

Precipitation *

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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. $\frac{\text{in}}{\text{hr}}$)
- 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 $T_r = 100$ 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)

U.S. 24 hour, 100 Year Frequency Rainfall

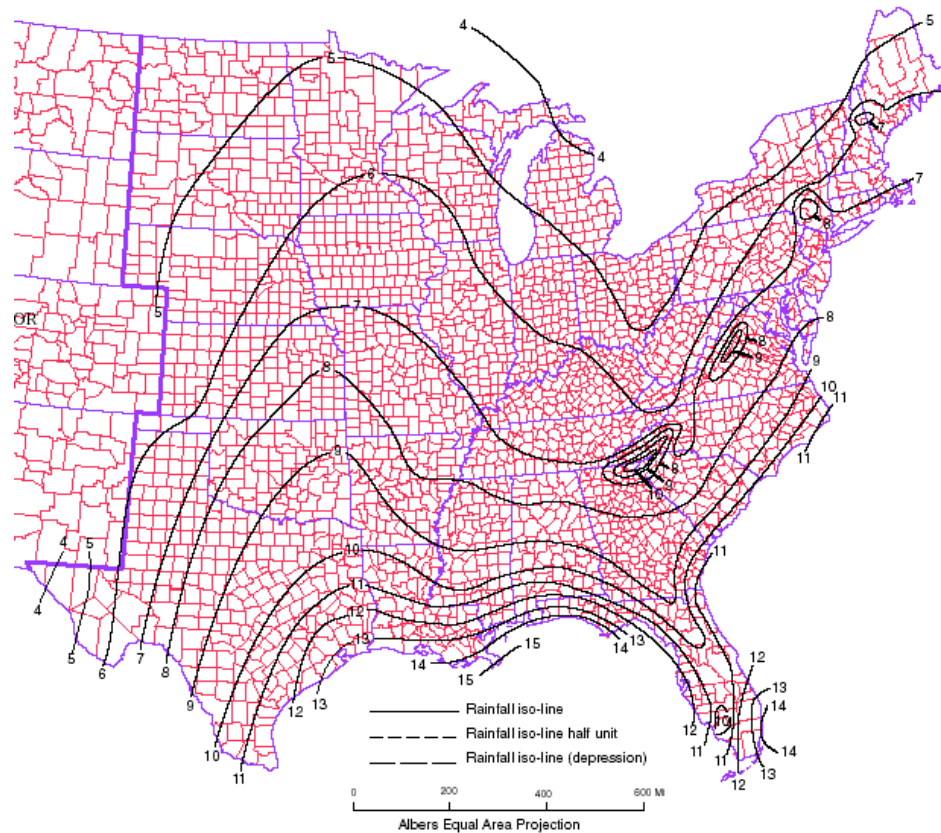


Figure 1: U. S. Twenty-four hour rainfall (in inches) to be expected once in 100 years [SCS, 1986, Fig. B-8].

