# CITY OF MEBANE
# NORTH CAROLINA

# *STORM SEWER DESIGN MANUAL*

MARCH 2006

# STORM SEWER DESIGN MANUAL

The purpose of this manual is to set forth a uniform procedure for designing and checking the designs of proposed storm sewer systems for the City of Mebane. Individuals are to use this manual in the preliminary layout of storm sewer design to minimize revisions during the review process. It is not the intent of this manual to provide an explanation for every design problem encountered, nor is it a substitute for experience, sound judgement, and engineering knowledge.

The City of Mebane will use these guidelines along with sound engineering principles to review the detailed drawings submitted for review. These standards shall apply to all storm sewer design installations within the <;ty <:>KMbe'. _Ap.y_ Yi i<J_n_!2_h_ §(;!_c.1.ig_n_ apgi:t!9_1P-!-l_tJ1 yy_ written approval by the City Engineer prior to construction.

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## *Introduction*

In the field of storm drainage design, there are numerous methods and theories to which engineers may refer. To simplify design and review processes, the procedures for design and construction are presented in this manual. It is not required that engineers designing storm drainage installation adhere entirely to these methods; however, the methods presented in this manual will be considered minimum design standards and any other methods must equal or surpass these design standards.

Presented in this manual are procedures, charts, and tables, which will be helpful in.111e-cres1gn-oTeonunefciaf mid reSfclentiai aeveiopmentsfo Meoane. -Also lisfea are - requirements concerning storm drainage design and construction, including requirements for Flood Studies.

# *DESIGN PROCEDURES*

The procedures presented in this manual will consist of five distinct and separate steps to storm drainage design as it is applied to the storm sewer system for the City of Mebane. In cases where roadway drainage is not a consideration, some of the steps will not apply.

1) Determine the amount of water discharged at the point of design. This is basic to the hydraulic design of any drainage structure whether it is a channel, culvert, pipe system, or an inlet.
2) Determine the capacity of the gutter and allowable roadway area to transport the quantity of runoff collected on the roadway.
3) Determine the intake capacity of the inlet structure receiving the runoff.
4) Determine the actual size for the discharge pipe based on the calculated discharge and the most economical slope.
5) Determine the QIOO Water Surface Elevations and evaluate its impact on structures (Flood Study).

## DETERMINATION OF DISCHARGE

The City of Mebane uses two methods for determining storm drainage, discharge design depending on whether the drainage basin is above or below 200 acres in area. Use the Rational Method for areas under 200 acres and the Basin Lag-time Method for areas over 200 acres.

### The Rational Method
(Method for Estimating Rainfall Runoff in Drainage Areas Under 200 Acres)

The Rational Formula is:

$$Q=CIA$$

Where
Q = peak discharge of drainage basin in cubic feet per second (cfs)
C = coefficient of runoff
I = intensity of rainfall in inches per hour for a storm of a given frequency and duration equal to the time of concentration
A = area of drainage basin in acres

When selecting representative values used in the rational formula, consider the following:

1) Coefficient of Runoff = C

A list of runoff coefficients to be used in design computations is shown on page 8. Select a C value coinciding with the characteristics of the drainage area after development. When the drainage area involves a combination of coefficients a weighted average must be computed. The type of land and development used in selecting a C value will be compatible with the current zoning maps.

2) Rainfall Intensity = I

There is a direct relationship between rainfall intensity and the time of concentration. The duration of the design storm is equal to the time of concentration of the drainage basin in question. The time of concentration is the time required for a particle of water to flow from the most remote point in any section of the drainage area to the point of design.

A velocity of 8-feet per second would provide a reasonable design velocity for determining the time of concentration throughout the watershed of the Mebane area. Since 8-feet per second = 480 ft./min., a design figure of 500 ft./min. is actually used to simplify computations.

A further assumption is made that in the uppermost reaches of the watershed where the following applies. The sheet velocity of the runoff will be such that it will travel 800-feet in 10 minutes in business areas and 500-feet in 10 minutes in residential ;--0€'.fere-being-ro-lk--etsd-in-we-ll-d-efineawateroeur-ses-where-i-t-s--veleeity wi-H-then--be 500 ft./min.

As an example of application, suppose that in a residential area it is found by scaling from a 200-foot scale topographic map that the distance from the ridgeline to a point on a watercourse is 3000-feet. The time of concentration will be found as follows:

| | | |
|---|---|---|
| 3000 ft. | | |
| - 500 ft. | = | 10 min. |
| 2500 ft. @ 500 ft./min | = | 5 min. |
| Time of concentration | = | 15 min. |

Using the time of concentration determine the rainfall intensity (I) from the appropriate rainfall and runoff chart found on pages 9 – 13. Storm sewer systems carrying street or public runoff are to be designed to carry a 10-year return period storm. This requirement will apply to all public and private developments.

1) *Drainage Area* = A

The acreage of the watershed in question can be computed from topographic maps by marking the ridgelines and planimetering the designated areas. Provide copies of the drainage area delineation mapping.

Once the values for C, I, and A are determined it is a simple procedure to calculate the peak discharge rate for the site using the equation, Q = CIA.

## AVERAGE VALUES OF THE RUNOFF COEFFICIENT

Below are the runoff coefficients to be used in calculating storm water runoff. All drainage must be designed based on proposed land use for the entire drainage basin and must be assumed to be developed.

| Type of Development: | Runoff Coefficient |
|---|---|
| Residential, Single Family | 0.65 |
| Apartments, Condominiums, and Industrial Parks | 0.80 |
| Paved Areas (Downtown Areas, Shopping Centers, etc.) | 0.95 |
| Playgrounds, Parks, Cemeteries, etc. | 0.40 |

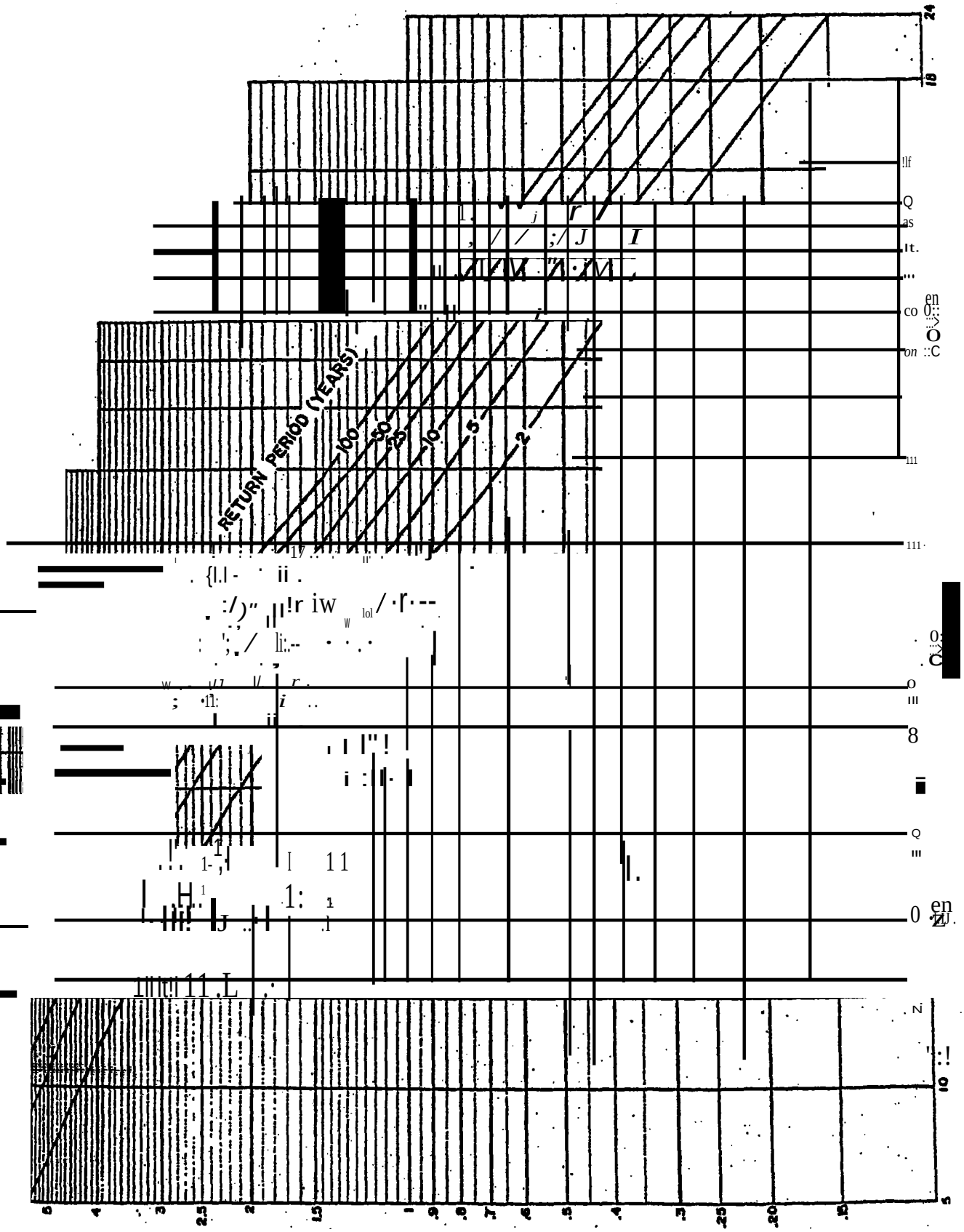
Storm Drainage Design Return Period

| | |
|---|---|
| Street Runoff Drainage Systems | 10-years |
| Drainage-Structures-for Main-Drainage -Channels | IUO-years |

The finished floor elevation of all permanent structures must be constructed a minimum of two feet above the 100-year flood elevation as established by FEMA Maps or as established by flood studies as required in this manual.

In those areas with no flood study, the finished floor elevation of all permanent structures must be constructed at least 2 ft. above the elevation of the downstream roadway or embankment and must be at least 2 ft. above the highest adjacent grade.

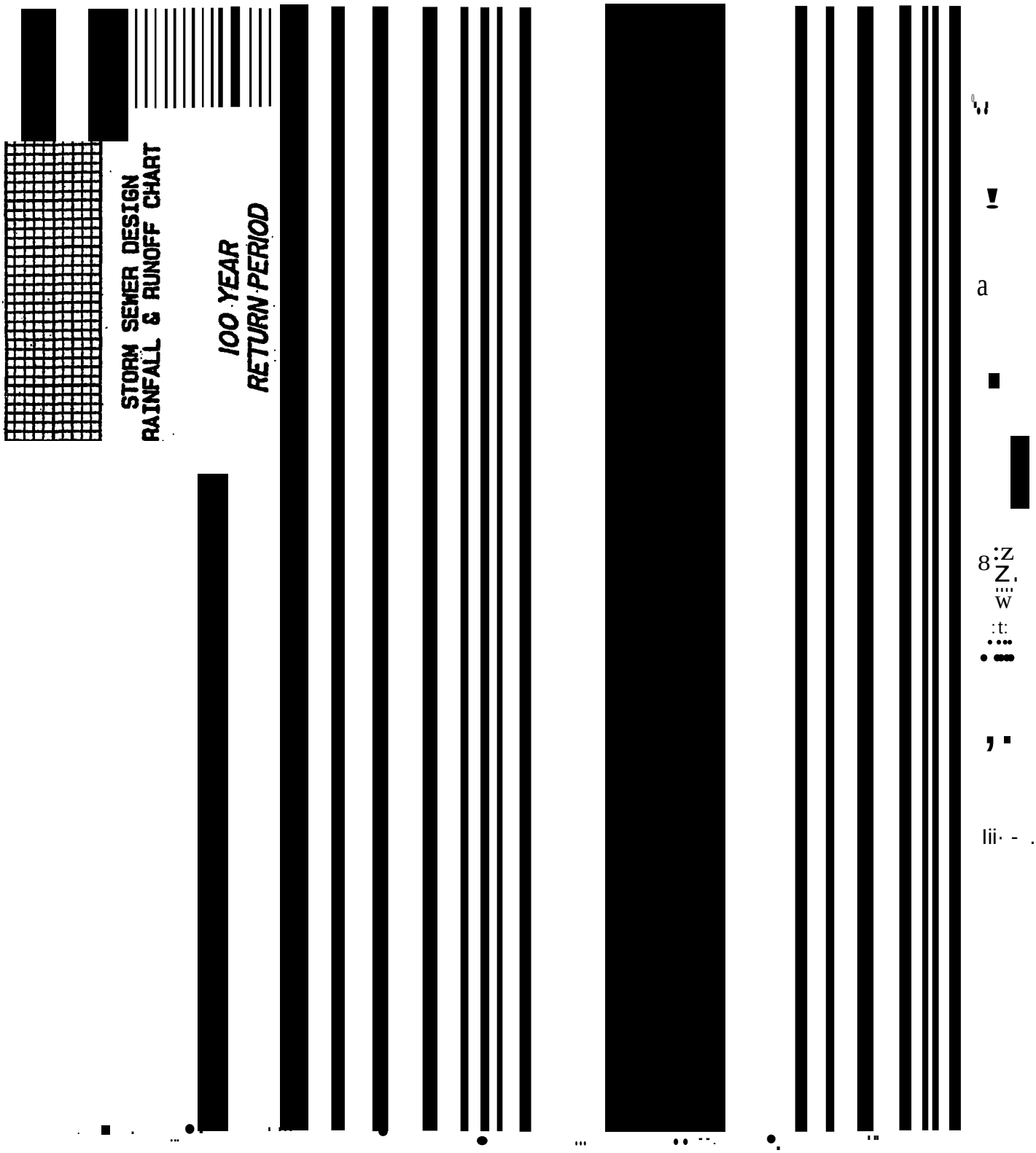
Rainfall Intensity· Duration:·.; Freqticy Curves



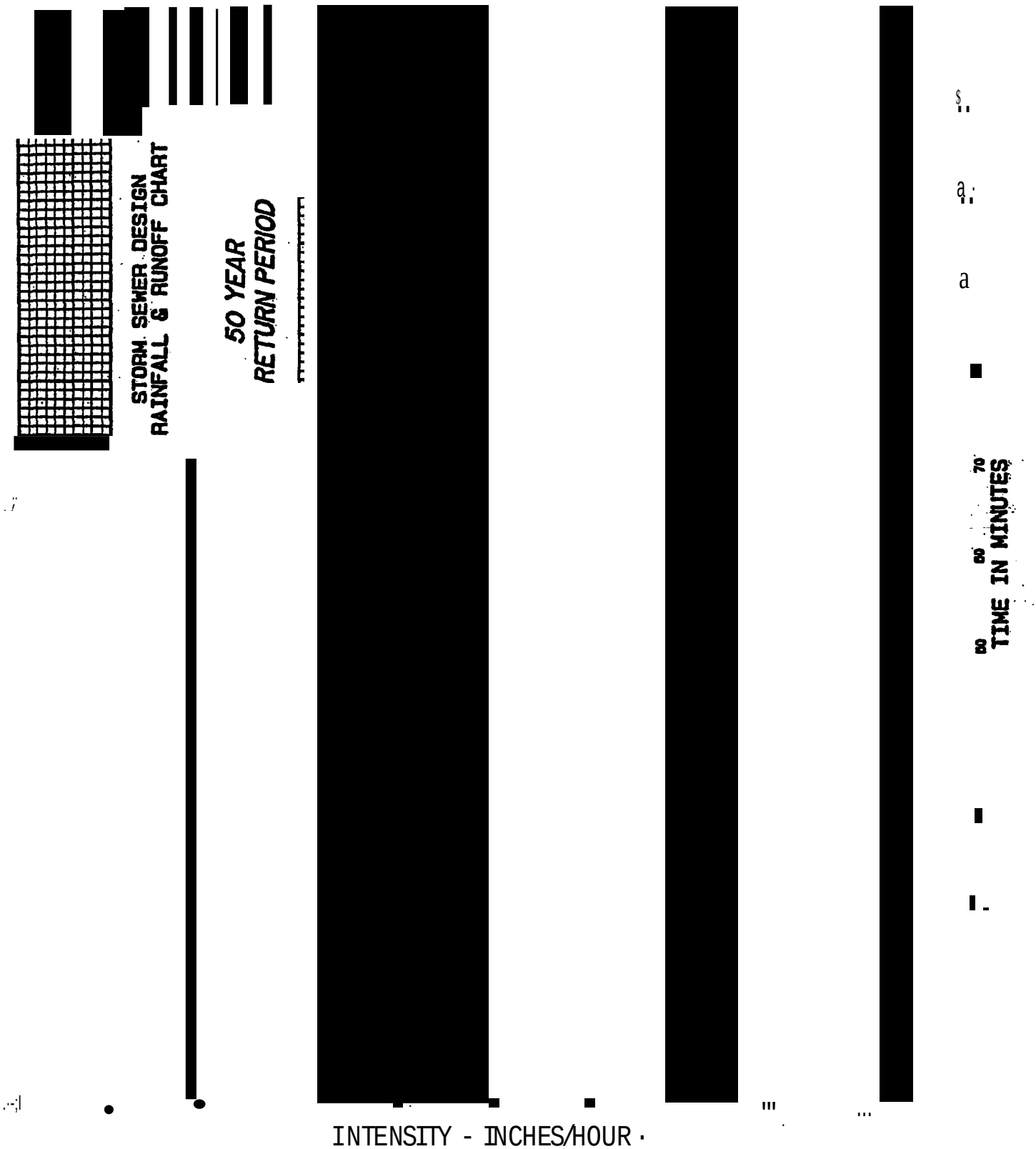
!NTENSTy
1CHES/HOUR

9 .

