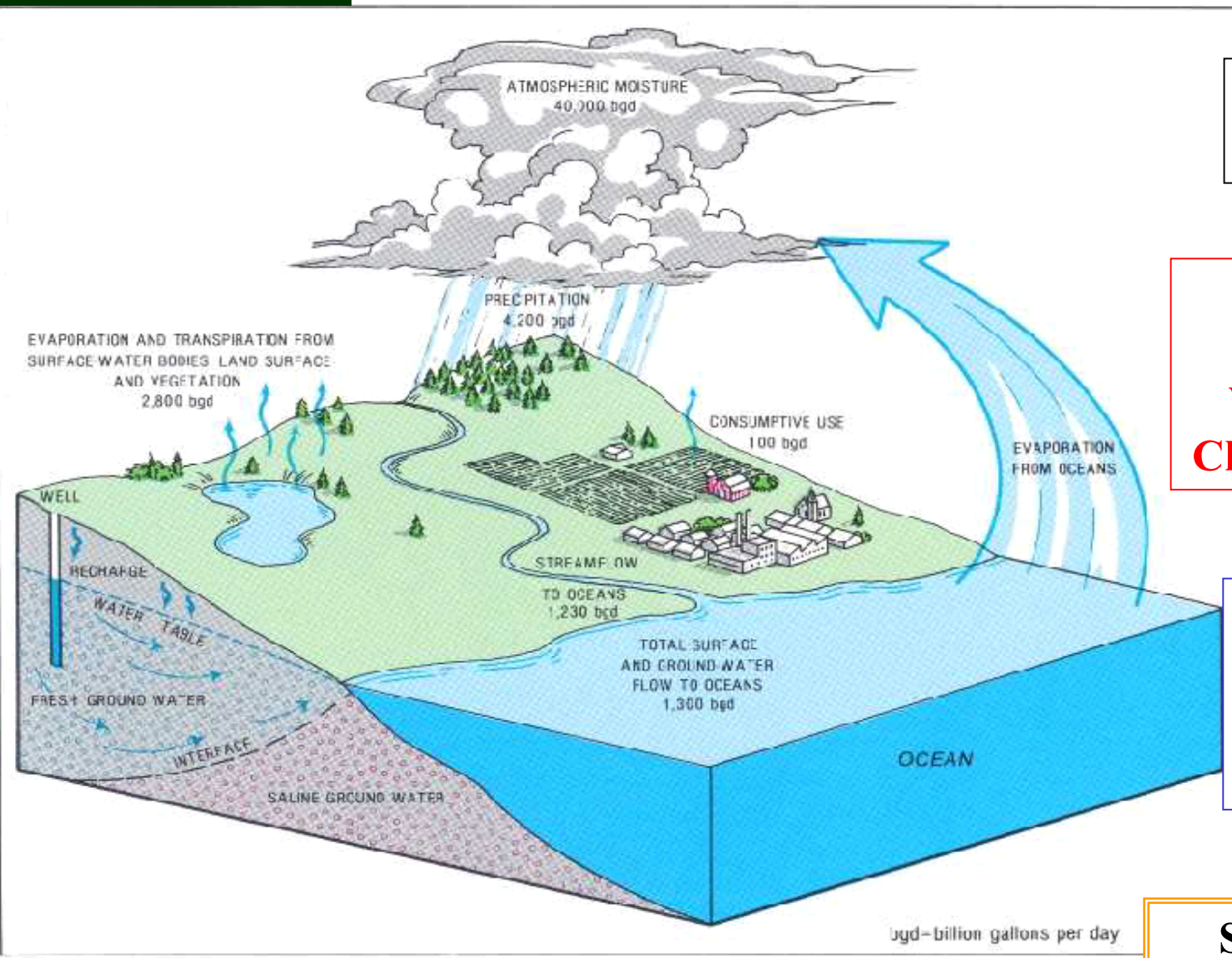
The Hydrology of the Lake Michigan Region

Douglas Cherkauer
Department of Geosciences
University of Wisconsin-Milwaukee

Topics

- Concept of Water Budget (Lake Michigan)
- Ground Water Systems
- Human Impacts of Hydrologic Systems
- Implications for Planning and Management

Water Budget



The continuous hydrologic cycle.

