



CITY OF  
**EAU  
CLAIRE**

# AQUIFER PRODUCTIVITY AND SUSTAINABLE USE

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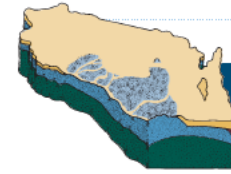
Work Session  
June 7, 2022



**GANNETT FLEMING**

## 4 Aquifers - Statewide

- Sand and Gravel
- Eastern Dolomite
- Sandstone and Dolomite
- Crystalline Bedrock
- Eau Claire is underlain by 3 of the 4
  - Sand and Gravel – very productive
  - Sandstone – moderate productivity
  - Crystalline – infrequently tapped locally



## Wisconsin's aquifers

### Sand and gravel aquifer

The sand and gravel aquifer is the surface material covering most of the state except for parts of southwest Wisconsin. It is made up mostly of sand and gravel deposited from glacial ice or in river floodplains. The glacial deposits are loose, so they're often referred to as soil — but they include much more than just a few feet of topsoil. These deposits are more than 300 feet thick in some

places in Wisconsin.

The glaciers, formed by the continuous accumulation of snow, played an interesting role in Wisconsin's geology. The snow turned into ice, which reached a maximum thickness of almost two miles. The ice sheet spread over Canada, and part of it flowed in a general southerly direction toward Wisconsin and neighboring states. This ice sheet transported a great amount of rock debris, called **glacial drift**.



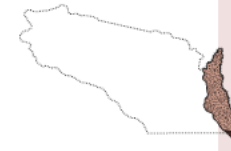
### Eastern dolomite aquifer

The eastern dolomite aquifer occurs in eastern Wisconsin from Door County to the Wisconsin-Illinois border. It consists of Niagara dolomite underlain by Maquoketa shale.

These rock formations were deposited 400 to 425 million years ago. Dolomite is a rock similar to limestone; it holds

groundwater in interconnected cracks and pores. The water yield from a **well** in this aquifer mostly depends on the number of fractures the well intercepts. As a result, it's not unusual for nearby wells to vary greatly in the amount of water they can draw from this layer.

Groundwater in shallow portions of the eastern dolomite aquifer can easily become contaminated in places where



### Sandstone and dolomite aquifer

The sandstone and dolomite aquifer consists of layers of sandstone and dolomite bedrock that vary greatly in their water-yielding properties. In dolomite, groundwater mainly occurs in fractures. In sandstone, water occurs in pore spaces between loosely cemented

sand grains. These formations can be found over the entire state, except in the north central portion.

In eastern Wisconsin, this aquifer lies below the eastern dolomite aquifer and the Maquoketa shale layer. In other areas, it lies beneath the sand and gravel aquifer. These rock types gently dip



### Crystalline bedrock aquifer

The crystalline bedrock aquifer is composed of various rock types formed during the Precambrian Era, which lasted from the time the Earth cooled more than 4,000 million years ago, until about 600 million years ago, when the rocks in the sandstone and dolomite aquifer began to be formed. During this lengthy period, sediments, some of which were rich in

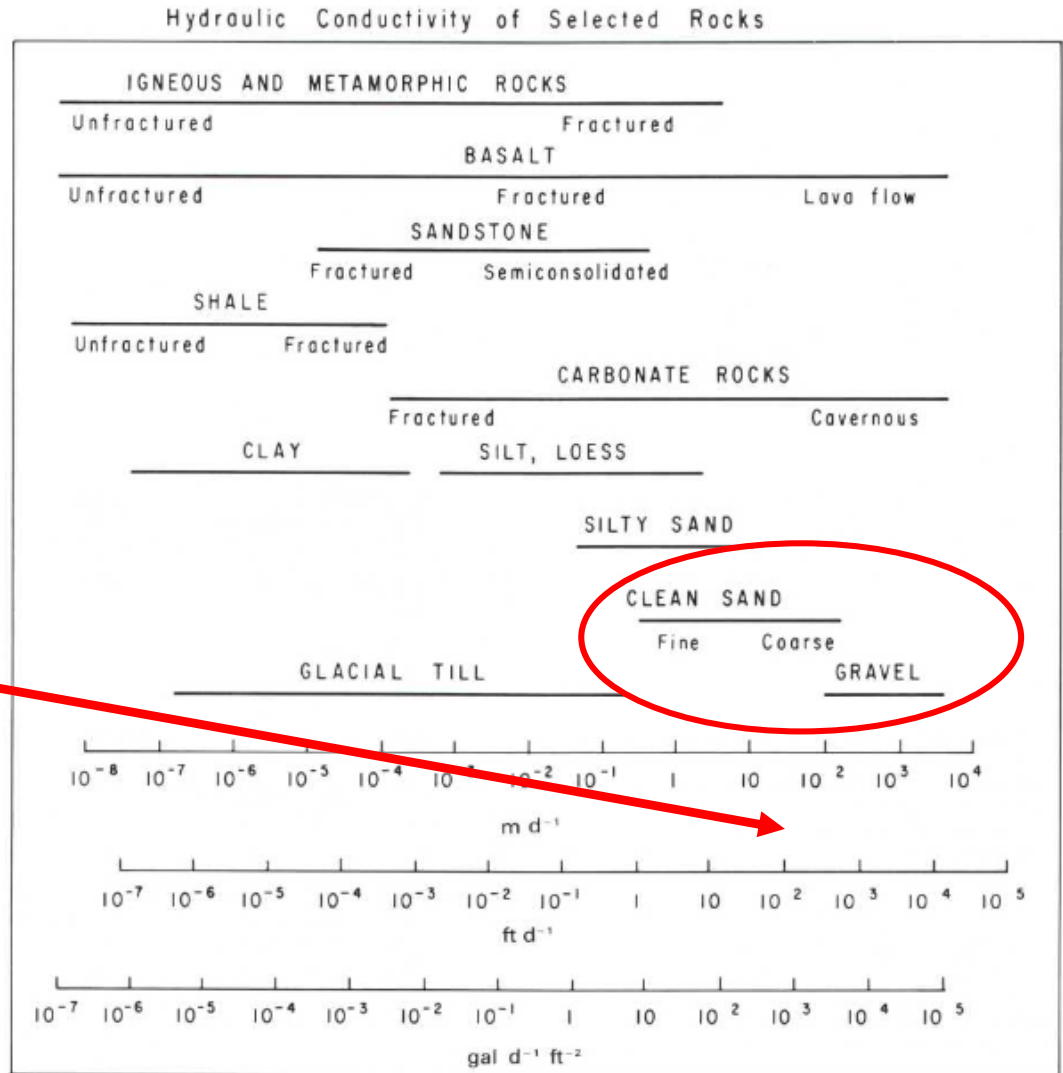


# Glacial Outwash, Sand and Gravel Aquifer at Eau Claire

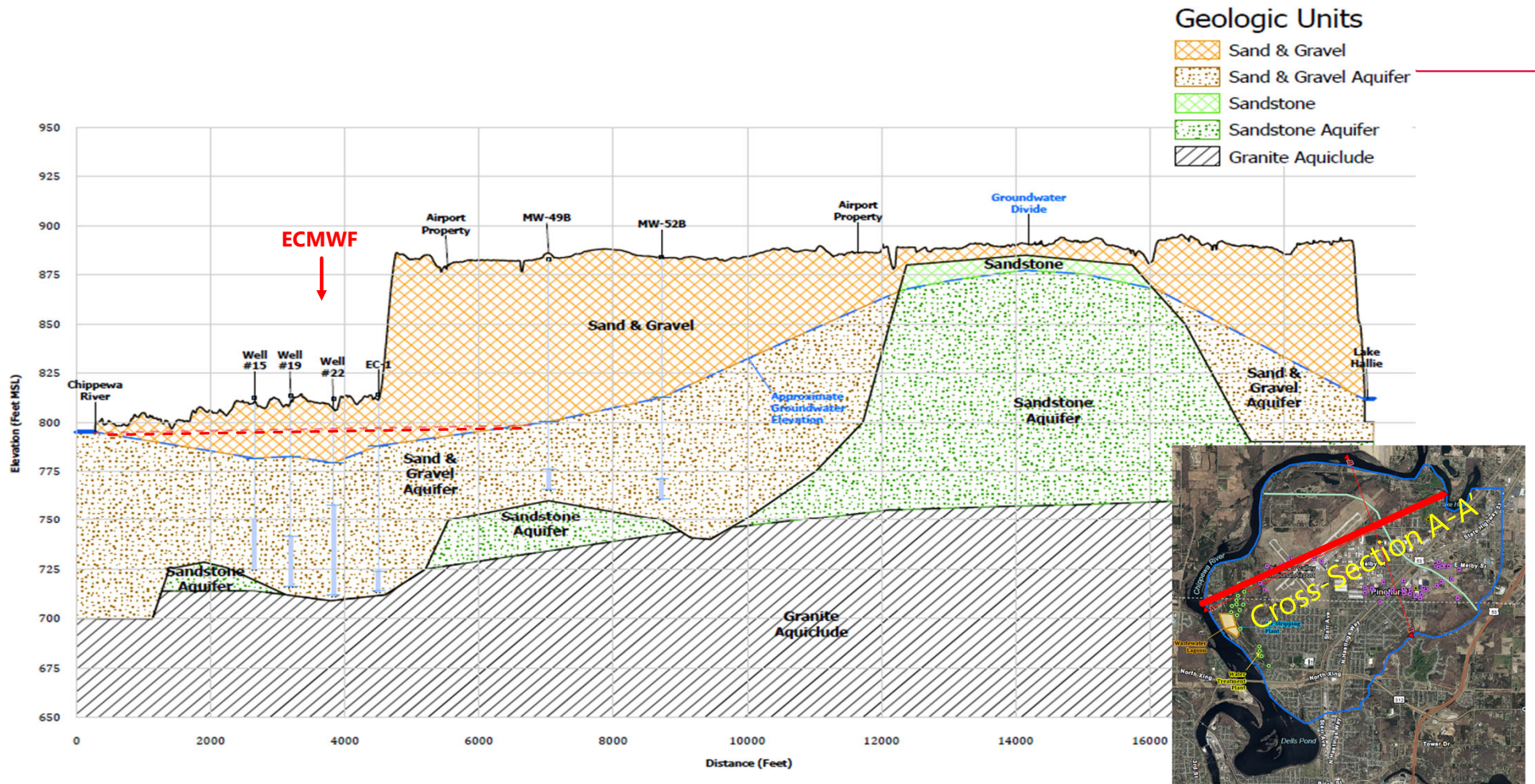


# High Hydraulic Conductivity

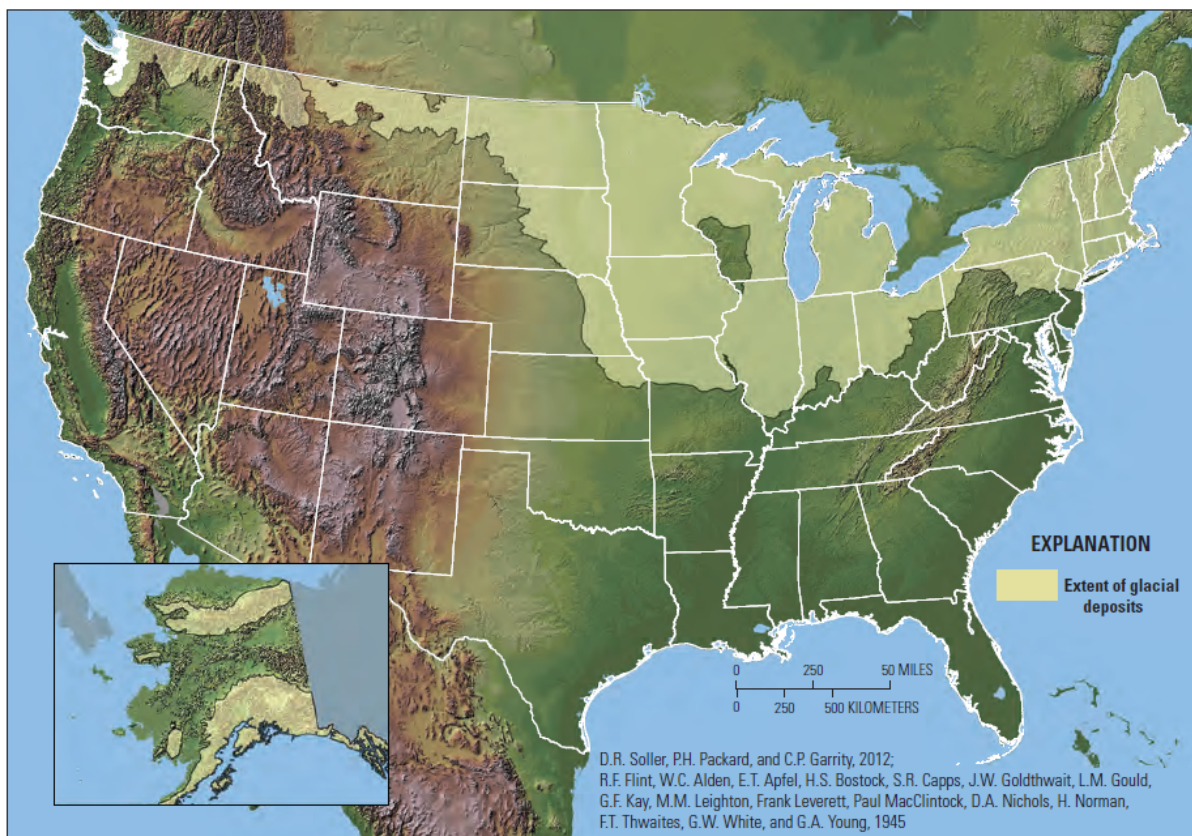
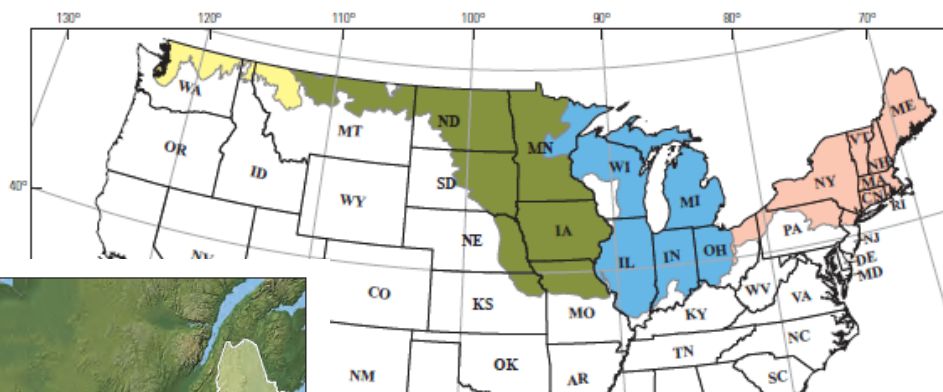
Eau Claire Sand and Gravel Aquifer



