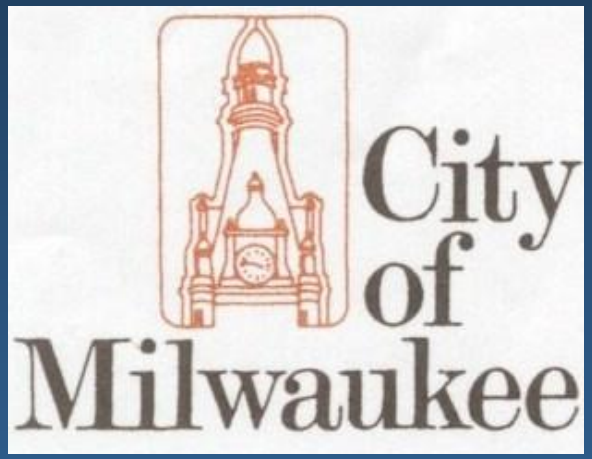
Climate Trends in Southeastern Wisconsin



Presentation to City of Milwaukee Flooding Study Task Force

January 6, 2011

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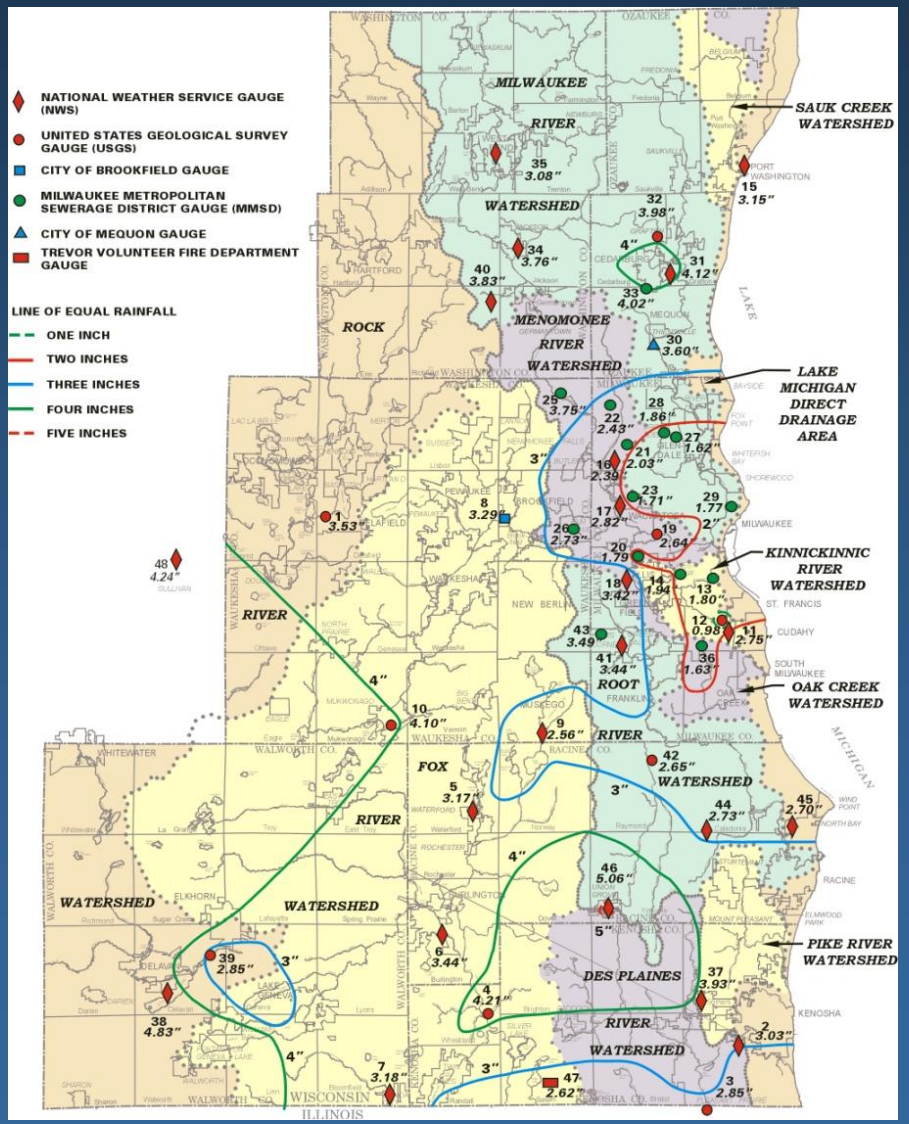
#155158

Rainfall Frequency in the Southeastern Wisconsin Region - Recent Extreme Storms

- August 6, 1986
- June 16-18, 1996 (Port Washington)
- June 20-21, 1997
- August 6, 1998
- May 2004 (3-day rainfalls shown)
- June 5 through 14, 2008
- June 19, 2009
- July 14 and July 22-23, 2010



Background on Rainfall and Flood Probabilities

- Traditionally referred to recurrence intervals (R.I.) (i.e., a 100-year recurrence interval rainfall or flood)
- Led to public confusion that such an event would only occur once every 100 years
- Probability of occurrence = (1/R.I.)*100
- Therefore, a 100-year event actually has a 1 percent probability of occurring or being exceeded in any given year, and a 50-year event has a 2-percent-annual-probability
- The lower the annual probability, the less likely that the event will occur

- Risk of rainfall events or floods occurring over a given period of time:
  - 100-year event over a 30-year period (common mortgage term) = 26 %
  - 10-year event over a 10-year period = 65 %
  - Five-year event over a 10-year period = 89 %

Background on Rainfall and Flood Probabilities

- Rainfall probability information is generally developed for a particular "point" location (e.g., a rain gauge)
  - The probability of occurrence of a rainfall of a given magnitude occurring over a larger area (e.g., a city or region) is greater than the probability of the same rainfall occurring at a specific point
- Rainfall probability information is developed for storms of specific durations
  - Thus, there are multiple rainfall depths with the same probability, with each depth corresponding to a duration of rain.
    - For example, in the Southeastern Wisconsin Region, the 100-year storm depth varies from 0.74 inches over a five-minute period to 7.46 inches over a 10-day period
  - Also, as an example, a rainfall of 3.64 inches over a two-hour period has a recurrence interval (R.I.) of 100 years, but the same rainfall over a 24-hour period has a R.I. of about ten years

The Concept of "Stationarity"

- A data set, such as observed rainfall depths or streamflows, is considered to be "stationary" if "it is free of trends, shifts, or periodicity (cyclicity)." (Source: David R. Maidment, *Handbook of Hydrology*, 1993)
- Under conditions where stationarity governs, a long-term data set representing past events can be used to develop rainfall frequency or flood frequency relationships that would be assumed to be valid in the future. This is the foundation of many hydrologic analyses.
- Examples of factors that can result in nonstationarity of rainfall data include influences on the 1) amount of rainfall, 2) single-storm and seasonal distribution of rainfall over time, and 3) possible effects from changes in land use over time. Thus, climate change may result in nonstationarity of rainfall over time, requiring new, or revised approaches to developing rainfall frequency estimates in the future.
- Examples of changes that can result in nonstationarity of streamflow data include changes in land use over time, changes in the stormwater management system, and changes in the stream system. These changes can be addressed through development of hydrologic models that "normalize" land use and system characteristics to represent a consistent existing or future condition.

Characterization of June 2008 Rainfalls in Southeastern Wisconsin

- Why are these rains of interest?
- What was unusual about these rains?
- What were the probabilities of occurrence of the rains?
- What were the effects of the rains?
- How do these rains compare with past severe storms?

Why are the 2008 rains of interest?

