.	6.0	0.5
Advance Drainage Systems, Inc. (Set 1)	8.0	1.15
Advance Drainage Systems, Inc.	8.0	0.5

DISCUSSION OF RESULTS

A Fortran computer program was written to determine the effect of the following variables: S, n, F, Q, V, and RE where,

S = Slope (ft/ft)

n = Manning's coefficient of roughness

F = Darcy-Weishbach coefficient

Q = Flow rate (cfs)

V = Average velocity (fps)

RE = Reynolds number

All the variables were considered in the analysis with the main emphasis being on Manning's n with respect to S (slope) and Q (flow rate) and their relationships from the standpoint of the validity of Manning's equation for corrugated plastic tubing.

The plot of S versus Q for each set of tubing are shown in Figure 6 through 12. The curves were drawn by using second order least square fittings.

The flow rates plotted in Figures 6 through 12 were determined by a 90° V-Notch Weir. The actual formula obtained from the calibration of V-notch weir was used for the calculation of the flow rate. This was $Q = 2.52H^{2.54}$.

FIGURE 6

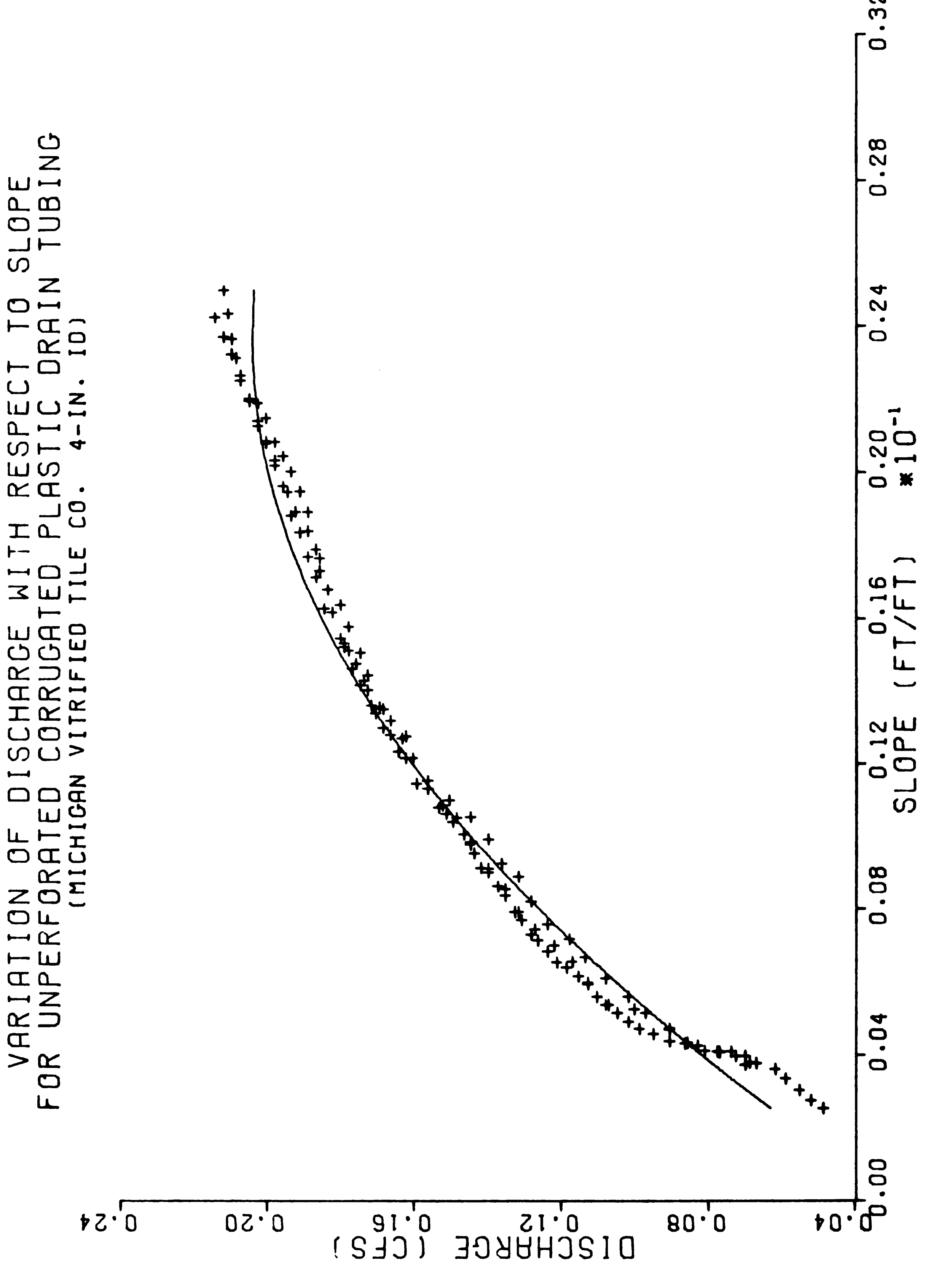
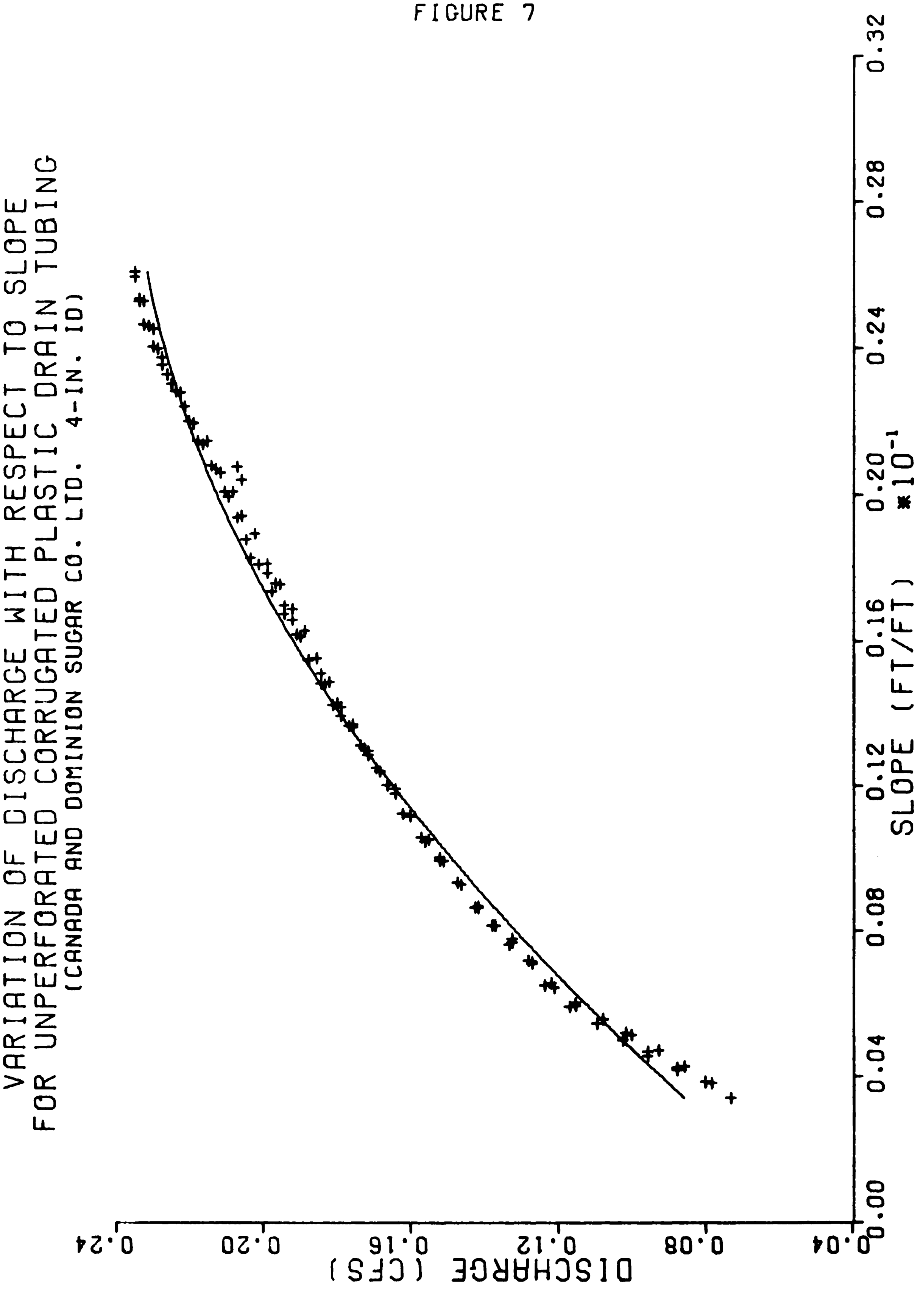

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(MICHIGAN VITRIFIED TILE CO. 4-IN. ID)
SLOPE (FT/FT) *10⁻¹
DISCHARGE (CFS)
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.04
0.08
0.12
0.16
0.20
0.24

FIGURE 7



VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(CANADA AND DOMINION SUGAR CO. LTD. 4-IN. ID)
DISCHARGE (CFS)
0.04
0.08
0.12
0.16
0.20
0.24
SLOPE (FT/FT) *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32

FIGURE 8

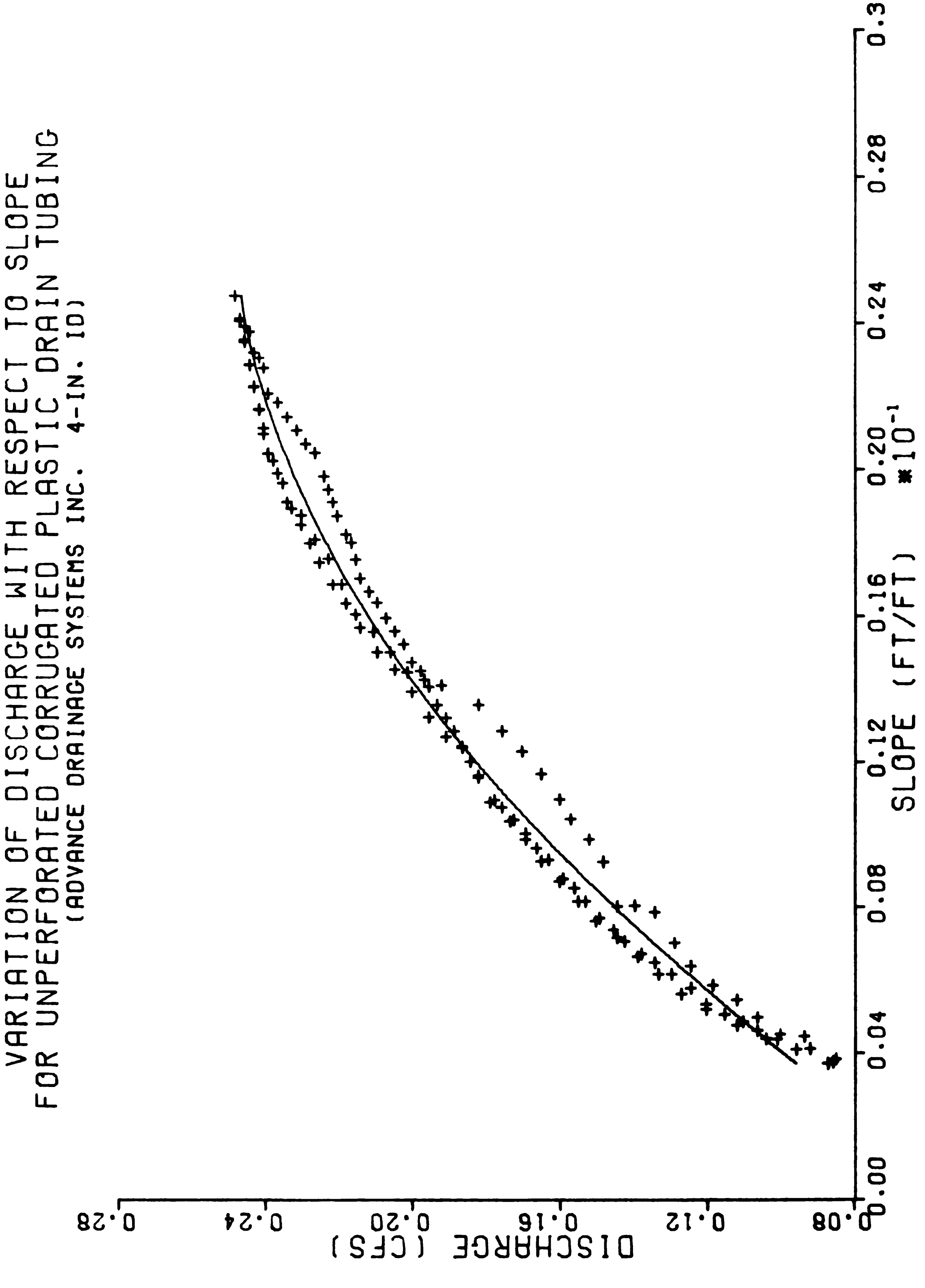

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 4-IN. ID)
SLOPE (FT/FT) *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
DISCHARGE (CFS)
0.08
0.12
0.16
0.20
0.24
0.28

FIGURE 9

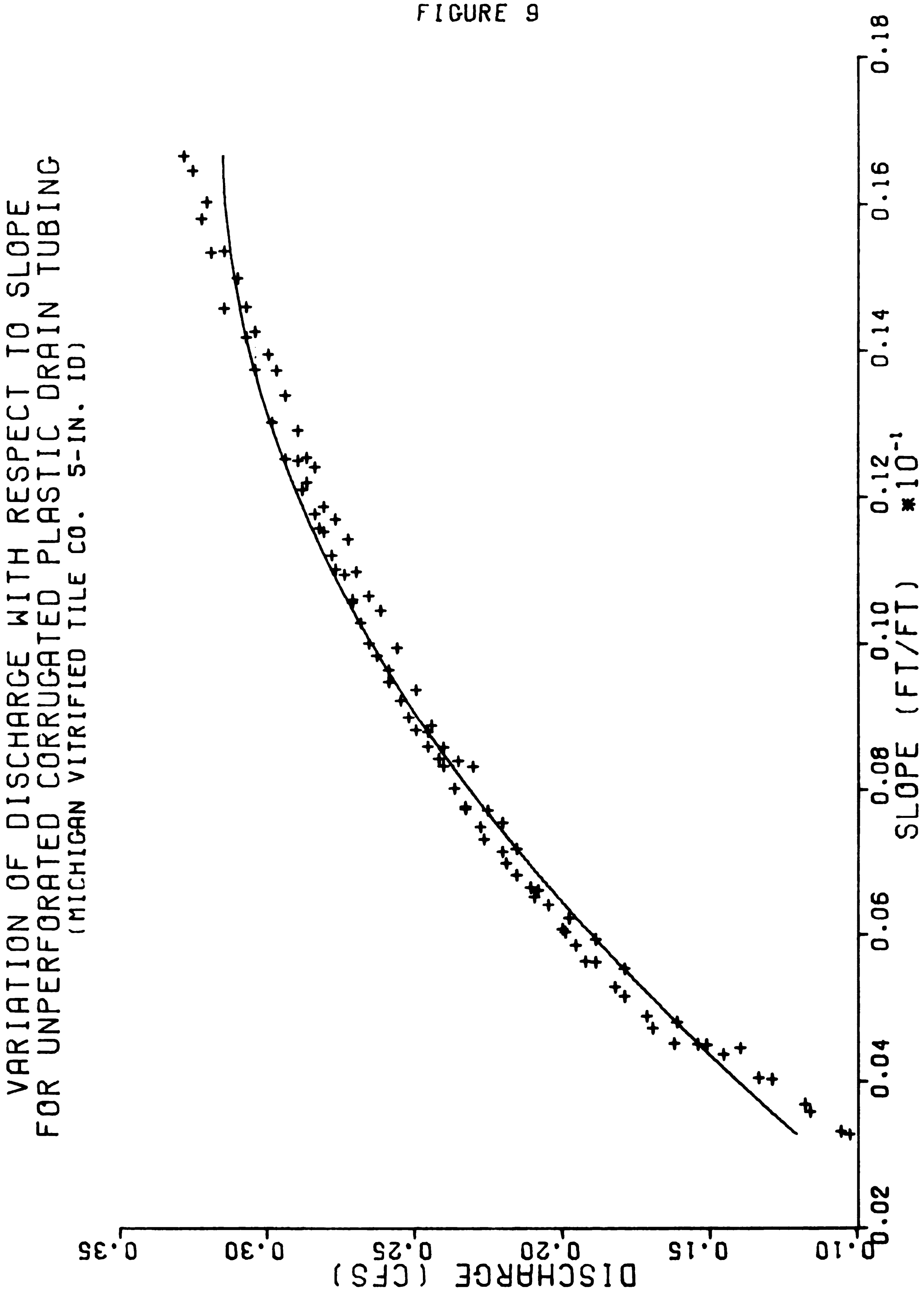

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(MICHIGAN VITRIFIED TILE CO. 5-IN. ID)
SLOPE (FT/FT) *10⁻¹
DISCHARGE (CFS)
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.10
0.15
0.20
0.25
0.30
0.35

FIGURE 10

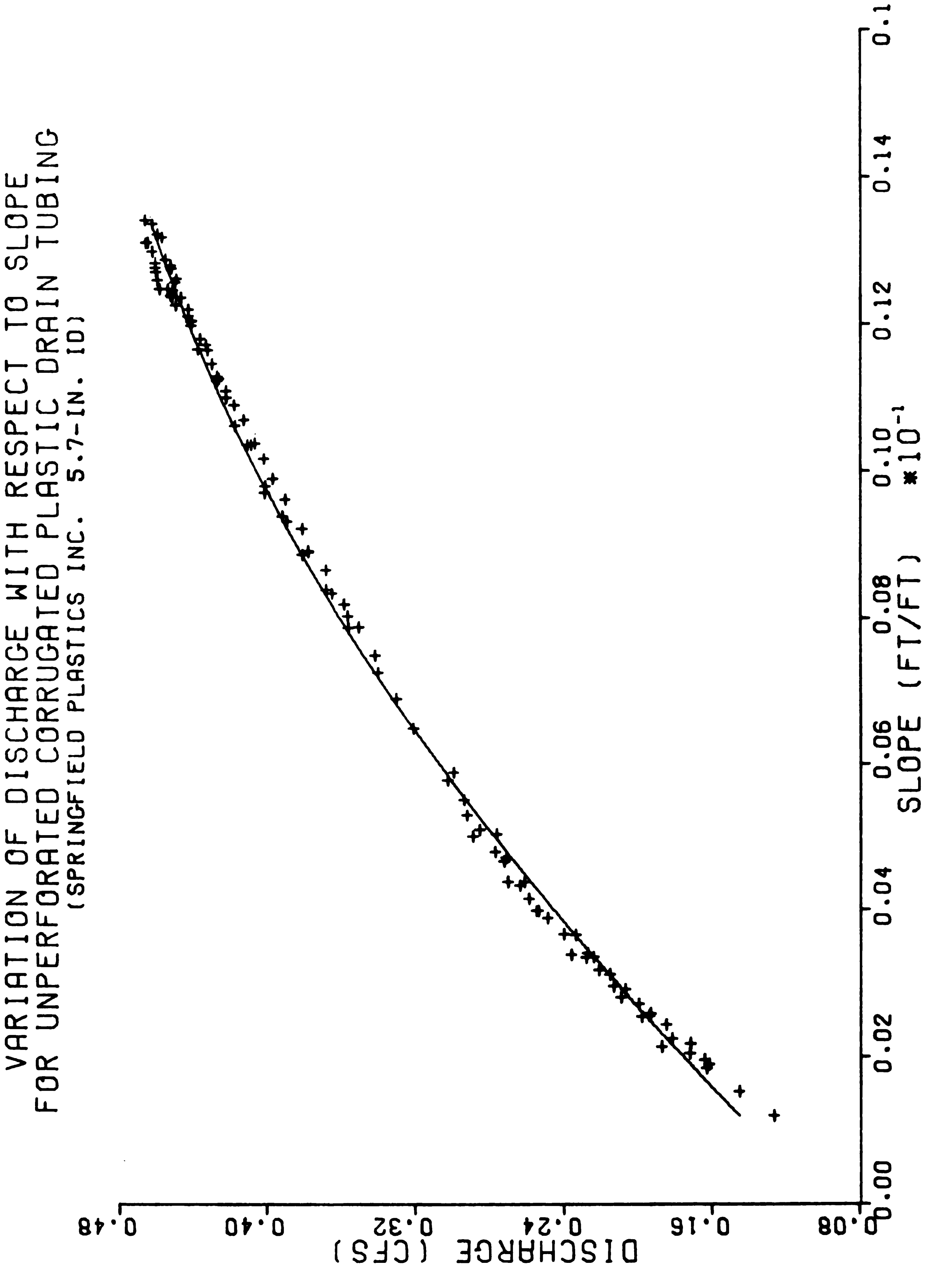

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(SPRINGFIELD PLASTICS INC. 5.7-IN. ID)
SLOPE (FT/FT) *10⁻¹
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
DISCHARGE (CFS)
0.08
0.16
0.24
0.32
0.40
0.48

