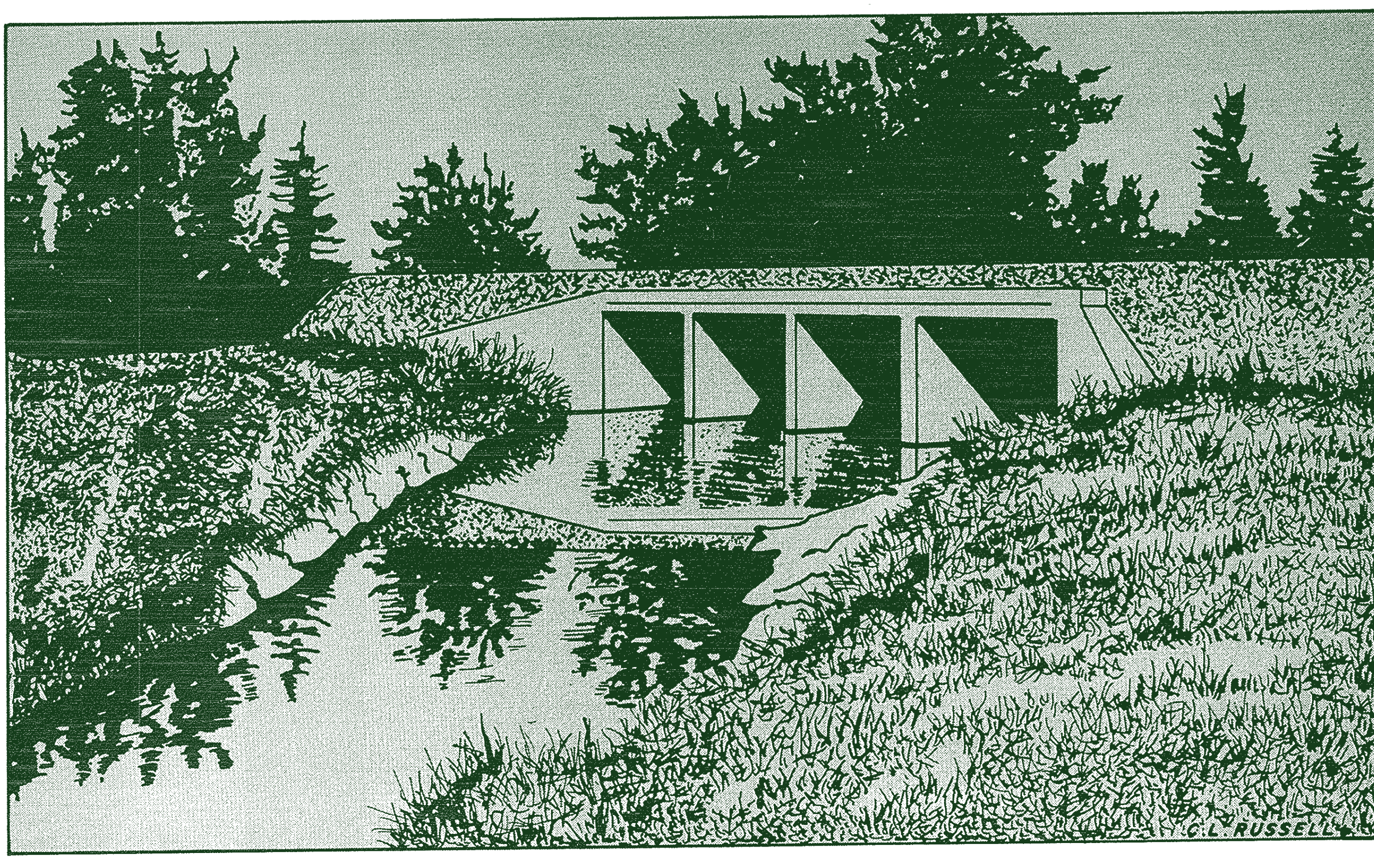
# City of Greensboro

Stormwater Management Division




# STORM DRAINAGE DESIGN MANUAL

FEBRUARY 2008

REVISED EDITION

# ***Storm Drainage 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 and culverts for the City of Greensboro Water Resources Department. Engineers 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 judgment, and engineering knowledge.

The City of Greensboro Stormwater Management Division 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 and culvert designs and installations within the City of Greensboro. In addition, these standards apply to applicable areas outside the City Limits that have been established under an Agreement between Guilford County and the City of Greensboro.

The City of Greensboro makes no warranty of any kind, express or implied, with respect to the information provided in this manual. The end user assumes all risk and liability for any losses, damages, claims or expenses resulting from the use of this manual. The end user further agrees to indemnify, defend and hold harmless the City, its officers, agents and employees from any and all claims, suites, losses, damages or cost, including attorney’s fees, arising from use of this manual. The City has made every reasonable effort to provide appropriate information for use in the design of stormwater infrastructure in the City of Greensboro and surrounding areas.

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**January 2007**

***City of Greensboro, North Carolina***

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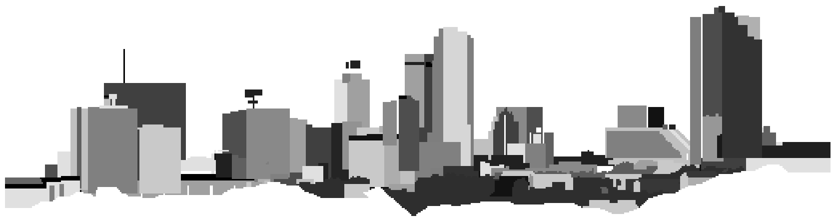


# *Introduction*

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 to be utilized by the Stormwater Management Division are presented in this manual. It is not required that engineers designing storm drainage installations adhere to these methods; however, the methods presented in this manual will be considered acceptable minimum design standards and any other methods must equal or surpass these design standards. The acceptability of other methods will be determined by the Stormwater Management Division.

Presented in this manual are procedures, charts, and tables which the Stormwater Management Division hopes will be helpful in the design of commercial and residential developments in Greensboro and the surrounding areas. Also listed are requirements concerning storm drainage design and construction.

A typical storm drainage data sheet is shown on page 102. Although it is not a requirement, it is the desire of the Division that this form be utilized and submitted with each plan since it does contain the required design data. Using this form will help minimize the review process time. Computer program printouts are acceptable as long as the required information is included. Energy grade line analysis is required for the submission of both public and private storm drainage systems. Refer to page 97 in the Storm Drainage Design Requirements for additional information.

# *Design Criteria*

Storm Drainage Design Return Period

Stormwater Conveyance Systems............................................................ 10-years
Gutter Flow Capacity and Inlet Spacing (5-minute) .................................... 2-years
Culverts and Bridges for Open Channel Crossings:
Major City Streets.......................................................................... 50-years
Including Thoroughfares, Major, Minor and Collector Streets
Minor City Streets.......................................................................... 25-years
Including Subcollector, Local and Residential Streets
Culverts and Bridges over FEMA Regulated Floodways........................... 100-years

*Street classifications can be obtained by contacting the City of Greensboro Transportation Department.

Flood Protection Requirements for Structures

The reference level of all permanent structures, including basement, located within a Special Flood Hazard Area (SFHA) must be elevated no lower than the regulatory flood protection elevation. Associated electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities shall be designed and/or located so as to prevent water from entering or accumulating within the components during condition of flooding. The Special Flood Hazard Areas are those identified under the Cooperating Technical State (CTS) agreement between the State of North Carolina and FEMA in its Flood Insurance Study (FIS) and its accompanying Flood Insurance Rate Maps (FIRM), for Guilford County. When base flood elevation data is not available from a federal, State or other source as outlined in Section 30-7-5.6(C) of the Greensboro Development Ordinance, the reference level shall be elevated no lower than the regulatory flood protection elevation. All subdivisions, manufactured dwelling sites and other development proposals located in floodplains without established base flood elevations shall provide base flood elevation (BFE) data. For additional information on Flood Damage Prevention Requirements, refer to Section 30-7-5 of the Greensboro Development Ordinance.

# ***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 Greensboro. 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 discharge velocity and design erosion control devices where necessary.*

## ***DETERMINATION OF DISCHARGE***

The City of Greensboro uses three 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 either the Basin Lag-Time Method or the Natural Resources Conservation Service Method as outlined in Technical Release 55 (TR-55) 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 10. 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 (or composite value) must be computed. The type of land and development used in selecting a **C** value will be compatible with the current zoning maps and will be based on the ultimate built-out conditions.

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 of the drainage area to the point of design.

From an extensive storm sewer study of practically every water course within the City Limits of Greensboro (1932), it has been observed that a velocity of 8-feet per second would afford a reasonable design velocity for determining the time of concentration throughout the watersheds of the Greensboro 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, 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 areas, before being collected in well-defined watercourses or pipe systems where its velocity will then be 500 ft./min. In public systems, the minimum time of concentration in the sheet flow area will be 10 minutes. On private systems, at the designer's discretion, the minimum time of concentration can be less than 10 minutes.

As an example of this 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 first 150 feet of this area would consist of sheet flow before getting into a combination channel / pipe system. The time of concentration will be found as follows:

| | | | | |
|---|---|---|---|---|
| 3000 ft. | | | | |
| -150 ft. | of *sheet flow* @ 500 ft./10 min. | = | ~~3 min.~~ | |
| | ➥ 10 minute minimum required | | ➥ | 10.0 min. |
| 2850 ft. | of *channelized flow* @ 500 ft./min. | = | | 5.7 min. |
| | Time of concentration | = | | 15.7 min. |

Using the time of concentration determine the rainfall intensity (**I**) from the appropriate rainfall and runoff chart found on pages 11-18. Storm sewer systems carrying street or public runoff are to be designed to carry a 10-year return period storm, with non-pressurized flow in the pipes. As determined by the Unified Development Ordinance, this requirement will apply to all public and private developments.

3) *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. The City of Greensboro uses a 1" = 200' scale map with a 2-foot interval contour for designing and checking storm sewer. Copies of these maps are available both digitally and in hard copy and may be purchased from the Engineering Records Section of the City of Greensboro Engineering & Inspections Department or the GIS Division of the MIS Department.

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 FOR GREENSBORO AND VICINITY

Below are the runoff coefficients to be used in calculating storm water runoff. All drainage must be designed based on the built out conditions for the current land use zoning.

| 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 |

## INTENSITY-DURATION-FREQUENCY TABLE FOR GREENSBORO, NC

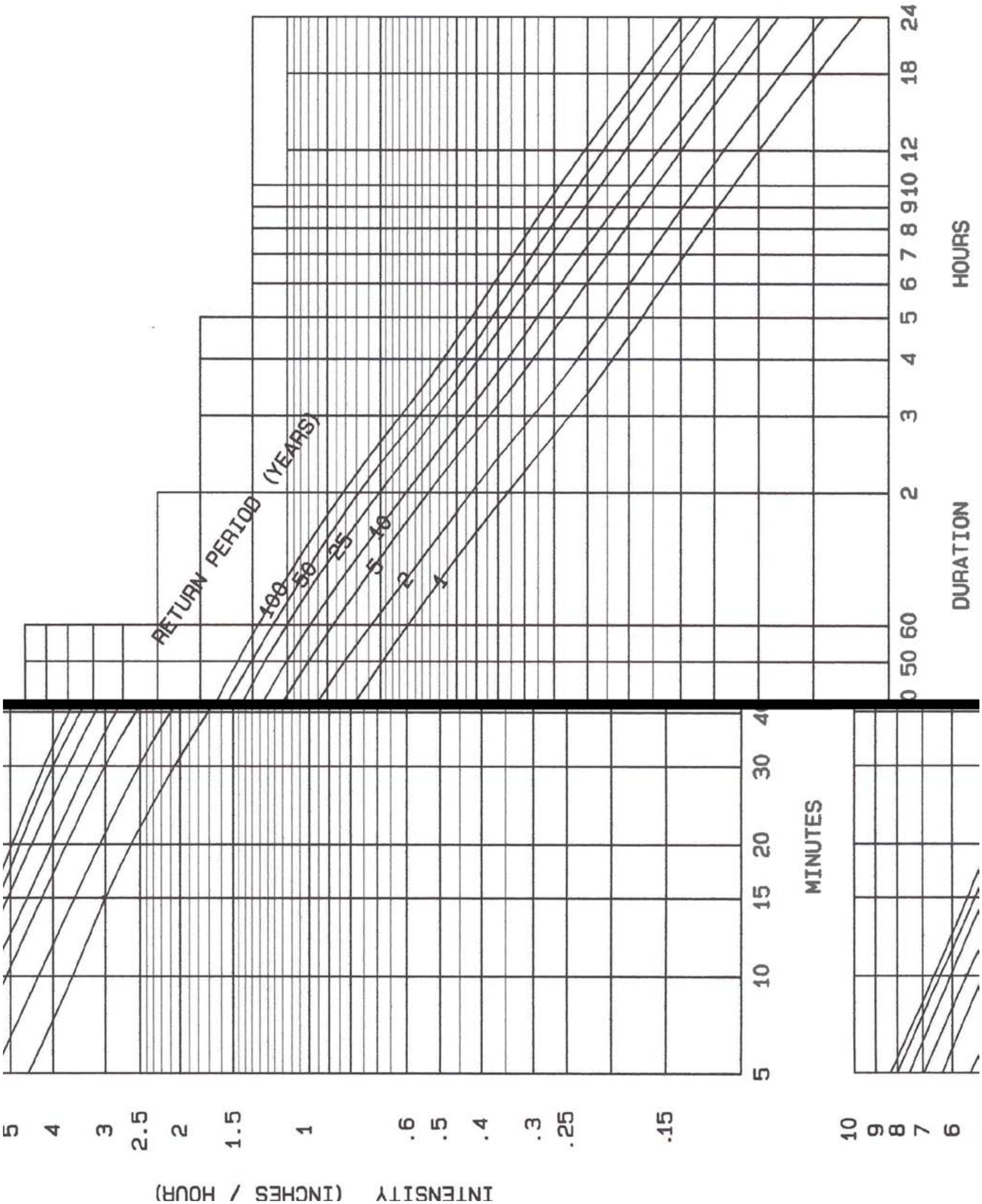
**Precipitation Intensity Estimates (inches/hour)**

| Rainfall Duration | Annual Exceedance Probability (1 in __ years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1-yr | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| 5 min | 4.57 | 5.44 | 6.34 | 6.87 | 7.55 | 7.96 | 8.31 |
| 10 min | 3.65 | 4.35 | 5.08 | 5.49 | 6.02 | 6.33 | 6.6 |
| 15 min | 3.05 | 3.65 | 4.28 | 4.63 | 5.09 | 5.35 | 5.56 |
| 30 min | 2.09 | 2.52 | 3.04 | 3.35 | 3.77 | 4.03 | 4.26 |
| 60 min | 1.3 | 1.58 | 1.95 | 2.18 | 2.51 | 2.73 | 2.93 |
| 2 hr | 0.77 | 0.93 | 1.16 | 1.31 | 1.53 | 1.68 | 1.83 |
| 3 hr | 0.55 | 0.66 | 0.83 | 0.94 | 1.09 | 1.21 | 1.31 |
| 6 hr | 0.33 | 0.4 | 0.5 | 0.57 | 0.67 | 0.75 | 0.83 |
| 12 hr | 0.2 | 0.24 | 0.30 | 0.34 | 0.41 | 0.46 | 0.51 |
| 24 hr | 0.12 | 0.14 | 0.18 | 0.20 | 0.24 | 0.27 | 0.3 |

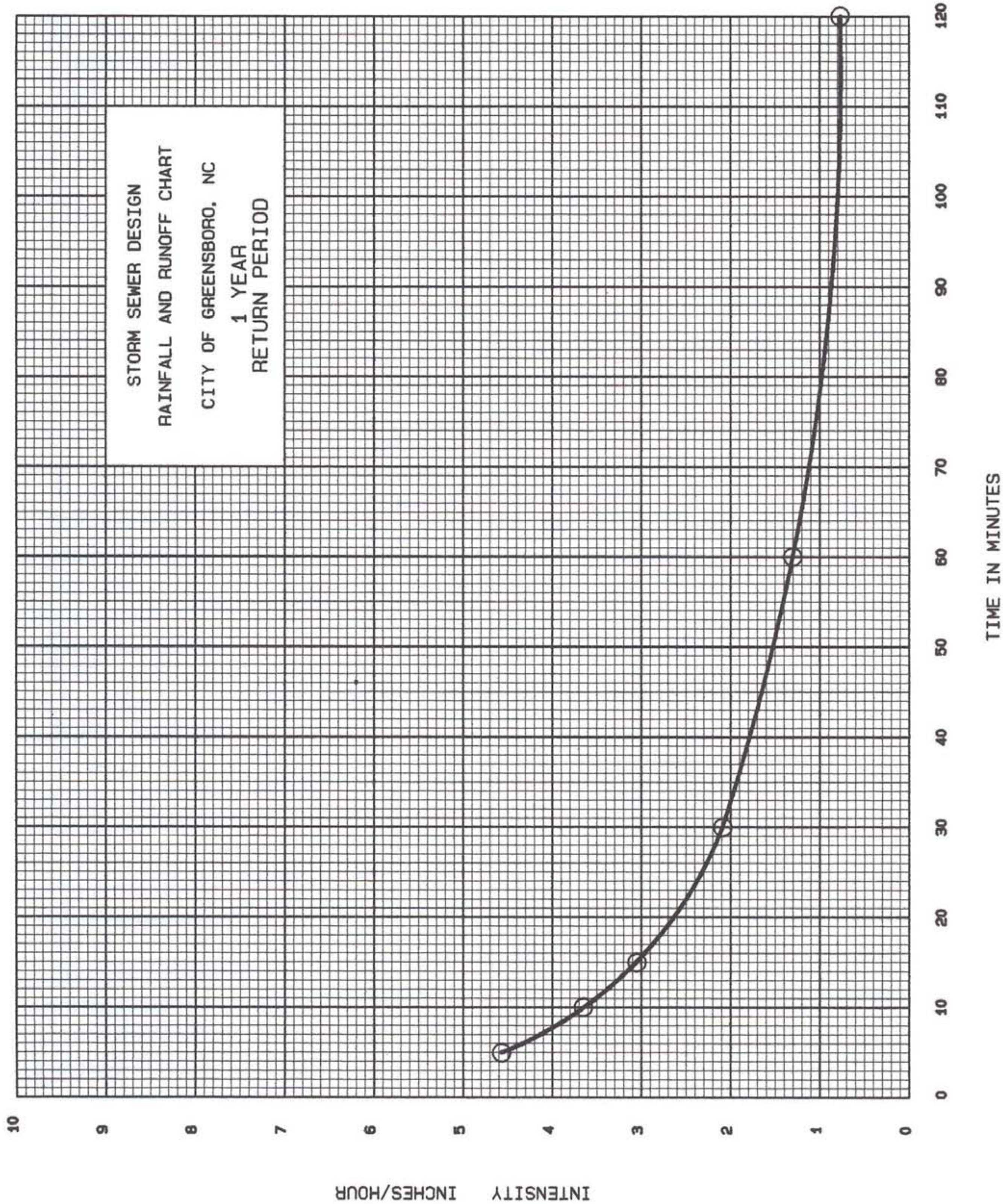
Source: NOAA Atlas 12, Vol. 2, Version 3 (2004) for East Greensboro – 36.089 N 79.769 W

Note: For the 1, 2, and 5 year recurrence intervals, precipitation values were obtained from a partial duration series. The 10, 25, 50, and 100-year recurrence interval precipitation values were obtained from an annual maximum series

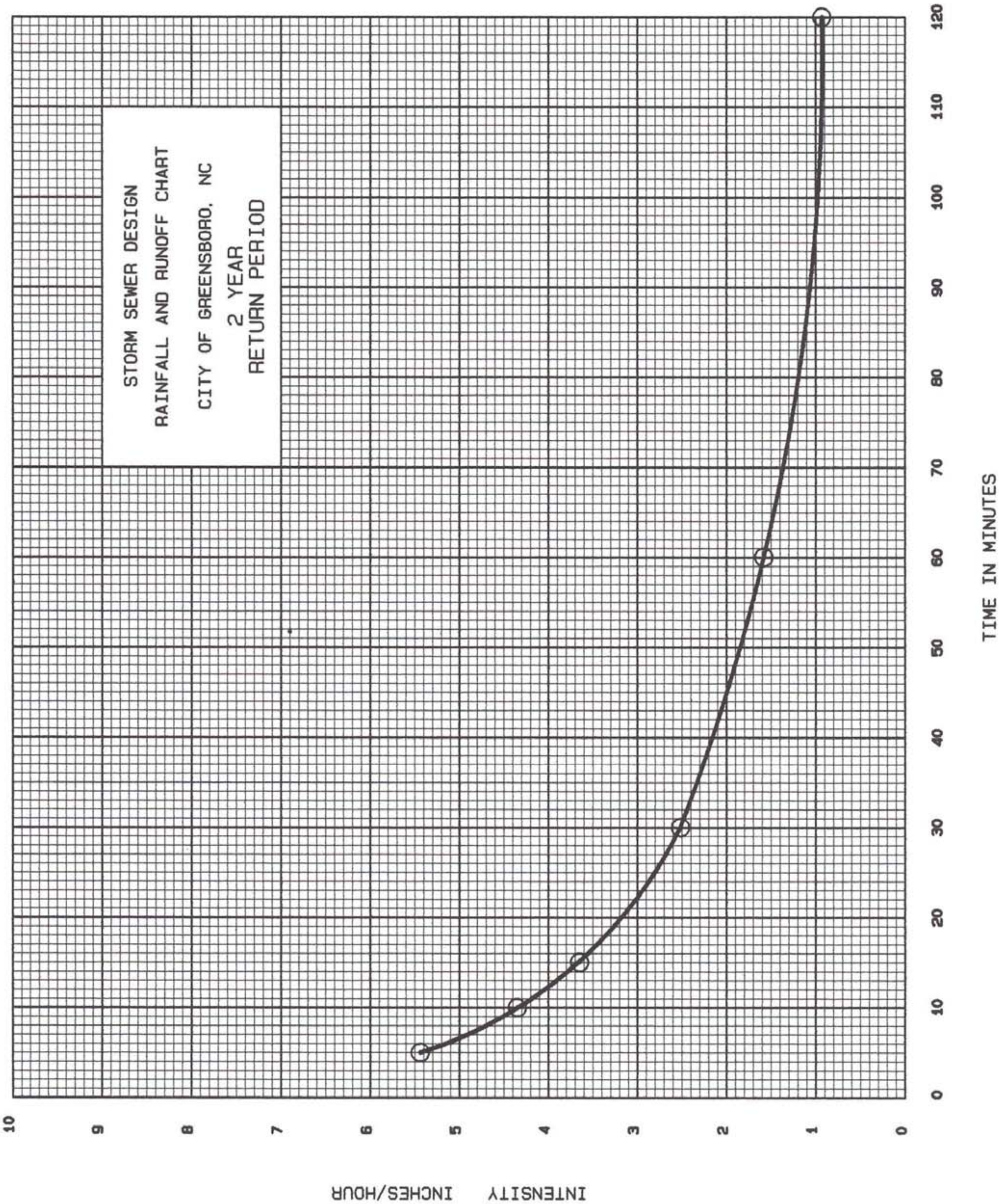
## Rainfall Intensity-Duration-Frequency Curves for Greensboro, NC



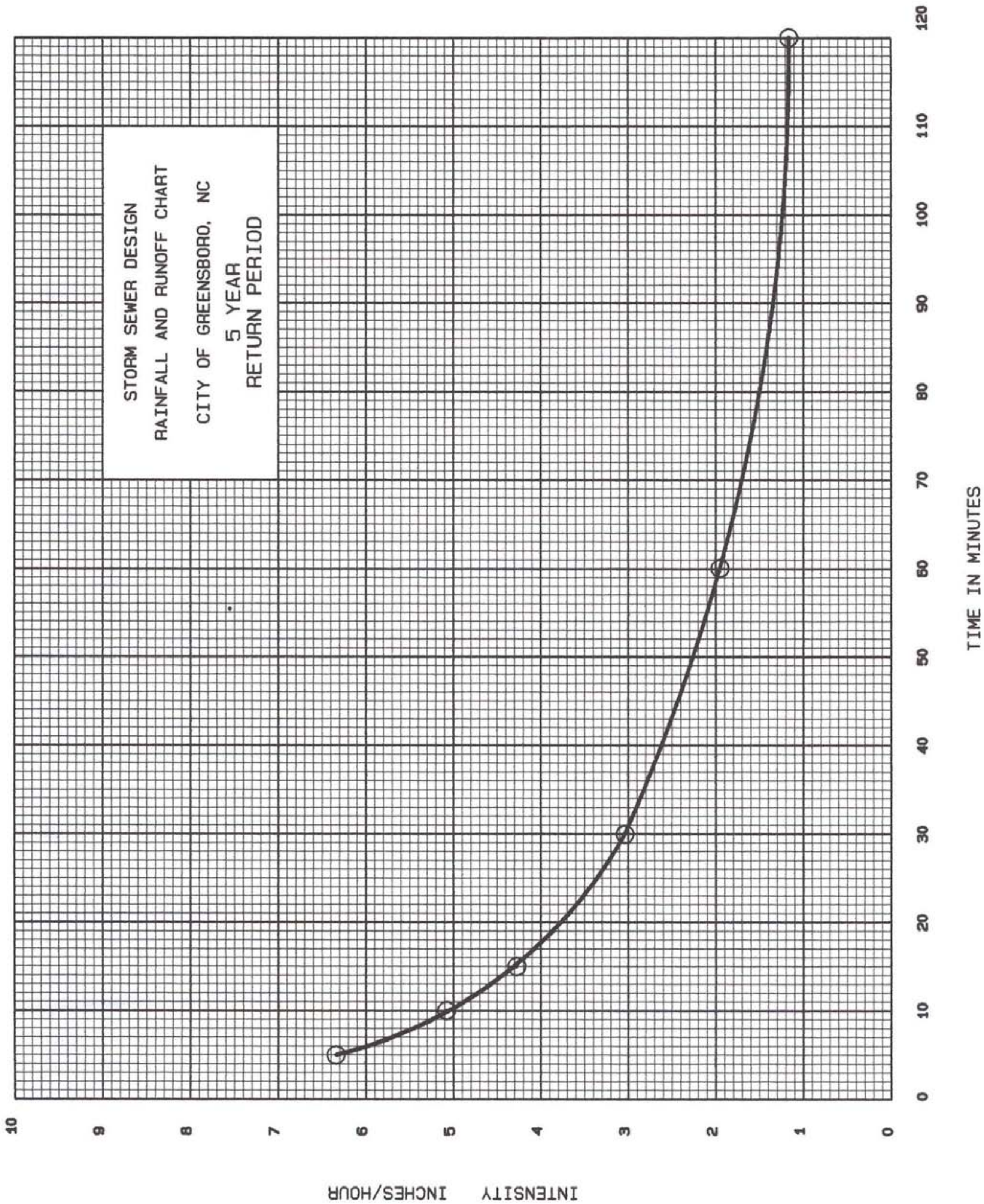
**Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC**
**1-year Return Period**



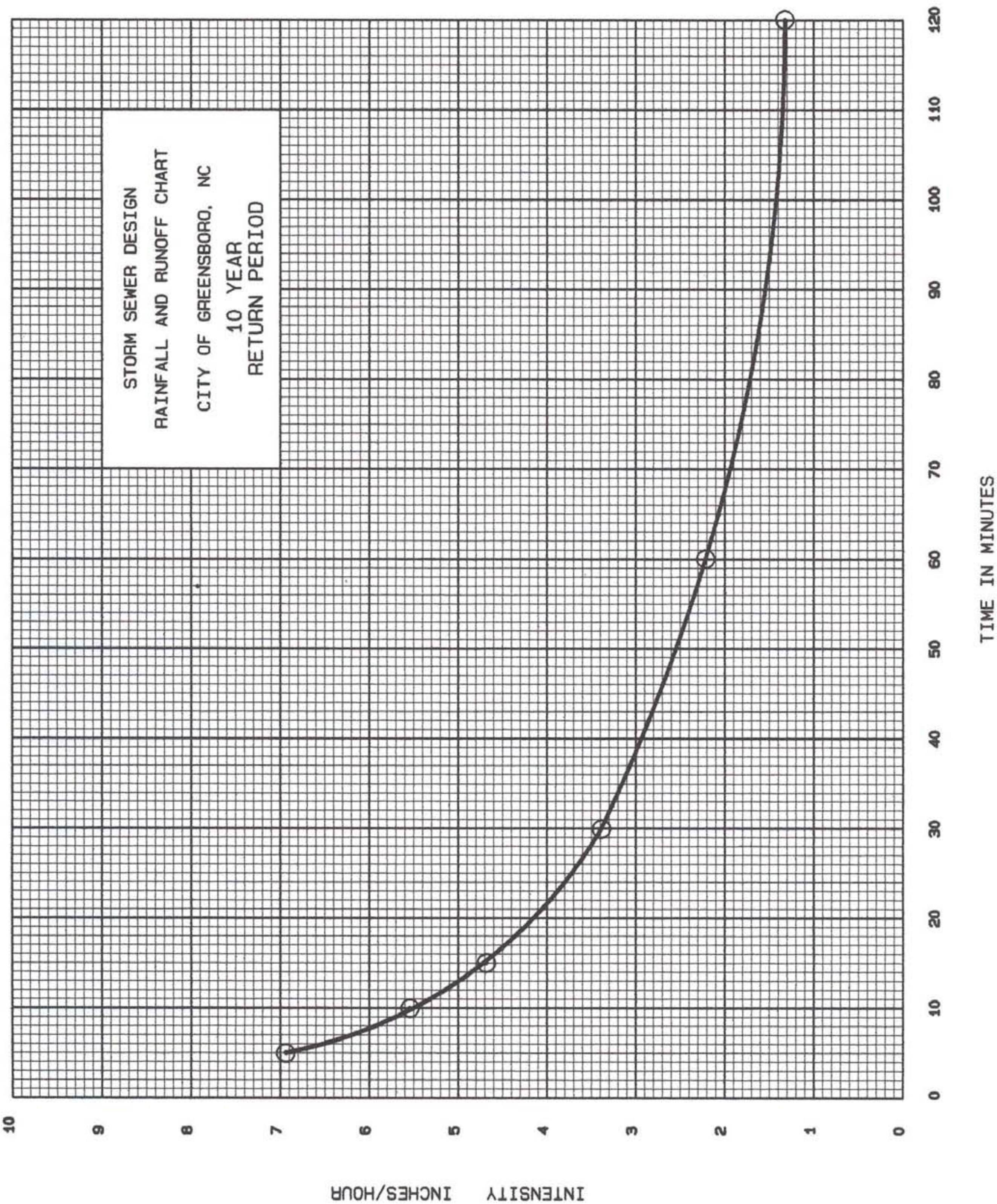
## Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC
## 2-year Return Period



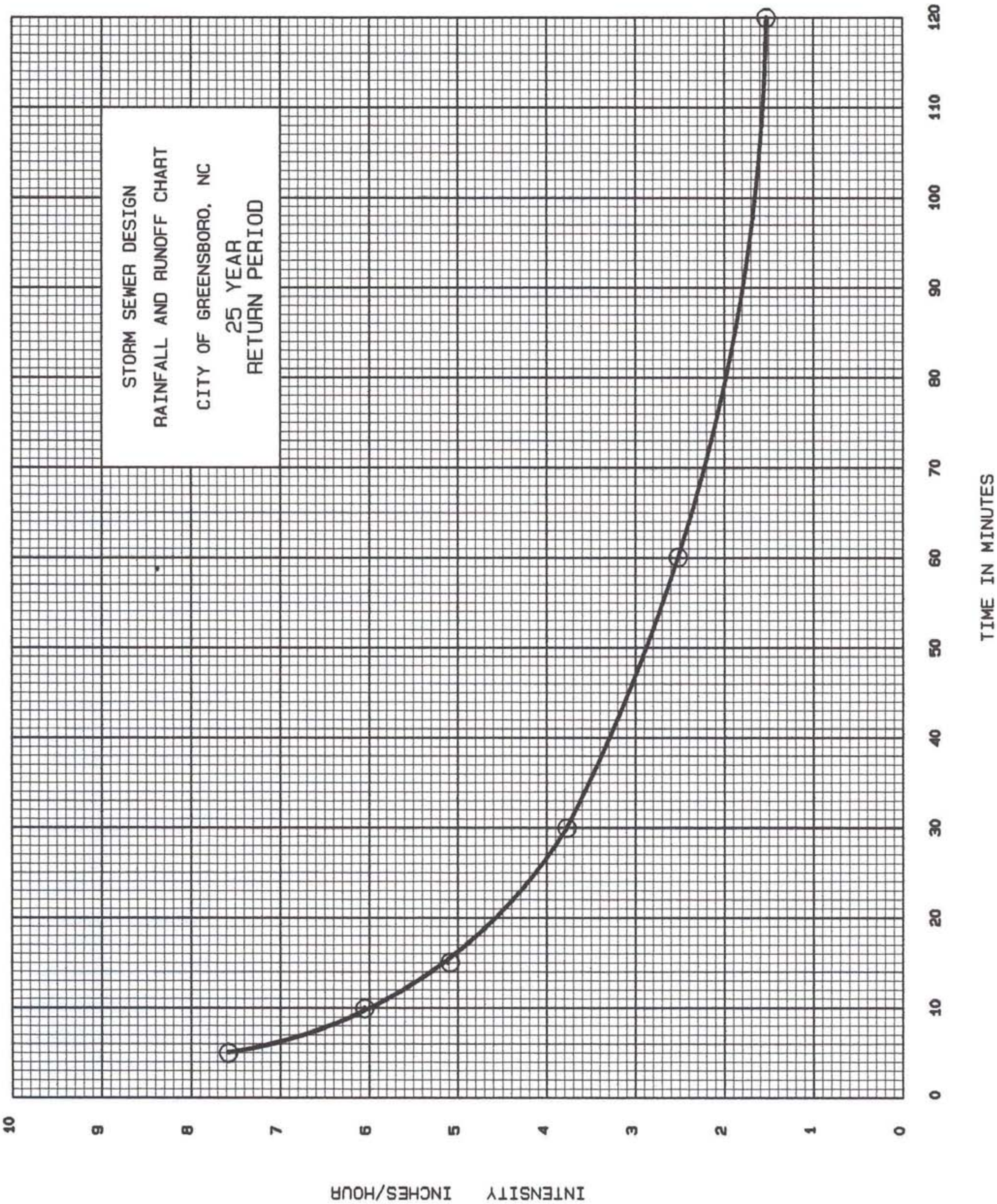
## Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC
## 5-year Return Period



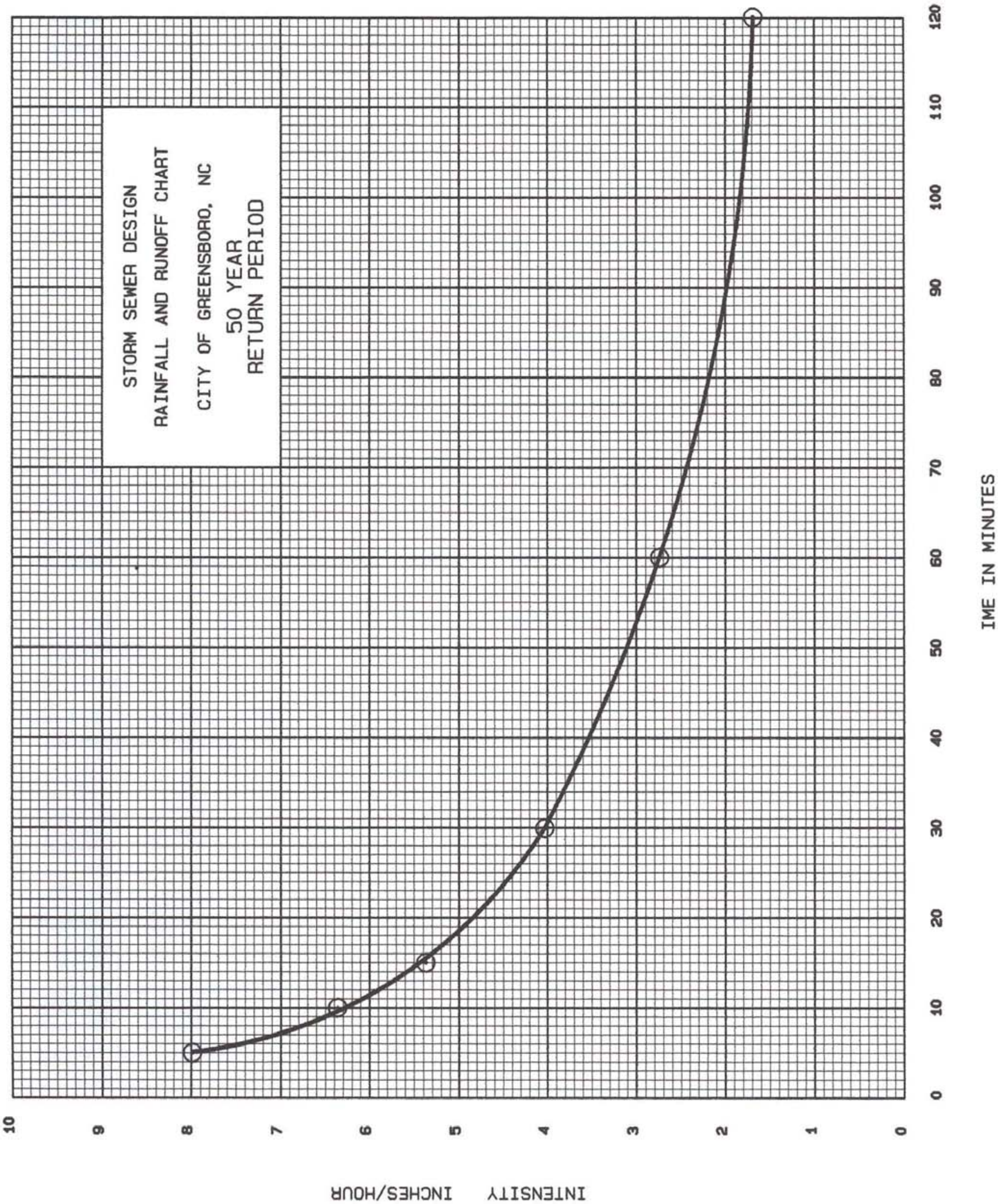
## Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC
## 10-year Return Period



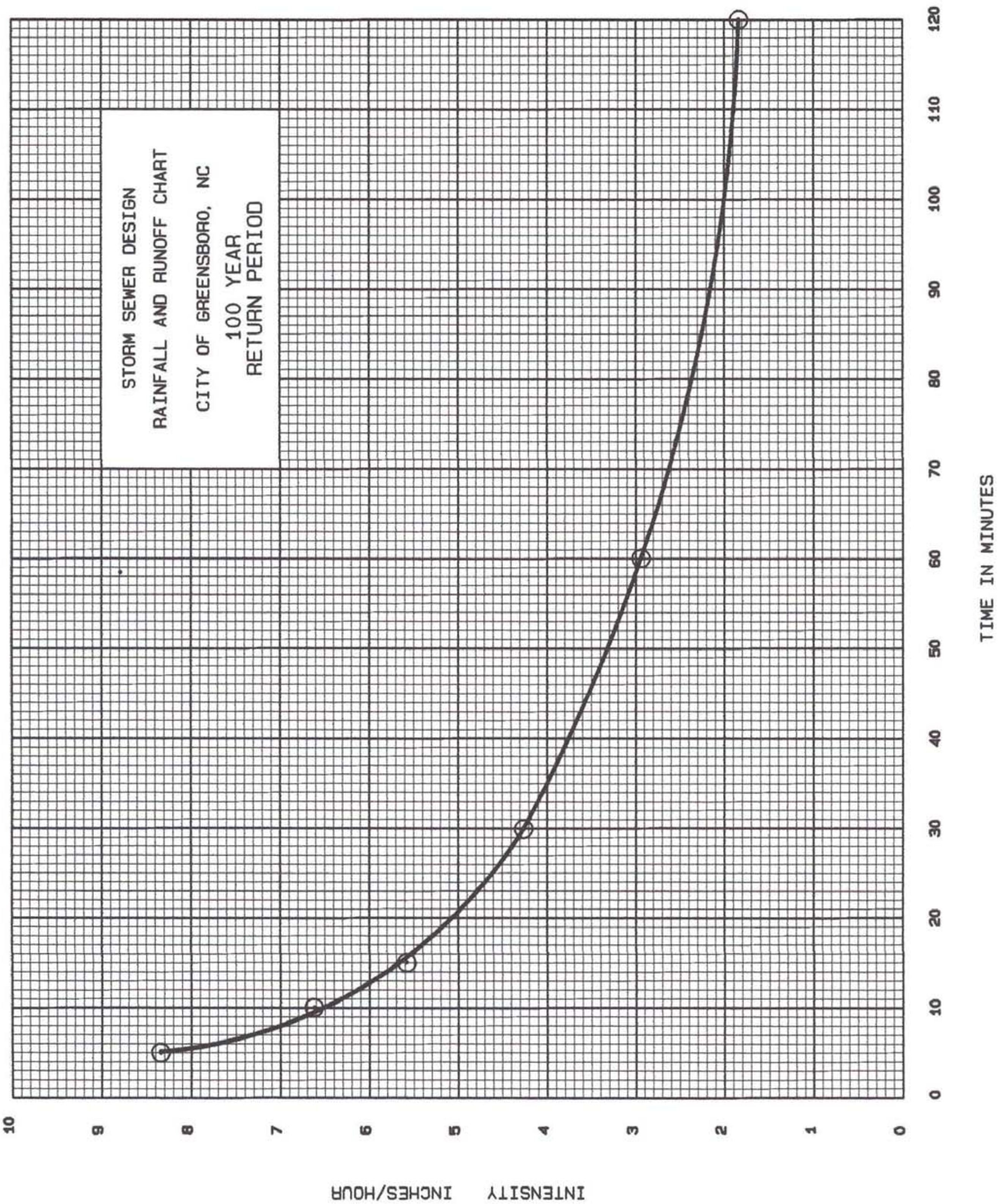
**Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC**
**25-year Return Period**



## Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC
## 50-year Return Period



**Storm Sewer Design Rainfall & Runoff Chart for Greensboro, NC**
**100-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:

$$T = 0.49\left(L/\sqrt{S}\right)^{.50} I^{-.57}$$

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
I = Ratio of the area of impervious cover to the total drainage area

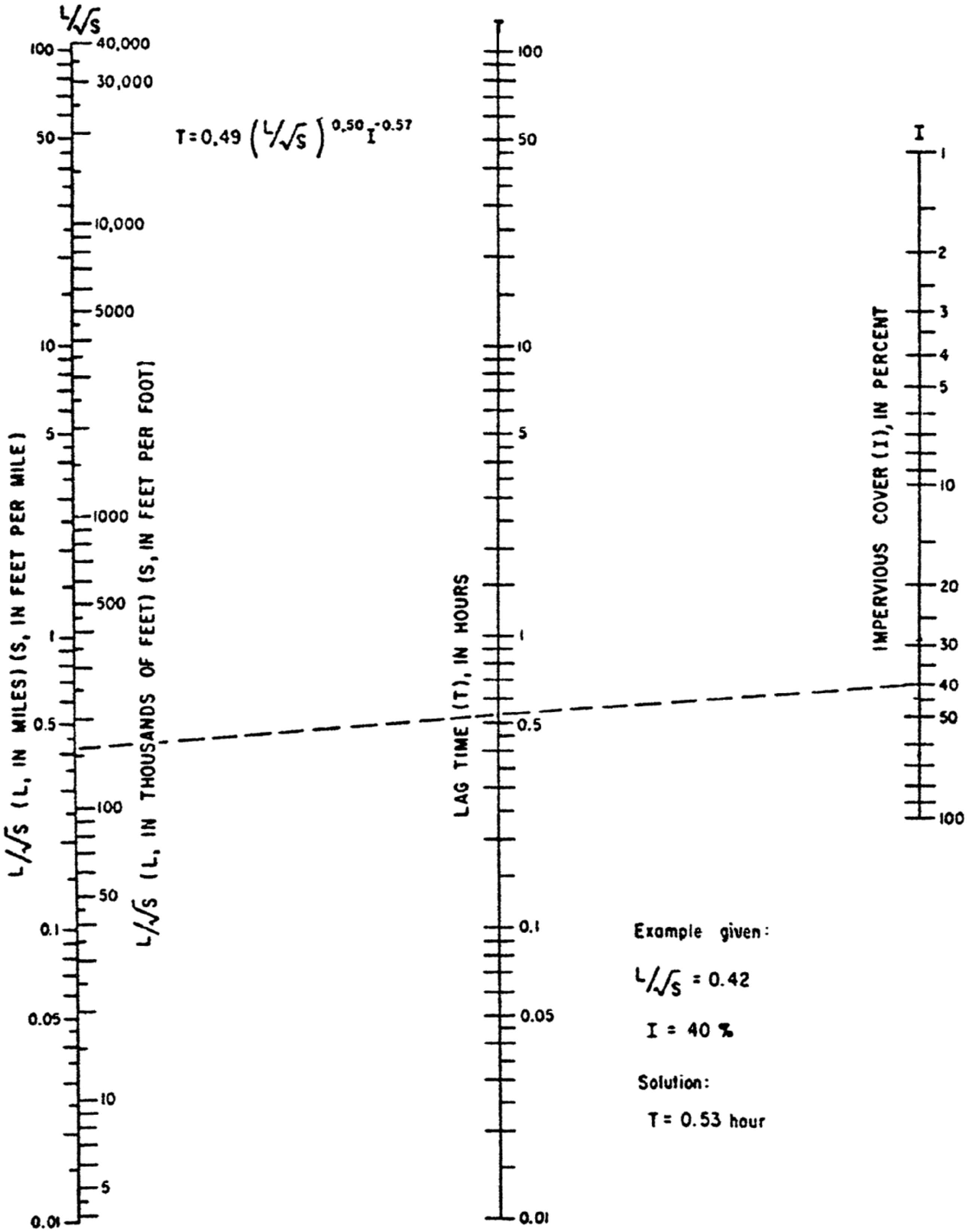
2) Once the Basin Lag-Time has been determined, the following equations can be used to determine the appropriate peak discharge.

$$Q_2 = 221\, A^{0.87} \times T^{-0.60} \qquad Q_{20} = 735\, A^{0.72} \times T^{-0.43}$$
$$Q_5 = 405\, A^{0.80} \times T^{-0.52} \qquad Q_{25} = 790\, A^{0.71} \times T^{-0.42}$$
$$Q_{10} = 560\, A^{0.76} \times T^{-0.48} \qquad Q_{50} = 990\, A^{0.67} \times T^{-0.37}$$
$$Q_{15} = 630\, A^{0.74} \times T^{-0.45} \qquad Q_{100} = 1200\, A^{0.63} \times T^{-0.33}$$

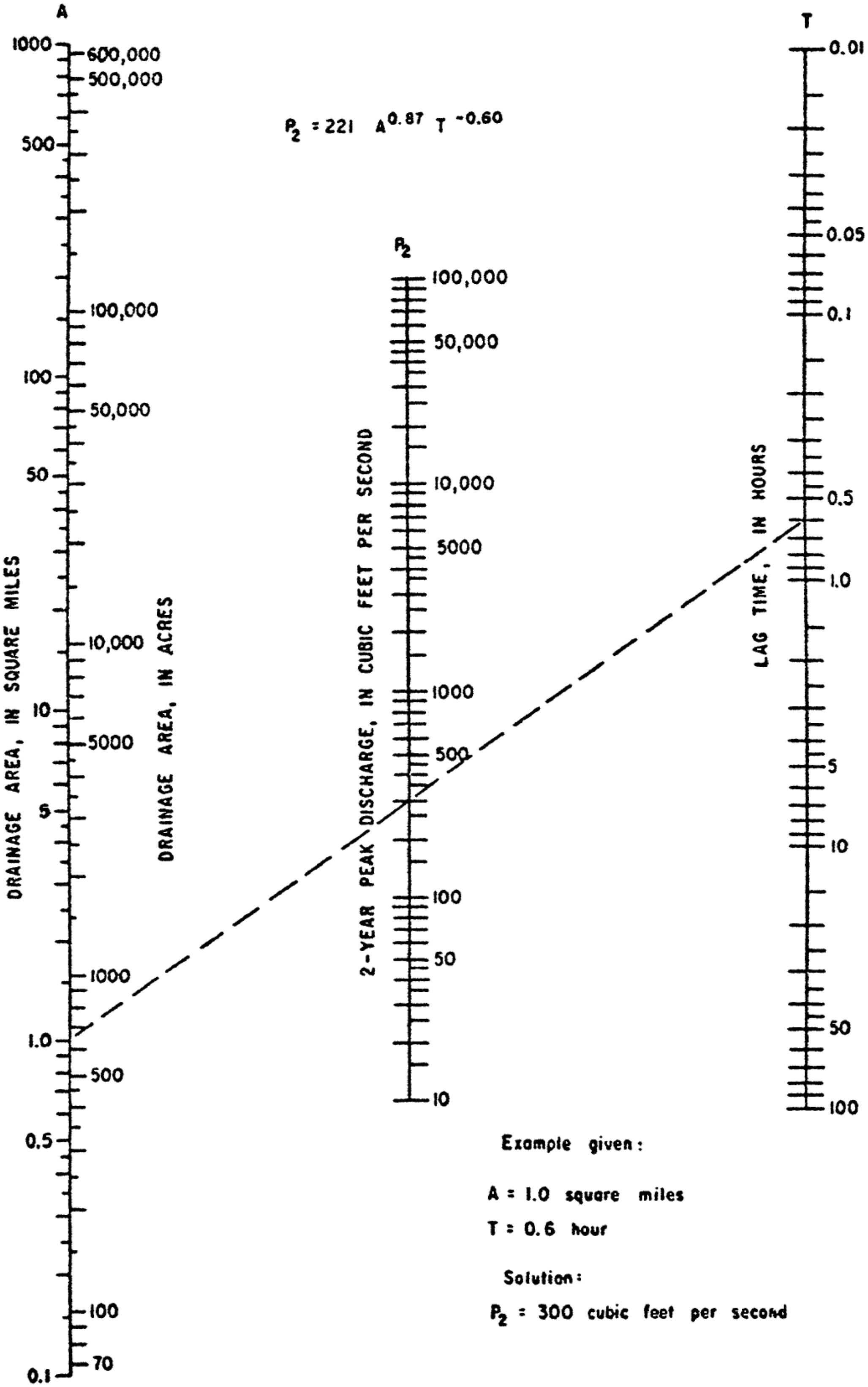
$Q_I$ = Peak discharge for the flood having the recurrence interval indicated by the subscript in cfs.
A = Drainage Area in square miles
T = Lag-Time in hours

Pages 20 - 28 include a set of nomographs with an example, which can be used in lieu of the above formulas.

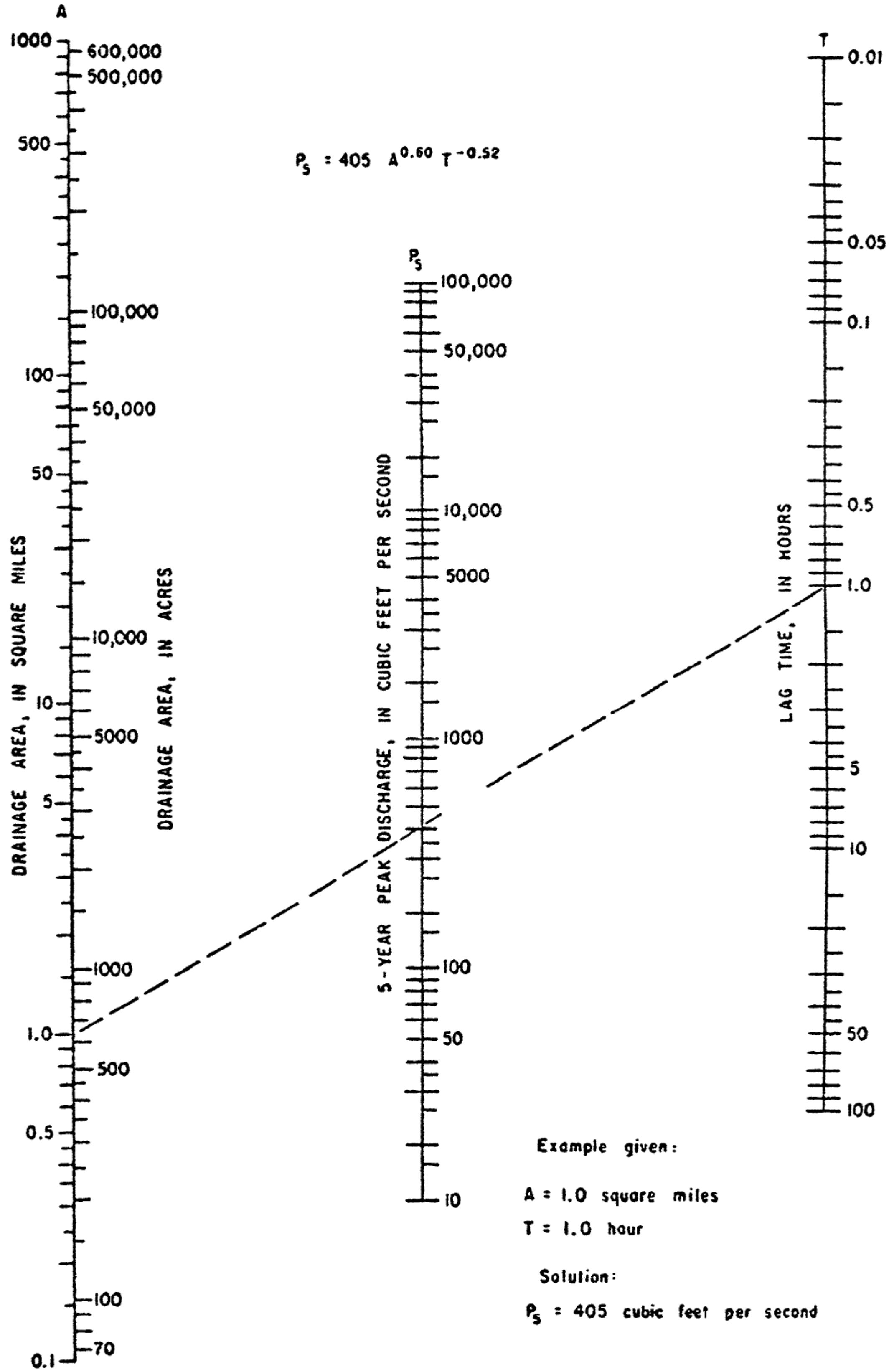
## Nomograph for Estimating Basin Lag-Time



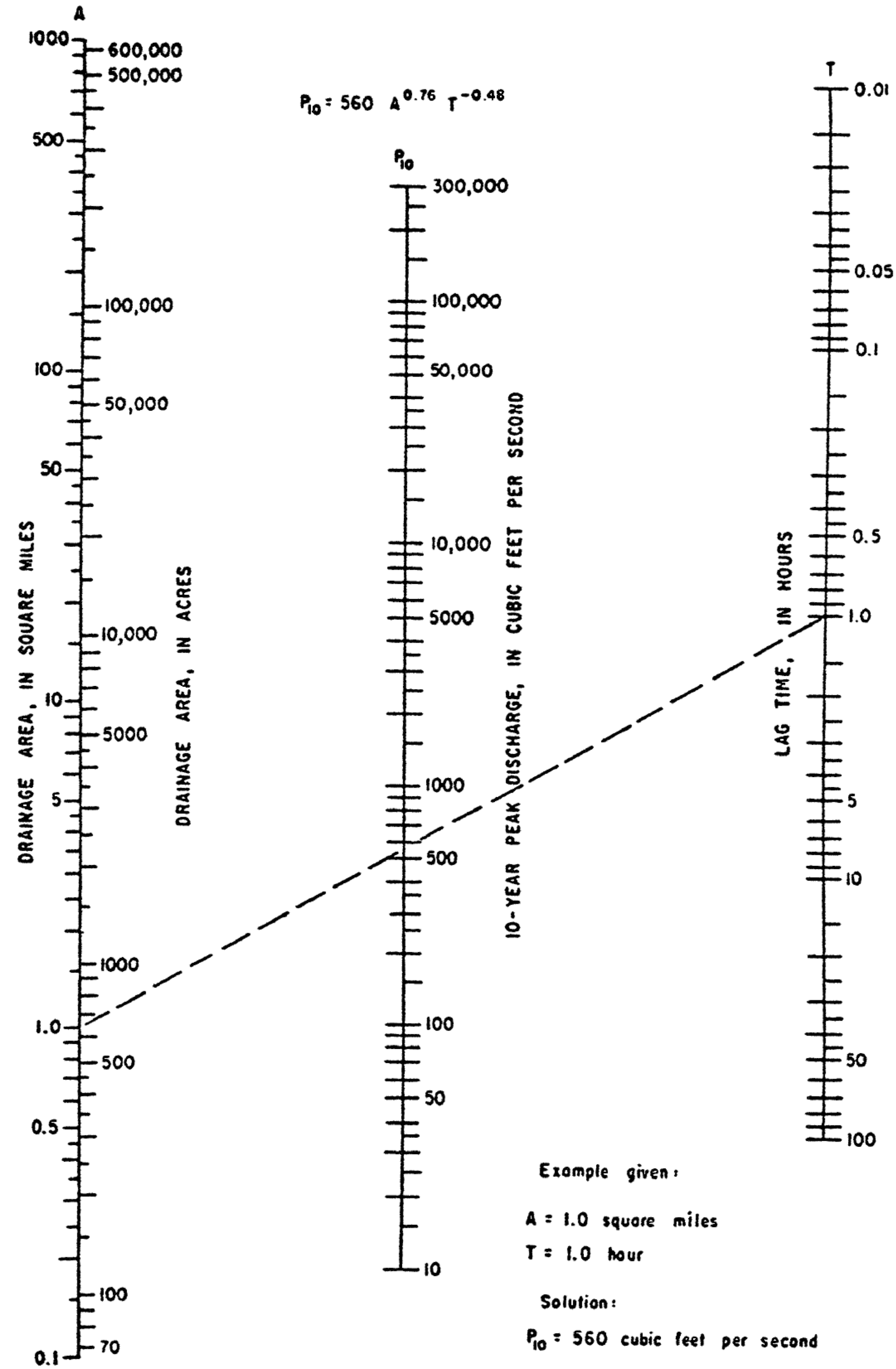
## Nomograph for Estimating 2-year Flood-Peak Discharge



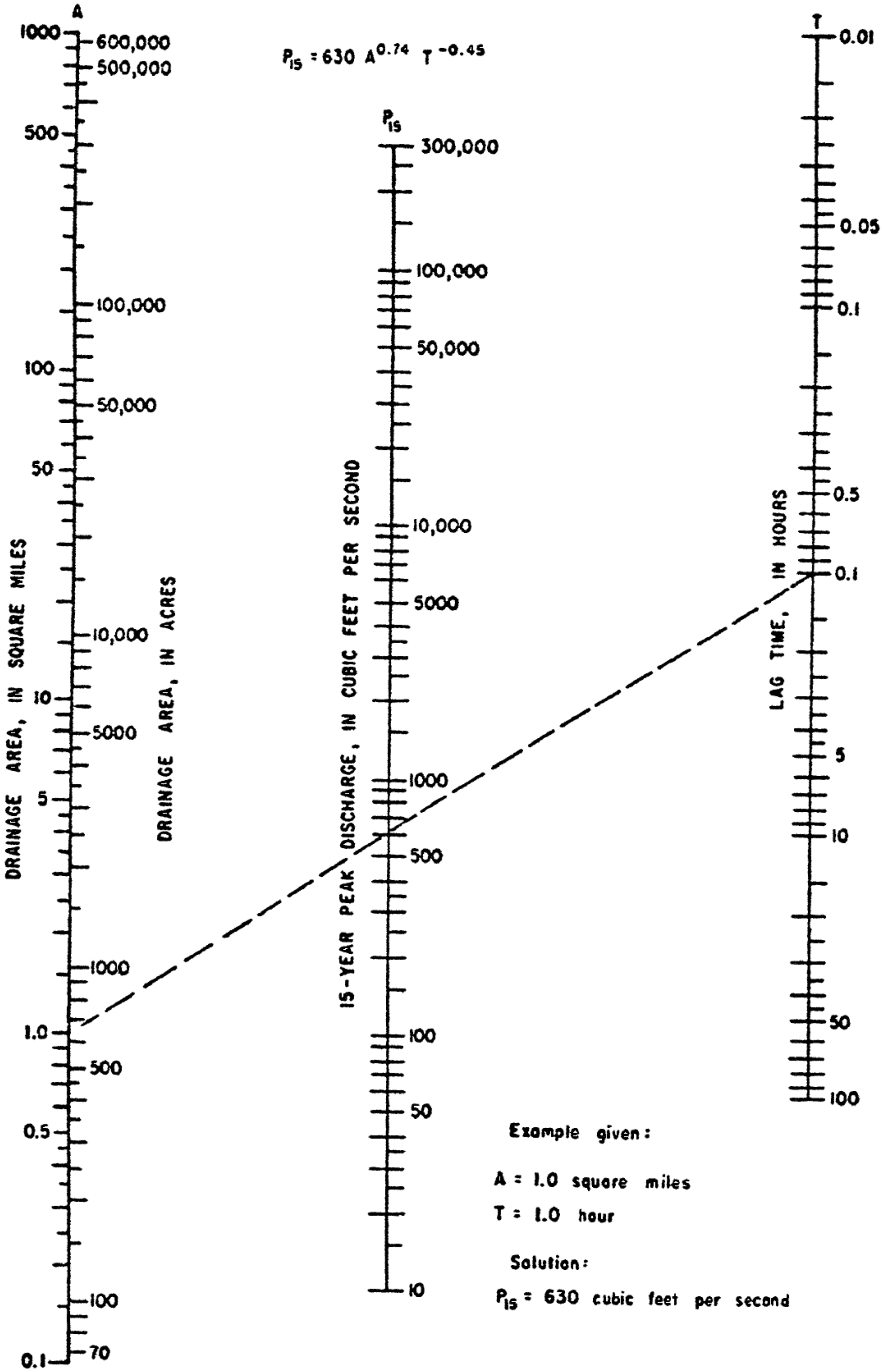
## Nomograph for Estimating 5-year Flood-Peak Discharge



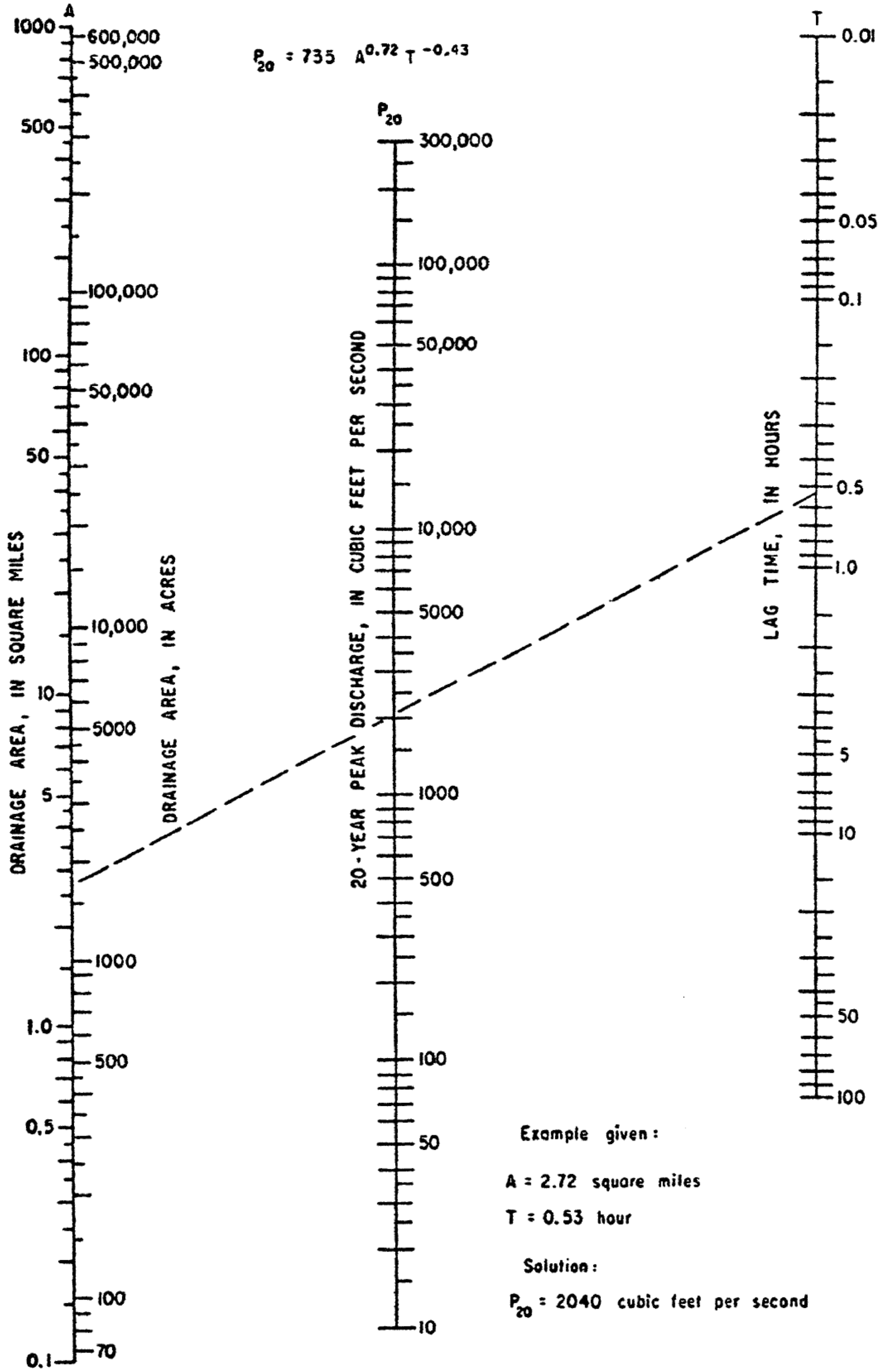
## Nomograph for Estimating 10-year Flood-Peak Discharge



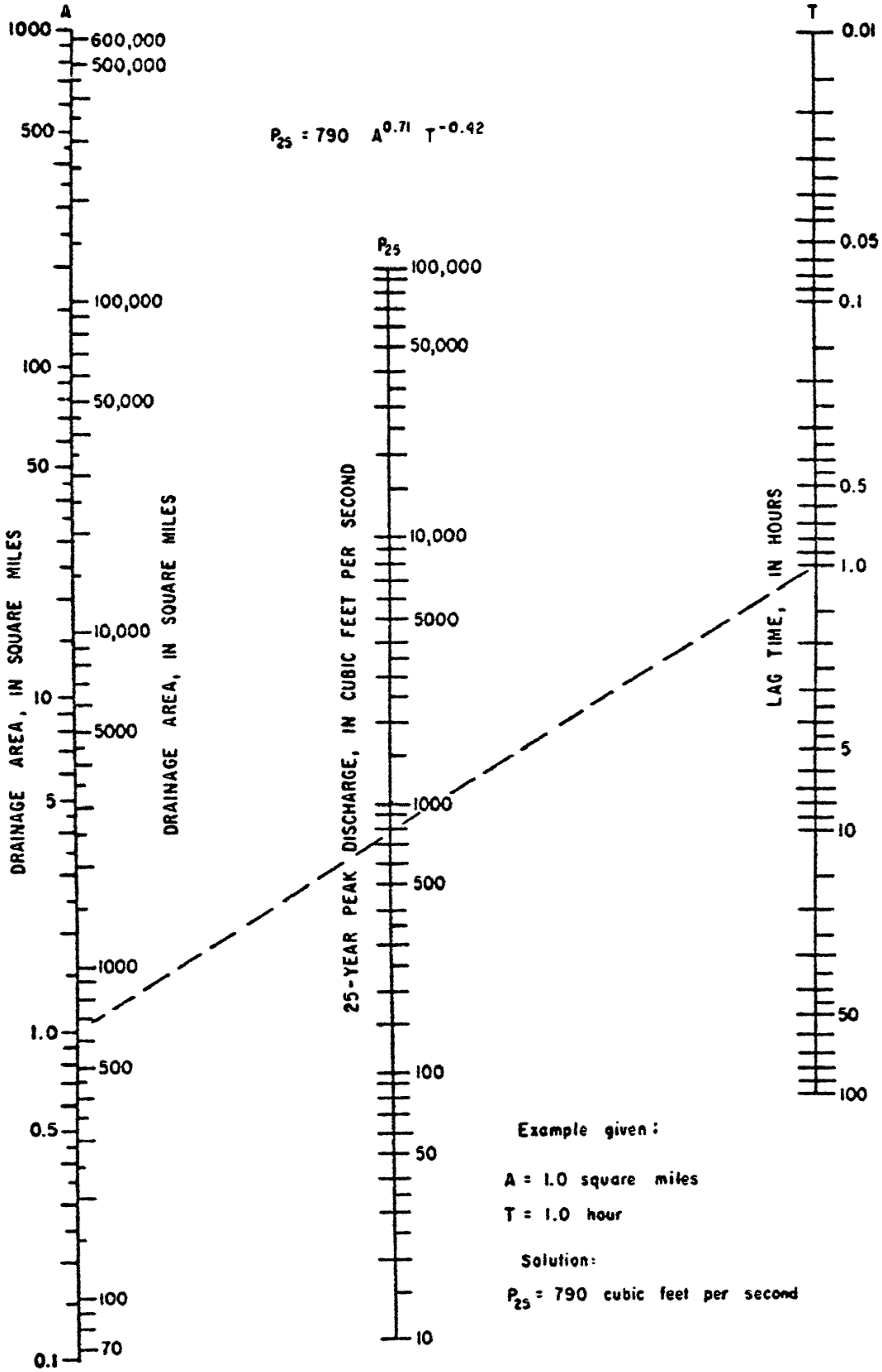
## Nomograph for Estimating 15-year Flood-Peak Discharge



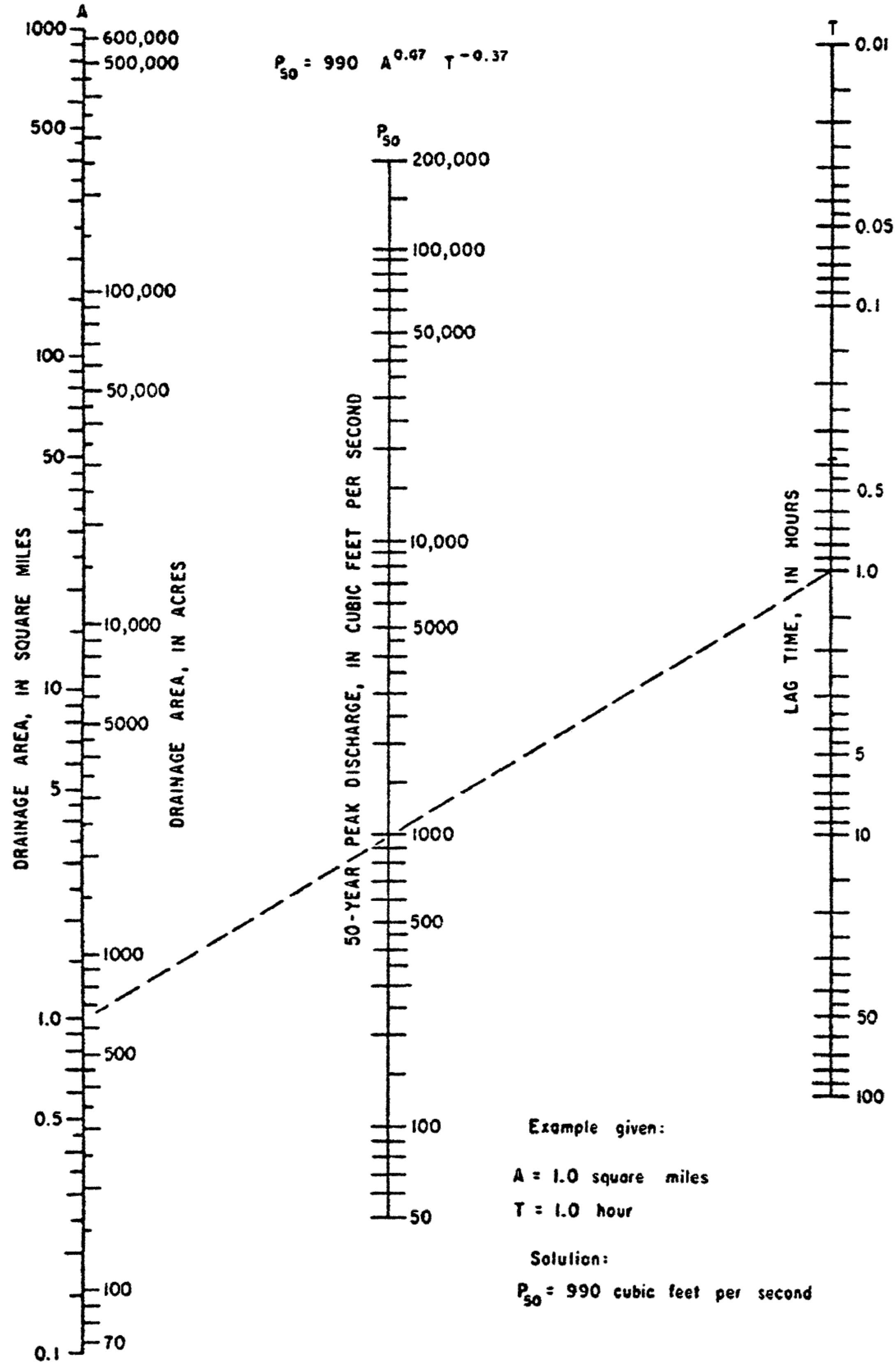
## Nomograph for Estimating 20-year Flood-Peak Discharge



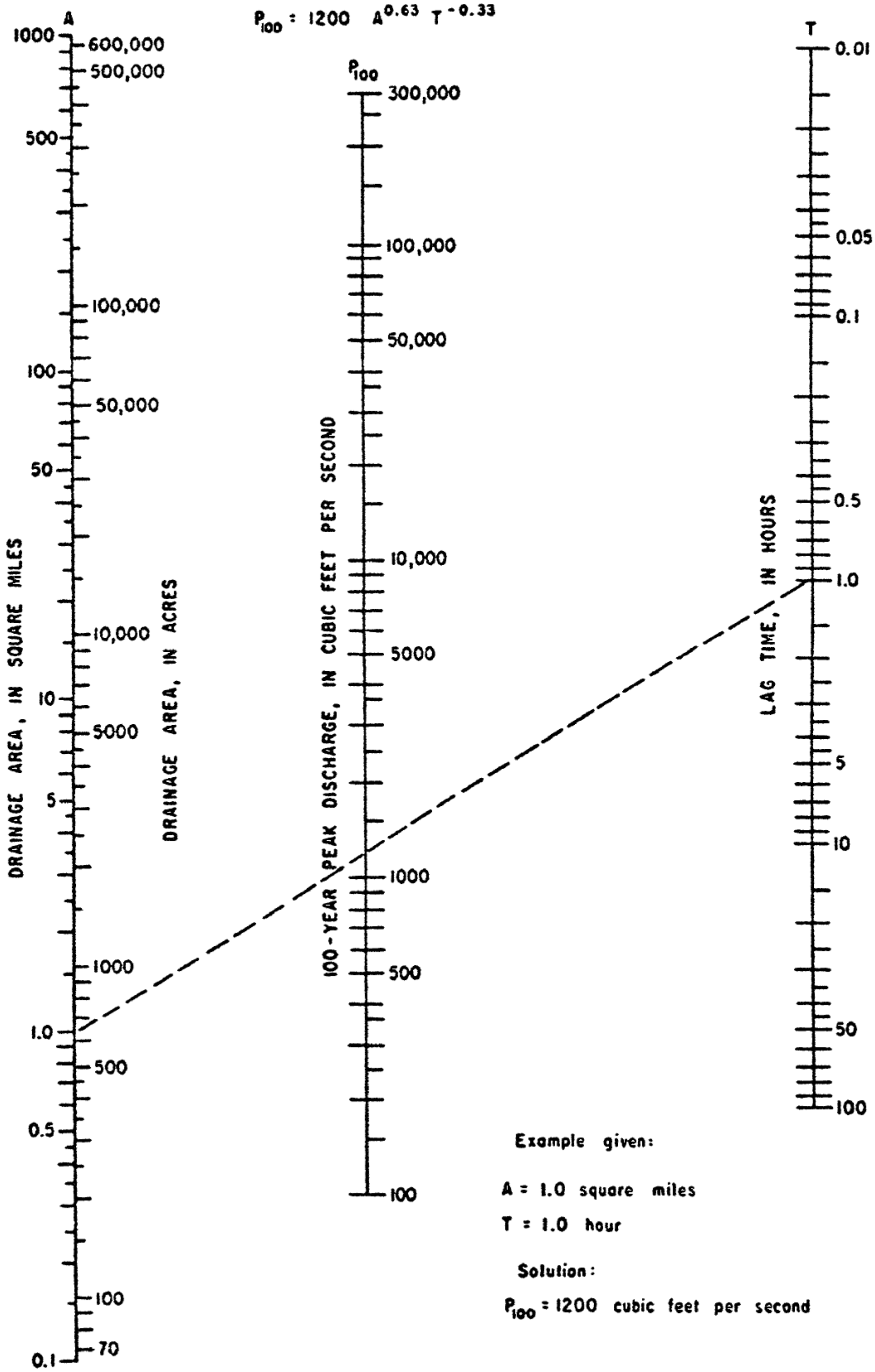
## Nomograph for Estimating 25-year Flood-Peak Discharge



## Nomograph for Estimating 50-year Flood-Peak Discharge



## Nomograph for Estimating 100-year Flood-Peak Discharge



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:

$$S = \frac{686\,ft - 605\,ft}{2.26mi - 0.27mi} = \frac{81\,ft}{1.99mi} = 41.0\,ft \;\; per\ mile$$

3) Compute Length-Slope factors:

$$L/\sqrt{S} = 2.66/\sqrt{41.0} = 0.42$$

4) Determine lag-time from page 20, 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 20-year flood-peak discharge from page 25. 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 20-year flood-peak discharge value, $Q_{20}$ = 2040 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.

## TR-55 Method

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

The National Resource Conservation Service (NRCS), formerly Soil Conservation Service (SCS), has developed a method for estimating runoff and peak discharge in urban watersheds. These procedures are presented in Technical Release 55, better known as TR-55. Refer to the TR-55 for more details of the procedure and examples of its application.

The City of Greensboro allows this method, TR-55, to be used to determine peak flows for sizing large culvert crossings with drainage areas greater than 200 acres.

When using TR-55, to determine the peak discharge the following limitations must be observed:

- When determining peak runoff to be used for culvert design, the drainage basin is to be assumed to be built out according to the land use for the current zoning.
- The watershed must be hydraulically homogeneous with a weighted CN used for the entire basin.
- Apply an $F_p$ factor for ponds or swamps that are not in the $T_c$ flow path.
- This method is not to be used if the weighted CN is less than 40.
- Time of Concentration, $T_c$, with this method must range between 0.1 hours and 10 hours.
- This method is based on open and unconfined flow overland or in channels. If the flow passes through a pipe system, the time of concentration for that segment of flow will be the calculated pipe travel time.
- This method is based on the 24-hour duration storm for the particular return period of interest.
- The SCS Rainfall Distribution Type for the City of Greensboro is Type II.

**Four Steps to Determine Peak Discharge**

1. Select or determine the composite Curve Number, CN, for the watershed, weighted by the sub-areas.
2. Determine the runoff, Q, in inches. ("Q" in TR-55 is different than "Q" in the Rational Formula). Here, Q is the depth in inches of runoff over the watershed area.
3. Determine the Time of Concentration, $T_c$.
4. Determine Peak Discharge, $Q_p$, in cfs (cubic feet per second)

**Determine the Curve Number, CN**

Use Figure 2-3, and Figure 2-4, Table 2-2A and Worksheet 2 (pages 36, 37 and 41) to calculate the Curve Number for the drainage basin.

