8.0 Streets

8.1 Introduction

Streets are designed to function as transportation corridors. Conveyance of stormwater drainage is a secondary function and must be designed to maintain the safety of the transportation corridor. A second objective of street drainage design is protection of the pavement and subgrade from deterioration due to stormwater runoff.

Streets can be included as parts of both the minor and the major drainage conveyance systems. The street can function as a conveyance corridor as part of the minor drainage system and will quickly remove nuisance flows from the more frequent storm events consistent with the safety criteria for the transportation function of the street. As part of the major drainage system, the street functions as an emergency flow corridor conveying large flows to minimize the damage to the ambient environment.

Street conveyance of stormwater runoff consists of two hydraulic phases. Precipitation impacting the street is directed by street grades as sheet flow into the curb and gutter system or a roadside ditch where runoff is concentrated and conveyed as open channel flow. Depending on the magnitude of the design storm, the curb and gutter or roadside swales may discharge into a storm sewer system or other designated outfall. Streets designed to efficiently convey stormwater runoff can reduce long-term maintenance costs of repairing deterioration caused by surface runoff.

Hydraulic analysis of street conveyance capacity and design of streets as drainage corridors requires determination of the allowable gutter and roadside swale flow capacity. When the allowable capacity is equaled or exceeded, a storm sewer system is required to reduce the storm runoff in the streets to depths in accordance with regulatory criteria governing transportation safety.

8.2 Street Classifications and Allowable Drainage Encroachments

The integration of planning concepts, theoretical design, and long-term maintenance of streets as drainage corridors is consistent with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual, but is organized with reference to street classifications specific for the City of Greenwood Village (Village). Streets within the Village are classified for drainage purposes as local, collector, or arterial streets. The allowable drainage encroachment into the driving lanes becomes more restrictive with increasing transportation capacity, as described in Table 8-1 for both the minor and major storm events.

Table 8-1: Allowable Use of Streets for the Local Drainage System

	Minor Storm Runoff[1]			Major Storm Runoff		
Street Classification	Design Storm (Recurrence Interval) [1]	Maximum theoretical Street Encroachment[2]	Maximum Depth of cross street flow	Design Storm (Recurrence Interval)	Maximum Theoretical Depth [2]	Maximum depth of cross street flow
Local	2-yr or 5-yr	No overtopping of curb or backside of roadside ditch. Flow may spread to crown of street.	6 inches depth in cross pan	100-yr	Residential dwelling, public, commercial, and industrial buildings should be no less than 12" above the 100-yr flood at the ground line, unless buildings are floodproofed. The depth of water at the gutter flowline shall not exceed 12 inches. Drainage easements shall be provided for all areas flooded by the major storm runoff.	18 inches of depth at gutter flowline.
Collector	2-yr or 5-yr	No over topping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	Where cross pans are allowed, depth of flow shall not exceed 6 inches	100-yr	(same as Local)	18 inches of depth at gutter flowline.
Arterial	2-yr or 5-yr	No overtopping of curb or backside of roadside ditch. Flow spread must leave at least a 10-foot width free of water in each direction.	None	100-yr	Residential dwelling, public, commercial, and industrial buildings should be no less than 12" above the 100-yr flood at the ground line, unless buildings are floodproofed. To allow for emergency vehicles, the depth of water shall not exceed the street crown or 12 inches at the gutter flowline. Drainage easement shall be provided for all areas flooded by the major storm runoff.	12 inches or less over crown.[3]

(1) The2-year design storm shall apply to residential areas. The 5-year design storm shall apply to commercial, business, and industrial areas.

(2) The maximum allowable street flow shall be the product of the flow calculated at the "Maximum Theoretical Street Encroachment" and the required correction factor.

(3) Cross street flow is only allowed when the flow in a drainageway exceeds capacity of a road culvert and subsequently overtops the crown of the streets.

