The Response of a Regional Aquifer to Prolonged Over Pumping: The Southeastern Wisconsin Deep Sandstone Aquifer

By John Jansen, P.G., Ph.D., and Joy Loughry
Aquifer Science and Technology
Funded by Great Lakes Protection Fund
Project conducted in partnership with CH2M Hill

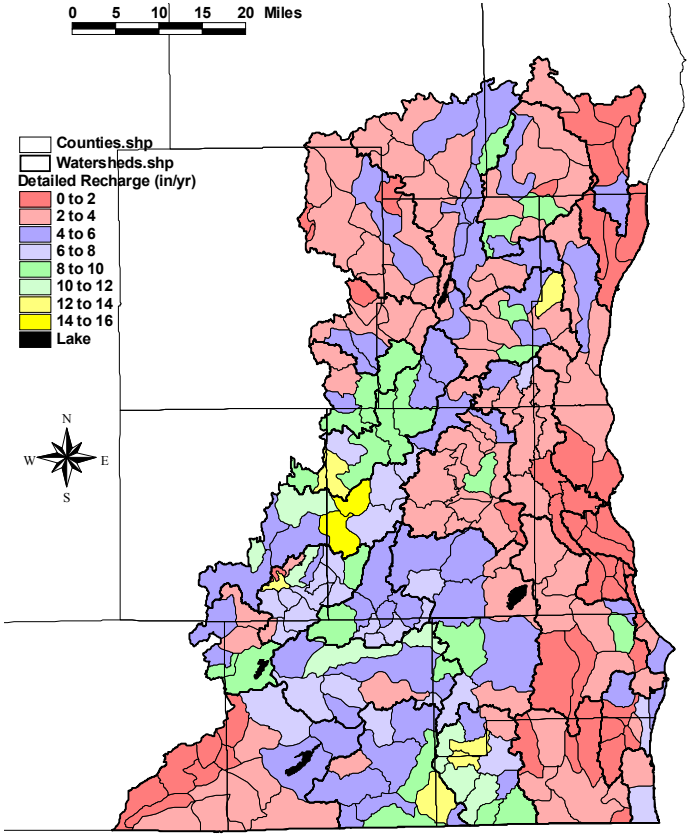
What is the safe yield of your aquifer?

Simplest Answer: The amount you can pump on a continuous basis without running out of water

- Aquifer mining happens slowly
- Often too late to turn back when problems are apparent
- Ignores long term impacts to environment
- Leads to declining water quality

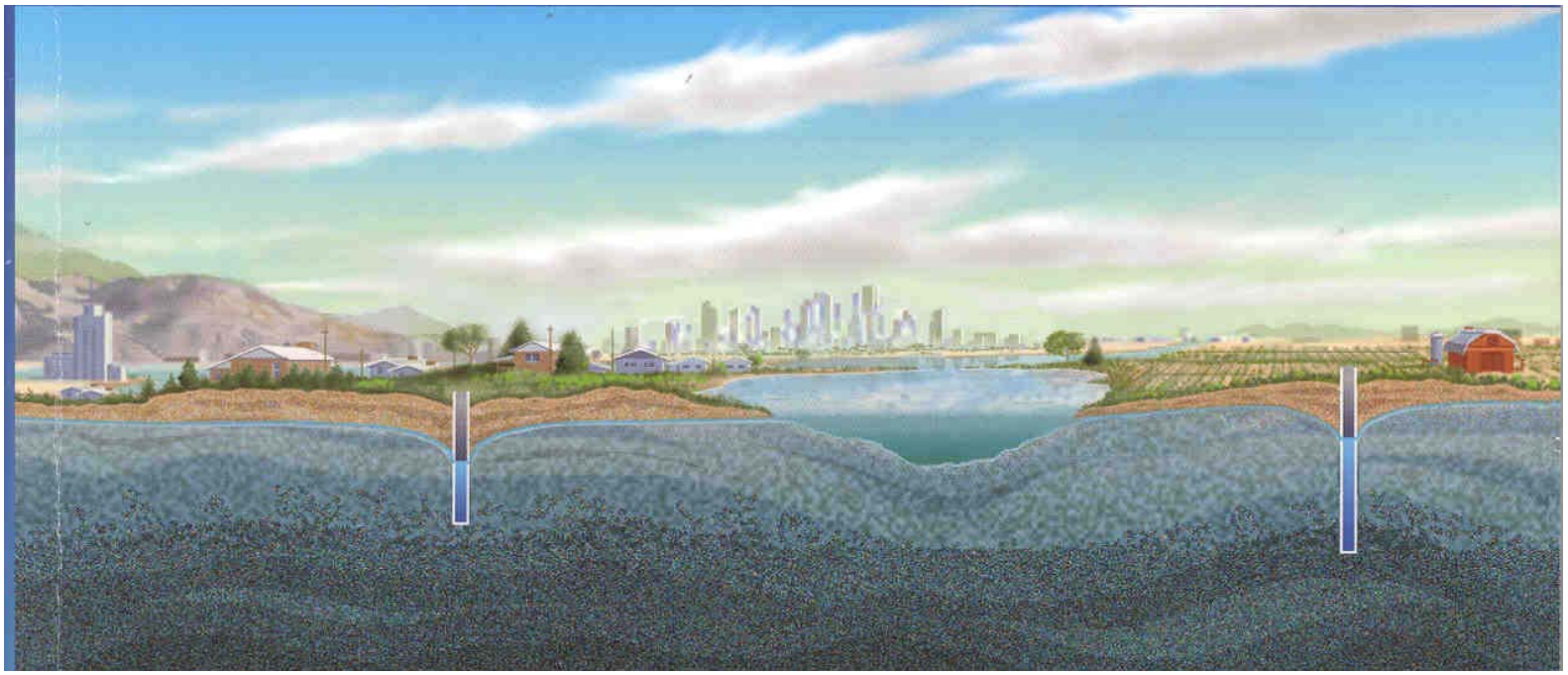
What is the safe yield of your aquifer?

- *Less simple answer: A pumping rate that does not exceed the recharge rate of the aquifer*



- Ignores need for base flow to streams
- Results in impacts to wetlands, streams, lakes, and other water dependent natural resources
- Proved to be a disaster in western Kansas

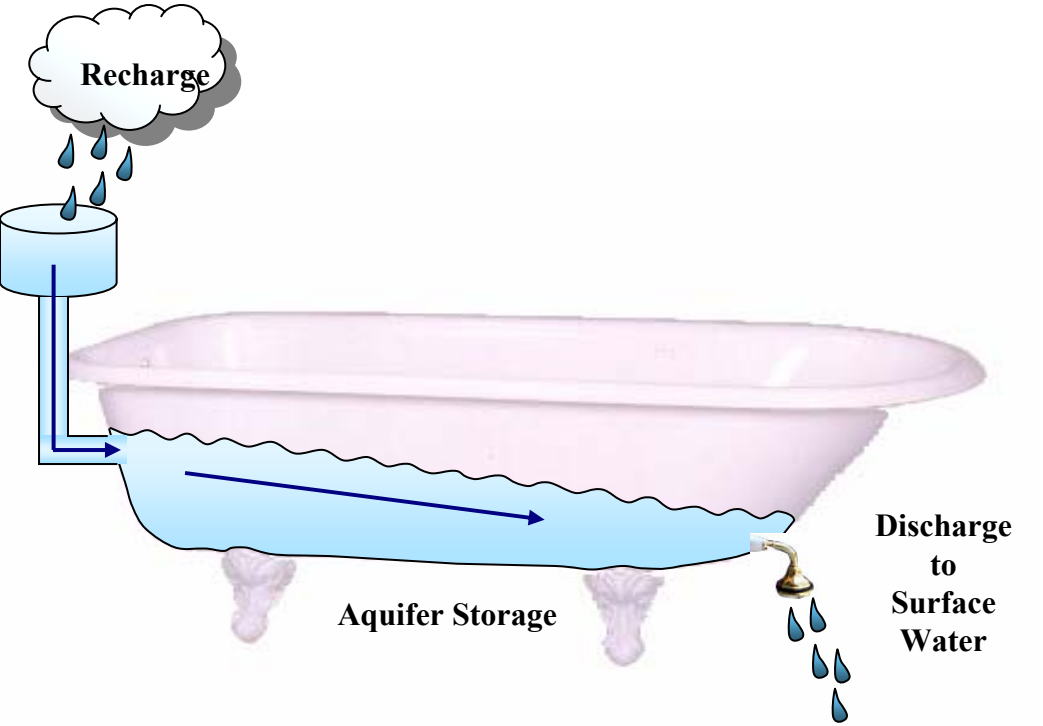
Learning to live on a budget….



