BOARD OF COUNTY COMMISSIONERS
ALLEN COUNTY, OHIO

301 N. Main Street, Lima, OH 45801

STORMWATER DESIGN SPECIFICATIONS

Final Adopted Copy

February 1, 2001

TABLE OF CONTENTS

I. STATUTORY AUTHORITY AND TITLE

These Specifications accompany the regulations that have been adopted by the Board of County Commissioners (the “Board”), Allen County, Ohio in accordance with and pursuant to the legal authority of Article XVIII, Section 3 of the Ohio Constitution, Section 307.79 of the Ohio Revised Code, and the Rules of 1501: 15-1-01 and 02 of The Ohio Administrative Code to be administered by a Board appointed agency (“Agency”).

The official title of the regulations are known as the “Allen County Stormwater Management and Sediment Control Regulations” (SMSCR).

This document shall be known as the "Allen County Stormwater Design Specifications" (SDS).

II. PLANNING NEW STORM DRAINAGE FACILITIES

A. The current list of standards to be used in the design of storm drainage is as follows:

1. These regulations, Stormwater Management and Sediment Control Regulations of Allen County, Ohio.

2. Subdivision Regulations of Allen County, Ohio.

3. Standard Construction Drawings, Office of the Allen County Engineer, Allen County, Ohio, (latest revision).

4. Construction & Material Specifications by State of Ohio Department of Transportation, (latest edition).

B. Preparation and approval of plans and specifications:

1. The Board shall require all design plans, quantities, and itemized cost estimates for the stormwater facilities be prepared and stamped by a Registered Professional Engineer or a Registered Landscape Architect when the duties to be performed or the certifications that are to be made are within the powers and authority of a Landscape Architect pursuant to sections 4703.30 to 4703.49 of the Revised Code.

Layout Planning

When planning a new development, various drainage concepts should be evaluated before decisions are made as to site layout and grading, street location and alignments. Plans should be based upon incorporating natural waterways, artificial channels, storm sewers, and other drainage works into the development.

As a part of any SWMSCP, a fundamental study of the drainage pattern of areas contiguous to the development must be made. Tributary flows having a direct effect on the storm sewerage of the proposed site shall be determined and included in the design capacities for storm conduits within the development. A map showing the drainage patterns of the surrounding basin shall be submitted with the Plan. A U.S.G.S. topographical map may be sufficient for this presentation.

Planning the alignment of a storm sewer system should be done in connection with the street layout and grading plan. The location of catch basins, manholes, storm sewer conduits, and drainage channels shall be approved by the Designee. Provisions must be made to accommodate runoff from upstream areas without diversion onto neighboring properties.

System Sizing

All new storm sewer systems must be adequate to convey anticipated runoff of a watershed from a 10-year, 24-hour frequency storm at just full flow. Pressure flows for ten (10) year design storms shall be avoided. The existing outlet must be adequate to accept the additional runoff from the proposed subdivision without overloading. If the existing outlet is inadequate for such additional flow, an improved outlet or some time-release method of discharge (detention), satisfactory to the Designee, must be provided. Stormwater runoff and design criteria for pipe size will be determined from a hydrologic analysis using a method as designated in Section II, Runoff Analysis. The method utilized shall be comparable to the watershed area, which is being evaluated.

Maintenance and Storm Drainage Easements

Where easements will be required for drainage channels or storm sewers, they shall be labeled as such on the site plan and design calculations shall be submitted to conform to Section 3.4 of these regulations.

III. RUNOFF ANALYSIS AND METHODS FOR ESTIMATING RUNOFF

The total watershed that produces stormwater runoff across the site being developed, shall be included when estimating flood discharge runoff. Dependent on watershed size, four principle methods shall be used to estimate design discharge.

1. For small watersheds of 25 acres or less, the design runoff shall be determined by the Rational Method. This method may also be used for catch basin hydrology.

2. For 25 - 50 acres of an urbanizing watershed, the design runoff shall be estimated by using the method as published, Urban Hydrology for Small Watersheds (Technical Release 55, TR55), USDA, Natural Resource Conservation Service. This method may be applicable to areas up to 300 acres depending upon the topography.

3. For watersheds larger than 25 acres draining rural undeveloped land with no significant impervious areas and no existing storm sewers, the design runoff shall be estimated by using the method published in the U.S.G.S. Techniques for Estimating Flood-Peak Discharges of Rural, Unregulated Streams in Ohio (WRI Rep. 89-4126) (computer program available), a replacement of the ODNR Bulletin 45 method.

4. For watersheds larger than 25 acres draining developed land with significant impervious areas (parking lots, roofs), or having existing storm sewers, the design runoff shall be estimated by one of the following:

    a) U.S.G.S. Estimation of Peak-Frequency Relations, Flood Hydrographs, and Volume-Duration-Frequency Relations of Ungaged Small Urban Streams in Ohio (Rep. 93-135).

5. A method approved by the Agency or its Designee.

The Rational Method

The Rational Method for estimating peak runoff utilizes the Rational Formula, Q = C I A, where:

Q = peak runoff rate in cubic feet per second;

C = runoff coefficient corresponding to surface imperviousness;

I = rainfall intensity in inches per hour corresponding to the storm design frequency and time of concentration,

A = area of the watershed tributary to the point under design in acres.

Coefficient of Imperviousness

The following tables list runoff coefficients to be used for assessment calculation of Petitioned Ditch Projects, as well as calculations utilizing the Rational Formula. The selected factor shall reflect the anticipated land use according to the Planning Commission's long range plan. These coefficients are consistent and applicable to all drainage improvements in Allen County. The table lists coefficients for various surfaces that may be used to develop a composite runoff coefficient based on the percentage of different surfaces within a drainage area. The Agency or Designee may require breakdown of acres by land use for evaluation of runoff rates.

The designer should refer to the Soil Survey of Allen County, Ohio, publication by the Ohio Department of Natural Resources for general locations of various soil types in the development area.

Developments on highly permeable soils, such as Spinks and certain Casco and Fox soils, with a permeability rate of six (6) inches per hour or greater, may reduce the imperviousness coefficient on agricultural, open space, and yard areas by 50 percent of the tabulated values.

Runoff Coefficients for Petitioned Ditch Projects (Table 1)

Road R/W		0.80
Railroad		0.35
Agricultural		0.20
Residential	x ⟨2 Ac	0.25
	2 ∃x ⟨ 1	0.30
	x ′1	0.35
Industrial		0.50-0.90
Commercial (Mall)		0.85-0.95
Grass (Parks, etc.)		0.20
Woods (Light to dense underbrush)		0.10-0.30

Values of c, Runoff Coefficient (Table 2)

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, sandy soil	
Flat (2 percent)	0.05 to 0.10
Average (2 to 7 percent)	0.10 to 0.15
Steep (> 7 percent)	0.15 to 0.20
Lawns, heavy soil	
Flat (2 percent)	0.13 to 0.17
Average (2 to 7 percent)	0.18 to 0.22
Steep (> 7 percent)	0.25 to 0.35
Composite c-values:	
Business	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single Family	0.30 to 0.50
Multi-units, detached	0.40 to 0.60
Multi-units, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yards	0.20 to 0.35
Unimproved	0.10 to 0.30

Note: The ranges of c values presented are typical for return periods of 2–10 years. Higher values are appropriate for larger design storms. Suggested multiplier factors for larger design storms are

Storm	Multiplier
25-year	1.15
50-year	1.20
100-year	1.25

Note: Adjusted n-value cannot exceed 1.00.

Table 2 Values of c, runoff coefficient. (Courtesy of ASCE & Water Environmental Federation, Design and Construction of Urban Stormwater Management Systems.)

Rainfall Intensity
The basis for computing rainfall intensity shall be the ten-year rainfall intensity duration curve for the Lima-Allen County area. This curve, relating the expected rainfall intensity in inches per hour, to the storm duration in minutes, is expressed in tabular form on Page 16, and shall be used to estimate design discharges.

The ten-year values can be converted to other recurrence years by applying the following factors:

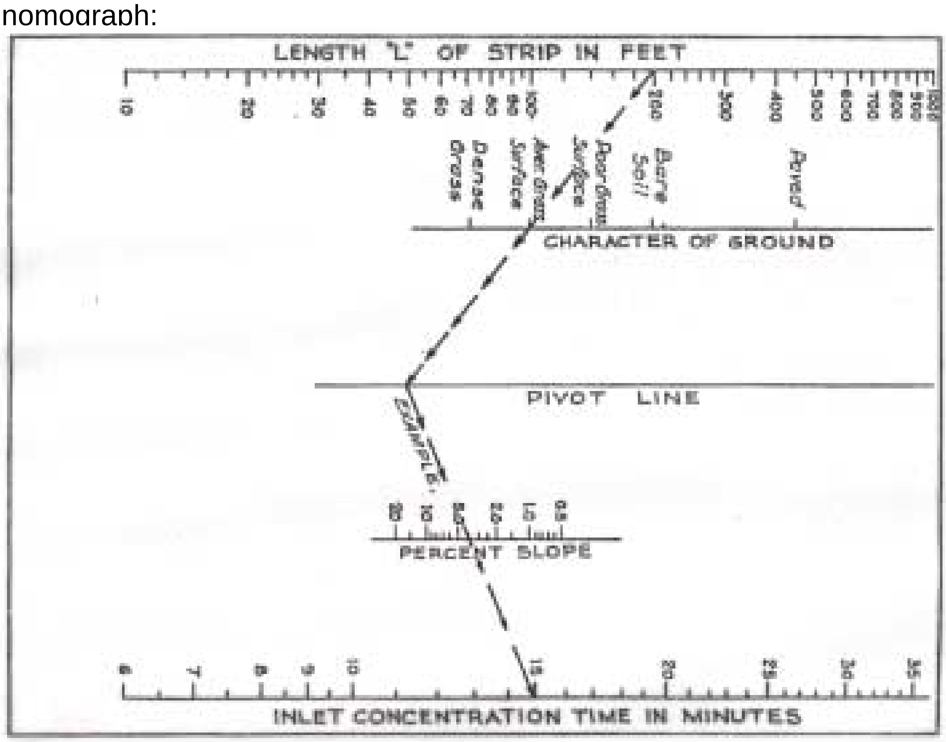
TO CONVERT TO	MULTIPLY TABLE VALUE BY
1 year frequency	0.55
2 year frequency	0.67
5 year frequency	0.86
10 year frequency	1.00
25 year frequency	1.21
50 year frequency	1.43
100 year frequency	1.55

Time of Concentration
One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most remote part of the drainage area under consideration to the design point. The time of concentration determines the average rainfall rate on the rainfall intensity-duration-frequency curve.