8.3 Design Criteria

The hydraulic analysis and design of streets for drainage conveyance shall be in accordance with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

The Village requires grading of property along the edge of streets to minimize flooding of areas beyond the street right-of-way. The initial 15 feet behind a curb must slope towards the street at a minimum 2% grade. For streets with roadside ditches, the ground 15 feet from the edge of the pavement must be 9 inches higher than the elevation of the edge of the pavement.

8.3.1 Curb and Gutter

All curb and gutter designs shall be in accordance with Village standards. Use of other curb and gutter designs requires prior approval by the City Manager or designee.

8.3.2 Roadside Ditches

The Village strongly encourages the use of grass-lined roadside ditches for stormwater conveyance. Roadside ditches shall be designed in accordance with the criteria in this Section.

8.3.2.1 Hydraulic Design Criteria

<u>Conveyance Capacity</u>. Roadside ditches in residential developments shall be designed to convey the 2-year design discharge in accordance with criteria given in Table 8-2. Roadside ditches in non-residential developments shall be designed to convey the 5-year design discharge in accordance with criteria given in Table 8-2. A pipe conveyance system shall be required when the design discharge exceeds the ditch capacity.

<u>Frictional Resistance</u>. The conveyance shall be computed using the Manning roughness coefficient (n) given in Figure 7-1. Maximum flow depths shall be determined using an n-value from Retardance Curve C which represents unmaintained channel conditions. Maximum limiting velocities shall be determined using an n-value from Retardance Curve D which represents maintained channel conditions.

Flow Velocity. Roadside ditches shall conform to the specifications for a Type I ditch shown in Figure 8-1. Use of a Type II or a Type III ditch is discouraged and requires approval by the City Manager or Designee. The maximum allowable velocity as a function of ditch type is presented in Table 8-2 for flood conveyance purposes. Refer to Chapter 16.0 for velocity limits for water quality control purposes.

Table 8-2: Roadside Ditch Capacities [(1) (2) (3)]

	DITCH TYPE I		DITCH TYPE II		DITCH TYPE III	
Slope (%)	VEL (fps)	Q (cfs)	VEL (fps)	Q (cfs)	VEL (fps)	Q (cfs)
0.5	0.7	6	0.7	6	2.8	22
1.0	1.6	14	1.6	14	3.9	31
1.5	2.4	22	2.4	22	4.9	39
2.0	3.2	29	3.2	29	Not Permitted	
2.5	Not Permitted		4.0	36	Not Permitted	

[(1)]Water Resources Consultants, Inc.
[(2)]See Figure 8-1 for geometry of roadside ditch.
[(3)]Velocity and capacity are based upon Figure 7-1 in full flow conditions.

Vertical Alignment. The maximum allowable velocities will limit the longitudinal slope. Drop structures may be required where slopes exceed 2.5%. Steeper longitudinal slopes may be allowed when the ditch is flowing partially full. However, the maximum velocity and Froude numbers shall meet the limits specified in the UDFCD Drainage Criteria Manual.

Horizontal Alignment. The minimum radius of curvature shall be 25 ft.

Freeboard. Freeboard is not required for roadside ditches that conform to the cross sections shown in Figure 8-1.

Driveway Culverts. Driveway culverts in residential developments shall be sized to pass the 2-year design discharge without overtopping of the driveway. Driveway culverts in non-residential developments shall be sized to pass the 5-year design discharge without overtopping of the driveway. The minimum culvert size shall be 12 inch circular pipe, or the equivalent arch pipe, with flared end sections or headwalls.

8.3.2.2 Maintenance Requirements

Roadside ditches shall be designed to minimize long-term maintenance requirements by including design features that minimize deterioration from velocity-induced scour, sediment deposition at low velocity, and ponding of runoff.

Maintenance within public rights-of-way shall be performed by the Village. Maintenance within private street rights-of-way and in drainage easements on private property shall be performed by the owner of the property unless otherwise specified.

8.3.3 Drainage Easements

Drainage easements shall be provided for any areas inundated by the major storm runoff. These easements shall be shown on all drawings and plats.

