Appendix A
Erosion and Stormwater Runoff Calculations

Introduction

This appendix provides guidance for determining erosion potential and stormwater runoff calculations of peak flow, runoff volume, storage volume, hydraulic performance of outlet device, stage-storage-discharge, and channel geometry. Some of these calculations are also discussed within the text of Volume 1 and Volume 2, so the specific BMP profiles should also be reviewed when determining erosion and stormwater runoff calculations.

Erosion Calculations

Estimated Reduction for Disturbed Site Planning

SHORTCUT Method to evaluating relative changes

For the purposes of planning erosion and sediment control practices for disturbed sites, USLE or any of its forms will provide good qualitative evaluations of the results of practice application. For purposes of planning and evaluating SWPPPs for erosion and sediment control, qualitative evaluations are sufficient; absolute quantified values are not needed (unless having to meet specific TMDLs).

Basic Equation and Computation

The basic equation for USLE and RUSLE is

$$A = R\ K\ L\ S\ C\ P \quad \text{(eq. 1)}$$

where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Hillslope length and steepness
C = Cover-management
P = Support practice

For qualitative evaluative purposes, a specific A is not required. Since R and K will essentially remain constant on a site, equation 1 reduces to

$$Eff = 1 - LS\ C\ P \quad \text{(eq. 2)}$$

where: Eff = relative erosion control efficiency
LS = Hillslope length and steepness
C = Cover-management
P = Support practice

Equation 2 can be used to evaluate a site Eff before disturbance, during disturbance and after restabilization. A disturbed site will be allowed to produce some additional erosion and sediment, but restricted to a controlled amount (e.g. 10 to 15% increase over pre-disturbance condition). Therefore, the allowed Eff is:

$$Eff_{REQD} = 0.87 * Eff_{PRE}$$

where: Eff_{REQD} = relative efficiency required during disturbance
Eff_{PRE} = relative efficiency pre-disturbance
0.87 = allowed erosion and sediment increase during disturbance
(e.g. 15% above predisturbance condition 100/115 = 0.87)

Therefore, the Eff during disturbance must be greater than the Eff required (e.g., 0.87*$\mathbf{Eff_{PRE}}$)

$$\mathbf{Eff_{DIST}} > \mathbf{Eff_{REQD}}, \text{ where } \mathbf{Eff_{REQD}} = 0.87 * \mathbf{Eff_{PRE}}$$

Pre-disturbance evaluation

The site is broken down into sub-units that conform to planned disturbance (e.g., building pads, roads, cut/fill areas, etc.) and allow for erosion estimation and planning on a manageable basis. Location, topography, soil, ground cover and condition, and supporting practices are evaluated for the site, and appropriate RUSLE values are determined for the preexisting site (by subunits, weighted by area).

The management goal may now be set at some level of this value (e.g. 115% of predisturbance erosion). This goal will be met by erosion control measures (C and P factors) including seeding, mulching, sodding, terracing, diversions, silt barriers, etc. Slope steepness and length may change due to site grading and therefore must be evaluated. While RUSLE calculates soil erosion, not sediment delivery (RUSLE2 evaluates sediment delivery), supporting practices within sub-units can be evaluated with P factors. Certainly, controlling the “C” factor on a site is the most critical and manageable condition to controlling soil erosion (no source, no sediment delivery).

The goal is to always KEEP THE SOIL IN PLACE.

If accelerated erosion cannot be prevented, then measures to keep it on site (e.g. sediment traps) become critical and must also be evaluated for sediment-trapping efficiency. Typically, it is more costly to install and maintain sediment-trapping practices than it is to prevent erosion in the first place by managing cover (C).

Disturbance evaluation

The site is broken down into sub-units that conform to disturbance (e.g., building pads, roads, cut/fill areas, etc.). Grading, soil removal/excavation, ground cover and condition, and supporting practices are evaluated for the site, and appropriate RUSLE values are determined for the disturbed site (by subunits, weighted by area). Weighting can also be done over time (C = 1.0 for 30 days, C = 0.10 for 60 days, the C for 90-day disturbance period is C = 0.40).

The evaluated erosion is compared to the management goal (e.g. 115% of predisturbance erosion).

Practices are applied (e.g., mulching, sodding, terracing, diversions, silt barriers, etc.), and the calculation is redone until the applied BMPs achieve the erosion performance goal. If erosion control alone is not sufficient, sediment delivery control and removal must be provided and evaluated for trapping efficiency to demonstrate that the performance goal is met.

Proper installation and maintenance of BMPs is critical to ensure the plan performs as designed.

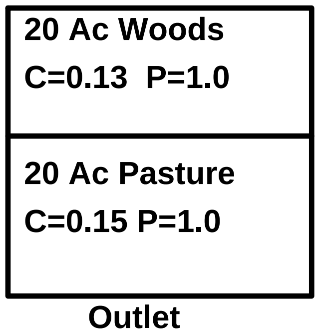
Use of USLE/RUSLE to Evaluate Site performance

$\mathbf{Eff_{DIST}} > \mathbf{Eff_{REQD}}$, where $\mathbf{Eff_{REQD}} = 0.87 * \mathbf{Eff_{PRE}}$

Example of performance-based Sediment and Erosion Control Evaluation

(Efficiency of disturbed site will be allowed to be 115% above pre-disturbance conditions)

Example assumes that LS is constant for the pre-disturbance and disturbance condition (LS = 1); only C&P evaluated.



Before Development

$\mathbf{Eff_{PRE} = 1 - C\ P}$

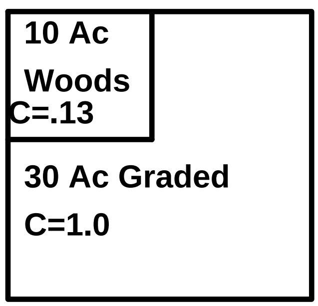
$\mathbf{= 1 - (1.0 * (0.13*20+0.15*20)/40 * 1.0)}$

$\mathbf{= 0.86}$

$\mathbf{Eff_{REQD} = 0.87*EFF_{PRE}}$

$\mathbf{= 0.87*0.86}$

$\mathbf{= 0.75}$



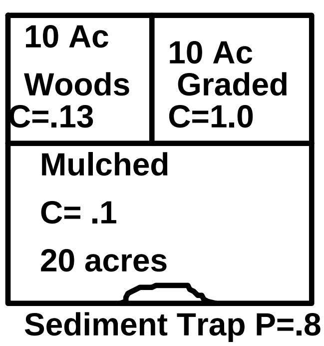
Construction w/o BMPs

$\mathbf{Eff_{DIST} = 1 - C\ P}$

$\mathbf{= 1 - [(0.13*10+1.0*30)/40 * 1.0]}$

$\mathbf{= 0.218 << 0.75}$

This is greater than the allowable 0.161



Construction w/ BMPs, mulch and sediment trap

$\mathbf{Eff_{DIST} = 1 - C\ P}$

$\mathbf{= 1 - [((0.13*10)+(1.0*10)+(20*0.1))/40)*0.8]}$

$\mathbf{= 0.73 < 0.75}$

Construction w/ BMPs Add Silt Fence in graded area, enlarge sediment trap

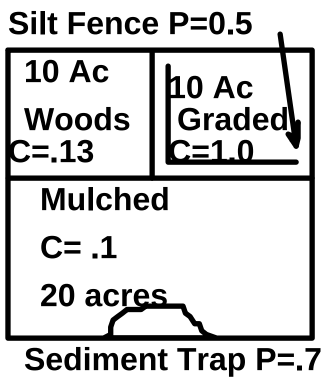
$\mathbf{Eff_{DIST} = LS\ C\ P}$

$\mathbf{= 1 - [((0.13*10)+(1.0*10)*0.5+(20*0.1))/40)*0.7]}$

$\mathbf{=}$

$\mathbf{Eff_{DIST} = 0.85 > 0.75}$

$\mathbf{Eff_{DIST} > Eff_{REQD}}$ **, plan is sufficient**



Examples of possible comparative values of C and P factors

Treatment	C-factor	P-factor	
Bare Soil	1.00	1.00	
Sediment Trap	1.00	0.10-0.90	
Silt Fence	1.00	0.50	LS reduced in some cases
Pavement	0.01	1.00	
Erosion Blankets	0.10-0.30	1.00	
Terraces	1.00	0.10-0.18	LS reduced in some cases
Buffer Strips	1.00	0.60-0.80	LS reduced in some cases

The following tables are from:

Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands
Terrence J. Toy and George R. Foster, Co-editors
Joe R. Galetovic, Publishing Editor
August 1998

The tables are shown for example purposes only. Actual values (C and P) for particular sites and BMPS should be evaluated using the RUSLE (Version 1.06) computer program (available at link below).

http://www.techtransfer.osmre.gov/NTTMainSite/Library/hbmanual/rusle.htm

Table A-1. C factor values for mulch under disturbed-land conditions

Type of Mulch	Gradient (%)	Placed Topsoil	Subsoil	Stripped Topsoil
Straw, 2 tons/acre, 91% cover at placement, 84% cover at 3 months				
	1	0.10	0.10	0.09
	6	0.07	0.08	0.06
	15	0.06	0.08	0.04
	30	0.07	0.10	0.04
	50	0.08	0.11	0.03
Straw, 1 ton/acre. 69% cover at placement, 50% cover at 3 months				
	1	0.24	0.24	0.23
	6	0.18	0.20	0.16
	15	0.18	0.20	0.14
	30	0.18	0.24	0.12
	50	0.20	0.26	0.12
Straw, ½ ton/acre, 36% cover				
	1	0.35	0.35	0.34
	6	0.29	0.31	0.26
	15	0.28	0.32	0.23
	30	0.29	0.35	0.22
	50	0.30	0.38	0.21
Straw, 2 ton s/acre, 20% rock fragment on soil before placement of mulch				
	1	0.09	0.09	0.09
	6	0.06	0.07	0.05
	15	0.06	0.08	0.04
	30	0.06	0.09	0.03
	50	0.07	0.10	0.03
Straw, 1/2 tons/acre, 20 % rock fragment on soil before placement of mulch				
	1	0.24	0.24	0.23
	6	0.18	0.20	0.16
	15	0.18	0.20	0.14
	30	0.18	0.24	0.12
	50	0.20	0.26	0.12
Gravel, 135 tons/acre, 90% cover				
	1	0.08	0.08	0.08
	6	0.05	0.05	0.05
	15	0.04	0.04	0.04
	30	0.03	0.03	0.03
	50	0.03	0.03	0.03

Table A-2. C values for bare soil at construction site

Condition	Practice	Factor
Fill		
	Packed, smooth	1
	Freshly disked	0.95
	Rough (Offset disk)	0.85
Cut		
	Below root zone	0.45
	Scalped surface (some roots remain from sod)	0.15
	Scalped surface (some roots remain from weeds)	0.42

Table A-3. C values for various types of vegetation cover

Type	Production Level (lb/acre)	C-value
Sod (bluegrass)	4000	0.001
Bromegrass	4000	0.002
Weeds		
	2000	0.01
	1000	0.04
	500	0.11
Oats (first four months)	5000 lb/acre at maturity	0.27
	2500 lb/acre at maturity	0.44
Oats (annual)	5000 lb/acre at maturity	0.17

Table A-4. P values for contour furrowing on a 300-ft hillslope with a 10% gradient at Lexington, Kentucky, and hydrologic soil group D (very high runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	1.00	1.00
Moderate (3-4)	0.70	0.95
Very high (>6)	0.41	0.89

Table A-5. P values for contour furrowing on a 300-ft hillslope with a 10% gradient at Denver, Colorado, and hydrologic soil group B (moderate runoff potential).