For urban storm sewers, the time of concentration consists of an inlet time, or time required for runoff to flow over the surface to the nearest inlet, and time of flow in the sewer to the point under consideration. Inlet time will vary with surface slope, depression storage, surface cover, antecedent rainfall and infiltration capacity of soil, as well as distance of surface flow. Pipe flow time can be calculated by Manning's Formula.

Overland flow paths should not be taken perpendicular to contours on proposed subdivisions since the land will be graded and swales will often intercept the natural contour, conducting water to the street in less time.

Inlet time or the initial time of concentration for overland flows can be estimated from the following nomograph:



Example: Determine the inlet time for an area where runoff from the most remote point must traverse 160 feet of lawn area (C-0.45), the 270 feet in a paved gutter to the point of concentration. Average ground slope is 2 percent and gutter slope of 1.5 percent.

From nomograph:	Time across lawn area	= 11.8 min.
	Gutter time	= <u>6.2 min.</u>
	Total inlet time	= 18.0 min.

U.S.G.S. Techniques for Estimating Flood-Peak Discharges of Rural Unregulated Streams in Ohio (WRI Rep 89-4126) Method

This method is used for computing flood-peak discharges with recurrence intervals between 2 and 100 years and should only be used for unregulated streams with drainage areas between 25 and 6,330 square miles. This method should not be used for areas where flood flows are significantly affected by regulations or there is urban runoff.

Information pertinent to the Lima-Allen County area has been abridged from the Water-Resources Investigations Report 89-4126 (WRI Rep 89-4126) and is included herein. However, since the monitoring of various streams is a continuing effort, the designer should research supplemental sources. He should obtain the most recent data available on stream discharges that may lend application to the area under study.

The regression equations developed for estimating peak flows Q_t for recurrence intervals 2, 5, 10, 25, 50, and 100 years are estimated below:

WRI Rep 89-4126 Method

Q_t = $(RC)\ (CONTDA):^{x}(SLOPE)^{y}(STORAGE+1)^{Z}$ where:

Q_t = Peak discharge in cubic feet per second for the "t" year recurrent interval:

RC = varying regression constants for different year storms for regions A, B, or C in Ohio. Allen County is in region B;

CONTDA = the contributing drainage area in square miles;

SLOPE = Main channel slope in feet per mile (between 1.3 and 500); computed as the difference between the elevations at 10 and 85 percent of the distance along the main channel from a specified location on the channel to the topographic divide, divided by the channel distance between the two points;

STORAGE = The percentage of the contributing drainage area occupied by lakes, ponds, and swamps (not to exceed 13%) as explicitly shown on U. S. Geological Survey 7.5-minute topographic quadrangle maps;

x,y,z, = varying regression exponents for 2, 5, 10, 50, & 100 year storm equations.

The multiple-regression equations are applicable to each of three regions in Ohio, in which Allen County falls in region B. The appropriate regression constants and regression exponents must be selected to estimate a flood-peak discharge for specified recurrence interval at an ungaged site within region B.

Regression Constant and Regression Exponent Characteristics for Allen County

Equation Number	Peak Flow Characteristic (Q_t)	Regression Constant (RC)	Contrib. Drainage Area Exp. (x)	Main Channel Slope Exp. (y)	Storage Exponent (z)
1	Q_2	40.2	0.782	0.172	-0.297
2	Q_5	58.4	0.769	0.221	-0.322
3	Q_{10}	69.3	0.764	0.244	-0.335
4	Q_{25}	82.2	0.760	0.264	-0.347
5	Q_{50}	91.2	0.757	0.276	-0.355
6	Q_{100}	99.7	0.756	0.285	-0.363

EXAMPLES

1. Compute the 100-year peak discharge for a site in Allen County, Ohio

The site characteristics are:

Drainage area	=	66.2 square miles
Slope	=	7.0 feet/mile
Storage	=	0.0%

The equation to use is $Q_t = (RC)(CONTDA)^X(SLOPE)^Y(STORAGE+1)^Z$

$$Q_{100} = 99.7(CONTDA)^{0.756}(SLOPE)^{0.285}(STORAGE+1)^{-0.363}$$
$$= 99.7(66.200)^{0.756}(7.0)^{0.285}(0.0+1)^{-0.363}$$
$$= 99.7 \times 23.80 \times 1.74 \times 1.00$$
$$= 4129 \text{ cubic feet per second}$$

2. The 10-year peak discharge is required for a very small-ungaged area in Sugar Creek Township, Allen County, Ohio.

The site characteristics are:

Drainage area	=	0.29 square miles
Slope	=	9.30 feet/mile
Storage	=	0.5%

$$Q_{10} =69.3(CONTDA)^{0.764}(SLOPE)^{0.244}(STORAGE+1)^{-0.335}$$
$$=69.3(0.292)^{0.764}(9.30)^{0.244}(0.5+1)^{-0.335}$$
$$=69.3 \times 0.390 \times 1.72 \times 0.873$$
$$=41 \text{ cubic feet per second}$$

IV. STORMWATER RUN-OFF CONTROL, ALLOWABLE PEAK RATE AND TOTAL VOLUME

The developer shall analyze the present and post-development runoff conditions, develop the critical year storm for design purposes, and establish adequate storage and outlet structures to accommodate the necessary detention/ retention for the site.

The intent of the stormwater management system is to convey the 10-year, 24-hour developed stormwater runoff from the site through the proposed detention/ retention basin and discharge at the 1-year, 24-hour frequency storm based upon pre-development conditions.

The ability to regulate the stormwater discharge is dependent on the detention/ retention basin volume and the proposed outlet structure. The basin and outlet system shall be analyzed by utilizing one of the following methods:

1. Urban Hydrology for Small Watersheds (Technical Release 55, TR55), USDA, Natural Resource Conservation Service, Dated June 1986.

2. Rational Method, Q=CIA, Manual Calculations.

3. Hydraflow, Computer program by "intelSOLVE", Program is based on the Rational Method.

4. Haestad Methods, POND 2 Software, which includes the US SCS TR55, Urban Hydrology for Small Watersheds.

5. A method approved by the Agency or its Designee.

V. HYDRAULIC DESIGN CRITERIA

Roughness Coefficients

The following coefficients shall be used for Manning's "n":

SURFACE	"n" VALUE
Polyvinyl Chloride (PVC) Sewer Pipe (SDR35)	0.009
Polyvinyl Chloride (PVC)	0.010
Polyethylene Smooth-Flow Ribbed Pipe (HDPE)	0.012
Reinforced concrete pipe, box, or arch	0.013
Clay Tile	0.014
Corrugated metal or aluminum pipe	0.024
Street pavement, concrete, or asphalt	0.015
Concrete or Asphalt line channels	0.015
Gunite channel line	0.016
Rock Channel Protection (Riprap)	0.035
Earth Channel with revetments or gabions	0.035
Earth channel, smoothly graded	0.025
Earth channel, sodded	0.040
Natural stream channel: regular section	
Grass, weeds, and light brush	0.045
Grass, weeds, and heavy brush	0.060

If trees are present in the channel, increase above values by 0.015. If irregular section with pools and channel meander, increase values by 0.015.

Flow Velocities

Minimum pipe velocities shall be three (3) feet per second.

Where pipes outlet into an erodible channel, measures shall be taken to lessen potentially destructive velocities. Erosion control devices such as stilling basins, riprap, or revetments may be required.

The following table list safe or permissible velocities for erodible channels.

CHANNEL MATERIAL	MAXIMUM VELOCITY (Feet Per Second)
Sand or sandy loam	2.5 fps.
Firm loam or silts	3.5 fps.
Clay, fine gravels	5.0 fps.
Shale, hard pans, coarse gravel	6.0 fps.
VEGETAL-LINED CHANNELS (SLOPES TO 5%)	
Alfalfa, crabgrass, lespedeza	3.5 fps.
Grass mixture	5.0 fps.
Kentucky bluegrass, brome, buffalograss	6.0 fps.

