SECTION 5

STORM DRAINAGE DESIGN

5-1 DRAINAGE POLICY – It is the policy of Sutter County to protect all new habitable structures from the 100-year (1%) flood event. It is the policy of Sutter County to protect two lanes of travel in each direction for arterial roadways from the 100-year (1%) flood event and one lane in each direction for all other public roads from the 10-year (10%) flood event.

5-2 PERMITS FROM OTHER PUBLIC AGENCIES - Where other public agencies assert jurisdiction over aspects of drainage improvements required by Sutter County, approval shall be provided by such jurisdictions prior to issuance of permits or approval of improvement plans.

5-3 COMPLIANCE WITH NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES) – For construction activities which disturb **1 acre or more** of land, a Notice of Intent (NOI) to comply with the terms of the State General Permit to Discharge Storm Water Associated with Construction Activity (WQ Order No. 99-08-DWQ) must be submitted to the State Water Quality Control Board.

NOI to be mailed to: State Water Resources Control Board
Division of Water Quality
Attn: Storm Water Permit Unit
P.O. Box 1977
Sacramento, CA 95812-1977

Additional information and forms may be obtained from the state web pages:
http://www.swrcb.ca.gov/stormwtr/construction.html
http://www.swrcb.ca.gov/stormwtr/gen_const.html

It is the responsibility of the owner/applicant to comply with all regulations and permits for storm water regulations through the California State Water Quality Control Board (SWQCB). Evidence of compliance shall be provided to the County at time of construction permit issuance by submission of a State WDID No. (The WDID No. is the number assigned by the State to each discharger covered under the General Permit). A copy of the **Storm Water Pollution Prevention Plan** (SWPPP) shall also be given to the County. See Appendix B for NPDES guidance information.

Regardless of the amount of disturbed land, Best Management Practices (BMP's) shall be required for each project to mitigate the discharge of pollutants and for erosion control. The most appropriate BMP's can be selected from California Storwater Quality Association's website at:
http://www.cabmphandbooks.com
http://www.co.sutter.ca.us/pdf/pw/construction_handbook.pdf

5-4 NATIONAL FLOOD INSURANCE PROGRAM --

The County of Sutter is a participant in the National Flood Insurance Program, and all development in the County shall comply with the County of Sutter Flood Damage Prevention Ordinance.

Amendments of the National Flood Insurance Program Flood Insurance Rate Maps may be required for developments located in a federal flood zone. Petitions for a Letter of Map Amendment (L.O.M.A.) or Letter of Map revision (L.O.M.R.), including any fee required by Federal Emergency Management Agency (F.E.M.A.), shall be submitted to the Public Works Department prior to approval of a tentative map or approval of improvement plans.

5-5 DRAINAGE CAPACITY DESIGN - All drainage systems shall be designed to accommodate the ultimate development of the entire upstream watershed.

5-6 SURFACE DRAINAGE GRADING DESIGN - The engineer shall be responsible for designing a grading plan which ensures storm waters from a 100 year design storm flow through a development without flooding structures in the event of malfunction or overloading of the drainage collection system.

5-7 DRAINAGE DIVERSIONS -

A. The diversion of natural drainage will be allowed only within the limits of the proposed improvement. All natural drainage shall enter and leave the improved area at its original horizontal and vertical alignment unless an agreement, the form of which shall be approved by the Director, has been executed with all affected property owners.

B. Temporary drainage diversions during construction shall be approved by the Director and appropriate district.

5-8 DRAINAGE EASEMENTS

A. All publicly maintained drainage facilities shall be located in one of the following:

1. Public street right-of-way

2. Public utility easement specifically dedicated to include drainage facilities

3. Dedicated drainage easement

B. Offsite drainage easements will be required whenever there is a concentrated discharge of drainage water.

C. Dedication of offsite easements shall be completed and submitted to the Director with copies of deeds or title reports for the affected properties before improvement plans will be approved.

D. Closed Conduits – Easements for closed conduits shall meet the following requirements:

1. Minimum width of fifteen feet with the centerline of the pipe at the mid-point.

2. For pipes exceeding 24″ in diameter or trenches exceeding eight feet in depth, the easement width to the next whole foot shall be based on the following formula unless otherwise approved by the Director:

   WIDTH = Trench depth + outside pipe diameter + four feet

   Trench depth is measured from finish grade to 0.5′ below pipe invert.

3. Minimum width of fifteen feet for side and back lot drains in a subdivision, all on one parcel of land.

E. Open Channels – Easements for open channels shall have sufficient width to contain the channel, fencing where required, and a 15 foot all weather access service road. A service road may not be required where the channel bottom is lined and a suitable access ramp is provided when approved by the Director.

5-9 RUNOFF CALCULATION – Runoff shall be calculated as follows:

A. Drainage areas under 100 acres –

1. The runoff to be used in storm drain design for drainage basins 100 acres and smaller without runoff storage facilities shall be computed using the Rational Method or unit hydrograph computation method described in 5.8B.

MODIFIED RATIONAL METHOD

$$Q = CiA \qquad \text{(Eq. 5-1)}$$

Q = The peak discharge, in cubic feet per second, cfs
C = Runoff coefficient, dimensionless
i = Design rainfall intensity, inches/hour, over a duration equal to t_c for the catchment
A = Catchment area, in acres

In any analyses in which the peak-only model is used, the design engineer must determine and demonstrate that the model is appropriate. If one or more of the following conditions are true, the peak-only method *should not* be used unless the engineer demonstrates conclusively that the effects of that condition are negligible:

- Natural or man-made ponding of stormwater in the basin affects peak discharge;
- Design and operation of larger drainage facilities is required;
- Routing is required;
- The basin is large enough that design-storm rainfall depths vary significantly;
- Differences in time of concentration of two areas within the basin causes variations in timing of peaks.

RAINFALL INTENSITY

The rainfall intensity (i) is expressed in inches per hour for a specified return interval (frequency). <u>The rainfall intensity is a function of the duration of the storm which is assumed to be equal to the time of concentration for runoff</u>. This is a convenient assumption because it facilitates access to a rainfall intensity-duration-frequency curve. The rainfall intensity is derived from this curve which is based upon actual measured rainfall data over some statistically significant time period.

Steps to estimate the design storm intensity for any basin are as follows:

1. Locate the basin of interest on the Sutter County mean annual precipitation (MAP) map, and determine from the map the mean annual rainfall for the basin. See Figure 5-1, page 5-9.

2. Time of concentration is defined as …*the time it takes for runoff to travel from the hydraulically most distant part of the storm area to the watershed outlet or other point of reference downstream. … [it] is generally understood as applying to surface runoff* (SCS, 1972). Flow time may be divided into sheet flow time, shallow flow time, and channel flow time. Use this value as the duration of the storm.

   A designer should use all possible guide tables, charts, references, other sources, and experience to estimate flow velocities. These tables should be included in the appendix of the drainage analysis. The designer should also take into account the impacts of future development as it relates to the velocity of water.

   A simple determination of Tc may involve the division of length of travel by estimated velocity of travel:

   $$Tc = \Sigma \text{ (Length of runoff route/ Runoff Velocity)} \qquad \text{(Eq. 5-2)}$$

   Many watersheds will exhibit varying types of ground cover, channel characteristics, vegetation and slopes; all of which significantly affect the velocity of travel. At best, the estimation of t_c is very subjective and therefore, requires considerable effort and justification. Some empirical equations exist but they should be used with caution because of limitations on applicability. Reference is made to the *Caltrans Highway Design Manual* for the empirical equations. This can be viewed online at http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm (Please note that unit conversion may be necessary).

Time of concentration has a practical minimum. It is recommended that a **minimum** tc of 10 minutes be used for moderate slopes (10:1 or flatter) and 5 minutes for steeper slopes which have no surface storage. This is because very intense, short duration bursts of rainfall can yield high intensity rates giving unrealistic intensities for small shed areas. This behavior can be seen by the logarithmic IDF curve.