8.4 Design Procedures

An effective street design integrates both the transportation and drainage functions. The philosophy of the Village is that street drainage design criteria should complement the transportation design criteria. The Village shall review street design projects from the dual perspective of transportation and drainage.

8.4.1 Minor Storm

The theoretical allowable street capacity for minor storm events shall be determined using the Manning Equation that has been modified for triangular gutter flow. A nomograph solution is given in Figure 8-2. A Manning's roughness coefficient (n) of 0.015 shall be used for paved surfaces. The theoretical gutter capacity shall be modified using reduction factors to account for random obstructions to gutter flow.

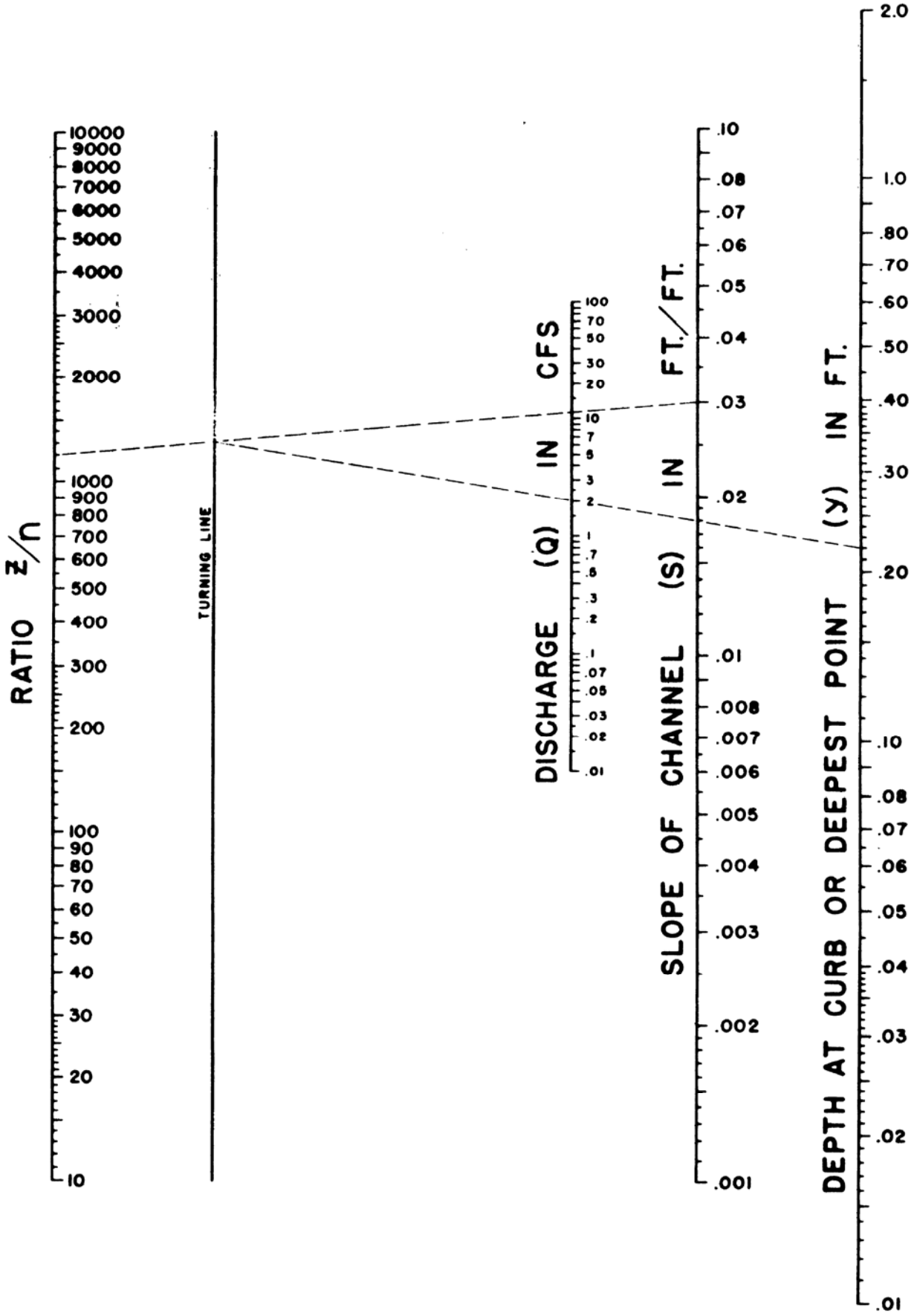
8.4.2 Major Storm

The theoretical allowable street capacity for major storm events is determined by applying the Manning Equation to the composite cross section consisting of the street, sidewalk, landscaped areas, and adjacent structural features that will confine the flow. A composite roughness coefficient (n) shall be derived by weighting the roughness coefficient for each section. A roughness coefficient of 0.015 shall be used for pavement and sidewalk areas, 0.025 for roadside ditches, and 0.050 for uncontrolled landscape areas.

Insert Figures 8-1 and 8-2

8.0 STREETS 1

8.1 INTRODUCTION 1
8.2 STREET CLASSIFICATIONS AND ALLOWABLE DRAINAGE ENCROACHMENTS 1
8.3 DESIGN CRITERIA 3
8.3.1 Curb and Gutter 3
8.3.2 Roadside Ditches 3
8.3.2.1 Hydraulic Design Criteria 3
8.3.2.2 Maintenance Requirements 4
8.3.3 Drainage Easements 5
8.4 DESIGN PROCEDURES 5
8.4.1 Minor Storm 5
8.4.2 Major Storm 5