- We are not running out of water!
- But we can't always find enough where we need it.
- How much can we pump?
- <u>What are the consequences?</u>

Safe Yield is a misguided concept

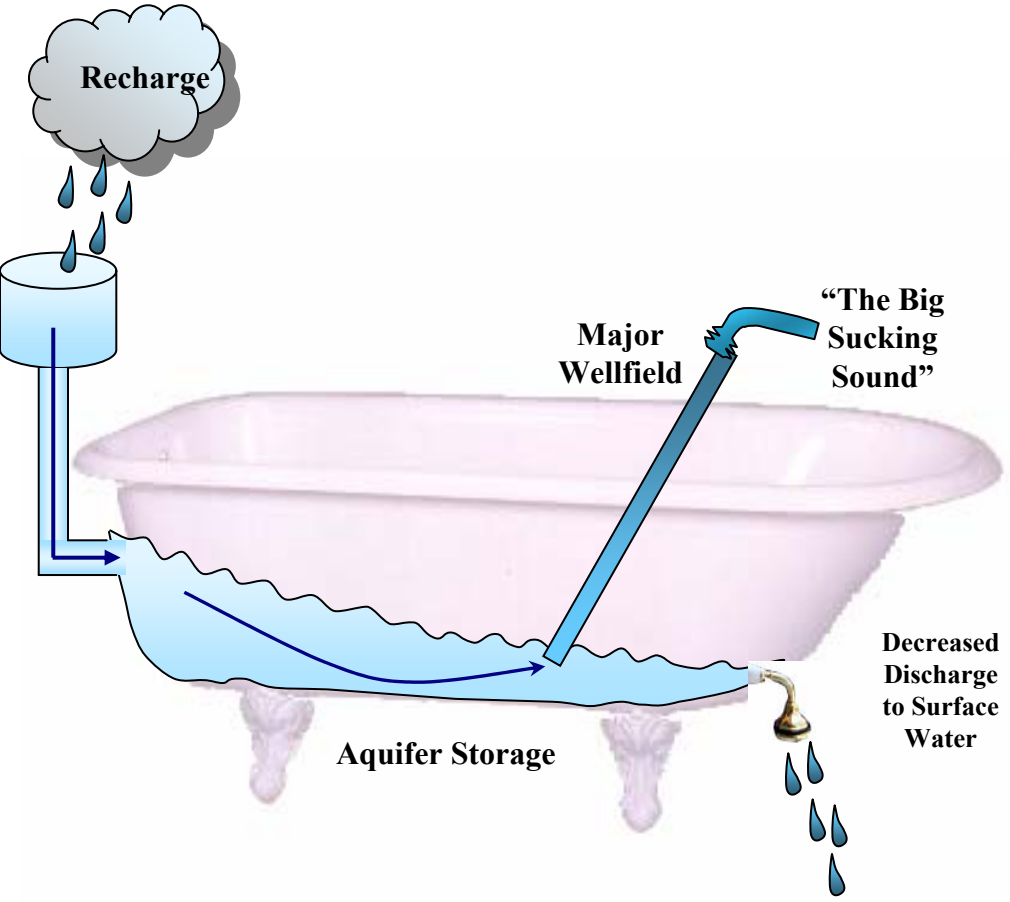
Pumped Water Comes From Capture of Regional Flow, Not Harvesting Recharge



- Water is rarely stagnant in nature
- Water moves from recharge areas to discharge areas
- Aquifer acts as a transport system and a storage vessel
- All the water in an aquifer has a purpose
- Water diverted at any point comes at the expense of some other point
- We need to start thinking in terms of capturing ground water flow, not harvesting a sustainable yield

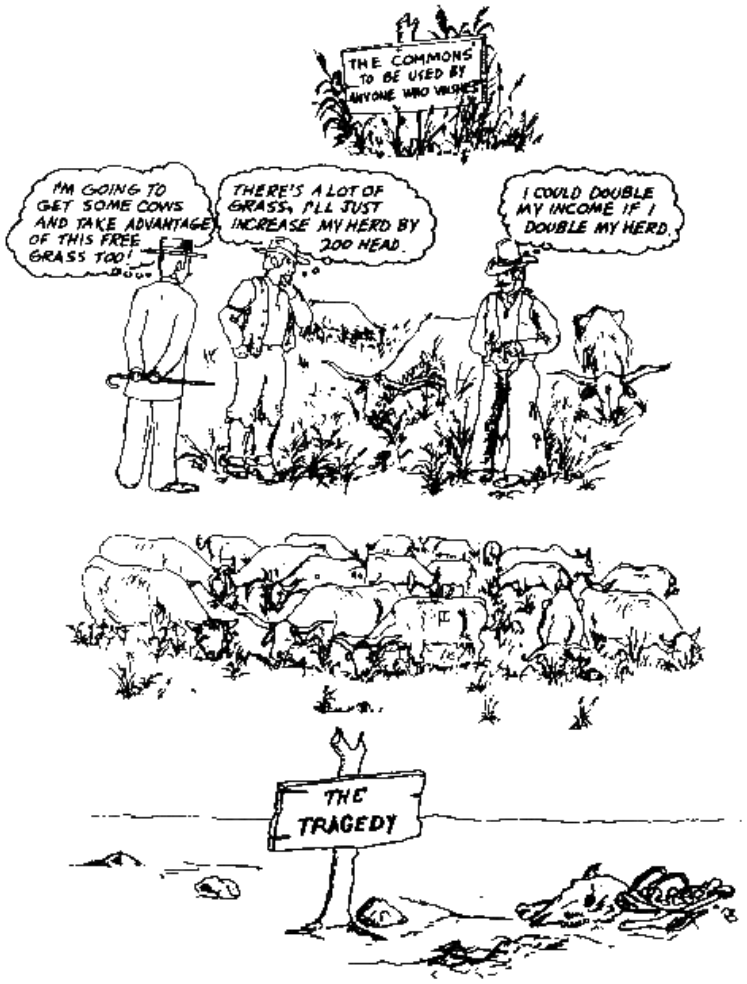
It is impossible to use a natural resource without impacting it

