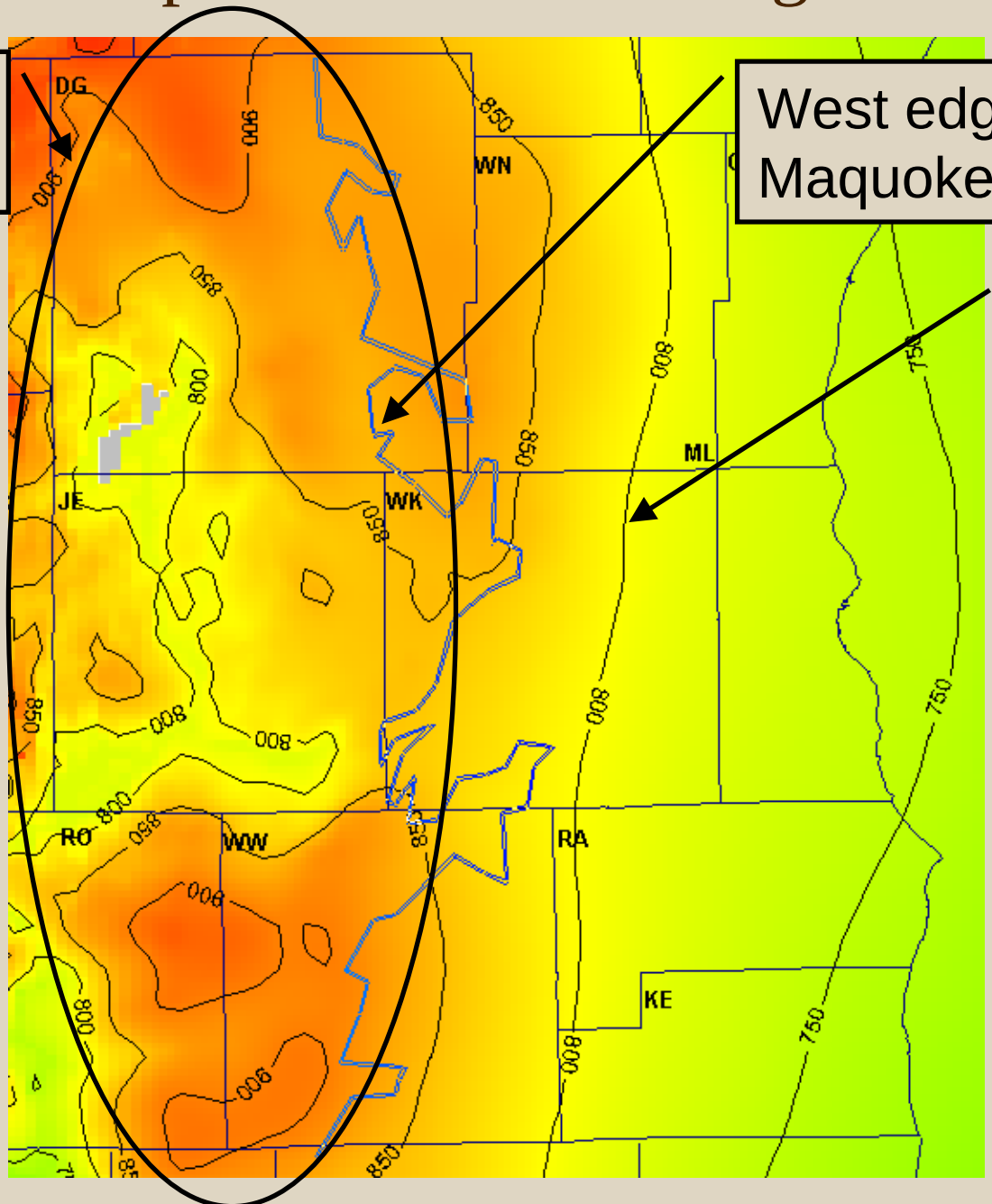
Simulated deep water levels through time

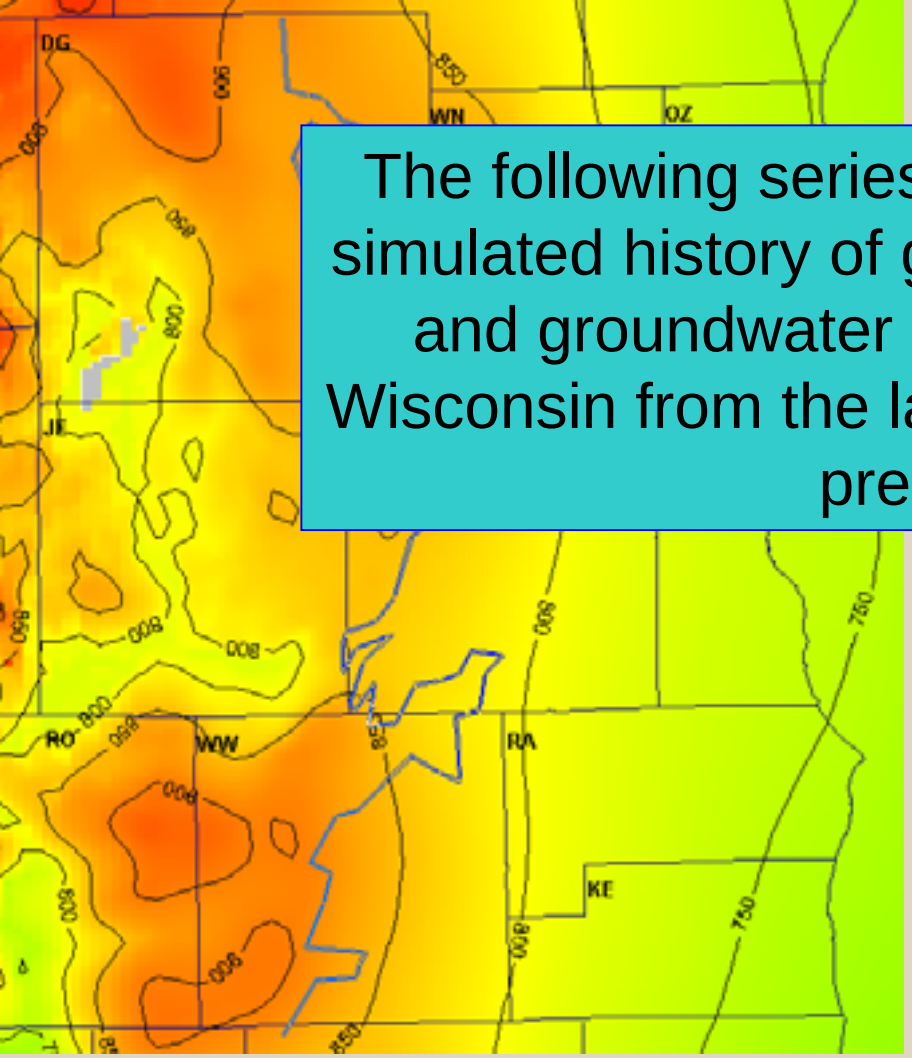
unconfined area

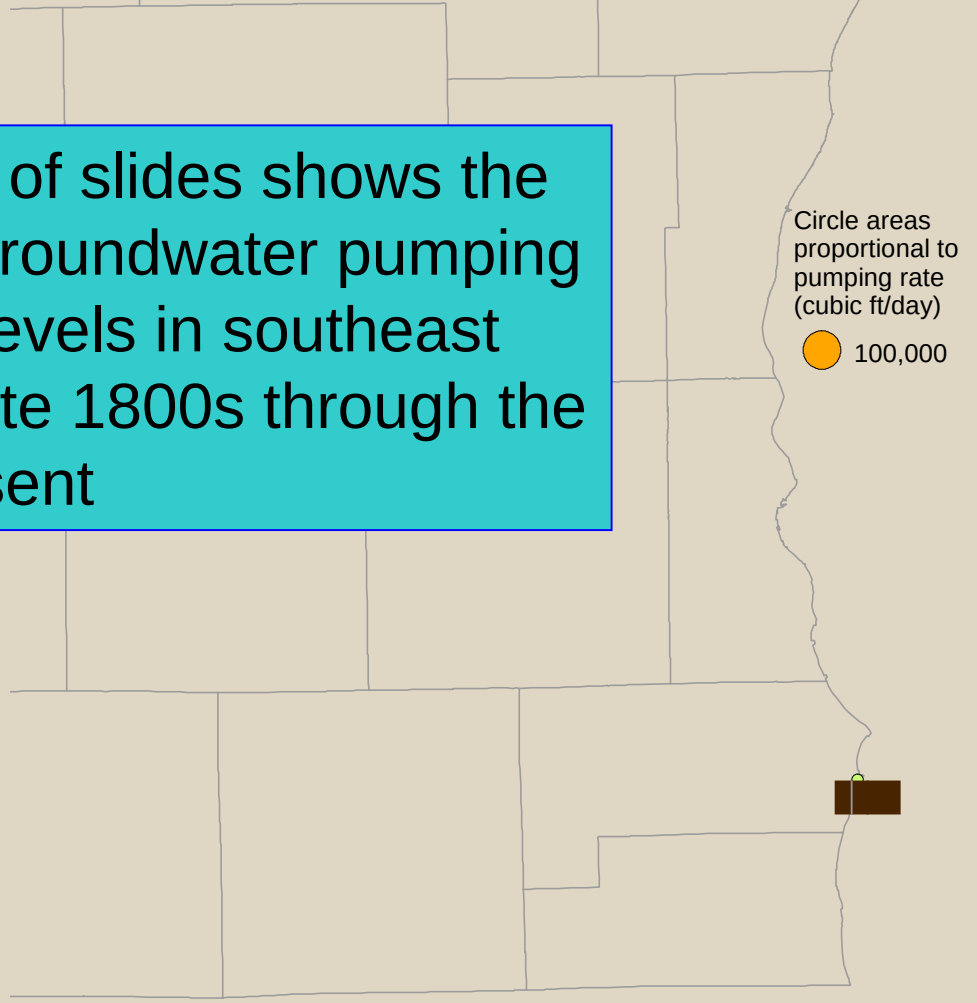


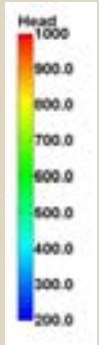
West edge of Maquoketa Shale

water elevations in deep sandstone (feet above sea level)

The following series of slides shows the simulated history of groundwater pumping and groundwater levels in southeast Wisconsin from the late 1800s through the present







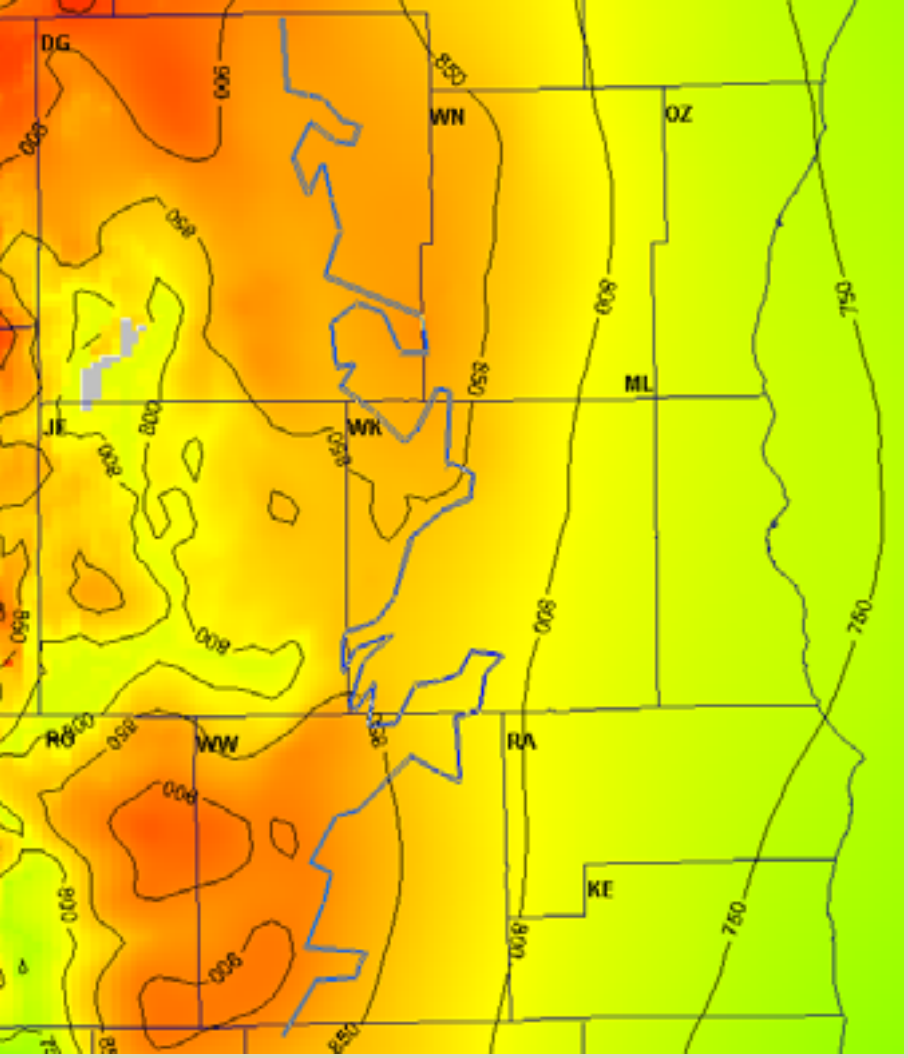
Water Levels in the Sandstone Aquifer (feet above sea level)

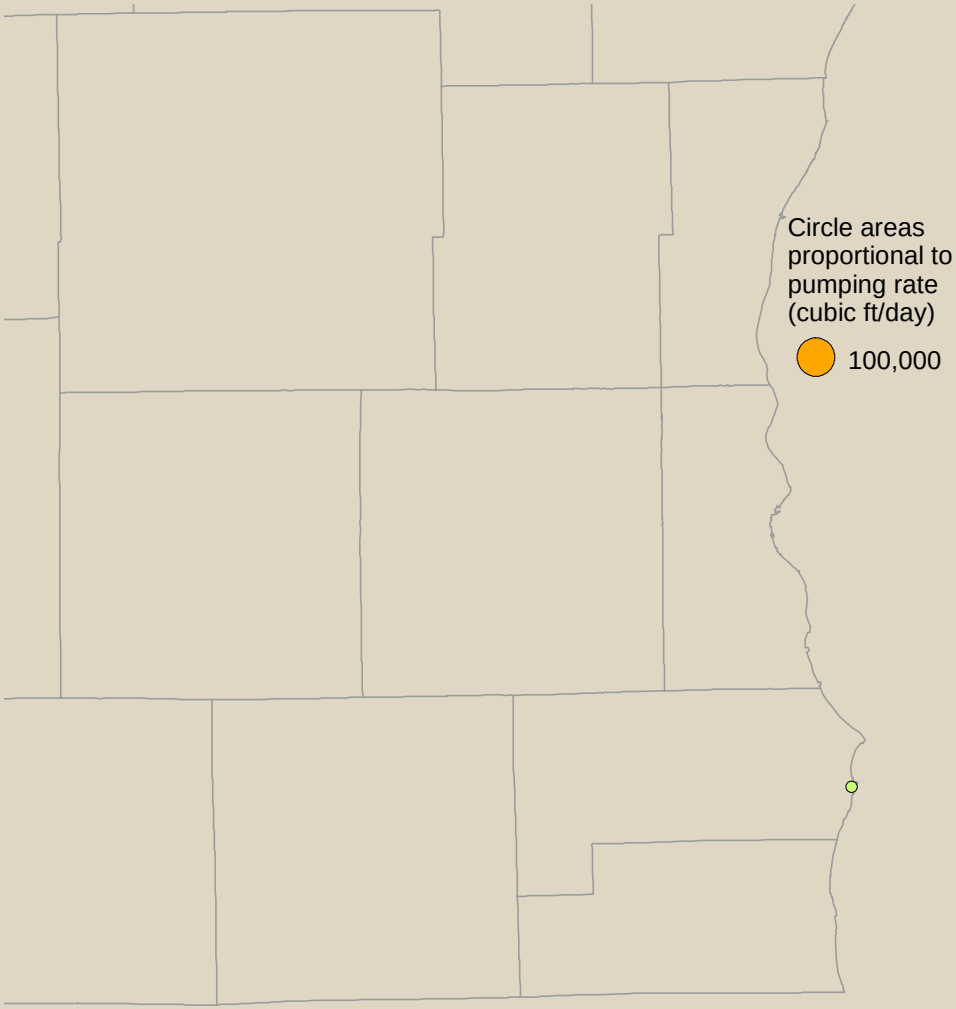
Well Locations and Pumping Rates

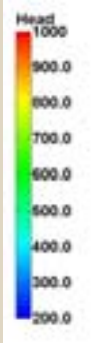
Shallow

Deep

Pre-1864





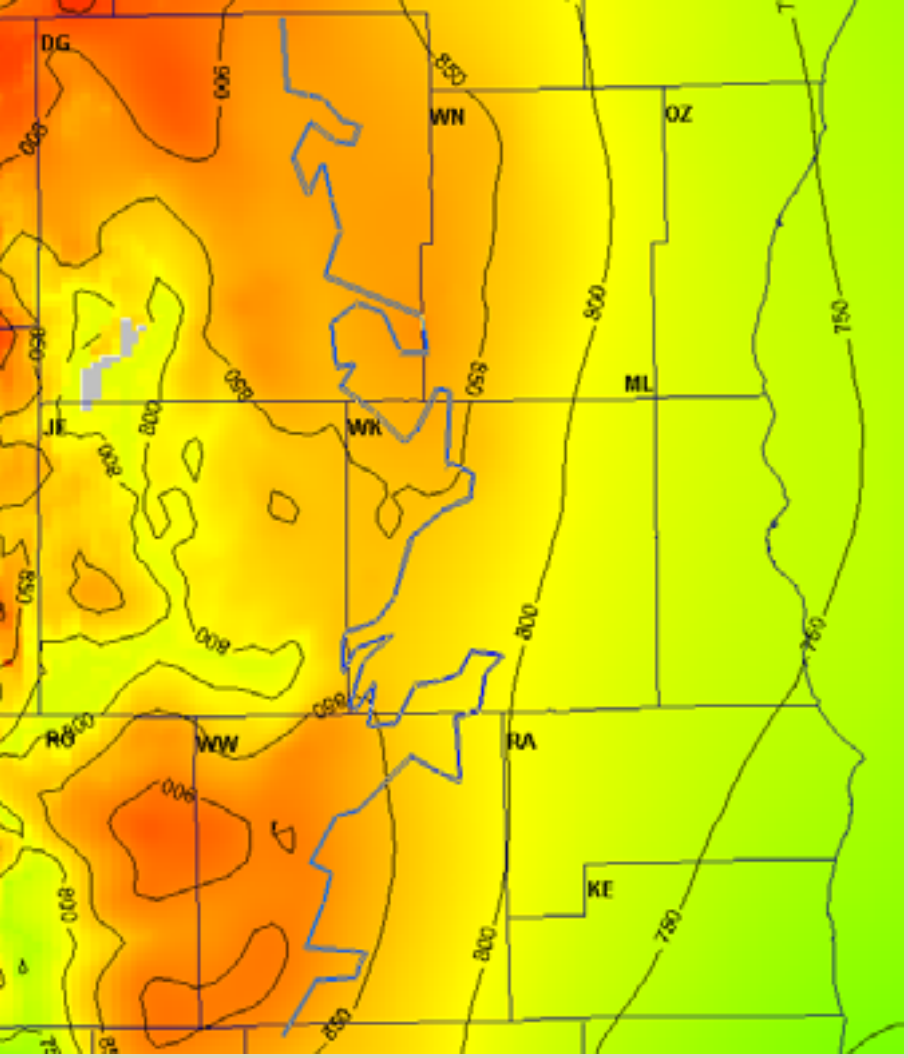


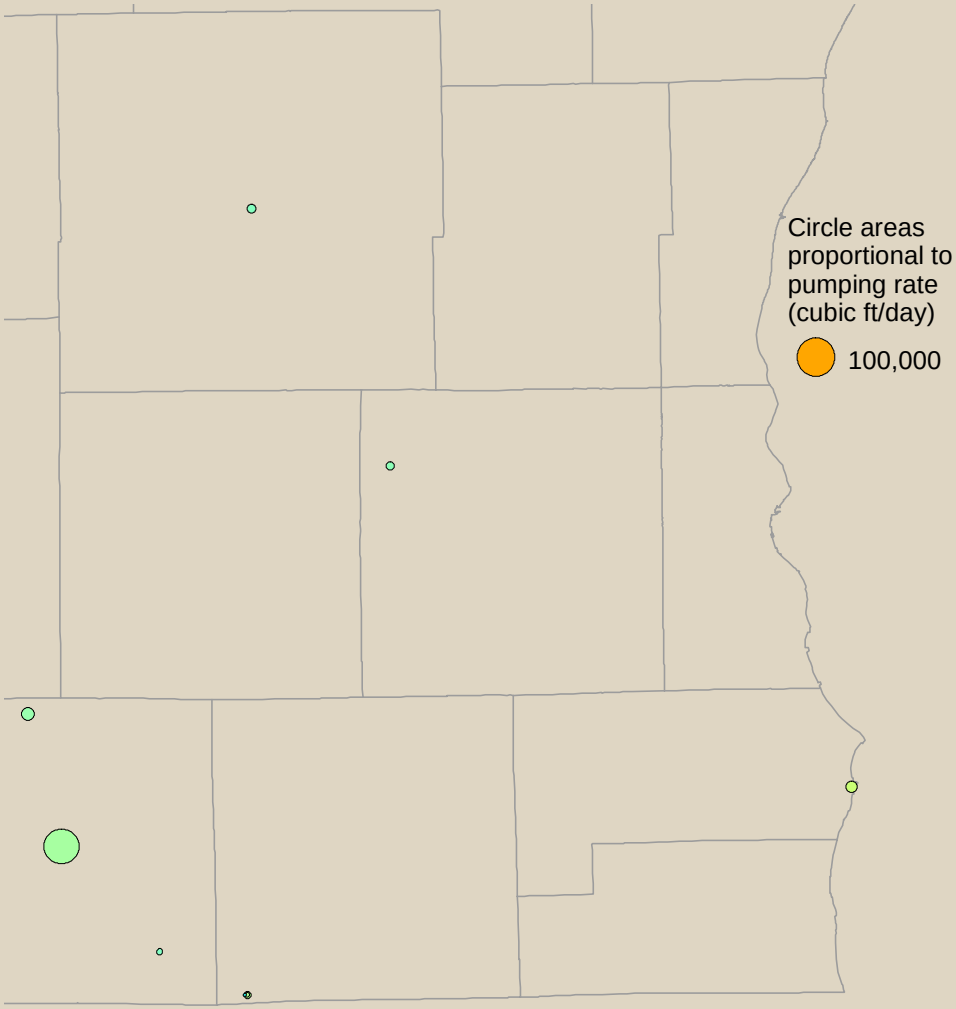
Water Levels in the Sandstone Aquifer
(feet above sea level)

