DEQ Certification Class Presentations

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July 2024

Virginia Department of Environmental Quality

Module 10

GRAPHICAL PEAK DISCHARGE METHOD (TR-55)

Module 10 Contents

10a. Urban Hydrology for Small Watershed (TR-55)

10b. TR-55 Peak Discharge Method

10c. Tabular Hydrograph Method

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Module 10a.

Urban Hydrology for Small Watersheds (TR-55)

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Urban Hydrology for Small Watersheds (TR-55)

- NRCS publication Technical Release Number 55 (TR-55): Urban Hydrology for Small Watersheds, 2nd edition (June 1986)
- Win TR-55 user guide (2009)

Module 10b.

TR-55 Peak Discharge Method

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Peak Discharge

TR-55 presents two methods for estimating peak discharge

Graphical Method

Provides:

peak discharge and **runoff volume**

Tabular Method

Provides:

peak discharge, runoff volume, and a **runoff hydrograph**

Graphical Peak Discharge Limitations

- Watershed must be hydrologically homogeneous (uniform distribution of land use, soils, and cover) – represented by **one CN**
- Only one main stream in watershed *(can be applied to multiple stream branches with nearly equal Tc)*
- No hydrograph generated, cannot be used for routing *(basin design)*
- Does not consider subsurface or groundwater flow

(Source: TR-55, Eq. 4-1)

$$q_p = q_u \times A_m \times Q \times F_p$$

Peak Discharge Equation

q_p = peak discharge (cfs)

q_u = unit peak discharge (cfs/mi²/in or csm/in) → Graph look up

A_m = drainage area (mi²)

Q = runoff (in)

F_p = pond and swamp adjustment factor

q_u

Graph look up

Tc Ia/P

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

Q = Runoff (in)

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= 0.2 x S (all losses before runoff begins)

Graphical Peak Discharge Procedure

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

1. Rainfall (P)

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

Determine rainfall

- Precipitation
  - NOAA Atlas 14
  - Distribution

Determine rainfall

NOAA Atlas 14, Volume 2, Version 3
Location name: Petersburg, Virginia, US*
Latitude: 37.1953°, Longitude: -77.3657°

POINT PRECIPITATION FREQUENCY ESTIMATES

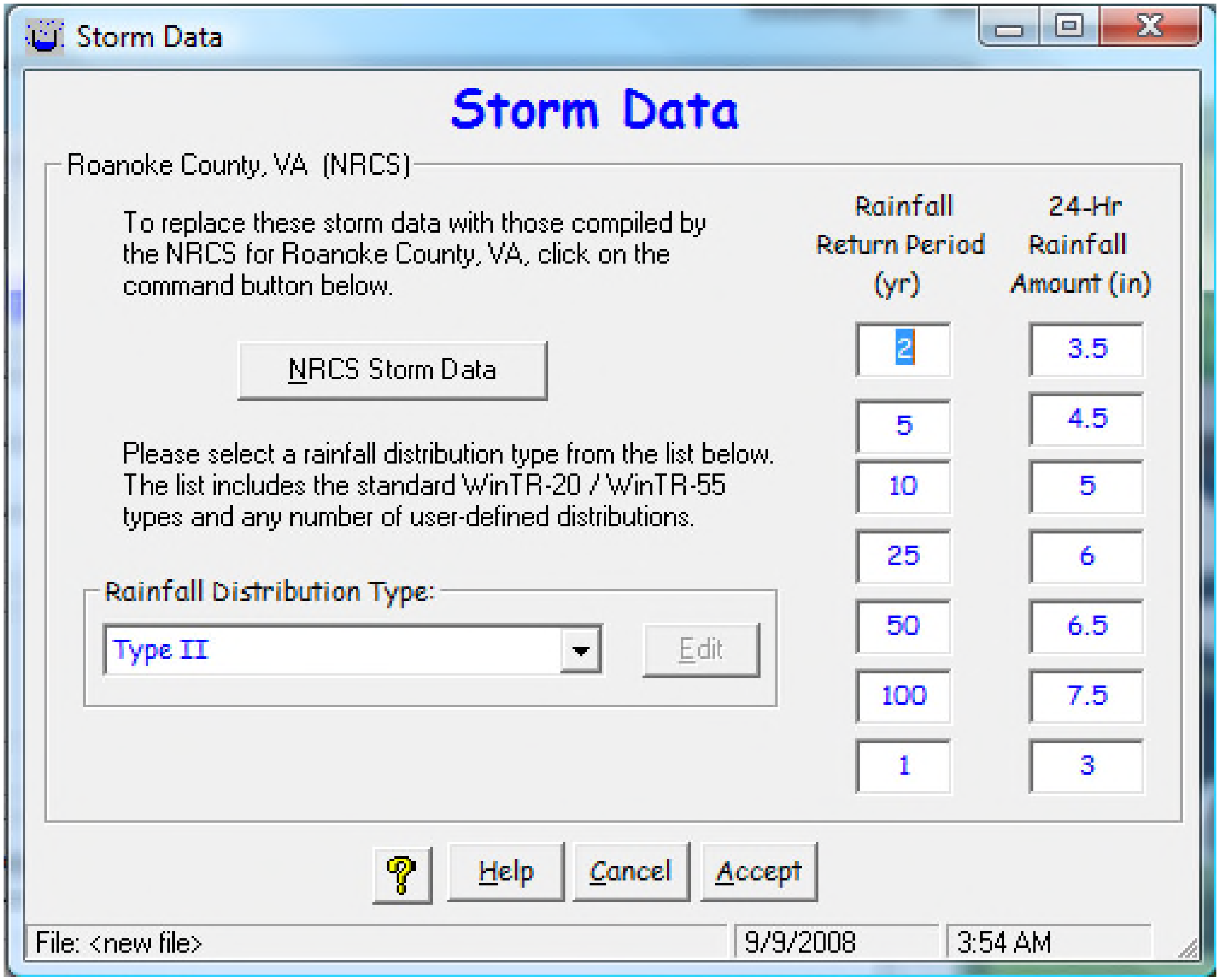
PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)						
	1	2	5	10	25	50	100
10-min	0.616 (0.553-0.689)	0.727 (0.654-0.810)	0.845 (0.760-0.941)	0.951 (0.853-1.06)	1.07 (0.951-1.18)	1.16 (1.03-1.29)	1.24 (1.10-1.38)
15-min	0.770 (0.691-0.861)	0.913 (0.822-1.02)	1.07 (0.961-1.19)	1.20 (1.08-1.34)	1.35 (1.21-1.50)	1.46 (1.30-1.63)	1.57 (1.39-1.74)
30-min	1.06 (0.948-1.18)	1.26 (1.14-1.41)	1.52 (1.37-1.69)	1.74 (1.56-1.94)	2.00 (1.79-2.22)	2.21 (1.96-2.45)	2.40 (2.12-2.67)
60-min	1.32 (1.18-1.47)	1.58 (1.43-1.76)	1.95 (1.75-2.17)	2.27 (2.04-2.53)	2.66 (2.38-2.96)	2.99 (2.66-3.32)	3.31 (2.93-3.67)
2-hr	1.57 (1.40-1.76)	1.89 (1.69-2.11)	2.34 (2.10-2.62)	2.76 (2.47-3.08)	3.30 (2.93-3.67)	3.76 (3.32-4.18)	4.22 (3.70-4.69)
3-hr	1.69 (1.50-1.90)	2.03 (1.81-2.28)	2.52 (2.26-2.83)	2.99 (2.66-3.35)	3.58 (3.17-4.01)	4.09 (3.60-4.58)	4.63 (4.04-5.16)
6-hr	2.03 (1.81-2.31)	2.44 (2.17-2.76)	3.04 (2.70-3.43)	3.61 (3.19-4.07)	4.36 (3.84-4.91)	5.03 (4.39-5.64)	5.72 (4.96-6.41)
12-hr	2.42 (2.16-2.76)	2.91 (2.60-3.30)	3.64 (3.24-4.12)	4.35 (3.85-4.91)	5.32 (4.67-5.98)	6.19 (5.39-6.94)	7.11 (6.14-7.96)
24-hr	**2.80 (2.56-3.09)**	**3.40 (3.11-3.75)**	4.36 (3.98-4.81)	**5.17 (4.70-5.70)**	6.35 (5.74-6.99)	7.36 (6.61-8.10)	8.46 (7.54-9.30)