# Cross-Section A – A', Looking Northwest, (Vertically Exaggerated)



# Extent of Glacial Deposits Northern Tier of the US



**USGS**  
science for a changing world

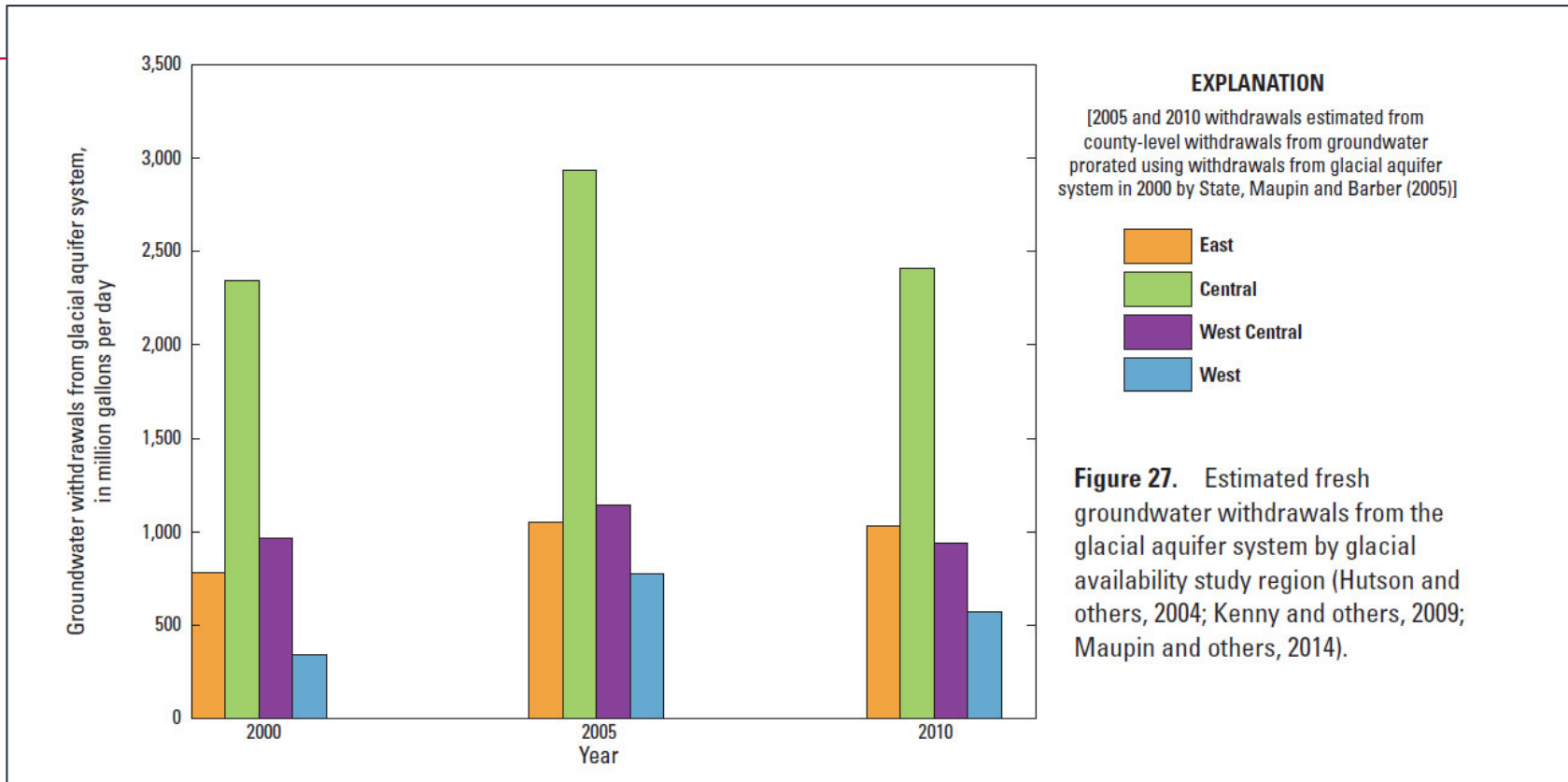
Water Availability and Use Science Program

**Generalized Hydrogeologic Framework and Groundwater Budget for a Groundwater Availability Study for the Glacial Aquifer System of the United States**

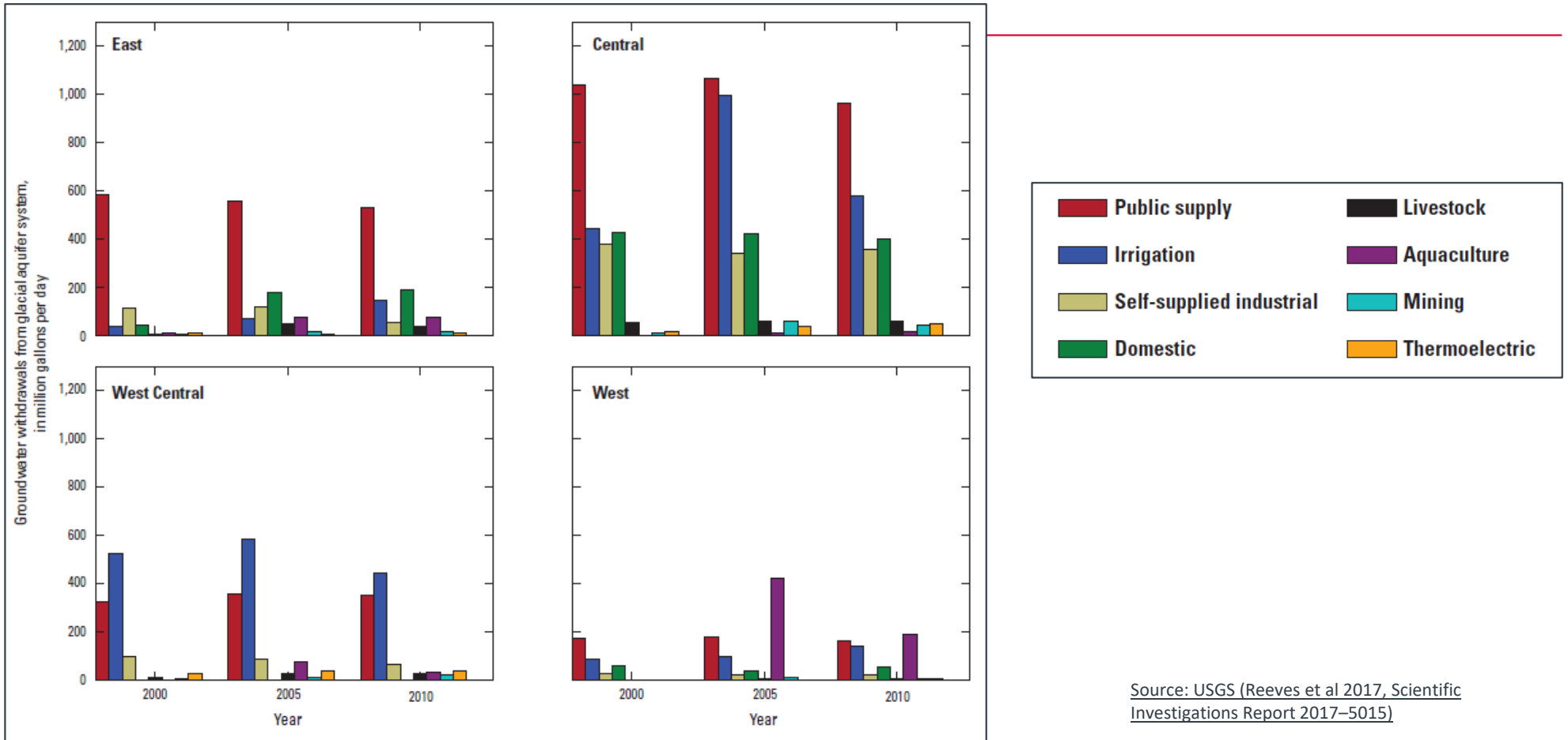
Scientific Investigations Report 2017–5015

U.S. Department of the Interior  
U.S. Geological Survey

# Central Region Glacial Aquifers are – *Highly Productive*



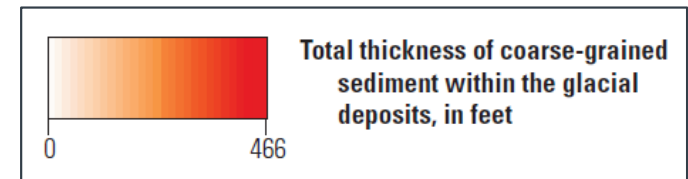
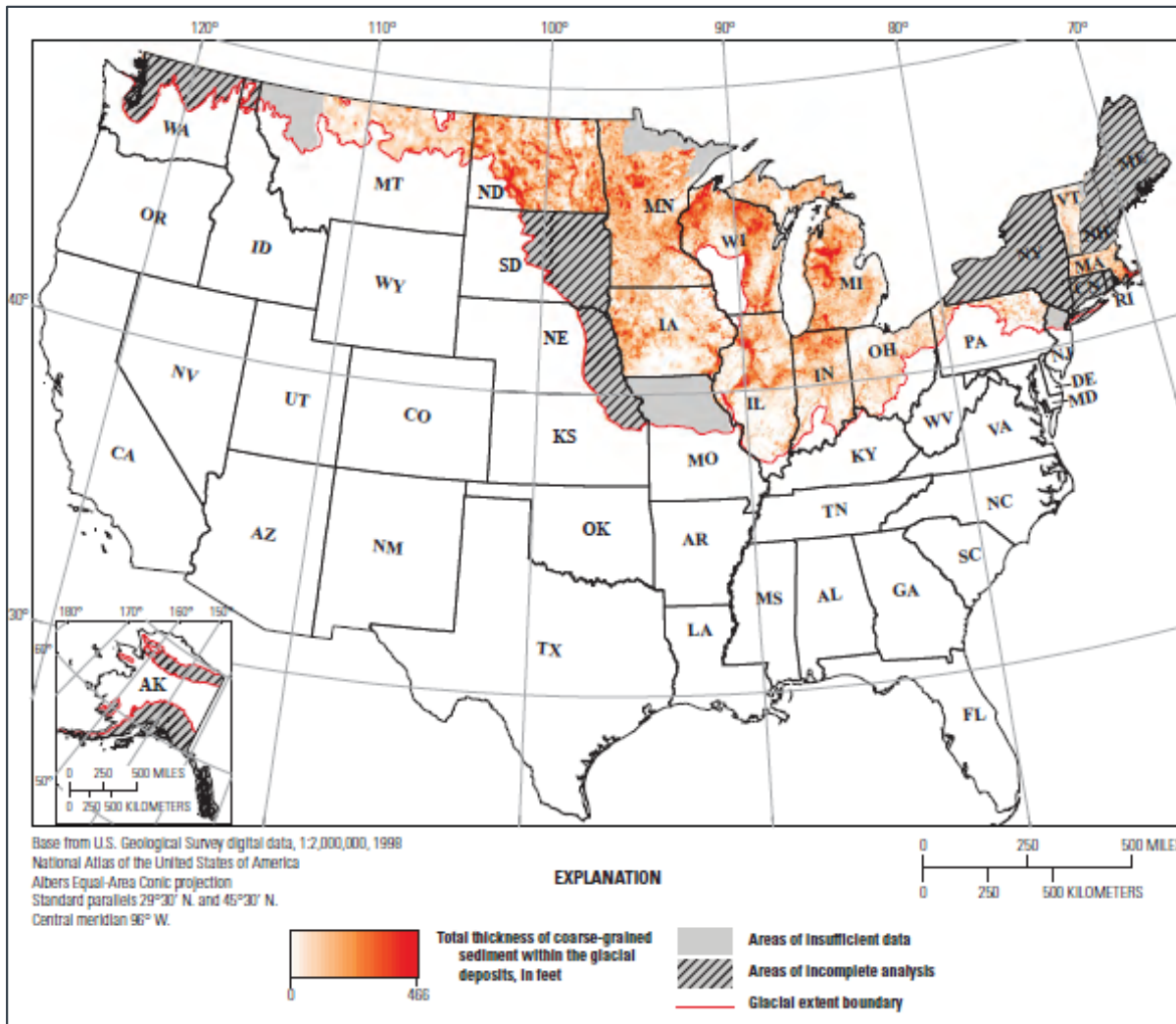
# Central Region Glacial Aquifer is – *Highly Productive & Economic Driver*



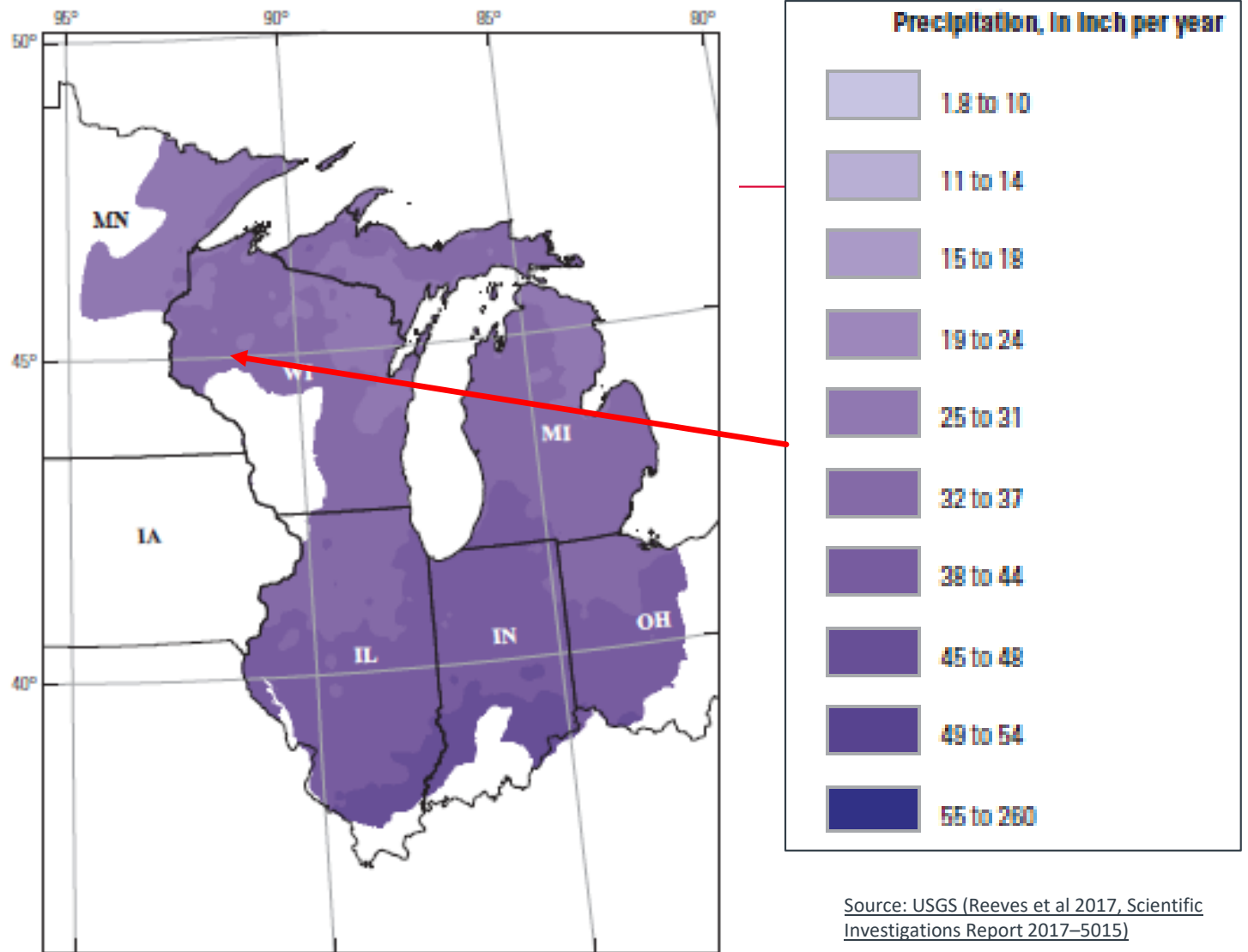
Source: USGS (Reeves et al 2017, Scientific Investigations Report 2017–5015)