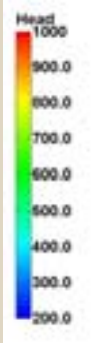
Well Locations and Pumping Rates

Shallow Deep

1864-1880





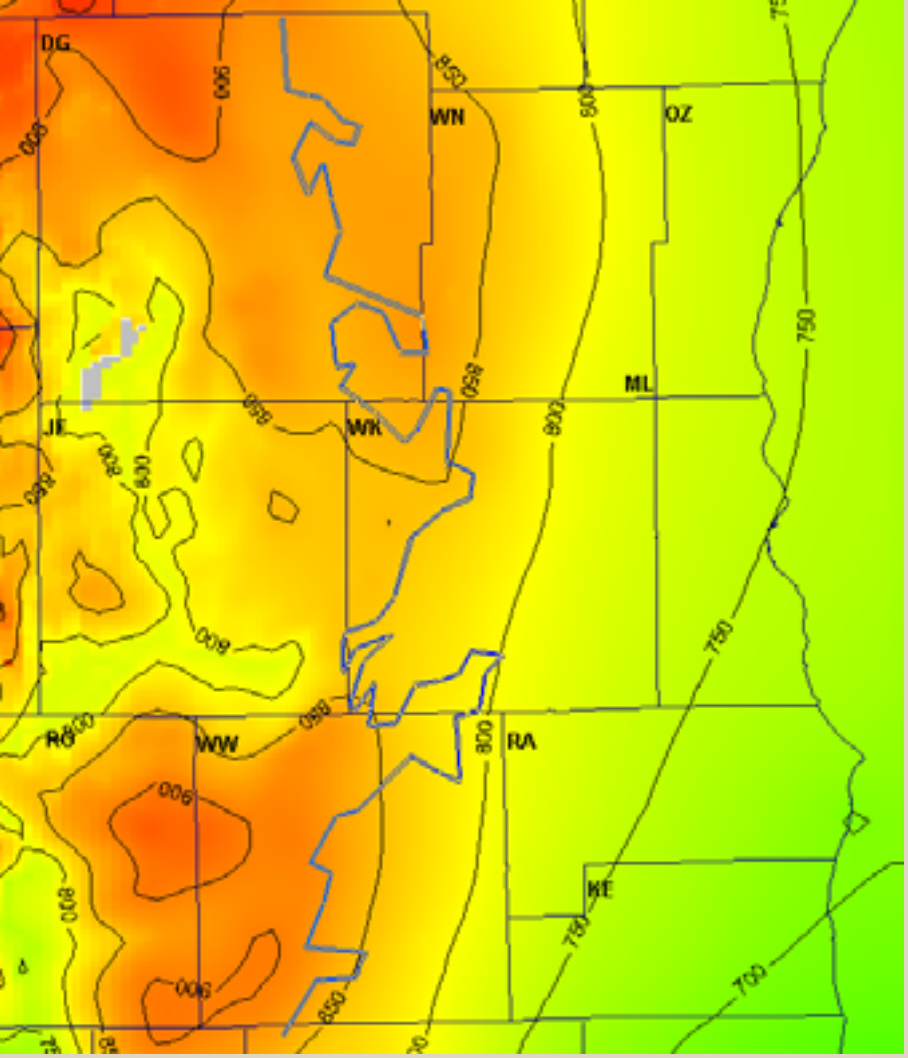


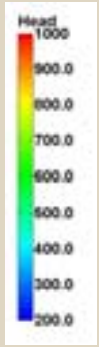
Water Levels in the Sandstone Aquifer
(feet above sea level)

Well Locations and Pumping Rates

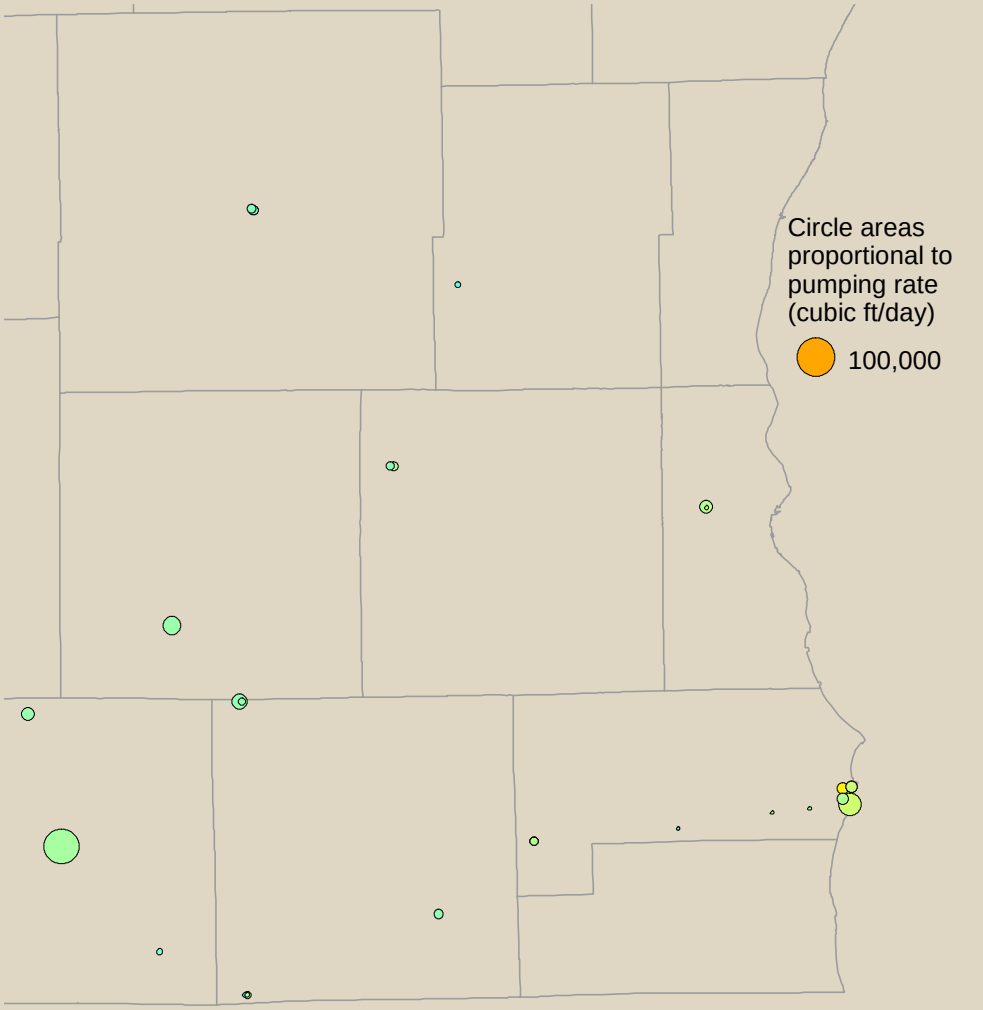
Shallow Deep

1880-1900





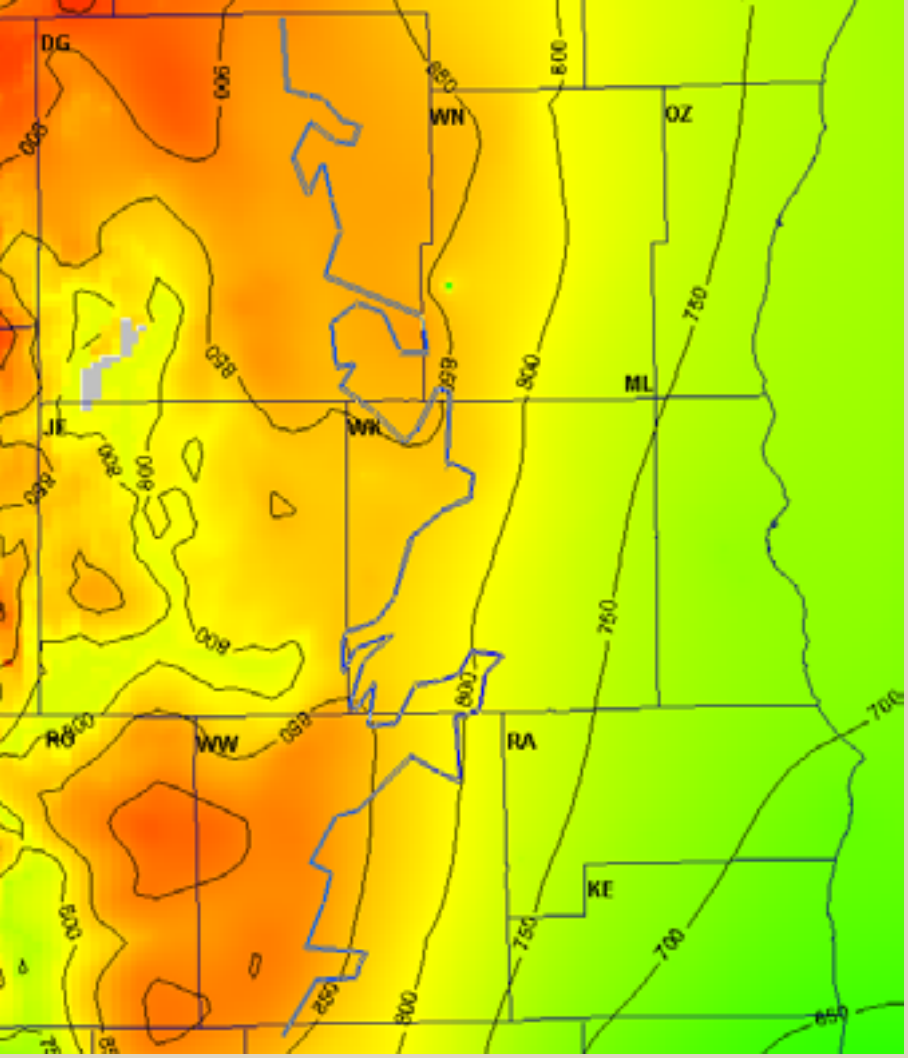
Water Levels in the Sandstone Aquifer
(feet above sea level)

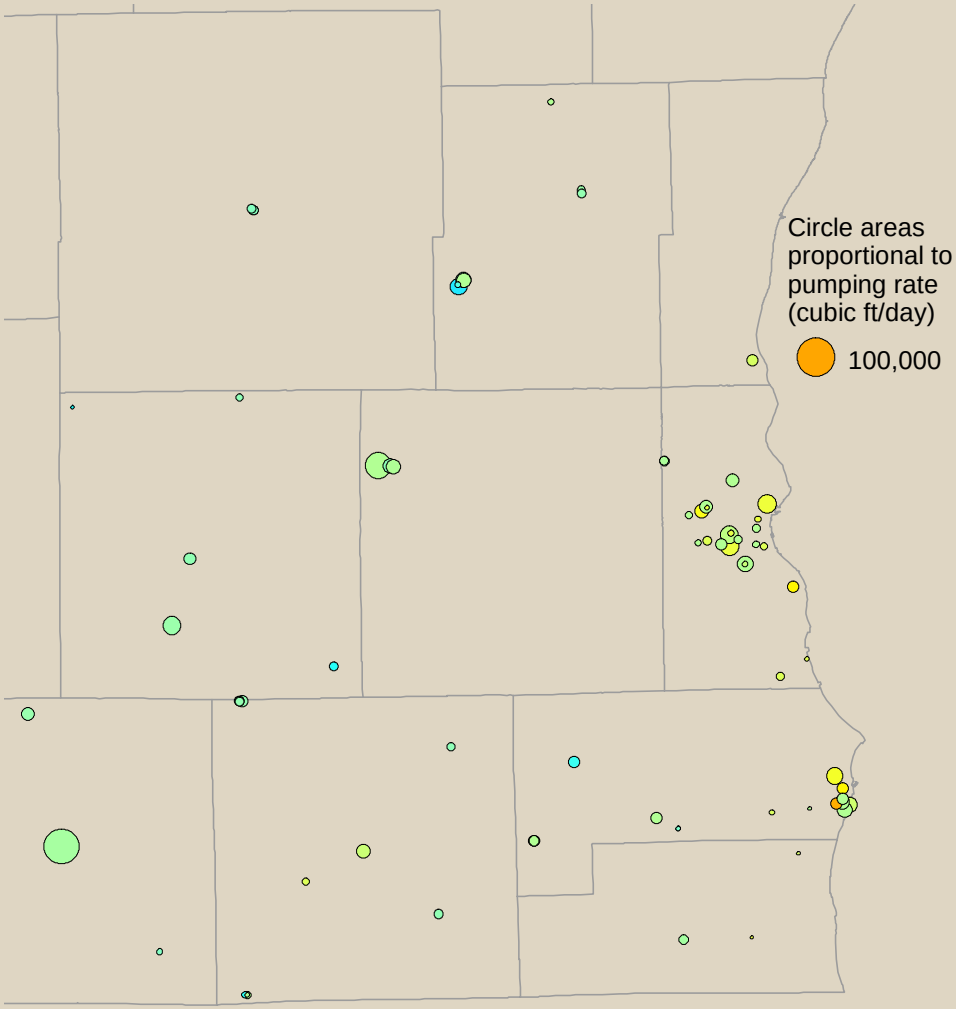


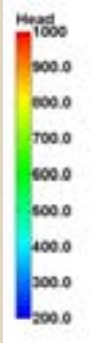
Well Locations and Pumping Rates

Shallow Deep

1900-1910





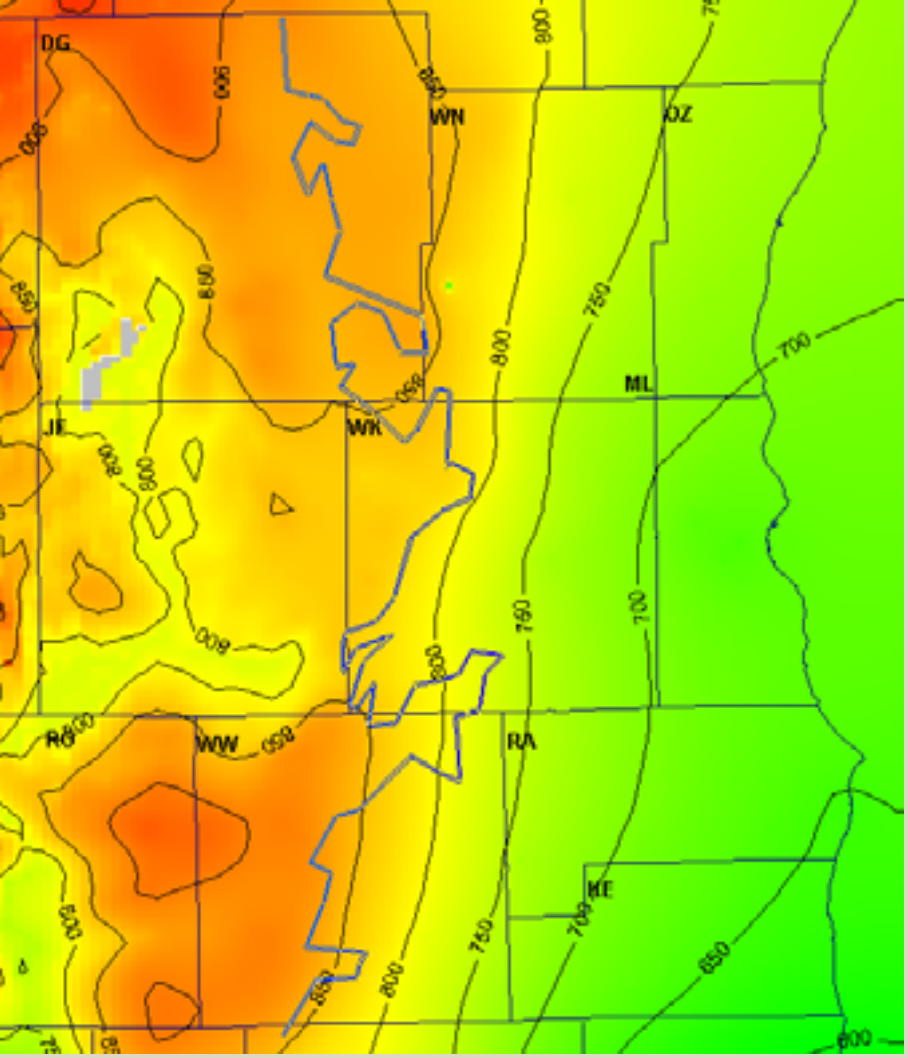


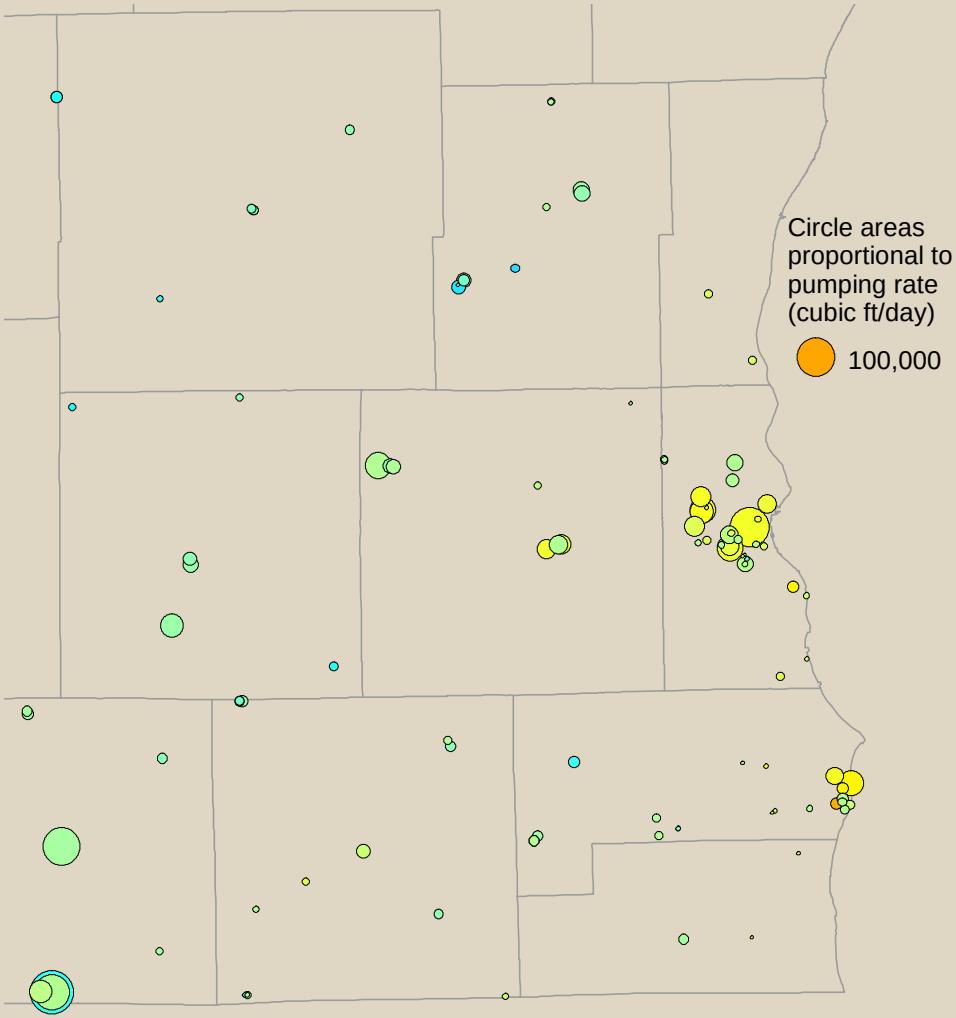
Water Levels in the Sandstone Aquifer
(feet above sea level)