VI. DESIGN PROCEDURES

Data

Sufficient data shall be submitted with the construction drawings so the Designee can ascertain the storm sewer design adequacy. Information to be submitted shall include:

1. A map of the area to be sewered having two (2) foot contours. (Minimum scale 1 inch = 200 ft.);

2. A map of the contiguous drainage basin;

3. A layout of the area to be sewered showing existing and proposed improvements, including lot grading;

4. Information regarding anticipated land use;

5. Location and elevation of the outfall point of the storm sewer system. If outletting into an open channel or stream, sufficient information must be provided to substantiate calculations for determining the outlet water surface (hydraulic gradient);

6. Information on existing and proposed utilities, sanitary sewers, or other conflicting substructures;

7. Calculations for the determination of inlet times;

8. A storm sewer hydrology computation sheet (See Sheet E-16). A procedural example, Sheet E-17, and various pipe capacity and velocity charts, Charts E-18, E-20, and E-21 & 22, are included for use with the computation sheet; and,

9. A gutter spread and inlet capacity computation sheet. (See Sheet E-23). A procedural example, Sheets E-24 and E-25, and various flow characteristic and inlet capacity charts, Charts E-26 to E-31, are included for use with the computation sheet.

Alignment

Storm sewers shall be on a constant grade between manholes.

All changes in direction, size, or slope of storm sewers shall be made only at manholes unless unusual conditions warrant the use of a concrete collar. In such cases, approval must be obtained from the County Engineer.

Grades

Storm sewer grades shall provide for a minimum velocity of three (3) feet per second for the design flow.

Grades shall be such that a minimum cover of three (3) feet can be maintained over the top of pipe. Minimum cover beneath roadways shall provide twelve (12) inches between the top of pipe and the bottom of subbase, with higher strength pipe being specified.

Substructure Crossings

Crossings with other major underground sewers and utilities should be on an angle greater than 45 degrees. If insufficient vertical clearance is available, a concrete cradle with or without steel reinforcement may be required. The allowable clearance without special support between storm and sanitary sewers shall be twelve (12) inches.

Manholes
Manhole spacing shall conform to the following table:

PIPE SIZE	MAXIMUM SPACING
15" or less	350 feet
18" or greater	500 feet

The inside diameter of manholes shall conform to the following table:

PIPE SIZE	MANHOLE DIAMETER
24" or less	4 feet
27" to 42"	5 feet

For pipe sizes over 42", manhole details shall be approved by the Agency or Designee.

Materials
Materials for storm sewers and appurtenant structures shall be approved by the Agency and Designee. When alternate types of materials are included for bidding purposes, hydraulic designs must be developed for each alternate material to demonstrate its acceptability.

The designer shall evaluate the trench conditions and pipe loading to determine strength classifications required for various conduits in the design.

Catch Basin Inlets
Catch basin inlets shall be curb opening with gutter grate combinations and shall be approved by the Designee. Any catch basin located outside of curb and gutter shall have flat grates with sufficient opening.

To determine pavement inlet spacing, the design discharge shall be based on the Rational Method using a two-year frequency, 15-minute duration design storm. For the Lima-Allen County area, the expected rainfall intensity for such a storm is 3.1 inches per hour.

The spread of water on the pavement shall be limited to eight (8) feet into the outside traveled lane for the design storm. On continuous grade streets, the maximum depth of flow shall be five (5) inches.

At all intersections, it will be necessary to remove one hundred percent (100%) of pavement flow to eliminate cross street flow. The inlets shall be located at the beginning of the upstream curb return before the crosswalk.

At sag locations, sufficient basins shall be provided to prevent 25-year storm flows from overtopping the street R/W lines. The capacity of grate inlets under sump conditions is presented graphically on page 33.

The maximum spacing between catch basins or from vertical crest point shall be 350 feet on curb and gutter streets and 450 feet on streets with roadside ditches.

Connector Pipes
All catch basin connector pipes shall connect to the main line at manholes unless otherwise approved by the Designee. The connector pipes shall be hydraulically sized to the catch basin capacity. Connector pipes under pavement shall be reinforced concrete pipe or an approved product. Direction changes shall not be designed between structures except where concrete collars may be necessary to avoid major substructure interference. Such designs will require approval.

Culvert Design

All culverts shall be designed with a uniform barrel cross section throughout their length. Location alignment, material specifications, and end treatments, (e.g., headwalls, wingwalls, riprap, apron slabs), shall be approved by the appropriate political subdivision.

The design discharge shall be computed for a 50-year frequency storm either by the appropriate method applicable to drainage area.

All new culvert designs must be of adequate capacity to convey anticipated runoff of a watershed from a fifty (50) year frequency storm at just full flow, using Manning's equation for capacity calculations. Pressure flows for fifty (50) year design storms shall be avoided. Culverts shall meet manufacturer's recommendations for minimum and maximum cover, for bedding, and for backfilling.

Flow line elevations of proposed culverts may be required by the County Engineer to be up to 1.5 feet below the existing ditch flow line, for anticipated ditch clean-outs. Consultation with the Allen County Engineer shall be made to determine the status of any open ditch encountered within the proposed development. The county engineer administers the Permanent Maintenance Program of Petitioned Ditch Projects.

Computation of culvert hydraulics and barrel sizing shall be prepared by a Professional Civil Engineer and shall be reviewed and approved by the appropriate political subdivision.

LIMA-ALLEN COUNTY AREA 10-YEAR RAINFALL INTENSITIES				
Rainfall Duration (Minutes)	**Rainfall Intensity (In./Hr.)**		**Rainfall Duration (Minutes)**	**Rainfall Intensity (In./Hr.)**
6.0 to 6.1	6.4		21.7 to 22.7	3.8
6.2 to 6.4	6.3		22.8 to 23.8	3.7
6.5 to 6.7	6.2		23.9 to 25.0	3.6
6.8 to 7.0	6.1		25.1 to 26.3	3.5
7.1 to 7.3	6.0		26.4 to 27.7	3.4
7.4 to 7.7	5.9		27.8 to 29.2	3.3
7.8 to 8.1	5.8		29.3 to 30.9	3.2
8.2 to 8.6	5.7		31.0 to 32.7	3.1
8.7 to 9.1	5.6		32.8 to 34.7	3.0
9.2 to 9.6	5.5		34.8 to 36.9	2.9
9.7 to 10.1	5.4		37.0 to 39.2	2.8
10.2 to 10.6	5.3		39.3 to 41.7	2.7
10.7 to 11.2	5.2		41.8 to 44.3	2.6
11.3 to 11.8	5.1		44.4 to 47.1	2.5
11.9 to 12.4	5.0		47.2 to 50.1	2.4
12.5 to 13.1	4.9		50.2 to 53.5	2.3
13.2 to 13.8	4.8		53.6 to 57.2	2.2
13.9 to 14.5	4.7		57.3 to 61.4	2.1
14.6 to 15.3	4.6		61.5 to 66.1	2.0
15.4 to 16.1	4.5		66.2 to 71.7	1.9
16.2 to 16.9	4.4		71.8 to 78.3	1.8
17.0 to 17.8	4.3		78.4 to 86.0	1.7
17.9 to 18.7	4.2		86.1 to 95.9	1.6
18.8 to 19.6	4.1		96.0 to 104.1	1.5
19.7 to 20.6	4.0		104.2 to 110.7	1.4
20.7 to 21.6	3.9		110.8 to 121.2	1.3

RATIO OF 20- AND 50-YEAR FLOODS TO MEAN ANNUAL FLOOD IN OHIO								
Drainage Area (acres)	**Frequency**		**Drainage Area (sq. mi.)**	**Frequency**		**Drainage Area (sq. mi.)**	**Frequency**	
	20-Year	**50-Year**		**20-Year**	**50-Year**		**20-Year**	**50-Year**
			0.01	2.85	3.56	10	2.17	2.63
			0.02	2.80	3.50	20	2.12	2.54
			0.03	2.75	3.41	30	2.08	2.50
			0.04	2.72	3.40	40	2.06	2.47
			0.05	2.70	3.35	50	2.04	2.45
6	2.86	3.58	0.06	2.65	3.26	60	2.04	2.44
7	2.85	3.56	0.07	2.63	3.24	70	2.03	2.44
8	2.84	3.55	0.08	2.62	3.22	80	2.02	2.42
9	2.83	3.54	0.09	2.60	3.20	90	2.00	2.40
10	2.82	3.50	0.10	2.58	3.17	100	1.98	2.38
11	2.75	3.41	0.20	2.52	3.12	200	1.94	2.29
12	2.70	3.35	0.30	2.49	3.06	300	1.92	2.27
13	2.64	3.25	0.40	2.45	3.01	400	1.89	2.23
14	2.6	3.20	0.50	2.43	2.99	500	1.87	2.21
15	2.59	3.19	0.60	2.42	2.98	600	1.86	2.19
16	2.58	3.17	0.70	2.41	2.96	700	1.84	2.15
17	2.57	3.16	0.80	2.40	2.95	800	1.83	2.14
18	2.56	3.15	0.90	2.38	2.90	900	1.82	2.13
19	2.55	3.14	1.00	2.37	2.89	1000	1.82	2.13
20	2.49	3.06	2.00	2.30	2.80	2000	1.78	2.08
21	2.45	3.01	3.00	2.26	2.73	3000	1.75	2.03
22	2.42	2.98	4.00	2.24	2.71	4000	1.73	2.01
23	2.40	2.95	5.00	2.23	2.70	5000	1.72	2.00
24	2.38	2.90	6.00	2.22	2.69	6000	1.70	1.97
25	2.37	2.89	7.00	2.20	2.66	7000	1.69	1.96
26	2.35	2.87	8.00	2.19	2.65	8000	1.68	1.95
27	2.34	2.85	9.00	2.18	2.64			
28	2.33	2.84	10.00	2.17	2.63			
29	2.28	2.78						
30	2.24	2.71						
31	2.21	2.67						
32	2.19	2.65						