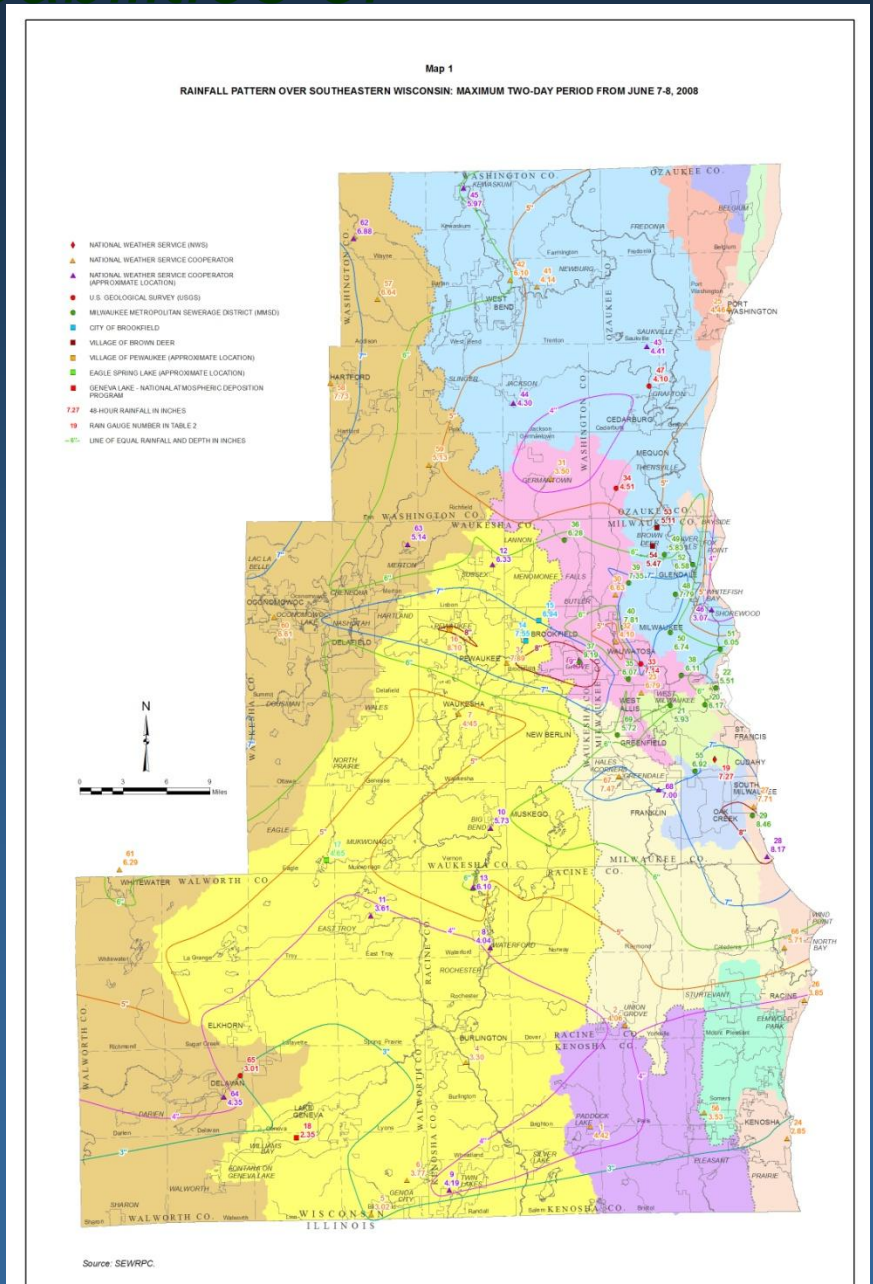
- They occurred over a 10-day period and included both relatively rare short-duration and long-duration rainfall depths.
- They caused sanitary sewer infiltration and inflow that contributed to widespread sewer overflows throughout southern Wisconsin.
- In some locations large floods occurred.
- In other locations flooding was limited

Kinnickinnic River at 9th Place and E. Cleveland Avenue, City of Milwaukee - June 7, 2008. Photo Source: MMSD

Edgerton Channel, E. Holmes Avenue, City of Cudahy - June 7, 2008. Photo Source: MMSD

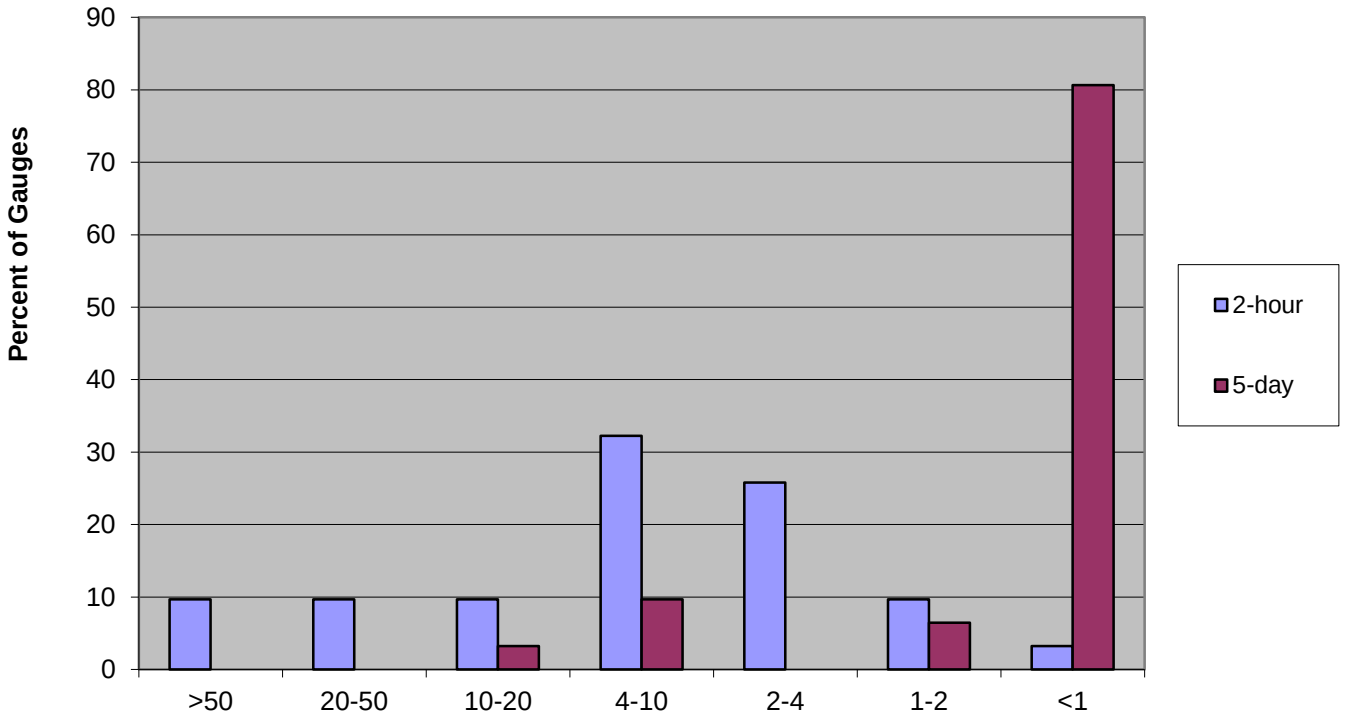
What were the probabilities of the 2008 rains?