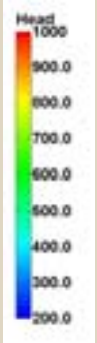
Well Locations and Pumping Rates

Shallow Deep

1910-1920





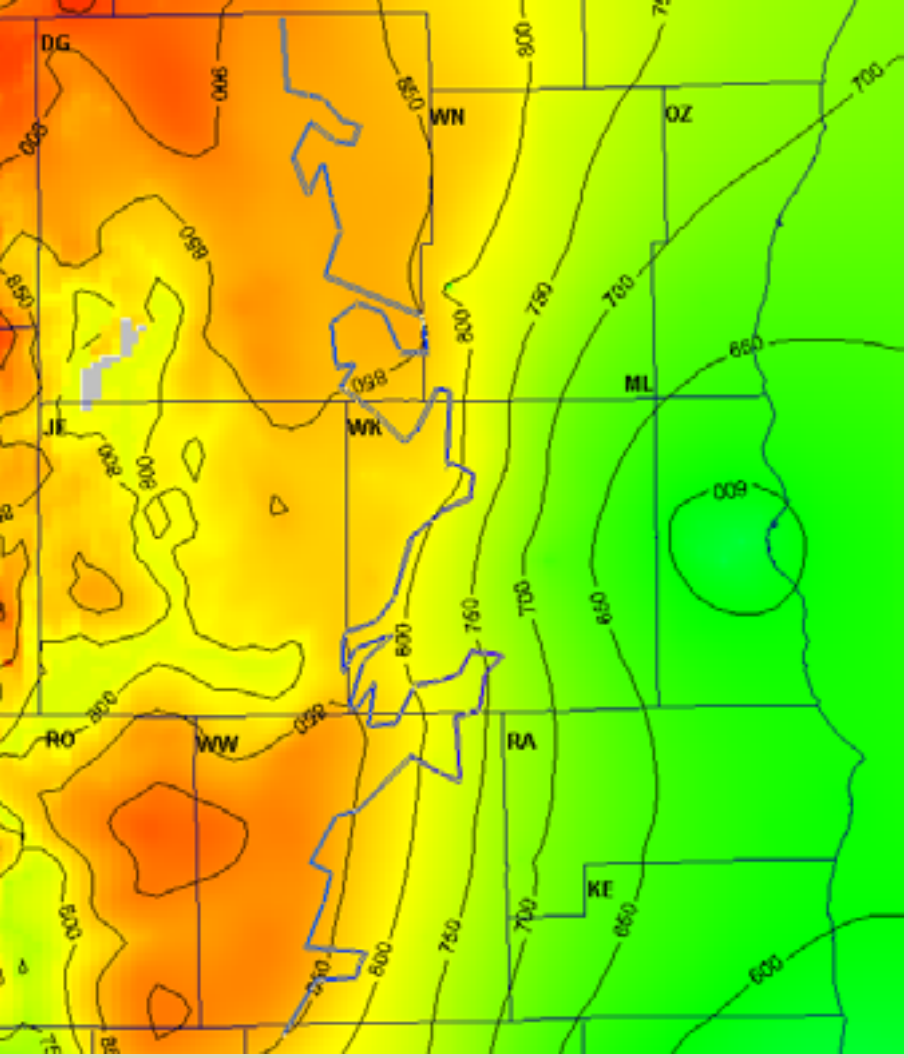


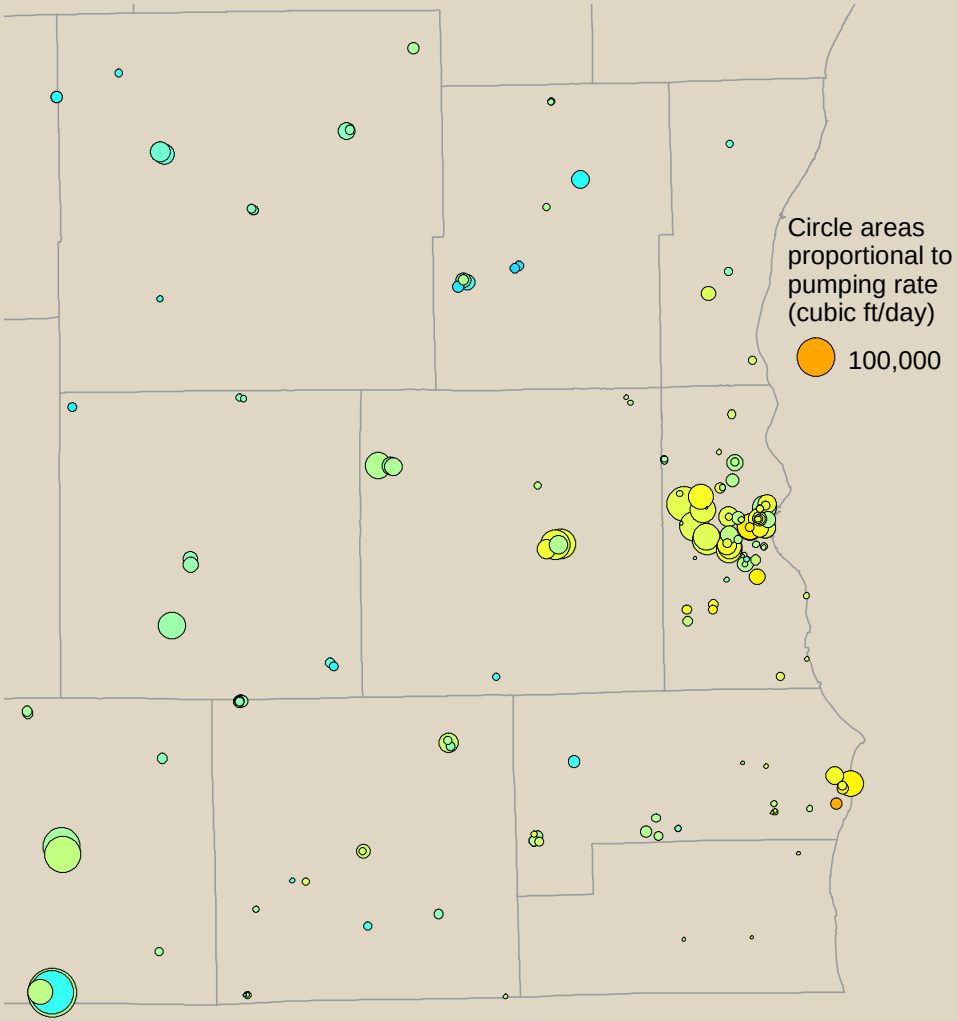
Water Levels in the Sandstone Aquifer
(feet above sea level)

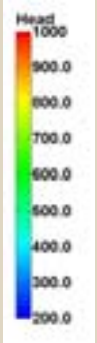
Well Locations and Pumping Rates

Shallow Deep

1920-1930





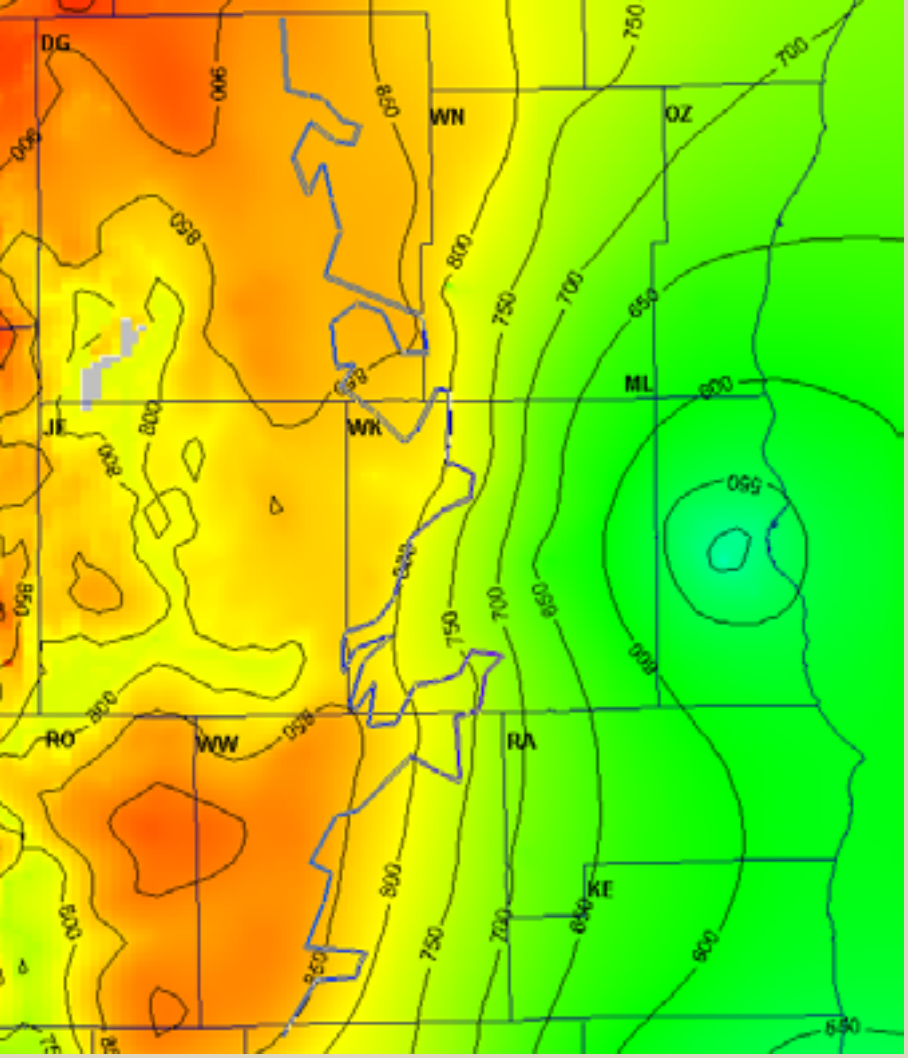


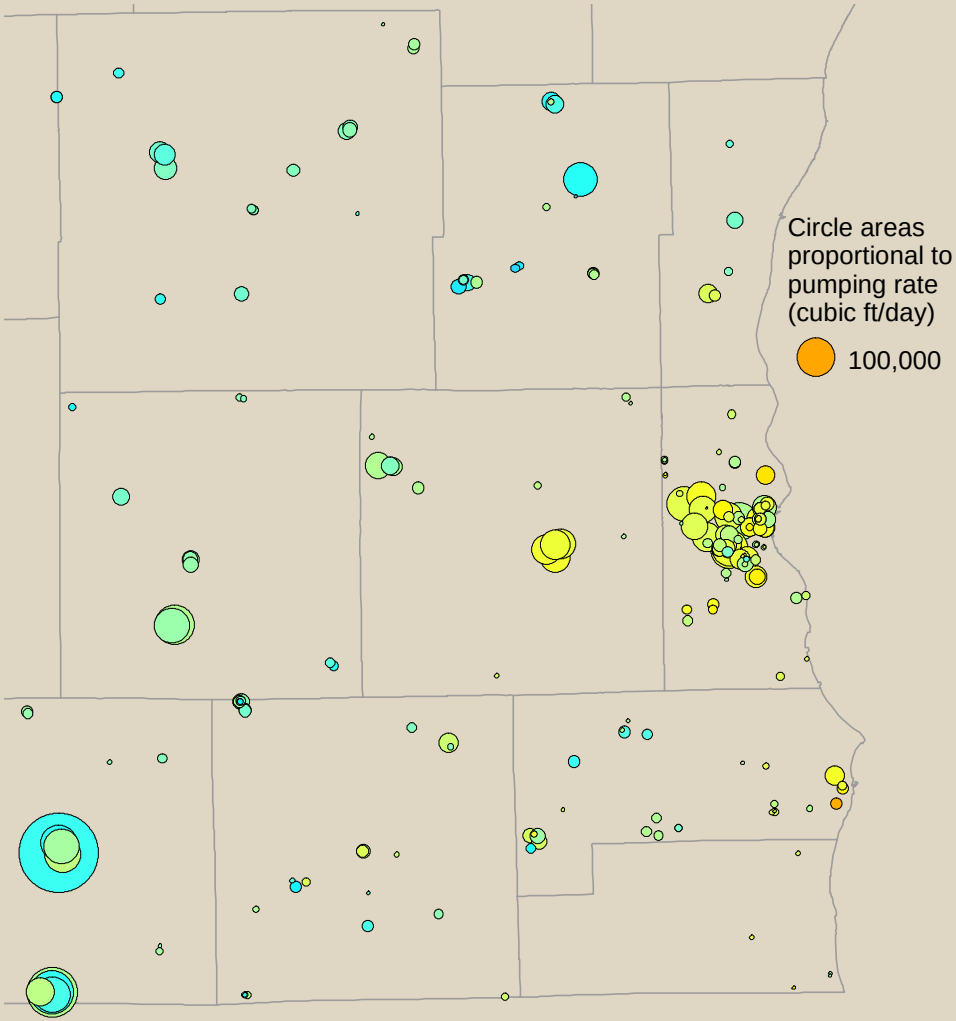
Water Levels in the Sandstone Aquifer
(feet above sea level)

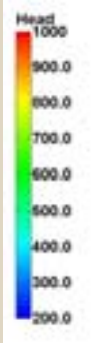
Well Locations and Pumping Rates

Shallow Deep

1930-1940





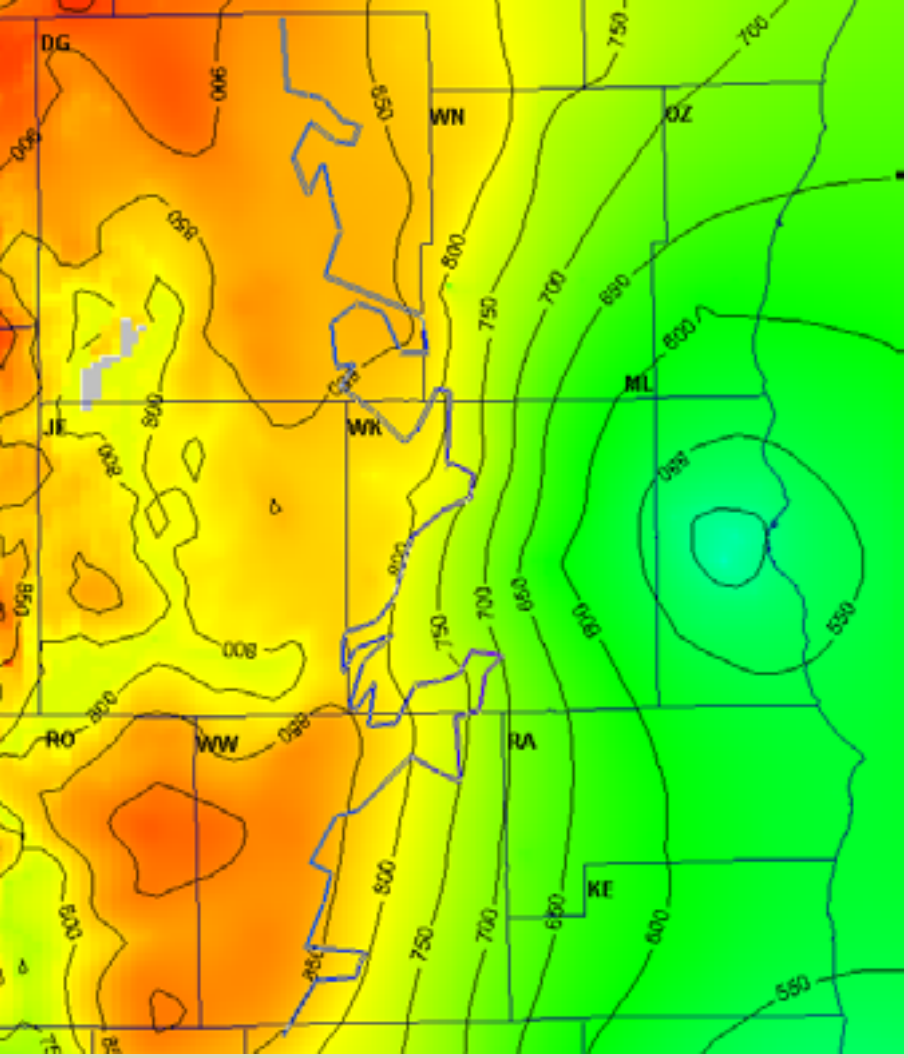


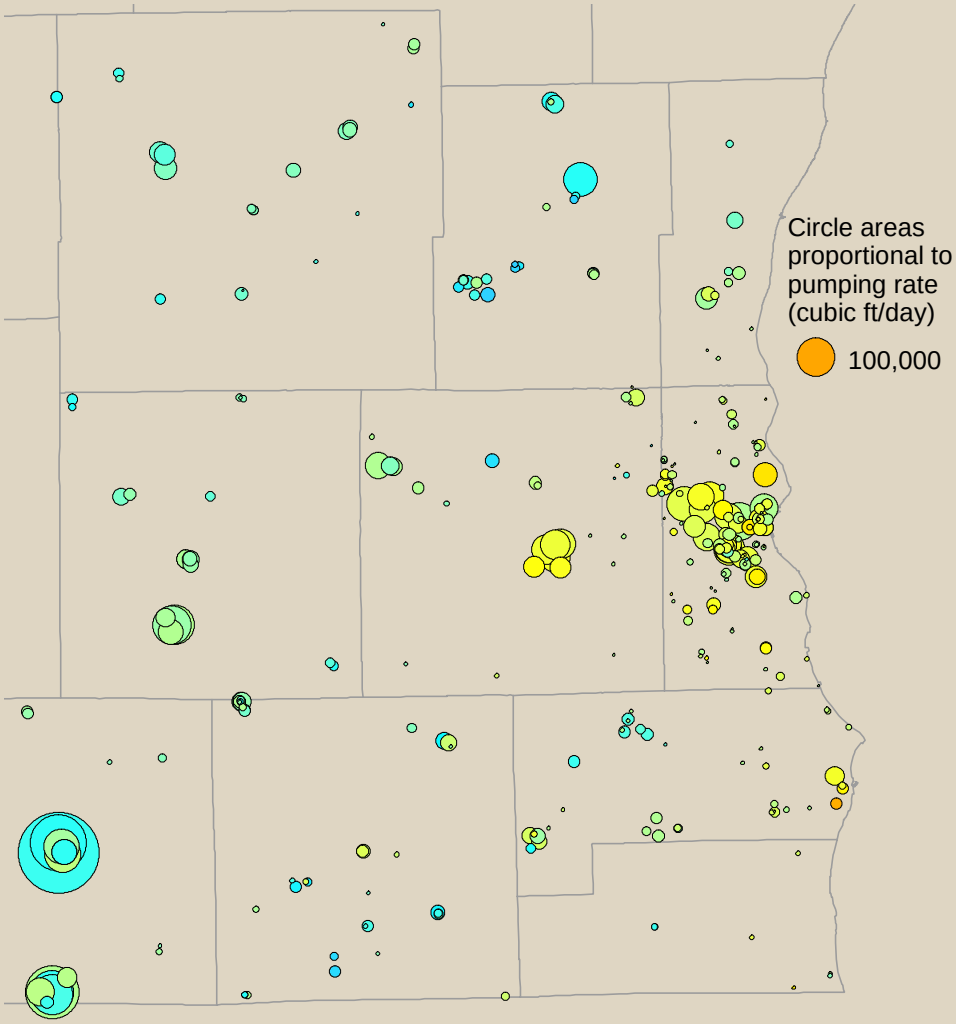
Water Levels in the Sandstone Aquifer
(feet above sea level)