Ridge Height (inches)	About 50% Cover	Nearly Bare Soil
Very low (0.5-2)	0.66	0.66
Moderate (3-4)	0.42	0.42
Very high (>6)	0.35	0.35

Table A-6. Sediment-delivery ratios for graded terraces on a sandy loam soil with a hillslope length of 300 ft and a 10% gradient at Lexington, Kentucky.

	Soil Loss on Inter-Terrace Interval (tons/acre/year)		
	6 t/ac/yr	**15 t/ac/yr**	**28 t/ac/yr**
Terrace Grade (%)		**SDR**	
0.1	0.20	0.12	0.10
0.2	0.32	0.18	0.13
0.5	0.78	0.36	0.23
0.75	1.00	0.53	0.32
1.0	1.00	0.71	0.42
1.5	1.00	1.00	0.62
2.0	1.00	1.00	0.83
2.5	1.00	1.00	1.00
3.0	1.00	1.00	1.00

Table A-7. Sediment-delivery ratios for graded terraces as a function of soil textures, which determines sediment characteristics based on a hillslope length of 300 ft and a 10% gradient at Lexington, Kentucky. Soil loss on the inter-terrace interval is 6 tons/acre/year.

	Terrace Grade (%)	
	0.1	**0.5**
Soil Texture	**SDR**	
Sand	0.14	0.77
Sandy loam	0.20	0.78
Silt loam	0.32	0.82
Silt	0.43	0.85
Clay	0.25	0.80

Table A-8. Width of pond used to compute P values for sediment-control barriers. Values are given as a percent of hillslope length above the barrier. The width used in RUSLE is the width of the barrier strip, plus the width of the pond obtained from this table.

	Effective width of barrier as a percent of hillslope length			
Hillslope gradient (%)	**Close-growing grasses**	**Straw bales, gravel, filter barriers**	**Stiff-grass hedges**	**Silt fences and berms**
<5	**5**	**8**	**12**	**15**
5-10	**3**	**5**	**8**	**10**
10-15	**2**	**3**	**4**	**5**

Table A-9. Some typical P values for barriers constructed on a silt loam soil at Lexington, Kentucky.

	Structure Type			
Gradient %	**Shortgrass Strip**	**Gravel Bag**	**Stiff Grass Hedge**	**Silt Fence**
<5	0.37	0.21	0.11	0.08
5-10	0.55	0.37	0.21	0.15
10-15	0.67	0.55	0.45	0.37

Table A-10. Sediment-delivery ratios for sediment basins that are well designed, constructed, and maintained with full sediment-storage capacity.

Soil texture	**Sediment delivery ratio**
Sand	0.01
Loamy sand	0.02
Sandy loam	0.03
Loam	0.05
Silt loam	0.06
Silt	0.07
Sandy clay loam	0.06
Clay loam	0.08
Clay loam	0.08
Silty clay loam	0.09
Sandy clay	0.10
Silty clay	0.12
Clay	0.14

As an approximation, the second basin can be assumed to trap only about 10 percent of the sediment from the first basin and that part of the sediment from the intervening area as determined by the sediment-delivery ratio for the soil type of that intervening area.

Table A-11. Effect of concave hillslope segments, sediment-control barriers, and basin sequences on the effectiveness of sediment basins.

Soil texture on upslope area producing sediment	**SDR of concave hillslope or barrier**	**SDR for sediment basin**	**SDR of 2nd sediment basin in series**
Silt loam	0.10	0.47	0.84
	0.50	0.11	0.75
High clay	0.10	0.90	0.90
	0.50	0.33	0.90
High sand	0.10	0.29	0.86
	0.50	0.06	0.84

Note: The values computed by RUSLE for sediment basins assume that the basins are well designed, constructed, and maintained.

Table A-12. Erosion and Sediment Control BMPS, Installed Costs and Effectiveness		
BMP	**Unit Cost Installed**	**Estimated Relative Erosion/Sediment Control Effectiveness (not a C or P factor)**
Erosion Control		
Fertilizer	$450-550 per acre	N/A
Seeding	$870-2170 per acre	50% (after germination)
Stolonizing	$2200 per acre + cost of stolons	90%
Hydraulic Mulching	$900-1200 per acre	50-60%
Compost Application	$900-1200 per acre	40-50%
Straw Mulching	$1800-2100 per acre	90-95%
Soil Binders		
Plant Material-based (Short-term)	$700-900 per acre	80-85%
Plant Material-based (Long-term)	$1200-1500 per acre	60-65%
Polymeric Emulsion Blends	$700-1500 per acre	30-70%
Petroleum Resin-Based	$1200-1500 per acre	25-20%
Cementitious Binder Based	$800-1200 per acre	80-85%
Bonded Fiber Matrices	$5000-6000 per acre	90-95%
Rolled Erosion Control Products		
Biodegradable		
Jute	$6000-7000 per acre	65-70%
Curled Wood Fiber	$8000-10500 per acre	85-90%
Straw	$8000-10500 per acre	85-90%
Wood Fiber	$8000-10500 per acre	85-90%
Coconut Fiber	$13000-14000 per acre	90-95%
Coconut Fiber Net	$30000-33,000 per acre	85-90%
Straw Coconut	$1000--12000 per acre	90-95%
Non-Biodegradable		
Plastic Netting	$2000-2200 per acre	<50%
Plastic Mesh	$3000-3500 per acre	75-80%
Synthetic Fiber w/Netting	$34000-40000 per acre	90-95%
Bonded Synthetic Fibers	$45000-55000 per acre	90-95%
Combination Synthetic and Bidegradable Fibers	$30000-36000 per acre	85-90%
Sediment Control		
Silt Fence	$1.50-2.00 per linear foot	Unknown
Fiber Rolls	$1.50-2.00 per linear foot	58%

Adapted from Table 8-2, IECA, How to Select, Install and Inspect Construction Site Erosion and Sediment Control BMPs for NPDES Storm Water Permit Compliance workbook.
Source: Erosion Control Pilot Study report, USR Greiner Woodward Clyde, June 2000, Table 4-1.

Stormwater Calculations

Stormwater Management Objectives

The objective of BMPs is to minimize the adverse effects of development by mimicking, as closely as possible, the runoff characteristics of the site in its undeveloped state. These characteristics include:

- Moderation of runoff peak flows and volumes to minimize downstream erosion and damage to in-stream aquatic habitat.
- Removal of pollutants such as sediment, nutrients, pathological bacteria and heavy metals.
- Infiltration of rainfall to replenish the water table and provide stable base flow to streams.

The preferred stormwater management approach is to preserve the natural storage, infiltration, and pollutant-treatment functions of each drainage area where practical and, where not practical, to construct BMPs that mimic those natural functions as closely as possible.

Stormwater calculations are required to analyze a proposed new development for its impacts on peak flows and volumes. Table A-13 summarizes the stormwater calculations methods that will be presented in this chapter.

Table A-13
Summary of Stormwater Calculations

Calculation of:	Allowable Methods
Peak Flow	Rational Method
Runoff Volume	Simple Method Discrete SCS Curve Number Method
Storage Volume	Stage-Storage Table
Hydraulic Performance of the Outlet Device	Weir Equations Orifice Equation
Stage-Storage-Discharge	Chainsaw Routing Others: HEC-HMS, WinTR-55, SWIMM
Channel Geometry	Manning Equation

Note: Designers may adopt different calculation methods, but the method chosen must provide equivalent or greater protection than the methods presented here.

Peak Flow Calculations

Peak flow calculations provide assistance in determining attenuation rate comparisons for pre- and post-development flow rates. These calculations are used to compute flow rates from the watershed when designing BMPs such as grassed swales, filter strips, and restored riparian buffers.

A common method that is used to determine peak runoff rate is the Rational Method. The Rational equation is given as:

$$Q = C * I * A$$

Where:

Q = Estimated design discharge (cfs)

C = Composite runoff coefficient (unitless) for the watershed

I = Rainfall intensity (in/hr) for the designated design storm in the geographic region of interest

A = Watershed area (ac)

The composite runoff coefficient reflects the surface characteristics of the contributing watershed. The range of runoff coefficient values varies from 0–1.0, with higher values corresponding to greater runoff rate potential. The runoff coefficient is determined by estimating the area of different land uses within each drainage area. Table A-14 presents values of runoff coefficients for various pervious and impervious surfaces. The Rational Method is most applicable to drainage areas approximately 20 acres or less.

Table A-14

Rational runoff coefficients (ASCE, 1975; Viessman and Lewis, 1996; and Malcom, 1999)

Description of Surface	**Rational Runoff Coefficients, C**
Unimproved Areas	0.35
Asphalt	0.95
Concrete	0.95
Brick	0.85
Roofs, inclined	1.00
Roofs, flat	0.90
Lawns, sandy soil, flat (<2%)	0.10
Lawns, sandy soil, average (2-7%)	0.15
Lawns, sandy soil, steep (>7%)	0.20
Lawns, heavy soil, flat (<2%)	0.15
Lawns, heavy soil, average (2-5%)	0.20
Lawns, heavy soil, steep (>7%)	0.30
Wooded areas	0.15

The appropriate value for ***I***, precipitation intensity in inches per hour, can be obtained from the NOAA Web site at: http://hdsc.nws.noaa.gov/hdsc/pfds/. This Web site provides precipitation intensity information.

The requirements of the applicable stormwater program will determine the appropriate values for ARI and storm duration. If the design is for a level spreader that is receiving runoff directly from the drainage area, the value for ***I*** should simply be one inch per hour (more information on level spreader design in Chapter 4 of Volume 1).

Runoff Volume

Some stormwater programs have a volume control requirement—that is, capturing the first 1 or 1.5 inches of stormwater and retaining it for 2 to 5 days. There are two primary methods that can be used to determine the volume of runoff from a given design storm: the Simple Method and the discrete SCS Curve Number Method. Both of these methods are intended for use at the scale of a single drainage area. Stormwater BMPs shall be designed to treat a volume that is at least as large as the volume calculated using the Simple Method. If the SCS Method yields a greater volume, then it can also be used.