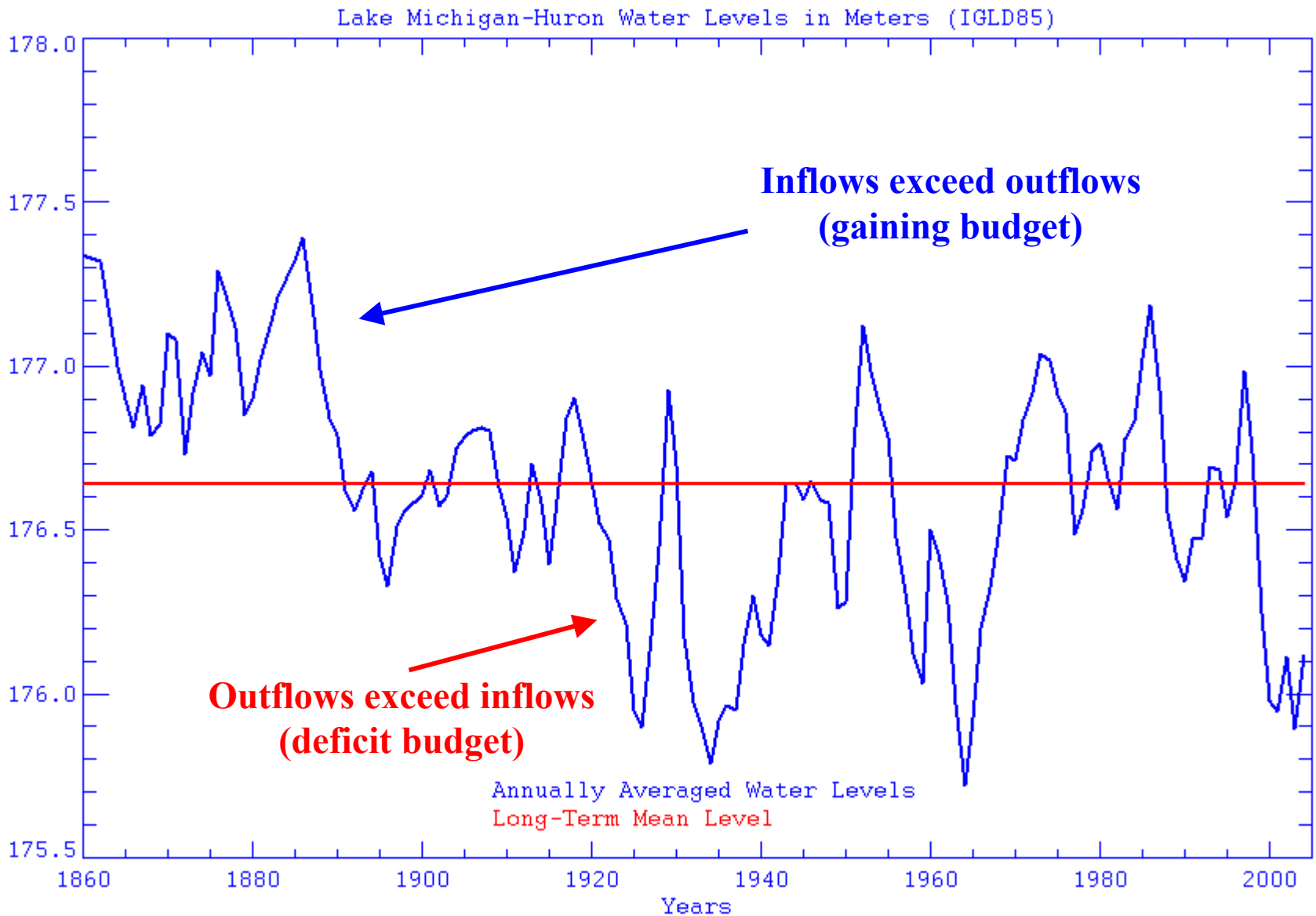
Continuity & Balance

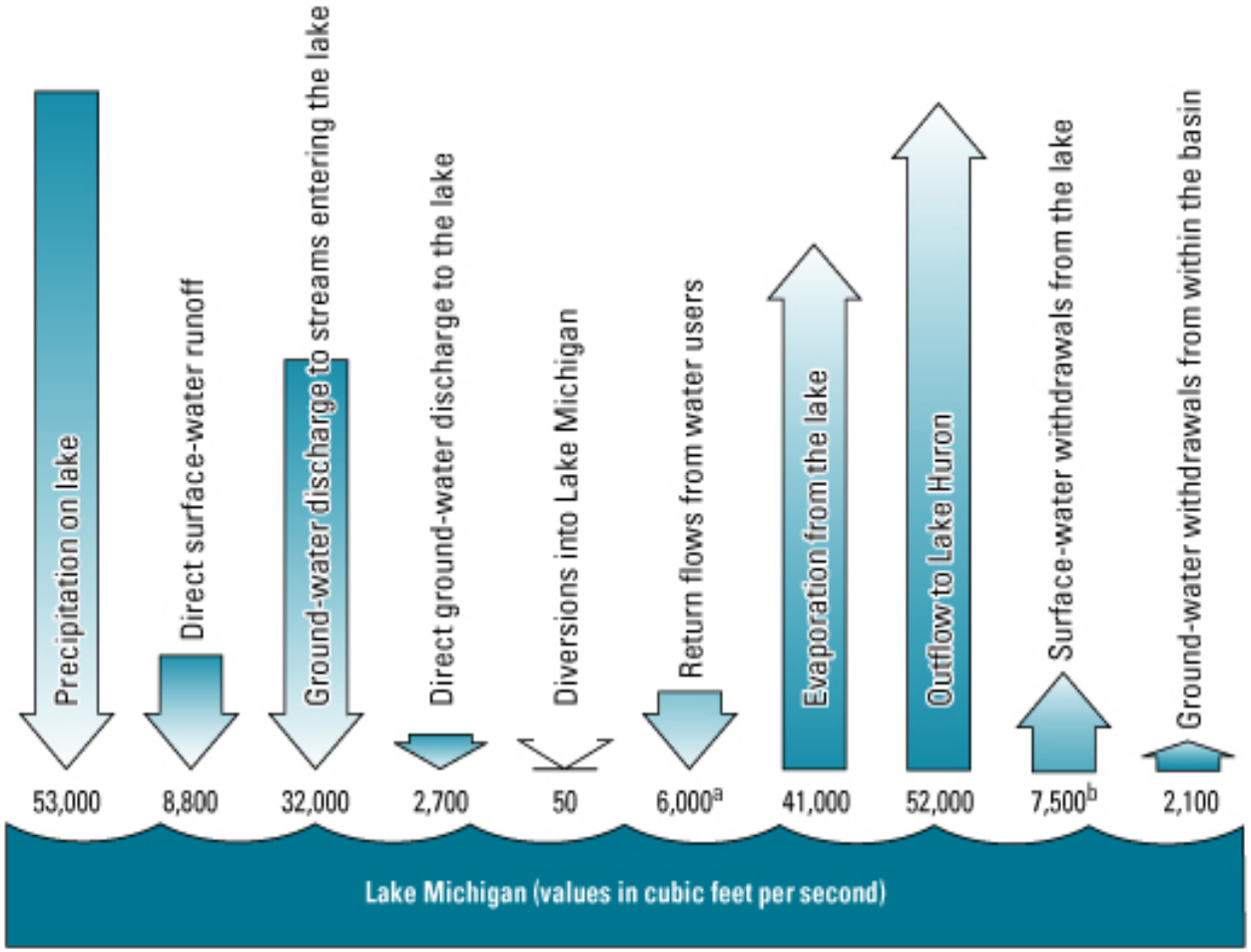
Bank account: Deposits - Withdrawals = Change in Balance

Water Budget: Inflows - Outflows = d(Storage)/time

Sustainability requires continuing the balance

Source: USGS


Lake Michigan-Huron Water Levels in Meters (IGLD85)
178.0
177.5
177.0
176.5
176.0
175.5
1860
1880
1900
1920
1940
1960
1980
2000
Years
Inflows exceed outflows
(gaining budget)
Outflows exceed inflows
(deficit budget)
Annually Averaged Water Levels
Long-Term Mean Level



[a]Return flow is reduced by 3,200 ft^3/s that is diverted out of the basin at Chicago, Ill.

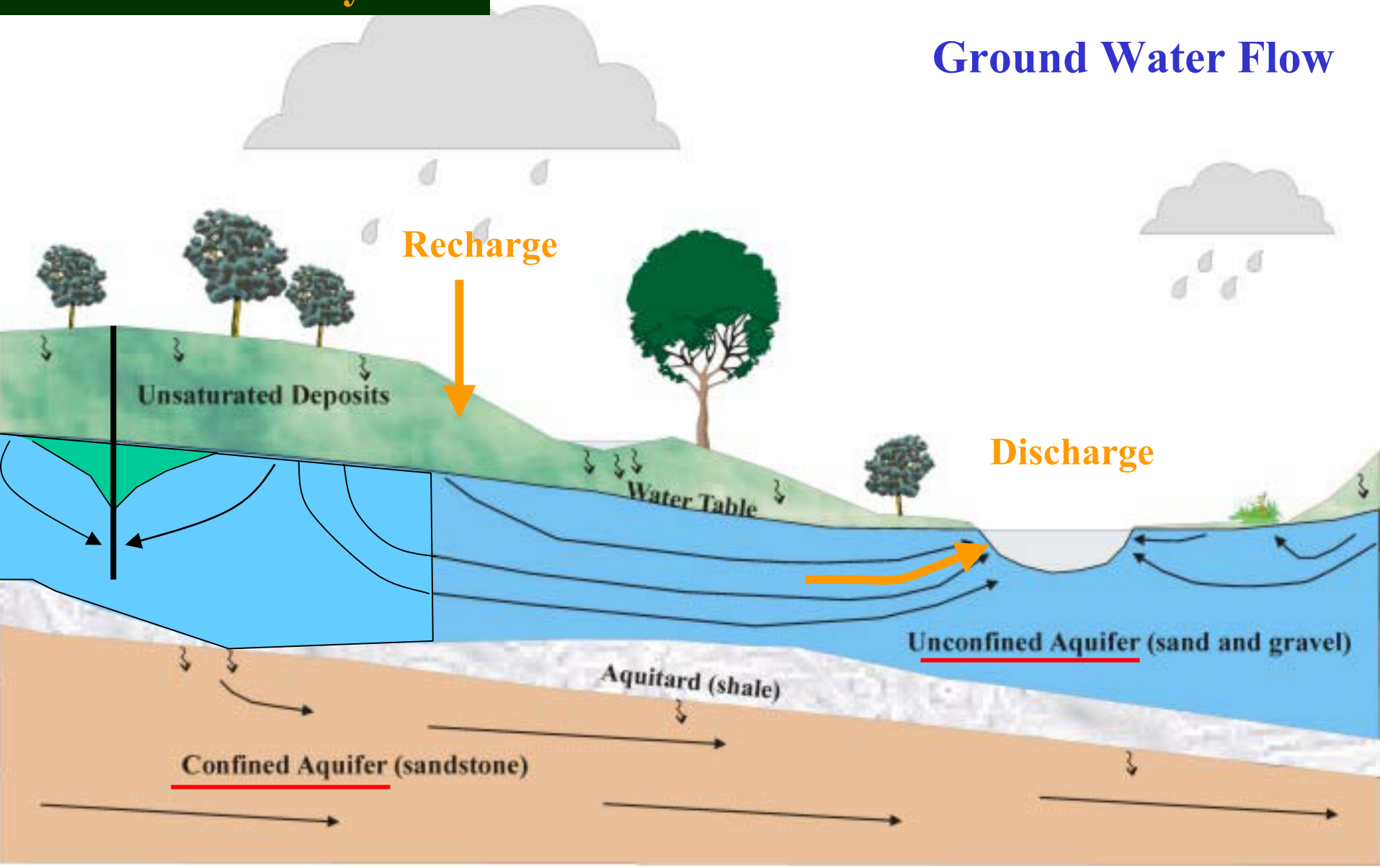
[b]Withdrawals for power plant cooling not included

When outflows exceed inflows, lake levels drop and vice versa

The intent of the Great Lakes Charter is to protect the water balance in the watershed.