Zero impact is not a practical or desirable goal



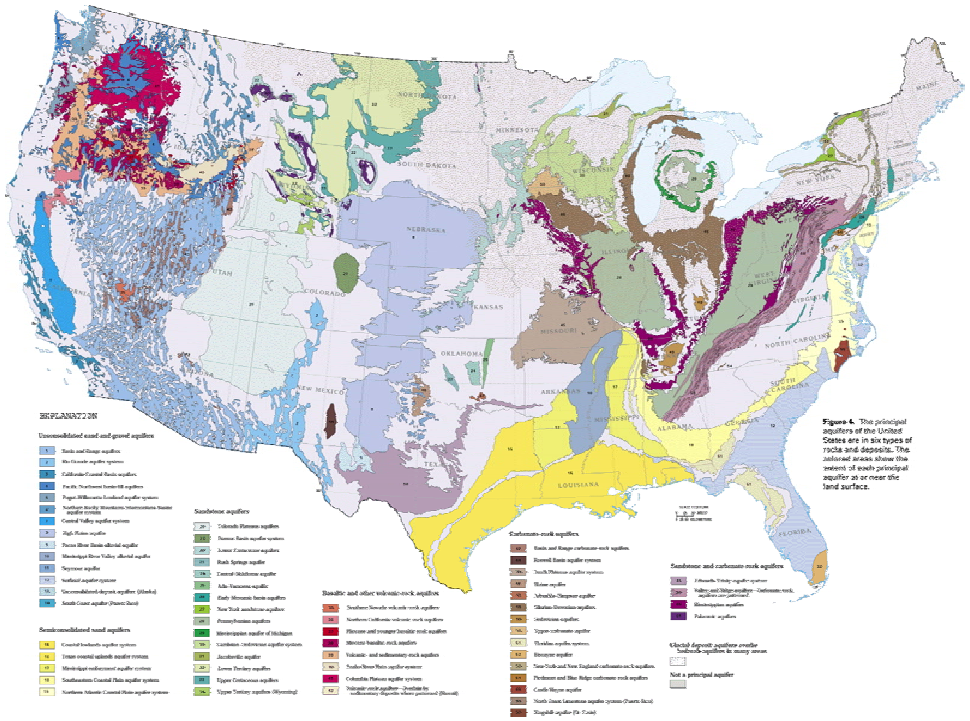
- Water intercepted by a well initially reduces storage but ultimately reduces discharge to surface water
- All water pumped from a well ultimately decreases discharge or comes from induced recharge
- Shallow aquifers have low storage but higher recharge, mining limited
- Regional confined aquifers have massive storage but low recharge, mining can go on for decades
- With better planning, we can make better compromises

The tragedy of the commons



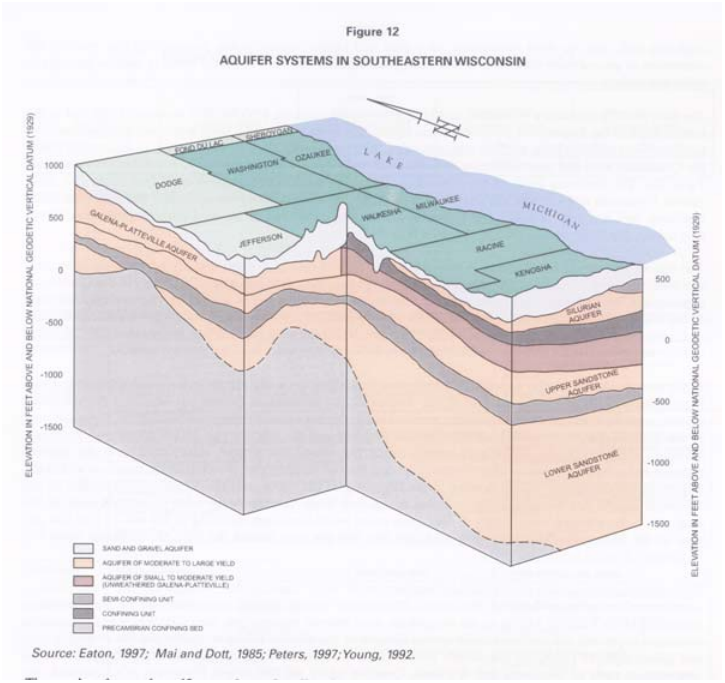
- Reasonable people will compete to maximize their benefit from a shared finite resource as they have no short term incentive to the contrary
- Long term planning requires cooperation or regulation
- Commonly held resources are quickly depleted unless controlled
- Glennon uses same analogy to describe over pumping aquifers in "Water Follies"
- His examples range from arid west to Minnesota and New England

Regional Aquifer Systems Create the Illusion of Limitless Supply



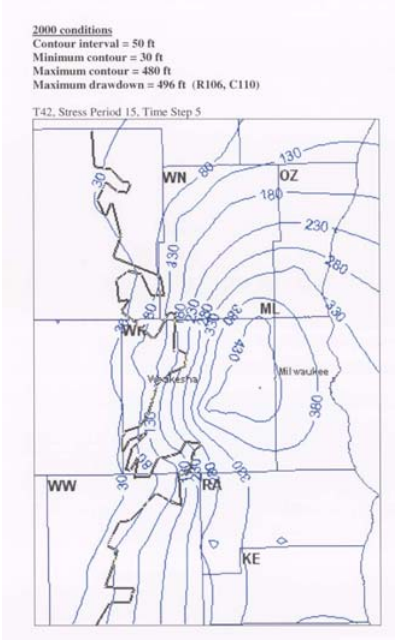
- The Ogallalla has been over drafted for decades
- The Coastal Aquifers have been over pumped and induced salt water intrusion
- Basins in the southwest have experienced tens of feet of subsidence
- Southeastern Wisconsin has been over pumping its major aquifer for decades

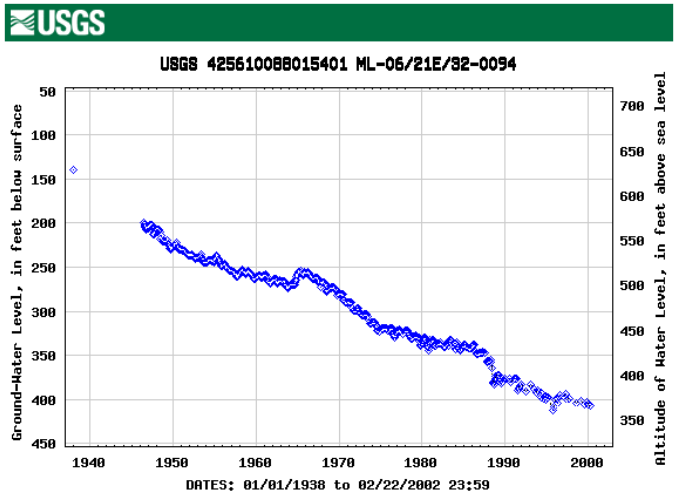
Major Aquifers in SE Wisconsin....



- **Sand and Gravel Aquifer...**near surface sand and gravel deposits throughout much of Wisconsin.
- **Dolomite Aquifer....**Silurian and Devonian limestone and dolomite units in eastern Wisconsin.
- **Sandstone Aquifer....**Cambrian and Ordovician sandstone, dolomite, and shale deposits in southern Wisconsin.
- **Pre-Cambrian Aquifer....** Fractured igneous and metamorphic rocks of north-central Wisconsin and Pre-Cambrian sandstone deposits of northwestern Wisconsin.