- Sheet flow time. This is the time for flow overland, in no clearly defined channel. The travel time can be estimated with the following equation:

$$T_t = \frac{0.007(\eta L)^{0.8}}{(P_2)^{0.5} S^{0.4}} \qquad \text{(Eq. 5-3)}$$

in which T_t = sheet flow travel time, in hour; η = overland-flow roughness coefficient; L = length of overland flow surface, in feet (<300 feet); P_2 = 2-Year, 24-hour rainfall depth, in inches; and S = land slope, in feet/foot. Overland flow roughness coefficients for a variety of land uses are shown in Table 5-1, page 5-10.

Note: In this empirical equation, a 2-Year, 24-hour rainfall is used because the IDF curve is logarithmic and very short storm durations (under 5 minutes for <300 feet of travel) would give unrealistic values for intensities.

- Shallow concentrated flow. This is the time for flow at shallow depths in rills or in streets or gutters. It can be estimated as the flow path length divided by the velocity. The velocity of shallow flow over an unpaved surface is estimated as:

$$V = 16.1345\sqrt{S_o} \qquad \text{(Eq. 5-4)}$$

in which V = shallow-concentrated flow velocity, in feet/second; and S_o = slope, in feet/foot. For flow over a paved surface, the velocity may be estimated as:

$$V = 20.3283\sqrt{S_o} \qquad \text{(Eq. 5-5)}$$

3. Using the MAP value from step 1, find the appropriate rainfall depth as a function of the MAP for the duration from step 2. See Table 5-2, pages 5-11 and 5-12.

4. Compute the intensity, i, as

$$i = \frac{\text{depth, inches}}{\text{duration , hour}} \qquad \text{(Eq. 5-6)}$$

(Conversion may be necessary from minutes to hours for some values from Step 2.)

RUNOFF COEFFICIENTS

Runoff coefficients are estimated as a function of return period, time of concentration, and land use and soil type. See Figures 5-2A, 5-2B and 5-2C, pages 5-13, 5-14, and 5-15. Determine the curve number (CN) from Tables 2-2a, 2-2b, 2-2c, and 2-2d in the Soil Conservation Service (SCS) Technical Release No. 55 (TR-55) for the basin area (see Appendix A, pages A-2 through A-5) and estimate the runoff coefficient (C) using Figures 5-2A, 5-2B, and 5-2C on pages 5-11, 5-12, and 5-13, respectively.

The percentage of rainfall resulting in runoff is commonly expressed as a relative percentage by the runoff coefficient. The runoff coefficient is based on several characteristics:

- Infiltration or the percolation of water into the soil
- Depression storage which intercepts and accumulates water
- Detention storage which is the interim storage of water
- Interception which is the initial "wetting" process by the rainfall
- Evaporation
- Transpiration of water by vegetation

Based upon an initial assumption in the Rational Method that storm runoff can be represented by a constant percentage of the precipitation intensity, the designer must assign a single relative percentage (runoff coefficient "C") for each quantitable segment of the watershed or watershed as a whole based upon consideration of current and future conditions.

$$C_w = \Sigma(C_i A_i) \;/\; \Sigma(A) \qquad \text{(Eq. 5-7)}$$

C_w: Weighted runoff coefficient
C_i: Coefficient of each individual area
A_i: Individual area

A: Total Area

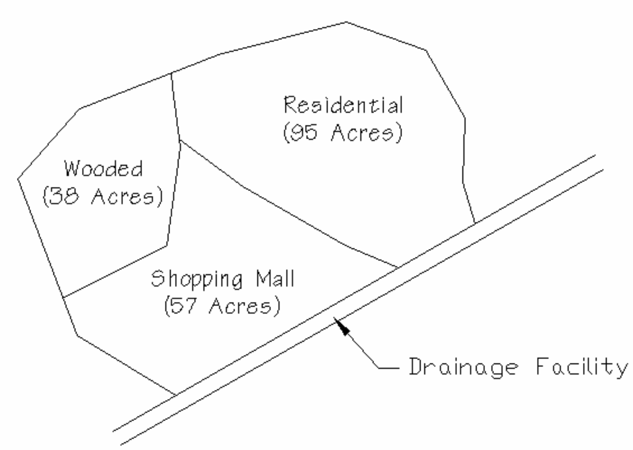
For example:

The information in the figure above showing the three individual areas can be put into a table:

Area Description	Individual Runoff Coeff "C"	Acreage
Wood	.35	38
Shopping Mall *	.85	57
Residential	.65	95
	Total	190

$$Cw = \frac{(.35 \times 38) + (.85 \times 57) + (.65 \times 95)}{190} = .65$$

*Note: it may also be appropriate to divide the Shopping Mall into individual weighted averages based on its multiple surfaces to derive at this value of .85 for "C".



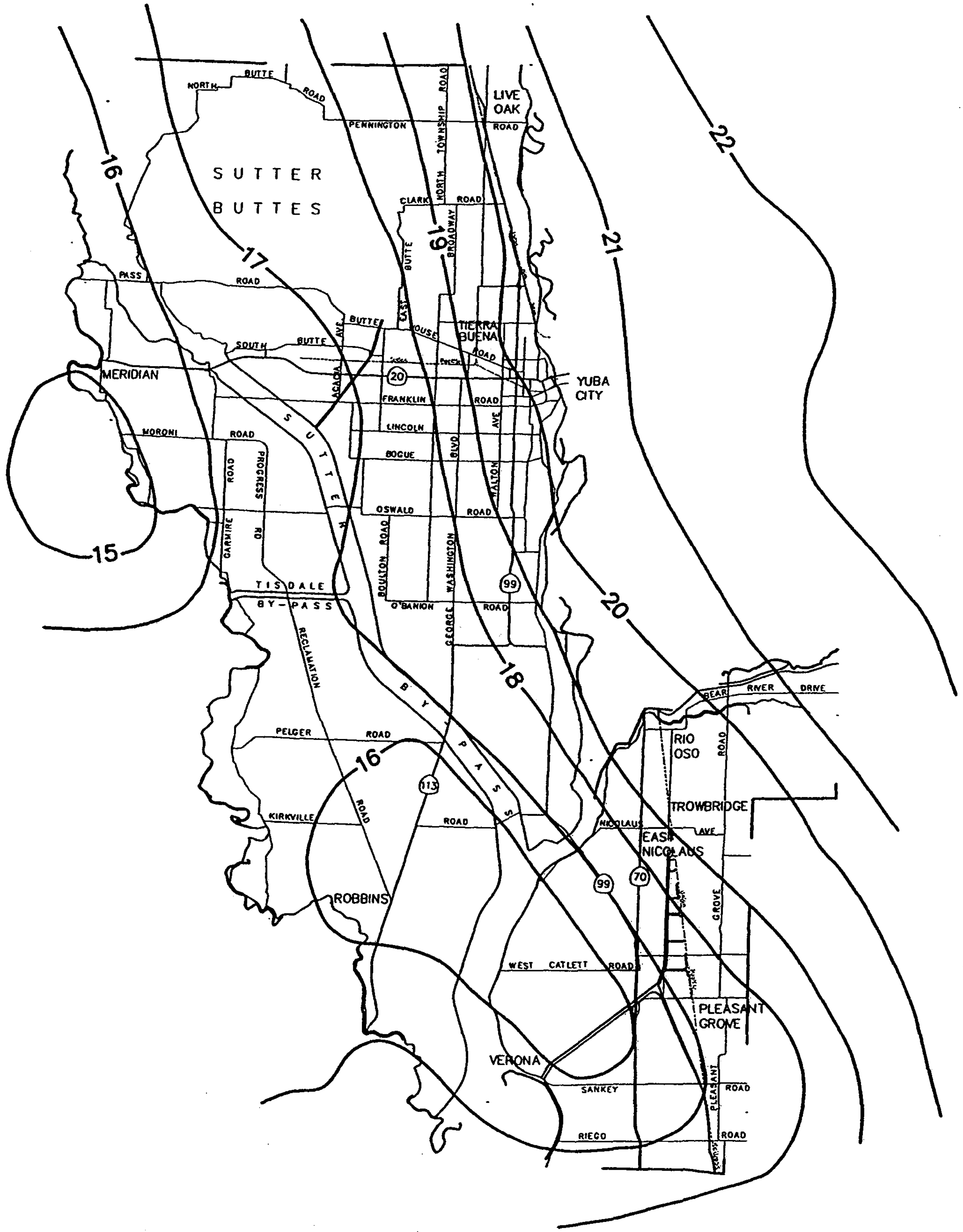


Figure 5-1
Mean Annual Precipitation (MAP)
Lines of Equal Average Annual Rainfall (inches)