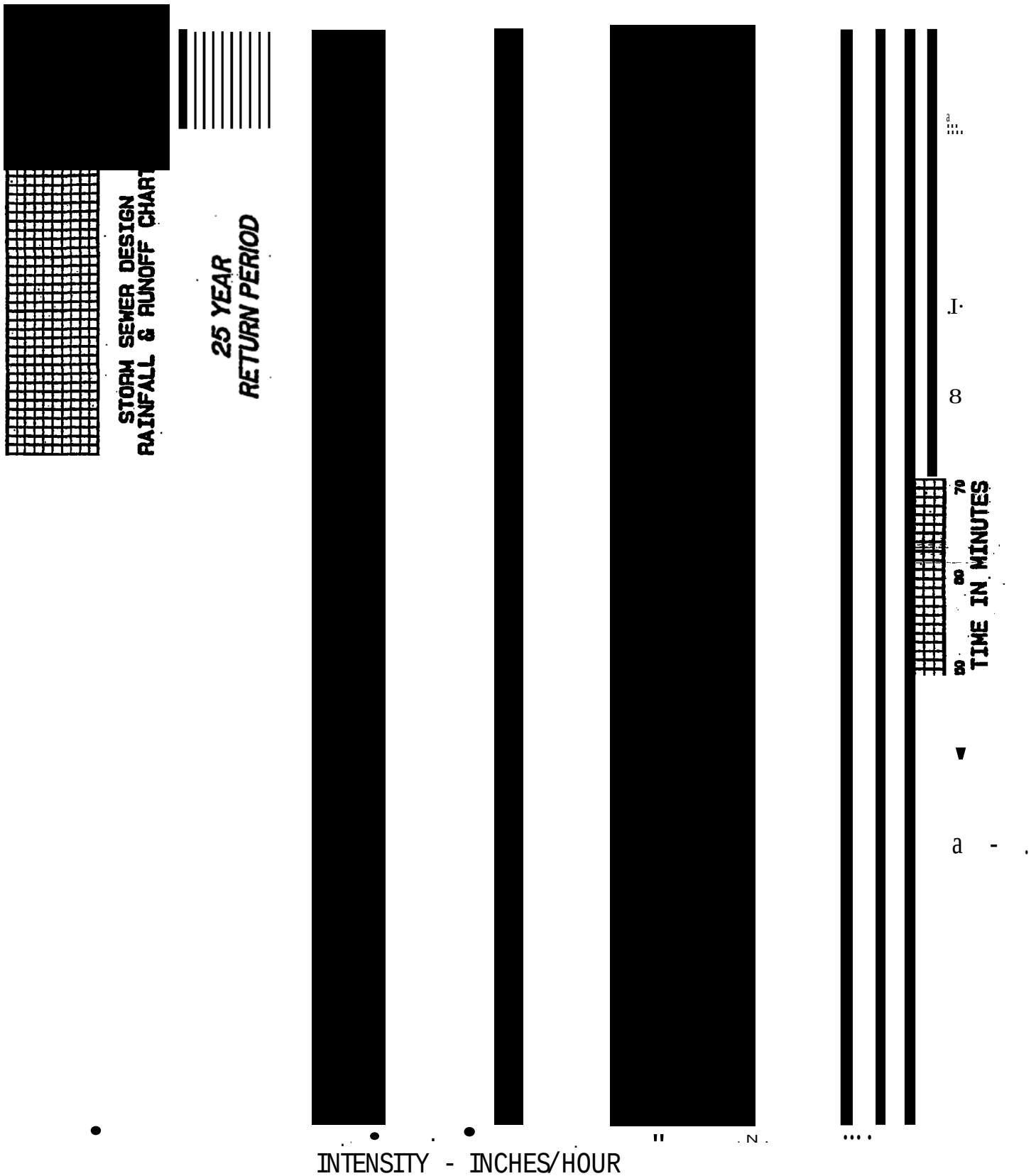
# fitorm. Sewer. Design Rahifall & Runoff. Chart
100-year Retmn Period



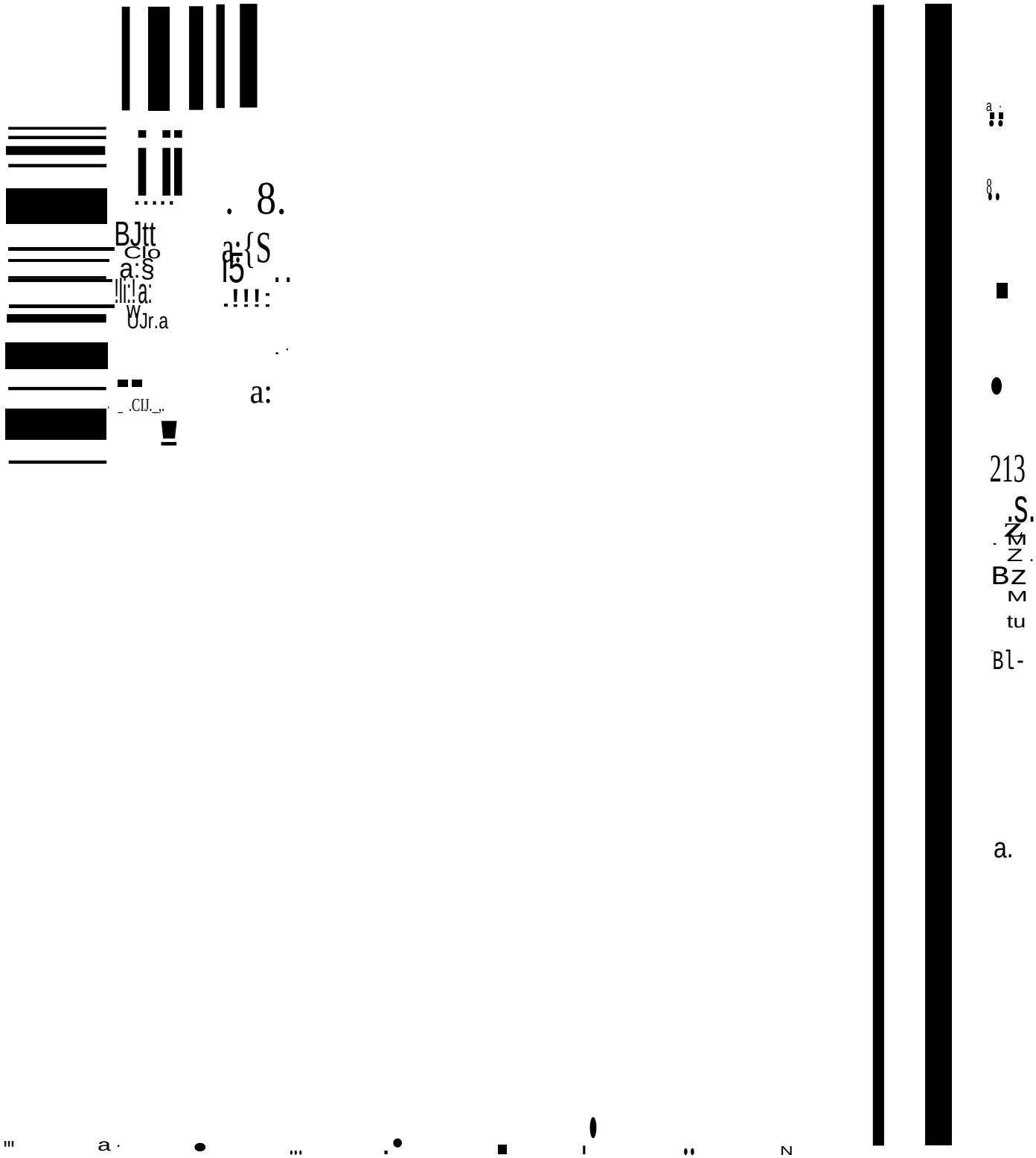
Storm Sewer Design Rainfall & Runoff chart
SO-year·Return. Period ·



Storm Sewer Desip Rainfall & Runoff Chart
25-year Return Period



Storm · Sewer Design Rainfall & Runoff Chart
10-year Return Period



## Basin Lag-Time Method

(Method for Estimating Rainfall Runoff in Drainage Areas Over 200 Acres)

The Basin Lag-Time Method is a mathematical regression model developed for the Piedmont Area of North Carolina by the United States Geological Survey. This method is acceptable in calculating rainfall runoff rates for drainage areas greater in area than 200 acres. Details of the Basin Lag-Time Method, prepared by the U.S. Geologic Survey, can be found in the 1972 open file report, Effect of Urban Development on Floods in the Piedmont Province of North Carolina, by Arthur L. Putnam.

The Basin Lag-Time Method is a combination of two steps leading to the calculation of peak discharge rates for the two, five, ten, fifteen, twenty, twenty-five, fifty and one-hundred year floods.

The two steps include:

1) The estimation of basin lag-time which is the average time interval in hours, between the occurrence of peak rainfall and the resultant peak runoff.

The equation for estimating *Basin Lag-Time* is:

$$T = 0.49\,(LI.JSy5°]- 0.S?$$

| | | |
|---|---|---|
| T | | Lag-Time in hours |
| L | = | Length of main water course in miles |
| S | | Stream bed slope of the main water course in feet per mile |
| ▮ | | Ratio of the area of impervious cover to the total drainage area |

2)

| | | | | | |
|---|---|---|---|---|---|
| Q2 | = | $221\,A^{0.87} \times T^{-0.6}$o | Q2o | | $735\,A^{0.72} \times T^{-0.43}$ |
| Q5 | = | $405\,A^{0.80} \times T^{-0.52}$ | Q25 | | $790\,A^{0.71} \times T^{-0.42}$ |
| Qio | = | $560\,A^{o.16} \times y^{-0.48}$ | Q5o | = | $990\,A^{o.67} \times T^{-0.37}$ |
| Q5 | = | $630\,A^{o.74} \times y^{-0.45}$ | Qioo | = | $1200\,A^{0.63} \times T^{-0.33}$ |

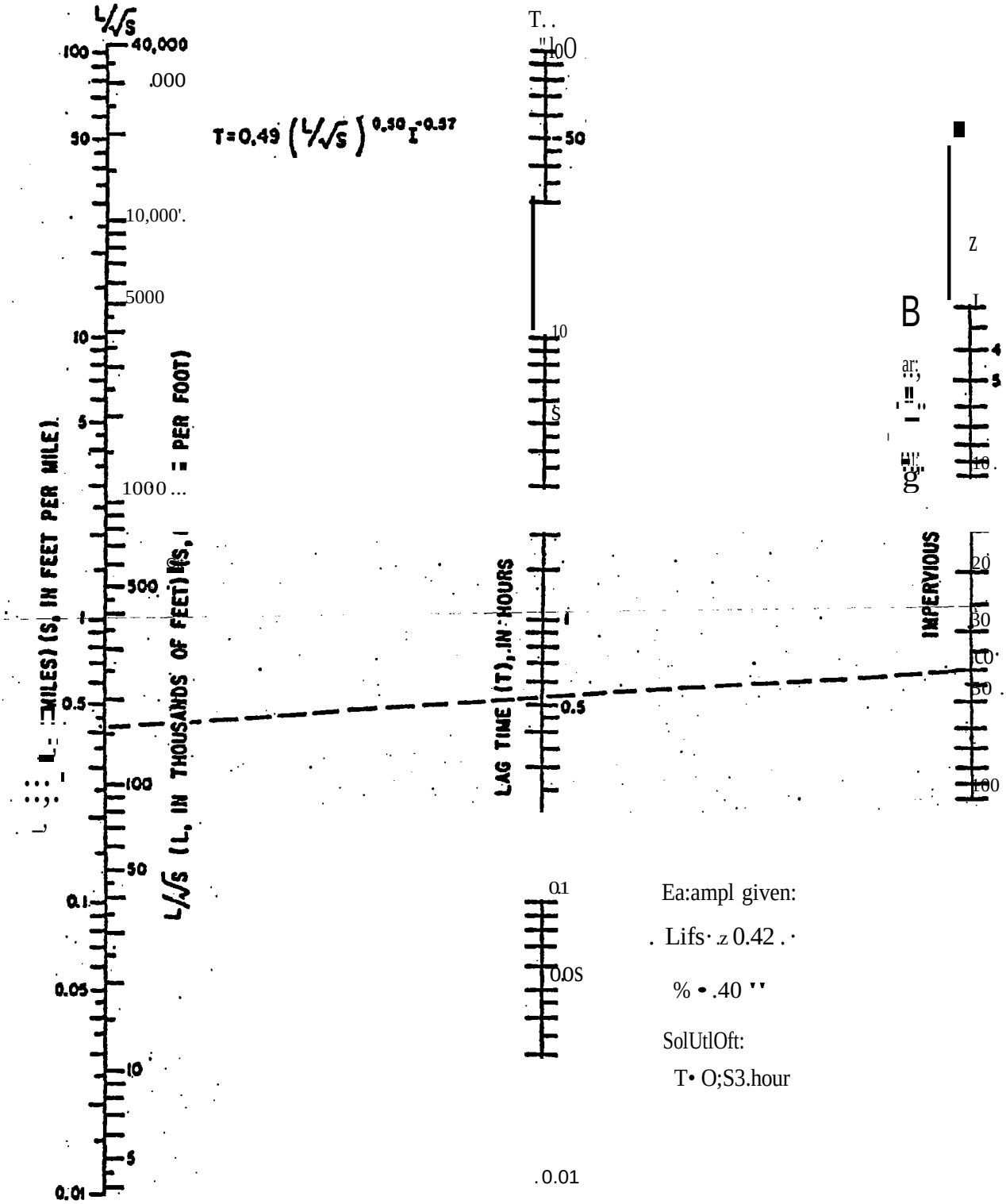
Q1 = Peak discharge for the flood having the recurrence interval indicated By the subscript in cfs.

A Drainage Area in square miles

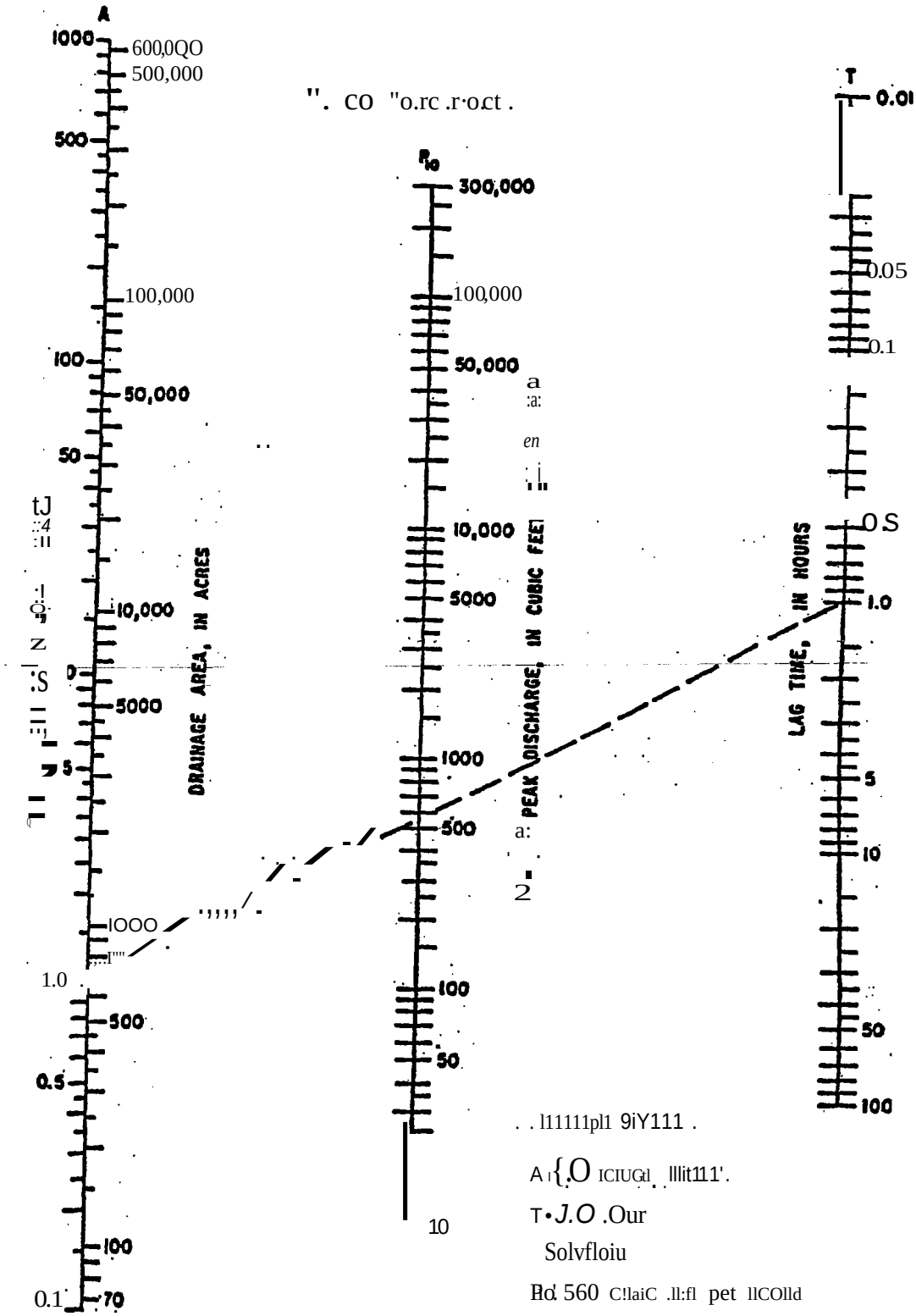
T = Lag-Time in hours

Pages 19 – 25 include a set of nomographs with an example, which can be used in lieu of the above formulas.