# Total Thickness of Sand and Gravel in Glacial Deposits from Well Logs

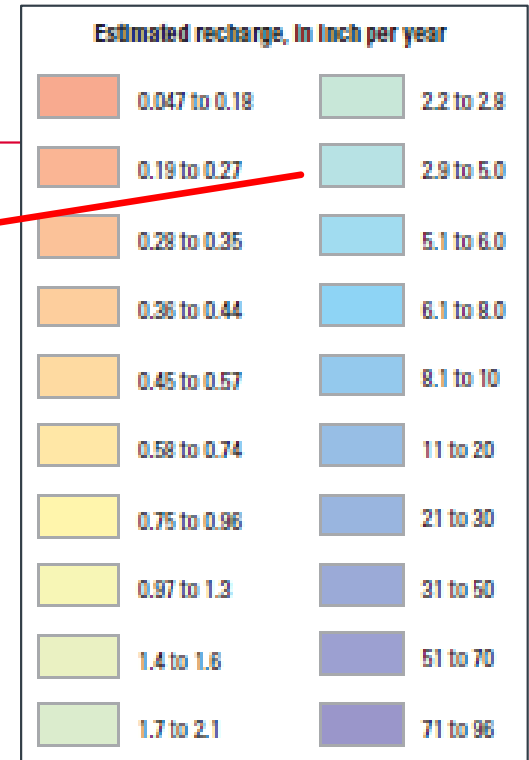
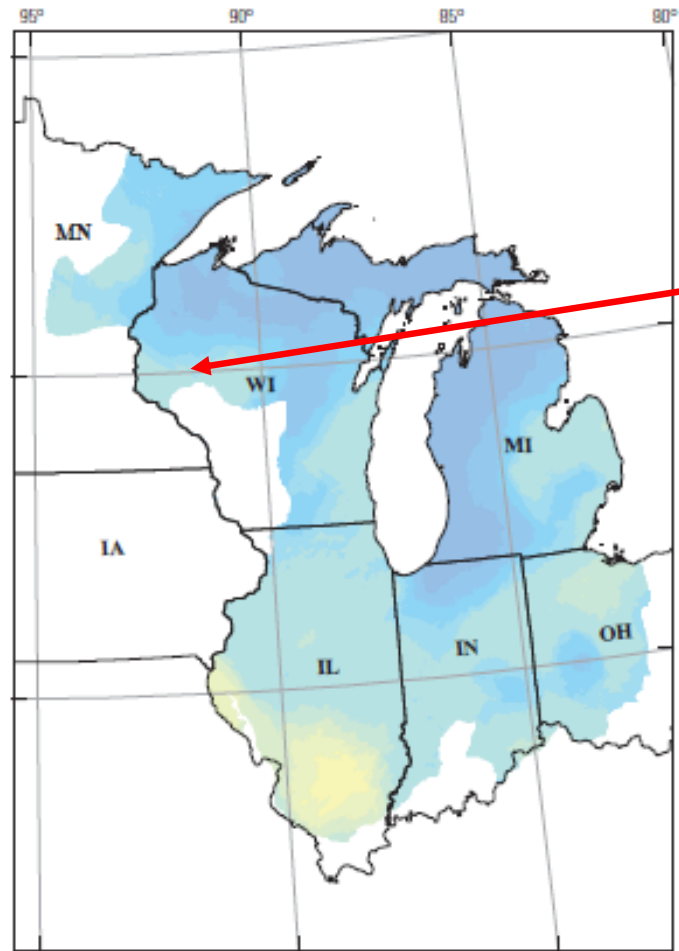


# Central Region - Annual Precipitation (Inches)

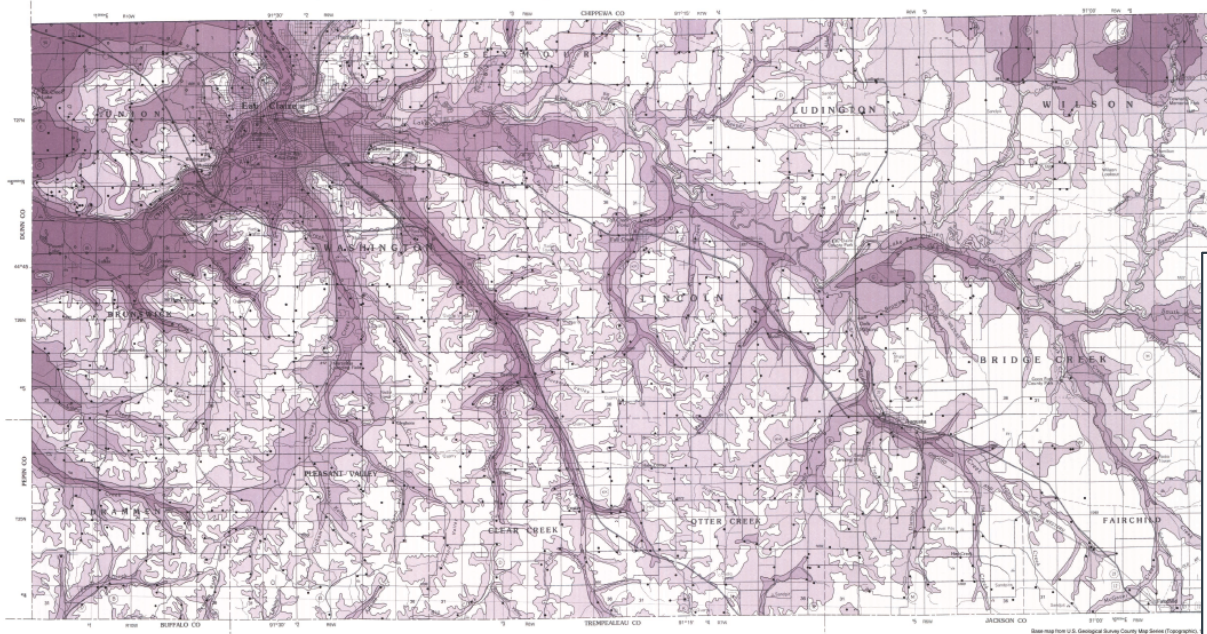


Source: USGS (Reeves et al 2017, Scientific Investigations Report 2017-5015)

# Central Region - Annual Groundwater Recharge (Inches)



## Depth to Bedrock Map of Eau Claire County, Wisconsin



## Glacial Valleys with Sand and Gravel

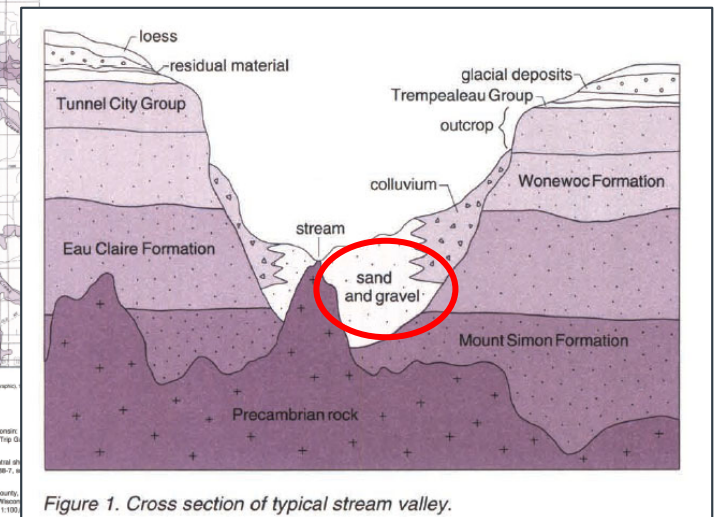


Figure 1. Cross section of typical stream valley.

D.M. Johnson, 1993

Miscellaneous Map 37

A product of the Eau Claire County Groundwater Resource Investigation, a joint project of the Wisconsin Geological and Natural History Survey and the Eau Claire County Board of Supervisors.

Depth to bedrock categories

- 0-5 ft bedrock at or near the land surface
- 5-25 ft bedrock often exposed in roadcuts, streambeds, and excavations
- 25-50 ft bedrock usually intersected by water wells and other borings
- 50-100 ft bedrock intersected only by deep drillholes
- 100+ ft approximate depth to bedrock, in feet below land surface
- well that does not intersect bedrock
- well that intersects bedrock

In Eau Claire County, bedrock is composed almost entirely of Cambrian sandstone, siltstone, and small amounts of shale. The Mount Simon Formation of the Elk Mound Group is the most extensively exposed unit. Cambrian rock is absent in the stream valleys of the northeast, where Precambrian basement rock is exposed, and is up to more than 250 feet thick in the southwest part of the county. In the hills of southern Eau Claire County, the Mount Simon is overlain by younger Cambrian sandstone, siltstone, and shale of the Elk Mound Group (the Eau Claire and Wonewoc Formations), the Tunnel City Group, and the St. Lawrence and Jordan Formations of the Trempealeau Group. The strata dip gently to the southwest.

Surficial deposits in Eau Claire County, which are up to 300 feet thick in the Chippewa River valley and absent in places in upland areas where bedrock occurs at the surface, consist primarily of relictium and materials of glacial and alluvial origin. Three glacial episodes have deposited surficial materials in Eau Claire County: the pre-Illinoian, Illinoian, and Wisconsin (oldest to youngest) (Blain, 1994). Pre-Illinoian lake sediment of the Koshong Member of the Racine Formation was deposited in lakes that were dammed by ice that blocked the westward drainage of the Chippewa River and its tributaries; the material is absent in the valleys of the north and southwest and where it has been eroded. A red sandy silt deposited in the northwestern part of the county during the Illinoian Glaciation and derived from the Superior Basin is included in the River Falls Formation. During the Wisconsin Glaciation, the Laurentide ice sheet advanced to the northeastern corner of the county, where it deposited silt and outwash.

Since glaciation, slope processes have reworked the glacial sediment as well as residual materials on bedrock. This reworking of sediment has resulted in the accumulation of colluvial deposits at the base of slopes. Figure 1 shows a cross section of a typical stream valley and the relationship of the bedrock to surficial deposits.

The depth to bedrock map presented here provides a general guide to the thickness of surficial materials. It is based on well records, the Eau Claire County soil survey (Soil Conservation Service, 1977), and field observations. The distribution of surficial deposits combined with the effects of erosion and mass wasting can cause significant differences in the depth to bedrock over short distances. Because of local complexity, this map should be used only as a guide to the general thickness of the materials. Detailed site-specific investigations, including drilling, are necessary to verify local conditions.

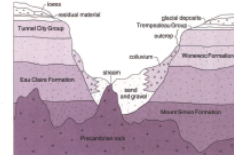


Figure 1. Cross section of typical stream valley.

### Sources of Information

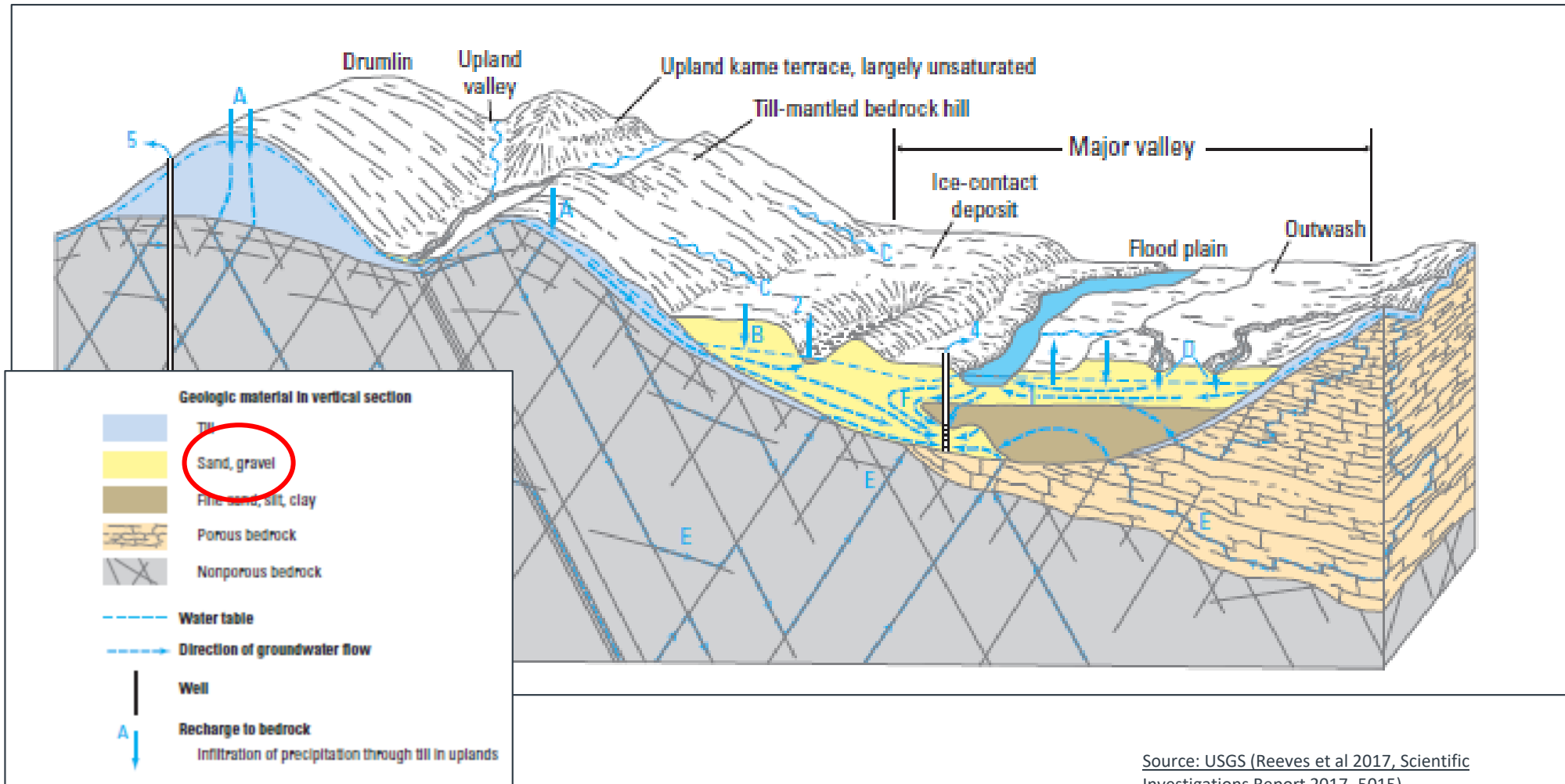
- Baker, R.W., 1984. Pleistocene history of west-central Wisconsin. Wisconsin Geological and Natural History Survey Field Trip Guide Book 11, 78 p.
- Brown, G.A., 1986. Bedrock geology of Wisconsin, west-central and Wisconsin Geological and Natural History Survey Map 88-7, 4:1,250,000.
- Celan, K.J., and Madison, F.W., 1989. Soils of Eau Claire County, Wisconsin, and their ability to attenuate contaminants. Wisconsin Geological and Natural History Survey Map 89-6, scale 1:100,000.
- Mulvey, M.D., Jr., ed., 1976. Upper Mississippi Valley basin-wide Wisconsin Geological and Natural History Survey Field Trip Guide Book 1, 39 p.
- Soil Conservation Service, 1977. Soil survey of Eau Claire County, Wisconsin. U.S. Department of Agriculture, 144 p. plus maps, scale 1:15,840.
- Wisconsin Department of Natural Resources well constructor's reports (1993-87).
- Wisconsin Geological and Natural History Survey published and unpublished geologic logs (1895-1985).