Rainfall Intensity-Duration-Frequency

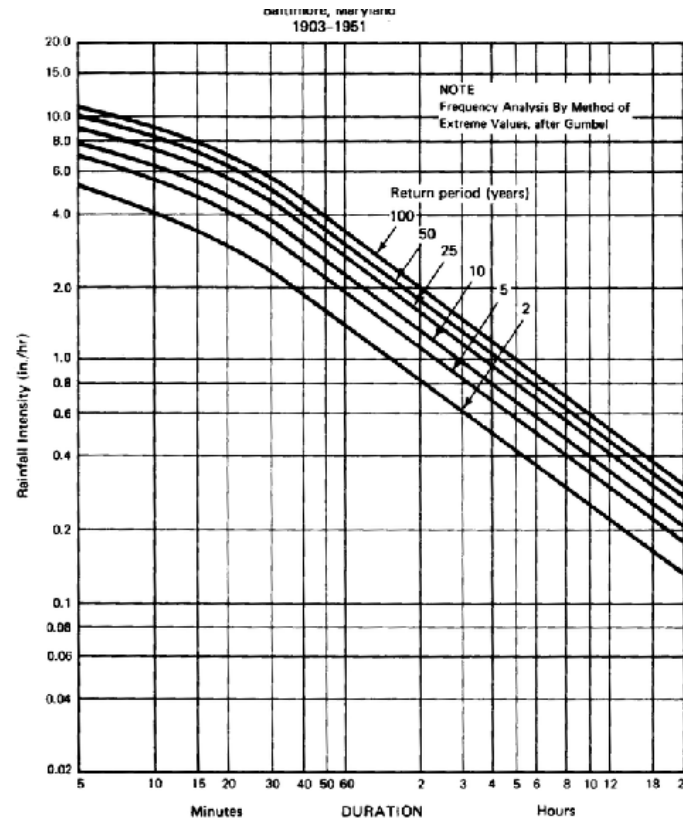


FIGURE 4-4 Rainfall intensity-duration-frequency. (National Weather Service, 1961.)

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.
- US Weather Bureau, Rainfall Frequency Atlas of the United States. Technical Paper No. 40, Washington, DC, May 1961.
- US Weather Bureau, Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands. Technical Paper No. 42, Washington, DC, 1961.

- US Weather Bureau, Rainfall-Frequency Atlas of the Hawaiian Islands. Technical Paper No. 43, Washington, DC, 1962.
- US Weather Bureau, Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska. Technical Paper No. 47, Washington, DC, August 1963.

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)