STORM SEWER COMPUTATION SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Manhole Station	Drainage Area		Time		Rainfall Intensity i	Runoff Coeff. C	ΔCA	ΣCA	Design Q	Pipe Length	Pipe Slope	Pipe Size	Velocity of Flow	Just Full Capacity
	ΔA	ΣA	Δt	Σt										
	Acres	Acres	Min.	Min.	in./hr.		Acres	Acres	cfs	ft.	ft./ft.	in.	fps	cfs

STORM SEWER COMPUTATION SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Manhole Station	Drainage Area		Time		Rainfall Intensity i	Runoff Coef. C	ΔCA	ΣCA	Design Q	Pipe Length	Pipe Slope	Pipe Size	Velocity of Flow	Just Full Capacity
	Δ A	Σ A	Δ t	Σ t										
	Acres	Acres	Min	Min	in./hr.		Acres	Acres	cfs	ft.	ft/ft	in.	fps	cfs
2 + 40	1.2	1.2		13.0	4.9	0.45	0.54	0.54	02.7					
			1.3							300'	0.006	15"	3.8	4.4
5 + 40	2.3	3.5		14.3	4.7	0.70	1.61	2.15	10.1					
			1.0							300'	0.006	21"	5.0	11.1

Column 1: Location of design point.

Column 2 & 3: ΔA = Increment of Area added between last point and this point.
ΣA = Total tributary area to this point.

Column 4 & 5: Δt = Time of flow between last point and this point. After initial time has been established, this is determined from pipe flows; Column 11÷(Column 14 x 60).
Σt = Total Time of flows to this point.

Column 6: From rainfall intensity duration curve (Chart A) corresponding to Σ t.

Column 7: Average runoff coefficient for the incremental area, _ A.

Column 8 & 9: ΔCA = Column 7 x Column 2.
ΣCA = Column 8 + Column 9 of previous line.

Column 10: Q = Σ CA x i; Column 9 x Column 6.

Column 11: Pipe length to next inlet or design point.

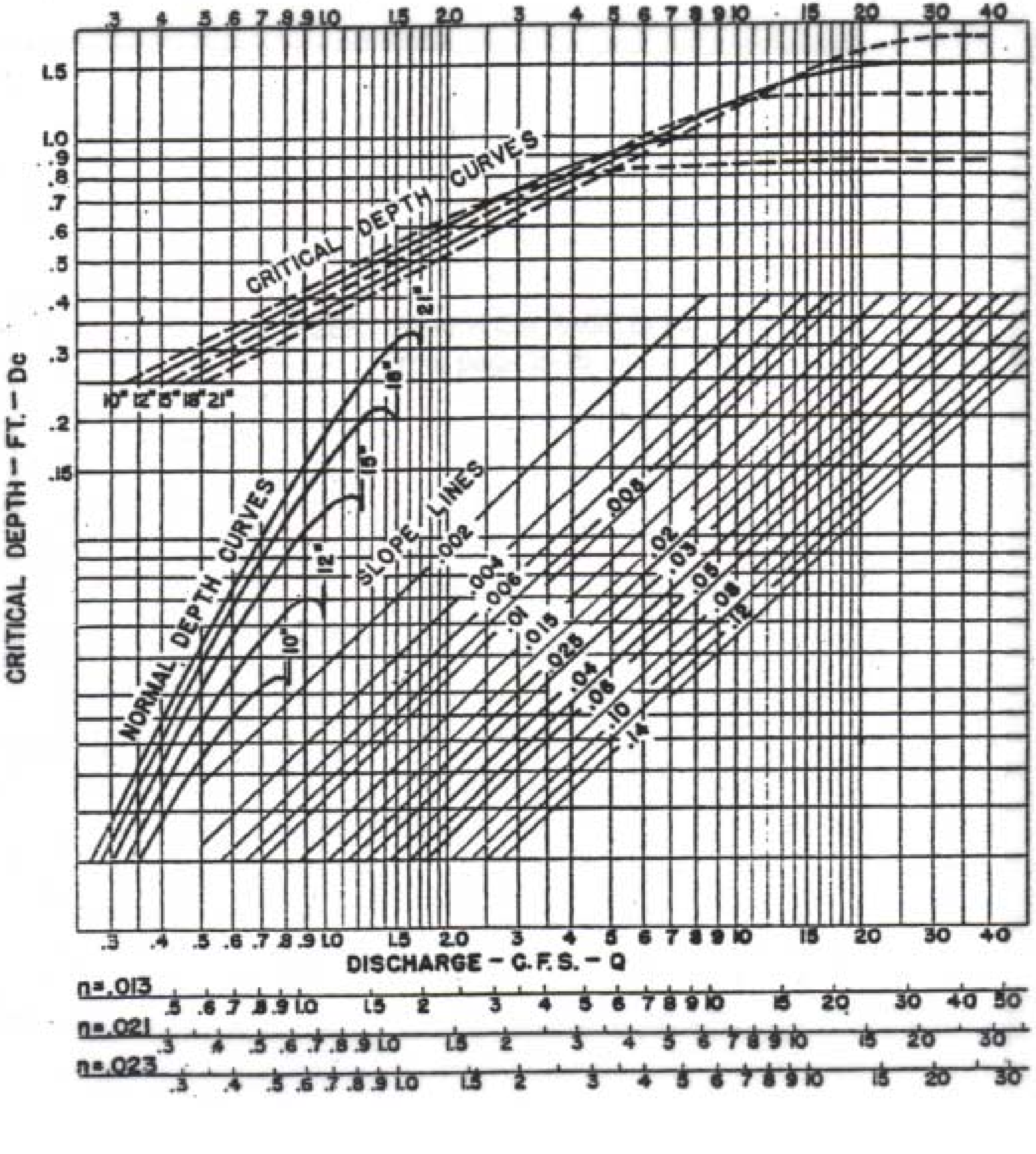
Column 12: Determined from grading plan and street profiles.

Column 13: Compute diameter, in inches, by equation, $d = [(1630 \times Q \times n) \div s^{1/2}]^{-}$, then use next largest manufactured pipe size, or interpolate from capacity charts.

Column 14: Compute by Manning's or interpolate from Pipe Velocity Charts.

Column 15: Compute by Manning's or interpolate from capacity charts.

NORMAL AND CRITICAL DEPTH CHART FOR PIPE CULVERTS
NORMAL DEPTH - FT.-D N=.015



Example: Given a "Q" of 1.0 c.f.s., find Normal and Critical Depths, on the Chart on the previous page, for a 12" concrete pipe, "n"-.015, on a slope of .01. For Normal Depth "D", follow the vertical discharge line marked 1.0 to the intersection of the slope line marked .01. From that point, follow horizontally, intersecting 12" normal depth curve. Thence from that intersection vertically to top of chart, reading a normal depth of 0.39 feet. For Critical Depth "Dc", follow the vertical discharge line marked 1.0 to the intersection of 12" critical depth curve. From that point, follow horizontally to the left margin, reading a critical depth of 0.42 feet.

Normal depth is the depth at which water will flow in a pipe by virtue of its slope and roughness based on Manning's Formula $A=(1.486/n)(R^{2/3})(S^{1.2})$ A.

Critical depth is the depth at which point, the control for determining the headwater changes. Always use n=.015 Discharge Scale to determine critical depth.

Example: Given a “Q” of 70 c.f.s., find the velocity in a 48” concrete pipe on a slope of 0.004.

