

Implementation of the New NOAA Precipitation-Frequency Atlas for Wisconsin



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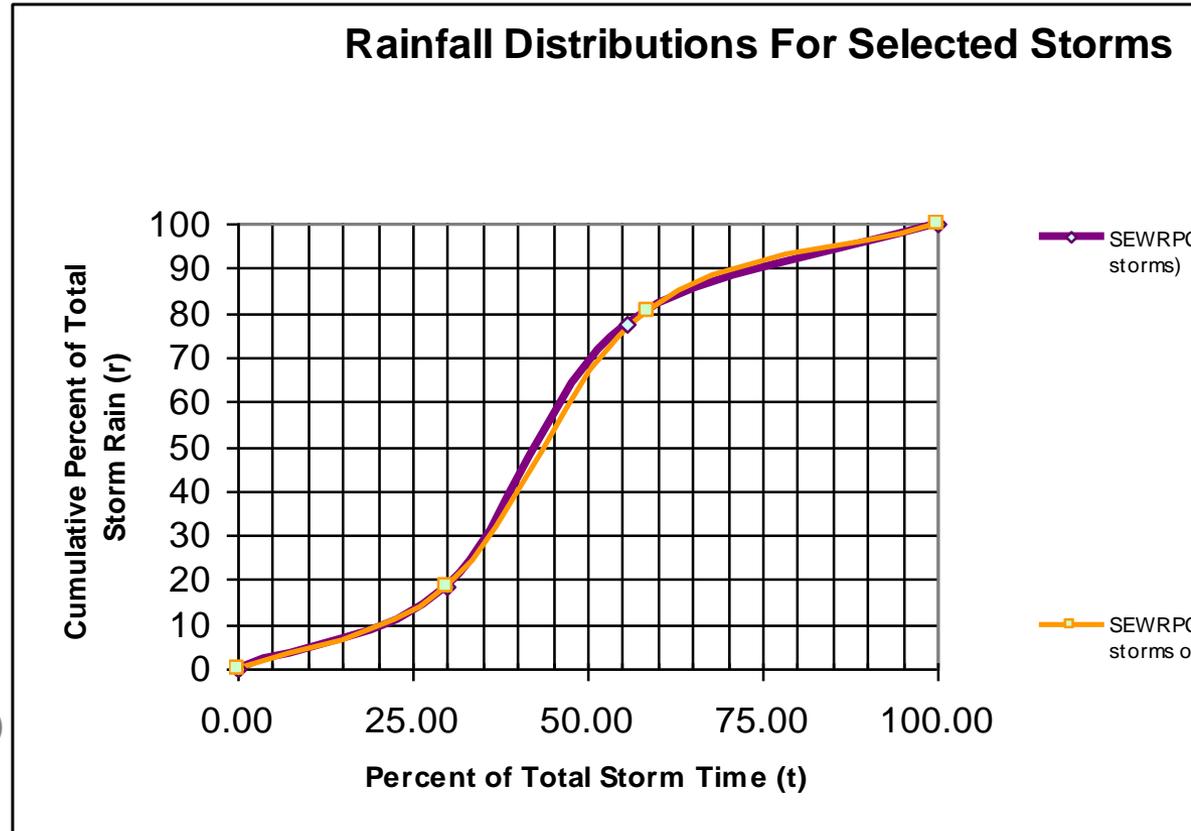
Overview

- Review past precipitation frequency studies
- Introduce NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0: Midwestern States*
 - Precipitation frequency information
 - Temporal storm distributions
- Compare precipitation frequency and temporal distribution information from various commonly-used sources with Atlas 14
- Proposed USDA Natural Resources Conservation Service approach to applying Atlas 14
- Status regarding use of Atlas 14 for regulatory projects in Wisconsin



What Is a Design Storm ?

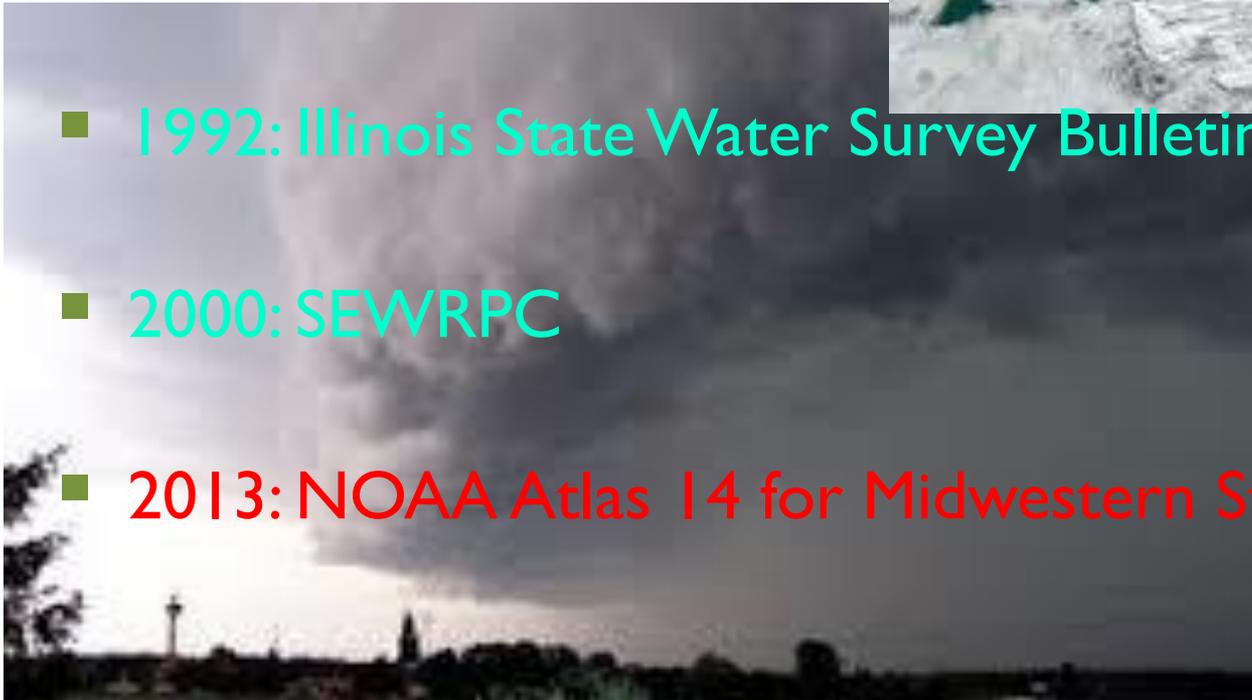
- Design storm is a hypothetical distribution of rainfall over time
- Individual design storms are developed for a given rainfall frequency and duration
 - Storm depth for a given frequency and duration is distributed over time
- Design storm is applied in a hydrologic model to estimate rates and volumes of runoff
 - Generally analyze storms of several durations for a given frequency
 - Results in “critical” (maximum) flow
- Hydrologic model results are used to size stormwater and floodland management facilities and for determining flood hazard areas





Sources of Design Rainfall Estimates

- 1961: U.S. Weather Bureau TP-40
- 1990: SEWRPC
- 1992: Illinois State Water Survey Bulletin 71
- 2000: SEWRPC
- 2013: NOAA Atlas 14 for Midwestern States





Sources of Design Rainfall Estimates

- U.S. Weather Bureau Technical Paper No. 40 (TP-40), *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*
 - Published in 1961 by U.S. Weather Bureau for the continental US
 - In Wisconsin, these rainfall depths were often applied with the SCS Type II time distribution



Sources of Design Rainfall Estimates

- Illinois State Water Survey Bulletin 71, *Rainfall Frequency Atlas of the Midwest*
 - Published in 1992
 - Developed for Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin
 - These rainfall depths are applied with a Huff time distribution





Sources of Design Rainfall Estimates

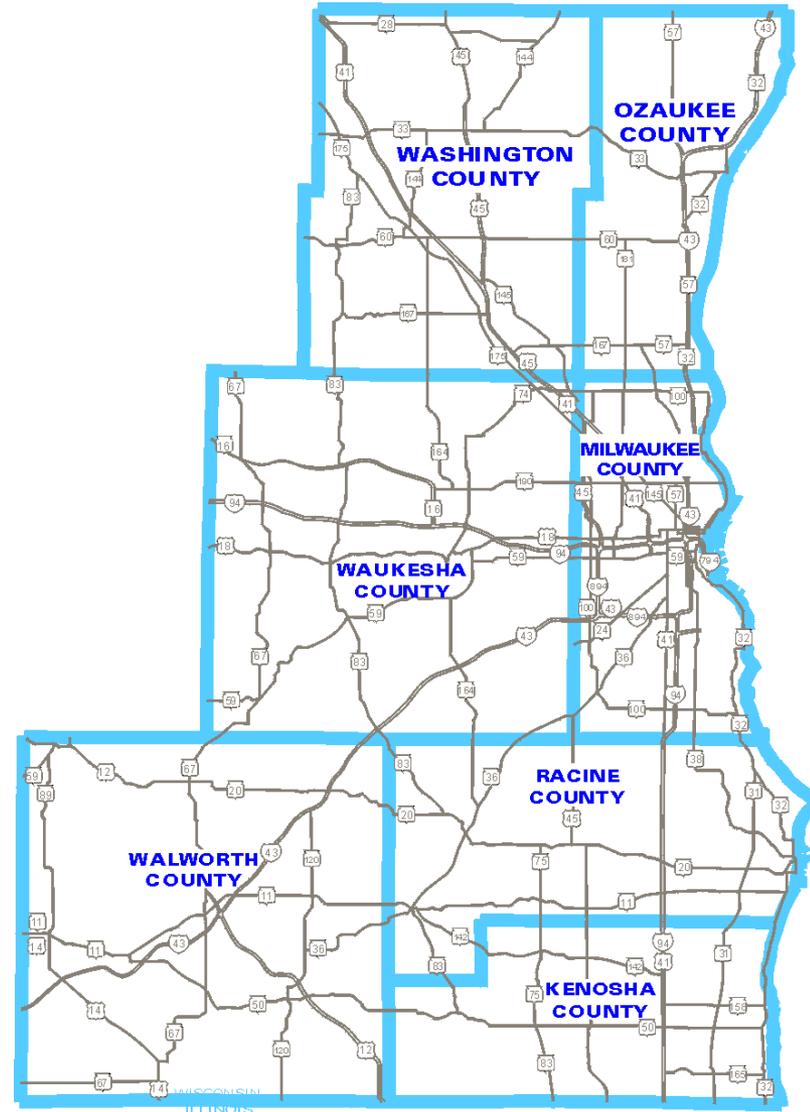
■ SEWRPC 1990

- Originally developed in 1969
- Updated in 1990 (Data from 1903-1986)
- Developed for Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties
- Design storms were developed with either the SCS Type II or Huff distributions



Sources of Design Rainfall Estimates

- SEWRPC 2000
 - Developed for seven-county Southeastern Wisconsin Region using data from 1891-1998
 - Rainfall depths are applied with a new time distribution for the Region
- SEWRPC Technical Report No. 40, *Rainfall Frequency in Southeastern Wisconsin, 2000*
 - Camp, Dresser & McKee Engineers
 - University of Wisconsin-Madison
 - SEWRPC staff
- Developed rainfall depths for recurrence intervals of 2, 5, 10, 25, 50, and 100 years
- Durations of 5 minutes through 10 days



Sources of Design Rainfall Estimates

- NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, Volume 8, Version 2.0: Midwestern States
 - NWS is currently revising throughout the country, applying a region-by-region approach
 - WDNR, WisDOT, and SEWRPC jointly funded the Wisconsin portion of the project
- Completed in 2013

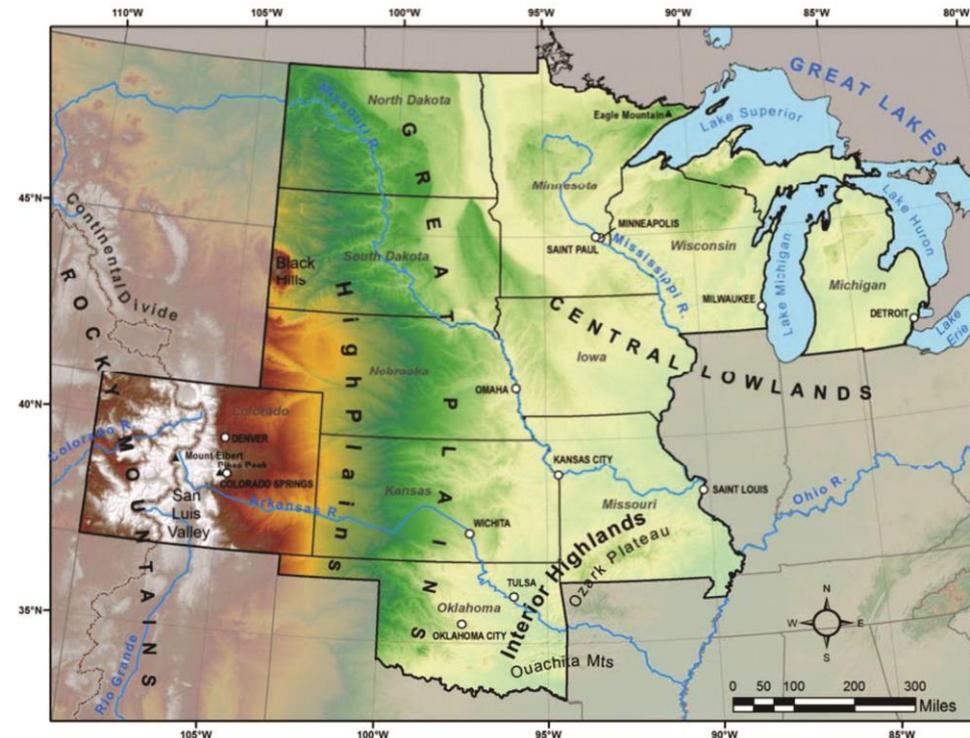


Figure 4.1.1. Project area for NOAA Atlas 14 Volume 8.
(The shaded relief was obtained from [USGS EROS Data Center](https://eros.data.gov/).)