DFW Weekly Precipitation

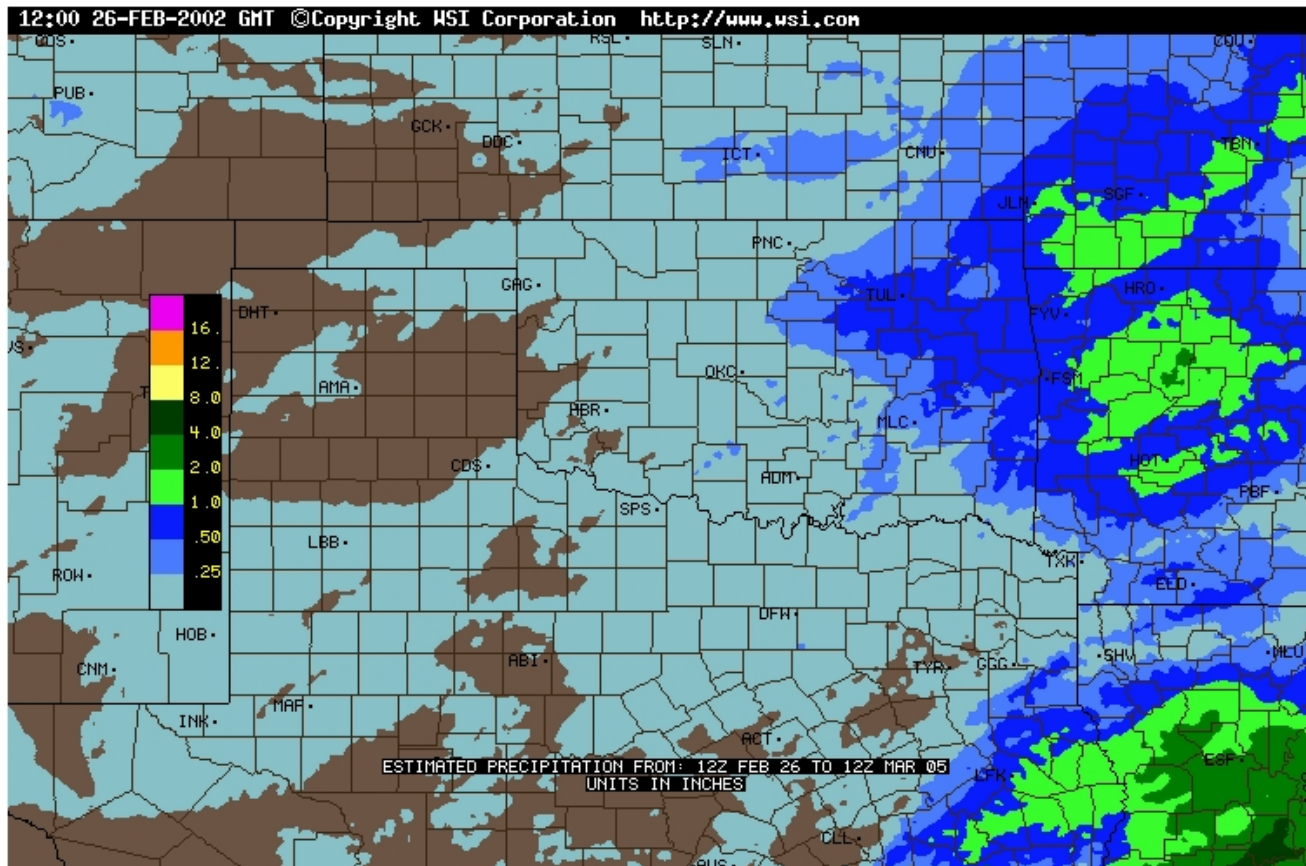


Figure 3: DFW NEXRAD Weekly Precipitation, obtained from Intellicast.

Rainfall Depth-Area Adjustment

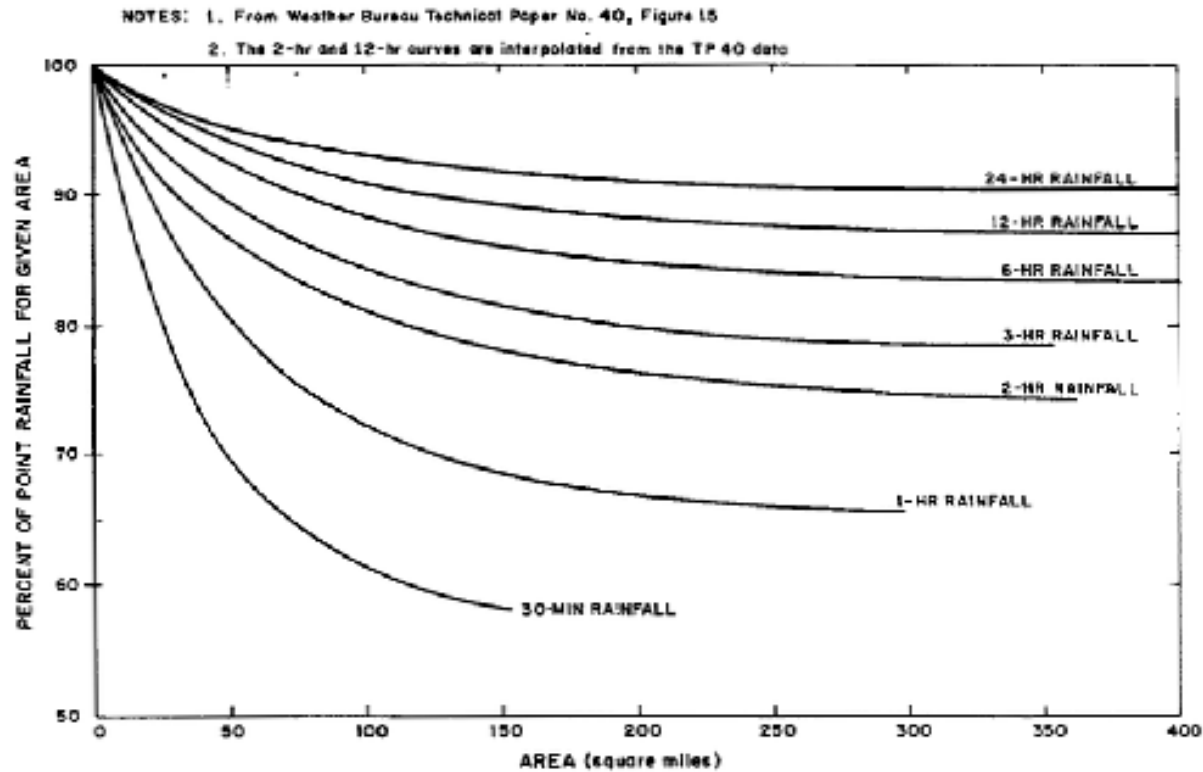


FIGURE 4-7 Depth-area curves for adjusting point rainfalls.