Simple Method

The Simple Method uses a minimal amount of information such as watershed drainage area, impervious area, and design storm depth to estimate the volume of runoff. The Simple Method was developed by measuring the runoff from many watersheds with known impervious areas and curve-fitting a relationship between percent imperviousness and the fraction of rainfall converted to runoff (the runoff coefficient). This relationship is presented below:

$$R_V = 0.05 + 0.9 * I_A$$

Where:

R_V = Runoff coefficient [storm runoff (in)/storm rainfall (in)], unitless

I_A = Impervious fraction [impervious portion of drainage area (ac)/ drainage area (ac)], unitless

Once the runoff coefficient is determined, the volume of runoff that must be controlled is given by the equation below:

$$V = 3630 * R_D * R_v * A$$

Where:

V = Volume of runoff that must be controlled for the design storm (ft^3)

R_D = Design storm rainfall depth (in) *(Typically, 1.0” or 1.5”)*

A = Watershed area (ac)

Discrete SCS Curve Number Method

The SCS method (U.S. Soil Conservation Service, 1985; 1986) is an alternative method for calculating the volume of stormwater runoff that is generated from a given amount of rainfall.

It may only be used when the site design is a Low Impact Development (LID). http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17541.wba

The SCS runoff equation is given below:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad \mathbf{Q^* =}$$

Where: Q^* = Runoff depth (in)

P = Rainfall depth (in)
S = Potential maximum retention after rainfall begins (in)

Note: Equation applies only when P > 0.25

S is related to the soil and surface characteristics of the drainage area through the curve number (CN) by the following equation:

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

Where: CN is the curve number, unitless.

The curve number, CN, describes the characteristics of the drainage area that determine the amount of runoff generated by a given storm: hydrologic soil group and ground cover. Soils are classified into four hydrologic soil groups (A, B, C, and D) based on their minimum infiltration rate, with A having the highest infiltration potential and D having the lowest. The four soil groups are summarized in Table A-15.

The required treatment volume is determined by multiplying the runoff depth (Q*) by the drainage area.

Table A-15

Four Hydrologic Soil Groups as Defined by the U.S. SCS (1986)

Group A	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). The textures of these soils are typically sand, loamy sand, or sandy loam.
Group B	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). The textures of these soils are typically silt loam or loam.
Group C	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). The texture of these soils is typically sandy clay loam.
Group D	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). The textures of these soils are typically clay loam, silty clay loam, sandy clay, silty clay, or clay.

Soils information for previously undisturbed sites can be obtained from a soil survey if one has been published for the county by the Natural Resource Conservation Service. This information is available from the online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/). The texture may be determined by soil analysis or from the local soil survey.

The type of ground cover at a given site greatly affects the volume of runoff. Undisturbed natural areas, such as woods and brush, have high infiltration potentials whereas impervious surfaces, such as parking lots and roofs, will not infiltrate runoff at all. The ground surface can vary extensively, particularly in urban areas, and Table A-16 lists appropriate curve numbers for most urban land use types according to hydrologic soil group. Land use maps, site plans, and field reconnaissance are all effective methods for determining the ground cover.

Table A-16

Runoff curve numbers in urban areas for the SCS method (U.S. SCS, 1986)

Cover Description	**Curve Numbers for Hydrologic Soil Group**			
Fully developed urban areas	A	B	C	D
Open Space (lawns, parks, golf courses, etc.)				
Poor condition (< 50% grass cover)	68	79	86	89
Fair condition (50% to 75% grass cover)	49	69	79	84
Good condition (> 75% grass cover)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Streets and roads:				
Paved; curbs and storm sewers	98	98	98	98
Paved; open ditches	83	89	98	98
Gravel	76	85	89	91
Dirt	72	82	85	88
Developing urban areas				
Newly graded areas	77	86	91	94
Pasture (< 50% ground cover or heavily grazed)	68	79	86	89
Pasture (50% to 75% ground cover or not heavily grazed)	49	69	79	84
Pasture (>75% ground cover or lightly grazed)	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay	30	58	71	78
Brush (< 50% ground cover)	48	67	77	83
Brush (50% to 75% ground cover)	35	56	70	77
Brush (>75% ground cover)	30	48	65	73
Woods (Forest litter, small trees, and brush destroyed by heavy grazing or regular burning)	45	66	77	83
Woods (Woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Woods (Woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77

Most drainage areas include a combination of land uses. The SCS Curve Number Model should be applied separately: once for areas where impervious cover is directly connected to surface water via a swale or pipe, and a second time for the remainder of the site. The runoff volumes computed from each of these computations should be added to determine the runoff volume for the entire site.

For the portion of the site that is ***not*** directly connected impervious surface, a composite curve number can be determined to apply in the SCS Curve Number Model. The composite curve number must be area-weighted based on the distribution of land uses at the site. Runoff from impervious areas that is allowed to flow over pervious areas has the potential to infiltrate into the soil (for example, where roof downspouts are diffused over a lawn). Disconnected impervious areas produce less runoff than impervious areas that are directly connected to a storm drainage system.

Table A-17

How to apply the SCS Curve Number Method

Step 1.	Divide the drainage area into land uses and assign an appropriate CN to each one (see Table A-16).
Step 2.	Compute Q* for any impervious surfaces that are directly linked to surface waters via a swale or pipe. Find the runoff volume from the directly connected impervious surfaces by multiplying Q* times the area of the directly connected impervious surfaces.
Step 3.	Composite a curve number for the remainder of the site by using a weighted average. If the composite CN is equal to or below 64, assume that there is no runoff resulting from either the 1 or 1½ inch storm. If the composite CN is above 64, compute Q* for this area. Find the runoff volume from the remainder of the site by multiplying Q* times the area of the remainder of the site.
Step 4.	Find the runoff volume from the whole site by adding the results of Step 2 and Step 3.

Storage Volume

Volume control is typically provided through detention structures with volume above the water operating level and below the required freeboard. Some BMPs do not have the capability to provide this volume control due to their design, and others can include storage volume within the media of the BMP. Each individual BMP chapter discusses the specific calculations for meeting the volume control requirements. However, since many of the BMPs use storage volume in a detention structure, this section will discuss an acceptable method of calculating that volume.

Storage volume within a detention structure shall be calculated using a stage-storage method. A table shall be provided showing incremental elevations of the BMP with square footage values at the listed elevations. The elevation increments shall be no more than 1 foot. Columns can then be produced showing the incremental volume and cumulative volume of storage provided. See Table A-18 below for an example of a storage volume calculation. This method can be used for basin shapes as simple as a rectangle or as intricate as a curved, landscape designed wetland feature. It can also be used to calculate sediment storage volume and operating volume within BMPs.

Table A-18

Stage-Storage Volume Calculation Table Example

Elevation	**Surface Area (sf)**	**Incremental Volume (cf)**	**Cumulative Volume (cf)**
less than 725	operating volume	0	0
725	10,000	0	0
726	13,000	11,500	11,500
727	16,500	14,750	26,250
728	21,500	19,000	45,250
729	26,000	23,750	69,000
over 729	freeboard	0	69,000

Hydraulic Performance of the Outlet Device

To successfully design a stormwater treatment system, it is crucial to analyze the way in which the outlet devices release stormwater outflow. Typically, these devices can be considered as either weirs or orifices. A weir is a dam placed horizontally along a stream or channel to raise its level or divert its flow. Some uses for weirs are in the design of stormwater BMPs are:

– Check dams in channels,
– Flow splitter devices,
– Flow into a pipe before it is completely submerged, and
– Level spreaders.

An orifice is simply a hole. In the design of stormwater BMPs, orifices are used to drain a BMP that is detaining stormwater for volume control and pollutant removal. It is important to determine the size of an orifice correctly so that the appropriate drawdown rate can be provided.

Weir Equations

Three kinds of weirs are typically used: sharp-crested, broad-crested, and v-notch. For sharp-crested and broad-crested weirs, the basic equation is:

$$\boldsymbol{Q = C_W \, L \, H^{1.5}}$$

Where: Q = Discharge (cfs)

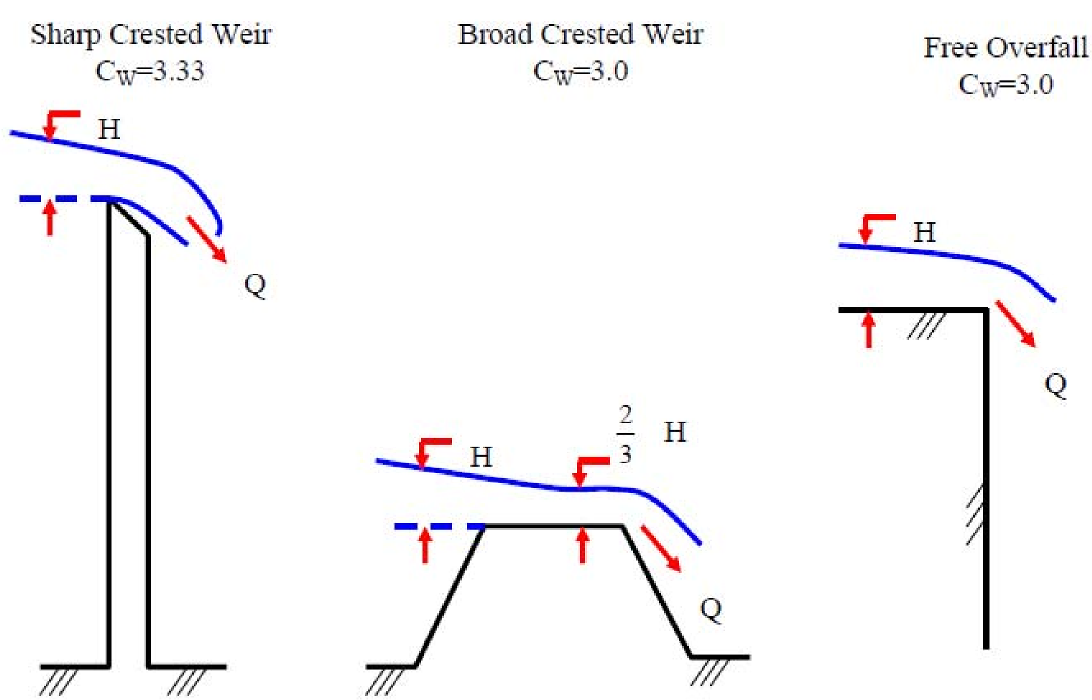
C_W = Coefficient of discharge (dimensionless) – see below

L = Length of weir (ft), measured along the crest

H = Driving head (ft), measured vertically from the crest of the weir to the water surface at a point far enough upstream to be essentially level

Figure A-1

Schematic sections through weirs (Malcom 1989)



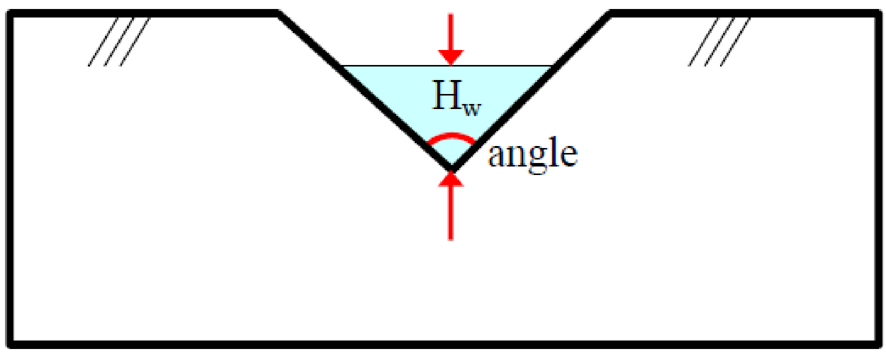
For v-notch weirs, the basic equation is:

$$\boldsymbol{Q = C_v H_w^{5/2}}$$

Where:

- Q = Discharge (cfs)
- C_v = Weir flow coefficient for V-notch weirs
  - 2.50 for 90 degrees
  - 1.44 for 60 degrees
  - 1.03 for 45 degrees
- H_w = Difference between pool elevation and notch (ft)

Figure A-2



Orifice Equation

The basic equation for orifices is:

$$Q = C_D A \sqrt{2gH_o}$$

Where: Q = Discharge (cfs)

C_D = Coefficient of discharge (dimensionless) – see Table A-19

A = Cross-sectional area of flow at the orifice entrance (sq ft)

g = Acceleration of gravity (32.2 ft/sec^2)

H_O = Driving head (ft), measured from the centroid of the orifice area to the water surface – **Note: Usually, use H_o/3 to compute drawdown through an orifice to reflect the fact that head is decreasing as the drawdown occurs.**

Figure A-3

Schematic section through an orifice

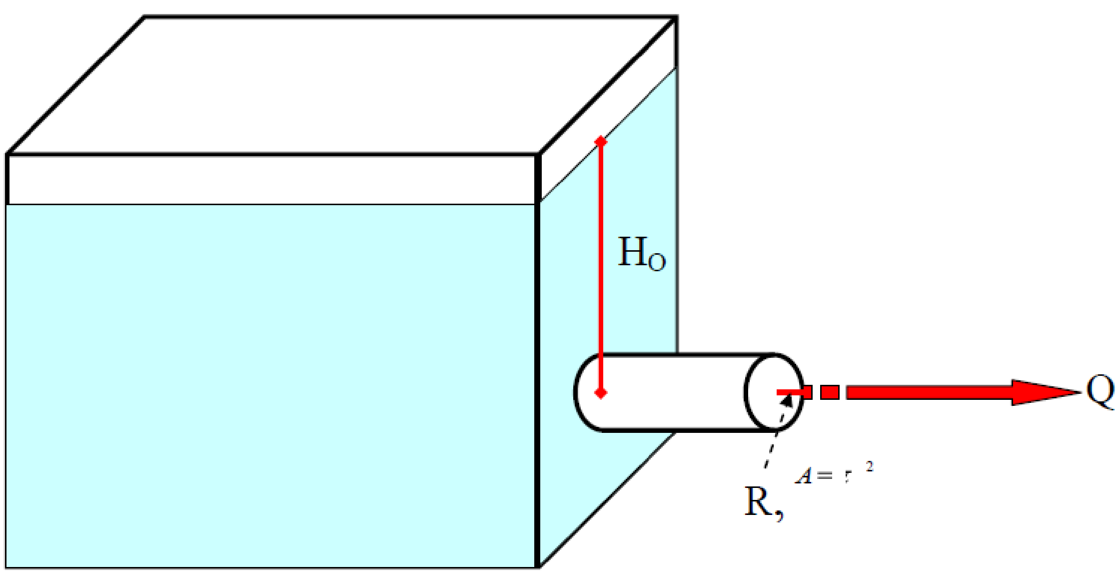


Table A-19

Values of Coefficient of Discharge, C_D (Malcom, 1989)

Entrance Condition	**C_D**
Typical default value	0.60
Square-edged entrance	0.59
Concrete pipe, grooved end	0.65
Corrugated metal pipe, mitered to slope	0.52
Corrugated metal pipe, projecting from fill	1.00

Stage-Storage-Discharge Model

Creating a stage-storage-discharge model is crucial for stormwater BMPs that involve detention of stormwater, particularly stormwater wetlands and wet detention basins. These BMPs provide volume control for the specified storm (for example, the 1- or 1½-inch storm) in a temporary pool that is above the permanent pool.

(Please note that some BMPs do not have the capability to provide this volume control due to their design, and others can include storage volume within the media of the BMP. Each BMP section will discuss the specific calculations for meeting the volume control requirements.)

Chainsaw Routing

The Chainsaw Routing method is appropriate for the routine design of small systems. Three sets of source data are needed to apply the Chainsaw Routing method:

- The inflow hydrograph,
- The size and shape of the storage basin, and
- The hydraulics of the outlet device.

The application of the Chainsaw Routing method is described in detail in *Elements of Urban Stormwater Design* (Malcom, 1989).

Other Models

Other models may be used to assist in determining stage-storage-discharge through a detention BMP. These models include:

- HEC-HMS, developed by the U.S. Army Corps of Engineers, provides a variety of options for simulating precipitation-runoff processes. This model can simulate unit hydrograph and hydrologic routing options. The latest version also has capabilities for continuous soil moisture accounting and reservoir routing operations. http://www.hec.usace.army.mil/software/hec-hms/download.html
- WinTR-55, develop by the NRCS, can be used to analyze the hydrology of small watersheds. A final version (including programs, sample data, and documentation) is now complete. http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-wintr55.html
- SWIMM, developed by the EPA, can be used to analyze stormwater quantity and quality associated with runoff from urban areas. Both single-event and continuous simulation can be performed on catchments having storm sewers, or combined sewers and natural drainage, for prediction of flows, stages and pollutant concentrations. http://www.epa.gov/ceampubl/swmm.htm

Channel Geometry

The Manning Equation is the model of choice for determining the cross section for a trapezoidal stormwater channel. It is applicable where (Malcom 1989):

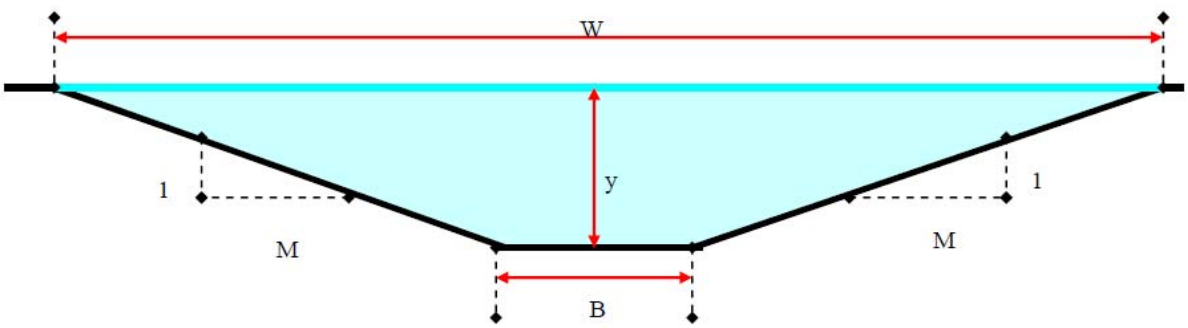
- Stormwater is flowing under the influences of gravity, and
- Flow is steady – it does not vary with time (Although discharge does vary during the passage of a flood wave, it is essentially steady during the time around the peak, the time of interest in channel design.)

The Manning Equation can be stated as:

$$Q = \frac{1.489}{} \; A\, R^{0.667}\, S^{0.5}$$

Where:
- Q = Peak discharge to the channel (cfs)
- n = Manning roughness coefficient (dimensionless)
- A = Cross-sectional area of flow (sq ft), the area through which flow takes place *(see below)*
- R = Hydraulic radius (ft), found by dividing cross-sectional area, A (sq ft), by wetted perimeter, P (ft) *(see below)*
- S = Longitudinal slope of the invert of the channel (ft fall/ft run).

Figure A-4
Diagram of a trapezoidal channel*



* M is governed by channel side slope requirements, which are typically 3:1 (M = 3) unless otherwise specified in this manual.

The Manning roughness coefficient is an experimentally determined value that is a function of the nature of the channel lining.

Table A-20
Rational runoff coefficients (adopted from Munson, et al., 1990 and Chow et al., 1988)

Channel lining	Manning roughness coefficient, n
Asphalt	0.016
Concrete, finished	0.012
Concrete, unfinished	0.014
Grass	0.035
Gravel bottom with riprap sides	0.033
Weeds	0.040

The cross-sectional area of flow, A, can be determined by the following equation:

$$A = By + My^2$$

The wetted perimeter, P, is the distance along the cross section against which the water is flowing. It does not include the free water surface. P can be determined by the following equation:

$$P = B + 2y\,(1 + M^2)^{0.5}$$

The hydraulic radius, R, can be determined by the following equation:

$$R = \frac{A}{P}$$

For the three equations above, the variables have the following meanings (also refer to Figure A-4):

A	=	Cross-sectional area of flow (sq ft)
B	=	Bottom width of the channel (ft)
M	=	Side slope ratio (ft horizontal/ft vertical) *(determined by channel side slope requirements)*
P	=	Wetted perimeter (ft)
R	=	Hydraulic radius (ft)
y	=	Depth of flow (ft)

Short Cut Floodrouting Method

To use the short cut floodrouting method, the designer must obtain information about the proposed floodwater impoundment site.

1. Hazard - A determination must be made about the possibility of road or building damage or personal injury from an overtopping or embankment failure. The short cut method is applicable only when none of the above hazards are present or could be present in the foreseeable future.

2. Permits - Structure sites in urban areas or those with embankments greater than 8 feet will require a construction permit from the Department of Environmental Quality - Office of Land and Water.

3. Flow Data - Structure design should be able to control a minimum 10-year, 24-hour storm on the watershed area unless a larger storm is needed for outlet erosion control or for other reasons. The peak inflow rate, qi, can be determined using EFM2 procedures, found at the end of this chapter, or other acceptable method. The peak inflow rate calculations must consider future development in the watershed.

   The stormwater release peak outflow rate, qo, may be chosen (set pipe size, concrete or vegetative spillway width) or calculated knowing qi, volume of runoff (Vr), and volume of storage available. Many times, the downstream channel capacity will determine the release rate to avoid out-of-bank flooding.

4. Floodwater Storage - The pool area of the proposed structure must be surveyed to determine how much storage volume is available for floodwater impoundment. Upstream property lines must be located to identify any storage limit. This value can be calculated knowing Vr, qi, and qo.

   An approximate storage volume can be calculated using the maximum pool depth, D, and pool surface area, A, in the formula: Volume = 0.4 D × A. This should not be used for final design calculations.

5. Short Cut Floodrouting – [http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17549.wba] The short cut floodrouting method is based on average storage and routing effects of the structure using two ratios:

   qo/qi : peak outflow to peak inflow
   Vs/Vr : volume of storage available to volume of runoff

   The following graph (Figure A-5) has been developed to show the relationship of these ratios. The upper curve for storm types II and III applies to Mississippi.