Determine rainfall

$$q_p = q_u A_m Q F_p$$

Use WinTR55 software



2. Curve Number

1. Determine 24-hour rainfall (P) for desired design storm

2. Calculate weighted CN for site

3. Use CN with table to determine initial abstraction (I_a)

4. Calculate expected runoff depth (Q)

5. Determine time of concentration (t_c)

6. Compute I_a/P ratio

7. Use t_c and I_a/P to find q_u from chart

8. Determine pond and swamp adjustment factor (F_p)

9. Combine all above factors and calculate peak discharge (q_p)

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Curve Number

CN indicates
runoff potential of an area

weighted CN

Curve Number

- CN determination:
  - Soils
  - Hydrologic conditions
    - (good, fair, poor)
  - Cover type
  - Treatment (sometimes)

weighted CN

Curve Number

- CN determination:
  - 4 Curve Number Tables
    - Urban

      Cover type- vegetation, bare soil, and impervious surfaces.
    - cultivated agricultural lands
    - other agricultural lands
    - arid and semiarid rangelands

weighted CN

Curve Number

- Need Hydrologic Soil Group (HSG) for each of the soils at site and area of each soil type
- Soils information from:
  - Site drawings or plan
  - NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/)

weighted CN

Hydrologic Soil Groups

Group A: Low runoff potential

Group B: Moderately low runoff potential

Group C: Moderately high runoff potential

Group D: High runoff potential

Hydrologic Soil Groups

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

weighted CN

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

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2/]	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

Figure 10-3 Runoff CNs for Urban Areas (TR-55, 1986)

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description: Cover type	Cover description: Hydrologic condition	Curve numbers for hydrologic soil group: 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

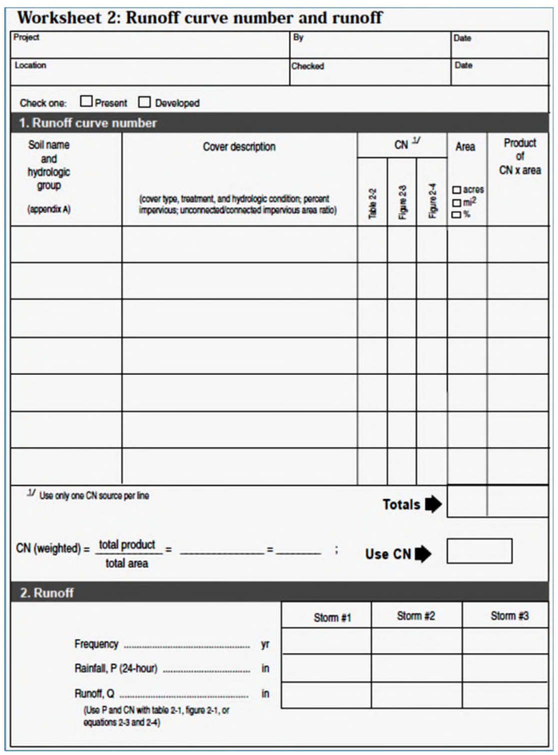
1 Average runoff condition, and $I_a = 0.2S$.

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.

Figure 10-4 Runoff Curve Numbers for Other Agricultural Lands

- Calculate weighted average CN for site
- **TR-55 Worksheet 2 for CN**


Worksheet 2: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Figure 2-3	CN 1/ Figure 2-4	Area ☐ acres ☐ mi2 ☐ %	Product of CN x area

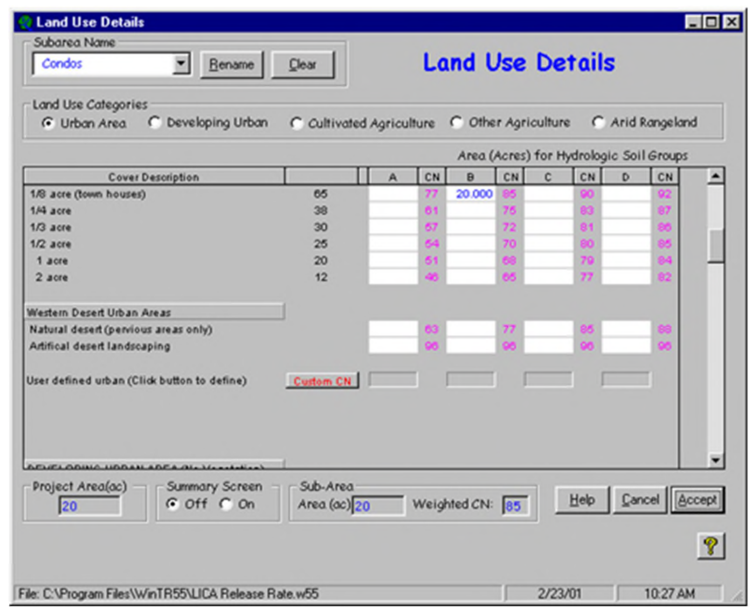
1/ Use only one CN source per line

Totals ➡

CN (weighted) = total product / total area = ________ = ______ ; Use CN ➡

2. Runoff

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



weighted CN

Exercise:

Determine a composite curve number given the following data for existing pre-development conditions:

24 acres - open space, soil c

16 acres - 1/2 acre lots, 25% impervious, good condition, soil b

18 acres - woods Soil D

Solution : (24*74) +(16*70)+(18*77) =

1776+1120+1386=4282/58= 73.8 Round to 74

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weighted CN

Worksheet 2: Runoff curve number and runoff

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1] Table 2-2	CN [1] Figure 2-3	CN [1] Figure 2-4	Area ☐ acres ☐ mi2 ☐ %	Product of CN x area

[1] Use only one CN source per line

Totals ➡

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

2. Runoff

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

Q&A

Determine rainfall

NOAA Atlas 14, Volume 2, Version 3
Location name: Petersburg, Virginia, US*
Latitude: 37.1953°, Longitude: -77.3657°

POINT PRECIPITATION FREQUENCY ESTIMATES

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]							
Duration	Average recurrence interval (years)						
	1	2	5	10	25	50	100
10-min	0.616 (0.553-0.689)	0.727 (0.654-0.810)	0.845 (0.760-0.941)	0.951 (0.853-1.06)	1.07 (0.951-1.18)	1.16 (1.03-1.29)	1.24 (1.10-1.38)
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24-hr	2.80 (2.56-3.09)	3.40 (3.11-3.75)	4.36 (3.98-4.81)	5.17 (4.70-5.70)	6.35 (5.74-6.99)	7.36 (6.61-8.10)	8.46 (7.54-9.30)

1. Precipitation

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

Cover description		Curve numbers for hydrologic soil group			
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Streets and roads:					
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Residential districts by average lot size:					
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1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85

2. Curve Number (CN)

3. Initial Abstraction

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

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initial abstraction (I_a)

- Look up Ia values in TR-55 manual

Table 4-1 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

4. Runoff Depth (Q)

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

initial abstraction (I_a)

Runoff Depth (Q)

- Solve for Q (runoff depth):
  - SCS Runoff equation (p.21)
  - Tabular method (p.23), TR-55 Manual
  - Graphical method (p.22), TR-55 Manual

initial abstraction (I_a)

Runoff Depth (Q)

$q_p = q_u A_m Q F_p$

Runoff Equation

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

Q = Runoff (in)
P = Rainfall (in)
S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10$$

CN = Curve number
I_a = Initial abstraction (in)
= 0.2 x S
= (all losses before runoff begins)

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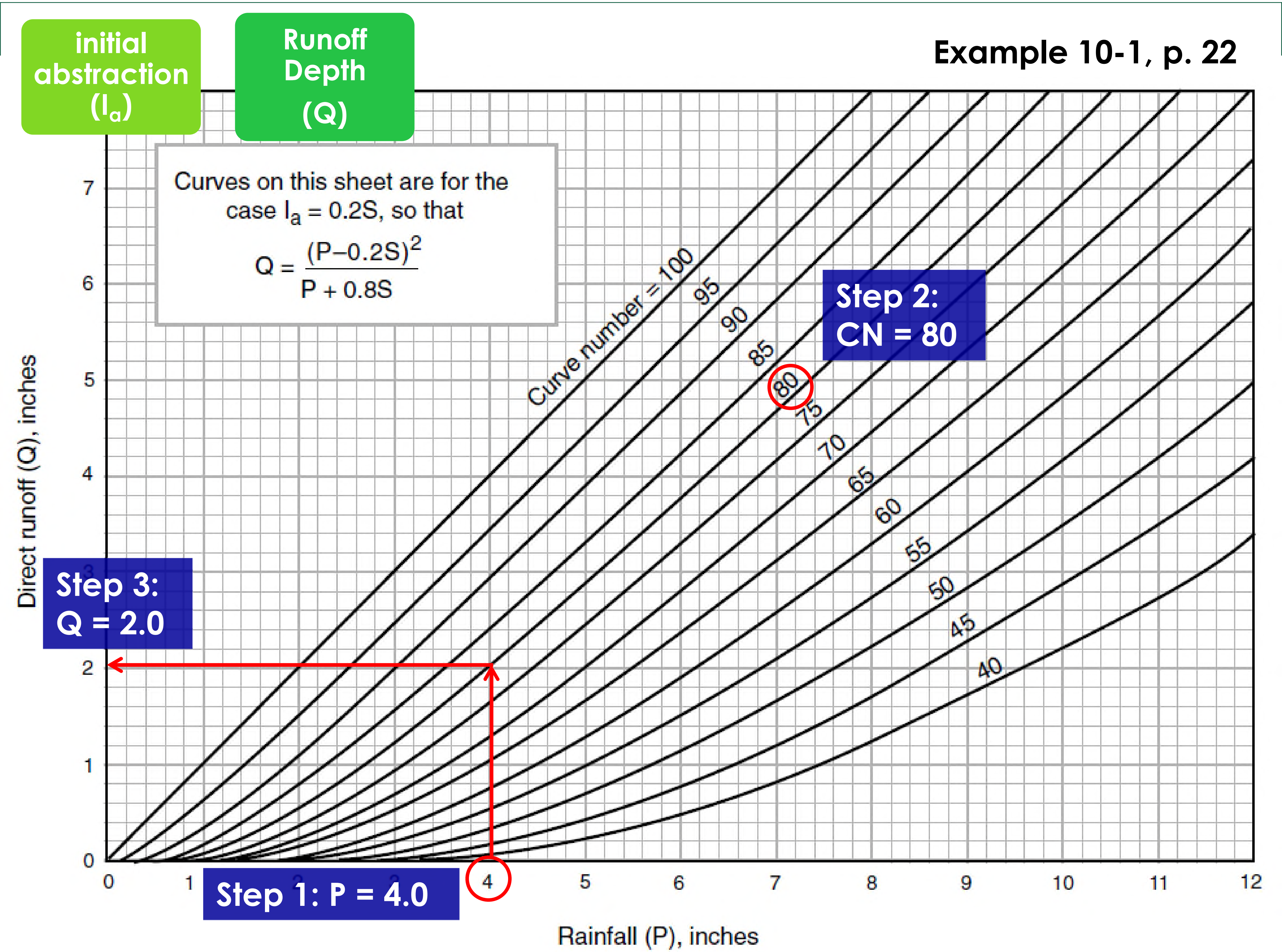
Example 10-1

Given a watershed with a CN of 80, what would be the direct runoff (Q) from a rainfall (P) of 4.0 inches?

(Instructions given for graphical. Tabular method is 10-2.)

Example 10-1, p. 22



Find Q
p. 23

Or
TR-55
Manual

Table 2-1 Runoff depth for selected CN's and rainfall amounts [1]

	Runoff depth for curve number of—												
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
	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	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
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	6.76
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	7.76
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	8.76
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	9.76
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	10.76
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	11.76
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	12.76
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	13.76
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	14.76

[1] Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Runoff Equation Example 10-1

T... off... ed CN's and rainfall amounts 1/

initial abstraction (I_a)

Runoff Depth (Q)

Runoff depth for curve number of—

Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	[illegible]	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	[illegible]	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
[illegible]	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	[illegible]	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	[illegible]	4.85	5.41	5.76
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	6.76
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	7.76
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	8.76
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	9.76
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	10.76
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	11.76
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	12.76
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	13.76
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	14.76

Step 1: P = 4.0

Step 2: CN = 80

Step 3: Q = 2.04

Runoff Depth (Q)

Runoff Equation Example

P = rainfall (in)

CN = runoff curve number

S = potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN}\right) - 10 = \left(\frac{1000}{80}\right) - 10 = 2.5$$

I_a = initial abstraction (in)

= 0.2 x S

= 0.2 x 2.5

= 0.5

$$Q = \frac{(P - 1_a)^2}{(P - 1_a) + S}$$

$$= \frac{(4.0 - 0.5)^2}{(4.0 - 0.5) + 2.5} = 2.04$$

Equations on page 21

Runoff Equation Example 10-1

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Runoff Exercise:

Given a watershed with a CN of 85, what would be the direct runoff (Q) from a rainfall (P) of 2.5 inches?

P = rainfall (in)

CN = runoff curve number

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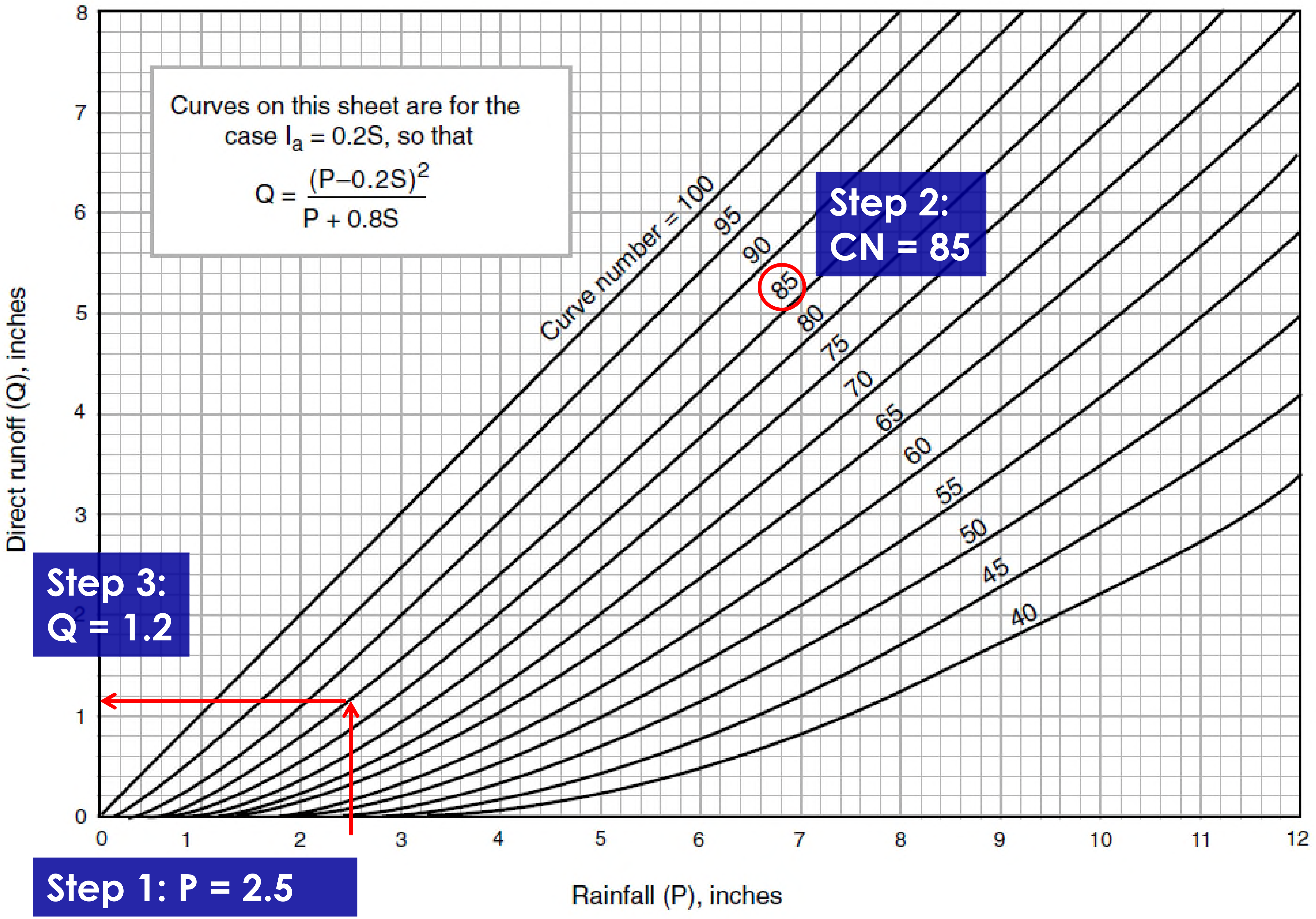
Runoff Exercise



Q&A

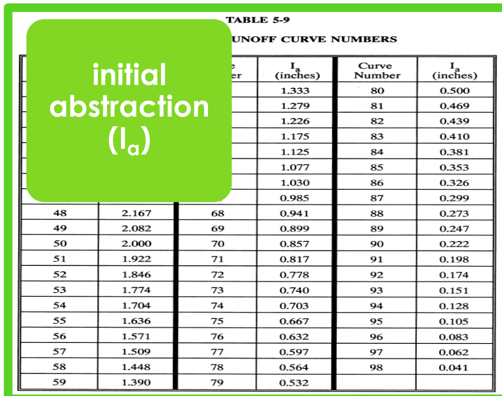


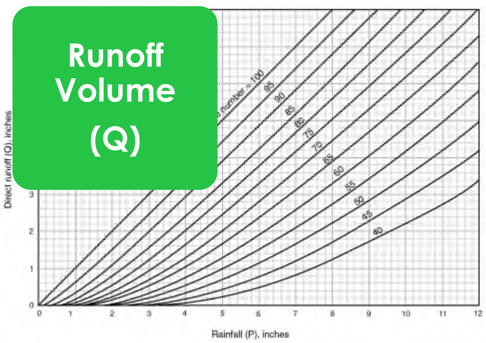
TABLE 5-9

UNOFF CURVE NUMBERS

		e er	I_a (inches)	Curve Number	I_a (inches)
			1.333	80	0.500
			1.279	81	0.469
			1.226	82	0.439
			1.175	83	0.410
			1.125	84	0.381
			1.077	85	0.353
			1.030	86	0.326
			0.985	87	0.299
48	2.167	68	0.941	88	0.273
49	2.082	69	0.899	89	0.247
50	2.000	70	0.857	90	0.222
51	1.922	71	0.817	91	0.198
52	1.846	72	0.778	92	0.174
53	1.774	73	0.740	93	0.151
54	1.704	74	0.703	94	0.128
55	1.636	75	0.667	95	0.105
56	1.571	76	0.632	96	0.083
57	1.509	77	0.597	97	0.062
58	1.448	78	0.564	98	0.041
59	1.390	79	0.532		

initial abstraction (I_a)

3. Initial Abstraction



Runoff Volume (Q)

4. Runoff Depth

Q

5. Time of Concentration

1. Determine 24-hour rainfall (P) for desired design storm

2. Calculate weighted CN for site

3. Use CN with table to determine initial abstraction (I_a)

4. Calculate expected runoff depth (Q)

5. Determine time of concentration (t_c)

6. Compute I_a/P ratio

7. Use t_c and I_a/P to find q_u from chart

8. Determine pond and swamp adjustment factor (F_p)

9. Combine all above factors and calculate peak discharge (q_p)

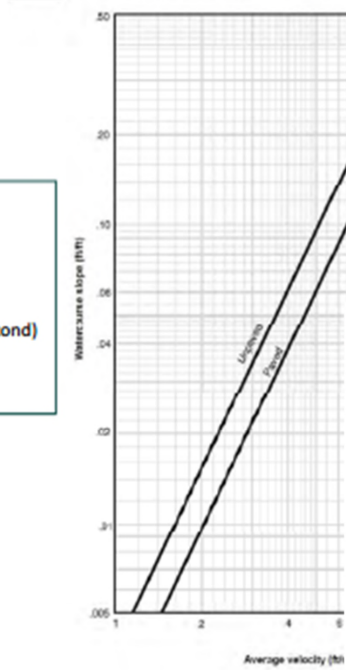
$$Tt = \left(\frac{L}{V \times t} \right)$$

L = flow length (feet)

V = average velocity (feet/second)

t = conversion factor

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



See Module 9 and Chapter 3 of TR-55 (1986)

Figure 15B-2 Cerrelli's and Humpal's shallow concentrated flow

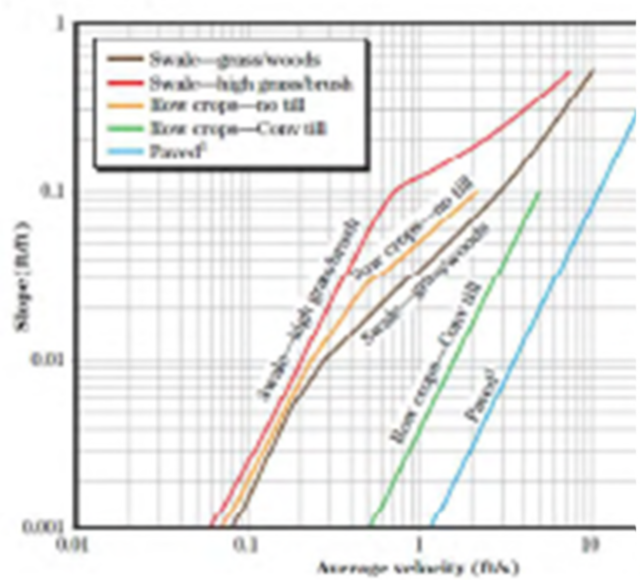


Figure 15-4 Velocity versus slope for shallow concentrated flow

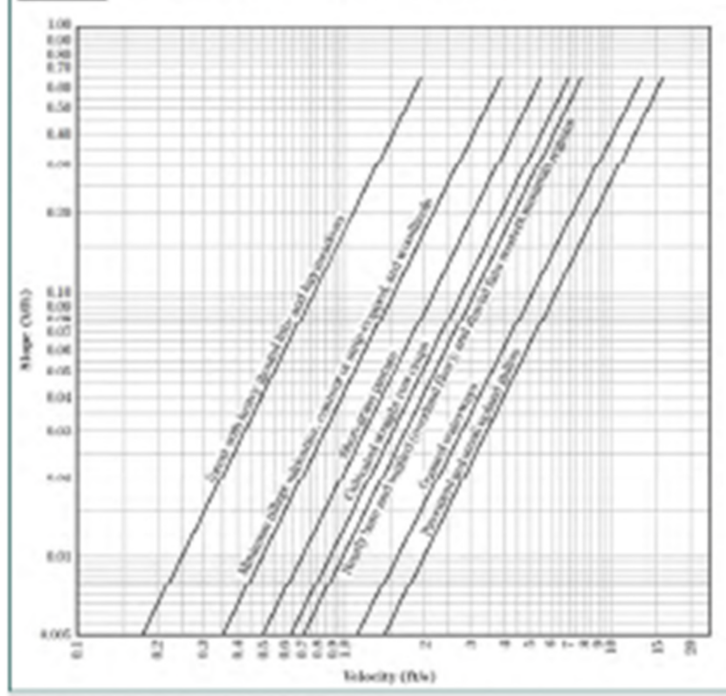


Table 15-3 Equations and assumptions developed from figure 15-4

Flow type	Depth (ft)	Manning's n	Velocity equation (ft/s)
Pavement and small upland gullies	0.2	0.025	$V=20.328(s)^{0.5}$
Grassed waterways	0.4	0.050	$V=16.135(s)^{0.5}$
Nearly bare and untilled (overland flow); and alluvial fans in western mountain regions	0.2	0.051	$V=9.965(s)^{0.5}$
Cultivated straight row crops	0.2	0.058	$V=8.762(s)^{0.5}$
Short-grass pasture	0.2	0.073	$V=6.962(s)^{0.5}$
Minimum tillage cultivation, contour or strip-cropped, and woodlands	0.2	0.101	$V=5.032(s)^{0.5}$
Forest with heavy ground litter and hay meadows	0.2	0.202	$V=2.516(s)^{0.5}$

Source: NEH, 2010. Chapter 15.

Table 15B-1 Assumptions used by Cerrelli and Humpal to develop shallow concentrated flow curves

Curve type	Flow shape	Width (ft)	Depth (ft)	Hydraulic radius, R (ft)	Retardance	n value
Wide swale—lawn/mature woods	Parabolic	10	0.4	0.27	D	
Wide swale—high grass/brush	Parabolic	10	0.4	0.27	C	
Row crops—no till	Parabolic	7.5	0.3	0.21	D	
Row crops—conventional tillage/bare gully	Parabolic	7.5	0.3	0.21		0.035
Paved 1/	Triangular	12	0.4	0.13		0.014

1 The assumptions and limits for the paved condition used to define the paved line in figure 15B-2 are not the same as those used for the pavement and small upland gullies line shown in figure 15-4. Velocities obtained using figure 15-4 and/or table 15-3 should not be combined with those obtained from figure 15B-1.

Source: NEH, 2010. Chapter 15

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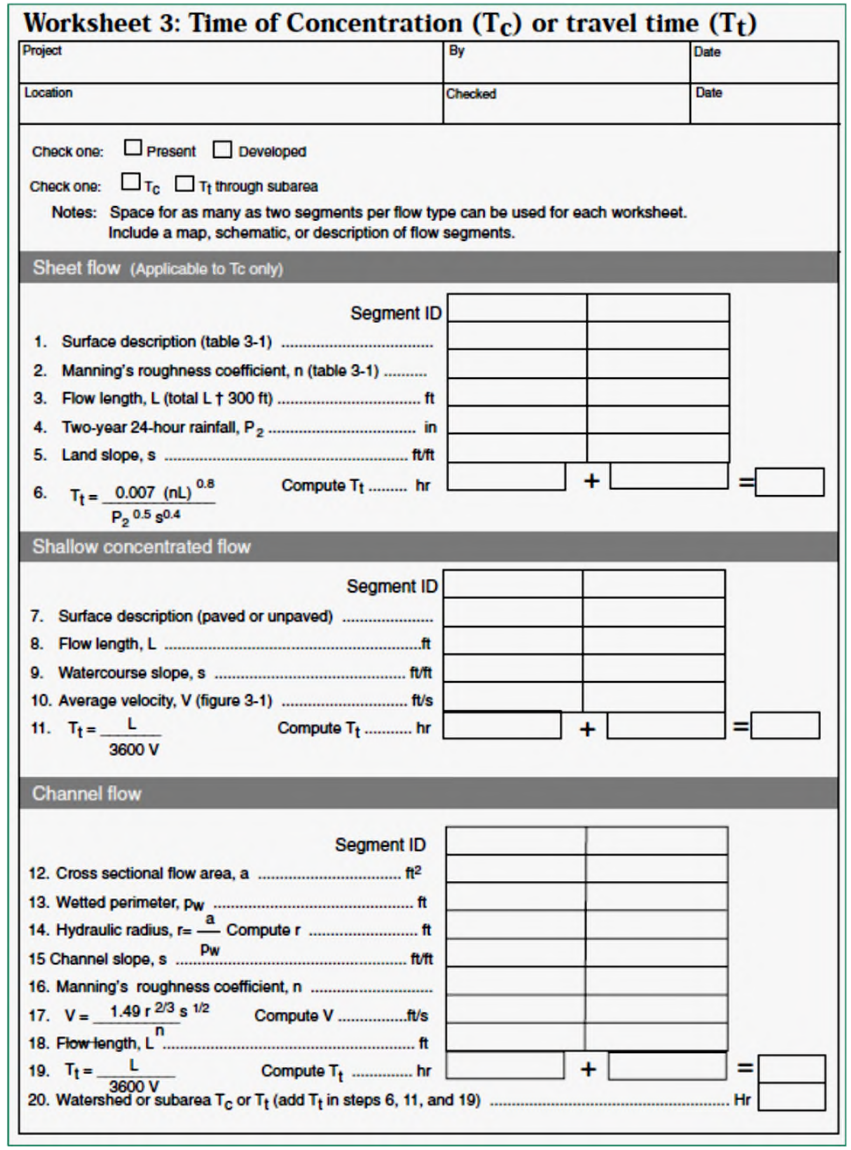
T_c

Time of Concentration

Worksheet on p. 53 of Module 9

TR-55 Manual

Use Win TR55



Worksheet 3: Time of Concentration (T_c) or travel time (T_t)

Project	By	Date
Location	Checked	Date

Check one: ☐ Present ☐ Developed

Check one: ☐ T_c ☐ T_t through subarea

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

Sheet flow (Applicable to Tc only)

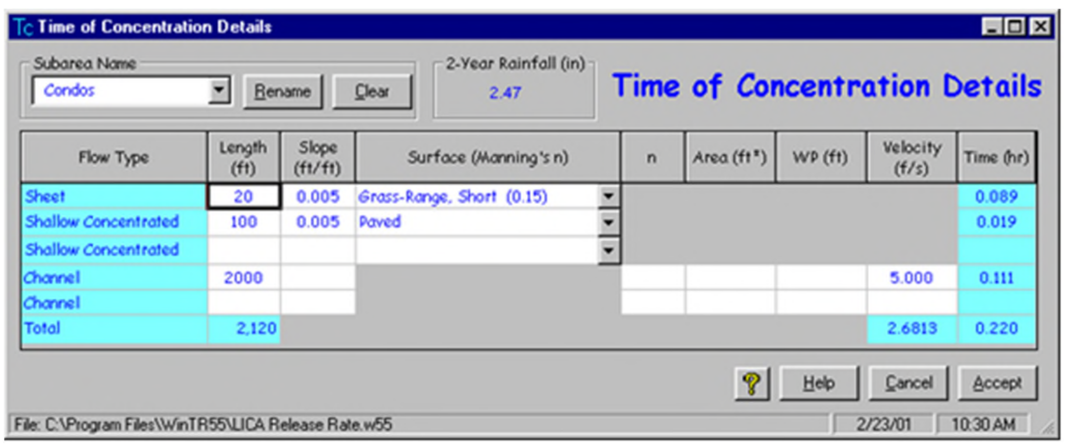
Segment ID			
1. Surface description (table 3-1)			
2. Manning's roughness coefficient, n (table 3-1)			
3. Flow length, L (total L † 300 ft) ... ft			
4. Two-year 24-hour rainfall, P_2 ... in			
5. Land slope, s ... ft/ft			
6. $T_t = \dfrac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T_t ...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

Shallow concentrated flow

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

Channel flow

Segment ID			
12. Cross sectional flow area, a ... ft²			
13. Wetted perimeter, p_w ... ft			
14. Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r ... ft			
15 Channel slope, s ... ft/ft			
16. Manning's roughness coefficient, n			
17. $V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V ... ft/s			
18. Flow length, L ... ft			
19. $T_t = \dfrac{L}{3600\ V}$ Compute T_t ... hr		+	=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) ... Hr			



Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	20	0.005	Grass-Range, Short (0.15)					0.089
Shallow Concentrated	100	0.005	Paved					0.019
Shallow Concentrated								
Channel	2000						5.000	0.111
Channel								
Total	2,120						2.6813	0.220

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6. Ia/P ratio & 7. Find q_u

1. Determine 24-hour rainfall (P) for desired design storm

2. Calculate weighted CN for site

3. Use CN with table to determine initial abstraction (I_a)

4. Calculate expected runoff depth (Q)

5. Determine time of concentration (t_c)

6. Compute I_a/P ratio

7. Use t_c and I_a/P to find q_u from chart

8. Determine pond and swamp adjustment factor (F_p)

9. Combine all above factors and calculate peak discharge (q_p)

I_a/P

Find q_u

Find q_u on chart -

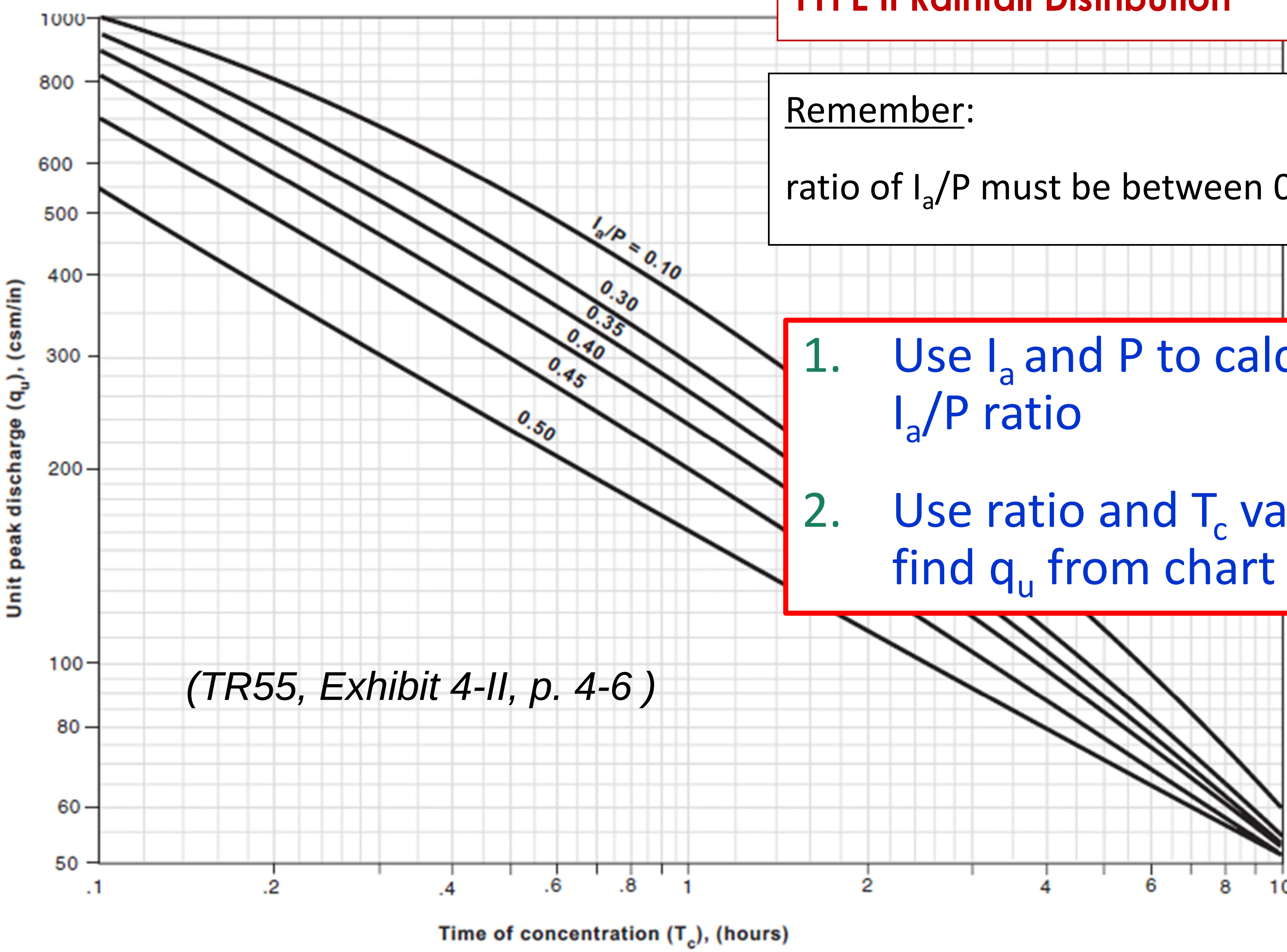
Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution

TYPE II Rainfall Distribution

Remember:

ratio of I_a/P must be between 0.1 - 0.5.

1. Use I_a and P to calculate I_a/P ratio
2. Use ratio and T_c value to find q_u from chart



(TR55, Exhibit 4-II, p. 4-6)

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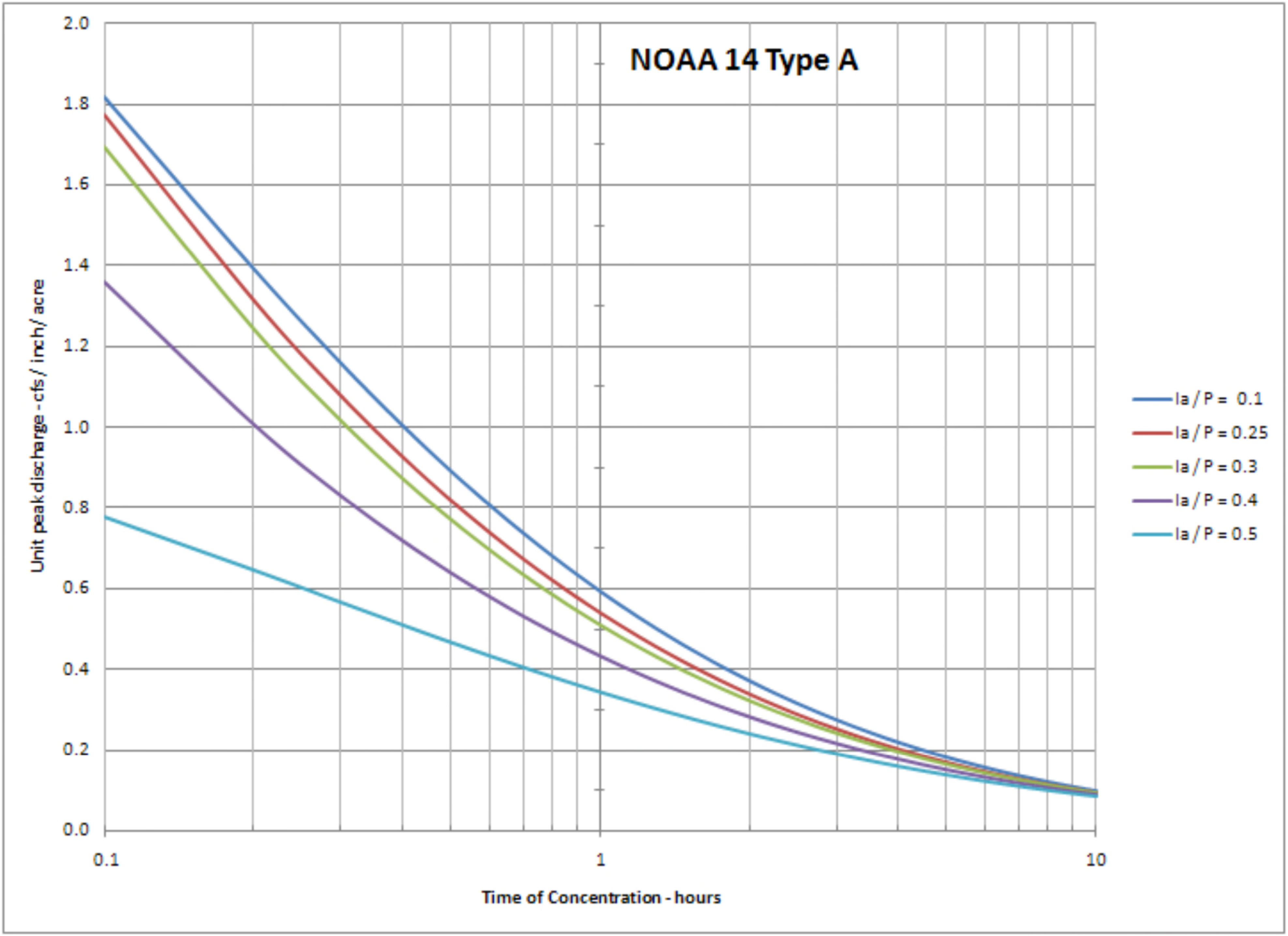
NOAA 14 Type A
Unit peak discharge - cfs / inch / acre
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.1
1
10
Time of Concentration - hours
Ia / P = 0.1
Ia / P = 0.25
Ia / P = 0.3
Ia / P = 0.4
Ia / P = 0.5

8. Swamp Adjustment Factor

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. **Determine pond and swamp adjustment factor (F_p)**
9. Combine all above factors and calculate peak discharge (q_p)

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Pond/swamp factor (F_p)

$$q_p = q_u A_m Q F_p$$

- Factor needed **<u>if</u>** ponds and/or swamps scattered throughout watershed, but not on path used to determine Tc
- Determine percentage of drainage area represented by swamps and/or ponds

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

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

Figure 10-19: Pond and Swamp Adjustment Factor (TR-55, 1986)

9. Peak Discharge

1. Determine 24-hour rainfall (P) for desired design storm
2. Calculate weighted CN for site
3. Use CN with table to determine initial abstraction (I_a)
4. Calculate expected runoff depth (Q)
5. Determine time of concentration (t_c)
6. Compute I_a/P ratio
7. Use t_c and I_a/P to find q_u from chart
8. Determine pond and swamp adjustment factor (F_p)
9. Combine all above factors and calculate peak discharge (q_p)

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peak discharge (q_p)

Calculate Peak Discharge

$$q_p = q_u \times A_{mi} \times Q \times F_p$$

q_p (cfs)

q_u (csm/in) from previous step

Q (in) from previous step

A_{mi} (mi^2) from site plan

F_p from previous step

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Typical worksheet

$q_p = q_u A_m Q F_p$

Worksheet 4: Graphical Peak Discharge method

Project: Heavenly Acres	By: RHM	Date: 10/15/85
Location: Dyer County, Tennessee	Checked: NM	Date: 10/17/85

Check one: ☐ Present ☒ Developed

1. Data

Drainage area .... A_m = 0.39 mi² (acres/640)

Runoff curve number .... CN = 75 (From worksheet 2), Figure 2-6

Time of concentration .... T_c = 1.53 hr (From worksheet 3), Figure 3-2

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

Pond and swamp areas sprea throughout watershed .... = – – percent of A_m (– – acres or mi² covered)

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	25		
3. Rainfall, P (24-hour)	in	6.0		
4. Initial abstraction, I_a (Use CN with table 4-1)	in	0.667		
5. Compute I_a/P		0.11		
6. Unit peak discharge, qu (Use T_c and I_a/P with exhibit 4– II)	csm/in	270		
7. Runoff, Q (From worksheet 2). Figure 2-6	in	3.28		
8. Pond and swamp adjustment factor, F_p (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond ans swamp area.)		1.0		
9. Peak discharge, q_p	cfs	345		

(Where $q_p = q_u A_m Q F_p$)

Worksheets/instructions:TR55 manual: http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Tools_Models/other/TR55.html.

TR55 Windows program: http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR55.html.

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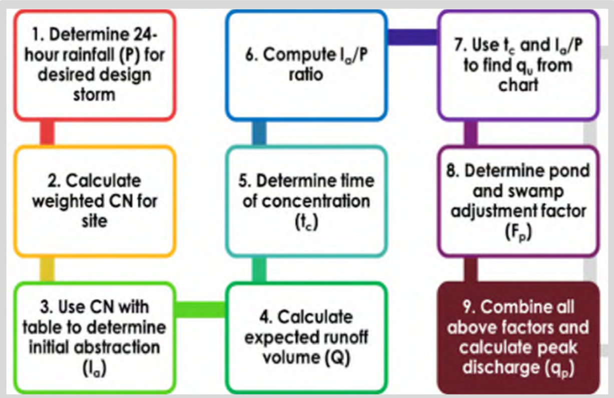
Q&A



Graphical Peak Discharge Method TR-55

Module 10c.

Tabular Hydrograph Method

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Tabular Hydrograph Method

- For large non-uniform watersheds
- Time of concentration must be less than 2 hours
- Acreage of individual sub-watersheds should not differ by a factor of 5 or more
- Use TR-20 or other models when limitations can't be met

Tabular Hydrograph Method

NOTE:

TR-55 documentation should be referenced for complete procedures and limitations of the Tabular Method.

Examples and worksheets can be found in TR-55 (1986). Revisions to TR-55 along with instructions and examples for the windows software application are available in the WinTR-55 User Guide. The technical reference for WinTR-55 is the NRCS National Engineering Handbook.

Work Problems
Graphical Peak Discharge