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

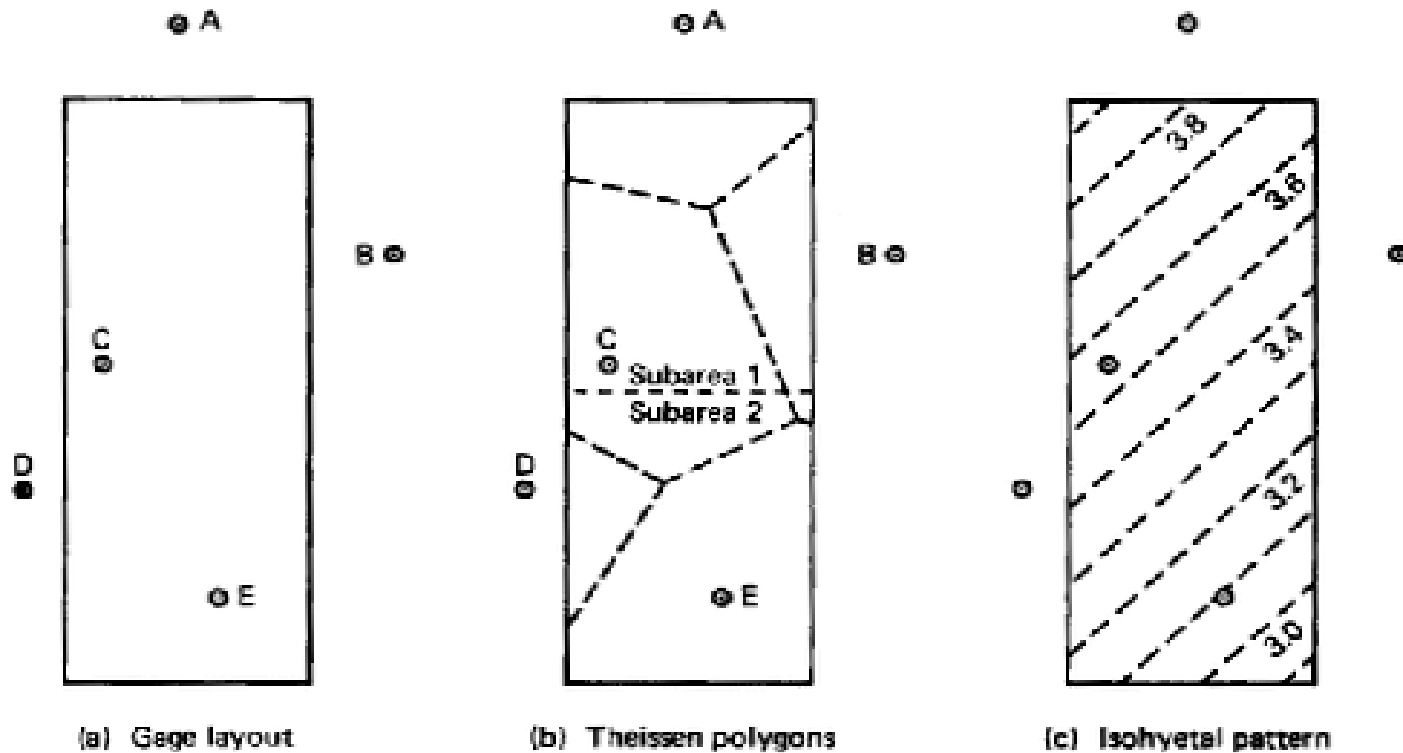


FIGURE 4-12 Hypothetical watershed for calculating weighted average rainfall.

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)