**Determine Runoff "Q" in inches**

In the TR-55 method, "Q" is the runoff from a watershed measured in inches and is determined by the formula:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q = Runoff in inches
P = 24-hour rainfall in inches; see table below for the Greensboro area (taken from the Duration – Frequency Table for a selected rainfall frequency)
S = Potential maximum retention after runoff begins, in inches
$I_a$ = Initial Abstraction
$I_a$ = 0.2 S

$$S = \frac{1000}{CN} - 10$$

| Depth – Duration – Frequency Table (P) | | | | | | |
|---|---|---|---|---|---|---|
| Duration | 2 – yr (in) | 5 – yr (in) | 10 – yr (in) | 25 – yr (in) | 50 – yr (in) | 100 – yr (in) |
| 24 HR | 3.38 | 4.21 | 4.82 | 5.73 | 6.43 | 7.15 |

Use the bottom of Worksheet 2 on page 41 to determine Runoff "Q".

## Determine Time of Concentration

Travel time is the time it takes water to travel from one location to another in a watershed. Water moves through the watershed in segments as sheetflow, shallow concentrated flow, open channel flow or pipe flow. Time of Concentration is the sum of the travel times of the consecutive flow segments.

$$T_c = T_{t1} + T_{t2} + T_{tn}$$

Use Worksheet 3, on page 42, to determine the Time of Concentration.

## Sheet Flow

Sheet flow can be determined by the use of this formula:

$$T_t = \frac{0.007 n L^{4/5}}{P_2^{\,1/2} S^{2/5}}$$

| | | |
|---|---|---|
| $T_t$ | = | Sheet flow travel time in hours |
| n | = | Manning's "C" for sheet flow (See table 3-1) |
| L | = | Length of flow in feet (limit to 100') |
| $P_2$ | = | 2 year, 24 Hr. rainfall (inches) (in Greensboro, use 3.50 in.) |
| S | = | Slope of sheet flow area (ft./ft.)<br>(Change in elevation divided by length of sheet flow area) |

**Table 3-1** Manning's Roughness Coefficient for Sheet Flow

| Surface Description | "n" |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel, bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated soils | |
| Residue cover < 20% | 0.06 |
| Residue cover > 20% | 0.17 |
| Grass | |
| Short prairie grass | 0.15 |
| Dense grasses | 0.24 |
| Bermuda grass | 0.41 |
| Range (natural) | |
| Woods | |
| Light underbrush | 0.40 |
| Dense underbrush | 0.80 |

When selecting "n" consider cover height to 0.1 ft.

**Shallow Concentrated Flow**

Use Figure 3-1, on page 38, to determine Shallow Concentrated Flow.

**Channel Flow and Pipe Flow**

Use Manning's formula to determine the velocity of the channel flow. The velocity and length of channel can easily be converted to travel time in the open channel.

$$V = \frac{1.49R^{2/3}S^{1/2}}{n}$$

| | | |
|---|---|---|
| V | = | Velocity in feet per second |
| R | = | Hydraulic Radius in feet (area/wetted perimeter A/Pw) |
| A | = | Cross sectional Area of flow in square feet ($ft^2$) |
| Pw | = | Wetted Perimeter of flow area in feet |
| S | = | Channel Slope (decimal) |
| n | = | Manning's roughness coefficient of open channel flow (unitless) |

**Determine the Peak Discharge ($Q_p$) is cubic feet per second (cfs)**

The peak discharge ($Q_p$) which is used to determine culvert sizes can be found by using Worksheet 4, on page 43. The peak discharge can also be found using this formula:

$$Q_p = q_u A_m Q F_p$$

| | | |
|---|---|---|
| $Q_p$ | = | Peak discharge in cubic feet per second (cfs) |
| $q_u$ | = | Unit peak discharge from Exhibit 4-II (page 39) |
| $A_m$ | = | Drainage Area (square miles) |
| Q | = | runoff (inches) |
| $F_p$ | = | Pond or Swamp adjustment factor (applies to detention ponds) |

**Table 4-2**
Adjustment factor ($F_p$) for pond and swamp areas that are spread throughout the watershed

| Percentage of pond and swamp areas | $F_p$ |
|---|---|
| 0 | 1.00 |
| 0.2 | 0.97 |
| 1.0 | 0.87 |
| 3.0 | 0.75 |
| 5.0 | 0.72 |

**Table 4-1**
$I_a$ for runoff curve numbers

| Curve Number | $I_a$ (inches) | Curve Number | $I_a$ (inches) |
|---|---|---|---|
| 40 | 3.00 | 70 | 0.857 |
| 41 | 2.878 | 71 | 0.857 |
| 42 | 2.762 | 72 | 0.817 |
| 43 | 2.651 | 73 | 0.778 |
| 44 | 2.545 | 74 | 0.703 |
| 45 | 2.444 | 75 | 0.667 |
| 46 | 2.348 | 76 | 0.632 |
| 47 | 2.255 | 77 | 0.597 |
| 48 | 2.167 | 78 | 0.564 |
| 49 | 2.082 | 79 | 0.532 |
| 50 | 2.000 | 80 | 0.500 |
| 51 | 1.922 | 81 | 0.469 |
| 52 | 1.846 | 82 | 0.439 |
| 53 | 1.774 | 83 | 0.410 |
| 54 | 1.704 | 84 | 0.381 |
| 55 | 1.636 | 85 | 0.353 |
| 56 | 1.571 | 86 | 0.326 |
| 57 | 1.509 | 87 | 0.299 |
| 58 | 1.448 | 88 | 0.273 |
| 59 | 1.390 | 89 | 0.247 |
| 60 | 1.333 | 90 | 0.222 |
| 61 | 1.279 | 91 | 0.198 |
| 62 | 1.226 | 92 | 0.174 |
| 63 | 1.175 | 93 | 0.151 |
| 64 | 1.125 | 94 | 0.128 |
| 65 | 1.077 | 95 | 0.105 |
| 66 | 1.030 | 96 | 0.083 |
| 67 | 0.985 | 97 | 0.062 |
| 68 | 0.941 | 98 | 0.041 |
| 69 | 0.899 | | |

**Plan Submittal**

When submitting plans for construction review, the runoff calculations must be submitted with the plans. Calculations can be completed manually or by using the computer program WinTR-55, which is acceptable as long as methods set forth in this chapter are used. Provide copies of the input and output information if WinTR-55 is utilized.

**Figure 2-1** Solution of runoff equation.

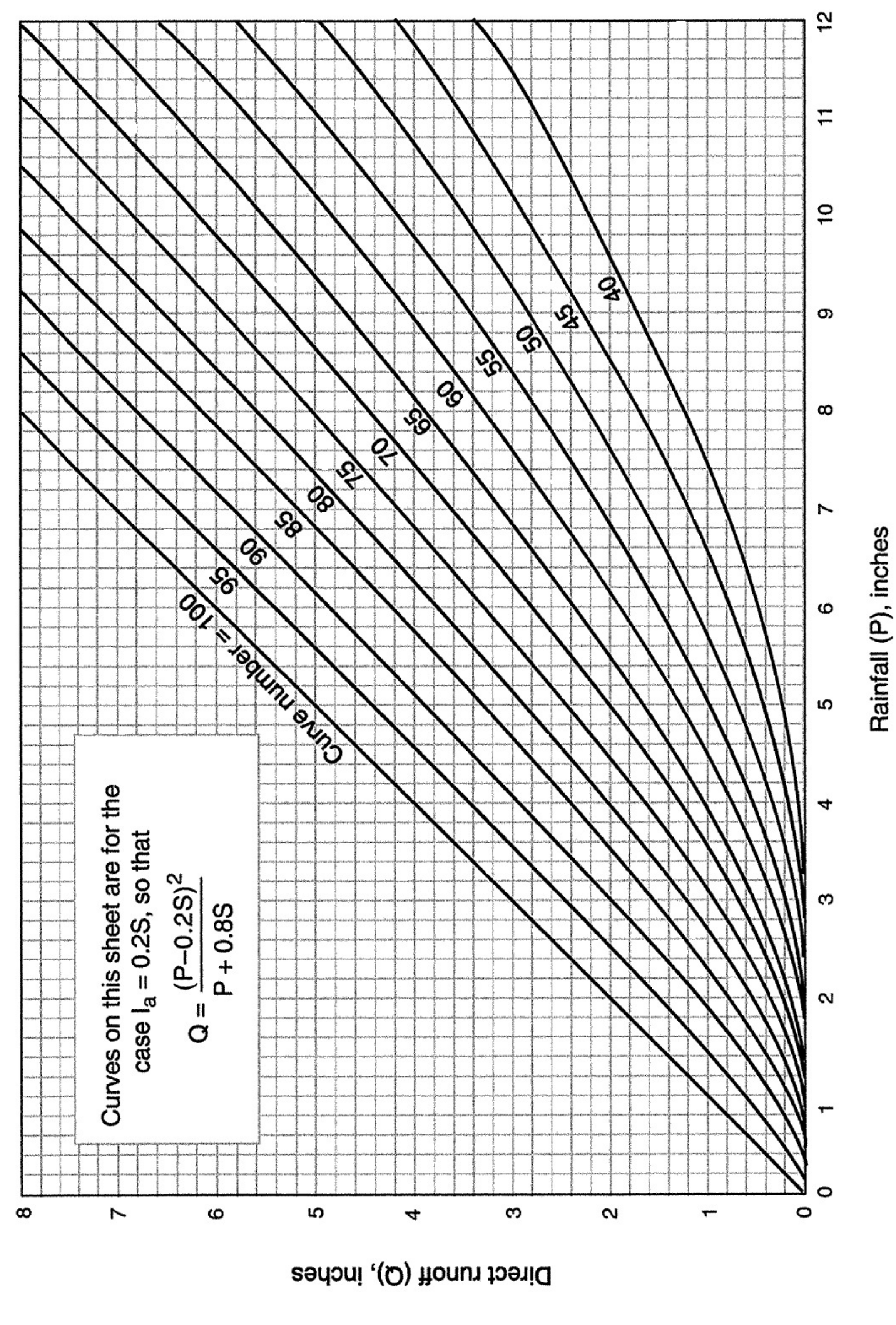


**Figure 2-3** Composite CN with connected impervious area.

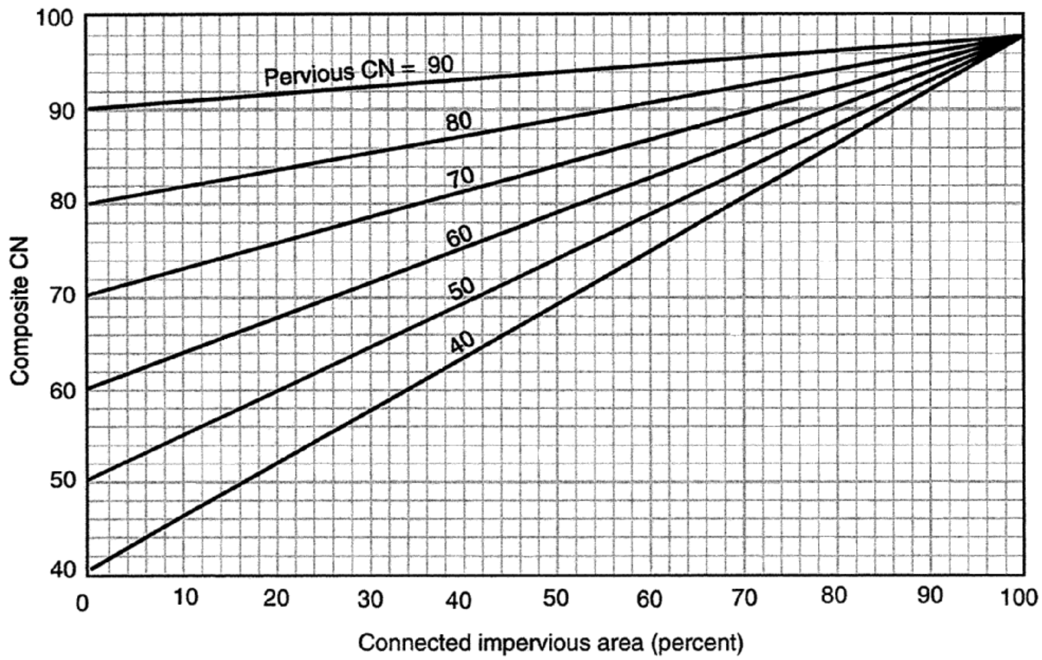



**Figure 2-4** Composite CN with unconnected impervious areas and total impervious area less than 30%

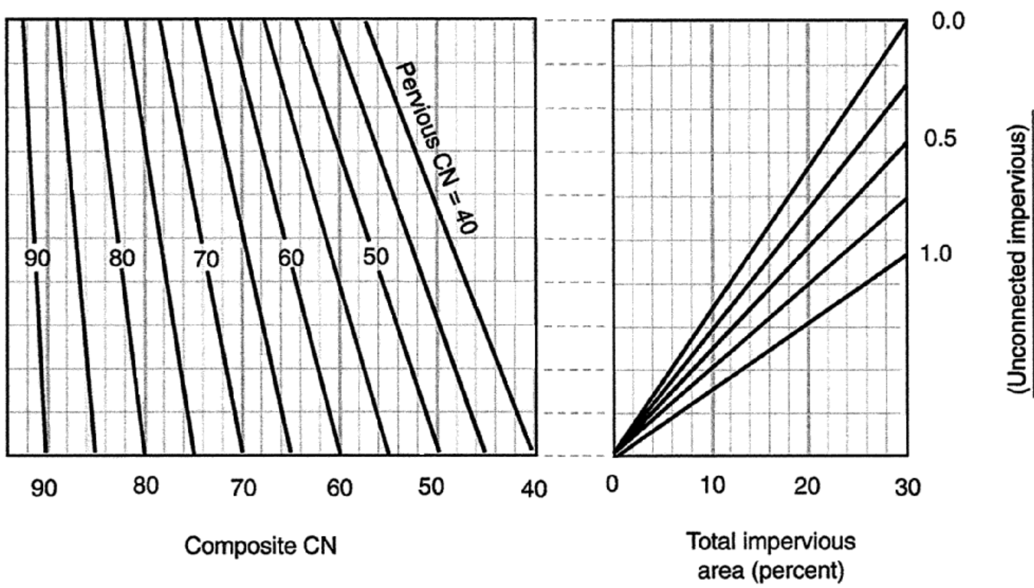


**Table 2-2a** Runoff curve numbers for urban areas [1]

| Cover type and hydrologic condition | Average percent impervious area [2] | Curve numbers for hydrologic soil group A | B | C | D |
|---|---|---|---|---|---|
| *Fully developed urban areas (vegetation established)* | | | | | |
| Open space (lawns, parks, golf courses, cemeteries, etc.) [3]: | | | | | |
| Poor condition (grass cover < 50%) | | 68 | 79 | 86 | 89 |
| Fair condition (grass cover 50% to 75%) | | 49 | 69 | 79 | 84 |
| Good condition (grass cover > 75%) | | 39 | 61 | 74 | 80 |
| Impervious areas: | | | | | |
| Paved parking lots, roofs, driveways, etc. (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| Streets and roads: | | | | | |
| Paved; curbs and storm sewers (excluding right-of-way) | | 98 | 98 | 98 | 98 |
| Paved; open ditches (including right-of-way) | | 83 | 89 | 92 | 93 |
| Gravel (including right-of-way) | | 76 | 85 | 89 | 91 |
| Dirt (including right-of-way) | | 72 | 82 | 87 | 89 |
| Western desert urban areas: | | | | | |
| Natural desert landscaping (pervious areas only) [4] | | 63 | 77 | 85 | 88 |
| Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders) | | 96 | 96 | 96 | 96 |
| Urban districts: | | | | | |
| Commercial and business | 85 | 89 | 92 | 94 | 95 |
| Industrial | 72 | 81 | 88 | 91 | 93 |
| Residential districts by average lot size: | | | | | |
| 1/8 acre or less (town houses) | 65 | 77 | 85 | 90 | 92 |
| 1/4 acre | 38 | 61 | 75 | 83 | 87 |
| 1/3 acre | 30 | 57 | 72 | 81 | 86 |
| 1/2 acre | 25 | 54 | 70 | 80 | 85 |
| 1 acre | 20 | 51 | 68 | 79 | 84 |
| 2 acres | 12 | 46 | 65 | 77 | 82 |
| *Developing urban areas* | | | | | |
| Newly graded areas (pervious areas only, no vegetation) [5] | 77 | 86 | 91 | 94 | |
| Idle lands (CN's are determined using cover types similar to those in table 2-2c). | | | | | |

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

**Figure 3-1** Average velocities for estimating travel time for shallow concentrated flow

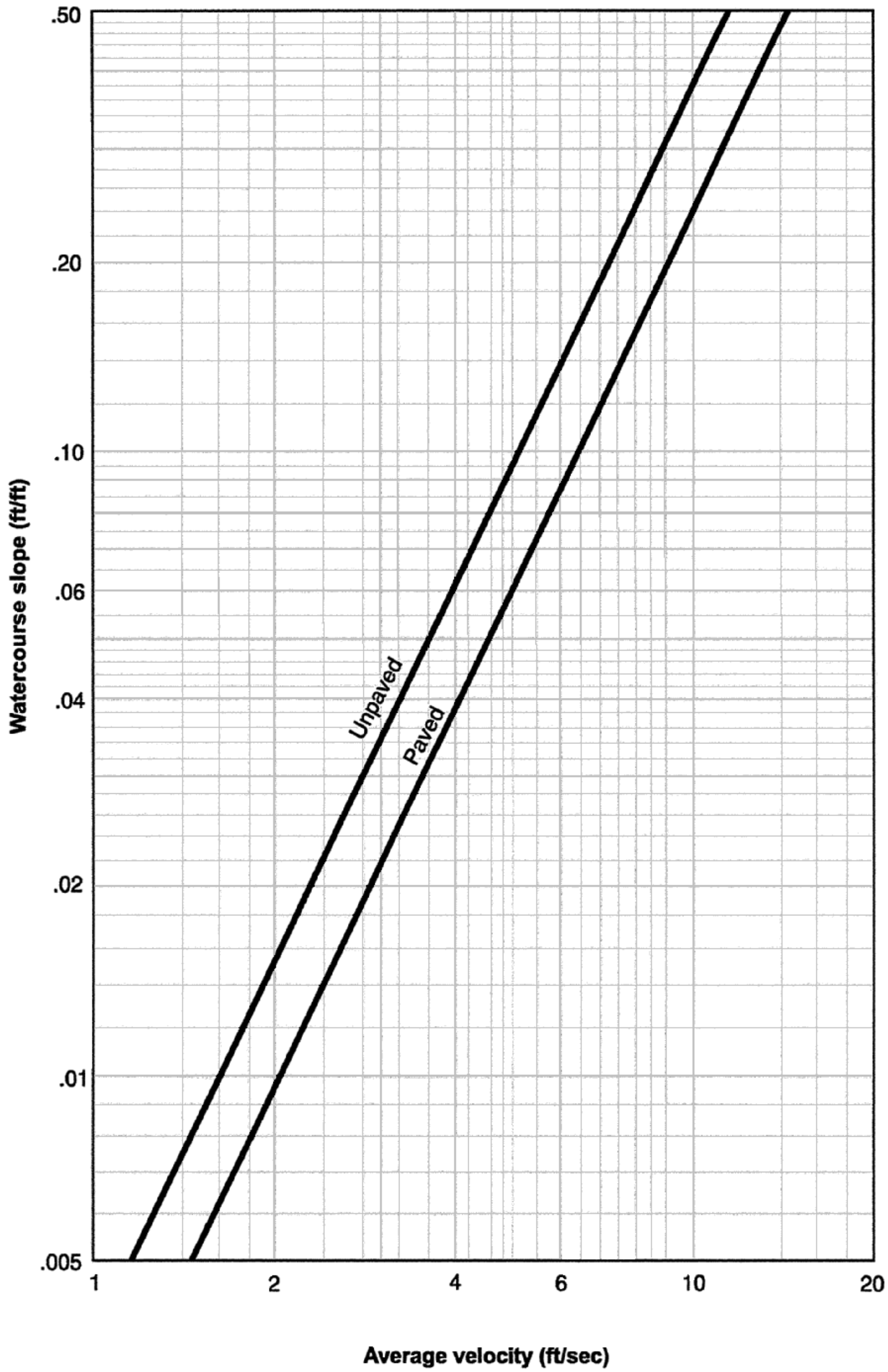
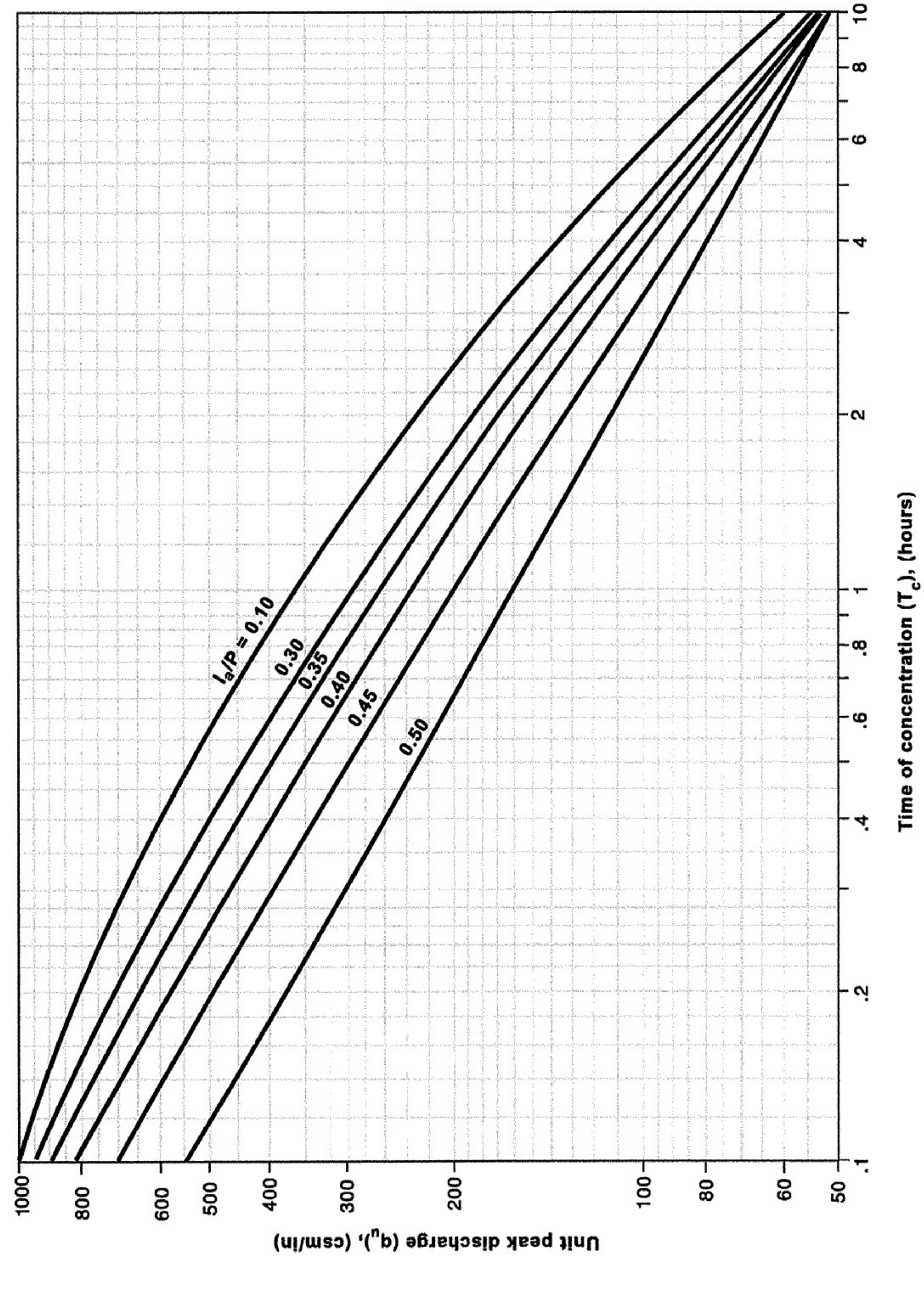


**Exhibit 4-II** Unit peakdischarge ($q_u$) for NRCS (SCS) type II rainfall distribution



# Appendix A Hydrologic Soil Groups

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

**Group A** soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (greater than 0.30 in/hr).

**Group B** soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

**Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

**Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

## Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983).

| *HSG* | *Soil textures* |
|---|---|
| A | Sand, loamy sand, or sandy loam |
| B | Silt loam or loam |
| C | Sandy clay loam |
| D | Clay loam, silty clay loam, sandy clay, silty clay, or clay |

## Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

## Worksheet 2: Runoff curve number and runoff

| Project | By | Date |
|---|---|---|
| Location | Checked | Date |

Check one: ☐ Present ☐ Developed

### 1. Runoff curve number

| Soil name and hydrologic group (appendix A) | Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio) | CN [1/] Table 2-2 | CN [1/] Figure 2-3 | CN [1/] Figure 2-4 | Area ☐ acres ☐ $mi^2$ ☐ % | Product of CN x area |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | **Totals ➡** | | | |

[1/] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ______________ = _______ ; **Use CN ➡** ☐

### 2. Runoff

| | | Storm #1 | Storm #2 | Storm #3 |
|---|---|---|---|---|
| Frequency ........................ | yr | | | |
| Rainfall, P (24-hour) ................ | in | | | |
| Runoff, Q ........................ (Use P and CN with table 2-1, figure 2-1, or equation 2-3 and 2-4) | in | | | |

## Worksheet 3: Time of Consentration ($T_c$) or travel time ($T_t$)

| Project | By | Date |
|---|---|---|
| Location | Checked | Date |

Check one: ☐ Present ☐ Developed

Check one: ☐ $T_c$ ☐ $T_t$ through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet.
Include a map, schematic, or description of flow segments.

### Sheet flow (Applicable to $T_c$ only)

| Segment ID | | | |
|---|---|---|---|
| 1. Surface description (table 3-1) .................................. | | | |
| 2. Manning's roughness coefficient., *n* (table 3-1) .......... | | | |
| 3. Flow length, L (total L ≤ 300 ft) ................................ ft | | | |
| 4. Two-year 24-hour rainfall, $p_2$ ................................. in | | | |
| 5. Land slope, s ....................................................... ft/ft | | | |
| 6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute $T_t$ ......... hr | | + | = |

### Shallow concentrated flow

| Segment ID | | | |
|---|---|---|---|
| 7. Surface description (paved or unpaved) ..................... | | | |
| 8. Flow length, L ..........................................................ft | | | |
| 9. Watercourse slope, s ........................................... ft/ft | | | |
| 10. Average velocity, V (figure 3-1) ............................ ft/s | | | |
| 11. $T_t = \frac{L}{3600\ V}$ Compute $T_t$ ........... hr | | + | = |

### Channel flow

| Segement ID | | | |
|---|---|---|---|
| 12. Cross sectional flow area, a ................................ $ft^2$ | | | |
| 13. Wetted perimeter, $P_w$ ............................................. ft | | | |
| 14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r ......................... ft | | | |
| 15 Channel slope, s .................................................... ft/ft | | | |
| 16. Manning's roughness coefficient, *n* ............................ | | | |
| 17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ................ft/s | | | |
| 18. Flow length, L ........................................................... ft | | | |
| 19. $T_t = \frac{L}{3600\ V}$ Compute $T_t$ .............. hr | | + | = |
| 20. Watershed or subarea $T_c$ or $T_t$ (add $T_t$ in steps 6, 11, and 19) ........................................................ Hr | | | |

# Worksheet 4: Graphical Peak Discharge method

| Project | By | Date |
|---|---|---|
| Location | Checked | Date |

Check one: ☐ Present ☐ Developed

1. Data

Drainage area ........................................ $A_m$ = ______________ $mi^2$ (acres/640)

Runoff curve number ................................CN = ______________ (From worksheet 2)

Time of concentration ................................ $T_c$ = ______________ hr (From worksheet 3)

Rainfall distribution ...................................... = _______________ (I, IA, II III)

Pond and swamp areas spread throughout watershed .................................. = ____________ percent of $A_m$ ( ________ acres or $mi^2$ covered)

| | | Storm #1 | Storm #2 | Storm #3 |
|---|---|---|---|---|
| 2. Frequency | yr | | | |
| 3. Rainfall, P (24-hour) | in | | | |
| 4. Initial abstraction, $I_a$ (Use CN with table 4-1) | in | | | |
| 5. Compute $I_a/P$ | | | | |
| 6. Unit peak discharge, $q_u$ (Use $T_c$ and $I_a/P$ with exhibit 4– _____ ) | csm/in | | | |
| 7. Runoff, Q (From worksheet 2) Figure 2-6 | in | | | |
| 8. Pond and swamp adjustment factor, $F_p$ (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond ans swamp area.) | | | | |
| 9. Peak discharge, $q_p$ | $ft^3s$ | | | |

( Where $q_p = q_u A_m Q F_p$ )

***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.

**On private drives where non-standard curb and gutter is to be used, the engineer must supply inlet capacity and gutter spread calculations to show 1) that gutter flow will not top the curb height, 2) the gutter flow spread requirements are met and 3) that inlet capacities are not exceeded.**

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 spread and develop tables showing the quantity of runoff allowable for the more commonly used street sections**. The width of flow shall not exceed 8-feet from the face of curb.**

**Curb inlets will be spaced so that these two limits will not be exceeded during a 2-year, 5 minute 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 and spread to find the area (**a**) and the hydraulic radius (**R**) in the equation for open channel flow we have the maximum flow as a constant (for the given cross slope) multiplied by the longitudinal slope taken to the ½ power.

***Example:***

*Given:* *Street width 30' F-F*

*$S_t$ (Transverse Slope) = .026 ft./ft.*

*$S_L$ (Longitudinal Slope) = 2% or .02 ft./ft.*

*Find:* *$Q_{max}$ (Maximum allowable flow)*

$$Q = A\frac{1.486}{n} R^{2/3} S^{1/2}$$

$$A = \left[\frac{(.239 + .156)}{2}(2)\right] + \left(\frac{.156}{2}\right)(6) = .863sf$$

$$P = 8.239\,ft$$

$$R = \frac{.863}{8.239} = 0.1047$$

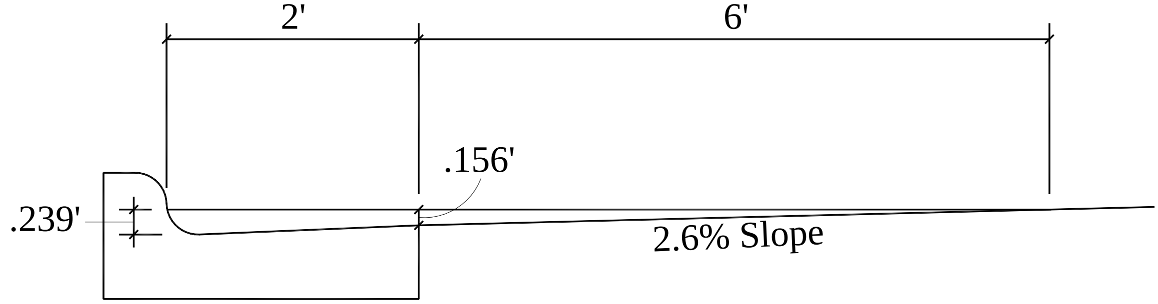
$$Q = .863 \times \frac{1.486}{.015} \times (0.1047)^{2/3} \times S^{1/2}$$

$$Q = 18.99 \times S^{1/2}$$

$$for\ S = .02 \quad Q = 12.80 \times (.02)^{1/2} = 2.69cfs$$

*Using 8 ft. for maximum spread and .239 for maximum depth*

Allowable Spread




Using this method, tables have been developed showing maximum flow rates for different combinations of cross slope and longitudinal slope for three common street widths. Using these tables the designer can quickly determine if the calculated flow is allowable at the designated location. These tables were calculated for City of Greensboro standard curb and gutter. For different street widths or non-standard curb, the engineer must supply gutter spread calculations.

## Gutter Capacity for City Standard Street Widths

(Maximum spread = 8')

| | *26' F-F* | *30' F-F* | *36' F-F* | *40' F-F* | *48' F-F* |
|---|---|---|---|---|---|
| *Maximum Depth* | .219 | .239 | .211 | .223 | .233 |

| ***Longitudinal Slope*** | | *26' F-F* | *30' F-F* | *36' F-F* | *40' F-F* | *48' F-F* |
|---|---|---|---|---|---|---|
| | | ***Cross Slope (Street)*** | | | | |
| | *ft/ft* | *.0227* | *.026* | *.0213* | *.0233* | *.025* |
| | *.006* | 1.20 | 1.47 | 1.10 | 1.25 | 1.39 |
| | *.008* | 1.39 | 1.70 | 1.26 | 1.44 | 1.60 |
| | *.01* | 1.55 | 1.90 | 1.41 | 1.61 | 1.79 |
| | *.0125* | 1.74 | 2.12 | 1.58 | 1.80 | 2.00 |
| | *.015* | 1.90 | 2.33 | 1.73 | 1.98 | 2.19 |
| | *.0175* | 2.06 | 2.51 | 1.87 | 2.14 | 2.37 |
| | *.02* | 2.20 | 2.69 | 2.00 | 2.28 | 2.53 |
| | *.025* | 2.46 | 3.00 | 2.24 | 2.55 | 2.83 |
| | *.03* | 2.69 | 3.29 | 2.45 | 2.80 | 3.10 |
| | *.035* | 2.91 | 3.55 | 2.65 | 3.02 | 3.35 |
| | *.04* | 3.11 | 3.80 | 2.83 | 3.23 | 3.58 |
| | *.045* | 3.30 | 4.03 | 3.00 | 3.42 | 3.80 |
| | *.05* | 3.47 | 4.25 | 3.16 | 3.61 | 4.01 |
| | *.055* | 3.64 | 4.45 | 3.32 | 3.79 | 4.20 |
| | *.06* | 3.81 | 4.65 | 3.46 | 3.95 | 4.39 |

*Maximum flow with 8' spread in cfs*

## ***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 2-year, 5-minute 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 sump situation will be as follows:

**1) Continuous Slope:**

- COG Standard No. 402
  "Standard Brick Masonry Curb Inlet": 4.0 cfs
- COG Standard No. 403
  "Standard Brick Masonry Curb Inlet": 6.0 cfs

**2) Sump Condition:**

- COG Standard No. 402
  "Standard Brick Masonry Curb Inlet": 6.0 cfs
- COG Standard No. 403
  "Standard Brick Masonry Curb Inlet": 9.0 cfs

These are absolute maximum capacities. A flow greater than these values will require the inlet spacing to be adjusted.

**When the engineer elects to use curb inlets in private streets and private storm sewer systems that differ from City of Greensboro standards, calculations will be required to be submitted to show that inlets will function properly. The engineer must specify and label on the drawings the inlets that are to be used.**

**NCDOT Standard No. 840.03 "Grate, Frame, and Hood"**

The capacity of the inlet with grate, frame & hood at a low point in grade will be determined from the capacity graph included in this section and found on page 52. Enter the graph with the maximum depth at the face of curb allowed by the pavement cross slope and the spread of water on the pavement, read the maximum capacity for the inlet under consideration. If the maximum capacity is less than the calculated flow, additional inlets will be required to prevent flooding. The designer should keep in mind that City of Greensboro standard curb inlets are required in sumps and these grate inlets will be allowed only with prior approval from the City of Greensboro Stormwater Management Division.

## GENERAL RULES FOR LOCATING CURB INLETS

1) All curb inlets on City of Greensboro maintained storm sewer lines must be City of Greensboro 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 Greensboro Stormwater Management Division.

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 on “Determination of Gutter Capacity” starting on page 44 and shown in the table on page 46.

3) 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 flow across the intersection.

4) No public street runoff is allowed to enter private property. A rise of 6” may be provided as part of a standard driveway apron or a curb inlet must be installed upstream of the driveway turnout.

5) 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 of Greensboro Stormwater Management Division.

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

7) 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. The City of Greensboro Stormwater Management Division must approve this conversion. Refer to City of Greensboro Standard Drawings 420A, B & C as shown in the Roadway and Utility Standard Drawings Manual.

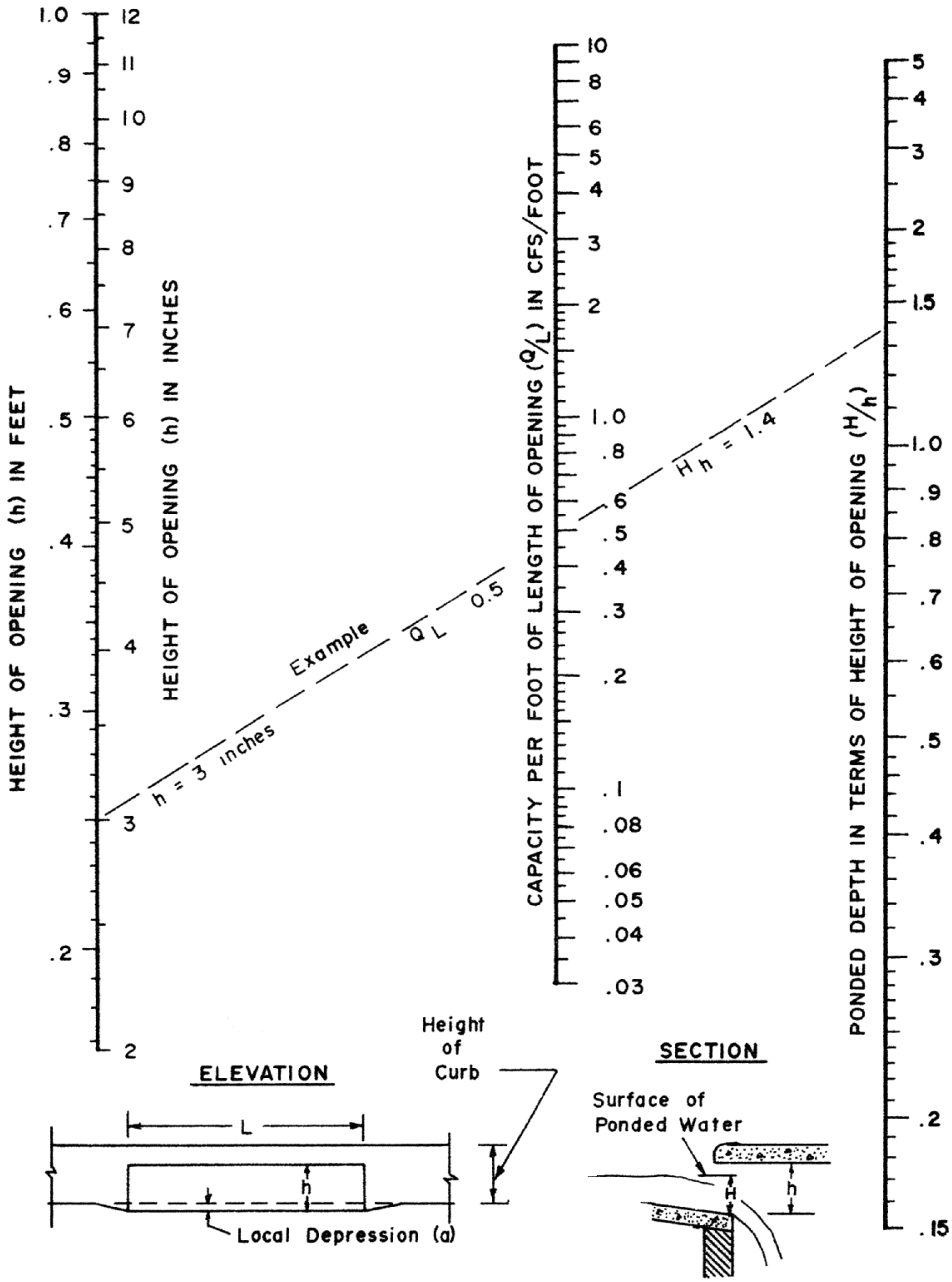
8) Curb inlets in locations other than sumps may be converted to grate inlets by permission from the City of Greensboro Stormwater Management Division as long as the grate inlet is installed in the gutter flow line and not over the existing curb inlet box. Since standard curb inlets are constructed behind the curb, 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. Refer to City of Greensboro Standard Drawings 420A, B & C.

9) Spill gutter is not allowed because of the sheeting and freezing problems that can occur. Therefore, COG Standard No. 405 (20” x 26”) grate inlets will be required at low ends of islands to pick up gutter flow to that point.