FIGURE 11

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 6-IN. ID)

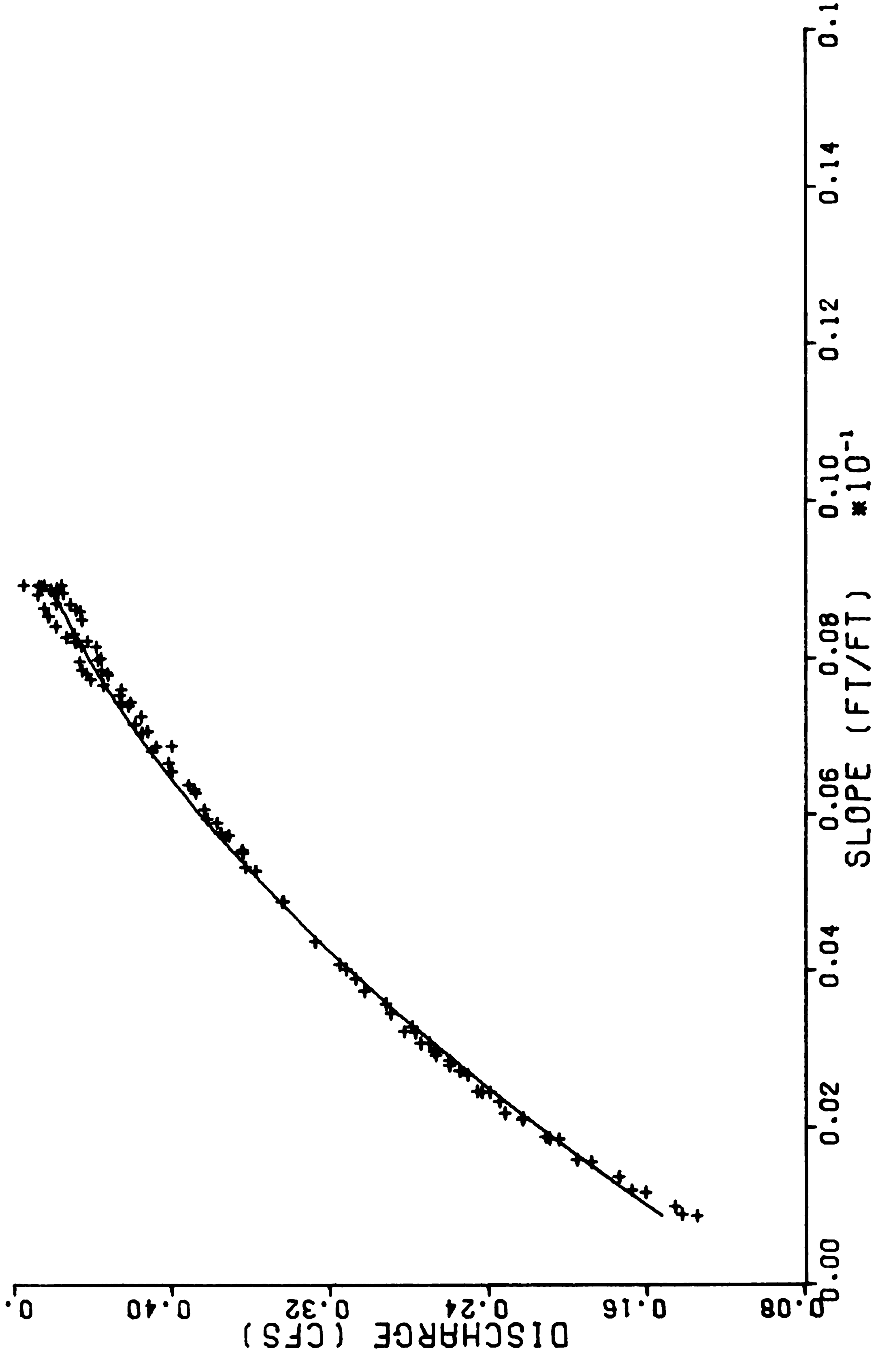


FIGURE 12

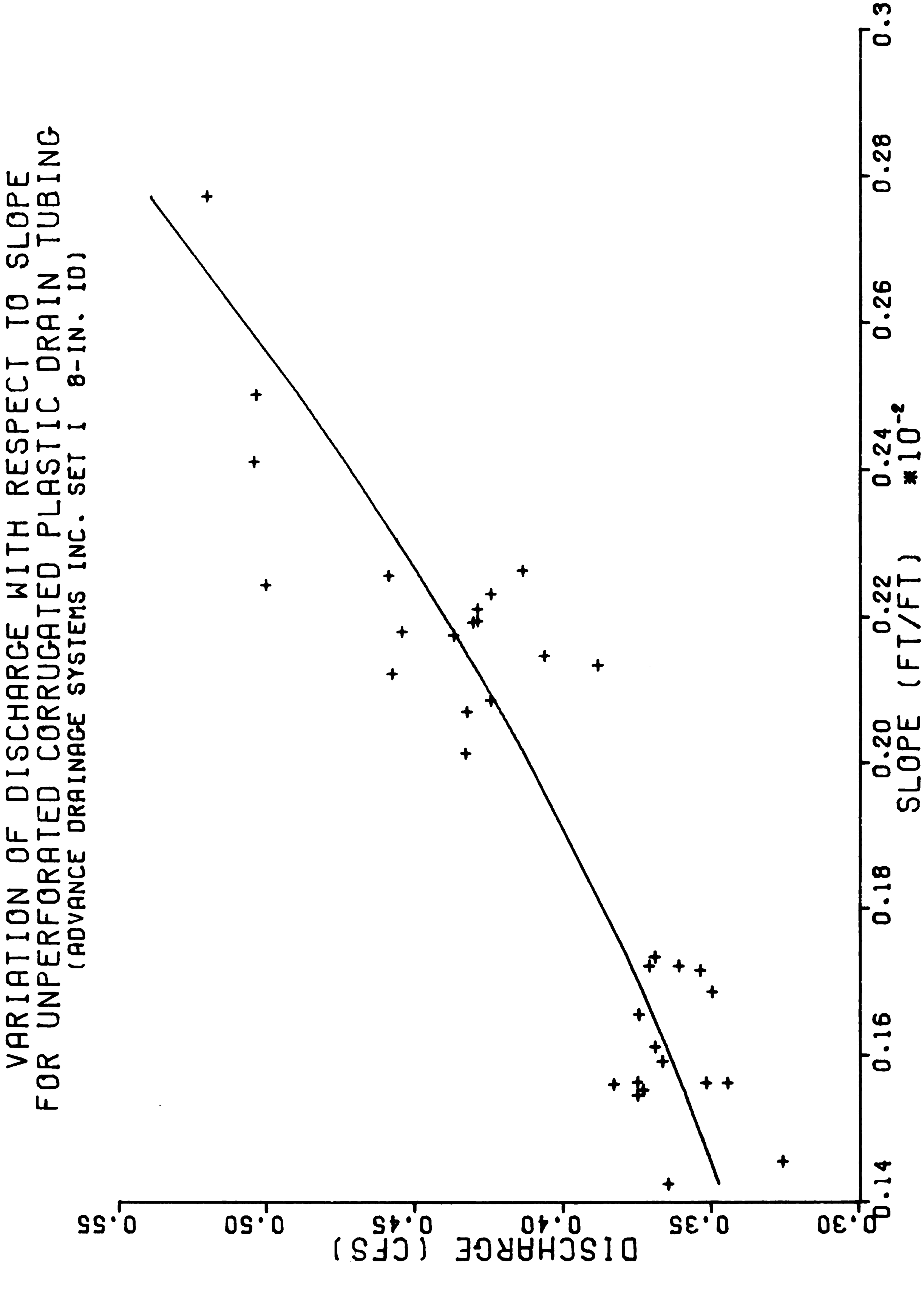

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET I 8-IN. ID)
DISCHARGE (CFS)
0.30
0.35
0.40
0.45
0.50
0.55
SLOPE (FT/FT) *10⁻²
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30

FIGURE 13

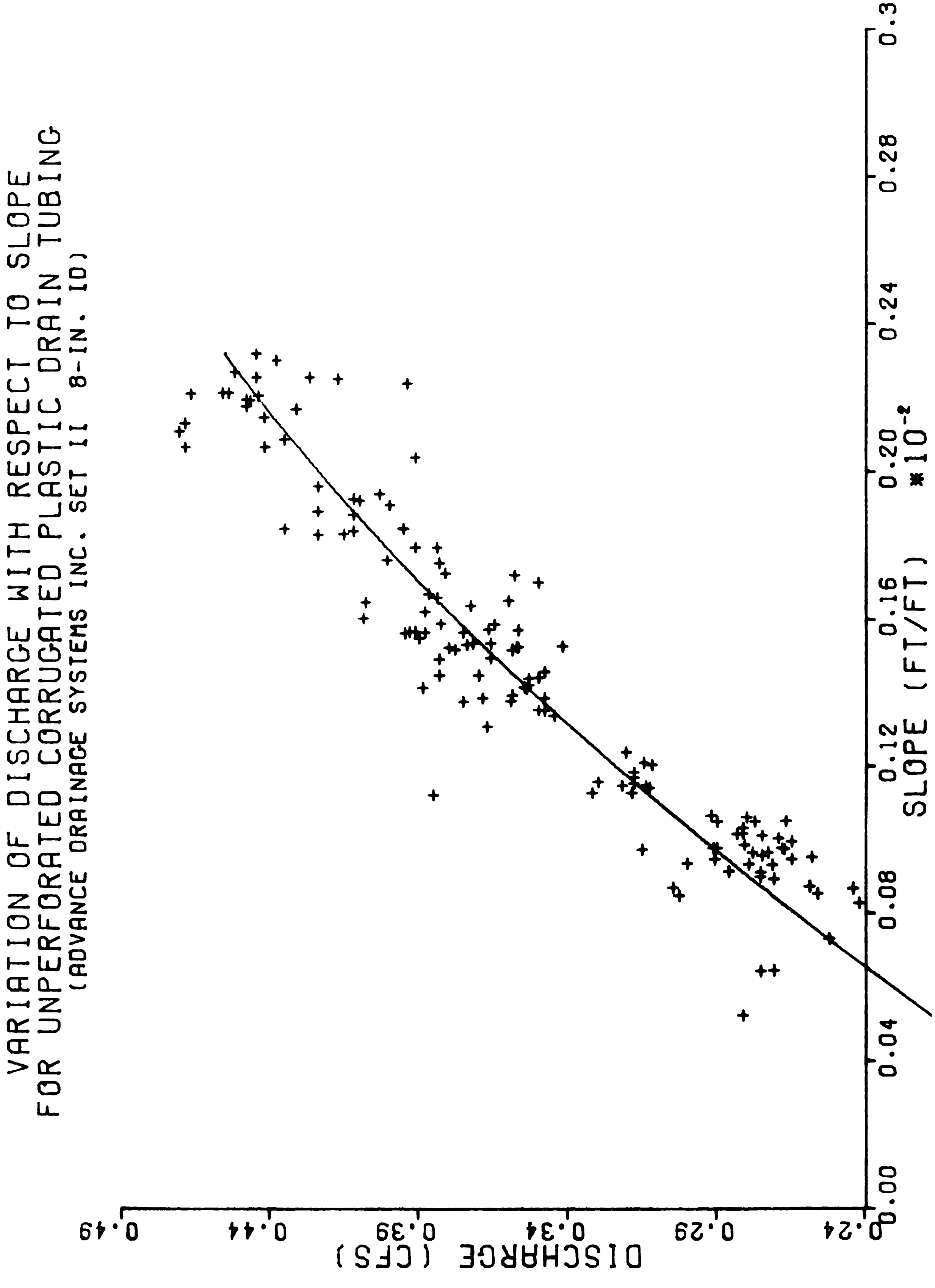

VARIATION OF DISCHARGE WITH RESPECT TO SLOPE
FOR UNPERFORATED CORRUGATED PLASTIC DRAIN TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET II 8-IN. ID)
SLOPE (FT/FT) $*10^{-2}$
DISCHARGE (CFS)
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.24
0.29
0.34
0.39
0.44
0.49

Figure 8 shows on the plot hysteresis between discharge and slope. This was probably due to experimental error on one of the replications.

Discharges measured by flowmeters appear in Figure 10 and 11. The curves show a smooth relationship between flow rates and slopes.

Widely scattered data points were obtained for two 8-inch tubing as shown in Figures 12 and 13. This was attributed to the method used to determine the rate of flow. This could be explained by the over accuracy of the method. As was mentioned in the experimental procedure section, a picture of the monometer board was taken at 5 seconds intervals. When the picture was snapped this gave an instantaneous location of the water levels in the monometer tubes. In other words, this did not allow consideration of fluctuations in the monometers. However, in the procedure of measurement taken by eye, the reading obtained was arrived at after the fluctuations diminished or if the fluctuations were too erratic an average reading was taken.

In the original plotting of the data, the data points were more widely scattered than in Figure 12 and 13. Actually these figures show re-evaluated values of the data points. The reevaluation was done to minimize the error on over-accuracy in such a way that the head drops used for each set of measurements, was obtained by considering the head drops on the preceeding and following measurements and taking the average of the two. This procedure was used for all the measurements.

Generally speaking, a fairly smooth parabolic relationship was obtained for discharge versus slope data. This relationship could be expressed as $Q = CS^m$. According to Manning's equations, these variable correspond to:

Q = Discharge

S = Slope

$m = \frac{1}{2}$

$$C = \frac{1.489}{n} R^{2/3} A$$

where:

n = Manning's coefficient

R = Hydraulic radius

A = Cross-sectional area

In order to verify Manning's equation the power m was determined from the data obtained for each set by using the least squares fitting method. This was done by taking the logarithms of both sides of the equation such as $\log Q = \log C + m \log S$ and these values are plotted. Straight lines were obtained for each set and the slope of these lines provided the m values. The values obtained, ranged from m = .5274 to .6132 or in other words the power m differed from the Manning m by .02 to .11.

Despite Manning's assumption that n remains constant, it was found that Manning's n coefficient changes with the slope as shown in Figures 14-21. Generally, the data points behave as assuming the constant n values on

FIGURE 14

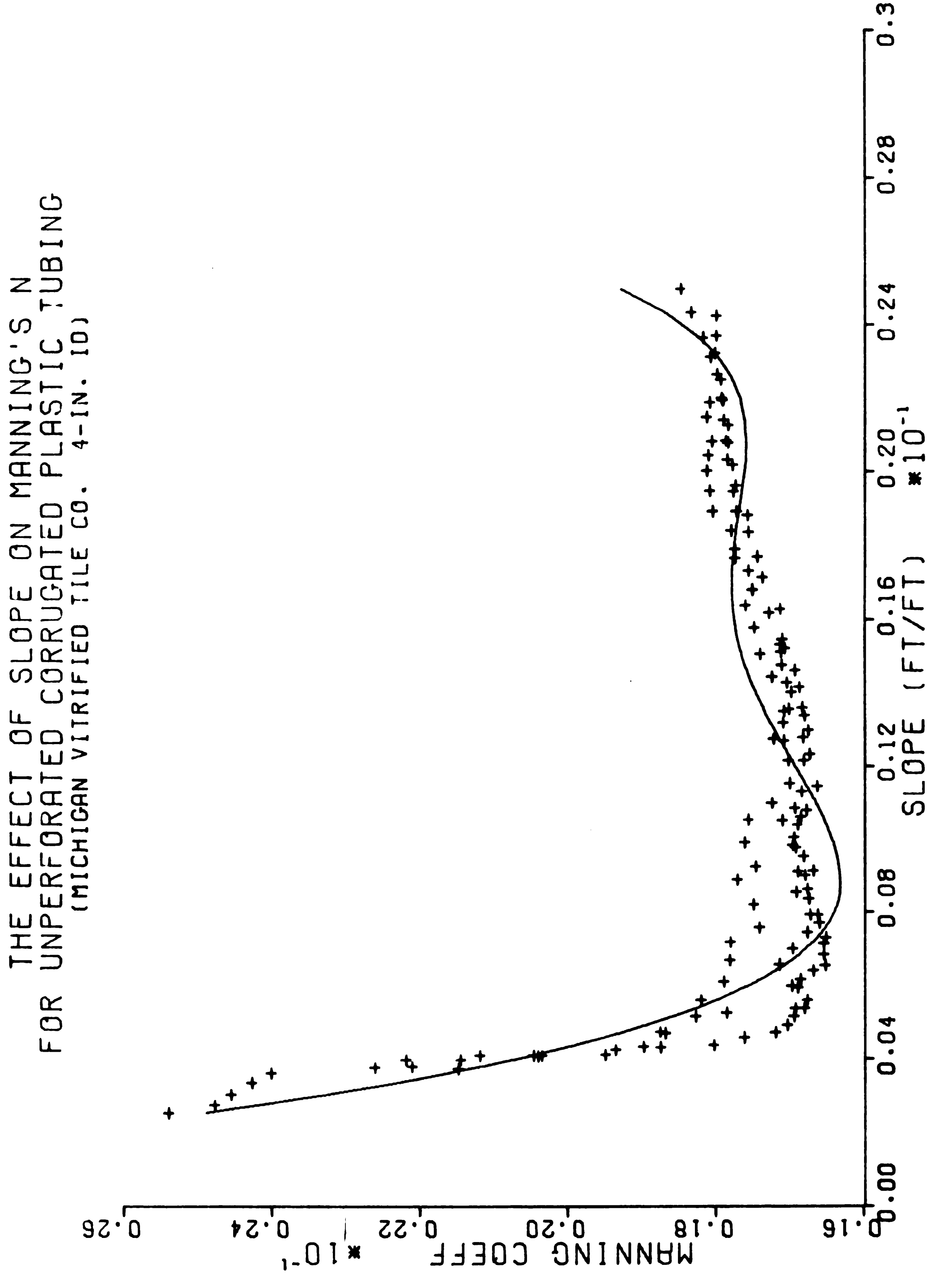

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(MICHIGAN VITRIFIED TILE CO. 4-IN. ID)
SLOPE (FT/FT) *10^-1
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
MANNING COEFF *10^-1
0.16
0.18
0.20
0.22
0.24
0.26

FIGURE 15

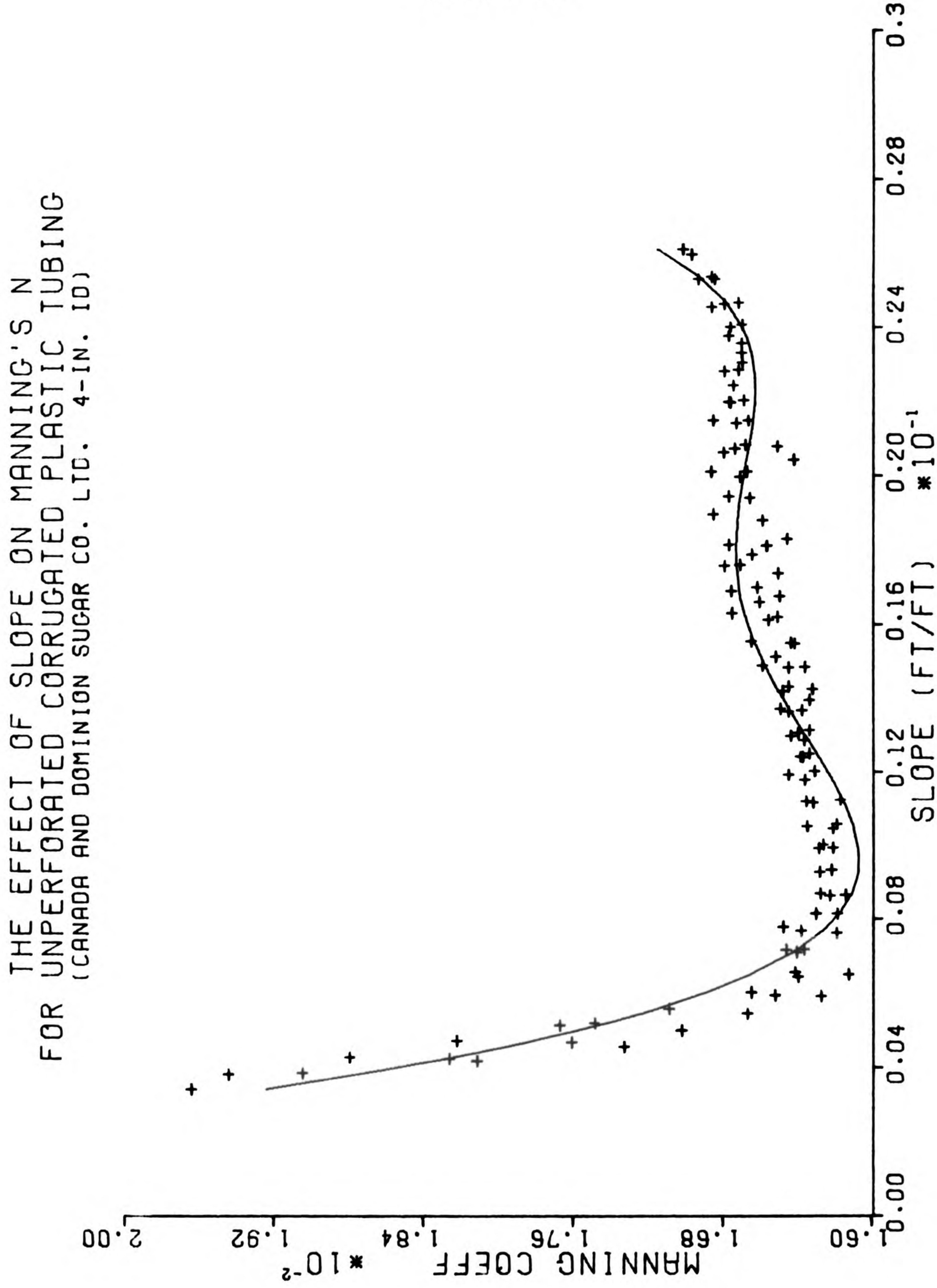

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(CANADA AND DOMINION SUGAR CO. LTD. 4-IN. ID)
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
SLOPE (FT/FT) $*10^{-1}$
1.60
1.68
1.76
1.84
1.92
2.00
MANNING COEFF $*10^{-2}$