- 31 gauges were analyzed
- Two-hour storms had probabilities of occurrence ranging from < 0.6 %, or 175 year recurrence interval, (Elm Grove) to > 50%, or less than two-year R.I., (Mequon, Cedarburg, Kenosha)
- 1-, 2-, 3-, 5-, and 10-day rains had lower probabilities
  - 1-day: Elm Grove, 7.52”, 0.3%, 355 years
  - 2-day: Elm Grove, 9.19”, <0.2%, >500 years
  - 3-day: MMSD South Shore WWTP, 9.41”, <0.2%, >500 years
  - 5-day: MMSD SS WWTP, 11.27”, <0.2%, >500 years
  - 10-day: Elm Grove, 13.05”, <0.2%, >500 years



What were the probabilities of the June 2008 rains?

June 2008 Rains: Ranges of Probability by Rainfall Duration



What were the effects of the June 2008 rains?

- **New "floods of record" (PRELIMINARY EVALUATION):**

  - **MILWAUKEE RIVER WATERSHED**
    - Milwaukee River near Cedarburg, 27-year record (Ozaukee County), **1%**
    - Lincoln Creek at Sherman Boulevard, 5-year record (Milwaukee County) **2 TO 10%**
  - **MENOMONEE RIVER WATERSHED**
    - Little Menomonee River at Milwaukee, 7-year record (Milwaukee County) **>10%**
    - Honey Creek at Wauwatosa 10-year record (Milwaukee County) **4 TO 10%**
  - **KINNICKINNIC RIVER WATERSHED**
    - Wilson Park Creek at St. Luke's Hospital, 11-year record (Milwaukee County) **2 TO 4%**
  - **OAK CREEK WATERSHED**
    - Oak Creek at South Milwaukee, 45-year record (Milwaukee County) **0.2 TO 1%**
  - **ROOT RIVER WATERSHED**
    - Root River at Franklin, 46-year record (Milwaukee County) **0.2 TO 1%**
    - Root River Canal at Raymond, 45-year record (Racine County) **1 TO 2 %**
    - Root River at Racine, 45-year record (Racine County) **<0.2 %**
  - **BARK RIVER WATERSHED**
    - Bark River at Nagawicka Road, 6-year record (Waukesha County)
    - Bark River near Rome, 25-year record (Jefferson County) **0.2 TO 1%**
  - **FOX RIVER WATERSHED**
    - Mukwonago River at Mukwonago, 35-year record (Waukesha County) **<0.2 %**

Characterization of July 2010 Rainfalls in Southeastern Wisconsin

- Why are these rains of interest?
- What was unusual about these rains?
- What were the probabilities of occurrence of the rains?
- What were the effects of the rains?
- How do these rains compare with past severe storms?

GARY PORTER / GPORTER@JOURNALSENTINEL.COM

Two homes in the 1900 block of W. Eggert Place are scheduled to be demolished after Thursday night's torrential rains destroyed portions of their foundations.

Streets are flooded at E. Edgewood and N. Oakland avenues. Heavy rains Thursday, including more than 7 inches on the northwest side, flooded basements and left traffic snarled.

Photo source: Milwaukee Journal Sentinel

Why are the 2010 rains of interest?

- They generally occurred on three days within a 10-day period and included both relatively rare short-duration and long-duration rainfall depths.
- They caused sanitary sewer infiltration and inflow that contributed to sewer overflows.
- In some locations, rains were so intense that they overwhelmed the capacity of the storm sewer system and caused flooding and damage in areas remote from streams
- In some locations large floods occurred.
- In other locations flooding was limited.

BRAD VEST / BVEST@JOURNALSENTINEL.COM

Melissa Schwartz, who was stranded on N. Bartlett Ave. near E. Locust St. on Milwaukee's east side, calls for help Thursday on her cellphone.

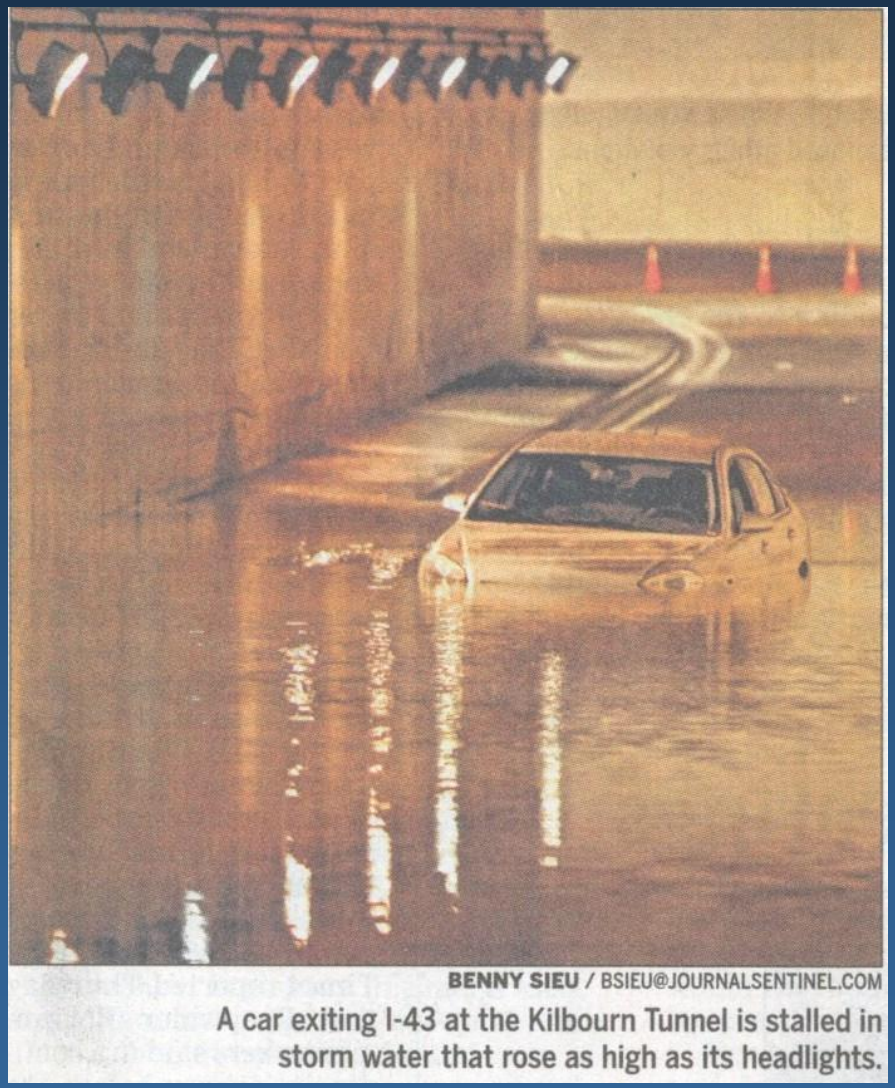
BRAD VEST / BVEST@JOURNALSENTINEL.COM

Rushing storm water pushes away sewer covers near E. Locust St. and N. Bartlett Ave.

Photo source:
Milwaukee Journal Sentinel

What were the probabilities of the 2010 rains?