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 James M. Robertson, Director and Steve Geoghegan



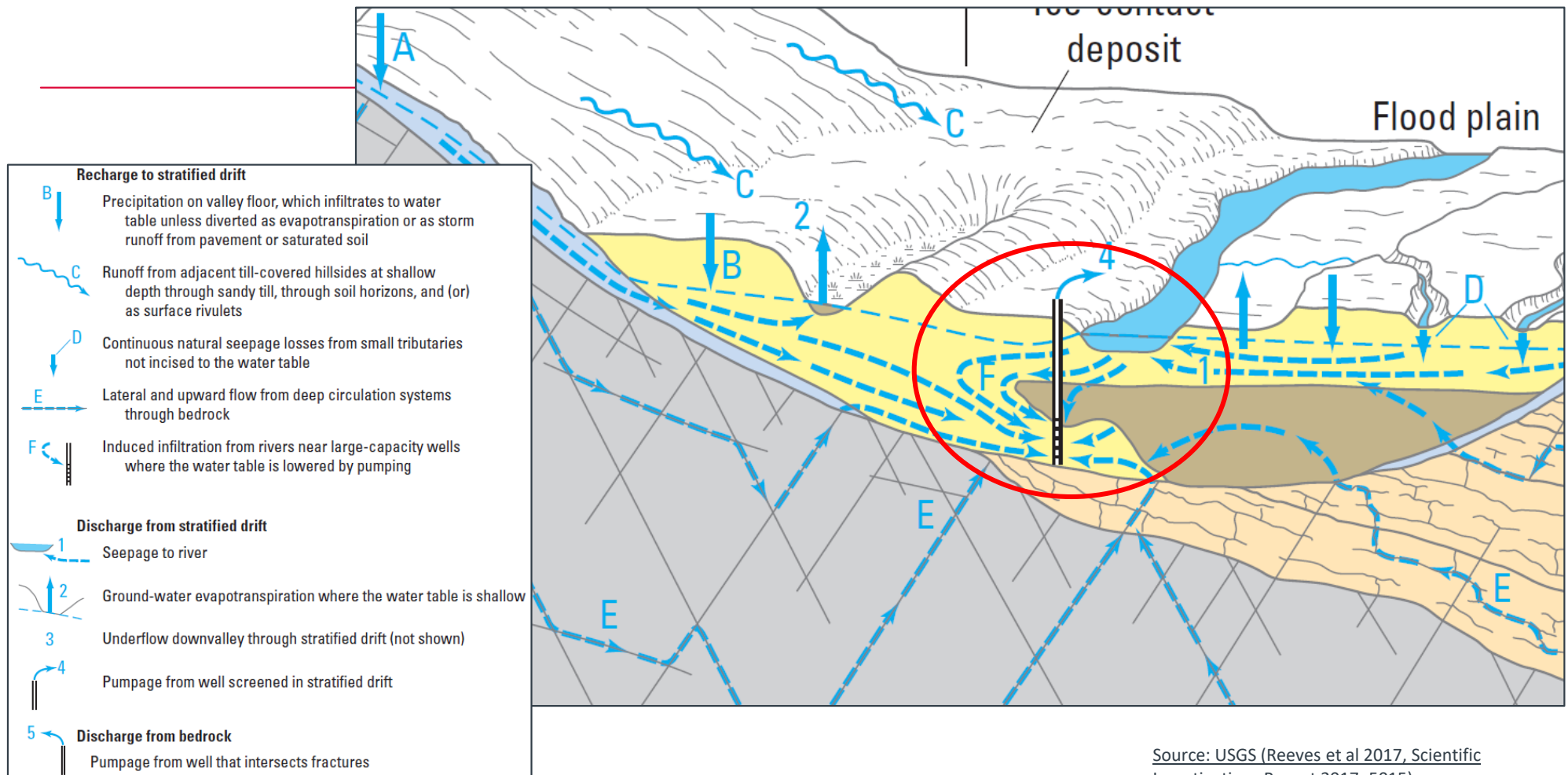
Source: WGNHS Miscellaneous Map 37 (Johnson 1993)

# Typical Glacial Valley with Sand and Gravel



Source: USGS (Reeves et al 2017, Scientific Investigations Report 2017-5015)

# Typical Glacial Valley with Sand and Gravel & Recharge Components



Source: USGS (Reeves et al 2017, Scientific Investigations Report 2017-5015)

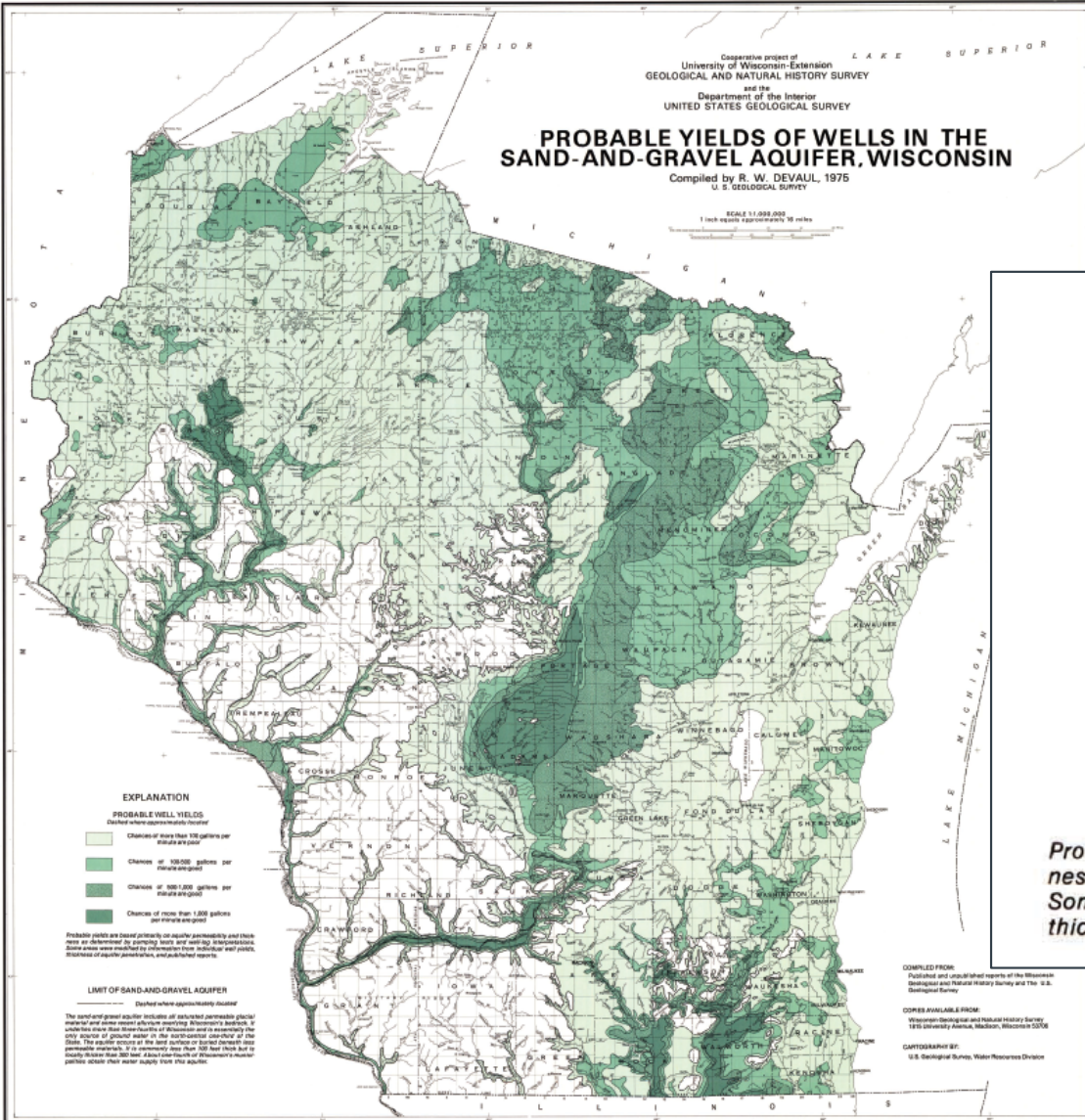
Cooperative project of  
 University of Wisconsin-Extension  
 GEOLOGICAL AND NATURAL HISTORY SURVEY  
 and the  
 Department of the Interior  
 UNITED STATES GEOLOGICAL SURVEY

## PROBABLE YIELDS OF WELLS IN THE SAND-AND-GRAVEL AQUIFER, WISCONSIN

Compiled by R. W. DEVAUL, 1975  
 U.S. GEOLOGICAL SURVEY





SCALE 1:1,000,000  
 1 inch equals approximately 16 miles

# Probable Well Yields in Sand and Gravel



### EXPLANATION

#### PROBABLE WELL YIELDS Dashed where approximately located

-  Chances of more than 100 gallons per minute are poor
-  Chances of 100-500 gallons per minute are good
-  Chances of 500-1,000 gallons per minute are good
-  Chances of more than 1,000 gallons per minute are good

*Probable yields are based primarily on aquifer permeability and thickness as determined by pumping tests and well-log interpretations. Some areas were modified by information from individual well yields, thickness of aquifer penetration, and published reports.*

Source: WGNHS Miscellaneous Map 54 (Devaul, 1975)

Map from U.S. Geological Survey  
 Draw from map, 1975

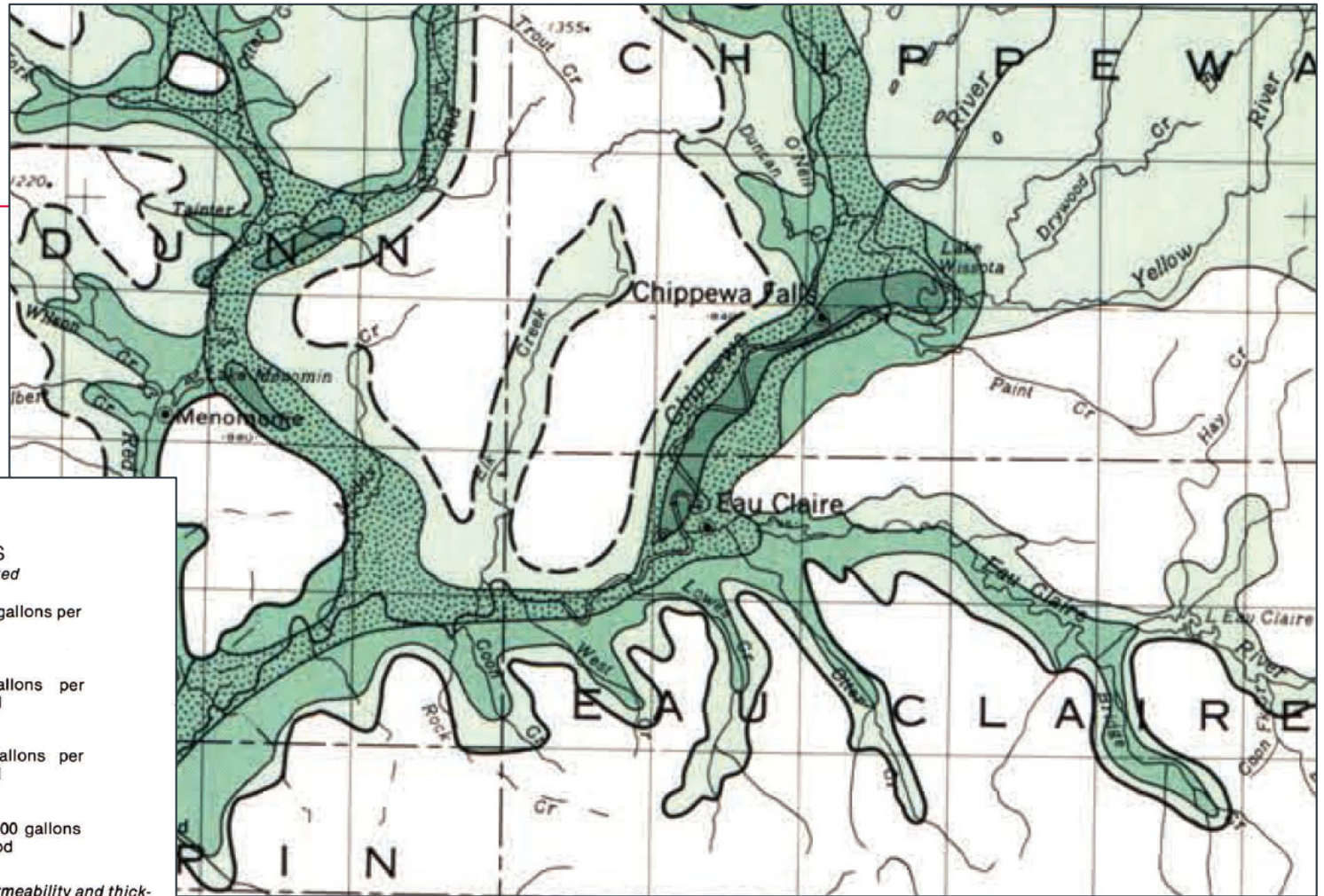
Compiled from:  
 Published and unpublished reports of the Wisconsin Geological and Natural History Survey and the U.S. Geological Survey

Copies available from:  
 Wisconsin Geological and Natural History Survey  
 1475 University Avenue, Madison, Wisconsin 53706

Cartographer:  
 U.S. Geological Survey, Water Resources Division





Lambert conformal conic projection based on standard parallels 37° and 45°

# Probable Well Yields in Sand and Gravel



**EXPLANATION**

**PROBABLE WELL YIELDS**  
*Dashed where approximately located*

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Source: WGNHS Miscellaneous Map 54 (Devaul, 1975)



# Potential Well Yields in Sand and Gravel of Chippewa County

## POTENTIAL YIELDS OF WELLS IN THE SAND-AND-GRAVEL AQUIFER OF CHIPPEWA COUNTY, WISCONSIN

MISCELLANEOUS MAP SERIES

I.D. LIPPELT  
1988

This map of potential yields of wells in the sand-and-gravel aquifer is a part of the Chippewa County Groundwater Resource Assessment, a joint project of the Wisconsin Geological and Natural History Survey and the Chippewa County Board of Supervisors.