TABLE 5-1. ROUGHNESS COEFFICIENTS (η)

Surface Description (1)	Roughness Coefficient (2)
Smooth surfaces (concrete, asphalt, gravel, or bare soil	0.011
Fallow (no residue)	0.05
Cultivated soils: Residue cover < 20% Residue cover > 20%	 0.06 0.17
Grass: Short grass prairie Dense grasses Bermuda	 0.15 0.24 0.41
Range (natural)	0.13
Woods: Light underbrush Dense underbrush	 0.40 0.80
Precast Concrete Pipe	0.015
Concrete Cast-In-Place	0.015
Vitrified Clay Pipe	0.013
Polyethylene Pipe	0.015
Ribbed Steel Pipe	0.015
Polyvinyl Chloride Pipe	0.015
Concrete Box Culvert	0.015
Corrugated Metal Pipe 2-2/3″ x 1/2″ Corrugations	0.024
Corrugated Metal Pipe 3″ x 1″ Corrugations	0.026
Multi-Plate Arch Pipe	0.031
Open Channel Fully Lined	0.015
Earth Channel, Clean, Uniform Sides	0.035
Open Channel with Lined Bottom, Clean Sides	0.025
Natural Channel	0.050 or as specified

TABLE 5-2. DESIGN RAINFALL DEPTHS AS A FUNCTION OF MAP

SUTTER COUNTY DESIGN RAINFALL – 2 YEAR RETURN PERIOD

MAP	5 min	10 min	15 min	30 min	1 hr	2 hr	3 hr	6 hr	12 hr	1 day	2 day	3 day	4 day	5 day	6 day	8 day	10 day	15 day	20 day	30 day	60 day	Year
15	0.17	0.22	0.26	0.35	0.47	0.62	0.74	0.99	1.32	1.76	2.07	2.37	2.58	2.83	3.07	3.47	3.73	4.34	4.74	5.67	8.20	14.69
16	0.17	0.23	0.27	0.36	0.48	0.64	0.76	1.01	1.36	1.81	2.14	2.46	2.69	2.94	3.20	3.61	3.90	4.55	4.99	5.97	8.65	15.67
17	0.17	0.23	0.28	0.37	0.49	0.66	.078	1.04	1.39	1.86	2.21	2.55	2.79	3.06	3.32	3.76	4.07	4.77	5.23	6.27	9.11	16.65
18	0.18	0.24	0.28	0.38	0.51	0.68	0.80	1.07	1.43	1.91	2.28	2.64	2.90	3.18	3.45	3.91	4.24	4.98	5.48	6.57	9.57	17.63
19	0.18	0.25	0.29	0.39	0.52	0.69	0.82	1.10	1.47	1.96	2.35	2.73	3.00	3.29	3.57	4.05	4.41	5.19	5.73	6.86	10.03	18.61
20	0.19	0.25	0.30	0.40	0.53	0.71	0.84	1.12	1.50	2.01	2.42	2.82	3.11	3.41	3.70	4.20	4.58	5.41	5.98	7.16	10.49	19.58
21	0.19	0.26	0.31	0.41	0.54	0.73	0.86	1.15	1.54	2.05	2.49	2.91	3.21	3.52	3.83	4.35	4.75	5.62	6.23	7.46	10.95	20.56
22	0.20	0.26	0.31	0.42	0.56	0.75	0.88	1.18	1.57	2.10	2.56	3.00	3.32	3.64	3.95	4.49	4.92	5.83	6.48	7.76	11.41	21.54

SUTTER COUNTY DESIGN RAINFALL – 10 YEAR RETURN PERIOD

MAP	5 min	10 min	15 min	30 min	1 hr	2 hr	3 hr	6 hr	12 hr	1 day	2 day	3 day	4 day	5 day	6 day	8 day	10 day	15 day	20 day	30 day	60 day	Year
15	0.26	0.35	0.41	0.55	0.73	0.97	1.15	1.54	2.06	2.75	3.40	3.94	4.33	4.59	4.99	5.58	5.96	6.80	7.52	8.92	12.74	21.12
16	0.27	0.35	0.42	0.56	0.75	1.00	1.19	1.58	2.12	2.83	3.51	4.09	4.51	4.78	5.20	5.82	6.23	7.13	7.91	9.40	13.46	22.53
17	0.27	0.36	0.43	0.58	0.77	1.03	1.22	1.63	2.17	2.90	3.63	4.24	4.69	4.97	5.40	6.06	6.50	7.47	8.31	9.87	14.17	23.94
18	0.28	0.37	0.44	0.59	0.79	1.06	1.25	1.67	2.23	2.98	3.75	4.39	4.86	5.16	5.61	6.29	6.77	7.80	8.70	10.34	14.88	25.35
19	0.29	0.38	0.45	0.61	0.81	1.08	1.28	1.71	2.29	3.06	3.86	4.54	5.04	5.35	5.81	6.53	7.04	8.14	9.10	10.81	15.59	26.76
20	0.29	0.39	0.47	0.62	0.83	1.11	1.31	1.76	2.35	3.13	3.98	4.69	5.22	5.54	6.02	6.77	7.32	8.47	9.49	11.28	16.31	28.17
21	0.30	0.40	0.48	0.64	0.85	1.14	1.35	1.80	2.40	3.21	4.10	4.84	5.40	5.72	6.22	7.00	7.59	8.81	9.88	11.75	17.02	29.57
22	0.31	0.41	0.49	0.65	0.87	1.16	1.38	1.84	2.46	3.29	4.21	4.99	5.57	5.91	6.43	7.24	7.86	9.14	10.28	12.22	17.73	30.98

SUTTER COUNTY DESIGN RAINFALL – 25 YEAR RETURN PERIOD

MA P	5 min	10 min	15 min	30 min	1 hr	2 hr	3 hr	6 hr	12 hr	1 day	2 day	3 day	4 day	5 day	6 day	8 day	10 day	15 day	20 day	30 day	60 day	Year
15	0.30	0.40	0.48	0.64	0.86	1.14	1.35	1.81	2.42	3.23	4.06	4.72	5.18	5.63	5.89	6.55	7.00	7.85	8.74	10.35	14.68	23.74
16	0.31	0.42	0.49	0.66	0.88	1.18	1.39	1.86	2.48	3.32	4.20	4.90	5.39	5.86	6.13	6.83	7.31	8.24	9.19	10.90	15.51	25.32
17	0.32	0.43	0.51	0.68	0.90	1.21	1.43	1.91	2.55	3.41	4.34	5.08	5.60	6.09	6.38	7.10	7.63	8.62	9.65	11.44	16.33	26.91
18	0.33	0.44	0.52	0.69	0.93	1.24	1.47	1.96	2.62	3.50	4.48	5.26	5.81	6.32	6.62	7.38	7.95	9.01	10.11	11.99	17.15	28.49
19	0.34	0.45	0.53	0.71	0.95	1.27	1.51	2.01	2.69	3.59	4.62	5.44	6.02	6.55	6.86	7.66	8.27	9.40	10.57	12.53	17.97	30.07
20	0.35	0.46	0.55	0.73	0.97	1.30	1.54	2.06	2.75	3.68	4.76	5.62	6.24	6.78	7.10	7.94	8.59	9.78	11.03	13.08	18.79	31.66
21	0.35	0.47	0.56	0.75	1.00	1.33	1.58	2.11	2.82	3.77	4.90	5.80	6.45	7.01	7.34	8.21	8.90	10.17	11.48	13.62	19.61	33.24
22	0.36	0.48	0.57	0.77	1.02	1.37	1.62	2.16	2.89	3.86	5.04	5.98	6.66	7.24	7.58	8.49	9.22	10.56	11.94	14.17	20.43	34.82