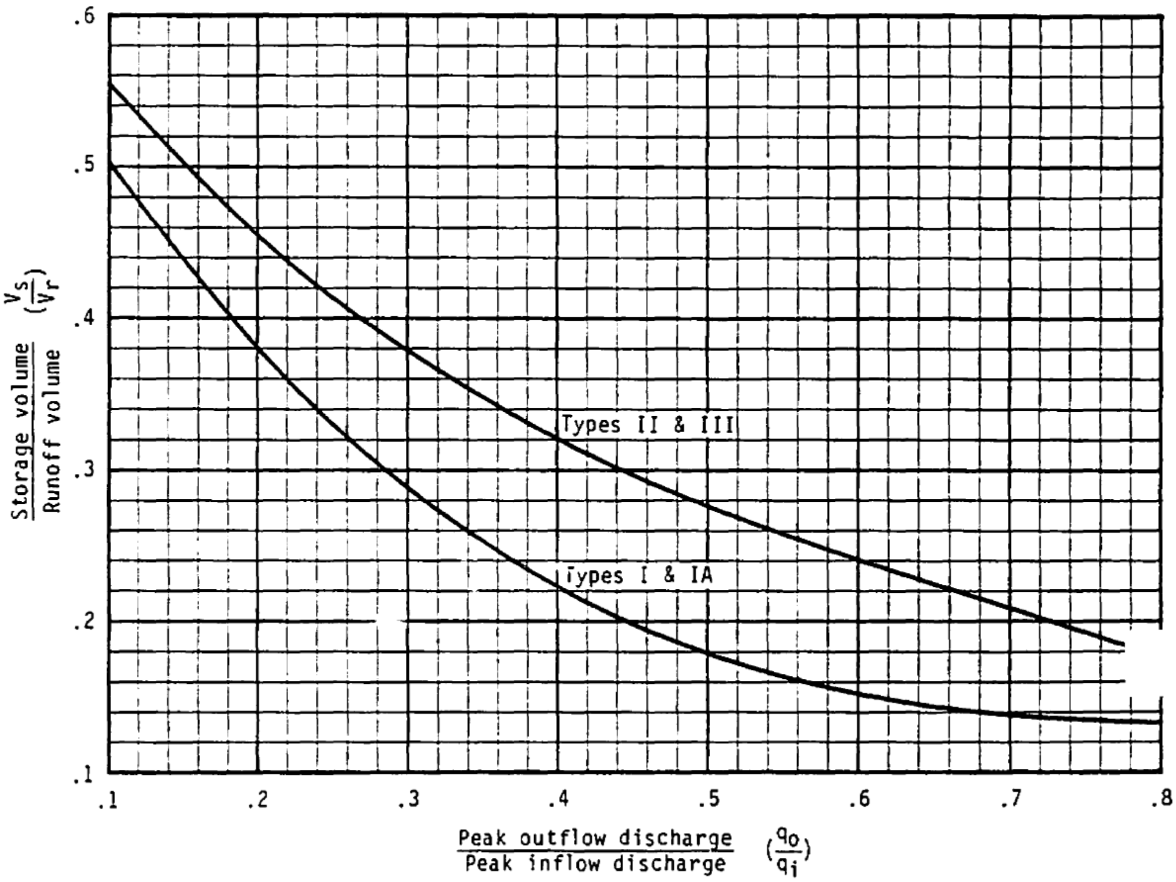


Figure A-5. Approximate detention basin routing for rainfall Types II and III.

The most common desired values, or unknowns, are Vs (Volume of stormwater storage) or q_O (Peak outflow).

To find Vs (in acre-feet) knowing the other three ratio values, compute the qo/qi value. Enter bottom of graph at that value, move up to the Type II and III line intersect, and then move horizontally to the left reading the Vs/Vr value. Vs = (Value) × Vr

To find q_O (in cfs) knowing the other three ratio values, compute the Vs/Vr value. Enter the left side of graph at that value, move horizontally to the Type II and III line intersect, and then move down to the bottom reading the qo/qi value. qo = (Value) × qi.

Notice that the qo/qi ratio is valid between 0.1 and 0.8 while the Vs/Vr ratio is valid between 0.1 and 0.6. An engineer experienced in floodrouting should provide designs for ratios outside these ranges.

Sample Problem 4:

A development is being planned in a 75-acre watershed that outlets into an existing concrete-lined channel designed for present conditions. If the channel capacity is exceeded, damages will be substantial. The watershed is in the Type II storm distribution region. The present channel capacity, 180 cfs, was established by computing discharge for the 25-year-frequency storm by the Graphical Peak Discharge method.

The developed-condition peak discharge (qi) computed by the same method is 360 cfs, and runoff (Q) is 3.4 inches. Since outflow must be held to 180 cfs, a detention basin having that maximum outflow discharge (qo) will be built at the watershed outlet.

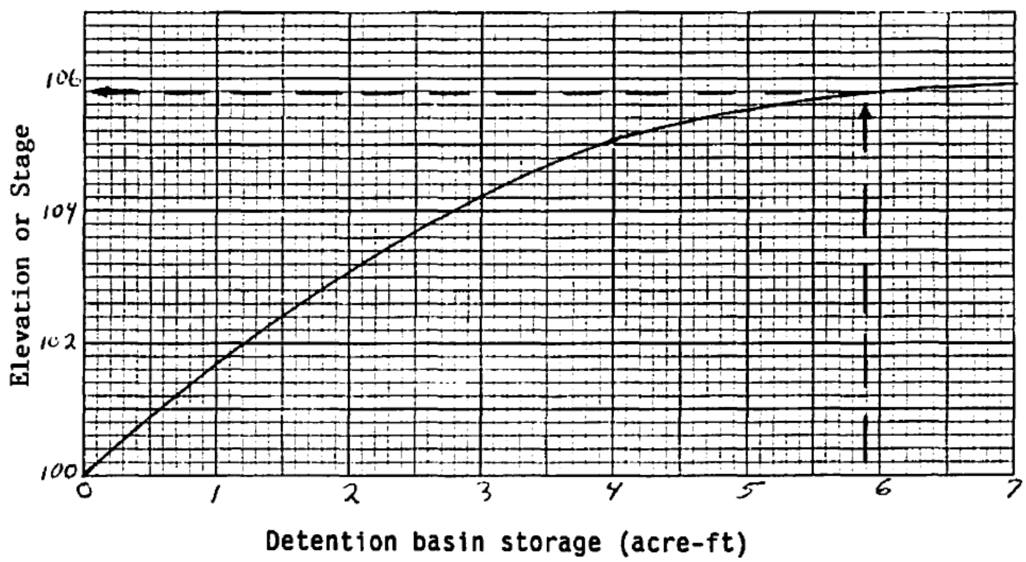
How much storage (Vs) will be required to meet the maximum outflow discharge (qo) of 180 cfs, and what will be the approximate dimensions of a rectangular weir outflow structure? Use worksheet 4 to estimate required storage and maximum storage elevation.

Worksheet 4: Detention basin storage computation

Project Leisure Dr. By RLU Date 5-12-93

Location Anywhere, MS Checked PI Date 5-13-93

Circle one: Present Developed Weir outflow structure



1. Data:
   Drainage area.......A_m = 75 acre
   Rainfall distribution
   Type II, III = II

	1st stage	2nd stage
2. Frequency......yr	25	
3. Peak inflow discharge, $q_p = q_i$.......cfs (From worksheet 3)	360	
4. Peak outflow discharge, q_o............cfs [1/]	180	

5. Compute q_o/q_i.	.50	
6. V_s/V_r ratio... (Use q_o/q_i with figure 6-2)	0.28	
7. Runoff volume, V_r..........ac-ft (V_r = Q x 12 x Am)	21.2	
8. Storage volume, V_s..........ac-ft ($V_s = V_r$ x Ratio Vs/Vr)	5.9	
9. Storage elev. (From plot)	105.8	

1/ 2nd stage q_o includes 1st stage q_o.

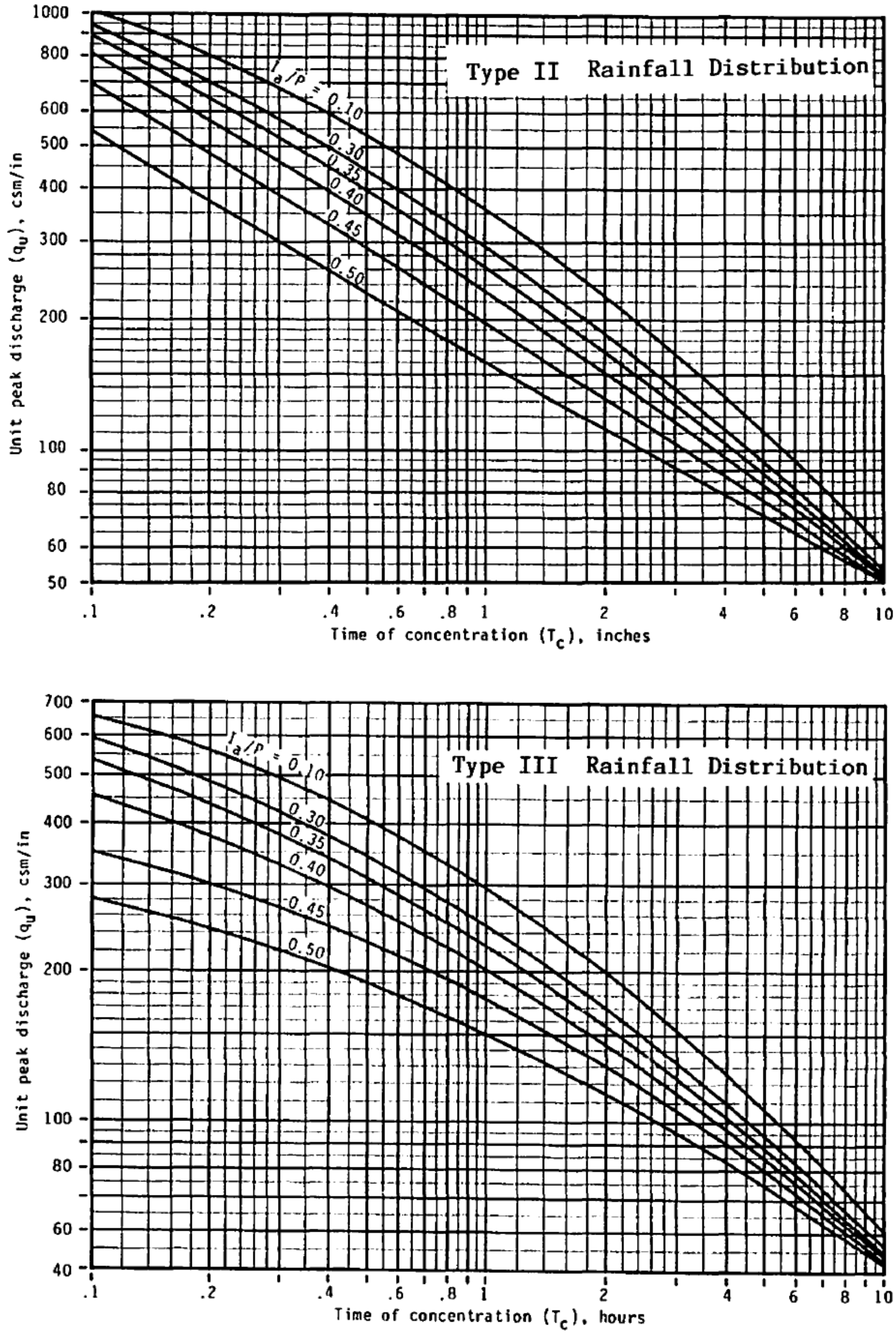


Figure A-6. Unit peak discharge (qu).