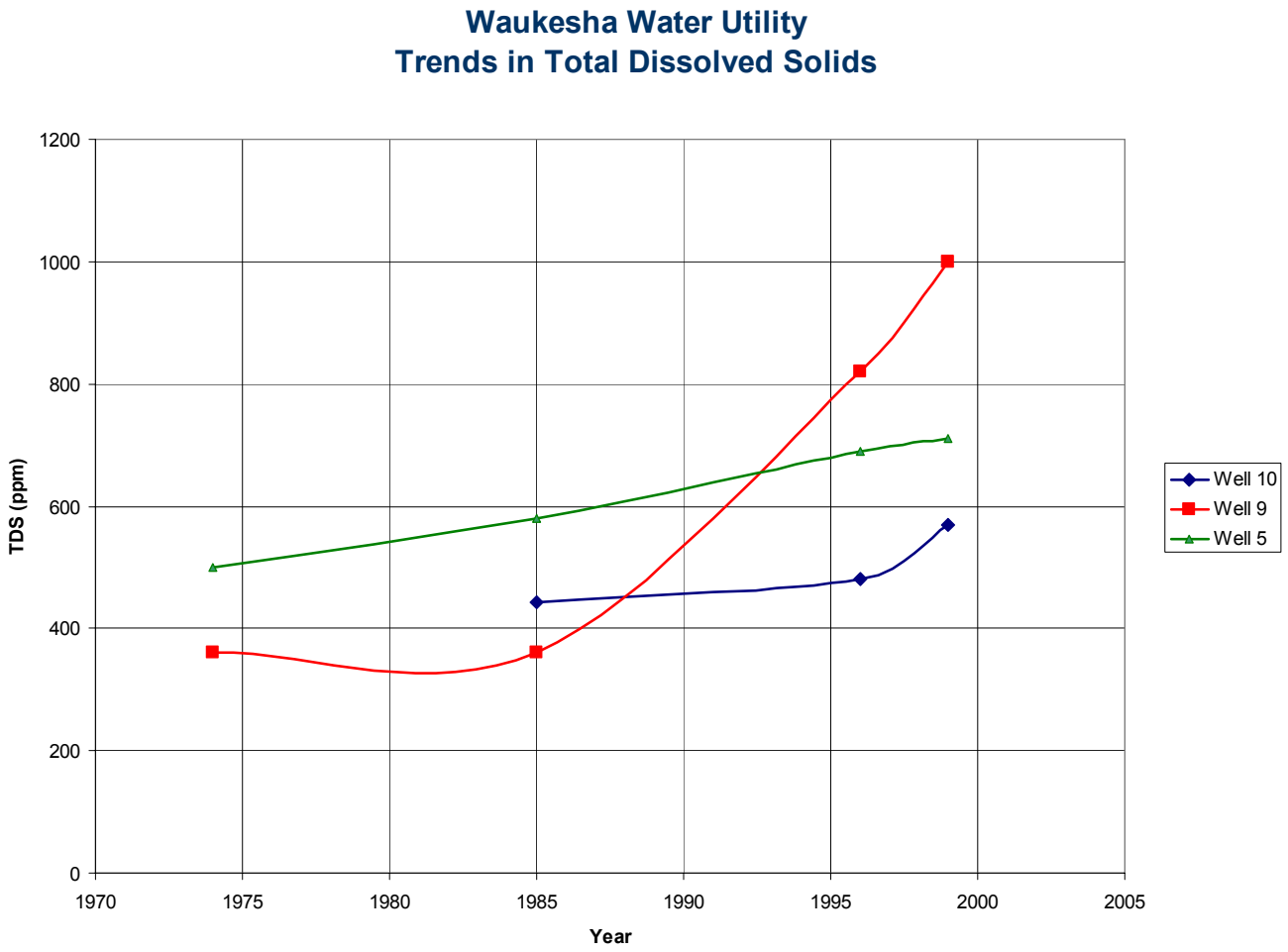
Over use of the sandstone aquifer of eastern Wisconsin has caused large cones of depression and changes in water quality





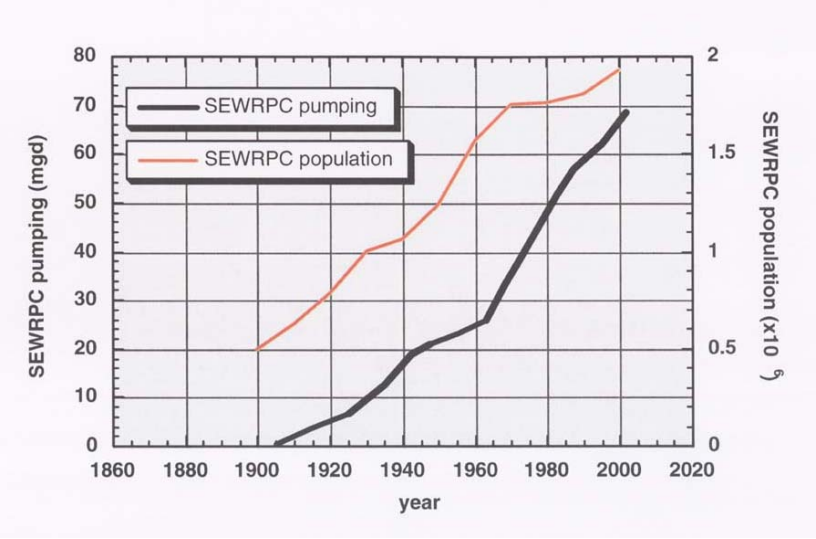
- Almost 500 feet of decline since the aquifer was developed.
- In Most of Southeastern Wisconsin head is declining at over 5 feet/year
- Cone reversed flow to Lake Michigan and increased capture of shallow water from west
- Pulling saline water from bottom of aquifer into some wells

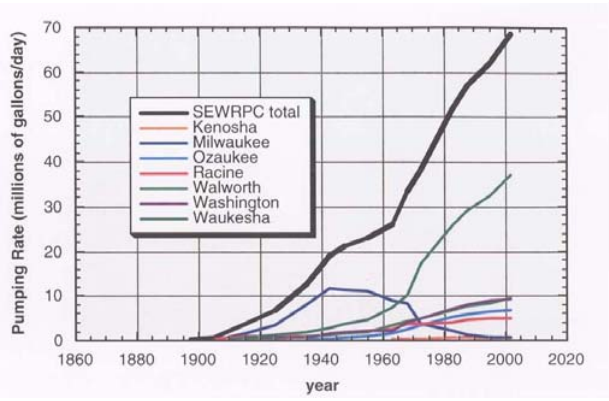
Declining Head Impacting Water Quality

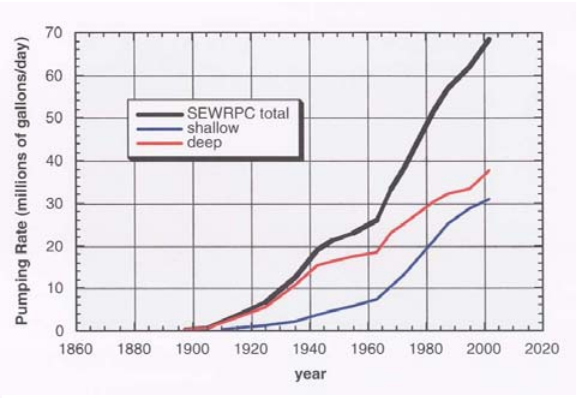


- Salinity levels rising in several sandstone wells in Waukesha County and Fox River Valley
- Caused by vertical migration of saline water in response to over pumping

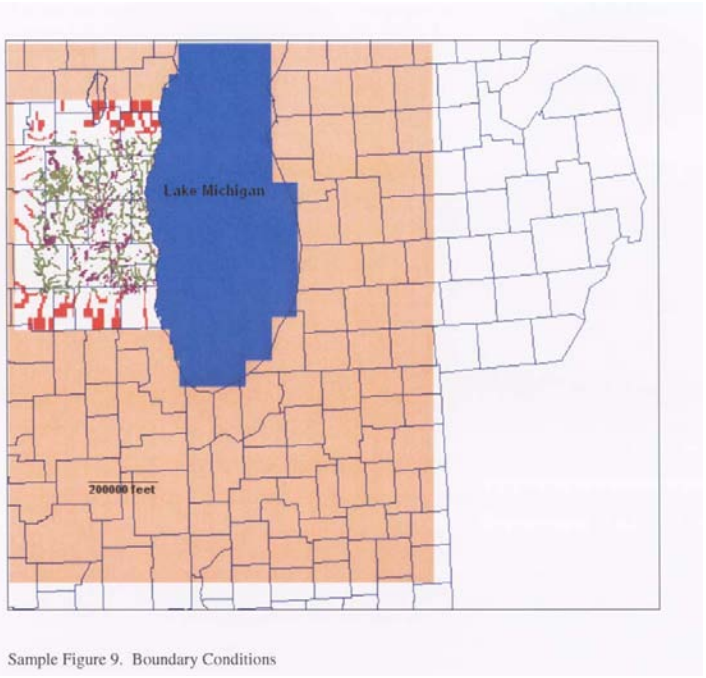
Water demand rising faster than population growth







