Rainfall Intensity-Duration-Frequency (IDF) Curves

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Rainfall Intensity-Duration-Frequency (IDF) Curves

Basic Method

The Duration-Frequency-Depth (DFD)[1] curves can be used to derive rainfall intensities for the Rational Method. The rainfall intensity can be determined using the following steps:

1. Determine the Mean Seasonal Precipitation from the District isohyet map. (Dwg. No. B-166).
2. Choose the design storm frequency and use the appropriate DFD drawing.
3. Choose a time of concentration on the time axis (T in minutes).
4. Choose a curve that corresponds to the MSP for the site (interpolate if needed).
5. Find the corresponding precipitation depth (P in inches) on the vertical axis.
6. Calculate the rainfall intensity with the following equation including a conversion to intensity in inches per hour:
   Rainfall Intensity (in/hr) = P ÷ T (min)*60min

Creating IDF Curves.

For small calculation efforts, the above method is adequate. For many engineering efforts in land development, engineers use computer programs to design extensive drainage systems. These models require Intensity-Duration-Frequency (IDF) curves. The District receives numerous requests for IDF curves each year. In the past we have directed engineers to the above process.

You can follow the above procedure for several times of concentration to develop an IDF curve. A method presented below "simplifies" the process for calculations for times of concentration (TOC) less or equal to 60 minutes. Once this method is coded into a spreadsheet, the creation of other IDF curves would be automated and less time consuming.

The DFD curves are almost linear between 5 and 60 minutes on the Precipitation DFD curves log-log plots. If we add a break at the 20 minute point, we get two line segments that closely match the curves. Using these lines and some regression equations we can calculate an IDF curve as close as we could expect to take them off the DFD curves by hand.

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[1] The DFD curves can be found at http://www.co.contra-costa.ca.us/index.aspx?NID=530.

Basic log-log regression equations, similar to the linear regression equation, can be used to perform a linear interpolation of precipitation values. Below are some basic equations.

Linear regression equations:

$$y = a \cdot x + b$$

Where: a = slope
     b = the y intercept
     x = independent variable
     y = dependant variable

For a linear regression on a log-log plot between Time1 (T_1) and Time2 (T_2) the following regression equation applies:

$$P = 10 \wedge {}^{(a \cdot \log (T) + \log (b))} \quad \text{and}$$

$$I = P \div T \cdot 60$$

Where: P = Precipitation (inches) for time T
     I = Intensity (inches/hour) for time T
     T = time (minutes)
     a = slope on log plot = Delta log (D)/Delta log (T)
       where :
       Delta log (T) = log (T2)-log (T1)
       Delta log (D) = log (D2)-log (D1)
     log (b) = intercept = log (y intercept) = log (D2)-log (T2) · a
     Di = rainfall depth for Ti
     i = time interval number

The depths can be found on the DFD curves using T_1 = 5min and T_2 = 20min. The values of "a" and "b" can be calculated using the above equations. A similar exercise can be done for T_1 = 20min and T_2 = 60min. Once this is done, the equation I = P/T*60 can be used to determine the rainfall intensity "I" for any time of concentration "T" between 5 and 60 minutes. If the equations are established in a spreadsheet, then a full range of intensities can be calculated for a given project location, and an IDF curve can created between 5 and 60 minutes. Again, once this method is coded into a spreadsheet, creating other IDF curves can automated.

Reasons to follow this procedure:

1. With the equations developed for the site, any time of concentration may be used. There is no discrete limit to the times used and no need to manually interpolate rainfall depths.

2. You only need to read three numbers for depth off of the DFD curves is need.

3. Using the equations, engineers should be able to create spreadsheets of their own to create the IDF curves they need.

4. Spreadsheets are compatible with most storm drain modeling programs used today which allow the user to copy and paste columns of numbers.

5. Some engineers have created spreadsheets for Rational Method calculations. The use of spreadsheets for creating IDF curves would be compatible with those personalized calculation tools.

6. The District has IDF curves that were published in 1975. To use them, engineers would need to read the values from the charts. Human error is introduced when reading several intensities for large projects.

Using the DFD curves has several advantages.

1. It allows the District to publish and maintain just one set of standard curves; the DFD curves.

2. Most engineering companies doing business in Contra Costa County already have DFD curves.

3. The curves can be used for the Rational Method and also for the District's UH method.

APPENDIX A   Intensity-Duration-Frequency Curve Example

Example for creating a Rainfall Intensity-Duration-Frequency (IDF) Curve Table

Step 1.   Determine the Mean Seasonal Precipitation depth for the site using drawing B-166:

For this Example P = 12.5 inches/year

Step 2.   Determine the 5, 20, and 60 minute storm depths for the 10 year storm for the 12.5 inch/year isohyet.