FIGURE 16

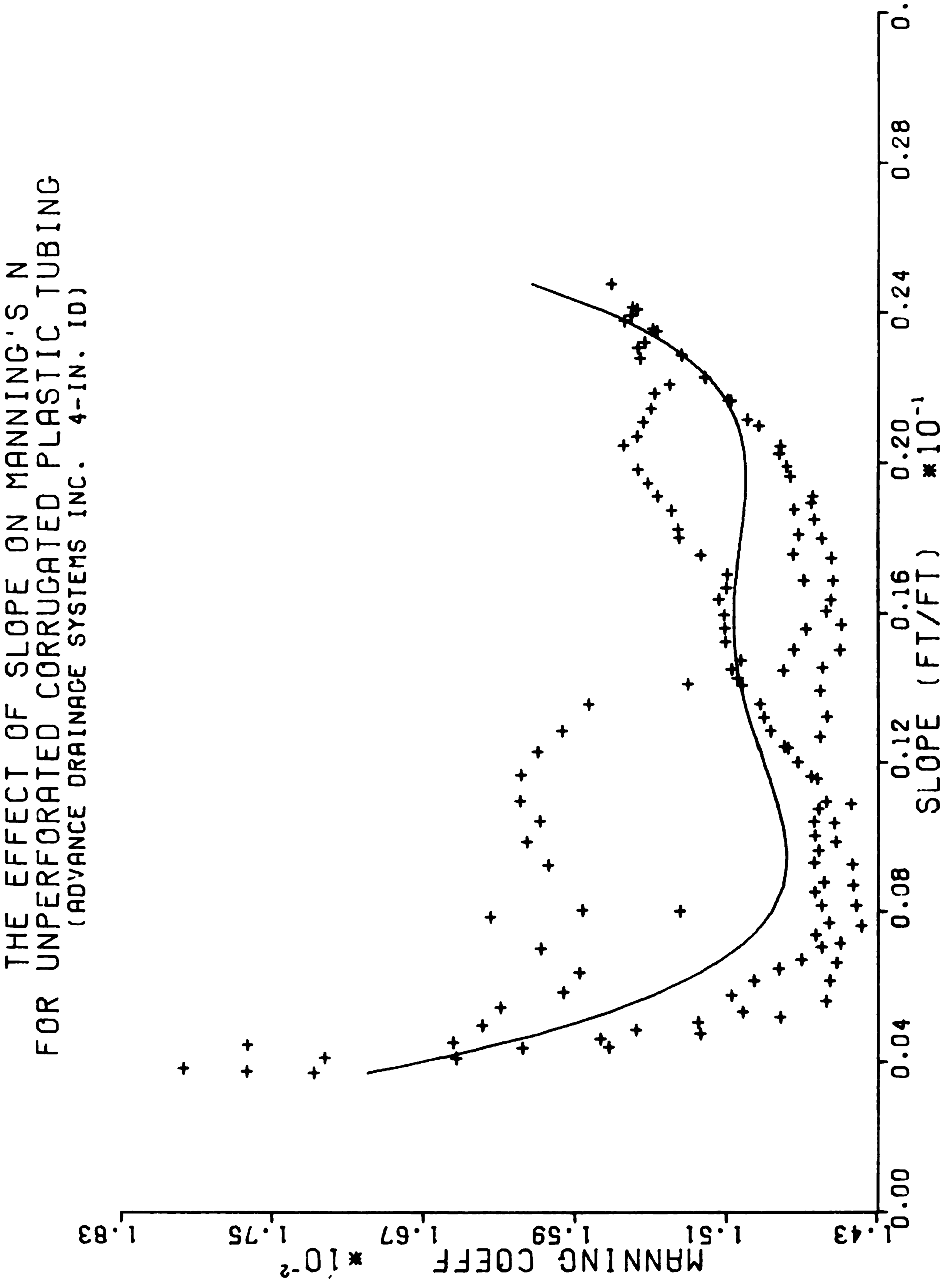
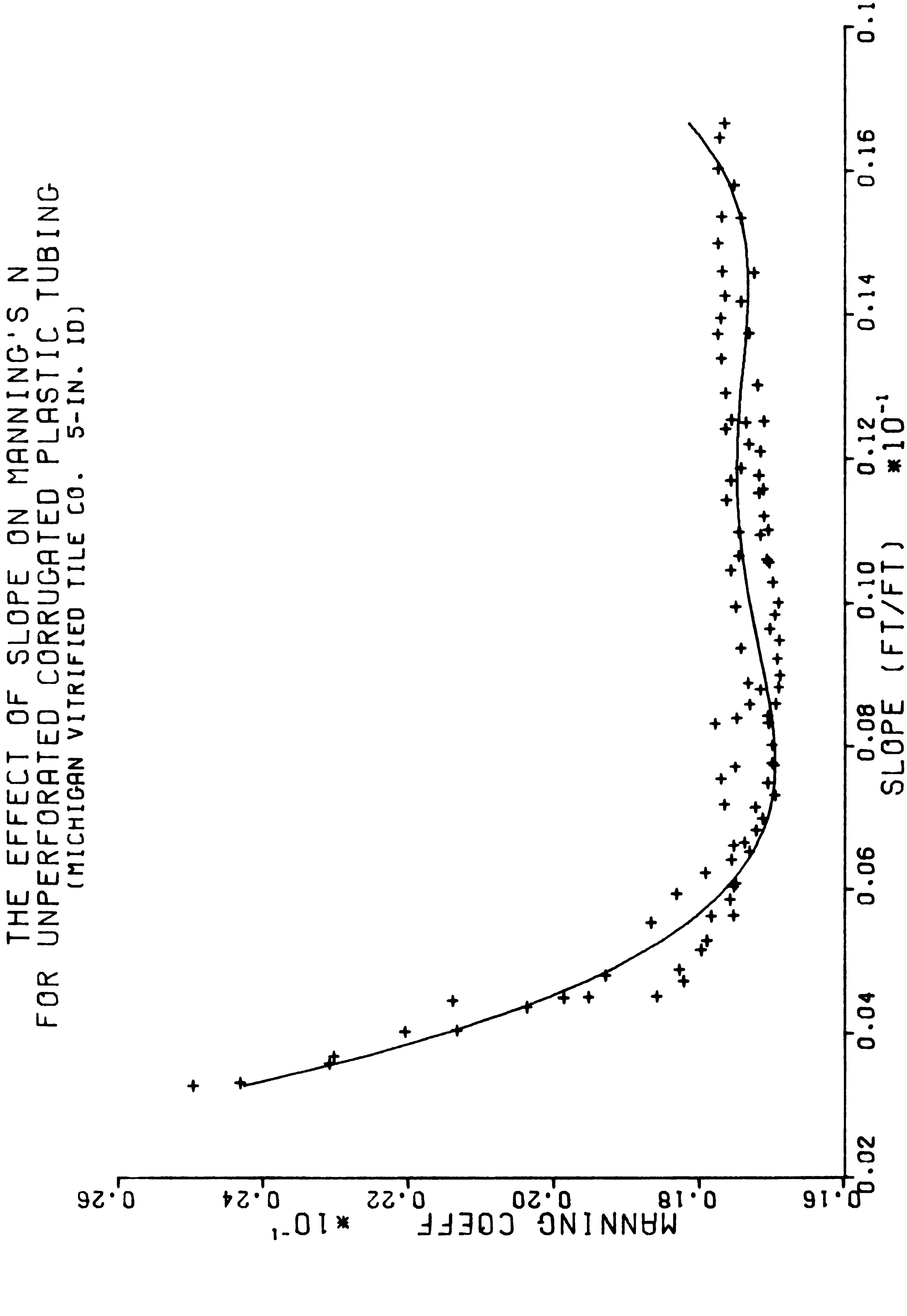

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 4-IN. ID)
SLOPE (FT/FT) *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
MANNING COEFF *10⁻²
1.43
1.51
1.59
1.67
1.75
1.83

FIGURE 17



THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(MICHIGAN VITRIFIED TILE CO. 5-IN. ID)
SLOPE (FT/FT) *10^-1
MANNING COEFF *10^-1
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.16
0.18
0.20
0.22
0.24
0.26

FIGURE 18

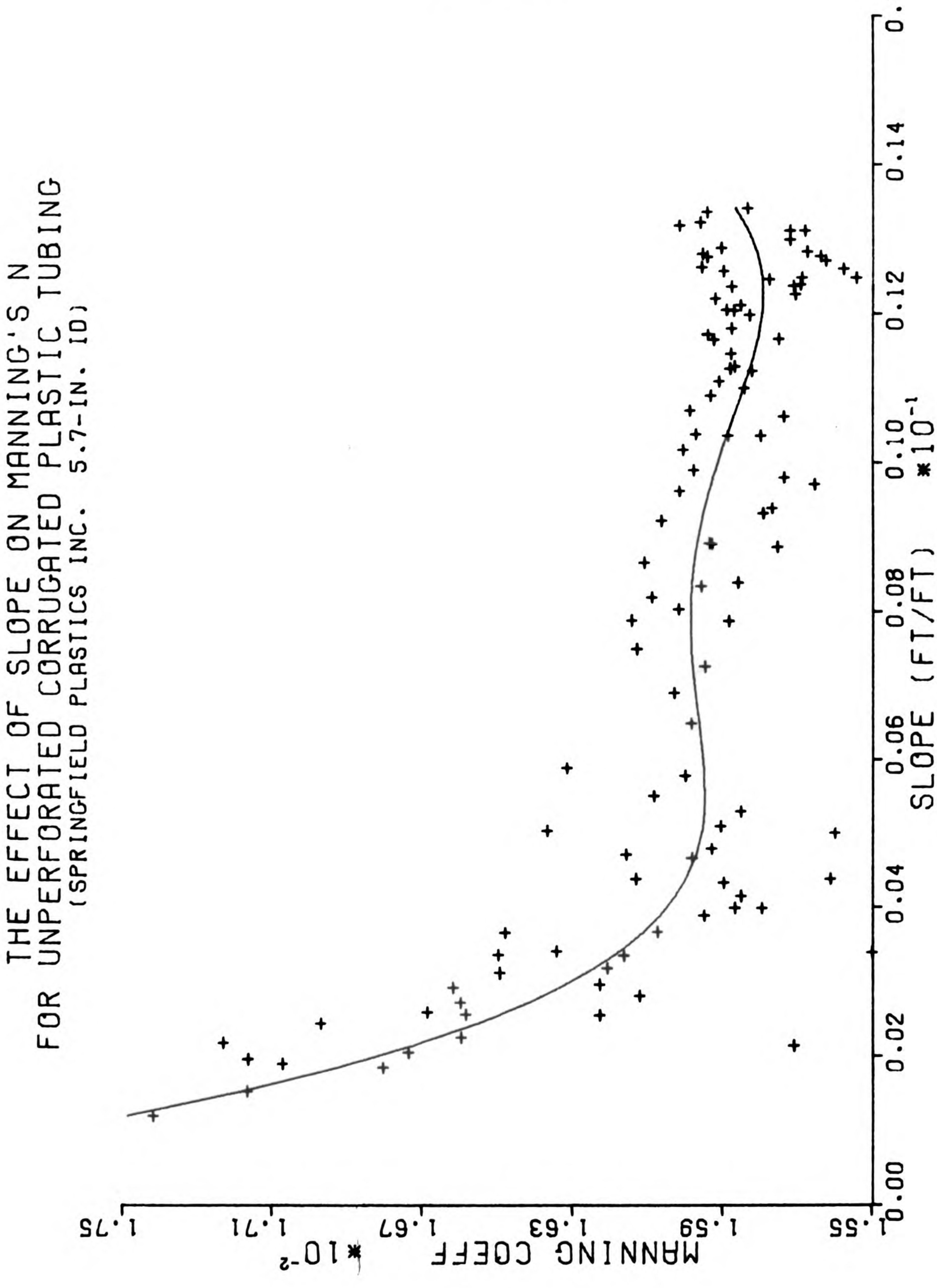

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(SPRINGFIELD PLASTICS INC. 5.7-IN. ID)
SLOPE (FT/FT) *10⁻¹
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
MANNING COEFF *10⁻²
1.55
1.59
1.63
1.67
1.71
1.75

FIGURE 19

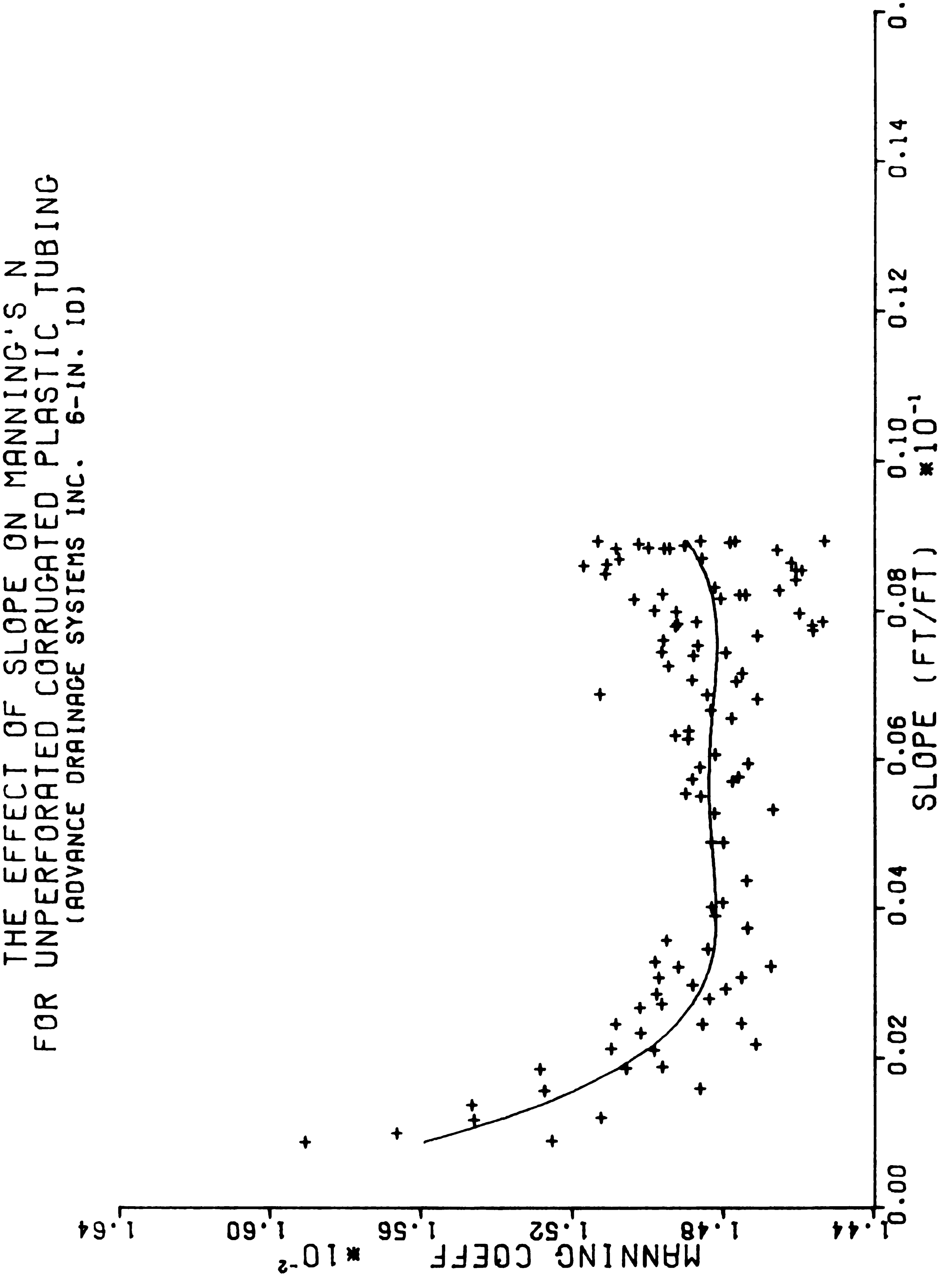

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 6-IN. ID)
SLOPE (FT/FT) *10⁻¹
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
MANNING COEFF *10⁻²
1.44
1.48
1.52
1.56
1.60
1.64