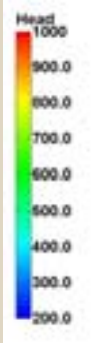
Well Locations and Pumping Rates

Shallow Deep

1940-1945





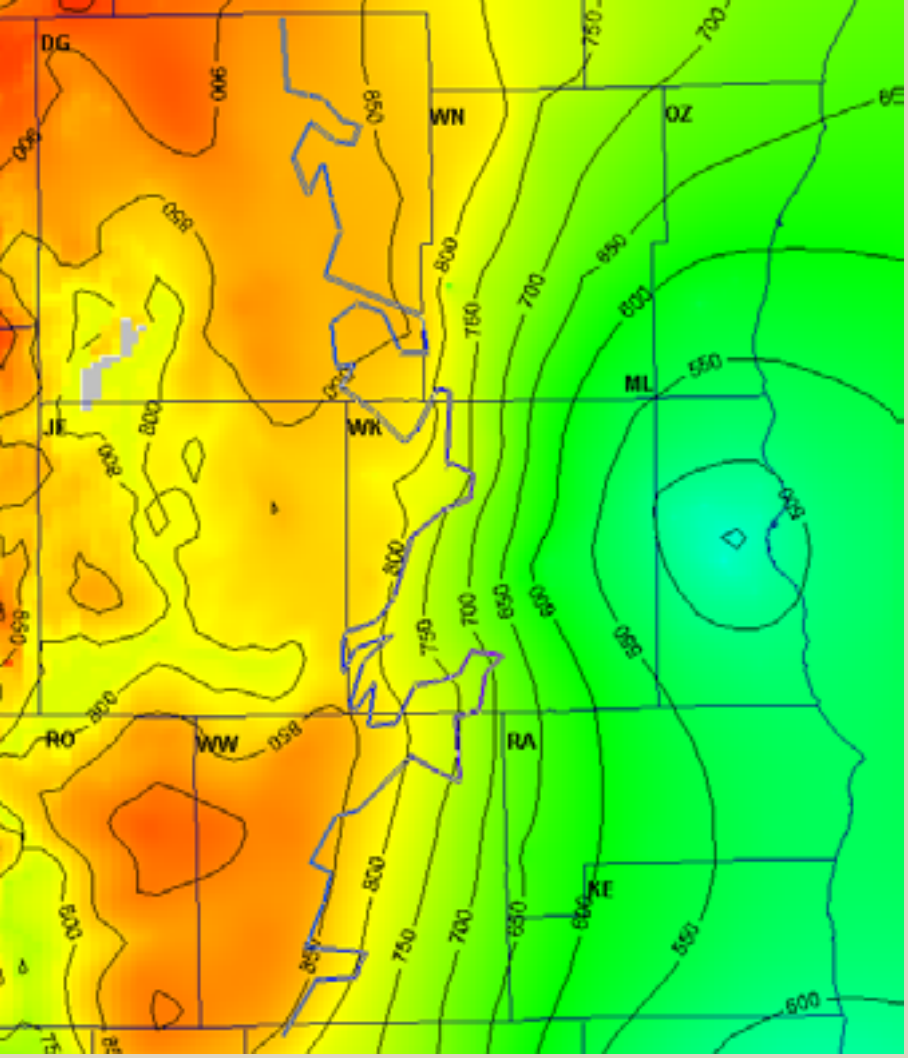


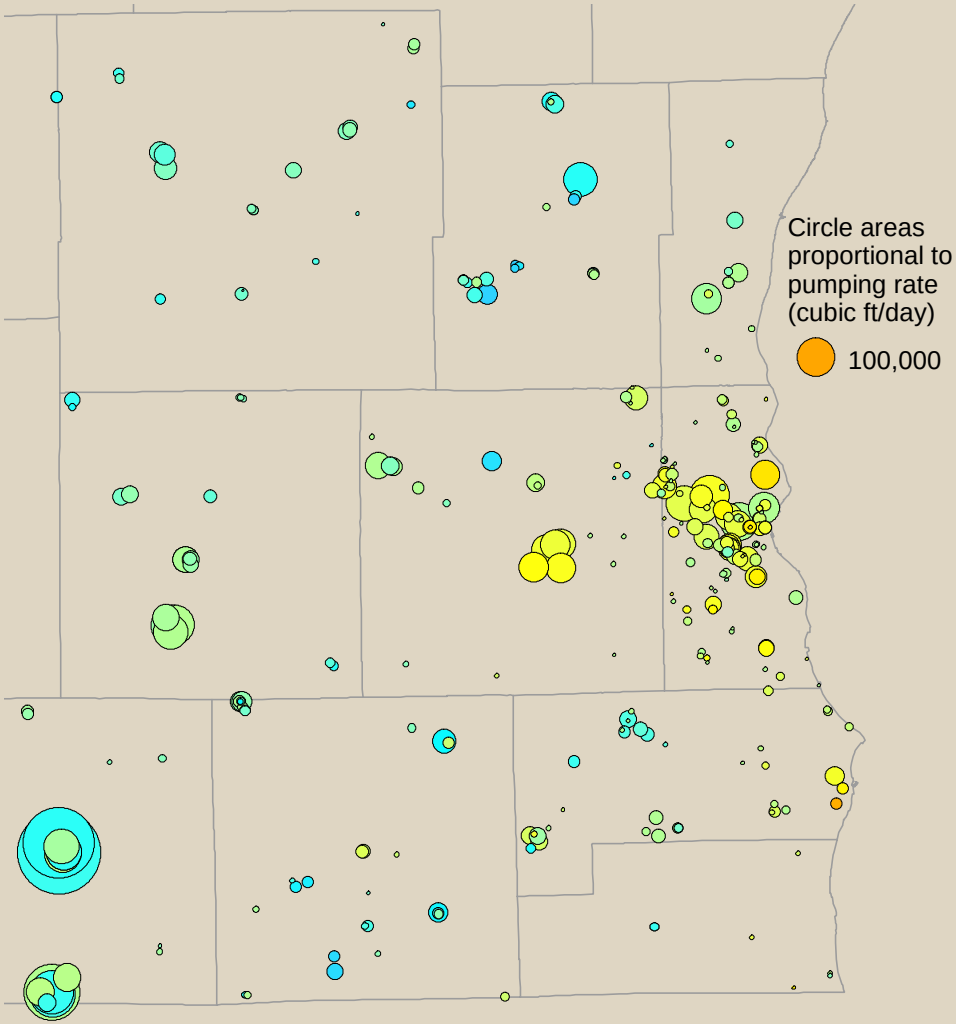
Water Levels in the Sandstone Aquifer
(feet above sea level)

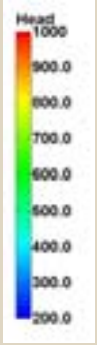
Well Locations and Pumping Rates

Shallow Deep

1945-1950





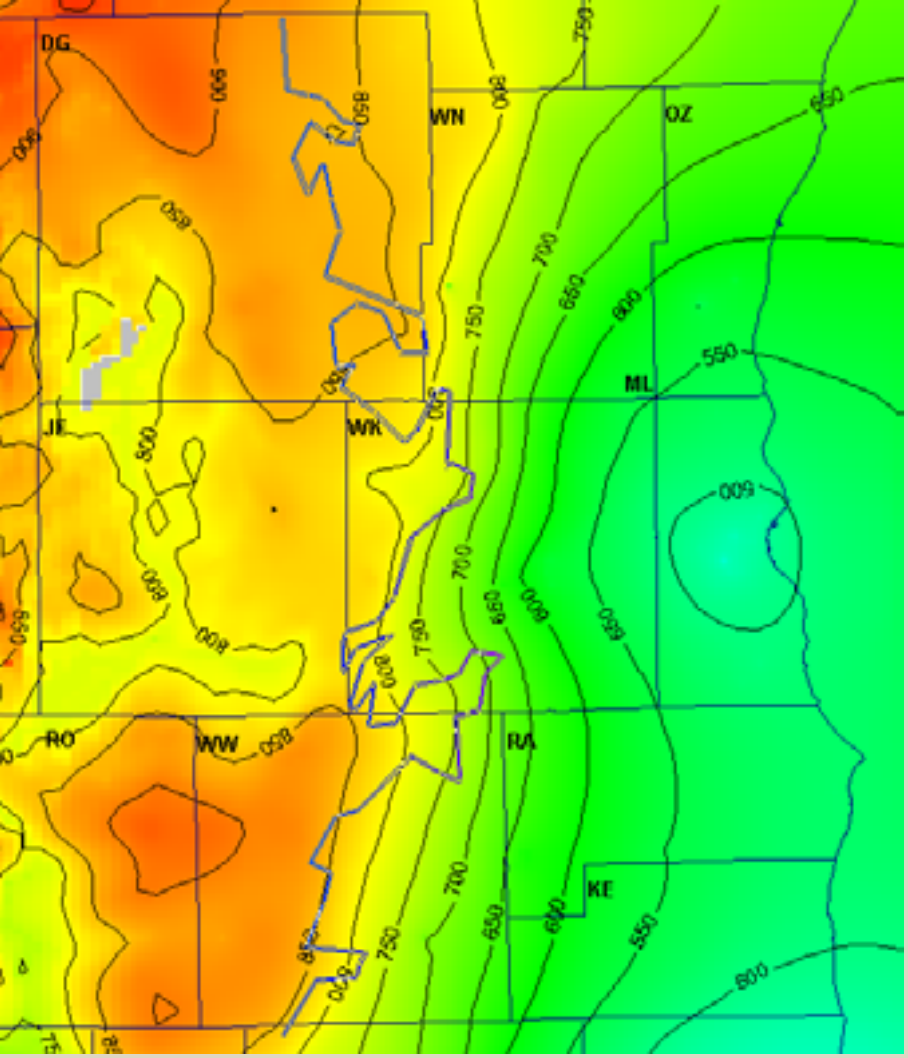


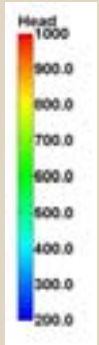
Water Levels in the Sandstone Aquifer
(feet above sea level)

Well Locations and Pumping Rates

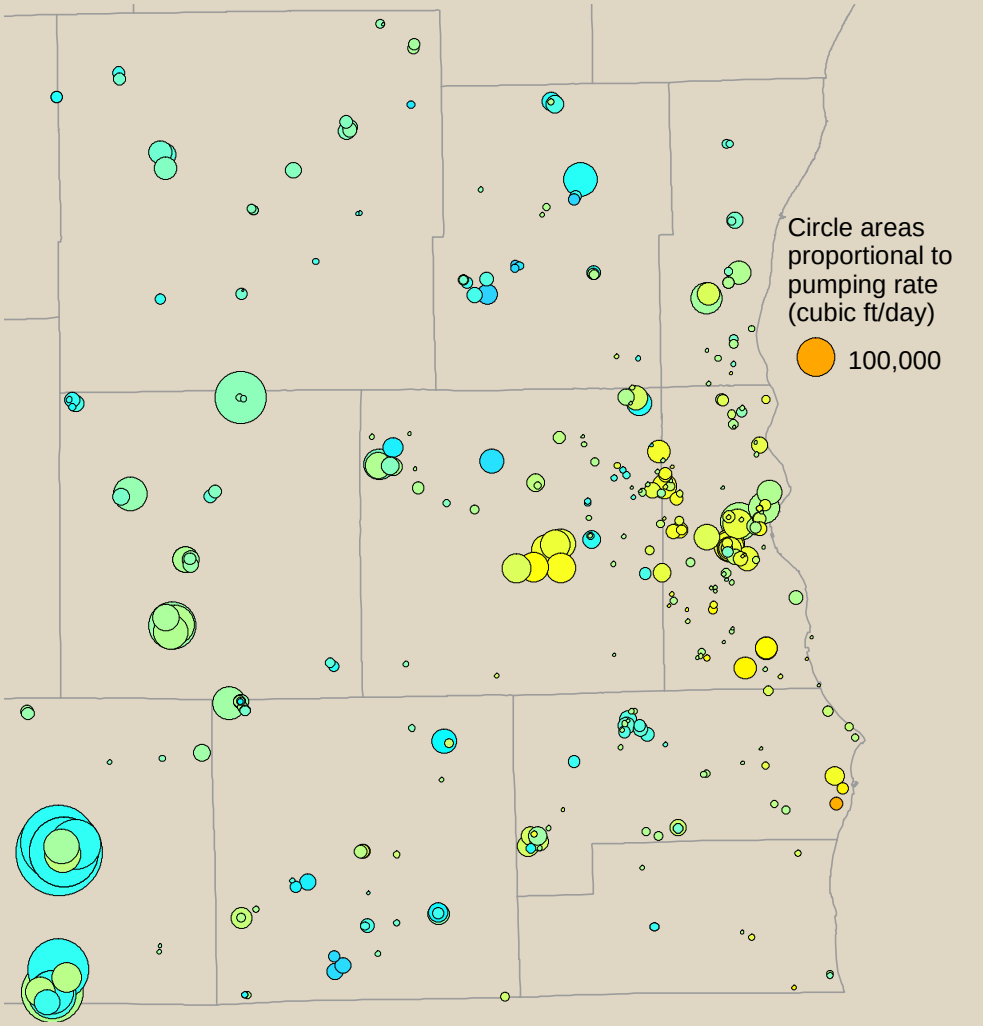
Shallow Deep

1950-1961





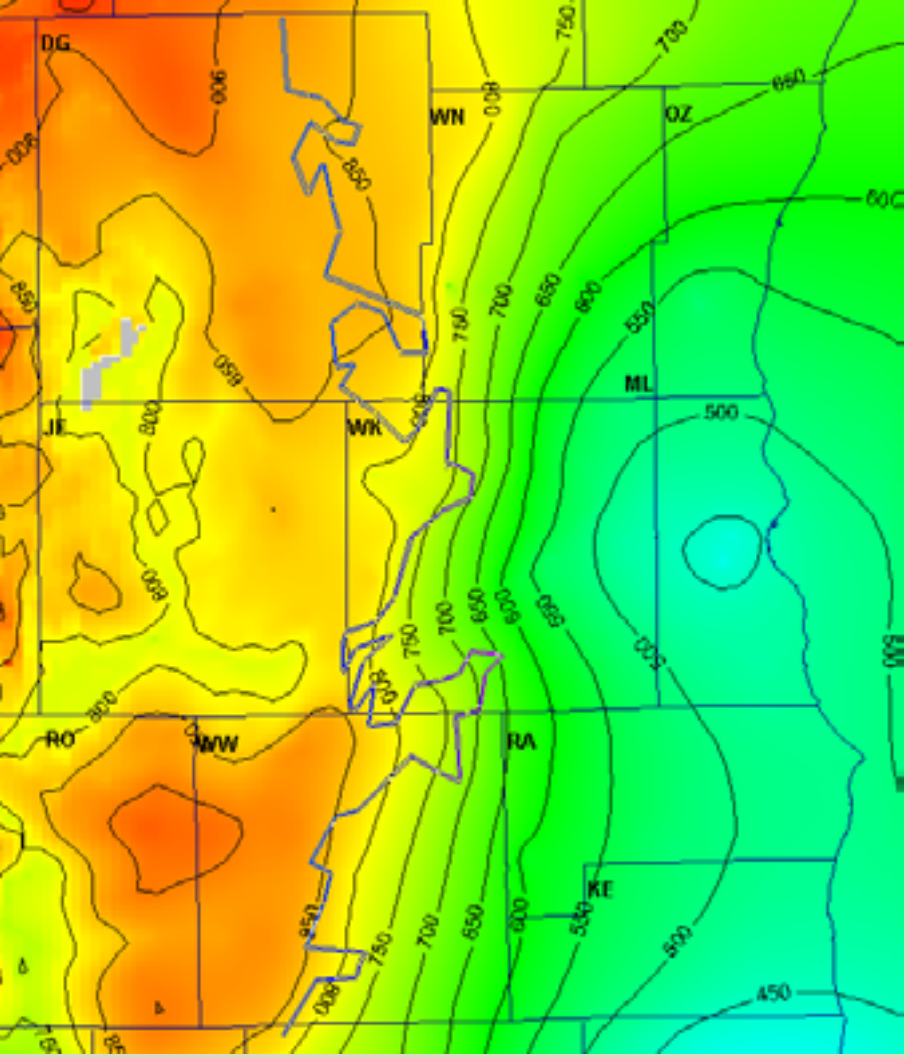
Water Levels in the Sandstone Aquifer
(feet above sea level)