NOAA NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE



NOAA Atlas 14

- 2013 NOAA Atlas 14 supersedes:
 - 1961 U.S. Weather Bureau TP No. 40, 30 minutes to 24 hour durations and RI from 1 to 100 years
 - 1964 U.S.W.B. TP No. 49, Two- to 10-day durations and RI from 2 to 100 years
 - 1977 National Weather Service Hydro 35, five- to 60-minute durations



NOAA Atlas 14

- Analyzed data from 16,227 U.S. Federal, Environment Canada, state, and local stations
 - One-day: 11,918
 - One-hour: 2,657
 - 15-minutes, or variable: 1,652
 - In general, only stations with ≥ 30 years of data were considered, but for hourly stations ≥ 20 years



NOAA Atlas 14

- Low outliers were typically removed
- High outliers: Compared with nearby concurrent depths, and also reviewed observation forms, monthly reports, and historical publications

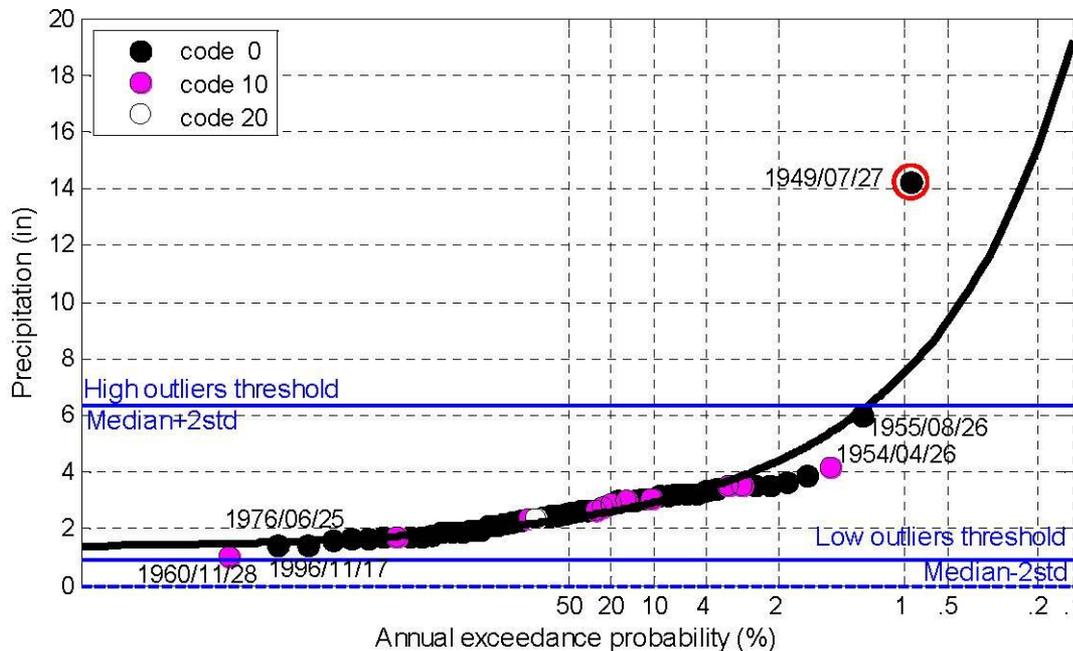


Figure 4.5.1. Outlier tests for 24-hour AMS at station 21-0826. Data quality codes were assigned to annual maxima during the extraction process (Section 4.3).



NOAA Atlas 14

- Parametric and non-parametric statistical tests were made on annual mean series to evaluate climate stationarity (Appendix 2)
- Conclusion: Accepted assumption of stationarity
- Research being conducted to represent IDF relationships under non-stationary climate (ASCE Journal of Hydrologic Engineering, October 2013)
- FHWA asked NOAA to evaluate precipitation frequency relationships applying a non-stationary analysis method. Investigating non-stationary models.



NOAA Atlas 14

- Precipitation frequency relationships developed using annual maximum series
- Smoothed precipitation-frequency across durations
- Converted annual maximum series to partial duration series



- Generalized extreme value (GEV) distribution adopted for all stations and durations

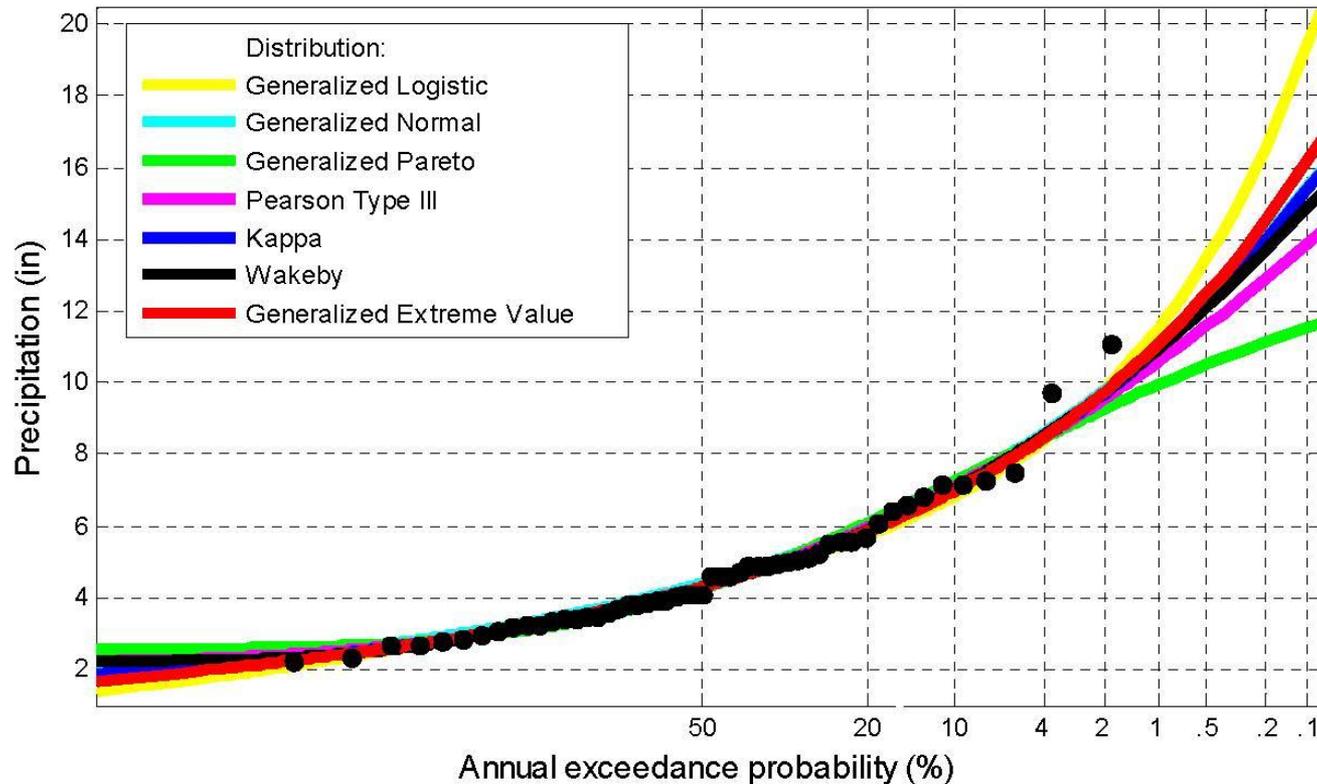


Figure 4.6.3. Probability plots for selected distributions for 1-day AMS at station Nowata (34-6485) in Oklahoma.



NOAA Atlas 14: Gridded Precipitation-Frequency

- Developed gridded precipitation-frequency estimates at 30 arc-seconds resolution
- Station mean annual maximum (MAM) precipitation for 17 durations from 15 minutes through 60 days was interpolated to produce grid



NOAA Atlas 14: Gridded Precipitation-Frequency

- Strong linear relationships between:
 - MAM and two-year precip and
 - Precip-freq relationships for consecutive frequencies

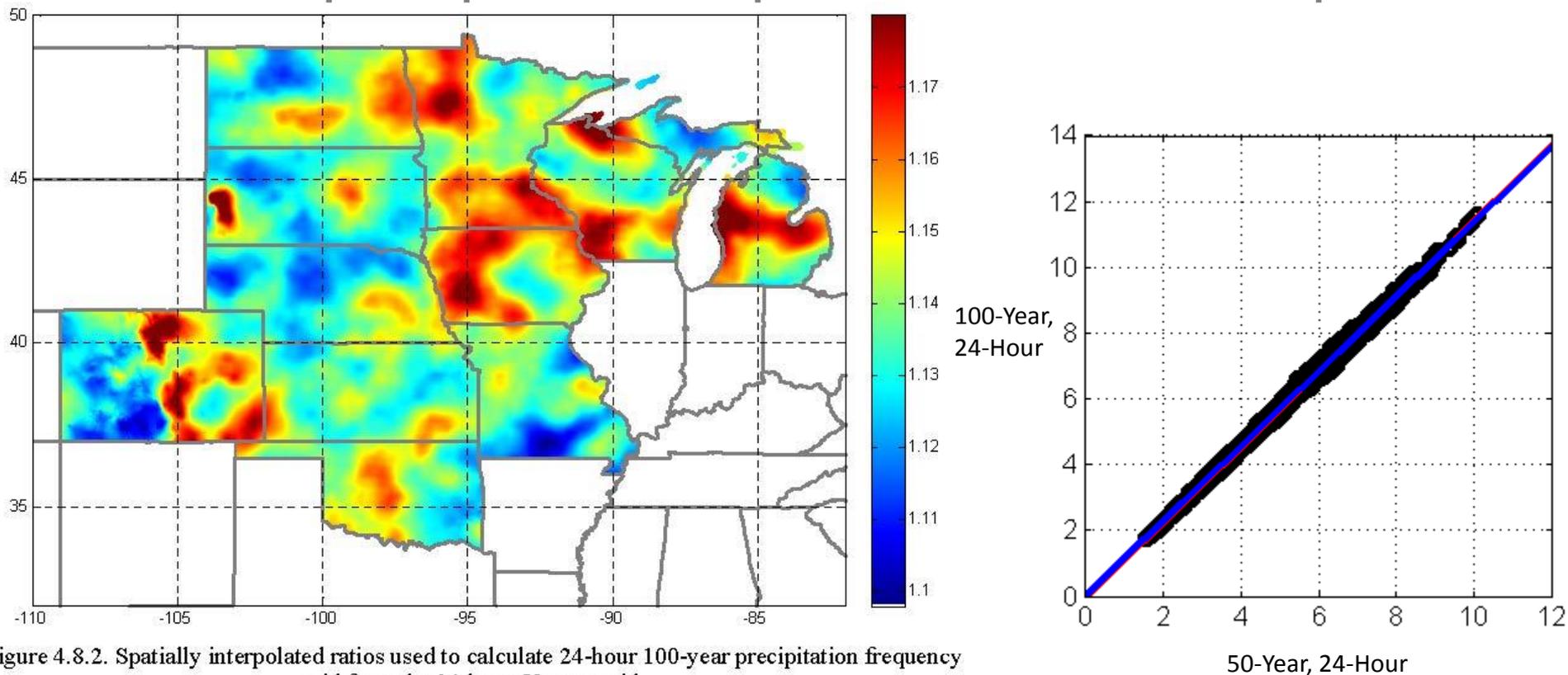


Figure 4.8.2. Spatially interpolated ratios used to calculate 24-hour 100-year precipitation frequency grid from the 24-hour 50-year grid.