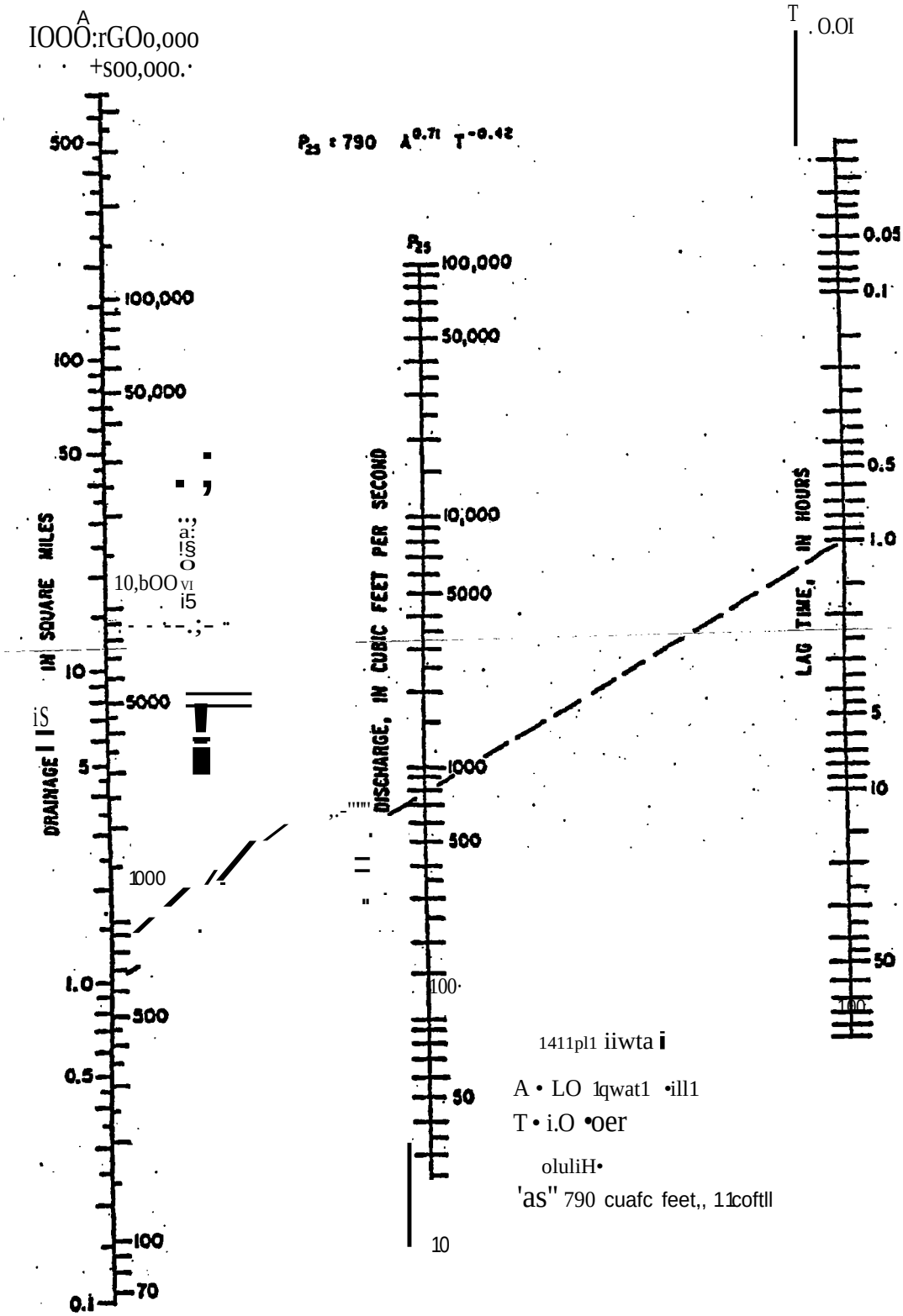
# Nomograph for Estimating Basin Lag-Tie



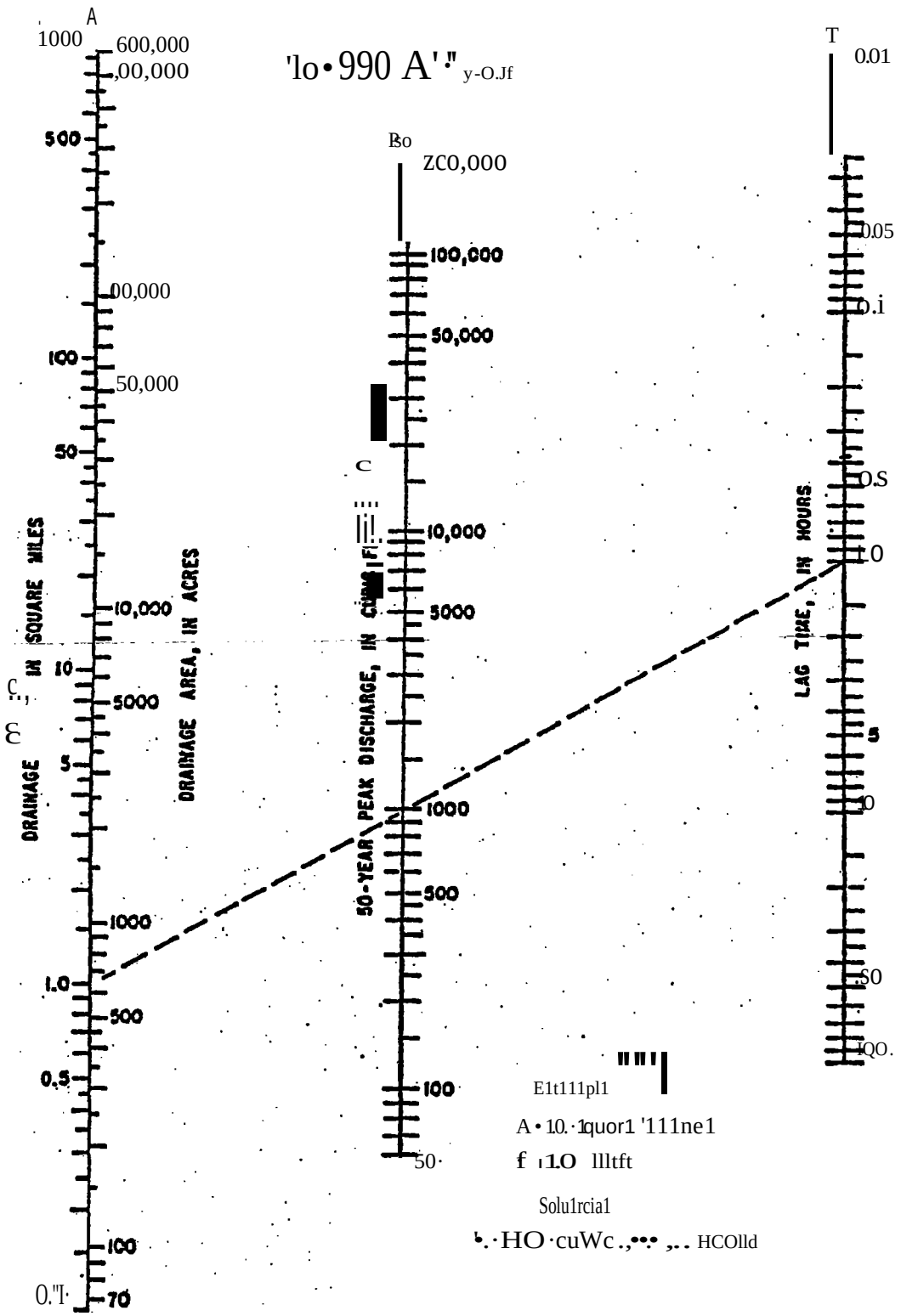
·Nomomph for Esimatlng 10-year Flood-Peak Discharge.



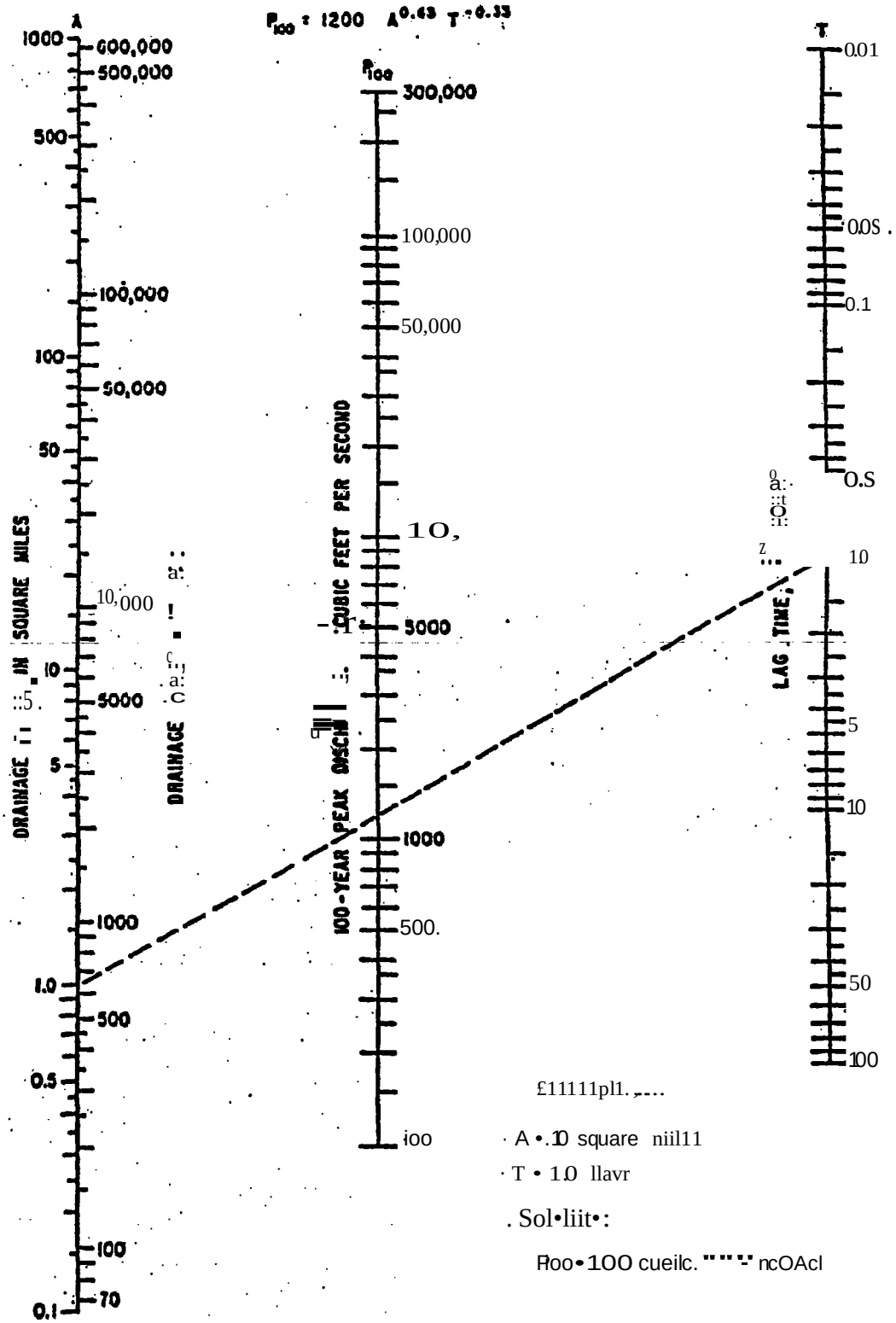
. Nomo·gi;aph fb·Estimating 25-year Flood-Peak Discharge



Nomograph for _Estimating 50-yeai: Flood-Peak Discharge .



## Nomograph for Estimating 100-year Flood Peak Discharge




£11111pl1. ....

A •.10 square niil11

T • 1.0 llavr

. Sol•liit•:

Roo•100 cueilc. ncOAcl

The following example illustrates the use of the Basin Lag-Time Nomographs:

1) Find the 20-year flood-peak discharge given the following Drainage Basin Information:

A = 2.72 square miles
I = 40 (impervious area)
L = 2.66 miles from the design site to the rim of the Drainage Basin.
= 0.27 miles from the design site to a point that is 10 percent of the distance to the rim of the drainage basin.
= 2.26 miles from the design site to a point that is 85 percent of the distance to the rim of the drainage basin.
Elevation = 605 feet at the point that is 10 percent of the distance to the rim of the drainage basin.
= 686 feet at the point that is 85 percent of the distance to the rim of the drainage basin.

2) Compute Slope:

$$S = \frac{686\,fl - 605\,fl}{mile\ 2.26\,mi - 0.27\,mi} = \frac{81\,fl}{4\ 1.99\,mi} = 1.0\,fl.per$$

3) Compute Length-Slope factors:

$$Y.JS = 2.66;\ J_{4\ 0}^{1.} = 0.42$$

4) Determine lag-time from page 15, plot the value of impervious cover, I = 40, on the scale at the right; then plot the value of the length-slope factor, L/S = 0.42, on the scale at the left. Connect these two points with a straight line and read the lag-time value, T-0.53 hours, on the center scale.

5) Determine the 25-year flood-peak discharge from page 17. Plot the value of lag-time, T = 0.53 hours, on the scale at the right; then plot the value of drainage area, A – 2.72 square miles, on the scale at the left. Connect these two points with a straight edge and read the 25-year flood-peak discharge value, Q2S = 1100 cubic feet per second, on the center scale.

It would be advisable that the answer be verified with the appropriate equation, until the use of the nomographs is understood.

## DETERMINATION OF GUTTER CAPACITY

The capacity of the gutter and roadway pavement is dependent upon the physical characteristics of the facility in question. The cross slope of the pavement section, the slope of the gutter, the longitudinal grade and the roughness interrelate to determine the runoff carrying capacity of a street section. Equations and nomographs have been derived based on these parameters, as well as the depth of flow at the curb and the spread of water in the street.

Since the depth of flow and/or the spread into the street are normally the controlling factors, the approach taken for this section was to set limits for speed and develop tables showing the quantity of runoff allowable for the more commonly used street sections. Two limits have been set for this purpose. The first is that the flow shall not encroach within 8-feet of the street centerline. The second limit is that the width of flow shall not exceed 10-feet from the face of curb.

Curb inlets will be spaced so that these two limits will not be exceeded during a 10-year design storm. In special cases where flow is allowed to bypass inlets on a continuous slope, inlets located downhill in the sump will be designed to handle that extra flow. Normally, multiple inlets are not allowed. If there is enough flow to require multiple inlets, the gutter capacity requirements probably have been exceeded.

Using the maximum width of flow for a given street width, the maximum depth of flow can be determined for various pavement cross slopes. Using the maximum depth an.a spread to nnollle area-caJan.a- llie liyCinUifc radlus-{R) rn-tle-equation-foropen - - channel flow we have the maximum flow as a constant (for the given cross slope) multiplied by the longitudinal slope taken to the *Yz* power.

Example:

Given: Street width 30' F-F

$S_1$(Transverse Slope) = 0.25 ft./ft.

SL(Longitudinal Slope) = 2% or .02 ft./ft.