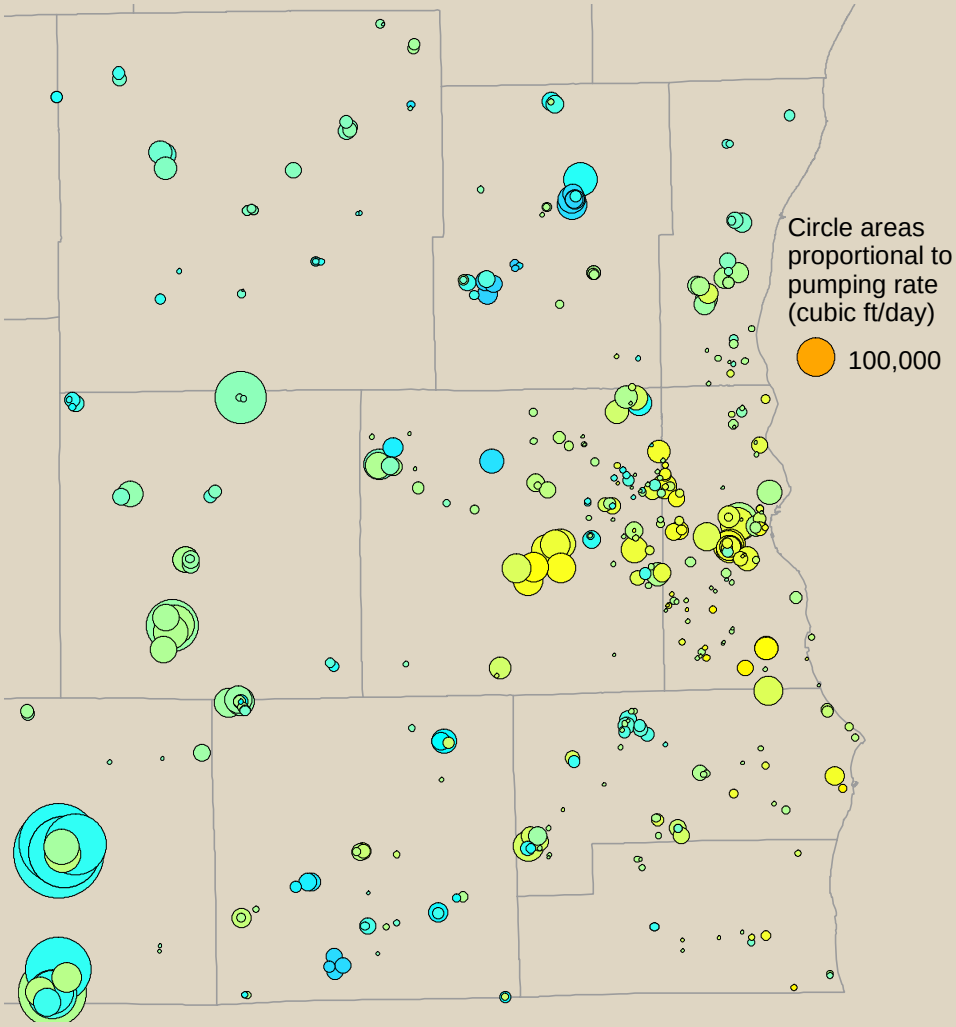


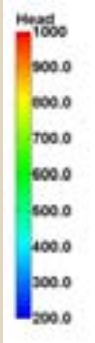
Well Locations and Pumping Rates

Shallow Deep

1961-1965





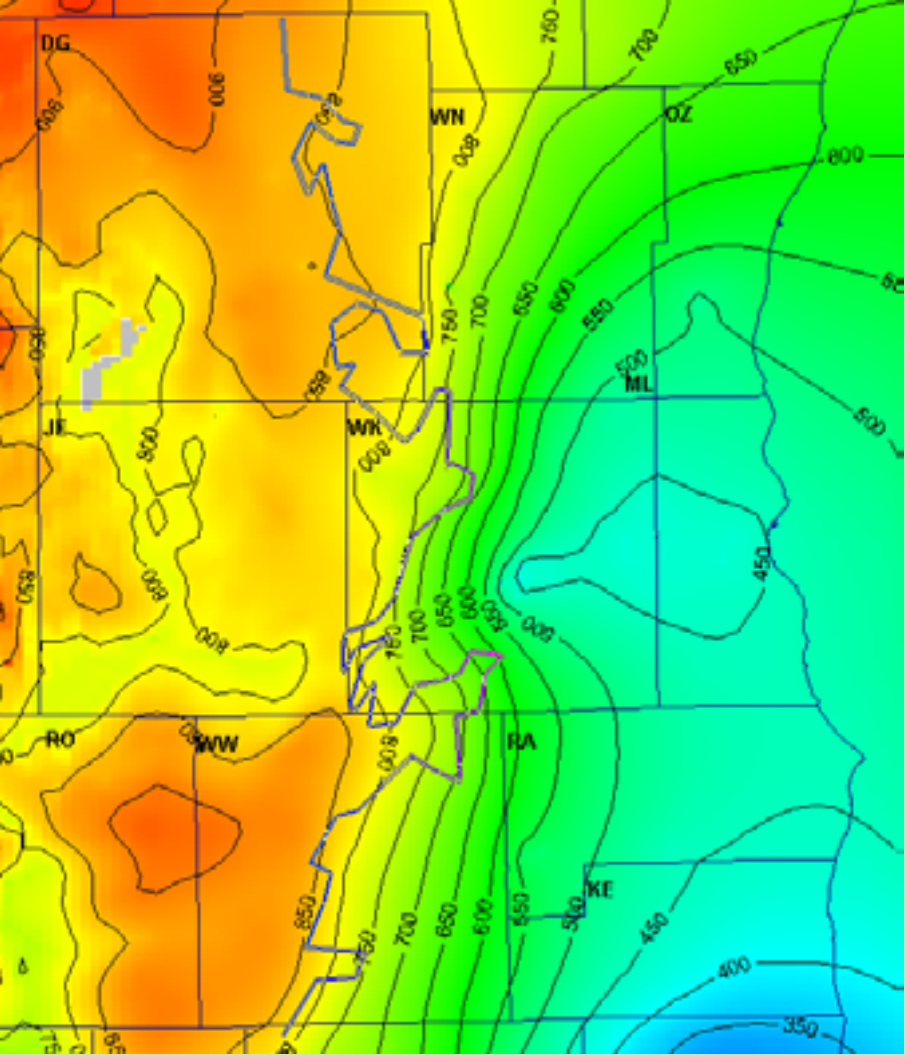


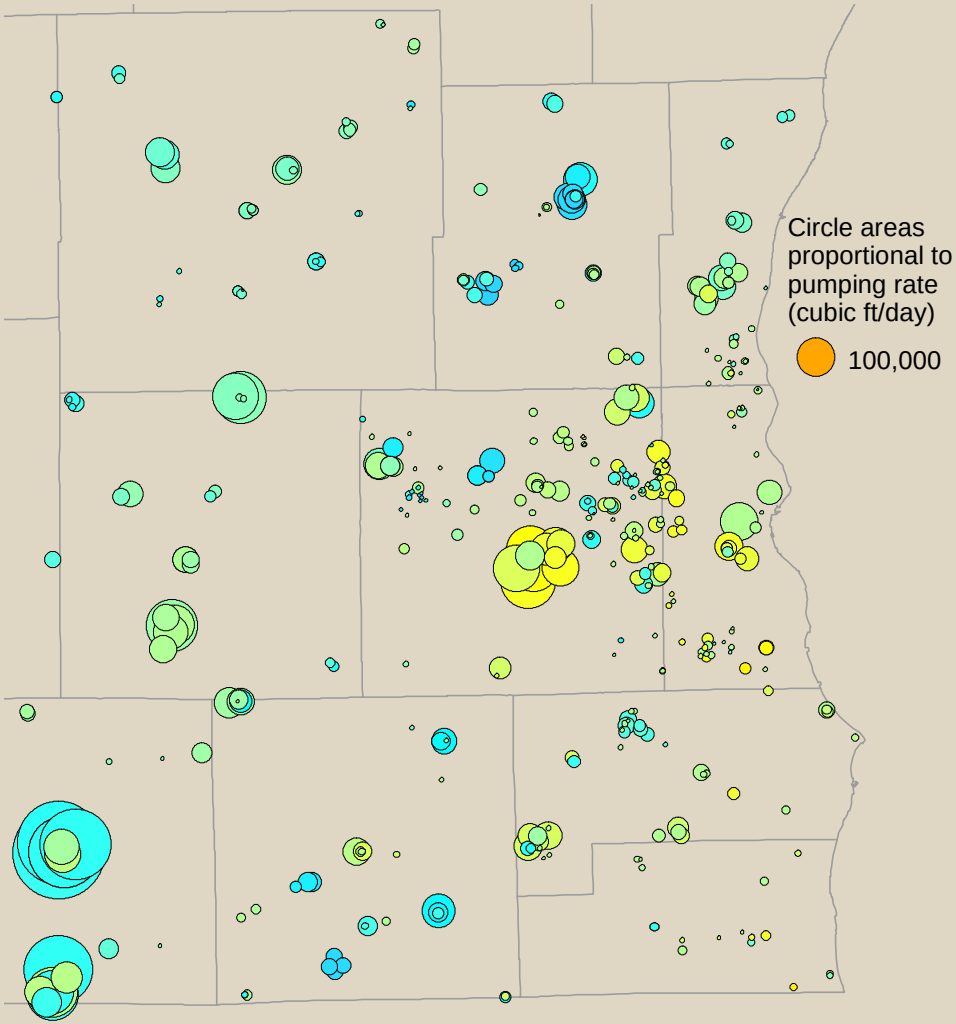
Water Levels in the Sandstone Aquifer
(feet above sea level)

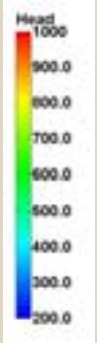
Well Locations and Pumping Rates

Shallow Deep

1965-1970





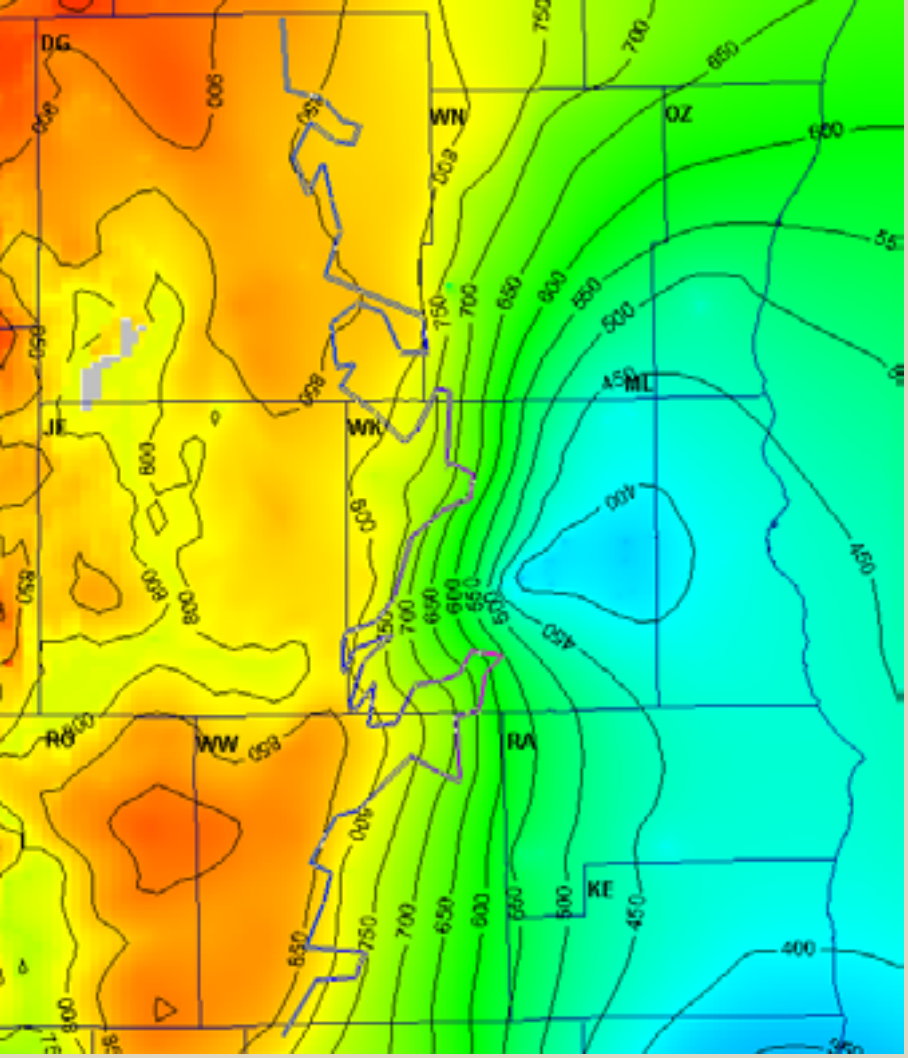


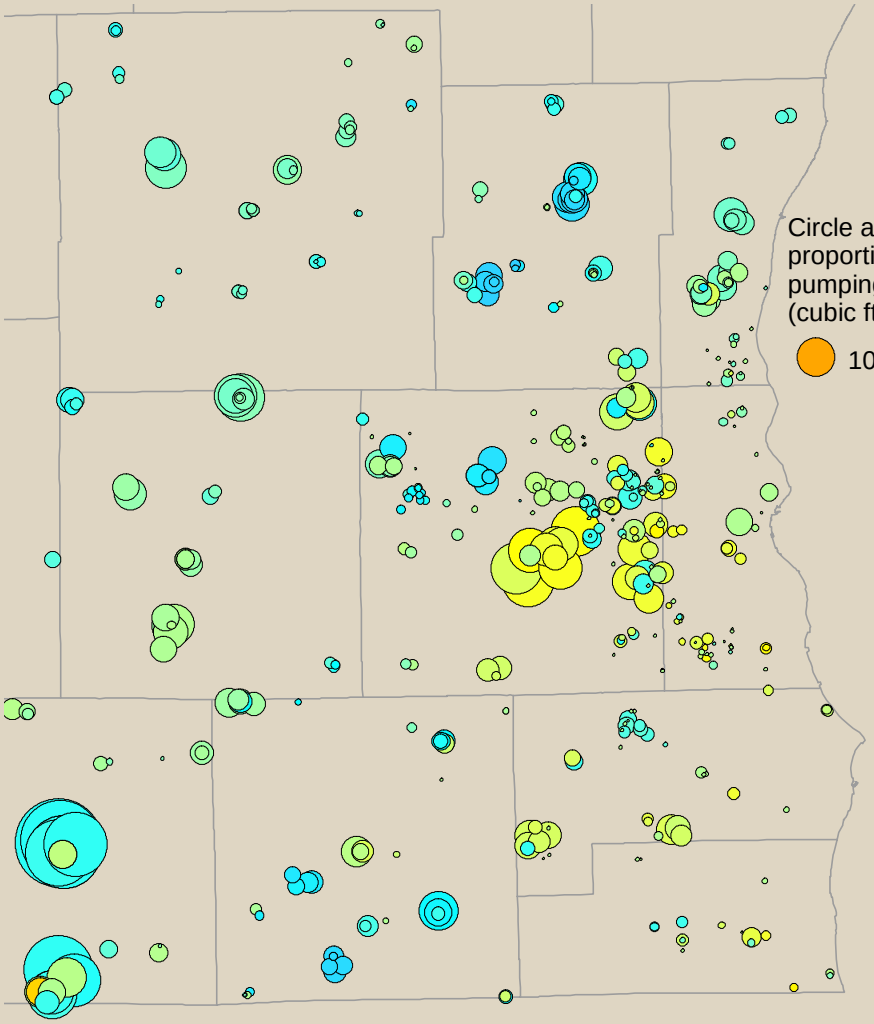
Water Levels in the Sandstone Aquifer
(feet above sea level)

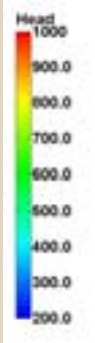
Well Locations and Pumping Rates

Shallow Deep

1970-1980





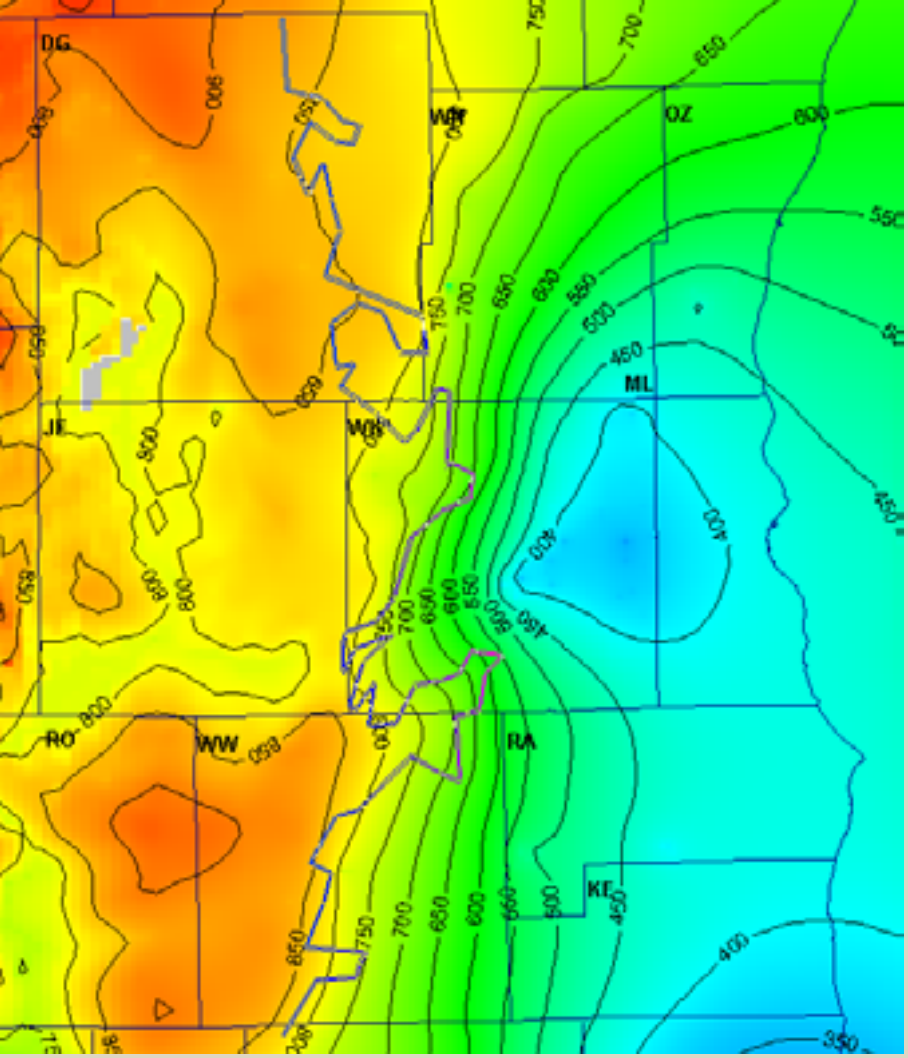


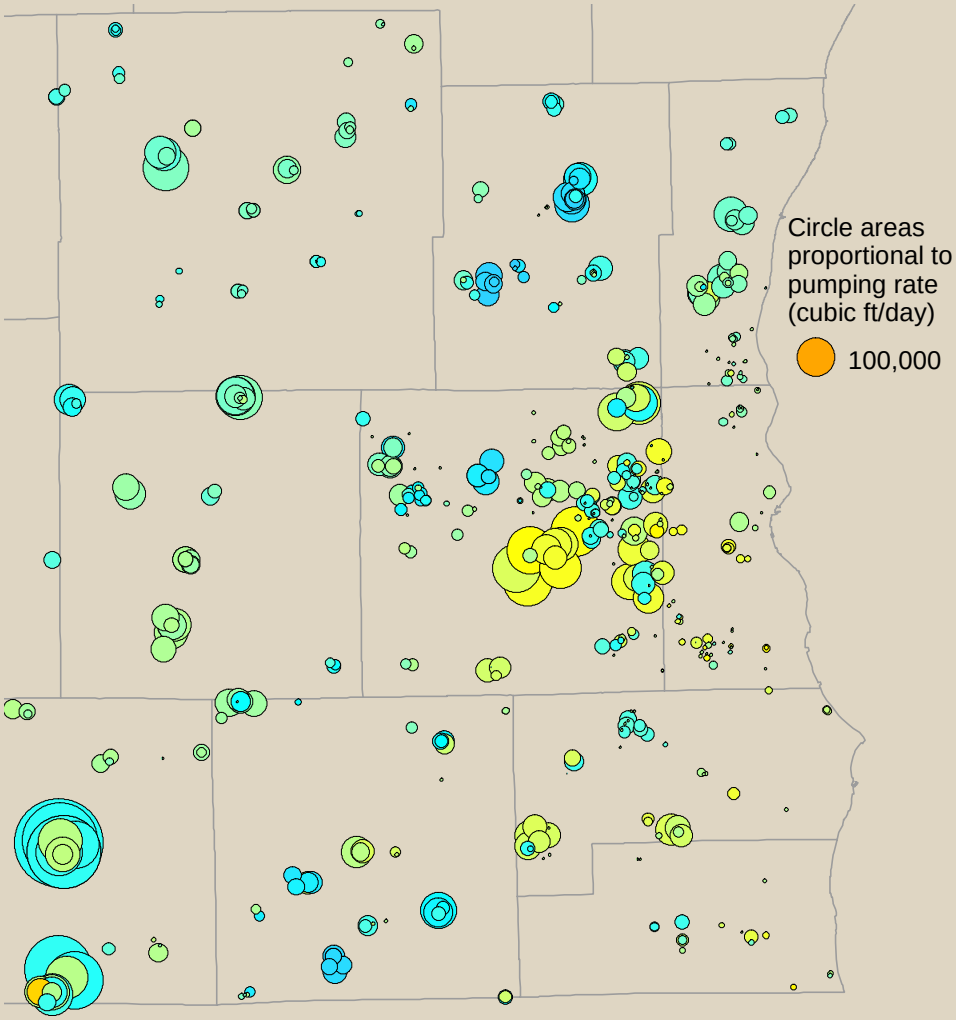
Water Levels in the Sandstone Aquifer
(feet above sea level)