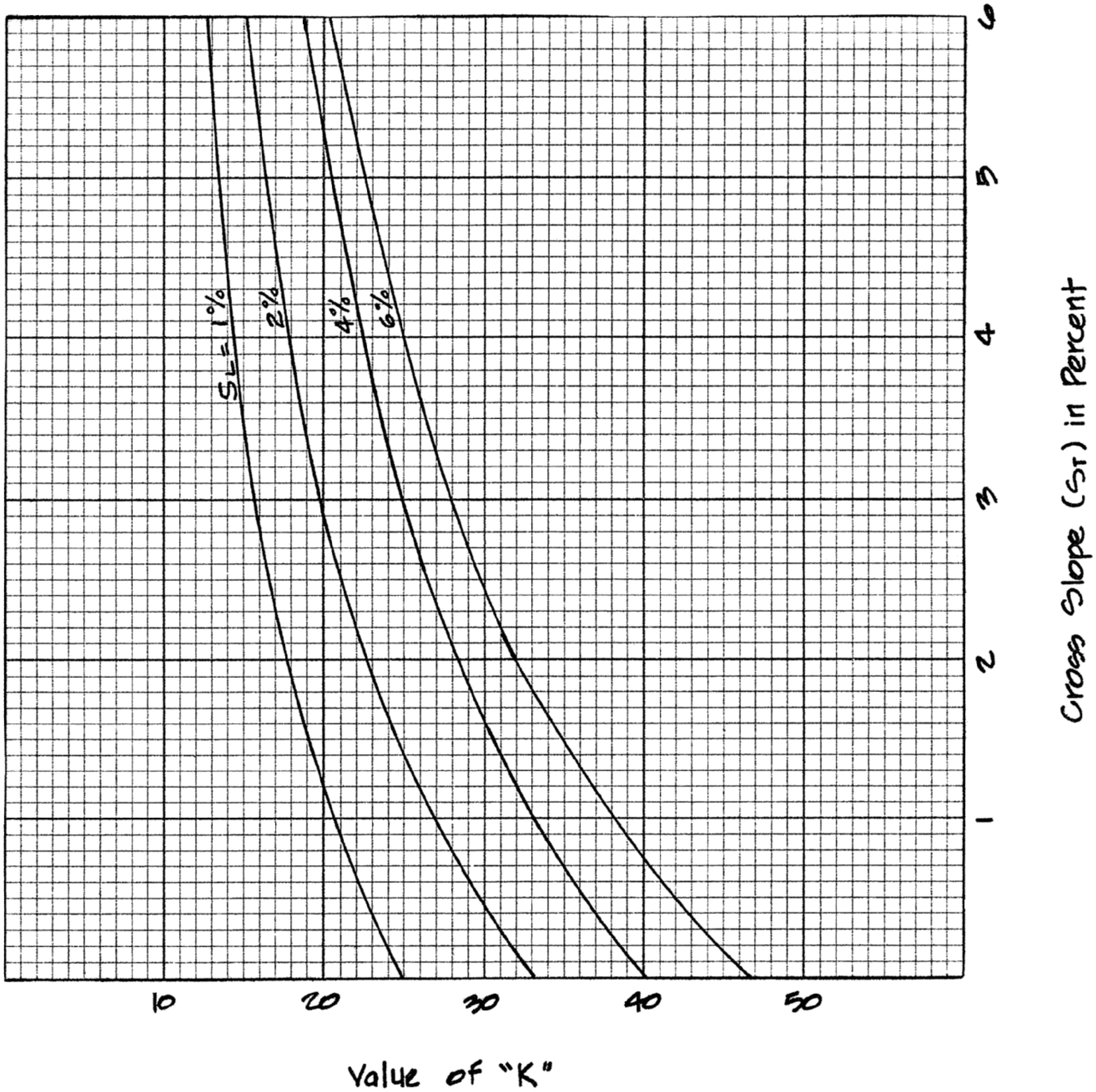
10) All curb inlets located on Cul–De–Sacs will be COG Standard No. 403 “Standard Brick Masonry Curb Inlet”.

11) Anywhere a curb inlet must be converted to a junction box it must be completely removed and rebuilt as a COG Standard Manhole. Exceptions for extra deep structures can be made by special approval by the Stormwater Management Division.

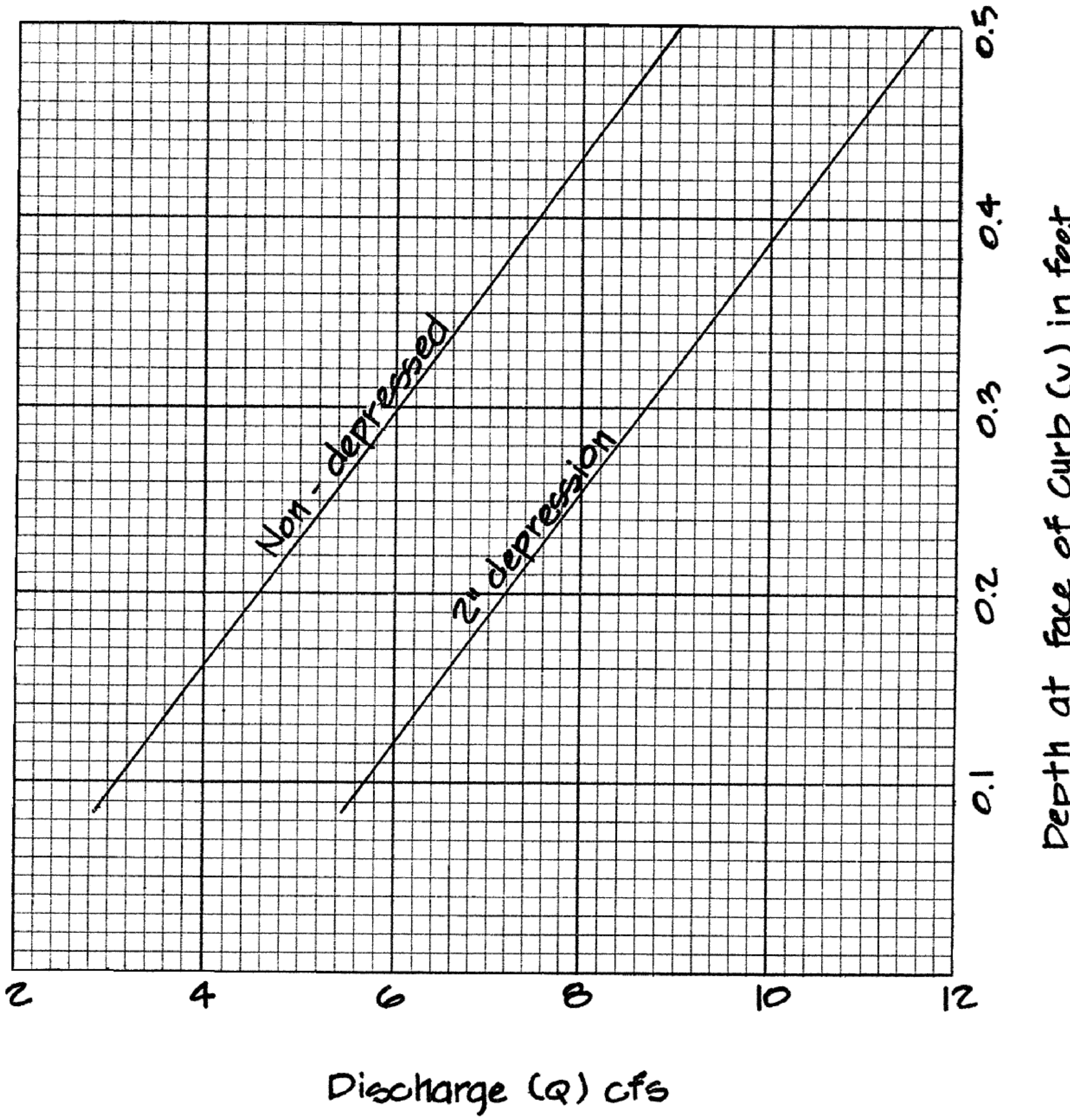
**CAPACITY OF CURB OPENING INLETS AT A SUMP**



**_K_ VALUES FOR GRATE WITH HOOD**
**NON-DEPRESSED**



**CAPACITY OF GRATE WITH HOOD**
**AT THE LOW POINT IN 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 50**. 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, with a maximum height opening of 8-inches. However, safety is a major concern, especially in residential areas. Large openings can become a hazard to children and pets. In those cases more that one inlet is advised. In residential areas or other areas where ponding depth above the top of the yard inlet may be hazardous to the public, the capacity of the yard inlet will be limited to the capacity shown in the table below.

| Yard Inlet Specifications | | | | |
|---|---|---|---|---|
| ***Standard Number*** | ***Outside Dimensions*** | ***Width of Opening*** | ***Height of Throat*** | ***Capacity with No Ponding*** |
| *424 / 425* | *4' X 4'* | *2' 8"* | *5"* | *7.5 cfs* |
| *438 / 439* | *6' X 6'* | *4' 8"* | *5"* | *13.0 cfs* |
| *441 / 442* | *5' X 5'* | *3' 8"* | *5"* | *10.3 cfs* |

## COG STANDARD NO. 408 "STEEL FLUME"

For safety reasons sheet flow from parking lots is not allowed to flow out drive entrances into the street. In the winter months, this water could freeze and create a traffic hazard. In these situations and where storm sewer is not available, the area should be graded so that water will flow to one or more specific points and a COG Standard No. 408 “Standard 5”x12” Steel Flume” installed to carry that runoff through the sidewalk and curb and into the gutter. Any concentrated flows that enter the street right-of-way must use COG Standard 408. Flumes greater than 12” in width and ‘open-top’ flumes are not allowed.

The formula to determine the capacity of a flume is:

$$\mathbf{Q = C_w\, L\, H^{3/2}}$$

**$C_w$** = weir coefficient = 3.0
**L** = width of weir
**H** = height of weir

**Q** = $( 3.0 )( 1' )( .42' )^{3/2}$
**Q** = 0.8 cfs = capacity of a COG Standard No. 408 “Steel Flume”

**<u>If runoff exceeds 0.8 cfs multiple flumes must be installed.</u>**

## GRATES

The capacity of rectangular grates is determined from an equation relating the flow (**Q**) to head and opening area. The chart below gives the capabilities of the four grate sizes that have been assigned City of Greensboro Standard numbers operating under different amounts of head.

| GRATE CAPACITIES | | | | | | |
|---|---|---|---|---|---|---|
| | *Q* | *Q* | *Q* | *Q* | *Q* | *Q* |
| | *OPENING* | *12"* | *9"* | *6"* | *3"* | *1"* |
| *GRATE* | *AREA* | *HEAD* | *HEAD* | *HEAD* | *HEAD* | *HEAD* |
| #*405* | 1.50 | 4.8 | 4.2 | 3.4 | 2.4 | 1.4 |
| #*406* | 1.90 | 6.1 | 5.3 | 4.3 | 3.1 | 1.75 |
| #*407* | 1.95 | 6.3 | 5.4 | 4.4 | 3.1 | 1.8 |
| #*434* | 2.81 | 9.0 | 7.85 | 6.4 | 4.5 | 2.6 |

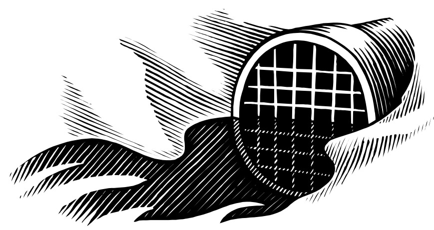
$$Q = CA\sqrt{2gh} \times {}^{2}\!/_{3} \qquad (\text{factor for clogging})$$
$$= 0.6A\sqrt{64.4h} \times {}^{2}\!/_{3}$$

Where
- **Q** = Capacity in cfs
- **C** = Orifice coefficient 0.6 for openings with square edges (0.8 for openings with rounded edges)
- **A** = Net area of opening in square feet
- **g** = 32.2 ft./sec.
- ***h*** = Allowable head on inlet in feet

## *DETERMINATION OF PIPE AND CULVERT 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 storm sewer system.
2) The second method is for pipes in a culvert situation. Whenever there is a possibility of water ponding at the mouth of a pipe or if it might have a submerged outlet, the pipe should be checked for both inlet and outlet control. See the section on Culvert Design on page 57.



### *Sizing pipes within a storm sewer system*

The capacity of a pipe, which is a link in a drainage system, can be calculated using Manning's Formula. Nomographs or hydraulic calculators may be used to determine the required pipe size by using the calculated discharge, a roughness coefficient 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. No downsizing of downstream piping is allowed due to blockage concerns. As a final check, EGL analysis is performed from the downstream hydraulic control to verify the proposed storm sewer system will operate under non-pressurized flow conditions – refer to page 97 for additional guidance.

The following table gives values for **n** depending on the materials to be used:

| **Values of (n)** | |
|---|---|
| ***Type of pipe*** | |
| *Reinforced Concrete Pipe (RCP)* | 0.013 |
| *High Density Polyethylene (HDPE)* | 0.012 |

See policies on acceptable pipe materials in the appendices.

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 on pages 63-67.

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

When a pipe or other type of conduit carries stream flow under a road or railroad structure, that pipe or conduit 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. It will be the designer's responsibility to verify that the backwater effect of the new culvert does not negatively affect the upstream culvert.

A culvert design form is included on page 103 and nomographs are included on pages 67 - 86 which can be used to determine culvert capacity. Select the appropriate chart according to type of structure for each condition of inlet control or outlet control. Culvert runoff for major stream crossings (with drainage areas larger than 200 acres) should be determined using either the 'Basin-Lag Time Method' or the 'TR-55 Method', both of which are presented in this manual.

### *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, H, is the depth of water above the invert of 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 or existing culvert upstream from the proposed installation. In any case the maximum headwater to depth ratio (H/d) of 1.2 should not be exceeded.

### *Outlet Control*

For outlet control to exist the culvert must be flowing full and/or the outlet submerged. Nomographs on pages 74 - 86 may be used to determine headwater depths for culverts under outlet control.

### *Headwater Limitations*

The allowable headwater shall be limited to the most restrictive of the following upstream controls:

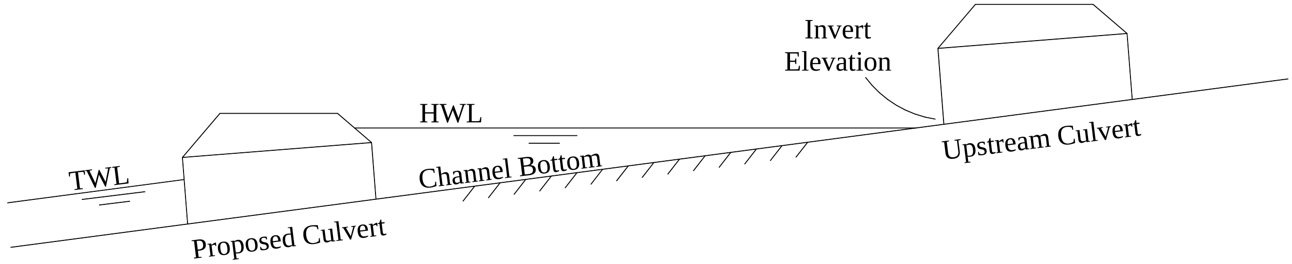
1) 12 inch freeboard for culverts up to 3 feet in diameter
2) 18 inch freeboard for culverts larger than 3 feet in diameter
3) Upstream property damage
4) Freeboard requirements apply to the low point in the road grade that is not at the culvert location.
5) $HW/D \leq 1.2$
6) The headwater should be checked for the 100-year flood to ensure compliance with the locally adopted flood protection ordinance.
7) The maximum acceptable outlet velocity should be identified. Either the headwater should be set to produce acceptable velocities, or stabilization or energy dissipation should be provided.
8) In general, the constraint which gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.
9) If there is insufficient headwater elevation to convey the required discharge, it will be necessary to either use a larger culvert, lower the inlet invert, use an irregular cross-section, use an improved inlet if in inlet control, multiple barrels, or use a combination of these measures. If the inlet invert is lowered, special consideration must be given to scour.

### *Backwater Effect of New / Modified Culverts*

When designing a new or modifying an existing culvert installation, the designer should verify that the Headwater Level, HWL, of the proposed culvert does not raise the normal depth tailwater level of any culvert immediately upstream (within a mile) for the design storm (i.e. 50-year, 25-year storm).

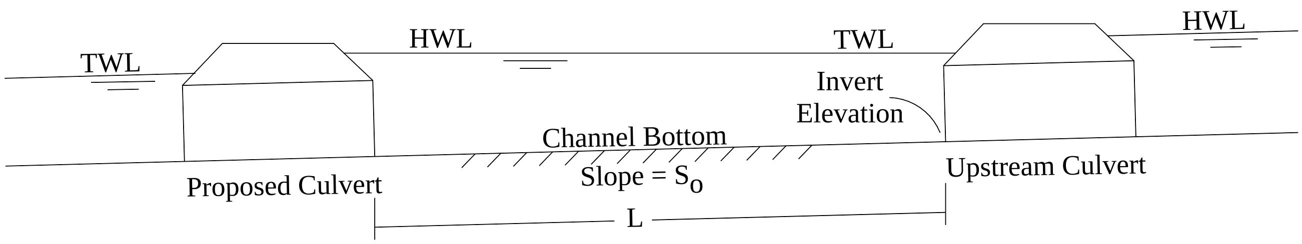
The proposed culvert should be analyzed to determine which of the following cases apply:

Case 1: Proposed Headwater Level, HWL, is below the invert elevation of the upstream culvert – No evaluation is required.

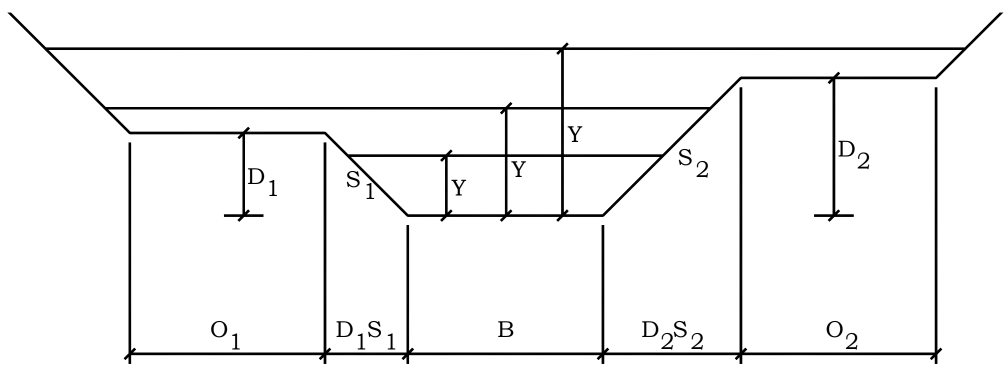


Case 2: Proposed Headwater Level, HWL, is higher than the invert elevation of the upstream culvert.

- Obtain a typical cross-section at the upstream culvert outlet and determine the normal depth using the Manning Equation.
- Compute the backwater profile to verify that the tailwater level at the upstream culvert is not raised by more than 1% of the tailwater depth. If the tailwater level is impacted by more than 1% of the tailwater depth, refer to page 59, item #9.

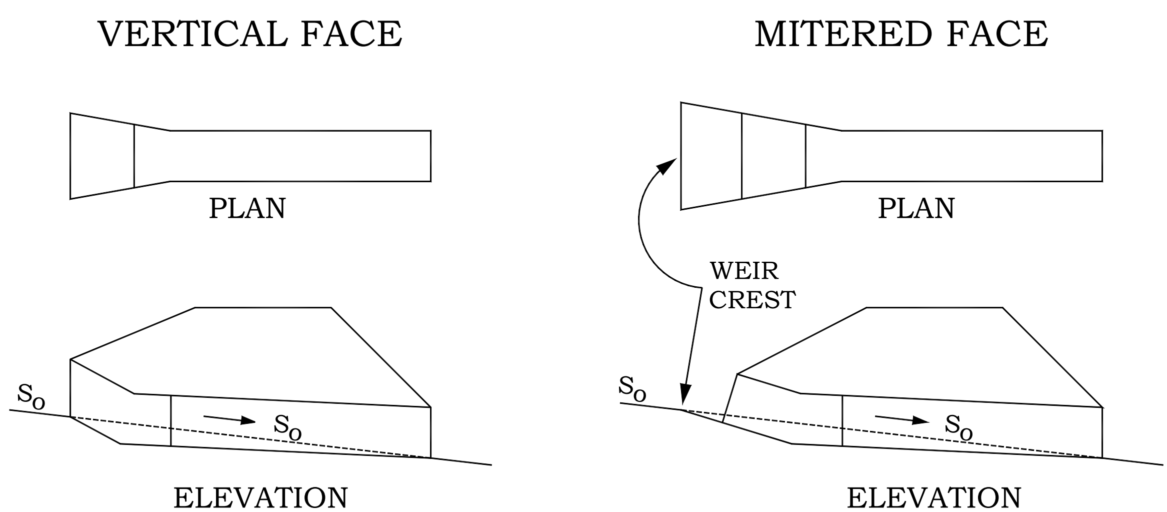



The Stormwater Management Division has provided, on their website, a sample backwater calculation spreadsheet that can be submitted as an acceptable computational procedure. The diagram below provides the variables that will be needed to complete the calculations.



***Design of Improved Inlets***

In inlet control, only entrance configuration and headwater depth determine the culvert's hydraulic capacity. Barrel characteristics and tailwater depth are of no consequence. These culverts usually lie on relatively steep slopes and flow only partly full. Entrance improvements can result in full or nearly full flow, thereby increasing culvert capacity significantly. Improved or tapered inlets for box culverts under inlet control are allowed within the City of Greensboro infrastructure. Complete calculations according to the FHWA HDS-5, 2005 pages 79-122 must be submitted along with the design for review.




***Culvert Endwalls***

Endwalls or flared end sections are required on the upstream and downstream ends of roadway culverts. See the policy "Acceptable Culverts for Enclosing Large Storm Drainage Channels at Road Crossings", in Section V on page 114.

***Plan Review***

**Any plans submitted to the Engineering Division for construction plan review should include 1) culvert runoff calculations, 2) a culvert design form as shown on page 103, 3) inlet and outlet control nomographs as shown on pages 67-86 4) a topographical map delineating the drainage area for the culvert and 5) information on the backwater effect on upstream culverts, if any exist within one mile upstream.**

### *Culvert Nomographs*

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

1) The entrance loss coefficient $\mathbf{K_e}$ values may be found on the chart in this manual.

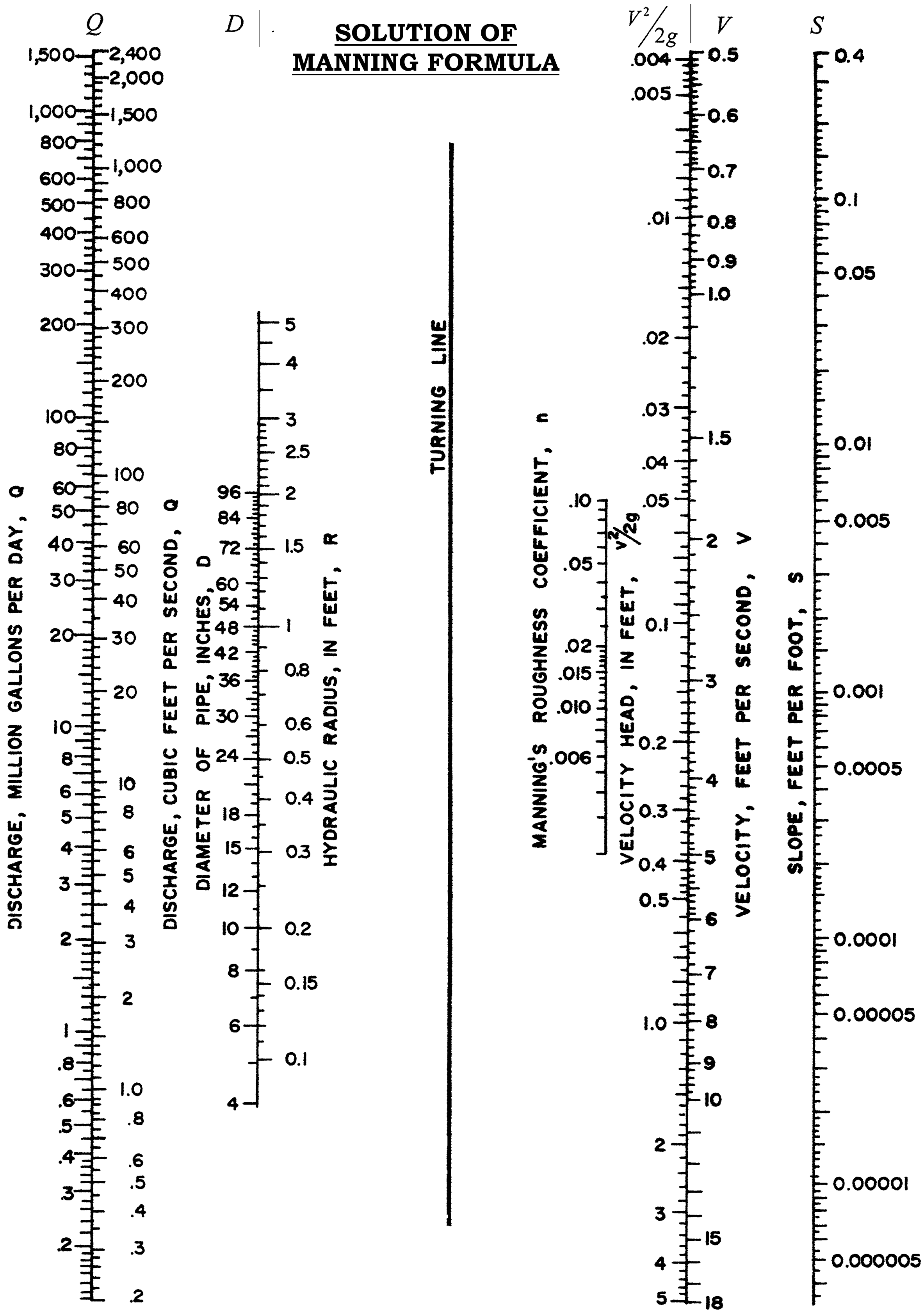
2) The tailwater conditions or the tailwater depth may be determined by downstream conditions or from known flood information. If the tailwater depth cannot be determined it may be assumed that the tailwater elevation is the crown of the pipe. The designer is warned that this may be an oversimplification 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.

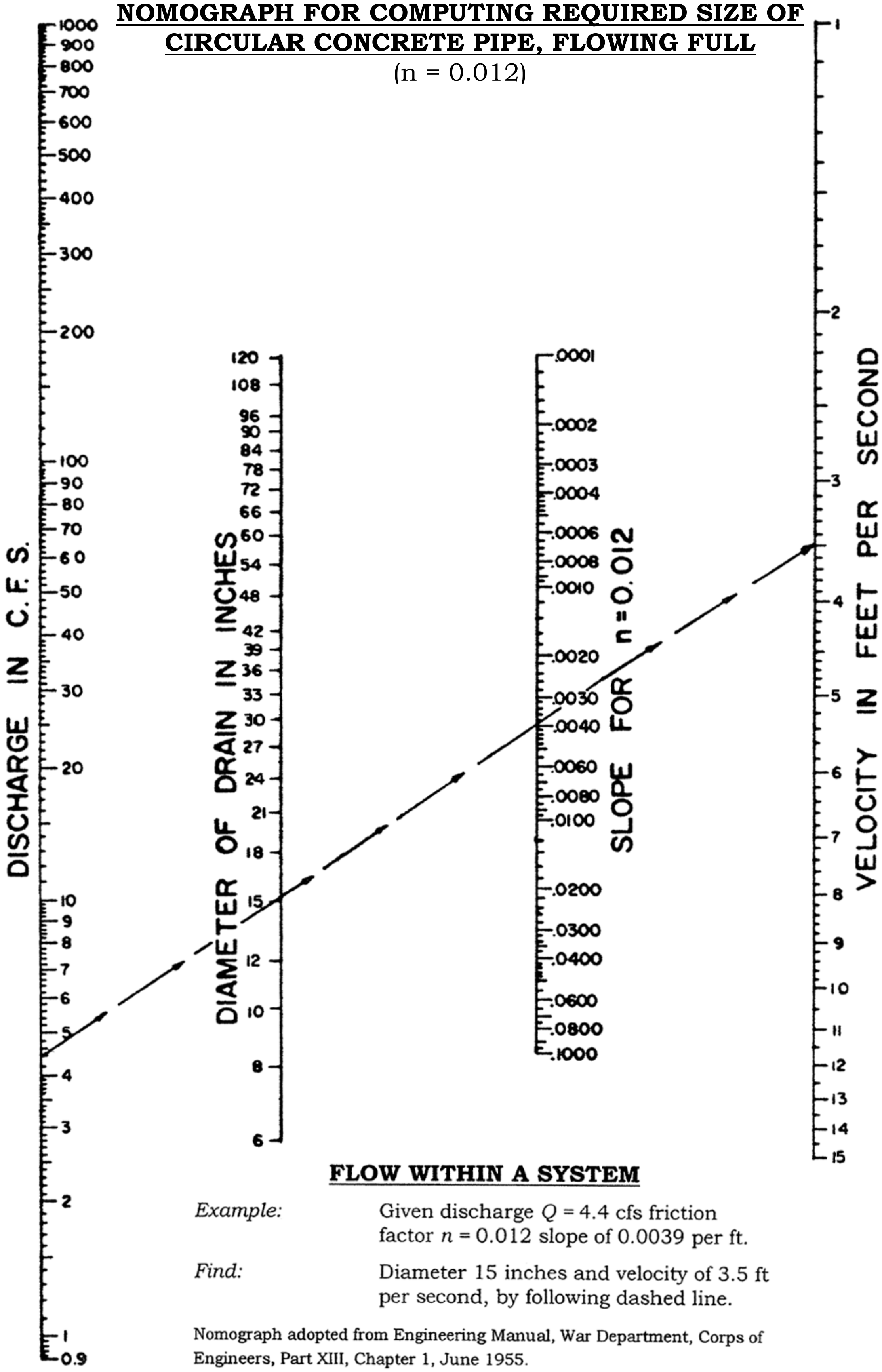
## COEFFICIENT OF ENTRANCE LOSS $K_e$

| Type of Structure and Design of | Entrance Coefficient $K_e$ |
|---|---|
| Pipe, Concrete | |
| Projecting from fill | 0.5 |
| Headwall or headwall and wingwalls | 0.5 |
| Mitered to conform to fill slopes | 0.7 |
| Pipe or pipearch, corrugated aluminum | |
| Projecting (no headwall) | 0.9 |
| Headwall or headwall and wingwalls | 0.5 |
| Mitered to conform to fill slopes | 0.7 |
| Reinforced concrete box culvert | |
| Headwall | 0.5 |
| Wingwall at 30 degrees to 75 degrees to barrel | 0.4 |
| Wingwalls at 10 degrees to 25 degrees to barrel | 0.5 |


SOLUTION OF MANNING FORMULA
TURNING LINE
DISCHARGE, MILLION GALLONS PER DAY, Q
DISCHARGE, CUBIC FEET PER SECOND, Q
DIAMETER OF PIPE, INCHES, D
HYDRAULIC RADIUS, IN FEET, R
MANNING'S ROUGHNESS COEFFICIENT, n
VELOCITY HEAD, IN FEET, $V^2/2g$
VELOCITY, FEET PER SECOND, V
SLOPE, FEET PER FOOT, S

## NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR CONCRETE PIPE, FLOWING FULL

(n = 0.012)




### FLOW WITHIN A SYSTEM

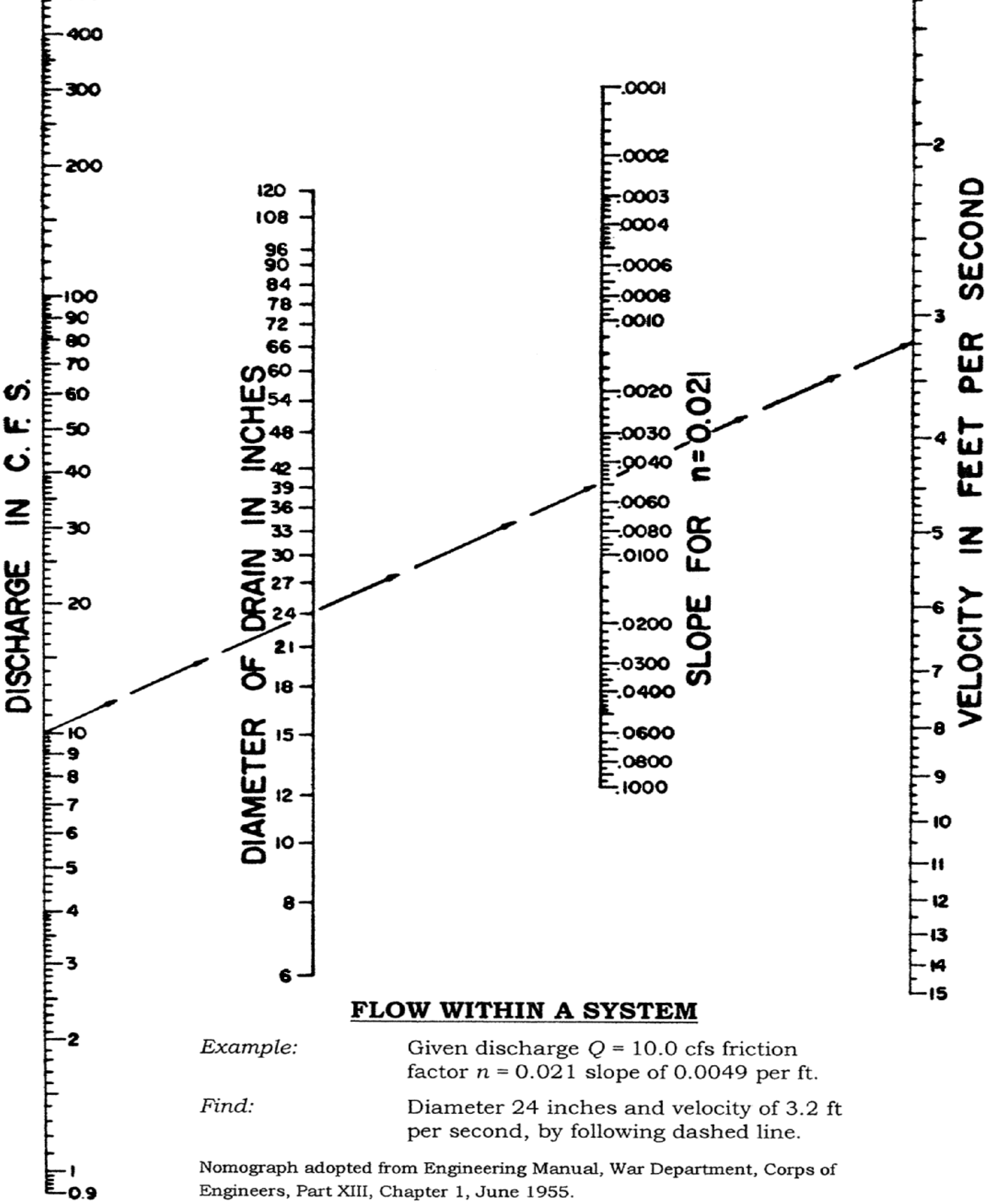
*Example:* Given discharge $Q$ = 4.4 cfs friction factor $n$ = 0.012 slope of 0.0039 per ft.

*Find:* Diameter 15 inches and velocity of 3.5 ft per second, by following dashed line.

Nomograph adopted from Engineering Manual, War Department, Corps of Engineers, Part XIII, Chapter 1, June 1955.

## NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR CORRUGATED METAL PIPE, FLOWING FULL

(n = 0.021)



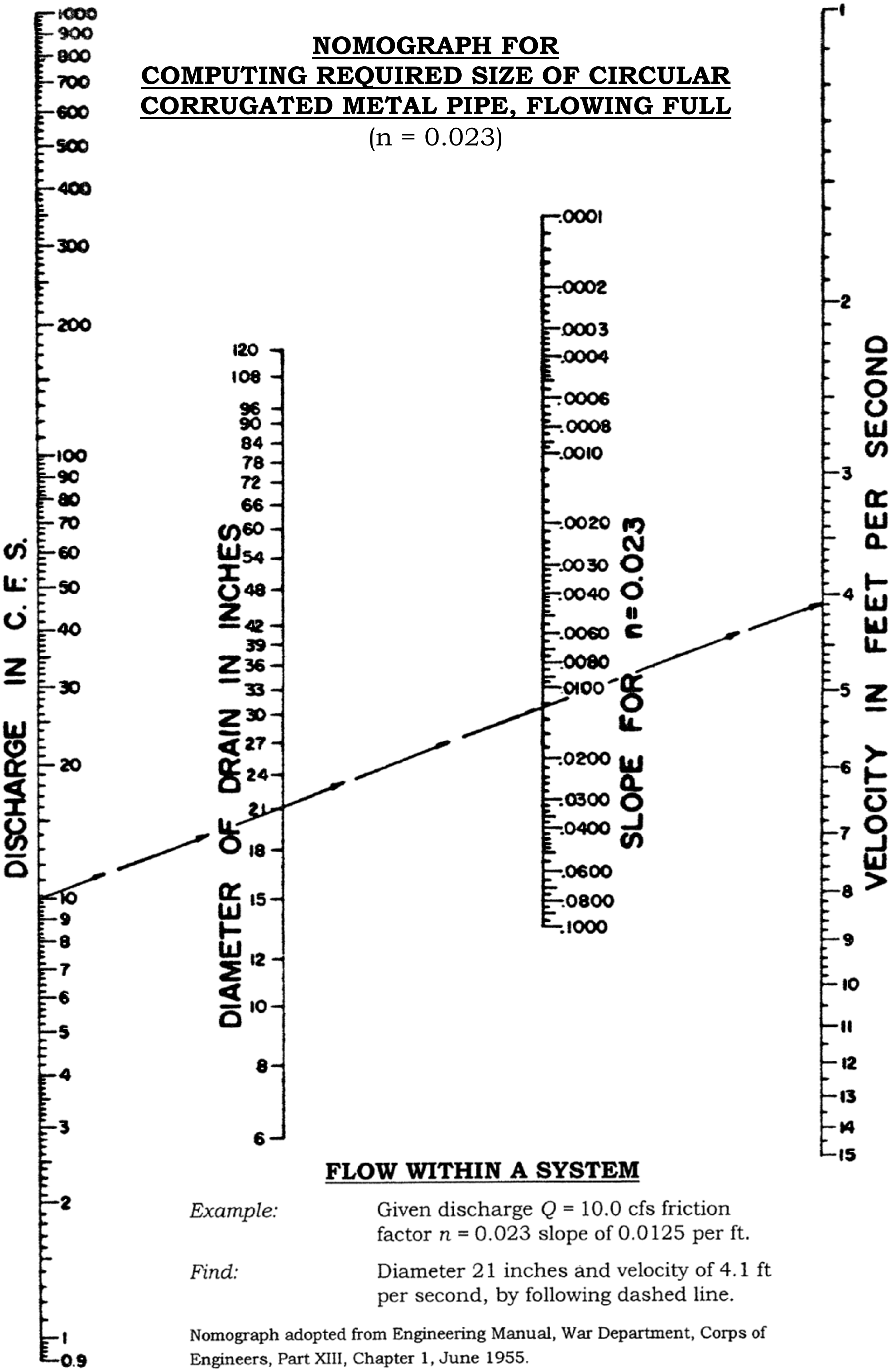

### FLOW WITHIN A SYSTEM

| | |
|---|---|
| *Example:* | Given discharge $Q$ = 10.0 cfs friction factor $n$ = 0.021 slope of 0.0049 per ft. |
| *Find:* | Diameter 24 inches and velocity of 3.2 ft per second, by following dashed line. |

Nomograph adopted from Engineering Manual, War Department, Corps of Engineers, Part XIII, Chapter 1, June 1955.

## NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR CORRUGATED METAL PIPE, FLOWING FULL

(n = 0.023)




### FLOW WITHIN A SYSTEM

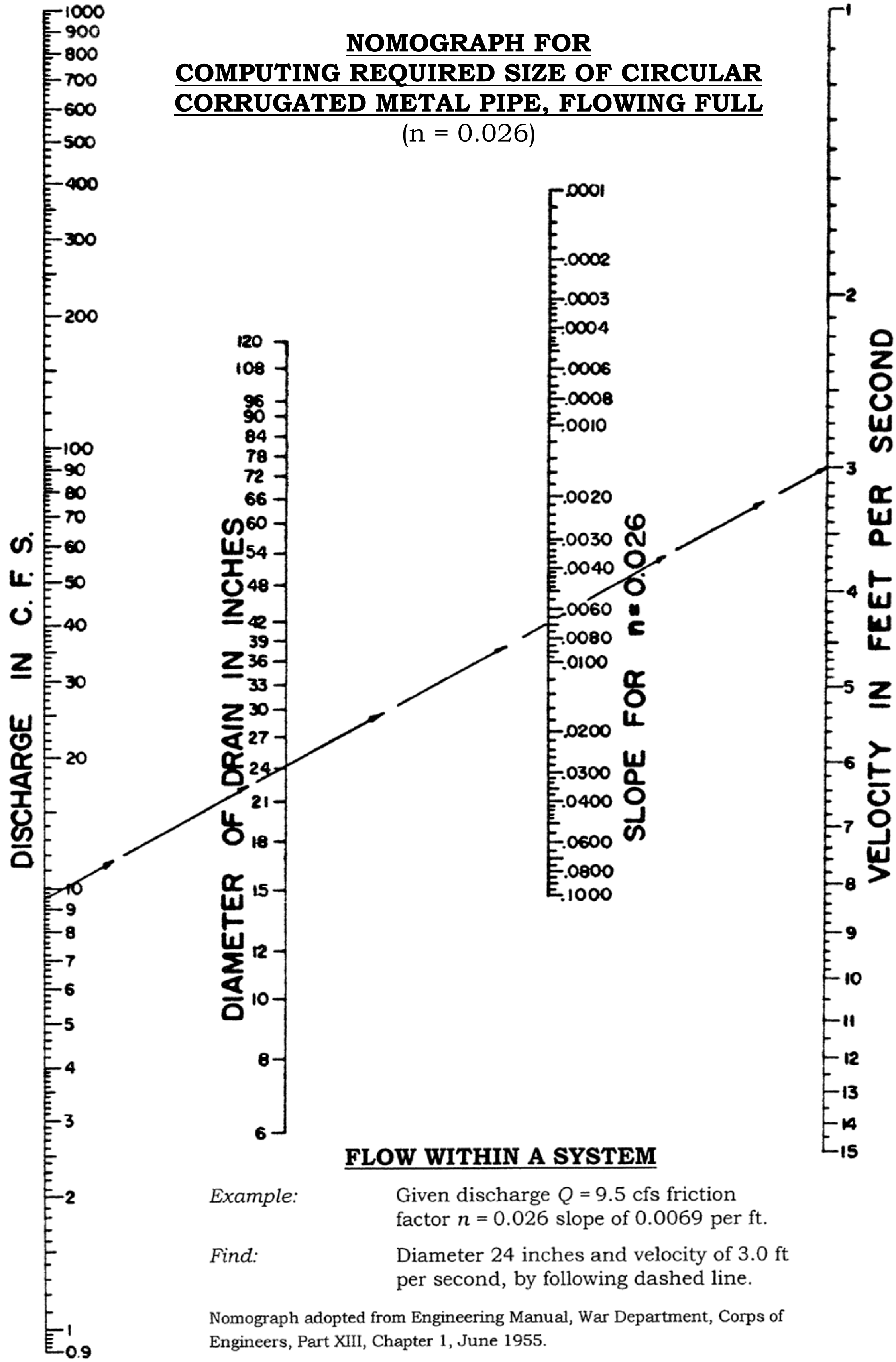
*Example:* Given discharge $Q$ = 10.0 cfs friction factor $n$ = 0.023 slope of 0.0125 per ft.

*Find:* Diameter 21 inches and velocity of 4.1 ft per second, by following dashed line.

Nomograph adopted from Engineering Manual, War Department, Corps of Engineers, Part XIII, Chapter 1, June 1955.

## NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR CORRUGATED METAL PIPE, FLOWING FULL

(n = 0.026)



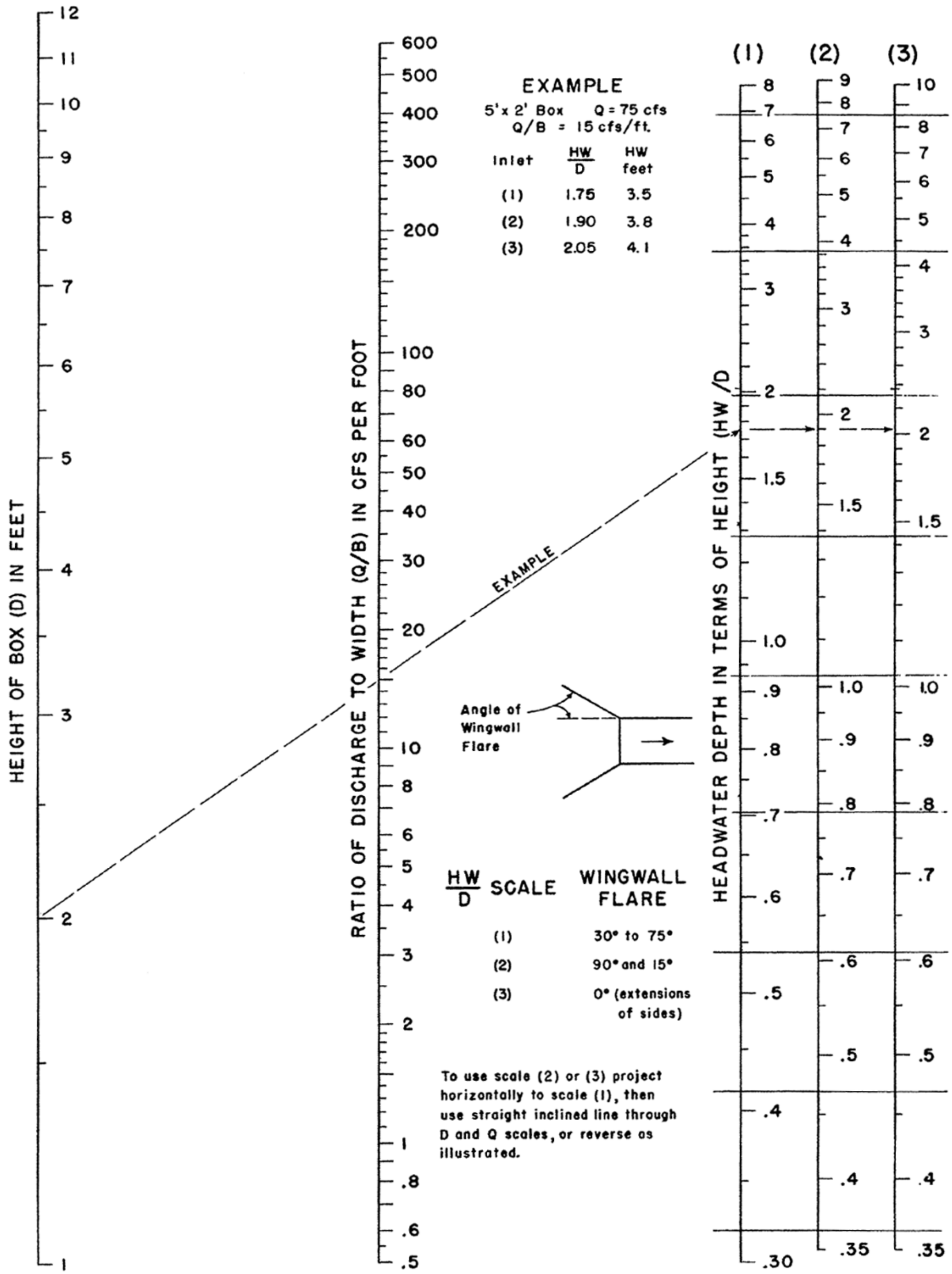

### FLOW WITHIN A SYSTEM

*Example:* Given discharge $Q$ = 9.5 cfs friction factor $n$ = 0.026 slope of 0.0069 per ft.

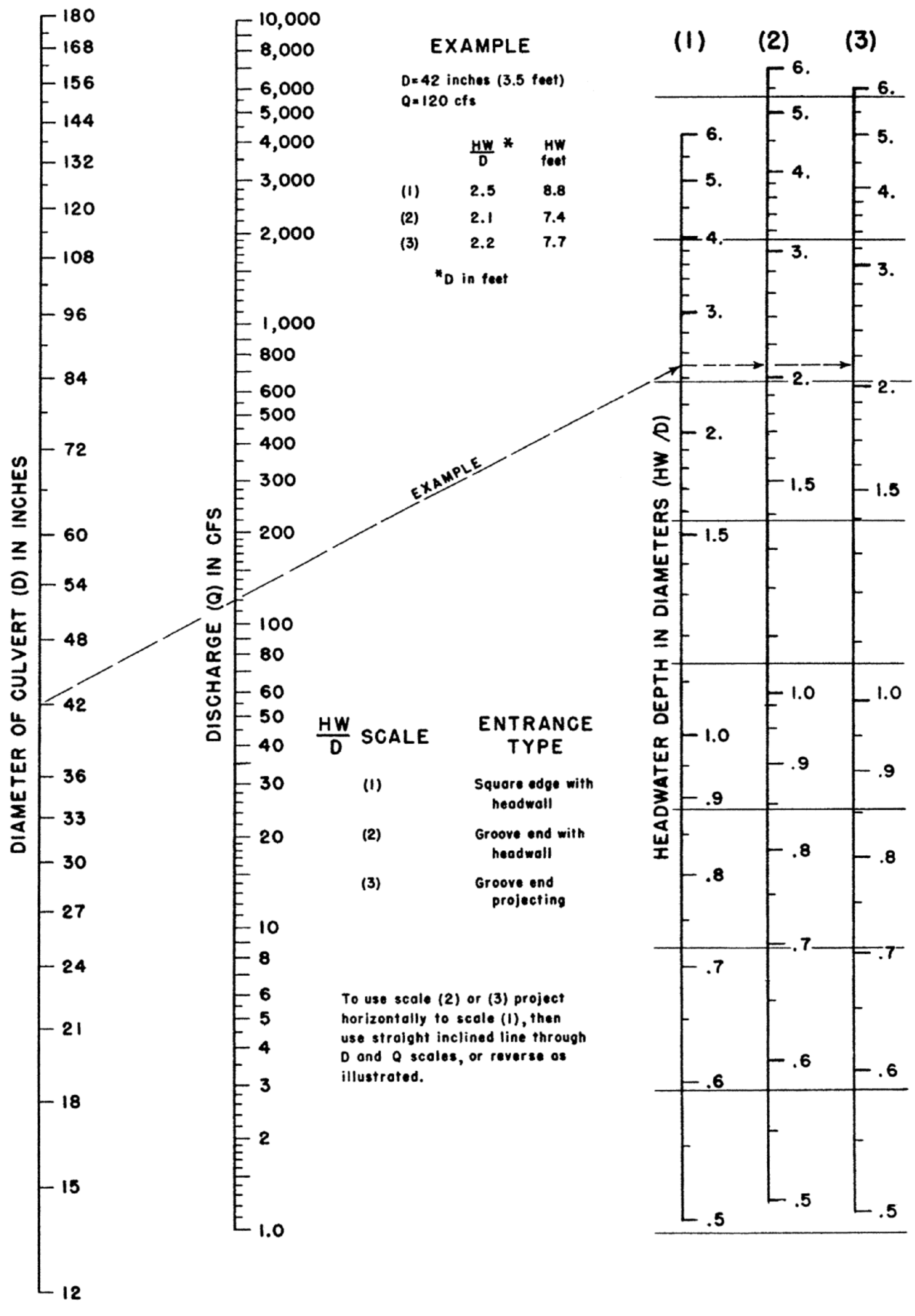
*Find:* Diameter 24 inches and velocity of 3.0 ft per second, by following dashed line.

Nomograph adopted from Engineering Manual, War Department, Corps of Engineers, Part XIII, Chapter 1, June 1955.

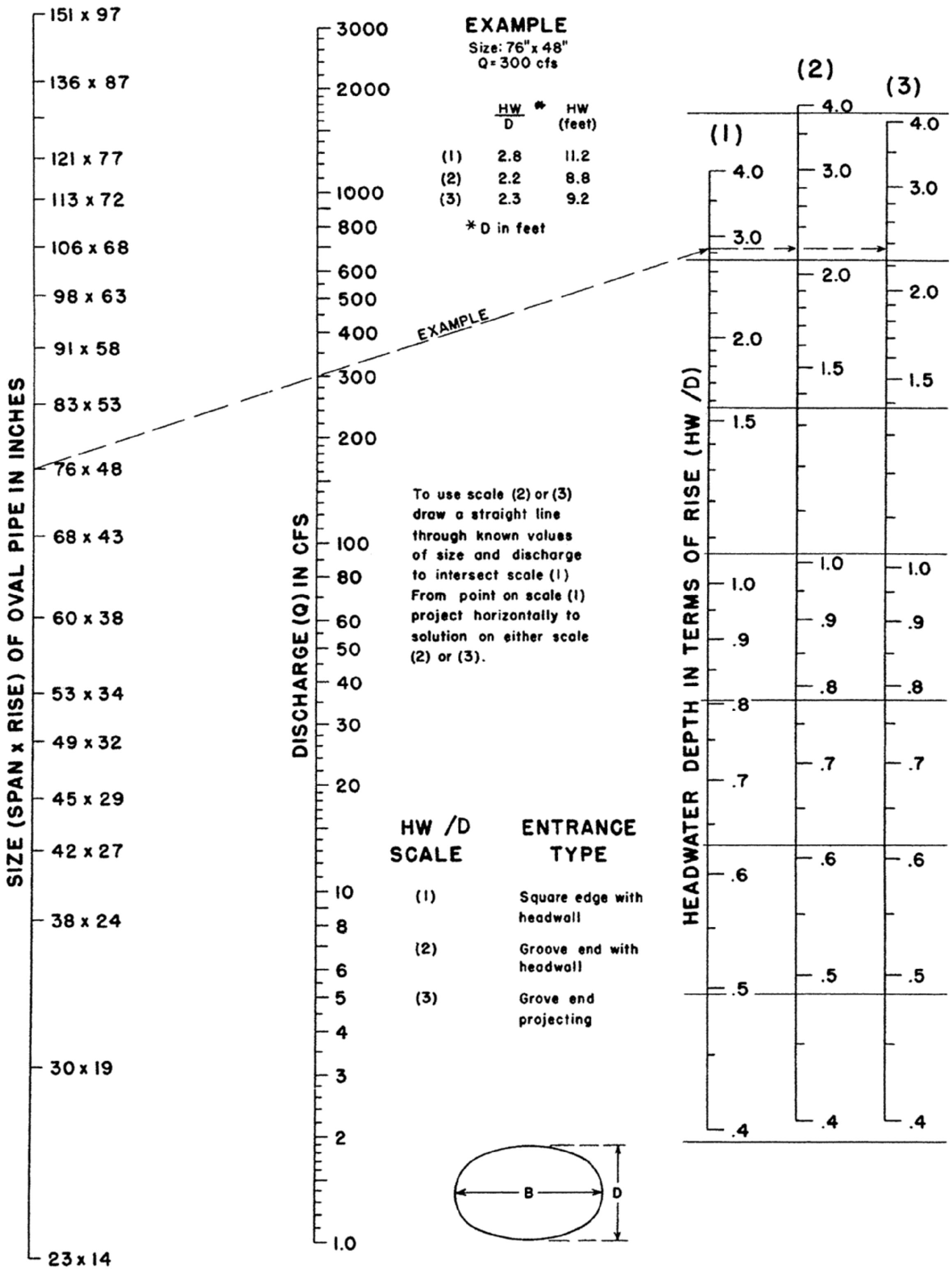
## CULVERT DESIGN-INLET CONTROL HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL



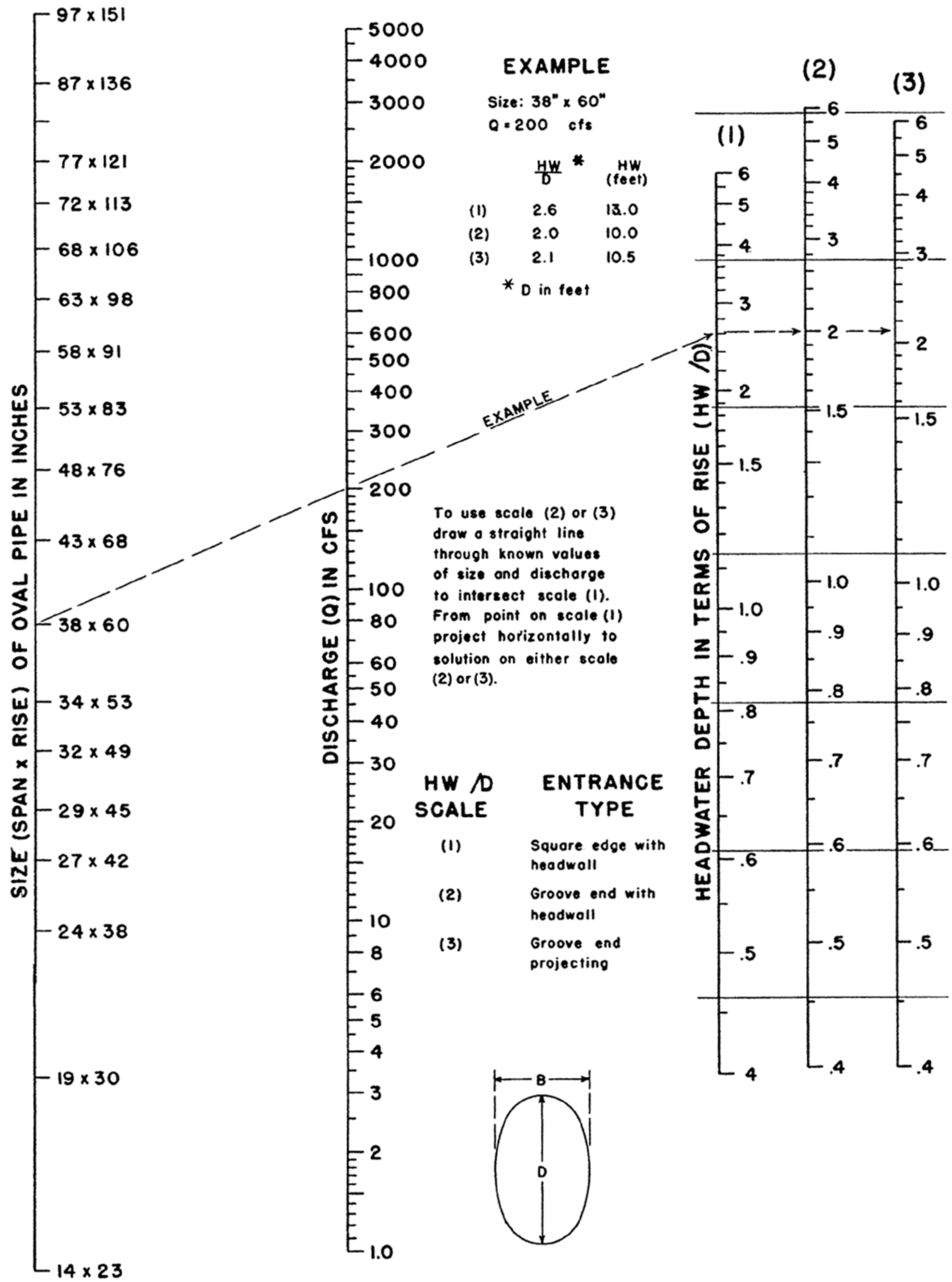
## CULVERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS
## WITH INLET CONTROL



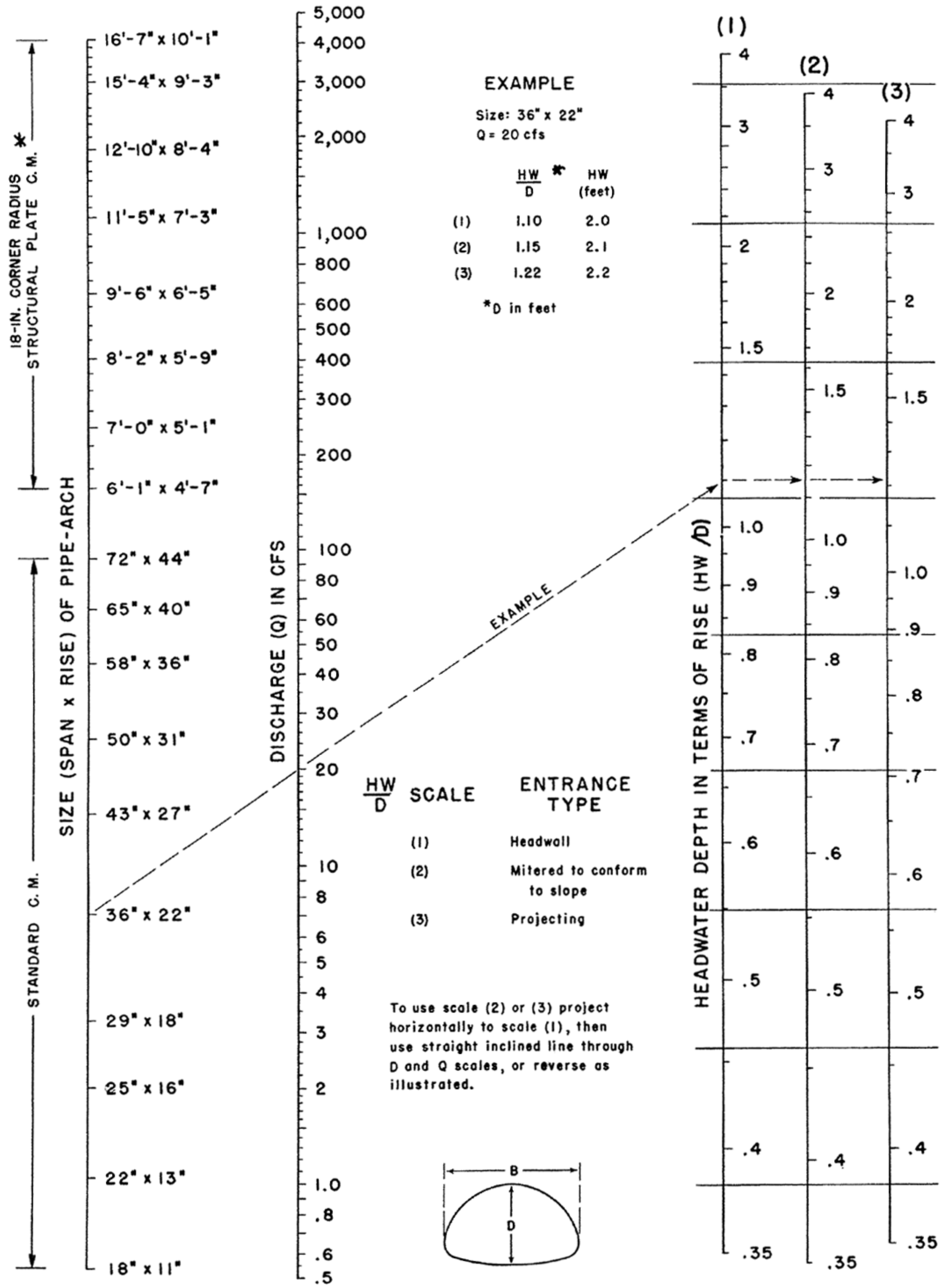
## CULVERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS
## LONG AXIS HORIZONTAL WITH INLET CONTROL



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



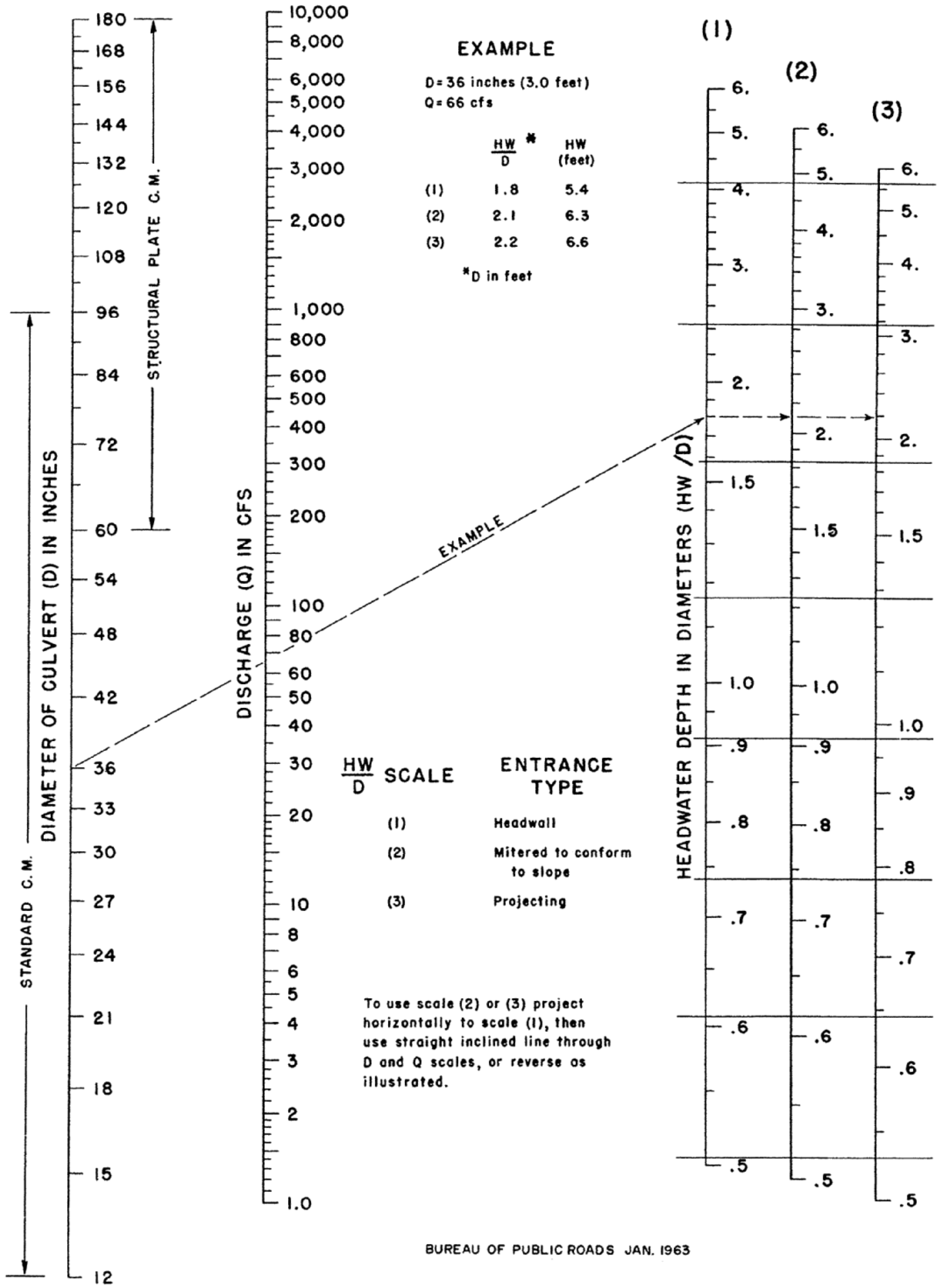
## CULVERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR CORRUGATED METAL PIPE CULVERTS
## WITH INLET CONTROL



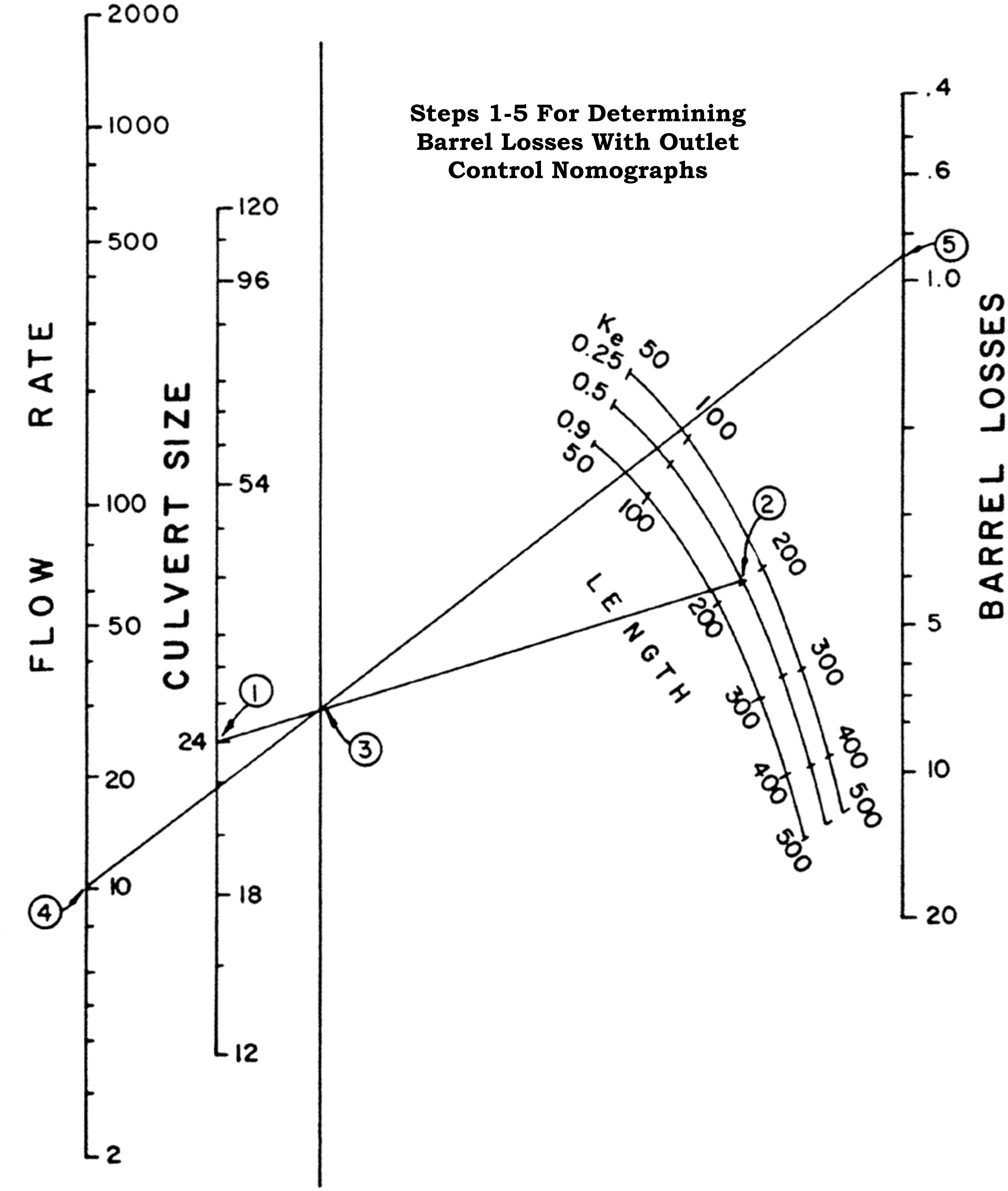

*ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

BUREAU OF PUBLIC ROADS JAN. 1963

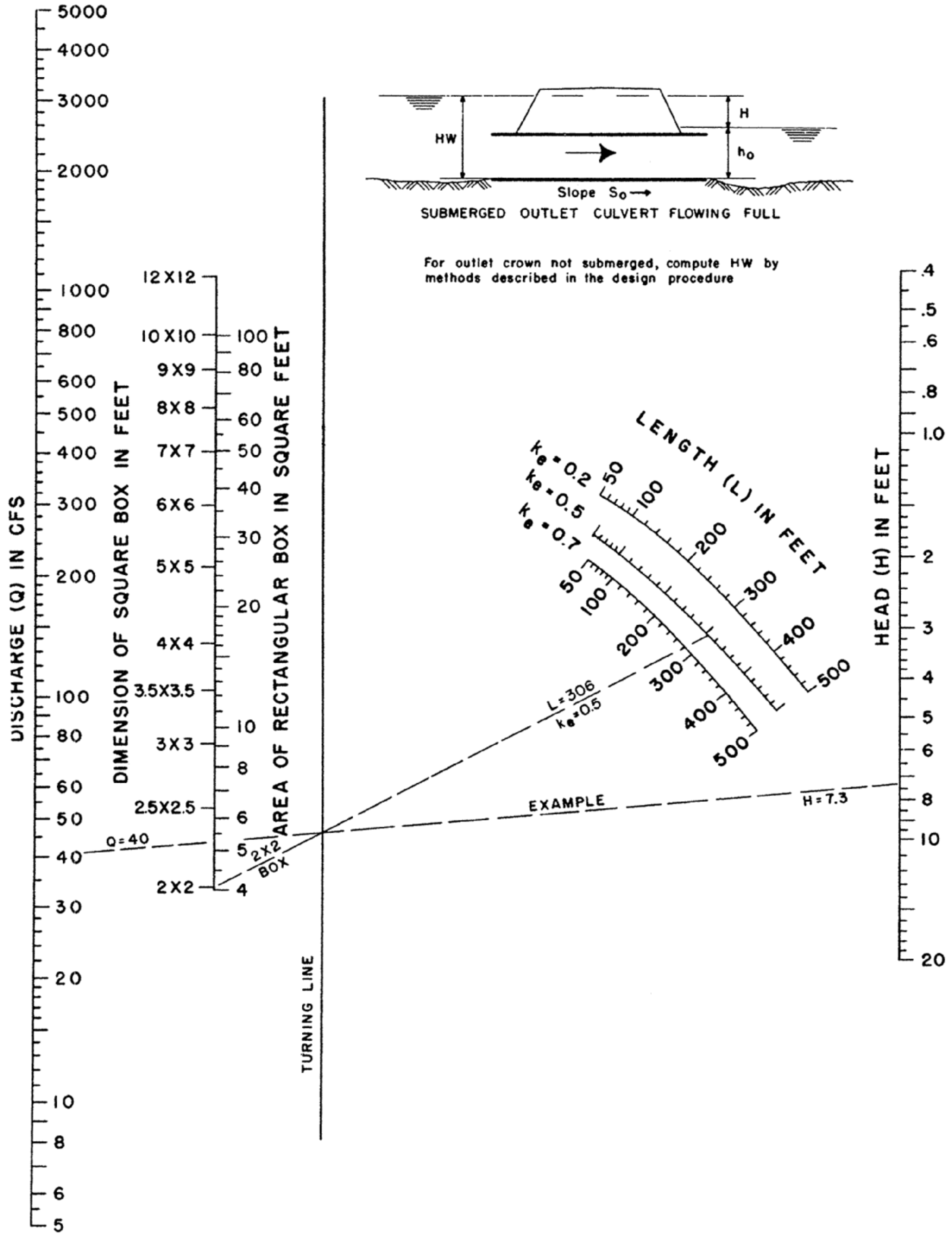
## CULVERT DESIGN-INLET CONTROL
## HEADWATER DEPTH FOR CORRUGATED METAL PIPE ARCH CULVERTS WITH INLET CONTROL



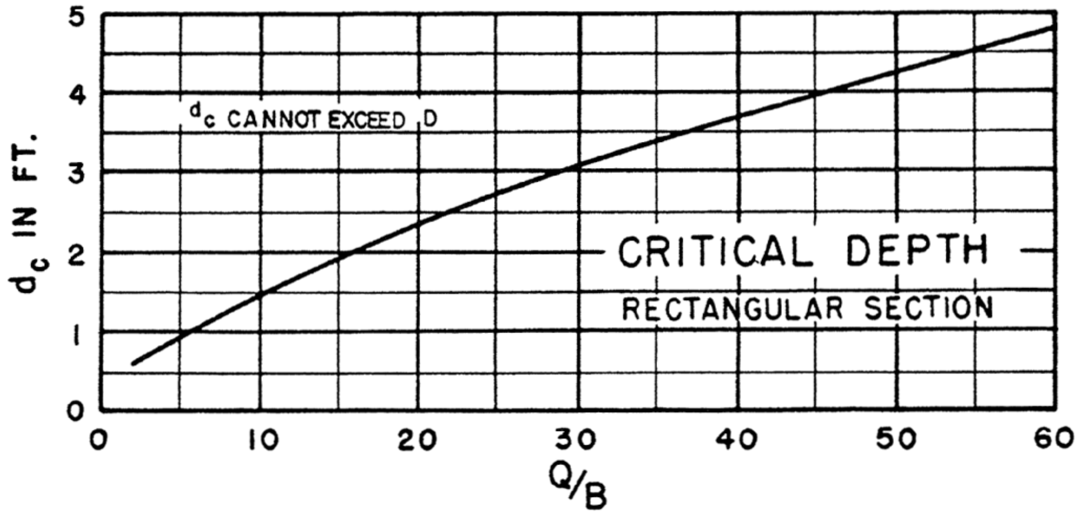
## OUTLET CONTROL NOMOGRAPH

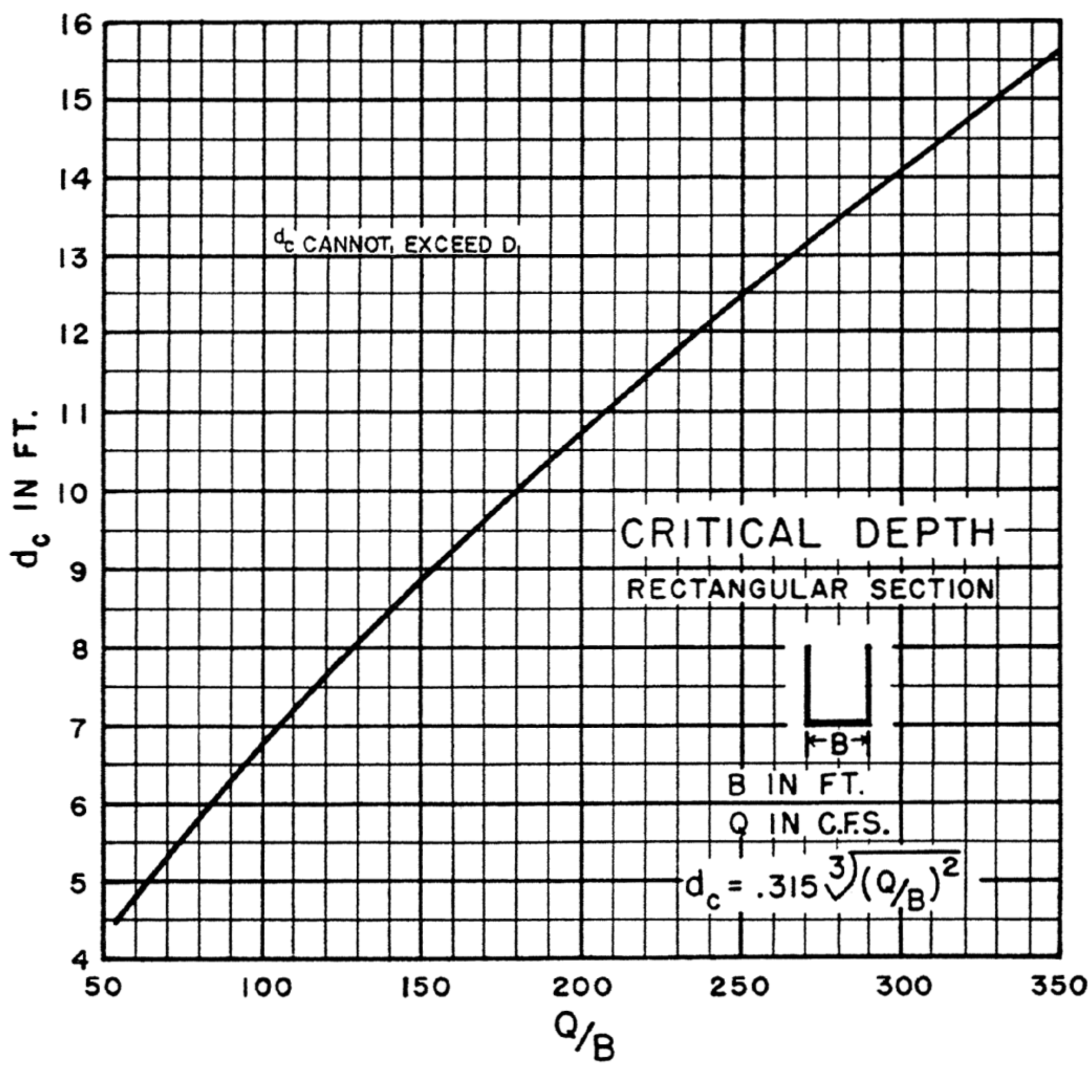


**CULVERT DESIGN-OUTLET CONTROL**
**HEAD FOR CONCRETE BOX CULVERTS**
**FLOWING FULL**
(n = 0.012)



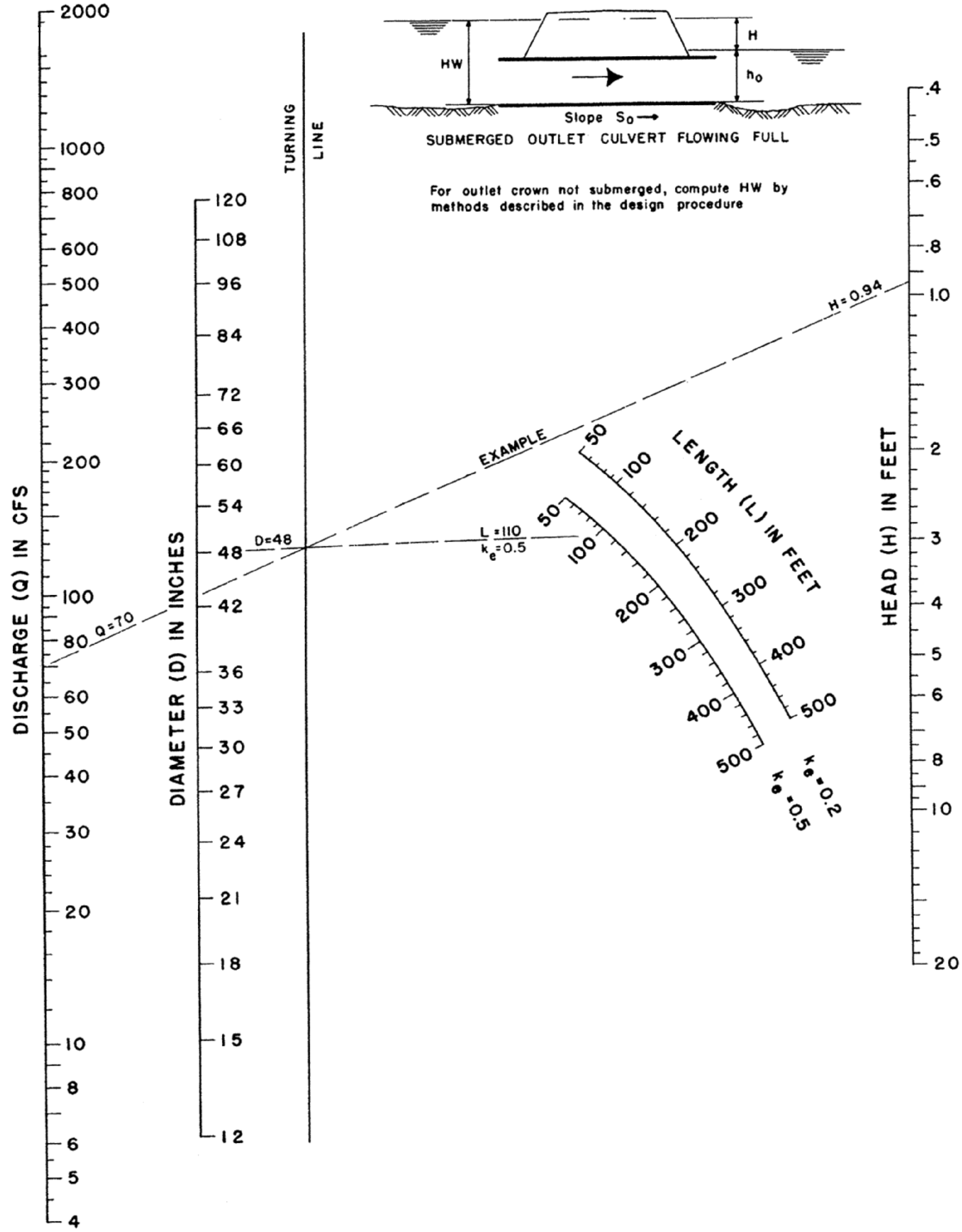
## CRITICAL DEPTH FOR RECTANGULAR SECTION