- To date, data from 38 gauges have been analyzed
- Two-hour storms had probabilities of occurrence ranging from < 0.2 %, or >500-year recurrence interval, (Milwaukee, 5335 N. Teutonia) to > 50%, or less than two-year R.I., (Cedarburg, Kenosha)
- 1-, 2-, and 10-day rains had lower probabilities
  - 1-day: Milwaukee, 3626 W. Fond du Lac, 7.98”, ~0.2%, ~500 years
  - 2-day: Milwaukee, 3626 W. Fond du Lac, 8.98”, <0.2%, >500 years
  - 10-day: Milwaukee, 3626 W. Fond du Lac, 14.62”, <0.2%, >500 years



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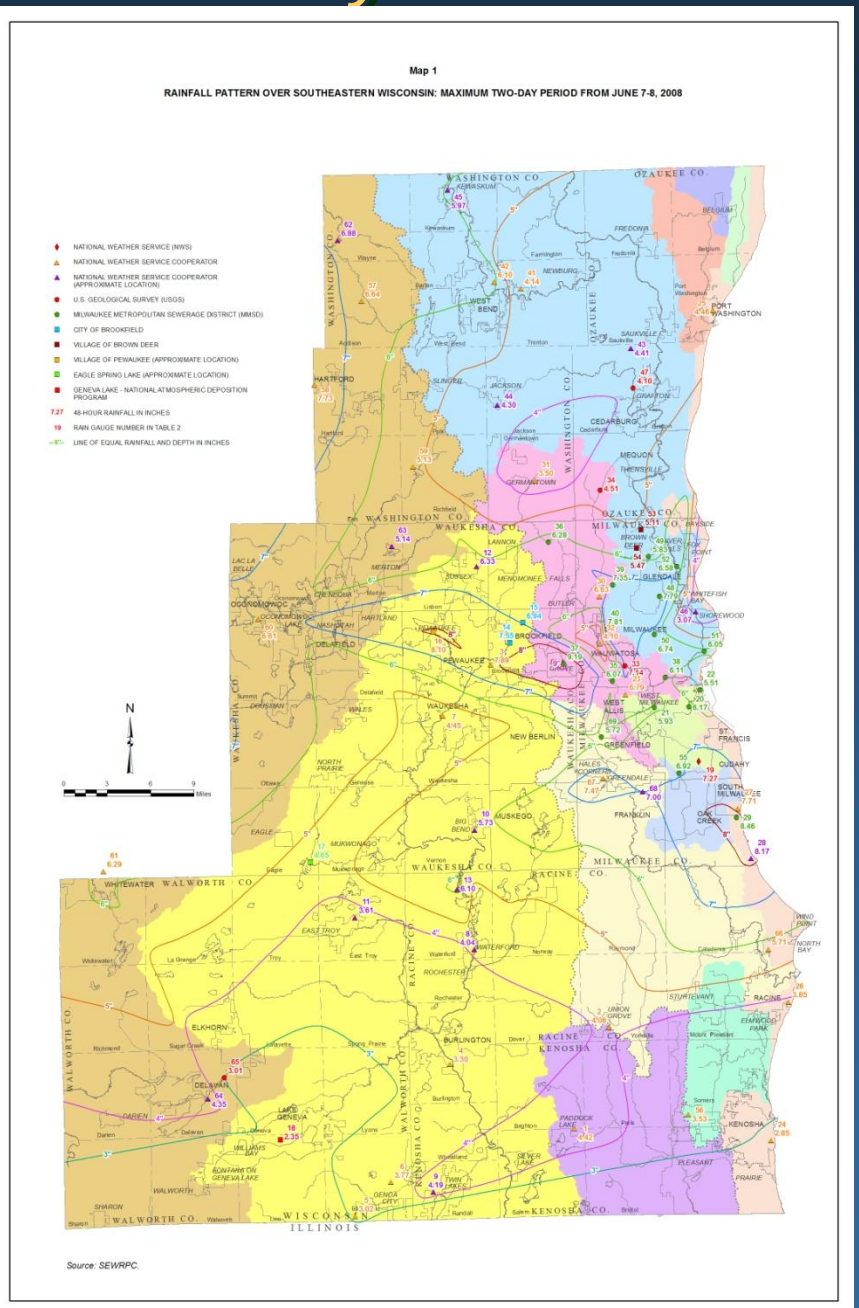
A car exiting I-43 at the Kilbourn Tunnel is stalled in storm water that rose as high as its headlights.

Photo source: Milwaukee Journal Sentinel

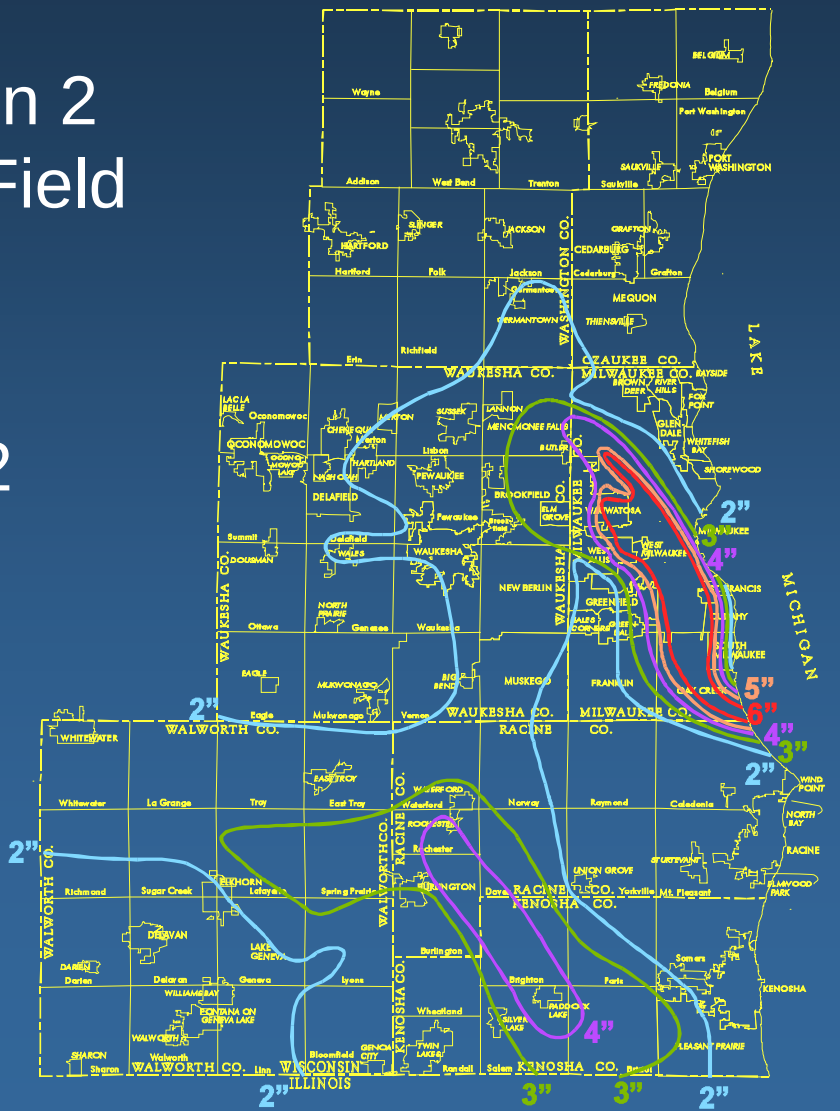
What were the effects of the July 2010 rains?