Find: Qmax (Maximum allowable flow)

$$Q = A \frac{1.486}{n} R^{213} s^{112}$$

Using 7 ft. for maximum spread and .208 for maximum depth.

$$A = [(.208;.125)(2)] + (.15)<5) = .646 sf$$

$$P = 7.208 ft$$

$$R = \frac{646}{7.208} = 0.0896$$

$$Q = 6.46 x \frac{1.486}{0.15} x (0.0896)\ 2/3 x Sil\ 2$$

$$Q = l\ 2.80 x S1/2$$

$$for\ S = .02 \quad Q = 12.80 x (.02)112 = 1.8l\ cfe$$

Using this method, tables have been developed showing i µaximum tlow races 101 different combinations 9f · cross slope and longituwnal slope. for three common street widths. Using these- tables, the desigiter can · quickly determill if the calculated flow · is allowable at the designated location

## Gutter Capacity for Streets with 2'-6" Standard Curb and Gutter

| | |
|---|---|
| Street Width (Face.to Face) | 26 ft. |
| Centerline Encroachment Limit . | 8 ft. |
| Maxhrimn Spread | 5 ft. |

| Maximum Depth (ft.) | Cross Slope (%) 15 | ·2 | 25 | 3 | 35 | 4 |
|---|---|---|---|---|---|---|
| | 0.128 | 0.143 | 0.158 | 0.173 | cuss | 0.203 |

MUimum Flow in Gutter at Maximum Spread (cfs)

| Longi al Slope %) | Cross Slop (%) 1.5 | 2 | 2.S | 3 | :3.5. | 4 |
|---|---|---|---|---|---|---|
| 65 | -e-22 | 030 | 6:46 | ·aS0-- | - 1>:62 | 0:74 |
| 06 | 0.24 | 0.33 | 0.44 | ·0.55 | 0.68 | 0.81 |
| 08 | 0.28 | 0.38 | 0.51. | 0.64 | 0.78· | 0.94 |
| 1 | 0.31 | 0.43 | 0.57 . | 0;71 | 0.88 | 1.05 |
| 1is | ·035 | 0.48 | 0.63 | 0.80 | 0.98 | 1.17 |
| 1.5 | 038 | 0.53 | 0.69 | 0.87 . | 1.07" | 1.29 |
| 1.75 | 0.41 | 0.57 | 0.75 | 0;94 | 1.16 | 1.39 |
| 2 | 0.44 | 0.61 | 0.80 | 1.01 | 1.24 | 1.49 |
| 2.5 | 0A9 | 0.68 | 0.89 | 1.13 | 1.38 | 1.66 |
| 3 | 0.54 | Or75 | 0.98 | 1.24 | 1.52 | 1.82 |
| 35 | 0.5$ | 0.81 | 1.06. | 1.34 | 1.64 | "1.96 |
| . 4 | 0.62 | os6· | 1.13 | 1.43 | 1.15 | "2.10 |
| 4.5 | 0.66 | 0.91 | 1.20 | 1.51 | 1.86 | 2.23 |
| 5 | 0.69 | 0.96 | "i.26· | 1.60 | 1.96 | 2.35 |
| 55 | 0.73 | 1.01 | 1.33 | 1.67 | i.05 | 2.46 |
| 6 | 0.76 | i.os· | 1.38 | 1.75 | 2.15· | 2.57 |

).

# Gutter Capacity for Streets with ·2-· Standard Curb and Gutter

| | |
|---|---|
| Str•Width (Face to Face) | 30 ft. |
| Centerline Encroachment Limit | 8 ft. |
| Maximum Spread | 7 ft. |

| Maximum Depth (ft.) | Cross Slope (%) 1.5 | 2 | 2 | 3 | 3.5 | 4 |
|---|---|---|---|---|---|---|
| | OJ58 | 0.183 | 0.208 | 0.233 | 0.258 | 0.283 |

Maximum Flow in Gutter at Maximum Spread (cfs)

| Longitudinal Slope (%) | Cross Slope (%) 1.5 | .2 | 25 | 3 | 35 | 4 |
|---|---|---|---|---|---|---|
| 05 | 0.45 | 0.66 | 0.91" | 1.18 | 1.48 | 1.81 |
| 06 | 0.49 | 0.72 | 0.99 | ".1.29 | 1.62 | 1.9'8 |
| 08 | 0.56 | ·0.83 | 1.15 | 1.49" | 1.88 | .2.29 |
| 1 | f163 | 0..:93 | 1.28 | 1.67 | ·2-,JO. | 256 |
| 1.25 | 0.70 | 1.04 | 1.43 | 1.87 | 2.35 | 2.86 |
| 15 | 0.77 | .14 | 1.57 | 2.04 | 2.57 | 3.14 |
| 1.75 | 0.83 | 1.23 | ·1.69 | 2.21 | 2.77 | 3.39 |
| 2 | 0.89 | 1.32 | 1.81 | 2.36 | 2.97 | 3.62 |
| 25 | ·1.00 | 1.48 | 2.02 | 2.64 | 3.32 | 4.05 |
| 3 | 1.09 | 1.62 | 2.22 | 2.89 | 3.63 | 4.44 |
| 3S | 1.18 | 1.75 | 2.40 | .12 | 3.92 | 4.79 |
| .4 | 1.26 | 1.87 | 2.56 | 3.34 | 4.20 | "5.12 |
| 4.5 | 1.34 | t.98 | 2.72 | 3.54 | 4.45" | :5.44 |
| 5 | 1.41 | 2.09 | 2.86 | 3.73 | 469 | 5.73 |
| 55 | 1.48 | 2.19 | 3.00 | 3.92 | 4.92 | 6.01 |
| 6 | 1.54 | 2.29 | 3.14 | 4.09 | 5.14 | 6.28 |

## Gutter Capacity for Streets with 2'.:.(i" Sdard Curb and Gutter

| | |
|---|---|
| Street Width (Face to Face) | 40 ft |
| Centerline Encroac Jit Limit | 8 ft. |
| Maximum Spread | 10 ft. |

| Maximum Depth (ft.) | Coss_Slope (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 |
| | 0.203 | 0.243 | 0.283 | 0.323 | 0.363 | 0.403 |

Maxbilum Flow in Gutter at Maximum Spread (cfs)

| Longitudinal Slope (%) | Cross Slope (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 |
| 0.5 | 1.03 | 1.59 | 2.24 | 2.98 | 3.79 | 4.68 |
| 0.6 | 1.13 | 1.75 | 2.46 | 3.26 | 4.15 | 5.12 |
| 0.8 | 1.31 | 2.03 | 2.84 | 3.77 | 4.80 | 5.92 |
| 1 | 1.46 | 2.25 | 3.17 | 4.21 | 5.36 | 6.61 |
| 1.25 | 1.63 | 2.52 | 3.55 | 4.71 | 5.99 | 7.40 |
| 1.5 | 1.79 | 2.76 | 3.89 | 5.16 | 6.57 | 8.10 |
| 1.75 | 1.93 | 2.98 | 4.20 | 5.57 | 7.09 | 8.75 |
| 2 | 2.07 | 3.19 | 4.49 | 5.96 | 7.58 | 9.35 |
| 2.5 | 2.31 | 3.56 | 5.01 | 6.66 | 8.48 | 10.46 |
| 3 | 2.53 | 3.90 | 5.50 | 7.30 | 9.29 | 11.46 |
| 3.5 | 2.73 | 4.22 | 5.94 | 7.88 | 10.03 | 12.37 |
| 4 | 2.92 | 4.51 | 6.35 | 8.43 | 10.72 | 13.23 |
| 4.5 | 3.10 | 4.78 | 6.73 | 8.94 | 11.37 | 14.03 |
| 5 | 3.27 | 5.04 | 7.10 | 9.42 | 11.99 | 14.79 |
| 5.5 | 3.43 | 5.29 | 7.44 | 9.88 | 12.57 | 15.51 |
| 6 | 3.58 | 5.52 | 7.77 | 10.32 | 13.1 | 16.20 |

t

DETERMINATION OF INLET CAPACITY

All curb inlets on public or private streets will be spaced so that they can pick up the gutter flow for a 10-year storm event. They must be spaced using the capacities below so that the maximum gutter flows are not exceeded.

The maximum allowable volume of flow to curb inlets on continuous slopes or in a sunip situation will be as follows:

1.) Continuous Slope:

- 4' - 0" wide curb inlet: 4.0 cfs
- 6' - O" wide curb inlet: 6.0 cfs

2.) Sump Condition

- 4' - O" wide curb inlet: 6.0 cfs
- 6' - O" wide curb inlet: 9.0 cfs

These are absolute maximum capacities. A flow greater than these values will rnquire the- inle-t-spaeing to be adjusted

## GENERAL RULES FOR LOCATING CURB INLETS

1) All curb inlets on City of Mebane maintained storm sewer lines must be City of Mebane standard structures as shown in the Roadway and Utility Standard Drawings Manual and so designated on the plans. Non-standard inlets or other structures for special situations require prior approval from the City of Mebane.

2) Curb inlets must be installed at any point along a continuous slope so that the gutter flow shall not exceed the maximum allowable gutter flow as established in the section of "Determination of Gutter Capacity" starting on page 21 and shown in tables on pages 22, 23, and 24.

3) Curb inlets must be installed at the PC or PT of radius so that no gutter flow will be allowed to sheet flow across an intersection.

4) Curb inlets must be located at any point of radius where the intersecting street falls away so steeply that the gutter flow will have a tendency to jump out of the gutter-and sheet-flowacrossihe intersection. --

5) Curb inlets must be installed above any driveway turnout so that no gutter flow will enter private property.

6) In certain cases, the NCDOT Standard Inlet No. 840.03 "Grate, Frame and Hood" will be allowed where conditions prohibit the use of City standard inlets. This will only be allowed with approval of the City.

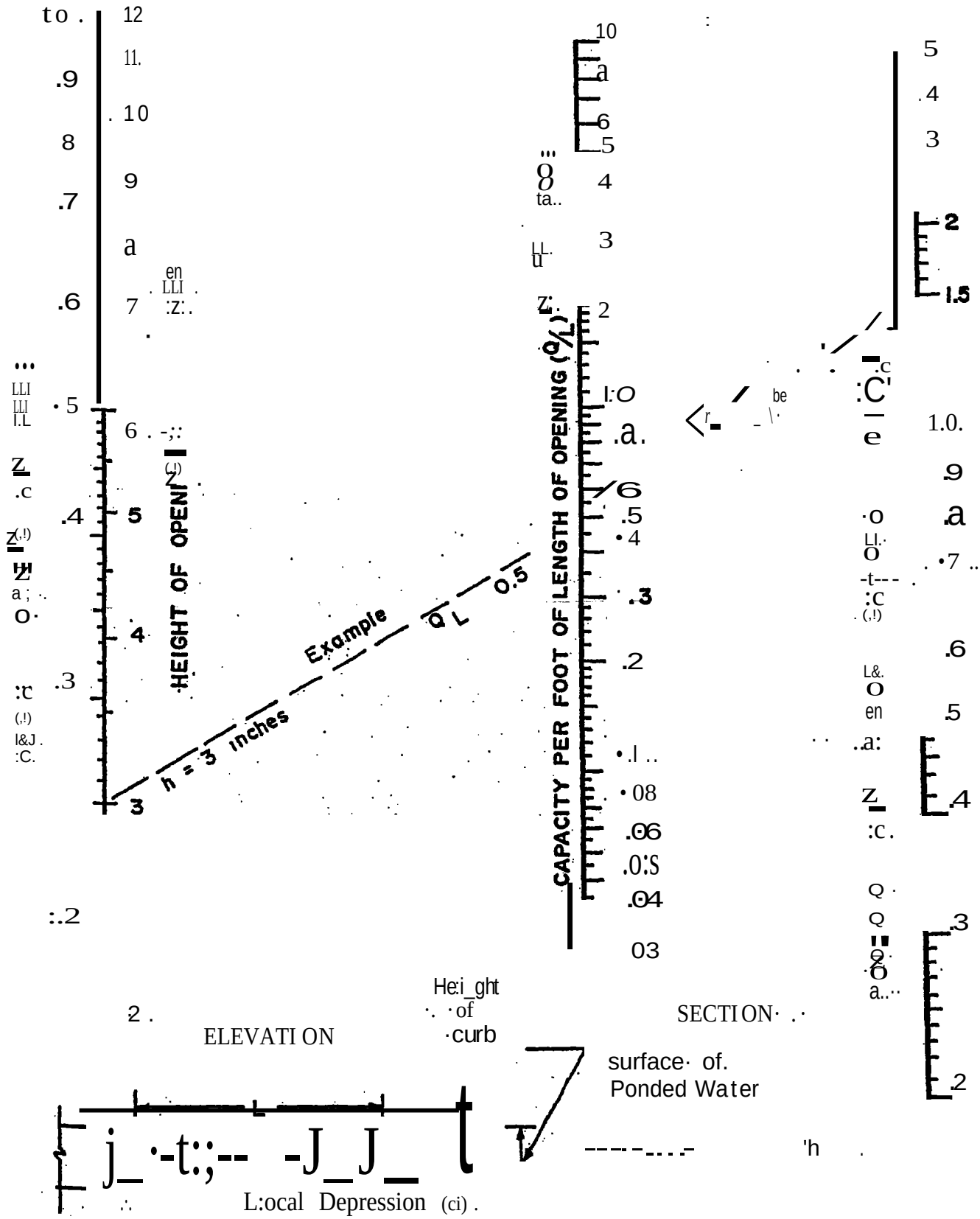
7) Double inlets are not allowed. Usually, ifthere is enough runoff to require a double inlet, the gutter capacity has been exceeded and additional inlets are required uphill.

8) Existing curb inlets in a sump cannot be converted to grate inlets to make room for a private drive entrance unless new curb inlets are installed at points of radius on both sides of the drive entrance. The grates have a tendency to get clogged up and create traffic hazards during heavy storm events.

9) Curb inlets in locations other than sumps may be converted to grate inlets by permission as long as the grate inlet is installed in the gutter flow line and not over the existing curb inlet box. The existing box is not located in the flow line. In most cases the existing box will be removed and the new grate box will be built over the existing pipe and in the gutter line.

10) Spill gutter is not allowed because of the sheeting and freezing problems that can occur.