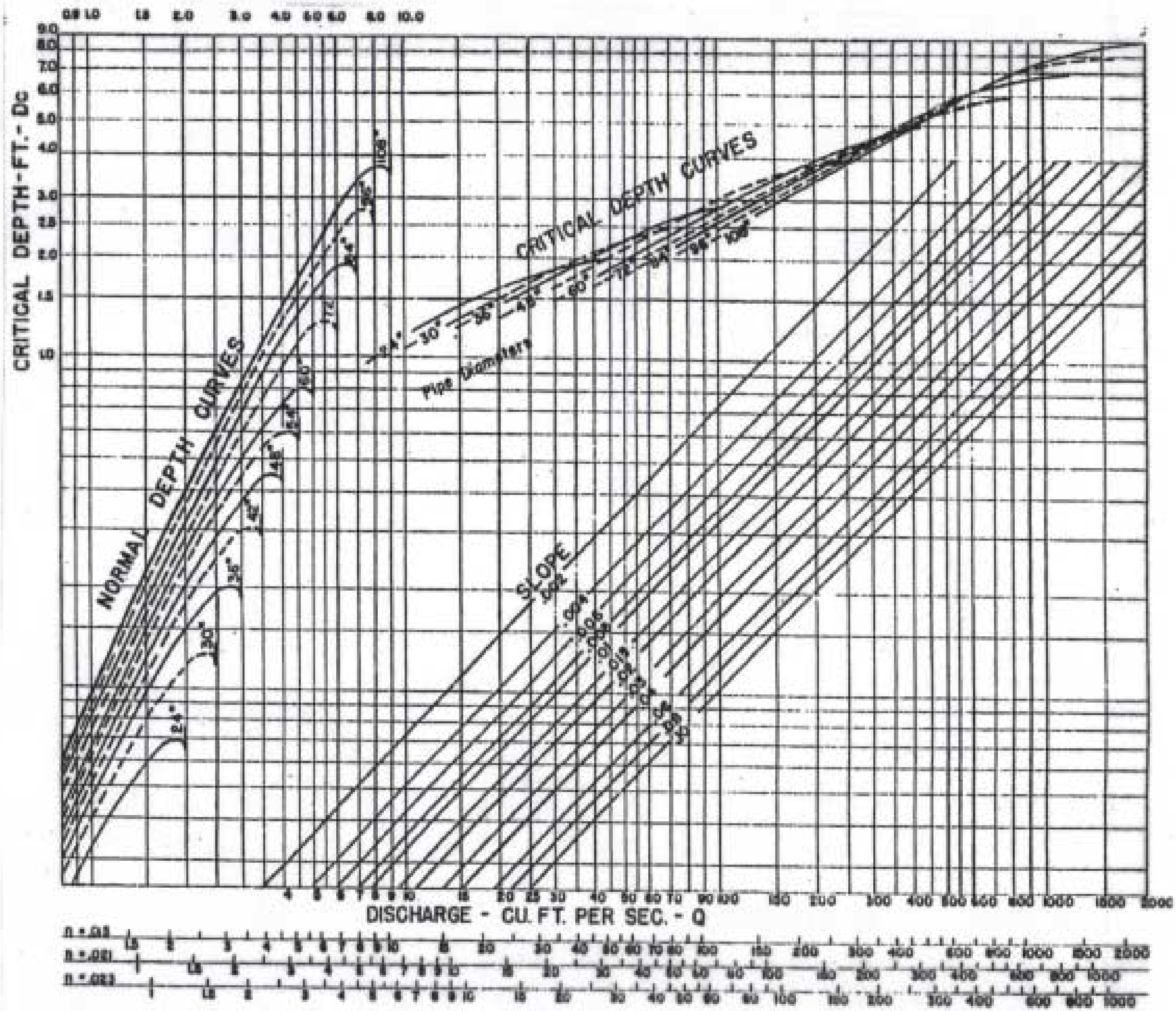
From the Pipe Capacity Curve, the normal depth reads 3.0 feet. Enter Chart C and follow the vertical normal depth line marked 3.0 feet to the 48” curve intercept. From this intersection move horizontally to the left margin reading a velocity of 10 f.p.s. This is the velocity for 100 c.f.s. The velocity, for 70 c.f.s., will equal 10 x (70/100) or 7.0 f.p.s.

NORMAL AND CRITICAL DEPTH CHARTS FOR PIPE CULVERTS
NORMAL DEPTH - FT.-D n=.015

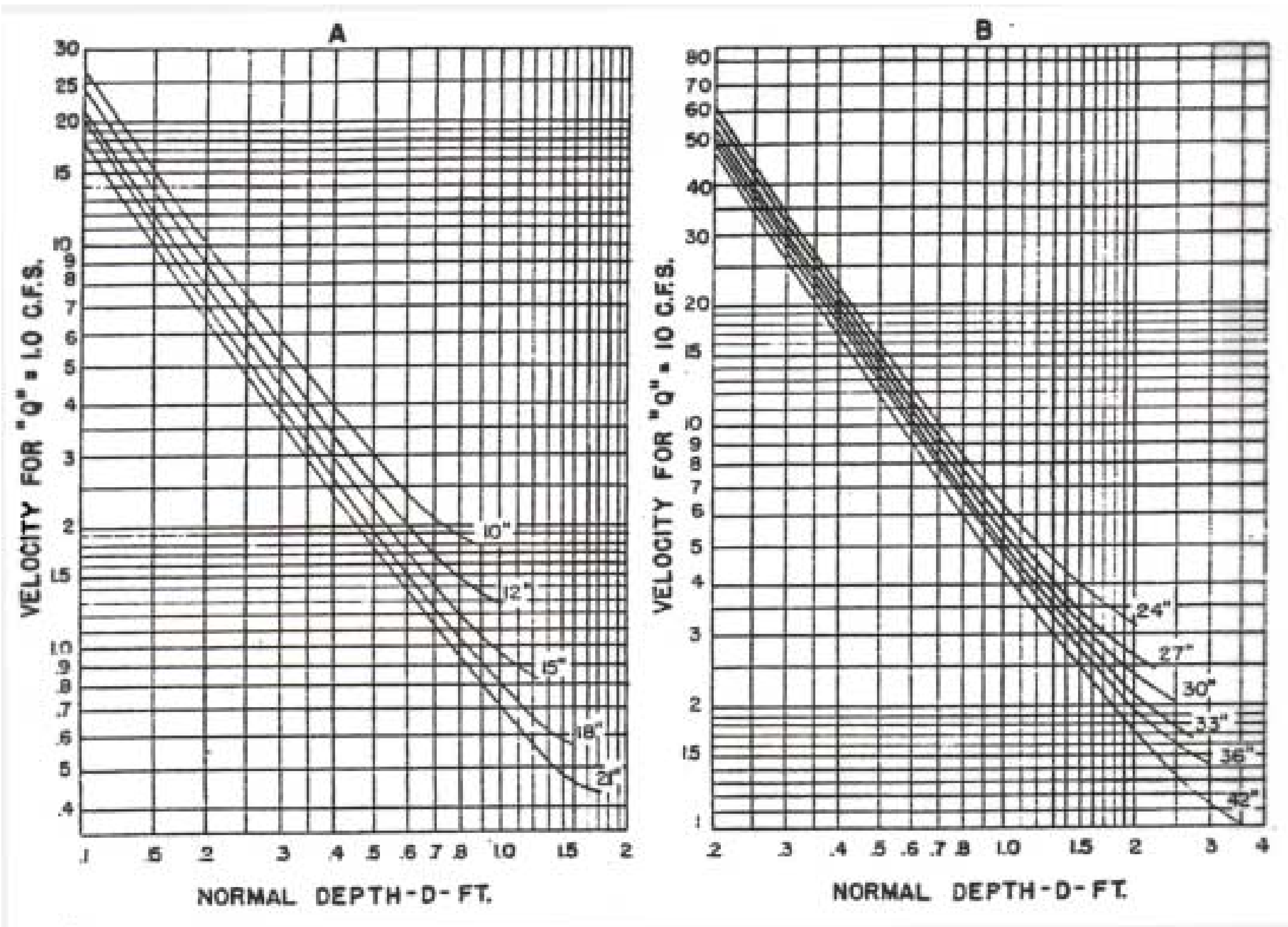
Example: Given a "Q" of 100 cfs, find normal and critical depth for a 48" concrete pipe on a slope of 0.01.

(1) For normal depth, follow the vertical discharge line marked 100 to the intersection of the slope line marked .01. From that point, move horizontally intersecting the 48" normal depth curve. From that intersection, move vertically to the top of chart reading a normal depth of 2.7 feet.

(2) For critical depth, follow the vertical discharge line marked 100 to the intercept of the 48" critical depth curve, thence move horizontally to the left margin reading a critical depth of 3.0 feet.