- **New "floods of record" (PRELIMINARY EVALUATION):**
  - **MILWAUKEE RIVER WATERSHED**
    - Milwaukee River at Estabrook Dam, 96 years of record, ~18,800 cfs, 0.2% probability
    - Lincoln Creek at Sherman Boulevard, 7 years of record, 9,700 cfs, <0.2% probability
  - **MENOMONEE RIVER WATERSHED**
    - Little Menomonee River at Appleton Avenue, 9 years of record, 2,000cfs, 1 to 2% probability
  - **OAK CREEK WATERSHED**
    - Oak Creek at South Milwaukee, 47 years of record, 2,590 cfs, 0.2% probability
- **Kinnickinnic River watershed streams, Menomonee River main stem, Root River main stem: >1% probability**



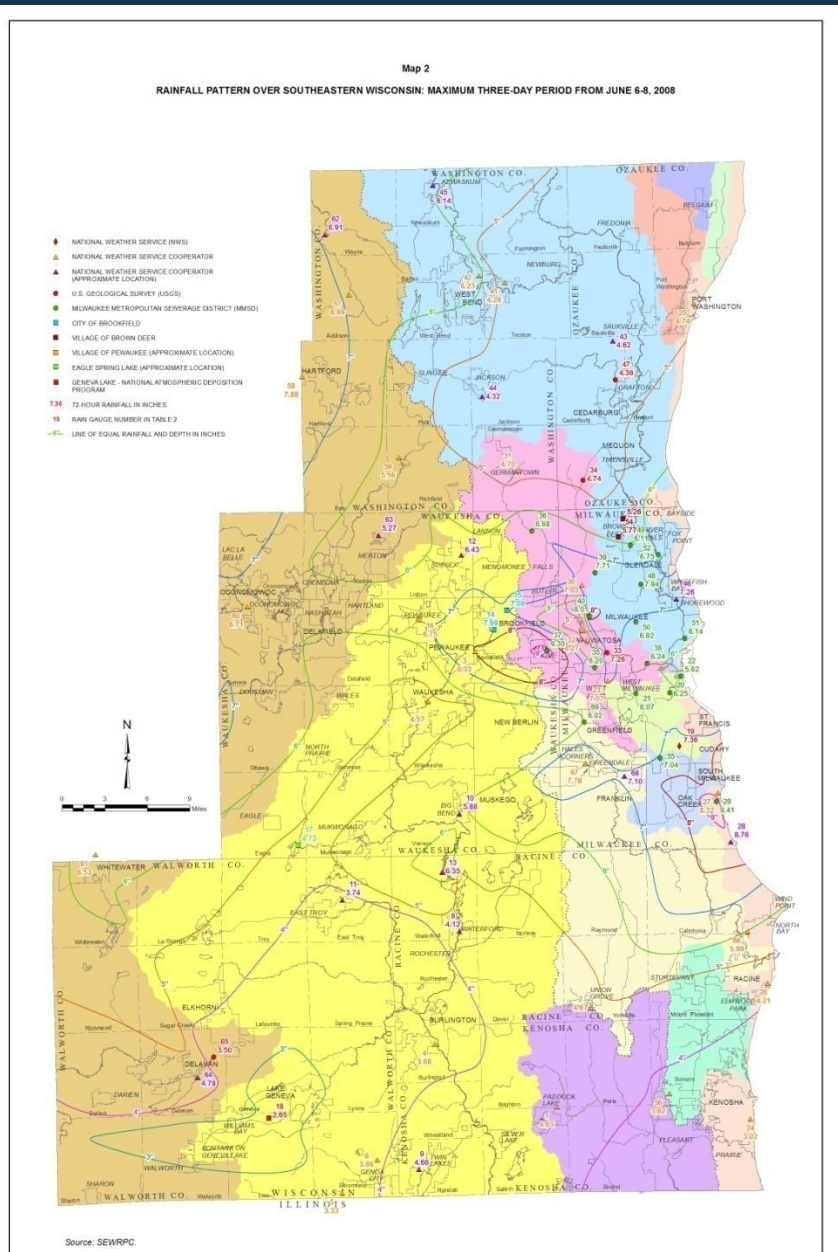
How do the 2008 and 2010 rains compare with past severe storms?

- August 6, 1986: 5.24 inches in 2 hours at Milwaukee Mitchell Field (0.14 %)
- June 7 2008: 4.05 inches in 2 hours at Elm Grove (0.6%)
- July 2010 5.72” in 2 hours at 5335 N. Teutonia, Milwaukee (0.09%)



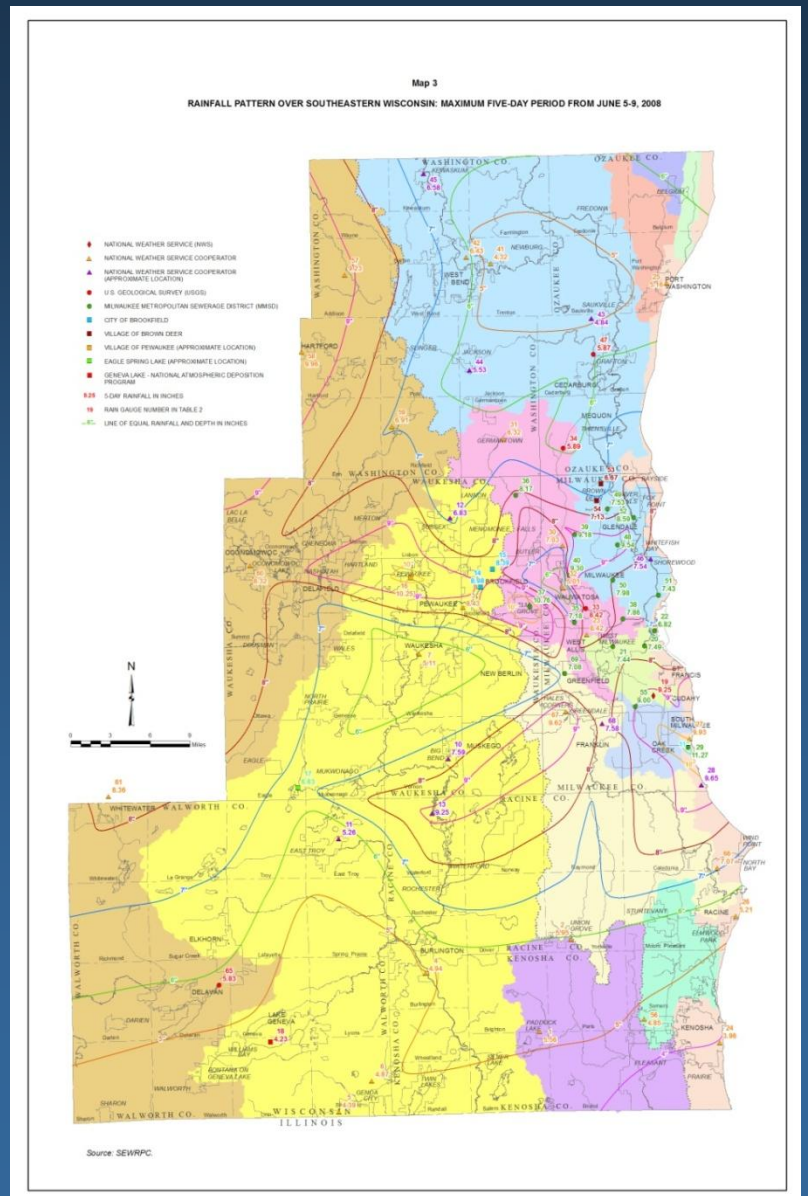
How do the 2008 and 2010 rains compare with past severe storms?