FIGURE 20

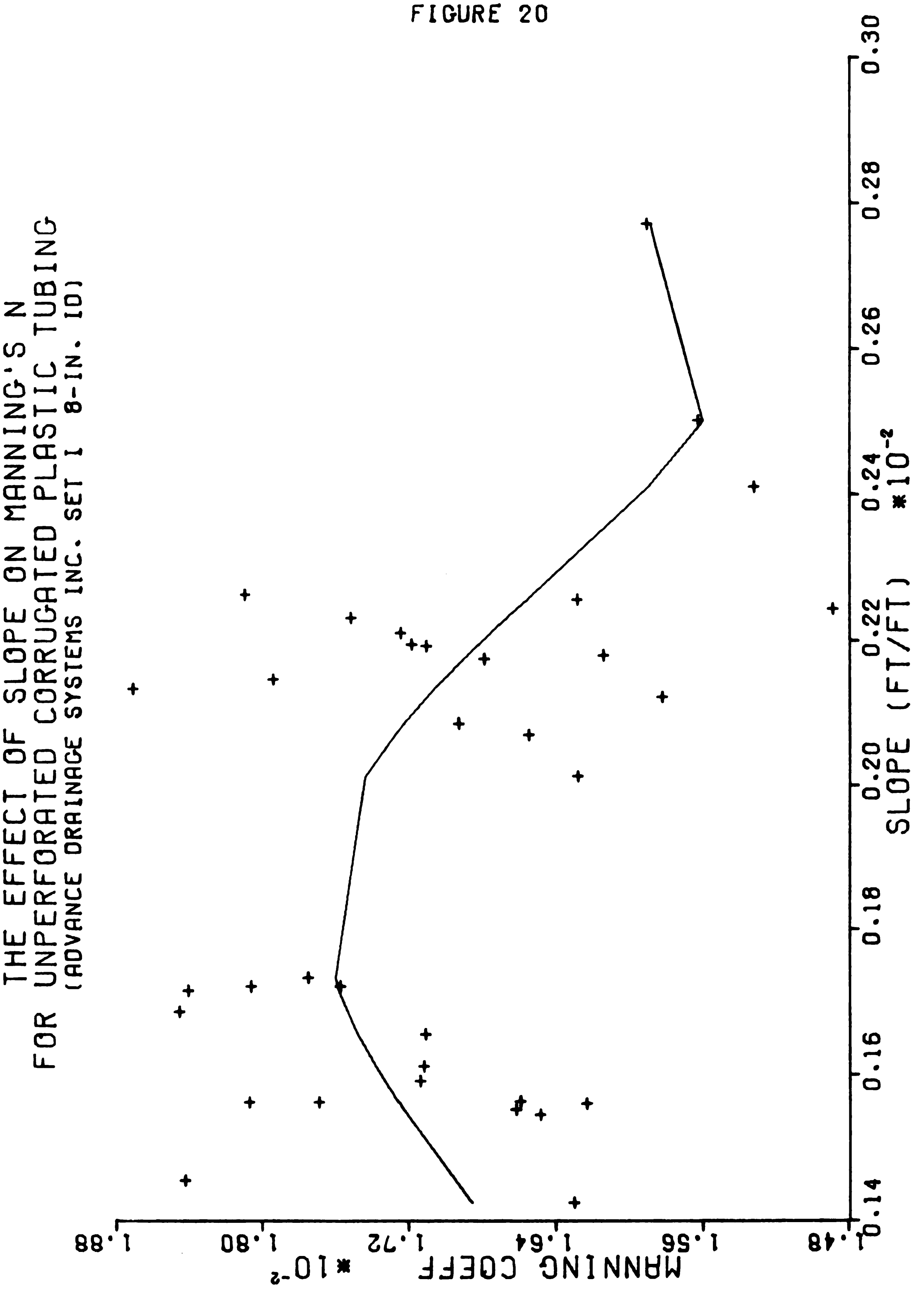
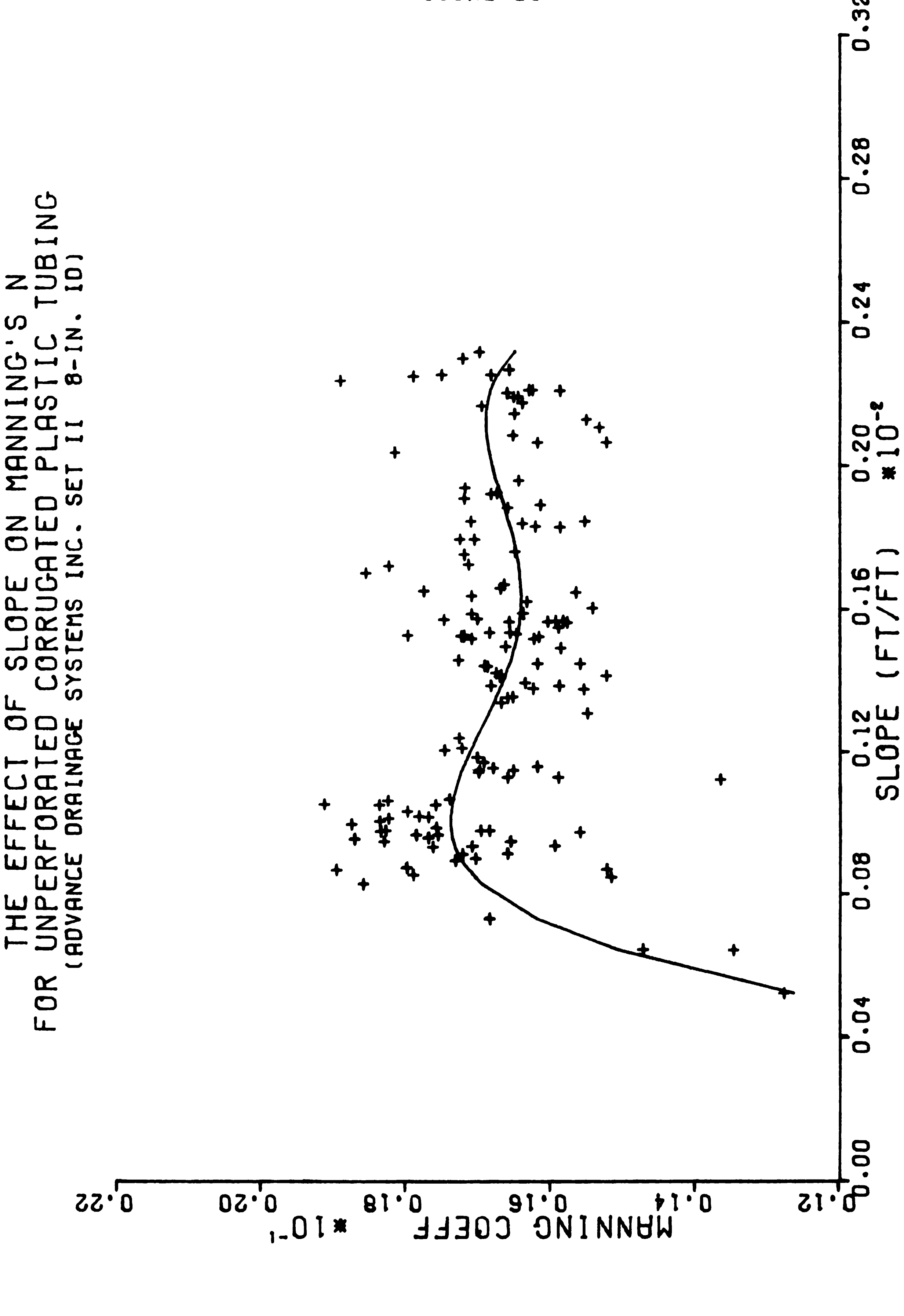

THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET I 8-IN. ID)
MANNING COEFF *10⁻²
1.48
1.56
1.64
1.72
1.80
1.88
SLOPE (FT/FT) *10⁻²
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30

FIGURE 21


THE EFFECT OF SLOPE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET II 8-IN. ID)
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
SLOPE (FT/FT) *10^-2
0.12
0.14
0.16
0.18
0.20
0.22
MANNING COEFF *10^-1

higher slopes, but on lower slopes they behave by making a curvature upward. The critical slope, where the data points show transition from a fairly constant n value to a rapidly increasing n value, is found to be between .006 and .008 ft/ft.

The behavior of Manning's n with respect to slope, was first thought to be related to the higher exponential values found for slopes in Manning's equation. By observing the data points it was assumed that Manning's n value was an inverse function of some power of the slope as in $n = \frac{C}{S^{\alpha}}$ and the exponent α was related to the difference found on Manning's power for the slopes. In order to verify this, the original computer programming was modified considering the new exponential values found for each set of tubing lines. The new Manning's n values were determined for the corresponding tubing and they were re-plotted in the same manner. All the curves obtained from the re-plotting were essentially similar to the previous curves. This seems to point to the fact that Manning's n was not an inverse function of slope. This was verified by using a Calcom plotter to obtain the best fitted curves to the data points. In the fitting process, the n^{th} order polynomial least square fitting was used. The fourth order equations gave the best fitted curves as shown on Figures 14 through 22.

The same phenomenon of the behavior of Manning's n can also be seen on the plots of discharge versus

Manning's coefficient for each set as shown in Figure 22 through Figure 29. In the same manner, Manning's n values are fairly constant on higher flow rates and sharply increases on lower discharges. For each set, Reynolds numbers strictly defines the turbulent flow for the critical velocities. This implies that even though the range of validity of Manning's equation is satisfied, the equation itself does not hold true for values of discharge beyond the critical discharges. This might be due to effects of corrugations on the flow of water through the tubing.

When the curves representing the same diameter of tubing are superimposed, the wider corrugated tubes reflect a higher value of Manning's n than the tubes with a narrower corrugation spacing.

The varying diameters of the tubes showed no significant effects on Manning's n coefficient for the same type of corrugation pattern (Figures 14 and 17).

It was observed that the type of corrugation had an effect on Manning's n coefficient. The helical corrugated tubing displayed higher n values than the regular corrugated tubing as seen in Figures 15 and 16.

FIGURE 22

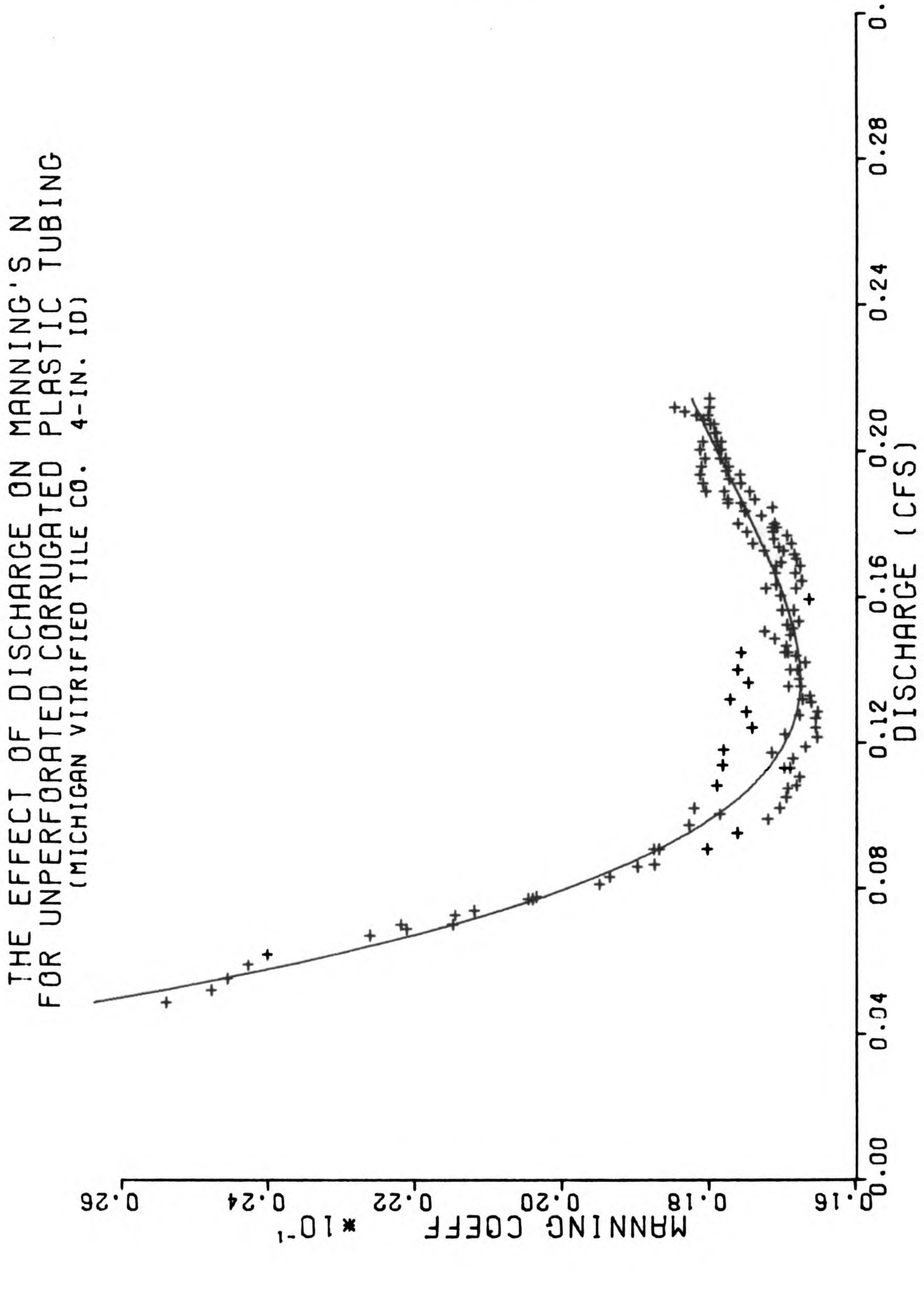

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(MICHIGAN VITRIFIED TILE CO. 4-IN. ID)
DISCHARGE (CFS)
MANNING COEFF *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.16
0.18
0.20
0.22
0.24
0.26

FIGURE 23

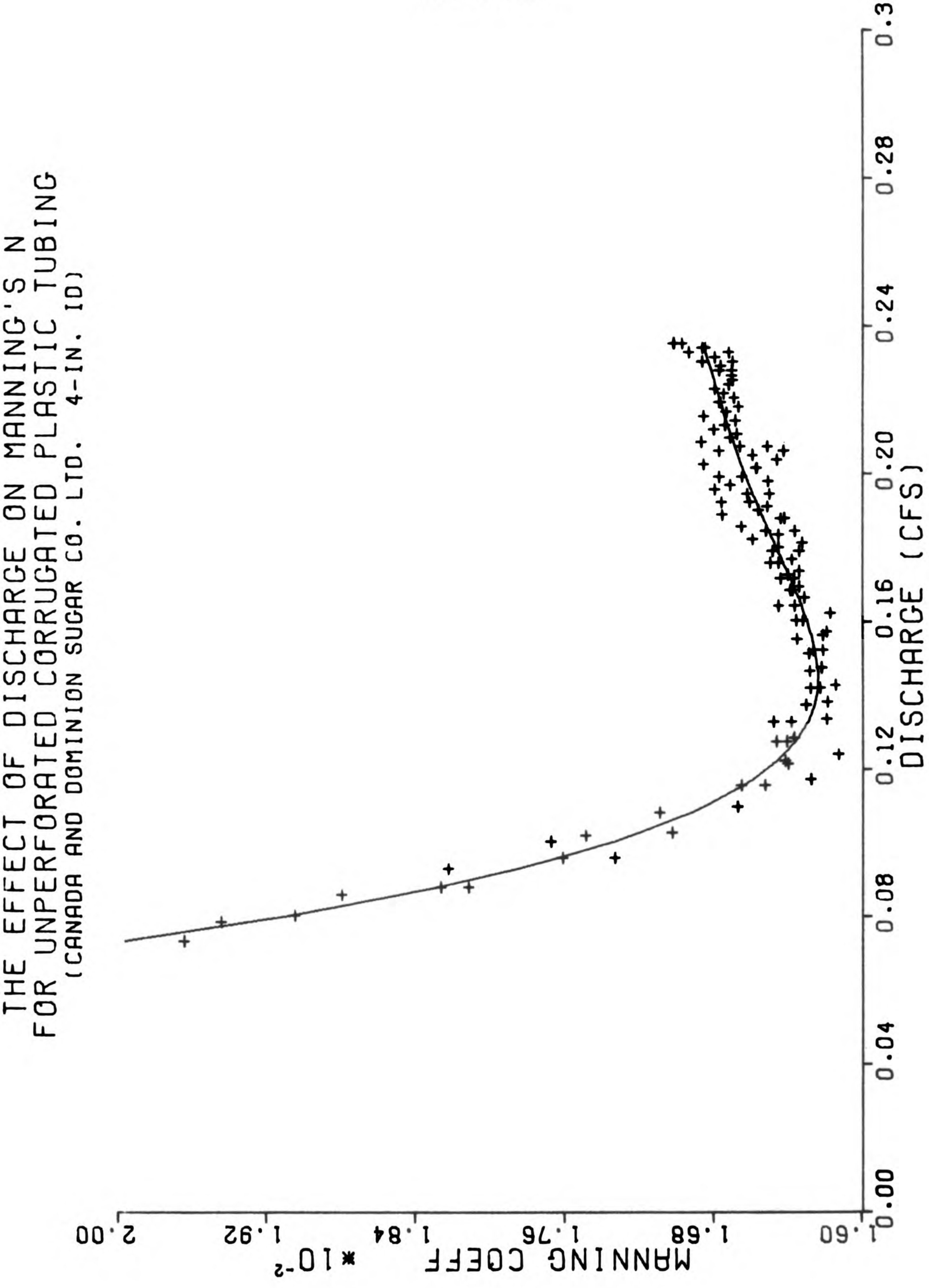

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(CANADA AND DOMINION SUGAR CO. LTD. 4-IN. ID)
DISCHARGE (CFS)
MANNING COEFF *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
1.60
1.68
1.76
1.84
1.92
2.00

FIGURE 24

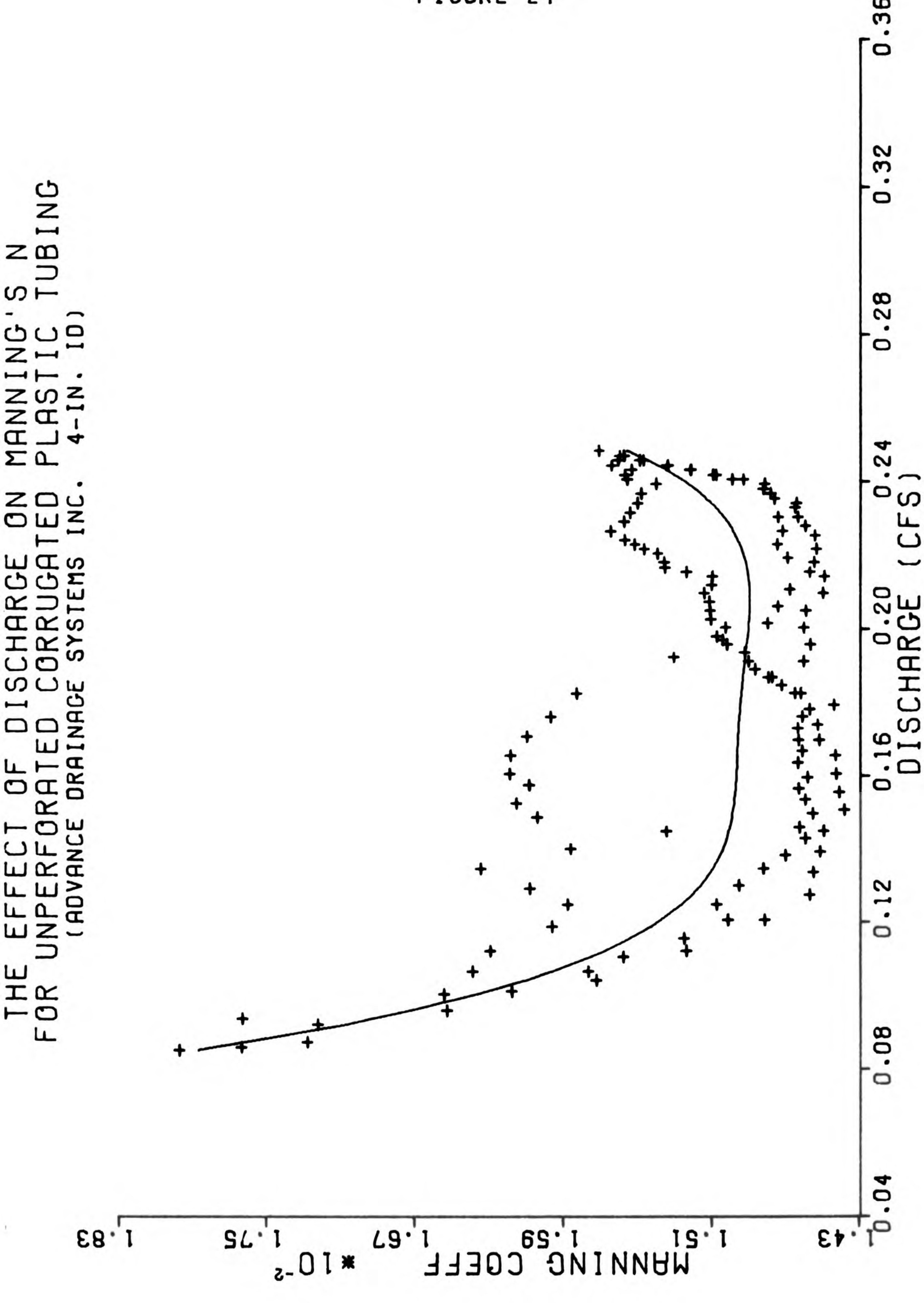

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 4-IN. ID)
DISCHARGE (CFS)
MANNING COEFF *10⁻²
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
1.43
1.51
1.59
1.67
1.75
1.83

FIGURE 25

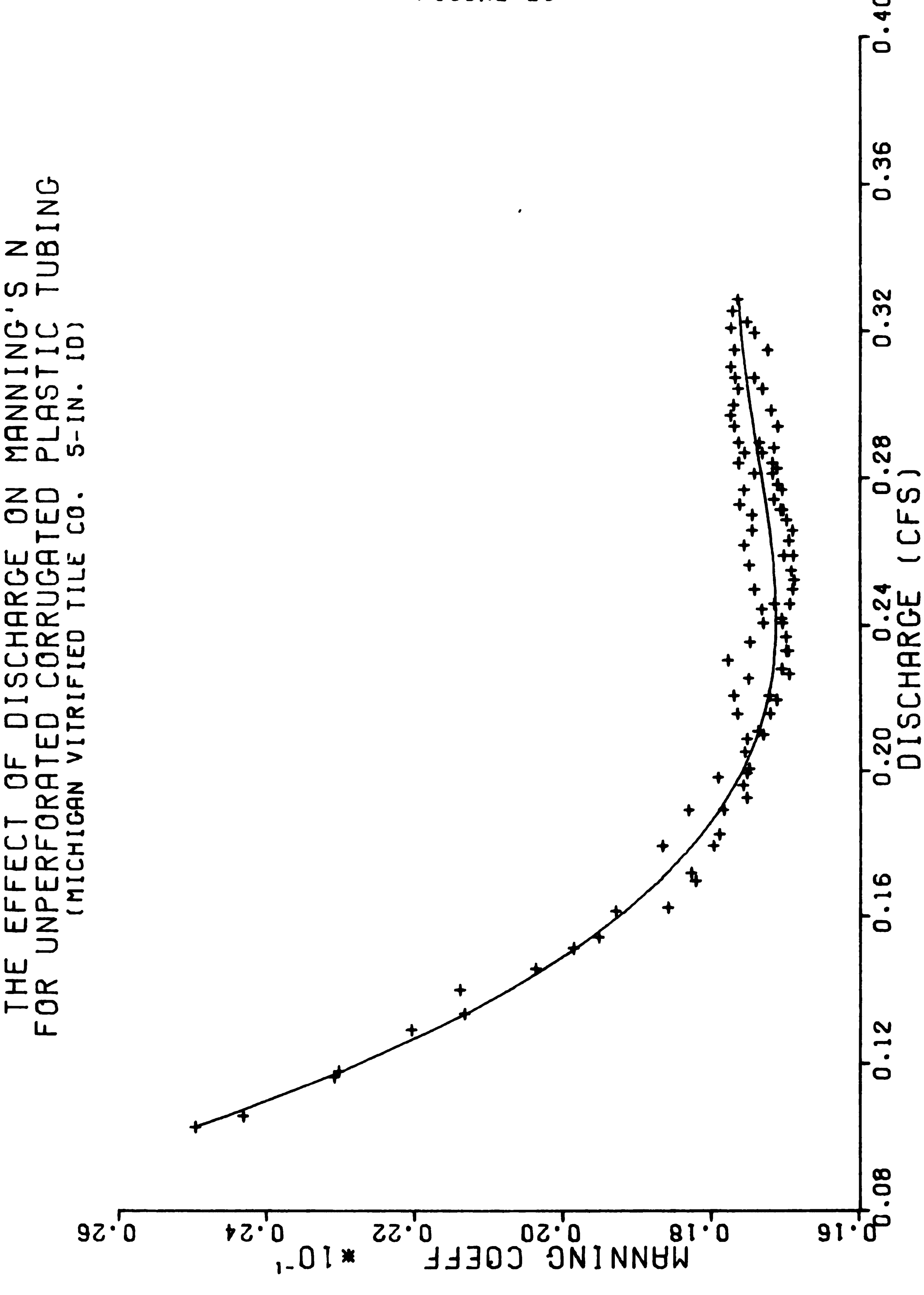

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(MICHIGAN VITRIFIED TILE CO. 5-IN. ID)
DISCHARGE (CFS)
MANNING COEFF *10⁻¹
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40
0.16
0.18
0.20
0.22
0.24
0.26

FIGURE 26

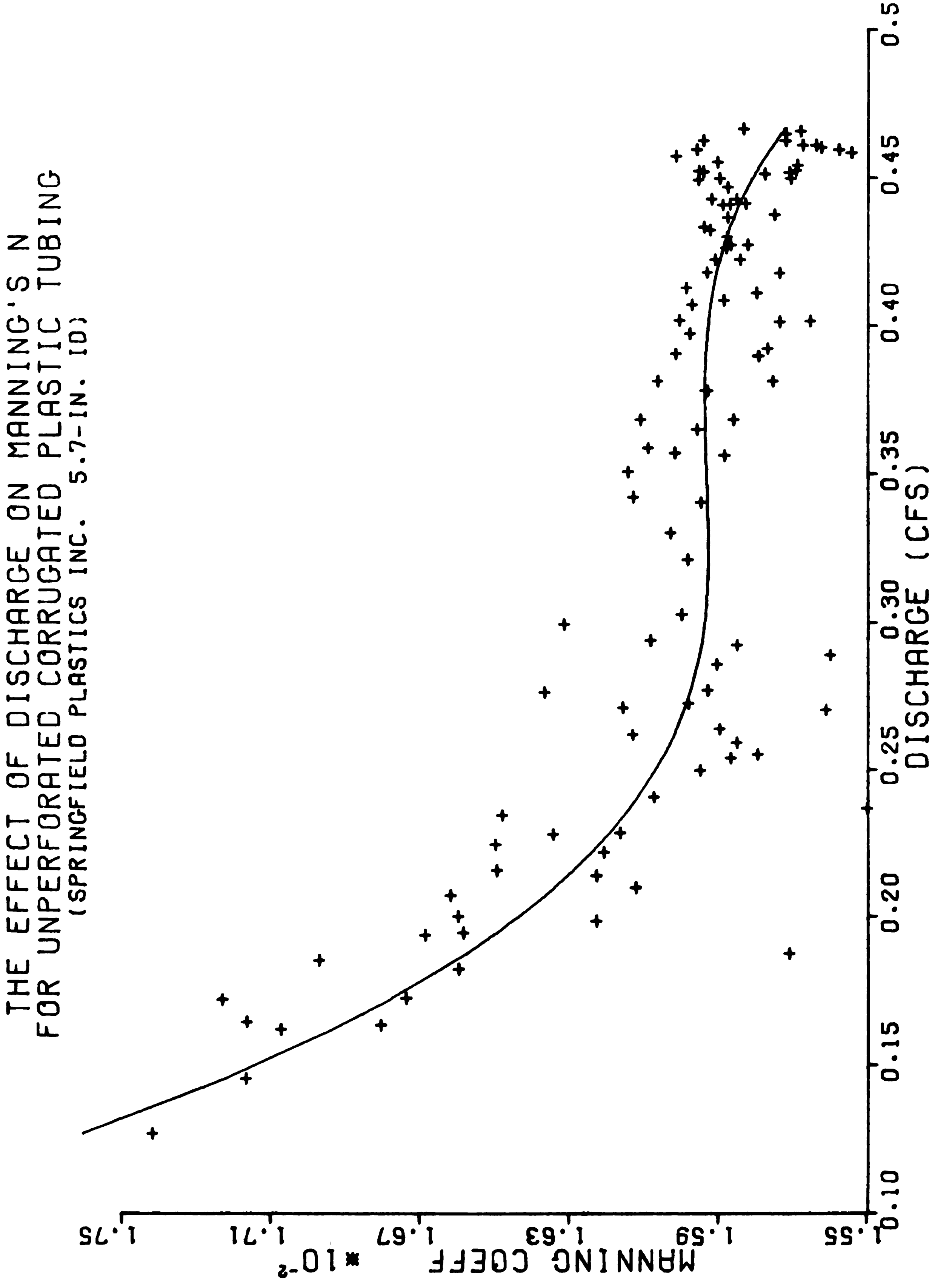

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(SPRINGFIELD PLASTICS INC. 5.7-IN. ID)
DISCHARGE (CFS)
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
MANNING COEFF *10⁻²
1.55
1.59
1.63
1.67
1.71
1.75

FIGURE 27

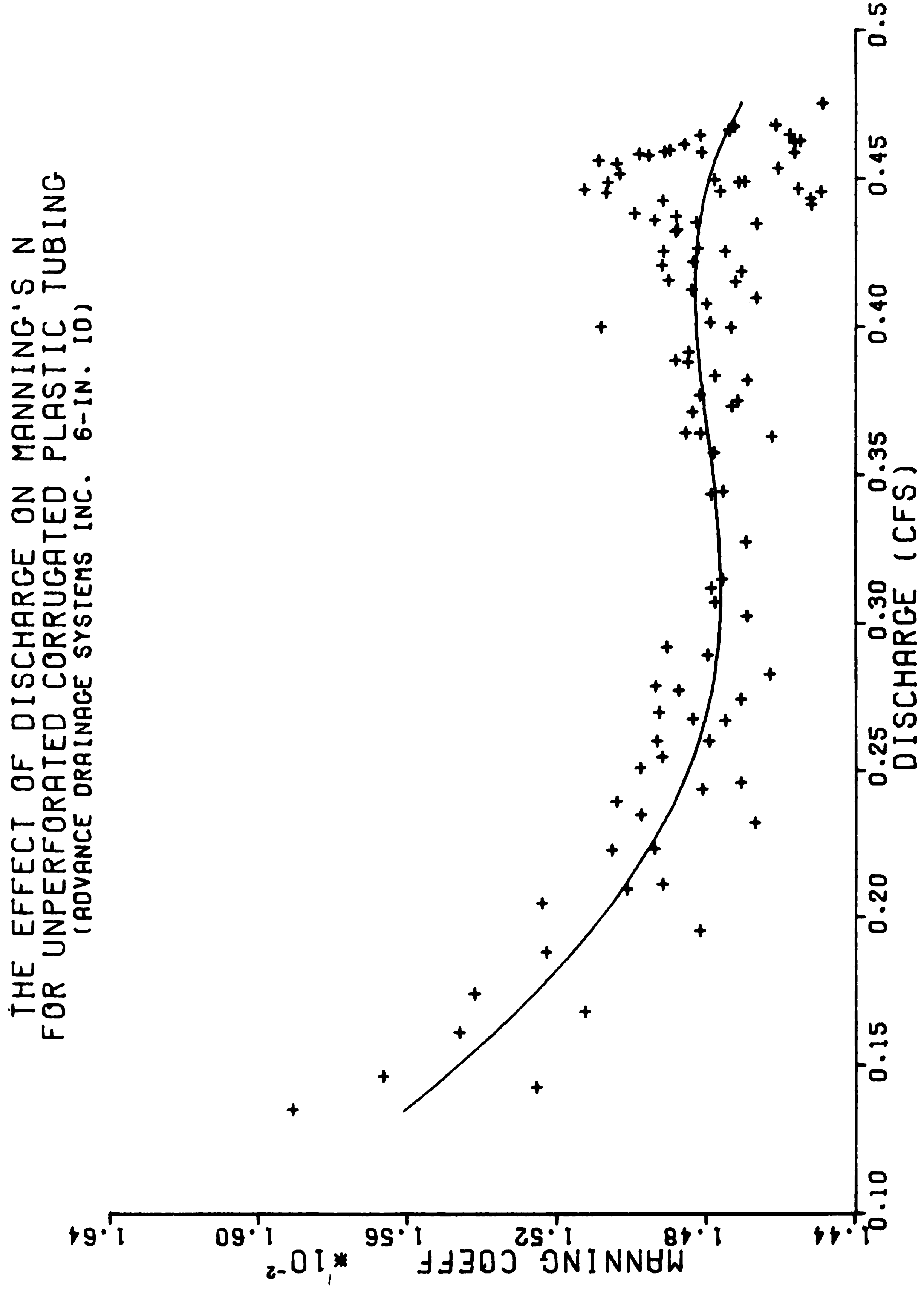
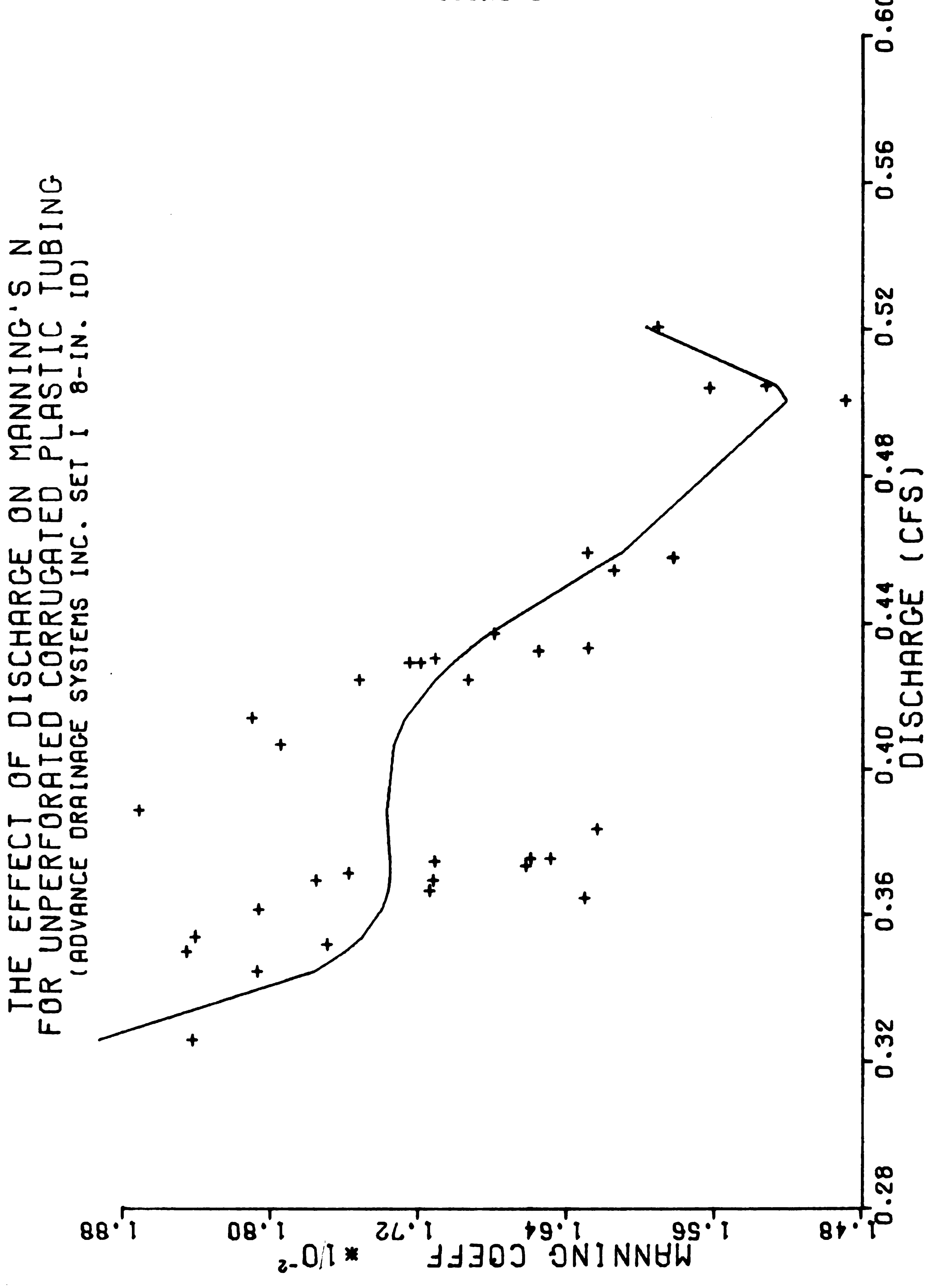
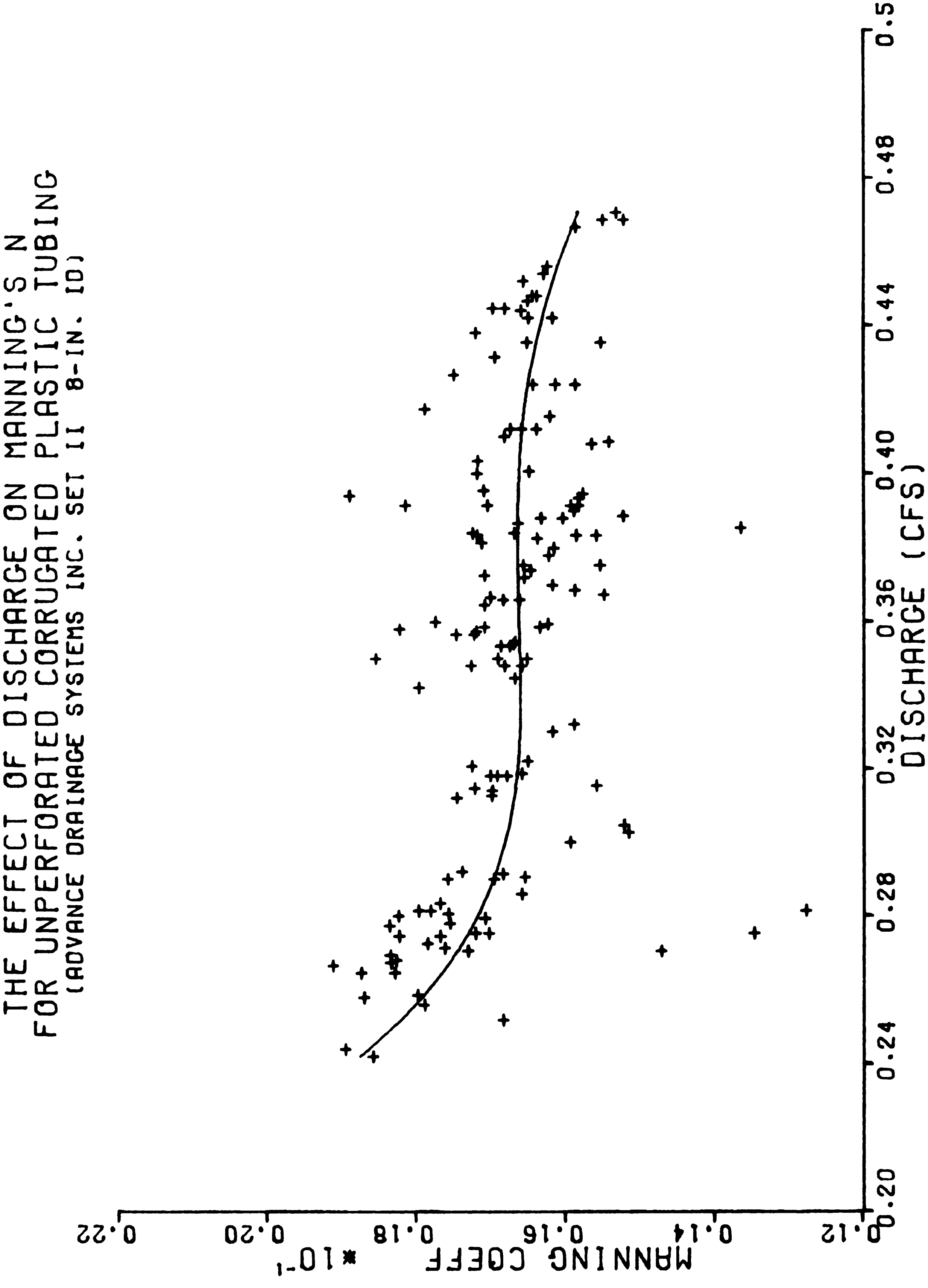

THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. 6-IN. ID)
DISCHARGE (CFS)
MANNING COEFF *10⁻²
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
1.44
1.48
1.52
1.56
1.60
1.64

FIGURE 28



THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET I 8-IN. ID)
DISCHARGE (CFS)
MANNING COEFF * 1/0⁻²
0.28
0.32
0.36
0.40
0.44
0.48
0.52
0.56
0.60
1.48
1.56
1.64
1.72
1.80
1.88

FIGURE 29


THE EFFECT OF DISCHARGE ON MANNING'S N
FOR UNPERFORATED CORRUGATED PLASTIC TUBING
(ADVANCE DRAINAGE SYSTEMS INC. SET II 8-IN. ID)
MANNING COEFF *10⁻¹
0.12
0.14
0.16
0.18
0.20
0.22
DISCHARGE (CFS)
0.20
0.24
0.28
0.32
0.36
0.40
0.44
0.48
0.52

CONCLUSION

1. The coefficient of Manning's formula became a dependent function of slope beyond the slope of .006 and .008 ft/ft.

2. The corrugation spacing had an effect on Manning's n coefficient with the wider spacing giving a higher n value.

3. The varying diameters of the tubing with the same type of corrugation showed no significant effect on Manning's n.

4. The varying types of corrugation had an effect on Manning's coefficient with the helical corrugated tubing giving a higher n value than the regular corrugated tiles.

SUGGESTIONS FOR FUTURE WORK

1. Further studies should be continued to determine the exact behavior of the Manning's n on lower slopes.

2. The same experiment should be repeated under partly full conditions.

3. An experiment should be conducted on perforated corrugated plastic tiles under water intake condition through the tile line as an objective of determining the behavior of Manning's n under field inflow conditions.

RECOMMENDATIONS FOR FIELD INSTALLATIONS

Recommended Manning n values are tabulated in Table 2 for each set of tile lines. These n values should be used on slopes greater than .008 ft/ft for design purposes. In designing drainage systems with slopes less than .008 ft/ft, the designer should refer to Darcy-Weishbach equation for basic calculations.

TABLE 2.--Recommended Manning n values for slopes greater than .008 ft/ft.

Type of Tiles	Average n
Michigan Vitrified Tile Co., 4-in.	.0178
Canada Dominion Sugar Co., Ltd., 4-in.	.0169
Advance Drainage Systems, Inc., 4-in.	.0151
Michigan Vitrified Tile Co., 5-in.	.0178
Springfield Plastics Inc.	.0159
Advance Drainage Systems, Inc., 6-in.	.0150
Advance Drainage Systems, Inc., 8-in. (Set I)	.0180
Advance Drainage Systems, Inc., 8-in. (Set II)	.0150

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APPENDIX

MANOMETER, WEIR AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Advance Drainage Systems, Inc. 4-inch ID

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir* h inches	Temp. F°
1	14.32	11.50	8.63	5.61	10.61	68
2	14.06	11.27	8.55	5.57	10.60	68
3	13.80	11.13	8.49	5.54	10.59	68
4	13.55	10.92	8.33	5.51	10.58	68
5	13.30	10.72	8.24	5.48	10.57	68
6	13.03	10.53	8.11	5.45	10.56	68
7	12.71	10.32	7.94	5.41	10.54	69
8	12.46	10.11	7.82	5.37	10.52	69
9	12.15	9.97	7.71	5.33	10.50	70
10	11.96	9.77	7.60	5.29	10.48	70
11	11.73	9.58	7.47	5.24	10.46	70
12	11.49	9.40	7.34	5.19	10.44	71
13	11.23	9.21	7.22	5.14	10.41	71
14	10.99	9.01	7.08	5.09	10.38	71
15	10.71	8.80	6.96	5.05	10.35	72
16	10.42	8.60	6.84	5.00	10.31	72
17	10.20	8.42	6.73	4.95	10.27	72
18	9.92	8.24	6.61	4.90	10.23	72

*h values correspond to heads measured on the weir with respect to a datum. Value of h - 5.85" gives head causing flow over the weir.

Advance Drainage Systems, Inc., 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
19	9.62	8.05	6.50	4.85	10.19	72
20	9.38	7.86	6.39	4.80	10.15	72
21	9.13	7.62	6.20	4.70	10.11	72
22	8.82	7.44	6.08	4.65	10.07	72
23	8.54	7.23	5.92	4.60	10.03	72
24	8.28	7.04	5.79	4.55	9.99	72
25	8.03	6.83	5.65	4.48	9.95	72
26	7.76	6.65	5.55	4.42	9.91	72
27	7.49	6.48	5.42	4.36	9.86	72
28	7.23	6.29	5.29	4.30	9.81	72
29	6.94	6.03	5.11	4.20	9.76	72
30	6.68	5.86	5.01	4.10	9.70	72
31	6.41	5.68	4.89	4.02	9.64	72
32	6.16	5.47	4.75	3.94	9.59	73
33	5.89	5.28	4.64	3.86	9.51	73
34	5.63	5.09	4.50	3.75	9.43	73
35	5.36	4.88	4.32	3.64	9.33	73
36	5.10	4.69	4.16	3.52	9.23	73
37	4.83	4.43	3.92	3.36	9.12	73
38	4.55	4.20	3.73	3.22	9.00	73
39	14.32	11.49	8.71	5.62	10.61	73
40	14.07	11.38	8.57	5.58	10.60	73
41	13.80	11.07	8.62	5.54	10.59	73
42	13.52	10.87	8.30	5.48	10.58	74
43	13.26	10.69	8.16	5.44	10.57	74
44	13.04	10.50	8.06	5.40	10.56	74
45	12.74	10.30	7.94	5.36	10.55	74
46	12.50	10.16	7.82	5.32	10.32	74
47	12.20	9.87	7.70	5.28	10.51	74
48	12.01	9.76	7.57	5.24	10.48	74
49	11.72	9.60	7.45	5.20	10.45	74

Advance Drainage Systems, Inc., 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
50	11.51	9.39	7.36	5.16	10.42	74
51	11.21	9.18	7.21	5.12	10.39	74
52	10.90	8.87	7.08	5.08	10.36	74
53	10.65	8.75	6.96	5.02	10.32	74
54	10.40	8.59	6.84	4.98	10.28	74
55	10.15	8.40	6.72	4.93	10.24	74
56	10.02	8.30	6.61	4.88	10.20	50
57	9.81	8.13	6.46	4.73	10.16	50
58	9.55	7.92	6.33	4.66	10.07	50
59	9.24	7.73	6.22	4.61	10.01	50
60	8.98	7.51	6.08	4.55	9.96	50
61	8.69	7.29	5.93	4.48	9.91	50
62	8.39	7.09	5.82	4.43	9.86	50
63	8.14	6.90	5.68	4.38	9.83	50
64	7.87	6.70	5.52	4.32	9.78	51
65	7.60	6.50	5.41	4.27	9.74	51
66	7.30	6.30	5.30	4.22	9.70	51
67	7.02	6.10	5.17	4.12	9.65	51
68	6.85	5.88	5.00	4.00	9.59	51
69	6.48	5.68	4.85	3.95	9.53	51
70	8.19	5.47	4.74	3.88	9.48	51
71	5.91	5.26	4.60	3.79	9.41	51
72	5.64	5.05	4.46	3.66	9.33	51
73	5.37	4.86	4.29	3.57	9.26	52
74	5.09	4.66	4.14	3.46	9.18	52
75	4.82	4.43	3.95	3.33	9.07	52
76	4.55	4.25	3.73	3.18	8.97	52
77	14.31	14.51	8.64	5.57	10.62	54
78	14.20	11.41	8.55	5.52	10.61	54
79	14.10	11.30	8.47	5.48	10.60	54
80	14.02	11.23	8.42	5.44	10.59	54

Advance Drainage Systems, Inc., 4-inch ID.--Continued.

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
81	13.80	11.11	8.39	5.43	10.58	54
82	13.73	11.04	8.34	5.41	10.57	54
83	13.61	10.92	8.25	5.39	10.56	54
84	13.32	10.70	8.12	5.35	10.55	54
85	13.20	10.60	8.07	5.31	10.53	54
86	13.02	10.50	8.01	5.28	10.51	54
87	12.87	10.40	7.94	5.26	10.49	54
88	12.71	10.30	7.87	5.24	10.47	54
89	12.60	10.20	7.81	5.22	10.45	54
90	12.35	10.04	7.72	5.20	10.43	54
91	12.20	9.90	7.64	5.17	10.42	54
92	12.05	9.79	7.56	5.15	10.41	54
93	11.89	9.67	7.48	5.13	10.40	54
94	11.67	9.50	7.36	5.09	10.38	55
95	11.56	9.40	7.28	5.06	10.37	55
96	11.36	9.29	7.21	5.03	10.36	55
97	11.16	9.15	7.15	5.01	10.35	55
98	11.01	9.02	7.08	4.99	10.33	55
99	10.87	8.93	7.00	4.96	10.31	55
100	10.66	8.77	6.87	4.91	10.29	55
101	10.50	8.66	6.81	4.88	10.27	55
102	10.35	8.52	6.75	4.85	10.25	55
103	10.13	8.40	6.65	4.82	10.23	55
104	10.01	8.31	6.58	4.79	10.21	55
105	9.82	8.18	6.50	4.76	10.19	55
106	9.62	8.01	6.42	4.73	10.17	55
107	9.48	7.90	6.37	4.71	10.15	55
108	9.32	7.81	6.30	4.69	10.13	55
109	9.11	7.64	6.20	4.64	10.11	55
110	8.94	7.50	6.12	4.60	10.09	55
111	8.76	7.39	6.03	4.57	10.07	55

Advance Drainage Systems, Inc., 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
112	8.45	7.22	5.92	4.53	10.04	55
113	8.38	7.12	5.87	4.50	10.01	55
114	8.22	7.00	5.78	4.47	9.98	55
115	8.05	6.88	5.70	4.44	9.95	55
116	7.87	6.73	5.60	4.40	9.92	55
117	7.71	6.62	5.51	4.36	9.89	55
118	7.48	6.41	5.39	4.31	9.85	55
119	7.34	6.32	5.32	4.27	9.82	55
120	7.17	6.20	5.24	4.23	9.79	55
121	6.96	6.05	5.12	4.19	9.75	55
122	6.79	5.94	5.06	4.13	9.71	55
123	6.62	5.80	4.97	4.07	9.68	55
124	6.41	5.66	4.86	3.99	9.63	56
125	6.27	5.53	4.79	3.93	9.59	55
126	6.11	5.41	4.72	3.88	9.54	56
127	5.88	5.34	6.41	3.81	9.48	56
128	5.69	5.12	4.54	3.75	9.43	56
129	5.51	5.00	4.42	3.68	9.37	56
130	5.35	4.88	4.34	3.59	9.31	56
131	5.20	4.76	4.23	3.53	9.26	56
132	5.04	4.64	4.12	3.46	9.19	56
133	4.93	4.43	3.96	3.31	9.09	56
134	4.56	4.70	3.78	3.20	8.98	56

MANOMETER, WEIR AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Canada Dominion Sugar Co., Ltd., 4-inch ID

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
1	14.87	11.73	8.66	5.46	10.52	54
2	14.51	11.48	8.49	5.39	10.50	54
3	14.21	11.23	8.38	5.35	10.48	54
4	13.89	11.04	8.76	5.32	10.46	55
5	13.62	10.81	8.17	5.29	10.44	55
6	13.37	10.66	8.07	5.27	10.41	55
7	13.16	10.50	7.91	5.24	10.39	56
8	12.90	10.31	7.86	5.21	10.37	56
9	12.65	10.09	7.68	5.17	10.34	56
10	12.38	9.80	7.59	5.14	10.31	57
11	12.08	9.71	7.45	5.08	10.27	57
12	11.80	9.52	7.31	5.02	10.27	57
13	11.52	9.34	7.19	4.99	10.24	58
14	11.22	9.10	7.07	4.97	10.21	58
15	10.94	8.88	6.92	4.85	10.18	58
16	10.70	8.70	6.81	4.85	10.15	58
17	10.41	8.50	6.70	4.81	10.12	58
18	10.10	8.29	6.51	4.76	10.09	58
19	9.82	8.18	6.41	4.69	10.05	58
20	9.55	7.90	6.29	4.64	10.01	58

Canada Dominion Sugar Co., Ltd., 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
21	9.26	7.70	6.17	4.59	9.97	58
22	8.98	7.49	6.02	4.51	9.94	58
23	8.70	7.30	5.90	4.46	9.90	59
24	8.42	7.08	5.78	4.40	9.86	59
25	8.12	6.90	5.64	4.36	9.82	59
26	7.88	6.69	5.52	4.30	9.78	59
27	7.61	6.51	5.41	4.25	9.73	59
28	7.32	6.30	5.29	4.20	9.68	59
29	7.04	6.08	5.14	4.10	9.63	59
30	6.76	5.87	5.02	4.00	9.58	59
31	6.50	5.79	4.90	3.92	9.52	59
32	6.20	5.42	4.74	3.83	9.47	59
33	5.91	5.20	4.59	3.75	9.39	59
34	5.66	5.08	4.50	3.67	9.30	59
35	5.38	4.88	4.35	3.56	9.21	59
36	5.10	4.65	4.24	3.42	9.12	59
37	4.80	4.46	3.95	3.30	9.01	59
38	4.52	4.19	3.87	3.17	8.90	59
39	4.25	3.93	3.59	3.00	8.79	59
40	3.90	3.65	3.34	2.82	8.60	59
41	3.54	3.34	3.05	2.62	8.39	59
42	14.89	11.72	8.69	5.52	10.52	58
43	14.58	11.40	8.51	5.43	10.51	58
44	14.26	11.28	8.40	5.38	10.49	58
45	14.02	11.06	8.30	5.35	10.47	58
46	13.74	10.88	8.19	5.32	10.45	58
47	13.52	10.73	8.08	5.29	10.42	58
48	13.20	10.49	7.94	5.26	10.39	58
49	12.98	10.28	7.83	5.21	10.36	58
50	12.63	10.08	7.69	5.18	10.33	58
51	12.40	9.91	7.58	5.14	10.30	58

Canada Dominion Sugar Co., Ltd., 4- inch ID.--Continued.

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
52	12.10	9.71	7.43	5.09	10.28	58
53	11.88	9.56	7.33	5.04	10.25	58
54	11.53	9.33	7.19	4.99	10.22	59
55	11.30	9.11	7.09	4.95	10.19	59
56	11.00	8.91	6.95	4.90	10.16	59
57	10.69	8.70	6.75	4.82	10.13	59
58	10.38	8.50	6.66	4.78	10.10	59
59	10.09	8.31	6.53	4.73	10.07	59
60	9.80	8.09	6.41	4.69	10.04	59
61	9.59	7.87	6.30	4.64	10.01	59
62	9.30	7.70	6.18	4.59	9.98	60
63	9.00	7.50	6.05	4.53	9.94	60
64	8.78	7.32	5.95	4.48	9.90	60
65	8.46	7.14	5.81	4.43	9.86	60
66	8.17	6.89	5.67	4.38	9.81	60
67	7.90	6.69	5.53	4.33	9.77	60
68	7.61	6.50	5.40	4.27	9.72	60
69	7.33	6.31	5.30	4.22	9.67	60
70	7.07	6.09	5.14	4.13	9.62	61
71	6.78	5.87	4.99	4.00	9.57	61
72	6.50	5.67	4.86	3.93	9.51	61
73	6.19	5.48	4.74	3.86	9.44	61
74	5.92	5.27	4.61	3.77	9.37	61
75	5.68	5.05	4.49	3.64	9.28	61
76	5.34	4.84	4.25	3.48	9.18	61
77	5.11	4.69	4.17	3.40	9.08	61
78	4.83	4.48	3.96	3.29	8.98	61
79	4.54	4.18	3.75	3.16	8.87	61
80	4.22	3.89	3.53	2.98	8.73	61
81	3.91	3.75	3.34	2.82	8.58	61
82	14.92	11.74	8.69	5.50	10.52	63

Canada Dominion Sugar Co., Ltd., 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
83	14.60	11.44	8.52	5.44	10.51	63
84	14.30	11.29	8.42	5.40	10.50	63
85	14.05	11.09	8.33	5.36	10.48	63
86	13.84	10.91	8.22	5.32	10.46	63
87	13.53	10.70	8.06	5.28	10.43	63
88	13.19	10.50	7.94	5.24	10.40	63
89	12.96	10.31	7.83	5.70	10.38	63
90	12.68	10.12	7.69	5.17	10.35	63
91	12.90	9.90	7.58	5.14	10.32	63
92	12.09	9.70	5.44	5.09	10.29	63
93	11.90	9.60	5.36	5.04	10.28	63
94	11.60	9.36	7.22	5.00	10.26	63
95	11.50	9.27	7.17	4.96	10.24	63
96	11.38	9.17	7.12	4.92	10.22	63
97	11.25	9.08	7.05	4.89	10.20	63
98	11.00	8.91	6.93	4.86	10.18	63
99	10.82	8.80	6.87	4.83	10.16	63
100	10.62	8.70	6.80	4.81	10.14	63
101	10.35	8.50	6.68	4.77	10.12	63
102	10.18	8.37	6.59	4.73	10.09	63
103	10.04	8.26	6.51	4.70	10.08	63
104	9.81	8.09	6.43	4.67	10.06	63
105	9.67	7.97	6.35	4.64	10.04	63
106	9.53	7.88	6.28	4.60	10.02	63
107	9.29	7.71	6.17	4.56	9.99	63
108	9.16	7.60	6.09	4.53	9.97	63
109	9.00	7.50	6.02	4.50	9.95	63
110	8.80	7.32	5.93	4.47	9.92	63
111	8.46	7.12	5.79	4.42	9.88	63
112	8.17	6.90	5.67	4.36	9.83	63
113	7.91	6.69	5.54	4.30	9.78	63

Canada Dominion Sugar Co., Ltd., 4-inch ID.--Continued.

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
114	7.60	6.49	5.36	4.25	9.73	63
115	7.33	6.28	5.26	4.20	9.67	63
116	7.04	6.10	5.15	4.10	9.62	63
117	6.81	5.90	5.00	4.00	9.57	63
118	6.51	5.69	4.88	3.92	9.51	63
119	6.22	5.50	4.78	3.84	9.45	63
120	5.95	5.28	4.63	3.76	9.37	63
121	5.69	5.07	4.49	3.65	9.29	63
122	5.38	4.95	3.27	3.52	9.20	63
123	5.10	4.67	3.16	3.40	9.12	63
124	4.81	4.48	3.94	3.29	9.01	63
125	4.53	4.19	3.74	3.14	8.90	63
126	4.22	3.90	3.56	3.00	8.75	63
127	3.89	3.64	3.34	2.81	8.59	63

MANOMETER, WEIR AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Michigan Vitrified Tile Company, 4-inch ID

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
1	13.50	10.45	7.70	5.30	10.28	77
2	13.20	10.30	7.55	5.16	10.26	77
3	13.15	10.44	7.55	5.30	10.27	78
4	13.00	10.30	7.40	5.20	10.25	78
5	12.80	10.10	7.32	5.12	10.23	78
6	12.50	9.95	7.25	5.06	10.21	78
7	12.30	9.85	7.18	5.00	10.19	78
8	12.10	9.70	7.10	4.95	10.17	78
9	11.90	9.54	7.02	4.94	10.15	78
10	11.70	9.38	6.95	4.93	10.13	78
11	11.30	9.18	6.80	4.92	10.11	78
12	11.10	8.90	6.70	4.90	10.10	78
13	10.80	8.78	6.60	4.80	10.08	78
14	10.50	8.50	6.50	4.75	10.06	78
15	10.20	8.30	6.40	4.70	10.04	78
16	9.90	8.10	6.30	4.65	10.02	78
17	9.70	7.90	6.20	4.60	10.00	78
18	9.40	7.70	6.05	4.55	9.92	78
19	9.00	7.50	5.85	4.45	9.88	78
20	8.80	7.30	5.70	4.40	9.85	78

Michigan Vitrified Tile Company, 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
21	8.55	7.10	6.60	3.35	9.81	78
22	8.20	6.90	5.40	4/30	9.76	78
23	8.00	6.75	5.35	4.25	9.70	78
24	7.70	6.50	5.25	4.15	9.65	76
25	7.40	6.30	5.10	4.10	9.61	76
26	7.20	6.15	5.00	4.05	9.56	76
27	6.94	5.92	4.90	4.00	9.52	76
28	6.60	5.72	4.70	3.90	9.47	76
29	6.40	5.42	4.60	3.80	9.40	76
30	6.1	5.33	4.50	3.70	9.35	76
31	5.80	5.14	4.35	3.62	9.28	77
32	5.55	4.94	4.20	3.55	9.20	77
33	5.30	4.70	4.10	3.44	9.14	77
34	5.00	4.55	3.96	3.30	9.05	77
35	4.70	4.38	3.75	3.20	8.94	77
36	4.55	4.20	3.60	3.10	8.86	77
37	4.45	4.11	3.52	3.03	8.80	78
38	4.35	4.00	3.40	2.95	8.74	78
39	4.21	3.86	3.34	2.87	8.69	78
40	4.06	3.72	3.20	2.78	8.60	78
41	3.90	3.58	3.15	2.70	8.55	78
42	3.72	3.48	3.03	2.65	8.48	78
43	3.56	3.35	2.94	2.59	8.42	78
44	3.40	3.23	2.88	2.50	8.35	78
45	3.21	3.06	2.70	2.38	8.22	78
46	3.00	2.85	2.55	2.20	8.08	78
47	13.85	10.85	7.80	5.16	10.35	66
48	13.60	10.62	7.65	5.10	10.33	66
49	13.36	10.50	7.53	5.05	10.31	66
50	13.11	10.28	7.41	5.00	10.29	67
51	12.82	10.05	7.31	4.95	10.27	68

Michigan Vitrified Tile Company, 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
52	12.60	9.86	7.20	4.92	10.25	68
53	12.35	9.69	7.11	4.89	10.23	68.5
54	12.10	9.52	7.02	4.86	10.21	68.5
55	11.81	9.35	6.93	4.83	10.18	69
56	11.60	9.24	6.88	4.81	10.16	69
57	11.37	9.15	6.82	4.78	10.13	70
58	11.10	8.94	6.78	4.75	10.10	70
59	10.78	8.73	6.70	4.73	10.08	70.5
60	10.60	8.59	6.61	4.71	10.05	70.5
61	10.35	8.42	6.49	4.68	10.03	71
62	10.05	8.18	6.32	4.64	10.00	71
63	9.78	8.02	6.21	4.60	9.98	71.5
64	9.40	7.83	6.05	4.56	9.95	71.5
65	9.28	7.65	5.93	4.51	9.92	71.5
66	9.00	7.42	5.81	4.46	9.89	72
67	8.73	7.26	5.70	4.39	9.86	72
68	8.46	7.08	5.61	4.34	9.82	72
69	8.18	6.86	5.50	4.29	9.78	72
70	8.00	6.70	5.40	4.23	9.74	72
71	7.70	6.50	5.28	4.18	9.70	72
72	7.40	6.28	5.16	4.13	9.65	72
73	7.11	6.08	5.00	4.05	9.60	72
74	6.84	5.85	4.87	4.00	9.56	72
75	6.58	5.75	4.72	3.94	9.51	72
76	6.30	5.50	4.60	3.80	9.45	72
77	6.06	5.30	4.50	3.70	9.39	72
78	5.80	5.10	4.40	3.64	9.34	72
79	5.51	4.90	4.30	3.56	9.27	72
80	5.26	4.70	4.14	3.35	9.18	72
81	5.00	4.53	3.99	3.30	9.05	72
82	4.75	4.38	3.80	3.20	8.98	72

Michigan Vitrified Tile Company, 4-inch ID.--Continued.

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
83	4.50	4.18	3.60	3.05	8.85	72
84	4.30	3.97	3.40	2.99	8.74	72
85	14.15	11.10	7.95	5.20	10.33	72
86	13.84	10.87	7.76	5.13	10.32	72
87	13.55	10.63	7.65	5.08	10.31	72
88	13.32	10.44	7.55	5.03	10.30	72
89	13.05	10.26	7.44	4.98	10.29	72
90	12.80	10.08	7.32	4.94	10.27	72
91	12.52	9.90	7.24	4.90	10.25	72
92	12.32	9.79	7.13	4.85	10.23	72
93	12.09	9.60	7.03	4.81	10.21	72
94	11.80	9.42	6.91	4.78	10.17	72
95	11.50	9.20	6.82	4.76	10.17	72
96	11.31	9.10	6.74	4.74	10.15	72
97	11.05	8.94	6.66	4.72	10.13	72
98	10.84	8.76	6.56	4.71	10.11	72
99	10.50	8.60	6.47	4.69	10.09	72
100	10.40	8.45	6.42	4.60	10.07	72
101	10.10	8.31	6.36	4.50	10.05	72
102	9.99	8.23	6.30	4.54	10.04	72
103	9.95	8.15	6.25	4.53	10.03	72
104	9.80	8.05	6.20	4.51	10.01	72
105	9.62	7.90	6.11	4.50	9.99	72.5
106	9.50	7.80	6.03	4.48	9.99	72.5
107	9.34	7.66	5.98	4.46	9.98	72.5
108	9.23	7.57	5.93	4.42	9.96	73
109	9.07	7.41	5.85	4.40	9.94	73
110	8.98	7.38	5.77	4.38	9.92	73
111	8.77	7.29	5.72	4.36	9.90	74
112	8.69	7.21	5.68	4.34	9.88	74
113	8.39	7.02	5.54	4.30	9.85	74

Michigan Vitrified Tile Company, 4-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
114	8.30	6.94	5.48	4.26	9.82	74.5
115	8.08	6.78	5.42	4.22	9.79	74
116	8.00	6.71	5.37	4.20	9.77	75
117	7.90	6.64	5.32	4.18	9.75	75
118	7.76	6.53	5.26	4.16	9.72	75
119	7.63	6.47	5.20	4.14	9.70	75.5
120	7.52	6.38	5.15	4.12	9.69	75.5
121	7.35	6.27	5.08	4.09	9.67	75.5
122	7.28	6.20	5.04	4.06	9.65	75.5
123	7.12	6.08	5.00	4.03	9.62	75.5
124	7.00	5.98	4.30	4.00	9.60	75.5
125	6.82	5.86	4.87	3.98	9.57	75.5
126	6.72	5.78	4.82	3.97	9.55	75.5
127	6.55	5.69	4.74	3.94	9.52	75.5
128	6.46	5.61	4.69	3.91	9.50	75.5
129	6.31	5.52	4.65	3.86	9.47	75.5
130	6.12	5.38	4.57	3.77	9.44	75.5
131	6.01	5.30	4.49	3.72	9.41	75
132	5.89	5.20	4.43	3.68	9.37	75
133	5.76	5.11	4.38	3.63	9.34	75
134	5.61	5.01	4.32	3.60	9.31	75
135	5.50	4.92	4.28	3.56	9.28	75
136	5.37	4.81	4.20	3.51	9.24	75
137	5.23	4.72	4.15	3.46	9.20	75
138	5.10	4.62	4.06	3.40	9.16	75
139	5.01	4.55	4.00	3.36	9.11	75
140	4.86	4.46	3.91	3.29	9.05	75
141	4.76	4.38	3.82	3.22	8.99	75
142	4.60	4.30	3.66	3.16	8.91	75
143	4.50	4.20	3.60	3.06	8.55	75
144	4.40	4.04	3.48	2.99	8.78	75
145	4.26	3.91	3.38	2.91	8.72	75

MANOMETER, WEIR AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Michigan Vitrified Tile Company, 5-inch ID

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
1	11.18	9.97	7.83	5.92	11.19	57
2	11.76	9.81	7.74	5.90	11.17	57
3	11.43	9.62	7.63	5.88	11.14	57
4	11.35	9.54	7.59	5.86	11.11	57
5	11.20	9.45	7.51	5.83	11.09	58
6	11.03	9.31	7.41	5.80	11.06	58
7	10.90	9.21	7.31	5.77	11.03	58
8	10.73	9.09	7.27	5.74	11.01	58
9	10.62	9.01	7.23	5.71	10.99	58
10	10.43	8.89	7.16	5.67	10.98	58
11	10.25	8.74	7.10	5.64	10.95	59
12	10.09	8.62	7.05	5.61	10.92	59
13	9.95	8.56	6.98	5.59	10.90	59
14	9.77	8.40	6.89	5.56	10.88	59
15	9.66	8.30	6.80	5.54	10.86	59
16	9.51	8.19	6.71	5.51	10.84	59
17	9.38	8.07	6.64	5.47	10.81	60
18	9.23	7.97	6.59	5.44	10.79	60
19	9.08	7.86	6.53	5.40	10.77	60
20	8.88	7.68	6.41	5.36	10.73	60

Michigan Vitrified Tile Company, 5-inch ID.--Continued.

	Manometers					
Meas. No.	1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
21	8.69	7.58	6.36	5.30	10.70	60
22	8.55	7.48	6.30	5.25	10.67	60
23	8.32	7.33	6.22	5.16	10.63	60
24	8.18	7.22	6.15	5.10	10.60	60
25	8.07	7.13	6.08	5.05	10.57	60
26	7.87	6.97	5.99	4.99	10.53	60
27	7.72	6.88	5.90	4.95	10.50	60
28	7.58	6.76	5.82	4.90	10.46	60
29	7.40	6.61	5.72	4.84	10.40	60
30	7.23	6.50	5.66	4.78	10.36	60
31	7.11	6.39	5.58	4.72	10.32	60
32	6.95	6.25	5.49	4.64	10.27	60
33	6.70	6.12	5.39	4.60	10.23	60
34	6.66	6.04	5.30	4.56	10.19	60
35	6.50	5.92	5.22	5.48	10.13	60
36	6.32	5.81	5.16	4.41	10.09	60
37	6.20	5.72	5.08	4.35	10.04	60
38	6.00	5.54	4.92	4.31	9.95	60
39	5.88	5.43	4.83	4.27	9.88	60
40	5.72	5.29	4.73	4.10	9.80	60
41	5.57	5.14	4.60	4.00	9.71	60
42	5.25	4.89	4.38	3.80	9.58	60
43	4.93	4.65	4.14	3.62	9.40	60
44	4.61	4.37	3.92	3.43	9.25	60
45	4.30	4.10	3.72	3.25	9.06	60
46	4.00	3.81	3.50	3.07	8.87	60
47	12.02	10.02	7.89	6.06	11.18	62
48	11.89	9.91	7.80	6.00	11.16	62
49	11.69	9.77	7.73	5.95	11.13	62
50	11.59	9.68	7.68	5.93	11.11	63
51	11.40	9.55	7.60	5.90	11.09	63

Michigan Vitrified Tile Company, 5-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
52	11.24	9.44	7.54	5.87	11.06	63
53	11.07	9.31	7.46	5.84	11.04	64
54	10.91	9.22	7.39	5.81	11.02	64
55	10.76	9.09	7.30	5.77	10.99	64
56	10.65	8.99	7.26	5.73	10.97	64
57	10.50	8.87	7.19	5.70	10.95	65
58	10.28	8.72	7.10	5.65	10.92	65
59	10.11	8.62	7.06	5.61	10.90	65
60	10.01	8.54	6.99	5.56	10.89	65
61	9.77	8.38	6.87	5.52	10.86	65
62	9.68	8.30	6.81	5.49	10.83	65
63	9.55	8.19	6.73	5.46	10.80	65
64	9.37	8.03	6.65	5.43	10.78	66
65	9.21	7.91	6.57	5.39	10.75	66
66	9.10	7.84	6.53	5.35	10.72	66
67	8.88	7.66	6.40	5.30	10.68	66
68	8.56	7.45	6.24	5.21	10.63	66
69	8.35	7.27	6.15	5.17	10.59	66
70	8.18	7.15	6.05	5.10	10.56	66
71	8.05	7.04	6.00	5.04	10.52	66
72	7.98	6.93	5.92	4.99	10.48	66
73	7.71	6.87	5.89	4.95	10.44	66
74	7.60	6.76	5.80	4.90	10.40	66
75	7.42	6.62	5.71	4.85	10.36	66
76	7.11	6.38	5.52	4.75	10.30	57
77	6.89	6.24	5.44	4.66	10.21	57
78	6.70	6.08	5.34	4.57	10.13	57
79	6.45	5.86	5.18	4.46	10.04	57
80	6.12	5.68	5.05	4.37	9.97	57
81	5.97	5.51	4.89	4.25	9.87	57
82	5.70	5.27	4.70	4.09	9.77	57

Michigan Vitrified Tile Company, 5-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
83	5.54	5.11	4.56	3.94	9.65	57
84	5.25	4.88	4.36	3.81	9.53	57
85	4.95	4.63	4.16	3.67	9.38	57
86	4.64	4.37	3.94	3.47	9.21	57
87	4.30	4.12	3.75	3.29	9.05	57
88	4.03	3.82	3.48	3.07	8.83	57
89	11.46	9.60	7.61	5.98	11.12	53
90	11.12	9.35	7.49	5.90	11.09	53
91	10.89	9.25	7.38	5.83	11.04	53
92	10.71	9.10	7.32	5.80	11.02	53
93	10.41	8.86	7.20	5.75	10.98	53
94	10.18	8.70	7.10	5.70	10.95	53
95	9.99	8.55	7.00	5.66	10.91	54
96	9.74	8.40	6.87	5.61	10.87	54
97	9.50	8.23	6.77	5.57	10.83	55
98	9.27	8.02	6.62	5.50	10.79	55
99	9.00	7.83	6.47	5.44	10.75	55
100	8.84	7172	6.42	5.41	10.70	55
101	8.56	7.50	6.32	5.35	10.65	56
102	8.34	7.36	6.21	5.20	10.60	56
103	8.11	7.18	6.09	5.14	10.56	56
104	7.83	6.97	5.99	5.05	10.50	56
105	7.59	6.79	5.87	4.97	10.45	56
106	7.39	6.65	5.75	4.89	10.39	56
107	7.13	6.44	5.63	4.79	10.31	56
108	6.87	6.26	5.52	4.70	10.22	56
109	6.63	6.07	5.36	4.61	10.16	56
110	6.41	5.92	5.23	4.52	10.07	56
111	6.18	5.72	5.09	4.38	9.99	56
112	5.94	5.52	4.93	4.26	9.89	56
113	5.70	5.33	4.76	4.13	9.78	56

Michigan Vitrified Tile Company, 5-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Weir h inches	Temp. F°
114	5.45	5.07	4.56	3.95	9.67	57
115	5.21	4.87	4.38	3.80	9.54	57
116	4.94	4.60	4.27	3.75	9.38	57
117	4.59	4.34	3.95	3.47	9.19	57
118	4.29	4.10	3.72	3.30	9.04	57
119	4.00	3.84	3.49	3.08	8.84	57

MANOMETER, FLOWMETER AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Springfield Plastics, Inc., 5.7-inch ID

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters* 1 (sec)	2 (sec)	Temp. F°
1	27.432	25.800	24.244	22.706	37.9	49.5	58
2	27.556	25.9 8	24.381	22.825	37.9	49.8	58
3	27.550	25.956	24.408	22.868	38.1	50.0	58
4	27.532	25.987	24.450	22.913	38.2	50.2	58
5	27.582	26.075	24.550	22.982	38.2	50.2	58
6	27.632	26.100	24.575	23.056	38.3	50.2	58
7	27.675	26.150	24.625	23.144	38.4	50.2	58
8	27.706	26.200	24.714	23.212	38.4	50.5	58
9	27.744	26.225	24.756	23.244	38.8	50.9	58
10	27.800	26.300	24.844	23.331	39.0	51.0	58
11	27.818	26.337	24.856	23.362	39.0	51.2	58
12	27.868	26.363	24.875	23.381	39.0	51.3	58
13	27.887	26.394	24.963	23.463	39.2	51.4	58
14	27.944	26.500	25.056	23.582	39.8	52.2	58
15	28.000	26.575	25.150	23.682	40.0	52.3	58
16	28.038	26.637	25.225	23.787	40.4	52.9	58
17	28.075	26.725	25.294	23.863	40.6	53.5	58
18	28.125	26.775	25.40	24.000	40.9	53.9	58
19	28.175	26.818	25.494	24.113	41.3	54.3	58

*The data for the flowmeters indicate the time required for the passage of 10 cubic feet of water.

Springfield Plastics, Inc., 5.7-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
20	28.181	26.856	25.525	24.188	41.7	54.8	58
21	28.237	26.956	25.675	24.362	42.0	55.7	58
22	28.284	27.031	25.750	24.432	42.6	56.2	58
23	28.331	27.131	25.863	24.600	43.2	57.0	58
24	28.369	27.200	25.944	24.718	43.7	57.8	58
25	28.394	27.288	26.025	24.850	44.2	58.5	58
26	28.494	27.362	26.212	25.031	45.0	59.4	58
27	28.525	27.413	26.281	25.212	46.0	61.0	58
28	28.532	27.488	26.376	25.332	46.3	61.7	58
29	28.594	27.582	26.506	25.488	47.7	63.0	58
30	28.625	27.650	26.656	25.682	48.8	65.0	58
31	28.663	27.738	26.750	25.838	20.2	66.0	58
32	28.706	27.987	27.200	26.613	33.4	0	58
33	28.738	28.038	27.438	26.813	34.2	0	58
34	28.763	28.200	27.588	27.050	36.1	0	58
35	28.788	28.269	27.694	27.225	37.0	0	58
36	28.812	28.319	27.775	27.331	38.6	0	58
37	28.838	28.369	27.850	27.413	39.4	0	58
38	28.862	28.438	27.963	27.550	41.6	0	58
39	28.875	28.500	28.050	27.682	43.8	0	58
40	28.900	28.538	28.113	27.768	45.1	0	58
41	28.918	28.600	28.219	27.918	47.7	0	58
42	28.938	28.644	28.294	28.031	50.4	0	58
43	28.975	28.700	28.406	28.213	53.3	0	58
44	29.000	28.768	28.500	28.269	58.0	0	58
45	29.037	28.818	28.575	28.375	61.2	0	58
46	29.063	28.881	28.688	28.5 3	68.7	0	58
47	29.106	28.963	28.800	28.678	78.8	0	58
48	29.038	27.425	25.838	24.206	37.7	49.7	58
49	29.075	27.463	25.875	24.262	38.1	50.0	58
50	29.106	27.544	25.944	24.366	38.4	50.8	58

Springfield Plastics, Inc., 5.7-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
51	29.131	27.613	26.100	24.518	38.8	51.4	58
52	29.150	27.650	26.156	24.600	39.1	51.7	58
53	29.175	27.738	26.250	24.725	39.3	52.0	58
54	29.200	27.782	26.350	24.863	39.8	52.7	58
55	29.188	27.813	26.438	24.982	40.2	53.0	58
56	29.238	27.894	26.575	25.188	41.2	54.2	58
57	29.256	27.932	26.644	25.432	47.0	55.7	58
59	29.300	28.088	26.856	25.568	47.8	56.4	58
60	29.350	28.169	27.025	25.813	43.8	57.8	58
61	29.388	28.256	27.150	26.000	44.8	59.2	58
62	29.425	28.332	27.294	26.225	26.0	61.0	58
63	29.456	28.432	27.464	26.425	47.7	63.0	58
64	29.500	28.538	27.606	26.663	49.4	65.0	58
65	29.544	28.650	27.788	26.932	51.8	67.8	58
66	29.600	28.806	28.031	27.269	54.3	73.0	58
67	29.650	28.925	28.250	27.568	58.1	76.5	58
68	28.000	27.388	26.794	26.200	34.5	0	58
69	28.038	27.469	26.925	26.356	36.7	0	58
70	28.044	27.563	27.018	26.494	37.9	0	58
71	28.050	27.613	27.131	26.613	39.2	0	58
72	28.000	27.378	27.175	26.725	42.3	0	58
73	28.063	27.625	27.750	26.844	44.6	0	58
74	28.025	27.682	27.344	26.956	46.8	0	58
75	28.044	27.744	27.450	27.119	51.4	0	58
76	28.063	27.813	27.556	27.250	54.9	0	58
77	28.088	27.875	27.644	27.381	60.8	0	58
78	28.106	27.932	27.713	27.482	65.4	0	58
79	28.125	27.988	27.800	27.575	75.0	0	58
80	28.050	26.568	25.063	23.544	37.7	49.4	58
81	28.069	26.418	24.918	23.288	38.2	50.6	58
82	28.044	26.463	24.988	23.388	38.6	51.0	58

Springfield Plastics, Inc., 5.7-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
83	28.088	26.513	25.025	23.482	38.9	51.3	58
84	28.100	26.550	25.088	23.563	39.0	51.7	58
85	28.113	26.588	25.194	23.700	39.6	52.6	58
86	28.131	26.625	25.244	23.775	39.8	52.8	58
87	28.144	26.688	25.362	23.932	40.7	53.6	58
88	28.163	26.725	25.432	24.081	41.1	54.4	58
89	28.181	26.838	25.582	24.244	42.0	55.6	58
90	28.206	26.938	25.706	24.475	43.0	56.8	58
91	28.238	27.025	25.894	24.732	43.3	58.6	58
92	28.256	27.133	26.088	24.882	45.1	59.5	58
93	28.300	27.225	26.175	25.088	46.5	61.4	58
94	28.312	27.294	26.325	25.300	48.0	63.8	58
95	28.350	27.375	26.438	25.450	49.0	65.4	58
96	28.375	27.482	26.600	25.675	50.8	68.8	58
97	28.394	27.582	26.756	25.913	53.0	70.6	58
98	28.418	27.775	27.113	26.438	34.0	0	58
99	28.435	27.813	25.306	26.563	35.0	0	58
100	28.432	27.875	27.262	26.625	36.2	0	58
101	28.438	27.918	27.319	26.750	36.9	0	58
102	28.450	27.956	27.418	26.875	38.2	0	58
103	28.475	28.025	27.506	27.088	40.1	0	58
104	28.494	28.094	27.606	27.188	42.7	0	58
105	28.506	28.144	27.675	27.294	43.9	0	58
106	28.525	28.219	27.763	27.425	46.4	0	58
107	28.544	28.256	27.832	27.513	48.3	0	53
108	28.563	28.306	27.894	27.606	50.0	0	58
109	28.582	28.344	27.944	27.675	51.6	0	58
110	28.606	28.381	28.000	27.750	54.0	0	58
111	28.625	28.432	28.088	27.863	58.1	0	58
112	28.663	28.488	28.188	28.000	61.7	0	58

MANOMETER, FLOWMETER AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Advance Drainage Systems, Inc., 6-inch ID

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
1	26.786	25.738	24.725	23.550	37.3	50.0	61
2	26.750	25.706	24.656	23.525	36.0	50.5	61
3	26.675	25.638	24.625	23.488	27.2	50.1	61
4	26.575	25.569	24.569	23.450	37.6	50.2	61
5	26.568	25.612	24.618	23.482	38.0	50.0	61
6	26.556	25.575	24.588	23.468	38.0	50.1	61
7	26.513	25.544	24.562	23,475	38.0	51.0	61
8	26.494	25.556	24.587	23.506	38.2	52.0	61
9	26.459	25.537	24.575	23.494	38.6	52.5	61
10	26.425	25.481	24.487	23.469	38.5	52.8	61
11	26.381	25.513	24.550	23.513	38.7	53.0	61
12	26.363	25.462	24.525	23.531	38.8	53.1	61
13	26.332	25.456	24.525	23.518	39.1	53.2	61
14	26.324	25.468	24.537	23.537	39.4	53.2	61
15	26.332	25.487	24.556	23.575	40.0	54.0	61
16	26.312	25.450	24.587	23.587	40.8	55.0	61
17	26.294	25.425	24.606	23.613	41.0	56.0	61
18	26.269	25.456	23.632	23.682	41.0	57.0	61
19	26.256	25.506	24.700	23.800	42.0	58.1	61
20	26.231	25.525	24.732	23.875	42.9	59.8	61

Advance Drainage Systems, Inc., 6-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
21	26.225	25.544	24.787	23.925	44.0	60.7	61
22	26.219	25.550	24.856	24.075	44.9	62.6	61
23	26.219	25.587	24.913	24.163	46.0	64.0	61
24	26.244	25.644	25.044	24.319	47.2	66.0	61
25	26.262	25.719	25.175	24.494	49.5	70.0	61
26	26.262	25.744	25.225	24.606	33.0	0	61
27	26.256	25.894	25.494	25.038	35.0	0	61
28	26.250	25.919	25.525	25.094	36.0	0	61
29	26.250	25.932	25.581	25.175	37.3	0	61
30	26.244	25.963	25.632	25.262	39.2	0	61
31	26.238	26.000	25.688	25.356	41.0	0	61
32	26.256	26.019	25.738	25.413	42.5	0	61
33	26.256	26.038	25.782	25.556	44.8	0	61
34	26.256	26.069	25.850	25.575	47.2	0	61
35	26.256	26.106	25.913	25.682	51.0	0	61
36	26.256	26.131	25.969	25.719	56.2	0	61
37	26.256	26.169	26.050	25.863	63.6	0	61
38	26.262	26.212	26.082	25.950	74.0	0	61
39	25.850	24.832	23.763	22.632	37.5	50.4	61
40	25.838	24.800	23.782	22.644	38.0	50.8	61
41	25.831	24.787	23.768	22.637	38.0	50.9	61
42	25.806	24.782	23.768	22.663	38.0	51.0	61
43	25.794	24.850	23.863	22.794	38.8	52.0	61
44	25.763	24.864	23.888	22.819	39.2	52.3	61
45	25.732	24.852	23.906	22.844	39.8	53.6	61
46	25.719	24.813	23.919	22.875	40.0	53.8	61
47	25.706	24.806	23.925	22.932	40.3	54.2	61
48	25.701	24.864	24.013	23.013	41.0	54.9	61
49	25.694	24.906	24.081	23.150	42.0	56.3	61
50	25.752	25.000	24.244	23.356	43.4	58.8	61
51	25.757	25.056	24.350	23.487	44.8	60.5	61

Advance Drainage Systems, Inc., 6-inch ID.--Continued.

Meas. No.	Manometers 1 inch	2 inches	3 inches	4 inches	Flowmeters 1 (sec)	2 (sec)	Temp. F°
52	25.33	25.100	24.450	23.650	46.5	62.3	61
53	25.738	25.144	24.518	23.750	47.9	64.2	61
54	25.744	25.169	24.568	23.832	48.5	65.9	61
55	25.744	25.200	24.650	23.979	50.6	68.3	61
56	25.750	25.256	24.756	24.169	53.0	71.8	61
57	25.763	25.425	25.050	24.575	35.8	0	61
58	25.775	25.462	25.131	24.656	37.0	0	61
59	25.787	25.494	25.181	24.750	38.4	0	61
60	25.794	25.525	25.225	24.825	39.8	0	61
61	25.800	25.544	25.281	24.906	41.7	0	61
62	25.806	25.588	25.356	25.031	44.8	0	61
63	25.813	25.625	25.432	25.137	48.7	0	61
64	25.806	25.663	25.487	25.239	53.0	0	61
65	25.800	25.682	25.525	25.300	57.2	0	61
66	25.794	25.700	25.562	25.369	62.0	0	61
67	25.800	25.725	25.613	25.437	68.3	0	61
68	25.800	25.738	25.632	25.487	74.5	0	61
69	27.944	26.950	25.950	24.713	37.2	50.5	66
70	27.918	26.913	25.925	24.700	37.6	51.0	66
71	27.900	26.894	25.906	24.675	37.8	51.5	66
72	27.856	26.882	25.887	24.650	37.8	51.6	66
73	27.844	26.863	25.869	24.644	38.0	51.7	66
74	27.837	26.850	25.850	24.638	38.0	52.0	66
75	27.825	26.863	25.887	24.675	38.4	52.2	66
76	27.800	26.869	25.894	24.675	38.7	52.4	66
77	27.775	26.856	25.887	24.656	38.9	52.7	66
78	27.744	26.844	25.669	24.725	39.0	52.8	66
79	27.737	26.800	25.900	24.750	39.2	53.2	66
80	27.725	26.813	25.912	24.768	39.6	53.7	66
81	27.706	26.806	25.925	24.800	39.8	54.0	66
82	27.694	26.863	25.963	24.863	40.2	54.2	66

Advance Drainage Systems, Inc., 6-inch ID.--Continued.

	Manometers				Flowmeters		
Meas. No.	1 inch	2 inches	3 inches	4 inches	1 (sec)	2 (sec)	Temp. F°
83	27.687	26.869	26.013	24.932	40.8	55.3	66
84	27.675	26.882	26.050	24.975	41.2	56.0	66
85	27.663	26.888	26.088	25.031	41.7	56.7	66
86	24.475	23.644	22.844	21.918	42.0	57.2	66
87	24.438	23.618	22.863	21.944	42.5	57.8	66
88	24.393	23.582	22.882	21.968	43.0	59.0	66
89	24.362	23.637	22.944	22.069	44.4	61.0	66
90	24.344	23.663	22.975	22.150	44.9	62.0	66
91	24.331	23.675	23.000	22.206	45.7	63.0	66
92	24.312	23.682	23.031	22.238	46.5	63.8	66
93	24.288	23.688	23.063	22.284	47.4	65.0	66
94	24.306	23.844	23.394	22.825	31.7	0	66
95	24.294	23.856	23.400	22.838	32.0	0	66
96	24.269	23.863	23.406	22.863	32.5	0	66
97	24.262	23.863	23.450	22.906	33.0	0	66
98	24.250	23.869	23.456	22.956	34.2	0	66
99	24.244	23.869	23.463	22.994	34.5	0	66
100	24.231	23.875	23.500	23.063	35.3	0	66
101	24.219	23.888	23.537	23.106	36.4	0	66
102	24.212	23.894	23.563	23.151	37.4	0	66
103	24.200	23.900	23.582	23.188	38.4	0	66
104	24.194	23.918	23.637	23.300	40.6	0	66
105	24.185	23.937	23.700	23.388	43.0	0	66
106	24.185	23.963	23.718	23.425	44.7	0	66
107	24.185	23.982	23.750	23.513	47.6	0	66
108	24.181	24.000	23.818	23.675	51.2	0	66
109	24.181	24.044	23.900	23.744	59.4	0	66
110	24.169	24.075	23.994	23.838	70.0	0	66

HEAD, MANOMETER AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Advance Drainage Systems, Inc., 8-inch ID (Set I)

		Manometers				
Photo* No.	Head inches	1 inch	2 inches	3 inches	4 inches	Temp. F°
1-1	24.920	23.460	23.130	22.770	22.410	56
1-2	22.710	20.300	19.920	19.680	19.300	56
1-3	20.470	19.030	18.690	18.330	18.000	56
1-4	18.410	16.980	16.620	16.320	15.890	56
1-5	16.280	14.780	14.410	14.050	13.720	56
2-1	29.720	28.430	28.12	27.890	27.640	56
2-2	27.780	26.510	26.220	26.930	25.750	56
2-3	25.830	24.480	24.240	24.010	23.780	56
2-4	23.880	22.570	22.310	22.040	20.810	56
2-5	21.930	20.710	20.440	20.150	19.900	56
2-6	20.150	18.830	18.500	18.220	18.000	56
2-7	18.130	16.890	16.600	16.330	16.050	56
2-8	16.140	14.920	14.610	14.320	14.090	56
3-1	28.410	27.110	26.950	26.700	26.460	56
3-2	26.600	25.490	25.380	25.090	24.900	56
3-3	24.760	23.810	23.610	23.390	23.200	56
3-4	22.960	23.000	22.840	22.620	22.440	56
3-5	21.280	20.320	20.110	19.830	19.700	56

*An unknown experimental error occurred during the experiment. Therefore data obtained from the photographs (1-1 through 7-8) were disregarded for actual computations.

Advance Drainage Systems, Inc., 8-inch ID (Set I).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
3-6	19.620	18.650	18.420	18.210	17.990	56
3-7	17.790	16.880	16.670	16.430	16.290	56
3-8	16.090	15.140	14.900	14.680	14.460	56
4-1	26.420	25.690	25.470	25.240	25.040	56
4-2	24.800	23.920	23.730	23.700	23.380	56
4-3	23.130	22.330	22.120	21.890	21.710	56
4-4	21.510	20.72	20.520	20.320	20.180	56
4-5	19.940	18.150	19.950	19.740	19.600	56
4-6	18.320	17.530	17.400	17.400	17.200	56
4-7	16.730	15.920	15.710	15.420	15.320	56
4-8	15.120	14.340	14.110	13.790	13.700	56
5-1	27.750	25.070	26.850	26.630	26.510	56
5-2	26.340	25.720	25.590	25.420	25.310	56
5-3	24.960	24.340	24.220	24.100	24.000	56
5-4	23.610	23.020	22.910	24.740	24.650	56
5-5	22.300	21.710	21.550	21.400	21.320	56
5-6	20.970	20.400	20.250	20.100	20.010	56
5-7	19.600	19.010	18.860	19.930	19.680	56
7-1	27.720	26.630	26.480	26.230	26.120	56
7-2	25.970	24.920	24.720	24.440	24.300	56
7-3	24.210	23.200	23.000	23.720	23.600	56
7-4	22.480	21.430	21.210	20.980	20.800	56
7-5	20.720	29.710	19.450	19.200	19.050	56
7-6	18.920	17.930	17.730	17.500	17.30	56
7-7	17.230	16.220	15.90	15.650	15.510	56
7-8	15.480	14.480	14.22	13.960	13.800	56
8-1	38.437	36.287	35.963	35.563	35.113	56
8-2	37.700	35.700	35.356	35.075	34.688	56
8-3	36.875	35.206	24.900	34.637	34.331	56
8-4	36.187	34.619	34.325	34.044	33.713	56
8-5	35.363	33.938	33.688	33.438	33.125	56

Advance Drainage Systems, Inc., 8-inch ID (Set I).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
8-6	34.686	33.344	33.063	32.857	33.544	56
8-7	34.000	32.719	32.486	32.250	31.950	56
8-8	33.313	32.063	31.806	31.563	31.275	56
8-9	32.687	31.438	31.188	30.938	30.663	56
8-10	32.094	30.875	30.606	30.376	30.119	56
8-11	31.413	3-.200	29.925	29.688	29.475	56
8-12	30.794	29.563	29.313	29.087	28.812	56
8-13	30.116	28.925	28.637	28.375	28.120	56
8-14	29.520	28.332	28.060	27.781	27.519	56
8-15	28.875	27.675	27.406	27.182	26.875	56
8-16	27.469	26.313	26.025	25.756	25.500	56
8-17	26.938	25.763	25.500	25.225	25.000	56
8-18	26.331	25.150	24.875	24.625	24.350	56
8-19	25.650	24.444	24.185	23.913	23.656	56
9-1	30.319	29.457	29.311	29.156	29.956	56
9-2	29.913	29.044	28.856	28.706	28.513	56
9-3	29.344	28.518	28.319	28.131	27.944	56
9-4	28.813	27.936	27.763	27.606	27.419	56
9-5	28.250	27.413	27.225	27.063	26.850	56
9-6	27.688	26.876	26.675	26.475	26.280	56
9-7	26.622	25.781	25.594	25.419	25.219	56
9-8	26.063	25.219	25.031	24.844	24.656	56
9-9	25.588	24.719	24.475	24.294	24.106	56
9-10	25.013	24.187	24.000	23.813	23.625	56
9-11	24.436	23.688	23.438	23.250	23.063	56
9-12	23.900	23.079	22.831	22.644	22.456	56
9-13	23.375	22.563	22.375	22.188	22.000	56
9-15	22.250	21.425	21.238	21.050	20.862	56
9-16	21.769	20.938	20.750	20.544	20.313	56

Advance Drainage Systems, Inc., 8-inch ID (Set I).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
9-17	21.375	20.488	20.238	20.050	19.863	56
9-18	20.775	19.888	19.700	19.513	19.306	56
9-19	20.218	19.313	19.125	18.931	18.738	56
9-20	19.606	18.750	18.544	18.356	18,206	56

HEAD, MANOMETER AND TEMPERATURE MEASUREMENT

COLLECTED DURING ROUGHNESS FLOW TESTS ON

CORRUGATED, UNPERFORATED PLASTIC TUBING

Advance Drainage Systems, Inc., 8-inch ID (Set II)

		Manometers				
Photo No.	Head inches	1 inch	2 inches	3 inches	4 inches	Temp. F°
2-6	3.1075	28.700	28.172	27.725	27.234	57
2-7	30.500	28.125	27.594	27.106	26.638	57
2-8	29.900	27.500	26.938	26.456	26.012	57
2-9	29.350	26.919	26.406	25.913	25.456	57
2-10	28.768	26.338	25.825	25.356	24.856	57
2-11	27.600	25.198	24.625	24.138	23.656	57
2-12	26.475	24.044	23.475	23.012	22.544	57
2-13	25.894	23.475	22.938	22.463	21.968	57
2-14	25.288	22.838	22.300	21.850	21.350	57
2-15	24.669	22.250	21.675	21.175	20.725	57
2-16	23.519	21.075	20.513	20.013	19.531	57
3-1	33.386	32.069	31.725	31.488	31.256	57
3-2	32.618	31.352	31.044	30.786	30.569	57
3-3	32.013	30.732	30.413	30.144	29.920	57
3-4	31.338	30.081	29.760	29.534	29.331	57
3-5	30.606	29.350	29.070	28.859	28.610	57
3-6	29.925	28.695	28.412	28.150	27.912	57
3-7	29.262	28.000	27.669	27.407	27.206	57
3-8	28.594	27.350	27.050	26.775	26.563	57
3-9	27.919	26.700	26.413	26.163	25.925	57
3-10	27.269	26.031	25.733	25.469	25.212	57

Advance Drainage Systems, Inc., 8-inch ID (Set II).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
3-11	26.668	25.388	25.044	24.782	24.564	57
3-12	25.955	24.720	24.438	24.188	23.920	57
3-13	25.268	24.044	23.750	23.475	23.250	57
3-14	24.594	23.318	23.000	27.714	22.500	57
3-15	24.913	22.671	22.418	22.162	21.904	57
3-16	23.188	21.938	21.671	21.400	21.151	57
3-17	22.573	21.338	21.031	20.755	20.562	57
3-18	21.895	20.662	20.388	20.132	19.863	57
3-19	21.206	20.000	19.656	19.362	19.170	57
3-20	20.562	19.325	19.063	18.775	18.519	57
4-2	29.353	28.200	27.950	27.735	27.536	57
4-3	28.690	27.563	27.319	27.094	26.906	57
4-4	28.081	26.940	26.687	26.462	26.282	57
4-5	27.445	26.344	26.086	25.850	25.665	57
4-6	26.888	25.766	25.513	25.287	25.088	57
4-7	26.378	25.244	25.013	24.771	24.575	57
4-8	25.589	24.463	24.212	24.000	23.781	57
4-9	24.918	23.825	23.545	23.316	23.131	57
4-10	24.354	23.244	22.981	22.750	22.557	57
4-11	23.719	22.600	22.344	22.100	21.905	57
4-12	23.144	22.000	21.738	21.532	21.331	57
4-13	22.533	21.418	21.169	20.925	20.730	57
4-14	21.914	20.733	20.544	20.306	20.106	57
4-15	21.332	20.189	19.930	19.700	19.482	57
4-16	20.643	19.532	19.269	19.025	18.720	57
4-17	20.150	18.994	18.718	18.468	18.262	57
4-18	19.469	18.325	18.044	17.831	17.575	57
4-19	18.825	17.690	17.438	17.218	17.025	57
4-20	14.163	17.175	16.809	16.580	16.318	57
5-2	28.482	27.468	27.328	27.097	26.915	57
5-3	28.919	26.995	26.675	26.500	26.337	57

Advance Drainage Systems, Inc., 8-inch ID (Set II).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
5-4	27.330	26.331	26.125	25.925	25.771	57
5-5	26.735	25.725	25.453	25.325	25.144	57
5-6	25.569	25.559	25.325	25.135	24.986	57
5-7	25.013	25.013	24.800	24.600	24.412	57
5-8	24.410	23.418	23.175	22.994	22.825	57
5-9	23.850	22.855	22.641	22.426	22.262	57
5-10	23.258	22.263	22.038	21.853	21.625	57
5-11	22.700	21.718	21.505	21.300	21.131	57
5-12	22.141	21.154	20.875	20.710	20.572	57
5-13	21.606	20.613	20.376	20.166	19.994	57
5-14	21.068	20.063	19.818	19.613	19.441	57
5-16	19.889	18.838	18.594	18.420	18.238	57
5-17	19.233	18.238	18.031	17.831	17.663	57
5-18	18.662	17.670	17.450	17.262	17.106	57
5-19	18,069	17.081	16.888	16.695	16.518	57
5-20	17.488	16.525	16.312	16.109	15.875	57
6-2	29.031	28.235	28.069	27.894	27.769	57
6-3	28.444	27.688	27.500	27.325	27.195	57
6-4	27.905	27.159	26.980	26.800	26.664	57
6-5	27.338	26.563	26.375	26.194	26.044	57
6-6	26.796	26.031	25.820	25.631	25.483	57
6-7	26.269	25.475	25.262	25.081	24.925	57
6-8	25.188	24.406	24.175	23.986	23.840	57
6-9	24.663	23.850	23.625	23.456	23.296	57
6-10	24.162	23.288	23.081	22.900	22.736	57
6-11	23.541	22.732	22.532	22.353	22.195	57
6-12	23.012	22.219	22.013	21.825	21.674	57
6-13	22.465	21.675	21.469	21.284	21.138	57
6-14	21.915	21.136	20.915	20.735	20.582	57
6-15	21.350	20.544	20.356	20.166	20.000	57
6-16	20.782	19.984	19.765	19.575	19.418	57

Advance Drainage Systems, Inc., 8-inch ID (Set II).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
6-17	20.250	19.452	19.238	19.050	18.900	57
6-18	19.684	18.897	18.682	18.481	18.337	57
6-19	19.085	18.294	18.106	17.940	17.784	57
7-2	35.113	34.584	34.475	34.556	34.275	57
7-3	34.673	34.106	34.000	33.900	33.800	57
7-4	34.206	33.632	33.514	33.395	33.282	57
7-5	33.728	33.165	33.041	32.875	32.762	57
7-6	32.800	32.194	32.045	31.913	31.787	57
7-7	32.294	31.713	31.541	31.392	31.268	57
7-8	31.356	30.762	30.607	30.464	30.350	57
7-9	30.881	30.282	30.107	29.956	29.856	57
7-10	30.413	29.825	29.655	29.513	29.413	57
7-11	29.915	29.332	29.188	29.033	28.915	57
7-12	29.459	28.860	28.700	28.544	28.448	57
7-13	28.925	28.350	28.212	28.050	27.951	57
7-14	28.463	27.890	27.731	27.563	27.463	57
7-15	27.990	27.413	27.254	27.100	26.990	57
7-16	27.510	26.919	26.776	26.613	26.510	57
8-4	29.144	28.782	28.668	28.581	28.518	57
8-5	28.775	28.388	28.279	28.156	28.081	57
8-6	28.412	28.001	27.857	27.725	27.662	57
8-7	28.001	27.544	27.394	27.268	27.194	57
8-8	27.606	27.144	27.000	26.850	26.768	57
8-9	27.162	26.694	26.550	26.425	26.344	57
8-10	26.732	26.294	26.162	26.031	25.932	57
8-11	26.338	25.882	25.806	25.625	25.537	57
8-12	25.925	25.487	25.368	25.238	25.162	57
8-13	25.481	25.038	24.906	24.787	24.712	57
8-14	25.100	24.662	24.532	24.425	24.356	57
8-15	24.713	24.282	24.150	24.031	23.963	57
8-16	24.288	23.850	23.712	23.582	23.518	57

Advance Drainage Systems, Inc., 8-inch ID (Set II).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
8-17	23.813	23.482	23.288	23.169	23.094	57
8-18	23.413	23.000	22.863	22.738	22.668	57
8-19	23.000	22.575	22.444	22.318	22.256	57
8-20	22.588	22.175	22.039	21.918	21.855	57
8-21	22.175	21.748	21.625	21.500	21.418	57
8-22	21.795	21.356	21.218	21.088	21.000	57
9-3	30.250	29.875	29.800	29.730	29.688	57
9-4	29.795	29.418	29.325	29.238	29.188	57
9-5	29.438	29.063	28.936	28.825	28.768	57
9-6	28.069	28.625	28.506	28.394	28.312	57
9-7	28.663	28.200	28.081	27.938	27.856	57
9-8	28.268	27.794	27.650	27.513	27.418	57
9-9	27.863	27.362	27.225	27.088	27.000	57
9-10	27.418	26.918	26.788	26.650	26.550	57
9-11	27.019	26.513	26.382	26.250	26.162	57
9-12	26.575	26.000	25.964	25.825	25.738	57
9-13	25.763	25.288	25.150	25.088	24.938	57
9-14	25.325	24.850	24.718	24.588	24.506	57
9-15	24.868	24.406	24.262	24.132	24.069	57
9-16	24.456	24.000	23.856	23.738	23.656	57
9-17	24.044	23.575	23.438	23.306	23.232	57
9-18	23.638	23.169	23.025	22.888	22.794	57
9-19	23.212	22.738	22.600	22.468	22.362	57
9-20	22.769	22.300	22.169	22.044	21.950	57
10-3	29.200	28.413	28.188	27.988	27.795	57
10-4	28.675	27.845	27.613	27.413	27.231	57
10-5	28.206	27.282	27.050	26.850	26.688	57
10-6	27.595	26.731	26.531	26.337	26.175	57
10-7	27.037	26.219	26.025	25.825	25.675	57
10-8	26.456	25.688	25.482	25.300	25.169	57
10-9	25.888	25.013	24.918	24.750	24.618	57

Advance Drainage Systems, Inc., 8-inch ID (Set II).--Con't.

Photo No.	Head inches	Manometers 1 inch	2 inches	3 inches	4 inches	Temp. F°
10-10	25.400	24.650	24.450	24.288	24.150	57
10-11	24.844	24.106	23.913	23.750	23.625	57
10-12	24.366	23.588	23.413	23.232	23.106	57
10-13	23.794	23.069	22.864	22.718	22.568	57
10-14	23.288	22.569	22.375	22.200	22.062	57
10-15	22.732	22.000	21.800	21.625	21.500	57
10-16	22.212	21.469	21.288	21.106	20.988	57
10-17	21.688	20.918	20.750	20.506	20.418	57
10-18	21.163	20.425	20.225	20.050	19.900	57
10-19	20.644	19.913	19.718	19.538	19.406	57
10-20	20.100	19.356	19.165	18.969	18.844	57
10-21	19.525	18.788	18.588	18.400	18.281	57