- Statewide groundwater use up 33% from 1985 to 1995 while population increased less than 10%
- SE Wisconsin water usage up 42% from 1980 to 2000 while population up about 8%
- Biggest user in SE Wisconsin is Waukesha County
- Water use slightly higher from sandstone aquifer though mix is changing



Sample Figure 9. Boundary Conditions

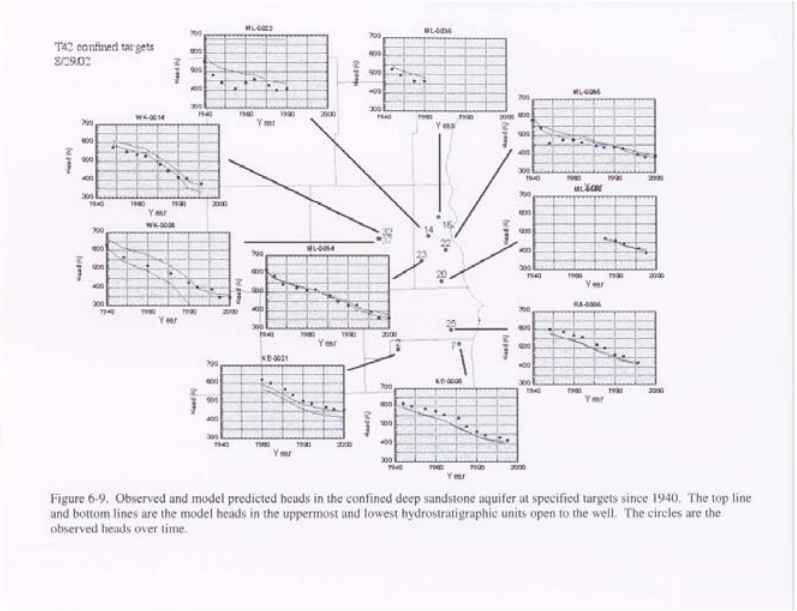


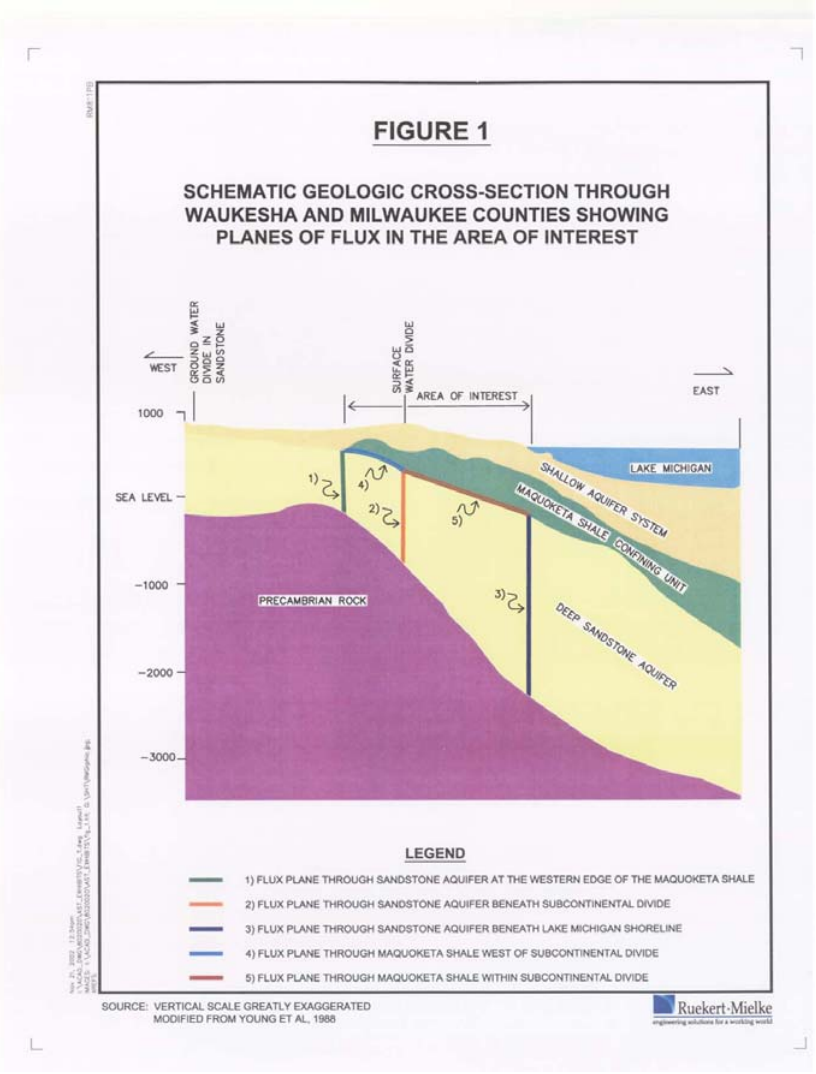
Figure 6-9. Observed and model predicted heads in the confined deep sandstone aquifer at specified targets since 1940. The top line and bottom lines are the model heads in the uppermost and lowest hydrostratigraphic units open to the well. The circles are the observed heads over time.

SEWRPC Groundwater Model is Available

- 4 year cooperative effort between SEWRPC, USGS, WGNHS and dozens of local communities
- 3-D model of groundwater system of southeastern Wisconsin
  - 18 layers
  - 530,000 active cells
- Extensive data collection and calibration
- Very powerful planning tool for regional groundwater management
- Has been cited as an example of cooperation and planning for the rest of the country

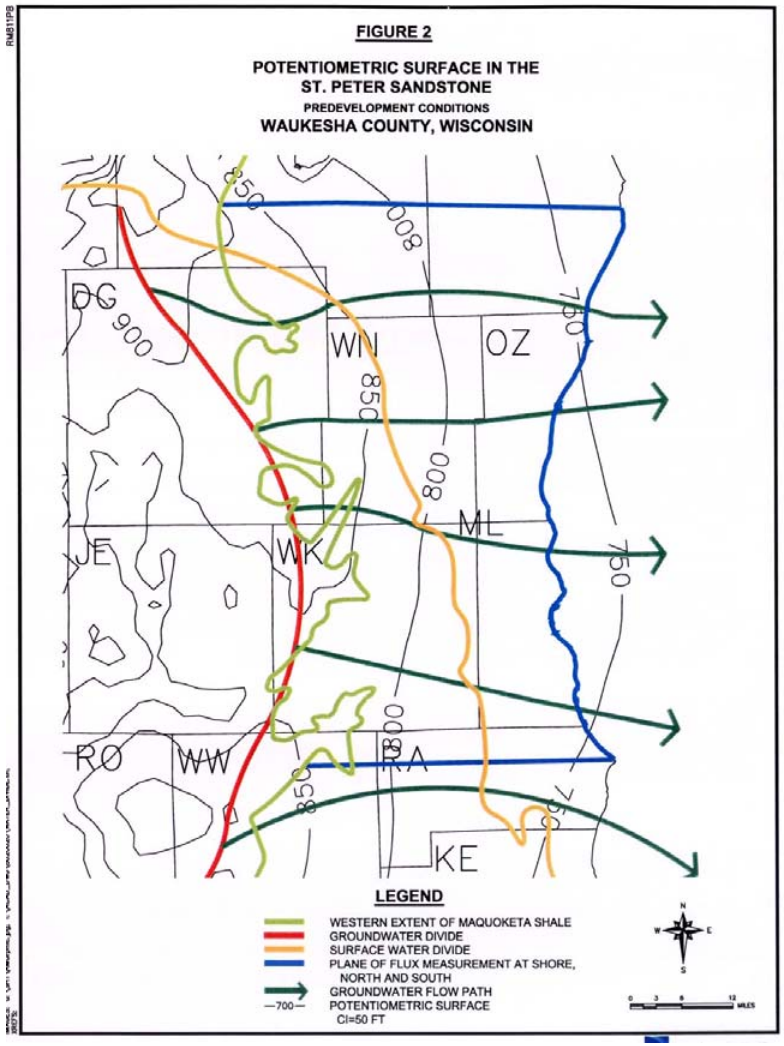
SEWRPC model used to estimate magnitude of changes to flow system due to pumpage