NOAA Atlas 14: Rain vs. Total Precipitation

- Precipitation-frequency relationships were developed using both liquid and frozen precipitation (liquid equivalent)
- Trivial difference between using rain and using total precipitation except at high altitudes in Colorado and South Dakota

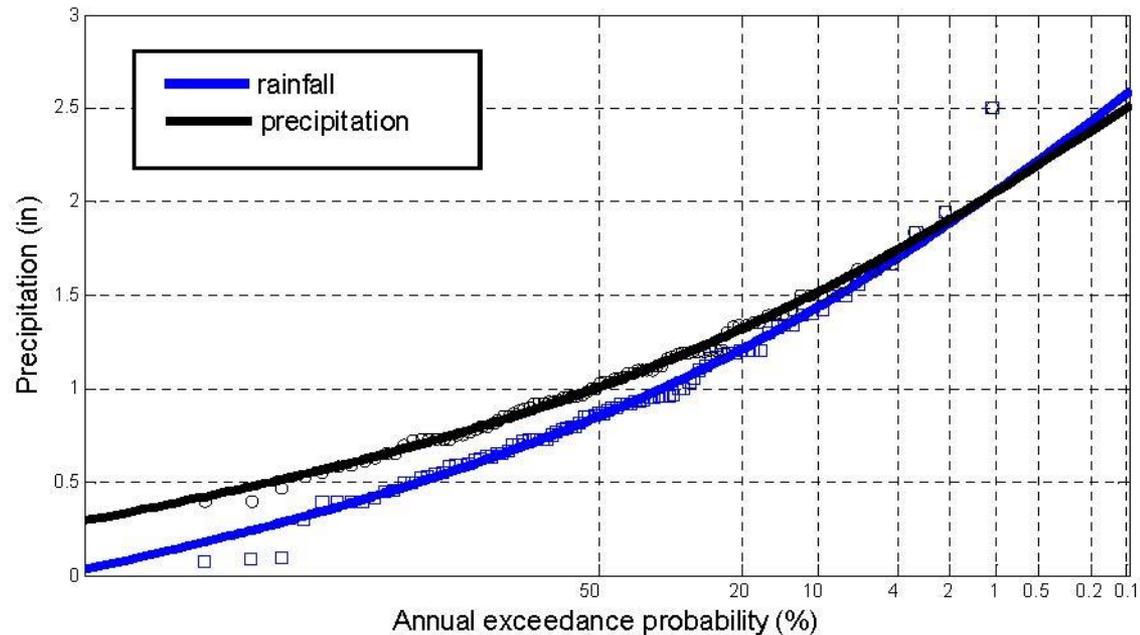
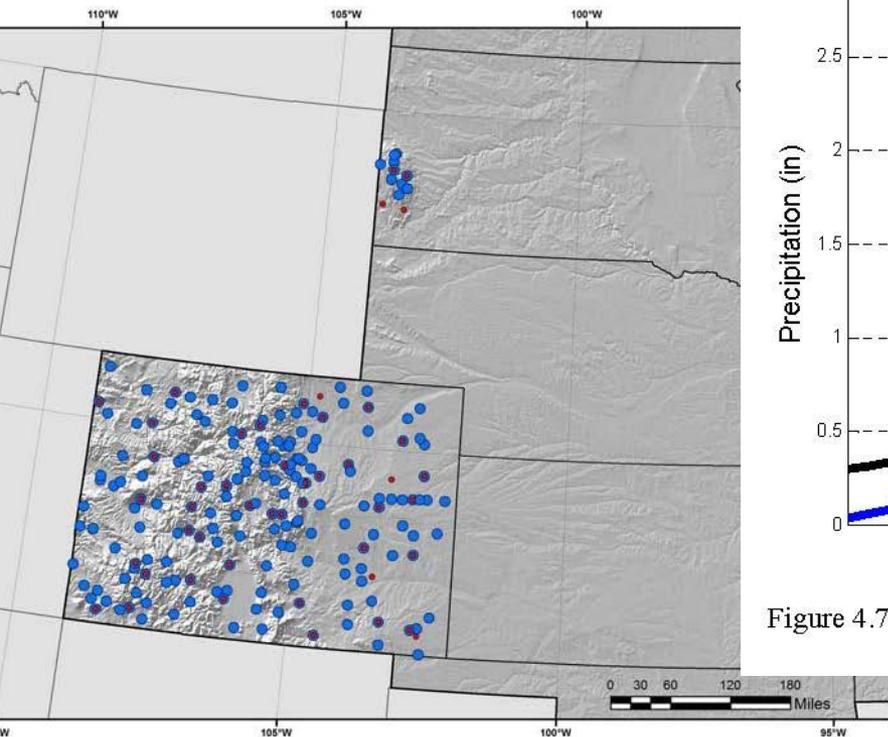


Figure 4.7.1. Probability distributions for the 24-hour rainfall and precipitation annual maximum series at station 05-1071 (elevation 7,946 ft).

Depth-duration frequency curves: Milwaukee, WI

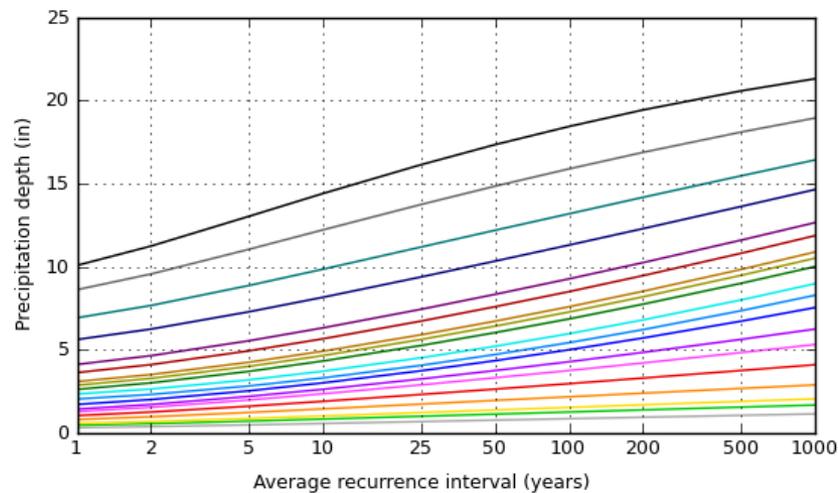
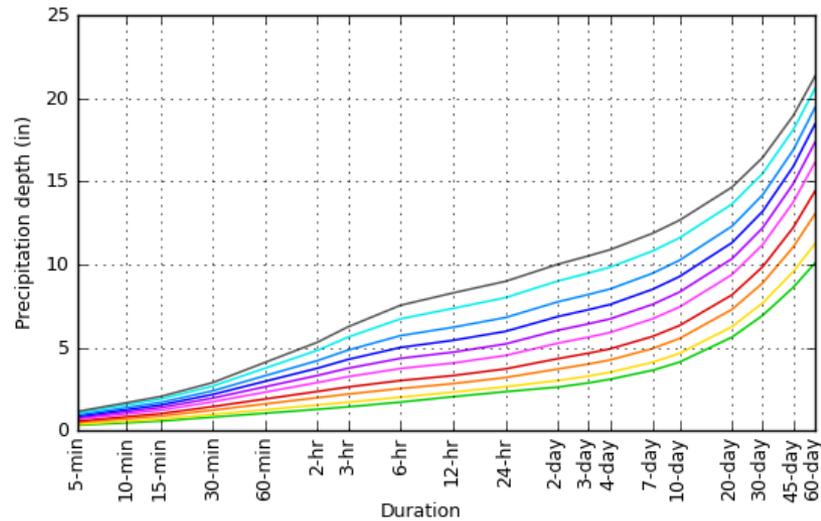
PDS-based depth-duration-frequency (DDF) curves
 Coordinates: 42.9550, -87.9044

Average recurrence interval (years)

- 1
- 2
- 5
- 10
- 25
- 50
- 100
- 200
- 500
- 1000

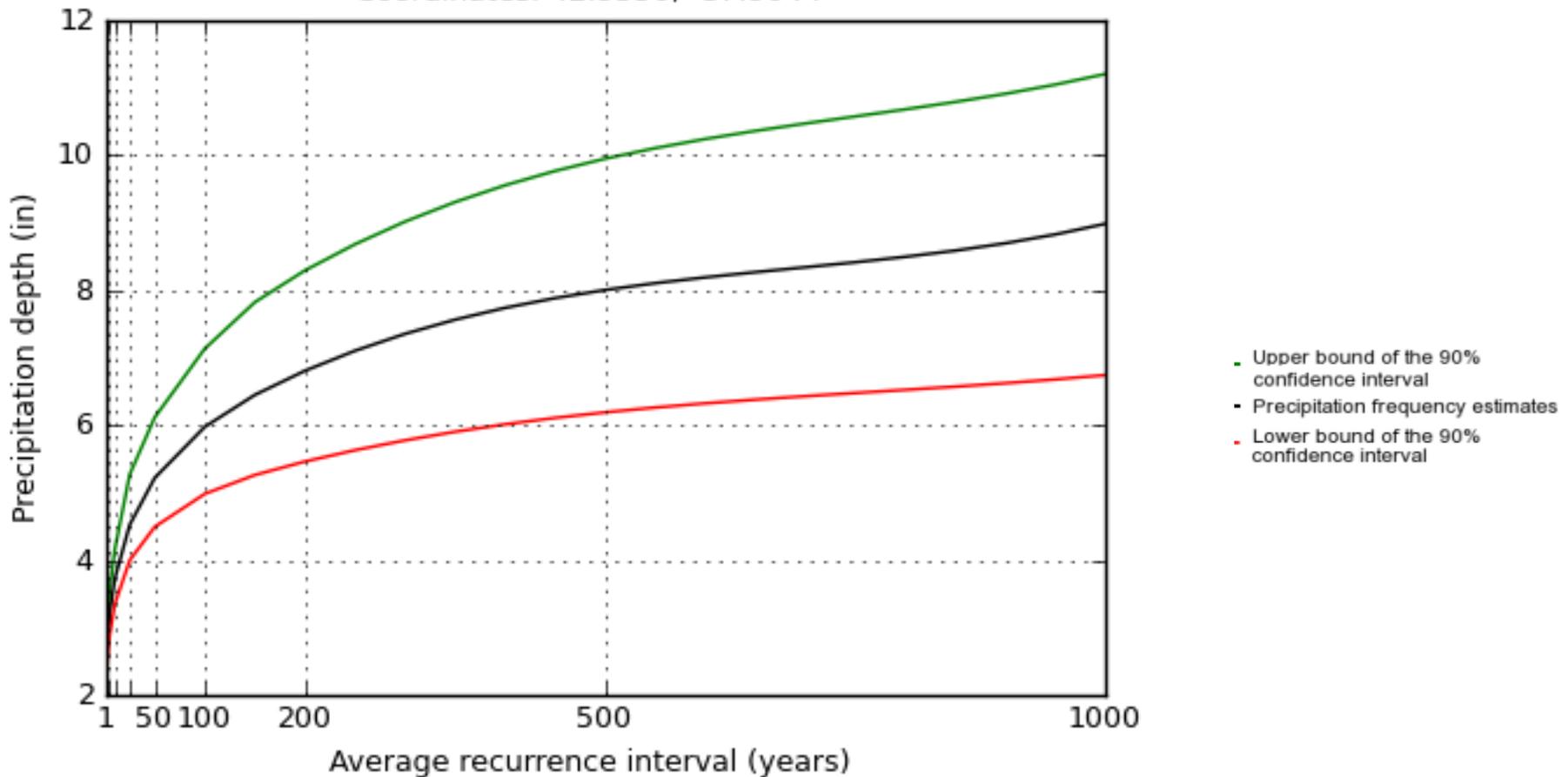
Duration

- 5-min
- 10-min
- 15-min
- 30-min
- 60-min
- 2-hr
- 3-hr
- 6-hr
- 12-hr
- 24-hr
- 2-day
- 3-day
- 4-day
- 7-day
- 10-day
- 20-day
- 30-day
- 45-day
- 60-day



90 % Confidence Intervals: Milwaukee, WI

24-hr PF estimates with 90% confidence intervals
Coordinates: 42.9550, -87.9044

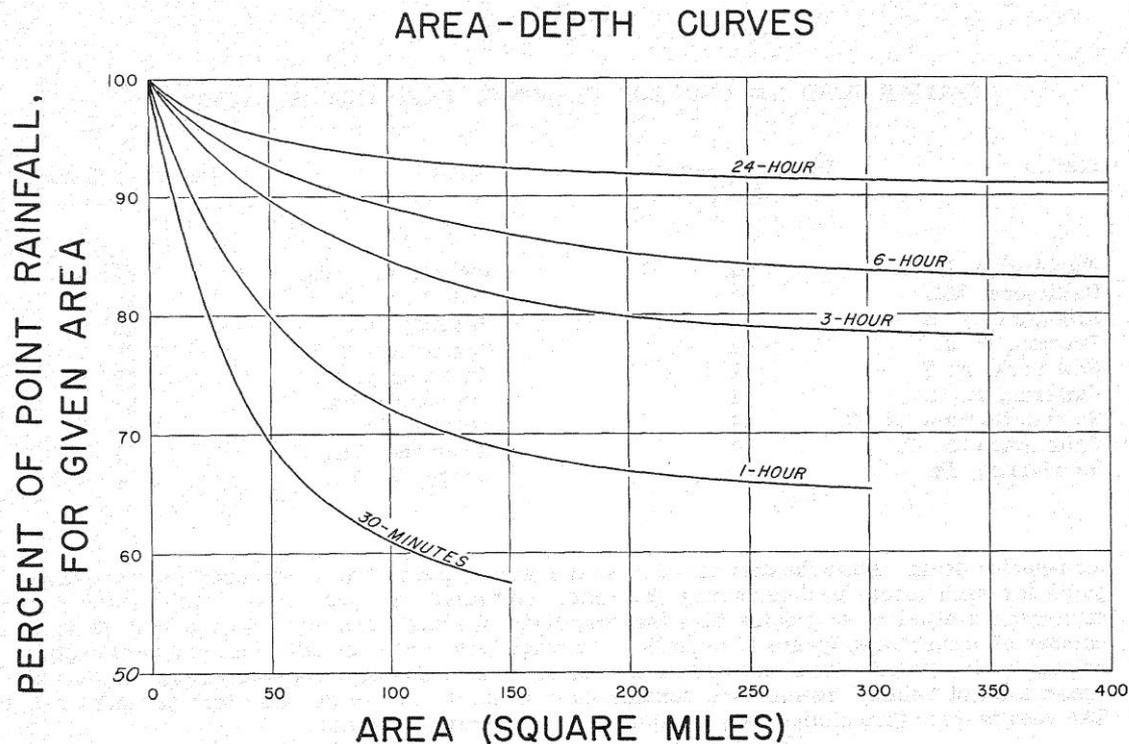




NOAA Atlas 14: Areal Reduction Factors (ARF)

Point precipitation-frequency estimates

- Areal reduction factors: Atlas 14 recommends using 1960 U.S. Weather Bureau TP 29
- NOAA is working on development of new areal reduction factors
- Possible approach: Use gridded precipitation to average over subwatershed, then apply ARF for entire watershed area studied





Rainfall Depths for Southeastern Wisconsin

■ Comparison of 100-year, 24-hour rain depths:

- Weather Bureau TP-40: 5.44 inches
- ISWS Bulletin 71: 6.24 inches
- SEWRPC 1990: 5.50 inches
- SEWRPC 2000: 5.88 inches
- NOAA Atlas 14: ~5.8 to 6.4 inches