Potential yields in the sand-and-gravel aquifer can vary greatly over short horizontal distances because of the abundance or scarcity of the sand and gravel, and the variability of the aquifer. In the western part of Chippewa County, potential yields usually increase in or adjacent to rivers and streams and decrease in upland areas. In the northeastern and north-central parts of Chippewa County, potential yields are usually less than 100 gallons of water per minute. The sand-and-gravel aquifer is absent in much of the southeastern part of the county. During extended periods of drought, maximum obtainable yields may decrease as a result of a reduction in the thickness of saturated aquifer.

The sand-and-gravel aquifer overlies bedrock, which in Chippewa County consists of Cambrian sandstone and Precambrian crystalline rock. In some areas of Chippewa County, the sandstone bedrock is deeply weathered and is poorly indurated. This weathered material is considered bedrock for the purpose of this map, although well screens may penetrate sand and gravel within the material. Therefore, some of the well construction reports have been interpreted, primarily on the basis of the geologic interpretation of the base south of latitude 43°N by Mackay and others (1971) and south of latitude 43°N by others (1987).

In areas where both the sand-and-gravel and the bedrock aquifers are present, well screens may reach to either water quality when choosing which water to use. Water from the bedrock aquifer may be harder or may contain more iron than water from the sand-and-gravel aquifer. However, the sand-and-gravel aquifer contributes to river runoff, is usually more susceptible to contamination from the surface.

### Explanation

potential yield (in gallons of water per minute) of wells that are appropriately constructed and fully developed (based on an assumed thickness of the aquifer and on yields obtained from existing irrigation, industrial, and domestic wells.

Potential yields are based on assumed thickness of the aquifer and on yields obtained from existing irrigation, industrial, and domestic wells.

Data have not been field checked.

Aquifer potential categories, in gallons of water per minute

- 0 saturated sand-and-gravel aquifer is absent
- 0-100 aquifer yields greatly; it may be thin, may contain iron or salt, or may be poorly sorted and densely packed
- 100-500 aquifer is commonly more than 20 ft thick and has sufficient recharge
- 500-1,000 aquifer is commonly more than 50 ft thick or is composed of coarse or well-sorted sand and gravel and has sufficient recharge
- 1000+ extent of this category is based on existing high-capacity wells

This map is intended to be a general guide to the aquifer potential of surficial deposits in Chippewa County. Where detailed site-specific information is required, users are advised to verify potential yields with test borings and pumping tests.

### Sources of data

- \* Wisconsin Department of Natural Resources well construction reports (1939-86).
- \* Wisconsin Geological and Natural History Survey published and unpublished geologic logs (1895-1985).
- \* Depth to Bedrock of Chippewa County, Wisconsin, by I.D. Lipfelt, 1988, Wisconsin Geological and Natural History Survey Miscellaneous Map Series, Map 68-1, scale 1:100,000.
- \* United States Geological Survey quadrangles (7.5-minute scale, nongraphic, 1971-76).
- \* Generalized Water-Table Elevation of Chippewa County, Wisconsin, by I.D. Lipfelt, 1988, Wisconsin Geological and Natural History Survey Miscellaneous Map Series, Map 68-1, scale 1:100,000.
- \* Bedrock Geology of Wisconsin, Northwest Sheet, by M.D. Murphree, Jr., G.L. Leberg, P.E. Myers, and W.B. Clark, 1987, Wisconsin Geological and Natural History Survey Regional Map Series, Map 67-1, scale 1:100,000.
- \* Bedrock Geology of Wisconsin, West-Central Sheet, by S.A. Elson, 1988, Wisconsin Geological and Natural History Survey Regional Map Series, Map 67-2, scale 1:100,000.
- \* Soils of Chippewa County and Their Ability to Absorb Contaminants, by A.W. Sutherland and P.W. Madison, 1987, Wisconsin Geological and Natural History Survey Map 67-3, scale 1:100,000.
- \* Wisconsin Geological and Natural History Survey Geology of Wisconsin Outcrop Descriptions.

UNIVERSITY OF WISCONSIN - EXTENSION

Published by and available from:  
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M.E. Clavin, Director and State Geologist  
3117 Mineral Point Road  
Madison, Wisconsin 53706

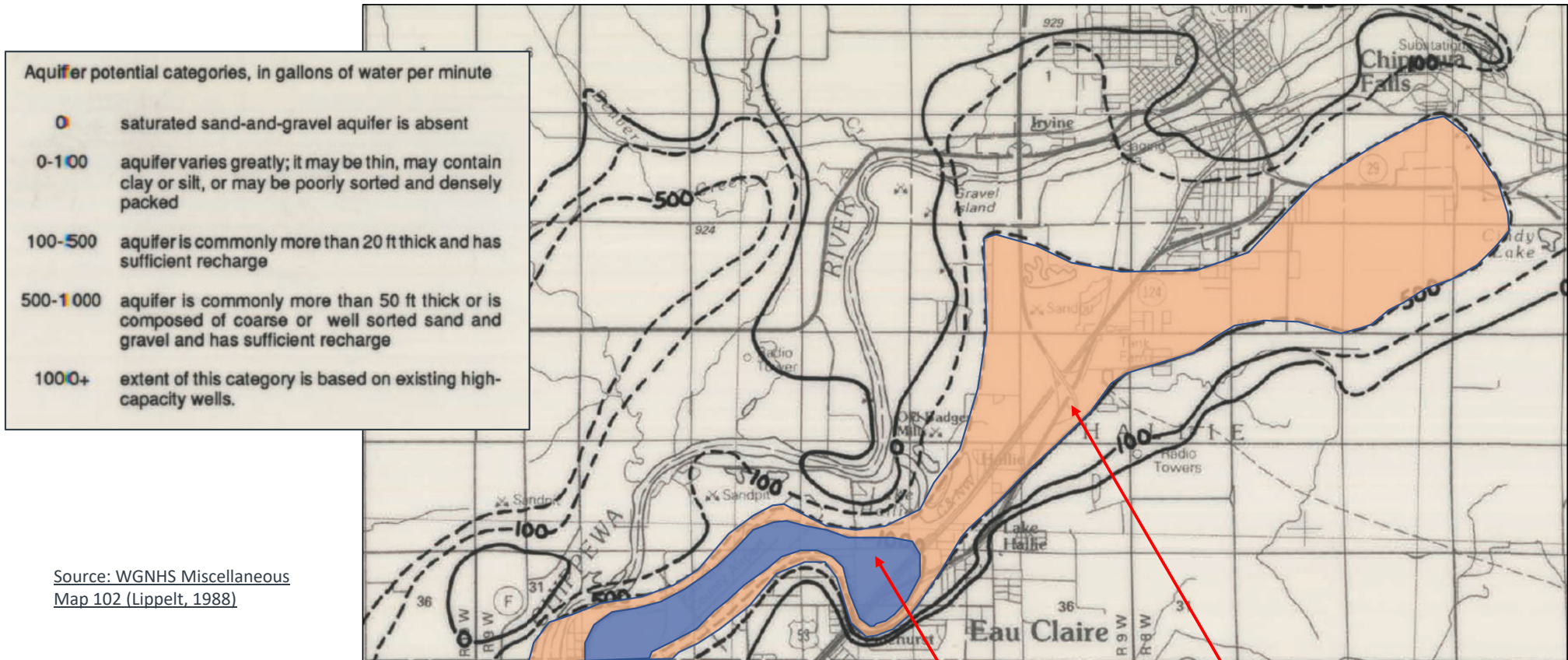
Wisconsin Geological and Natural History Survey Map 68-0



Source: WGNHS Miscellaneous Map 54 (Devaul, 1975)



# Potential Well Yields in Sand and Gravel of Chippewa County



1000 GPM

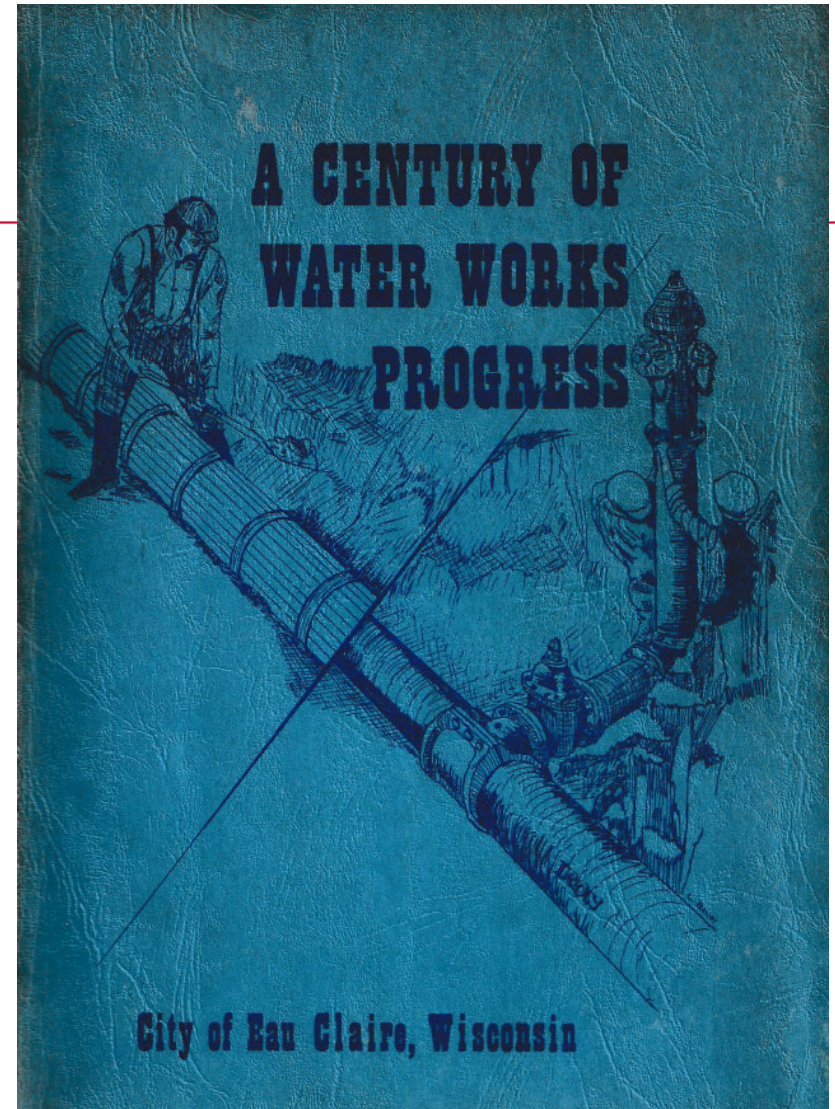
500 GPM



## Eau Claire - Water

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- Readily developed resource
  - “Shallow” wells with High Capacity
- Sand & Gravel Aquifer
  - Relatively thick
  - Porous
  - Permeable
- Available water with desirable quality
- Continual Replenishment
  - Interconnected to the Chippewa and other Rivers
  - Very large upland region underlain by Sand and Gravel
- Demonstrated reliability – about 140 years of history