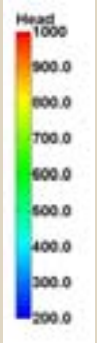
Well Locations and Pumping Rates

Shallow Deep

1980-1985





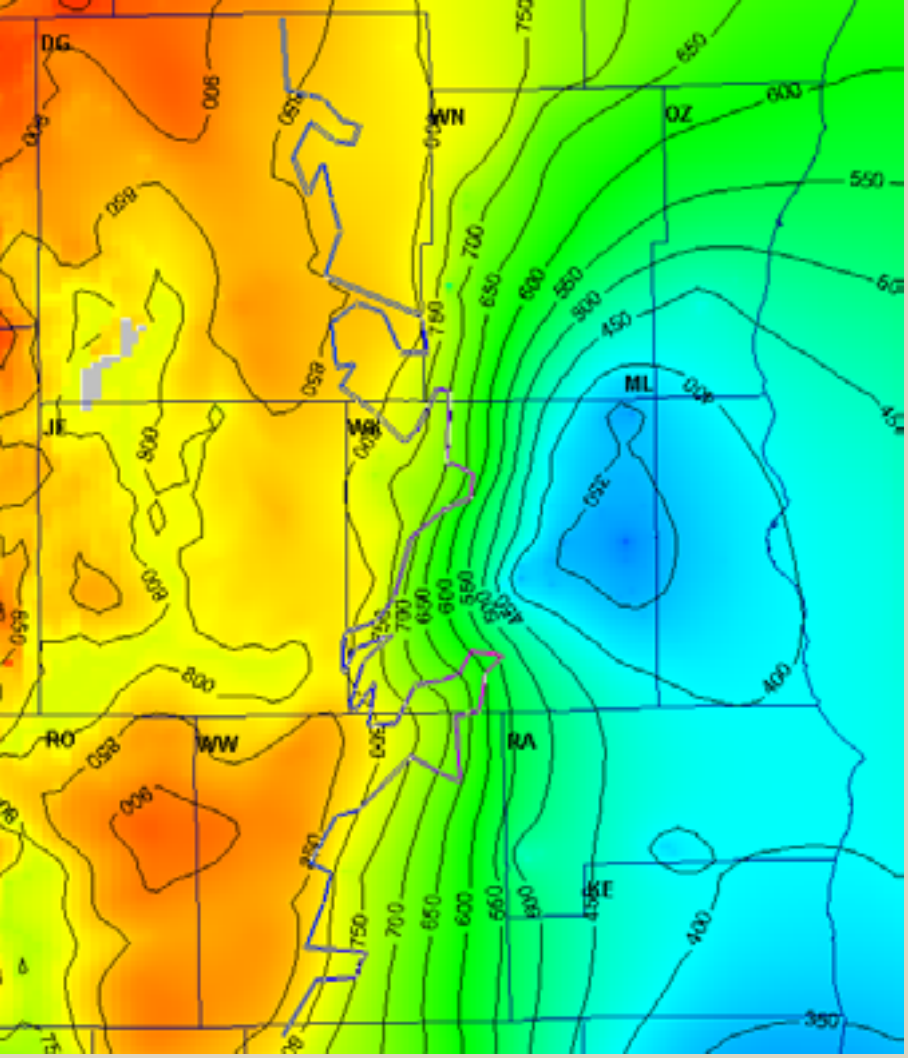


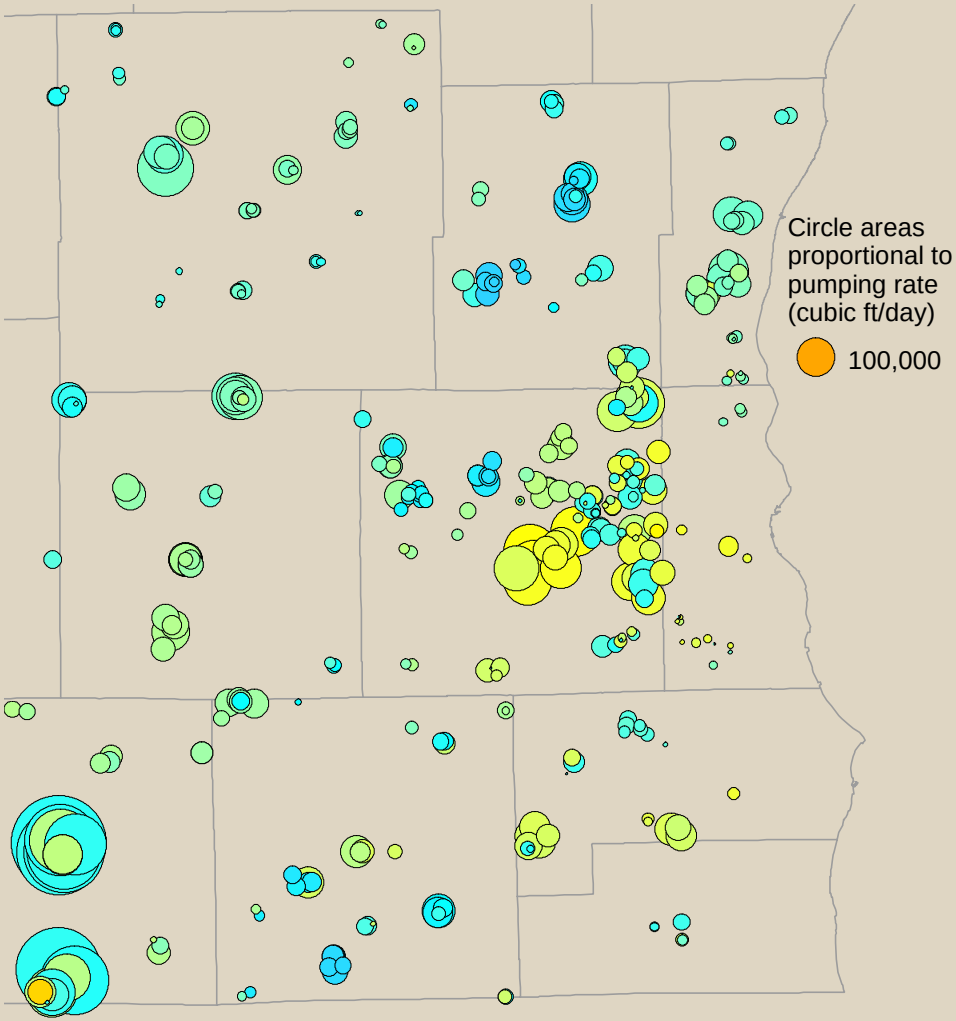
Water Levels in the Sandstone Aquifer
(feet above sea level)

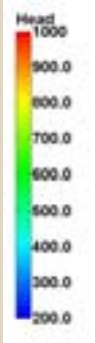
Well Locations and Pumping Rates

Shallow Deep

1985-1990





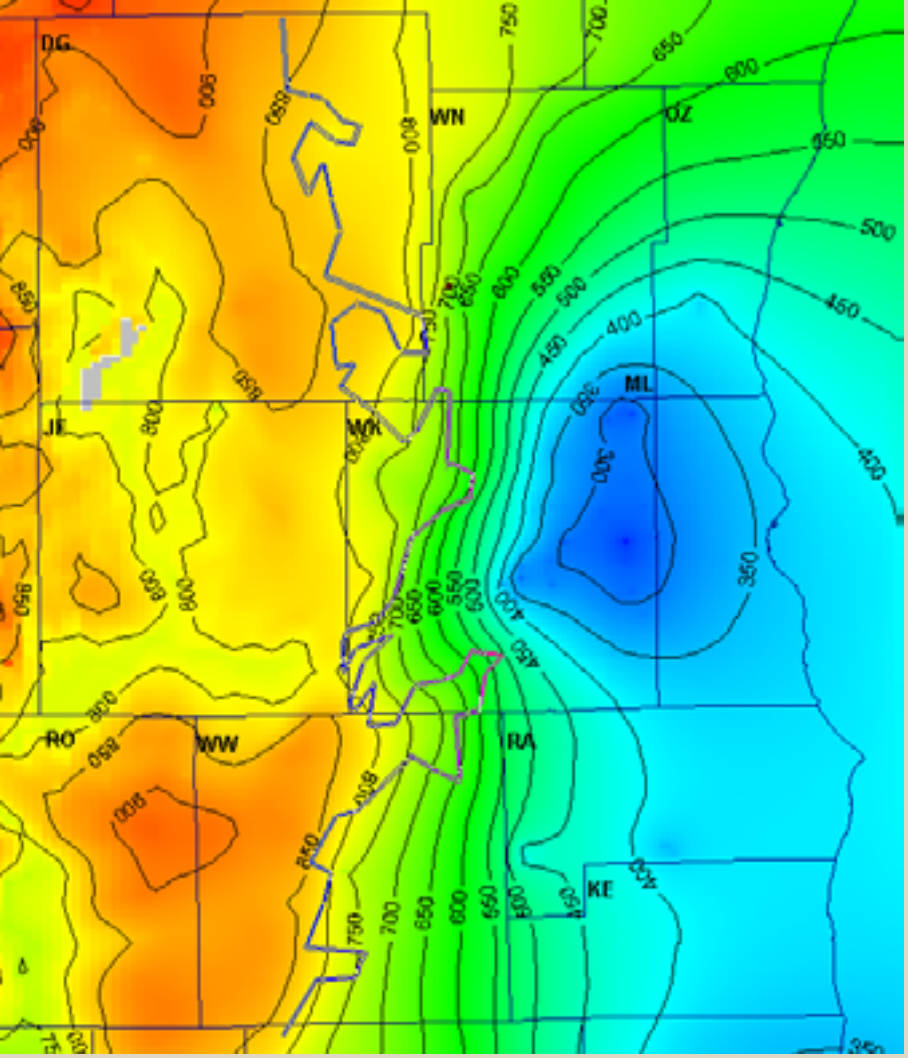


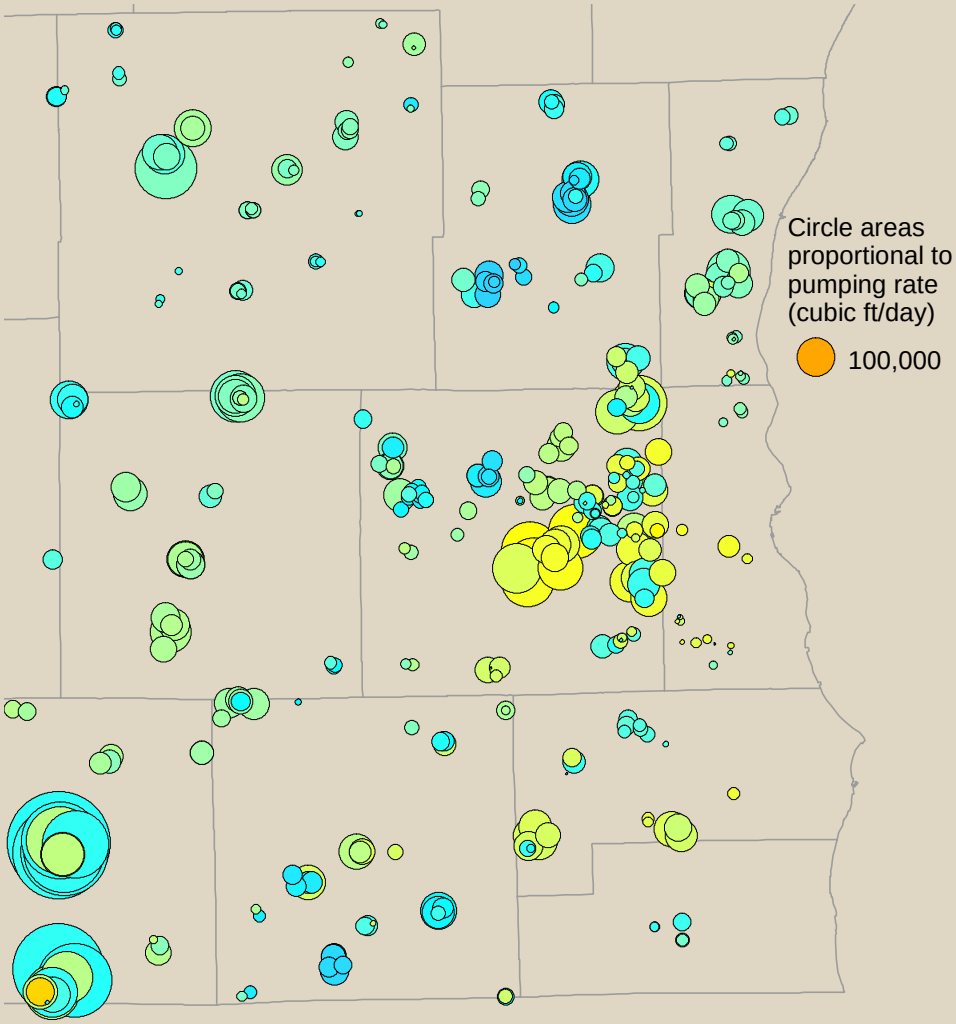
Water Levels in the Sandstone Aquifer
(feet above sea level)

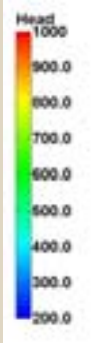
Well Locations and Pumping Rates

Shallow Deep

1990-2000







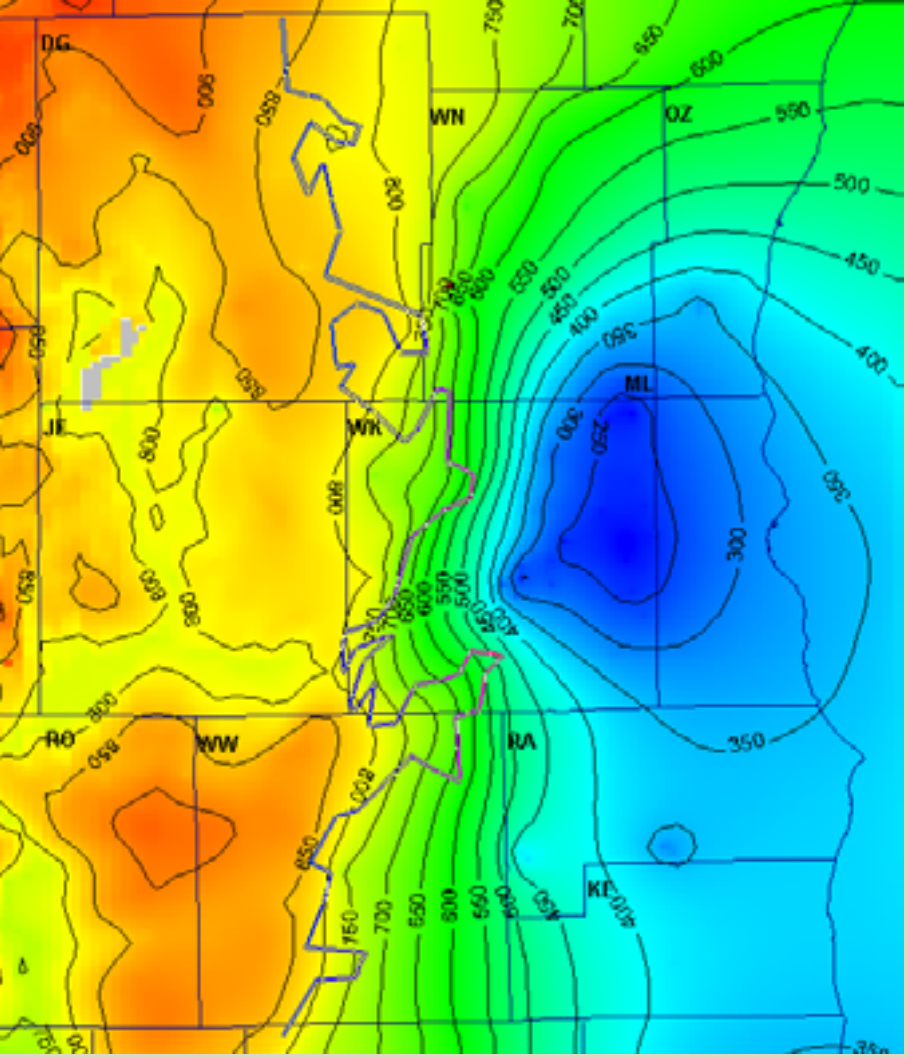
Water Levels in the Sandstone Aquifer
(feet above sea level)

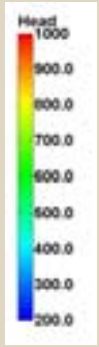
Well Locations and Pumping Rates

Shallow Deep

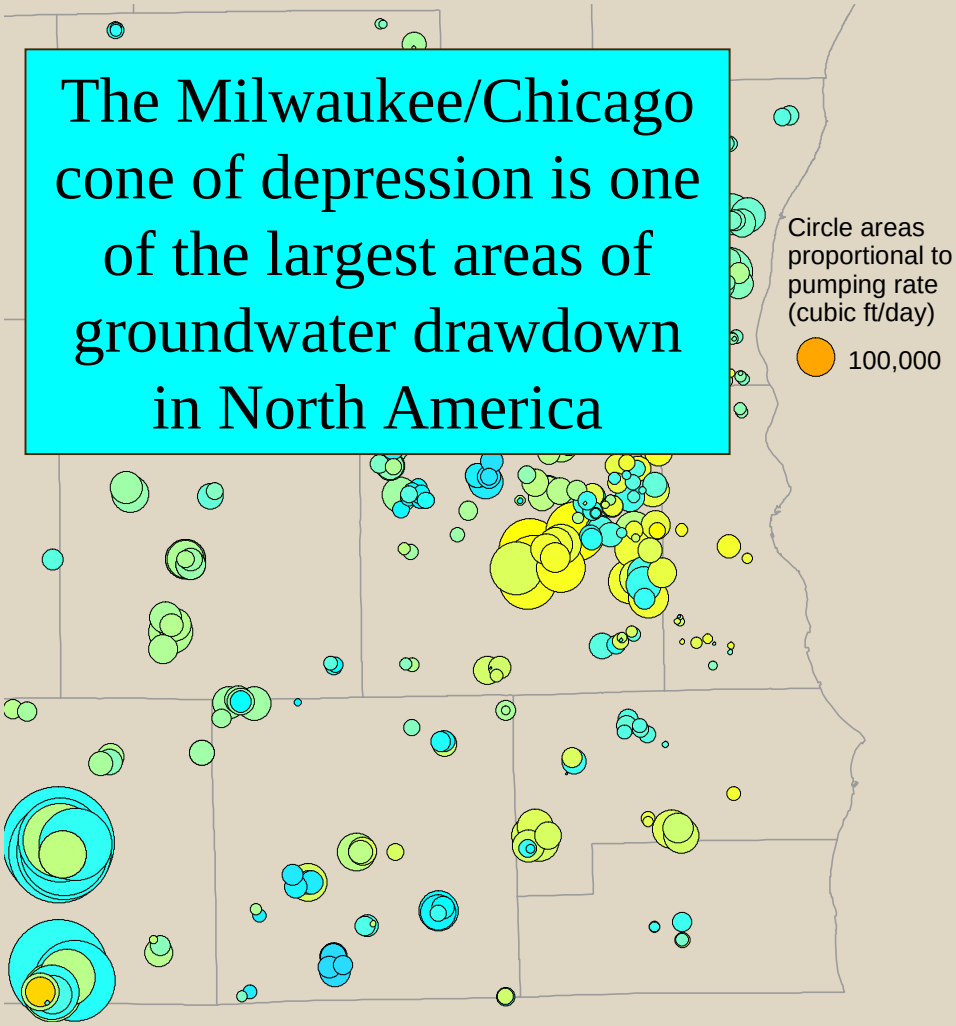
2000-2010

The Milwaukee/Chicago cone of depression is one of the largest areas of groundwater drawdown in North America





Water Levels in the Sandstone Aquifer
(feet above sea level)