Source: USGS

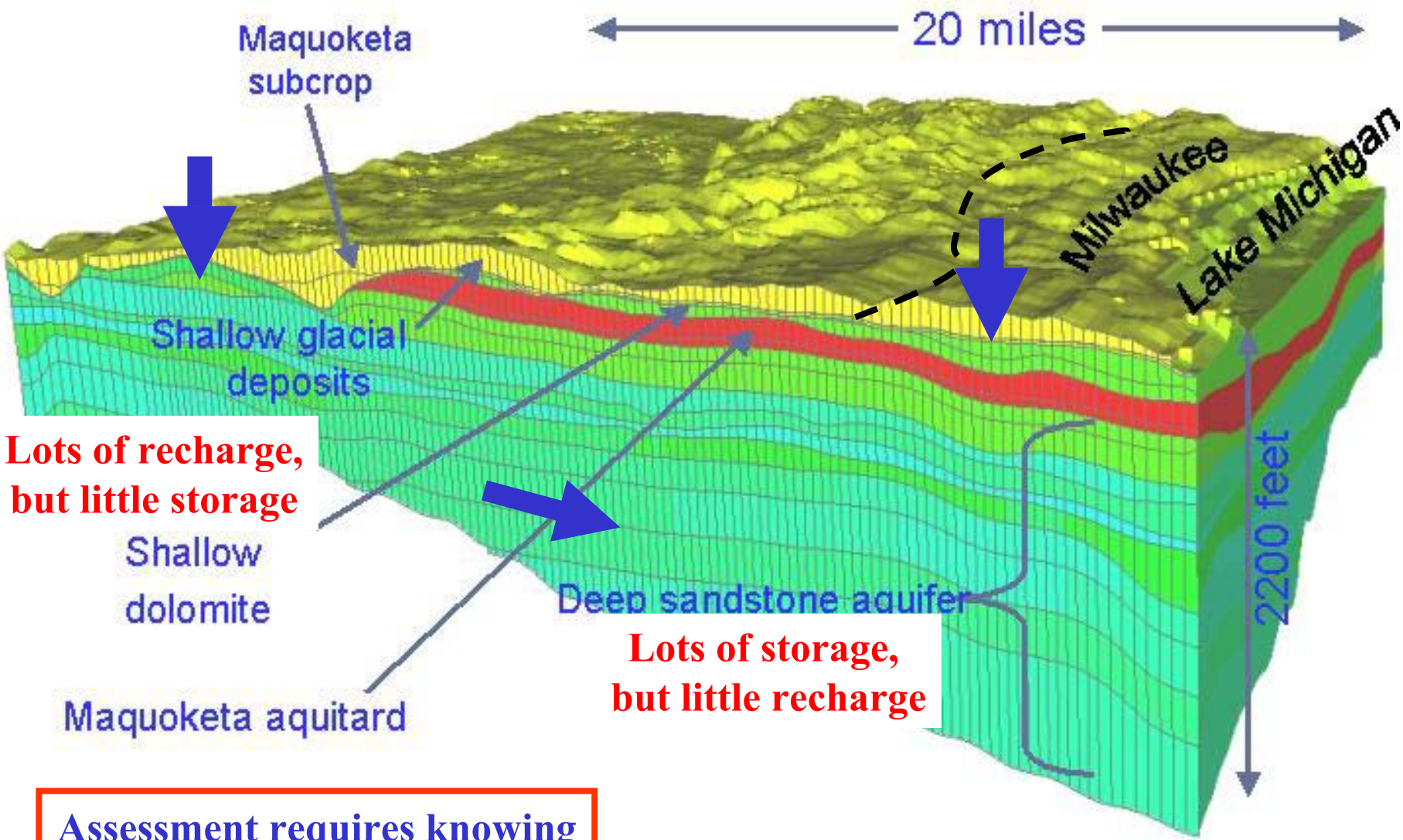
Ground Water Systems



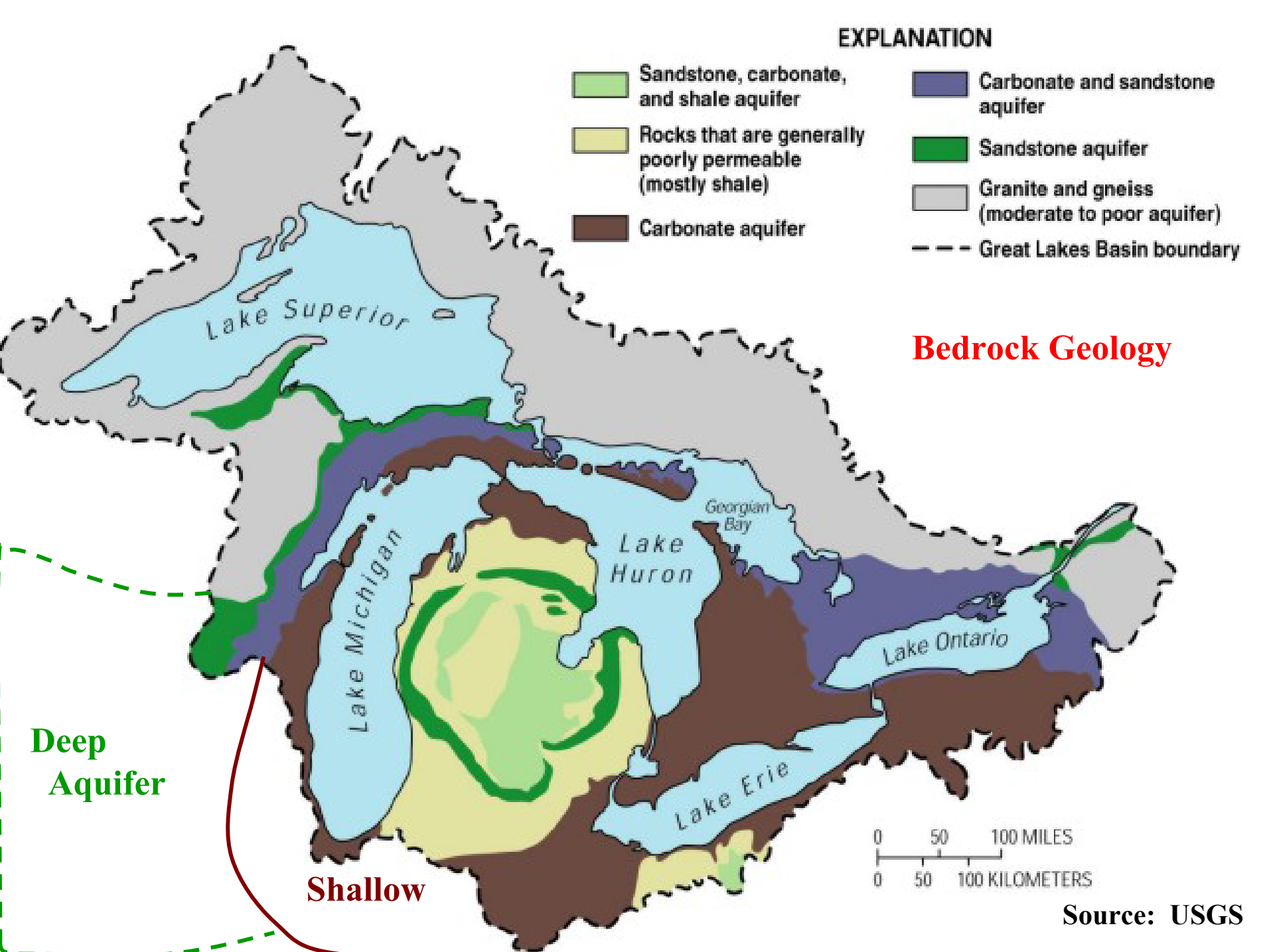
If discharge exceeds recharge, water level drops

Source: USGS

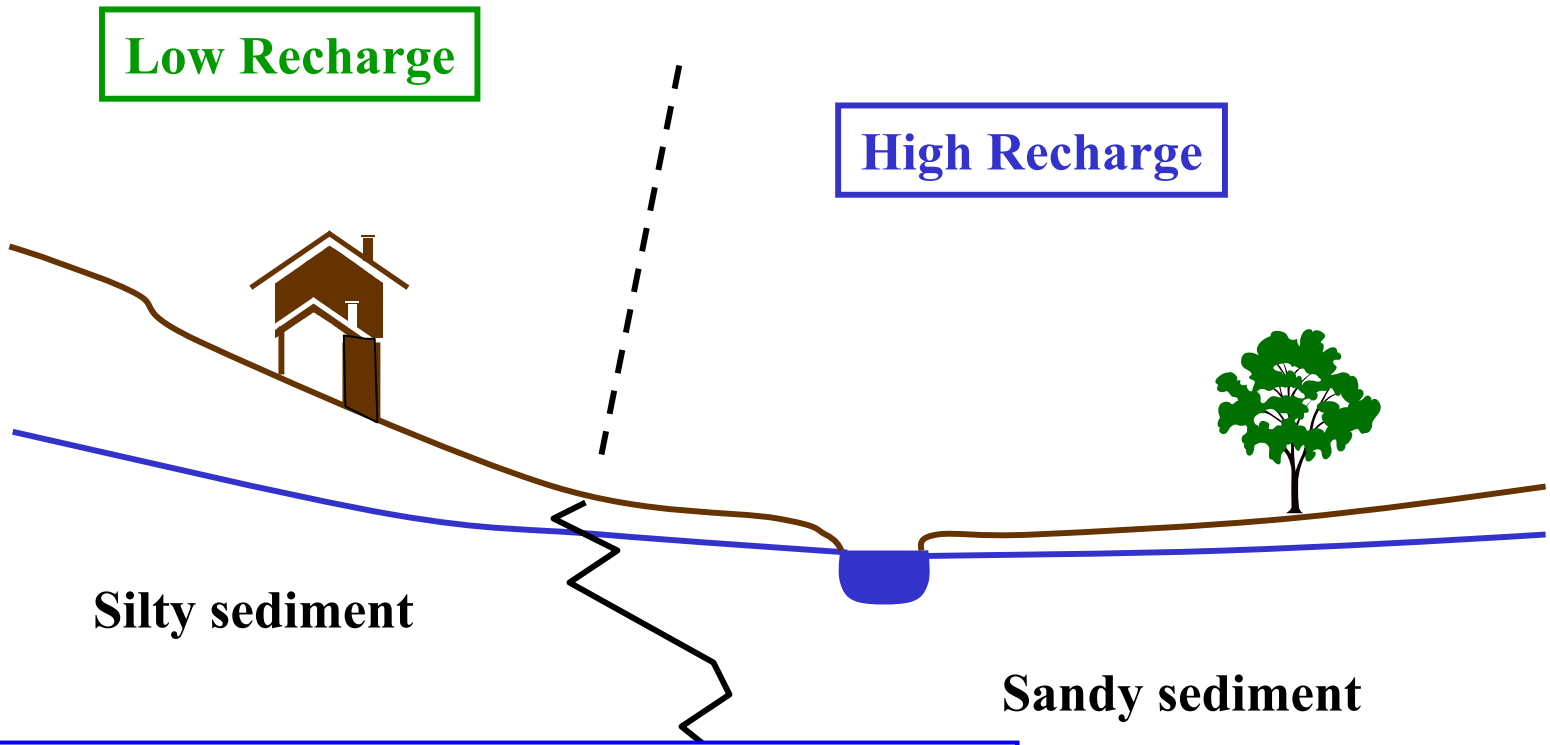
General hydrogeology of southeast Wisconsin



Assessment requires knowing recharge and inflows


EXPLANATION
Sandstone, carbonate, and shale aquifer
Rocks that are generally poorly permeable (mostly shale)
Carbonate aquifer
Carbonate and sandstone aquifer
Sandstone aquifer
Granite and gneiss (moderate to poor aquifer)
Great Lakes Basin boundary
Bedrock Geology
Lake Superior
Lake Michigan
Lake Huron
Georgian Bay
Lake Ontario
Lake Erie
0 50 100 MILES
0 50 100 KILOMETERS
Deep Aquifer
Shallow
Source: USGS