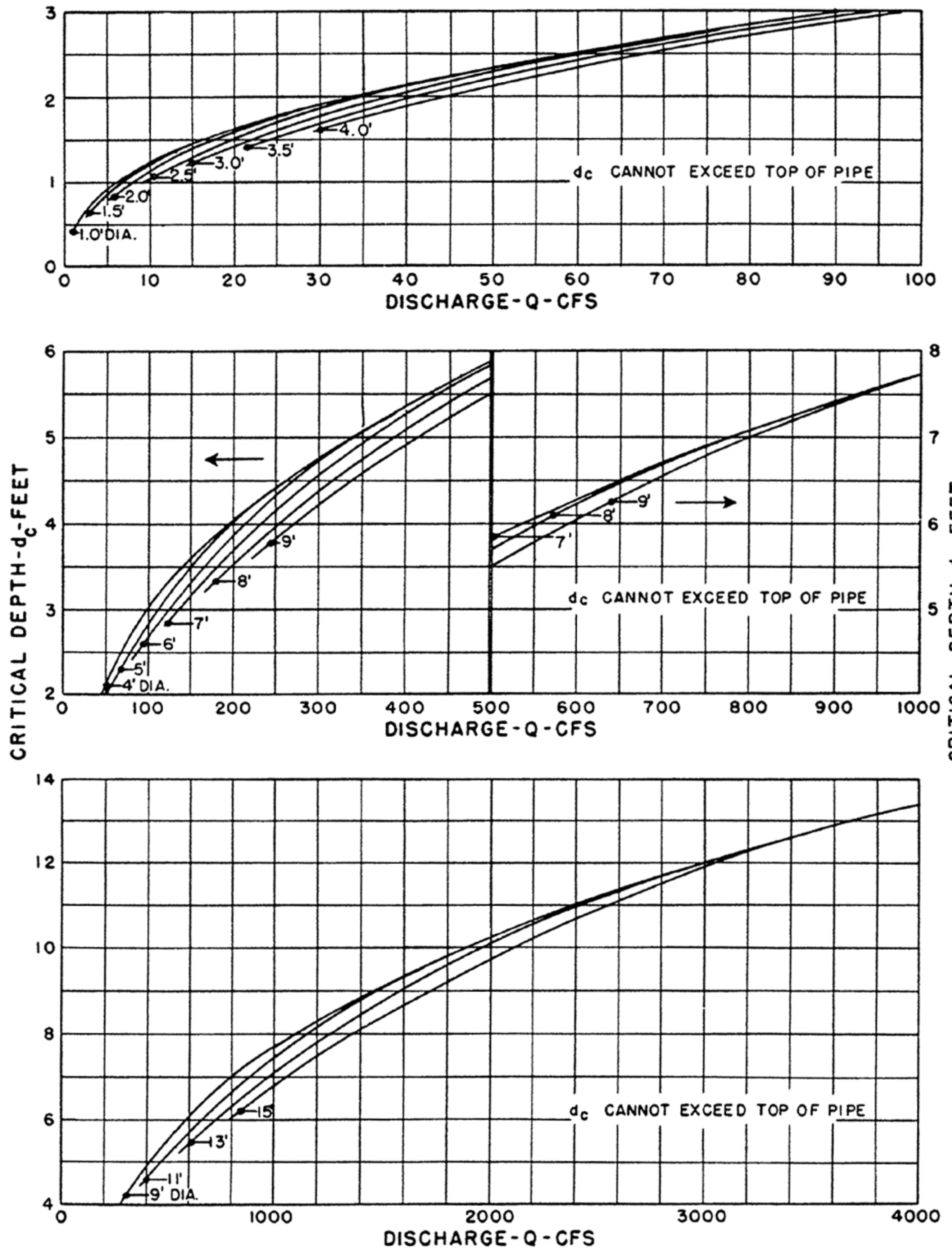



## CULVERT DESIGN-OUTLET CONTROL HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL

(n = 0.012)

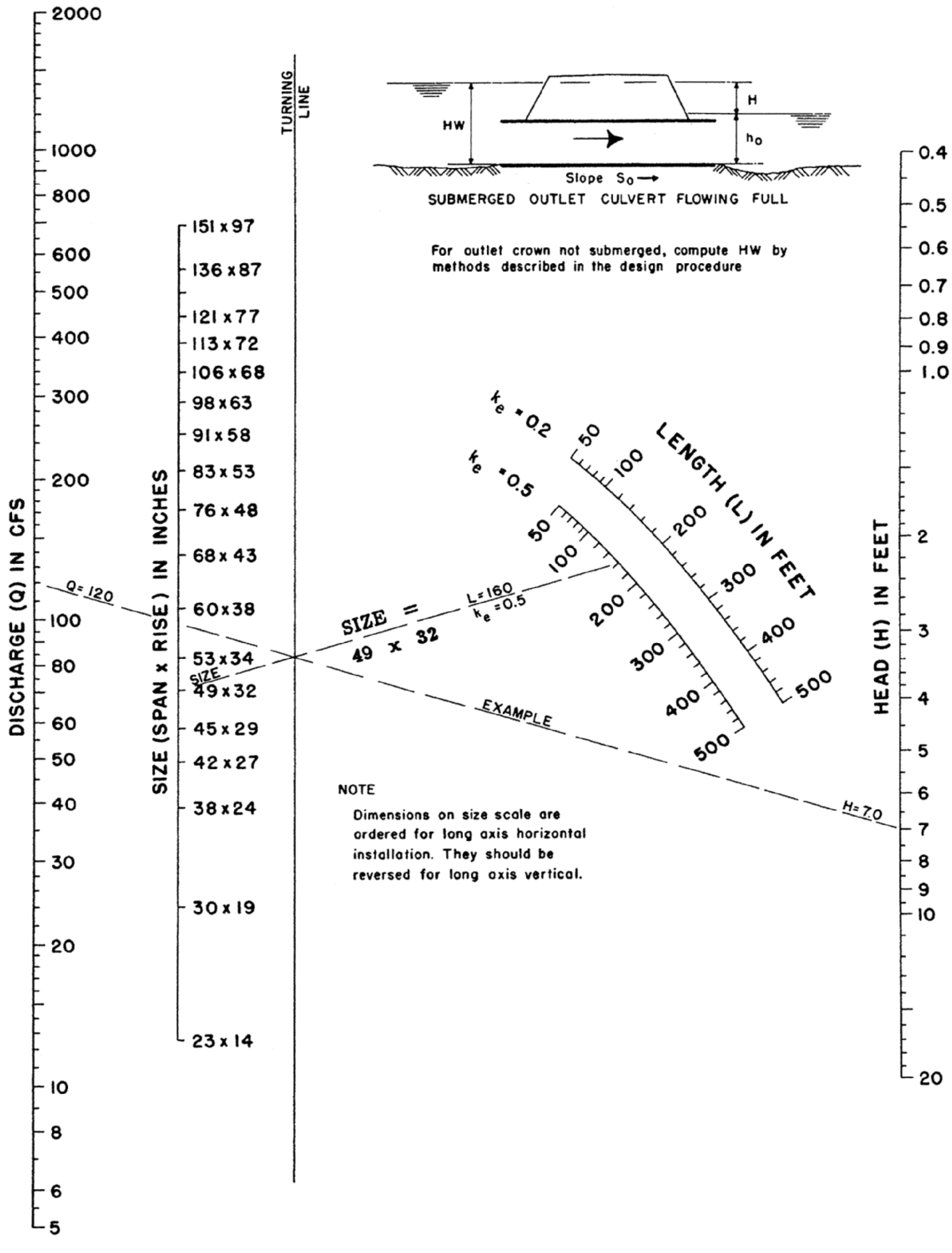


## CRITICAL DEPTH FOR CIRCULAR PIPE

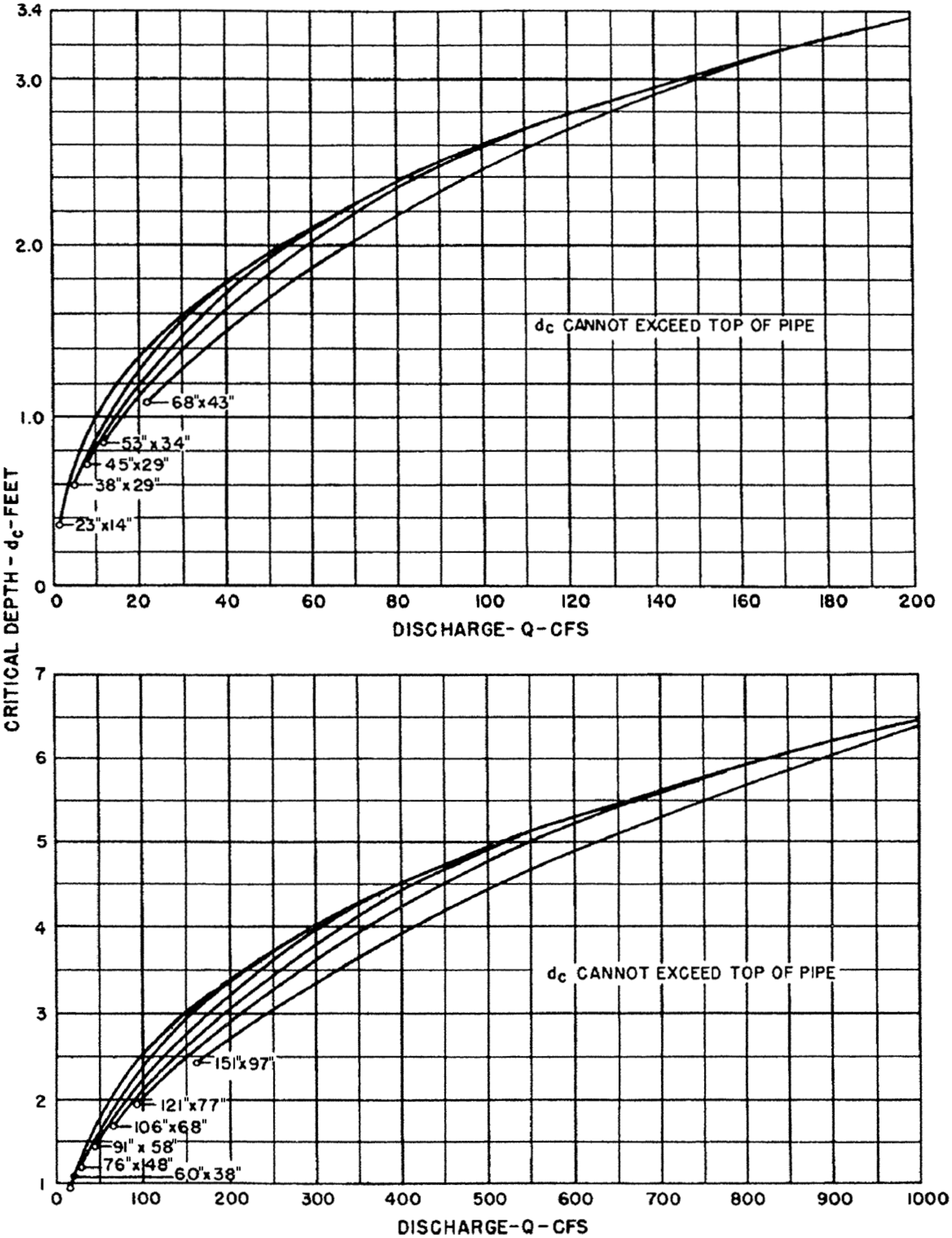


## CULVERT DESIGN-OUTLET CONTROL
## HEAD FOR OVAL CONCRETE BOX CULVERTS
## LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL

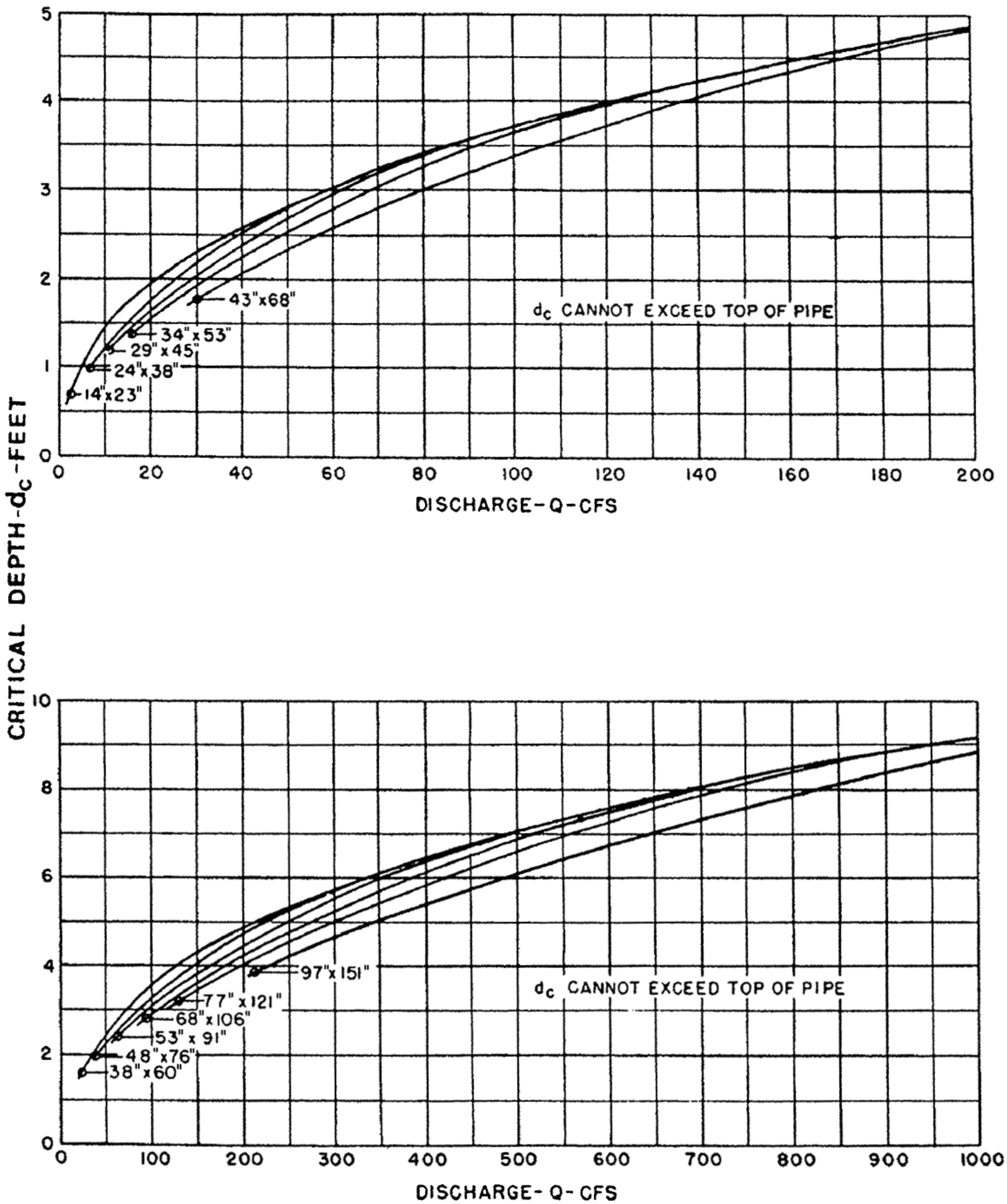
(n = 0.012)



# CRITICAL DEPTH FOR OVAL CONCRETE CULVERTS
## LONG AXIS HORIZONTAL

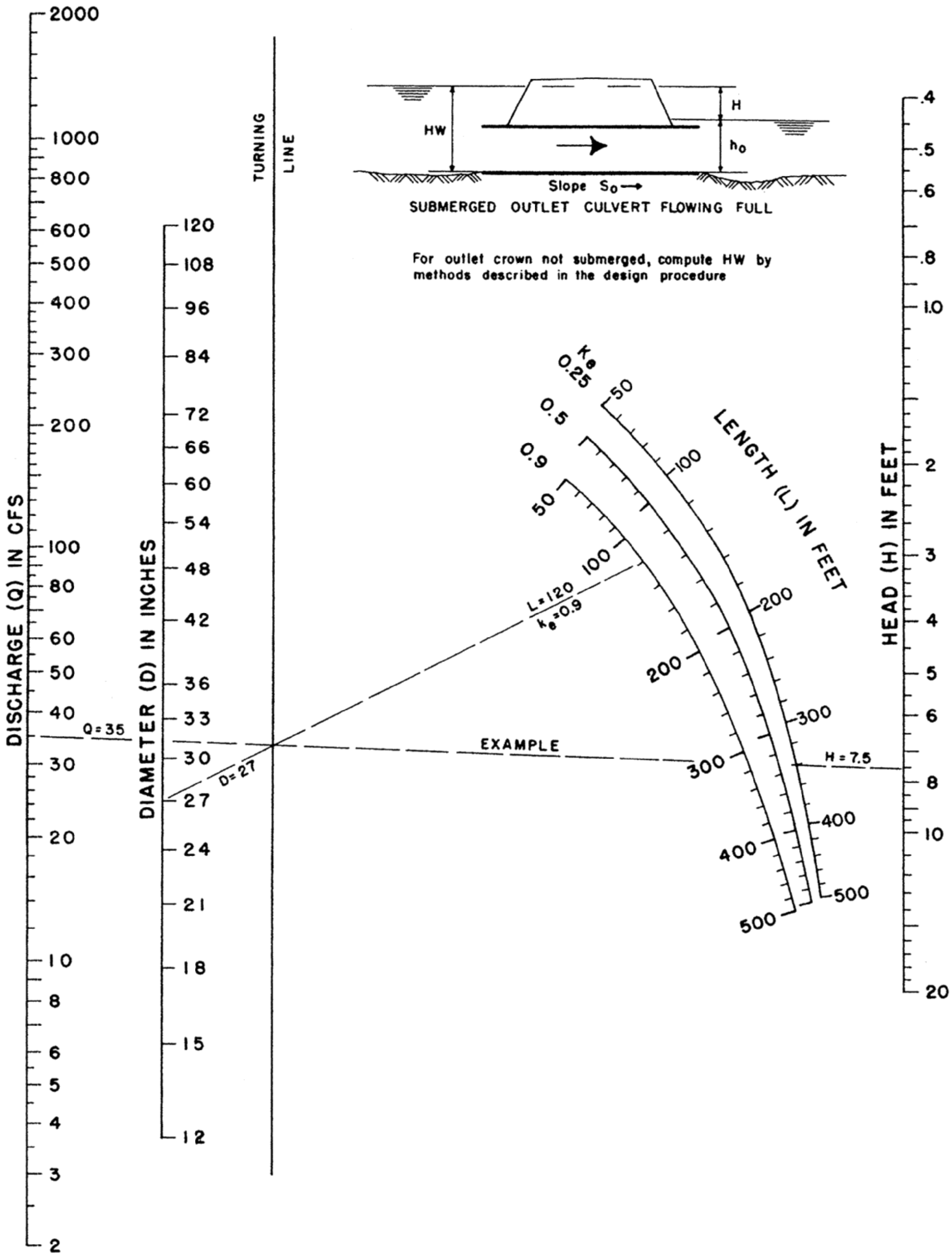


## CRITICAL DEPTH FOR OVAL CONCRETE CULVERTS
## LONG AXIS VERTICAL

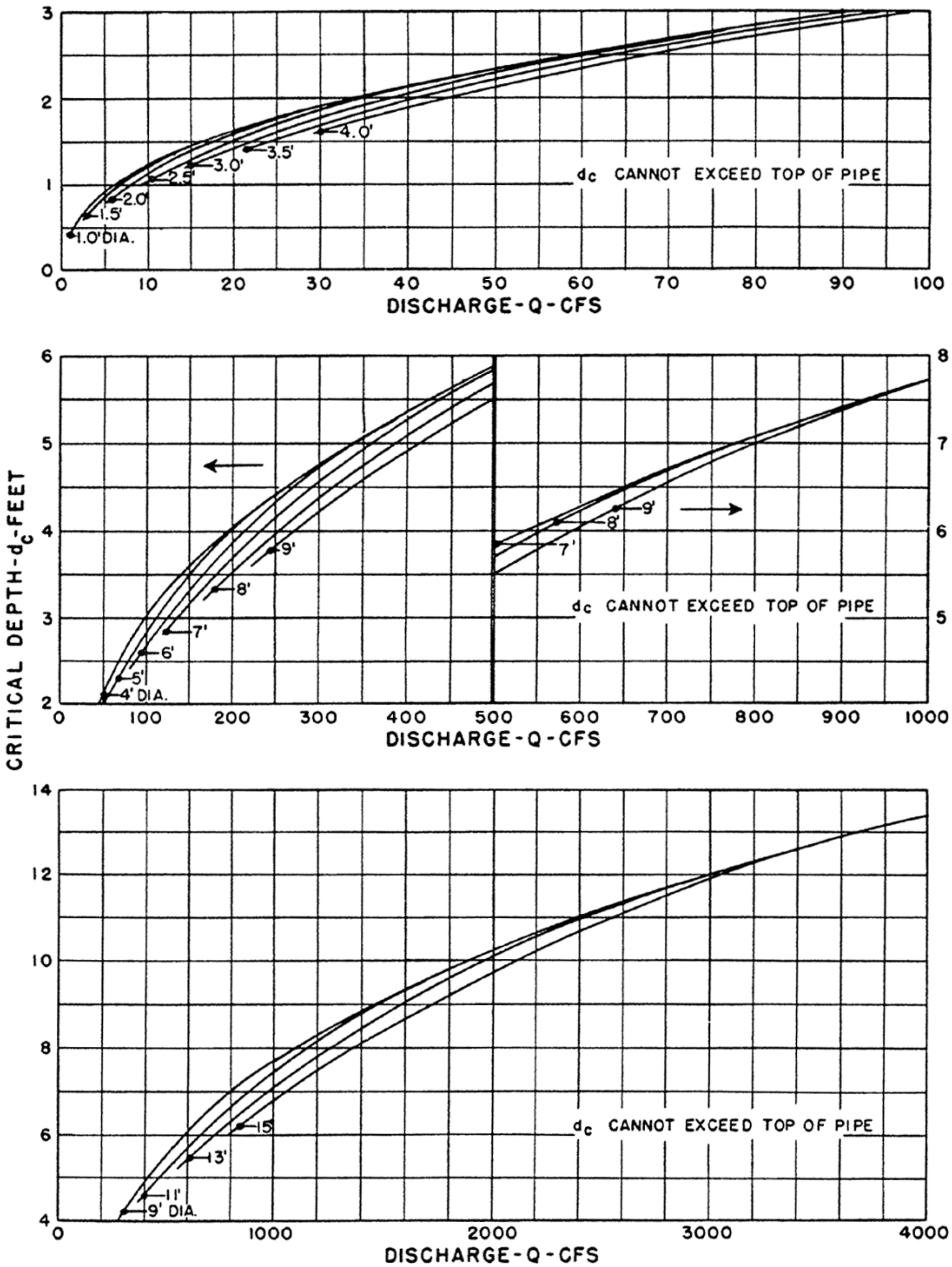


## CULVERT DESIGN-OUTLET CONTROL
## HEAD FOR STANDARD CORRUGATED METAL PIPE CULVERTS
## FLOWING FULL

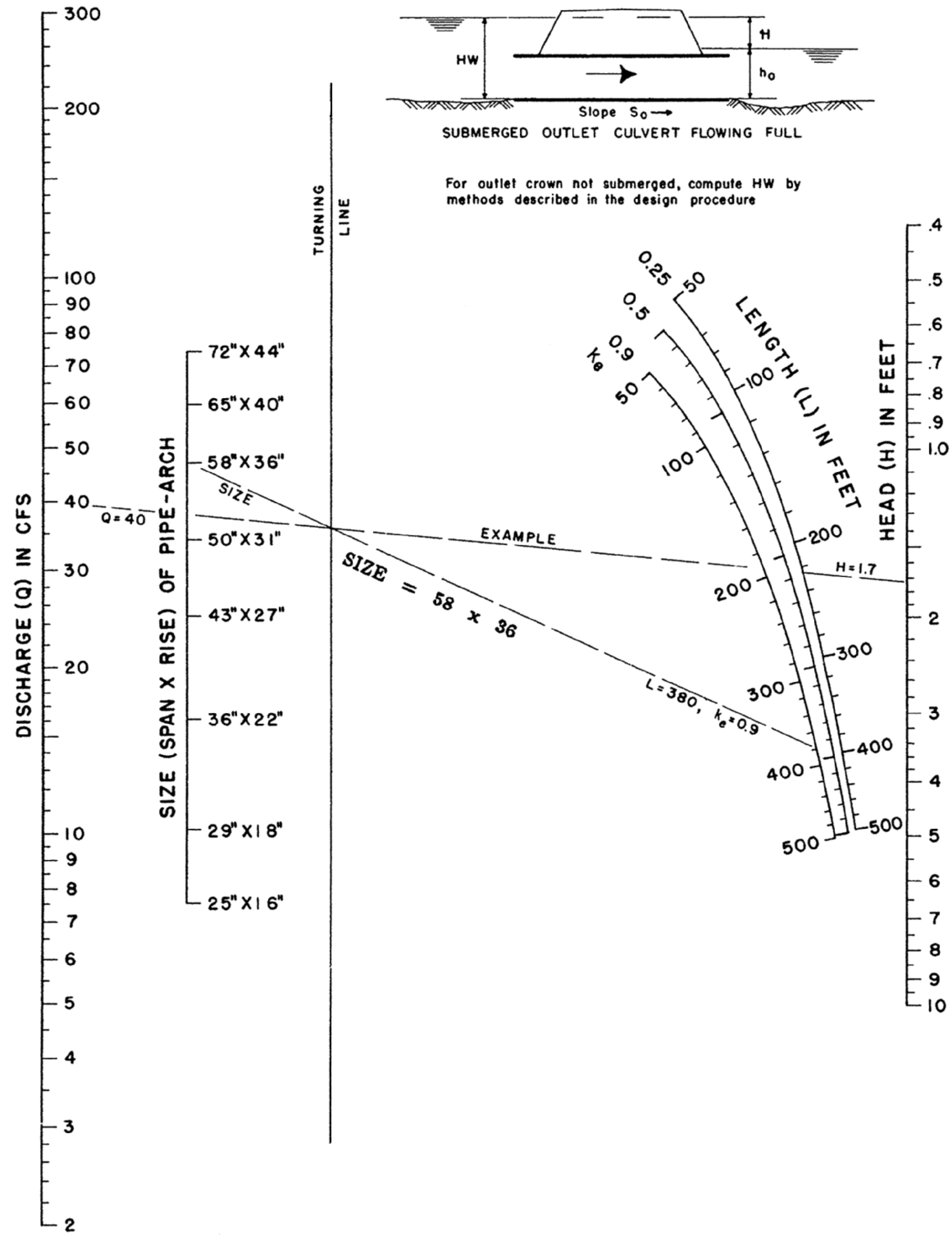
(n = 0.023)



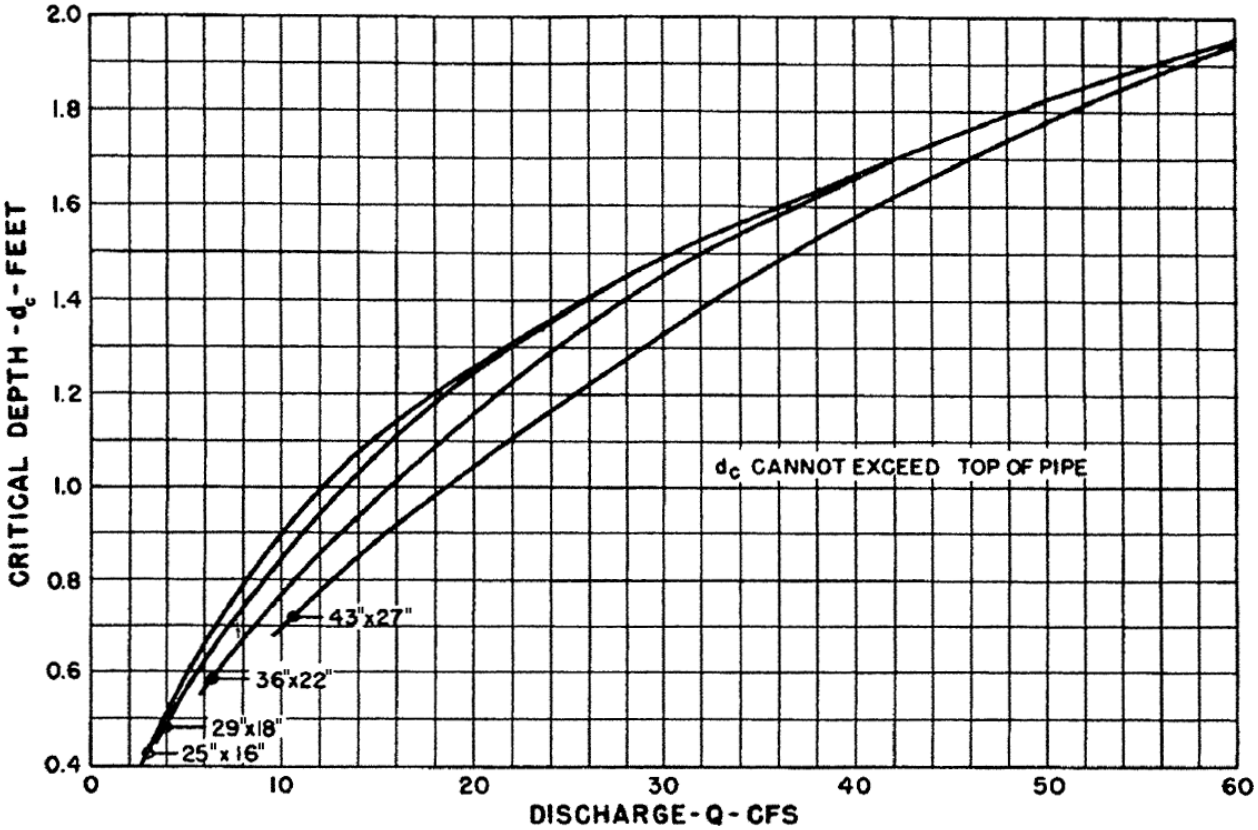
## CRITICAL DEPTH FOR CORRUGATED METAL PIPE CULVERTS

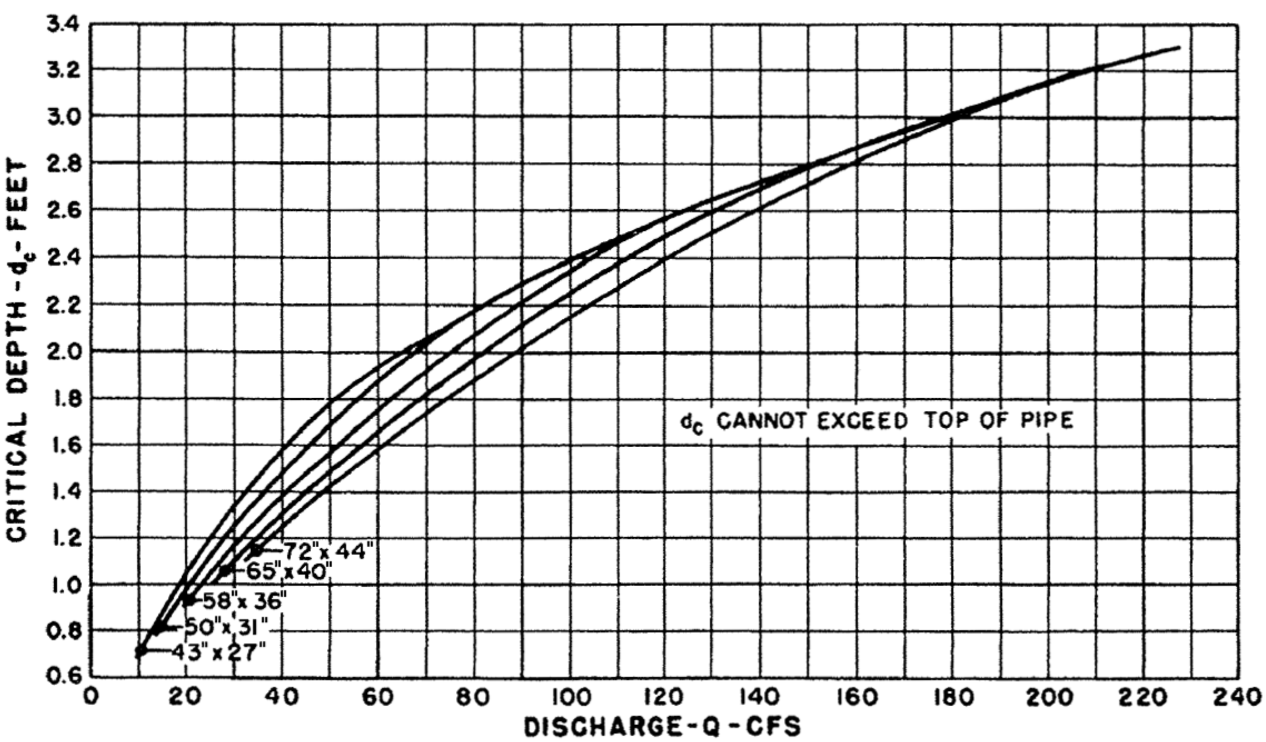


## CULVERT DESIGN-OUTLET CONTROL
## HEAD FOR STANDARD CORRUGATED METAL PIPE ARCH CULVERTS FLOWING FULL
(n = 0.023)

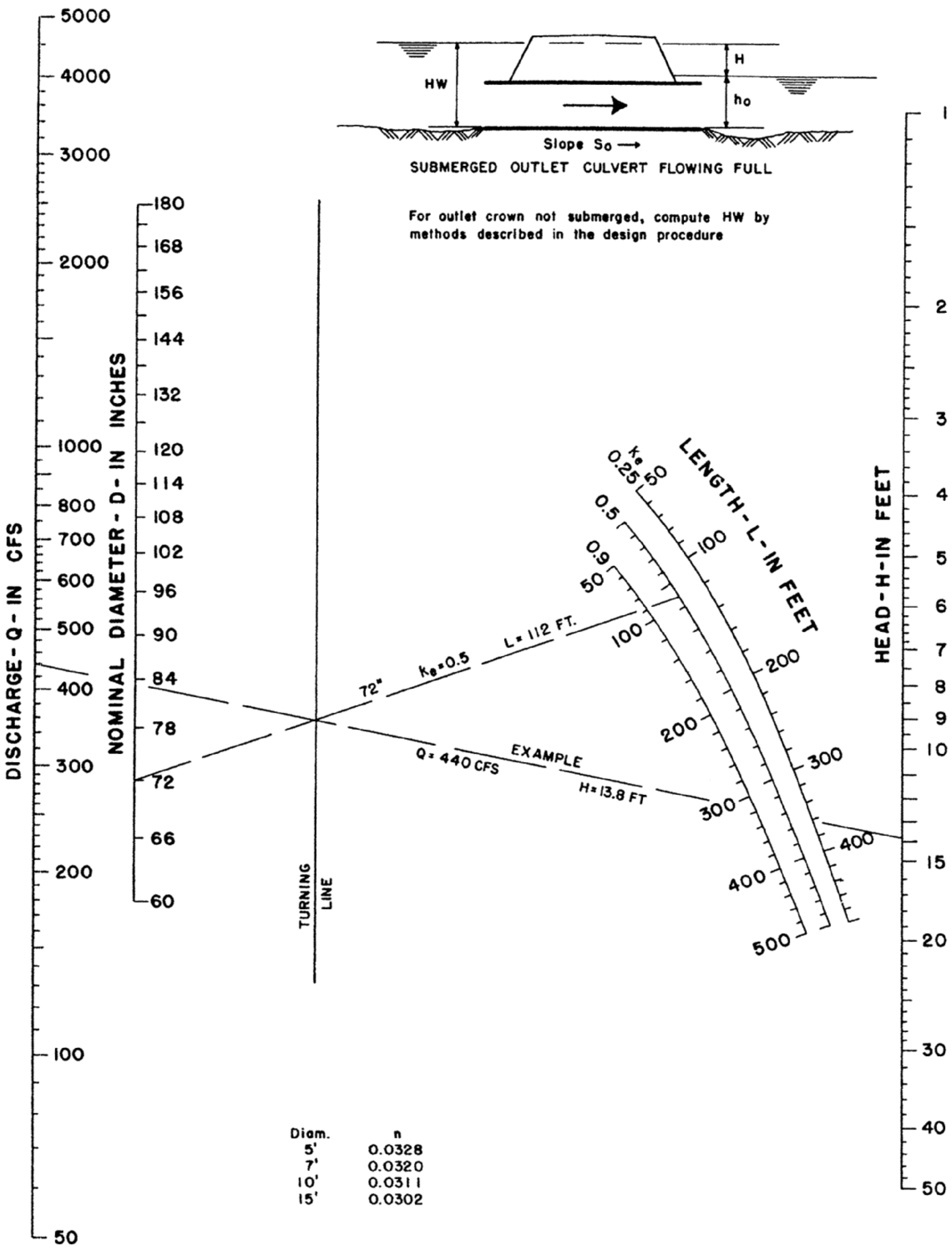


## CRITICAL DEPTH FOR STANDARD CORRUGATED METAL PIPE ARCH CULVERTS

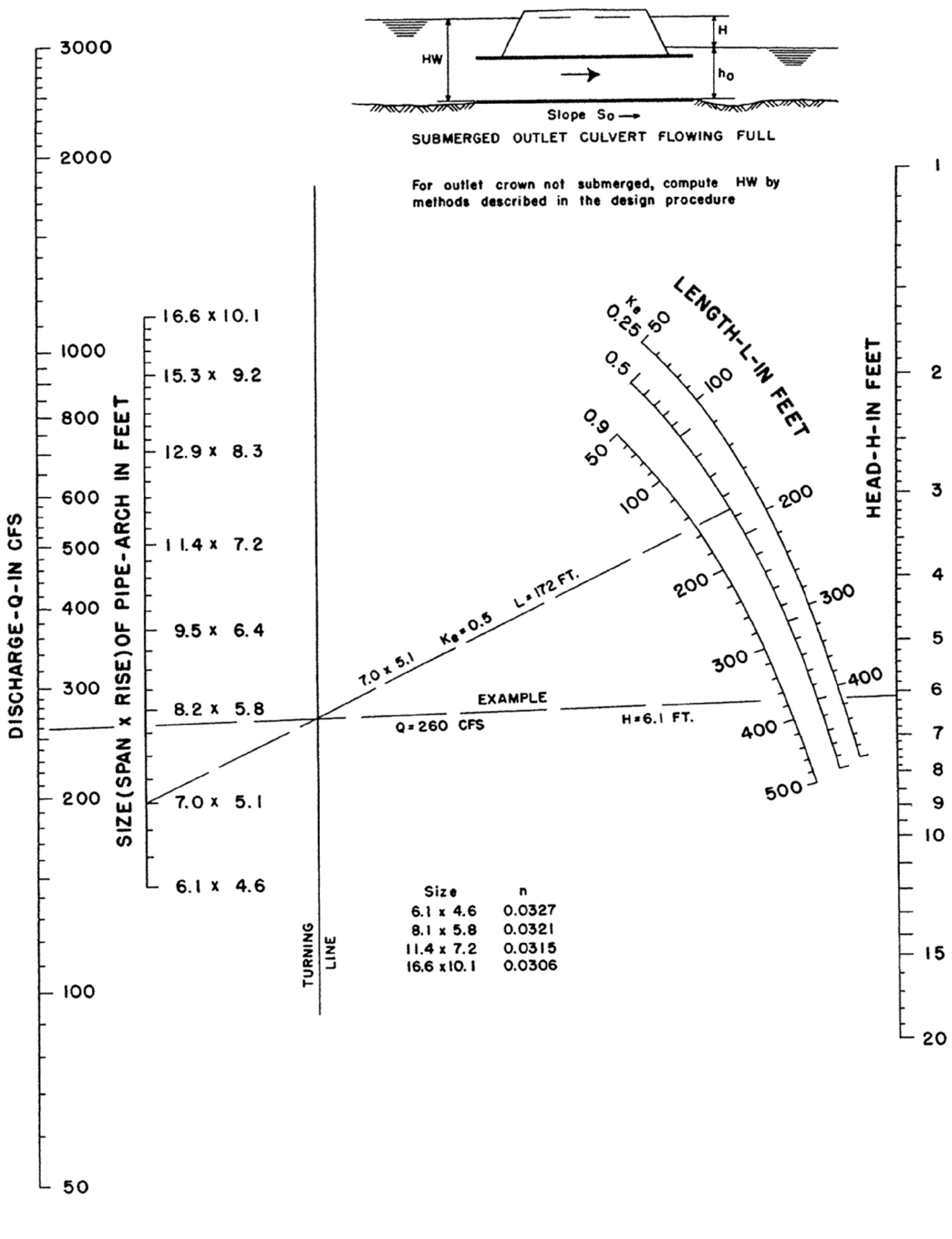


**CULVERT DESIGN-OUTLET CONTROL**
**HEAD FOR STRUCTURAL PLATE CORRUGATED METAL PIPE CULVERTS FLOWING FULL**
(n = 0.0328 TO 0.0302)