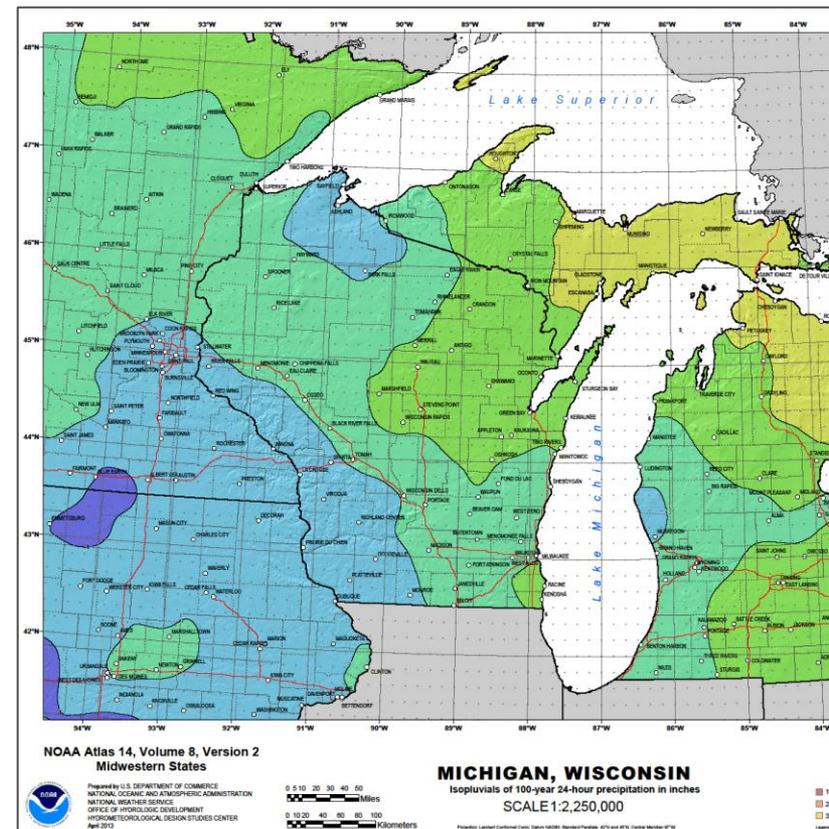
5 to 6 inches



6 to 7 inches



7 to 8 inches

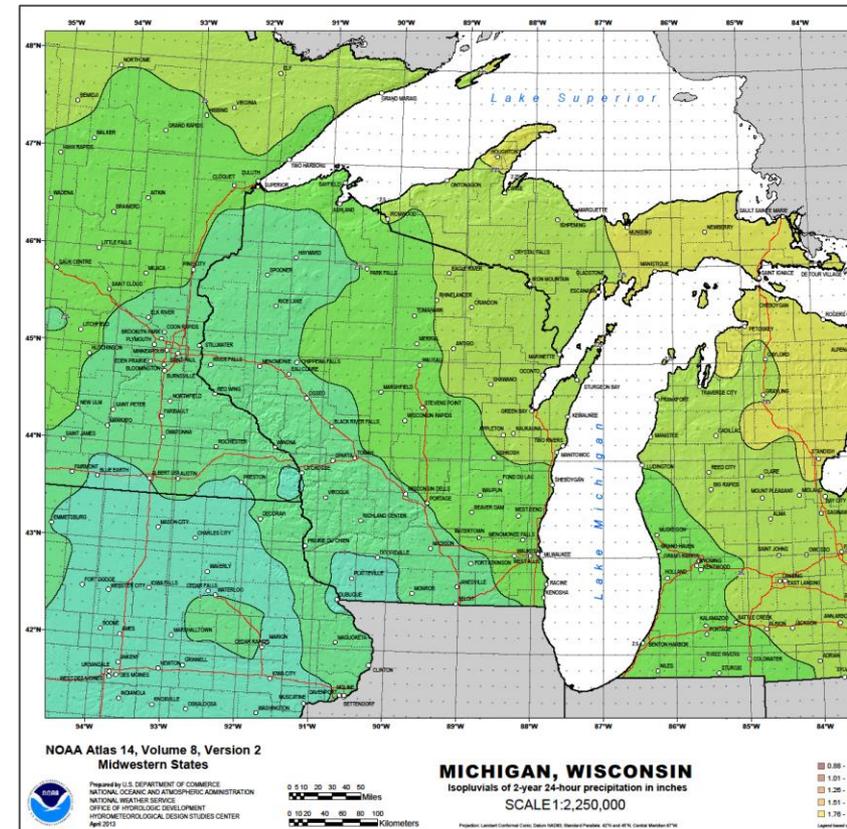




Rainfall Depths for MMSD Planning Area

■ Comparison of two-year, 24-hour rain depths:

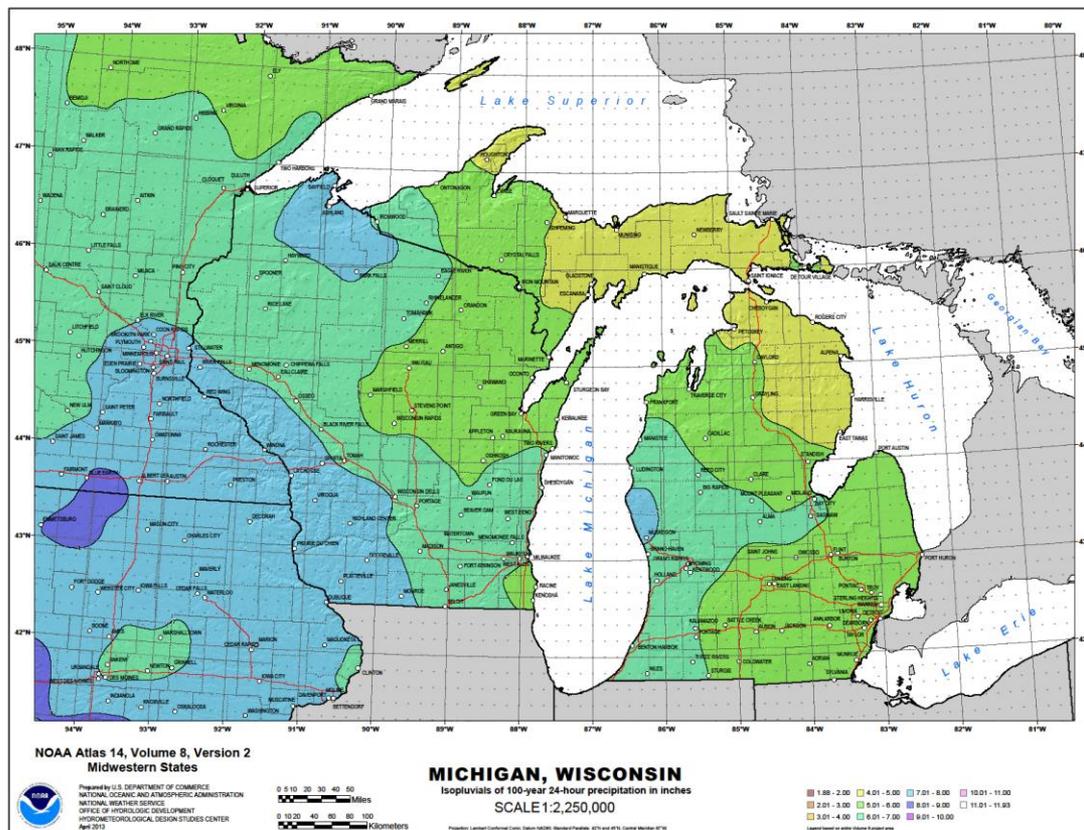
- Weather Bureau TP-40: 2.6 inches
- ISWS Bulletin 71: 2.70 inches
- SEWRPC 1990: 2.4 inches
- SEWRPC 2000: 2.57 inches
- NOAA Atlas 14: 2.65 inches





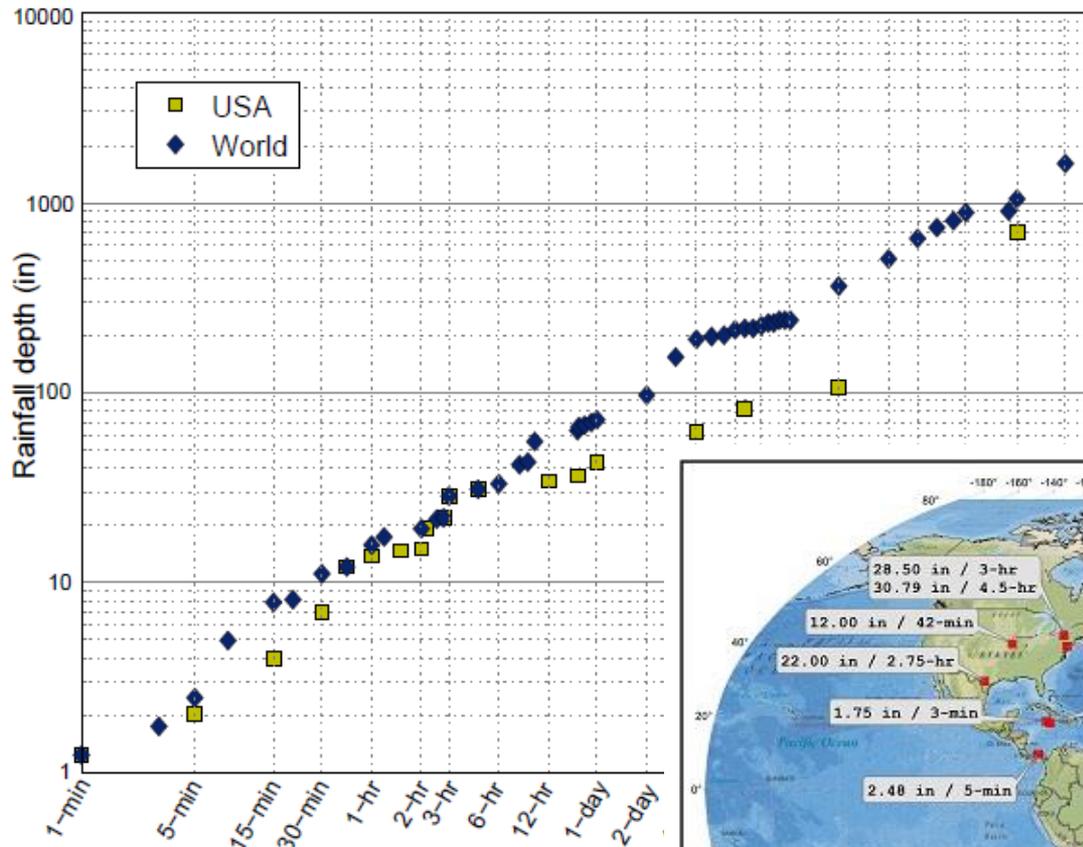
Accessing Precipitation-Frequency Information

- NOAA recommends using Precipitation Frequency Data Server (PFDS), or ASCII grids, rather than cartographic maps





Record point precipitation measurements (1-minute to 2-year)