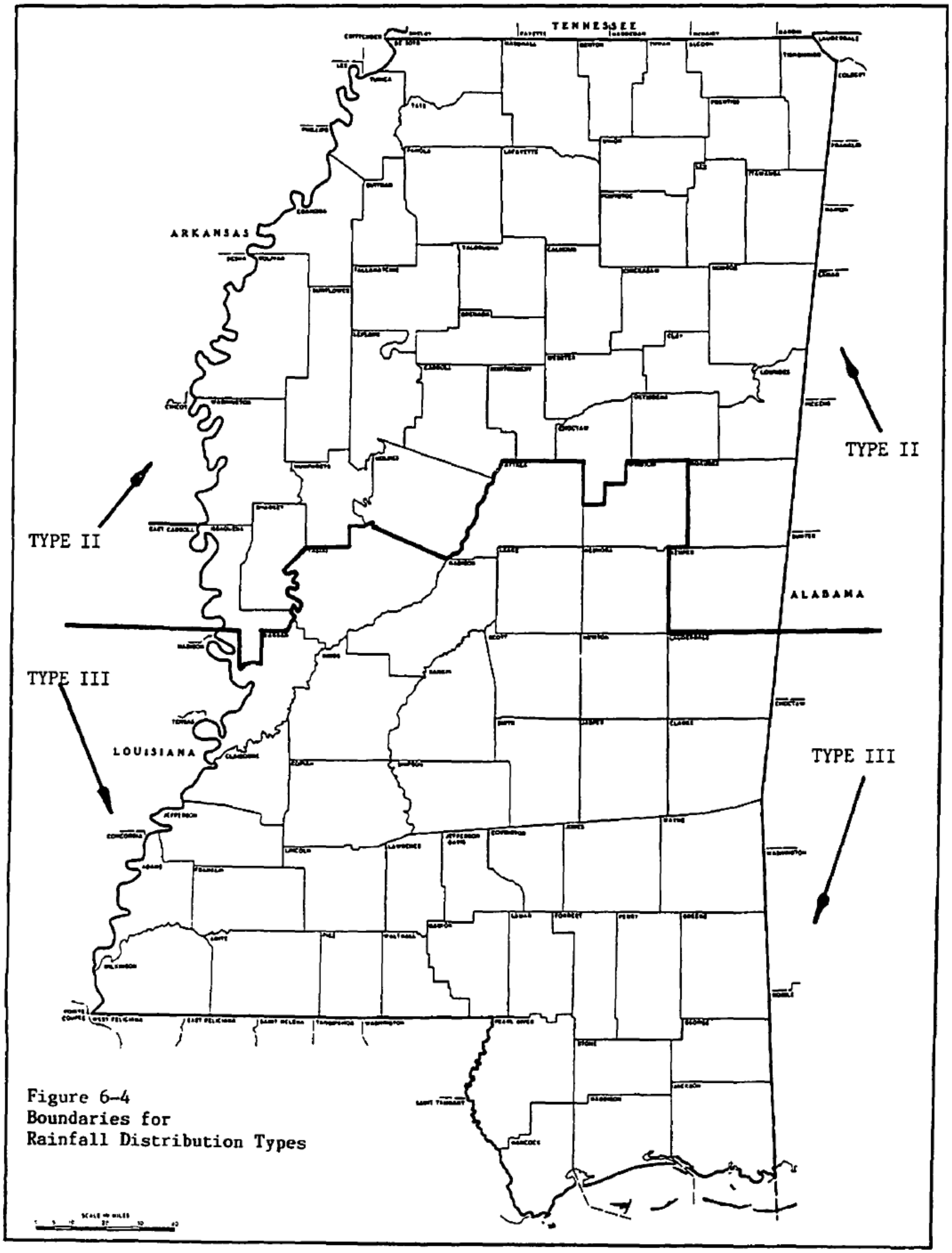


Figure A-7. Boundaries for rainfall distribution types

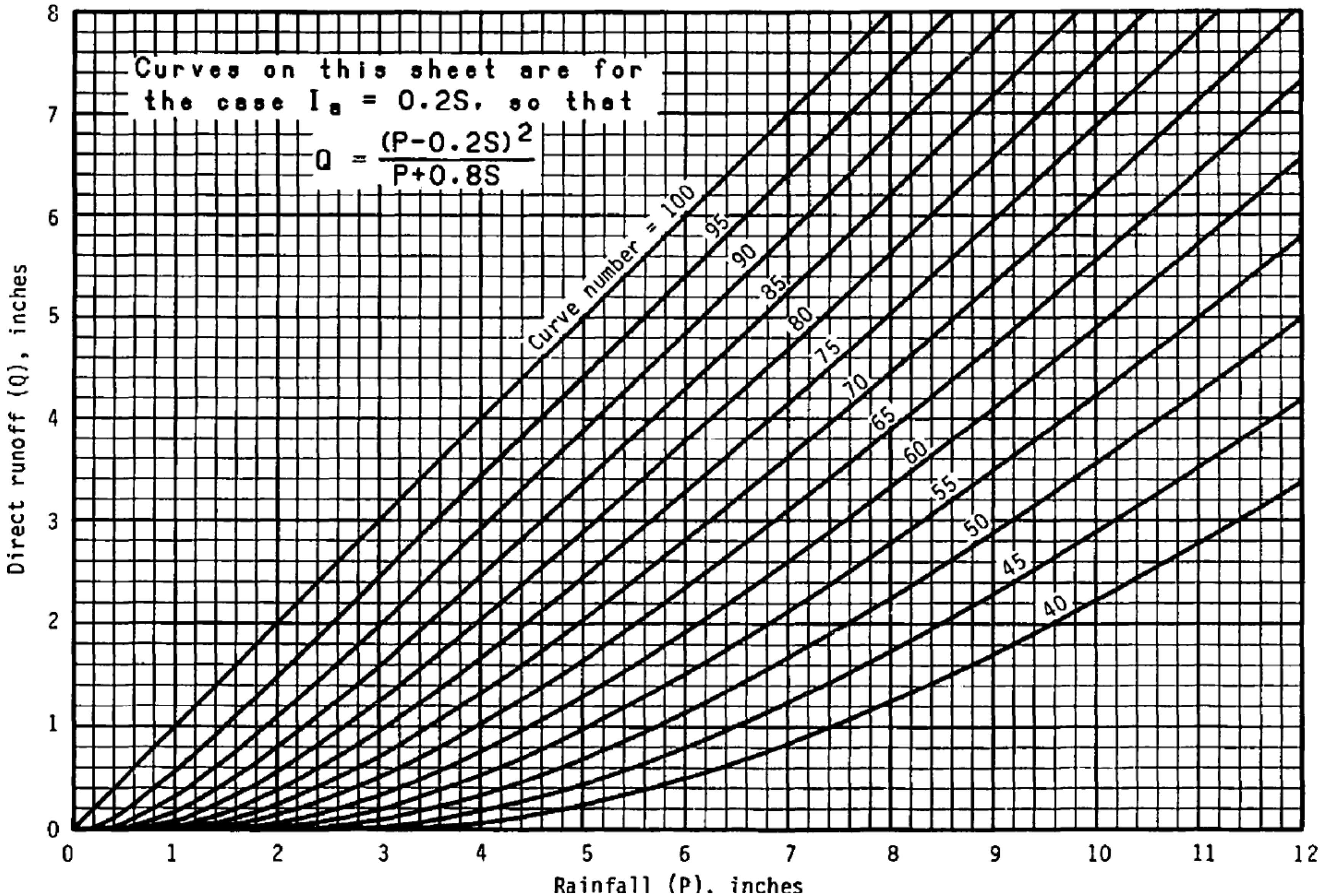


Figure A-8. Solution for runoff equation

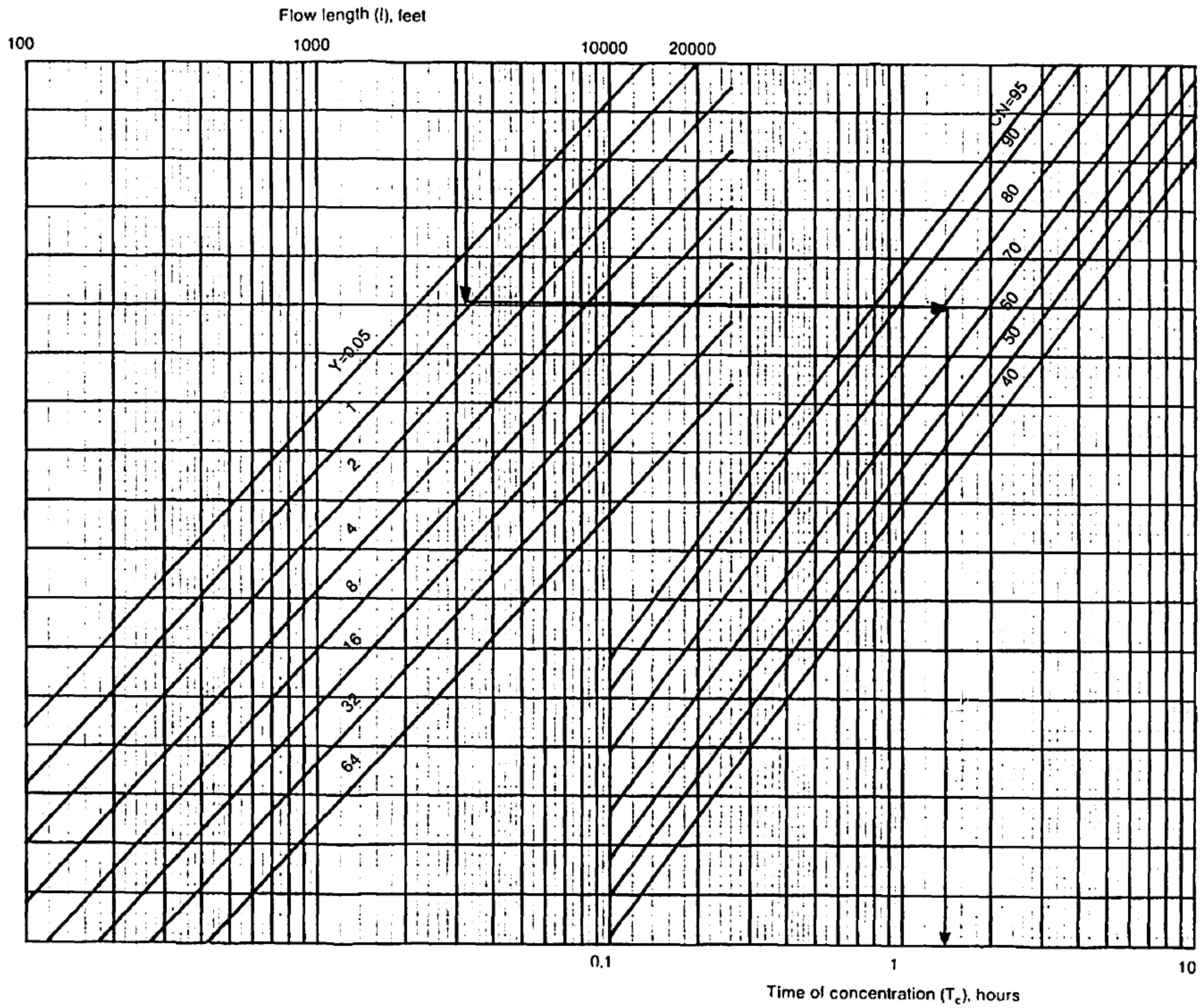


Figure A-9 . Time of concentration (T_c) nomograph

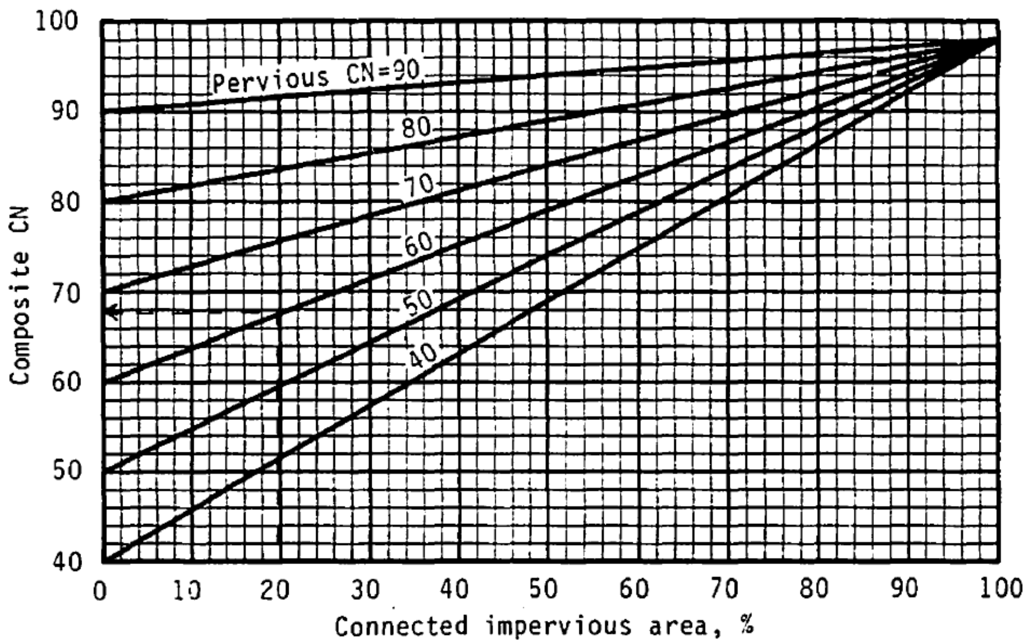


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Figure A-10. Composite CN with connected impervious area

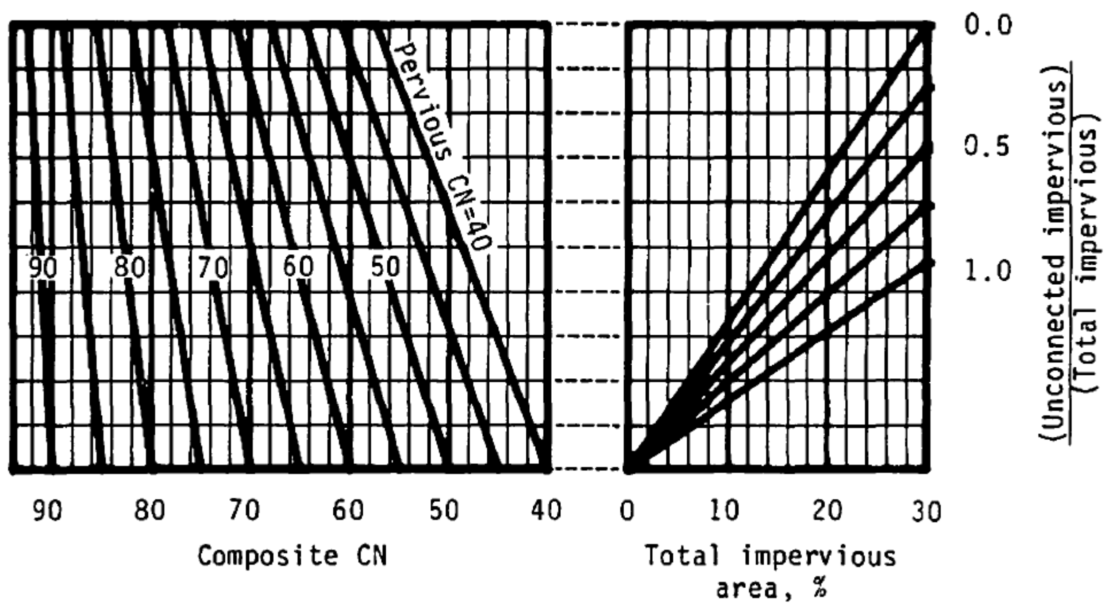

Figure A-11. Composite CN with unconnected impervious areas and total impervious area less than 30%

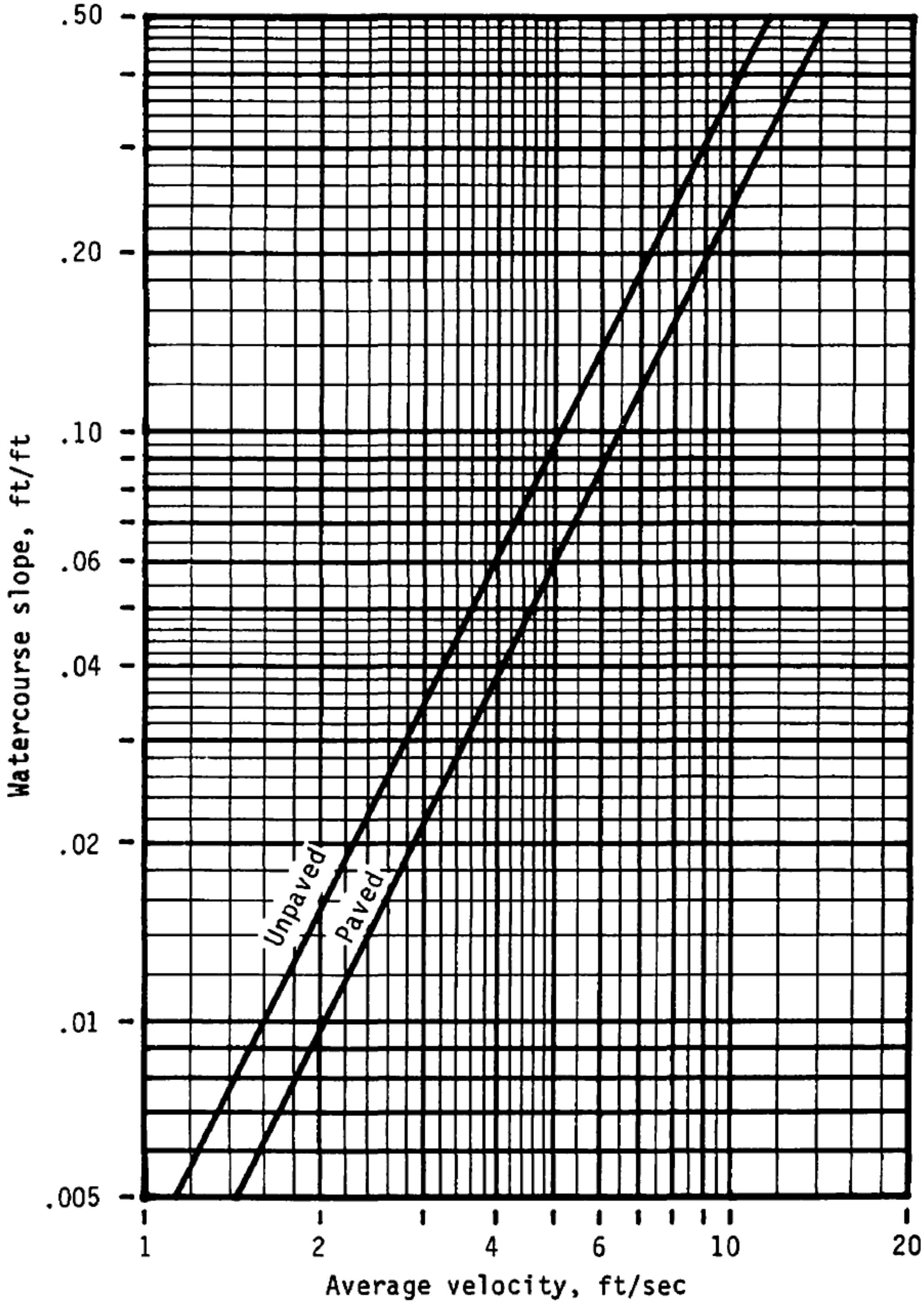

Figure A-12. Average velocities for estimating travel time for shallow concentrated flow

Table A-21. Rainfall frequency values (estimated precipitation for 24-hour period expressed in inches)

County	Storm Frequency						
	1 yr.	2 yr.	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
ADAMS	4.0	4.8	6.3	7.0	8.4	9.1	10.3
ALCORN	3.3	3.9	4.8	5.6	6.5	7.1	7.7
AMITE	4.2	4.8	6.4	7.4	8.6	9.4	10.6
ATTALA	3.7	4.3	5.4	6.3	7.2	8.1	8.8
BENTON	3.4	4.0	4.9	5.7	6.6	7.2	7.8
BOLIVAR	3.6	4.3	5.3	6.2	7.0	7.8	8.6
CALHOUN	3.5	4.1	5.2	5.9	6.9	7.6	8.3
CARROLL	3.6	4.2	5.3	6.2	7.1	6.2	8.6
CHICKASAW	3.5	4.1	5.1	5.9	6.8	7.6	8.3
CHOCTAW	3.6	4.2	5.3	6.2	7.0	7.9	8.6