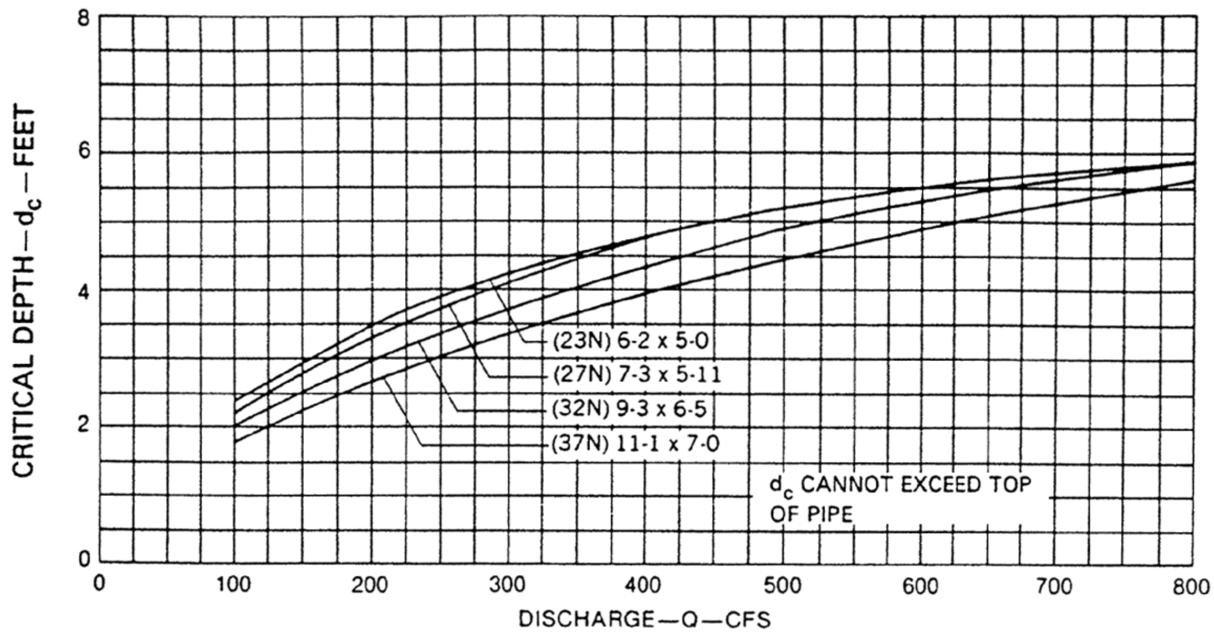


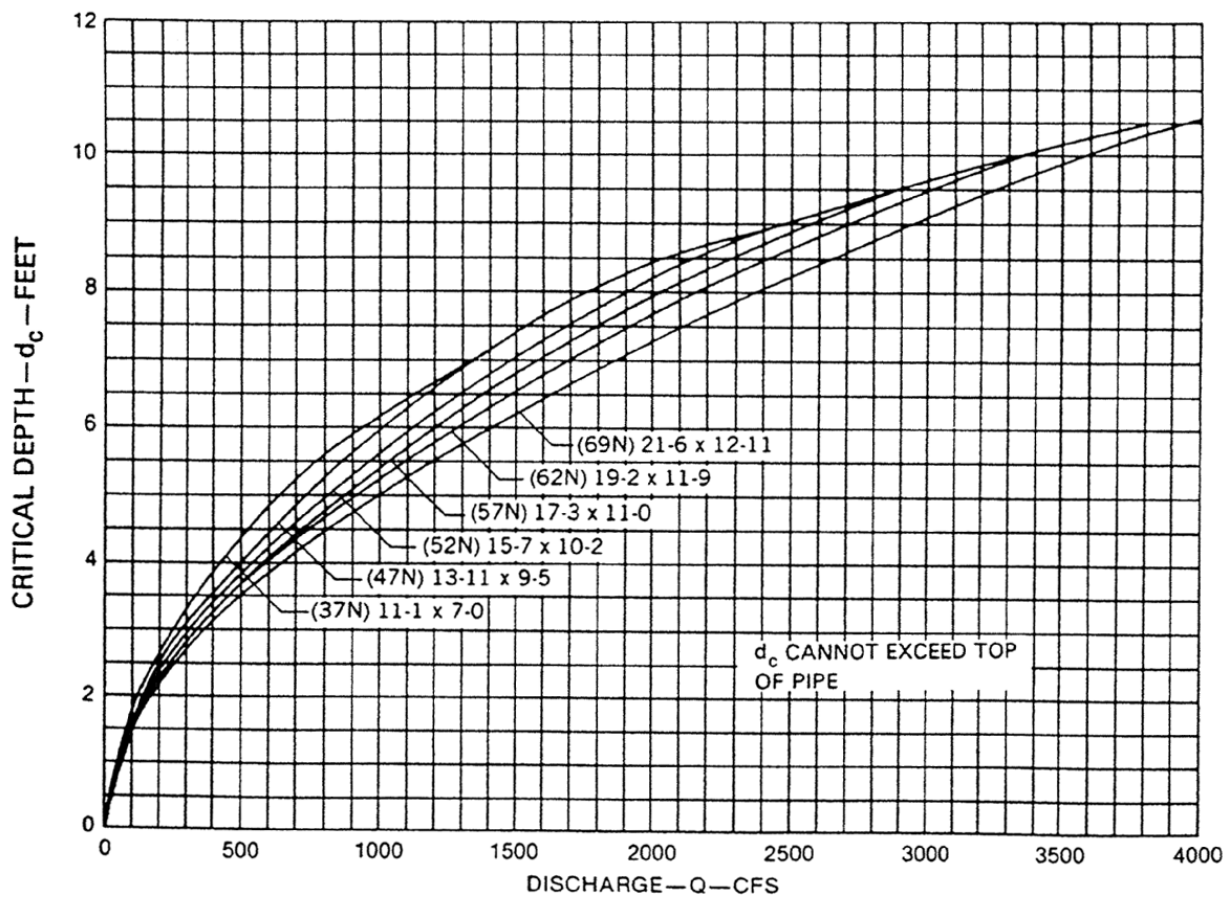
**CULVERT DESIGN-OUTLET CONTROL**
**HEAD FOR STRUCTURAL PLATE CORRUGATED METAL PIPE ARCH CULVERTS**
**18-INCH CORNER RADIUS FLOWING FULL**
(n = 0.0327 TO 0.0306)




| Size | n |
|---|---|
| 6.1 x 4.6 | 0.0327 |
| 8.1 x 5.8 | 0.0321 |
| 11.4 x 7.2 | 0.0315 |
| 16.6 x 10.1 | 0.0306 |

**CRITICAL DEPTH FOR STRUCTURAL PLATE CORRUGATED METAL PIPE ARCH CULVERTS**



## ***EROSION CONTROL DEVICES***

As part of the City of Greensboro's NPDES permit, the City is required to reduce water pollution arising from construction site erosion as well as erosion from permanent drainage channels. For those reasons many new rules are being adopted to bring the City into compliance with the Clean Water Act. New guidelines are now in effect to reduce erosion from construction sites as well as to assure the installation of structures to prevent scour at outlets and to protect ditch inverts from erosion by using adequate channel linings for the design flow.

Construction site erosion control measures are covered by the site-grading permit, and requirements for such can be obtained from the City's Erosion Control Inspectors.

### *Pipe Outlets*

For pipes discharging into an open ditch or stream, erosion control in the form of a flared end section or an endwall with a properly designed energy dissipater is required to help prevent undermining of the pipe and to prevent channel erosion.

For pipes that must discharge into stream buffers, the following restrictions apply:

- Streams located outside the Water Supply Watershed
  - Pipe outlet and level spreader are required to achieve sheet flow prior to flow entering 15' undisturbed area of buffer

- Streams located inside the Water Supply Watershed
  - Pipe outlet and level spreader required to achieve sheet flow prior to flow entering the 15' undisturbed area of the buffer

- Randleman Lake Watershed
  Upper and Lower Randleman Lake Watershed
  - Pipe outlet and level spreader are required to achieve sheet flow prior to flow entering Zone 2 which is 50' from the top of bank.

The most commonly used energy dissipater is a rip-rap pad at the outlet and often at the inlet of pipe systems. The City of Greensboro Engineering Division has developed a standard erosion control device using rip-rap as shown in COG Standard No. 421 and No. 422, these standards are to be used when the outlet is a flared end section.

For designing a rip-rap pad for situations not covered by COG Standard No. 421 and No. 422, use the nomograph charts provided on pages 93 and 94. To use these charts enter from the bottom with the discharge (**Q**). Carry this **Q** vertically to intersect the pipe size in the lower set of curves. Move horizontally to the right to read the median stone size. Carry **Q** vertically to intersect the pipe size in the upper set of curves. Move horizontally to the left to read the minimum length of apron required.

The New York Dissipater Method, as shown in the North Carolina Erosion & Sedimentation Control Manual as well as on page 95, is also an accepted design method.

All rip-rap installations, whether they are at a pipe outlet or lining a channel, must have a filter fabric installed between the rip-rap and the bare soil.

Energy dissipater dimensions, stone sizes and filter fabric are to be shown on the construction plan and profile drawings in the plan view.

***Storm Drainage Channels***

All drainage channels, whether they are ribbon pavement side ditches, open channels, or tail ditches conveying runoff outside the right-of-way, must be protected from erosion. Open channels not a part of the construction must be left in their natural state except where pipe systems empty into them. Proper erosion control devices at the outlets must be installed. (See the paragraph on pipe outlets).

Clearing and grubbing of existing open channels will be limited to the length required for the installation of the roadway structure or utility and any required erosion control devices. Stream reaches outside those limits will be left in their natural state.

Any channel created, disturbed, or realigned during the construction period must be protected with a properly designed channel lining installed to combat the erosive forces. These devices can range from grass linings to erosion control matting to rip-rap. Channel linings must be designed to withstand the shear forces from a 10-year storm.

Calculations for open channels, whether they are side ditches or drainage channels must be clearly shown on the construction plans in tabular form as shown in this manual and referenced to the different reaches of the channel in the plan view.

CHANNEL DESIGN TABLE

| CHANNEL REACH | SHAPE | FLOW "Q" | LINING TYPE | LINING "n" | CHANNEL SLOPE | BOTTOM WIDTH | SIDE SLOPE | FLOW DEPTH | CAPACITY |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Channel lining design must meet or exceed the design methods shown in the North Carolina Erosion and Sediment Control Planning and Design Manual.

***Rip-rap classifications***

RIP-RAP STONE SIZE CLASSIFICATION
(Required stone sizes – inches)

| CLASS | MINIMUM DIAMETER | MID-RANGE DIAMETER | MAXIMUM DIAMETER |
|---|---|---|---|
| A | 2 | 4 | 6 |
| B | 5 | 8 | 12 |
| 1 | 5 | 10 | 17 |
| 2 | 9 | 14 | 23 |

Stone for plain rip-rap will consist of field stone or rough unhewn quarry stone. Broken concrete may be used in place of stone with the approval of the inspector. However, broken concrete that contains reinforcing steel will not be permitted.

No specific gradation of rip-rap within a rip rap class is required, however, the various sizes of the stone will be equally distributed within the required size range.

***Drainage inlet erosion control measures***

During the construction period, all storm sewer inlets will be protected by an inlet erosion control device as shown in COG Standard No. 431. The inlet devices will be installed immediately after the drainage structure has been constructed. They will be properly maintained by the developers' contractor to maximize efficiency in reducing sediment into the storm sewer system. Non-compliance can result in penalties and fines issued by the City of Greensboro Stormwater Division, as well at the City's Erosion Control Section.

During pipe installation, COG Standard #443 Temporary Pipe Inlet Protection must be installed by the contractor at the end of each day in the trench above the last pipe joint installed and at all proposed structure locations until they are completed.

## GRASS-LINED V DITCH

The grass-lined triangular swale is a hydraulic structure that is being widely used for controlling and collecting sheet runoff and transporting the water to a storm pipe or drainage ditch. The following information is included to set forth a procedure for designing and checking the designs of proposed grassed-lined swales.

### MAXIMUM AREA WHICH CAN BE DRAINED BY A SPECIFIED GRASS-LINED TRIANGULAR SWALE AT A SPECIFIED SLOPE

***Purpose:*** The figure on page 92 is a design aid which will assist the designer in finding the maximum area that can be drained by a grass-lined triangular swale of specified longitudinal and side slopes without excessive erosion of the channel lining.

***Basis:*** The derivation of the figure on page 92 is based on Manning's Equation and the Rational Formula. The area limitation given for a specified channel is that area which will cause the water to flow at an average cross-sectional velocity of 4-feet per second, considered being the threshold of erosion of the grass lining. The figure uses a roughness coefficient of 0.03 for the grass lining and a rainfall intensity of 7.5 inches per hour, the 10-year, 5-minute storm in density for Piedmont North Carolina.

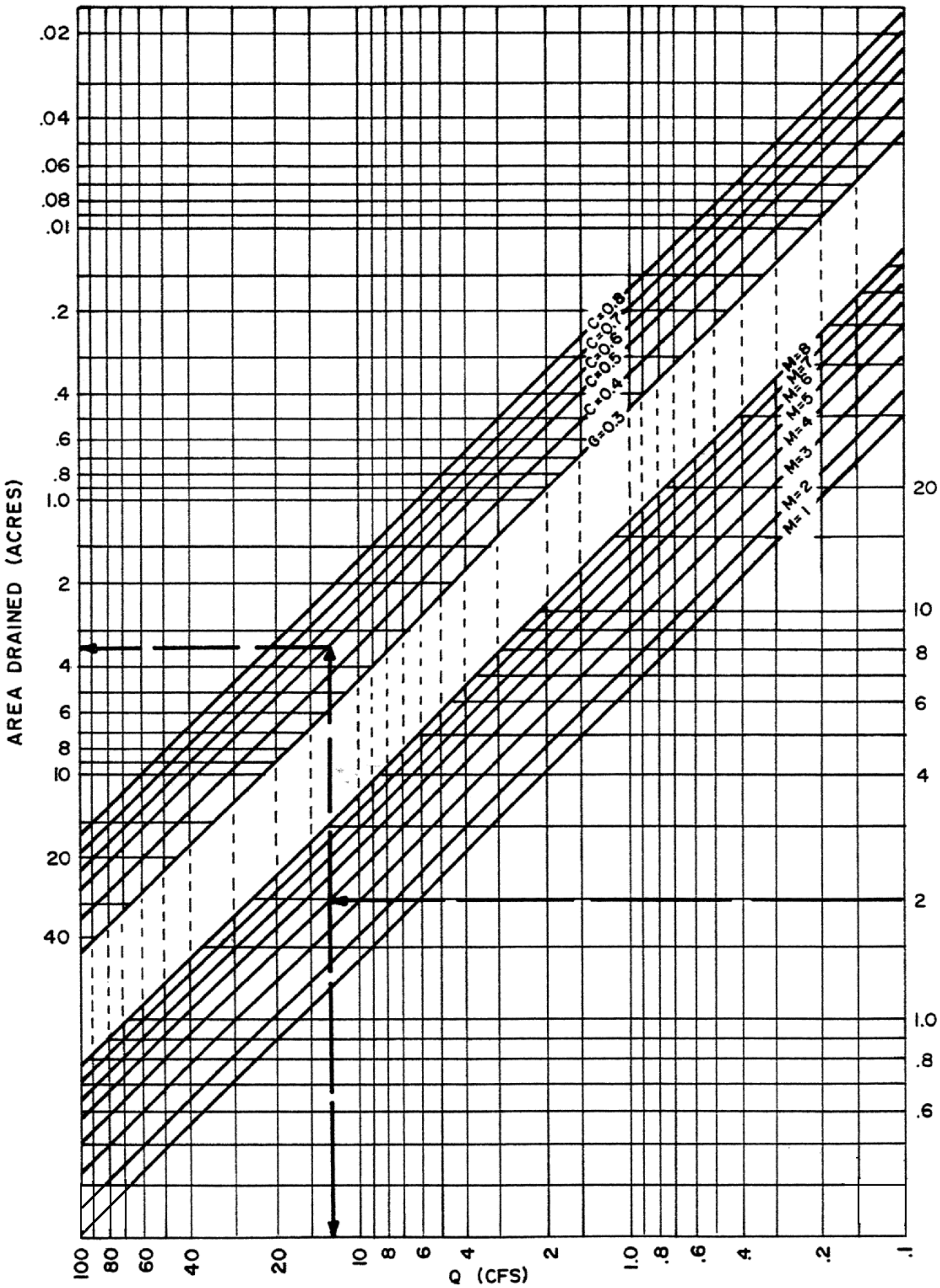
***Instructions:*** Use of the figure on page 92 requires three pieces of information:

1) **S**: longitudinal slope (percent)
2) **M**: side-slope (dimensionless ratio)
3) **C**: runoff coefficient (dimensionless).

Enter the figure from the lower right with **S**. Carry this **S** horizontally to the left to meet the proper **M** value. Then, carry upward (vertically) until the proper **C** is met. Now, move horizontally left to find the maximum area, which can be drained. If **Q** (flow) is desired, enter with **S**, move left to **M** and carry down (vertically) to **Q** at the bottom of the figure.

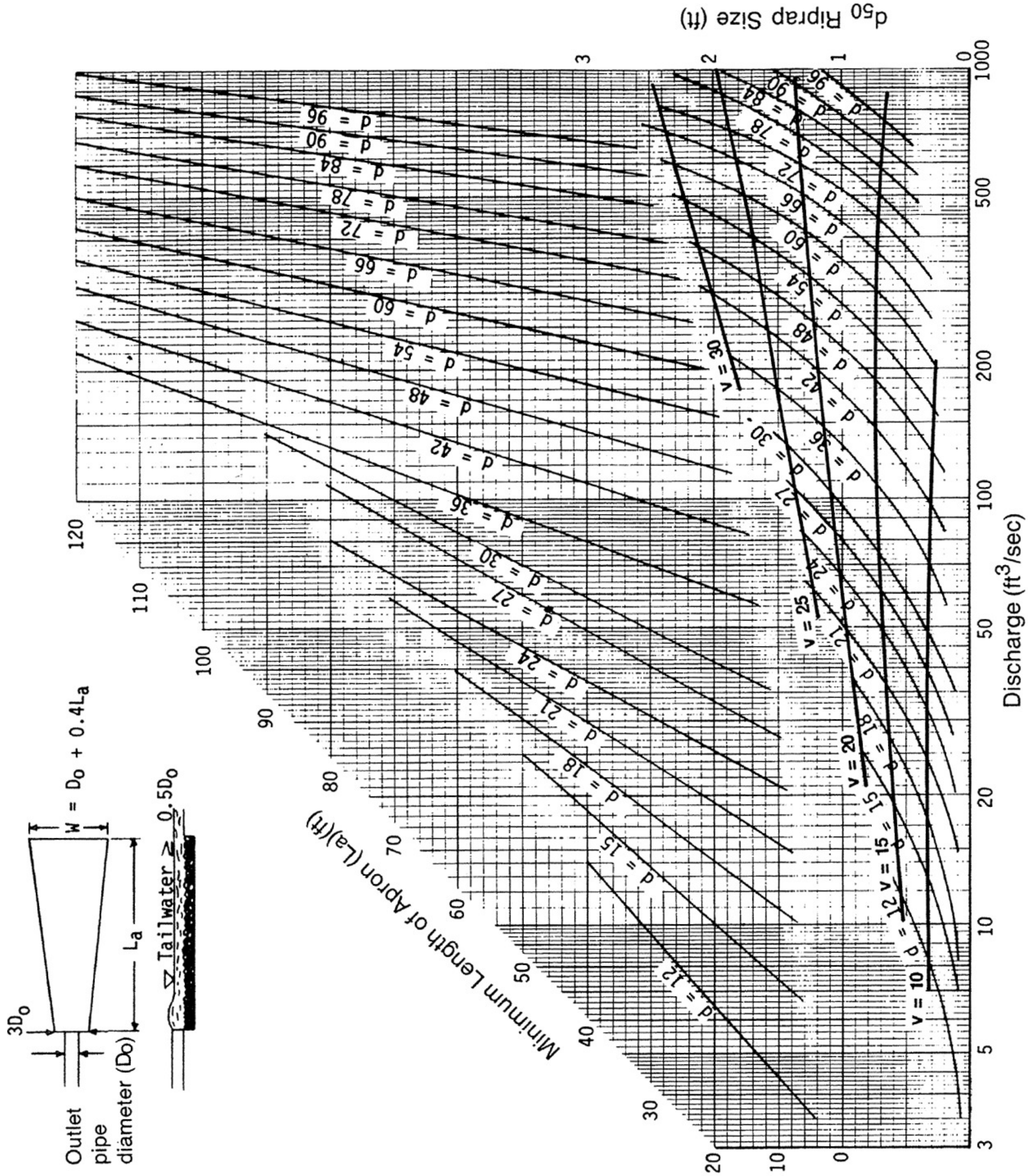
***Example:*** How much area can be drained by a channel having a 2 percent longitudinal slope and 4:1 side-slopes (**M** = 4) in a location where **C** = 0.5? (ans. 3.3 acres) What flow can the above channel carry without excessive erosion? (ans. 13 cfs)

## MAXIMUM AREA WHICH CAN BE DRAINED BY A SPECIFIED GRASS-LINED TRIANGULAR SWALE AT A SPECIFIED SLOPE



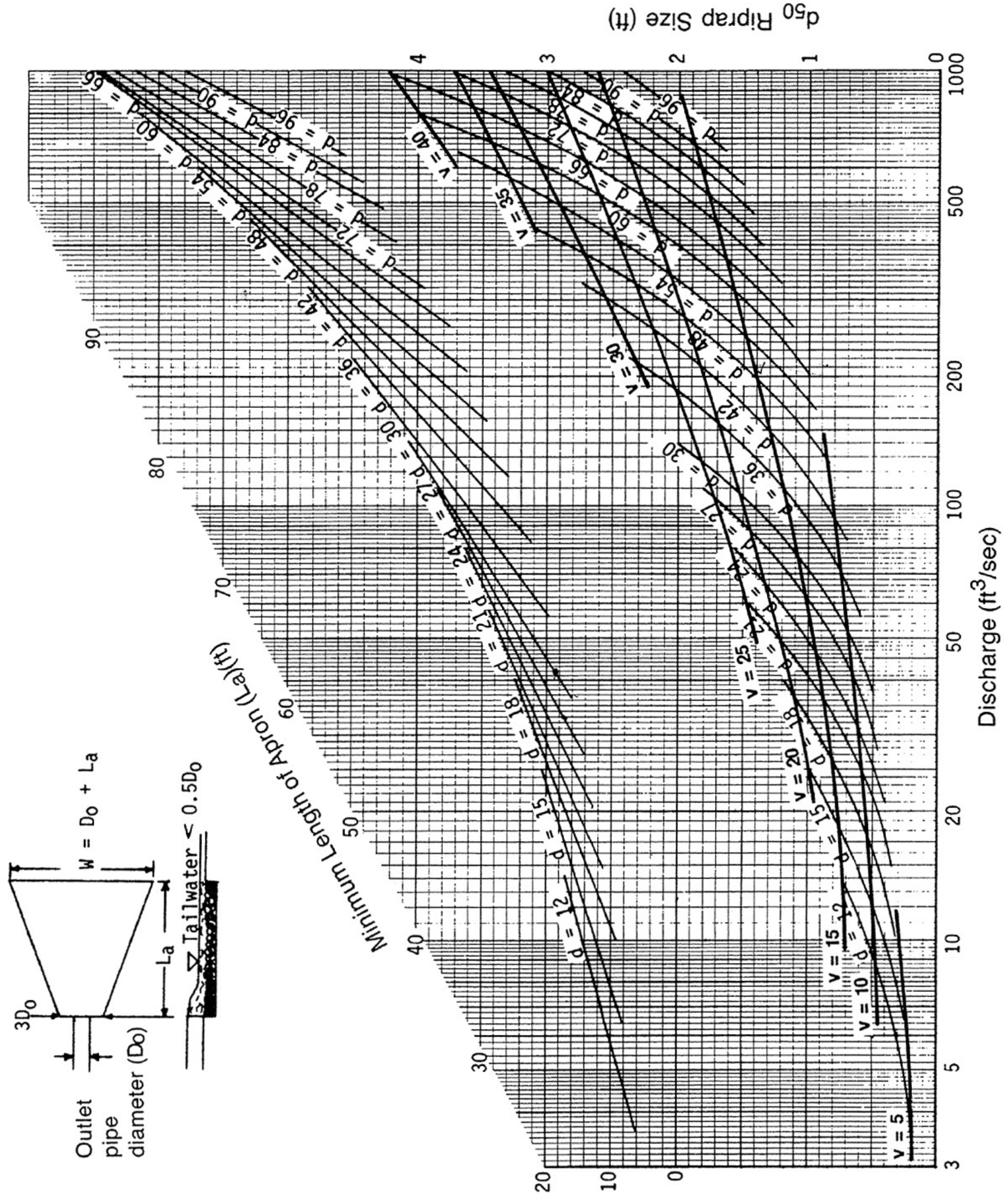
# DESIGN OF OUTLET PROTECTION
## <u>MAXIMUM</u> TAILWATER CONDITION

(Tw ≥ 0.5 diameter)



## DESIGN OF OUTLET PROTECTION
## <u>MINIMUM</u> TAILWATER CONDITION

(Tw < 0.5 diameter)



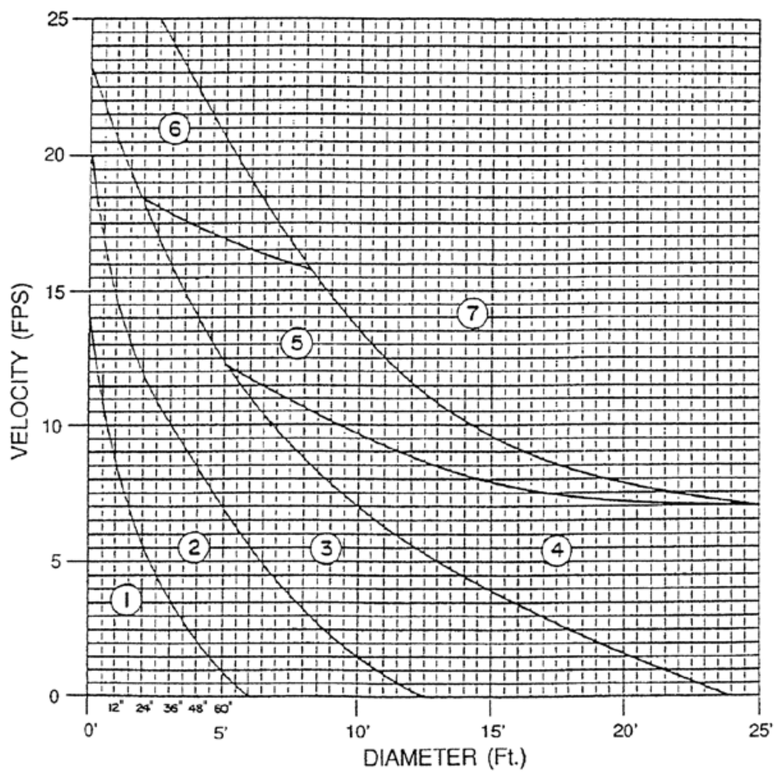
## New York DOT Dissipater Method for use in Defined Channels

Step 1: Compute flow velocity $V_O$ at culvert or paved channel outlet

Step 2: For pipe culverts, $D_O$ is the pipe diameter
For pipe arches, arch and box culverts and paved channel outlets, $D_O = A_O$ where $A_O$ = depth of flow based on cross sectional area of flow at the outlet

For multiple culverts, use $D_O = 1.25 \times D_O$ of single culvert

Step 3: For apron grades of 10% or steeper, use recommendations for the next higher zone




| Zone | Apron Material | | Length of Apron | |
|---|---|---|---|---|
| | | | To Protect Culvert<br>L1 | To Prevent Scour Hole Use L2 Always<br>L2 |
| 1 | Stone Filling (Fine) | CL. A | 3 × Do | 4 × Do |
| 2 | Stone Filling (Light) | CL. B | 3 × Do | 6 × Do |
| 3 | Stone Filling (Medium) | CL. 1 | 4 × Do | 8 × Do |
| 4 | Stone Filling (Heavy) | CL. 1 | 4 × Do | 8 × Do |
| 5 | Stone Filling (Heavy) | CL. 2 | 5 × Do | 10 × Do |
| 6 | Stone Filling (Heavy) | CL. 2 | 6 × Do | 10 × Do |
| 7 | Special Study Required - Energy Dissipater, Stilling Basin or Larger Size Stone | | | |

Width of Apron = 3 times the pipe diameter (minimum)

# ***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 Greensboro:

**General Requirements**

1) Storm sewers will have capacity to convey a 10-year storm within the pipe with no pressurized flow.

2) Culverts on Major, Minor and Collector Streets will have capacity to convey a 50-year storm event. Local streets will be designed to pass a 25-year storm event.

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 shall be 1.2 or less. See additional Headwater Limitations on page 57.

4) Storm sewer lines will be reinforced concrete pipe (RCP) Class III or Class IV or high density polyethylene pipe (HDPE) unless otherwise approved by the City Engineer. Only concrete pipe is allowed for driveway culverts.

5) Corrugated aluminum pipe may be used in culvert situations. Materials, gauge, corrugation, fabrication, etc. must meet NCDOT design criteria, specifications, and the City of Greensboro policy on acceptable corrugated aluminum pipe products. See the Culvert Policy on page 110 for further information.

6) Minimum size for storm sewer pipe carrying public runoff is 15-inches in diameter; 12-inch diameter pipe can be used by special approval of the Stormwater Management Division.

7) Minimum storm sewer pipe grade is 0.5 percent and the minimum flow velocity shall be 2.5 feet per second to avoid sediment depositions in the conduit.

8) The maximum flow velocity shall be 20 feet per second in concrete pipes and 10 feet per second in corrugated aluminum pipes to minimize abrasion damage to the interior surface of the pipes.

9) Maximum storm sewer pipe grade is 10.0 percent, expect as approved by the City of Greensboro Stormwater Management Division.

10) Minimum grade for tailditching is 1.0 percent.

11) Structures are required at changes in grade, changes in alignment, and at intersection of storm sewers.

12) Recommended manhole drops:
    a) Change in alignment $0^{o}$ to $45^{o}$, 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.

13) MINIMUM DESIRABLE CURB INLET DEPTH

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

14) MINIMUM MANHOLE DEPTHS:

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

15) Headwalls or flared end sections plus an appropriate energy dissipater will be required at the release point of all pipe systems. See the section on Erosion Control for acceptable energy dissipater design.

16) Pipe in culvert situations or storm sewer lines that will probably not be extended in the near future* 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) The pipe will be extended with a future phase of the same subdivision in the near future (within one year).

17) The maximum water surface elevation of the receiving stream (if higher than the water surface in the storm sewer at the outfall) or the water surface in the

junction with downstream storm sewer for the design condition (10-year event) shall be considered as the downstream hydraulic control as applicable.

18) Storm sewer systems shall be designed, as far as practicable, to provide for non-pressurized (open channel) flow in the pipes. This might require providing for higher upstream pipe crown elevation relative to the downstream pipe crown elevation at structures to account for the energy loss at the structure and insure open channel flow condition in the upstream pipe.

19) In situations where non-pressurized (open channel) flow conditions cannot be obtained because of constraints (such as flat terrain, outlet hydraulic control due to high elevation of receiving stream water surface at the storm sewer outfall, etc.), the design of the pressurized flow system shall meet the following criteria applicable to computations of the Energy Grade Line (EGL) and Hydraulic Grade Line (HGL):

    - **All** minor losses (in manholes, junctions, bends etc.) shall be considered in the energy gradient line and hydraulic gradient line analysis, and the hydraulic gradient on the upstream side of the structure in inlets, manholes, and junctions shall be a minimum of 1 foot below the bottom of inlet grate or cover of manhole or pipe junction.

20) The site development plans for a project submitted to the City's Technical Review Committee or through the Construction Plan Review Process shall include information on the elevation of water level (hydraulic gradient line on the upstream side of structure) in all inlets, manholes and junctions, evaluated for the 10-year recurrence design storm. The information shall be provided in graphical format in longitudinal profiles of the storm sewer system. This information shall be provided in the site development drawings, irrespective of the type of flows (open channel or pressurized) in the pipes.

21) On all multi-family and commercial projects, utility and construction plan approval is required prior to building permit approval.

22) The outlet of a storm sewer line will end at a reasonable distance from the property line to allow the installation of an energy dissipater.

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

24) Runoff from pipe outlets released to a perennial or intermittent stream must achieve sheet flow before reaching the 15' undisturbed buffer area.

25) 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

across the property line to tie the systems together. No gaps will be left in the system. If the closing of this gap creates a localized low spot, then a grated inlet must be provided.

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

27) Precast structures will be allowed on City of Greensboro maintained systems in accordance with the “Precast Structure Policy” found in the appendices.

28) Site drainage will not be allowed to flow out driveway entrances into streets. COG Standard No. 408 flumes or 4-inch pipe will be required to release water through the curb and into the gutter.

29) Outlets of City of Greensboro maintained storm sewer systems must be above the normal pool elevation of detention ponds. Inverts 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.

30) 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 and then a COG Standard No. 408 flume or a 4-inch pipe can tie in through the curb.

31) Site drainage must be tied into any existing storm drain system on or adjacent to the site.

32) There must be a 12-inch clearance between proposed utility lines and existing storm sewer lines.

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

34) Driveway culverts and paved driveways on ribbon paved streets must be installed in accordance with COG Standard No. 609. Reinforced concrete pipe is the only material allowed for driveway culverts.

35) Extensive energy dissipaters must be used where new commercial sites will be draining onto existing residential property. All reasonable methods to avoid draining onto private property must be tried before runoff will be allowed from commercial to residential properties.

## ADDITIONAL REQUIREMENTS FOR DRAINAGE PLANS
## (Subdivisions and Other Developments)

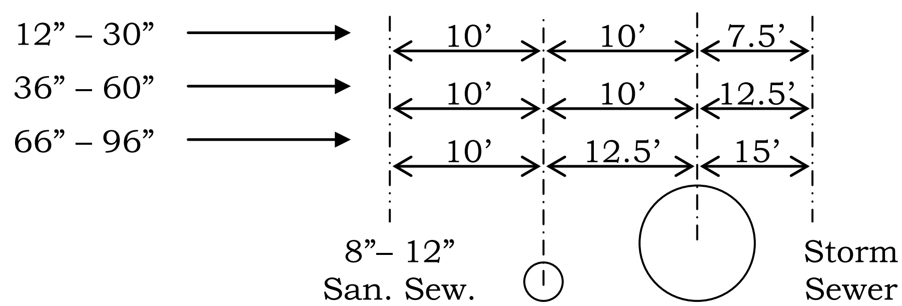
1) All water courses which carry a flow of 5 cubic feet per second (5 cfs) or more during a 10-year storm, as calculated in accordance with this manual, and which are not situated within a street right-of-way will be treated in accordance with Section 19-C of the City of Greensboro Subdivision Ordinance.

2) Drainage easements:
   a) 12"-30" pipe - 15'
   b) 36"-60" pipe - 20'
   c) 66"-96" pipe - 30'
   d) For pipes deeper than 10’, drainage easements shall be calculated based on twice the depth plus the nominal width of the pipe rounded to the nearest 5’ increment or as directed by the Stormwater Management Division. This will provide roughly a 1:1 slope for maintenance purposes.

3) Drainage Maintenance & Utility Easements for Unpiped Drainageways:
   a) 5 cfs to 16 cfs - 30' centered on channel
   b) 17 cfs to 70 cfs - 60' centered on channel
   c) 70 cfs and up - 100' + the width of the channel
      - Swales and berms carrying offsite runoff must adhere to the above easement widths. Where less than 5 cfs is calculated, no easements will be required.

4) Drainage, Maintenance and Utility Easements (D.M.U.E.) with storm and sanitary sewer lines.

Storm Sewer Sizes




or in accordance with 2d as outlined above

5) Where private swales are provided within a subdivision, a minimum 10’ private drainage easement will be required to allow flow across lots to an existing drainage system.

6) All proposed public storm sewer lines must be submitted to the Engineering Division for construction plan approval. The proposed line must be drawn on City of Greensboro plan and profile mylar. The installation of the storm sewer line must be inspected prior to acceptance of the line for City maintenance.

7) The following must be included on/with Site Drainage Plans:
   a) Location of inlets, manholes, pipelines.
   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 a form similar to that shown on page 102. Use of this form will greatly reduce the plan review turn around time.
   f) Computerized drainage calculation programs are allowable as long as they include the required information as shown on page 102 in a similar format.
   g) Culvert design form and appropriate nomographs.

# STORM DRAINAGE DESIGN DATA SHEET

PROJECT ______________________ ENGINEER ______________________

LOCATION ______________________ DATE ______________________

STORM FREQUENCY __________ YEAR

| LOCATION | | AREA | | C | INTENSITY | | | Q=CIA | GUTTER | E.G.L. | H.G.L. | PIPE | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TO | FROM | SUB | TOTAL | | L.B. | T.C. | I | CFS | FLOW* | | | SIZE | SLOPE | VEL. | |
| | | | | | | | | | | | | | | | |
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*PROVIDE RUNOFF QUANTITY JUST ABOVE RECEIVING INLET

PROJECT: ____________________

____________________

STATION: ____________________

SHEET ______ OF ______

CULVERT DESIGN FORM

DESIGNER / DATE: __________ / ______

REVIEWER / DATE: __________ / ______

**HYDROLOGICAL DATA**

SEE ADD'L. SHTS.

☐ METHOD: ____________________

☐ DRAINAGE AREA: ________ ☐ STREAM SLOPE: ________

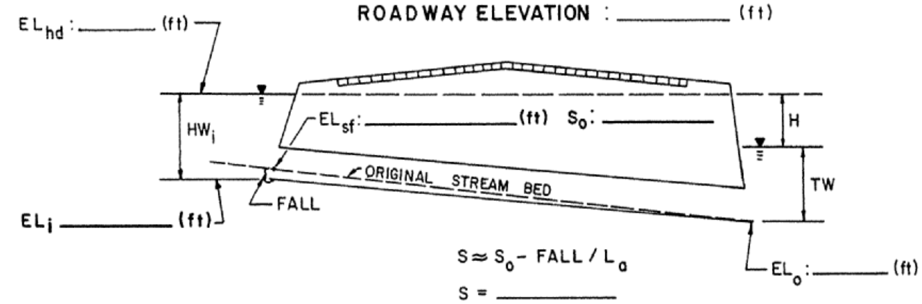
☐ CHANNEL SHAPE: ____________________

☐ ROUTING: ________ ☐ OTHER: ________

**DESIGN FLOWS/TAILWATER**

| R.I. (YEARS) | FLOW (cfs) | TW (ft) |
|---|---|---|
| | | |
| | | |

ROADWAY ELEVATION: ________ (ft)




$S \approx S_o - FALL / L_a$

S = ________

$L_a$ = ________

| CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE | TOTAL FLOW Q (cfs) | FLOW PER BARREL Q/N (1) | HEADWATER CALCULATIONS: INLET CONTROL $HW_i/D$ (2) | $HW_i$ | FALL (3) | $EL_{hi}$ (4) | OUTLET CONTROL TW (5) | $d_c$ | $\frac{d_c+D}{2}$ | $h_o$ (6) | $k_e$ | H (7) | $EL_{ho}$ (8) | CONTROL HEADWATER ELEVATION | OUTLET VELOCITY | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | |
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**TECHNICAL FOOTNOTES:**

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i / D = HW / D$ OR $HW_f / D$ FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L) / R^{1.33}\right] V^2 / 2g$

(8) $EL_{ho} = EL_o + H + h_o$

**SUBSCRIPT DEFINITIONS:**

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho. HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

**COMMENTS / DISCUSSION:**

**CULVERT BARREL SELECTED:**

SIZE: ____________________

SHAPE: ____________________

MATERIAL: ____________ n: ______

ENTRANCE: ____________________

# Precast Concrete Drainage Structures in City Maintained Storm Sewer Systems

Precast concrete drainage structures are used more and more in the installation of storm sewer systems. But, if not installed properly, they can become maintenance headaches. The City of Greensboro welcomes the use of these structures by contractors only if they are installed properly and do not compromise the integrity of the City's infrastructure. This policy introduces guidelines to be used for the installation of precast concrete structures. If these conditions do not work in your situation, the City recommends that the contractor construct a brick masonry box. The following guidelines should help determining when and where these structures are allowed.

**Notice of Disclaimer:**

The City of Greensboro requires that all public drainage structures adhere to the standard detail drawings as set forth in the "City of Greensboro Roadway and Utility Standard Drawings" manual. Any structure used by the contractors must meet the standards set forth in the detail drawings and the installation guidelines set forth in this policy. Any deviation from the two in the field installation will be the contractors and manufactures responsibility to correct.

**Size Considerations:**

The tops of all precast concrete boxes must have the proper outside dimension so that they will accept the City of Greensboro structure tops.

| | |
|---|---|
| Std. #402 | 43" x 70" O.D. |
| Std. #403 | 43" x 88" O.D. |
| Std. #424 | 48" x 48" O.D. |
| Std. #441 | 60" x 60" O.D. |
| Std. #438 | 72" x 72" O.D. |

The City of Greensboro Standard #412 curb inlet top must be used on all City of Greensboro curb inlets.

Grate inlet precast boxes must have the same or very close inside dimensions so that there is adequate bearing surface for the frame flange to be mortared directly to the top of the box. The grate inlet precast box to be used outside of the roadway may be oversized if a properly designed reinforced concrete slab with an opening the size of the inside dimensions of the standard box is cast into the slab to accept the grate and frame. The opening in the slab should be offset to one side to line up with the steps in the box. Refer to City of Greensboro standard drawings #404, 405, 406, 407, 409, 410, 434, and #435.

| | |
|---|---|
| Std. #409 | 18” x 24” I.D. |
| Std. #410 | 24” x 24” I.D. |
| Std. #435 | 24” x 36” I.D. |

**Precast concrete storm sewer manholes:**

Flat top manholes will not be allowed under paved roadways. Precast manholes will only be allowed in the roadway when a cone sections sits atop the manhole. This reduces the possibly of reflection cracking. The minimum depth of precast manholes depends on the pipe size, the diameter of the manhole, the height of the cone section and the height of the ring and cover. No pipes can enter the manhole through the cone section. It shall be the responsibility of the designer to consider these parameters when designing the storm sewer system if precast manholes are to be used. The only restriction the City will place on these structures is that NO flat tops will be allowed under roadway pavement.

No combination of brick masonry and precast concrete manholes will be allowed. Either one or the other type materials must be used for the structure. For example, brick cone sections will not be allowed on top of precast concrete riser sections.

Pipe openings in the manhole shall be cast or cored in the manhole by the manufacturer.

**Pipe Openings in Precast boxes:**

It is preferred that openings for pipe connections be cast or cored into the boxes by the manufacturer. However, because field connections are sometimes necessary, field openings in the precast boxes are allowed under the following conditions:

**Waffle Boxes:**

- No openings will be allowed through the corners of the waffle boxes.

- Field openings will only be made with a power concrete saw or a coring machine. Jack Hammers and sledge hammers are not to be used because they can cause stress cracks in the concrete that can compromise the longevity of the structure.

- There are tremendous lateral loads exerted on the sides of these boxes by the backfill. The opening should be cut as small as possible to allow the installation of the pipe. Once the pipe is installed, the opening will be sealed inside and out with type “S” mortar to create a waterproof seal.

**Precast Concrete Boxes:**

- No field openings will be allowed through the corners of the precast boxes. Any required openings through the corners of the precast boxes will be cast in place or cored by the manufacturer prior to the box being delivered to the site.

- Field openings in the boxes will be made with a power concrete saw or a coring machine. Jack Hammers and sledge hammers are not allowed for use in breaking through the sides of the boxes.

- The opening should be cut as small as possible to allow the installation of the pipe. Once the pipe is installed, the opening will be sealed inside and out with type “S” mortar to create a waterproof seal.

**Precast structure installation:**

- The contractor should adhere to the following installation guidelines when installing precast drainage structures:

- ONLY City of Greensboro standard #412 curb inlet tops will be allowed to be used on curb inlets that will become part of the City’s infrastructure. It is important that precast boxes are compatible with these lids. Therefore precast boxes and waffle boxes will be allowed only if installed as follows:

**Waffle Box Curb Inlets under 6 feet in depth:**

1. The depth of the box is not to exceed the manufacturer’s recommended maximum depth.

- Waffle boxes must have outside dimensions close to the outside dimensions of the City of Greensboro standard #402 and #403 curb inlet boxes.

- The contractor will have the inspector check the dimensions of the boxes prior to any installations. 30” x 60” waffle boxes are acceptable, but 36” x 60” are too large and must be corbelled in to fit the correct top dimensions.

- The top of the waffle boxes are to be set a minimum 24” below the top of curb elevation. The subdrain will sit on top of the box. Brick masonry will be used to adjust the front wall to the proper elevation and alignment to support the curb and gutter inlet throat. The inside of the front wall, when adjusted, must line up with the back of curb. The other three walls are to be corbelled in or out at the rate of ½” per brick to the correct elevation and outside dimensions of the C.O.G. std. #402 or #403 curb inlet to accept the City of Greensboro standard curb inlet top.

**Precast Concrete Curb Inlet Boxes under 6 feet in depth:**

- The front wall of the box will be 17 ½” lower than the other three walls. This is 7 ½” for the throat opening, 5” for the gutter throat section and 5” for the 4” VCP subdrain. The 4” subdrain will sit on the front wall. Brick masonry will be used up to the bottom of the gutter throat (12 ½” from the top of box).

- It is suggested that the boxes be set a few inches low so that the final grade can be adjusted with brick masonry.

- All boxes will have to be set with the inside front of the boxes exactly in line with the back of curb and gutter and align with the PCR or PTR at intersections. No false walls inside the box or add on footings on the outside the box will be allowed to support the curb and gutter. These are new systems being installed and proper construction methods must be employed. Misalignment will require that the boxes be reset even if the pipe is already installed.

**Precast concrete boxes and Waffle box requirements:**

- Pipes enter these boxes and sit on the bottom of the box. A concrete invert will be formed in the box up to the invert of the pipe to eliminate the possibility of standing water.

- All precast boxes will conform to the step requirements as shown on the individual standard drainage structure drawings.

If steps are installed in the ends/sides of the curb inlet boxes, the ring and covers in the lids will be offset to that end to allow access to the steps.

**Special structures for larger pipe sizes:**

- Oversize precast concrete structures may be used in lieu of masonry structures for large diameter pipe as long as the dimensions of the box are close to the design dimensions. All pipe openings in the box must be cast into the box during manufacturing. Steps must be cast or installed into the box for access. Tops shall have openings to accept C.O.G. standard castings (manhole, grate and frame or yard inlet). The location of the openings shall line up with the alignment of the steps. The openings around the pipe will be filled with grout from the inside and outside and wiped smooth. The bottom of the structure shall be filled with concrete up to the invert of the outgoing pipe. The contractor must submit a shop drawing to the Stormwater Management engineer for approval prior to installation of the structure.

- Oversize precast curb inlet bases to accommodate larger pipe sizes may be used under the following conditions. Once the oversize box is to an elevation above the top of all pipes, there must be a transition riser section or a properly designed transition slab that will allow the installation of a precast section or brick masonry structure that fits the dimensions and offsets to accept the subdrain, throat, and top of the City of Greensboro Standard #402 or #403 curb inlet or grate or yard inlets. It is suggested that the manufacturers design and submit for approval a precast transition riser or transition slab that can be used in most situations. Don't forget the steps accessibility in this design. If this shop drawing is on file with the City, it will speed field approval at construction time. If the contractor chooses, brick masonry may be corbelled in to the proper dimensions at the rate of ½" per brick course.

**Special structures for deep systems:**

- On curb inlets or yard inlets deeper than 6 feet or the manufacturer's recommended depth, manhole riser barrels which are stronger against deep soil pressures may be used to come up to grade. At some point a transition slab must be installed on top of the riser barrels to allow the installation of a City of Greensboro standard #402 or #403 curb inlet or #424 yard inlet. The transition slab will have an opening large enough for a man to access the steps in the riser barrel sections. Manufacturers are encouraged to submit a design for these transition slabs. With the design approved and on file, there should be no approval delay at construction time.

**Note to all designers and inspectors:**

- When determining pay item quantities for “Masonry Drainage Structures”, you must keep in mind that the quantities as shown in the Standards Manual are based on 8” walls and the thickness of walls of the precast structures are only 6” thick. Therefore you will need to calculate the wall volume and the pipe opening volume rather than take the quantities from the standard when precast structures are used.

# ACCEPTABLE CULVERTS FOR ENCLOSING LARGE STORM DRAINAGE CHANNELS AT ROAD CROSSINGS

## I. DETERMINATION OF CULVERT SIZE

A. The rainfall runoff amounts will be determined by the methods set forth in the **City of Greensboro Storm Sewer Design Manual**. Culvert runoff for major stream crossings should be determined using either the "Basin-Lag Time Method" or the TR-55 method. Both methods are presented in this manual.

B. Culverts and Bridges are to be sized for these Design Return Periods

Major City Streets ........................................................... 50-years
  Thoroughfares, Major and Minor Collector Streets
Minor City Streets ........................................................... 25-years
  Sub collector, Local and Residential Streets

All Street Classifications Over Regulated Floodways ............ 100-years

Street classifications can be obtained by contacting the City of Greensboro Transportation Department.

In compliance with the National Flood Insurance Program, it is necessary to consider the 100-year frequency flood at locations identified as being special flood hazard areas.

## II. ROAD CROSSING CULVERT SITUATIONS ALLOWED

A. General requirements for all road crossing culvert situations:

1. A minimum load bearing capacity of H-20 is required.
2. The minimum invert slope in 0.5%
3. Allowable end conditions are to be used on both upstream and downstream ends of the culverts.
4. Rip rap with filter fabric or other approved energy dissipater will be installed upstream and downstream from ends of the culvert. Rip rap will be placed on the banks of the stream to a height equal to the top of the culvert plus one foot at the inlet and outlet and then taper down to the end of the apron. Energy dissipaters are to be designed according to the acceptable methods as shown in the **North Carolina Erosion and Sedimentation Control Planning and Design Manual**

5. Headwater Elevation shall be limited to avoid damage to upstream property.

6. Ratio of HW/D ≤ 1.2

7. The 100-year flood elevation shall be determined for the designed structure to assure that no structures will be inundated during a 100 year storm.

8. Freeboard for new culverts shall be:

   12” for culverts less than or equal to 3’ in diameter
   18” for culverts over 3’ in diameter

B. Single Barrel Reinforced Concrete Pipe, n = 0.013

   1. Allowable end conditions:

      a) Reinforced Concrete Flared End Sections
      b) Reinforced concrete or masonry endwalls constructed to NCDOT specifications.
      c) The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

   2. The depth of cover will determine class of pipe.

C. Double Barrel Reinforced Concrete Pipe, n = 0.013

   1. Allowable end conditions:

      a) Reinforced concrete or masonry endwalls constructed to NCDOT specifications.
      b) The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

   2. The depth of cover will determine the class of pipe.

D. Single Barrel Corrugated Aluminum Pipe or Pipe-Arch

1. Allowable end conditions:

   a) Step bevel end section at 3:1 slope (minimum slope 2:1 under special conditions) with reinforced concrete toe walls (See section IV).
   b) Reinforced concrete or masonry endwalls constructed to NCDOT specifications.
   c) The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

E. Double Barrel Corrugated Aluminum Pipe or Pipe-Arch

1. Allowable end conditions:

   a) Step bevel end section at 3:1 slope (minimum slope 2:1 under special conditions) with reinforced concrete toe walls (See section IV).
   b) Reinforced concrete or masonry endwalls constructed to NCDOT specifications.
   c) The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

F. Single Barrel Aluminum Structural Plate Pipe and Pipe-Arch

1. Allowable end conditions:

   a) Step bevel end section at 3:1 slope (minimum slope 2:1 under special conditions) with reinforced concrete toe walls (see Section IV).
   b) Reinforced concrete or masonry endwalls constructed to NCDOT specifications.
   c) The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

G. Poured in place concrete box culverts with headwalls and endwalls.

H. Corrugated aluminum box culverts with headwalls and endwalls and adequate toe walls.

I. Precast concrete box culverts with headwalls and endwalls and adequate toe walls.

J. Precast “bottomless” or “three sided” concrete culverts.

**Note: Corrugated steel pipe, regardless of coatings, is no longer allowed in the City of Greensboro Infrastructure. Aluminum Alloy is the only corrugated pipe material allowed in the City’s Storm Conveyance System.**

**Note: Step bevel pipes will require a toe wall for anchorage and a rip rap or concrete slope collar to one foot above the top of pipe. See section IV.**

## III. CORRUGATED PIPE SPECIFICATIONS

A. Only the following corrugated aluminum products will be acceptable:

1. Corrugated aluminum alloy culvert pipe and pipe-arch as described in N.C.D.O.T. Specifications, section 1032-2. n = .024

2. Corrugated aluminum alloy structural plate pipe and pipe-arch as described in N.C.D.O.T. Specifications, section 1032-6. n = .024

## IV. REQUIRED END CONDITIONS ON CORRUGATED ALUMINUM PIPE

A. Corrugated Aluminum pipe installed with a step bevel end section with a slope of 3:1 (maximum 2:1 with special permission)

1. The endwall will include an eight-inch thick toe wall from the top of the step section to three feet below the bottom of the pipe and rest on a properly designed footing. A rip rap slope collar or a six-inch thick concrete slope collar will encompass the remainder of the end section from the toe wall to one foot above the top of pipe.

2. The width of the endwall will be twice the diameter of a round pipe or twice the span of the pipe-arch.

3. The pipe will be anchored into the endwall with anchor bolts spaced twelve inches on center around the circumference of the pipe.

4. All designs shall be prepared and sealed by a professional engineer.

B. Corrugated Aluminum pipe manufactured with a square end:

1. The wingwalls shall be designed in accordance with NCDOT standards and specifications.

2. The designer shall callout the NCDOT standard number for the endwall on the construction plans or include in the construction plans detailed construction drawings sealed and signed by a professional structural engineer.

## V. INSTALLATION OF NON-STANDARD REINFORCED CONCRETE ENDWALLS

A. Endwalls are required on the upstream and downstream ends of roadway culverts.

B. If NCDOT standard endwalls or flared end sections will not work for the project the engineer must submit, with the construction plan set, construction drawings for the endwalls to be used. The plans must show the plan and profile views, necessary section views and details with dimensions and steel layouts. The plans must meet all relevant NCDOT standards and specifications and shall be sealed and signed by a registered professional structural engineer.

C. Any drainage structure that is to become part of the City of Greensboro infrastructure shall be constructed in a manner according to generally accepted reinforced concrete construction practices and all construction shall be acceptable to and approved by the City of Greensboro Engineering Inspections Division.

D. Precast reinforced concrete endwalls will only be allowed if the contractor or engineer submits documentation from the manufacturer to the City of Greensboro Stormwater Management Division or the Engineering Inspector that the endwalls are manufactured to meet all relevant NCDOT standards and specifications. The documentation must be submitted prior to the installation of the endwalls.

# POLICY CONCERNING PIPE MATERIALS ALLOWED WITHIN THE CITY OF GREENSBORO STORM SEWER INFRASTRUCTURE

As of November 1, 2005, the City of Greensboro allows the use of Reinforced Concrete Pipe (RCP) and High Density Polyethylene Pipe (HDPE) within its storm sewer infrastructure.

Material and installation of both materials will be required to meet the standards and specifications set forth in the latest edition of the North Carolina Department of Transportation Standard Specifications for Roads and Structures, Division 3 and Division 10. See the attached sheet showing the installation requirements for both pipe materials.

- Specifically, as stated under sub article 1032-9(B), reinforced concrete pipe shall meet the standards of AASHTO M170.
- Sub article 1032-9(C) - reinforced concrete flared end sections shall meet the standards of AASHTO M170.
- Sub article 1044-7, high density polyethylene pipe shall meet the standards of AASHTO M 294 Type S.

In addition to the NCDOT standards and specifications stated above, the City of Greensboro adds the following requirements for storm sewer installation that will become part of the City's infrastructure:

Both pipe materials will be installed according to NCDOT specifications and guidelines. See sheet three of this policy.

Bell and spigot joints with flexible joint material will be required on reinforced concrete pipe. Bell and spigot joints will be required on HDPE pipe. All HDPE joints will be silt tight and conform to AASHTO M294.

All storm sewer installations will be inspected and approved by City of Greensboro Engineering Inspectors. Their inspection will include horizontal and vertical alignment, proper bedding, backfill compaction and structure construction for both pipe materials.

All storm sewer installations will be warranted by the contractor for a period of one year after being approved and accepted by the inspector.

All storm sewer installations will be designed and installed to prevent the possibility of floating problems.

The last section of the HDPE pipe system that is installed as an outfall to a stream or daylight and is not to be extended in the future, as determined by the City of Greensboro, will terminate with an NCDOT standard reinforced concrete endwall. If a flared end section is to be used, the last run of pipe, from the last drainage structure to the end of the line shall be reinforced concrete pipe with a reinforced concrete flared end section at the outfall.

Reinforced concrete pipe will still be required for driveway culverts. The minimum diameter is 15 inches.

For installations in the roadway, the construction depth over the pipe shall remain in place until the asphalt base course is put in place. For installations outside the right of way, the construction depth shall remain in place until there is no more need for construction traffic.

All storm sewer connections into structures shall be filled with grout and wiped flush on the inside and outside of the structure walls.

On the plan and profile drawings, the engineer shall indicate the pipe material to be used. If he/she wants to bid the project with two pipe material options, the engineer shall callout either RCP or HDPE pipe material and add a note to the plan that the other material can be used as an option. The engineer shall note the material used on the “as-built” drawings before they are submitted to the City.

If both pipe materials are to be used in a development, the contractor shall not change from one material to another material in the middle of a pipe run. Changes in materials shall only be allowed at drainage structures.

GDOT / Stormwater Maintenance being the ultimate owner of the public storm sewer system will be responsible for following these same requirements, except in certain maintenance conditions where they deem necessary, they will be allowed to deviate from these requirements to meet site specific installation requirements at their discretion.

## NCDOT PIPE INSTALLATION GUIDELINES

| | RC PIPE | HDPE PIPE |
|---|---|---|
| Specification Standard | NCDOT RCP | NCDOT HDPE |
| Minimum Cover - Traffic | 12 inches | 12 inches - (under pavement)<br>18 inches - (outside pavement) |
| Minimum Cover - Construction | 36 inches | 36 inches |
| Trench Width - Minimum | OD + 48 inches | OD + 48 inches |
| Bedding Soil Requirements | Class I - Class VI | Class I - Class VI |
| Bedding Thickness - Minimum | 6 inches | 6 inches |
| Bedding Compaction Level | 95% Standard Proctor | 95% Standard Proctor |
| Backfill Soil Requirements - Below Springline | Class I - Class VI | Class I - Class VI |
| Backfill Soil requirements - Above Springline | Class I - Class VI | Class I - Class VI |
| Backfill Height Above Crown | 12 inches | 12 inches |

# BUILDING PERMIT REQUIREMENTS RELATIVE TO OPEN DRAINAGE CHANNELS AND PIPE SYSTEMS

The City of Greensboro is responsible for maintenance of any storm sewer system that carries runoff from public streets or public property. A storm sewer system can be defined as a pipe system or an open channel or ditch that conveys the runoff across a piece of property. In order to perform that responsibility, a certain amount of area parallel to these systems is required for the maintenance of the systems. Therefore, individual building lots, regardless of zoning, having an open stream, channel, ditch or pipe system through which public runoff is passing shall meet the following requirements before a building permit is issued.

## A. Open Channels

A building permit will be issued for a structure adjacent to an open ditch or channel under the following conditions:

1. Adequate setbacks or easements must be provided for the maintenance of the open channels. These setbacks will be the same as easements as stated in the City of Greensboro Subdivision Ordinance.

   Required Setbacks:
   a) 5 cfs to 16 cfs - 30 feet centered on the channel
   b) 17 cfs to 70 cfs - 60 feet centered on the channel
   c) 70 cfs and over - 100 feet plus the width of an adequate trapezoidal channel.
2. The structure cannot be located within the setback or easement area for the drainage system.
3. An open channel or ditch cannot be relocated to comply with (2) above.
4. The finish floor elevation must be in accordance with the flood hazard prevention ordinance.
5. If the lot is located on the upstream side of the street and adjacent to an open channel, the finish floor elevation is to be above the top of curb elevation.
6. If the stream is a perennial stream, the setback must be outside the required stream buffer or the required setback whichever is greater.
7. The open channel or ditch can sometimes be piped to reduce the setback. In some cases on residential single family lots, the City of Greensboro will participate in piping the open ditch contact the Stormwater Management Division at 373-2055 for more details.

## B. Storm Sewer Systems

A building permit will be issued for a structure adjacent to a storm sewer system under the following conditions:

1. Adequate setbacks or easements must be provided for the maintenance of the piped systems. These setbacks will be the same as easements as stated in the City of Greensboro Subdivision Ordinance.

   Required Setbacks:
   a) 15" to 30" pipe - 15' setback centered on the pipe
   b) 36" to 60" pipe - 20' setback centered on the pipe
   c) 66" to 96" pipe - 30' setback centered on the pipe

2. The structure cannot be located within the setback or easement area for the pipe.
3. If there is a conflict between the proposed building and the easement, on the smaller pipes an easement release can be granted as long as the pipe will not be within the zone of influence of the proposed footing.
4. If the pipe must be relocated to accommodate the proposed building, the pipe can be relocated under the following conditions:

   a) The remove and replacement cost will be borne solely by the property owner.
   b) A plan and profile of the proposed relocation will be submitted to the City of Greensboro Engineering Division for review and approval.
   c) The Engineering Division inspectors will inspect the relocation.
   d) No Certificate of Occupancy will be issued on the building until the storm sewer relocation is approved.

5. Footing perimeter drains can be tied into the public storm system. The property owner must apply for a storm sewer permit from the City of Greensboro Stormwater Management Division.

## C. Private Drainage Systems

While the City of Greensboro does not maintain private drainage systems whether they are piped or open channels, the Stormwater Management Division recommends that proposed structures not be constructed over piped systems or close to open channels. If it seems necessary to build over these systems, we recommend that the property owner contact the Building Inspection Department for proper footing requirements in that situation.

# POLICY FOR CULVERTS & BRIDGES IN NEW DEVELOPMENTS

In any new development or subdivision where a proposed street is shown to cross a stream that would require either a concrete box culvert, precast concrete box culvert or precast concrete bottomless culvert or bridge and the street is to be dedicated to the City by plat, the following criteria will be used to determine the percent of participation by the City and the developer. This policy does not apply to reinforced concrete pipe culvert or corrugated metal culvert installations. An executed participation agreement is required prior to the beginning of any construction on the structure.

## I. Case 1 - City Participation - Local Subdivision Streets

A. If the stream crossing is necessary to provide access to portions of the new development and in the judgment of Transportation Department the stream crossing is not necessary in regard to traffic flow for the general public, the City will participate as follows:

1. The developer's engineer will design the structure and submit construction plans to the City for review and approval.
2. The City will inspect construction of the structure.
3. The developer will let the contract and pay the total cost of the structure including all design costs.

B. If in the judgment of the Transportation Department, additional crossings are required to provide adequate traffic circulation within the development, the City will participate as follows:

1. The developer's engineer will design the structure and submit construction plans, the contract proposal, and a cost estimate to the City for review and approval. The developer will let the contract and process progress payments.
2. The City will inspect the construction of the structure.
3. The City will reimburse 60% of the structure cost after the structure has passed final inspection. The developer will be responsible for the remaining 40% of the cost.
4. The developer will bear the entire design cost.

**II. Case 2 - City Participation - Direct access between two (2) existing arterial or collector streets**.

A. If the street is part of a subdivision collector system that will provide, now or in the future, direct access between two (2) arterial streets and the stream crossing is in the best interest of the City's proposed thoroughfare system, the City will participate as follows:

1. The developer's engineer will design the structure and submit construction plans, the contract proposal, and an estimate to the City for review and approval. The developer will let the contract and process progress payments.
2. The City will inspect construction of the structure.
3. The City will reimburse 70% of the construction cost after the structure has passed final inspection.
4. The developer will pay 30% of the structure cost. The developer's 30% is to cover only the width of R/W necessary to serve his development. Example: the City requires 48' of pavement and 70' of R/W. The development requires only 30' of pavement and 50' of R/W. The cost to the developer is 5/7 of the 30% amount.
5. The developer will bear the entire design cost.

**III. Case 3 - City Participation - Indirect access between two (2) existing arterial of collector streets.**

A. If a stream crossing ties two (2) developments together or is an indirect access between two (2) existing proposed arterial of collector streets and the City requires the stream crossing, the following will apply:

1. The developer's engineer will design the structure and submit construction plans, contract proposal, and an estimate to the City for review and approval. The developer will let the contract and process progress payments.
2. The City will inspect construction of the structure.
3. The City will reimburse 60% of the structure cost after the structure has passed final inspection.
4. The developer will pay 40% of the structure cost.
5. The developer will bear the entire design cost.

B. If the City does not require the stream crossing and the developer elects to construct the structure, the following will apply:

1. The developer's engineer will design the structure and submit construction plans to the City for review and approval.
2. The City will inspect the construction of the structure.

3. The developer will let the contract and pay the total cost of the structure including all design costs.

## IV. Case 4 - City Participation - Thoroughfare streets

A. No access

1. If the proposed steam crossing is to be part of the City's proposed thoroughfare system and the developer has no access, The City absorbs the total cost of the structure.

B. Access

If the proposed stream crossing is to be part of the City's proposed thoroughfare system and the developer is allowed access;

1. The developer's engineer will design the structure and submit construction plans, contract proposal, and an estimate to the City for review and approval. The developer will let the contract and process progress payments.
2. The City will inspect construction of the structure.
3. The City will reimburse 70% of the cost after the structure has passed final inspection.
4. The developer will pay 30% of the cost of the structure. The developer's 30% is determined by R/W width that his development needs. Example: The City requires 120' of R/W and the developer needs 50' of R/W, then the developer pays 5/12 of 30% of the structure costs.
5. The developer will bear the entire design costs.

## V. Case 5 - City Participation - Discontinuous street policy

A. When two properties are separated by a drainage way and the City of Greensboro requires a stream crossing, the discontinuous street policy will apply. Properties shall be considered separated when the drainage way and the property line is located in such a manner that no developable property is located between the drainage way and the property line, and the undevelopable property is to be dedicated to the City of Greensboro as Flood Plain and Open Space or as a drainage easement. Street construction involving this policy shall be required in accordance with the following:

1. The property owner subdividing first shall deposit with the City an amount equal to 50% of the two developers' share as determined in cases 1-4. The same will apply for the second developer at the time his property is developed. At the time of

the second subdivision the two developers will equally be responsible for the construction of the culvert. This includes any design and engineering costs. The first deposit along with any accrued interest will be refunded to the first developer for use in the construction of the culvert or bridge.

2. If the structure has not been built or under construction within 5 years from the time of deposit, all deposits and any accrued interest will be refunded to the developer. All refunds will be made on basis of an audit claim filed by the developer seeking reimbursement and he shall be released from all responsibility for future costs incurred from the construction of the structure, unless he shall become the subdivider of the adjacent property in question.
3. Interest will be computed on an annual basis and the rate used will be the average earnings rate for the City during the previous 12 months.
4. Final decision as to whether the culvert will be built at the time of the first or second development will be made by the City Engineering and Inspections Department.

## VI. General Conditions for participation on all types of structures

A. The City will not participate where the proposed crossing would require a pipe size 96 inches in diameter or less based on the minimum hydraulic requirements of the City.

B. The City's participation percentage as specified above pertains to the cost of the structure and direct construction costs only.

C. The developer(s) will be responsible for the entire design cost of the structure.

D. The developer(s) will be responsible for obtaining all local, state and federal permits required for the stream crossing and any associated costs thereto.

E. The developer is responsible for any mitigation costs associated with stream impacts

F. Whenever a deposit of funds is required by the application of case 5, such deposit will be in the form of a Cashier's Check that shall be placed in escrow for the specific use for which the deposit has been required or a Letter of Credit from the developer's bank, or an Administrative Hold on a savings account or Certificate of Deposit. See the appendix for examples of the Letter of Credit and the Administrative Hold.

G. In all instances the City Stormwater Management Division will approve the design of the structure.

H. The developer's engineer shall be responsible for the design of the structure.

I. In all cases the developer's engineer will submit to the City construction plans. In all cases except cases 1A and 3B, the developer's engineer will submit to the City construction plans, contract proposal, and a cost estimate for the review and approval. Upon approval, the developer will let the contract and process progress payments. Contract administration for all cases will be handled by the developer

J. The City of Greensboro Engineering and Inspections Department will inspect construction of the structure.

K. Except in case 5, the subdivision plat will not be approved until the improvements have been completed.

L. Streets shall be required to cross drainageways only where it has been determined by the Planning, Transportation and Engineering and Inspections Department that they are needed to provide an adequate traffic circulation system. The intent of this statement is to indicate that unnecessary crossings, particularly those involving the crossing of a major stream with a minor street, will be kept to a minimum.

M. All structural plans shall be prepared and sealed by a professional engineer.

N. The developer's engineer shall maintain an accurate list of all contract pay quantities. Within ten (10) days after completion of the structure, the developer's engineer shall furnish to the City of Greensboro the itemized list of pay quantities and a certification that these contract pay quantities are correct and were actually used for the construction of the structure.

O. The City reserves the right to inspect any items used for cost determination such as invoices, delivery tickets, etc.

P. Within ninety (90) days after the final inspection and acceptance of the structure, the City will reimburse the developer for the City's portion of the cost of the structure.

Q. Special conditions will be handled on a case per case basis.

## VII. Precast Box Culverts

Precast concrete box culverts will be allowed only if sealed shop drawings are submitted and approved in advance. Precast box culvert structures must be designed to meet the same standards as poured in place concrete box culverts, which include concrete bottoms and the application of headwalls and endwalls. There is a slightly greater expected maintenance cost in precast versus poured in place culverts. Unless the box culvert sections are installed with water tight joints as specified by the manufacturer, the City of Greensboro will participate with the developer at a 20% decrease in the amount of participation on any of the 5 participation cases. The water tight joints are to be shown on the plan and described in the specifications.

## VIII. Precast Concrete "Bottomless" Culverts

Precast Concrete "Bottomless Culverts are those where the precast concrete structure has no floor and the sides are designed to rest on footings outside the stream channel. One advantage of this type culvert is that it can minimize or eliminate impacts to the stream channel. The following conditions must be met to qualify for participation:

A. The precast culvert manufacturer must submit specifications and detailed shop drawings to the City of Greensboro Stormwater Management Division prior to their product being approved for use. They must meet City of Greensboro structural standards.

B. The developer's engineer shall supply required geotechnical information to the manufacturer for footing design.

C. The engineer shall submit hydraulic and hydrologic calculations to the City of Greensboro for approval and to the manufacturer for use in sizing the structure.

D. A stream channel stability analysis by a licensed professional engineer must be submitted to the City. The analysis should include existing and proposed channel conditions, stream velocities through the culvert, proposed scour protection, and water surface elevations. The analysis is to include the channel section through the culvert as well as up and down stream of the culvert. If necessary, the engineer shall indicate how the channel will be stabilized after construction.

E. In order for the City to participate at the levels stated in this policy, the stream channel and overbanks must be shown to be stable through the stream channel stability analysis and preserved during construction OR the developer must use natural stabilization techniques to stabilize the stream. Where the natural stream stabilization option is chosen, a qualified professional must prepare a plan.

F. Where the developer chooses to construct a larger culvert than one required by the City's minimum hydraulic design requirements, the City's level of participation will be based on the estimated construction cost of the culvert sized to meet the City's minimum hydraulic design requirements. For example, if a developer chooses to use a 25 foot span culvert to include a walking trail through the structure, but the minimum span required is only 14 feet to meet the City's hydraulic requirements, the City will base its participation percentage on the estimated construction cost of a 14 foot span. An estimate of the minimum size culvert must be provided to the City for review and approval along with the estimate of the proposed culvert as required in (I) of Subsection VI of this policy.

G. Compliance with stream protection and naturalization procedures will be inspected by the City of Greensboro Stormwater Management Division. The City will include an additional 10% to its participation level as stated in Subsection I, II, III, and IV of this policy. To qualify for the additional 10% participation, the engineer must adhere to Paragraphs D and E of Subsection VIII of this policy.

## Manufacturer Requirements for Precast Concrete Drainage Structures and Structure Tops

October 10, 2007

To: All Precast Concrete Structure Manufacturers, Developers, and Engineers

Re: Policy Concerning Precast Concrete Drainage Structures and Structure Tops

Effective Date: Immediately

The City of Greensboro has standard drawings for all structures that are allowed in the public drainage system. These structures are designed to withstand external forces to maximize the life of the structures and to reduce maintenance costs for the City. These drawings are maintained by the City of Greensboro Engineering Division in a manual titled “Roadway and Utility Standard Drawings” and are available online at the Engineering Division Web Page. All drainage structures used in the City drainage system whether site built or precast are to meet the standards set forth in those drawings.

It has come to light in recent weeks that at least one manufacturer has not been building precast curb inlet tops to standard. For that reason the City of Greensboro finds it necessary to make the following additions to the current standards in respect to Precast Concrete Drainage Structures:

- Company logos are to be stenciled or stamped on the structure or top in at least two locations.
    - The inlet tops are to be stenciled or stamped on the edges and not on the top or bottom of the top.
    - All precast boxes are to be stenciled or stamped on the inside and the outside of the structure.

- Each manufacturer is to submit a letter to the City of Greensboro Stormwater Management Division assuring that their structures and tops are built to City standards and that they warrant the structures and tops against manufacturing defects for a period of five (5) years from the time the City accepts the street for maintenance. The manufacturer will not be held responsible for damage outside normal wear and tear.

The letter should be addressed and sent to:

Kenney McDowell, PE
Stormwater Manager
City of Greensboro
2602 S. Elm-Eugene St
Greensboro, NC 27406

- The City always reserves the right to randomly test supplied materials to verify that they meet City Standards. Any substandard item found will be addressed at the supplier's expense.

Developers are to note that the infrastructure installed in the process of development is the developer's ultimate responsibility. Any part of the infrastructure that is to be taken over by the City is to be built to City standards. Therefore it is incumbent upon the developer to make sure these issues are addressed in all developments. If the inspector determines that a top of structure is substandard it is your responsibility, by working with your contractor and supplier to make the corrections. The inspector will not chase this down. If it is not corrected, the roadway will not be accepted for maintenance.

It should also be apparent that if a manufacturer does not make corrections and a pattern appears that they are not willing to bring their product up to standard, they risk their products being ineligible for use within the City of Greensboro.