- June 16-18, 1996
  - 9.87” in 24 hours at Port Washington (0.06%)
- June 20-21, 1997
  - 7.44 inches in 24-hours at 2647 N. Bartlett Ave., City of Milwaukee (0.30%)
- August 6, 1998
  - 8.30 inches in 24-hours at Village of Elm Grove (0.17%)
- June 2008
  - 7.52 inches in 24 hours at Elm Grove (0.28%)
- July 2010
  - 7.98 inches in 24 hours at 3626 W. Fond du Lac, Milwaukee (0.21%)



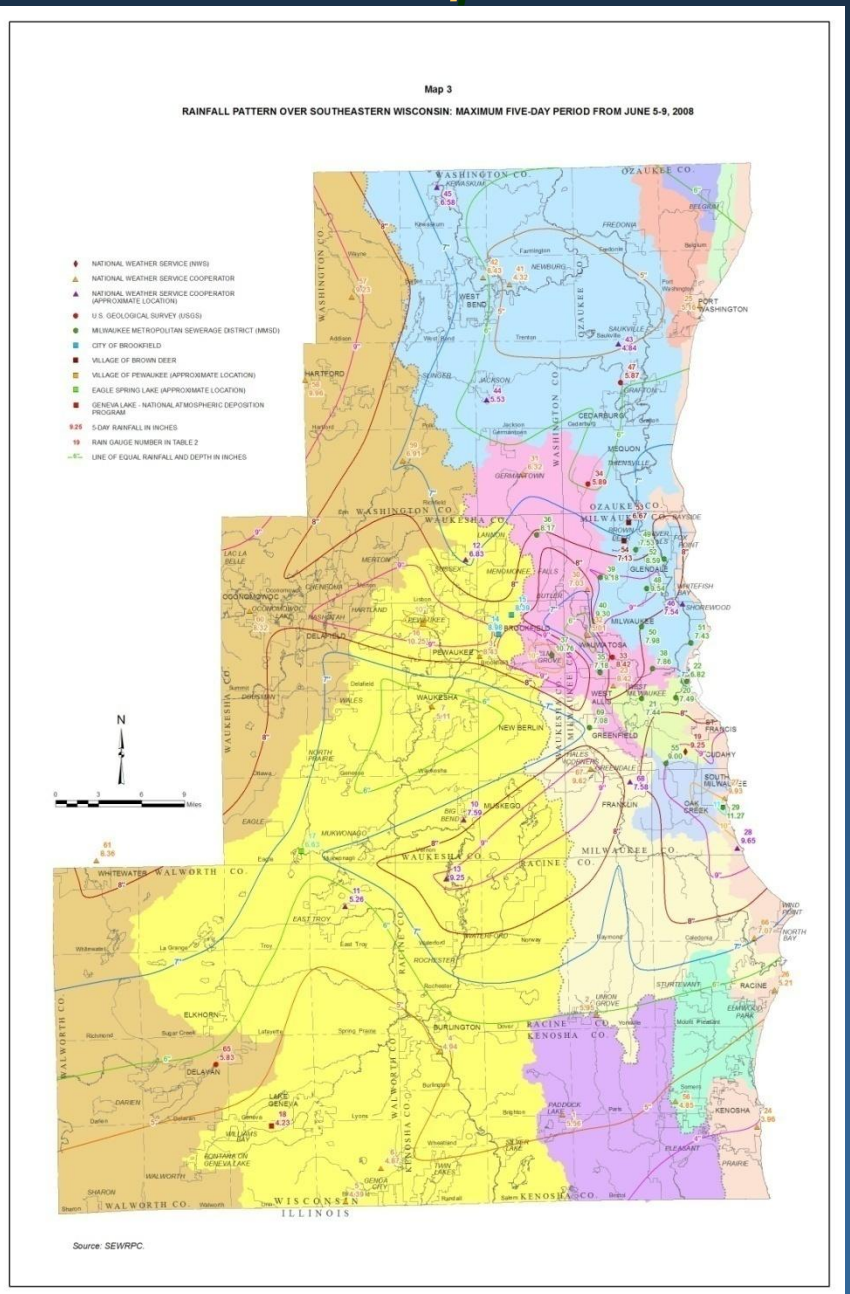
How do the 2008 and 2010 rains compare with past severe storms?

- August 3-6, 1924
  - 9.3” in 4 days at West Bend (<0.2%)
- June 16-18, 1996
  - 13.52” in 3 days at Port Washington (<0.2%)
- May 2004
  - 5.58” in 3 days at Kenosha Airport (2%)
  - 5.7” in 5 days at Kenosha Airport (2 to 4 %)
- June 2008
  - 9.41” in 3 days at MMSD SSWWTP (<0.2%)
  - 11.27” in 5 days at MMSD SSWWTP (<0.2%)
- July 2010 (Preliminary)
  - 8.98” in 3 days at 3626 W. Fond du Lac, Milwaukee (<0.2%)
  - 8.98” in 5 days at 3626 W. Fond du Lac, Milwaukee



How do the 2008 and 2010 rains compare with past severe storms?

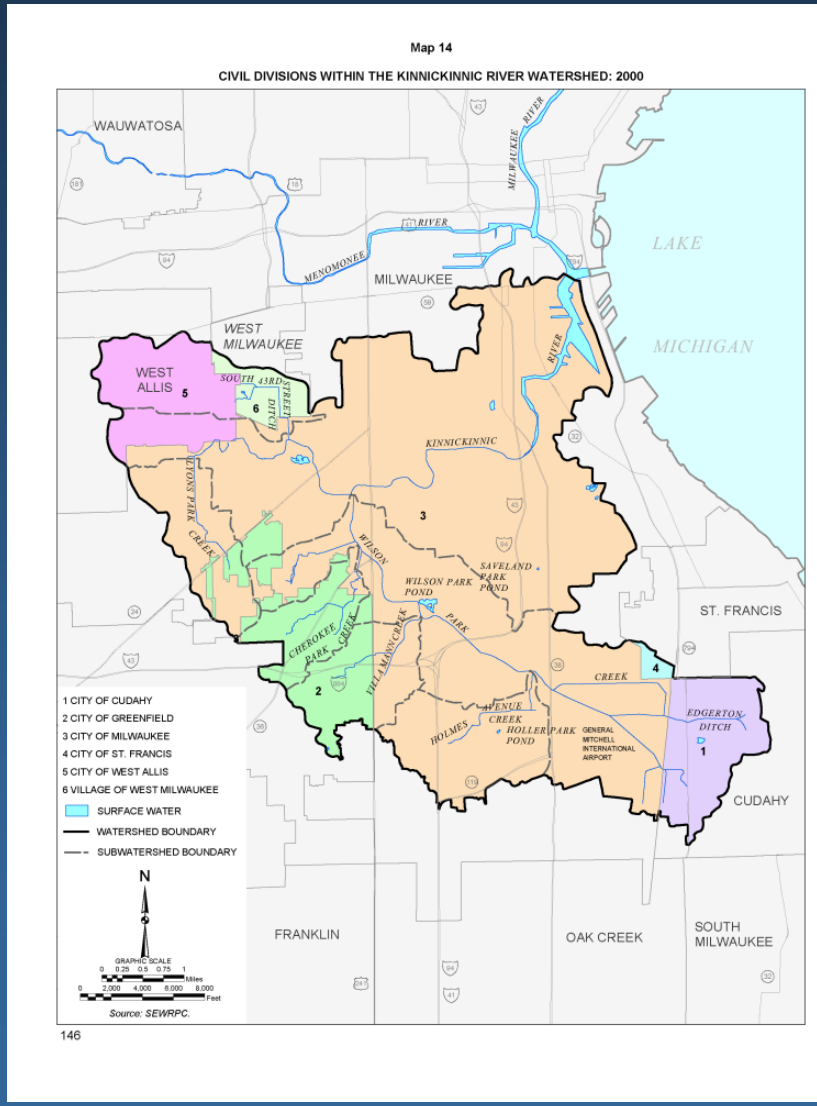
- May 2004
  - ~8.3 inches in 10 days at Union Grove (slightly <1%)
- June 2008
  - 15.35 inches in 10 days at Pewaukee (<0.2%)
- July 2010
  - 14.62 inches in 10 days at 3626 W. Fond du Lac, Milwaukee (<0.2%)



Frequency of Occurrence of Large Floods

- Kinnickinnic River (34 years of record)
  1. 8/6/1986: 10,600 cfs
  2. 6/7/2008: 6,490 cfs
  3. 7/9/2006: 6,260 cfs
  4. 7/2/2000: 6,170 cfs
  5. 7/22/2010: 6,120 cfs
  6. 7/19/2009: 5,390 cfs
  7. 7/21/1999: 4,980 cfs
  8. 7/14/1994: 4,720 cfs
  9. 7/4/2004: 4,600 cfs
  10. 6/21/1997: 4,420 cfs