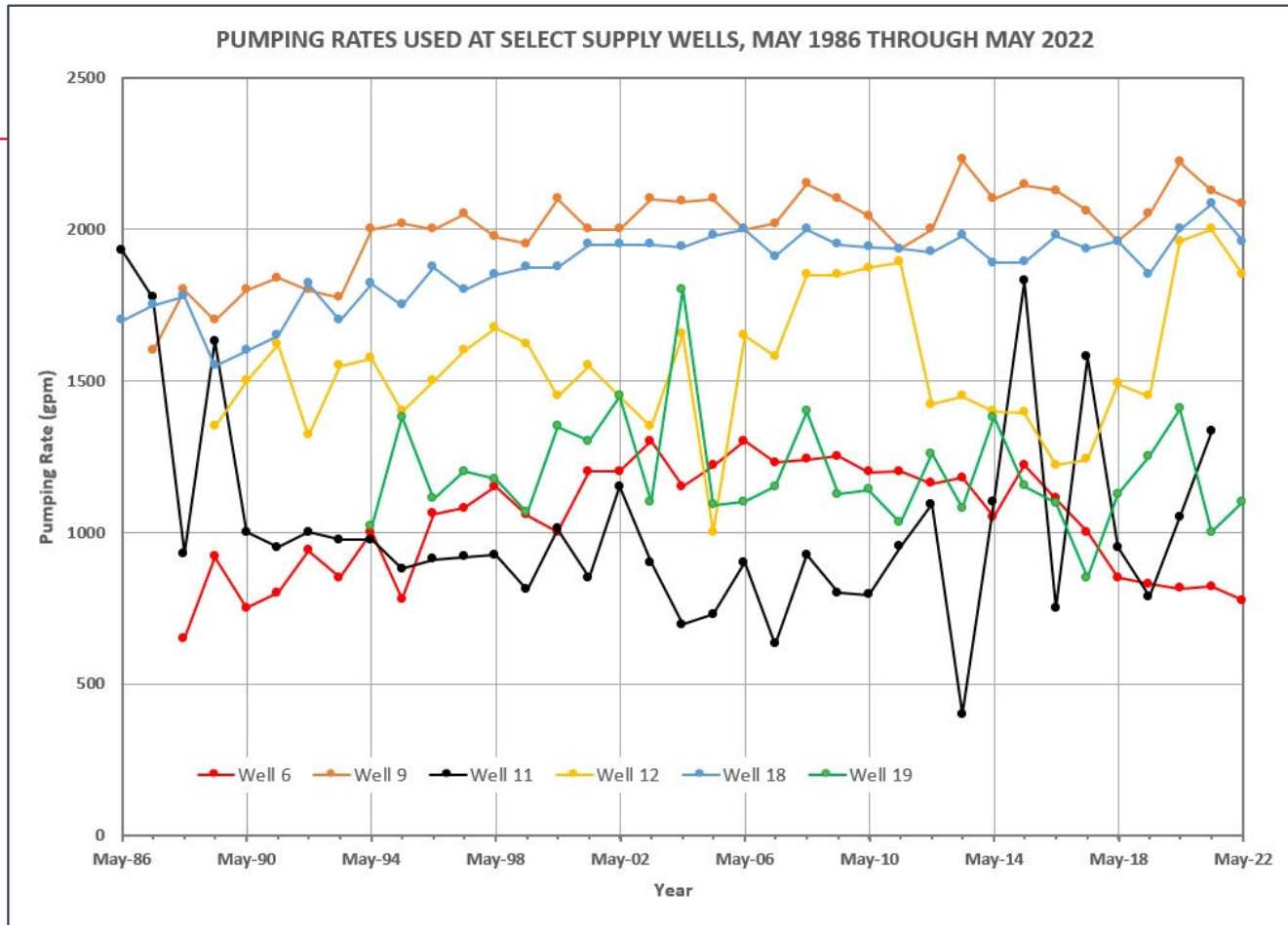


# Eau Claire Municipal Wellfield Characteristics

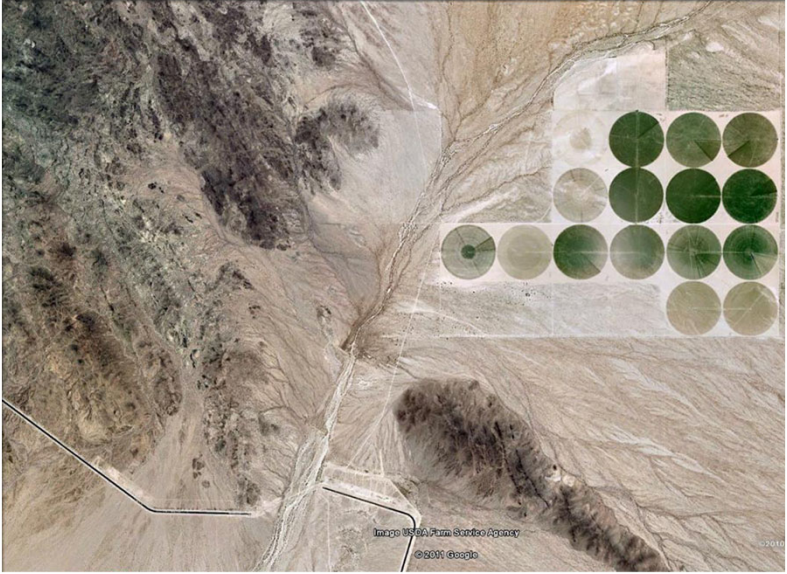
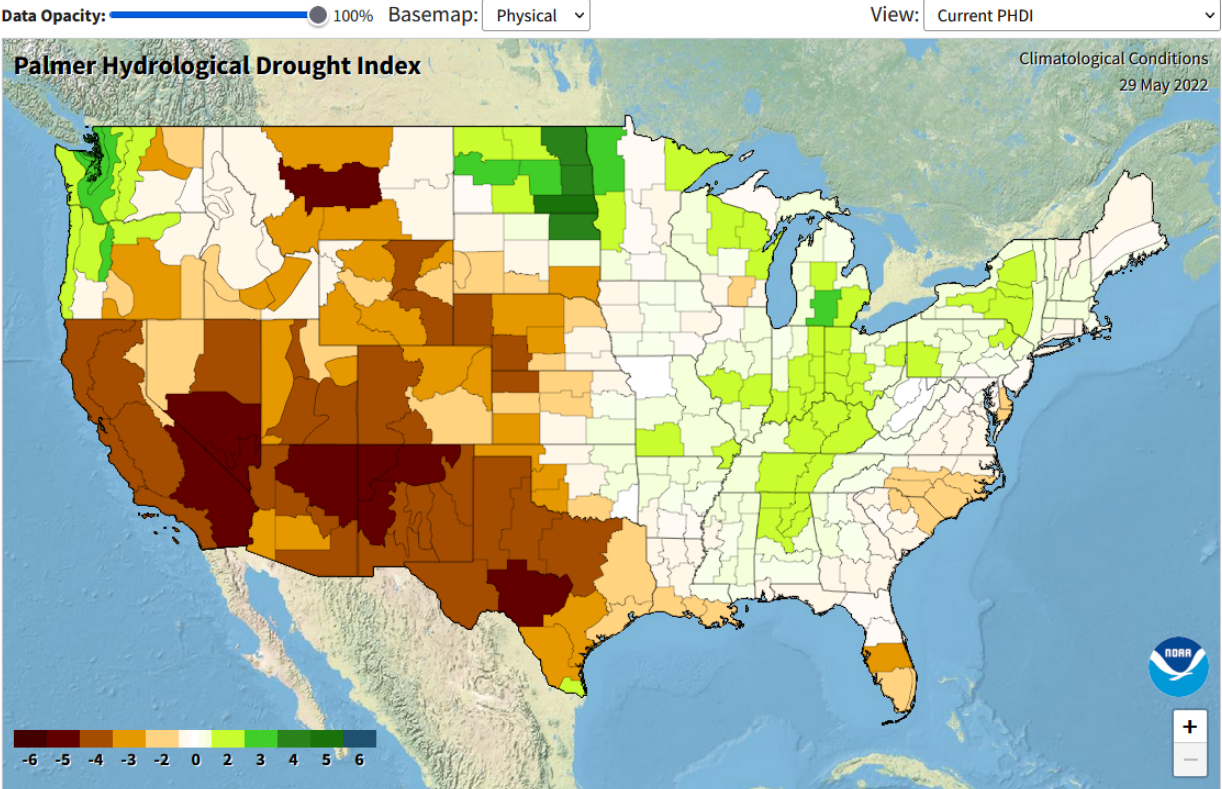
| Well ID  | Wellfield Location | Year In Service | Approx Surface EL. | Approx Pumping Rates (GPM) | Approximate Distance from River Edge (FT) | Screen Length (FT) | 05/2021 GW Depth (FT) | Pumping Rates South | Pumping Rates North |
|----------|--------------------|-----------------|--------------------|----------------------------|---|--------------------|-----------------------|---------------------|---------------------|
| Well #6  | Mid                | 1955 (1962)     | 803                | 800                        | 960                                       | 34                 | 14.6                  | 800                 |                     |
| Well #8  | North              | 1941            | 807                | 1080                       | 1,420                                     | 40                 | 23.9                  |                     | 1,080               |
| Well #9  | North              | 1947            | 809                | 2130                       | 1,340                                     | 30                 | 27.3                  |                     | 2,130               |
| Well #11 | North              | 1947            | 810                | 1330                       | 2,140                                     | 34                 | 31                    |                     | 1,330               |
| Well #12 | South              | 1954            | 804                | 2000                       | 580                                       | 34                 | 14                    | 2,000               |                     |
| Well #13 | South              | 1962            | 804                | 1400                       | 650                                       | 30                 | 15.8                  | 1,400               |                     |
| Well #14 | North              | 1968            | 808                | 1380                       | 1,620                                     | 38                 | 27.6                  |                     | 1,380               |
| Well #15 | North              | 1968            | 811                | 1450                       | 2,400                                     | 25                 | 30.5                  |                     | 1,450               |
| Well #16 | North              | 1975            | 808                | 1100                       | 1,960                                     | 35                 | 27.8                  |                     | 1,100               |
| Well #17 | North              | 1975            | 806                | 1200                       | 2,390                                     | 35                 | 26.4                  |                     | 1,200               |
| Well #18 | South              | 1977            | 808                | 2100                       | 720                                       | 35                 | 17.3                  | 2,100               |                     |
| Well #19 | North              | 1992            | 810                | 1100                       | 2,420                                     | 25                 | 31                    |                     | 1,100               |
| Well #21 | South              | 1992            | 808                | 1300                       | 980                                       | 35                 | 14.8                  | 1,300               |                     |
| Well #22 | North              | 2017            | 811                | 1600                       | 2,090                                     | 46                 | 32.4                  |                     | 1,600               |
| Well #23 | North              | 2017            | 817                | 1500                       | 1,750                                     | 25                 | 40.1                  |                     | 1,500               |
| Well #24 | North              | 2019            | 811                | 600                        | 1,820                                     | 35                 | 24                    |                     | 600                 |
|          |                    |                 |                    |                            |   |                    |                       | Subtotal            |                     |
|          |                    |                 |                    |                            |   |                    |                       | 7,600               | 14,470              |



# ECMWF – Range of Well Pumping Rates – Selected Wells



# Current Drought Index for Continental US



Typical Agricultural Pumping, Arizona

# Projected Southwest US Conditions to 2080

- USGS projects decreased streamflow
- Citing a changing climate and modeled radiative climate forcing's

*"an imposed, natural, or anthropogenic disturbance of the Earth's energy balance with space"*

- At Representative Concentration Pathway (RCP) 4.5
  - 51% of SW US basins impacted by 2080
  - Appreciable baseflow reductions

Contents lists available at [ScienceDirect](http://ScienceDirect)

Journal of Hydrology X

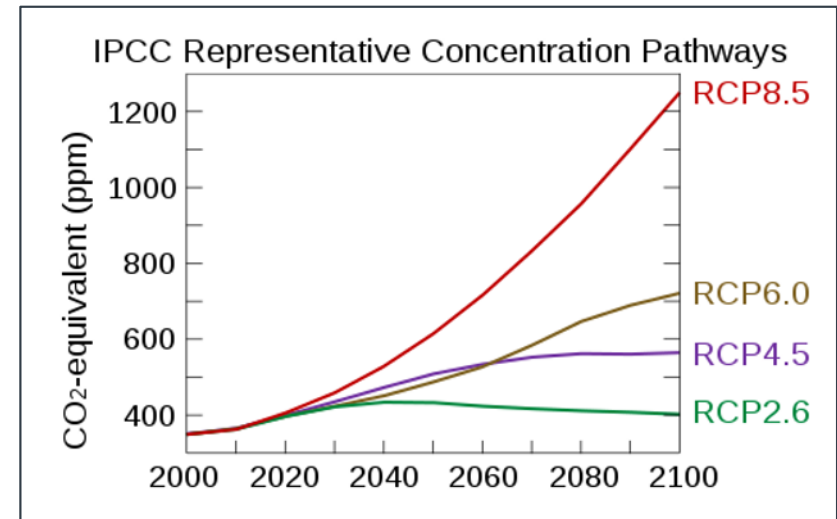
journal homepage: [www.sciencedirect.com/journal/journal-of-hydrology-x](http://www.sciencedirect.com/journal/journal-of-hydrology-x)

ELSEVIER

Changing climate drives future streamflow declines and challenges in meeting water demand across the southwestern United States

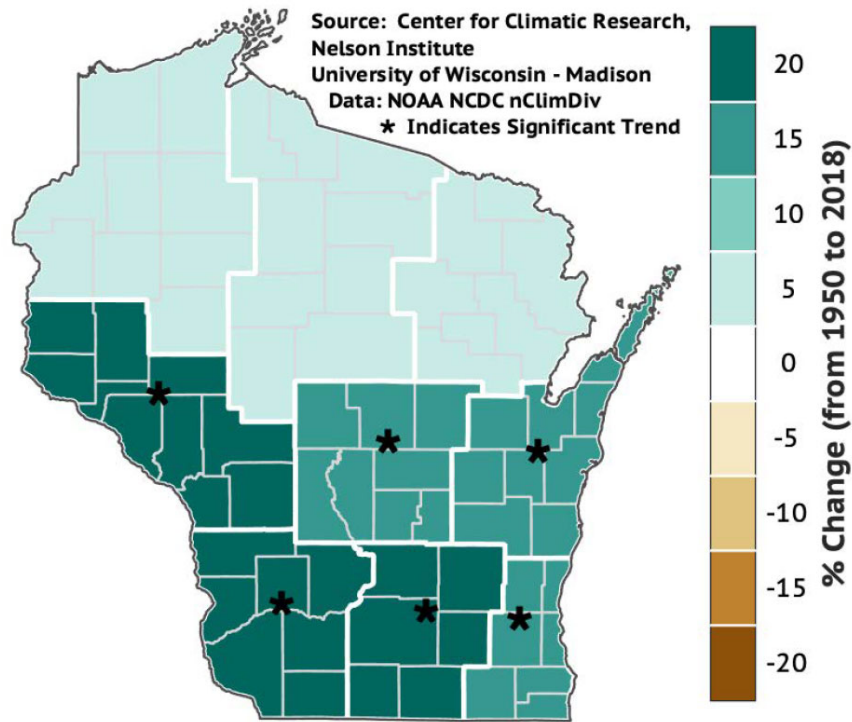
Olivia L. Miller<sup>a, \*</sup>, Annie L. Putman<sup>a</sup>, Jay Alder<sup>b</sup>, Matthew Miller<sup>c</sup>, Daniel K. Jones<sup>a</sup>, Daniel R. Wise<sup>d</sup>

<sup>a</sup> U.S. Geological Survey, Utah Water Science Center, 2329 W Orton Circle, Salt Lake City, UT 84119, United States  
<sup>b</sup> U.S. Geological Survey, Geosciences and Environmental Change Science Center, 104 CEOAS Admin Building, Oregon State University, Corvallis, OR 97331, United States  
<sup>c</sup> U.S. Geological Survey, Water Resources Mission Area, 3215 Marine St, Boulder, CO 80303, United States  
<sup>d</sup> U.S. Geological Survey, Oregon Water Science Center, 2130 S.W. Fifth Avenue, Portland, OR 97201, United States

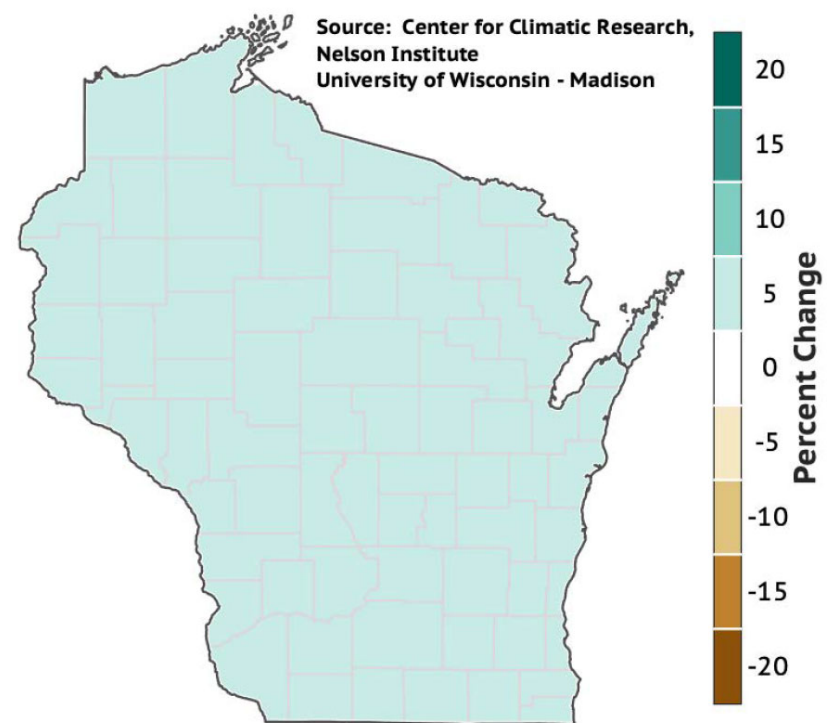


# Precipitation Patterns – Historical & Projected at RCP4.5

## Historical Change in Annual PRECIP (%) from 1950 to 2018



## Change in Annual PRCP (%), RCP45: 2041-2060 minus 1981-2010

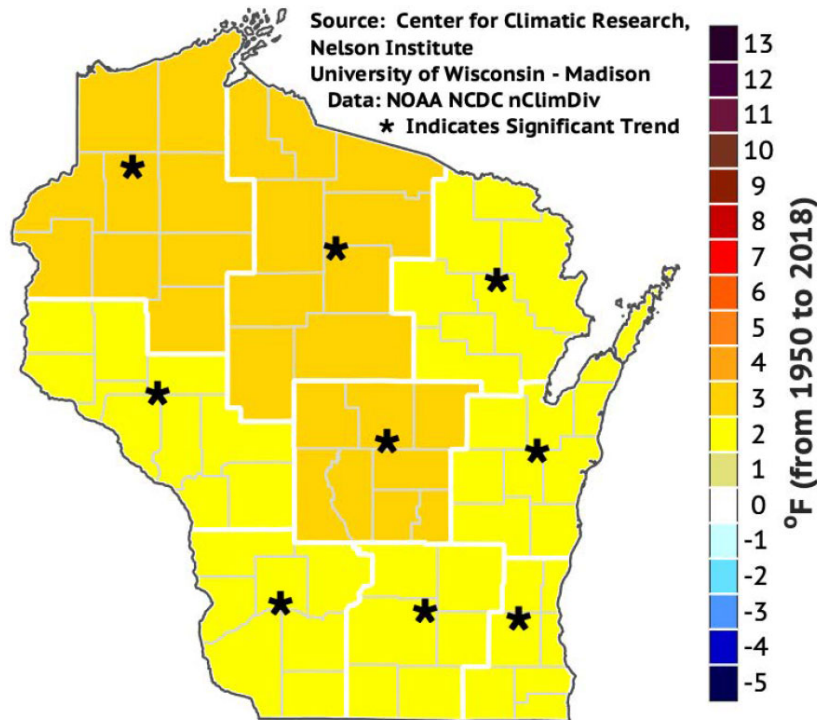


Source: Wisconsin Initiative on Climate Change Impacts (WICCI)  
<https://wicci.wisc.edu/>