SCS Hyetograph for 24 Hour Storm

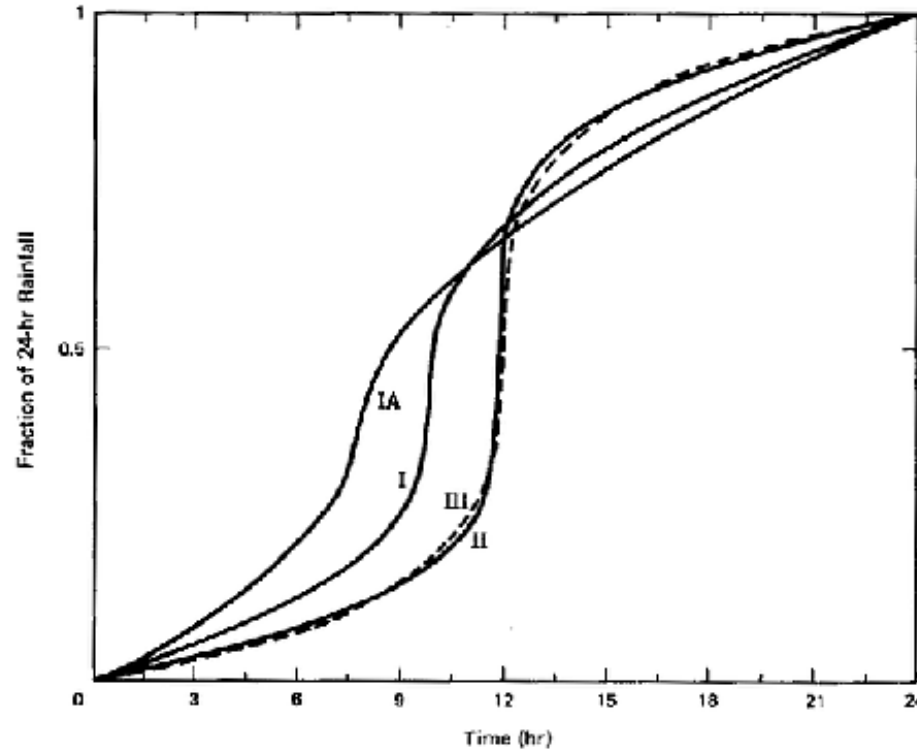


FIGURE 4-15 SCS 24-hour rainfall distributions (not to scale). (SCS, 1984.)

Figure 6: SCS 24 Hour Storm cumulative rainfall distributions. Applicable zones for Type-III shown in Fig. 7. After McCuen [2004].

SCS Zones for 24 Hour Storm



FIGURE 4-14 Approximate geographic areas for SCS rainfall distributions. (SCS, 1986.)

Figure 7: SCS 24 Hour Storm zones. For most of U.S. Type II storm is used. Cumulative rainfall curves for Type-III shown in Fig. 6. After McCuen [2004].

SCS vs. Constant Intensity Storm

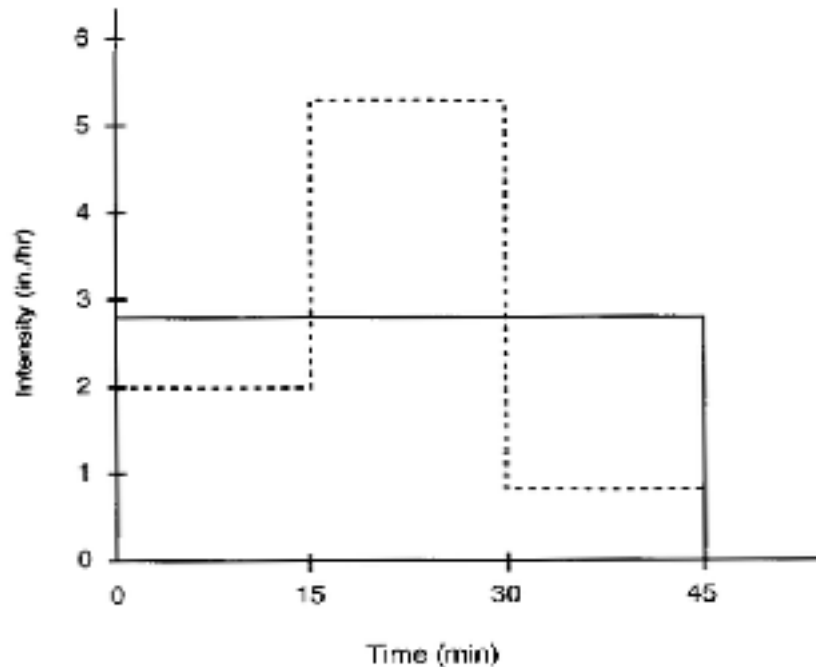


FIGURE 4-17 Comparison of a 45-minute constant-intensity design storm with the maximum three ordinates of the SCS type II design storm.

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.