Greenwood Village
Street Drainage Design
October 2003

Figure 8-2
Nomograph for Flow
In Triangular Gutters
Sheet 1 of 2

FIG 8-2,SHEET1.DWG TIFF:FIG0802.TIF

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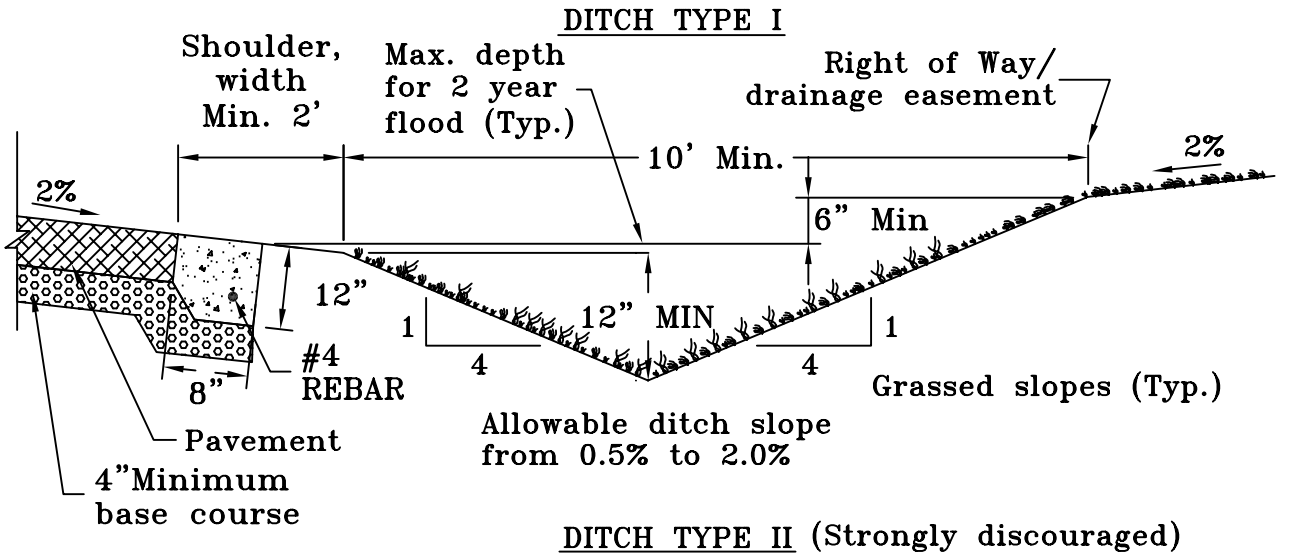
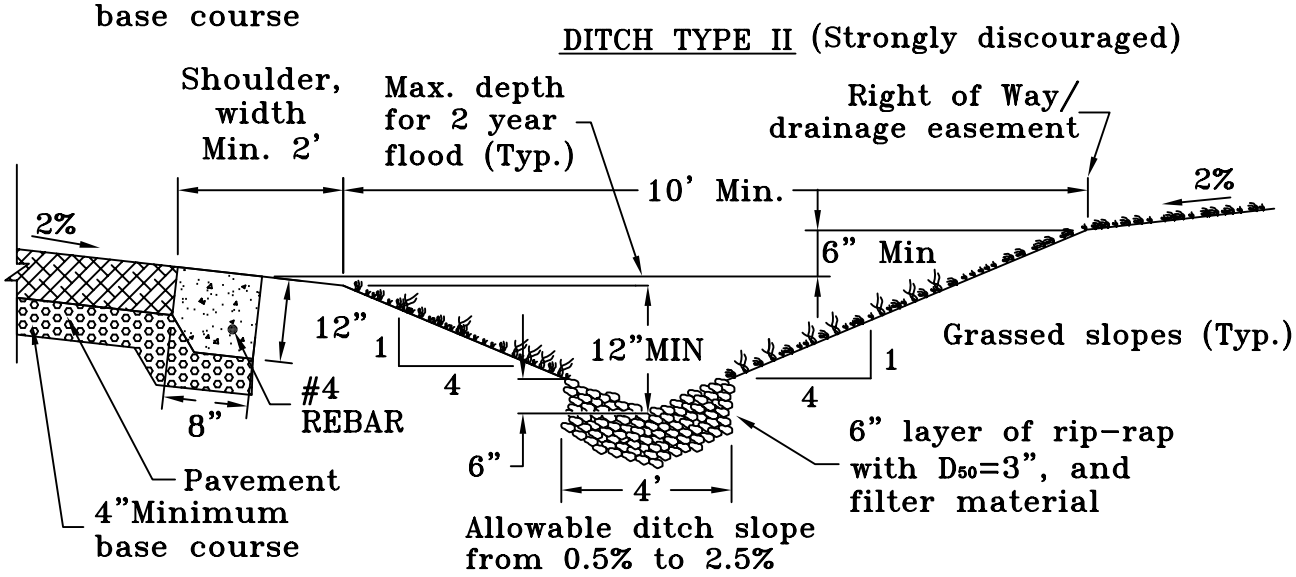
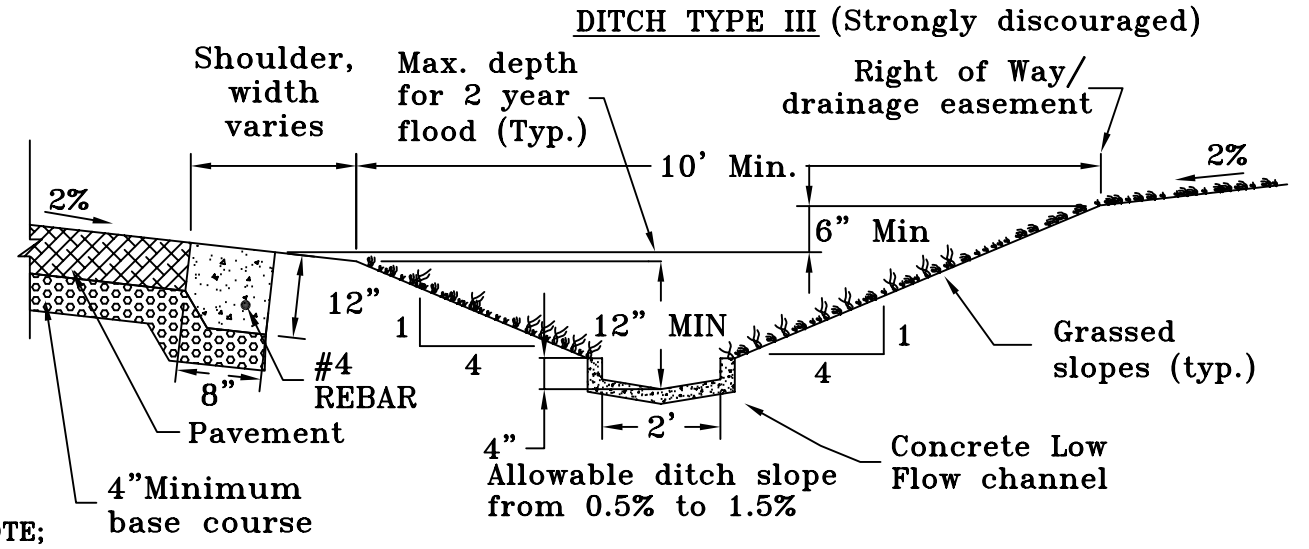