CLAIBORNE	3.9	4.6	6.0	6.9	7.8	8.8	9.6
CLARKE	3.9	4.7	6.0	6.9	7.9	8.9	9.8
CLAY	3.5	4.1	5.2	6.0	6.9	7.7	8.4
COAHOMA	3.5	4.2	5.2	6.0	6.9	7.7	8.4
COPIAH	3.9	4.6	6.0	6.9	7.9	8.8	9.7
COVINGTON	4.0	4.7	6.2	7.1	8.2	9.2	10.2
DESOTO	4.0	4.1	5.0	5.8	6.7	7.2	8.1
FORREST	4.2	4.9	6.5	7.7	8.8	10.0	11.2
FRANKLIN	4.0	4.8	6.3	7.0	8.3	9.0	10.1
GEORGE	4.4	5.4	7.3	8.5	9.7	11.1	12.3
GREENE	4.2	4.9	6.7	7.8	8.9	10.4	11.5
GRENADA	3.6	4.2	5.2	6.0	6.9	7.7	8.5
HANCOCK	4.7	5.8	7.5	8.7	10.5	11.4	12.5
HARRISON	4.7	5.8	7.5	8.8	10.5	11.4	12.6
HINDS	3.9	4.4	5.8	6.7	7.7	8.6	9.4
HOLMES	3.7	4.3	5.4	6.3	7.2	8.1	8.8
HUMPHREYS	3.7	4.4	5.4	6.4	7.3	8.2	8.8
ISSAQUENA	3.8	4.3	5.6	6.6	7.5	8.4	9.1
ITAWAMBA	3.4	3.9	5.1	5.8	6.6	7.3	8.0
JACKSON	4.7	5.9	7.7	9.0	10.5	11.5	13.0
JASPER	3.9	4.6	6.0	6.8	7.9	8.8	9.7
JEFFERSON	4.0	4.7	6.1	7.0	8.0	8.9	9.9
JEFF DAVIS	4.0	4.6	6.2	7.0	8.2	9.0	10.0
JONES	4.0	4.8	6.2	7.2	8.2	9.3	10.5
KEMPER	3.7	4.4	5.6	6.5	7.4	8.2	9.0
LAFAYETTE	3.5	4.1	5.1	5.8	6.8	7.4	8.2
LAMAR	4.2	4.9	6.5	7.6	8.6	9.8	11.0
LAUDERDALE	3.8	4.6	5.7	6.7	7.6	8.5	9.4
LAWRENCE	4.0	4.6	6.2	7.0	8.2	9.0	10.0
LEAKE	3.8	4.3	5.5	6.5	7.4	8.3	9.0
LEE	3.4	4.0	5.0	5.8	6.7	7.4	8.1
LEFLORE	3.6	4.3	5.3	6.2	7.1	7.9	8.6
LINCOLN	4.0	4.7	6.2	7.0	8.2	9.0	10.0
LOWNDES	3.6	4.2	5.3	6.1	7.0	7.8	8.5