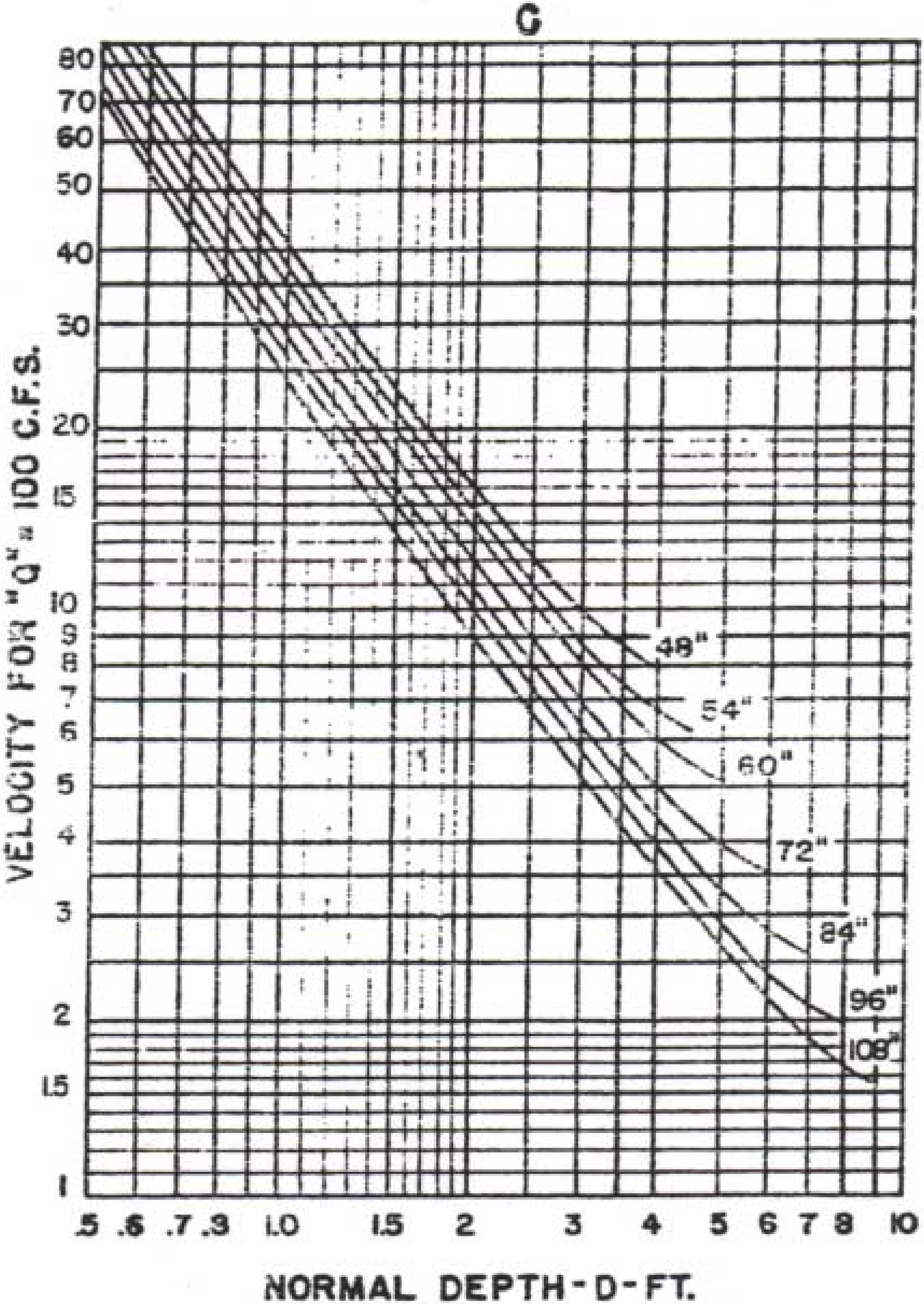
PIPE VELOCITY CURVES



Example: Given a "Q" of 70 c.f.s., find the velocity in a 48" concrete pipe on a slope of 0.004.

From the Pipe Capacity Curve, the normal depth reads 3.0 feet. Enter Chart C and follow the vertical normal depth line marked 3.0 feet to the 48" curve intercept. From this intersection move horizontally to the left margin reading a velocity of 10 f.p.s. This is the velocity for 100 c.f.s. The velocity for 70 c.f.s. will equal 10 x (70/100) or 7.0 f.p.s.

PIPE VELOCITY CURVES



GUTTER SPREAD AND INLET CAPACITY COMPUTATION SHEET

Inlet Hydrology							Depth and Spread				Combined Grate and Curb Inlet															
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
Inlet Location Station (R or L)	Drainage Area Acres	Coefficient of Imperviousness	Rainfall Intensity (3.1 in./hr.)	Runoff to Inlet (c.f.s.)	Previous Inlet By-Pass (c.f.s.)	Total Discharge (c.f.s.)	Street Grade ft./ft.	Cross Slope ft./ft.	Depth at Curb (y)	Spread from curb	Width of Grate (w)	Length of Grate (L)	Width of Flow Outside of Grate	Depth at Outside Edge of Grate (y')	Flow Outside of Grate (c.f.s.)	Flow Over Grate (c.f.s.)	Local Depression (a')	Ratio of Qa' to La'	100% Pick Up Length La'	Ratio of L to La'	Ratio of a' to y'	Ratio of Qb' to Qa'	Flow Over Side of Grate (Qb')	Total Flow Intercepted	Carry Over to Next Flow	Per Cent Pick Up
	A	C	i	cfs	cfs	Qt			ft.	ft.	ft.	ft.	ft.	ft.	Qa'	Qa	ft.		ft.				cfs	cfs	cfs	%

GUTTER SPREAD AND INLET CAPACITY COMPUTATION SHEET

Inlet Hydrology							Depth and Spread				Combined Grate and Curb Inlet															
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.
Inlet Location Station (R or L)	Drainage Area Acres	Coefficient of Imperviousness	Rainfall Intensity (3.1 in./hr.)	Runoff to Inlet (c.f.s.)	Previous Inlet By-Pass (c.f.s.)	Total Discharge (c.f.s.)	Street Grade ft./ft.	Cross Slope ft./ft.	Depth at Curb (y)	Spread from curb	Width of Grate (w)	Length of Grate (L)	Width of Flow Outside of Grate	Depth at Outside Edge of Grate (y')	Flow Outside of Grate (c.f.s.)	Flow Over Grate (c.f.s.)	Local Depression (a')	Ratio of Qa' to La'	100% Pick Up Length La'	Ratio of L to La'	Ratio of a' to y'	Ratio of Qb' to Qa'	Flow Over Side of Grate (Qb)	Total Flow Intercepted	Carry Over to Next Flow	Per Cent Pick Up
	A	C	i	cfs	cfs	Qt			ft.	ft.	ft.	ft.	ft.	ft.	Qa'	Qa	ft.		ft.				cfs	cfs	cfs	%
4+90 R	.90	.45	3.1	1.26		1.26	.011	.0208	.25	5.9	1.4	2.5	4.5	.09	.36	.90	.04	.032	11.3	.22	.43	.36	.13	1.03	.23	82%
8+40 R	.63 .24	.45 .70	3.1 3.1	.88 .52	.23	1.63	in sag					Std.	3A	C.B		Q/P = 1.63/4.74 = 0.34 ; H = 0.24 ; Spread 5.5'										

Column I: Station of inlet. Indicate whether Right (R) or Left (L).

Column 2: Tributary area between previous inlet and this inlet.

Column 3: Average runoff coefficient for the tributary area.

Column 4: Rainfall intensity. For Lima-Allen County Area = 3.1 inches per hour.

Column 5: Overland runoff. Column 2 x Column 3 x Column 4.

Column 6: Over spill from previous inlet. From Column 26 of previous inlet.

Column 7: Total flow to this inlet. Column 5 + Column 6.

Column 8: Longitudinal grade of street. From plan profile.

Column 9: Cross slope of street. From typical section or standard drawings. Convert from inches per foot to feet per foot in Chart G-5.

Column 10: Depth of flow at curb. Interpolate from Flow Curves or Nomograph (Charts G-3, G-4, G-5).

Column 11: Width of flow from curb. Interpolate from Flow Curves or Nomograph (Charts G-3, G-4, G-5).

Column 12 & 13: Width and length of grate. From standard drawing or manufacturer's specifications.

Column 14: Width of flow outside of grade. Column 11 minus Column 12.

Column 15: Depth of flow (y') on the pavement at a point in line with the outer edge of grade. Determine from nomograph G-4.

Column 16: Portion of the total flow flowing on the pavement beyond the outer edge of grate, (Qa'). Determine from nomograph G-4.

Column 17: The portion of the total flow flowing over grating area, (Qa). Column 7 minus Column 16.

Column 18: Depth of the local pavement depression at the outer edge of the grate, (a'). From typical section or standard drawing.

Column 19: The interception per foot of inlet opening if 100% of flow is intercepted, (Qa'/La'). Interpolate from Chart G-6a.

Column 20: Required length of inlet (La') to intercept 100% of flow. Column 16 □ Column 19.

Column 21: Ratio of actual inlet length (L) to 100% interception length (La'). Column 13 Column 20.

Column 22: Ratio of local depression (a') to depth at outside edge of grate (y'). Column 18 Column 15.

Column 23: The proportion of the flow intercepted by grate (Qb'/Qa'). Interpolate from Chart G-6b.