NOTE;

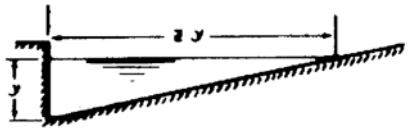
1. For street slopes greater than maximum allowed, landscaped check drops (2 ft maximum height) will be required.

Greenwood Village
Open Channels
October 2003

Figure 8-1
Roadside Ditch Sections
Types I, II, & III

FIG 8-1.dwg

P:\97003\027 Drainage Code Update 2003\Figures\FIG 8-1.dwg, Layout1, 10/15/2003 09:08:23 AM, 1:0.738301



EQUATION: $Q = 0.56\left(\frac{z}{n}\right) S^{1/2}\, y^{8/3}$

n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL

z IS RECIPROCAL OF CROSS SLOPE

REFERENCE: H. R. B. PROCEEDINGS 1946, PAGE 150, EQUATION (14)

EXAMPLE (SEE DASHED LINES)

GIVEN: $S = 0.03$

$z = 24$, $n = .02$; $z/n = 1200$

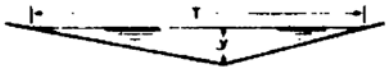
$y = 0.22$

FIND: $Q = 2.0$ CFS

INSTRUCTIONS

1. CONNECT z/n RATIO WITH SLOPE (S) AND CONNECT DISCHARGE (Q) WITH DEPTH (y). THESE TWO LINES MUST INTERSECT AT TURNING LINE FOR COMPLETE SOLUTION.

2. FOR SHALLOW V-SHAPED CHANNEL AS SHOWN USE NOMOGRAPH WITH $z = \frac{T}{y}$



3. TO DETERMINE DISCHARGE Q_x IN PORTION OF CHANNEL HAVING WIDTH X: DETERMINE DEPTH y FOR TOTAL DISCHARGE IN ENTIRE SECTION a. THEN USE NOMOGRAPH TO DETERMINE Q_b IN SECTION b FOR DEPTH $y' = y - \left(\frac{x}{z}\right)$

4. TO DETERMINE DISCHARGE IN COMPOSITE SECTION:- FOLLOW INSTRUCTION 3. TO OBTAIN DISCHARGE IN SECTION a AT ASSUMED DEPTH y; OBTAIN Q_b FOR SLOPE RATIO z_b AND DEPTH y' THEN $Q_T = Q_a + Q_b$

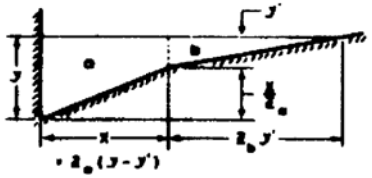


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Figure 8–2
Nomograph for Flow
In Triangular Gutters
Sheet 2 of 2

FIG 8-2,SHEET 2.DWG TIFF:FIG0802.PCX

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