Climate Change in the Great Lakes Region

Starting a Public Discussion

Tonight:

Climate Change and Potential Impacts on Wisconsin’s Lakes, Streams and Groundwater

Sea Grant University of Wisconsin

Wisconsin Coastal Management Program

NOAA

UW Extension

www.seagrant.wisc.edu/ClimateChange

or…Why are lake levels so low?

Tim Asplund
Wisconsin Dept of Natural Resources

Sandbar Lake, Bayfield County

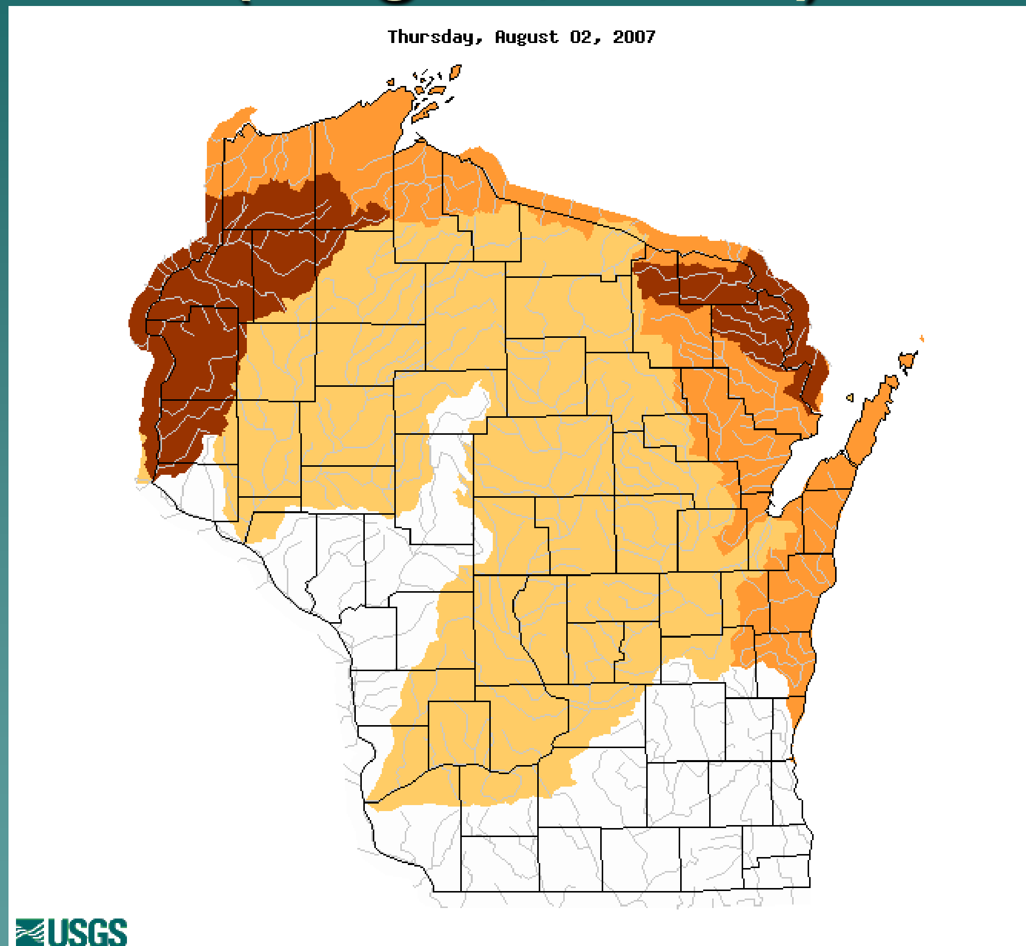
F. Koshere

“small lake”, Burnett County

F. Koshere

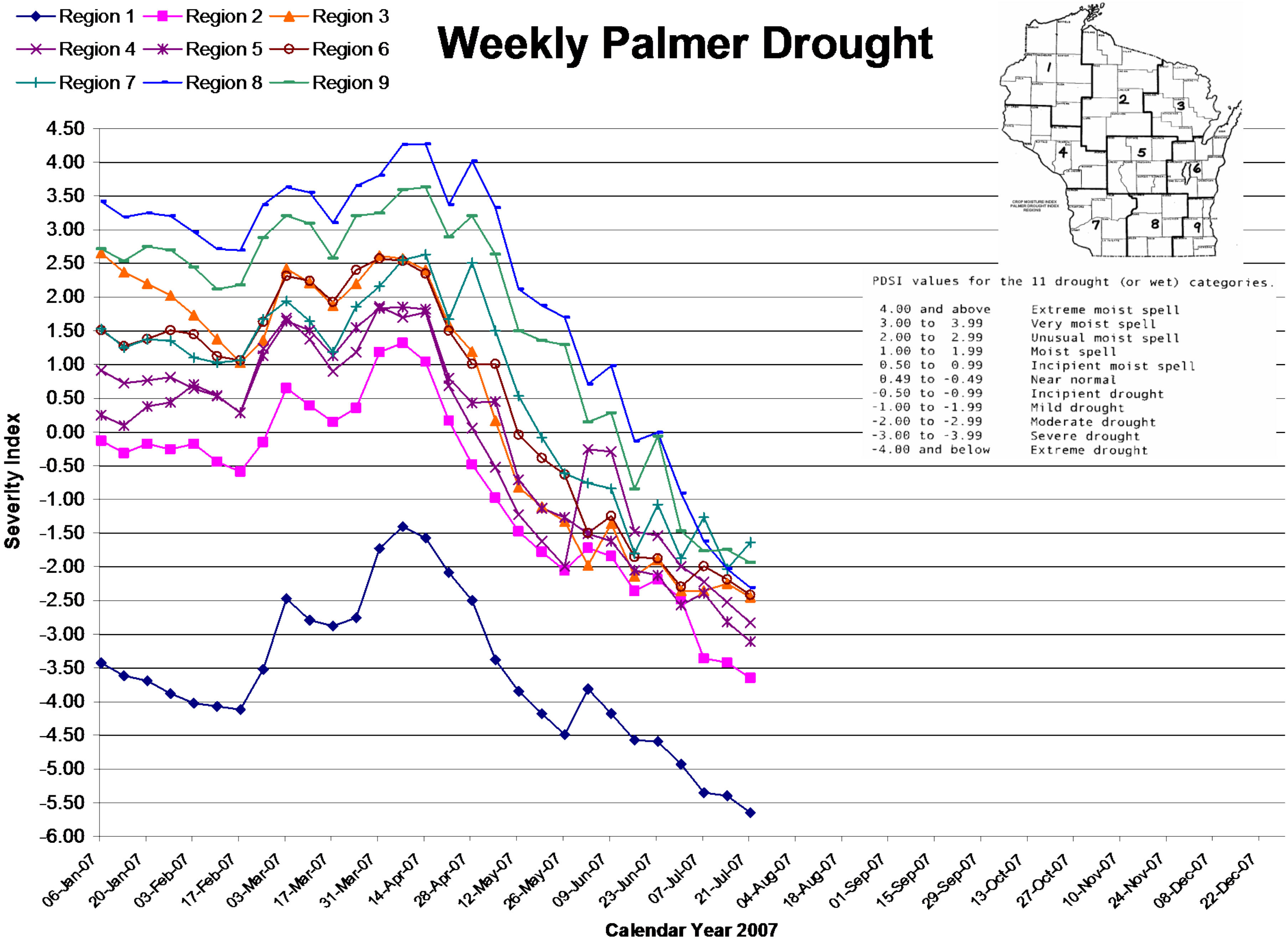
Tomahawk Lake, Bayfield County

Below normal 7-day avg. streamflow (Aug. 2, 2007)

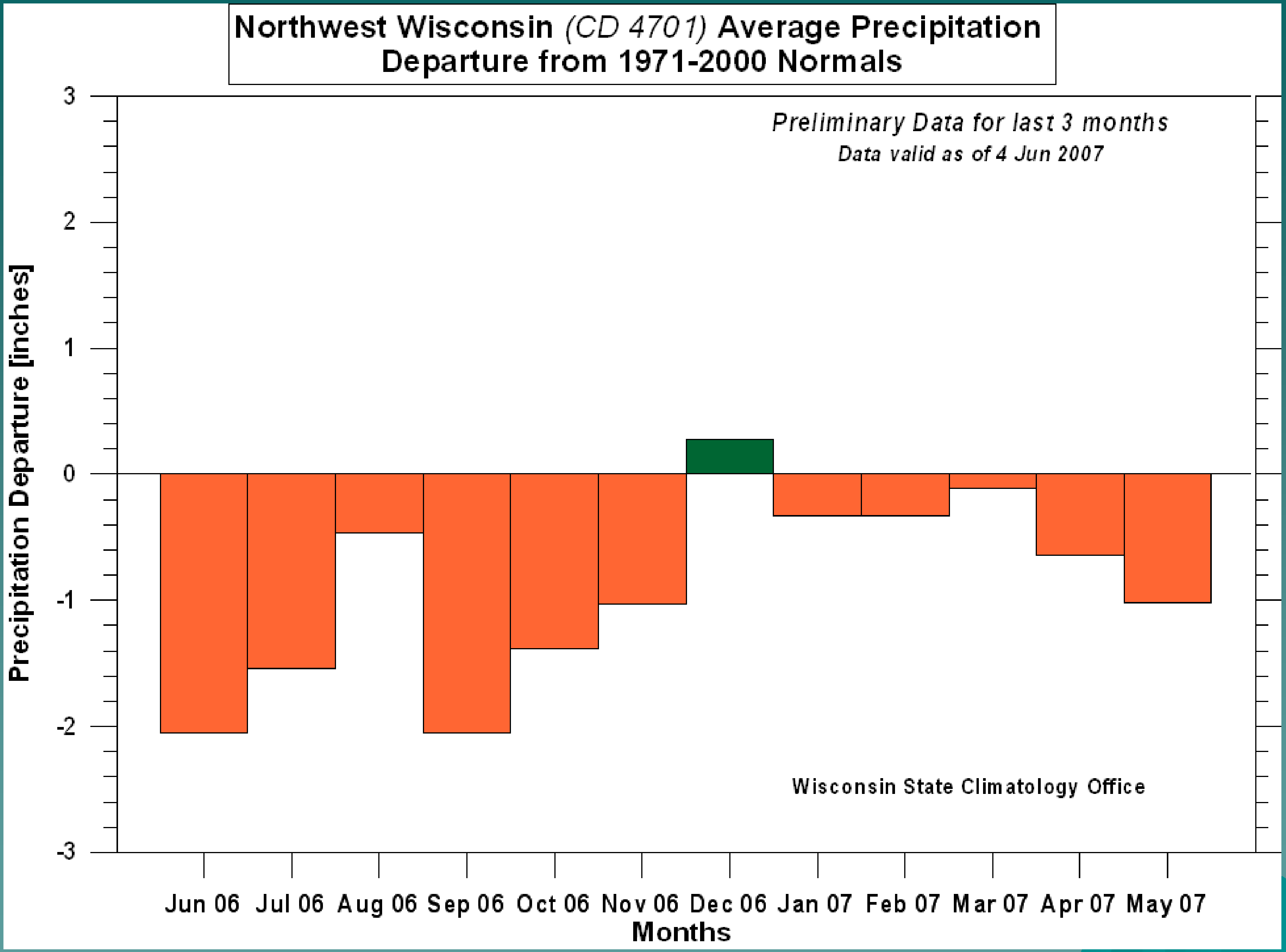


Explanation - Percentile classes				
Low	<=5	6-9	10-24	Insufficient data for a hydrologic region
Extreme hydrologic drought	Severe hydrologic drought	Moderate hydrologic drought	Below normal	

http://water.usgs.gov/waterwatch/



Data from WI State Climatology Office


Northwest Wisconsin (CD 4701) Average Precipitation
Departure from 1971-2000 Normals
Preliminary Data for last 3 months
Data valid as of 4 Jun 2007
Wisconsin State Climatology Office
Precipitation Departure [inches]
3
2
1
0
-1
-2
-3
Jun 06
Jul 06
Aug 06
Sep 06
Oct 06
Nov 06
Dec 06
Jan 07
Feb 07
Mar 07
Apr 07
May 07
Months

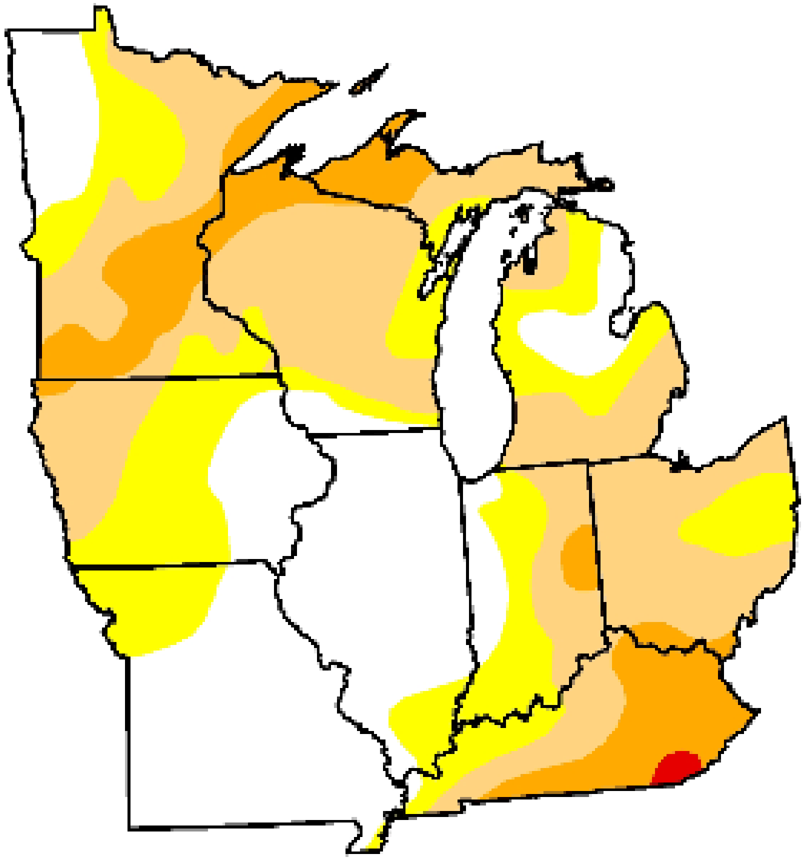
U.S. Drought Monitor

Midwest

July 24, 2007
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	32.4	67.6	44.3	12.3	0.3	0.0
Last Week (07/17/2007 map)	35.3	64.7	39.0	8.1	0.3	0.0
3 Months Ago (05/01/2007 map)	82.1	17.9	7.7	3.8	1.9	0.0
Start of Calendar Year (01/02/2007 map)	57.8	42.2	18.0	11.1	7.1	0.0
Start of Water Year (10/03/2006 map)	63.5	36.5	21.9	10.3	7.7	0.0
One Year Ago (07/25/2006 map)	47.3	52.7	33.7	14.3	6.3	0.0



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements

http://drought.unl.edu/dm

USDA National Drought Mitigation Center

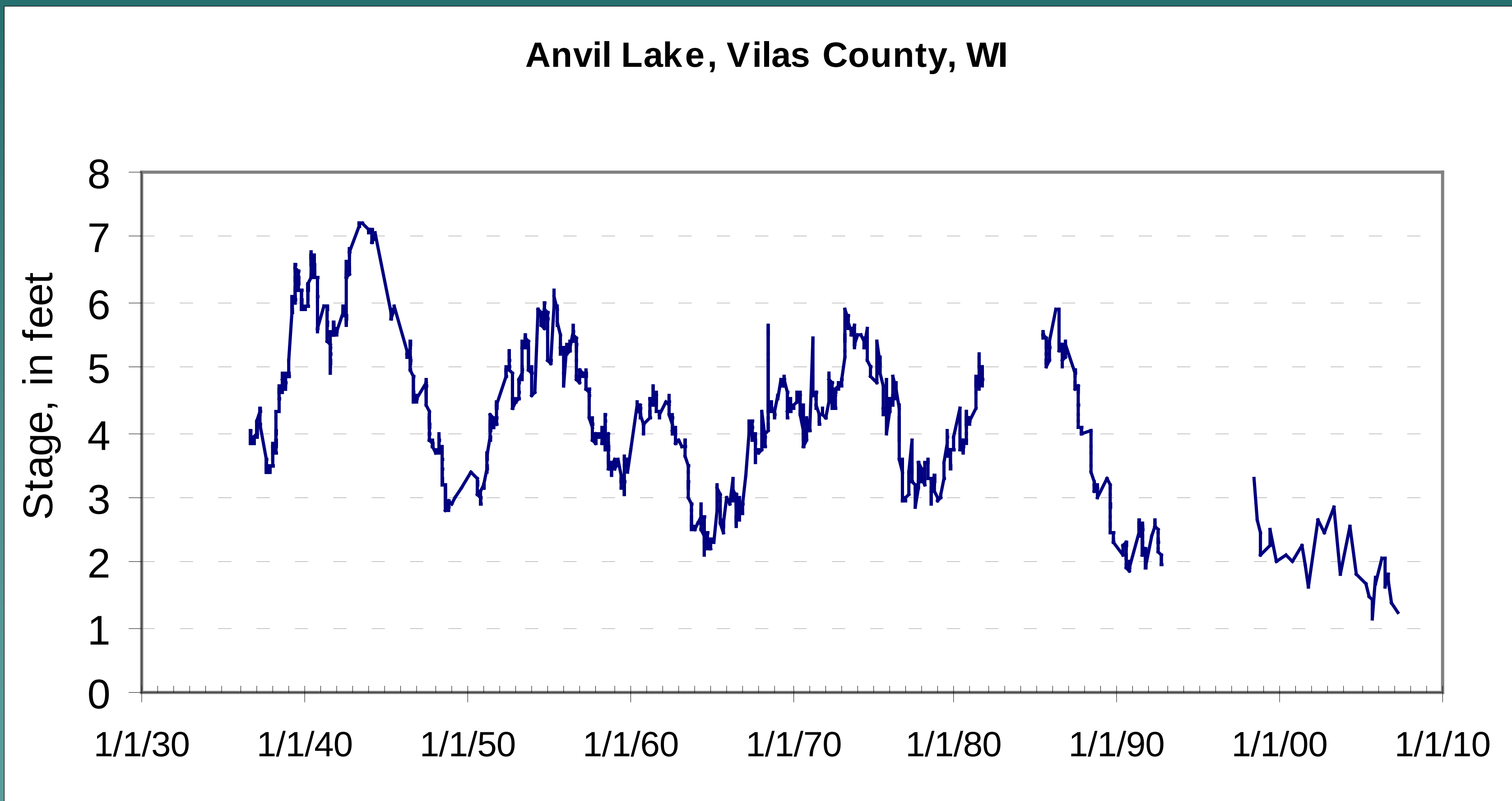
Released Thursday, July 26, 2007

Author: Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

Huron Lake, Waushara County

Long Lake, Waushara County

Anvil Lake Stage Record (1936 – 2006)



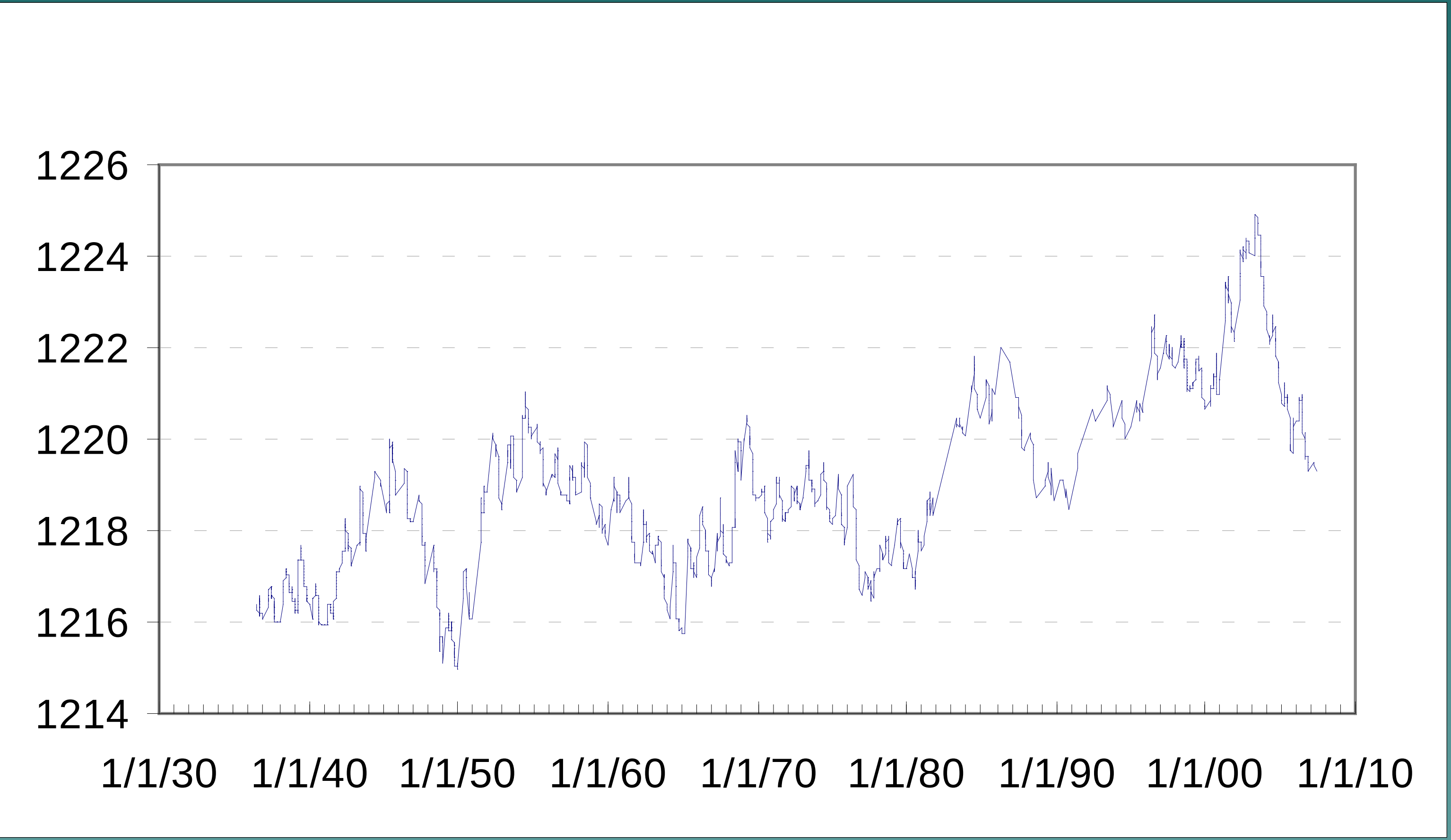
Some lakes are dropping over the long term

Source: USGS

But remember this?

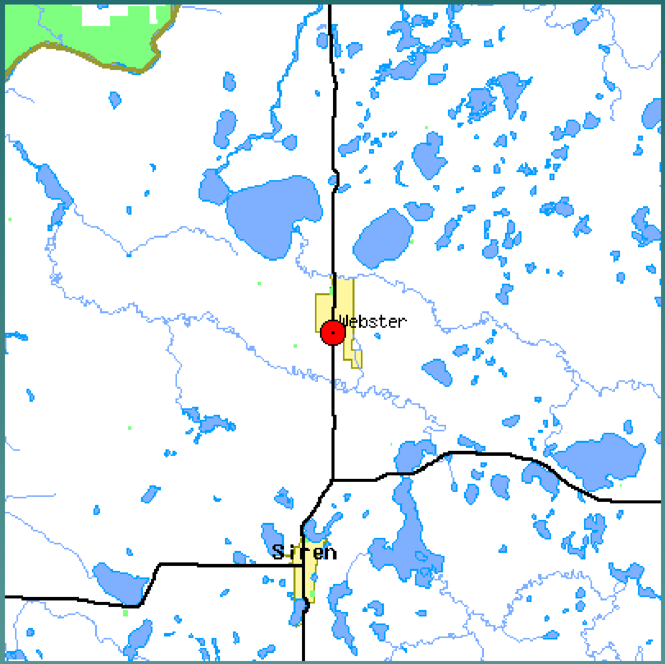
Shell Lake (WI) June 2002

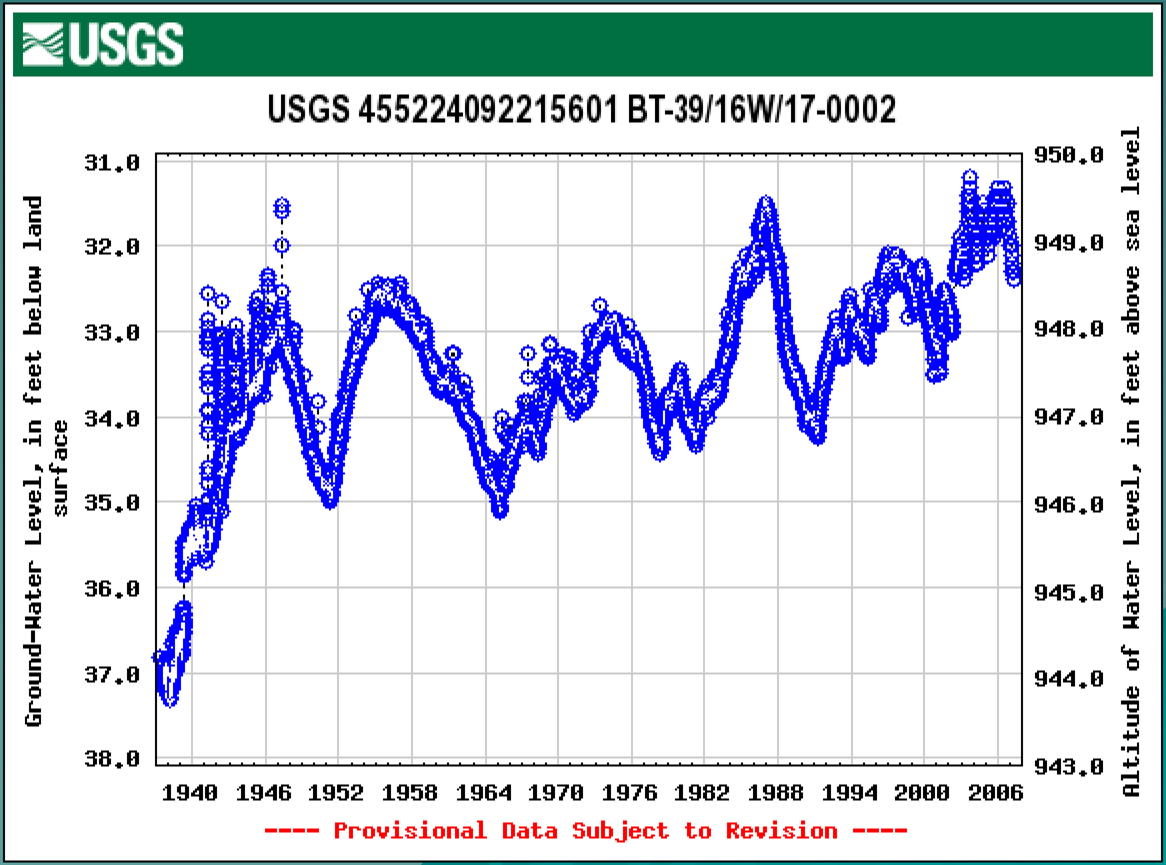
Shell Lake Stage Record (1936 – 2006)



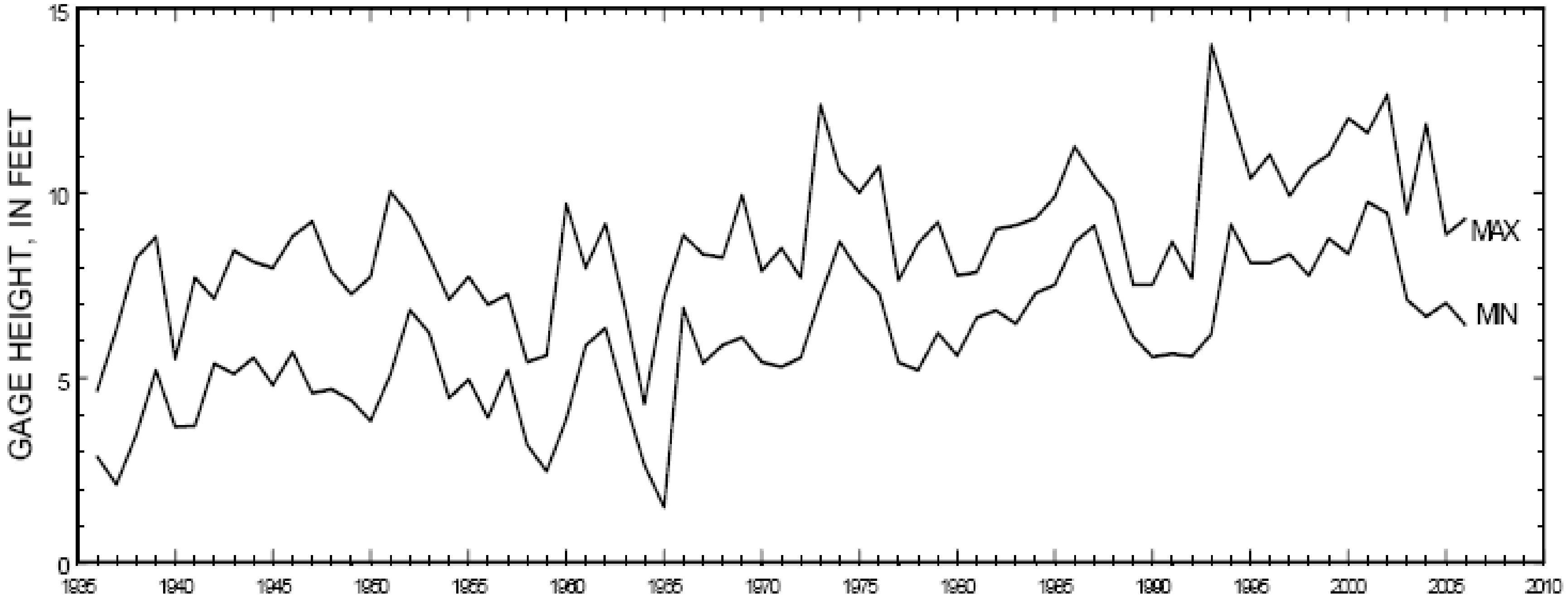
Source: USGS

BT-0002: Webster, WI





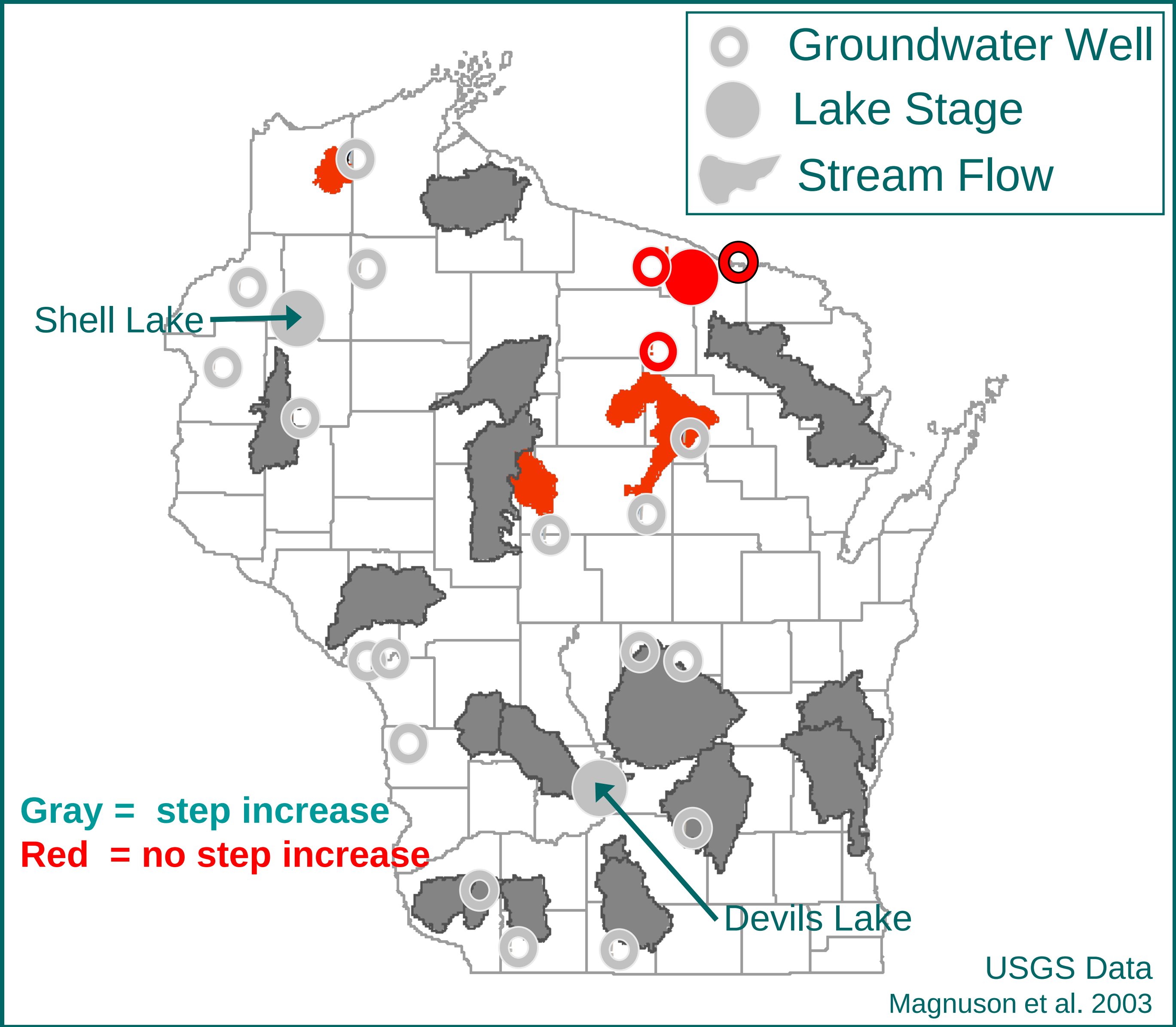
Devil's Lake Stage Record (1935-2006)



1935 1970 2005

Source: USGS

Step Increase in Lake Stage, Stream Flow, and Groundwater Levels after 1970



Which one is the future?

Maybe both!

Presentation overview

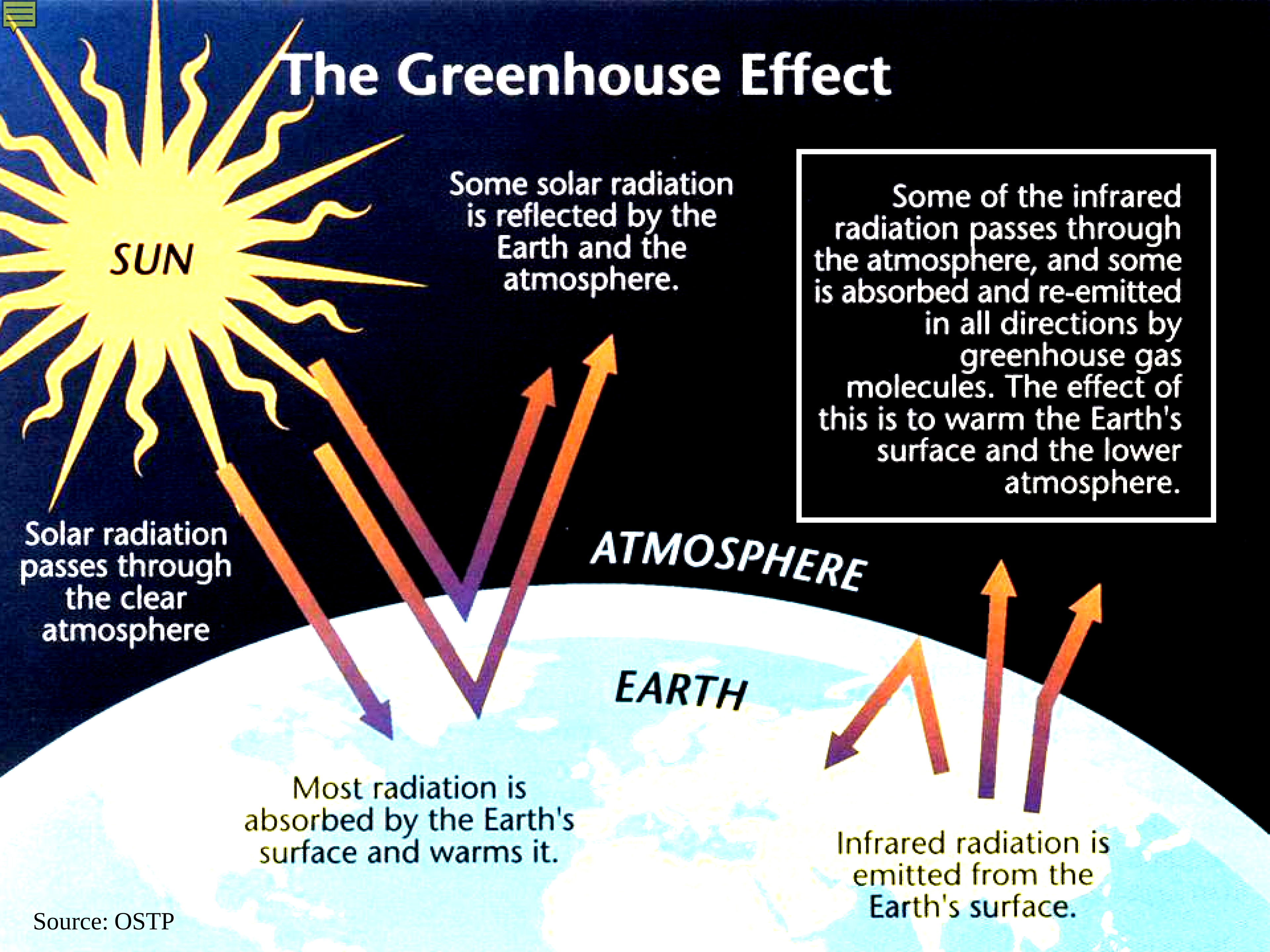
- Climate Change evidence
- Projections for Wisconsin
- Impacts to water resources
- Understanding water levels
- Case Studies
- Putting it all together
- What to do?

Global Warming Is Unequivocal:

- **The recent IPCC report has clearly stated that "warming of the climate system is unequivocal" and it is "very likely" caused by human activities.**

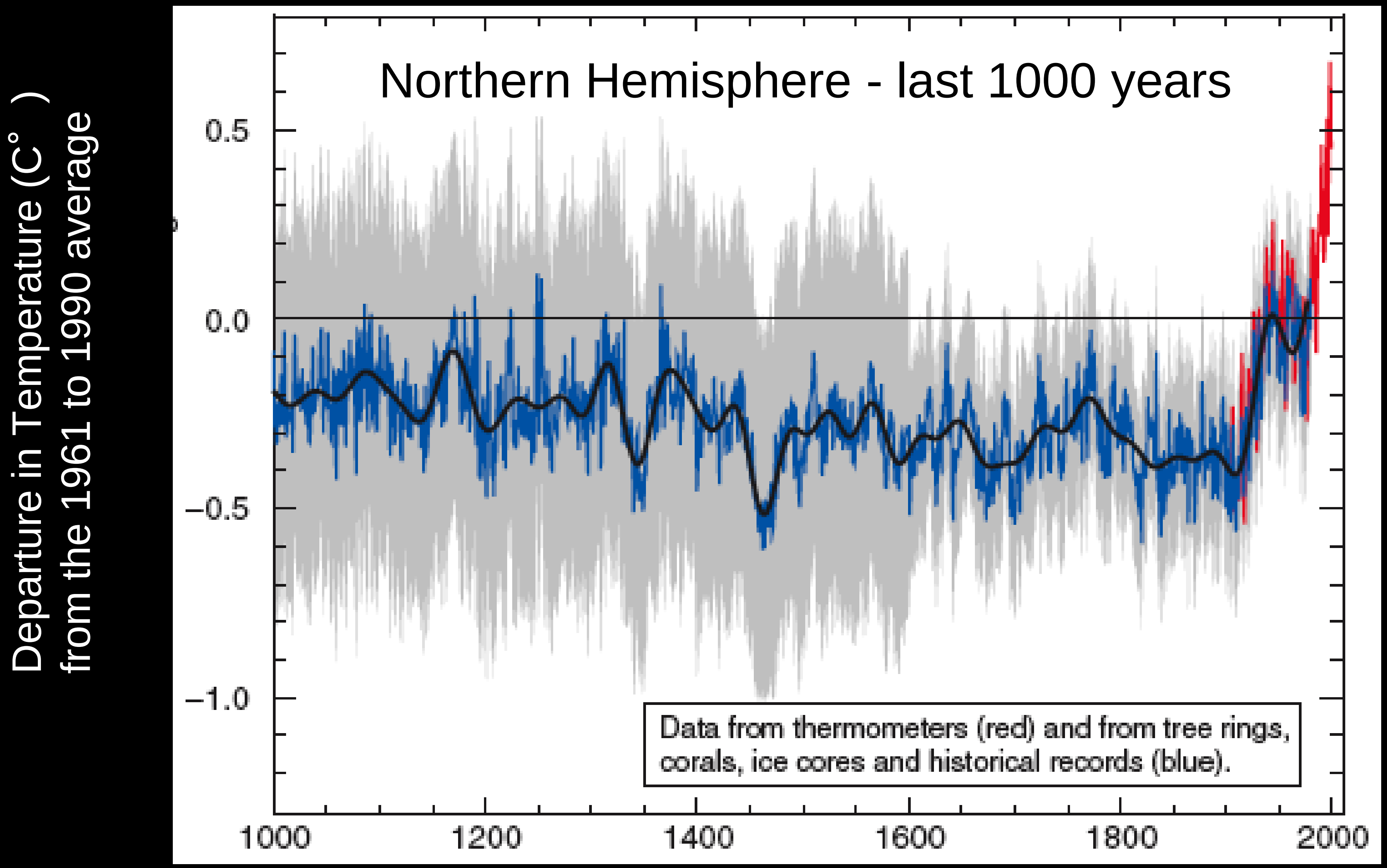
- **Moreover, most of the observed changes are now simulated by models over the past 50 years, adding confidence to future projections.**

Trenberth, 2007


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

Source: OSTP

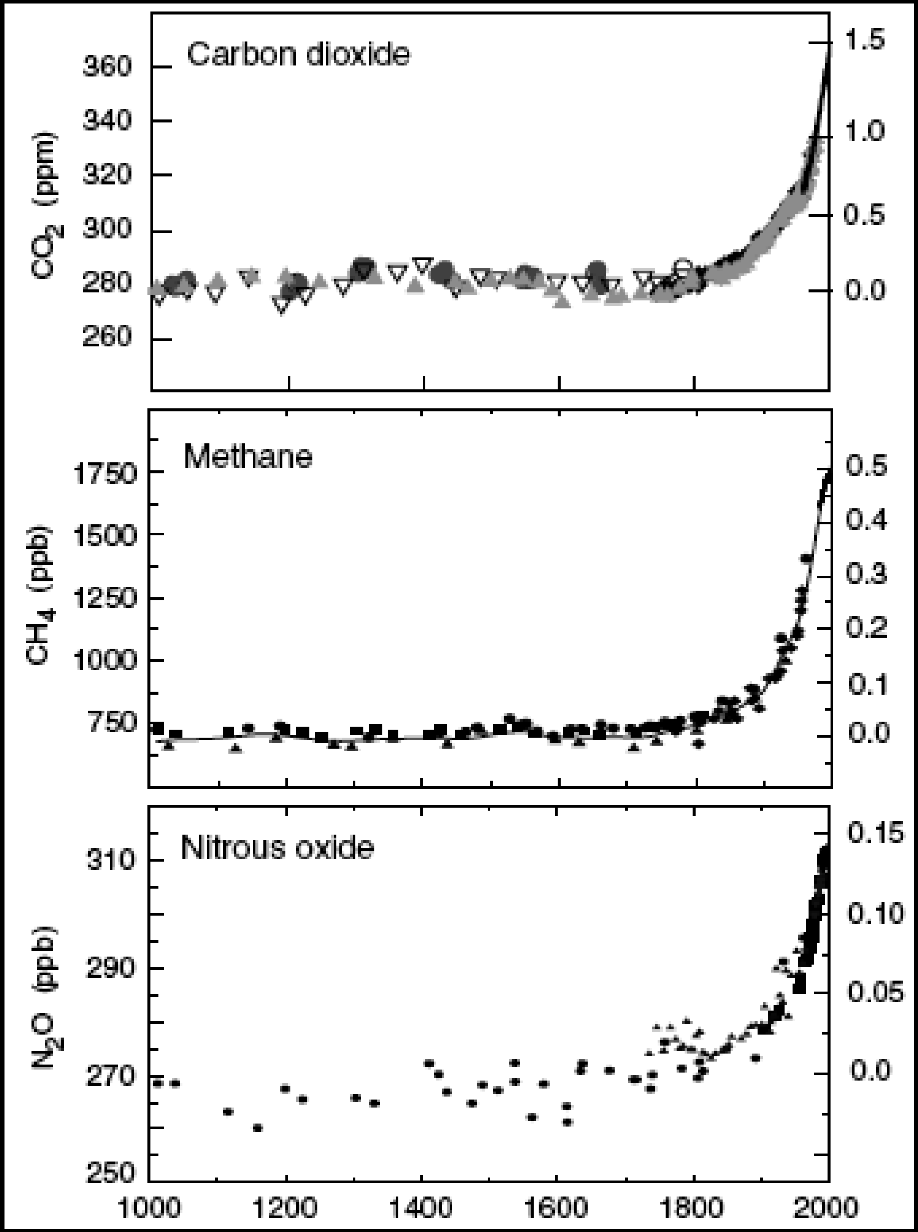
Variation in Earth Surface Temperatures



IPCC 2007

Greenhouse Gas Concentrations

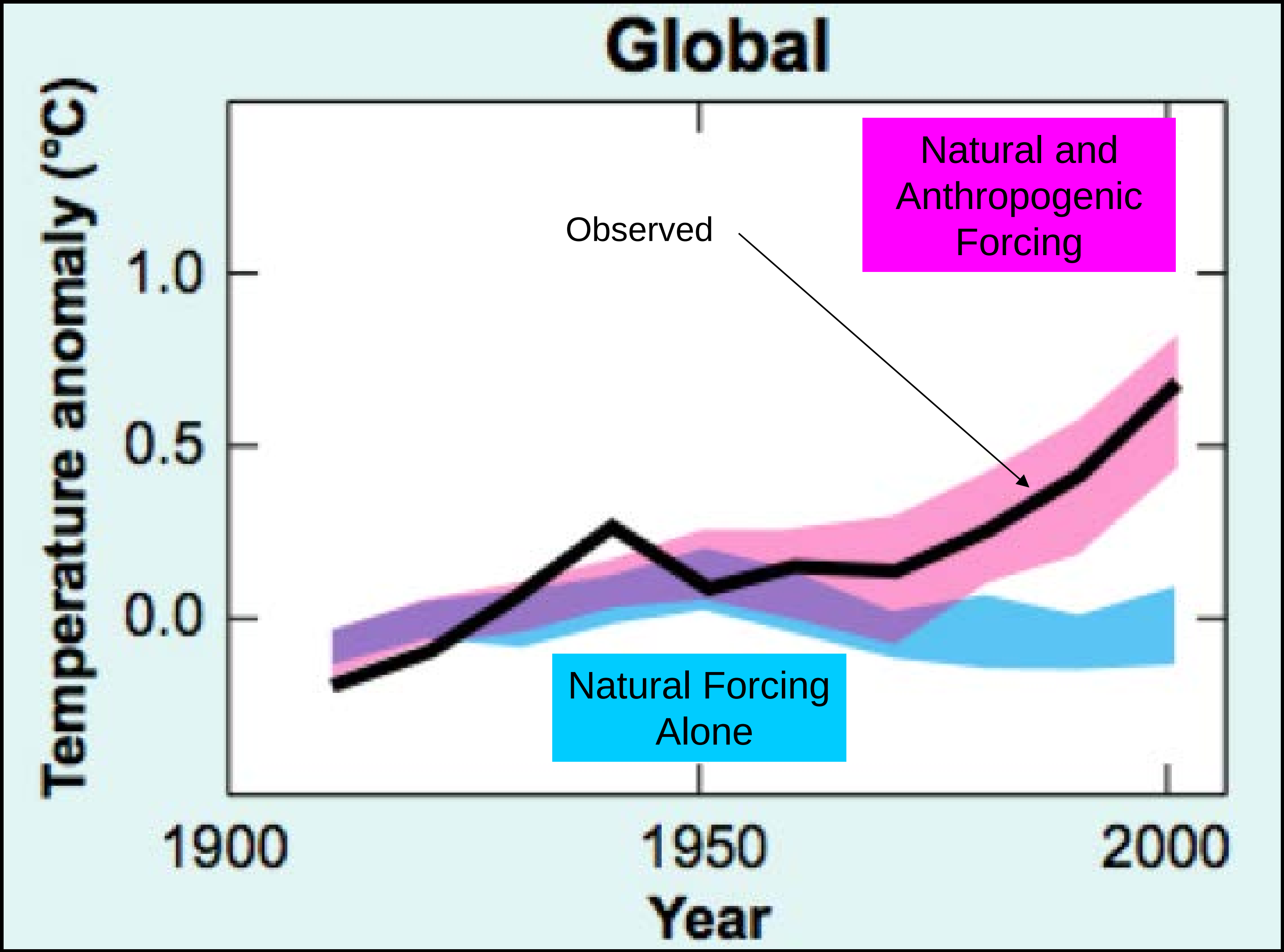
Atmospheric Concentrations



Radiative Forcing (Wper m^2)

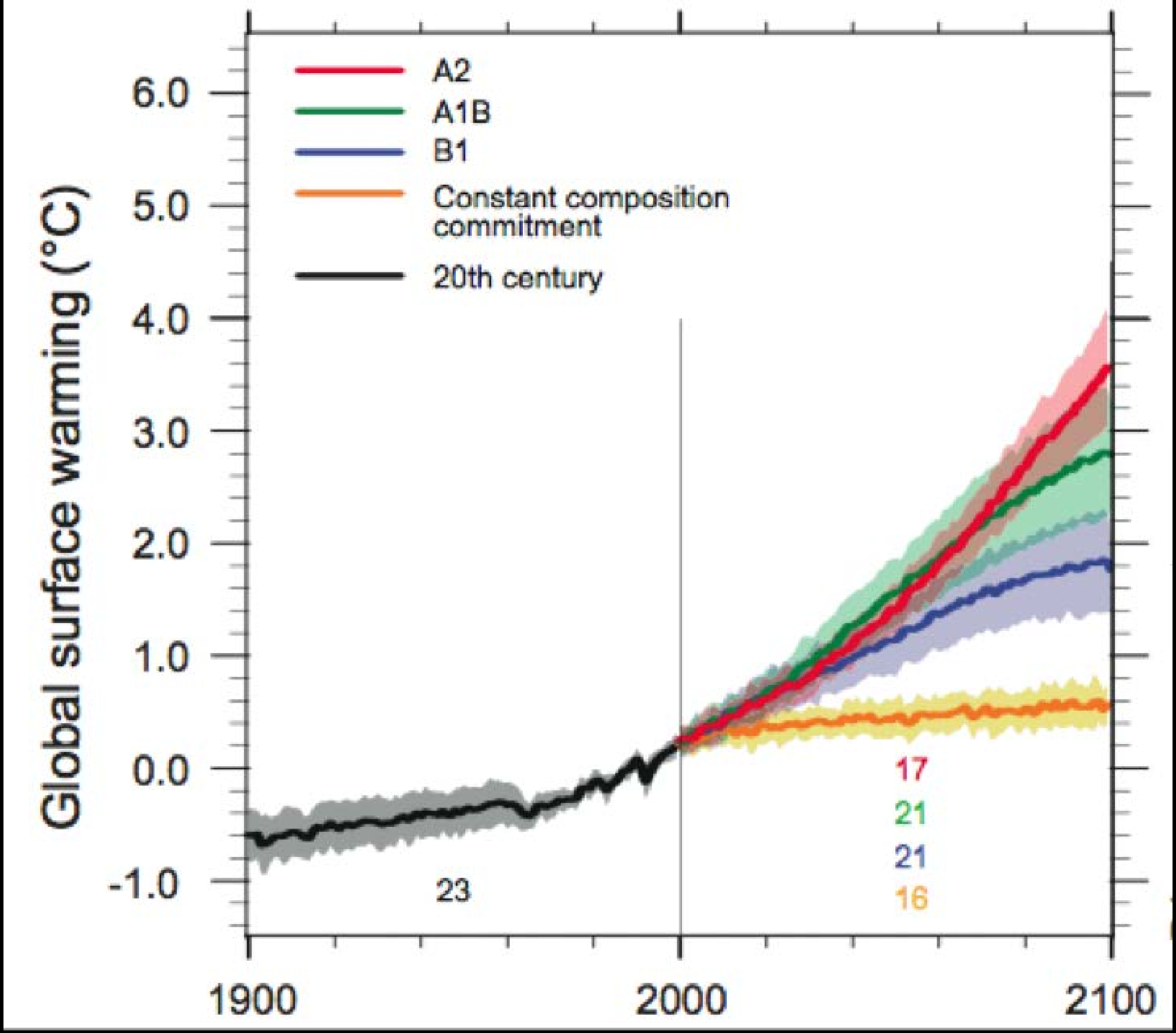
IPCC 2007

Simulated Annual Mean Surface Air Temperatures



IPCC 2007

Temperature Change in IPCC Scenarios



7.2° F

3.2° F

IPCC 2007

Evidence of Climate Change in the Great Lakes Region*

- Temperatures are rising, especially in winter.
- Extreme rainfall events (24-hr and 7-day) are becoming more frequent.
- Winters have become shorter.
- Spring is coming earlier.
- Duration of ice cover is shorter, especially on smaller lakes.

Source: *Edge of the Wilderness Scenic Byways*

*http://www.ucsusa.org/greatlakes

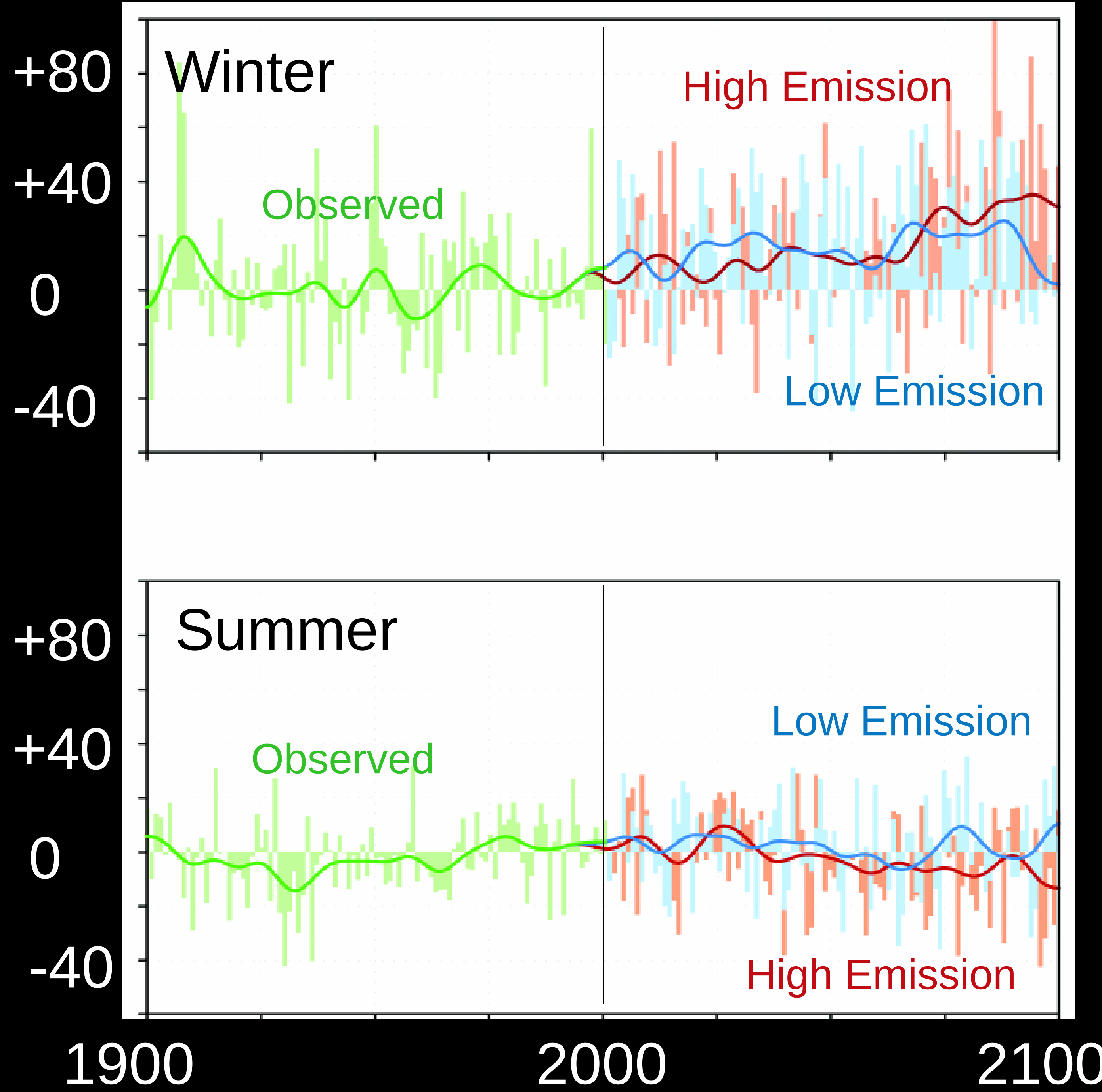
Projected Climate Changes in the Great Lakes Region by 2100

- **Temperature**
  - Winter 5-12 °F (3-7 °C)
  - Summer 5-20 °F (3-11 °C)
  - Extreme heat more common
  - Growing season several weeks longer
- **Precipitation**
  - Winter, spring increasing
  - Summer, fall decreasing
  - Drier soils, more droughts
- **More extreme events** – storms, floods
  - Could be 50-100% more frequent than now
- **Ice cover decline** will continue

Source: *Bob Allan*, NREL

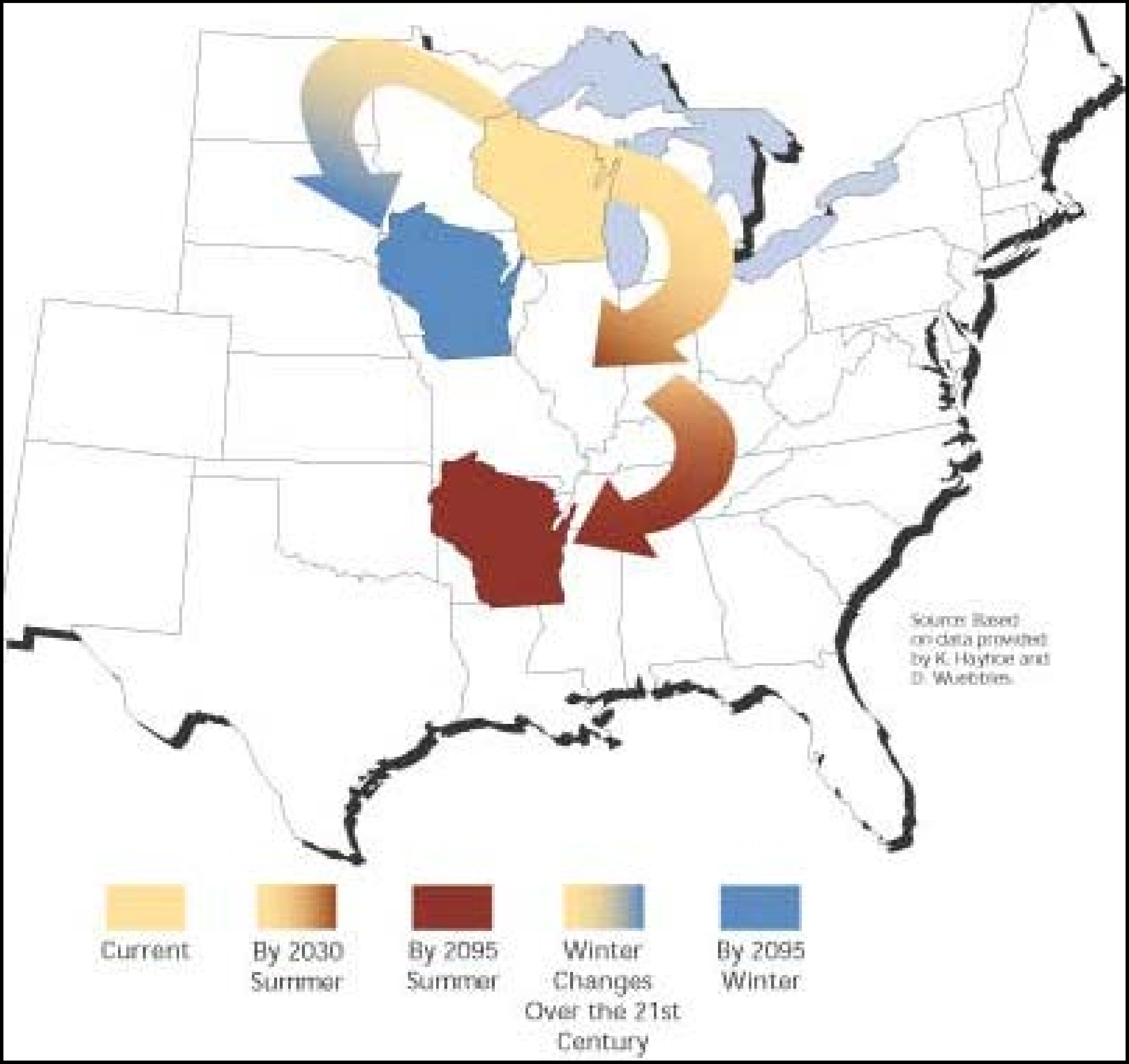
UCS/ESA 2003

Observed and projected change in average daily precipitation (%)



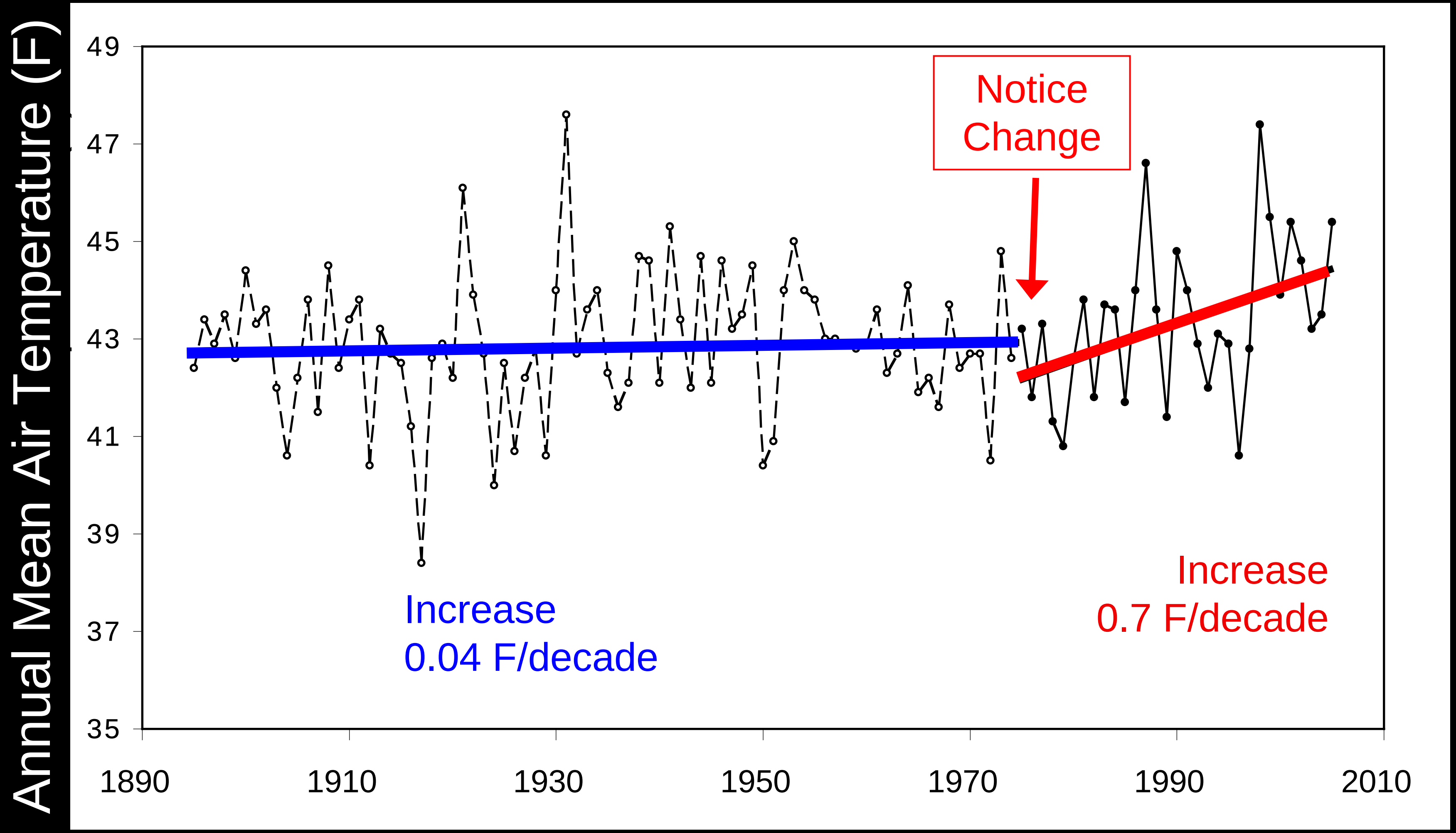
UCS/ESA 2003

Moving States - Going to Arkansas?



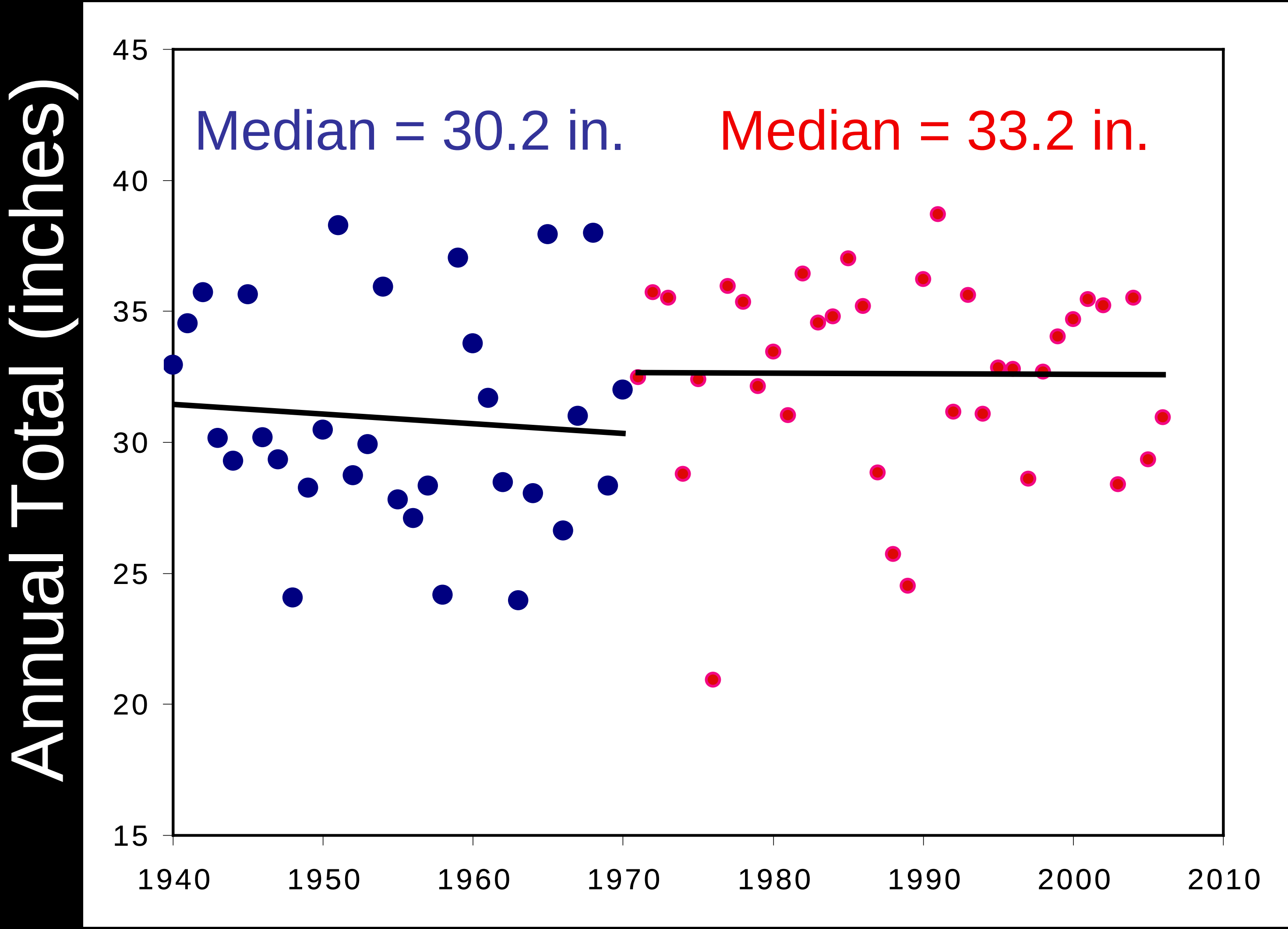
UCS/ESA 2003

Wisconsin Air Temperatures 1895-2005



Magnuson: Data from State Climatology Office

What happened to precipitation in Wisconsin?

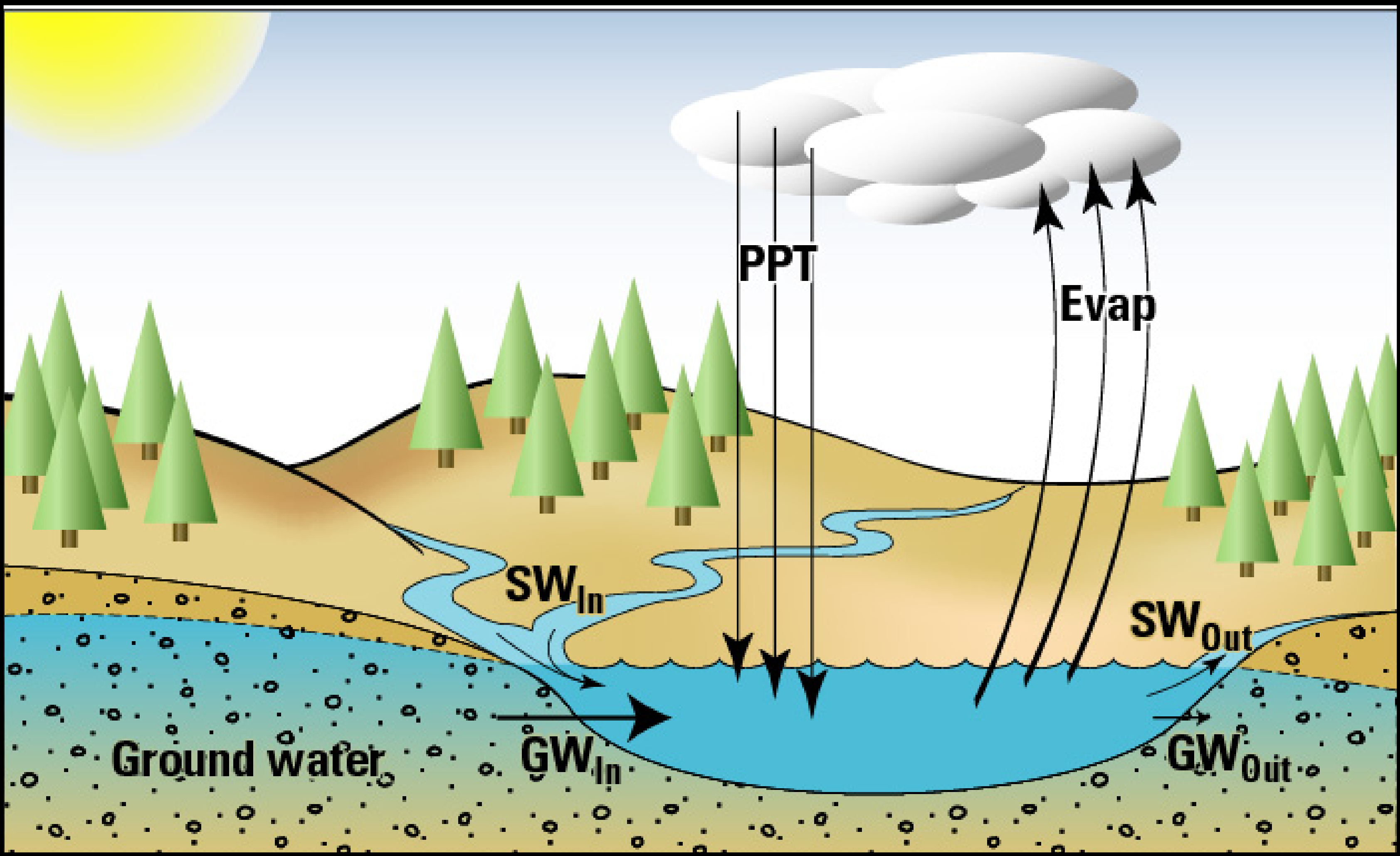


Magnuson 2006: Data from Wisconsin State Climatology Office

Climate change impacts on water resources

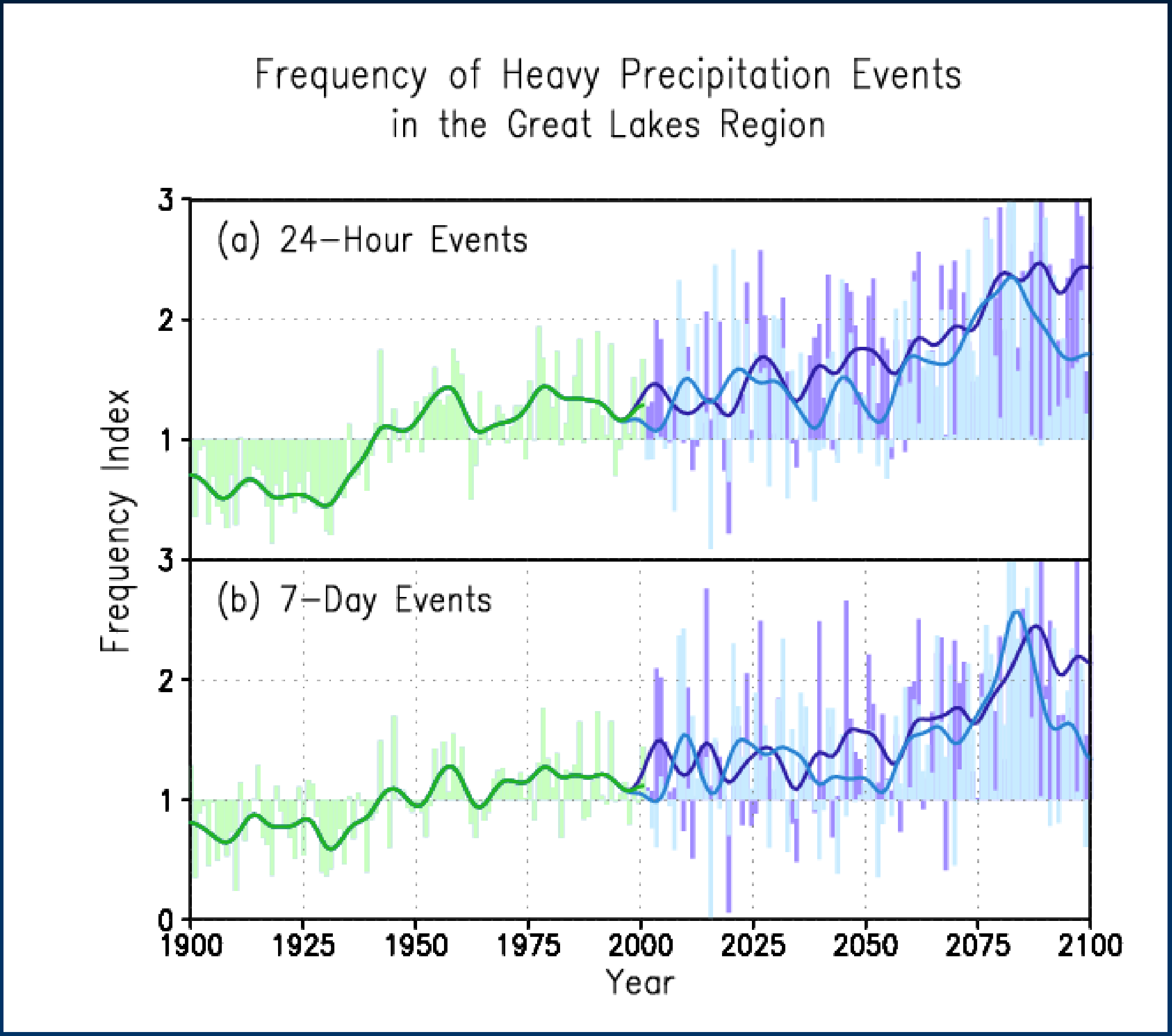
- Decreased ice duration on inland lakes and rivers
- Changes in species distributions (natives and exotics)
- Impacts to water quality of lakes, streams, rivers, and wetlands
- Altered hydrologic regimes at watershed scale (more extremes)

Changes in the Hydrologic Cycle



Krohelski 2003

Projected Precipitation Changes in the Great Lakes Region (by 2070-99)



- Doubling of heavy precipitation events
- Seasonal shifts in precipitation --

  * More rain in winter and spring (planting season)

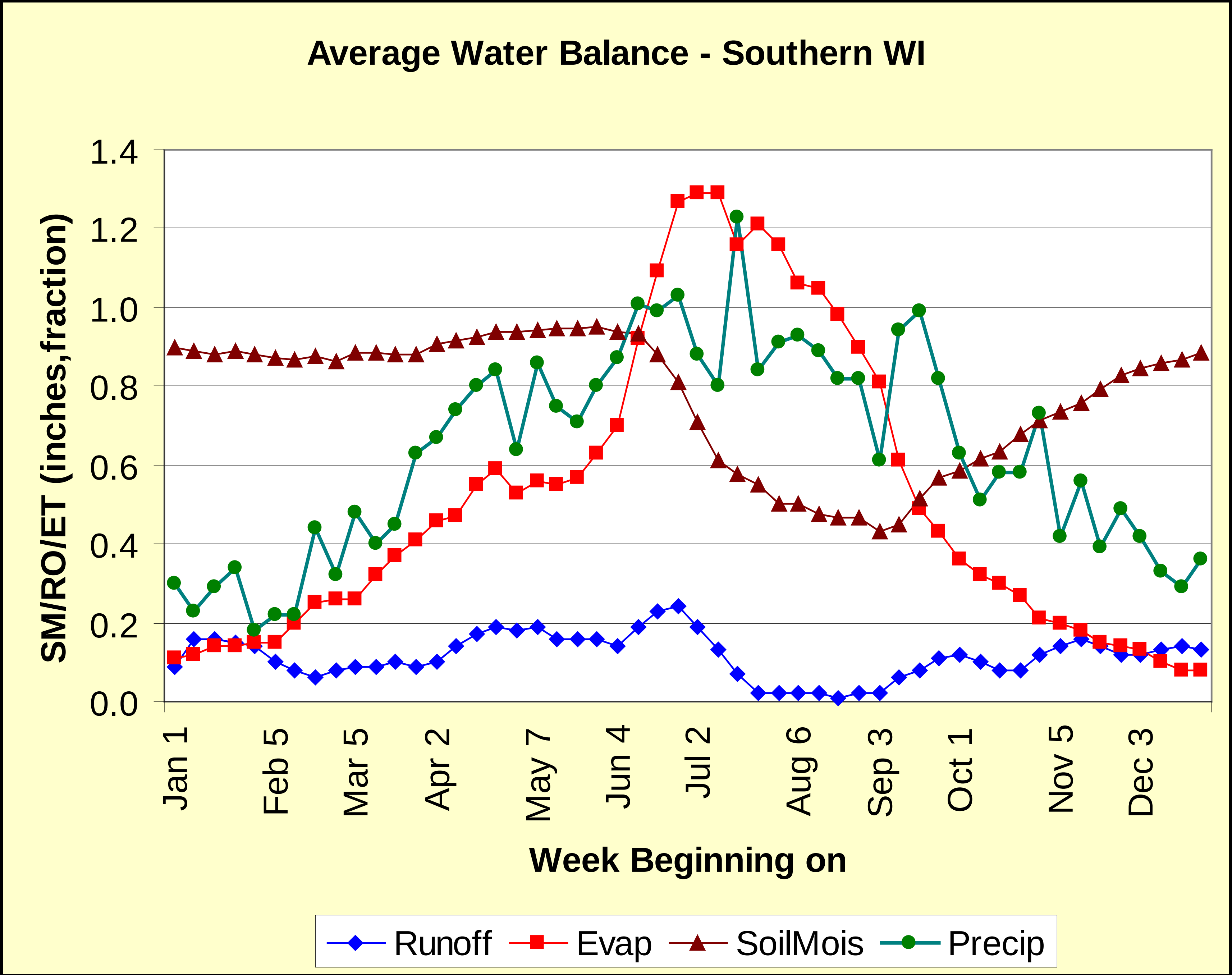
  * Less rain during the summer and fall growing seasons

UCS/ESA 2003

Rainfall Intensity

- Certain processes of the surface water balance are heavily influenced by rainfall intensity
- The rate of percolation of water into the soil is limited
- As rainfall intensity increases, soil moisture recharge tends to decrease and runoff tends to increase

Source: Kunkel, ISWS



Source: Kunkel, ISWS

Water Levels – Scenario #1

- Shorter duration of ice cover will increase evaporation in winter
- Warmer air temperatures will increase evapotranspiration
- Lower precipitation in summer will decrease soil moisture
- Lakes may go down

SOURCE: UCS/ESA 2003

Water Levels – Scenario #2

- Warmer, wetter winters
- Enriched CO_2 in atmosphere increases water use efficiency and increases runoff AND infiltration
- Long-term trend may be increased baseflow and groundwater levels
- Lakes may go up

Source: John Magnuson, 2007

Factors affecting lake water levels

- Lake morphology and hydrology
- Landscape position
- Natural variability (weather)
- Short term drought (and wet) cycles
- Climate change
- Human water use (i.e. pumping)

Lake Hydrology

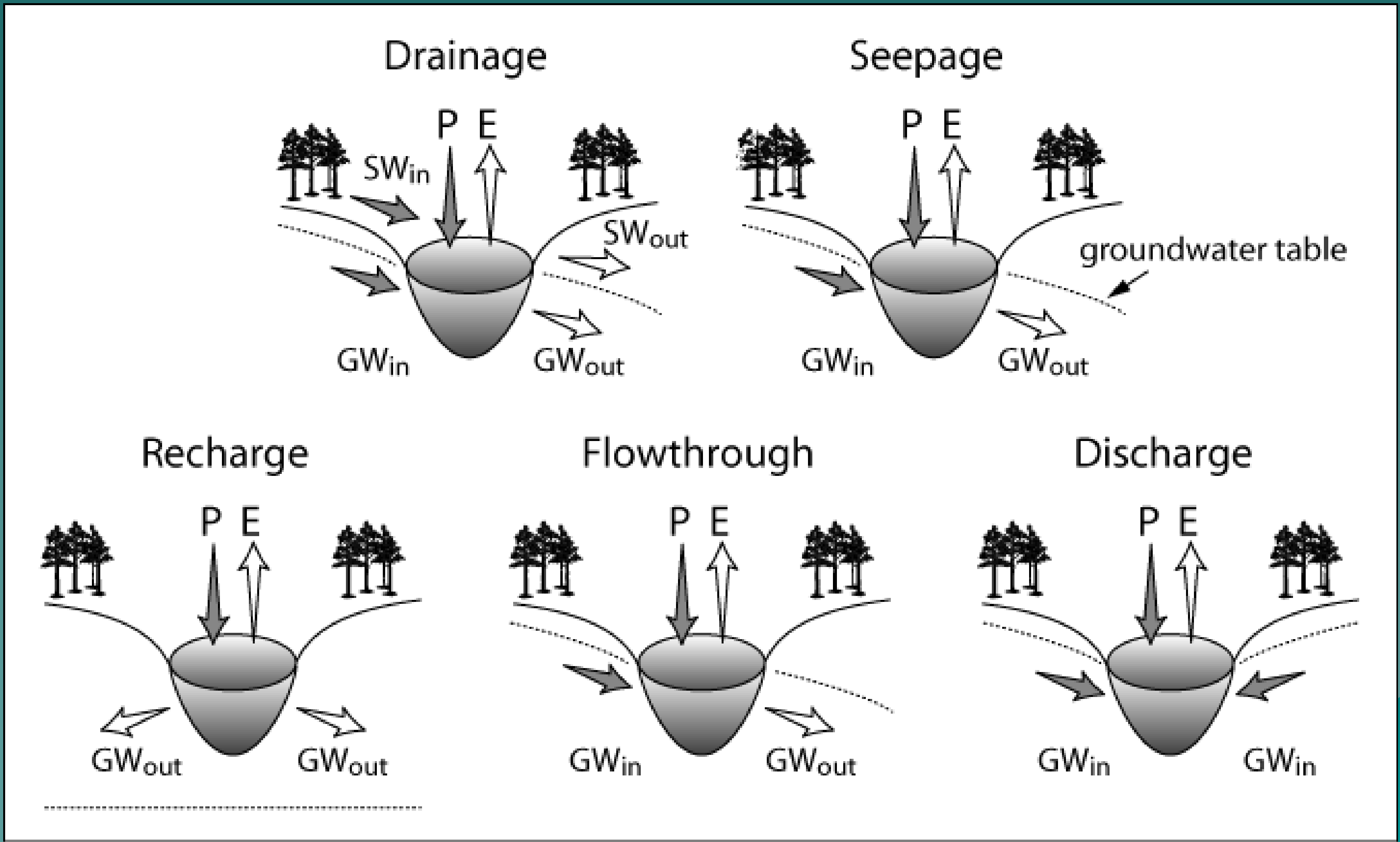
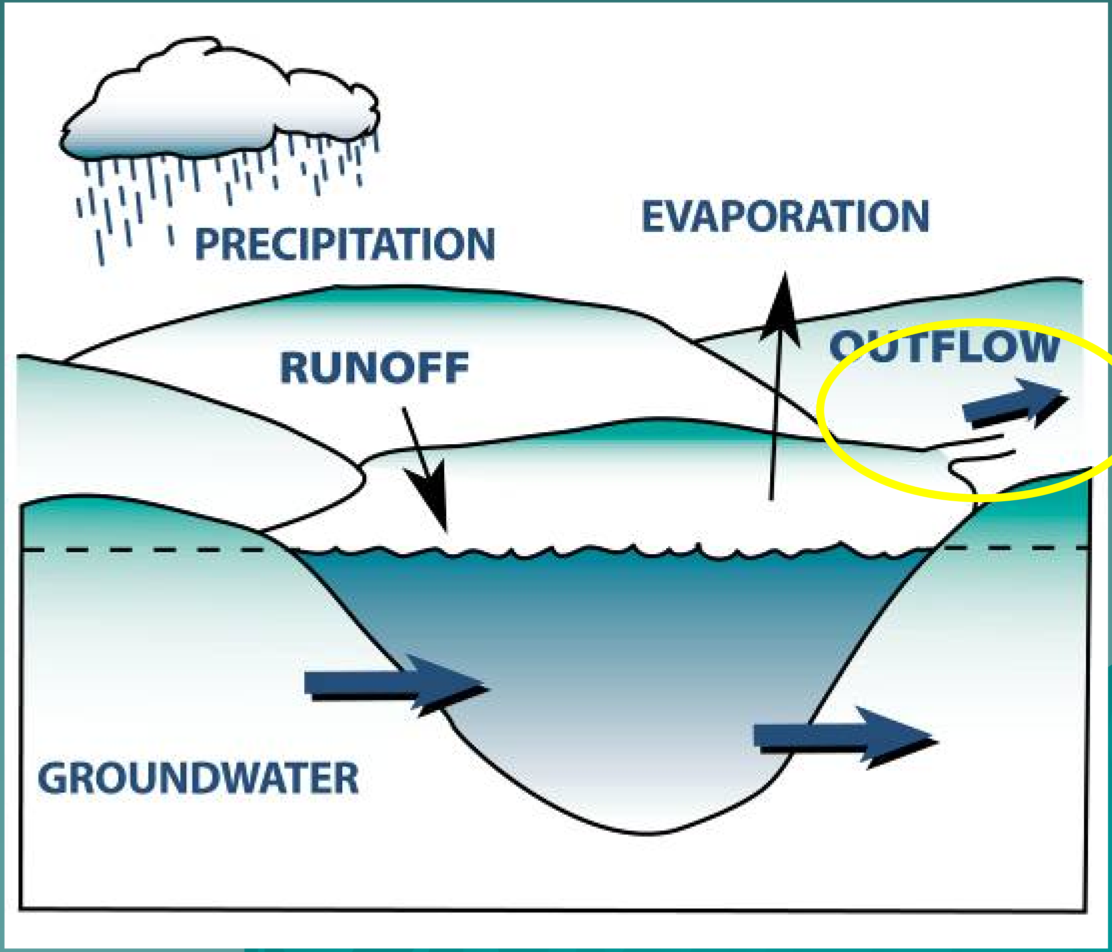


Fig 2.3

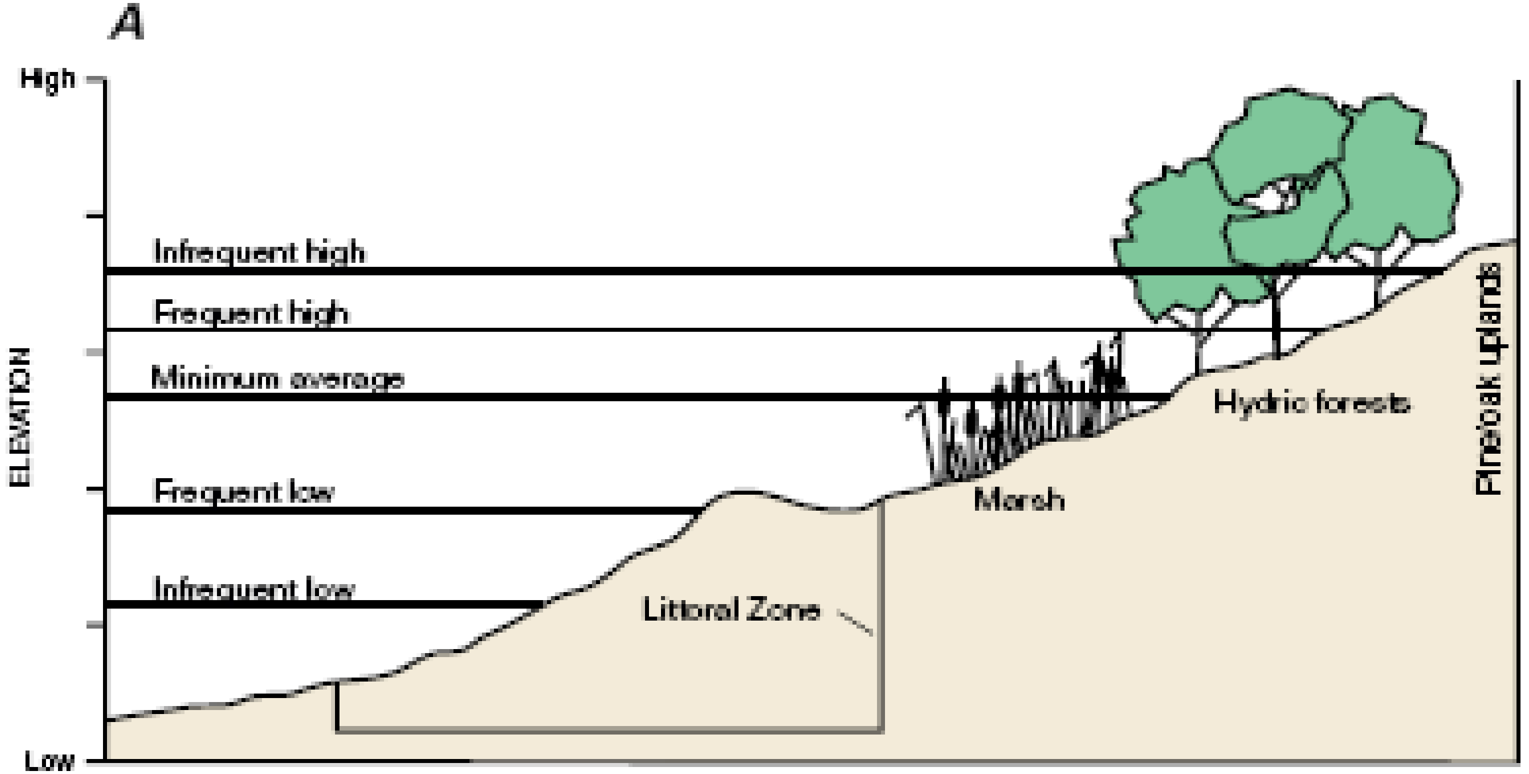
Magnuson et al. 2006

Groundwater Discharge

- Natural Lake
- Water Source
  - Groundwater
  - Precipitation
  - Limited Runoff
- May have springs
- Has Stream Outlet



Water levels vary naturally



Source: USGS Circular 1186

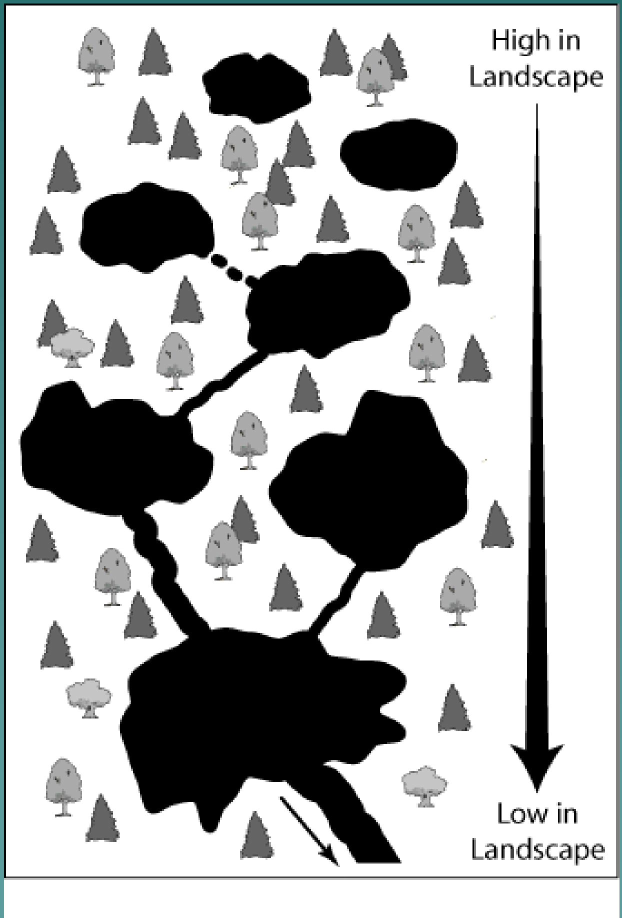
Natural variability

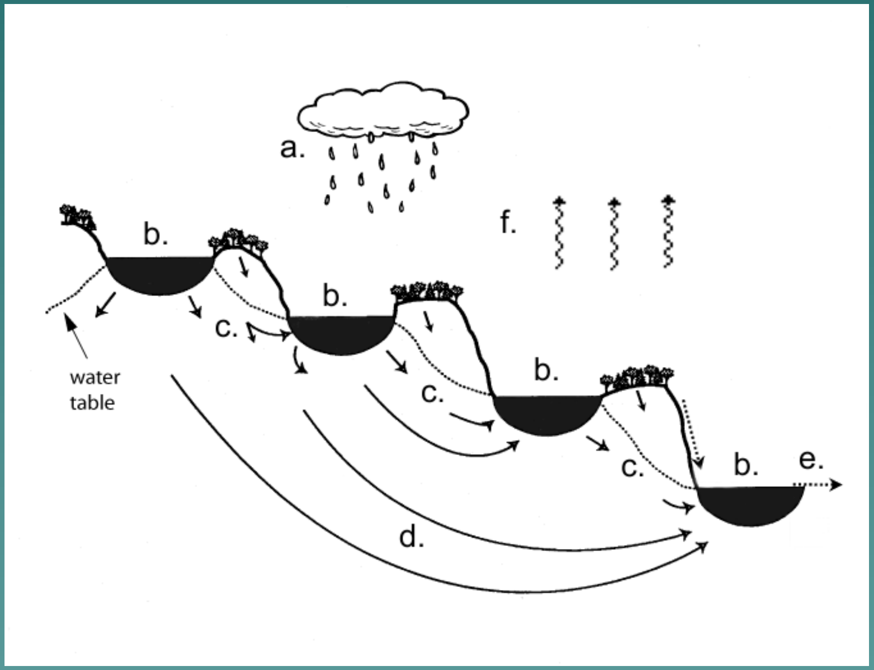
	Period of record (ft)	Average annual (ft)	Maximum annual (ft)	Minimum annual (ft)
Ground-water flow-through	2.5-10.5	0.8-2.7	1.2-5.5	0.3-1.4
Surface-water flow-through	2.6-7.8	1.0-2.6	2.1-4.7	0.5-1.2
Ground-water discharge	1.4-3.8	0.6-1.4	0.9-2.9	0.2-0.6

“A statistical analysis of data in table 1 indicates that ***9*** out of 10 natural lakes in the State will fluctuate within the following approximate ranges during periods of **20** years or longer.”

Source: USGS/WGNHS, “WI Lake Levels”

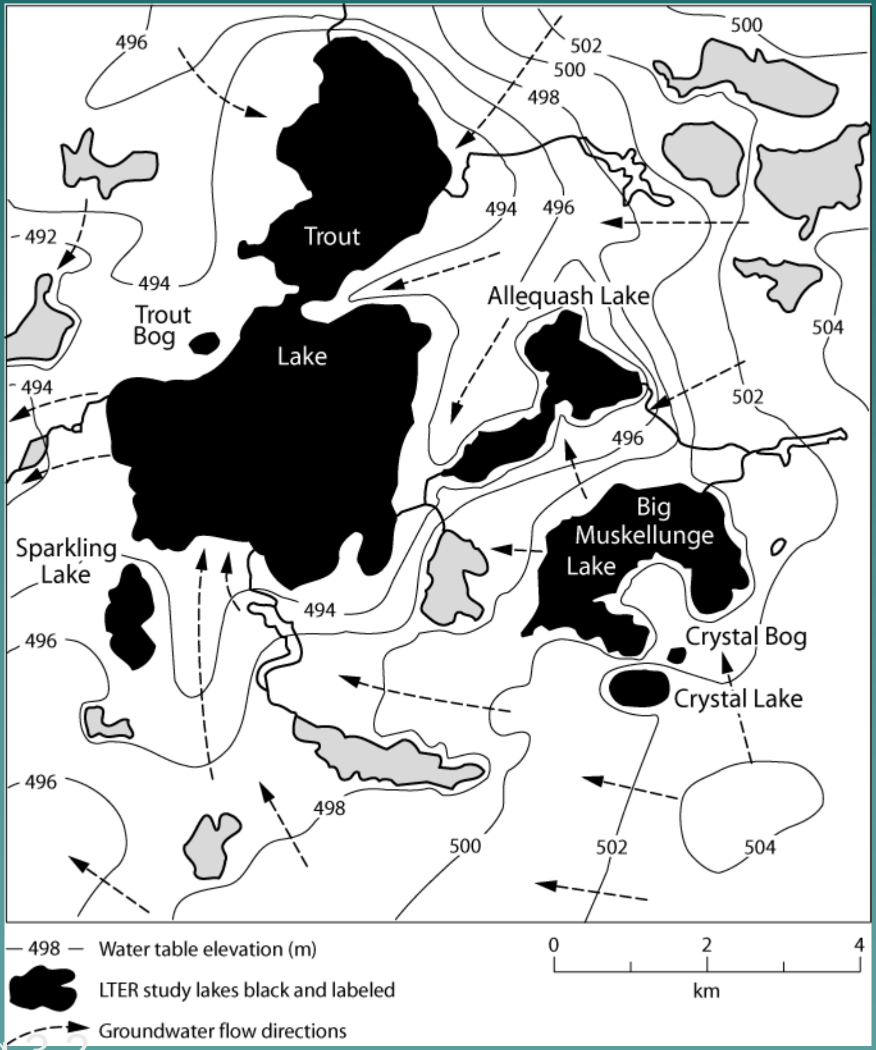
Landscape Position





Magnuson et al. 2006

Response of Lakes to Drought



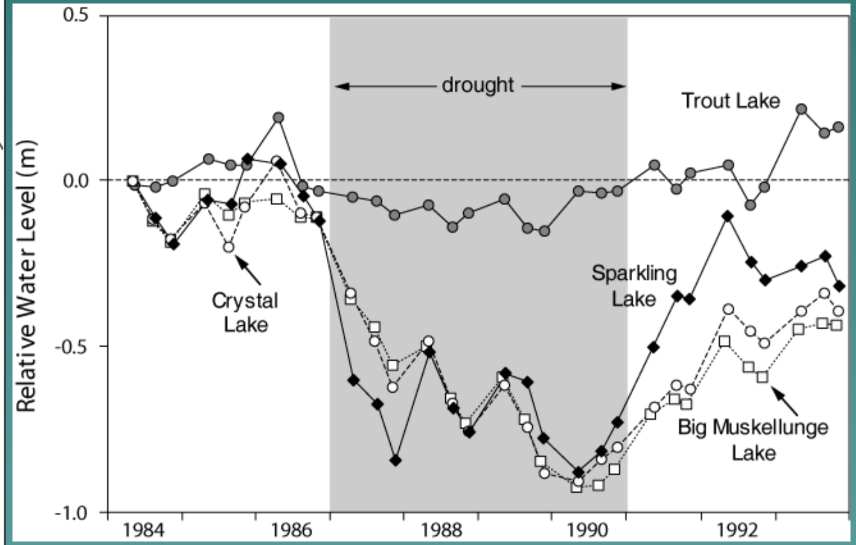
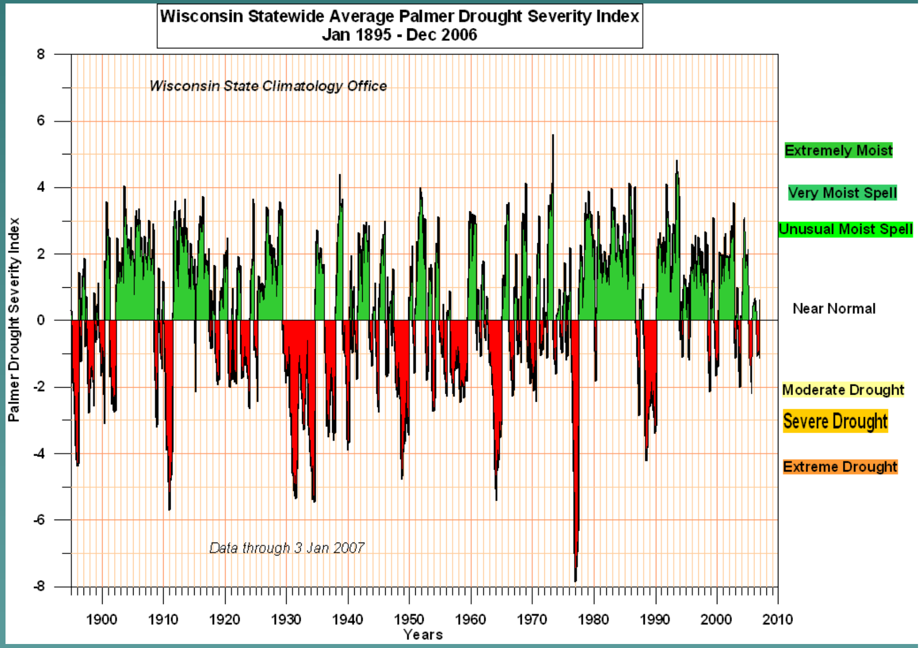
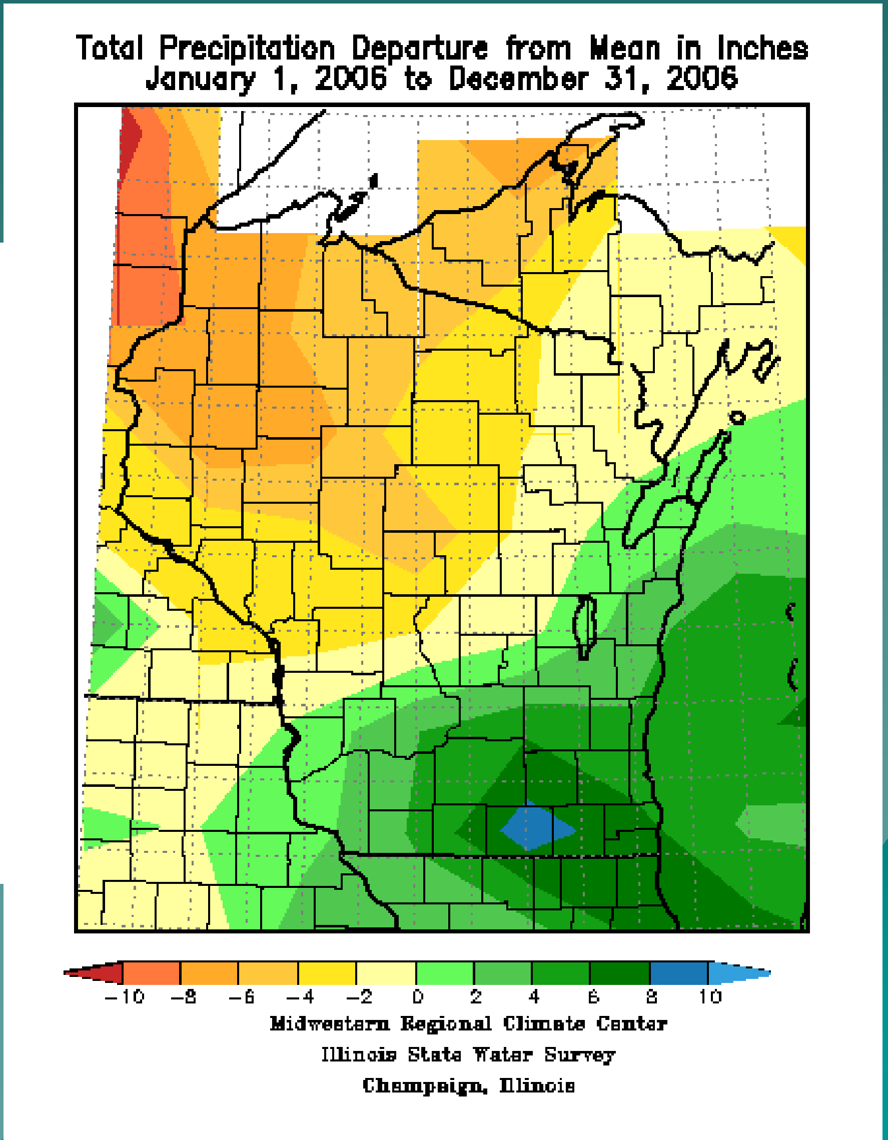


Fig 3.2

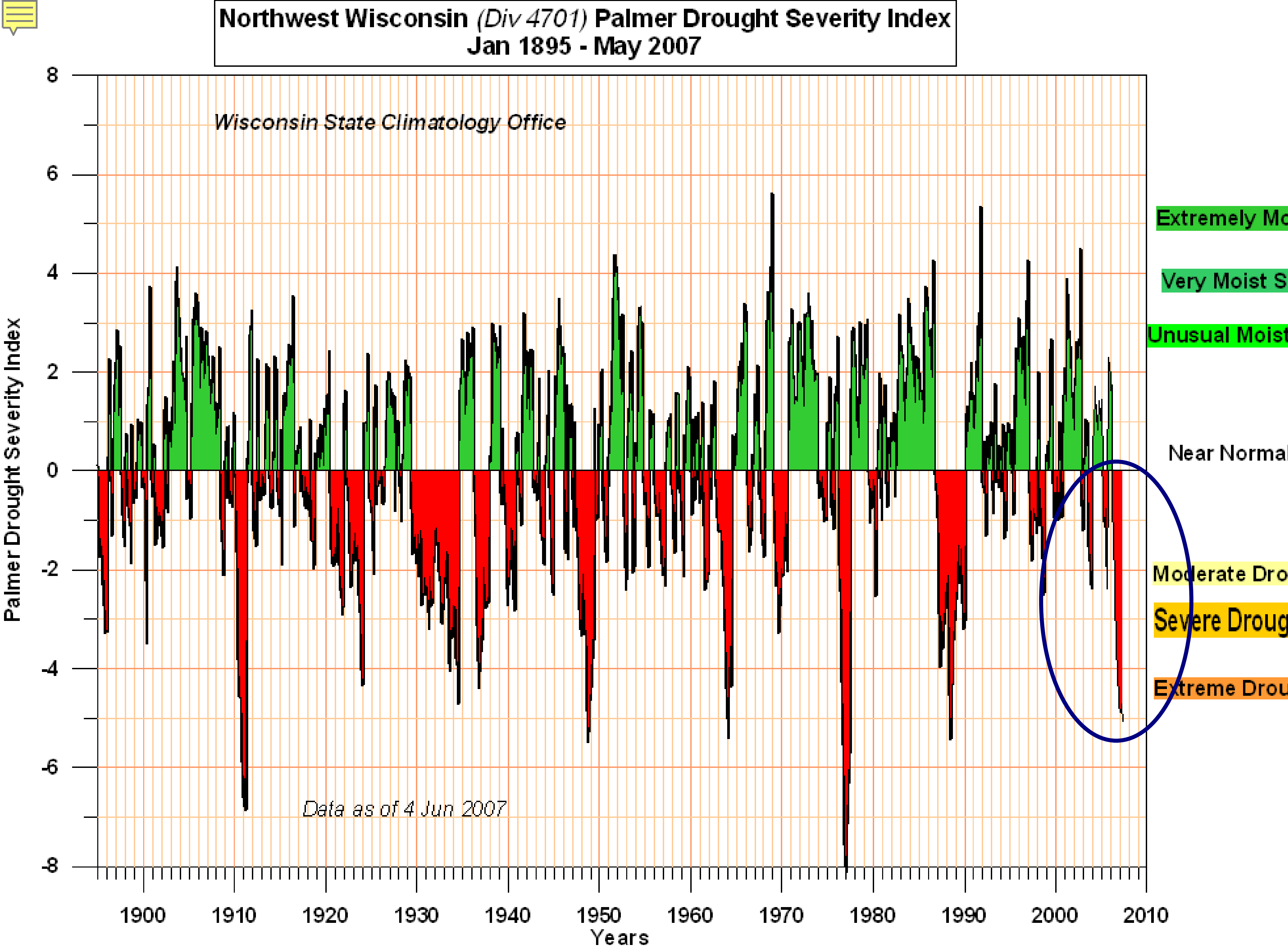
Magnuson et al. 2006

Are we in a drought now?





State Climatology Office
http://www.aos.wisc.edu/~sco/


Northwest Wisconsin (Div 4701) Palmer Drought Severity Index
Jan 1895 - May 2007
Wisconsin State Climatology Office
Data as of 4 Jun 2007
Palmer Drought Severity Index
Years
8
6
4
2
0
-2
-4
-6
-8
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1910
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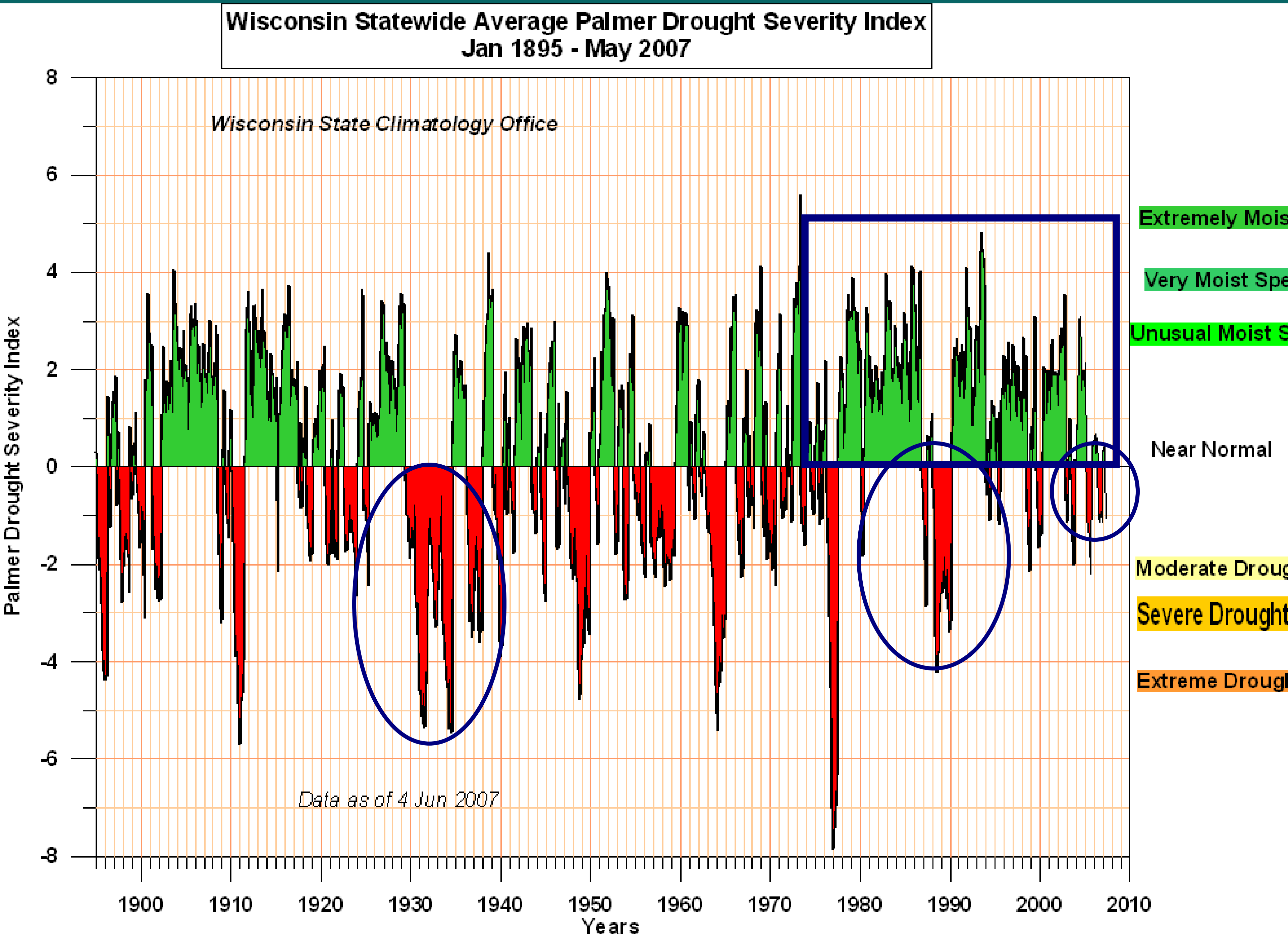
Wisconsin Statewide Average Palmer Drought Severity Index
Jan 1895 - May 2007
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Palmer Drought Severity Index
Years
8
6
4
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1900
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Near Normal
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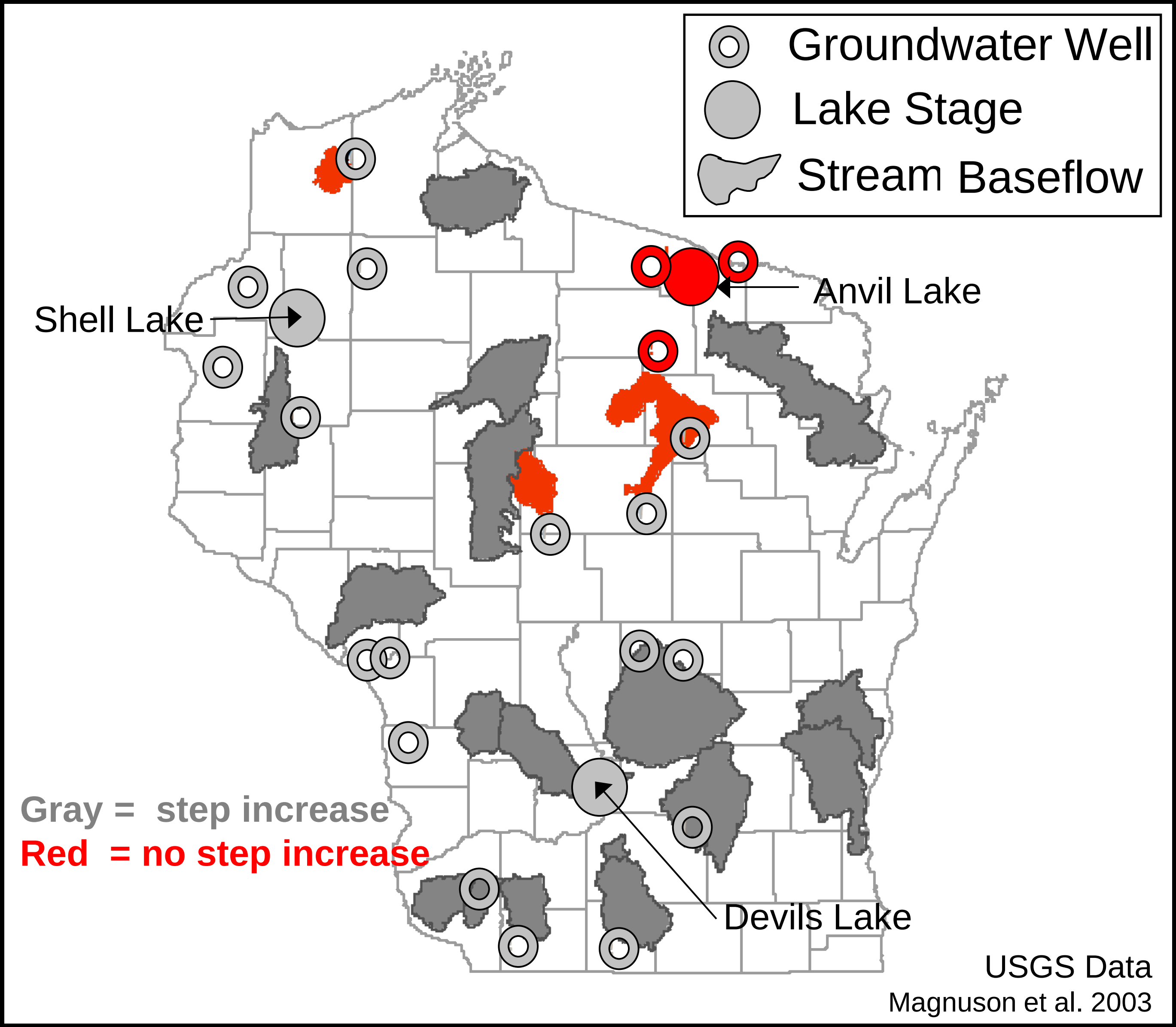
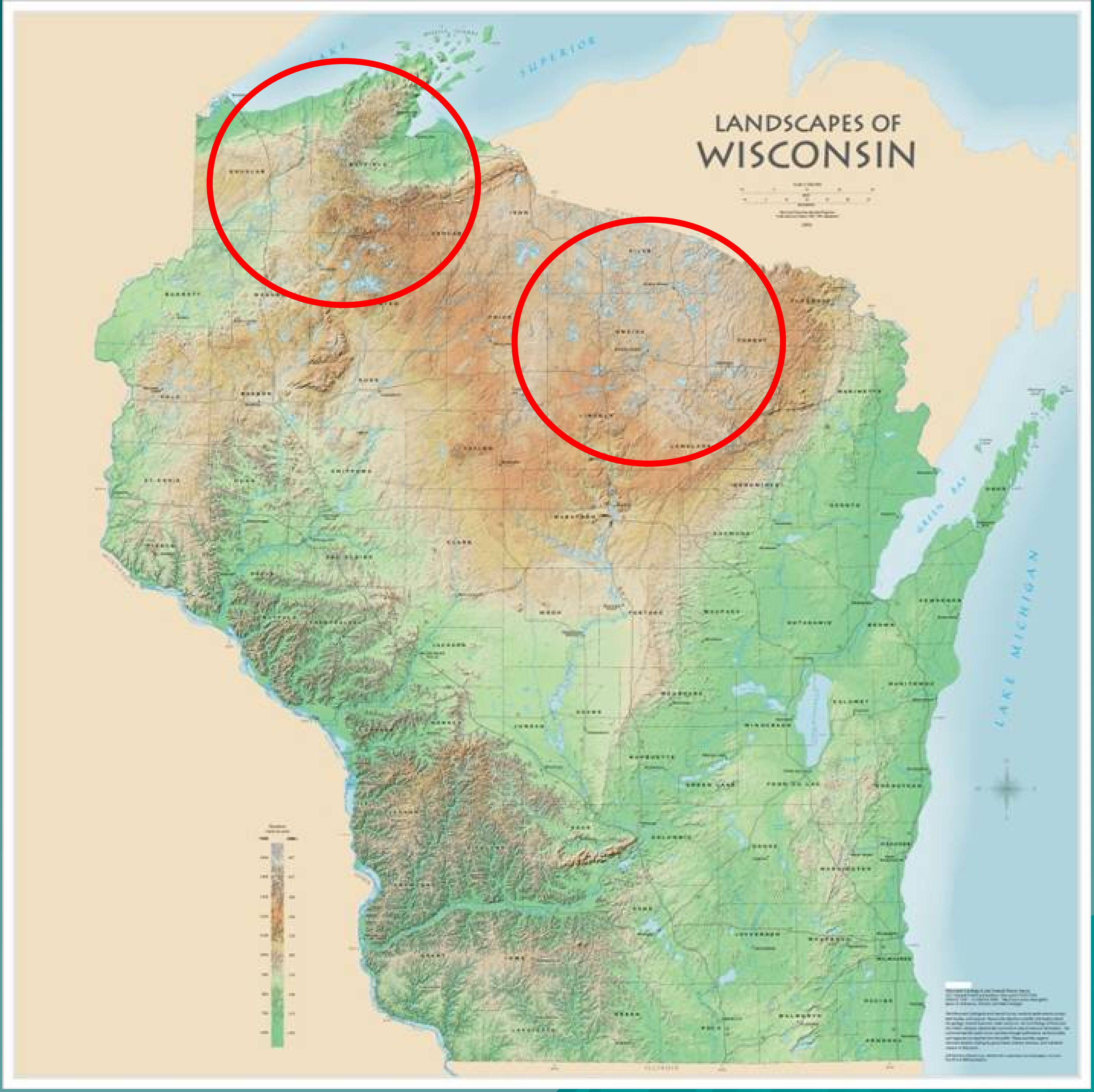
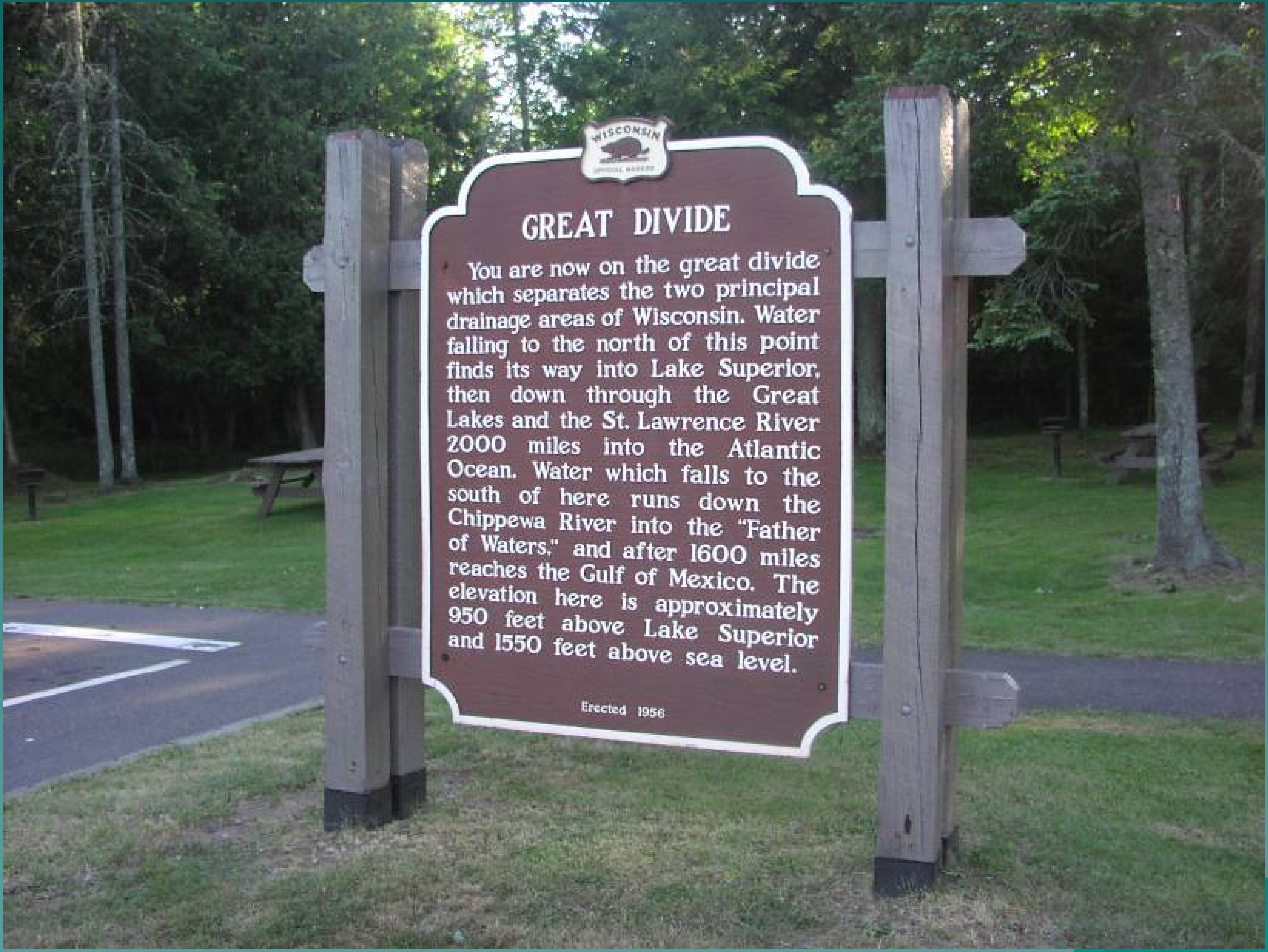
Step Increase in Lake Stage, Stream Flow, and Groundwater Levels after 1970



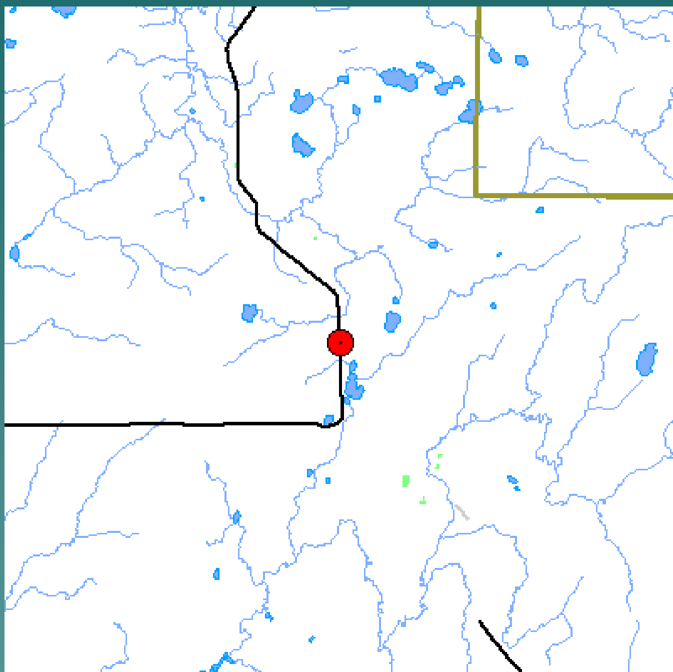


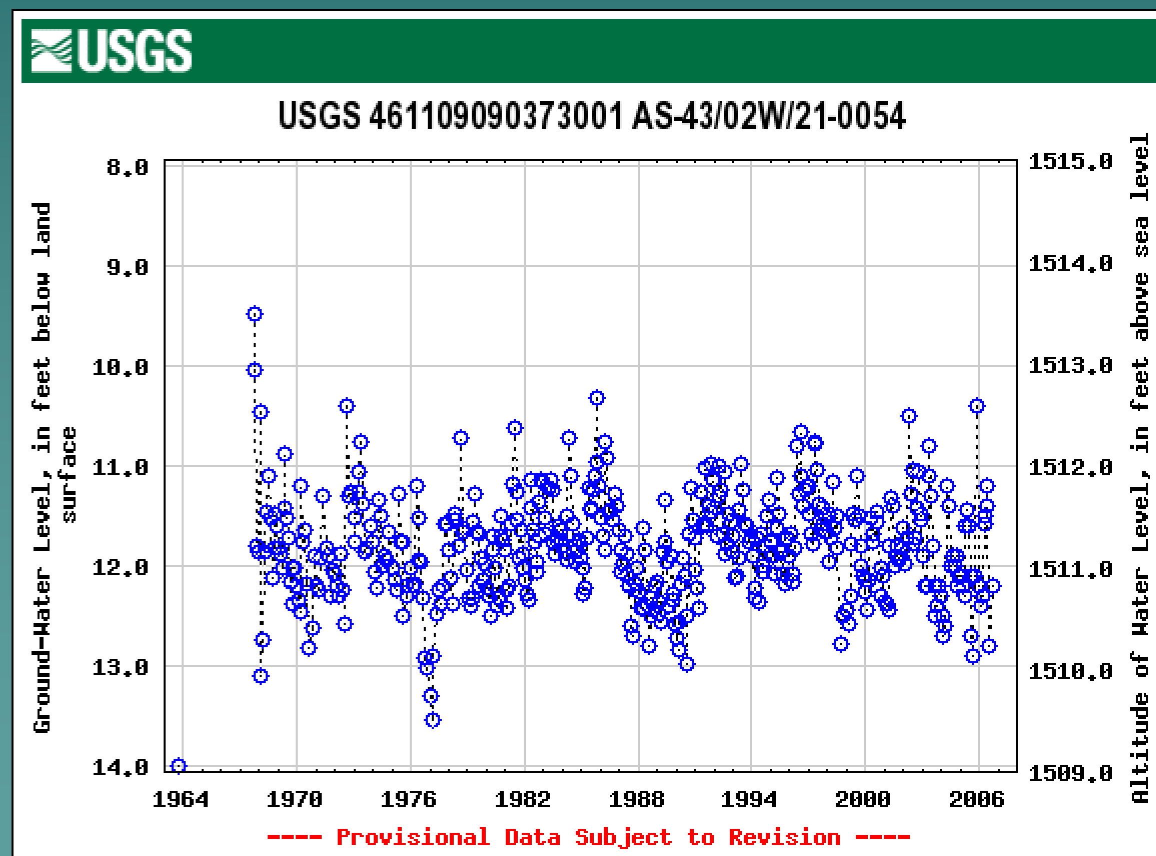
Source: WGNHS


WISCONSIN
OFFICIAL MARKER
GREAT DIVIDE
You are now on the great divide which separates the two principal drainage areas of Wisconsin. Water falling to the north of this point finds its way into Lake Superior, then down through the Great Lakes and the St. Lawrence River 2000 miles into the Atlantic Ocean. Water which falls to the south of here runs down the Chippewa River into the "Father of Waters," and after 1600 miles reaches the Gulf of Mexico. The elevation here is approximately 950 feet above Lake Superior and 1550 feet above sea level.
Erected 1956

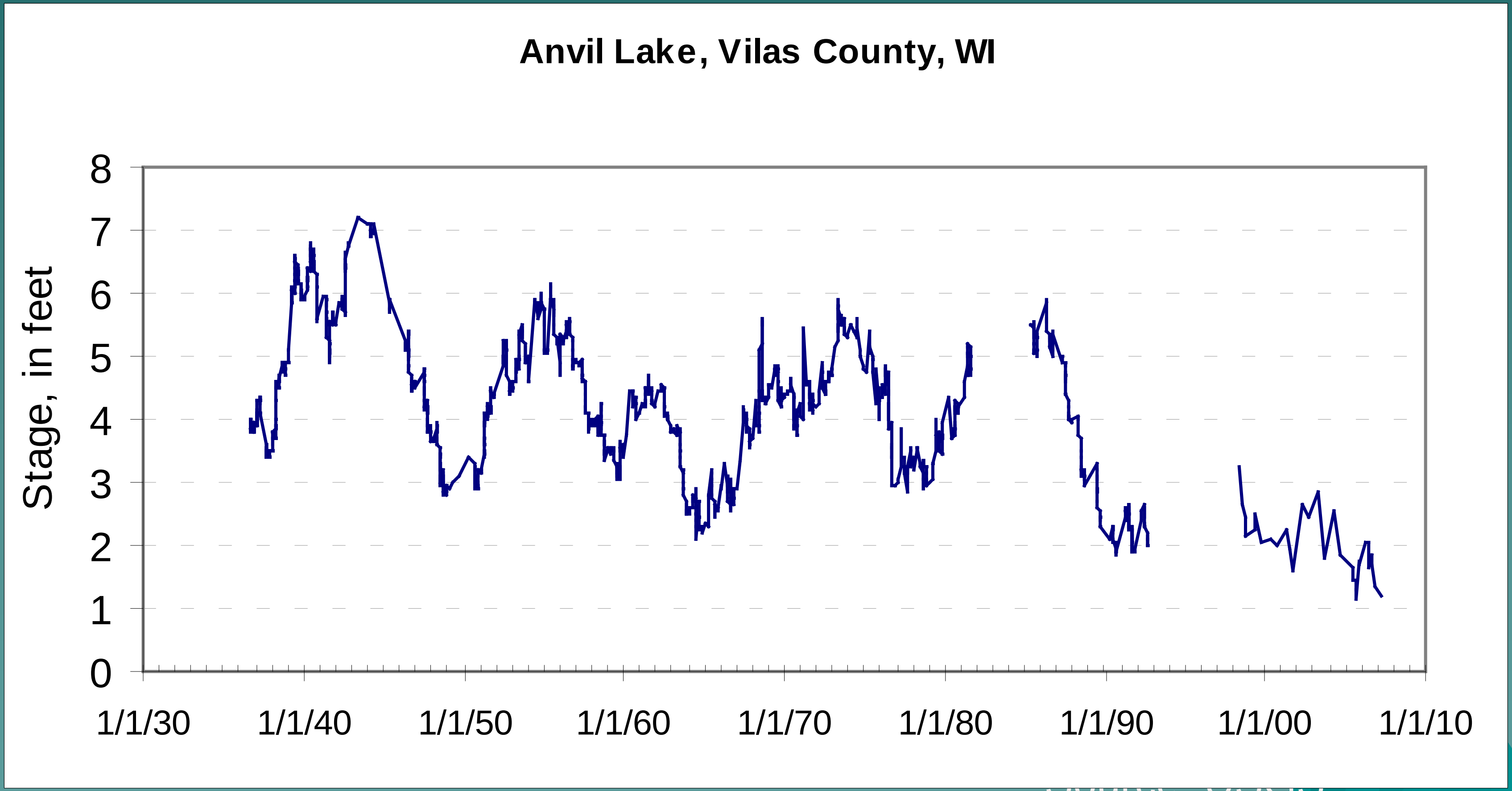
Well AS-0054; Glidden

AS-0054: Glidden, WI



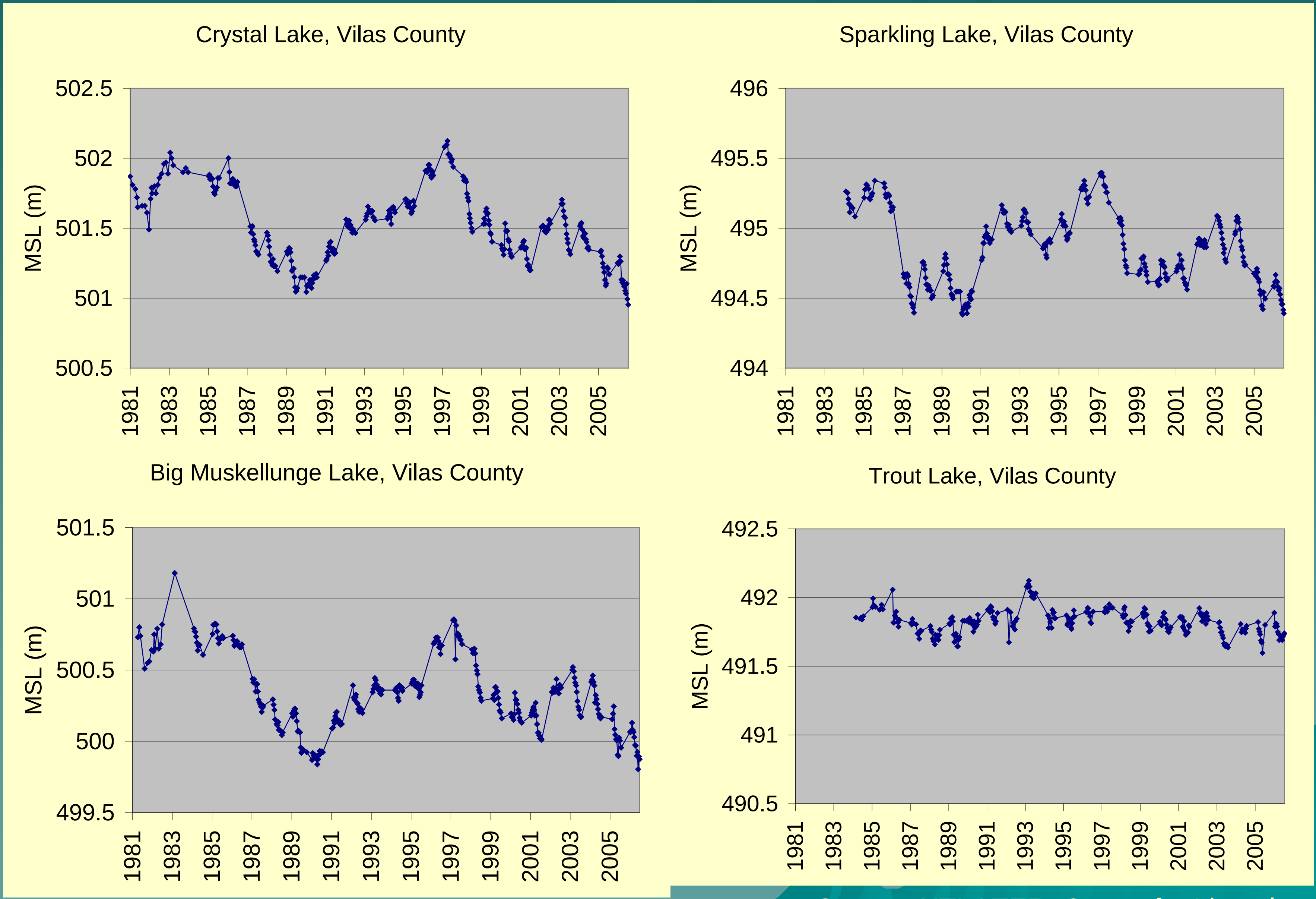


Anvil Lake Stage Record (1936 – 2006)



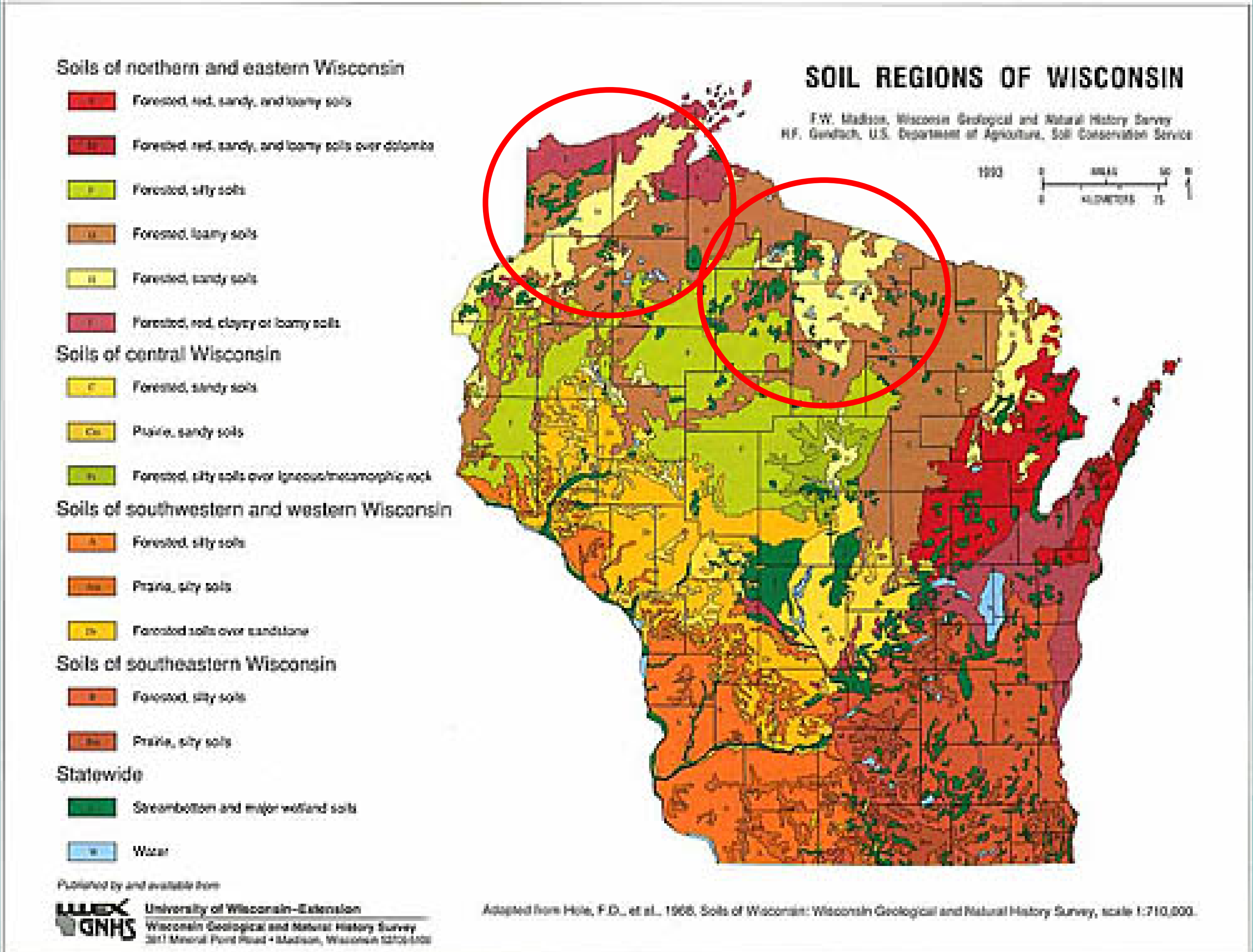
Source: USGS

LTER Lake Levels



Source: NTL LTER, Center for Limnology

Sandbar Lake, Bayfield County


SOIL REGIONS OF WISCONSIN
F.W. Madison, Wisconsin Geological and Natural History Survey
H.F. Gundlach, U.S. Department of Agriculture, Soil Conservation Service
1993
Soils of northern and eastern Wisconsin
Forested, red, sandy, and loamy soils
Forested, red, sandy, and loamy soils over dolomite
Forested, silty soils
Forested, loamy soils
Forested, sandy soils
Forested, red, clayey or loamy soils
Soils of central Wisconsin
Forested, sandy soils
Prairie, sandy soils
Forested, silty soils over igneous/metamorphic rock
Soils of southwestern and western Wisconsin
Forested, silty soils
Prairie, silty soils
Forested soils over sandstone
Soils of southeastern Wisconsin
Forested, silty soils
Prairie, silty soils
Statewide
Streambottom and major wetland soils
Water
Published by and available from
University of Wisconsin-Extension
Wisconsin Geological and Natural History Survey
Adapted from Hole, F.D., et al., 1968, Soils of Wisconsin: Wisconsin Geological and Natural History Survey, scale 1:710,000.

Response of lakes to changing climate

- Landscape position and lake type affects response of lakes to changes in climate
- Lakes higher in the landscape (both seepage and headwater) respond to changes in precipitation and evaporation
- Lakes lower in the landscape are buffered from short term dry periods and respond to longer term changes in groundwater recharge
- Local conditions are important!

Which one is the future?

Climate Change Impacts Will Not Occur in a Vacuum

- Population growth
- Increasing urbanization and sprawl
- Fragmentation of the landscape

Source: Peter J. Schulz

- Industrial pollution of air and water
- Social challenges
- Geographic variability and limits

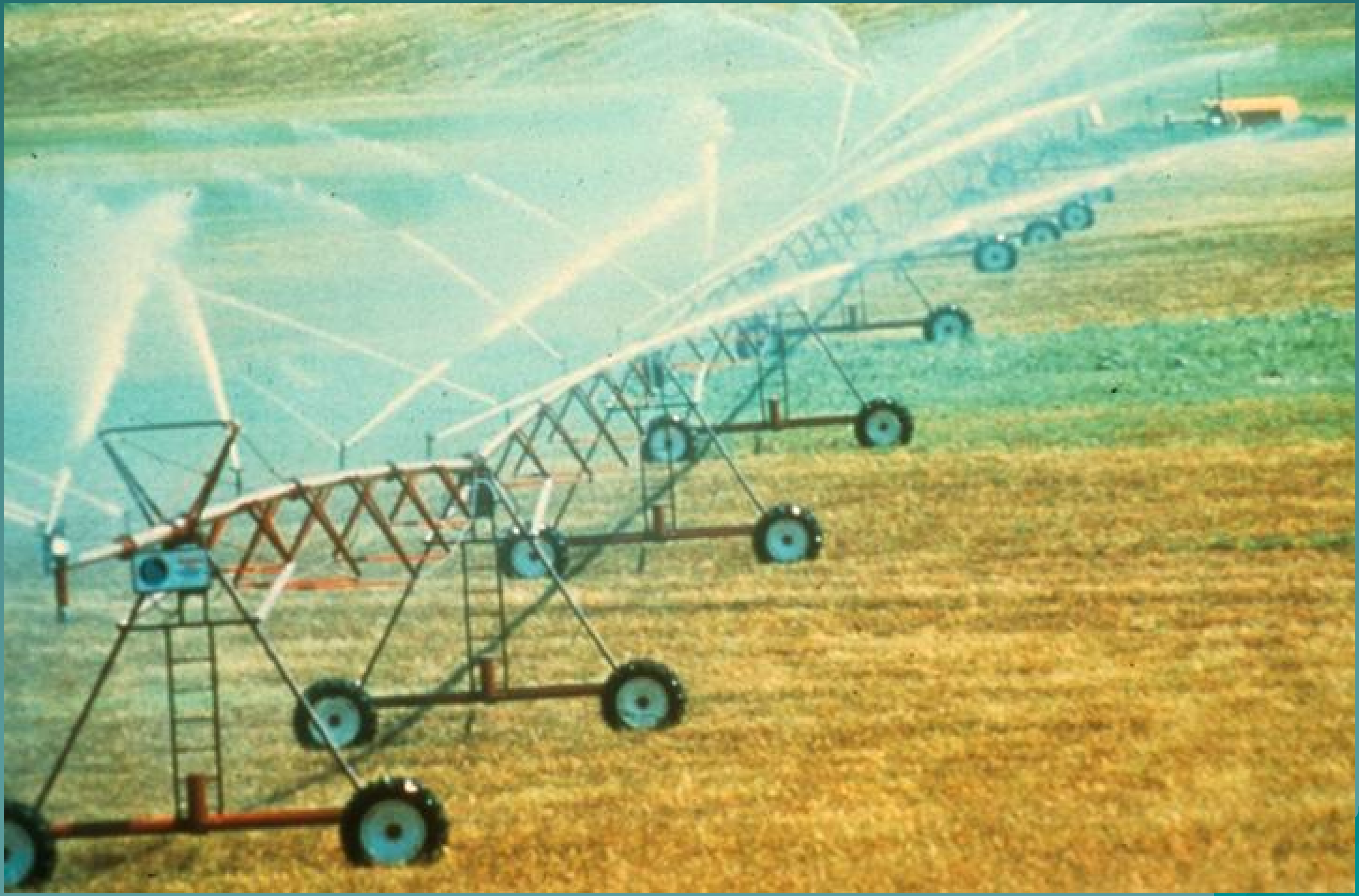
UCS/ESA 2003

Exacerbation of Existing Problems
Water Resources

- Groundwater recharge reduced, small streams likely to dry up
- Declines expected in average lake levels
- Pressure to increase water extraction from the Great Lakes
- ***More reliance on irrigation to grow crops***

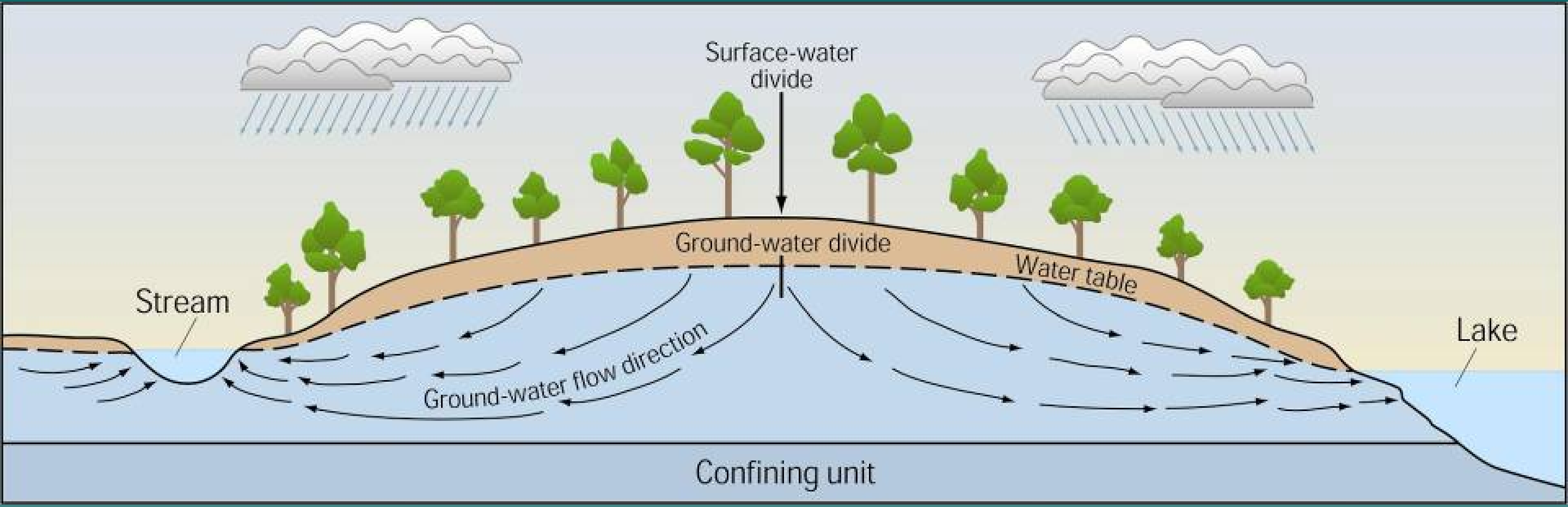
Source: *Dave Hansen, MN Extension Service*

Human water use and lakes

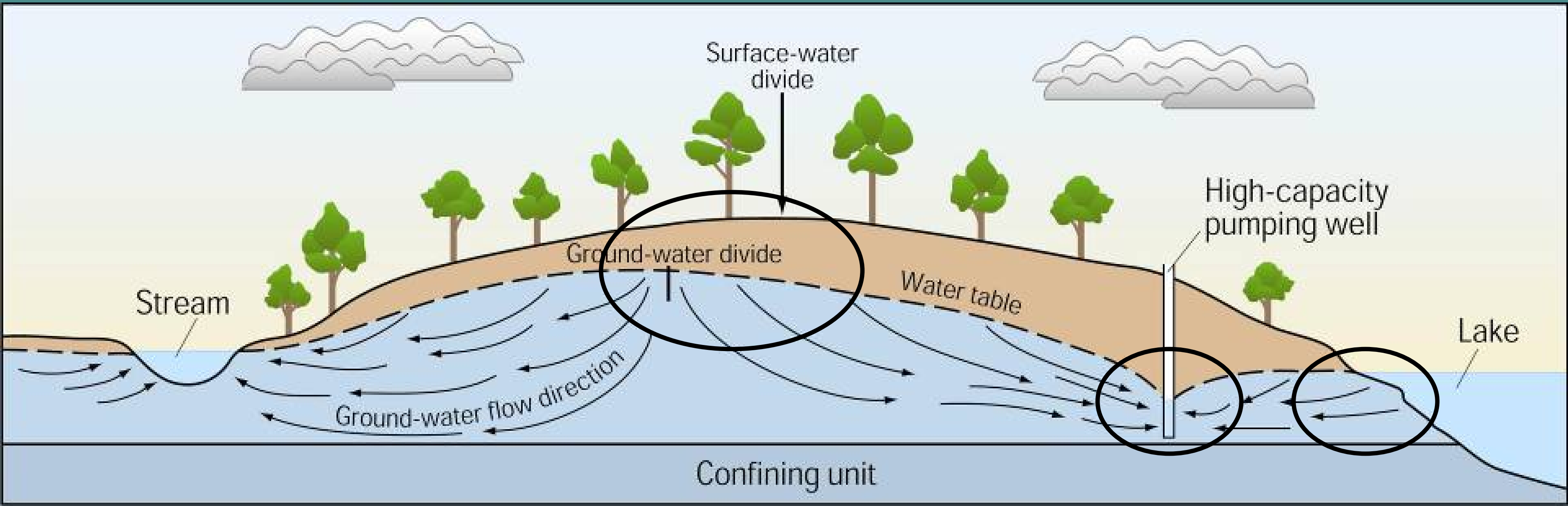


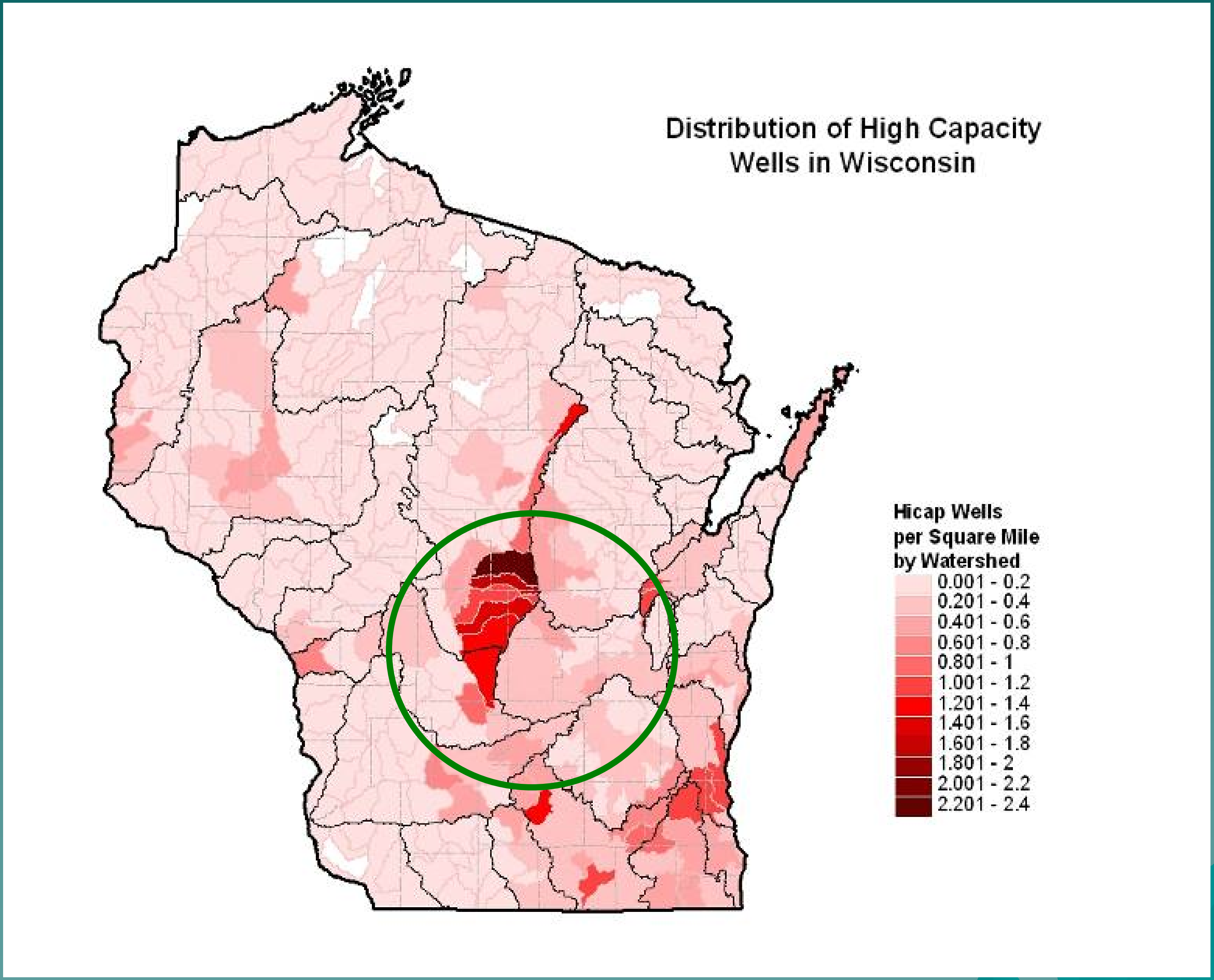
Natural

Source: Ken Bradbury

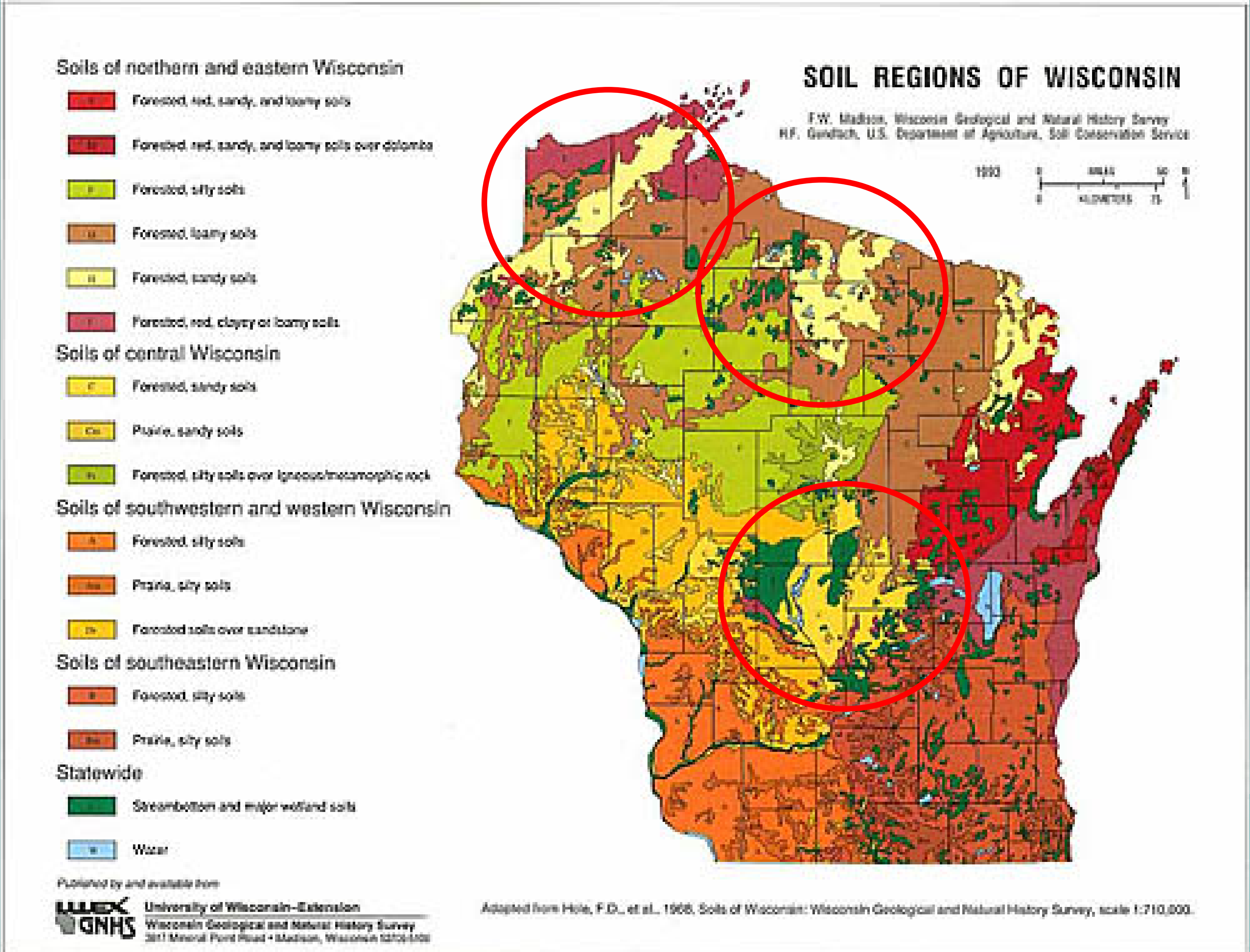


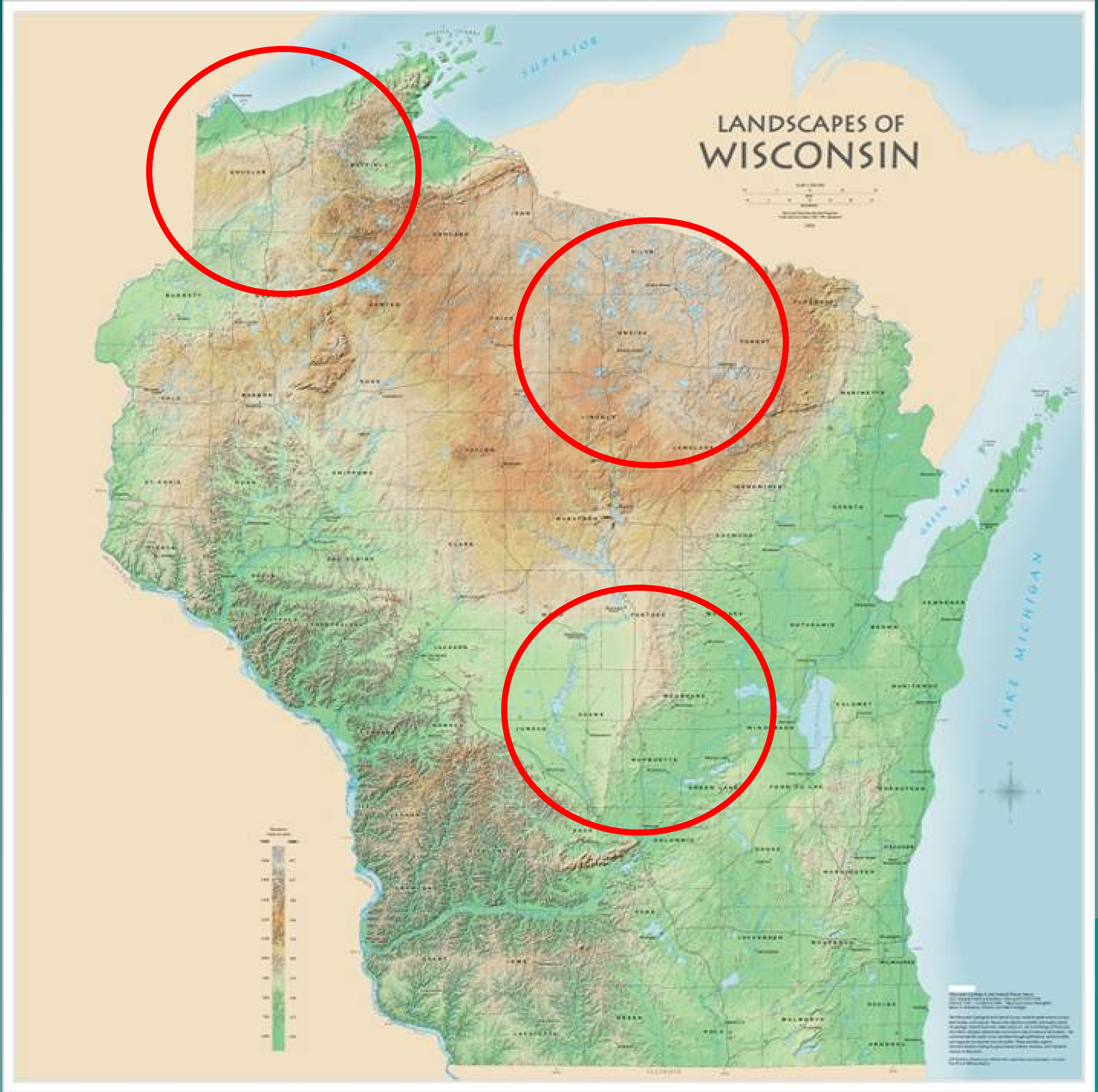
Affected By Pumping





Source: G. Kraft, UWSP


SOIL REGIONS OF WISCONSIN
F.W. Madison, Wisconsin Geological and Natural History Survey
H.F. Gundlach, U.S. Department of Agriculture, Soil Conservation Service
1990
MILES
KILOMETERS
Soils of northern and eastern Wisconsin
Forested, red, sandy, and loamy soils
Forested, red, sandy, and loamy soils over dolomite
Forested, silty soils
Forested, loamy soils
Forested, sandy soils
Forested, red, clayey or loamy soils
Soils of central Wisconsin
Forested, sandy soils
Prairie, sandy soils
Forested, silty soils over igneous/metamorphic rock
Soils of southwestern and western Wisconsin
Forested, silty soils
Prairie, silty soils
Forested soils over sandstone
Soils of southeastern Wisconsin
Forested, silty soils
Prairie, silty soils
Statewide
Streambottom and major wetland soils
Water
Published by and available from
University of Wisconsin-Extension
Wisconsin Geological and Natural History Survey
Adapted from Hole, F.D., et al., 1968, Soils of Wisconsin: Wisconsin Geological and Natural History Survey, scale 1:710,000.

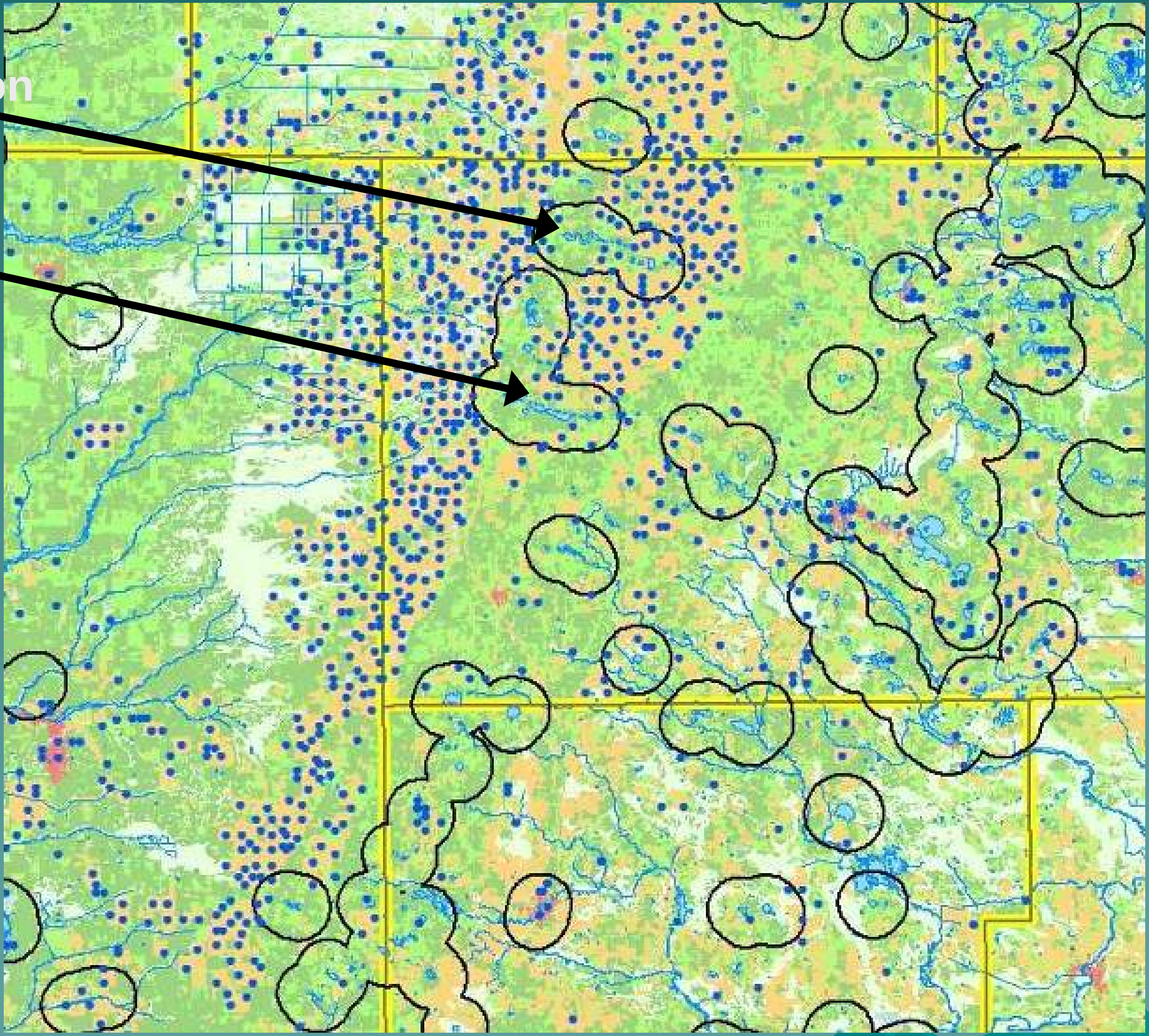


Source: WGNHS

Waushara County Lakes

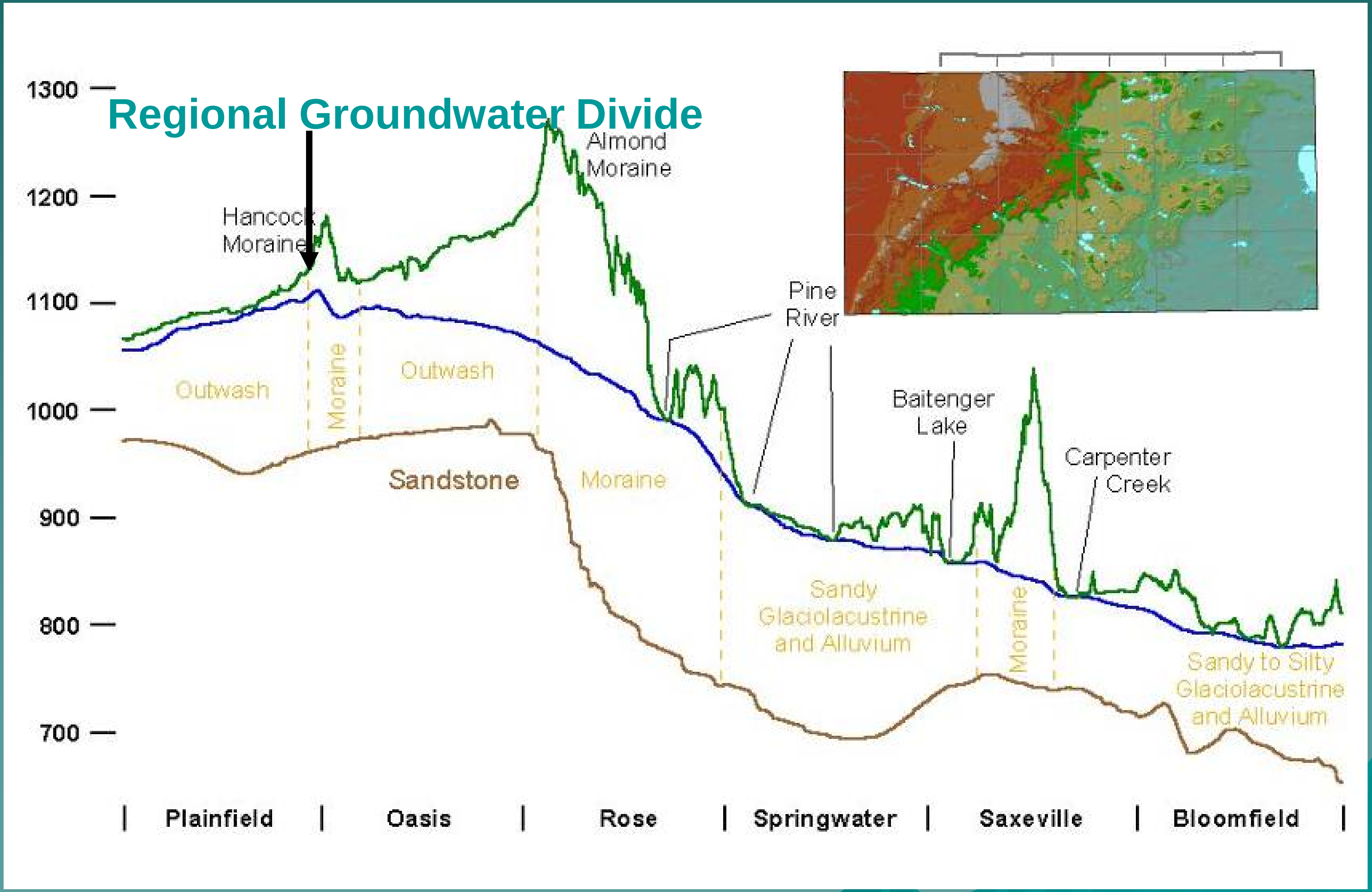
Long, Huron

Fish, Pine



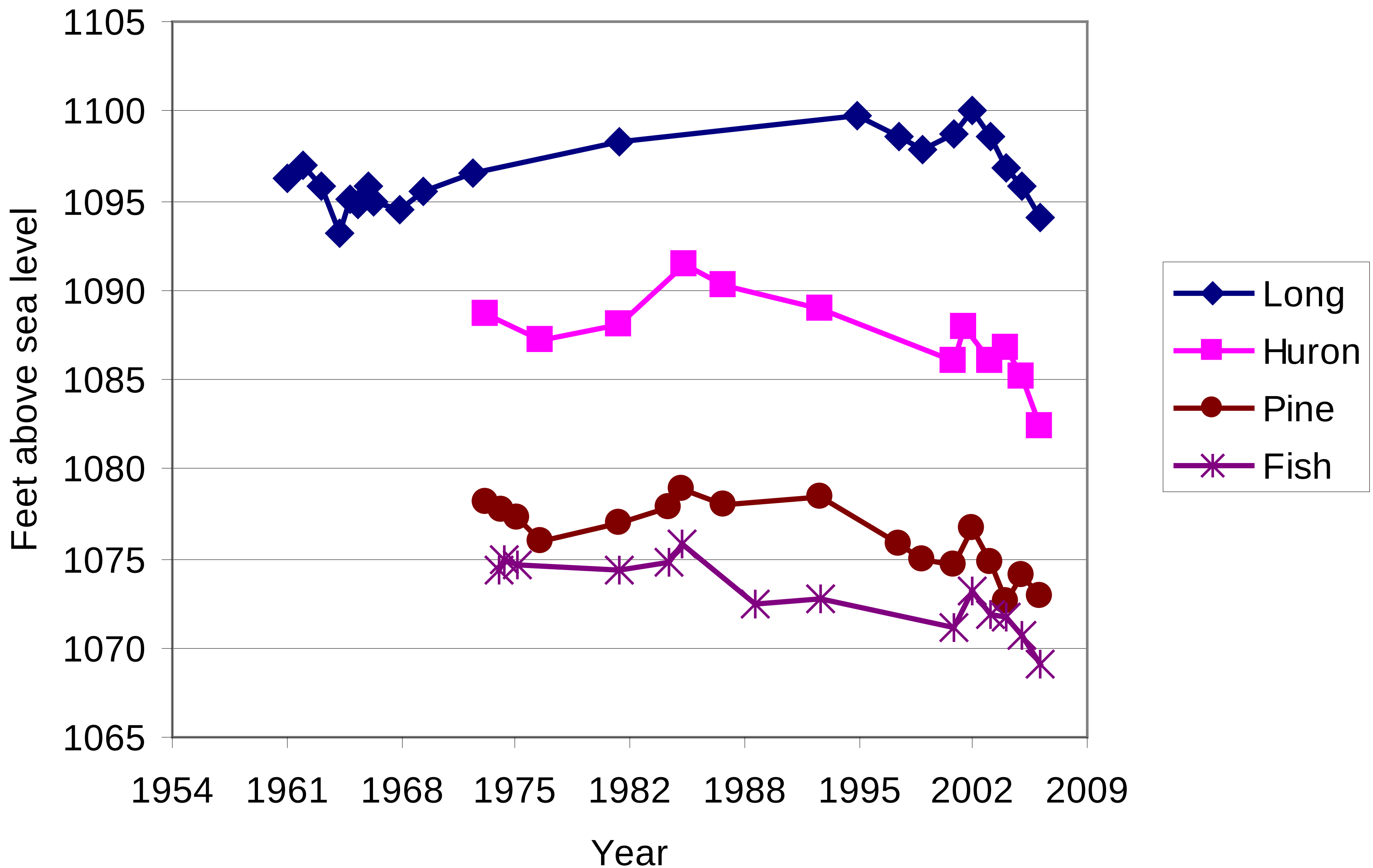
Source: G. Kraft, UWSP

A Slice through the Earth



Source: G. Kraft, UWSP

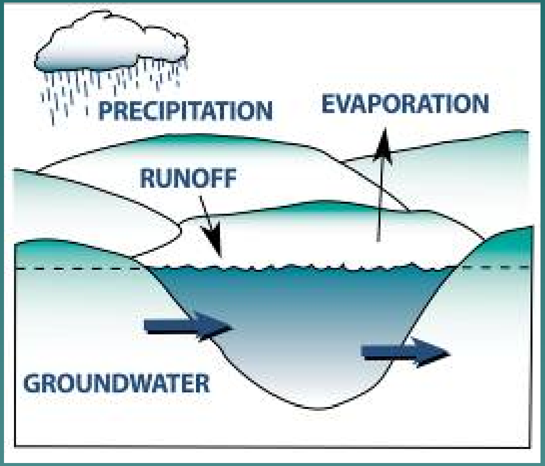
NW Waushara County Lakes

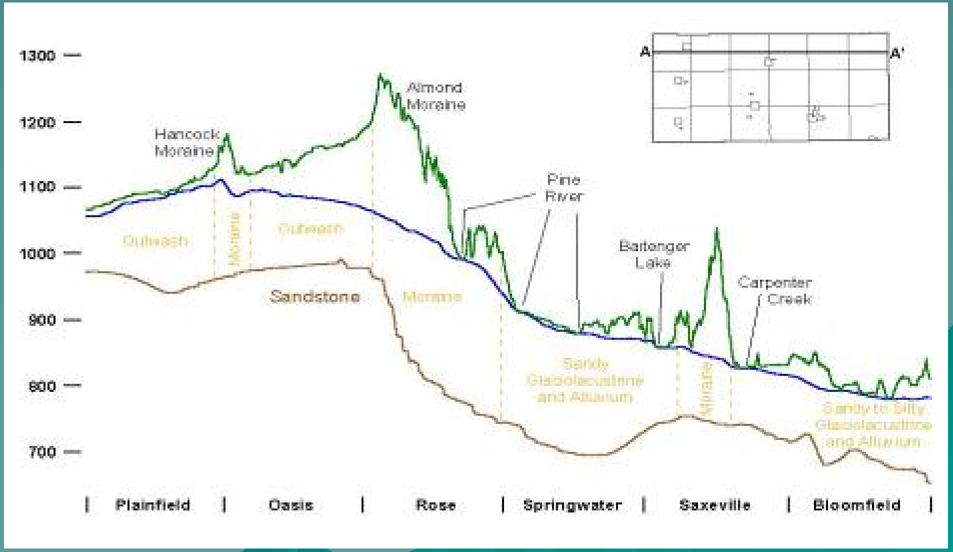


Data from Waushara Co. Planning and Zoning Dept.

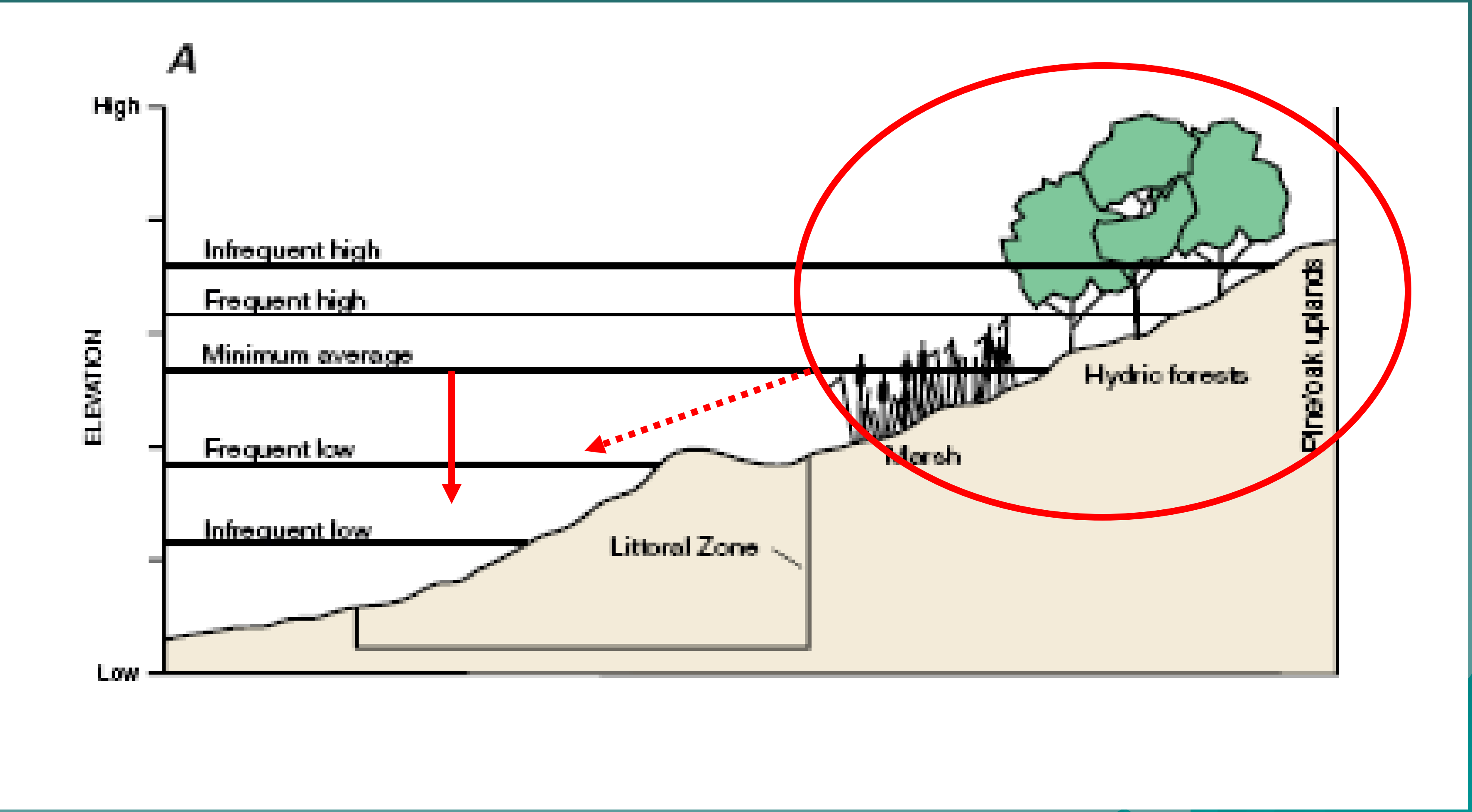
Waushara County Lakes

- Landlocked lakes, no outlet
- Vary 2.5 to 10 feet over decadal scale
- Lakes near major regional groundwater divide
- Recent declines after unusually high period in the 1990s
- Short-term drought in Central WI
- Major pumping center



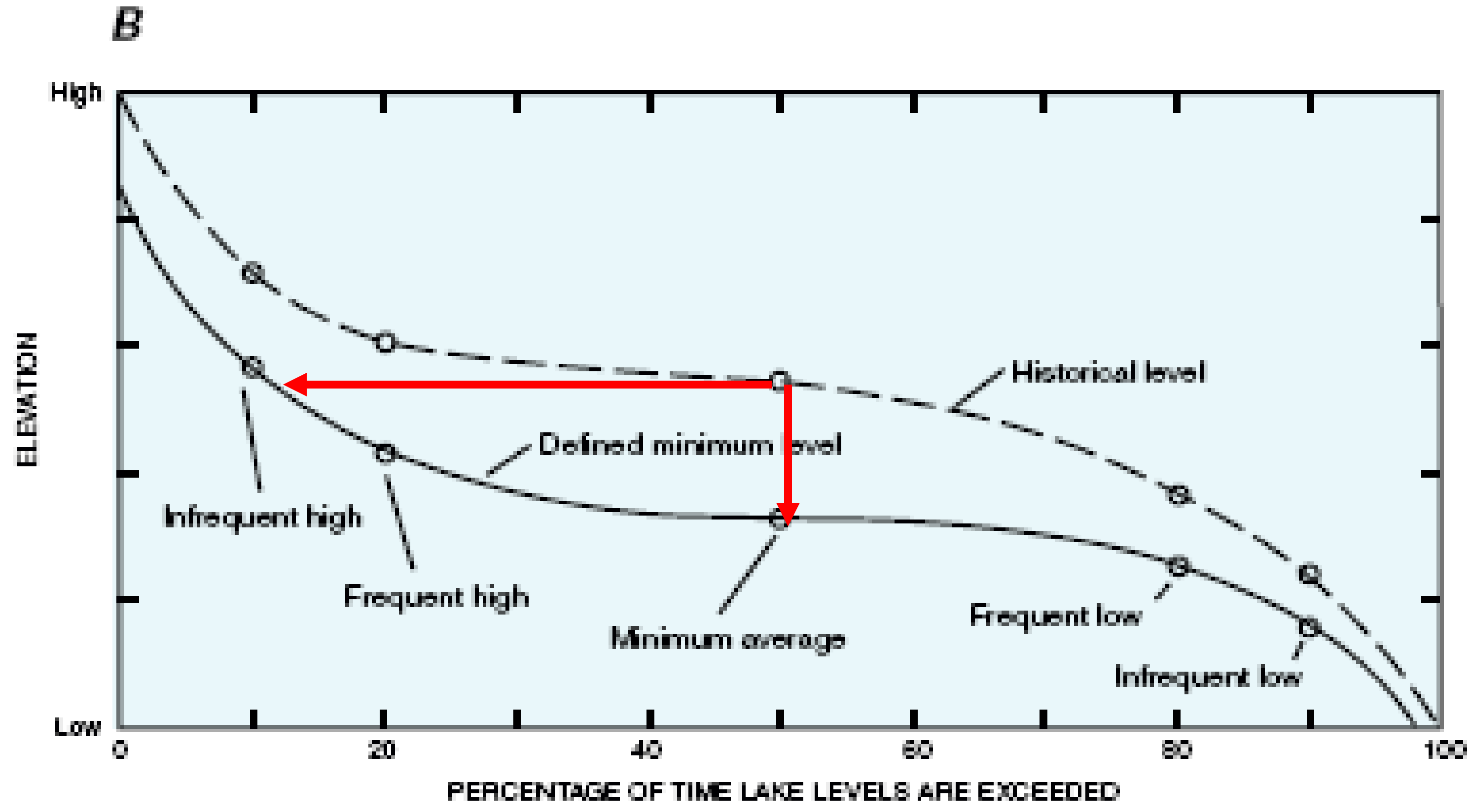


Implications of low water levels



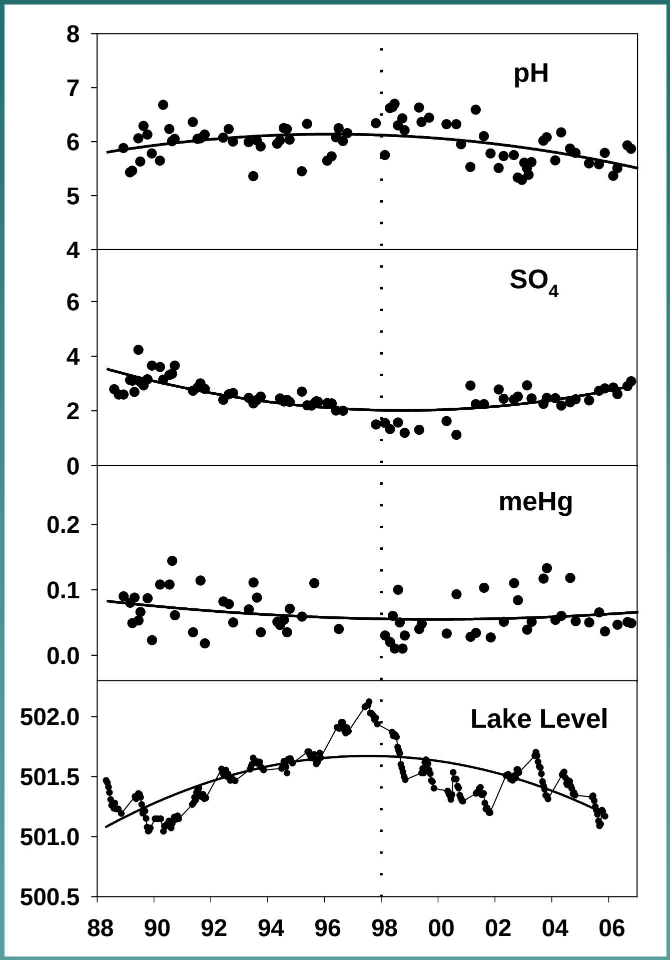
Source: USGS Circular 1186

Implications of low water levels



Source: USGS Circular 1186

Implications of low water levels



From Watras et al (in press)

- Dropping water levels exposes lake sediments
- Bacterial processes alter chemical composition in presence of oxygen
- Increased sulfate results in lowered pH and increased methyl mercury

Worst Impacts Are Not Inevitable

No-regrets solutions available now

A three-pronged approach to deal with climate change:

1. Reducing our emissions

2. Minimizing pressure the environment

3. Planning and preparing to m of a changing climate

Source: Claude Grondin

Reducing Our Emissions

- Energy Solutions
- Transportation Solutions
- Agricultural Solutions
- Forestry Solutions
- Integrated Strategies

Source: GW Wind Energy

Source: Warren Gretz, NREL

Source: NREL

Minimizing Pressure on Our Environment

- Air Quality Improvements
- Water Resource Protection

Source: D. Peck, Ramsar

- Habitat Protection
- Urban and Land Use Planning

Source: NRCS

Managing Climate Impacts

- Emergency Preparedness
- Agricultural and Forestry Adaptations
- Public Health Improvements
- Infrastructure Adjustments
- Education

Source: US Army Corps of Engineers

Source: John Pastor

" I hope I have justified the conviction, shared by many thoughtful people from all walks of life, that the problem can be solved. Adequate resources exist. Those who control them have many reasons to achieve that goal, not least their own security. In the end, however, success or failure will come down to an ethical decision, one on which those now living will be defined and judged for all
erations to come."

Source: Rick Lindroth

E.O. Wilson (2001)
The Future of Life

Acknowledgements

- Ken Bradbury, WGNHS
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