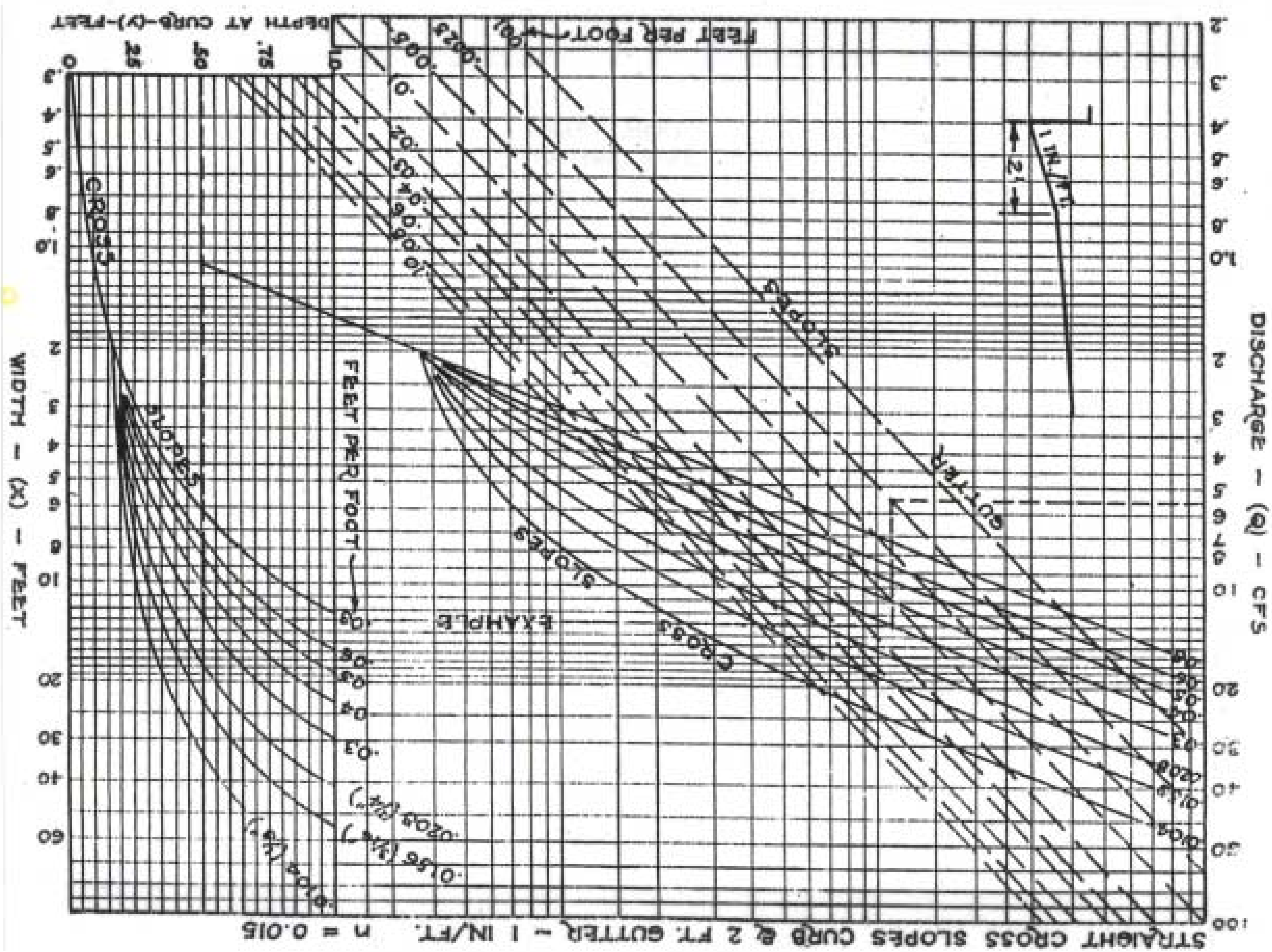
Column 24: Flow intercepted over outside edge of grate. (Qb's) Column 16 x Column 23.

Column 25: Total flow intercepted by this inlet. Column 17 x Column 24.

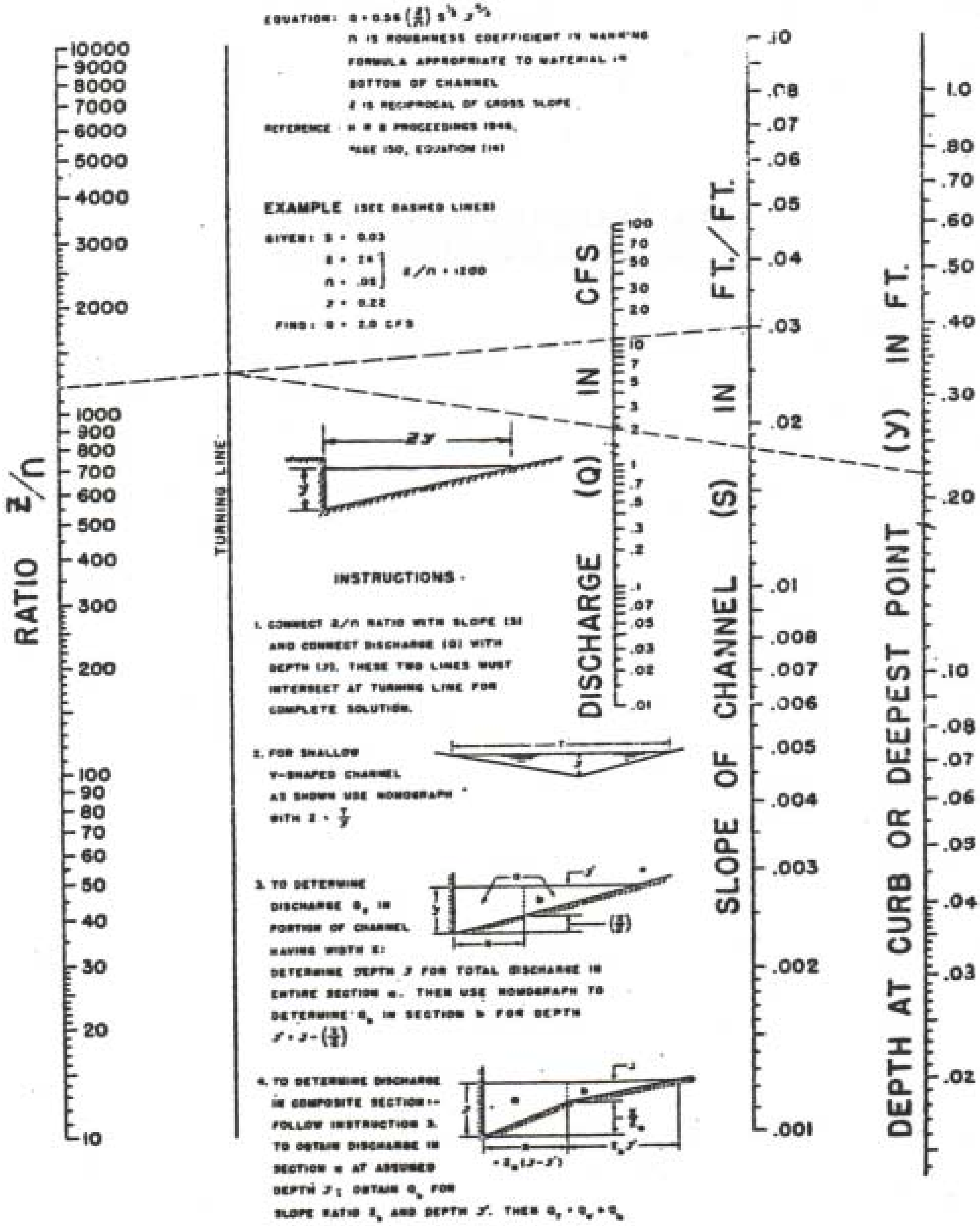
Column 26: Amount of total street flow, that will by-pass this inlet. Column 7 minus Column 25.

Column 27: Percentage of total street flow being intercepted by this inlet. Column 25 Column 7.