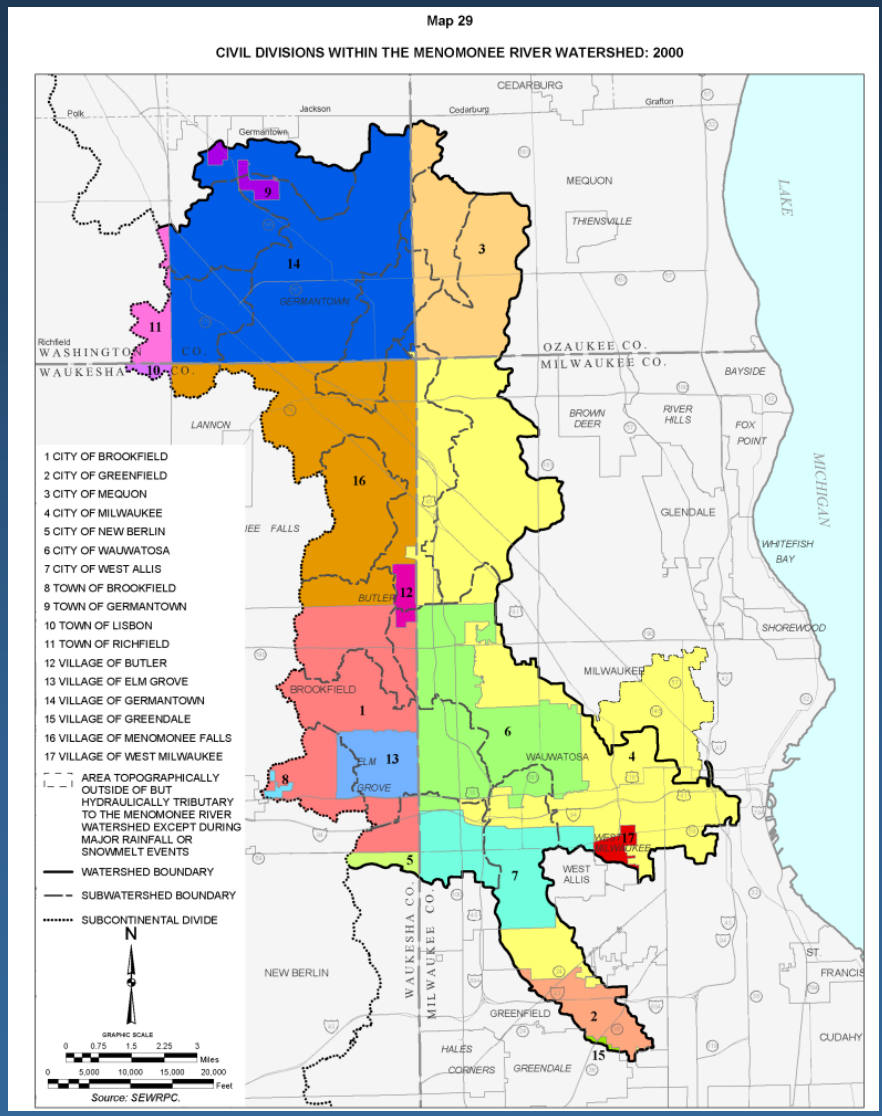
Source: USGS and SEWRPC



Frequency of Occurrence of Large Floods

- Menomonee River (49 years of record)
  1. 4/21/1973: 13,500 cfs
  2. 6/21/1997: 13,500 cfs
  3. 8/6/1998: 12,800 cfs
  4. 6/7/2008: 12,400 cfs
  5. 6/19/2009: 11,800 cfs
  6. 7/22/2010: 10,700 cfs
  7. 8/6/1986: 10,600 cfs
  8. 8/17/1983: 7,560 cfs
  9. 9/18/1972: 6,610 cfs
  10. 7/21/1999: 6,280 cfs

Source: USGS and SEWRPC

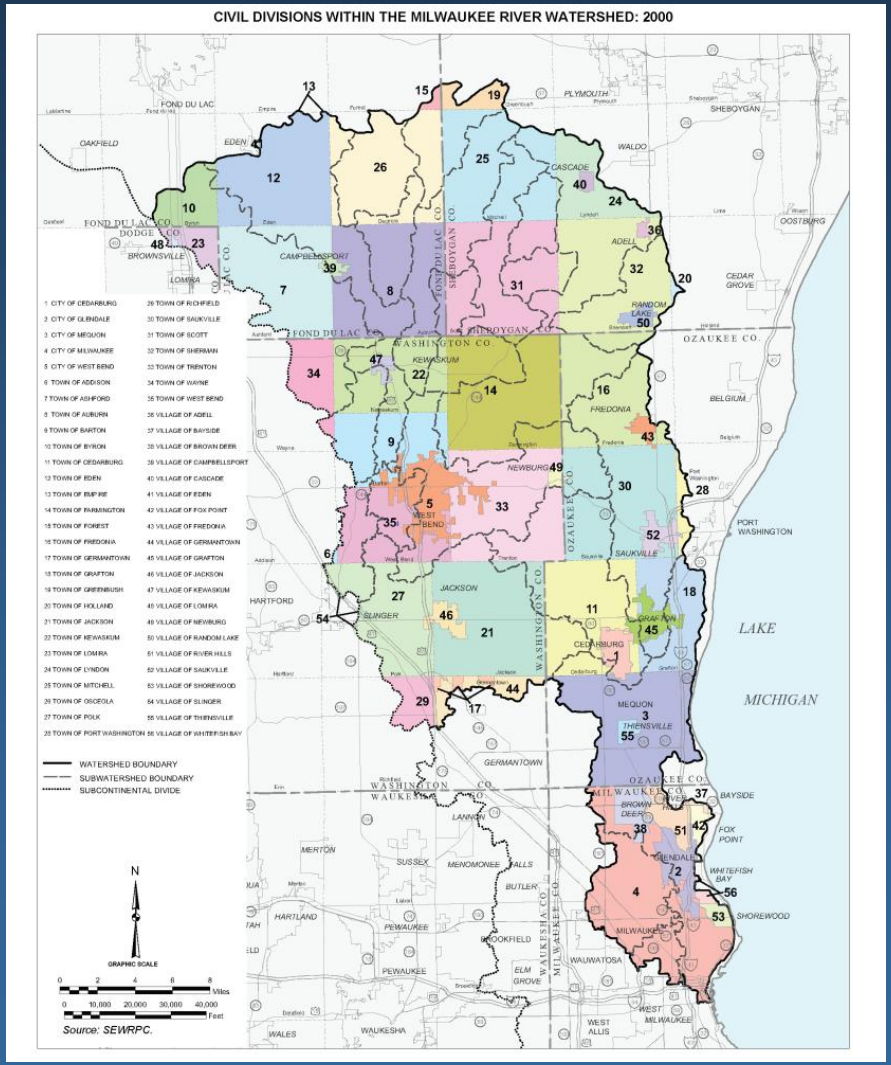


Frequency of Occurrence of Large Floods

- Milwaukee River
  (96 years of record)

1. 7/22/2010: ~18,800 cfs
2. 7/21/1997: 16,500 cfs
3. 3/20/1918: 15,100 cfs
4. 8/6/1924: 15,100 cfs
5. 4/21/1973: 12,600 cfs
6. 3/15/1929: 11,000 cfs
7. 6/7/2008: 10,400 cfs
8. 3/31/1960: 9,300 cfs
9. 4/3/1959: 8,780 cfs
10. 8/6/1998: 8,600 cfs