Time	5 min	20 min	60 min
Depth	0.200 in	0.388 in	0.649 in

Step 3.   Calculate the values of "a" and "log(b)"

Equations: log(Precipitation) = log(P) = log(Time) · a + log(b)
Precipitation = P = 10^(log(Time) · a + log(b))
Rainfall Intensity = P/Time · 60 (in/hr)

Step 4.   The equations for the precipitation depth curve for this example are:

For T = 5 to 20 minutes: $P = 10^{(0.478*\log(T) + (-1.033))}$ (See **Table A-1**)

For T = 20 to 60 minutes: $P = 10^{(0.468*\log(T) + (-1.020))}$ (See **Table A-2**)

Step 5.   Create the resulting IDF curve table for these equations:

(See **Table A-3** and **Figure A-1**)

Table A-1 Example IDF calculations for 5 to 20 minutes

5 to 20 minutes: - Assumes that curves are linear on the log-log scale.			
Delta log (Time)		0.602	log(20)-log(5)
Delta log (Depth)		0.288	log(Depth@20)-log(Depth@5) log(0.388 in)-log(0.200 in)
Slope on log-log	a	0.478	Delta log(Depth)/Delta log(Time) 0.0288/0.602
Intercept on log-log	log(b)	-1.033	log(Depth@20)-log(20)*a log(0.388 in)-log(20)*0.479

Table A-2 Example IDF calculations for 20 to 60 minutes

20 to 60 minutes: - Assumes that curves are linear on the log-log scale.			
Delta log (Time)		0.477	log(60)-log(20)
Delta log (Depth)		0.223	log(Depth@60)-log(Depth@20) log(0.649 in)-log(0.460 in)
Slope on log-log	a	0.468	Delta log(Depth)/Delta log(Time) 0.224 / 0.477
Intercept on log-log	log(b)	-1.020	log(Depth@60)-log(60)*a log(0.649 in)-log(60)*0.469

Table A-3 Example Intensity-Duration-Frequency (IDF) Curve Table

Time(min)	P(in)	I (in/hr)	Time(min)	P(in)	I (in/hr)	Time(min)	P(in)	I (in/hr)
5.0	0.20	2.40	30.0	0.47	0.94	55.0	0.62	0.68
5.5	0.21	2.28	30.5	0.47	0.93	55.5	0.63	0.68
6.0	0.22	2.18	31.0	0.48	0.92	56.0	0.63	0.67
6.5	0.23	2.09	31.5	0.48	0.91	56.5	0.63	0.67
7.0	0.23	2.01	32.0	0.48	0.91	57.0	0.63	0.67
7.5	0.24	1.94	32.5	0.49	0.90	57.5	0.64	0.66
8.0	0.25	1.88	33.0	0.49	0.89	58.0	0.64	0.66
8.5	0.26	1.82	33.5	0.49	0.88	58.5	0.64	0.66
9.0	0.26	1.77	34.0	0.50	0.88	59.0	0.64	0.65
9.5	0.27	1.72	34.5	0.50	0.87	59.5	0.65	0.65
10.0	0.28	1.67	35.0	0.50	0.86	60.0	0.65	0.65
10.5	0.29	1.63	35.5	0.51	0.86	**EQUATIONS ARE NOT GOOD ABOVE 60 MINUTES**		
11.0	0.29	1.59	36.0	0.51	0.85			
11.5	0.30	1.55	36.5	0.51	0.85			
12.0	0.30	1.52	37.0	0.52	0.84			
12.5	0.31	1.49	37.5	0.52	0.83			
13.0	0.32	1.46	38.0	0.52	0.83			
13.5	0.32	1.43	38.5	0.53	0.82			
14.0	0.33	1.40	39.0	0.53	0.82			
14.5	0.33	1.38	39.5	0.53	0.81			
15.0	0.34	1.35	40.0	0.54	0.81			
15.5	0.34	1.33	40.5	0.54	0.80			
16.0	0.35	1.31	41.0	0.54	0.79			
16.5	0.35	1.29	41.5	0.55	0.79			
17.0	0.36	1.27	42.0	0.55	0.78			
17.5	0.36	1.25	42.5	0.55	0.78			
18.0	0.37	1.23	43.0	0.56	0.77			
18.5	0.37	1.21	43.5	0.56	0.77			
19.0	0.38	1.20	44.0	0.56	0.77			
19.5	0.38	1.18	44.5	0.56	0.76			
20.0	0.39	1.16	45.0	0.57	0.76			
20.5	0.39	1.15	45.5	0.57	0.75			
21.0	0.40	1.13	46.0	0.57	0.75			
21.5	0.40	1.12	46.5	0.58	0.74			
22.0	0.41	1.11	47.0	0.58	0.74			
22.5	0.41	1.09	47.5	0.58	0.73			
23.0	0.41	1.08	48.0	0.58	0.73			
23.5	0.42	1.07	48.5	0.59	0.73			
24.0	0.42	1.06	49.0	0.59	0.72			
24.5	0.43	1.04	49.5	0.59	0.72			
25.0	0.43	1.03	50.0	0.60	0.72			
25.5	0.43	1.02	50.5	0.60	0.71			
26.0	0.44	1.01	51.0	0.60	0.71			
26.5	0.44	1.00	51.5	0.60	0.70			
27.0	0.45	0.99	52.0	0.61	0.70			
27.5	0.45	0.98	52.5	0.61	0.70			
28.0	0.45	0.97	53.0	0.61	0.69			
28.5	0.46	0.96	53.5	0.62	0.69			
29.0	0.46	0.96	54.0	0.62	0.69			
29.5	0.47	0.95	54.5	0.62	0.68			
Note: The value of P and I were calculated using values of "a" and "log(b)" that were not rounded off.								

Figure A-1 Example IDF Curve

(DRAFT) Rainfall Intensity-Duration-Frequency (IDF) Curves