- Model used to measure flow into Lake Michigan through sandstone aquifer before development
- Compared to current conditions to determine change
- Used to predict effects of future increases or reduction in pumpage



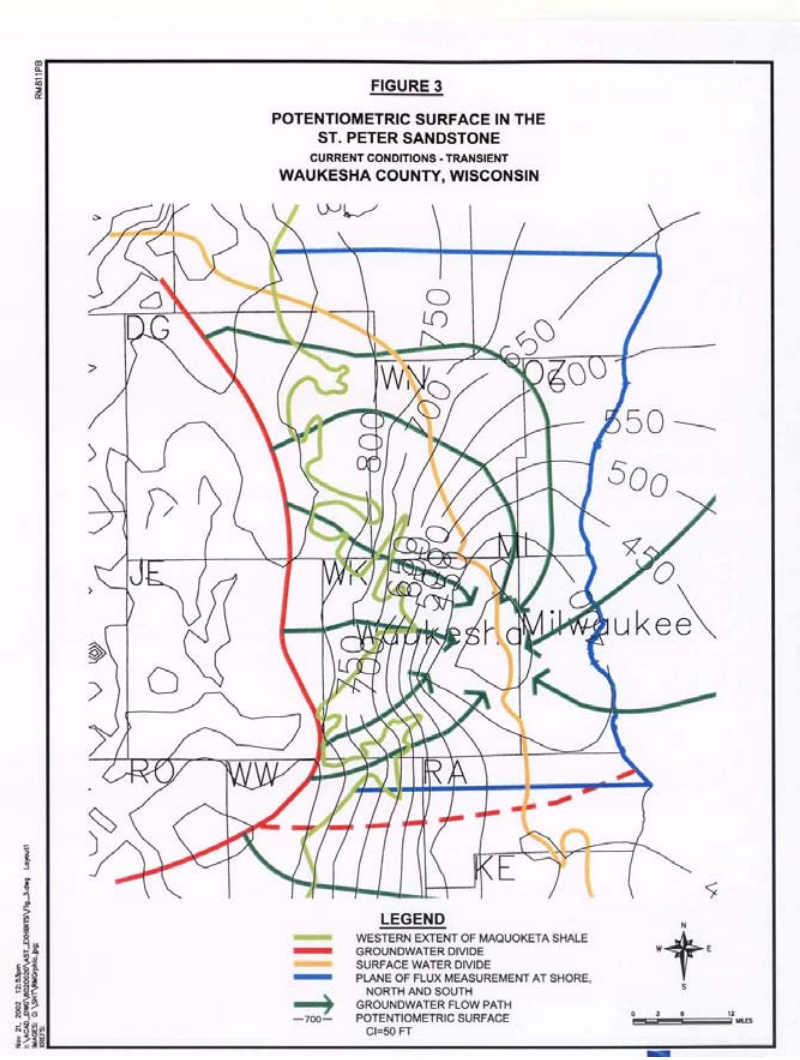
Sandstone aquifer formerly discharged into Lake Michigan

- Water entered aquifer west of subcontinental divide
- About 3 mgd flowed through aquifer to Lake Michigan
- Groundwater basin for Lake Michigan larger than surface water basin
- Water flowed upward through shale into shallow aquifers east of subcontinental divide
- Water flowed upward under Lake Michigan into lake

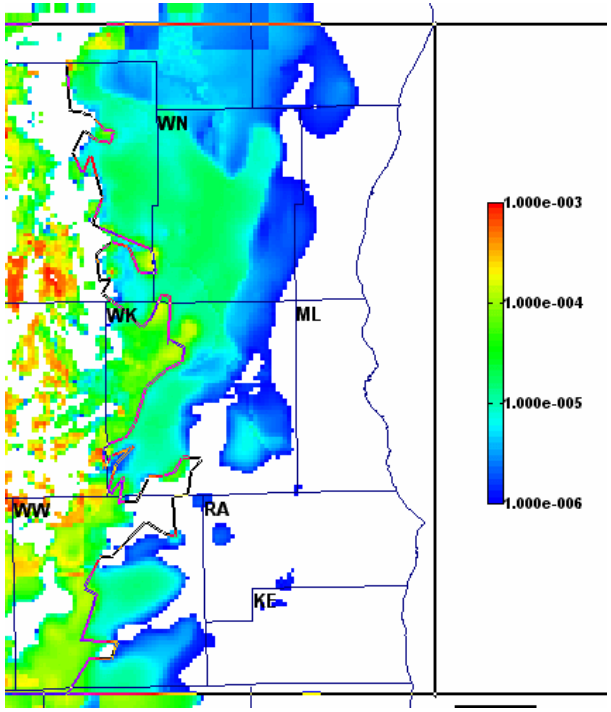


Heavy pumping has captured recharge from Lake Michigan and Waukesha County

- 25 mgd pumpage in area of interest (5mgd in Lake Michigan basin)
- Water now flows toward pumping center in Waukesha County
- 3 mgd now flows west under shoreline (6 mgd net change)
- 11 mgd downward flow from shallow aquifers through shale into sandstone aquifer (430% increase)
- Divide moved 10 to 20 miles west
- Recharge west of shale has increased to 8 mgd (1350% increase)
- Pumpage in Illinois created a new divide in Racine County

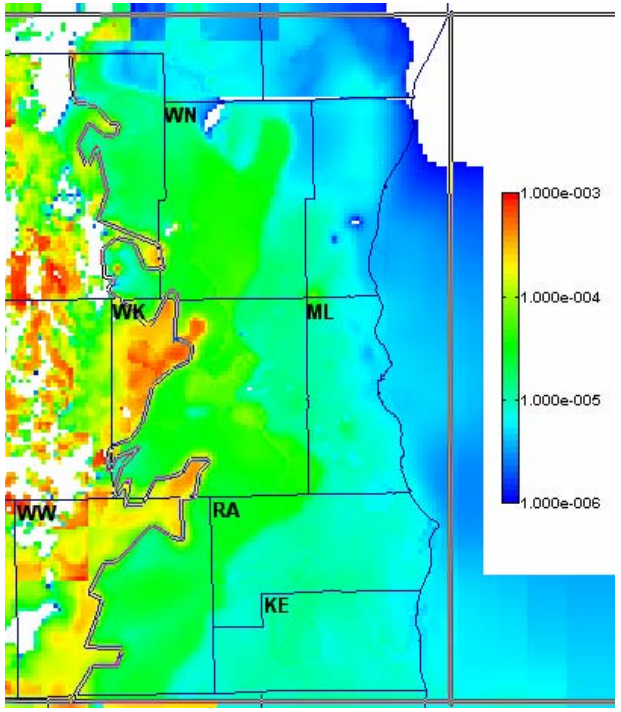


Change Vertical Gradient



Predevelopment

- Downward gradients west of subcontinental divide (mostly)
- Upward gradients east of divide