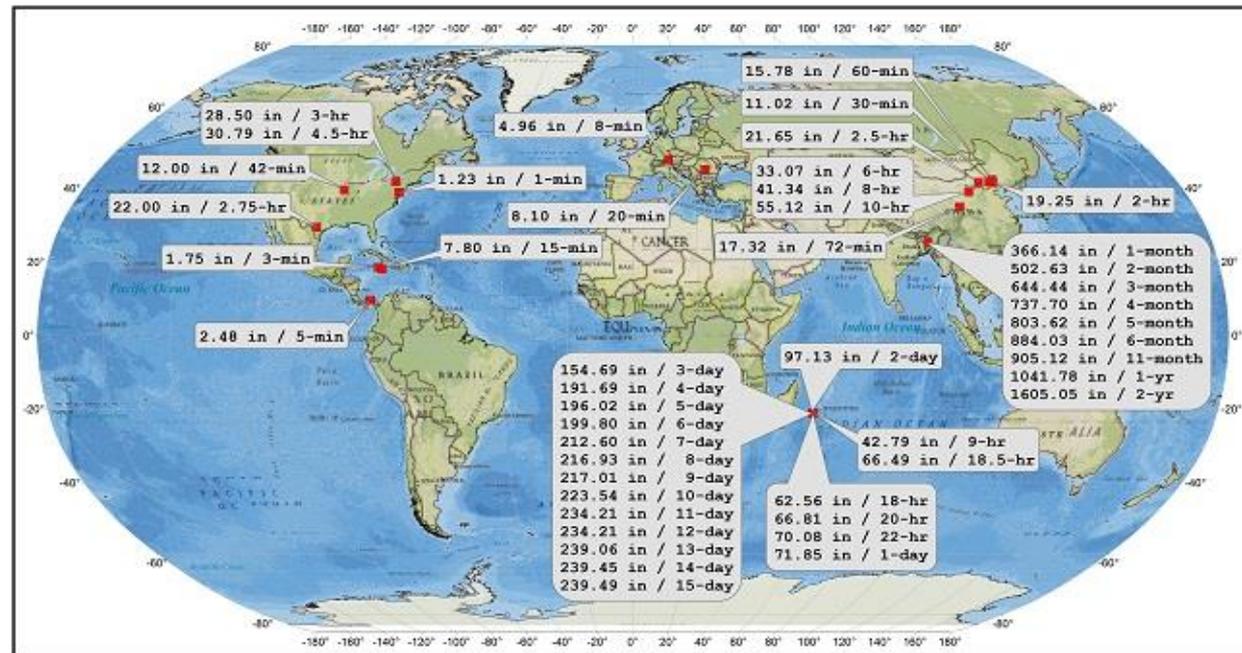
One-day Maximum Precipitation

USA: 40 to 50 inches

World: 70 to 80 inches

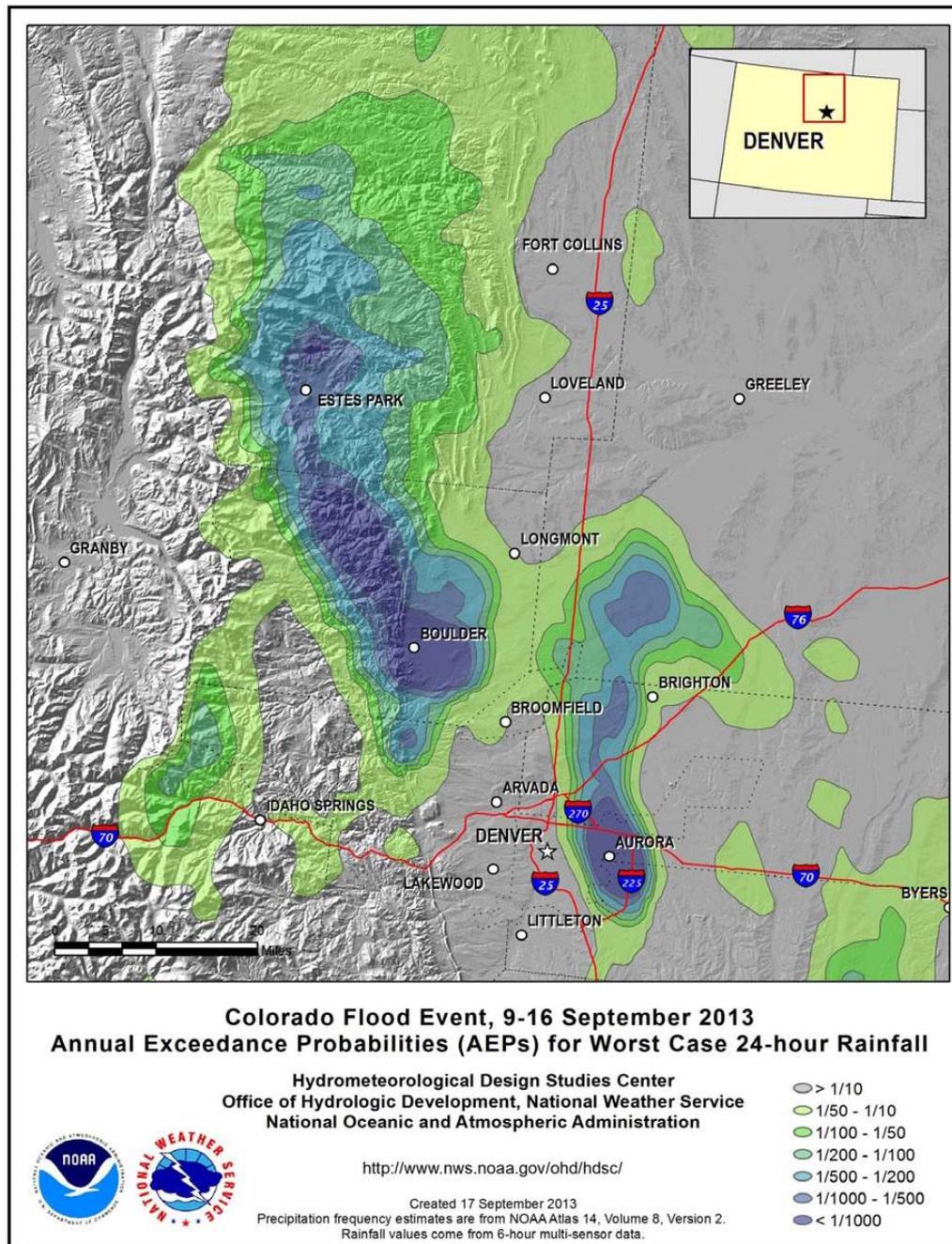
One-day, 1000-year RI

Milwaukee, WI: 8.99 inches

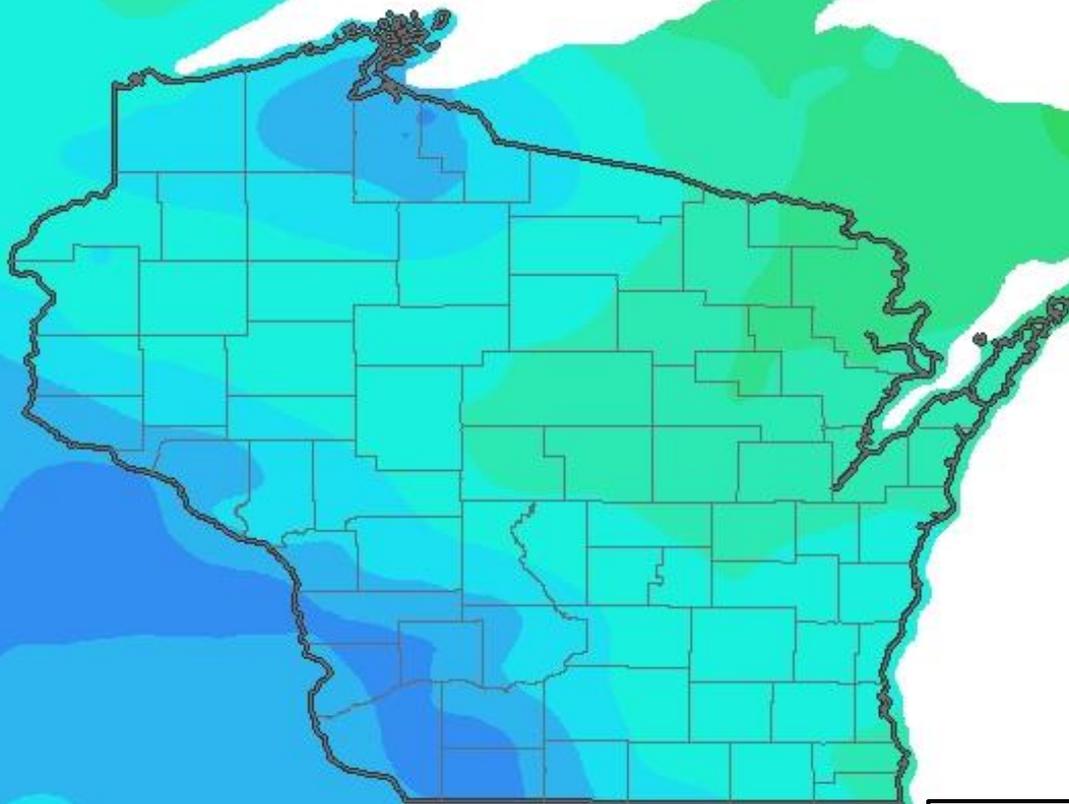




- NOAA Atlas 14 used to estimate probabilities of September 2013 Colorado rainfalls
- 1000-year, 4-day rain is about 8 inches. Observed 4-day rain (13" to 14") is at upper bound of 90% confidence interval for 1000-year R. I.



USDA - NRCS Implementation of NOAA Atlas 14 in Wisconsin



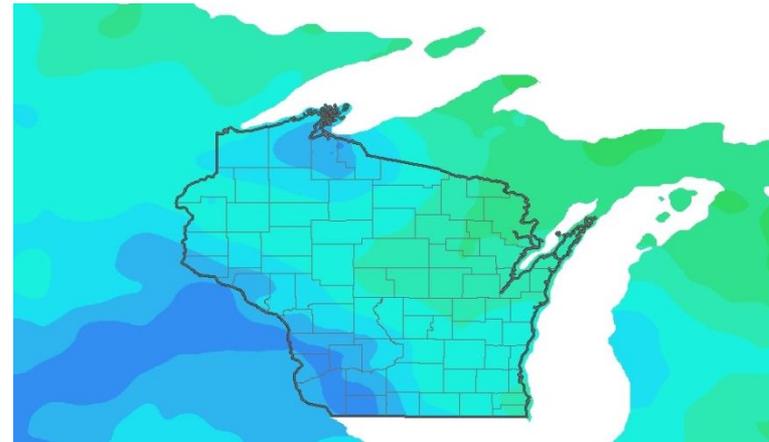
Annette Humpal, P.E.
USDA – NRCS
Hydraulic Engineer



NRCS Work to Implement NOAA Atlas 14

Background:

- NRCS Priority to Coordinate Nationwide to provide consistent methods for analyzing and using Atlas 14 data
- **NRCS National Water Quality and Quantity Team (WQQT)** assisted NRCS State Hydraulic Engineers in this work
 - The **WQQT** had done considerable study of the previously released Atlas 14 volumes and had developed methods for analyzing the data
 - These methods were used by NRCS to implement the NOAA Atlas 14 (Volume 8) data in Wisconsin





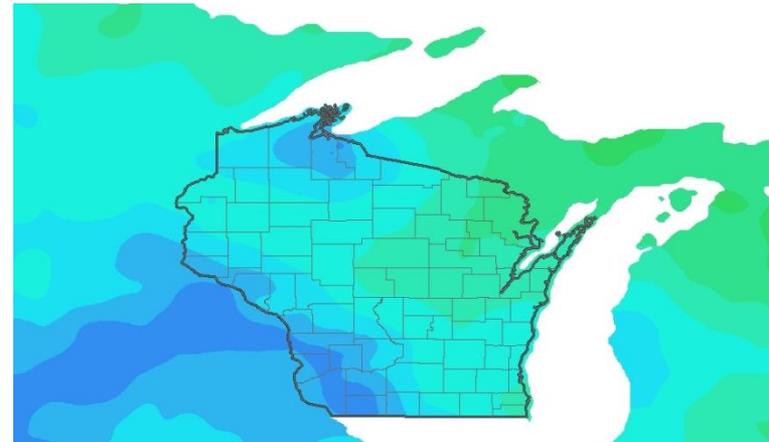
NRCS Work to Implement NOAA Atlas 14

■ NRCS Atlas 14 Work at a National and State Level:

● Analyzed the Atlas 14 data using GIS

- Developed Generalized Precipitation Depths by County and Storm Frequency
- Developed NRCS Temporal Storm Distributions

● Developed precipitation databases (of depths and temporal storm distributions) by County for use in the NRCS hydrology computer programs





NRCS Development of Precipitation Depths by County

- NRCS Analyzed the NOAA Atlas 14 data :
 - Used GIS to analyze the Atlas 14 **grid data** and develop mean precipitation depths **by County** and storm frequency (1-yr through 500-yr) for the 24-hr duration
 - **Representative Locations** were selected for each WI County from the Atlas 14 grid data. The Atlas 14 precipitation depths at each selected County representative (point) location are:
 - **Equal** to the County Mean for the 100-year, 24-hour Event
 - Within -1.0% and +1.9% (within 1 standard deviation) of the County Means for the 1-year through 50-year, 24 hour events
 - Precipitation Depths for representative County locations were used in NRCS Hydrology Program Databases
 - The intent of the “representative locations” is to prepare for future GIS capability of NRCS Hydrology programs



TP40 Versus NOAA Atlas 14 Precipitation Depths

10-Yr, 24-Hr Precipitation Depths

Percent Change From TP40 to NOAA Atlas 14 (Representative Location)

Iron County:

TP40: 3.80"

Atlas 14 (Mean): 4.03"

Atlas 14 (Rep. Loc.): 4.05"

Increase (Rep. Loc.): 6.6%

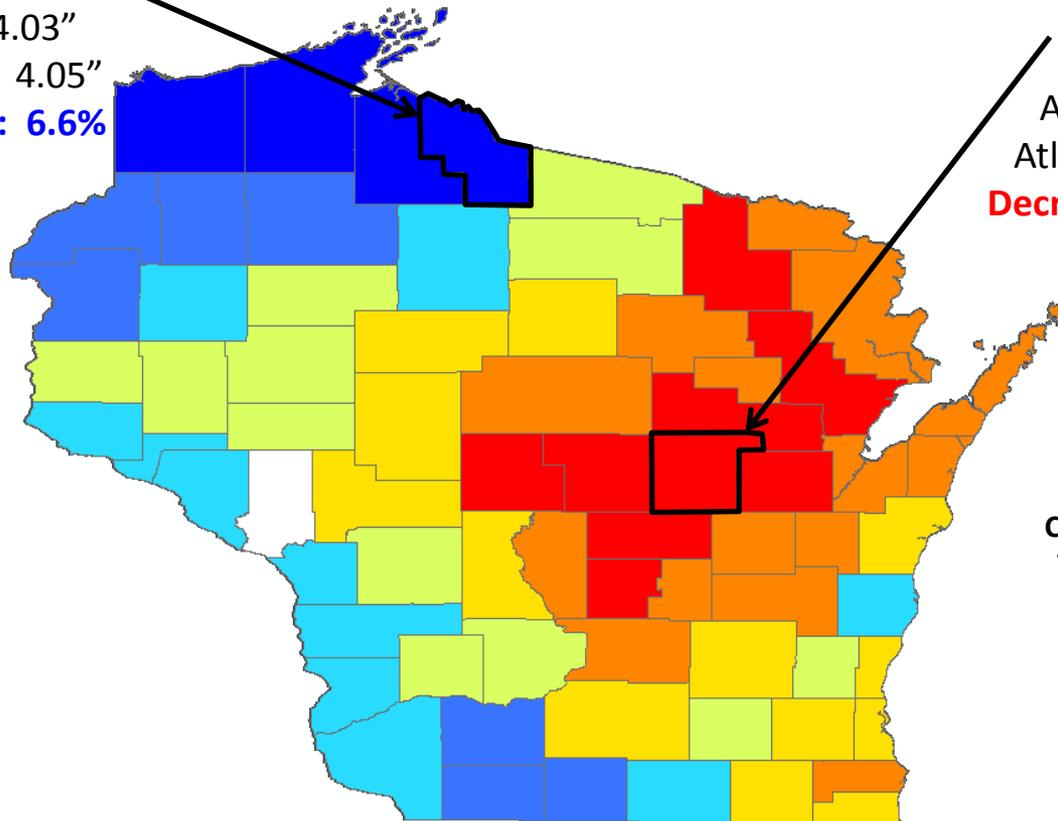
Waupaca County:

TP40: 3.90"

Atlas 14 (Mean): 3.57"

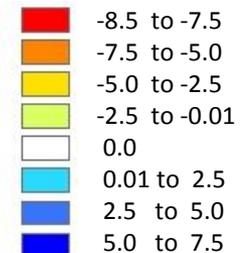
Atlas 14 (Rep. Loc.): 3.60"

Decrease (at Rep. Loc.): 7.7%



Change in Precipitation Depth From
TP40 to NOAA Atlas 14 (Rep. Loc.)