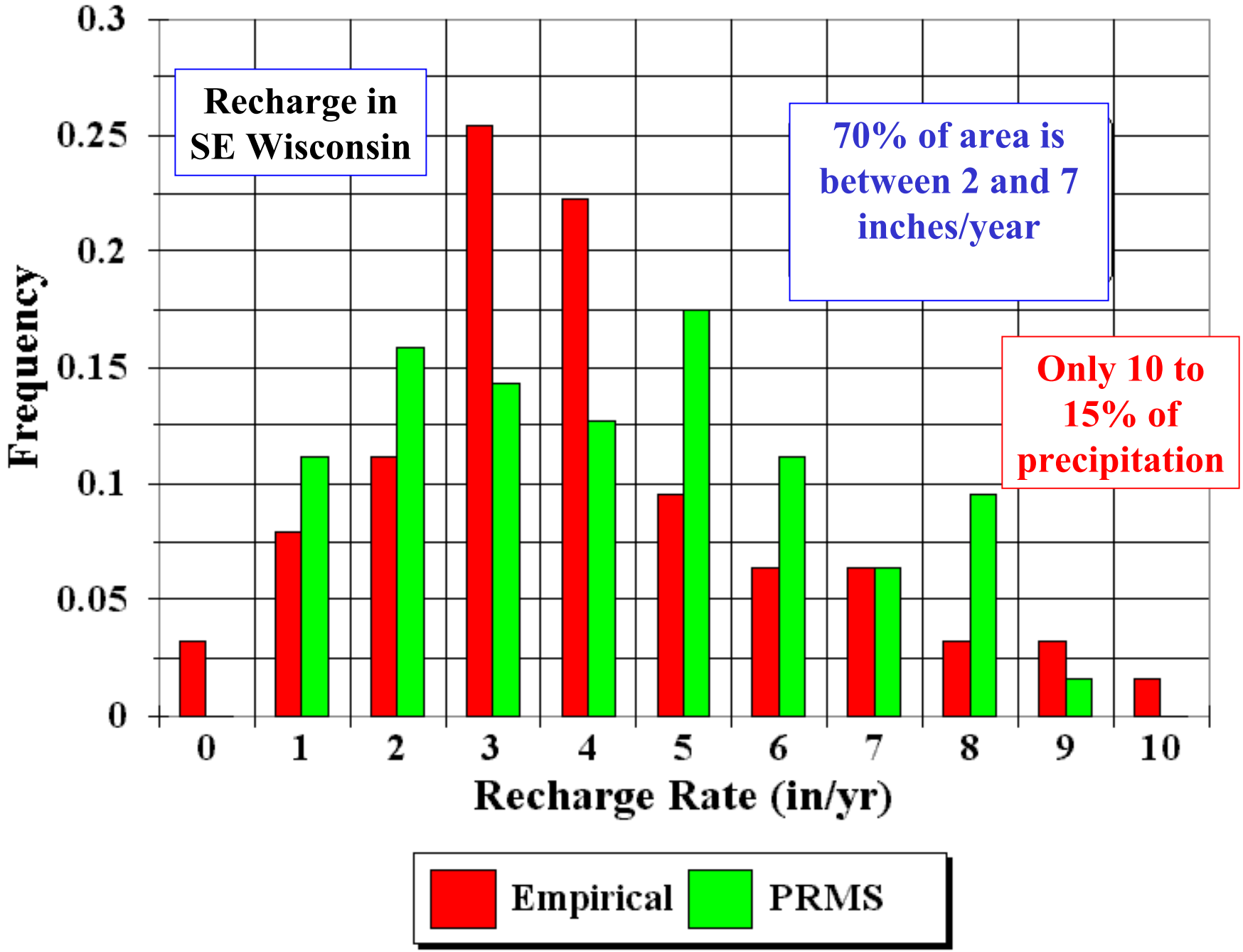
Estimating Based on Physical Properties

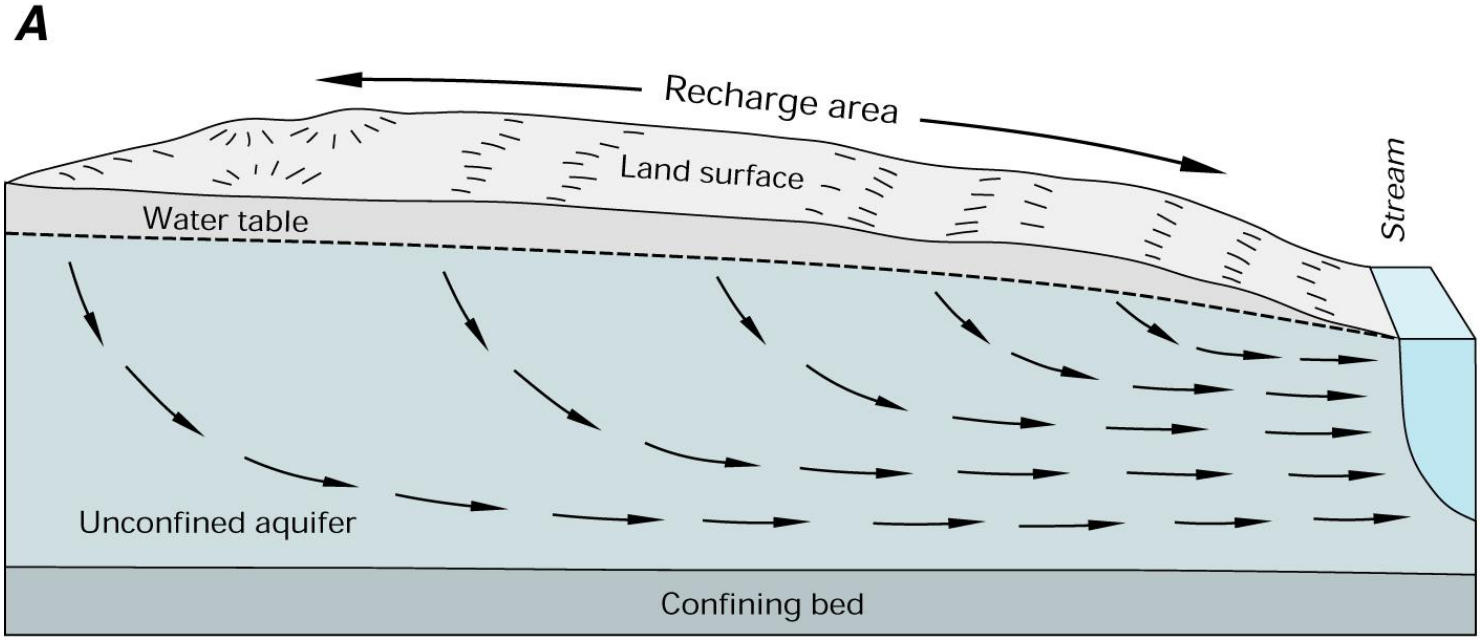


Factors:

Direct	*Inverse*
Soil permeability	*Surface slope*
Distance to channel	*Depth of water table*
Natural land cover	*Urban land cover*

Note: In SE Wisconsin, only 10 to 20% of precipitation becomes recharge


Recharge in SE Wisconsin
70% of area is between 2 and 7 inches/year
Only 10 to 15% of precipitation
Frequency
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
9
10
Recharge Rate (in/yr)
Empirical
PRMS



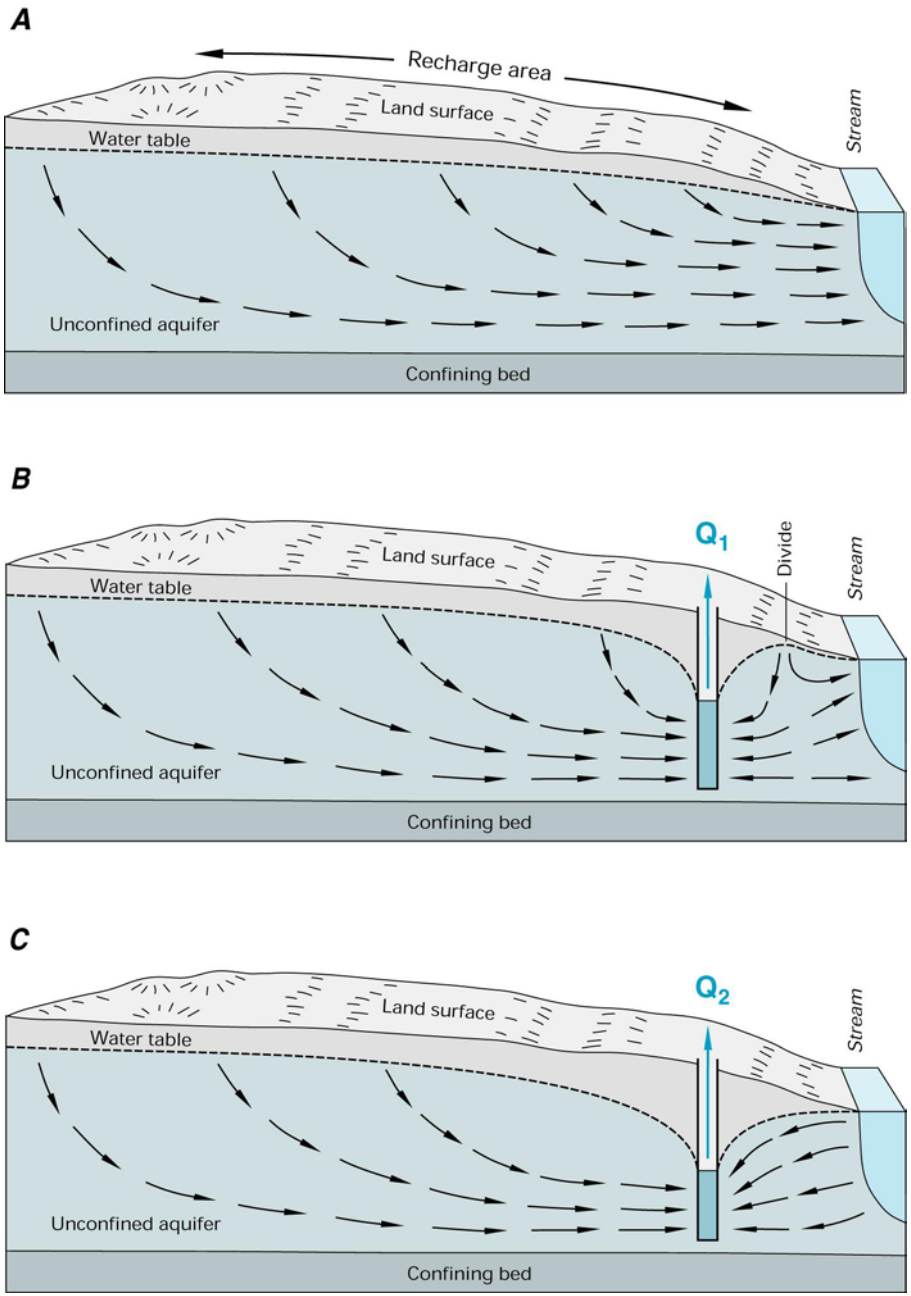
Natural ground water discharge is to surface water bodies.

In our area, 30% to 70% of a stream's total flow can be ground water discharge.

Ground water also maintains levels and temperatures in lakes and wetlands

Source: USGS

Unconfined aquifers



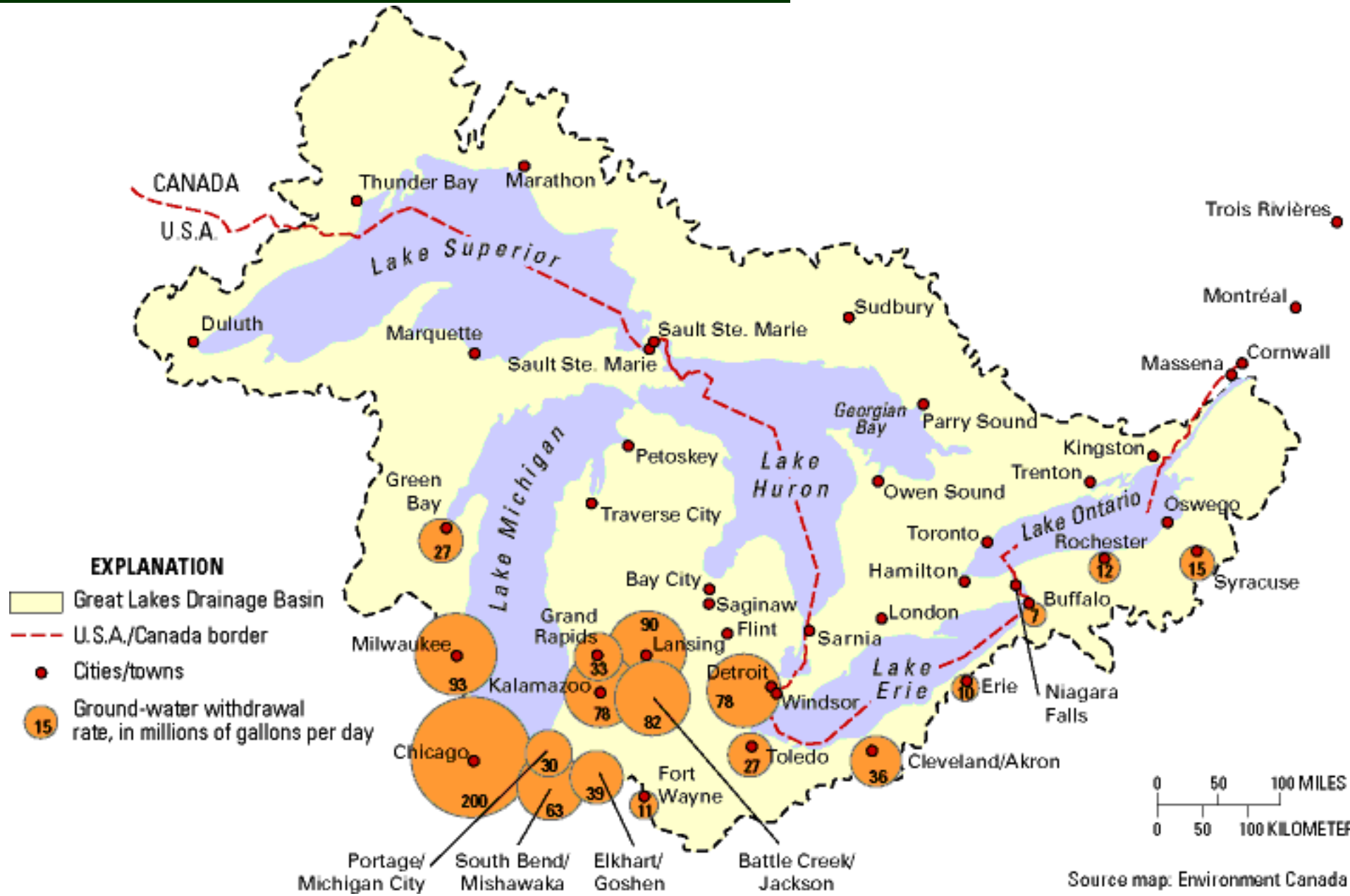
Upper limit on supply = recharge rate * surface area

Wells reduce water levels causing cones of depression

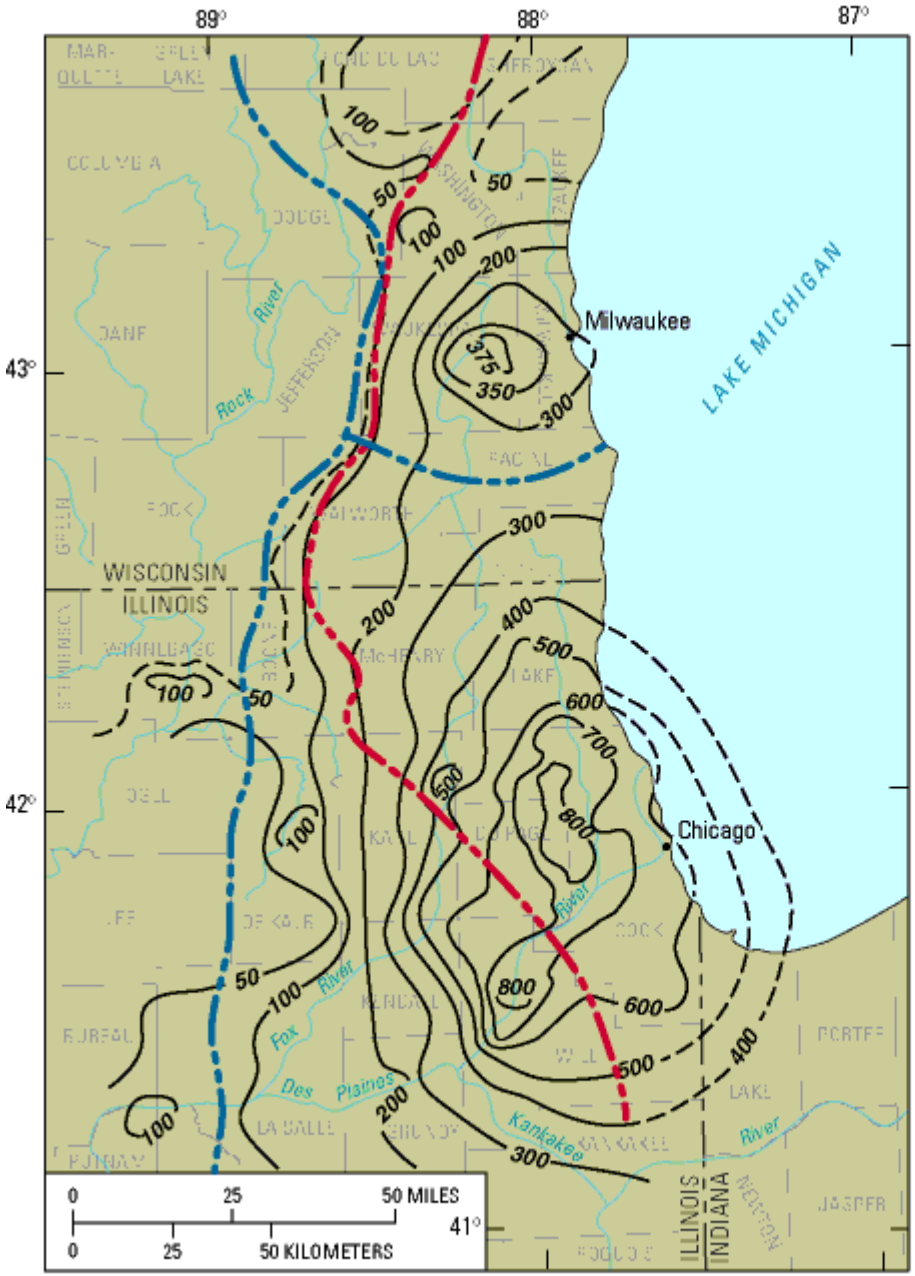
Without management, use will impact streams, lakes, wetlands

Source: USGS

Human Impacts on Hydrologic Systems



Source: USGS



Base from U.S. Geological Survey 1:2,000,000 Digital Data
Albers Equal-area Conic projection
Standard parallels 33° and 45°, central meridian –89°

EXPLANATION

700 — Line of equal water-level decline, 1864–1980—Dashed where approximate. Interval, in feet, is variable

Major ground-water divide (1980)

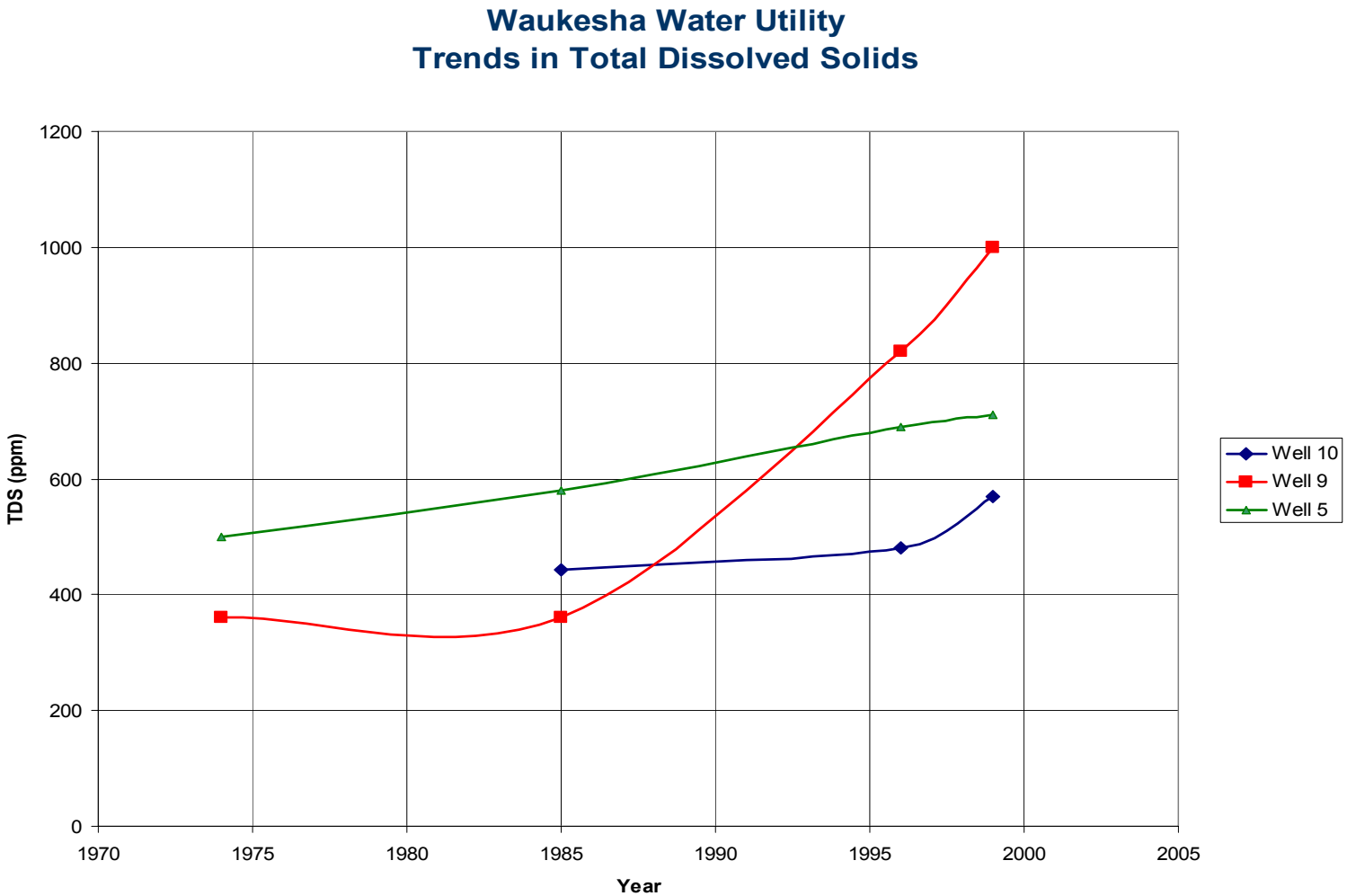
Pre-development ground-water divide (about 1864)

Deep Aquifer: water levels dropping, divide migrating west

Effect in the shallow aquifer has been much less – less pumping and more recharge

Source: USGS

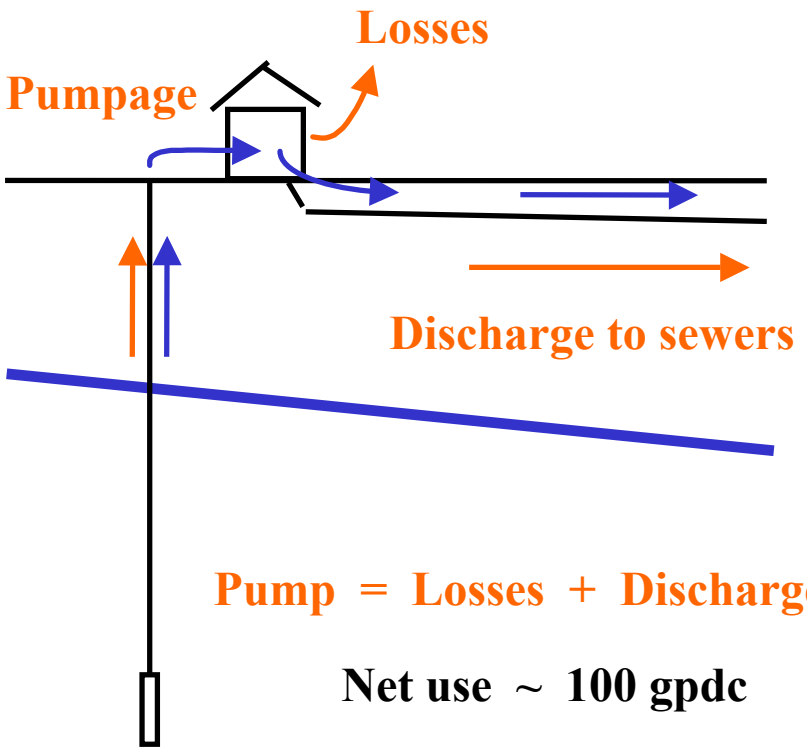
Declining Head Impacting Water Quality



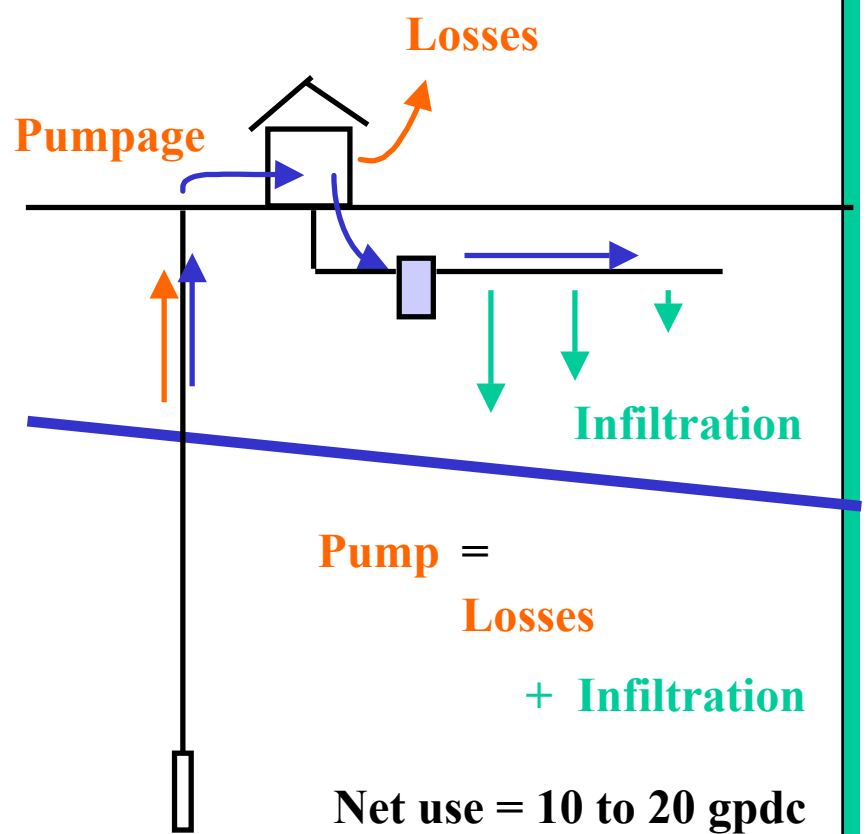
- Salinity levels rising in several sandstone wells in Waukesha County
- Caused by vertical migration of saline water in response to over pumping

Source: AS&T

Wasting system



Recycling System

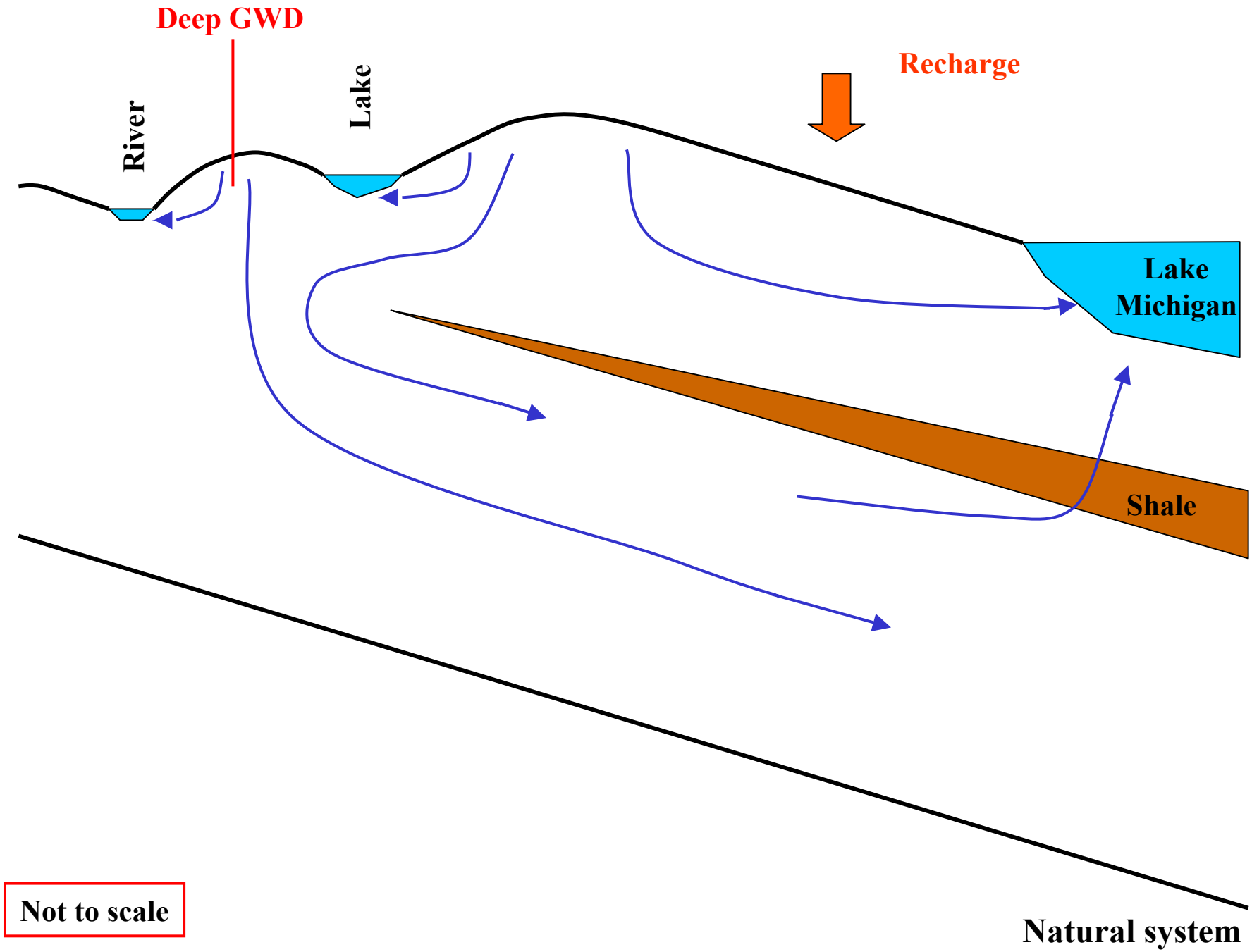


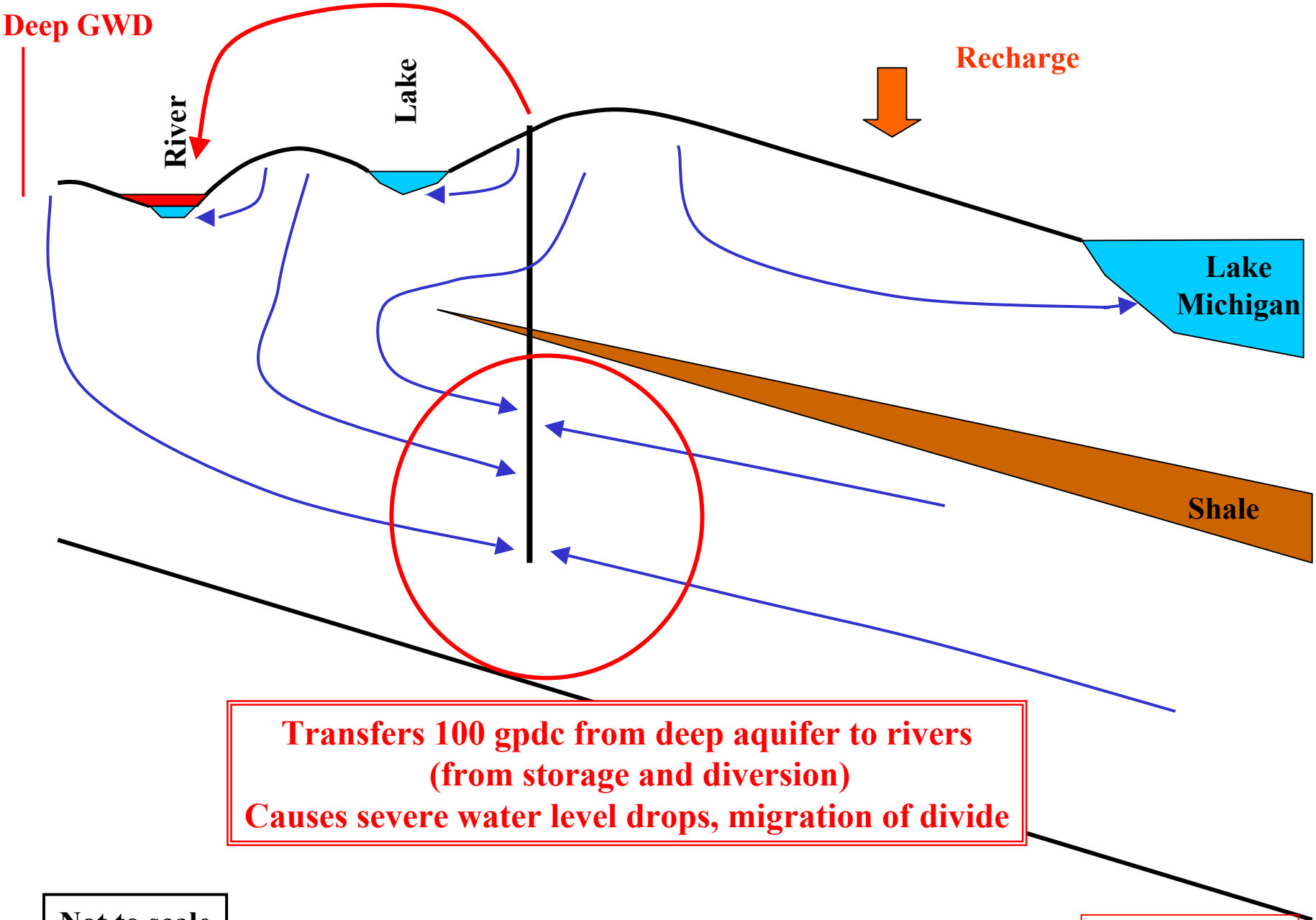
To protect water quality, regulations tend to move us from recycling to wasting.

For water quantity, this is counterproductive.

Alternatives to deficit budget in deep aquifer

- 1. Use Lake Michigan water, even outside the lake's watershed (despite Great Lakes Charter)
- 2. Transfer much of demand to the shallow aquifer
- 3. Manage the total water resource (quantity and quality)
  - Blend shallow aquifer with deep
  - Treat wastewater to highest standards
  - Return to the same system (reduces demand ~80%)

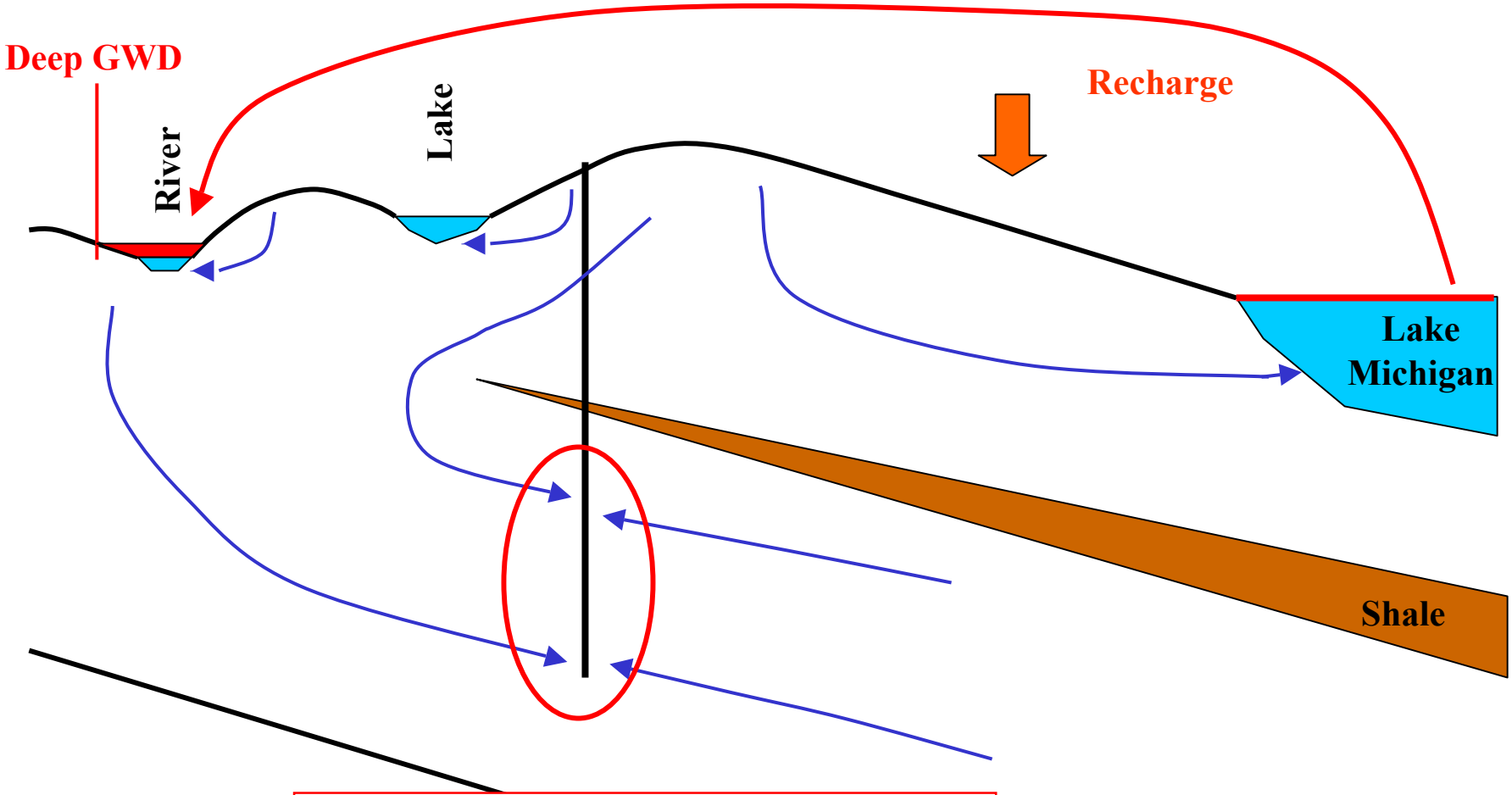

Deep GWD
Recharge
River
Lake
Lake Michigan
Shale
Not to scale
Natural system



Transfers 100 gpdc from deep aquifer to rivers (from storage and diversion)
Causes severe water level drops, migration of divide

Not to scale

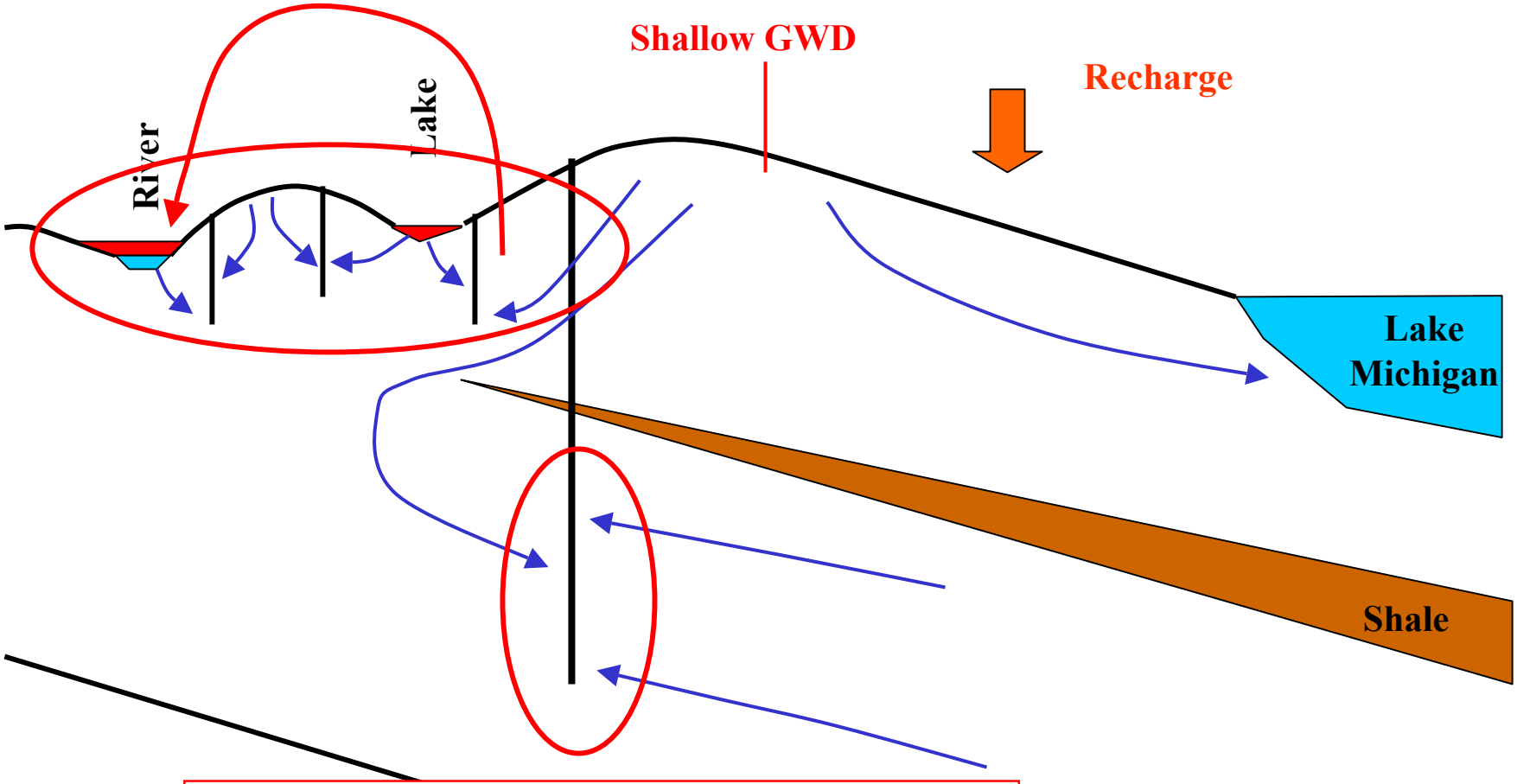
Throw-away of today



Reduces pumping of deep aquifer, but transfers effects of no management to Lake Michigan.
Very likely a temporary "fix"

Not to scale

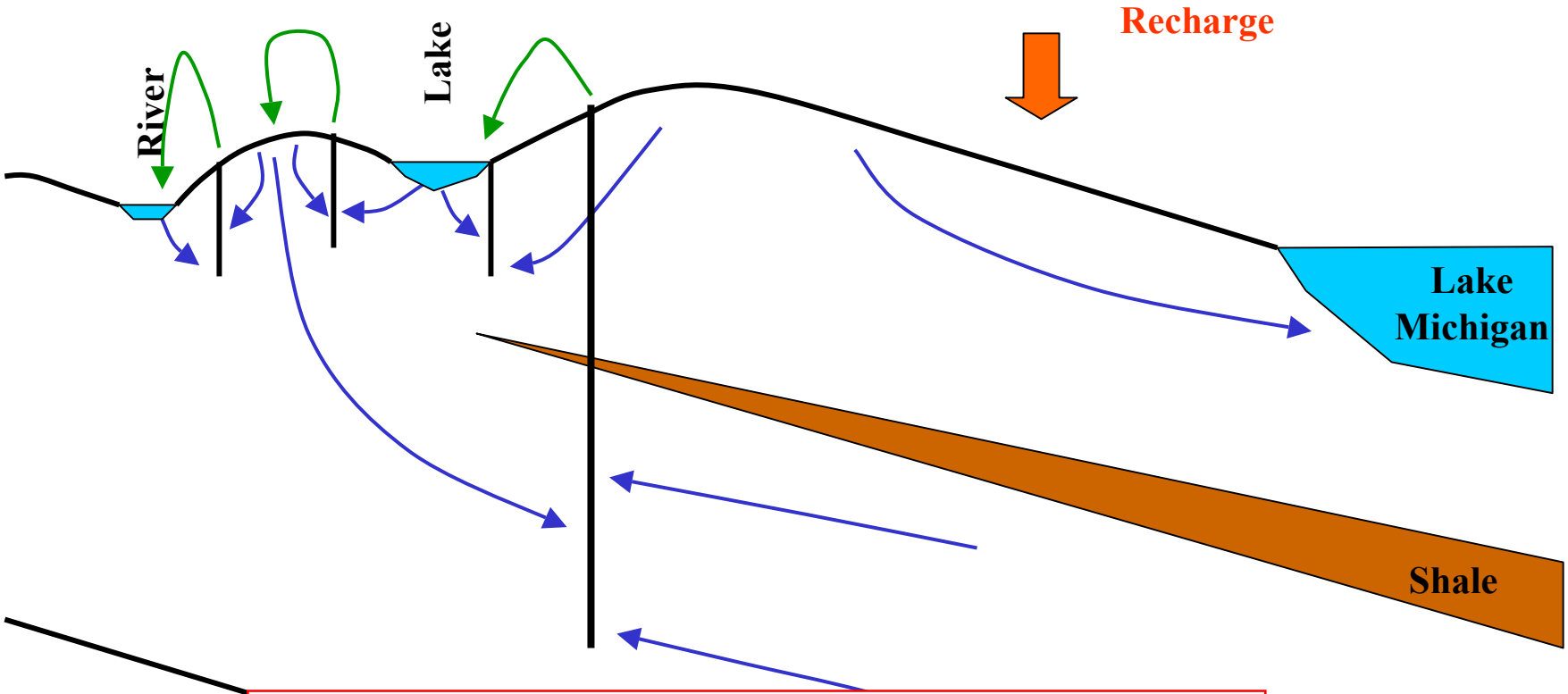
Alternative 1: Lake Michigan; no management



Reduces pumping from deep aquifer, but transfers lack of management to shallow and surface water bodies. Streams and wetlands dry up; lakes lowered.

Not to scale

Alternative 2: Use shallow aquifer; no management



Reduce use of deep aquifer, and blend with shallow
Treat wastewater to high standards; return to system
Manage balance between outflows and returns

Net loss from system drops from ~100 gpdc to <20 gpdc

Not to scale

System with Regional Management

Points to remember

- **Ground water and surface water systems are linked**

- **Sustainable supply to humans cannot exceed inflows to hydrologic system being used (and environmental stewardship would require using less)**

- **Within this framework, the once-through transfer of water from the deep aquifer or Lake Michigan the Mississippi is shortsighted, wasteful, and not sustainable** ***[And a large part of the perception of water "shortages". We're consuming, not managing.]***

Conclusions

- **Protection of Great Lakes requires enforcement of the Charter.**
- **Quick fixes to shortages have limits and are not sustainable.**
- **The long-range fix to our water problems is regional management – both quantity and quality, both surface and ground waters.**
- **It will not be easy, but it CAN be sustainable.**