Table 5-2 Continued

SUTTER COUNTY DESIGN RAINFALL – 100 YEAR RETURN PERIOD																						
MAP	5 min	10 min	15 min	30 min	1 hr	2 hr	3 hr	6 hr	12 hr	1 day	2 day	3 day	4 day	5 day	6 day	8 day	10 day	15 day	20 day	30 day	60 day	Year
15	0.37	0.49	0.58	0.77	1.03	1.38	1.64	2.19	2.92	3.90	5.02	5.85	6.38	6.92	7.15	6.66	8.32	9.26	10.38	12.28	17.28	27.16
16	0.38	0.50	0.60	0.80	1.06	1.42	1.68	2.25	3.00	4.01	5.19	6.07	6.64	7.20	7.44	6.94	8.70	9.71	10.92	12.92	18.25	28.97
17	0.39	0.52	0.61	0.82	1.09	1.46	1.73	2.31	3.08	4.12	5.36	6.29	6.90	7.49	7.73	7.22	9.08	10.17	11.47	13.57	19.22	30.78
18	0.40	0.53	0.63	0.84	1.12	1.50	1.77	2.37	3.16	4.23	5.53	6.52	7.16	7.77	8.03	7.51	9.46	10.62	12.01	14.22	20.18	32.59
19	0.41	0.54	0.64	0.86	1.15	1.53	1.82	2.43	3.24	4.33	5.71	6.74	7.42	8.05	8.32	7.79	9.83	11.08	12.56	14.86	21.15	34.40
20	0.42	0.56	0.66	0.88	1.18	1.57	1.86	2.49	3.33	4.44	5.88	6.96	7.68	8.34	8.61	8.07	10.21	11.53	13.10	15.51	22.12	36.21
21	0.43	0.57	0.68	0.90	1.21	1.61	1.91	2.55	3.41	4.55	6.05	7.18	7.94	8.62	8.91	8.35	10.59	11.99	13.65	16.16	23.08	38.02
22	0.44	0.58	0.69	0.92	1.24	1.65	1.95	2.61	3.49	4.66	6.22	7.41	8.20	8.90	9.20	8.64	10.97	12.45	14.19	16.81	24.05	39.83