10-Year, 24-hour (Percent)





TP40 Versus NOAA Atlas 14 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths

Percent Change From TP40 to NOAA Atlas 14 (Representative Location)

Ashland County:

TP40: 5.40"

Atlas 14 (Rep. Loc. = Mean): 7.37"

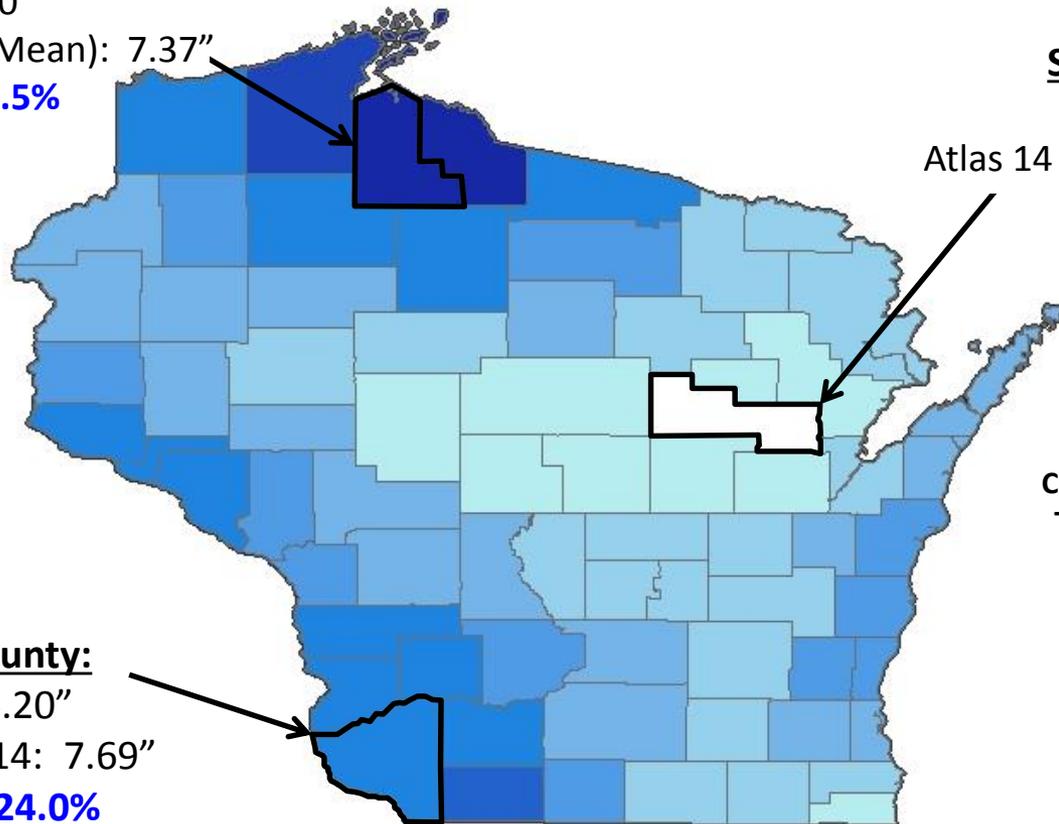
Increase 36.5%

Shawano County:

TP40: 5.40"

Atlas 14 (Rep. Loc. = Mean): 5.40"

No Change



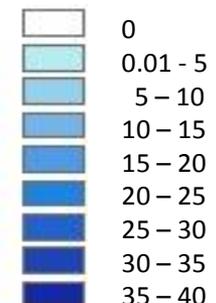
Grant County:

TP40: 6.20"

NOAA Atlas 14: 7.69"

Increase 24.0%

Change in Precipitation Depth From
TP40 to NOAA Atlas 14 (Rep. Loc.)
100-Year, 24-hour (Percent)





TP40 Versus NOAA Atlas 14 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths

Percent Change From TP40 to NOAA Atlas 14 (Representative Location)

Ashland County:

TP40: 5.40"

Atlas 14 (Rep. Loc. = Mean): 7.37"

Increase 36.5%

Shawano County:

TP40: 5.40"

Atlas 14 (Rep. Loc. = Mean): 5.40"

No Change

Grant County:

TP40: 6.20"

NOAA Atlas 14: 7.69"

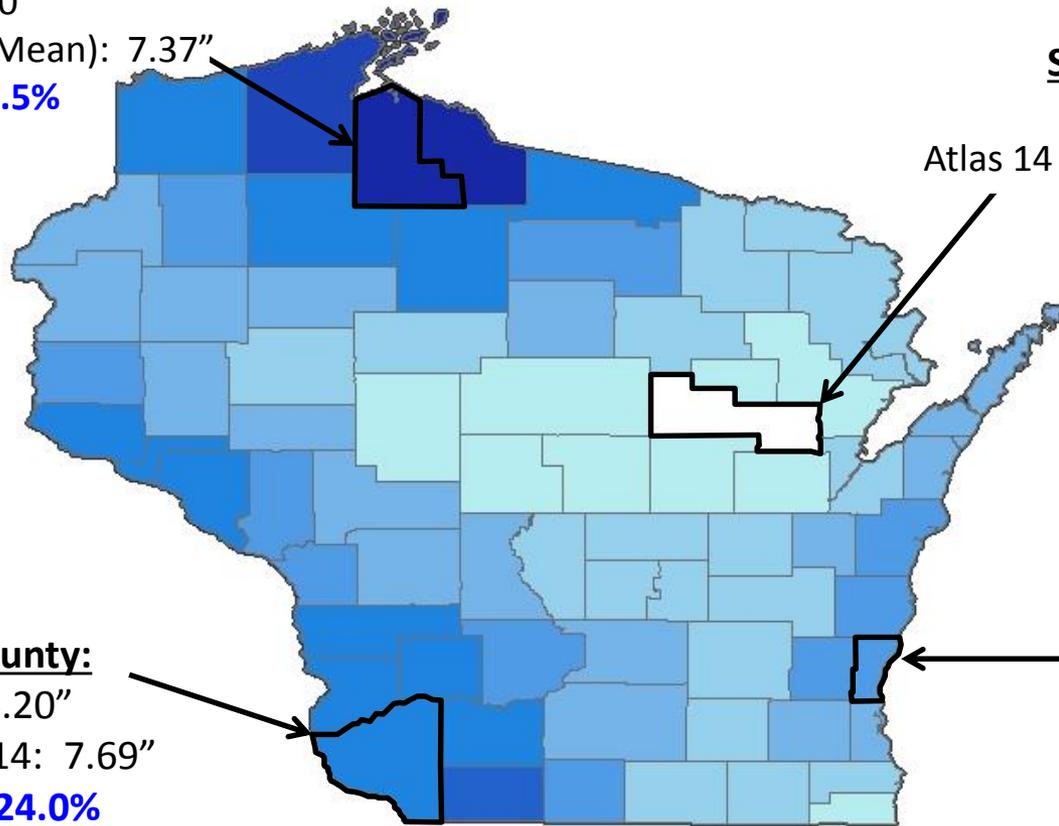
Increase 24.0%

Ozaukee County:

TP40: 5.40"

NOAA Atlas 14: 6.38"

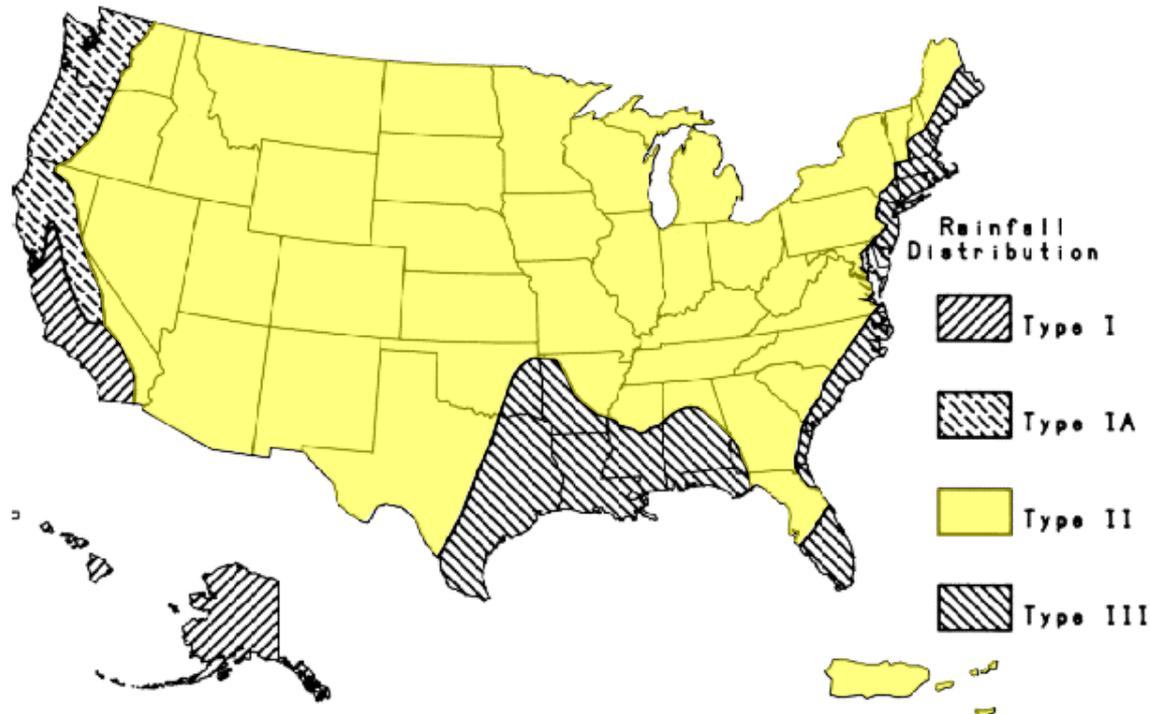
Increase 18.1%





Development of NRCS Temporal Distributions

- From their analysis of the *previously completed* NOAA Atlas 14, Volumes, the NRCS **WQQT** concluded ...
- The NRCS Type II Storm distribution **should not** be used with NOAA Atlas 14 precipitation depths.
- The use of rainfall distributions that cover large geographic regions (such as Type II), could lead to over- or under-estimation of peak discharge





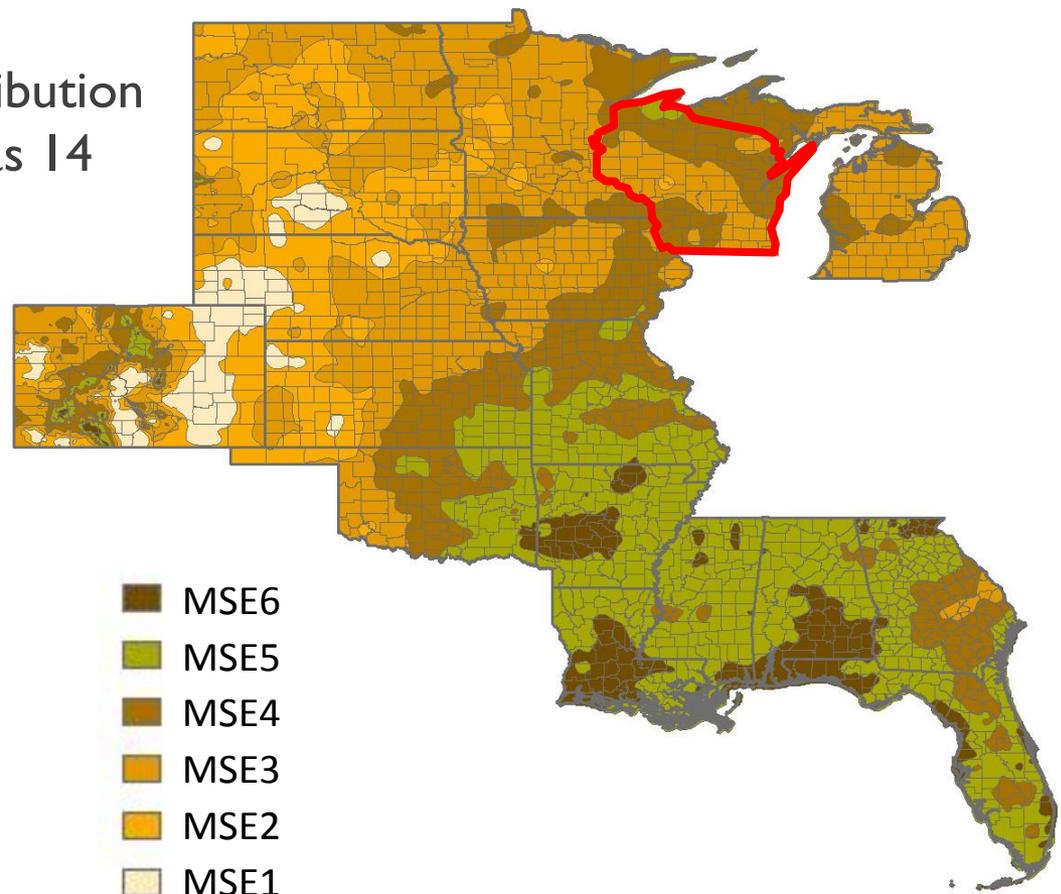
Development of NRCS Temporal Distributions

- The NRCS WQQT developed a procedure Using ArcGIS 10.0 for deriving temporal storm distributions for a wide range of climate conditions (tropical to arctic) which occur in the US.