Well Locations and Pumping Rates

Shallow Deep

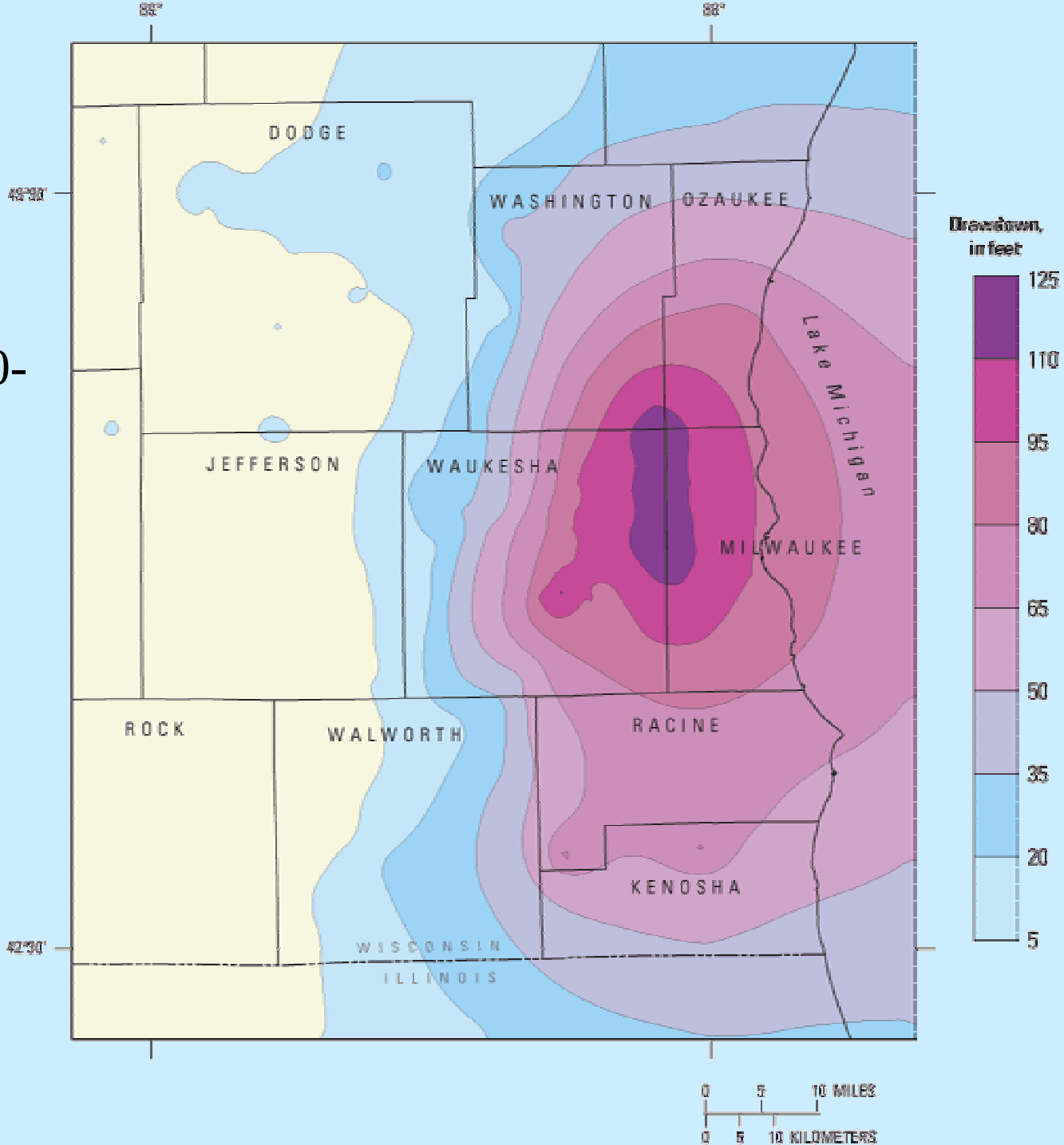
2010-2020

Cone of depression:

- The major pumping center in southeastern Wisconsin has shifted from the city of Milwaukee to eastern Waukesha County.

- The center of the cone of depression in the deep part of the flow system has shifted westward about eight miles from Milwaukee to near the Village of Elm Grove where deep water levels have dropped about 500 ft since the onset of pumping

Additional drawdown, 2000-2020



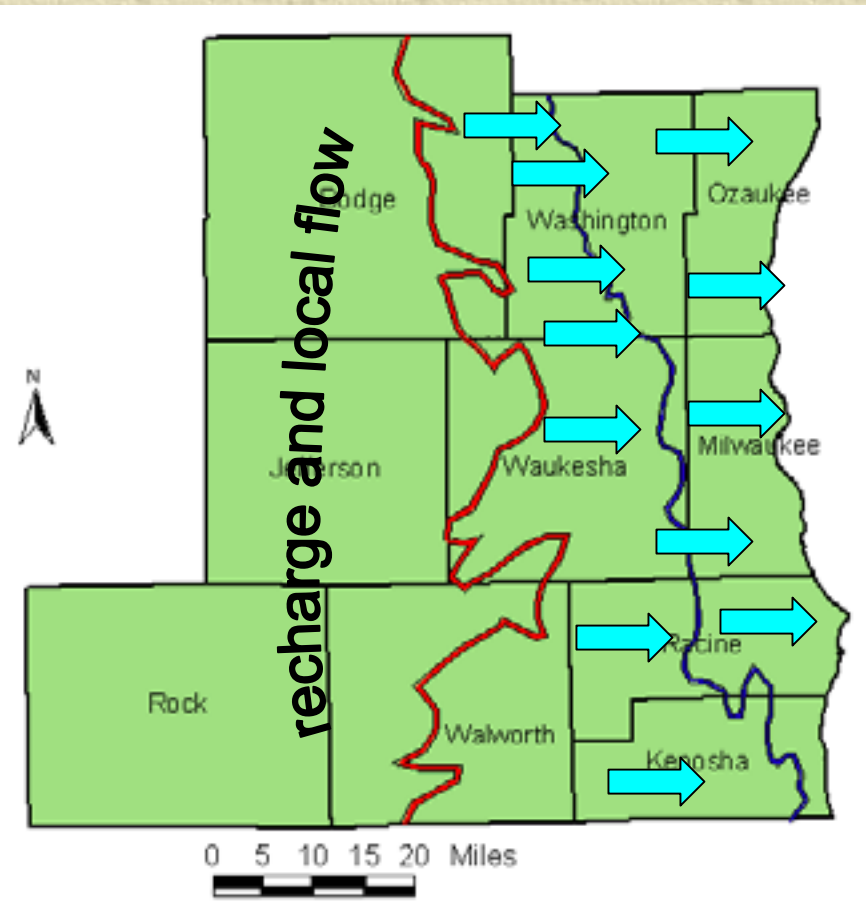
Effects of pumping:

- Pumping from the sandstone aquifer has reversed the direction of flow in the deep part of the flow system below the Lake Michigan coastline.

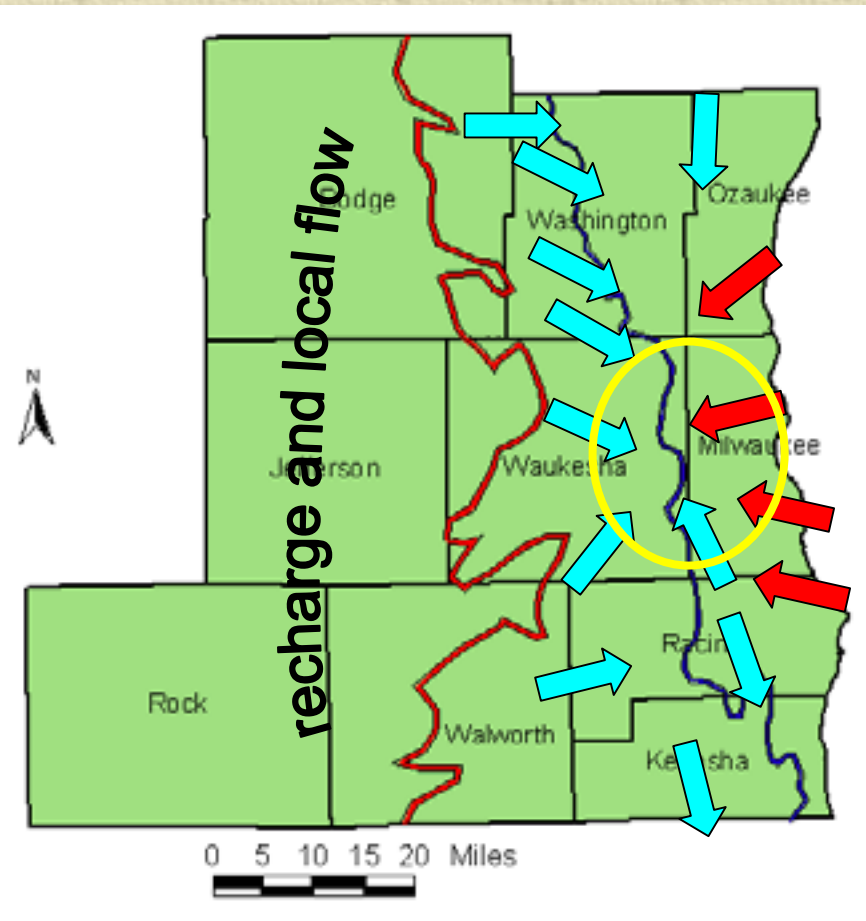
- From 1864 to 2000, pumping caused a 8.5% reduction of direct and indirect discharge of shallow groundwater to Lake Michigan.

Pumping has altered groundwater flow directions

1900



2000



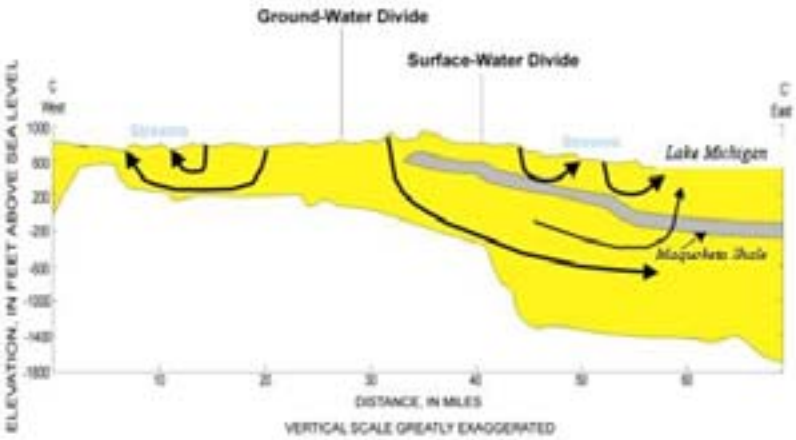
Sources of water:

- Water transferred from surface water within the SEWRPC region currently accounts for about 80% of combined shallow and deep pumping.

- Most of this water is groundwater captured by wells that would otherwise discharge to surface water, while a smaller part is water induced directly from streams and lakes.

- The remaining sources of water for shallow and deep wells are release of groundwater from storage below the seven-county region and below Lake Michigan (11%) and groundwater flow into the region (9%). Flow into the region is mostly from the west.

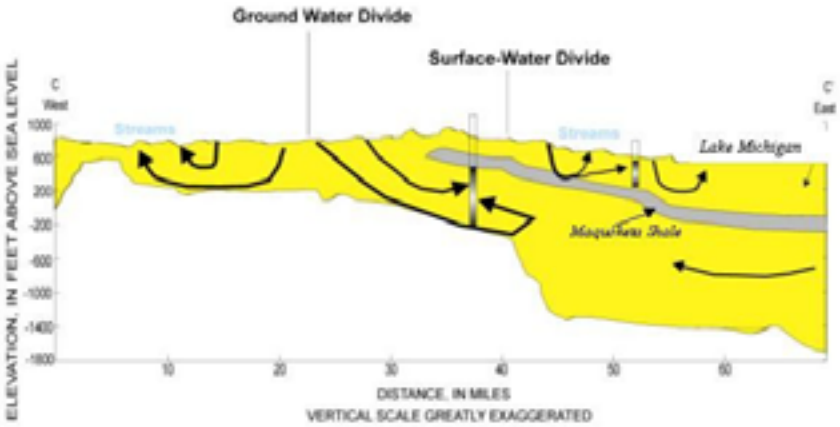
- **Pre-Development**—Deep bedrock aquifer
- Groundwater divide is west of watershed divide
- Recharge to deep aquifer flows to Lake Michigan
- All groundwater flows to surface water



Predevelopment

Pumping has caused the groundwater divide to shift westward

- **Year 2000**—Divide has moved west 10 miles
- Leakage to deep aquifer now captured by **wells**
- Flow under/to Lake Michigan captured by wells—no deep groundwater flows to the Lake anymore
- More of the shallow groundwater west of confining unit is diverted to the deep aquifer



Well Development

Consequences of development…

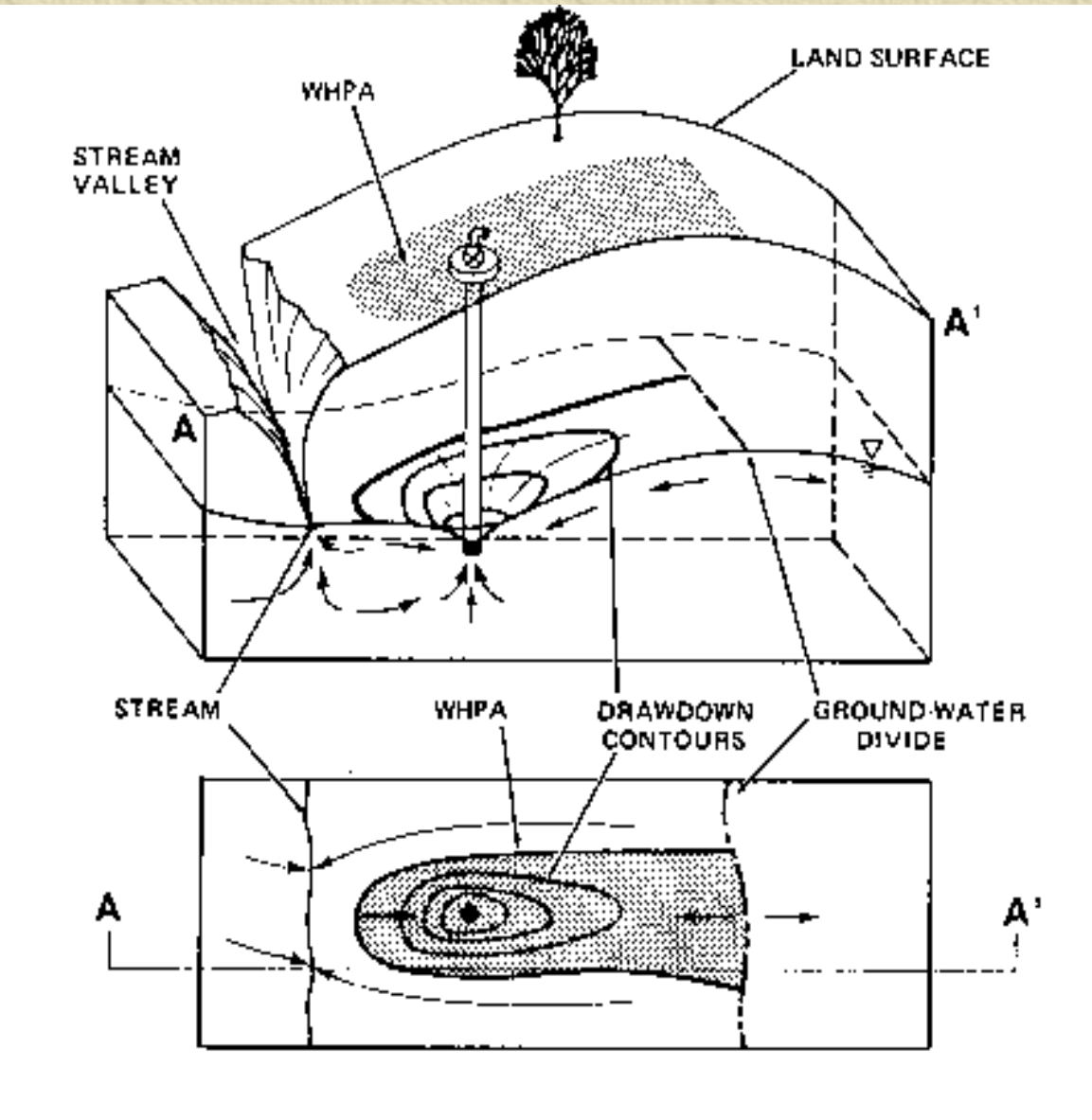
- Downward flow to sandstone aquifer from above (lakes, streams, and recharge) has increased by 19.7 mgd just within the 7-county SE Wisconsin region
- Flow toward Lake Michigan has reversed in the deep part of the flow system; 2.8 mgd once flowed under the coastline toward the Lake, now 3.7 mgd flows the other way, a change of 6.5 mgd
- Due to pumping Wisconsin loses to N. Illinois about 2.4 mgd through the deep part of the flow system

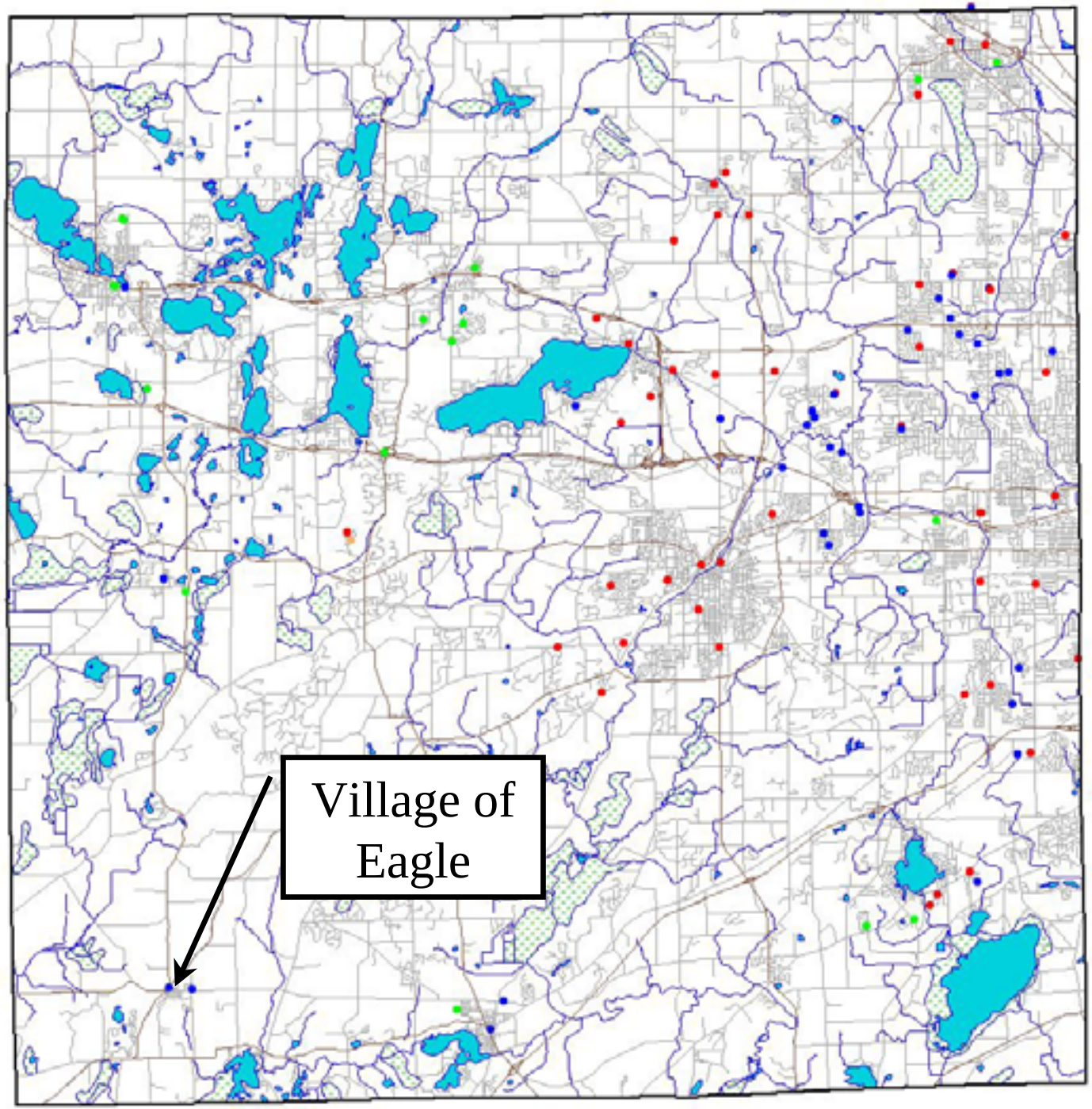
Other model uses

- Delineate contributing areas for water supply wells
- Delineate contributing areas for streams and springs