Precipitation: Annual Climatology (1971–2000)

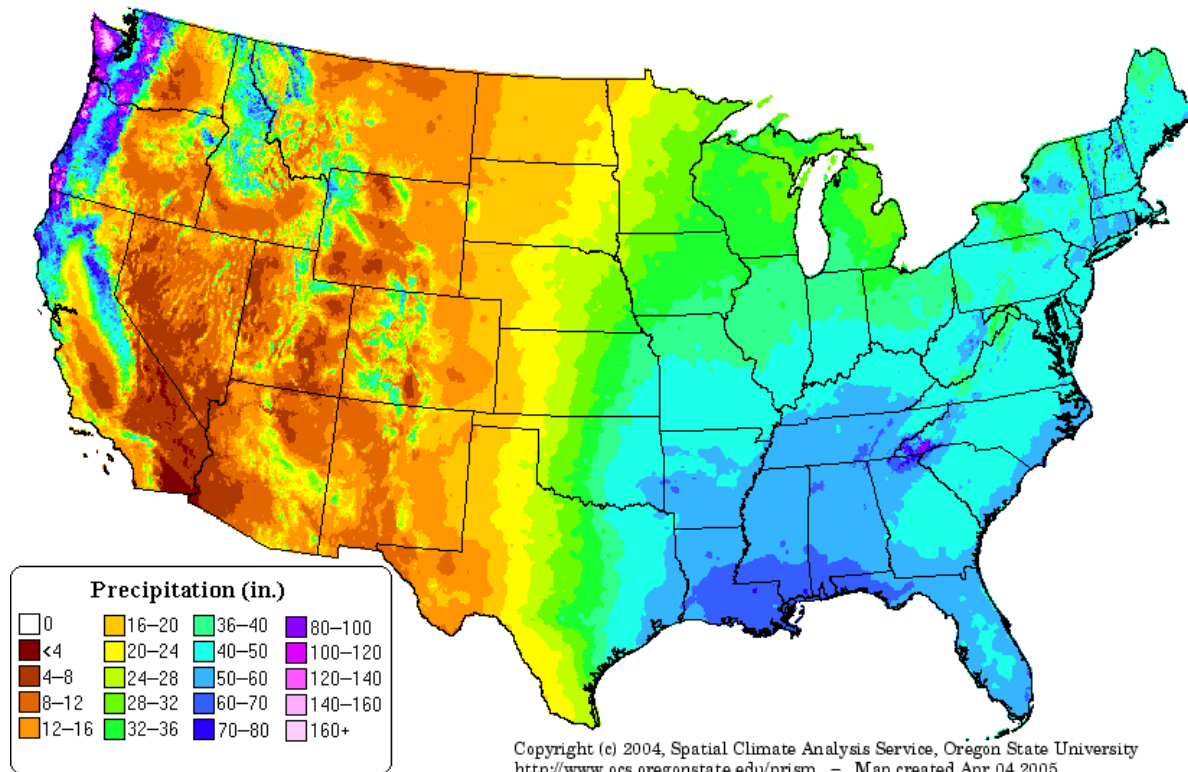


Figure 9: U.S. average annual precipitation. This and similar products available to .EDU users at NOAA/NCDC.