Developed temporal storm distribution Regions for MW and SE US (Atlas 14 Volumes 7 and 8)

Based on ratios of the Atlas 14 (25-yr, 1-hr)/(25-yr, 24-hr) precipitation depths

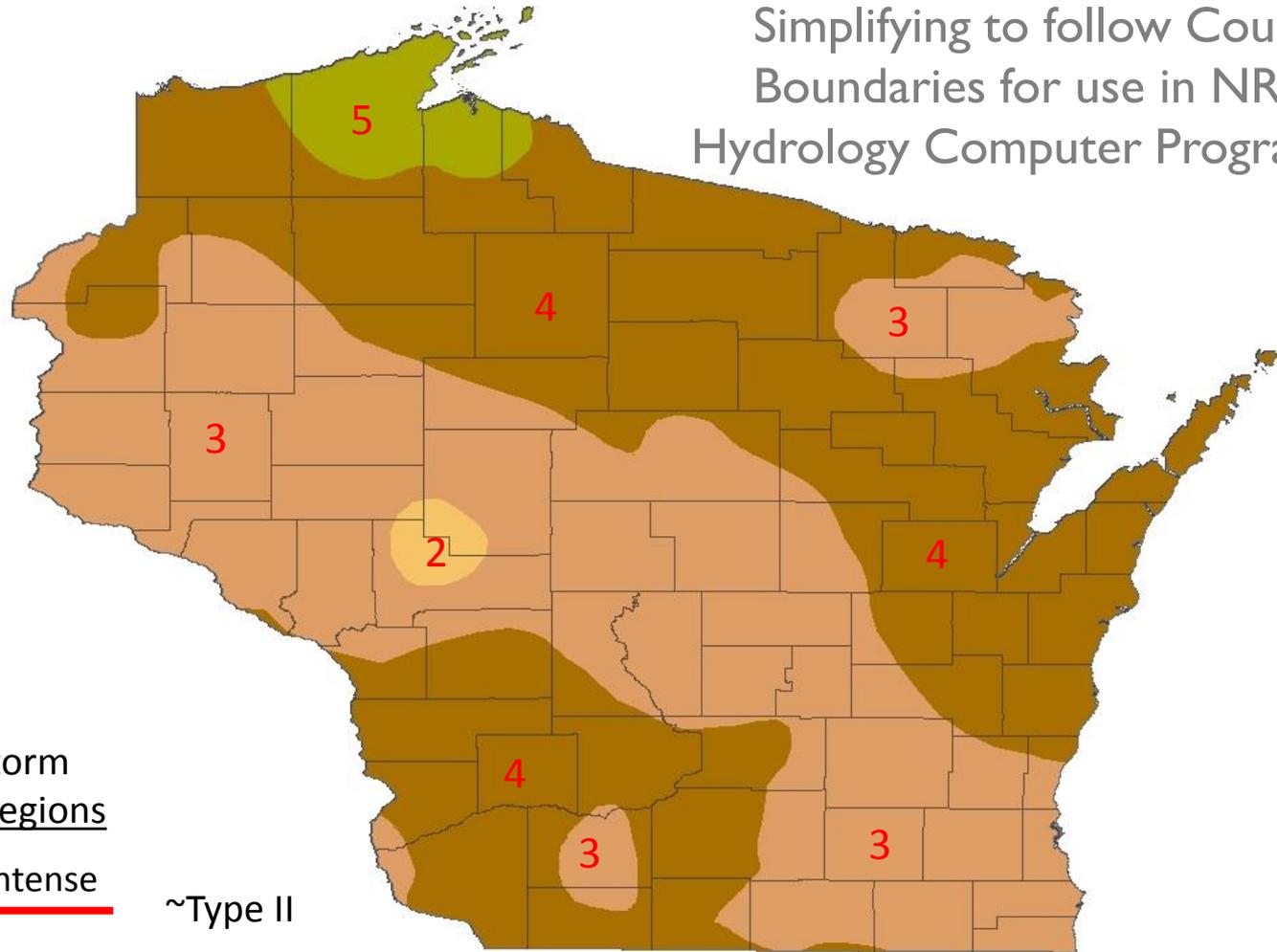
The distribution Regions were titled **MSE** (e.g. MSE1 to MSE6), since they were developed for the MW and the SE US





NRCS WQQT Storm Distribution Regions - WI

Simplifying to follow County Boundaries for use in NRCS Hydrology Computer Programs...



Tentative Storm Distribution Regions

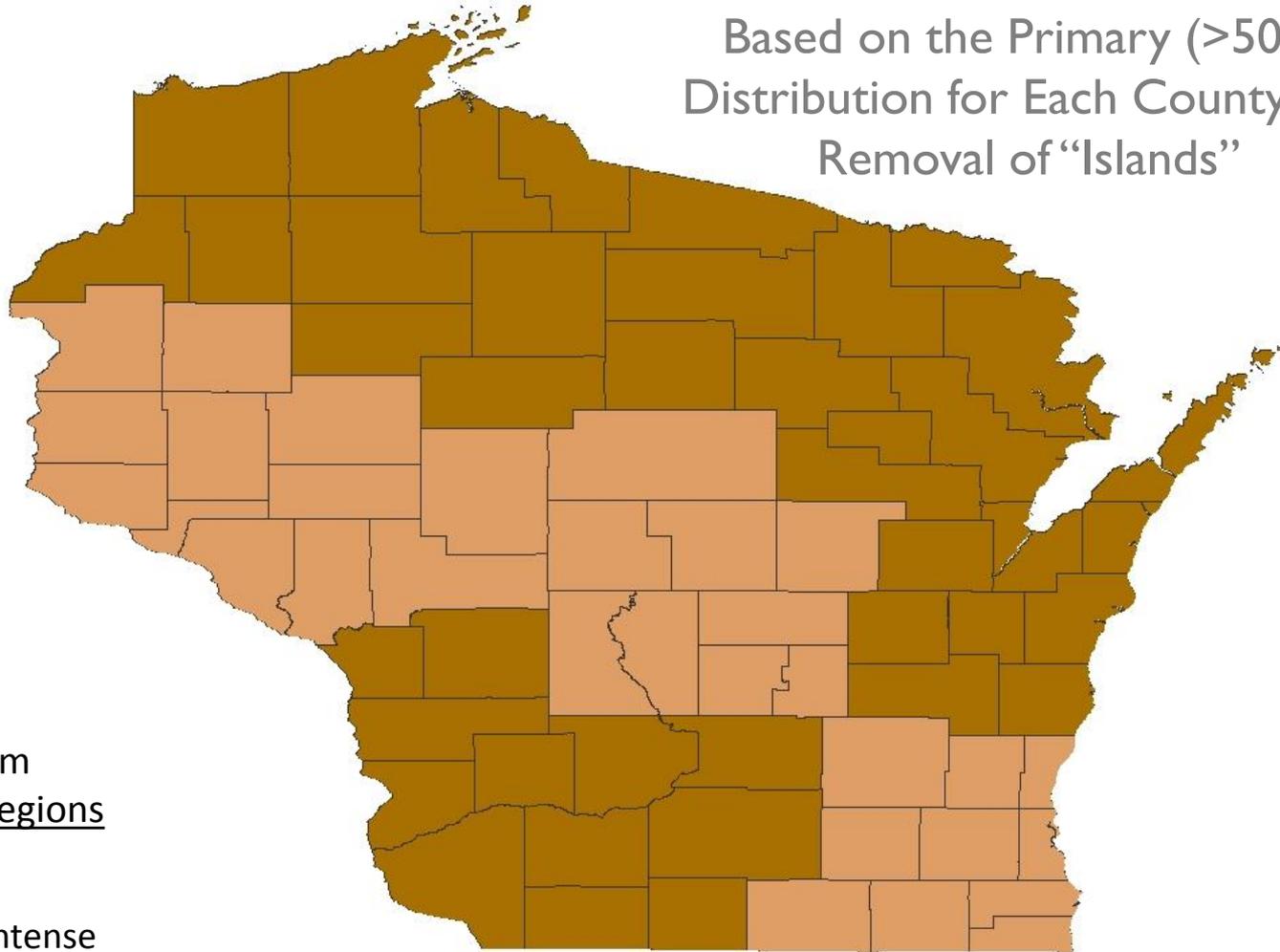
- MSE5 Less Intense
- MSE4
- MSE3
- MSE2 More Intense

← ~Type II



NRCS WI Storm Distribution Regions - Final

Based on the Primary (>50%)
Distribution for Each County and
Removal of "Islands"

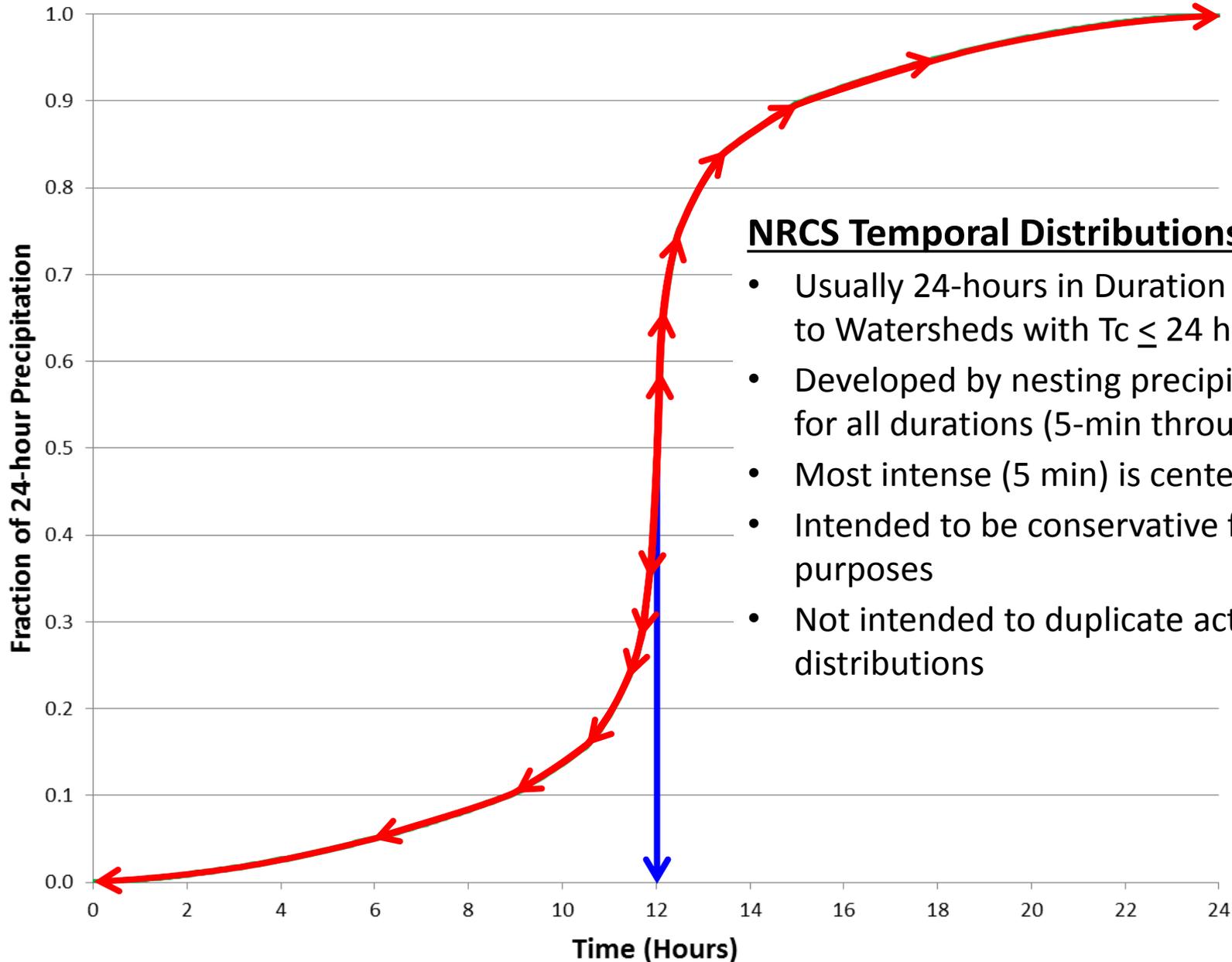


Final Storm Distribution Regions

- MSE4 Less Intense
- MSE3 More Intense

The New NRCS Storm Distributions were Applied by County in
the Hydrology Program Precipitation Databases