FIGURE 5-2A. RUNOFF COEFFICIENT FOR 100-YEAR STORM

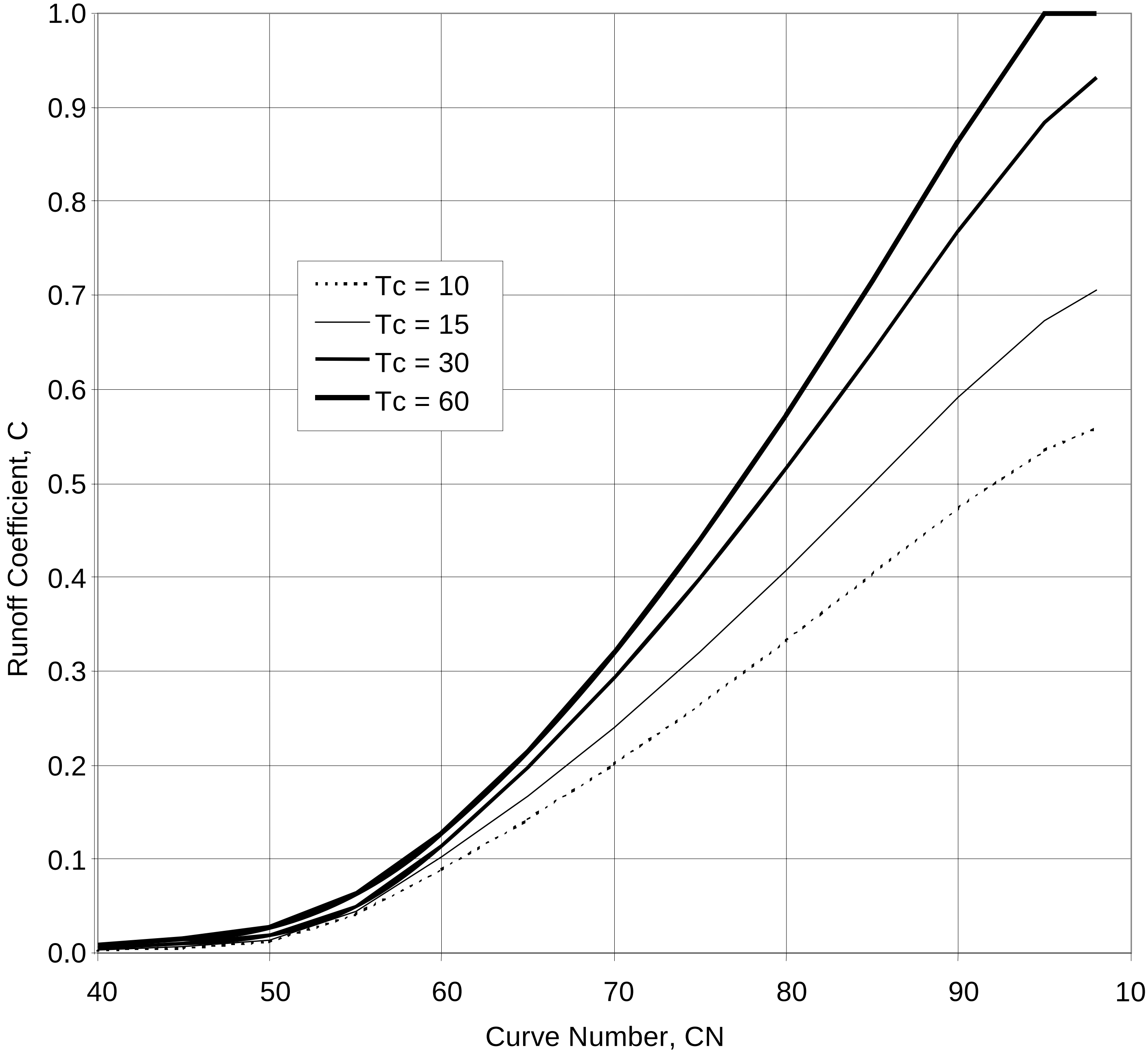


FIGURE 5-2B. RUNOFF COEFFICIENT FOR 25-YEAR STORM

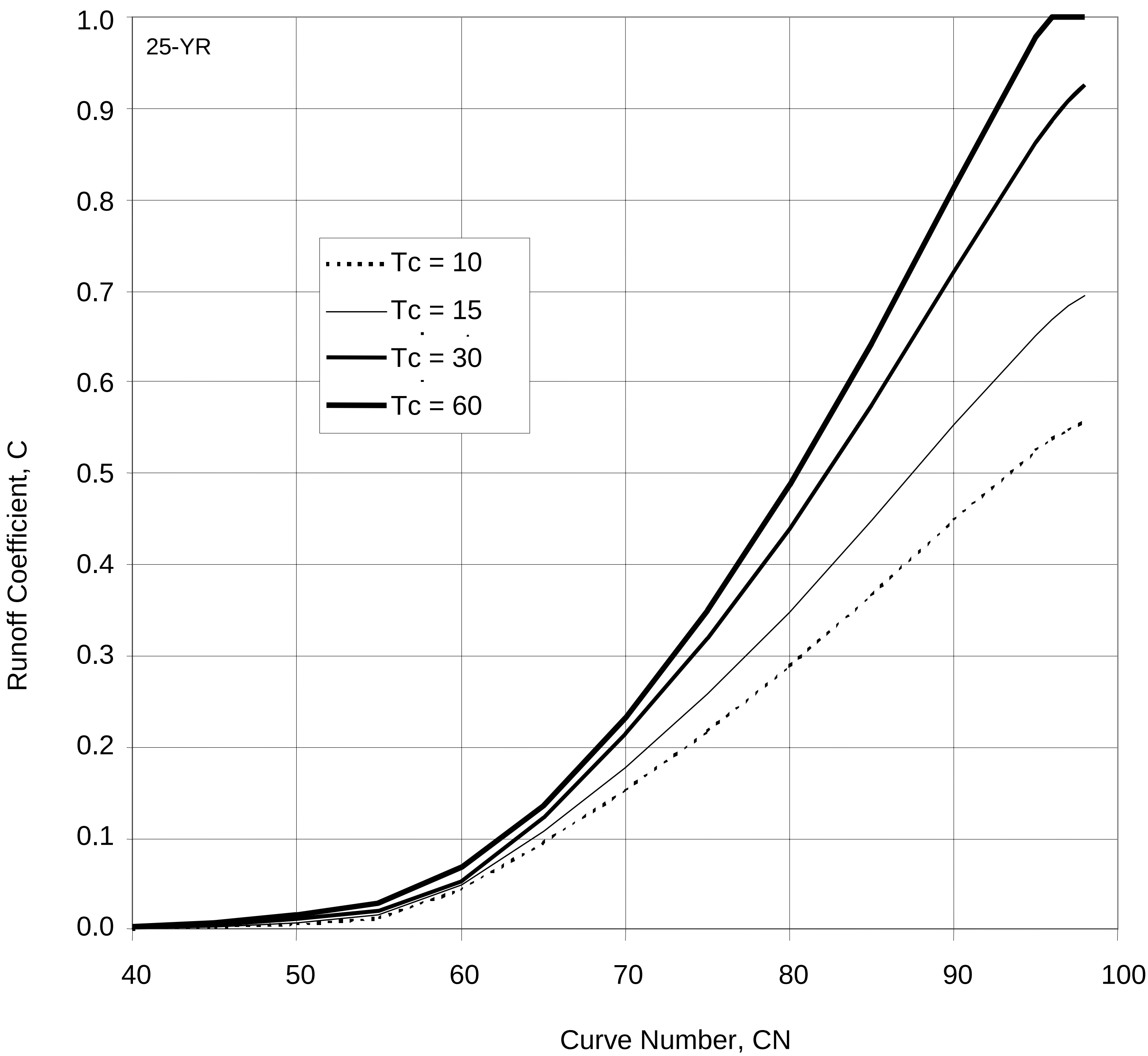
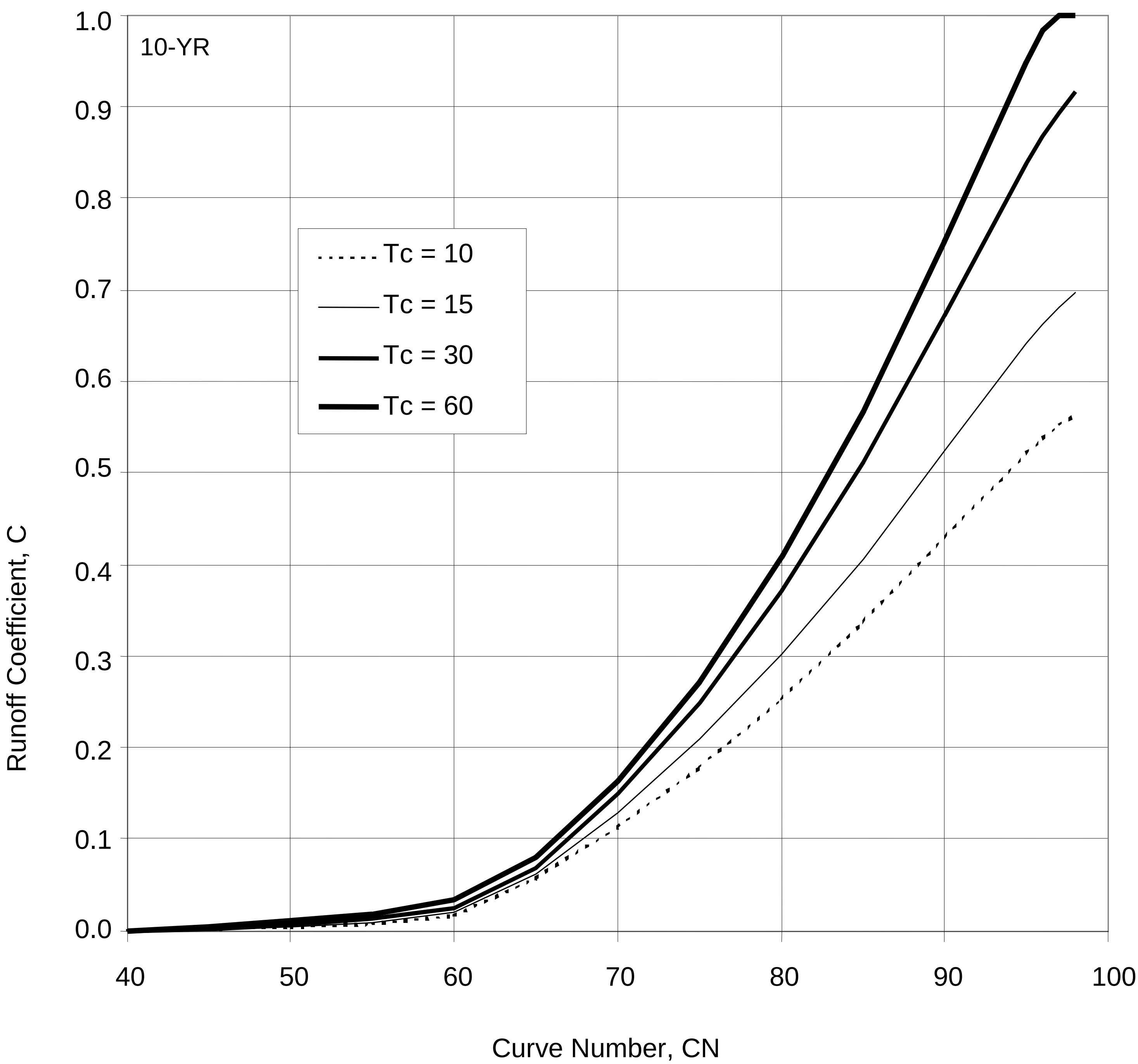


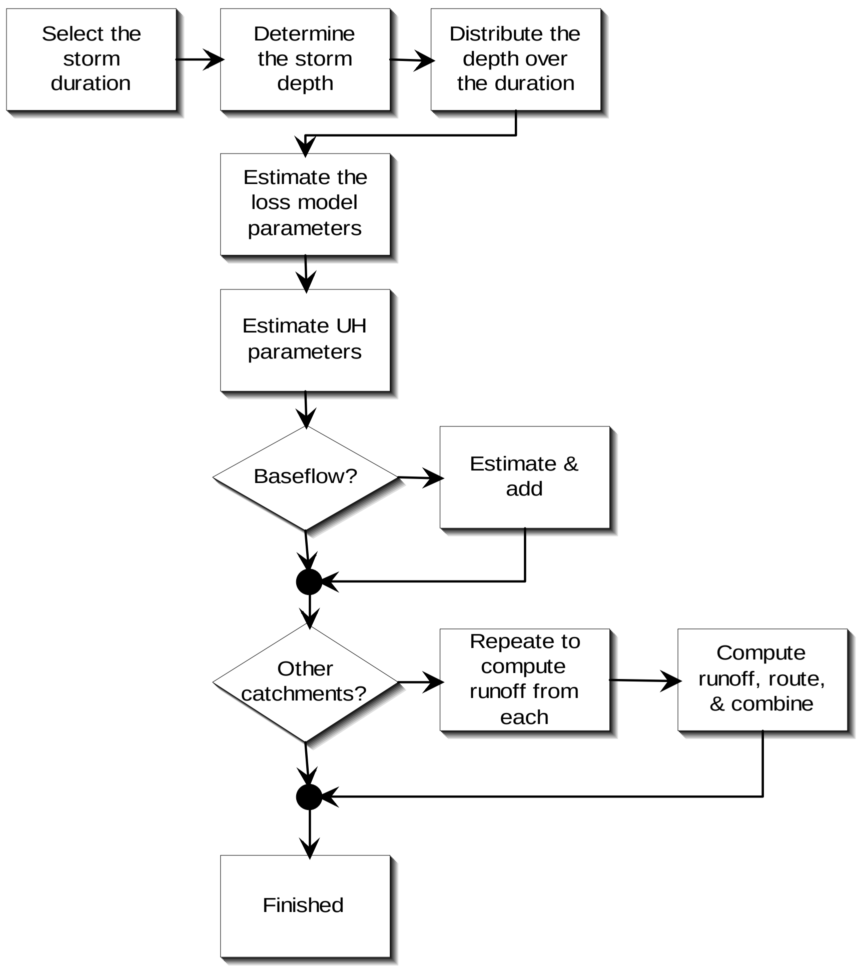
FIGURE 5-2C. RUNOFF COEFFICIENT FOR 10-YEAR STORM



B. Drainage areas greater than 100 acres –

1. The runoff to be used in storm drainage design for drainage basins greater than 100 acres, or watershed areas of any size utilizing runoff storage, shall be computed using a rainfall-runoff computer model such as HEC-1 developed by the U.S. Army Corps of Engineers, unless otherwise approved by the Director.

Stormwater runoff hydrographs can be determined with the procedure illustrated below.



For analysis of complex basins, divide the basin, compute runoff hydrographs from the individual subbasins, then route and combine the contributions from the subbasins, as shown.

To ensure that the entire basin contributes to the discharge at the outlet, a 24-hour design storm shall be used, unless otherwise directed by the Director.

Rainfall depth-duration-frequency relationships were developed as a function of mean annual precipitation (MAP). To estimate the design storm depth for any basin, the relationships are as follows:

1. Locate the basin of interest on the Sutter County MAP map, and determine from the map the mean annual rainfall for the basin. See Figure 5-1, page 5-9.

2. For the selected storm duration and frequency, find the appropriate depth estimated by Table 5-2, pages 5-11 and 5-12.

3. If the basin is sufficiently large or if it is oriented in such a fashion that MAP varies significantly within the basin, repeat steps 1 and 2 for a grid of points over the basin. Then compute an average of the point values.

4. For larger basins, adjust the design depth to an areal average depth. For a specified frequency and duration, the average rainfall depth over an area is less than the depth at a point. The U.S. Weather Bureau (1958) derived factors by which point depths are to be reduced to yield areal-average depths. The factors, expressed as a percentage of point depth, are a function of area and duration, as shown in Figure 5-3, page 5-20.

   Depth-reduction factors should to be used for analysis of runoff from large basins. However, point values should be used without reduction for areas up to 9.6 square miles and for durations less than 30 minutes.

Temporal Distribution of Rainfall

An SCS Type I temporal distribution for the 24-hour storm applies to Sutter County. See Table 5-3, page 5-21. To derive the required 24-hour storm depths, each fraction in columns 2 and 4 for the type I storm is multiplied by the adjusted 24-hour rainfall total depth. This yields cumulative rainfall depth.

Basin Representation

If a stormwater basin is sufficiently small and simple, it can be analyzed as a single unit. However, if rainfall or hydrologic characteristics vary significantly in a basin or if runoff hydrographs are required at intermediate locations, the engineer should subdivide the basin. With this subdivision, runoff from individual subbasins is computed with the hydrograph method, and the resulting hydrographs are combined. If necessary, the hydrographs are routed before combining to account for channel-flow impacts.

Subbasins will vary in size from a few acres to a few square miles, depending upon:

- Locations at which significant quantities of water enter the drainage system;
- Locations at which discharge peaks and hydrographs should be determined to permit facility design or evaluation;
- Existing and projected drainage patterns;
- Existing and projected land uses; and
- Physical characteristics of each subbasin, including slopes, vegetation, soil types.

Routing Model

When a basin is subdivided for analysis, hydrographs computed for the subbasins may be combined to find cumulative runoff. However, if the subbasin hydrographs represent runoff at points spatially removed, then streamflow routing may be required. Streamflow dynamic-wave routing is recommended because typically, the downstream boundary conditions significantly affect flow in streams in Sutter County.

Application of Computer Program HEC-1

For example, a HEC-1 input file with records necessary to compute the runoff due to a 24-hour design storm with the hydrograph procedure proposed is shown below. This example is for a 5 square mile basin at Live Oak, California. From the steps described in Section 5-8, the time of concentration for this catchment is one hour, and the CN is 70.

HEC-1 Sample Input

```
ID Example: Hypothetical 5 sq mi catchment at Live Oak, CA, w/ MAP=20"
IT    10                    300
KKLIVOAK
BA     5
* Depth of 100-yr 24-hr rainfall
PB  4.44
* PC records for SCS 24-hr storm, type IA, from TR-20
IN    30
PC     0     .01    .022    .036    .051    .067    .083    .099    .116    .135
PC  .156    .179    .204    .233    .268     .31    .425     .48     .52     .55
PC  .577    .601    .623    .644    .664    .683    .701    .719    .736    .753
PC  .769    .785      .8    .815     .83    .844    .858    .871    .884    .896
PC  .908     .92    .932    .944    .956    .967    .978    .989       1
UD  0.60
LS            70
ZZ
```

This input is included to illustrate the method in which the design-storm rainfall depth and distribution are specified and to emphasize the following critical points:

- *IT record:* The time step for computation is specified in the first field on this record. This value must be sufficiently small to permit adequate definition of the rising limb of the unit hydrograph. The time of rise is a function of the catchment lag. Consequently, the appropriate time step is related to the catchment lag. Following the recommendation of HEC, the computation time step should be less than 29% of the lag. In this example, that will be 29% of 60% of 1 hour. We selected 10 minutes.

  The number of runoff hydrograph ordinates to be computed is specified also on the IT record. The value must be sufficient to permit simulation of runoff from the entire rain storm. For example, with a 24-hour storm and a 10-minute interval, at least 144 ordinates are required just to simulate the duration of the rainfall, and additional ordinates are required to simulate runoff after the rain ends. In this example, 300 ordinates are specified. A common mistake in using HEC-1 is to specify a short time step for analysis of a longer-duration storm, but to fail to specify properly enough ordinates for runoff computation. For example, if a 1-minute time step is required for a small basin, at least 1440 ordinates must be specified just to simulate the duration of a 24-hour rainfall.

- *PB record:* The design storm depth, in inches, is specified on this record. This is the basin-average depth, with appropriate adjustments.

- *PC records:* These records provide the temporal distribution pattern for the design storm. In this case, the 24-hour SCS storm is specified. The time interval between successive values is specified on the IN record. Note that in this example, the rainfall values are given at a 30-minute interval, while the computations are made with a 10-minute interval.

- *UD record:* This record specifies the lag time of the SCS dimensionless unit hydrograph. The lag time is estimated as 60% of the time of concentration (SCS, 1971). In this example the lag time is 0.6 hours.
- *LS record:* The composite CN is specified in the second field of this record. In this example, it is 70. The program user may, in the first field, specify the initial abstraction, I_a. If the field is left blank, the program assigns $I_a = 0.2S$, which is the median value for the initial abstraction and is inherent in the CN tables provided by the SCS. The third field of this record is available to specify the percentage of rainfall that runs off without infiltration, interception, etc. However, if the CN tables from *TR-55* are used, the directly-connected impervious area is accounted for already in the CN estimates.

FIGURE 5-3. POINT-AREA REDUCTION FACTORS FOR DESIGN RAINFALL DEPTHS (FROM NATIONAL WEATHER SERVICE)

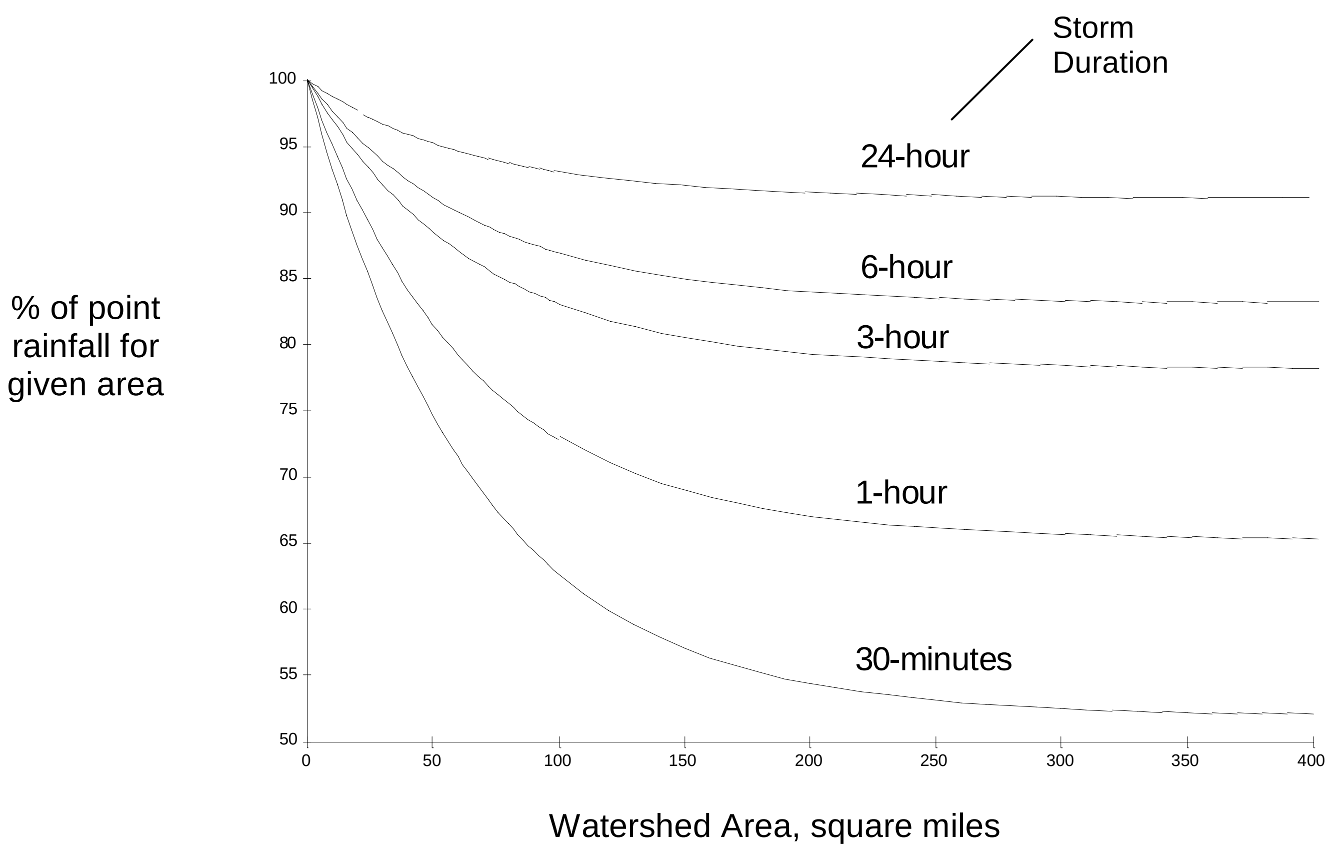


TABLE 5-3. SCS RAINFALL TEMPORAL DISTRIBUTIONS

Time (hours) (1a)	Fraction of 24-hour total	Time (hours) (lb)	Fraction of 24-hour total
	Type I (3a)		Type I (3b)
0.0	0.000	12.5	0.706
0.5	0.008	13.0	0.728
1.0	0.017	13.5	0.748
1.5	0.026	14.0	0.766
2.0	0.035	14.5	0.783
2.5	0.045	15.0	0.799
3.0	0.055	15.5	0.815
3.5	0.065	16.0	0.830
4.0	0.076	16.5	0.844
4.5	0.087	17.0	0.857
5.0	0.099	17.5	0.870
5.5	0.112	18.0	0.882
6.0	0.126	18.5	0.893
6.5	0.140	19.0	0.905
7.0	0.156	19.5	0.916
7.5	0.174	20.0	0.926
8.0	0.194	20.5	0.936
8.5	0.219	21.0	0.946
9.0	0.254	21.5	0.956
9.5	0.303	22.0	0.965
10.0	0.515	22.5	0.974
10.5	0.583	23.0	0.983
11.0	0.624	23.5	0.992
11.5	0.655	24.0	1.000
12.0	0.682	-	-

5-10 HYDRAULIC DESIGN CRITERIA – The following criteria shall be used for all hydraulic computations, unless otherwise authorized by the Director.

A. Flow Computations –

1. Manning's Equation shall be used to compute capacities of all open and closed conduits and all cross culverts which will become a part of the closed conduit system. Closed conduits shall be designed with full flow and open conduits with uniform flow.

2. The minimum "η" values to be used in Manning's formula shall conform to Table 5-1, page 5-10.

B. Pipe Criteria – Pipe criteria shall be as follows:

1. Closed conduits shall be designed for Q_{10} and in conformance with Section 5-1. The pipe slope shall equal the hydraulic gradient.

2. Minimum pipe diameter allowable on any closed conduit shall be 12 inches.

3. Minimum velocity in closed conduits shall be 2 feet per second (f.p.s.) when flowing full.

C. Open Channels - Open channels shall consist of concrete lined channels, lined bottom channels, or natural earth channels.

Criteria for permanent open channels shall be as follows:

1. Open channels shall be designed for the 100-year flood event.

2. Open channel design shall include a U.S. Army Corps of Engineers' HEC-2 water surface profile analysis and HEC-1 floodplain hydrology analysis or modified Rational Method Analysis.

3. Minimum velocity at 100-year flow

   a) 2 feet per second (f.p.s.)

4. Maximum velocity at 100-year flow

a) Earth channels, 6 f.p.s.

b) Lined channels, 10 f.p.s.

c) Bottom lined channels, 8 f.p.s.

3. The centerline curve radius of an open channel shall be equal to or greater than twice the bottom width (35-foot minimum).

4. A fifteen (15) foot all weather access service road is required where the channel bottom is not lined and a suitable access ramp not provided as approved by the Director.

D. Design Computation – The design computation for drainage shall include the following minimum information.

1. Watershed map (USGS topo map for offsite watersheds; separate plan for onsite watersheds)

2. Drainage area in acres

3. Flow in each pipe or channel reach

4. Invert elevations of each pipe or channel reach

5. Top of structure elevation or top of channel lining elevation

6. Hydraulic grade line elevation

7. Hydraulic gradient (HGL)

8. Pipe size, type, class, length, and gradient

9. Channel dimensions and water surface profile computations

E. Hydraulic Grade Lines (H.G.L.)

1. For closed conduits, the 10-year storm H.G.L. shall be a minimum 0.50 feet below the elevation of inlet grates and manhole covers. The hydraulic grade line shall be shown on the plans wherever the H.G.L. is above the top of the pipe.

2. For open channel systems, the H.G.L. shall be shown for the 10-year and 100-year flood events.

F. Drainage Profiles – A plan and profile shall be shown for all drainage systems which carry natural drainage originating upstream of the limits of the development. See Section 5-11 for extending profiles offsite.

5-11 DRAINAGE STRUCTURES – Drainage structure criteria shall be as follows:

A. Closed Conduits – The requirements for closed conduits are as follows:

1. Closed conduits shall be either cast-in-place concrete pipe, reinforced concrete pipe, vitrified clay pipe, corrugated metal pipe, high density polyethylene pipe, double walled high density polyethylene pipe, or other as approved by the Director.

2. Metal pipe to be constructed within a public easement or right-of-way shall be designed for a service life of fifty (50) years in accordance with the methods specified in Section 852.1 of the California Department of Transportation Highway Design Manual. The Engineer shall provide certified copies of the laboratory report giving the results of pH and resistivity tests. The report shall also include a map showing the location of each site where samples were taken.

   Unless otherwise specified by the Director, a minimum of two soil samples shall be taken for the first 1,000 lineal feet of pipe or fraction thereof on a project with a minimum of one additional sample being required for each additional 1,000 lineal feet of pipe or fraction thereof. The samples shall be taken along the approximate alignment and at the approximate depth of the pipe to be installed.

3. The specific type of pipe to be used shall be shown on the plans. If the developer proposes to use any type of pipe not shown on the approved plans, the plans shall be resubmitted for approval.

4. All pipes shall be constructed with a minimum cover of two feet unless other utilities or grade conditions prohibit. In no case shall minimum pipe cover be less than specified on Standard Drawings D-25.

Pipe strength requirements for minimum cover in the street may be taken from the Standard Drawings or may be determined in accordance with generally accepted engineering practice.

At locations where the minimum cover requirements cannot feasibly be obtained, the conduit shall be either encased in concrete or provided with a concrete cover or other method of pipe protection as approved by the Director.

5. In fill areas, or in areas with poor soil conditions where a good, firm, vertical-walled trench cannot be constructed, in lieu of using Standard Drawings D-25, the engineer shall design the pipe structural requirements in accordance with good engineering practice. If trench conditions are uncertain, a note shall be placed on the plans making it the contractor's responsibility to place the proper strength pipe if poor trench condition is encountered.