Source: USGS and SEWRPC

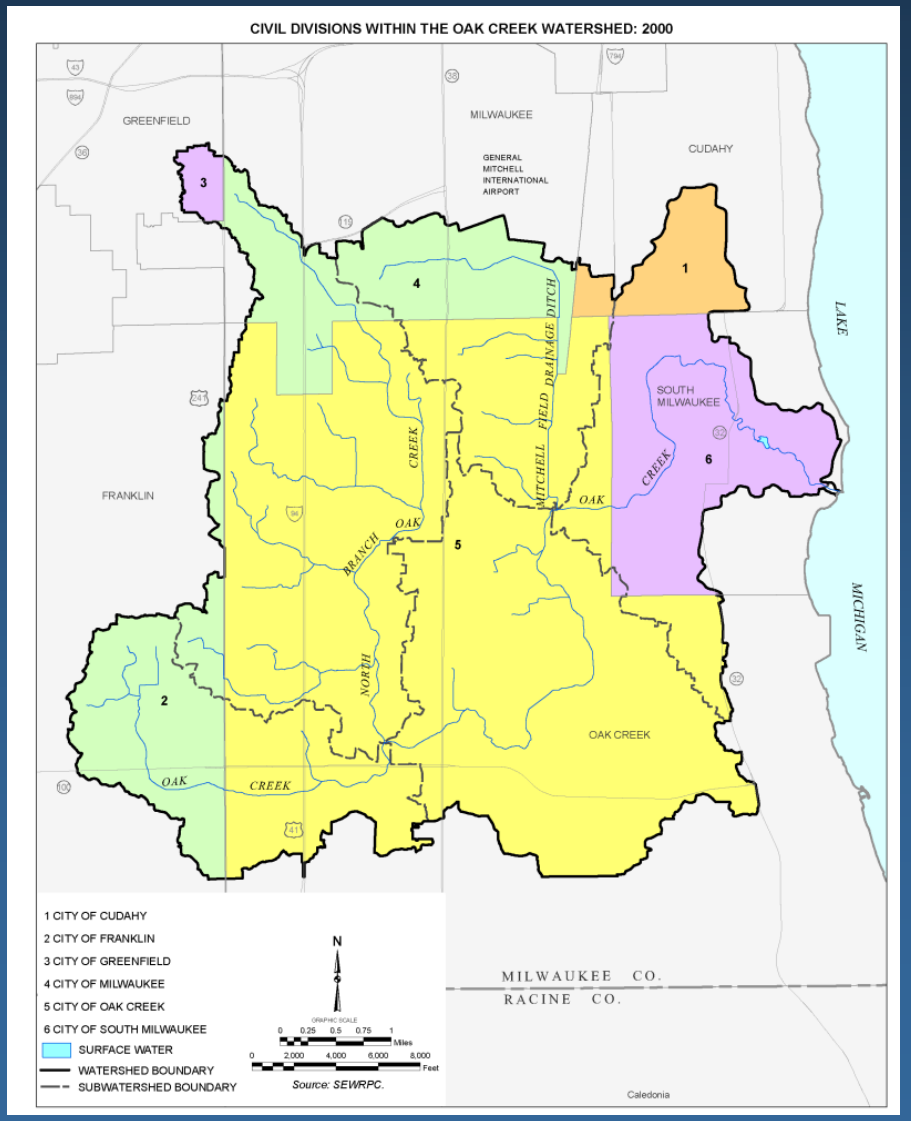


Frequency of Occurrence of Large Floods

- Oak Creek (47 years of record)

1. 7/22/2010: 2,590 cfs
2. 6/7/2008: 2,370 cfs
3. 8/6/1986: 1,140 cfs
4. 7/2/2000: 1,120 cfs
5. 6/21/1997: 1,110 cfs
6. 4/23/1999: 1,060 cfs
7. 9/13/1978: 1,020 cfs
8. 3/4/1976: 935 cfs
9. 9/18/1972: 916 cfs
10. 4/19/1993: 887 cfs

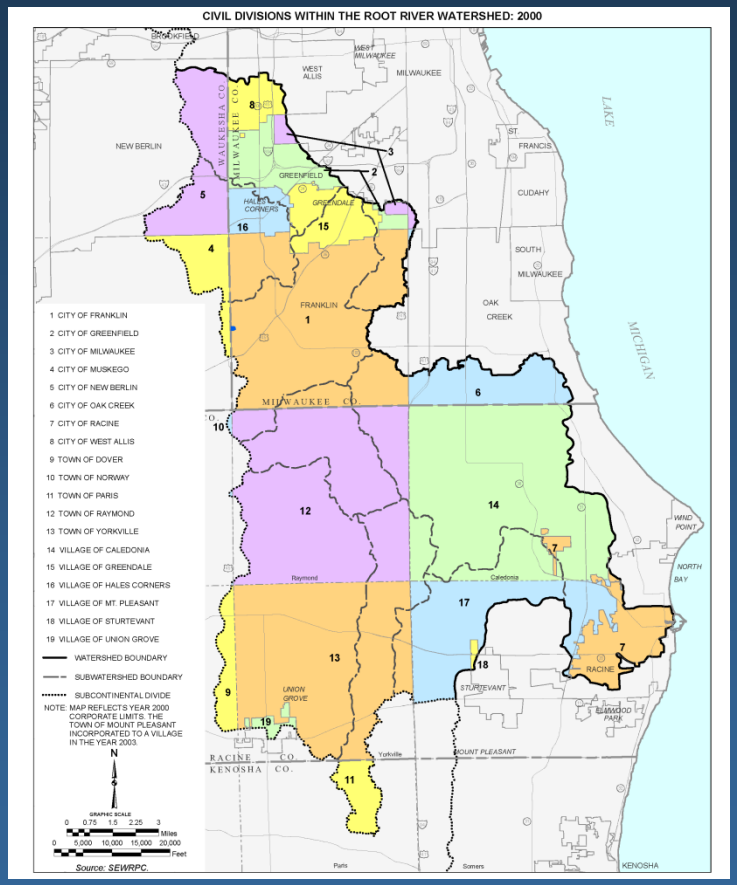
Source: USGS and SEWRPC



Frequency of Occurrence of Large Floods

- Root River (48 years of record)

1. 6/8/2008: 5,350 cfs
2. 3/30/1960: 5,130 cfs
3. 4/21/1973: 3,700 cfs
4. 7/23/2010: 3,440 cfs
5. 6/30/1969: 2,650 cfs
6. 7/3/2000: 2,420 cfs
7. 9/18/1972: 2,270 cfs
8. 6/20/2009: 2,260 cfs
9. 3/5/1976: 2,160 cfs
10. 6/13/1999: 2,050 cfs



Source: USGS and SEWRPC

Sources of Rainfall Frequency Estimates

- 2000: SEWRPC Technical Report No. 40, *Rainfall Frequency in Southeastern Wisconsin*, 2000
  - Prepared by CDM in cooperation with UW-Madison
  - Based on Milwaukee rainfall data for the 108-year period from 1891 to 1998
  - Updated a 1990 SEWRPC study using Milwaukee data for the 84-year period from 1903 through 1986
  - Used by municipalities and consultants in the Region

Sources of Rainfall Frequency Estimates

- 2012: NOAA Atlas 14 for Midwestern States
  - Updates U.S. Weather Bureau Technical Paper No. 40, that was issued in 1960
  - Funding for Wisconsin portion of the study provided by WisDOT, WDNR, and SEWRPC
  - Will utilize rainfall data through 2009
  - Using MMSD/City of Milwaukee rain gauge data as one source of information

Recommended Rainfall Depths for Southeastern Wisconsin Intensity-Duration-Frequency Curves