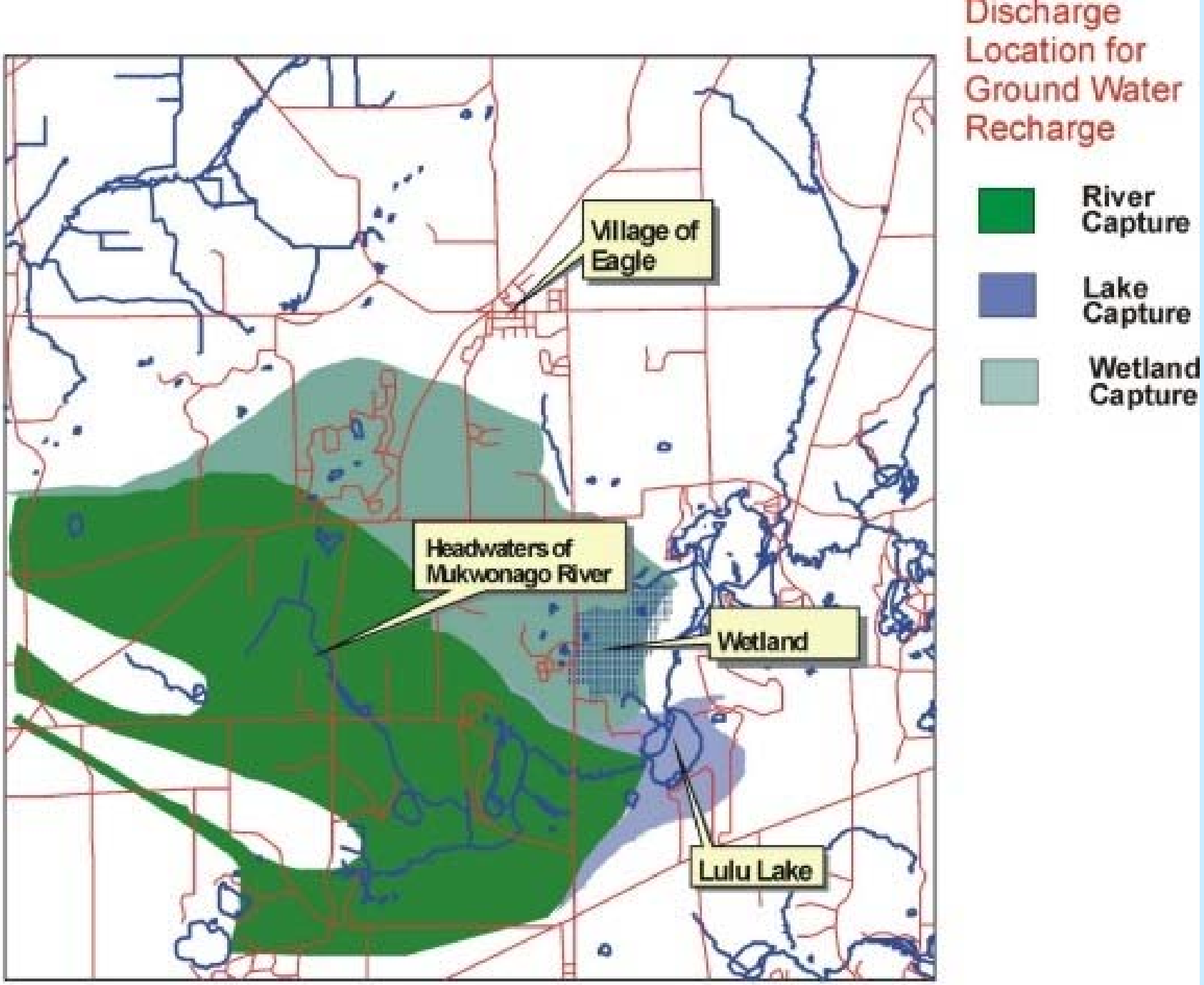
Example: submodel for Village of Eagle

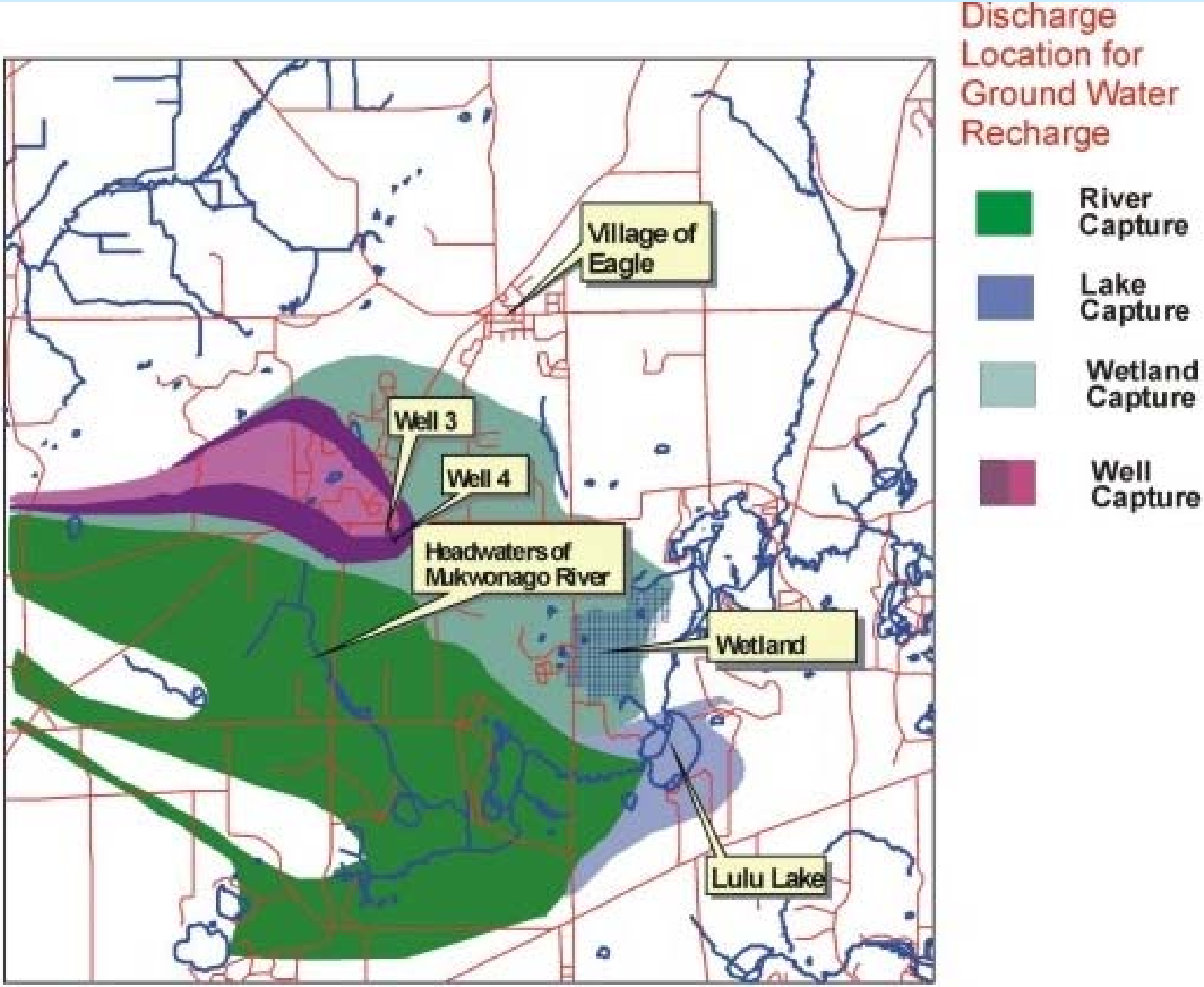
Capture zone, or ZOC



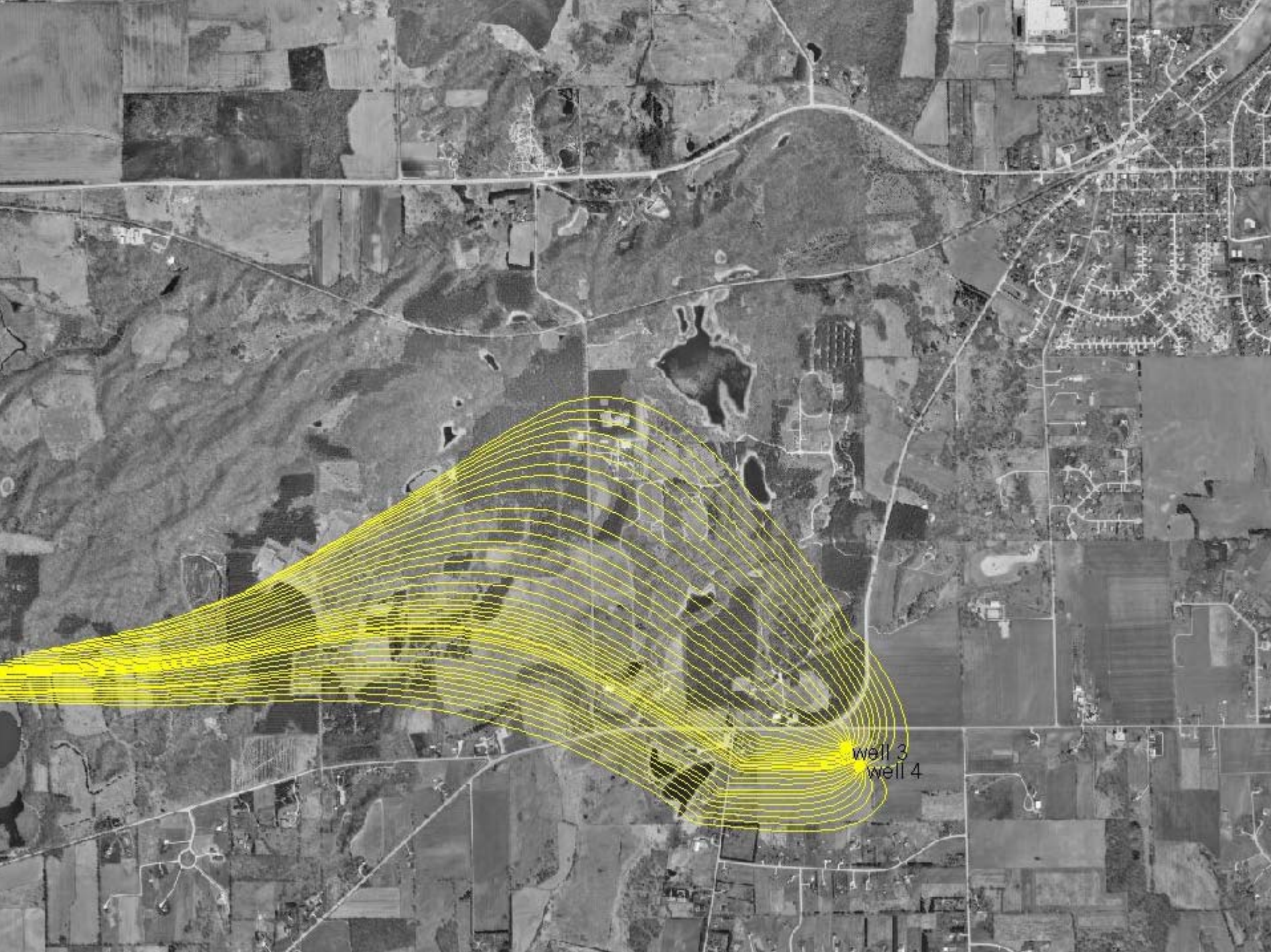


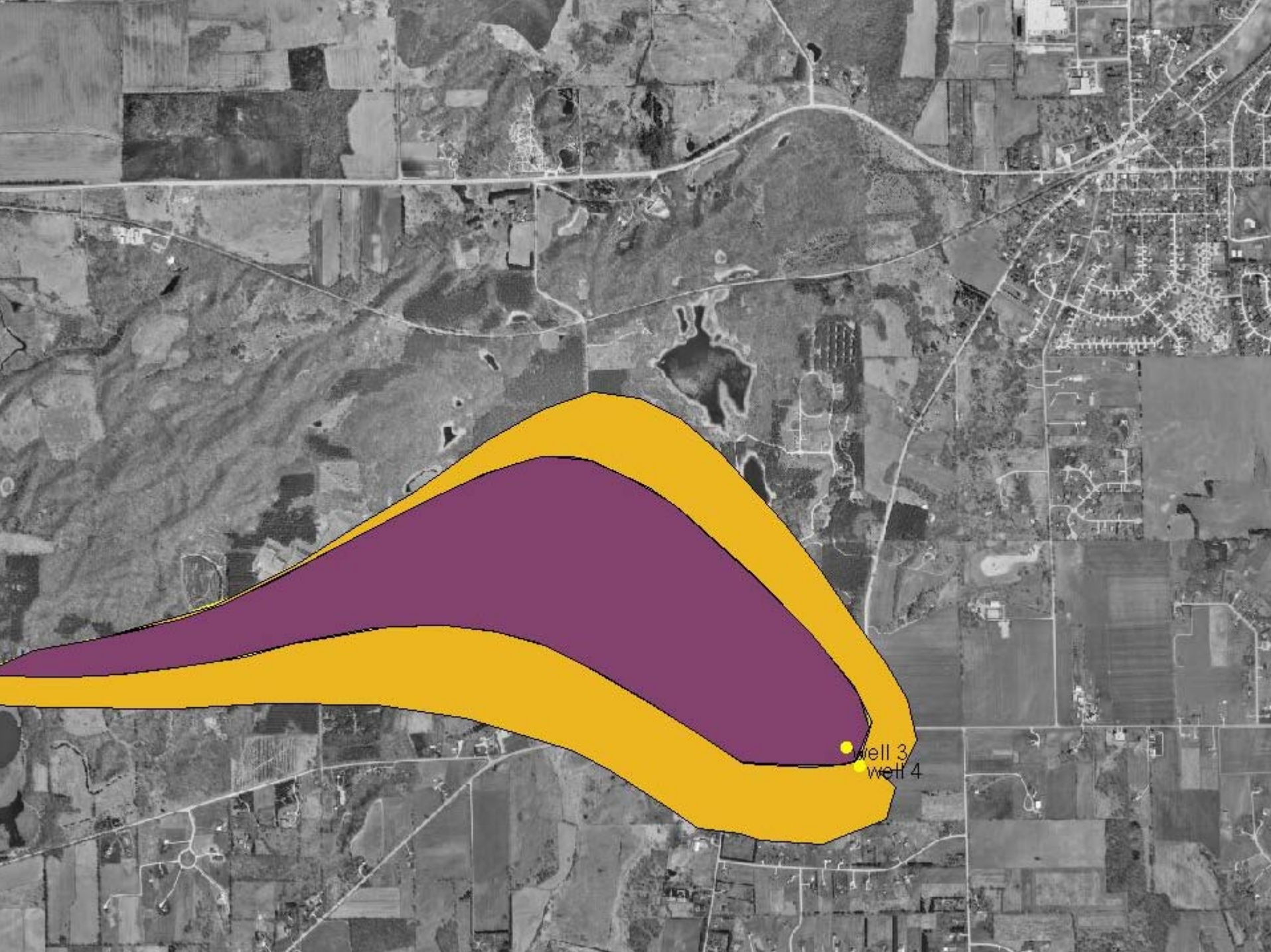
Waukesha Co,
Wisconsin

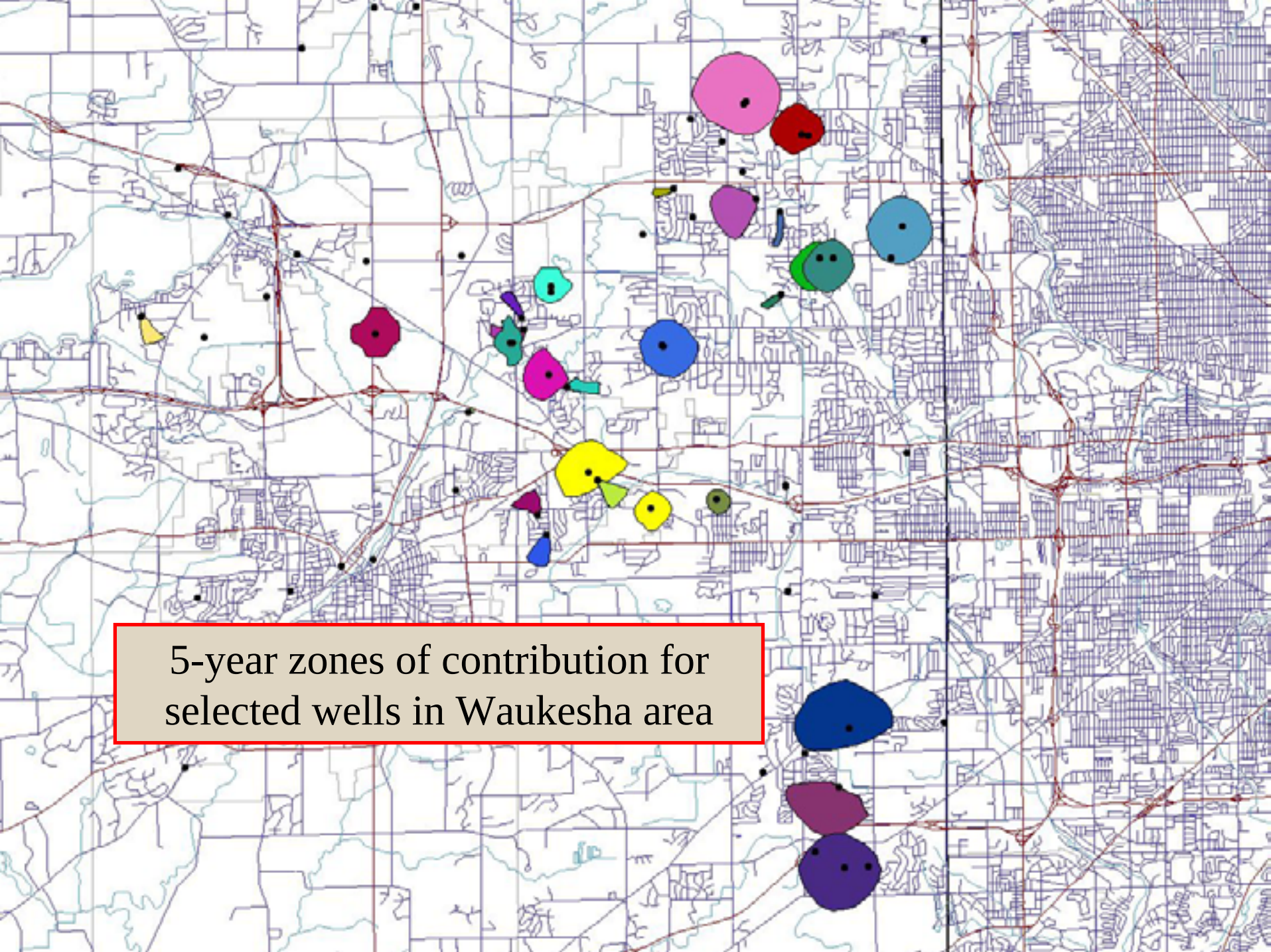

Discharge Location for Ground Water Recharge
River Capture
Lake Capture
Wetland Capture
Village of Eagle
Headwaters of Mukwonago River
Wetland
Lulu Lake


Discharge Location for Ground Water Recharge
River Capture
Lake Capture
Wetland Capture
Well Capture
Village of Eagle
Well 3
Well 4
Headwaters of Mukwonago River
Wetland
Lulu Lake

Village of Eagle
New wells
well 3
well 4


well 3
well 4


well 3
well 4



5-year zones of contribution for selected wells in Waukesha area

Summary

- The southeast Wisconsin groundwater flow model provides a state-of-the-art tool for investigating questions of groundwater flow in the region, for evaluating management options, and for developing site-specific analyses.