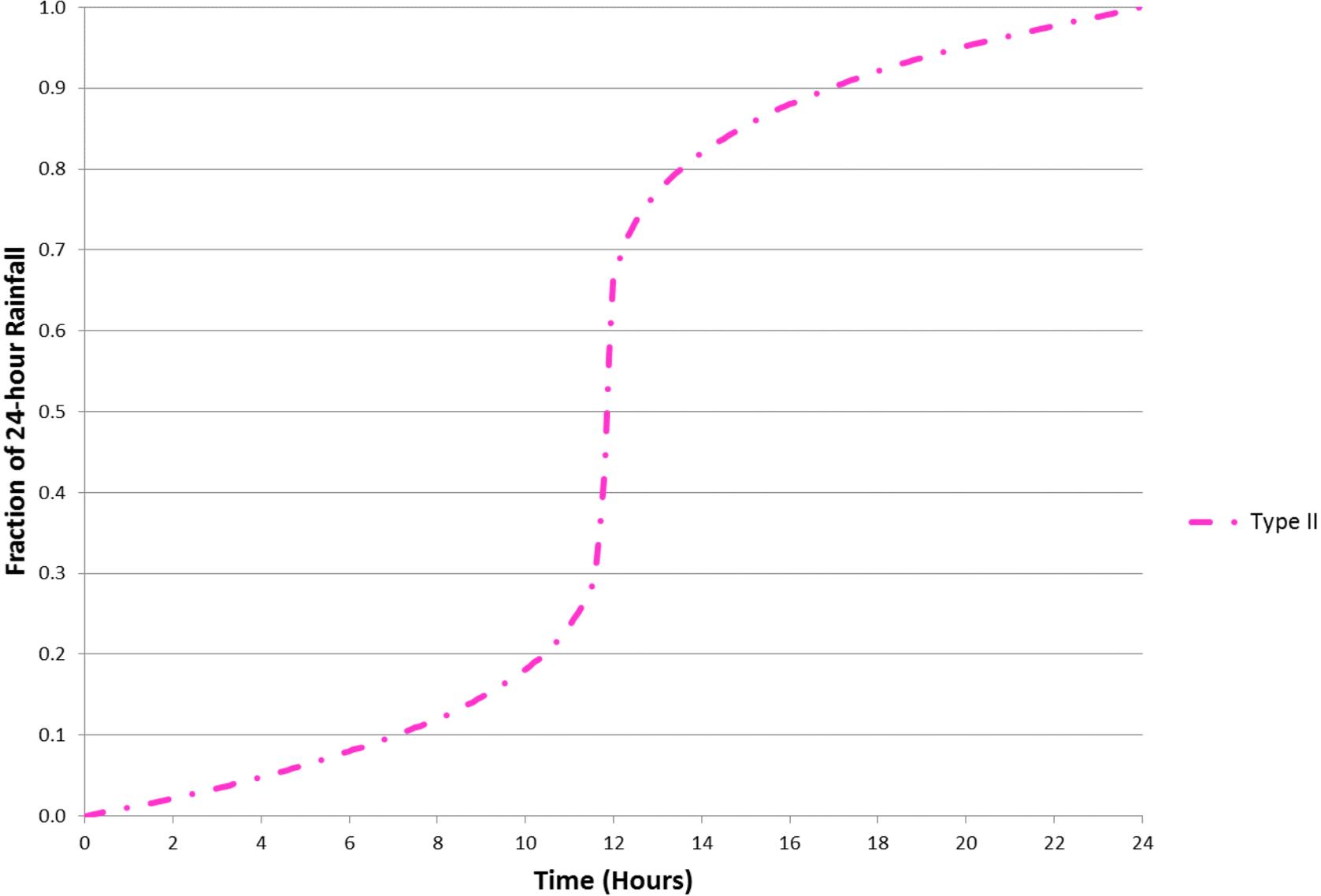
Development of a NRCS Temporal Storm Distribution



NRCS Temporal Distributions are:

- Usually 24-hours in Duration – applicable to Watersheds with $T_c \leq 24$ hours
- Developed by nesting precipitation depths for all durations (5-min through 24-hr)
- Most intense (5 min) is centered at 12 hrs
- Intended to be conservative for design purposes
- Not intended to duplicate actual storm distributions

Comparison of Storm Distributions





NRCS WQQT New Storm Distributions

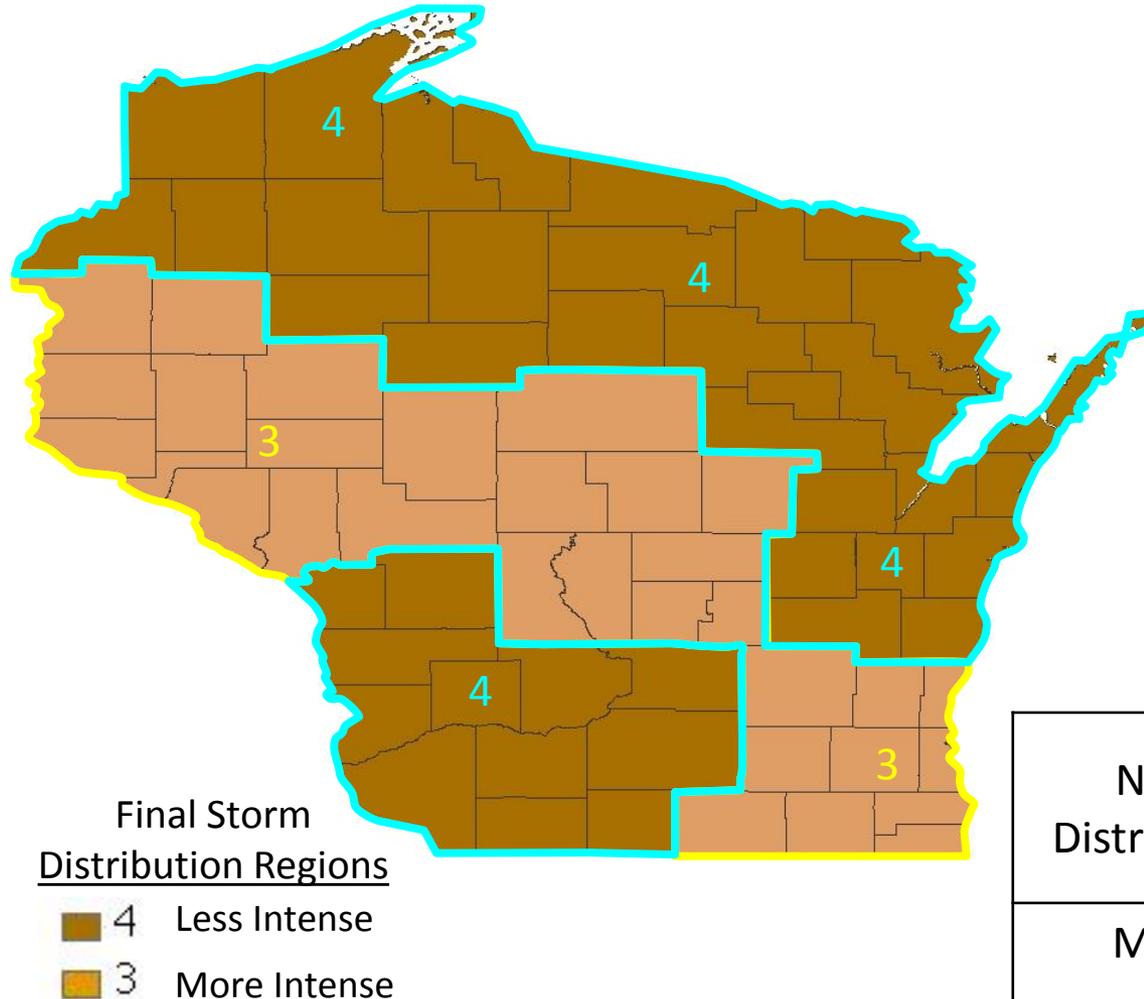
How will the New NRCS Storm Distributions Impact Computed Peak Discharge Values?





NRCS WQQT New Storm Distributions

Impact on Peak Discharge – Initial findings



NRCS Distribution	Change in Peak Discharge Versus for Type II Distribution
MSE3	~12% Increase



Proposed Temporal Storm Distributions

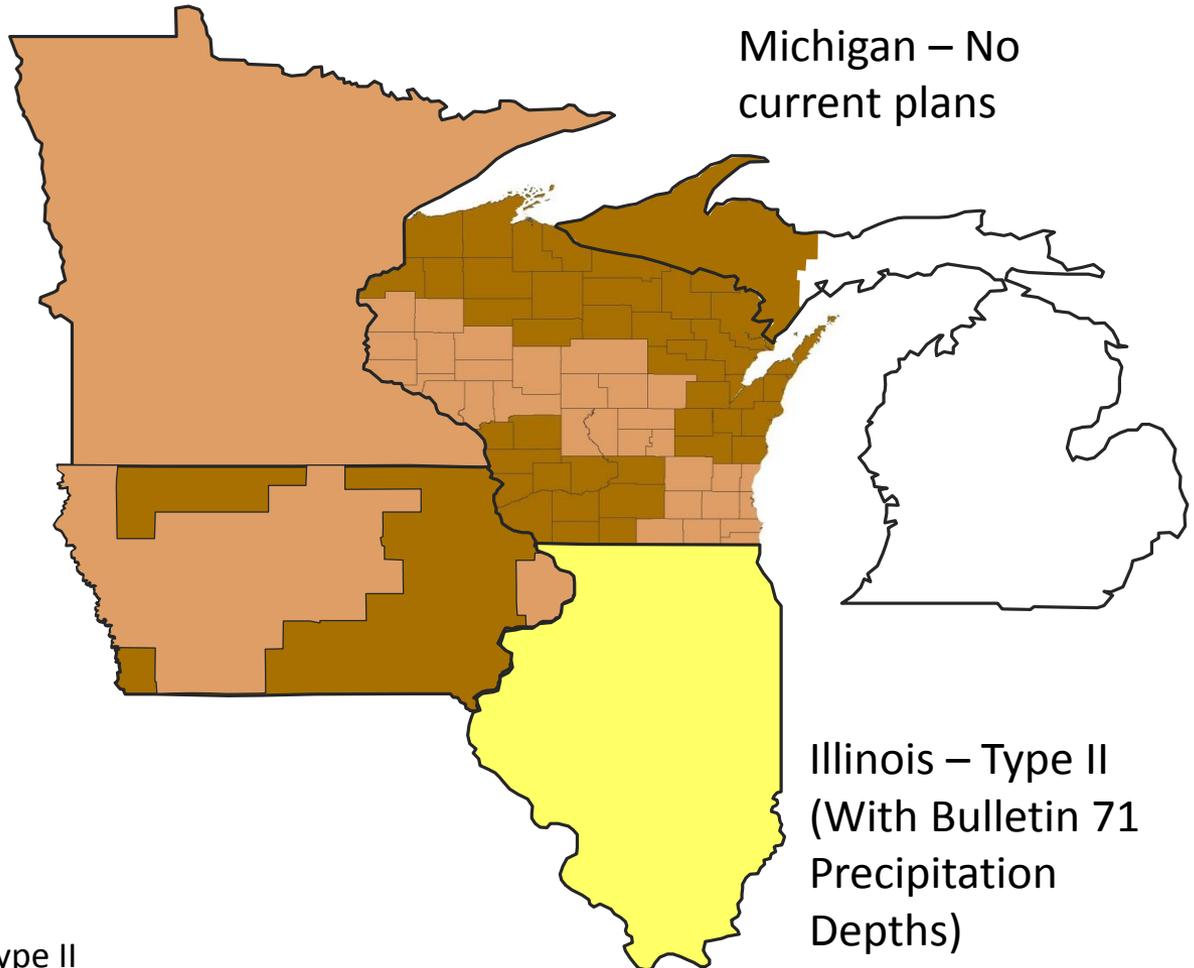
NRCS Plans in Neighboring States?

Minnesota tentatively plans to have All MSE3

Iowa – Currently on Hold, but eventually plans to have 2 Regions (MSE3 and MSE4)

Michigan – No current plans

Illinois – Type II (With Bulletin 71 Precipitation Depths)



Tentative Storm Distribution Regions

-  MSE3 (More Intense)
 -  MSE4
 -  MSE5 (Less Intense)
- ~Type II



Transitioning to Atlas 14 Data Use

- As of January 2015 NRCS WI Engineers are using NOAA Atlas 14 precipitation data for **all new projects**.
- NRCS Wisconsin Atlas 14 Data is available Online on the NRCS WI Hydrology Hydraulics Webpage:
 - Google “NRCS Wisconsin Hydrology Hydraulics”
 - Or <http://www.nrcs.usda.gov/wps/portal/nrcs/main/wi/technical/engineering/>



Transitioning to Atlas 14 Data Use

- The Following updates are available on the NRCS WI Hydrology Hydraulics Webpage:
 - Updated NRCS **WI** Hydrology (EFH2 and TR55) spreadsheets
 - **WI** Supplement to the NEH Part 650, Chapter 2 - information about the precipitation updates
 - New NRCS storm distribution data non-dimensional form (in spreadsheet) including applicable storm distribution to use by WI County
 - Additional NRCS WI Spreadsheets with updated precipitation data



Transitioning to Atlas 14 Data Use

- The Following updates are available on the NRCS WI Hydrology Hydraulics Webpage (Continued):
 - Wisconsin Precipitation and Soils Data files for the EFH2 (National NRCS Hydrology Program)
 - Coming Soon - Links to the **National** NRCS Hydrology Programs (EFH2, WinTR-55, WinTR-20?) with updated precipitation databases - When available, “**New**” will be included next to the link from the WI webpage



Temporal Distributions

- For studies to delineate regulatory floodplain limits, WDNR will accept peak flow determinations applying 1) the new NRCS distributions with Atlas 14 precipitation, or 2) critical duration analyses with Atlas 14 precipitation and:
 - The WDNR State distribution or
 - The SEWRPC 2005 distribution for the Southeastern Wisconsin Region
- WDNR will not accept Atlas 14 precipitation with the NRCS Type II distribution
- WDNR will no longer accept TP 40/NRCS Type II for studies initiated on March 1, 2015, or later, but they will accept that methodology for studies initiated before March 1, or study proposals submitted before March 1