# CAPACITY OF CURB OPENING INLETS AT A SUMP



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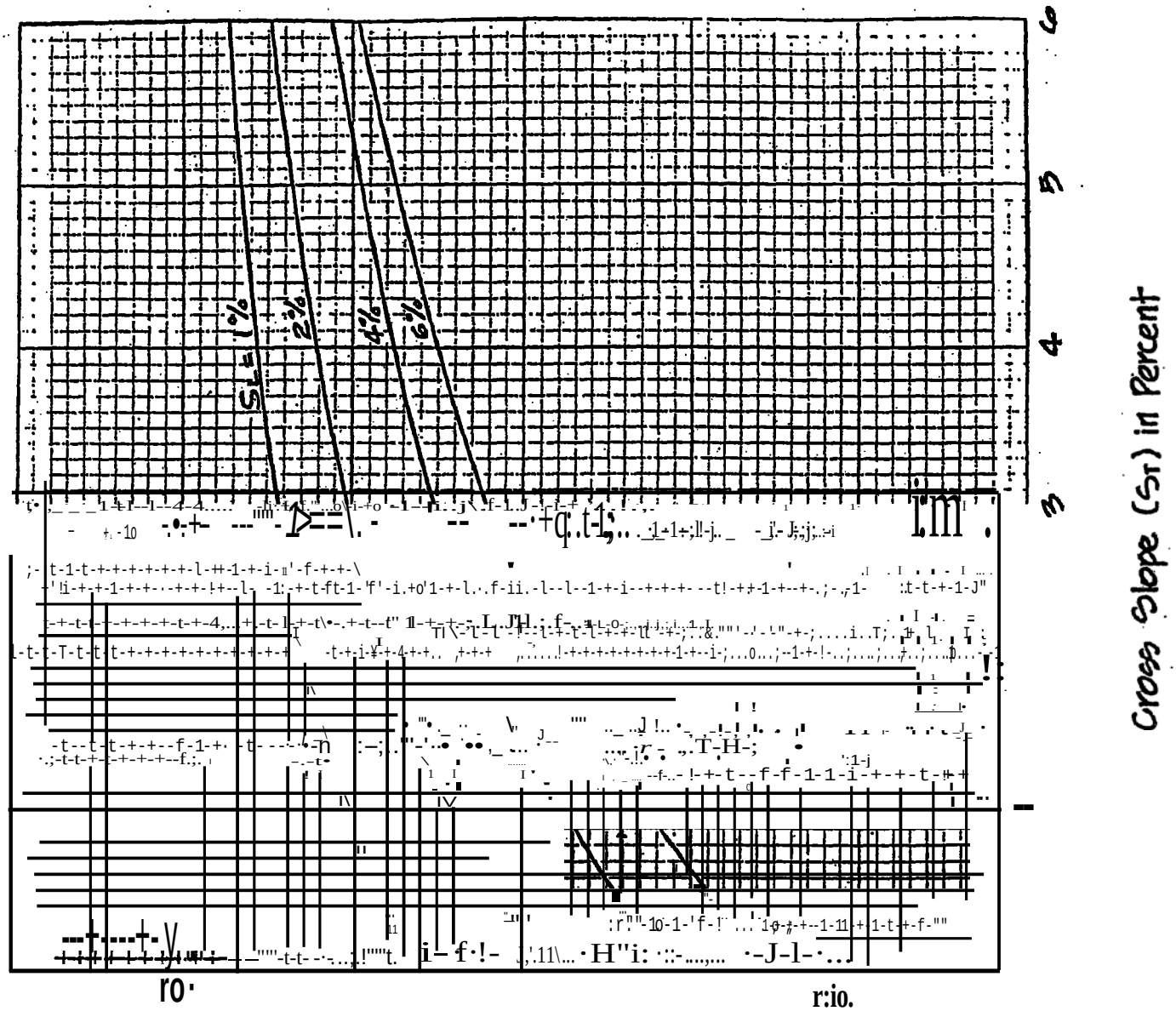
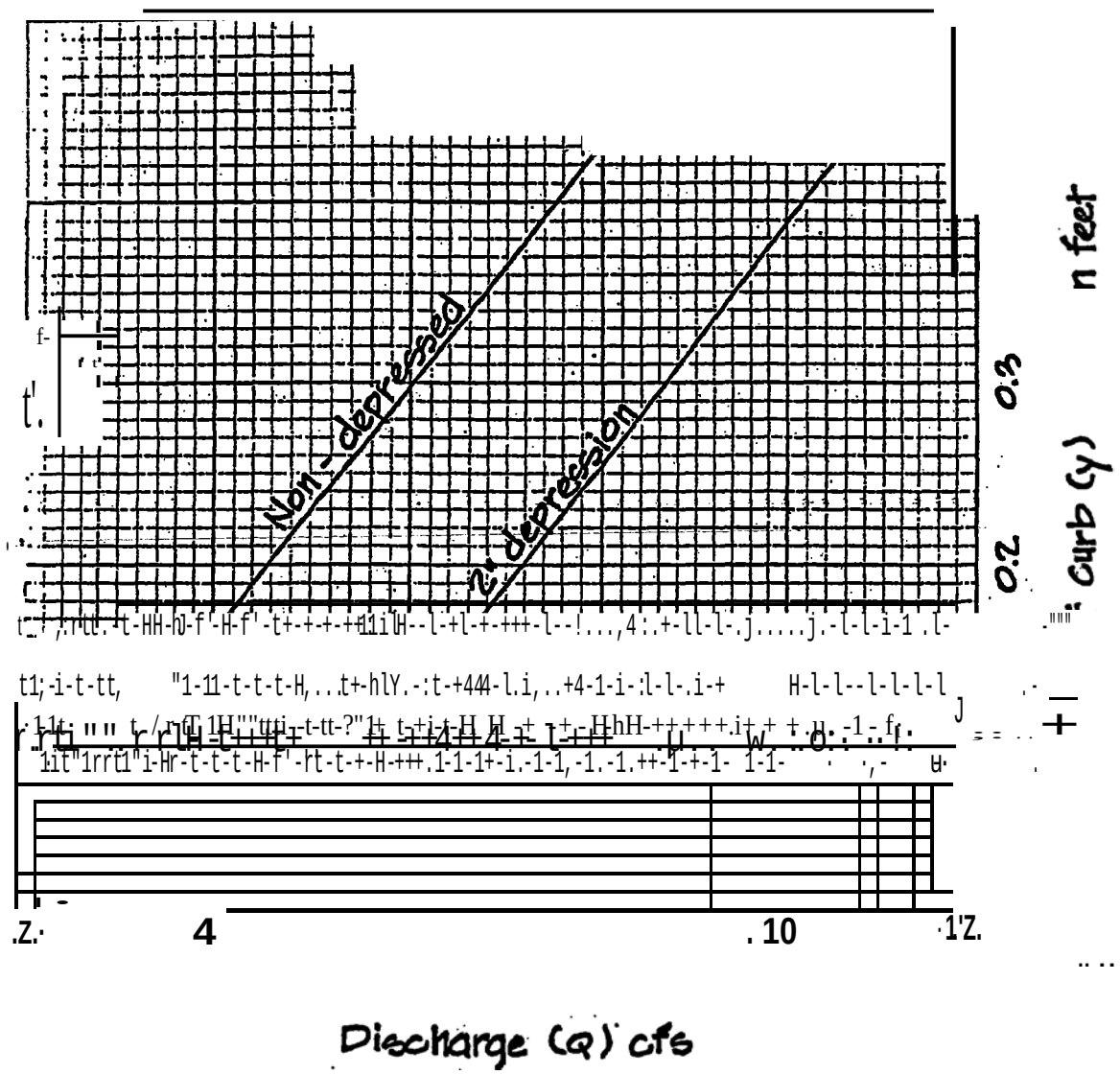
## K V.AI:,UES FOR GRATE WITH HOOD
## NON-DEPRESSED



## CAPACITY OF GRATE WITH HOOD
## AT THE LOW POINT nf° GRADE



## YARD INLETS

The capacity of the masonry yard inlet can be determined by using the nomograph for "Capacity of an Inlet at the Low Point in Grade", found on page 28. This nomograph is based on experimental determinations of the relation of head to discharge through a rectangular opening, operating submerged and unsubmerged.

This nomograph solves inlet capacity problems under the following conditions:

1) The inlet is located at a low point in the grade.
2) All flow coming to the inlet must eventually enter the inlet and will pond until sufficient head is built up so the outflow through the inlet will equal the peak inflow from the drainage area.

Procedure:

Enter the nomograph with any two of the three values h, Q/L, H/h and read the third.

| | | |
|---|---|---|
| Where h | = | Total height of opening in feet. |
| L | | Total length of opening in feet. |
| H | = | Depth of Water at the entrance in feet. |
| Q | = | Total peak rate of flow to the inlet in cfs. |

Normally Q, L, and h will be known and the nomograph can be used to determine the depth of water H at the inlet. Where more than one side of the inlet will be open to receive water the nomograph can still be used by dividing the flow (Q) by the number of openings or by multiplying the length (L) by the number of openings.

The height of opening on yard inlets is normally set at two courses of brick or 5-inches. For unusual conditions the height can be set by the designer to fit the situation. However, safety is a major concern, especially, in residential areas. Large openings can become a hazard to children and pets. In those cases more than one inlet is advised.

## DETERMINATION OF PIPE SIZES

The following are two methods to be used for determining the required pipe size:

1) The Manning Formula is used to determine a pipe size within a system.
2) This method is for pipes in a culvert situation. Whenever there is a possibility of water pounding at the mouth of a pipe or if it might have a submerged outlet, the pipe should be checked for inlet or outlet control. See the section on Culvert Design on page 33.

### Sizing pipes within a system

The capacity of a pipe, which is a link in a drainage system, can be calculated using the Manning Formula. Nomographs or hydraulic calculators may be used to determine the required pipe size by using the calculated discharge, a roughness coefficient of 0.013 (Manning's roughness coefficient for concrete pipe) and the design slope.

The pipe system should be sized starting at the uppermost collection point and proceeding down stream. Each run of pipe shall be sized to transport the runoff already in the system plus the discharge intercepted at the inlet pipe or structure at the upstream end of the run of pipe under consideration.

Where corrugated metal pipe is used, the method of sizing is basically the same as for sizing concrete pipe. The only difference is in the roughness coefficient. The value of the coefficient n is obtained as a weighted value from the values of 0.024 for uncoated galvanized steel pipe in a Y2-inch deep corrugation and 0.012 for a completely and smoothly asphalt lined pipe. For example, if 25 percent of the pipe's periphery is smoothly lines (paved) with asphalt and the remainder is galvanized of Yz-inch depth corrugation the n is computed thus:

$$\frac{(.25x.012) + (.75x.024)}{1.00} = .021$$

In a similar manner the value for n for a 1-inch deep corrugation may be computed using 0.027 for unpaved pipe and 0.012 for fully paved pipe.

The following table gives values for n obtained by such computations:

Composite Values of (n)

| Type of pipe | Yi inch deep corrugations | 1-inch deep corrugations |
|---|---|---|
| Unpaved | 0.024 | 0.027 |
| 25% paved | 0.021 | 0.023 |
| Fully Paved | 0.012 | 0.012 |

Nomographs in which the variables of slope, discharge, pipe diameter and velocity are plotted with each nomograph having the value of pipe roughness as a constant are included in this section, pages 35 – 38.

The following formula derived from the Manning Formula may be used to determine round pipe size:

$$D = 16\left[\frac{Qn}{\sqrt{S}}\right]^{3/8}$$

D = Diameter in inches
Q = Flow in cfs
n = roughness coefficient
S = Slope in ft. per ft.

## Culvert Design

Anytime there is the possibility of water ponding at the entrance of a pipe or if the outlet is submerged, that pipe is in a culvert situation. There are two types of control that can have an effect on the capacity of a culvert: inlet and outlet control. Both of these types of control must be considered in the design of culverts.

N9mog_rnpli inc;llJ4ci Qn_pag_es 39-_45 which can be usedio determine-culvert capacity. Select the appropriate chart according to type of structure for each condition of inlet control or outlet control.

## Inlet Control

Inlet control exists when the culvert is not flowing full and the entrance conditions of the culvert control the amount of flow through the culvert. Headwater depth is the depth of water on the upstream end of the culvert and is used on the nomograph to determine the capacity of the culvert. The designer must limit the allowable headwater depth to minimize the affect of backwater on the property upstream from the culvert. In any case the maximum headwater ratio of 1.2 should not be exceeded.

## Outlet Control

For outlet control to exist the culvert must be flowing full and the outlet must be submerged. Nomographs on pages 35 -45 may be used to determine headwater depths for culverts under outlet control.

Three pieces of information about the culvert are required in order to use the nomographs:

I) The entrance loss coefficient Ke values may be found on the chart below.

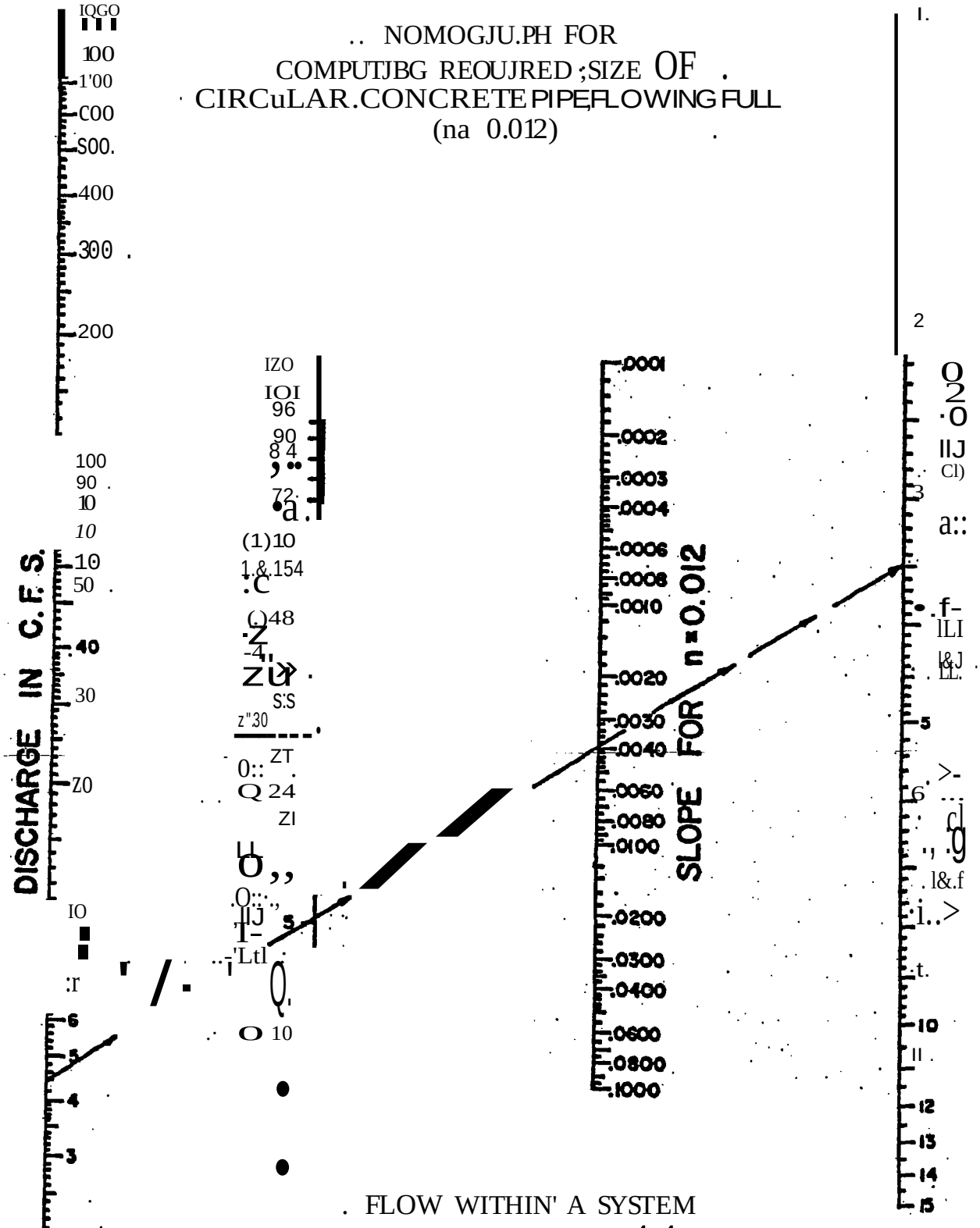
2) The tailwater conditions or the tailwater depth may be determined by downstream conditions or from known flood information. Ifthe tailwater depth cannot be determined it may be assumed that the tailwater elevation is the crown of the pipe. The designer is warned that this may be an oversimplification and extra effort should be taken to determine the tailwater elevation.

3) The length of the culvert is required.

By following the examples on the nomographs the designer can determine the head (H) created by the culvert. Once that is known, headwater can be determined as shown on the nomographs.

## COEFFICENT OF ENTRANCE LOSS Ke

| Type of Structure and Design of | Entrance Coefficient Ke |
|---|---|
| Pipe, Concrete | |
| Projecting from fill | 0.5 |
| Headwall or headwall and wingwalls | 0.5 |
| Mitered to conform to fillslopes | 0.7 |
| Pipe or pipearch, corrugated metal | |
| Projecting (no headwall) | 0.9 |
| Headwall or headwall and wingwalls | 0.5 |
| Mitered to conform to fillslopes | 0.7 |
| Reinforced concrete box culvert | |
| Headwall | 0.5 |
| Wingwall at 30 degrees to 75 degrees to barrel | 0.4 |
| Wingwalls at I0 degrees to 25 degrees to barrel | 0.5 |



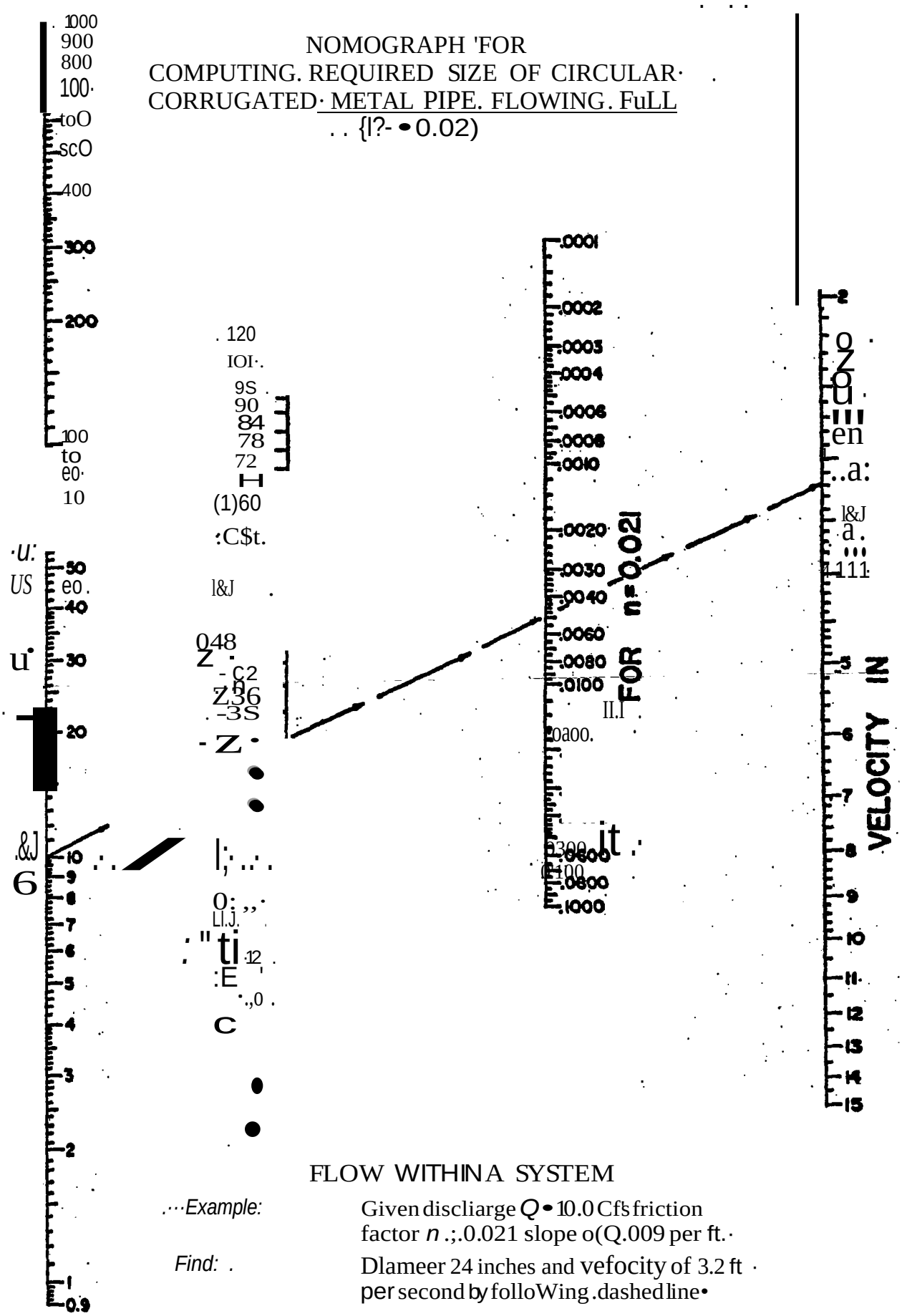

FLOW WITHIN' A SYSTEM

*Example:* Gven.dj_scharge $Q = 4.4$ cfs frictio factor $n = 0.012$ siape of 0.0039 peJ;" ft.