Table A-21. Rainfall frequency values (cont.).

	Storm Frequency						
County	1 yr.	2 yr.	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
MADISON	3.8	4.4	5.6	6.5	7.5	8.4	9.1
MARION	4.2	4.8	6.4	7.4	8.8	9.6	10.8
MARSHALL	3.4	4.0	5.0	5.7	6.7	7.2	7.9
MONROE	3.5	4.1	5.1	5.9	6.8	7.5	8.3
MONTGOMERY	3.6	4.2	5.3	6.2	7.0	7.8	8.6
NESHOBA	3.8	4.4	5.5	6.5	7.4	8.2	9.0
NEWTON	3.8	4.5	5.7	6.7	7.6	8.5	9.3
NOXUBEE	3.6	4.3	5.4	6.3	7.2	8.0	8.8
OKTIBBEHA	3.6	4.2	5.3	6.1	7.0	7.8	8.6
PANOLA	3.5	4.1	5.1	5.9	6.8	7.5	8.2
PEARL RIVER	4.4	5.0	7.0	8.2	9.4	10.5	11.7
PERRY	4.2	4.9	6.6	7.8	8.8	10.1	11.4
PIKE	4.2	4.8	6.4	7.4	8.5	9.5	10.6
PONTOTOC	3.5	4.0	5.1	5.8	6.8	7.4	8.1
PRENTISS	3.3	3.9	4.9	5.6	6.6	7.3	7.8
QUITMAN	3.5	4.2	5.2	6.0	6.9	7.6	8.3
RANKIN	3.9	4.4	5.8	6.7	7.7	8.6	9.4
SCOTT	3.8	4.5	5.7	6.6	7.6	8.5	9.3
SHARKEY	3.8	4.4	5.5	6.5	7.4	8.3	9.0
SIMPSON	3.9	4.5	6.0	6.9	7.8	8.8	9.7
SMITH	3.9	4.6	5.9	6.8	7.8	8.8	9.7
STONE	4.4	5.3	7.2	8.3	9.6	10.9	12.1
SUNFLOWER	3.6	4.3	5.3	6.2	7.1	7.9	8.7
TALLAHATCHIE	3.6	4.2	5.2	6.0	6.9	7.7	8.4
TATE	3.4	4.1	5.1	5.8	6.7	7.3	8.1
TIPPAH	3.4	4.0	4.9	5.6	6.6	7.2	7.8
TISHOMINGO	3.3	3.9	4.8	5.6	6.5	7.0	7.7
TUNICA	3.5	4.1	5.1	5.9	6.8	7.4	8.2
UNION	3.4	4.0	5.0	5.7	6.7	7.3	8.0
WALTHALL	4.2	4.8	6.4	7.4	8.6	9.6	10.8
WARREN	3.9	4.5	5.8	6.7	7.7	8.6	9.3
WASHINGTON	3.7	4.4	5.4	6.4	7.3	8.1	8.9
WAYNE	4.0	4.8	6.3	7.3	8.4	9.5	10.5
WEBSTER	3.6	4.2	5.2	6.1	7.0	7.7	8.5
WILKINSON	4.2	4.9	6.5	7.4	8.7	9.5	10.8
WINSTON	3.7	4.3	5.4	6.3	7.2	8.0	8.8
YALOBUSHA	3.5	4.1	5.2	6.0	6.9	7.6	8.4
YAZOO	3.8	4.4	5.5	6.5	7.4	8.3	9.0

Table A-22. Runoff depth for selected CN values and rainfall amounts.[1/]

—

Rainfall	Runoff (Q) for curve number of—											
	40	45	50	55	60	65	70	75	80	85	90	95
	inches											
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39

1/ Interpolate the values shown to obtain runoff depths for CN or rainfall amounts not shown.

Table A-23. Hydrologic groups for soils in Mississippi

SOIL NAME	HYDGRP	SOIL NAME	HYDGRP	SOIL NAME	HYDGRP	SOIL NAME	HYDGRP
Adaton	D	Croatan	D	Leverett	C	Quitman	C
Adler	C	Daleville	D	Lexington	B	Riedtown	C
Alaga	A	Darco	A	Linker	B	Riverwash	D
Alligator	D	Deerford	D	Longview	C	Robinsonville	B
Amagon	D	Demopolis	C	Loring	C	Rock Outcrop	D
Angie	D	Demopolis, Cobbly	D	Lorman	D	Rosebloom	D
Annemaine	C	Dorovan	D	Louin	D	Rosella	D
Ariel	C	Dubbs	B	Lucedale	B	Ruston	B
Arkabutla	C	Dubbs, Flooded	C	Lucy	A	Saffell	B
Arundel	C	Dulac	C	Luverne	C	Saucier	C
Askew	C	Dundee	C	Maben	C	Savannah	C
Atmore	B/D	Escambia	C	Malbis	B	Sessum	D
Atwood	B	Eustis	A	Mantachie	C	Sharkey	D
Basin	C	Eutaw	D	Marietta	C	Shubuta	C
Bassfield	B	Falaya	D	Mashulaville	B/D	Siwell	C
Baxterville	B	Falkner	C	Mathiston	C	Smithdale	B
Beauregard	C	Forestdale	D	Mayhew	D	Smithton	D
Belden	C	Freest	C	McLaurin	B	St. Lucie	A
Berndale	B	Freestone	C	McRaven	C	Steens	C
Beulah	B	Frizzell	C	Memphis	B	Stough	C
Bibb	D	Frost	D	Mhoon	D	Sulfaquepts	D
Bigbee	A	Gillsburg	C	Mooreville	C	Sumter	C
Binnsville	D	Grenada	C	Morganfield	B	Susquehanna	D
Bohicket	D	Griffith	D	Myatt	D	Swamp	D
Bonn	D	Gullied Land, Sandy	B	Nahunta	C	Sweatman	C
Bosket	B	Gullied Land, Clayey	D	Natchez	B	Talla	C
Boswell	D	Guyton	D	Neshoba	C	Tallapoosa	C
Bowdre	C	Handsboro	D	Newellton	D	Tensas	D
Brandon	B	Harleston	C	Nugent	A	Tippah	C
Brewton	C	Heidel	B	Oaklimeter	C	Tippo	C
Brooksville	D	Henry	D	Ochlockonee	B	Trebloc	D
Bruin	B	Houlka	D	Ocilla	C	Troup	A
Bruno	A	Houston	D	Okolona	D	Tunica	D
Bude	C	Hyde	B/D	Oktibbeha	D	Tuscumbia	D
Byram	C	Iuka	C	Ora	C	Tutwiler	B
Cadeville	D	Izagora	C	Osier	A/D	Udorthents	C
Cahaba	B	Jena	B	Ozan	D	Una	D
Caledonia	B	Johnston	D	Paden	C	Urban Land	
Calhoun	D	Kinston	B/D	Pamlico	D	Urbo	D
Calloway	C	Kipling	D	Pelahatchie	C	Vaiden	D
Cascilla	B	Kirkville	C	Peoria	D	Vaiden Calcareous	D
Catalpa	C	Kisatchie	D	Petal	C	Velda	B
Chenneby	C	Kolin	C	Pheba	C	Verdun	D
Chewacla	C	Lakeland	A	Pikeville	B	Vicksburg	B
Coastal Beaches	D	Latonia	B	Pits	B	Vimville	D
Collins	C	Lauderdale	D	Plummer	B/D	Wanilla	C
Columbus	C	Lax	C	Poarch	B	Waverly	B/D
Commerce	C	Leaf	D	Ponzer	D	Wehackee	D
Convent	C	Leeper	D	Pooleville	C	Wilcox	D
Crevasse	A	Lenoir	D	Prentiss	C	Williamsville	C
		Leven	B	Providence	C		

NOTE: Two hydrologic soil groups such as B/D indicate the drained/undrained situation.

Table A-24A. Runoff curve numbers for cultivated agricultural lands

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition.
[2] *Crop residue cover (CR)* applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table A-24B. Runoff curve numbers for other agricultural lands[1/]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1] Average runoff condition.
[2] *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.
[3] *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6] *Poor:* Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table A-24C. Runoff curve numbers for urban areas.[1/]

Cover description: 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 6-6A and 6B					

[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 6-2 or 6-3.
[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 6-2 or 6-3 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 6-2 or 6-3, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table A-25. I_a values for runoff curve numbers

Curve Number	I_a (in)	Curve Number	I_a (in)
40	3.000	68	0.941
41	2.878	69	0.899
42	2.762	70	0.857
43	2.651	71	0.817
44	2.545	72	0.778
45	2.444	73	0.740
46	2.348	74	0.703
47	2.255	75	0.667
47	2.167	76	0.632
49	2.082	77	0.597
50	2.000	78	0.564
51	1.922	79	0.532
52	1.846	80	0.500
53	1.774	81	0.469
54	1.704	82	0.439
55	1.636	83	0.410
56	1.571	84	0.381
57	1.509	85	0.353
58	1.448	86	0.326
59	1.390	87	0.299
60	1.333	88	0.273
61	1.279	89	0.247
62	1.226	90	0.222
63	1.175	91	0.198
64	1.125	92	0.174
65	1.077	93	0.151
66	1.030	94	0.128
67	0.985	95	0.105