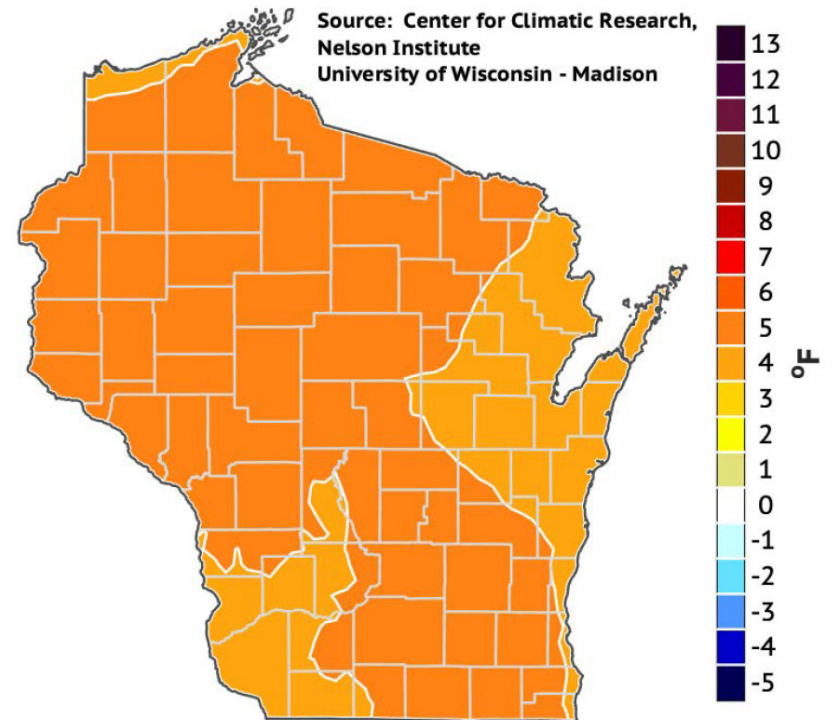


# Temperature Patterns – Historical & Projected at RCP4.5

## Historical Change in Annual TMAX from 1950 to 2018



## Change in Annual TMAX, RCP45: 2041-2060 minus 1981-2010



Source: Wisconsin Initiative on Climate Change Impacts (WICCI)  
<https://wicci.wisc.edu/>

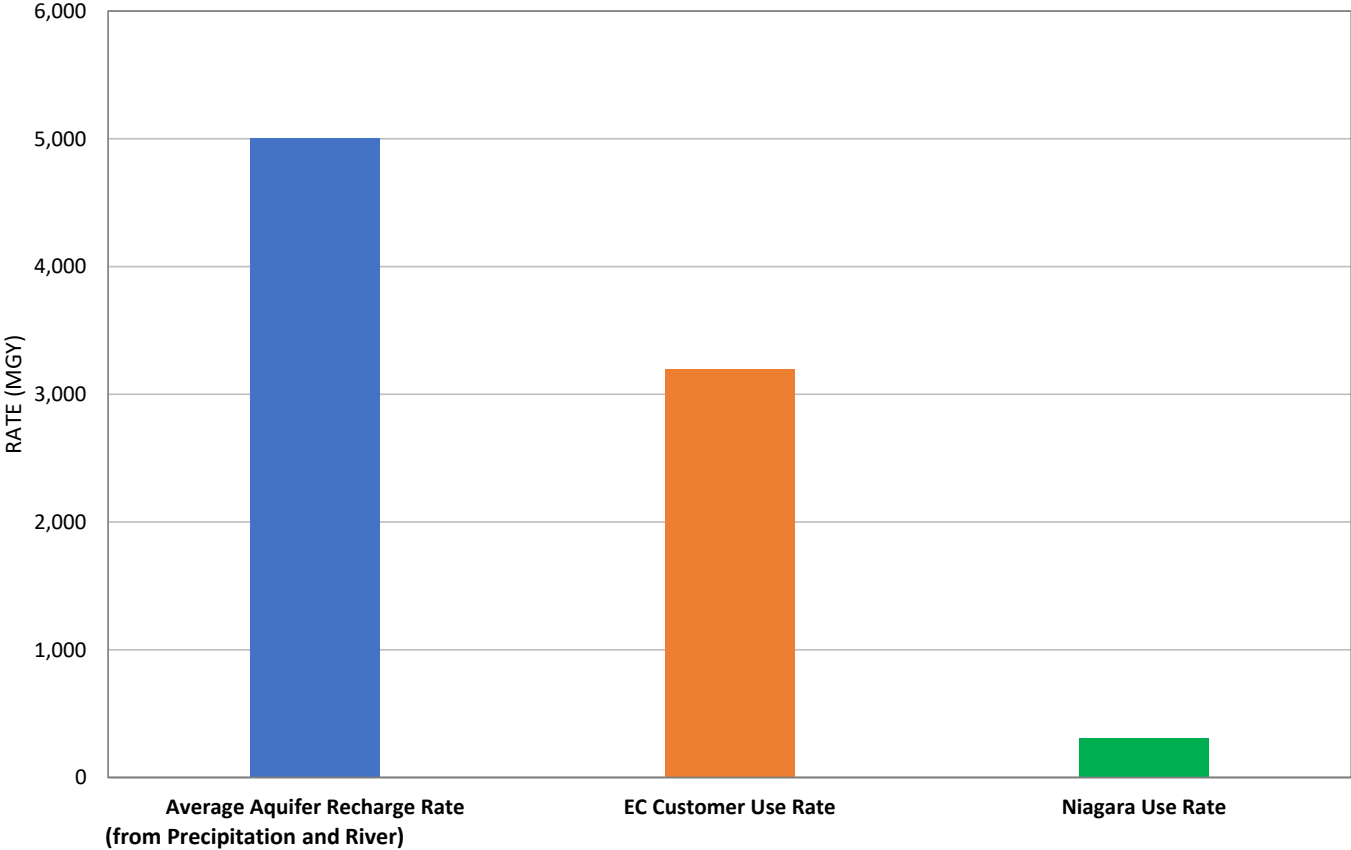
# Modeling Results and Aquifer Recharge

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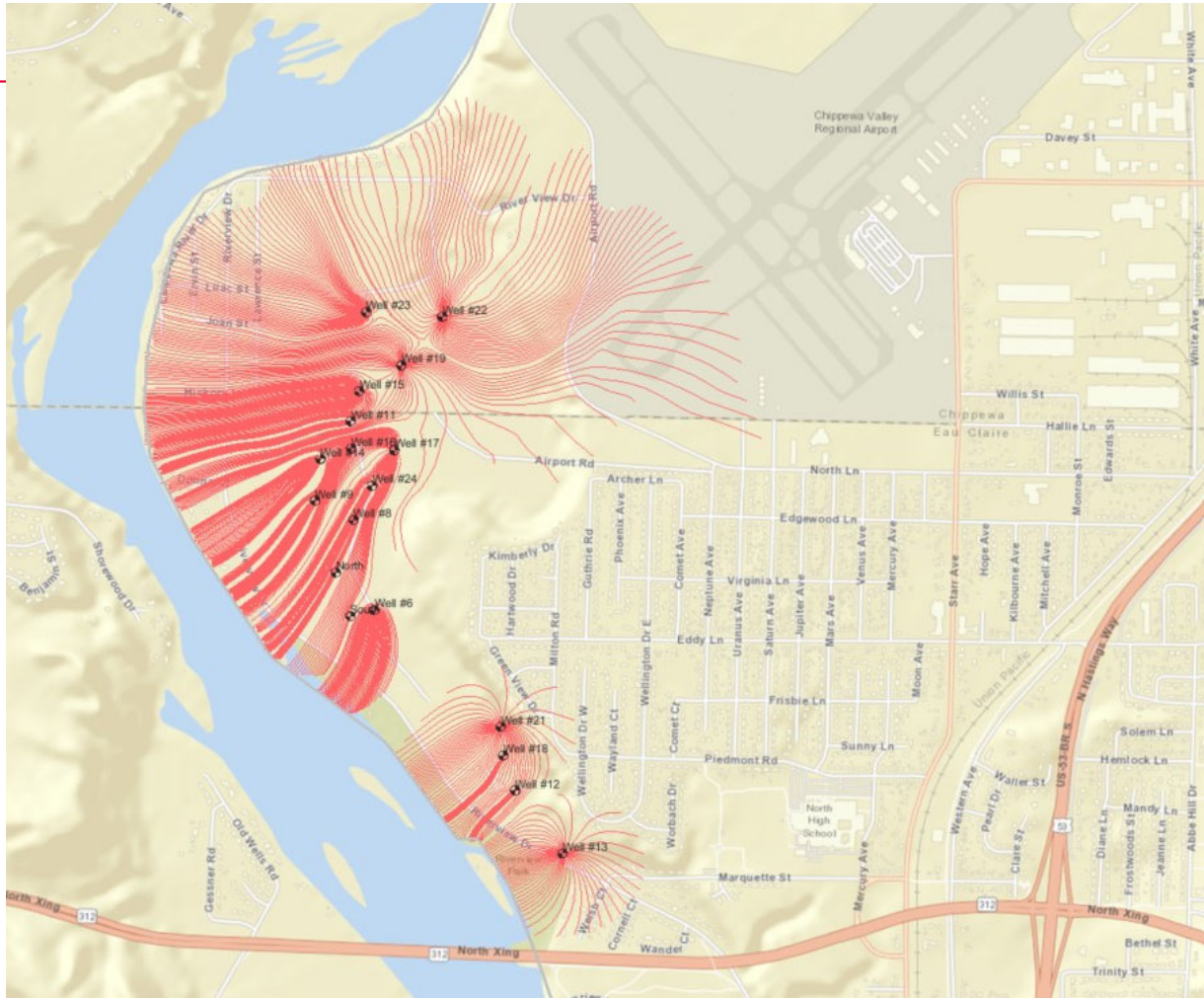


# Aquifer Recharge from Precipitation and Induced Recharge from River

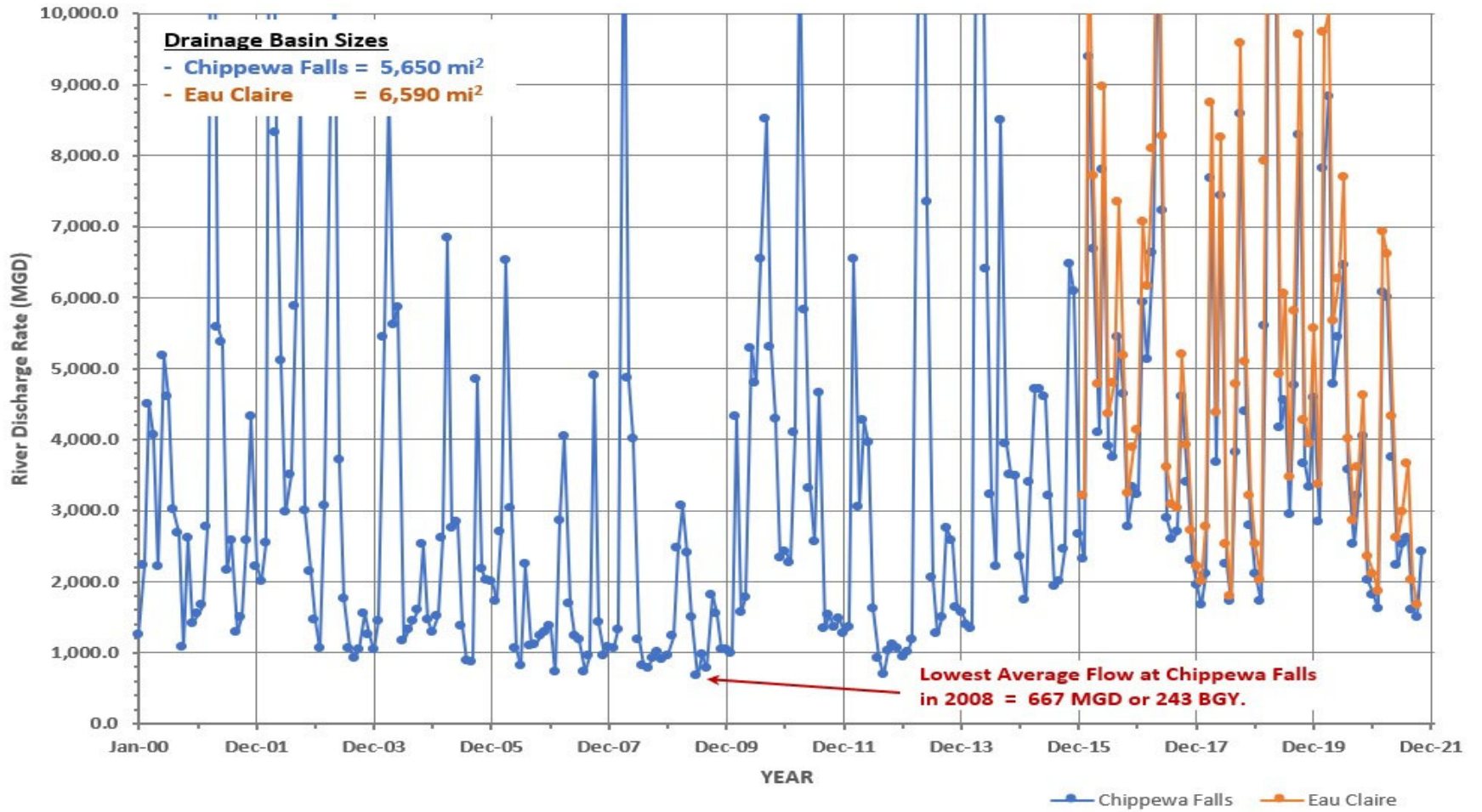
Average Annual Aquifer Recharge Rate vs. Annual Water Use Rates



