Introduction

• Precipitation is the ultimate driver of surface-water flow

• Normally concerned with actual storms (characterized by intensity-duration) and design storms (characterized by intensity-duration-frequency)

• Usually reported as a depth, i.e. a volume of water over a unit area give units of length (or depth), sometimes as a rate (e.g. \(\text{in/hr}\))

• Hydrologic models are generally based on a design storm, which in turn is based on long-term observations of actual storms for the area
Principal Characteristics

• principal characteristics of an actual or design storm are its *volume*, *duration*, and the *frequency* of occurrence of storms with the same volume and duration

• volume reported as a depth (e.g. 5 inches), assumes uniform rainfall over the entire watershed

• Frequency reported in two ways
  – *exceedence* probability $p$: probability that an event of specified depth and duration will be exceeded in a year
  – *return period* $T_r$: average length of time between events of a given depth and duration. This is the most common usage.
\[ p = \frac{1}{T_r}, \] so an event with 1% chance of occurring in any given year has \( p = 0.01 \) and \( T_r = 100 \text{ yr} \)
Rainfall Variations

• Rainfall of a given frequency varies widely across the U.S. (Fig. 1)

• Typically IDF relationship for an area is based on NWS observations, and is given graphically (Fig. 2) or by formula (see TX DOT)
Figure 1: U. S. Twenty-four hour rainfall (in inches) to be expected once in 100 years [SCS, 1986, Fig. B-8].
Figure 2: Rainfall Intensity-Duration-Frequency, Baltimore, MD. After [McCuen, 2004]
Texas Rainfall IDF Curves

- Texas Dept. of Transportation uses a formula to calculate rainfall IDF curves, with coefficients varying by county.

- The formula is discussed in their online Hydraulic Design Manual.

- Intensity $I$ for a given duration (time of concentration $t_c$ is assumed equal to duration in the TXDOT IDF formula, pg. 5-31) is given by $I = \frac{b}{(t_c + d)^e}$.

- Parameters $b$, $d$, $e$ are tabulated (see references on formula page), or $I$ can be solved for using an online spreadsheet.
IDF Data for Other U.S. Locations

Intensity-Duration-Frequency curves for other locations in the U.S. are available from the following publications:

- online indexes, e.g. NOAA precipitation data server.


Adjustment of Actual Storm Data

- Actual storms exhibit highly irregular rainfall distributions (Fig. 3)

- For large watersheds, point rainfall measurements represent extremes, and must be adjusted according to the area they will represent in the model (Fig. 4)

- Missing data must be *interpolated* from existing records. The following methods are commonly applied:
  
  - *station average*: simply assume the average of nearby station values for the time of interest
  
  - *normal ratio*: take weighted average of nearby stations, weights based on differences in average annual precipitation at each station
– *isohyetal*: contour the existing stations, determine the expected value at the point of interest (e.g. a missing gauge)
Figure 3: DFW NEXRAD Weekly Precipitation, obtained from Intellicast.
Rainfall Depth-Area Adjustment

Figure 4: Adjustment of point rainfall measurements according to typical areas observed for storms with given duration.
Determining Areal Average Rainfall

- Gauge results must be averaged to determine a single rainfall depth for modeling a watershed (or subbasin)

- Methods:
  - *station average*: as above, simplest approach is to just take an average of gauge data
  - *Theissen Polygon*: weight station data based on relative area represented by each station (Fig. 5). This is done trivially in WMS using *Natural Neighbor* interpolation.
Theissen Polygon Method

Figure 5: Determining areal average rainfall using Theissen polygons (same as natural neighbor interpolation) and isohyetal weighting. After McCuen [2004].
Choosing a Design Storm

Modeling is usually done assuming an ideal, or worst probable case storm. A variety of choices are possible:

- **constant-intensity**: most small urban watershed studies assume worst case is short-duration high-intensity storm based on IDF relationship

- **SCS 24-Hour storm**:
  - SCS has summarized 4 dimensionless rainfall distributions based on NWS records.
  - these give fraction of total storm distributed over 24 hours (Fig. 6)
  - essentially used to temporally redistribute constant intensity storm to something more realistic (Fig. 8)
Figure 6: SCS 24 Hour Storm cumulative rainfall distributions. Applicable zones for Type-I-III shown in Fig. 7. After McCuen [2004].
SCS Zones for 24 Hour Storm

Figure 7: SCS 24 Hour Storm zones. For most of U.S. Type II storm is used. Cumulative rainfall curves for Type I-III shown in Fig. 6. After McCuen [2004].
Figure 8: Comparison of SCS and constant intensity storms. After McCuen [2004].
Reasonable Storms

Use online weather data to decide if your model storm is reasonable:

- U.S. annual average precip. (Fig. 9)

- Rainfall frequency atlas maps online
Average Annual Precipitation, U.S.


Figure 9: U.S. average annual precipitation. This and similar products available to .EDU users at NOAA/NCDC.
NEXRAD Data

U.S. National Weather Service and FAA maintain the NEXRAD (NEXt generation RADar) system

- gridded rainfall intensity, really hourly estimates of depth
- grid size is 4x4 km, spatial coordinates are polar stereographic projection (NWS “HRAP” format)
- some controversy, often NEXRAD estimates are low compared to rain gauge data
- weekly precipitation plots are available from NOAA
Online access to Weather data

• NEXRAD
  – WeatherTap provides free data, requires user subscription though
  – NOAA has NEXRAD data available for selected watersheds, including Arkansas-Red River Basin (ABRFC)
  – free software available to read the files (in XMRG format), output as gridded file in HRAP coordinates, then translate to lat-long

• NOAA Weather Station tabulated data (Local Climatological Data, or LCD, Fig. 10)
  – free, at least to universities and government agencies
– daily precip. and hourly precip. measurements are tabulated
– start at NOAA publications summary (Local Climatological Data), select “LCD listing of Published Stations” to find station callsigns (e.g. DFW airport is “DFW”)
– then traverse link tree (first choose year, then station and month)

● NOAA/NWS General Data Info, see summary webpage
Bibliography