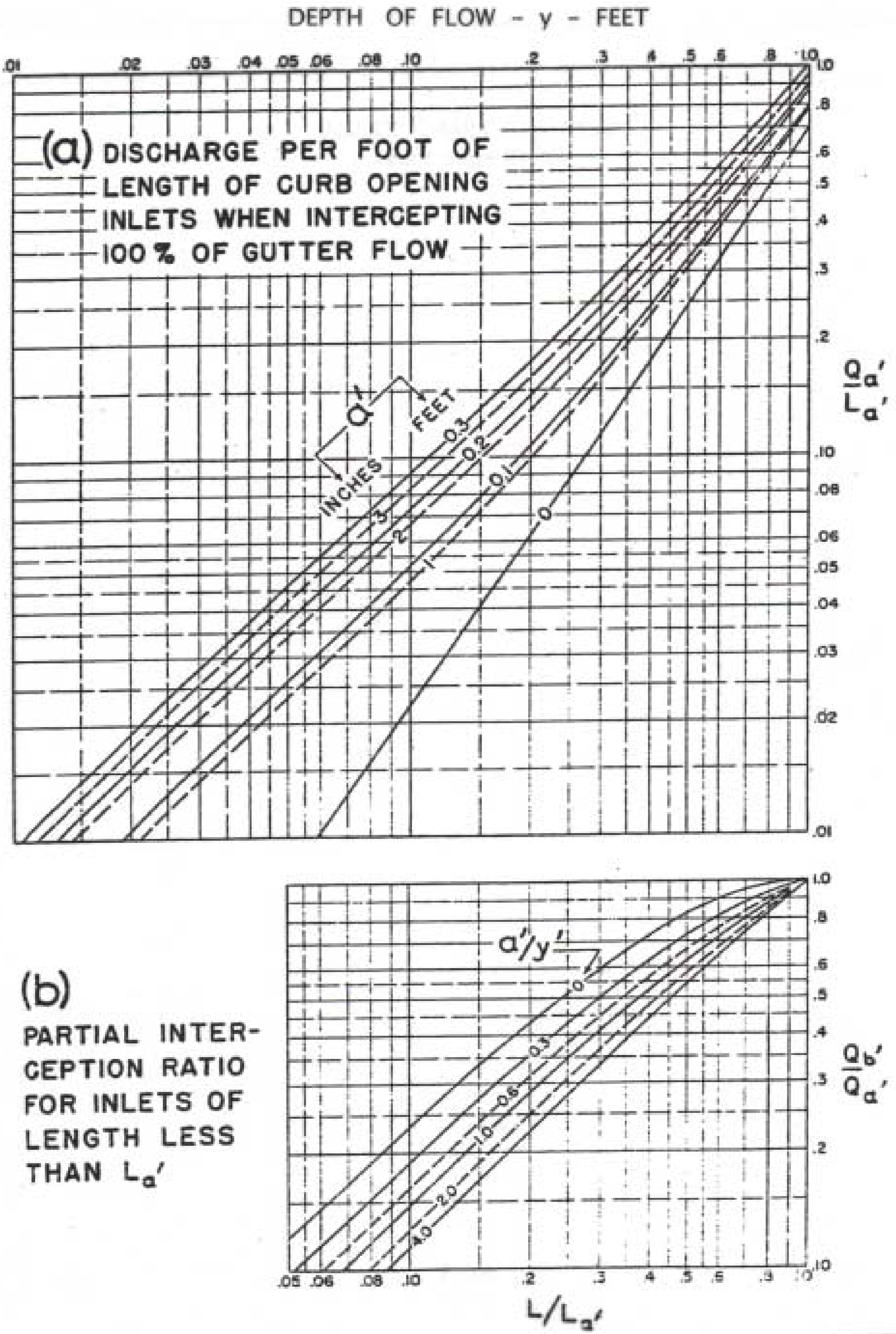
FLOW CHARACTERISTIC CURVES



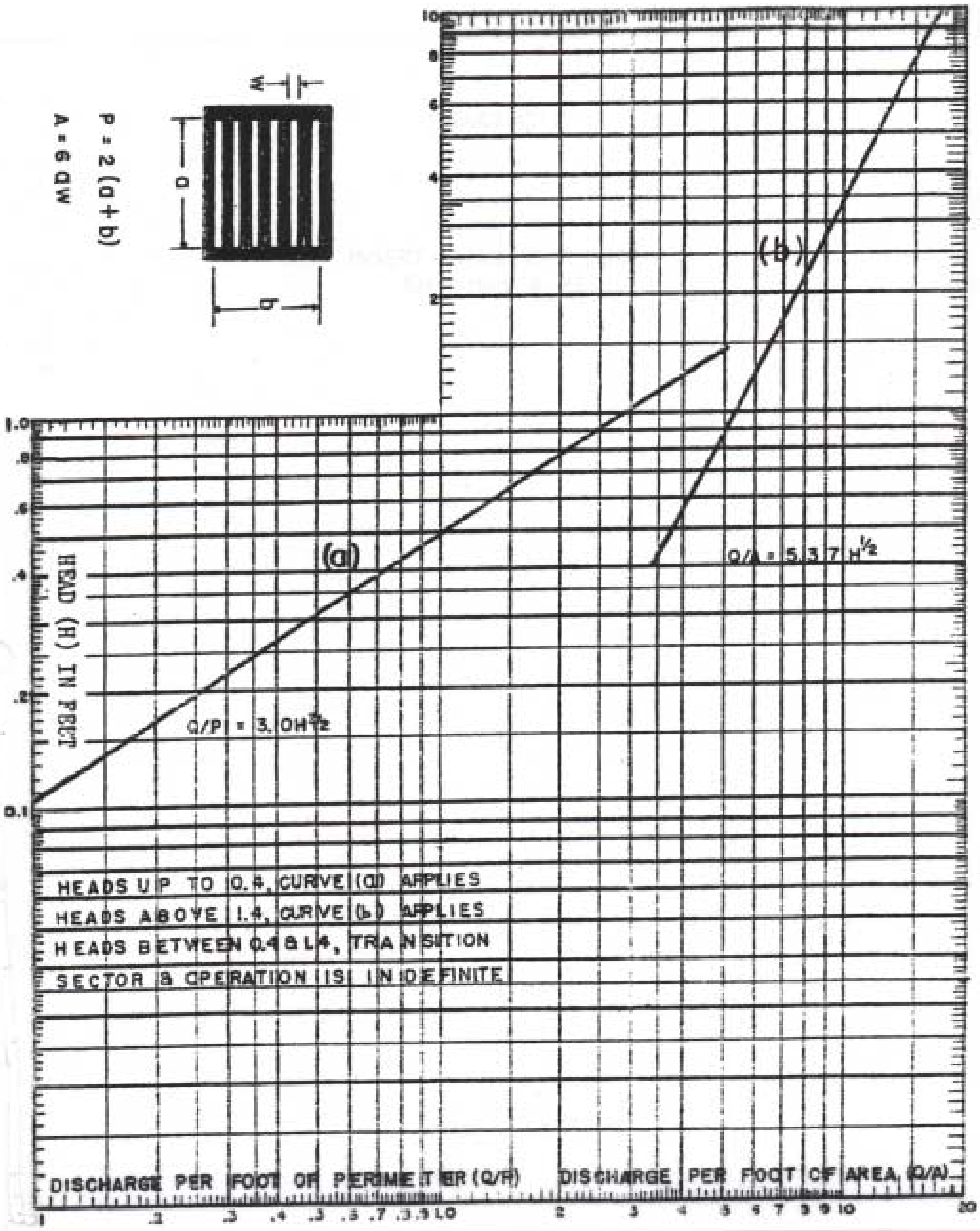
NOMOGRAPH FOR FLOW
IN TRIANGULAR CHANNELS



SLOPE EQUIVALENTS									
in./ft:	**in./ft.**	**ft/ft:**	**z**	**:z/0.015**	**in/ft:**	**in./ft.**	**ft/ft:**	**z**	**:z/0.015**
1/64	.0120	.0010	1000.0	66,666	19/32	.5938	.0495	20.21	1,347
	.0156	.0013	769.2	51,282		.6000	.0500	20.00	1,333
	.0246	.0020	500.0	33,333	5/8	.6250	.0521	19.20	1,282
1/32	.0313	.0026	384.0	25,640	21/32	.6563	.0547	18.29	1,219
	.0360	.0030	333.3	22,220		.6600	.0550	18.18	1,212
	.0480	.0040	250.0	16,666	11/16	.6875	.0573	17.47	1,163
	.0600	.0050	200.0	13,333		.7000	.0583	17.15	1,143
1/16	.0625	.0052	192.0	12,820	23/32	.7188	.0599	16.70	1,112
	.0720	.0060	166.7	11,113		.7200	.0600	16.67	1,111
	.0840	.0070	142.9	9,526	3/4	.7500	.0625	16.00	1,066
3/32	.0938	.0078	128.0	8,546		.7800	.0650	15.38	1,025
	.0960	.0080	125.0	8,333	25/32	.7813	.0651	15.36	1,024
	.1000	.0083	120.5	8,033		.8000	.0666	15.00	1,000
	.1080	.0090	111.1	7,406	13/16	.8125	.0677	14.77	985
	.1200	.0100	100.0	6,666		.8400	.0700	14.28	952
1/8	.1250	.0104	96.00	6,410	27/32	.8438	.0703	14.22	948
	.1320	.0110	90.90	6,060		.8500	.0708	14.12	941
	.1440	.0120	83.33	5,555	7/8	.8750	.0729	13.71	914
5/32	.1563	.0130	76.80	5,128		.9000	.0750	13.33	889
	.1680	.0140	71.43	4,762	29/32	.9063	.0755	13.24	882
	.1800	.0150	66.67	4,445	15/16	.9375	.0781	12.80	853
3/16	.1875	.0156	64.00	4,273		.9500	.0792	12.63	842
	.1920	.0160	62.50	4,167		.9600	.0800	12.50	833
	.2000	.0167	59.88	3,992	31/32	.9688	.0807	12.39	826
	.2040	.0170	58.82	3,921	1	1.000	.0833	12.00	800
	.2160	.0180	55.56	3,704		1.020	.0850	11.76	784
7/32	.2188	.0182	54.86	3,663		1.080	.0900	11.11	741
	.2280	.0190	52.63	3,509		1.140	.0950	10.52	701
	.2400	.0200	50.00	3,333		1.200	.1000	10.00	666
1/4	.2500	.0208	48.00	3,205	2	2.000	.1667	6.000	400
9/32	.2813	.0234	42.67	2,849		2.400	.2000	5.000	333
19/64	.2969	.0247	40.42	2,695		3.000	.2500	4.000	266
	.3000	.0250	40.00	2,667		3.600	.3000	3.333	222
5/16	.3125	.0260	38.40	2,564	4	4.000	.3333	3.000	200
21/64	.3281	.0273	36.57	2,438		4.800	.4000	2.500	166
11/32	.3438	.0286	34.94	2,331	5	5.000	.4167	2.400	160
	.3600	.0300	33.33	2,222	6	6.000	.5000	2.000	133
3/8	.3750	.0313	32.00	2,137	7	7.000	.5833	1.714	115
	.4000	.0333	30.00	2,000		7.200	.6000	1.667	111
13/32	.4063	.0339	29.54	1,967	8	8.000	.6667	1.500	100
	.4200	.0350	28.57	1,905		8.400	.7000	1.428	95
7/16	.4375	.0364	27.43	1,831	9	9.000	.7500	1.333	89
15/32	.4688	.0391	25.60	1,704		9.600	.8000	1.250	83
	.4800	.0400	25.00	1,666	10	10.00	.8333	1.200	80
1/2	.5000	.0417	24.00	1,603		10.80	.9000	1.111	74
17/32	.5313	.0443	22.59	1,505	11	11.00	.9167	1.091	73
	.5400	.0450	22.22	1,481		11.50	.9583	1.044	70
9/16	.5625	.0469	21.33	1,421	12	12.00	1.000	1.000	67



CAPACITY OF CURB OPENING INLETS ON CONTINUOUS GRADE



CAPACITY OF GRATE INLET IN SUMP WATER PONDED ON GRATE