*Find:* Diamete 15 inches and .velOci of 3.5 ft per second, by followirig daslied line•.

Ncmiograph adonted i"om En&ineermc Man&l, War Depent, coqj or. Sngineera, Pa.rt xm, Chapter I, June 1955.

NOMOGRAPH 'FOR
COMPUTING. REQUIRED SIZE OF CIRCULAR
CORRUGATED METAL PIPE. FLOWING. FuLL
. . {l?- • 0.02)




*Example:* Given discliarge $Q$ • 10.0 Cfs friction factor $n$ .;.0.021 slope o(Q.009 per ft.

*Find:* Dlameer 24 inches and vefocity of 3.2 ft per second by folloWing .dashed line•

. Nomograph adopted from.Engineering Manual, War Department, Corps or Enpneer, Part xm, Chapter 1, Jupe 1"955.

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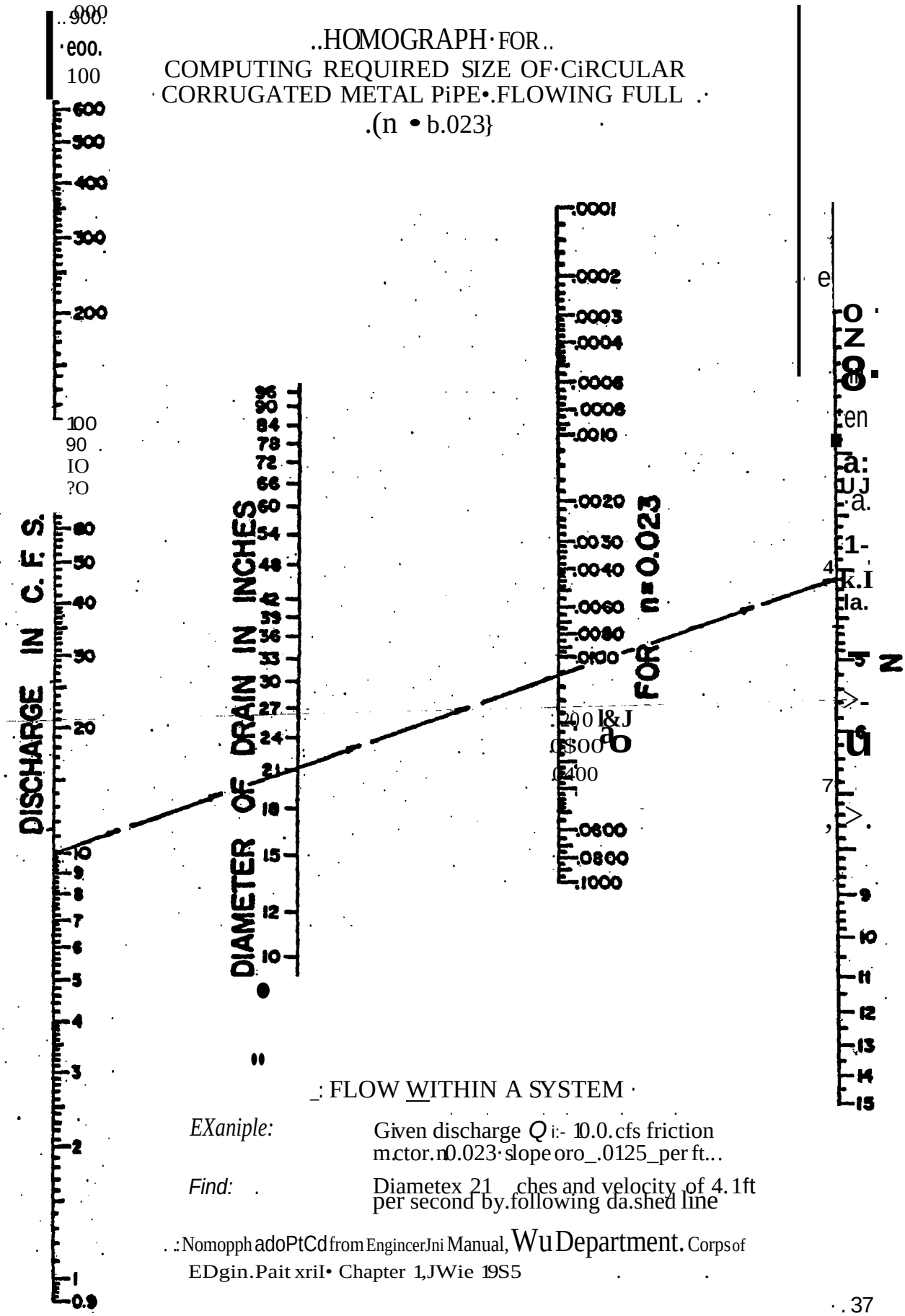
..HOMOGRAPH FOR..
COMPUTING REQUIRED SIZE OF CiRCULAR
CORRUGATED METAL PiPE•.FLOWING FULL
.(n • b.023}

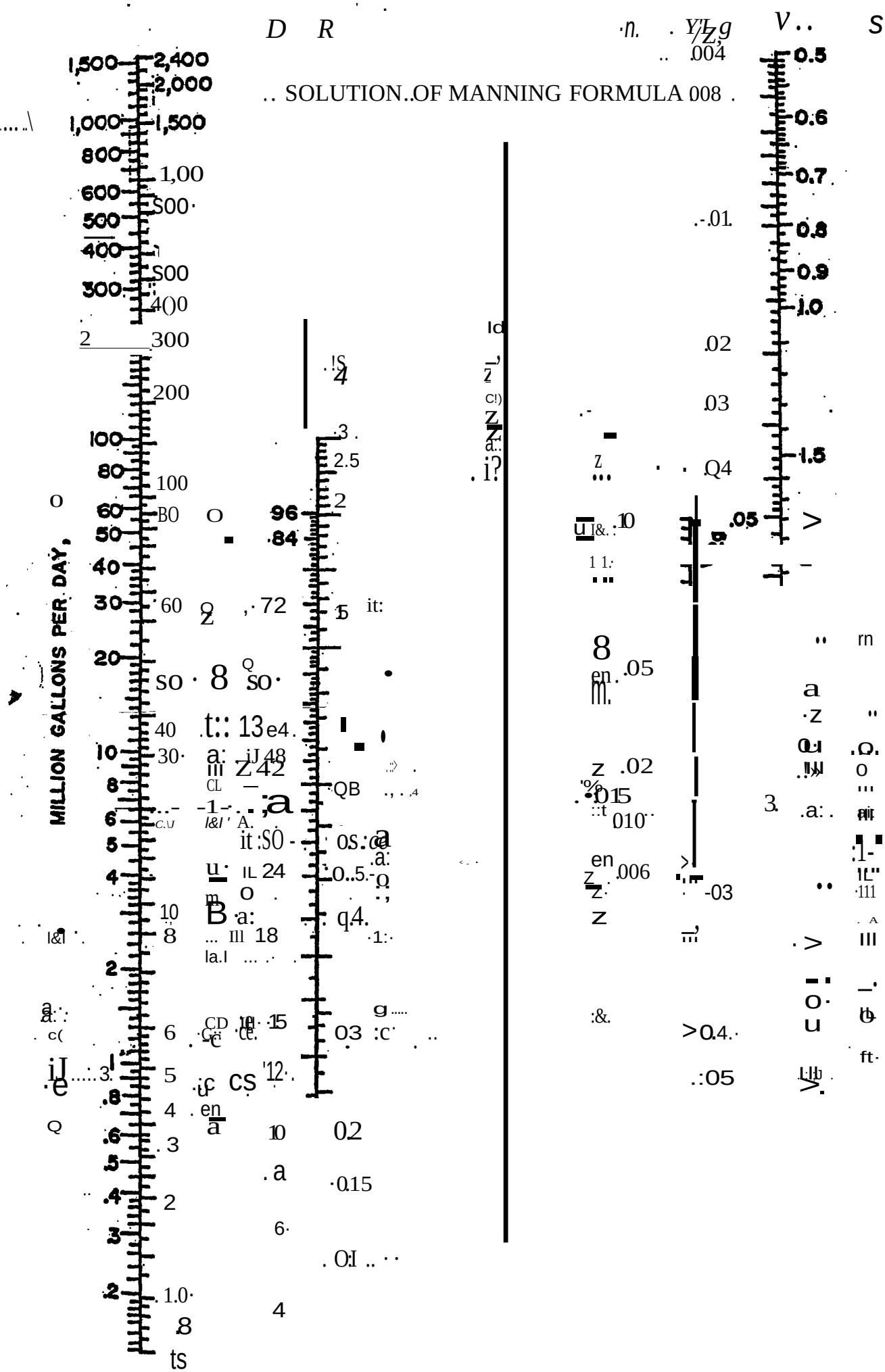


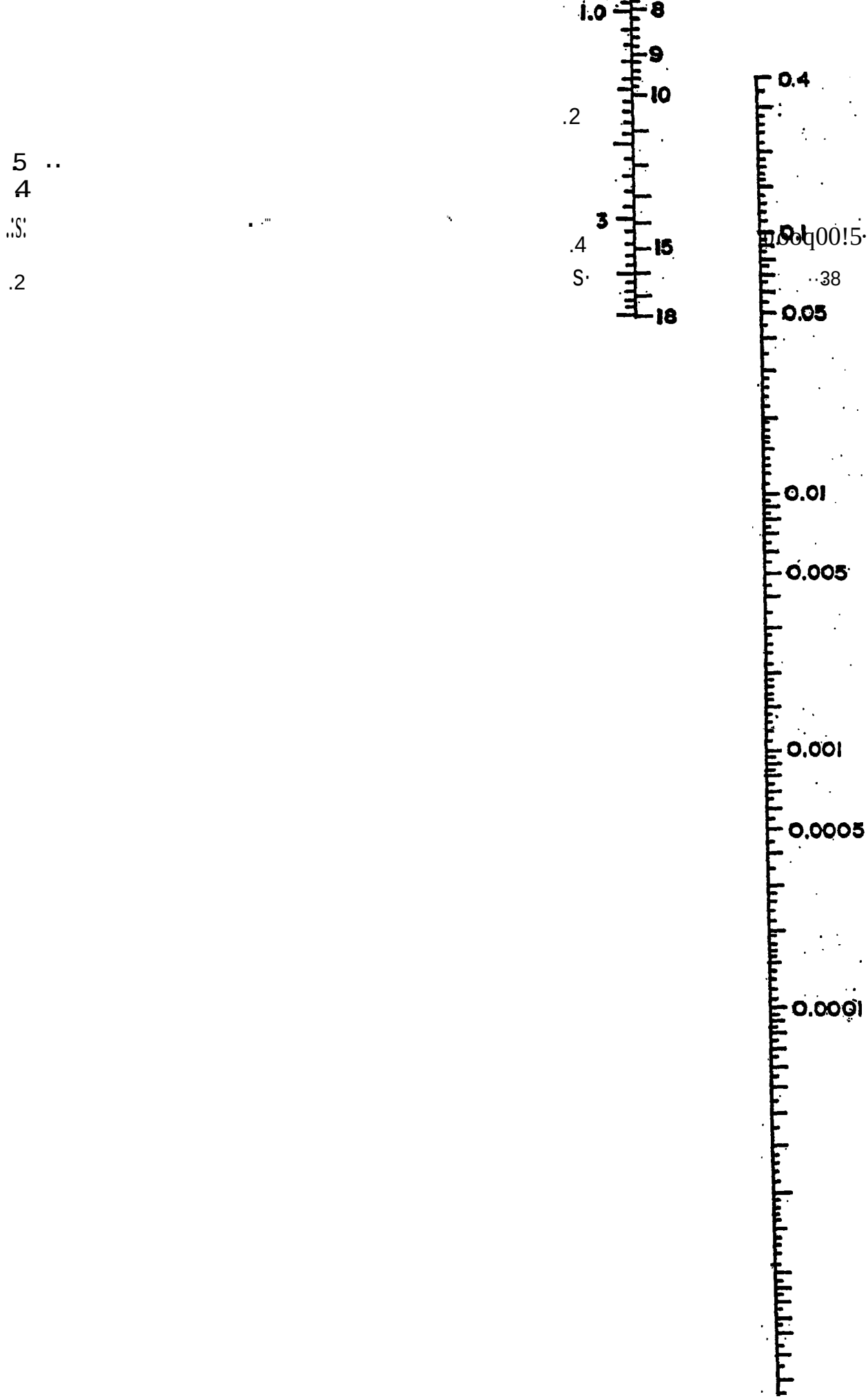

_: FLOW WITHIN A SYSTEM

*EXaniple:* Given discharge Q i:- 10.0. cfs friction m.ctor. n0.023· slope oro_.0125_per ft...

*Find:* Diametex 21 ches and velocity of 4.1ft per second by.following da.shed line

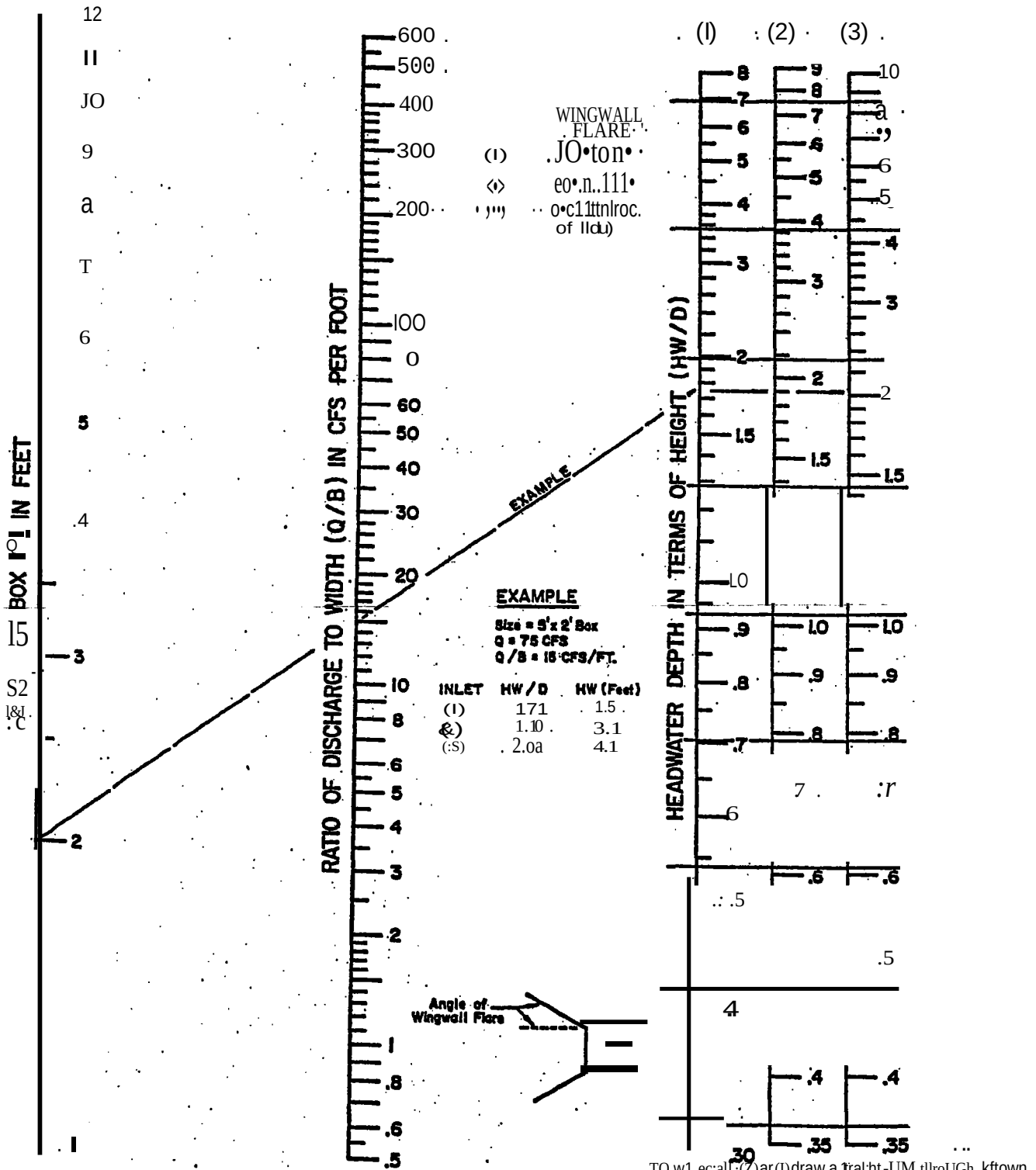
.:Nomopph adoPtCd from EngincerJni Manual, Wu Department. Corps of EDgin.Pait xriI• Chapter 1,JWie 19S5


D R
SOLUTION OF MANNING FORMULA
MILLION GALLONS PER DAY
0.00005


1.0
8
9
10
.2
3
.4
15
S
18
0.4
0.1
0.05
0.01
0.005
0.001
0.0005
0.0001

CULvERT DESIGN-INLET CONTROL.
HEADWATER DEPTH -FOR BOX CULVERTS.