# Simulated Groundwater Flow Lines to Pumping Wells Wellfield Withdrawal Rate During Typical Peak Demand Month



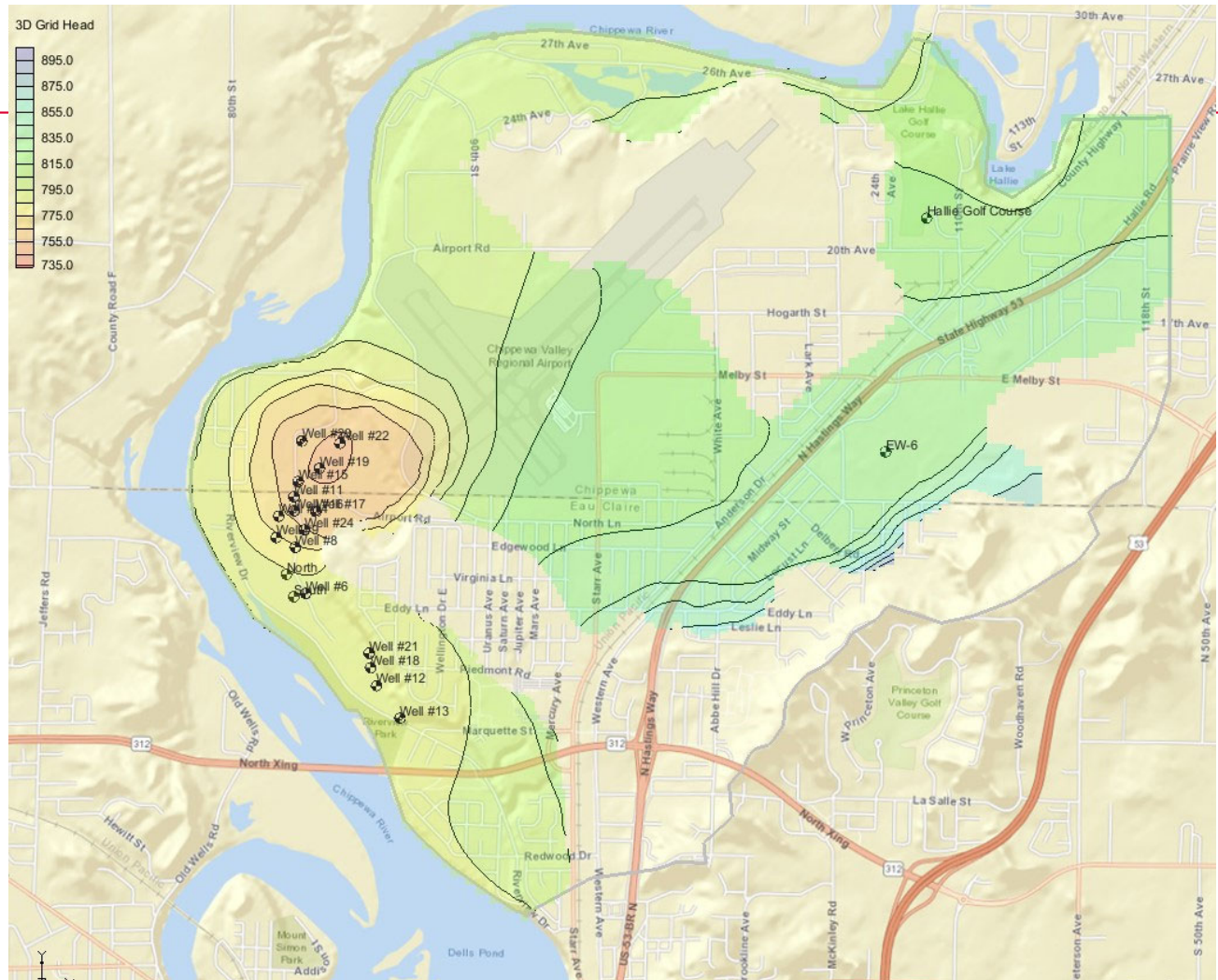
### CHIPPEWA RIVER DISCHARGE RATES, 2000 THROUGH 2021, USGS GAGE STATIONS



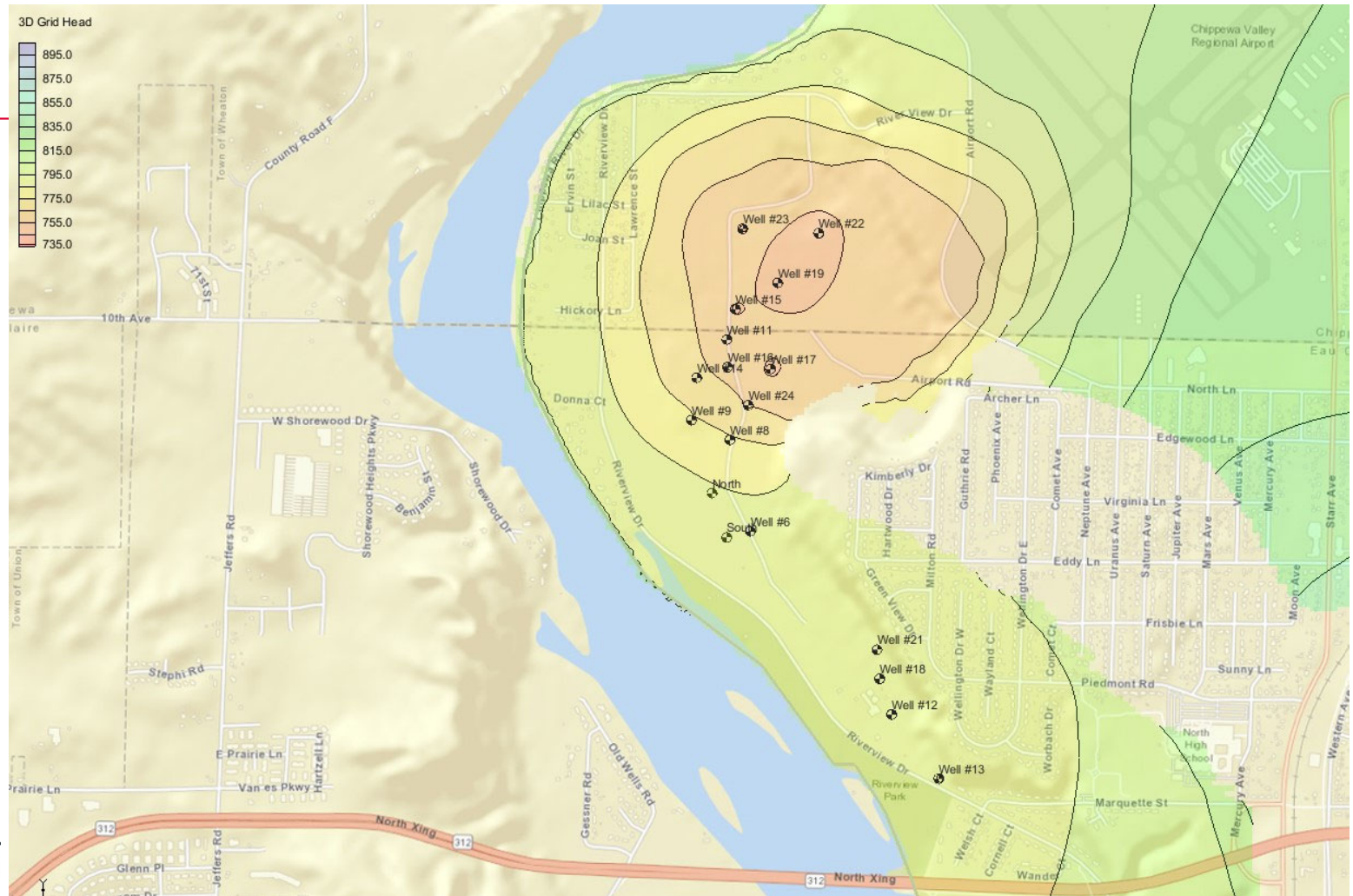
**Very High Baseflow Rates in the Chippewa River Can Support Groundwater Recharge to an Adjacent Pumped Aquifer.**



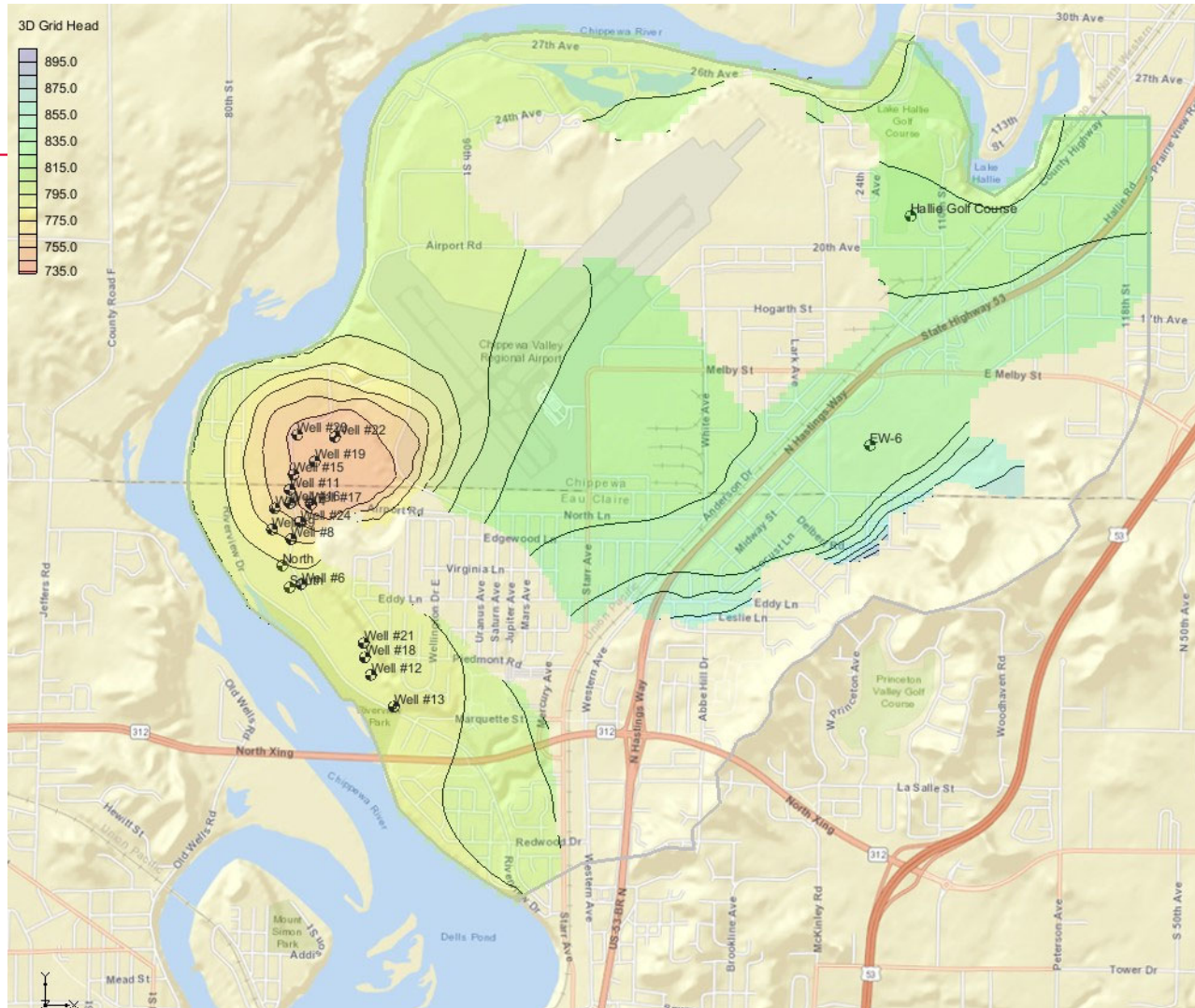
# Simulated Groundwater Elevations During Peak-Rate Pumping



# Simulated Groundwater GW Elevations During Peak-Rate Pumping

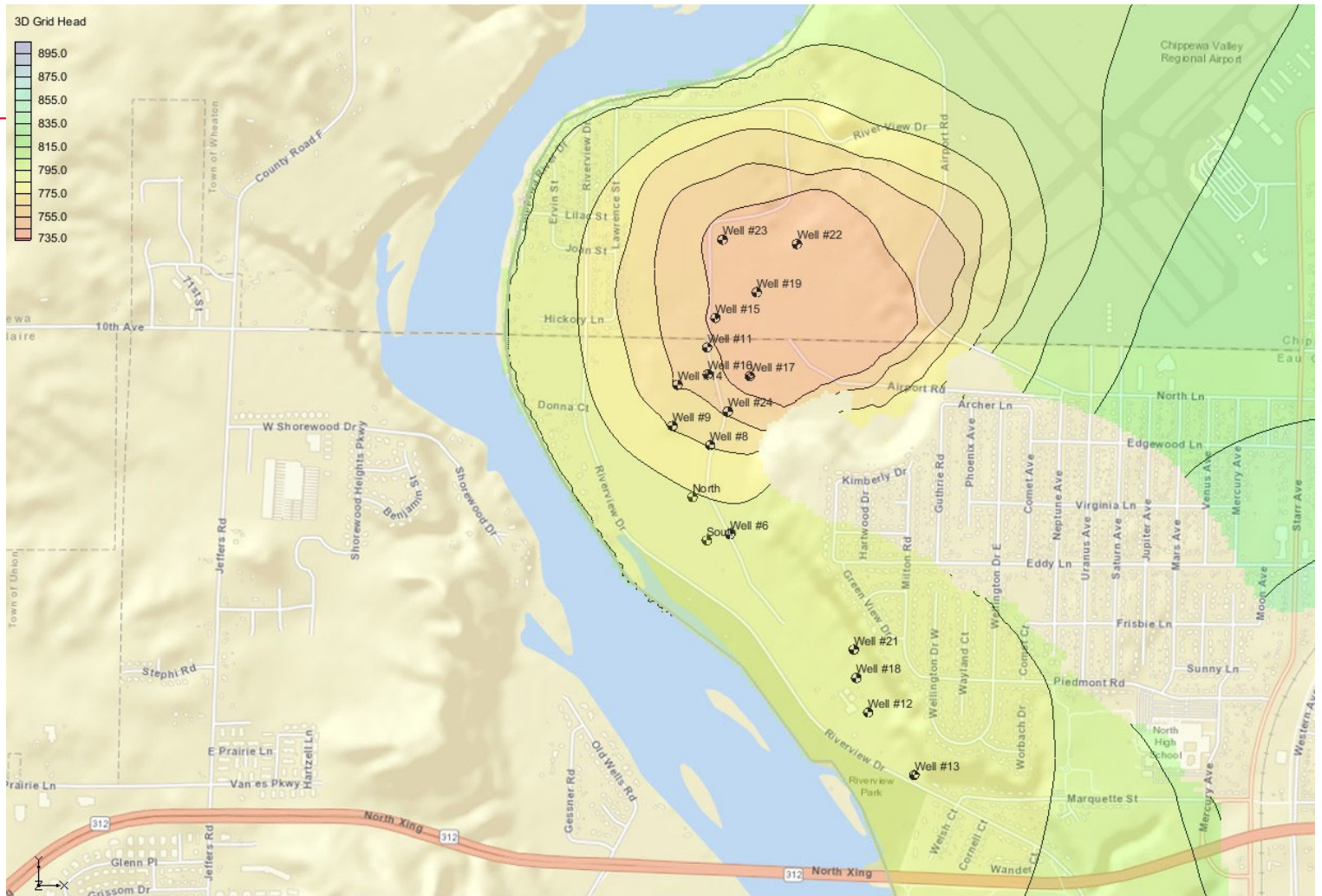


# Simulated GW Elevations During Peak-Rate + 0.850 MGD Pumping





# Simulated GW Elevations During Peak-Rate + 0.850 MGD Pumping



# Simulated Drawdown from Additional 0.850 MGD Wellfield Withdrawal