6. Pipe alignment Requirements –

   a) Publicly maintained drainage pipelines, including manholes, shall be located under street pavement outside of wheel path and a minimum of 24 inches from the lip of gutter to the outer wall of the conduit.

   b) All new storm drains shall be placed a minimum of fifty (50) feet from existing and proposed water wells or as approved by the Director of Environmental Health.

   c) Meandering and unnecessary angular changes of pipelines shall be avoided. Angular changes when necessary shall not exceed 90 degrees.

B. Pipeline Radius Criteria: All pipe placed on curves shall meet manufacturer's recommendations for curved alignment. All curves, radii, length of pipe joints, and types of pipe shall be shown on the plans.

C. Manholes - Requirements for manholes are as follows:

1. Standard precast concrete or saddle type manholes shall be used where required. Where special manholes or junction boxes are required, the design shall be approved by the Director. In no case

will junction boxes or manholes be allowed which are smaller than 48 inches inside dimension.

2. Manholes shall be located at junction points, angle points, and changes in conduit size. On curved pipes with radii of 200 feet to 400 feet, manholes shall be placed at the B.C. and E.C. and on 300 feet maximum intervals along the curve. On curves with radii exceeding 400 feet, manholes shall be placed at the B.C. and E.C. and on 400 feet maximum intervals along the curve for pipes 24 inches and less in diameter and 500 feet maximum intervals along the curve for pipes greater than 24 inches in diameter.

3. Spacing of manholes, junction boxes or inlets of such size as to be accessible for maintenance shall not exceed 500 feet for drains 24 inches and smaller in diameter, and 600 feet for pipes greater than 24 inches in diameter. The spacing of manholes shall be nearly equal whenever possible.

4. All manholes and junction boxes other than inlets shall have standard manhole covers as shown in the standard drawings.

5. Improvement plans shall include a special detail for all manholes at junction points where there is a change in pipe direction and pipe diameter exceeds 48 inches.

D. Inlets - Requirements for inlets are as follows:

1. Inlets shall be placed so the length of flow in the gutter does not exceed 500 feet in either direction. The depth of flow in the gutter at the inlet shall not exceed 0.35 feet. The flow rate used to check the depth shall include any runoff which may bypass upstream grates. The maximum allowable area draining to one onsite inlet shall be one (1) acre.

2. Inlets at sag points where bypass flow from upstream grates is possible shall be Standard Drawing D-5 and shall be used on all streets and in commercial and industrial areas.

3. Type F inlets may be used in unimproved medians. See Standard Drawing D-6.

4. Drainage inlets may be used as junction boxes. See Standard Drawing D-7. When used as junction boxes where pipe is changing

directions, the inside dimension requirements for junction boxes shall be met. Only the first three inlets of a drainage system may be used as junction boxes. Inlets shall not be used as junction boxes in sag points.

5. Drop inlets draining public streets may be connected directly to a drain line 36 inches in diameter or larger by means of a lateral not exceeding 15 inches in diameter and 50 feet in length and having a slope not exceeding 30 percent. At sag points the drop inlets shall be connected to a manhole.

E. Junction Boxes - The requirements for junction boxes are as follows:

1. Junction boxes shall be constructed of reinforced concrete or fabricated from reinforced concrete pipe section where size limitations permit, except when standard inlets are used as junction boxes as specified in Section 5-10(C).

2. Minimum wall thickness for reinforced concrete junction boxes shall be 6 inches.

3. The inside dimension of junction boxes shall be such as to provide a minimum of three inches clearance on the outside diameter of the largest pipe in each face.

4. All junction boxes shall be rectangular in shape unless otherwise approved by the Director.

F. Pipe Stubs – The criteria for pipe stubs shall be as follows:

1. Temporary pipe stubs shall be two sizes larger than the permanent pipe unless a flared end section or corrugated steel pipe (CSP) drop inlet is used.

2. A headwall and/or trash rack shall be required where the upstream pipe ends at a park or open field.

3. Whenever a pipe stub is required, all ditches and swales shall be "trained" toward the stub.

4. Pipe stubs shall be as deep as possible considering public safety.

G. Headwalls, Wingwalls, Endwalls, Trash Racks, Access Control Racks, and Railings – The requirements for these facilities are as follows:

1. All headwalls, wingwalls, and endwalls shall be considered individually and in general shall be designed in accordance with the Standards and Specifications of the California Department of Transportation.

2. Trash racks shall be provided where they are necessary to prevent clogging of culverts and storm drains and eliminate hazards. Trash racks shall be designed in conformance with Standard Drawings D-16 and D-17.

3. Access control racks shall be required on pipes 21″ or larger and shall conform to Standard Drawing D-18.

4. Metal beam guard rail or chain link fencing may be required by the Director at culverts, headwalls, box culverts, and on steep side slopes. When so required, the railing shall be installed in accordance with the Standard Specifications and Standard Plans.

5-12 <u>CHANNELS AND OUTFALL DESIGN</u> – The design of channels and outfalls shall be as follows:

A. Open Channels – Requirements for open channels are as follows:

1. Drainage may be conducted through an open channel under the following criteria:

   a) The flow rate exceeds the capacity of a 72 inch pipe.

   b) Minimum cover cannot be obtained over the outfall pipe.

   c) Upon approval of the Director.

2. Channel design shall include:

   a) Channels shall be constructed to a typical cross section. Fully lined channels shall be designed with side slopes of 1 horizontal to 1 vertical or flatter; channels with unlined sides shall be designed with side slopes of 1½ horizontal to 1 vertical or flatter.

b) Lined channels shall have a minimum bottom width of 8 feet and may have an access ramp for maintenance equipment. Exceptions must be approved by the Director.

c) A 15 foot all-weather service road shall be constructed for access. A road may not be required where the channel bottom is lined and a suitable access ramp is provided when approved by the Director.

d) Fencing where required by Section 5-12.

3. For all channels, either improved or natural, the following items shall be shown on improvement plans in addition to information heretofore required:

a) Approval by appropriate maintenance entity.

b) Typical sections and cross sections.

c) Profile of the existing channel and top of bank profile for a minimum of 1,000 feet each side of the development in order to establish an average profile grade through the development.

4. Interceptor Ditches – Interceptor ditches or approved alternates shall be placed at the top of the cut or bank where deemed necessary by the Director to prevent erosion of the channel bank. Runoff shall not be allowed to "sheet drain" over top of bank.

5. Erosion Protection – Erosion protection as specified by the Director shall be placed at the top of the cut or bank where deemed necessary by the Director to prevent erosion of the channel bank.

B. Outfall Profiles:

1. All drainage outfalls shall be shown both in plan and profile on the improvement plans for a distance of 1,000 feet or until a definite "daylight" condition is established.

All drainage ditches upstream of the improvement shall be shown on the plan and profile for a distance of at least 500 feet or until an average profile grade through the improvement is established.

The profiles shall include ditch flow-line and top of bank elevations.

2. When improvements are phased, the drainage outfall shall be shown as extending to the property boundary and beyond if required, although it may not be constructed with the current unit development. All temporary outfalls shall be shown both in plan and profile on the improvement plans.

5-13 FENCING REQUIREMENTS – The requirements for fencing (see Standard Drawing D-1) shall be as follows:

A. Improved channels in developed areas exceeding three (3) feet in depth and with side slopes 3:1 or steeper shall be fenced with six (6) foot chain link fence.

In all other areas fencing shall be placed upon the recommendation of the Director.

B. Drive gates shall be 12 feet wide minimum, and walk gates shall be 4 feet wide minimum.

C. Fences shall be located 6 inches inside the drainage easement lines and a minimum 12 inches from top of bank.

D. No fencing will be allowed within the floodway of an open water course.

5-14 FILL IN A FLOODPLAIN – Fill within the 100-year floodplain of a watercourse shall be compacted to 95 percent of the maximum density obtainable with the standard proctor test method issued by the American Society for Testing and Materials (ASTM Standard D-698) or an equivalent test method acceptable to Federal Emergency Management Agency (F.E.M.A.).