. WITH INLET CONTROL

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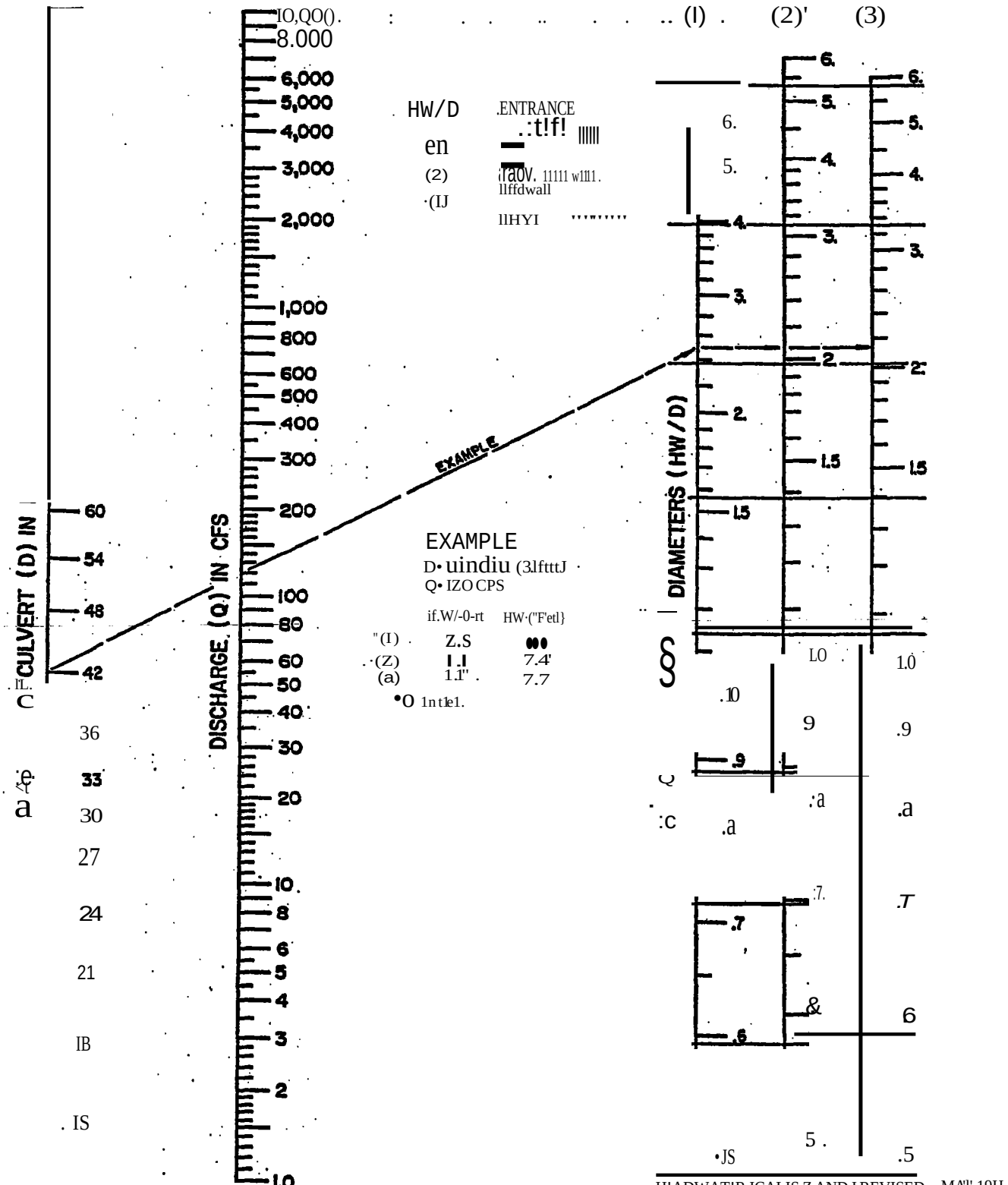
CULVERT DESIGN.ailET CONTROL
HEADWATER nmPT-H FOR .'QONCJmTE PIPE CTJLVER'l'S . . . .
WITH INLET-CON1ROL

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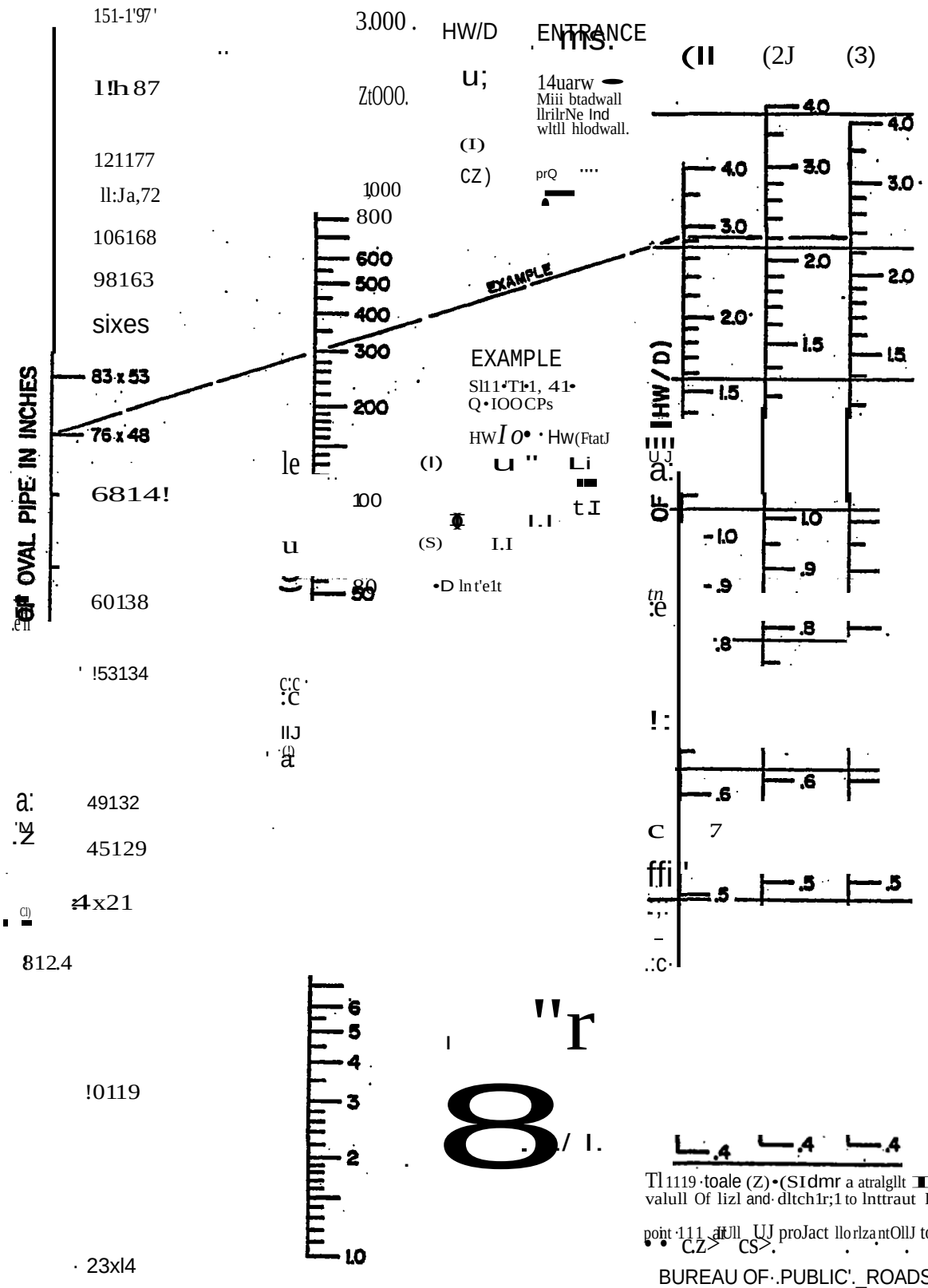
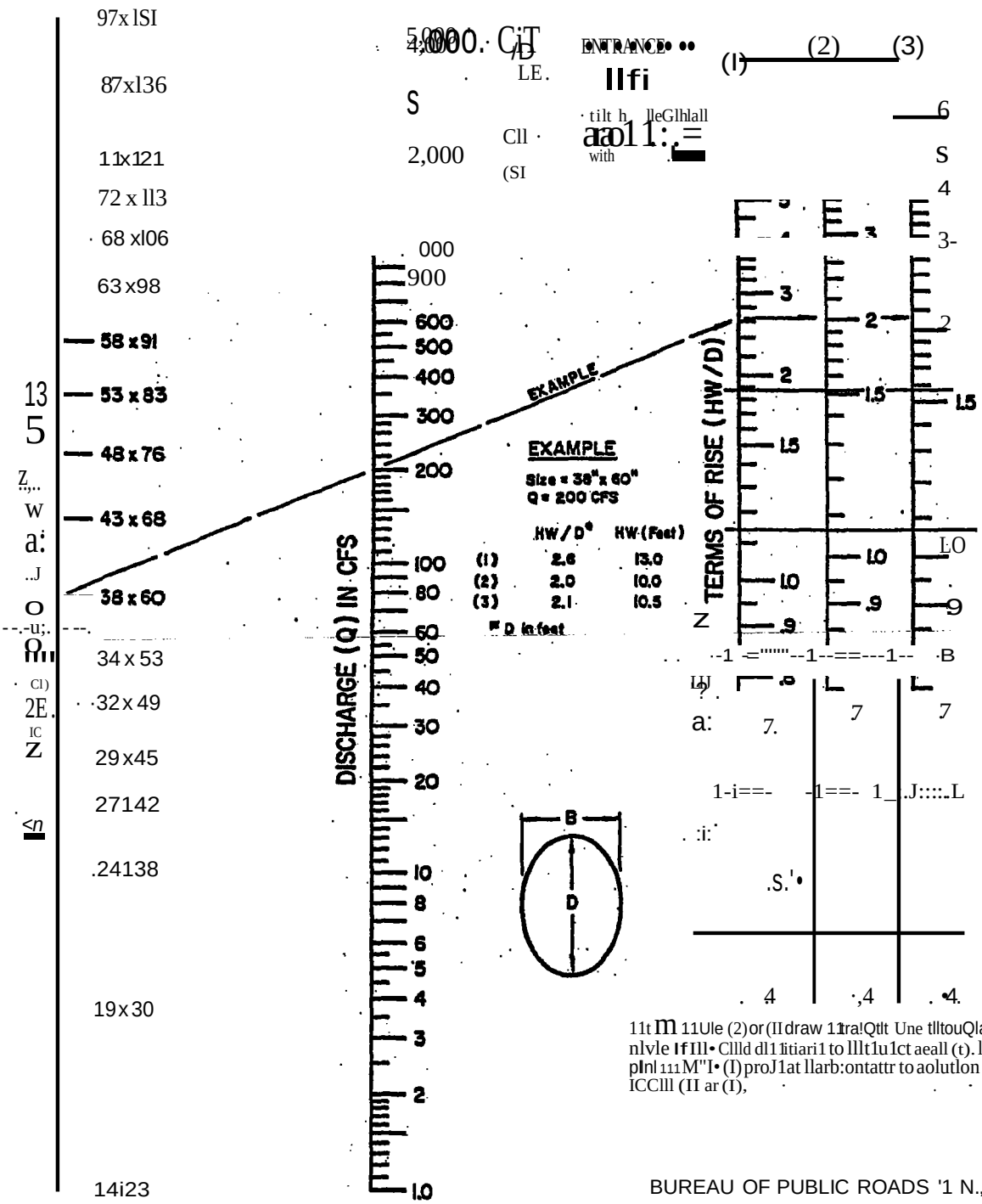
# CULvERT DESIGN-INLET CONTROL
## HEADWATER DEPTH.FOR .OVAL CONCRETE PIPE .CULVERTS
## LONG AXIS HORIZONTAL WITH.INLET CONROL



## CULVERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS
## LONG AXIS VERTICAL WITH INLET CONTROL

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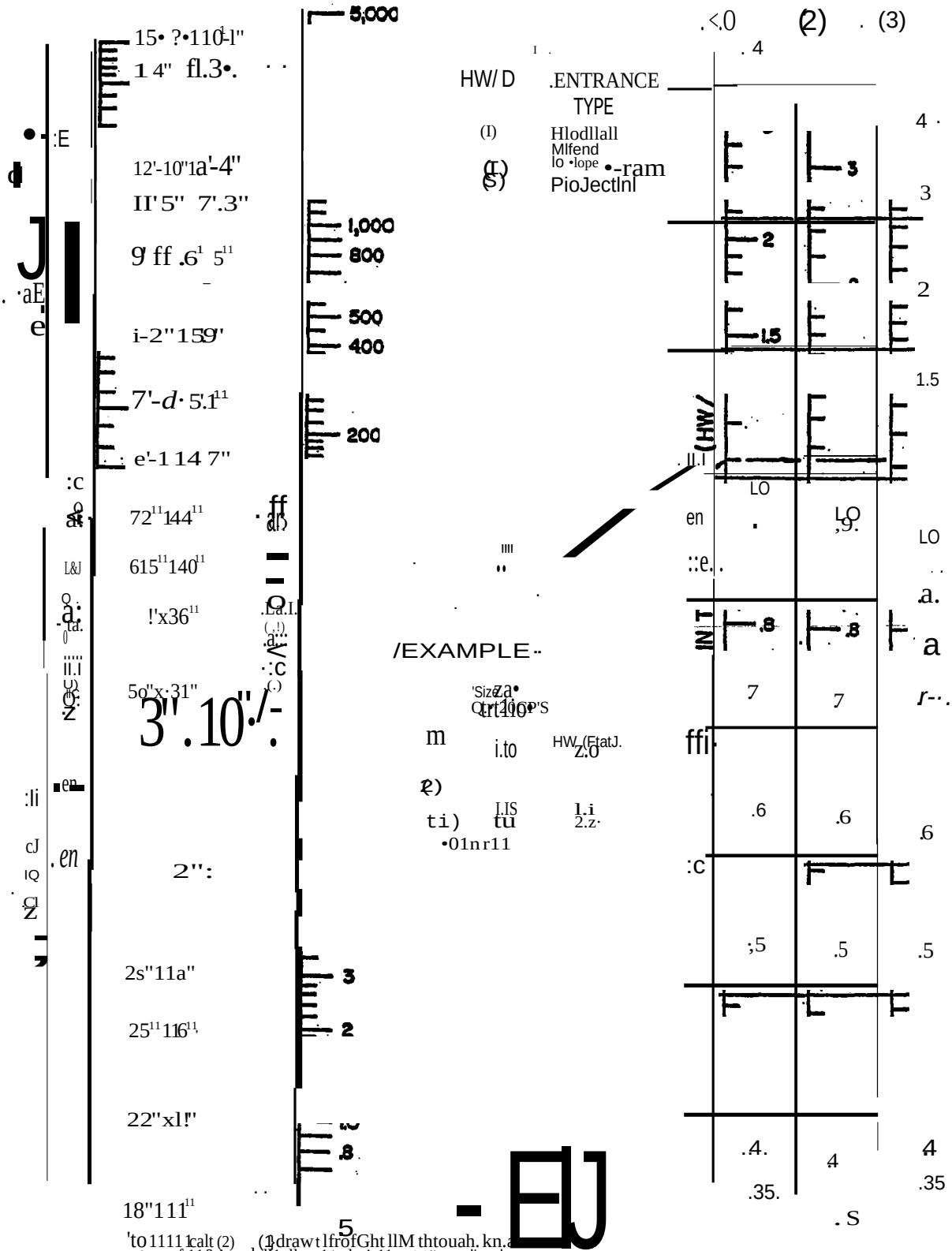
# CULvERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR CORRUGATED METAL PJPE CULVERTS WITH INLET CONTROL