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

NOAA Local Climatological Data, DFW Airport

HOURLY PRECIPITATION | **DALLAS-FORT WORTH, TX**
(WATER EQUIVALENT IN INCHES) | **JANUARY 2001** DFW WBAN # 03927

| DATE | FOR HOUR (LST) ENDING AT | | | | | | | | | | | | DATE | FOR HOUR (LST) ENDING AT | | | | | | | | | | | | DATE | 2400 LST | White Equiv. |
|------|--------------------------|---|---|---|---|---|---|---|---|----|----|----|------|--------------------------|----|----|----|----|----|----|----|----|----|----|----|------|----------|--------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | | | |
| 01 | | | | | | | | | | | | | 01 | | | | | | | | | | | | 01 | 0.00 | | |
| 02 | | | | | | | | | | | | | 02 | | | | | | | | | | | | 02 | 0.00 | | |
| 03 | | | | | | | | | | | | | 03 | | | | | | | | | | | | 03 | 0.00 | | |
| 04 | | | | | | | | | | | | | 04 | | | | | | | | | | | | 04 | 0.00 | | |
| 05 | | | | | | | | | | | | | 05 | | | | | | | | | | | | 05 | 0.00 | | |
| 06 | | | | | | | | | | | | | 06 | | | | | | | | | | | | 06 | 0.00 | | |
| 07 | | | | | | | | | | | | | 07 | | | | | | | | | | | | 07 | 0.00 | | |
| 08 | | | | | | | | | | | | | 08 | | | | | | | | | | | | 08 | 0.00 | | |
| 09 | | | | | | | | | | | | | 09 | | | | | | | | | | | | 09 | 0.00 | | |
| 10 | | | | | | | | | | | | | 10 | | | | | | | | | | | | 10 | 0.42 | | |
| 11 | | | | | | | | | | | | | 11 | | | | | | | | | | | | 11 | 0.00 | | |
| 12 | | | | | | | | | | | | | 12 | | | | | | | | | | | | 12 | 0.00 | | |
| 13 | | | | | | | | | | | | | 13 | | | | | | | | | | | | 13 | 0.08 | | |
| 14 | | | | | | | | | | | | | 14 | | | | | | | | | | | | 14 | 0.00 | | |
| 15 | | | | | | | | | | | | | 15 | | | | | | | | | | | | 15 | 0.00 | | |
| 16 | | | | | | | | | | | | | 16 | | | | | | | | | | | | 16 | 0.27 | | |
| 17 | | | | | | | | | | | | | 17 | | | | | | | | | | | | 17 | 0.24 | | |
| 18 | | | | | | | | | | | | | 18 | | | | | | | | | | | | 18 | 0.22 | | |
| 19 | | | | | | | | | | | | | 19 | | | | | | | | | | | | 19 | 0.00 | | |
| 20 | | | | | | | | | | | | | 20 | | | | | | | | | | | | 20 | 0.00 | | |
| 21 | | | | | | | | | | | | | 21 | | | | | | | | | | | | 21 | 0.00 | | |
| 22 | | | | | | | | | | | | | 22 | | | | | | | | | | | | 22 | 0.00 | | |
| 23 | | | | | | | | | | | | | 23 | | | | | | | | | | | | 23 | 0.00 | | |
| 24 | | | | | | | | | | | | | 24 | | | | | | | | | | | | 24 | 0.00 | | |
| 25 | | | | | | | | | | | | | 25 | | | | | | | | | | | | 25 | 0.00 | | |
| 26 | | | | | | | | | | | | | 26 | | | | | | | | | | | | 26 | 0.00 | | |
| 27 | | | | | | | | | | | | | 27 | | | | | | | | | | | | 27 | 0.13 | | |
| 28 | | | | | | | | | | | | | 28 | | | | | | | | | | | | 28 | 0.67 | | |
| 29 | | | | | | | | | | | | | 29 | | | | | | | | | | | | 29 | 0.51 | | |
| 30 | | | | | | | | | | | | | 30 | | | | | | | | | | | | 30 | 0.00 | | |
| 31 | | | | | | | | | | | | | 31 | | | | | | | | | | | | 31 | 0.00 | | |

MAXIMUM SHORT DURATION PRECIPITATION (See Note)

| Time Period (Minutes) | 5 | 10 | 15 | 20 | 30 | 45 | 60 | 80 | 100 | 120 | 150 | 180 |
|------------------------|-------|-------|-------|-------|------|------|------|------|------|------|------|------|
| Precipitation (Inches) | .13 | .13 | .13 | .13 | .15 | .16 | .17 | .20 | .27 | .32 | .34 | .39 |
| Ending Date | 29 | 29 | 29 | 29 | 29 | 29 | 29 | 28 | 29 | 29 | 29 | 29 |
| Ending Time (Hour:Min) | 11:25 | 11:25 | 11:25 | 11:25 | 2:28 | 0:24 | 0:38 | 2:28 | 0:27 | 0:18 | 0:13 | 0:41 |

Note: The sum of the hourly totals is given when it differs from the daily total. AWS does not edit ASOS hourly values but may edit daily and monthly totals. Hourly, daily, and monthly totals are printed as reported by the ASOS site.

Date and time are not entered for TRACE amounts.

Figure 10: Typical monthly climate summary for DFW Airport weather station, January 2001. Available online as <http://www5.ncdc.noaa.gov/pdfs/lcd/2001/DFW/200101DFW.pdf>.

Bibliography

R. H. McCuen. *Hydrologic Analysis and Design*. Prentice Hall, Upper Saddle River, New Jersey, 07458, 3rd edition, 2004. ISBN 0-13-142424-6. URL <http://www.prenhall.com>.

SCS. Urban hydrology for small watersheds. Technical Release TR-55, Soil Conservation Service, Hydrology Unit, June 1986. URL <http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html>.