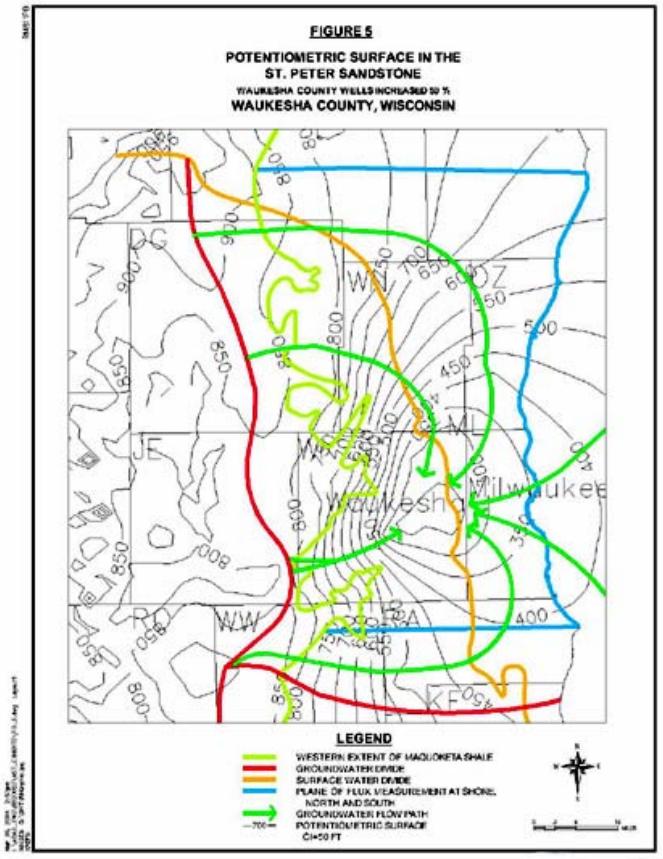


Current Conditions

- Downward gradients everywhere
- Greater recharge from shallow aquifers

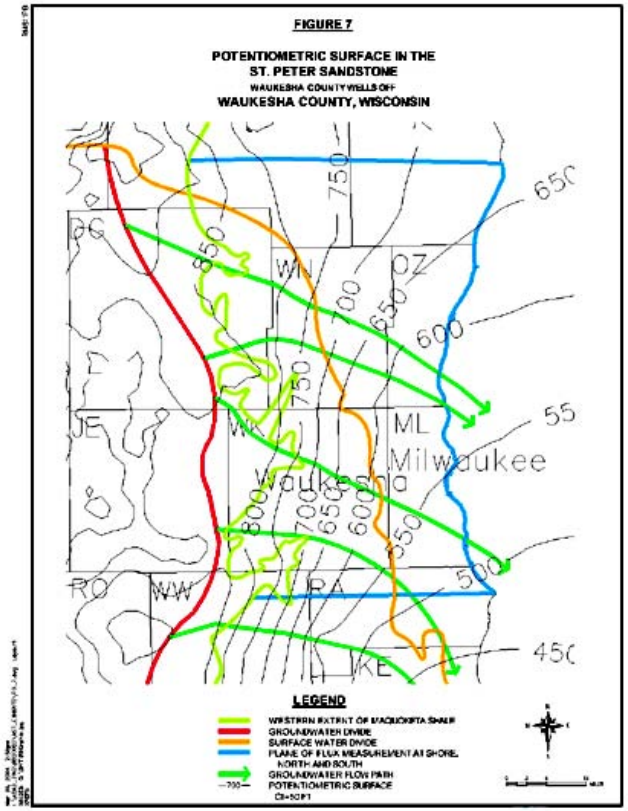
Figures from SEWRPC (in press)

Future Increased Pumpage in Waukesha County



- Pumpage up 50% from sandstone in Waukesha County west of divide
- Pumpage down 50% in Milwaukee County
- Cone deepens to about 600 feet
- Divides moves west and south
- Fluxes from under lake, through shale and from west of shale all increase

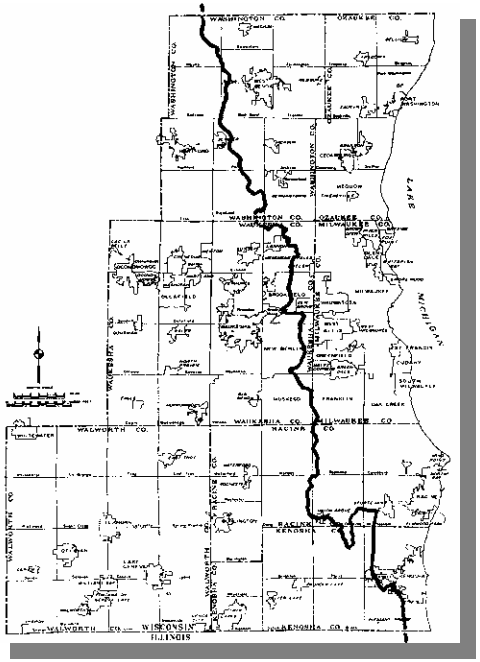
Impact of Reduced Pumpage

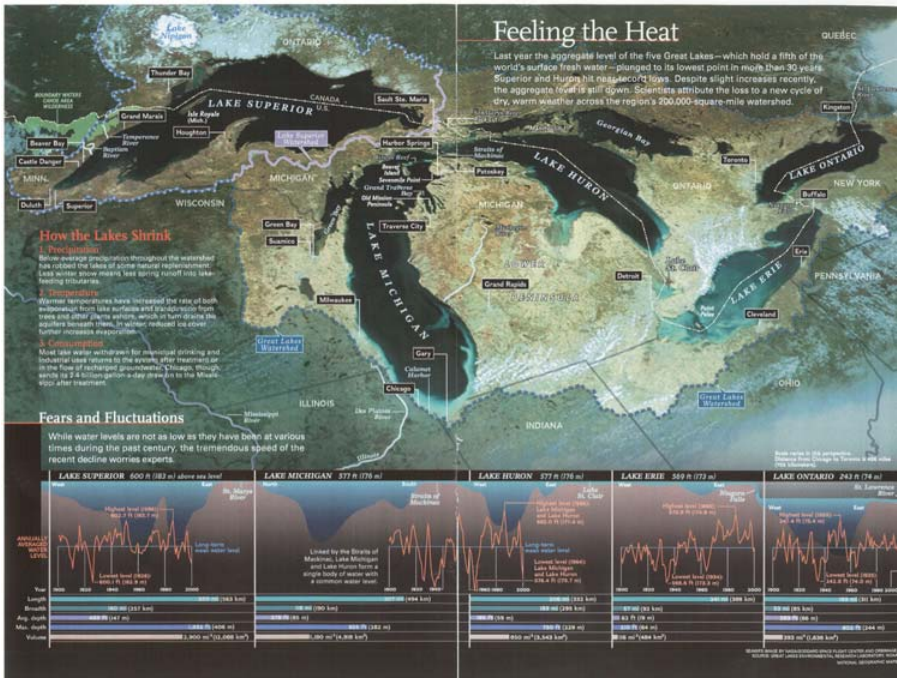


- All sandstone wells in Waukesha County off, all others at current pumping rate
- Simulates the effect of granting surface water diversion for Waukesha County
- Groundwater divide moves close to original position
- Head in western Waukesha County with 50 feet of predevelopment conditions
- Head in eastern Waukesha County within 200 feet of predevelopment conditions
- Recharge from shallow aquifer west of shale 4 mgd (down 52% from current)
- Recharge through shale 7 mgd (down 36% from current)
- Flux into Lake Michigan Basin 6 mgd (3 mgd over predevelopment and 5 mgd over current)
- Produces ecological improvements primarily in recharge area of sandstone aquifer, but outside Lake Michigan surface water basin

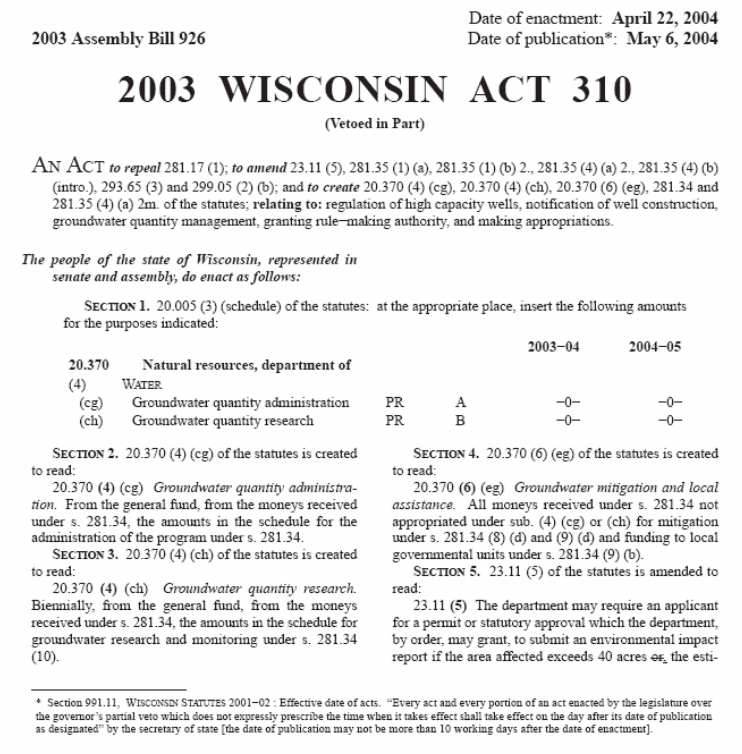
Annex 2001

- Most Recent Attempt to regulate diversions from Great Lakes Basin
- Requires ecological improvement within basin for any increase in withdrawl (within or out of basin)
- Attempts to recognize connection between surface water and groundwater
- Lake Michigan has two basins, one surface water, one groundwater
- Current version only recognizes ecological improvements within surface water basin
- Comments on final draft have been submitted and are being reviewed





New High Capacity Well Law Targets Southeast Wisconsin



2003 Assembly Bill 926

Date of enactment: **April 22, 2004**
Date of publication*: **May 6, 2004**

2003 WISCONSIN ACT 310

(Vetoed in Part)

AN ACT *to repeal* 281.17 (1); *to amend* 23.11 (5), 281.35 (1) (a), 281.35 (1) (b) 2., 281.35 (4) (a) 2., 281.35 (4) (b) (intro.), 293.65 (3) and 299.05 (2) (b); and *to create* 20.370 (4) (cg), 20.370 (4) (ch), 20.370 (6) (eg), 281.34 and 281.35 (4) (a) 2m. of the statutes; **relating to:** regulation of high capacity wells, notification of well construction, groundwater quantity management, granting rule–making authority, and making appropriations.

The people of the state of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION 1. 20.005 (3) (schedule) of the statutes: at the appropriate place, insert the following amounts for the purposes indicated:

				2003–04	2004–05
20.370	Natural resources, department of				
(4)	WATER				
(cg)	Groundwater quantity administration	PR	A	–0–	–0–
(ch)	Groundwater quantity research	PR	B	–0–	–0–

SECTION 2. 20.370 (4) (cg) of the statutes is created to read:

20.370 **(4)** (cg) *Groundwater quantity administration.* From the general fund, from the moneys received under s. 281.34, the amounts in the schedule for the administration of the program under s. 281.34.

SECTION 3. 20.370 (4) (ch) of the statutes is created to read:

20.370 **(4)** (ch) *Groundwater quantity research.* Biennially, from the general fund, from the moneys received under s. 281.34, the amounts in the schedule for groundwater research and monitoring under s. 281.34 (10).

SECTION 4. 20.370 (6) (eg) of the statutes is created to read:

20.370 **(6)** (eg) *Groundwater mitigation and local assistance.* All moneys received under s. 281.34 not appropriated under sub. (4) (cg) or (ch) for mitigation under s. 281.34 (8) (d) and (9) (d) and funding to local governmental units under s. 281.34 (9) (b).

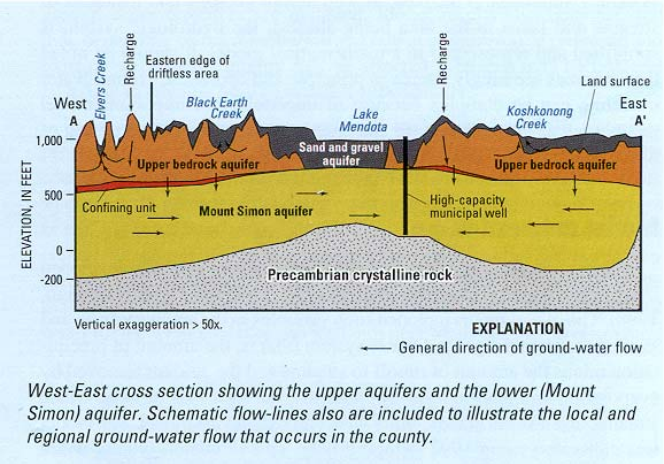
SECTION 5. 23.11 (5) of the statutes is amended to read:

23.11 **(5)** The department may require an applicant for a permit or statutory approval which the department, by order, may grant, to submit an environmental impact report if the area affected exceeds 40 acres ~~or~~, the esti-

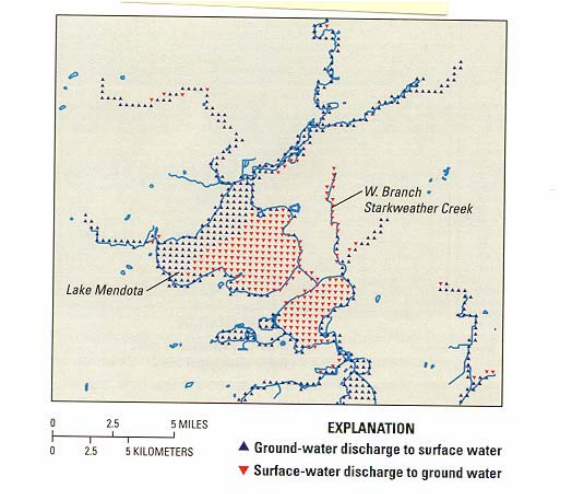
* Section 991.11, WISCONSIN STATUTES 2001–02 : Effective date of acts. "Every act and every portion of an act enacted by the legislature over the governor's partial veto which does not expressly prescribe the time when it takes effect shall take effect on the day after its date of publication as designated" by the secretary of state [the date of publication may not be more than 10 working days after the date of enactment].

- **SE Wisconsin is one of two groundwater management zones**
- **Requires WDNR to provide funding and support for regional management plan by 2007**
- **Provides for the WDNR to set management plan if groundwater management committee fails to act**
- **May be the start of regional planning?**

Heavy pumping in Dane County is impacting lakes and rivers



West-East cross section showing the upper aquifers and the lower (Mount Simon) aquifer. Schematic flow-lines also are included to illustrate the local and regional ground-water flow that occurs in the county.



- **Sandstone aquifer has declined over 60 feet from pre-development conditions.**
- **Draw down is inducing recharge from lakes and streams.**
- **Stream flows are diminishing and spring flows have ceased.**
- **Pumpage has captured surface discharge and induced recharge from lakes and streams**
- **Continued development will exacerbate problems unless mitigated**

From Hunt, Bradbury, and Krohelski, 2001

Before I slip out of here…

- Over pumping shallow aquifers can affect surface water
- Over pumping confined aquifers eventually impacts shallow systems and can impair water quality in the aquifer
- Flow into the Lake Michigan Basin in the sandstone has essentially stopped
- Increased pumping will cause net loss
- Current recharge to sandstone aquifer is seven times predevelopment, 72% from shallow aquifers west of the divide
- Increased recharge is reducing base flows to streams
- Biggest environmental benefit from reduced pumpage will occur outside surface water basin but within Lake Michigan groundwater basin