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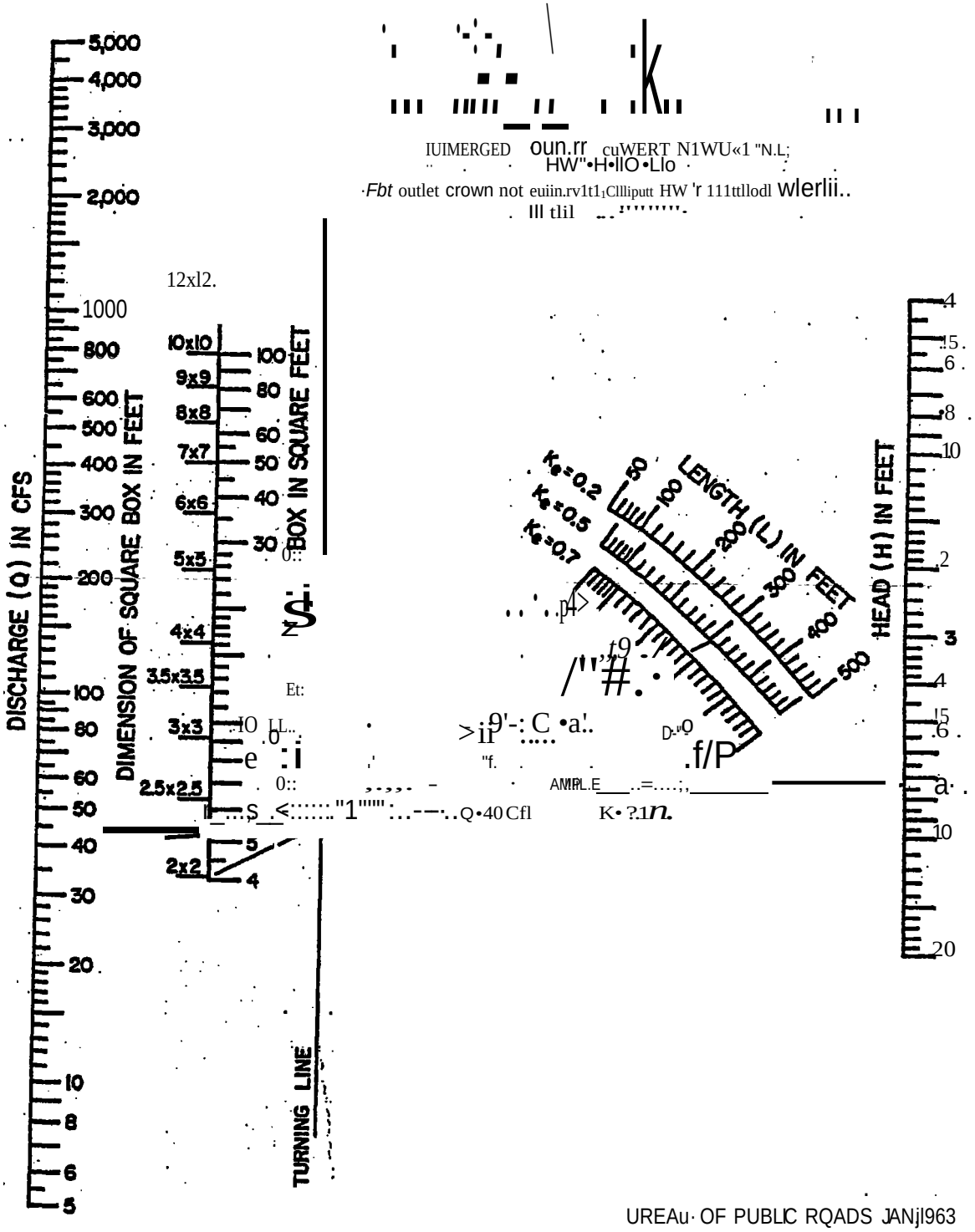
CULVERT DESIGN OUTLET CON'i'ROL
HEAD "FOR .CONCRETE "BOX CULVERTS
.FLOWING FULL

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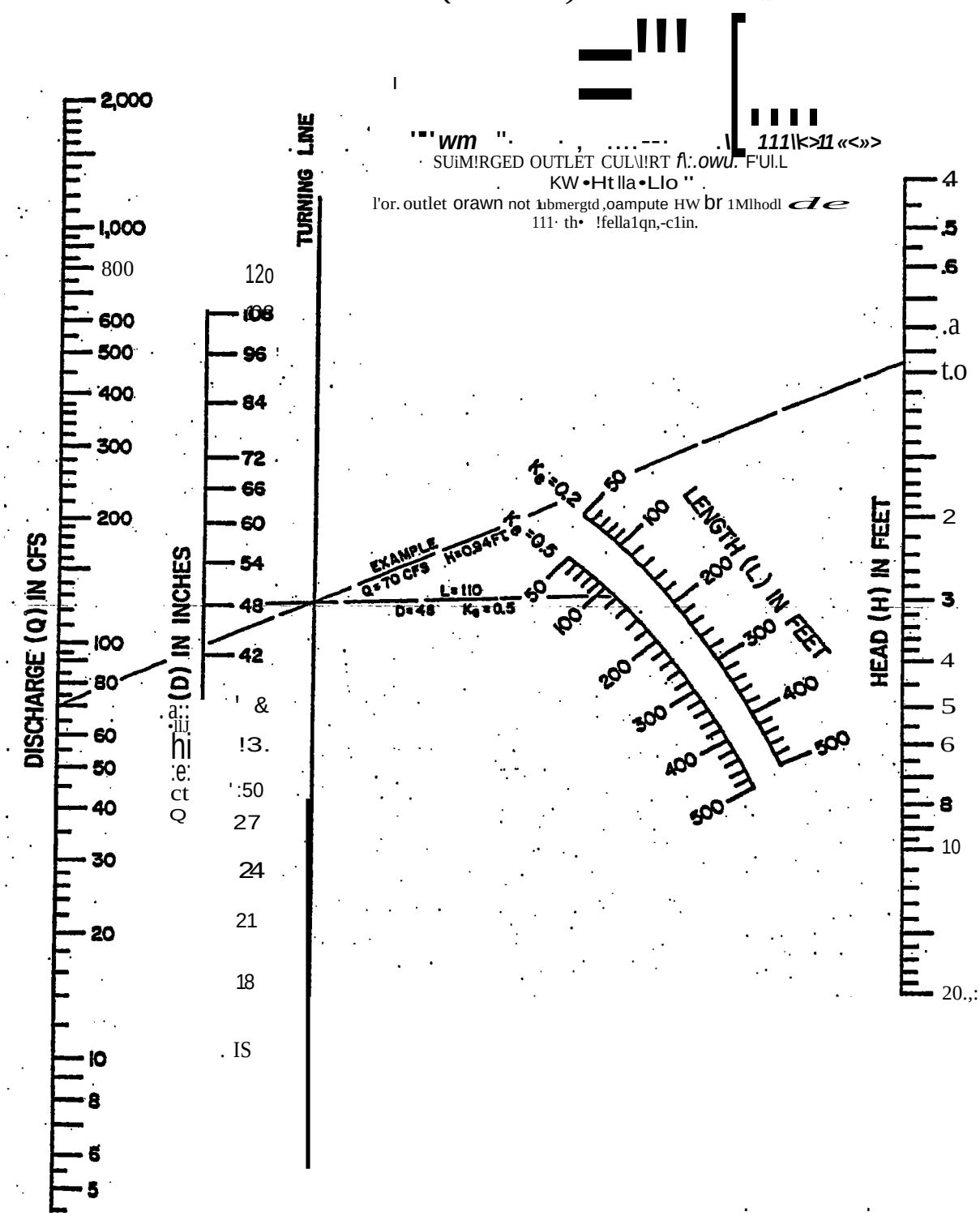
HEAD FOR CONCRE'l'E PIPE CULVERTS ·
· · FLOWING EULL " ·
. ·(n • 0.012):

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## Storm Drainage Design Requirements

The following is a list of requirements for storm drainage plans and for storm drainage lines that will eventually be maintained by the City of Mebane. The requirements also apply to private storm sewers and private drainage easements.

General Requirements

1) Storm sewers will have capacity to convey a 10-year storm within the pipe. The Q100 flows will be evaluated as required in the Flood Study section of this manual.

2) Culverts on major streams (Over 200 acres) will have capacity to convey a 100-year storm. Q will be determined using methods in this manual.

3) Storm sewer systems on culverts under inlet or outlet control will be designed accordingly to accommodate the maximum allowable headwater depth to fit surrounding terrain. The headwater to depth ratio should be held as close as possible to 1.2.

4) Storm sewer lines with size 15-inches through 66-inches will be reinforced concrete Class III or Class IV, or HDPE pipe (outside ofroad right-of-way) as approved by the NCDOT, Unless otfierivise approved by ilie-City.

5) Corrugated metal pipe, either aluminized steel or aluminum, above 66-inches diameter may be used under the following conditions:

   a) Materials, gauge, corrugation, fabrication, etc. must meet NCDOT design criteria, specifications, and the City of Mebane policy on acceptable corrugated metal pipe products.
   b) Full bituminous coating to be used where ph dictates.
   c) Aluminum arch pipe with concrete headwalls are also allowed when addressing stream impacts.

6) Minimum size for storm sewer pipe in streets is 15-inches in diameter.

7) Minimum storm sewer pipe grade is 0.5 percent.

8) Maximum storm sewer pipe grade is 10.0 percent.

9) Minimum grade for tailditching is 1.0 percent.

10) Manholes are required at changes in grade, changes in alignment, and at intersection of sewers.

11) Recommended manhole drops:
   a) Change in alignment 0° to 45°, 0.10 ft.
   b) Change in alignment greater than 45°, 0.20 ft.
   c) Change in pipe size, match top insides of pipes.
   d) Reverse flow conditions in a storm sewer system created by a tie in at a structure will not be allowed unless a manhole drop equal to the diameter of the outgoing pipe is provided.

12) MINIMUM DESIRABLE CURB INLET DEPTH

| | | | | | |
|---|---|---|---|---|---|
| 15" | -Front | 3.4' | 36" | -Front | 5.3' |
| 15" | -Back or Side | 1.9' | 36" | -Back or Side | 3.8' |
| 18" | -Front | 3.7' | 42" | -Front | 5.8' |
| 18" | -Back or Side | 2.1' | 42" | -Back or Side | 4.4' |
| 24" | -Front | 4.2' | 48" | -Front | 6.4' |
| 24" | -Back or Side | 2.7' | 48" | -Back or Side | 5.0' |
| 30" | -Front | 4.8' | 54 | -Front | 6.9' |
| 30" | -Back or Side | 3.2' | 54" | -Back or Side | 5.5' |

13) MINIMUM MANHOLE DEPTHS:

| | |
|---|---|
| 15" | 3.6' |
| 18" | 3.8' |
| 24" | 4.0' |
| 30" | 4.3' |

14) Headwalls or flared end sections plus an appropriate energy dissipater will be required at the release point of all pipe systems. Velocities existing energy dissipaters to be less than 5 ft./sec.

15) Pipe in culvert situations or storm sewer lines that will probably not be extended in the near future (see*) will have a headwall or flared end section on the upstream end.

* A headwall or flared end section will not be required if the property upstream from the pipe is:

a) Owned by the same property owner and the pipe will be extended in the near future (within one year).
b) A different section of the same subdivision and the pipe will be extended in the near future (within one year) with development of that section.

16) On all multi-family and commercial projects, approval is required prior to building permit approval.

17) The lower end of a storm sewer line will end far enough from the property line to allow the installation of an energy dissipater; except that it must be tied into existing storm sewer piping if available within 500 feet of the property.

18) Tail ditches from pipe ends to existing creeks will be armored beyond outlet erosion control device to prevent channel scour.

19) The upper end of a storm sewer line will be stubbed to the property line. However, if the upper property has a storm sewer line stubbed short of the property line for erosion control purposes, the new line must be extended acrossthe property line to tie the systems together; No gaps will be left in the system.

20) All pipe culverts and upper end of pipe systems will be sized to satisfy inlet or outlet control constraints. See the section on Culvert Design.

21) Precast structures may be allowed subject to City approval.

22) Precast boxes for curb inlets will be ordered with the height 24-inches lower than the finished grade. Once installed, a brick mason will be required to raise the top of the box to the proper height using brick and mortar to fit the curb grade. This is to keep from having to break out the front of the box to accommodate the curb and gutter.

23) Site drainage will not be allowed to flow out driveway entrance into streets.

24) Outlets of City maintained storm sewer systems must be above the normal pool elevation of detention ponds. Invert of drainage structures must be above the standpipe elevation of the detention pond. This is to assure that the pipe systems do not stand full of water for long periods of time and do not back up into the roadway during heavy rainstorms.

25) Private drain lines larger than 4-inches in diameter cannot tie directly into the curb and gutter. The pipe must tie into a junction box behind the curb.

26) Site drainage must be tied into any existing storm drain system.

27) There must be an 18-inch clearance between proposed utility lines and existing storm sewer lines.

28) Permits from the City are required before tying into any City storm sewer structure. The inspection is to insure a proper tie-in to reduce future maintenance problems.

29) Reinforced concrete pipe is the only material allowed for driveway culverts.

30) Extensive energy dissipaters must be used where new commercial site will be draining onto existing residential property. The City reserves the right to require on-site stormwater detention for release at pre-development flows on a case by case basis. The impact on downstream development and the impact on downstream piping systems will be taken into constaefattcmrorstormwarerdeten:tion-to be required:ln addtti-on, sta''e Storm Water Rules may require additional items not covered by this manual.

## ADDITIONAL REQUIREMENTS FOR DRAINAGE PLANS
(Subdivisions and Oth·er Developments)

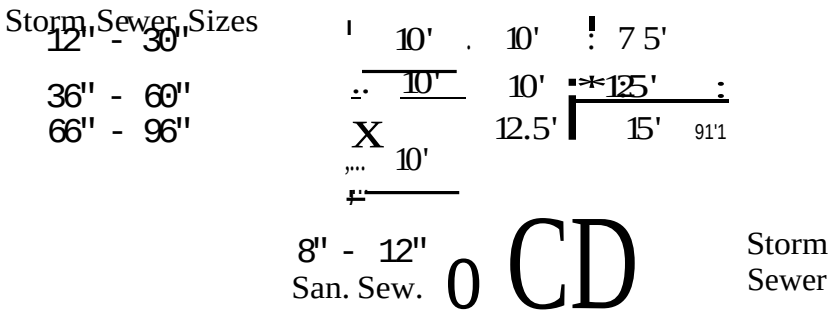
1) All water courses which carry a flow of 5 cubic feet per second (5 CFS) or more during a 10-year storm, as calculated in accordance with this manual, and which are not situated within a street right-of-way shall either be piped or have a drainage easement dedicated.

2) Drainaged easements for piped drainageway:
   a) 12" - 30" pipe - 15'
   b) 36" - 60" pipe - 20'
   c) 66" - 96" pipe - 30'

3) Drainage Easements for Unpiped Drainageways: ,
   a) 5 cfs to 16 cfs - 30' centered on channel
   b) 17 cfs to 70 cfs - 60' centered on channel
   d) 70 cfs and up - 100' + the width of the channel

Note: The drainageway easement width may be reduced from the above values to the width of the 100-year flood fringe as documented by flood studies

4) Drainage and utility easements with storm and sanitary sewer lines.




5) Any proposed storm sewer lines, which will be carrying street water, must be submitted to the City for construction approval. The installation of the storm sewer line must be inspected prior to acceptance of the line.

6) The following must be included on Site Drainage Plans.
   a) Location of inlets, manholes, pipelines, proposed pipe sizes.
   b) Clearly defined lines delineating areas drained to each inlet.
   c) Existing and proposed contour lines must be shown to 200-feet beyond the property line.
   d) Ditches swales, pipes, and drainage easements, which are adjacent to the proposed project.
   e) Drainage calculations on form similar to that shown on page 52, but including Hydraulic Grade Line Elevations for the Ql O and Ql OO flows and schematic profiles of pipe with hydraulic grade lines.

7) Flood Study

All new development that is 5 acres or more in size or that is adjacent to any drainageway or storm drainage system or is traversed by a drainageway or storm drainage system having 5 acres or more of contributing drainage area to the site shall be required to provide a detailed flood study as a part of the construction plans. The flood study shall be done using HEC-RAZ, Hydrostorm, or other modeling program approved in advance. All estimates of flow for the QlOO storm event shall be based on the drainage area being fully developed according to zoning in place and using the runoff coefficients contained in this manual.

For aH-unpiped drainageways, --eitb-er existing or new ,-the-Flood Study shaH be done to a point of 2 acres of contributing area. All new channels designed as a part of the project shall contain the QlOO flows within the channel with the minimum finish floor elevation being at least 2 feet above the QlOO water surface elevation (Base Flood Elevation) at the building corner. For piped systems, the QlO stormwater flow shall be designed to be within the pipe and the QlOO stormwater flow shall be designed to be no higher than the top of the curb (if in a street or parking lot location). In these areas, the minimum finish floor elevations of all structures shall be at least 1foot above the top of the curb at the building corner. If the storm piping is in an easement, the QlOO water surface elevations shall be contained within the structures and the minimum finish floor elevation shall be at least 2 feet above the QlOO water surface elevations. The Flood Study with supporting documents shall be contained in a document identified as such and shall be sealed by an engineer or surveyor.

The final plat shall include the QlOO water surface elevations along drainageway or channels with related floodway widths and drainage easement width that contains the QlOO flows.

# STORM-DRAIN GEDESIGN DATA SHEET

PROJECT ENGNEER DATE_____

LOCATION

sTORM FREQUENCY YEAR

| LOCATION | | AREA | | C | NTENSITY | | | Q=CIA-1 | PIPE | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TO | FROM | SUB. | TOTAL | | LB. | T.C. | | CFS | SIZE | SLOPE; | VEL | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | |