

Characterizing Groundwater/Surface Water Interactions in Lakes: White Bear Lake Study:



Groundwater and Surface-Water Interaction Partners

Lead: White Bear Lake
Conservation District

State

Minnesota Pollution Control Agency
(MN Legacy Funding)

Minnesota Department of Natural Resources

Minnesota Board of Water and Soil Resources

Region

Metropolitan Council

County

Ramsey County

Washington County

Cities

White Bear Lake

White Bear Township

Birchwood

Mahtomedi

Private

White Bear Lake Home Owners
Association

League of Women Voters
White Bear Lake Area

White Bear Lake VFW

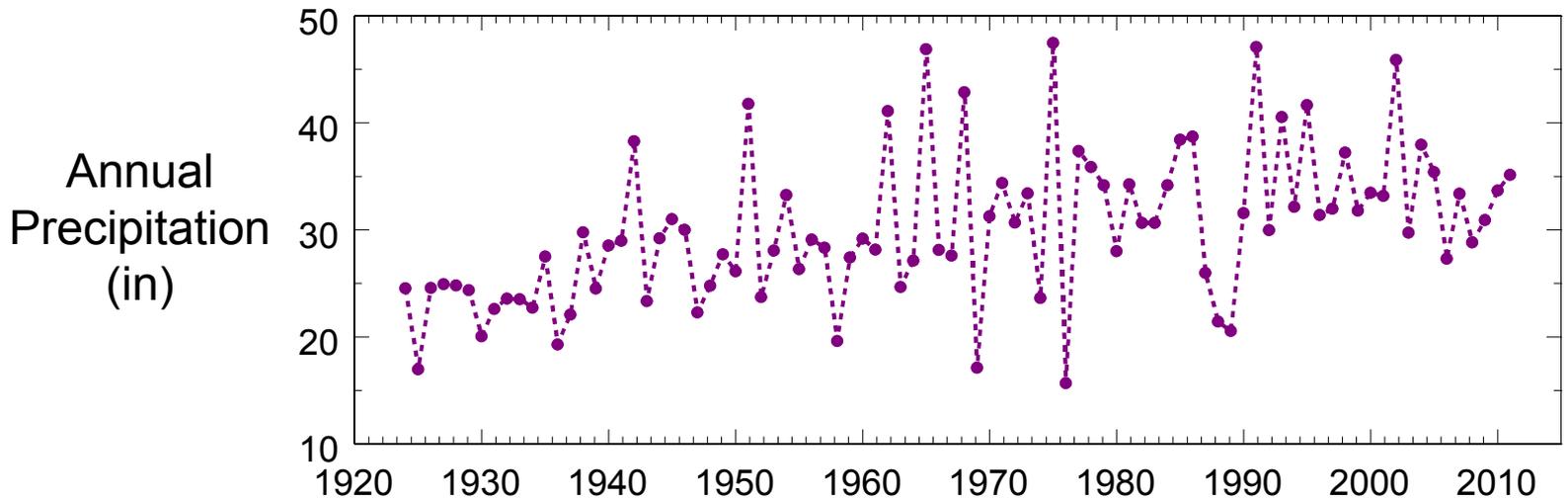
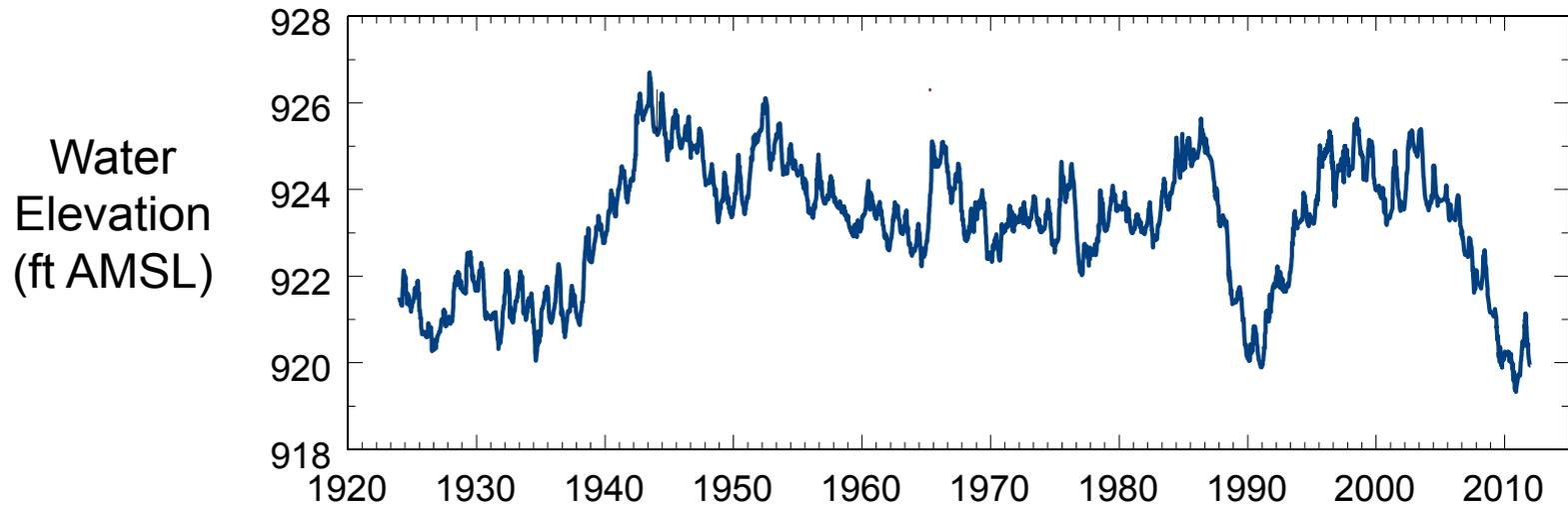
Watershed Organizations

Rice Creek Watershed District

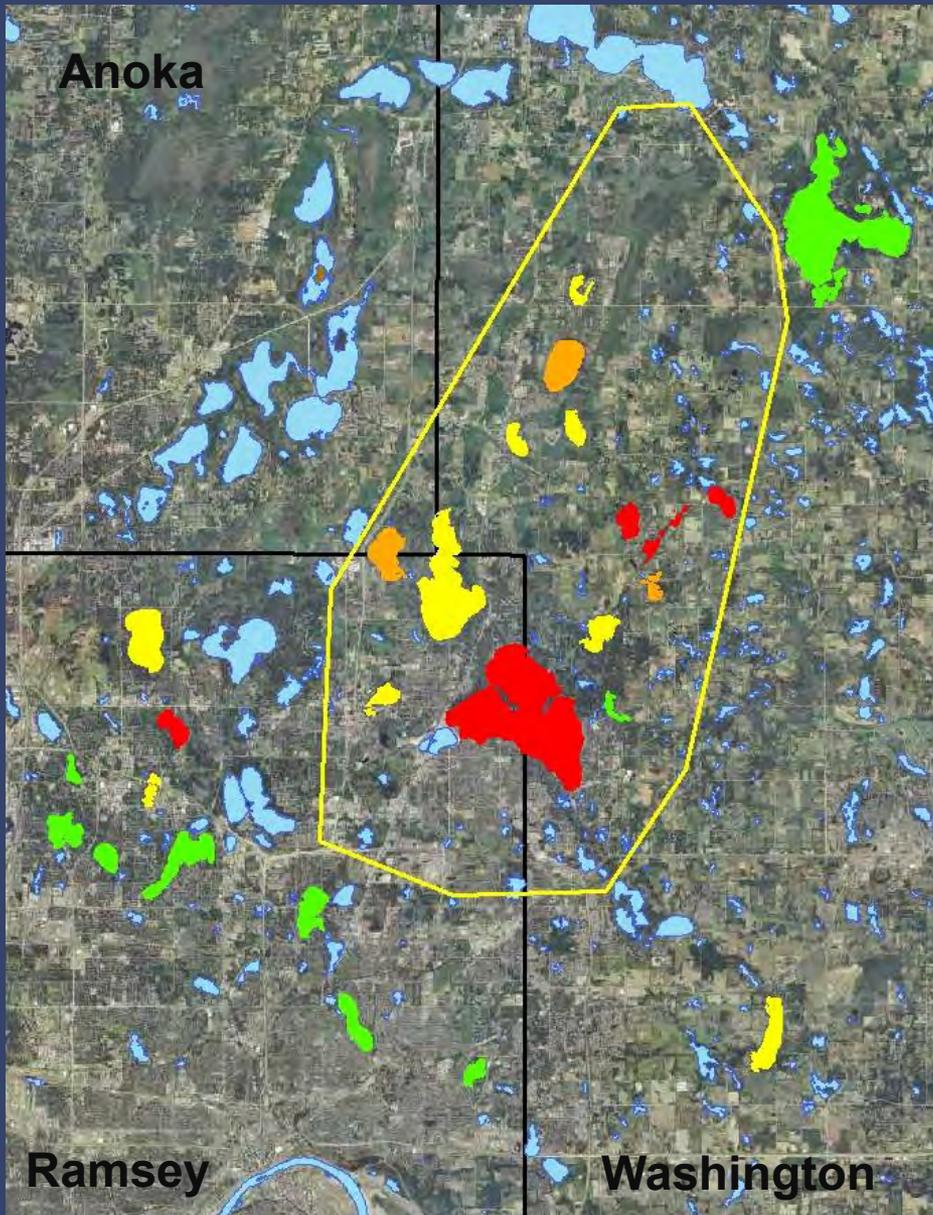
Vadnais Lakes Area Water
Management Organization

Thank You, Local Residents!

White Bear Lake Water Elevation and Precipitation 1924 - 2011

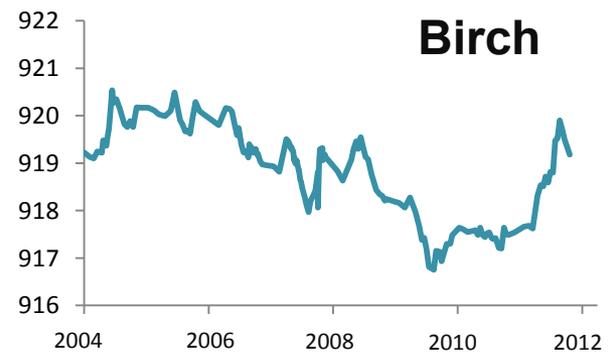
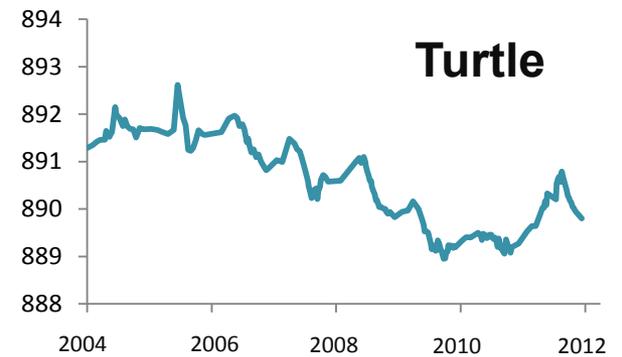
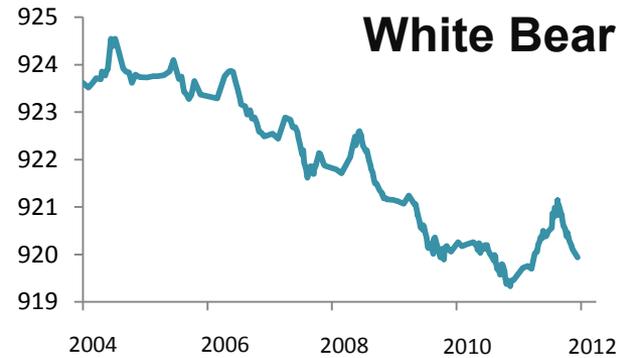
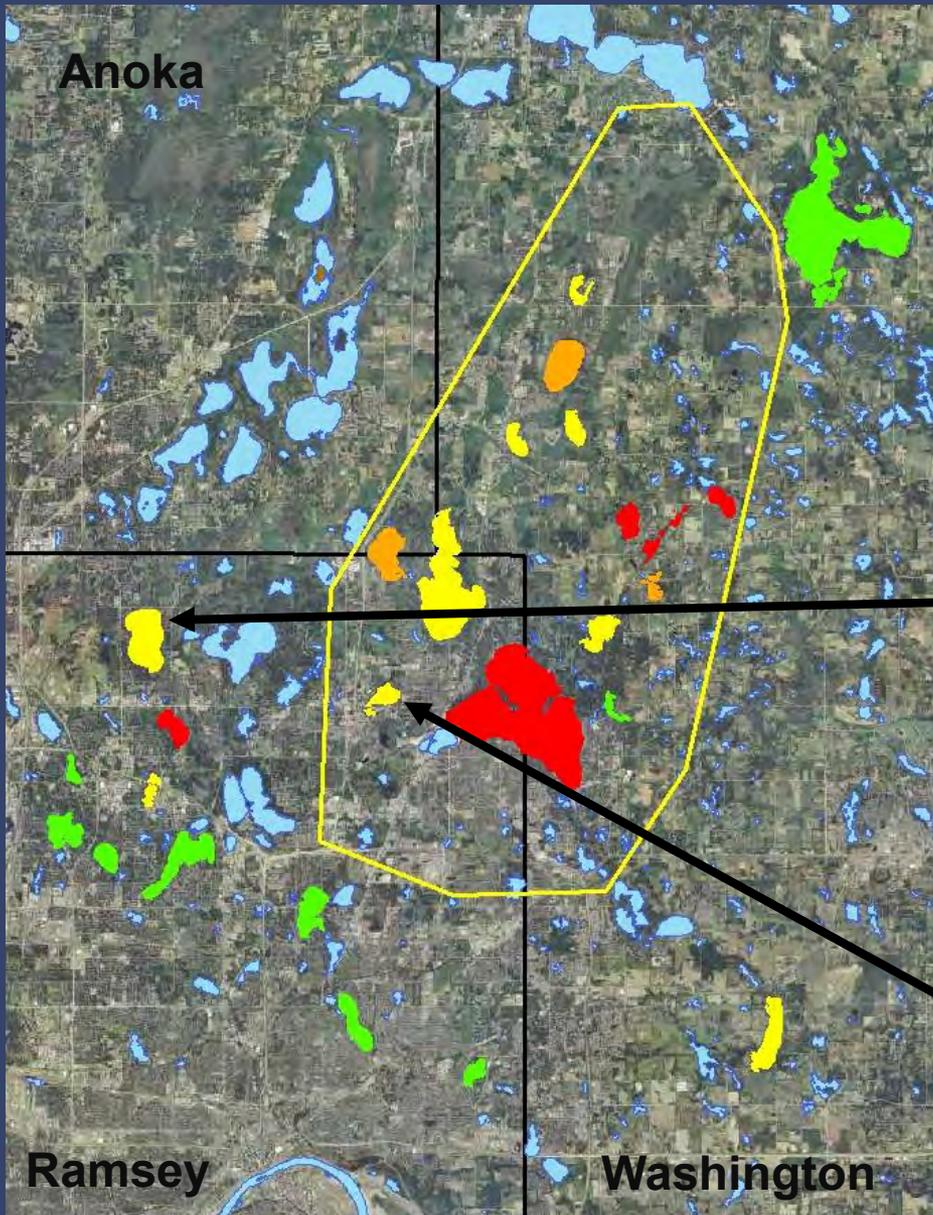


Lakes with Lower Water Levels – 2004-2011

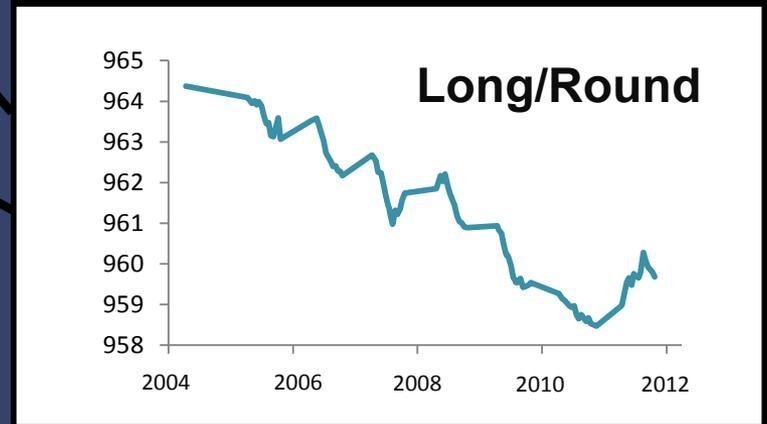
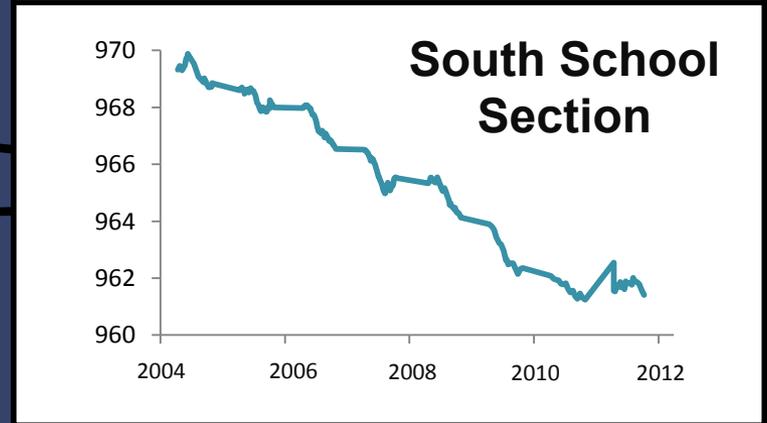
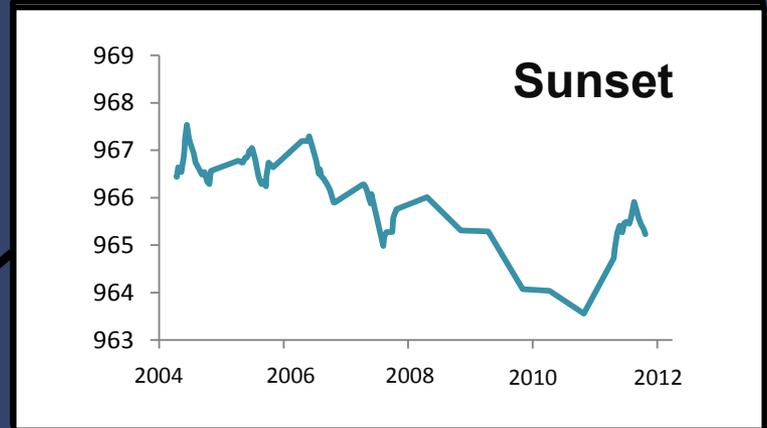
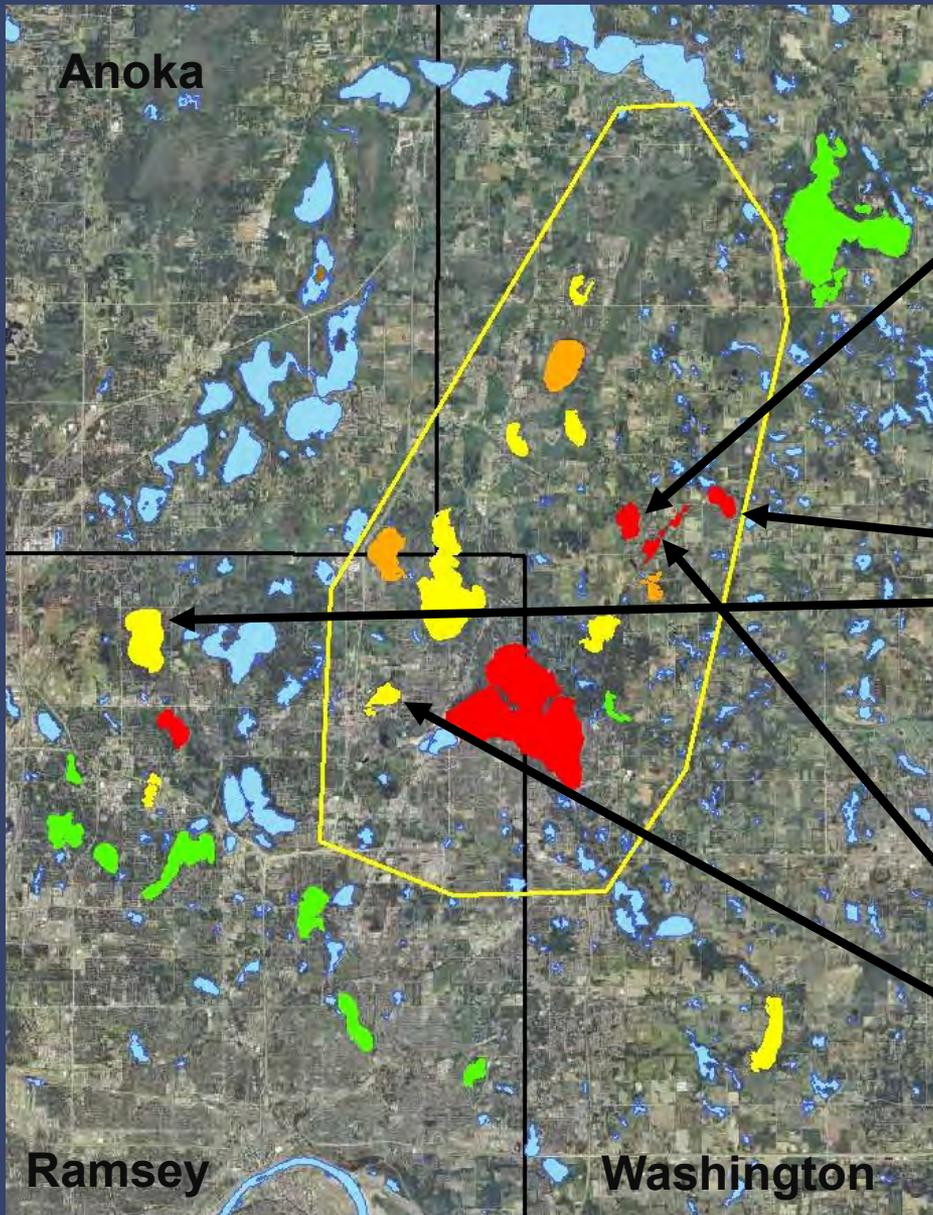


- Little change
- Minor decrease (1 foot or less)
- Moderate decrease (2-3 feet)
- Substantial decrease (4 or more feet)

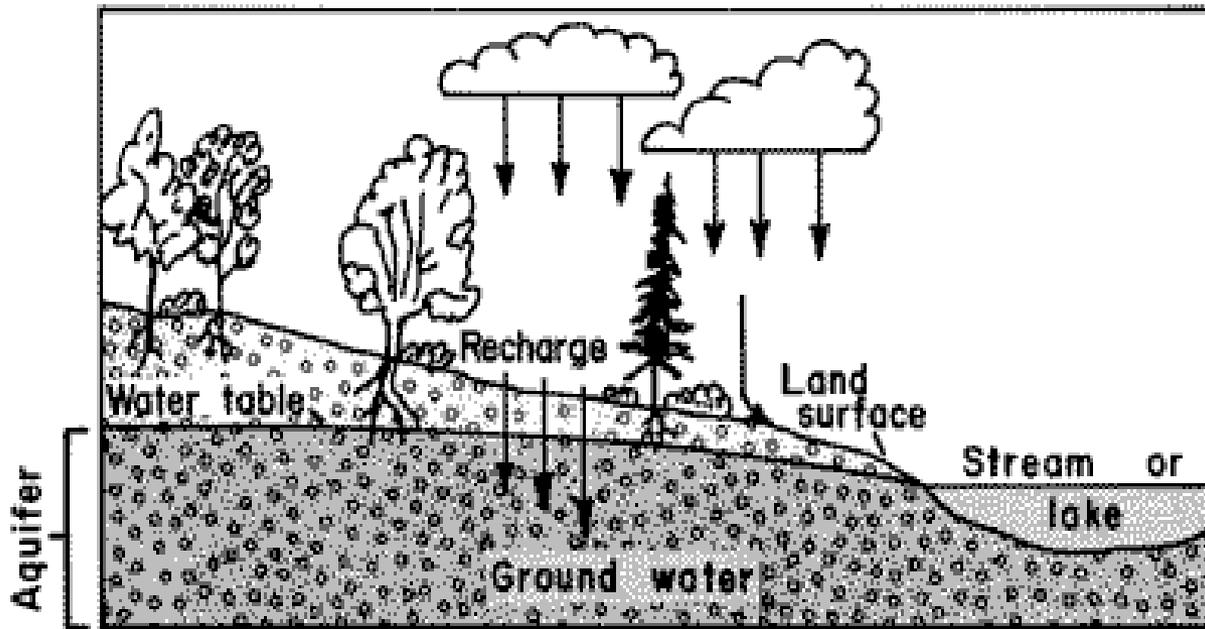
Lakes with Lower Water Levels – 2004-2011



Lakes with Lower Water Levels – 2004-2011



What is Groundwater?



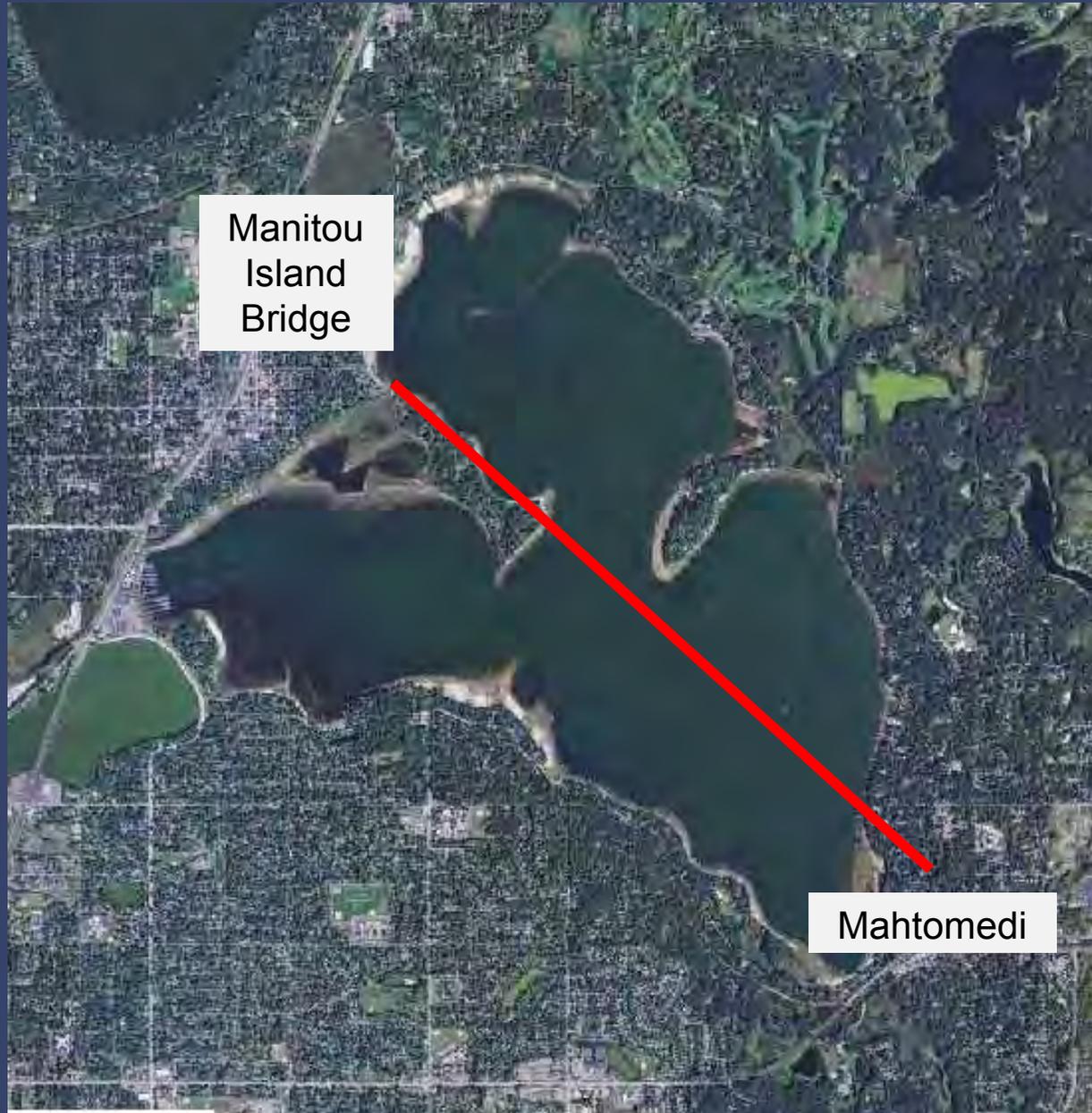
From U.S. Geological Survey Open-File Report 93-643

<http://pubs.usgs.gov/of/1993/ofr93-643/>

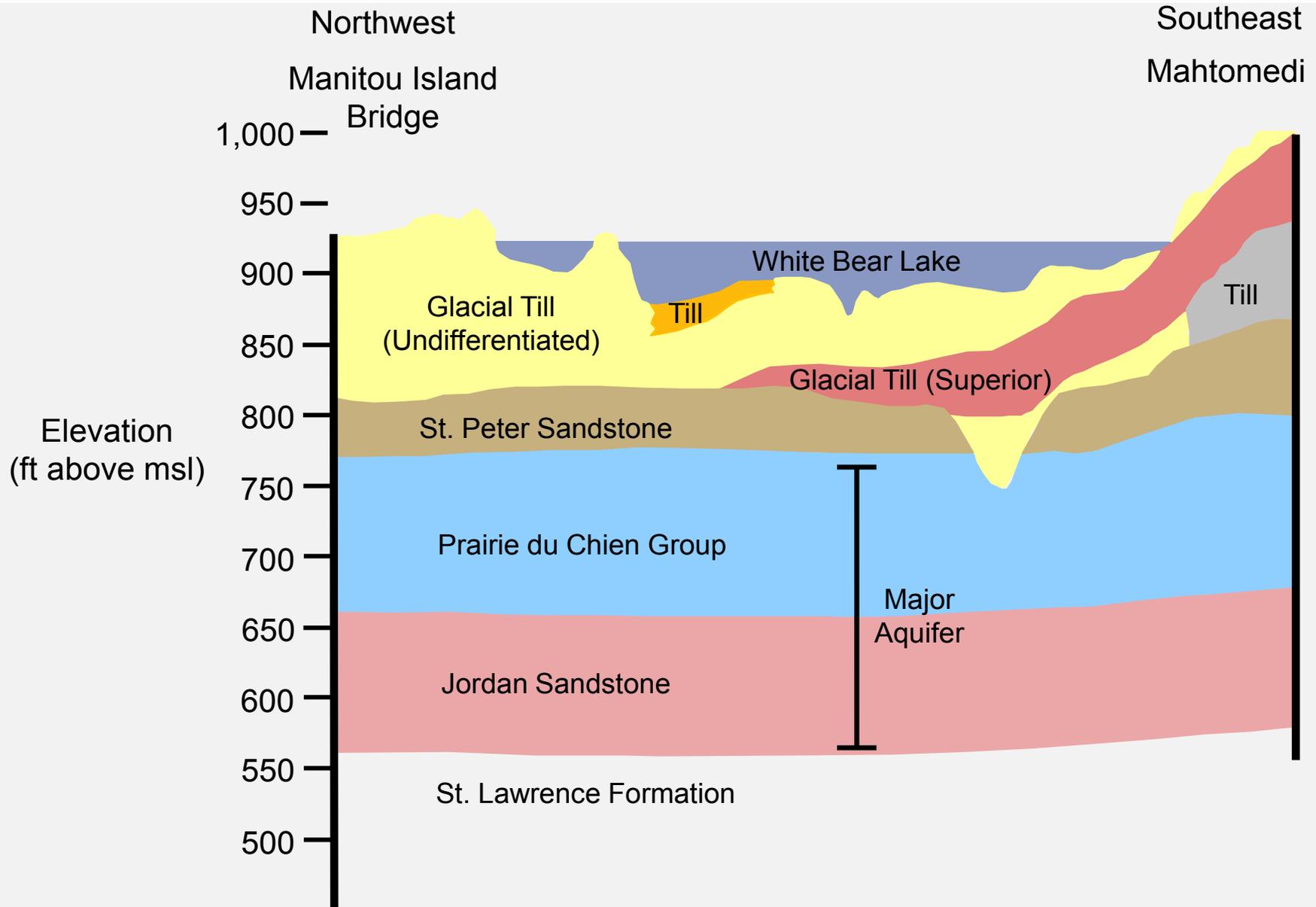
Groundwater - water below the land surface totally filling openings in underground rocks and sediments

Aquifer - underground rocks and sediments containing groundwater for water supplies

Geologic cross-section – White Bear Lake (Tipping, 2011)



Geologic cross-section – White Bear Lake (Tipping, 2011)



USGS Cooperative Study, 2011-2012

Objective

**characterize groundwater and surface water interactions
in White Bear Lake (groundwater inflow/outflow)**

Study Accomplishments

- 1) Precipitation/Groundwater/Lake Level Analysis**
- 2) Groundwater Level Synoptic Survey**
- 3) Temperature/Mini-piezometer/Seepage Meter Survey**
- 4) Lake Sediment Coring**
- 5) Water-Quality Survey – including Ecomapper**

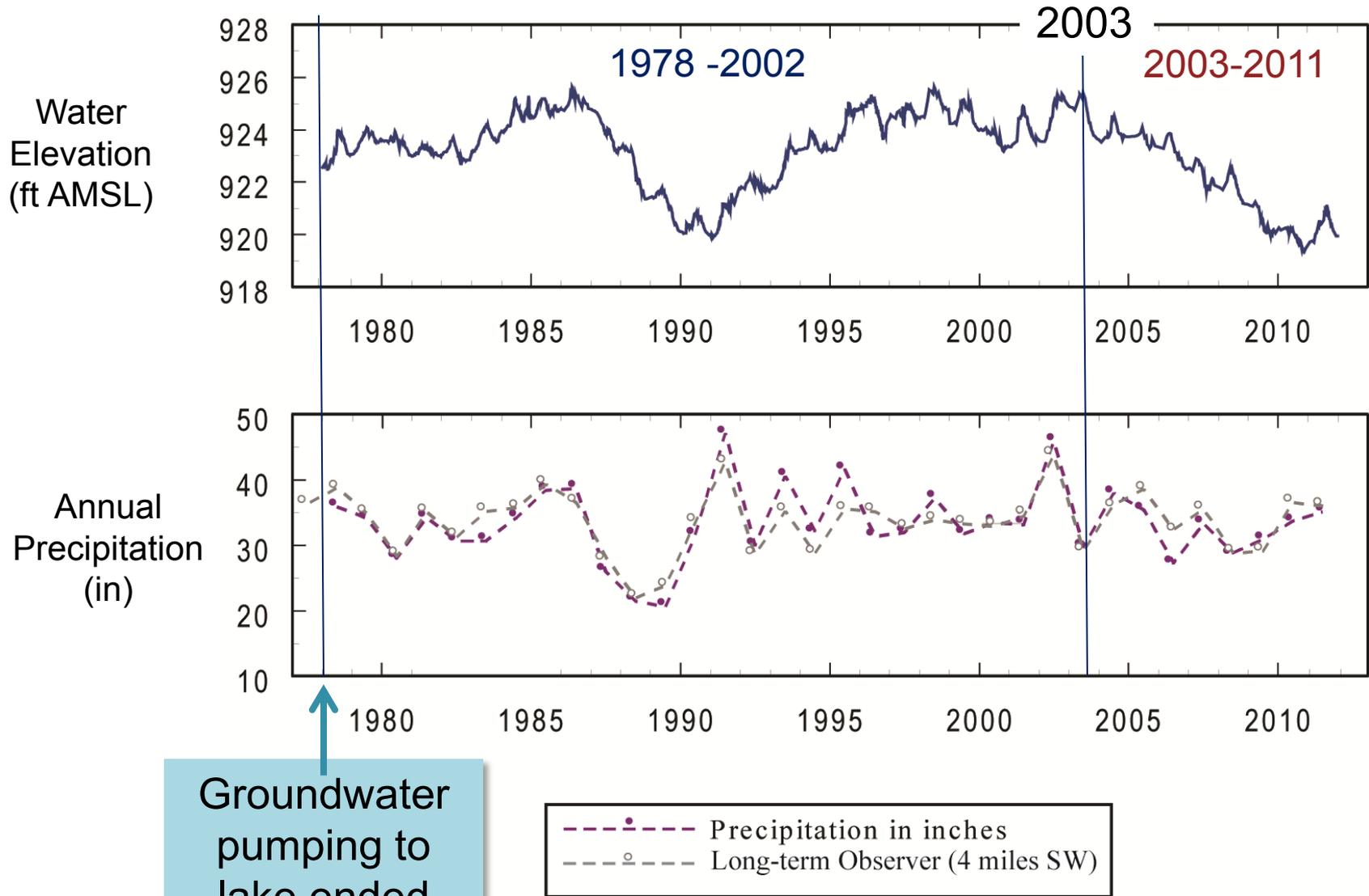
Conclusions on White Bear Lake

Low lake levels can be explained by higher regional pumping and lower precipitation

Groundwater flows into the lake from glacial sediments

Lake water flows out and reaches wells in Prairie du Chien/Jordan and glacial aquifers

White Bear Lake – Water Elevation and Precipitation, 1978-2011

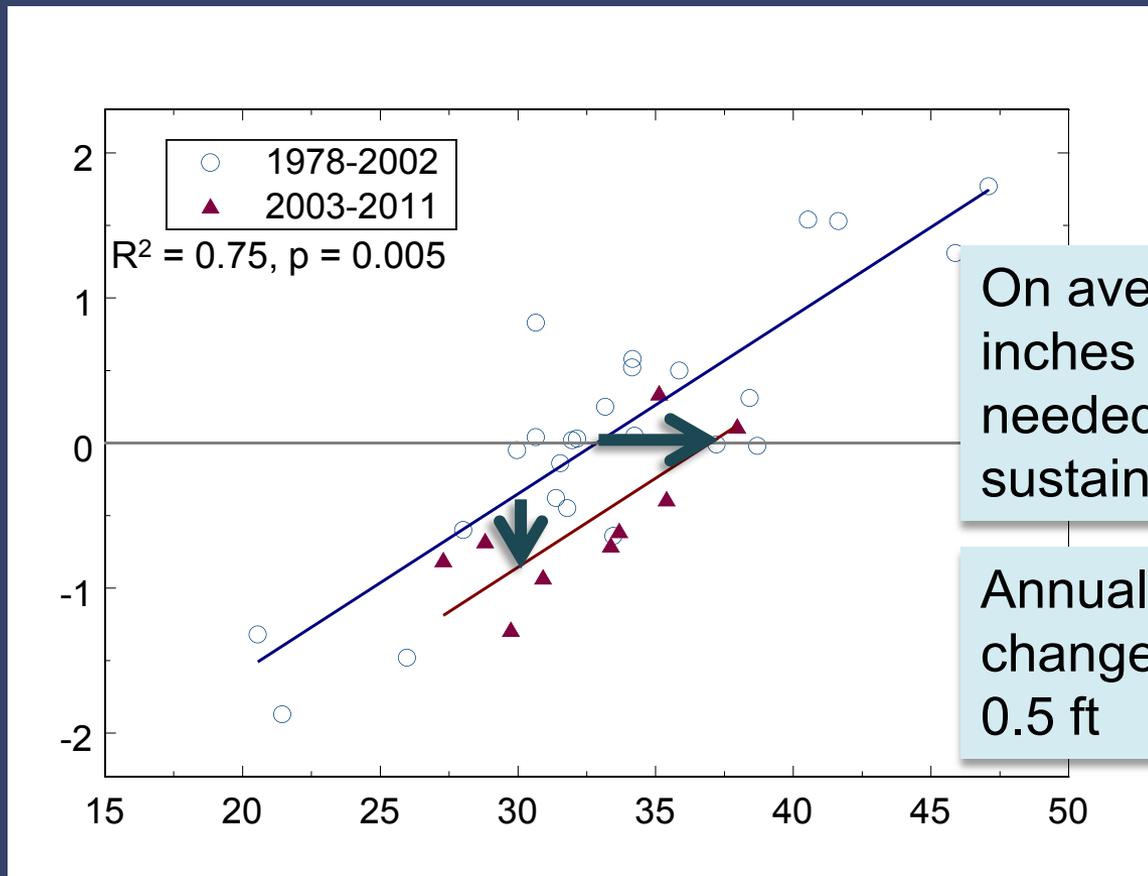


Groundwater pumping to lake ended



White Bear Lake Annual Lake Level Change versus Precipitation

Annual
Lake
Level
Change
(feet)



On average, 4 more inches of precip needed per year to sustain lake level

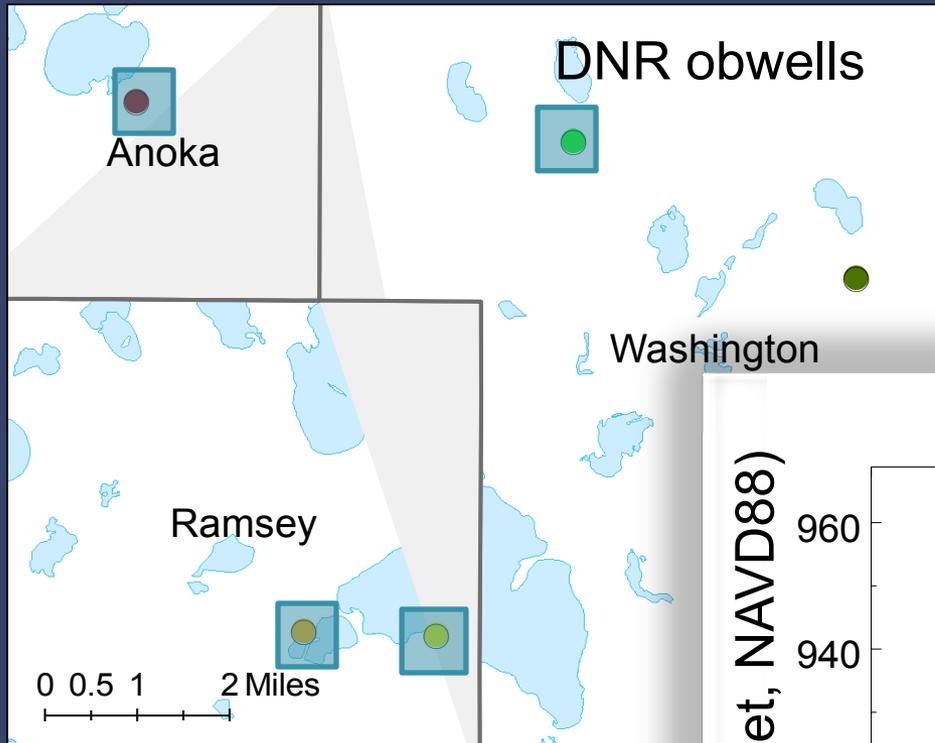
Annual lake level change reduced by 0.5 ft

Annual Precipitation (inches)

Significant in the summer (June, July, and August)

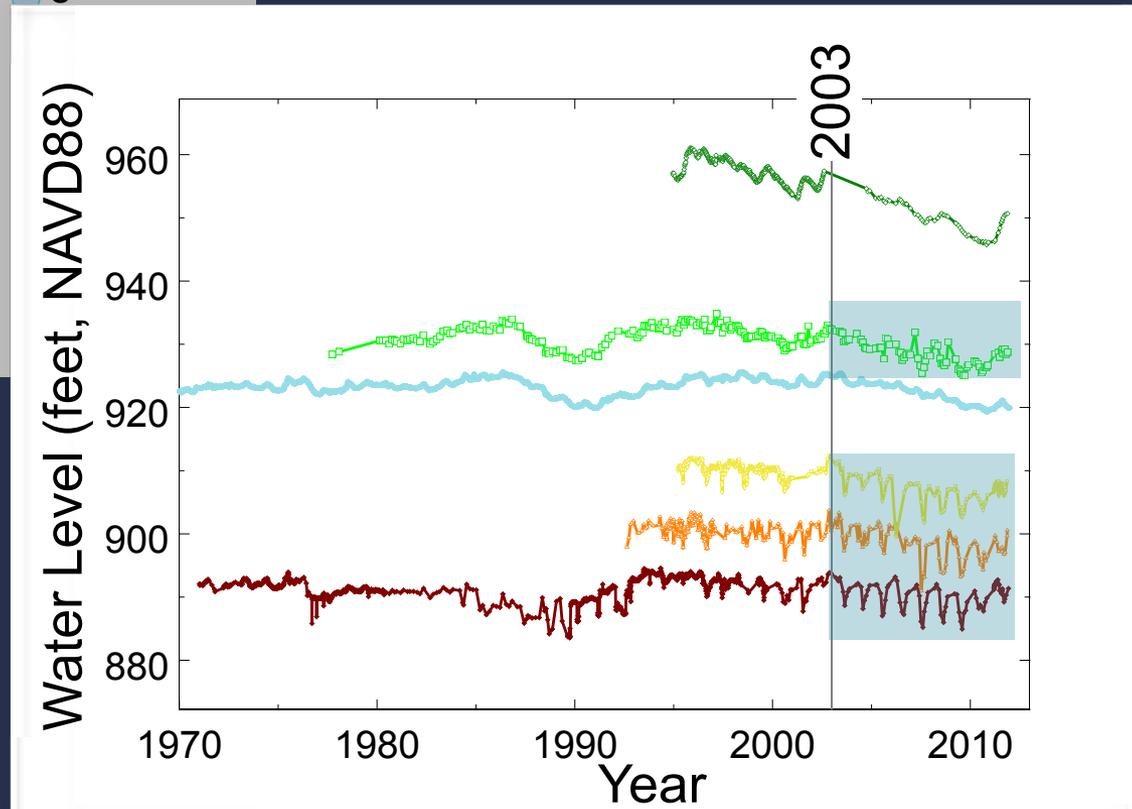


White Bear Lake and Prairie Du Chien Jordan Water Levels



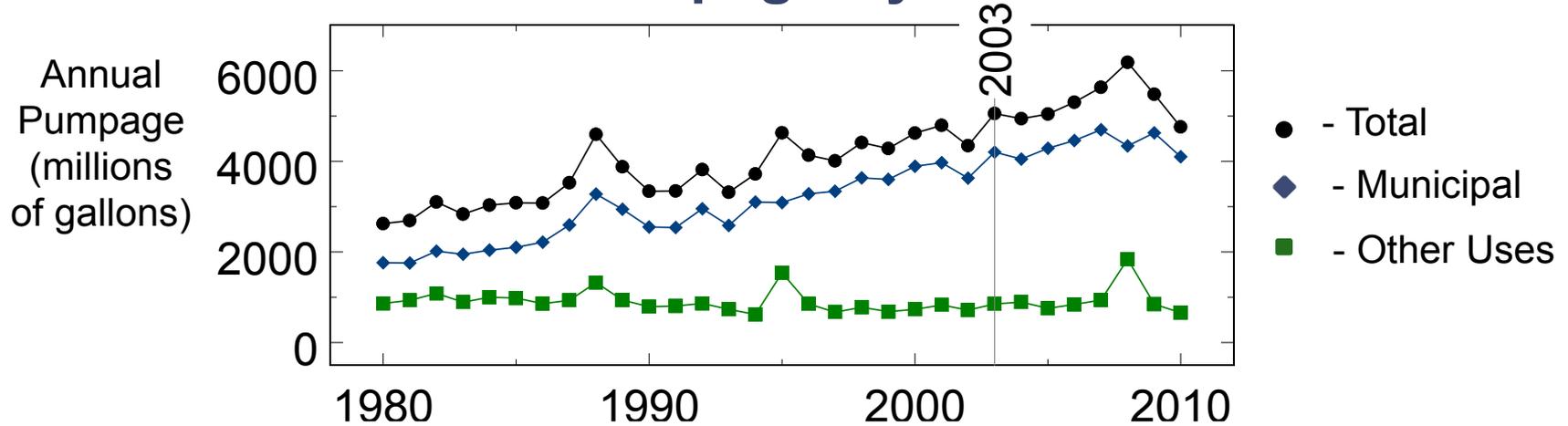
- Lake level follows PDCJ levels
- Increasing annual PDCJ variability

- Low levels consistently observed in the summer months since 2003



Annual Pumping from High-Capacity Wells - White Bear Lake Study Area 1980-2010

Pumpage By Use

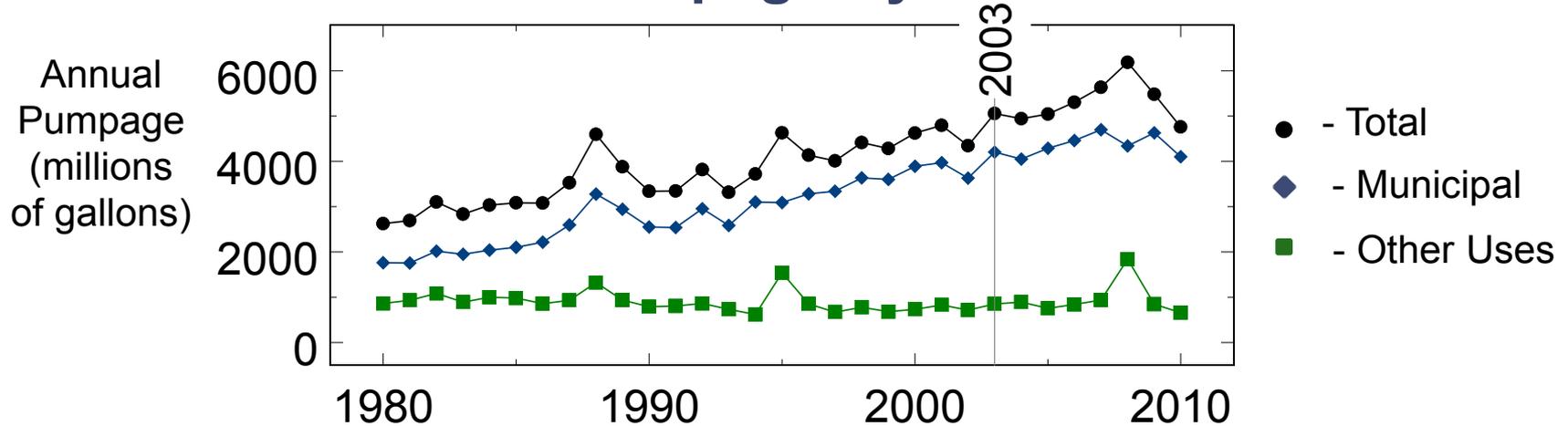


Municipalities included:

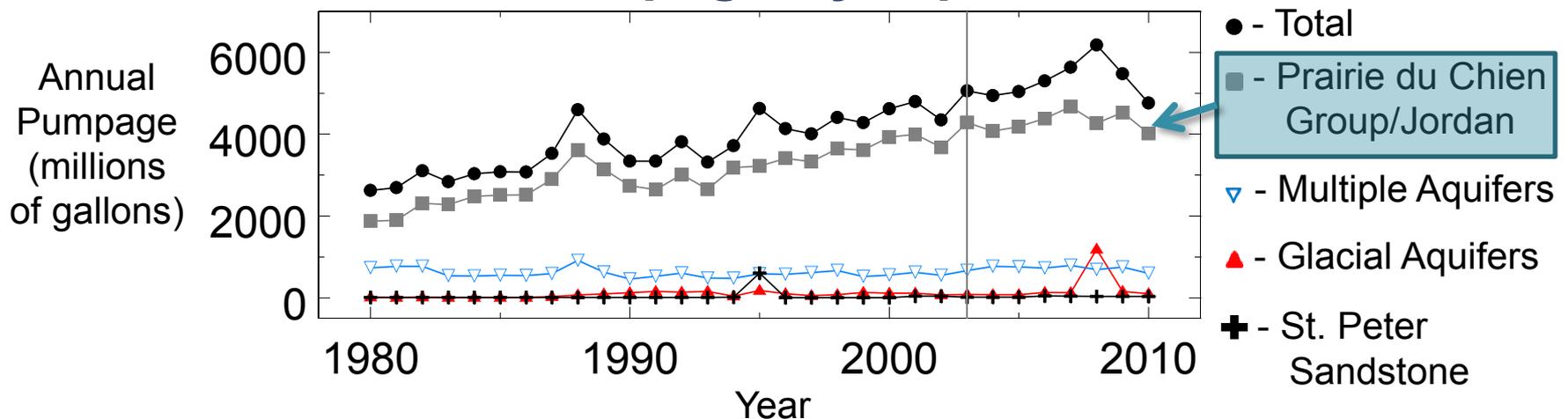
- Centerville
- Columbus
- Forest Lake
- Hugo
- Lino Lakes
- Mahtomedi
- North St. Paul
- Vadnais Heights
- White Bear Lake
- White Bear Township

Annual Pumping from High-Capacity Wells - White Bear Lake Study Area 1980-2010

Pumpage By Use



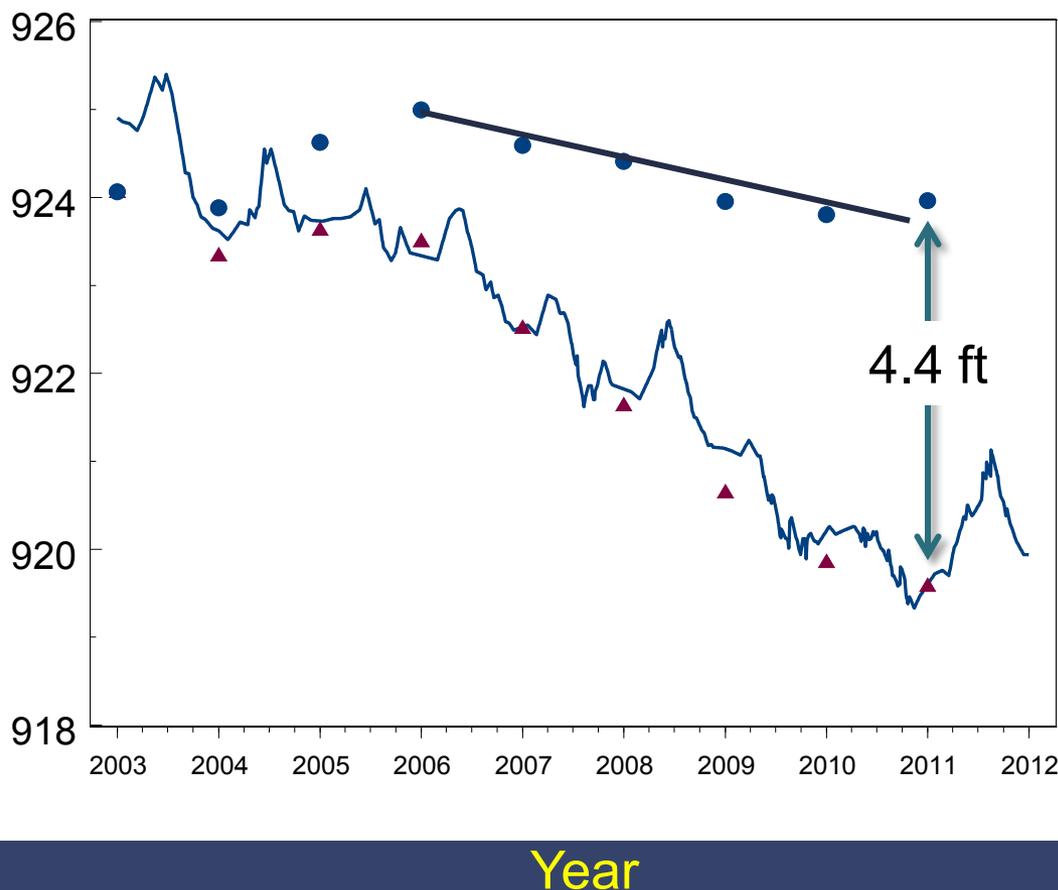
Pumpage By Aquifer



* Summer pumping from the PDCJ aquifer is increasing

Simulation of Pumping on White Bear Lake Levels 2003 - 2011

Water
Elevation
ft AMSL
(1912
datum)



Some years had low precipitation, and the lake level would have declined, even with less pumping

Pumping explains more of the recent decline.

- Observed Lake Level
- ▲ Modeled Lake Level at 2003-2010 Pumping Rates
- Modeled Lake Level at average 1980-2002 Pumping Rates



Groundwater Level Synoptic Survey

Measure water levels in wells and lakes
a short period of time

Two surveys

1) March - April (low pumping) 2) August (high pumping)

measured water levels in 238 wells and 66 lakes

USGS, State of Minnesota (DNR, MPCA, and BWSR), Met Council

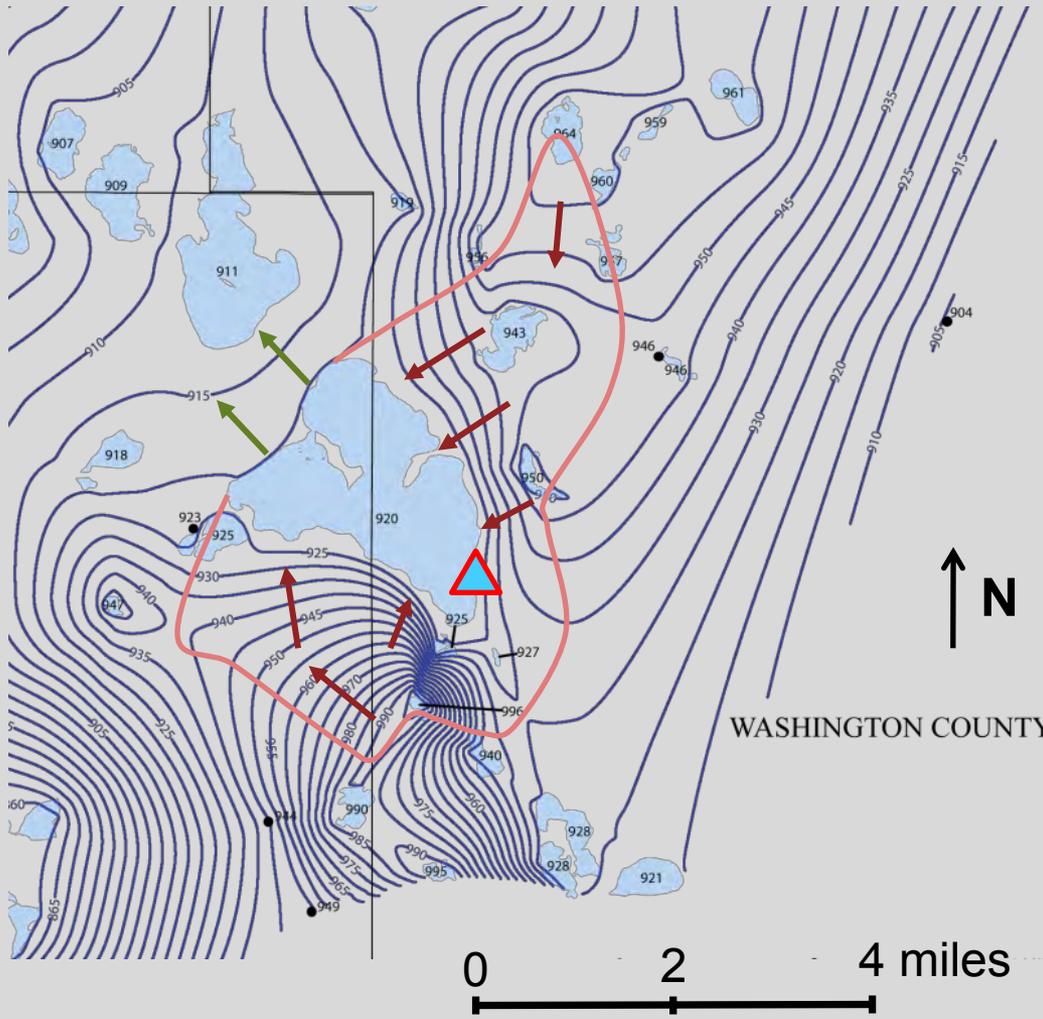
Results

**Regional Groundwater Levels for Aquifers in the
White Bear Lake Area**

Potentiometric Surface for Quaternary (Glacial) Water-table Aquifer

March 2011

12 wells and 66 lakes



● Well – water level measurement

— Potentiometric (Groundwater Elevation) Contour

← Direction of Groundwater Inflow

← Direction of Lake Water Outflow

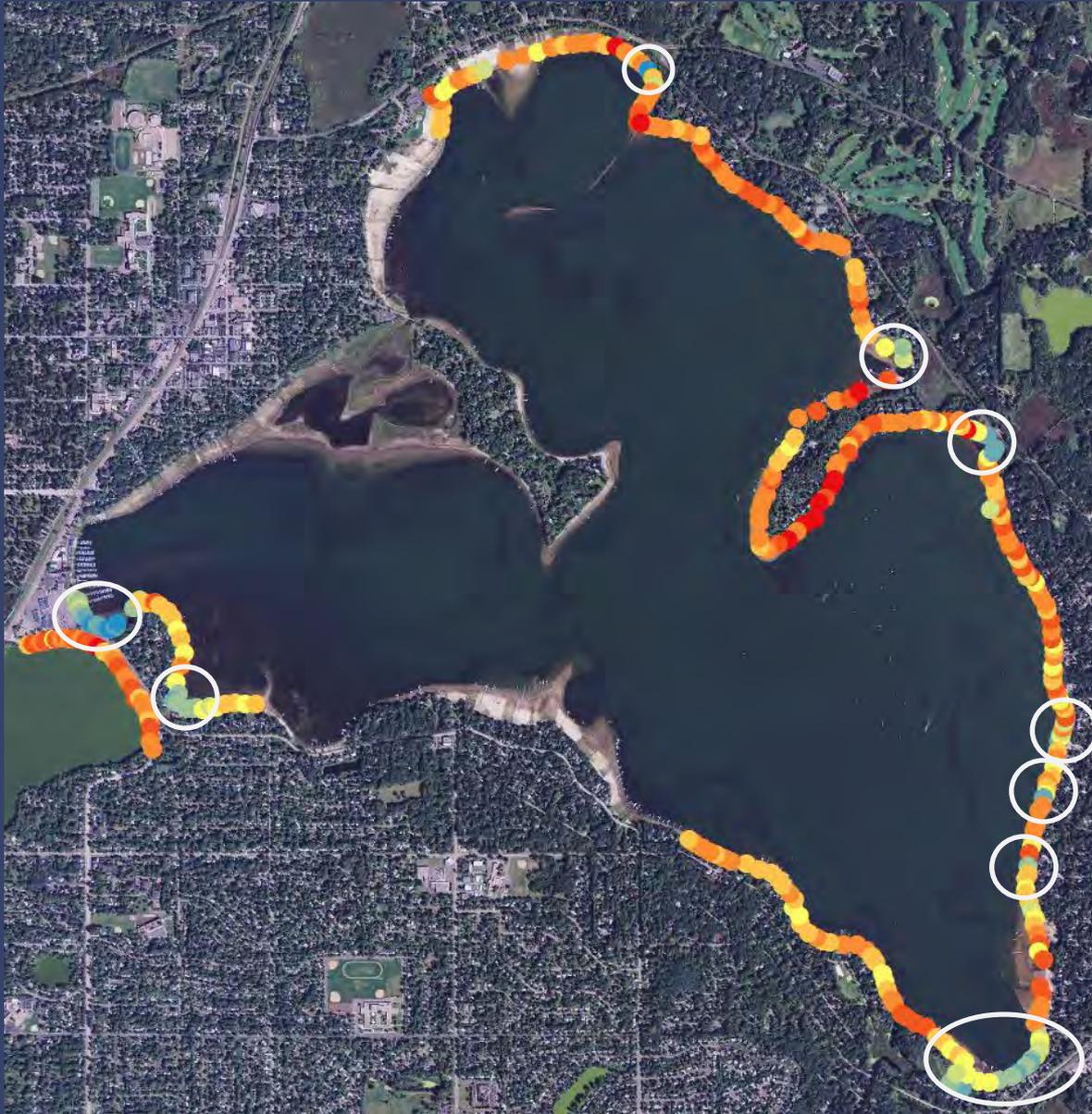
▲ Mahtomedi Public Beach

Iron Seeps forming at Mahtomedi Public Beach

Groundwater inflow to White Bear Lake



Water Temperatures in Nearshore Lake Sediments



July – September, 2011

Cooler Temperatures –
Groundwater Inflow
(springs)

Collected Water Samples



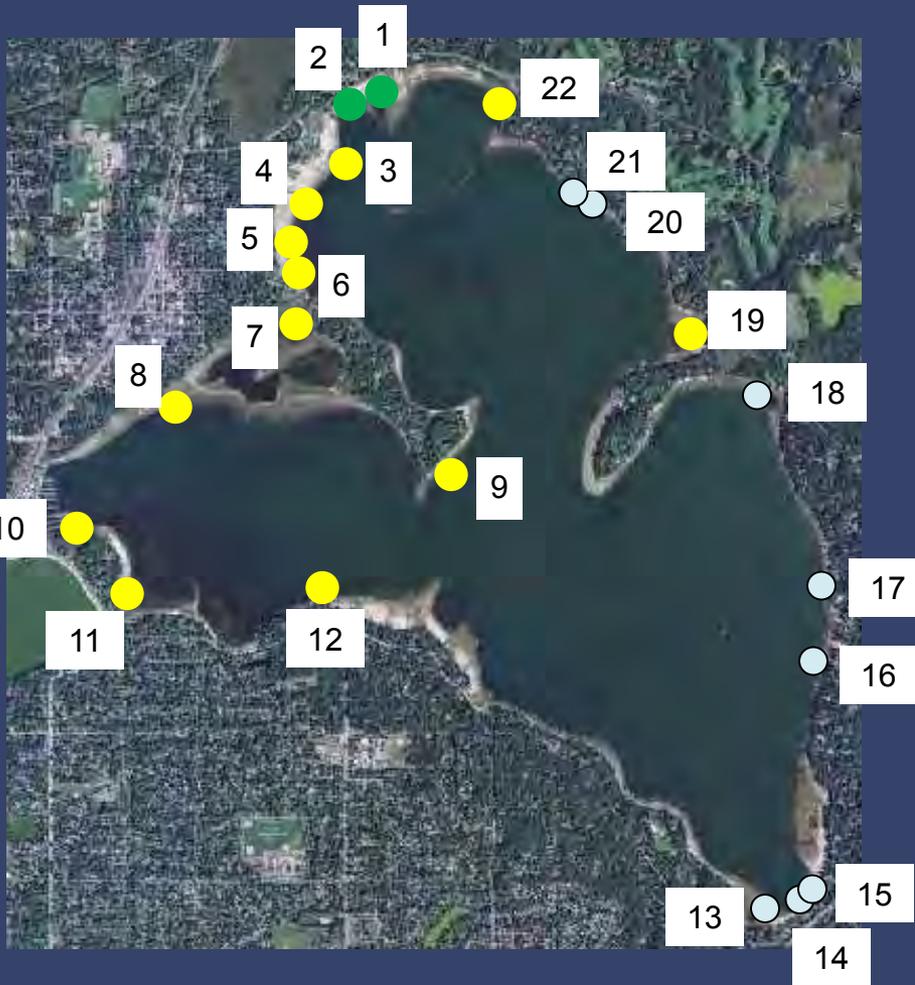
Seepage Meter Surveys – May and August/September 2011



- May - 9 nearshore transects - measured groundwater flux (inflow to lake or outflow to aquifer)
- August/September – 22 nearshore transects/single meters



Nearshore Seepage Meter Surveys – August 2011



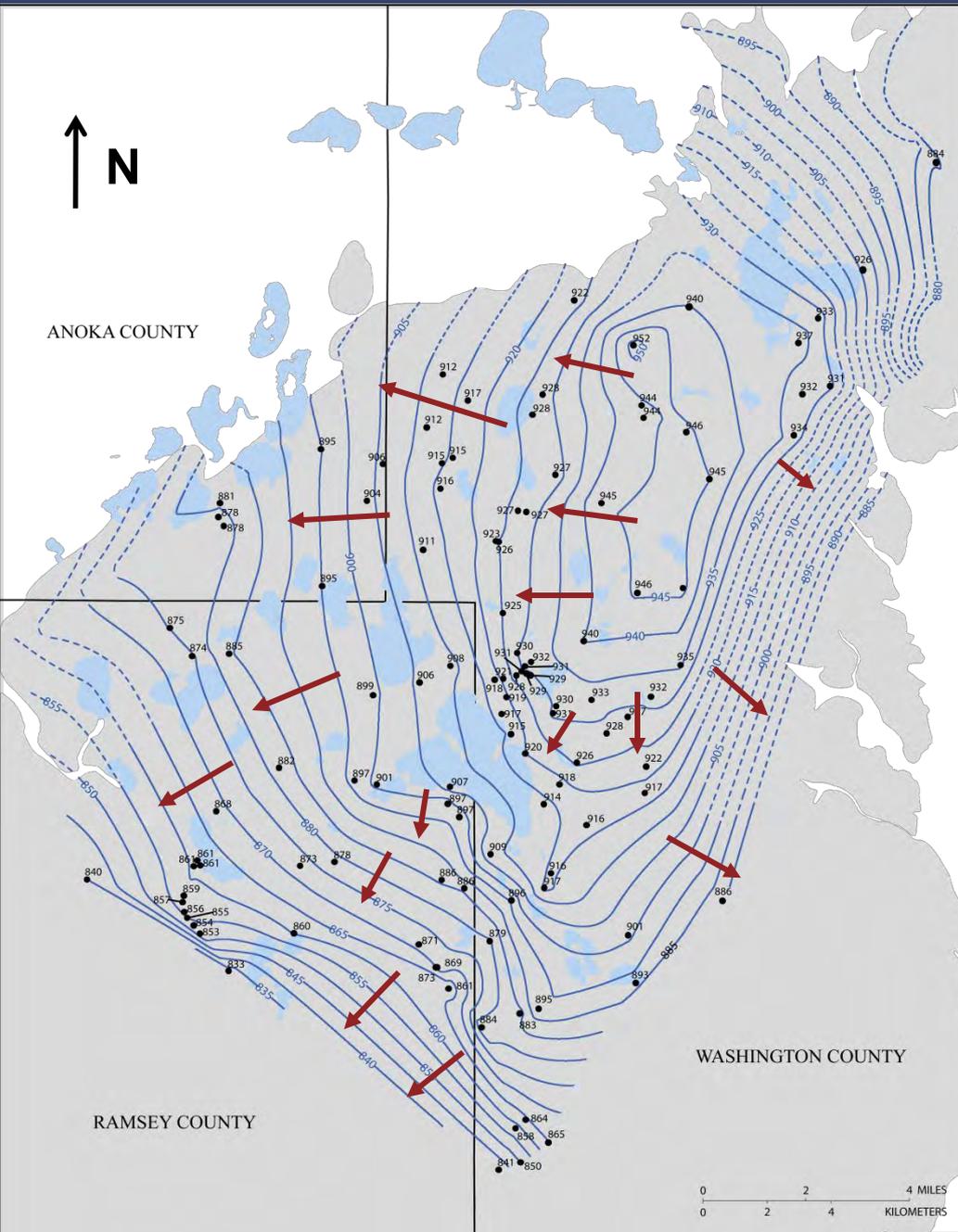
<u>Site</u>	<u>Average Flux (cm/day)</u>
1	-0.06
2	-0.13
3	0.14
4	1.11
5	0.13
6	0.16
7	0.02
8	0.12
9	0.17
10	0.08
11	0.57
12	0.29
13	3.03
14	27.6
15	7.00
16	20.3
17	3.22
18	6.87
19	0.76
20	26.6
21	3.00
22	0.40



Potentiometric Surface for Prairie Du Chien/Jordan Aquifer

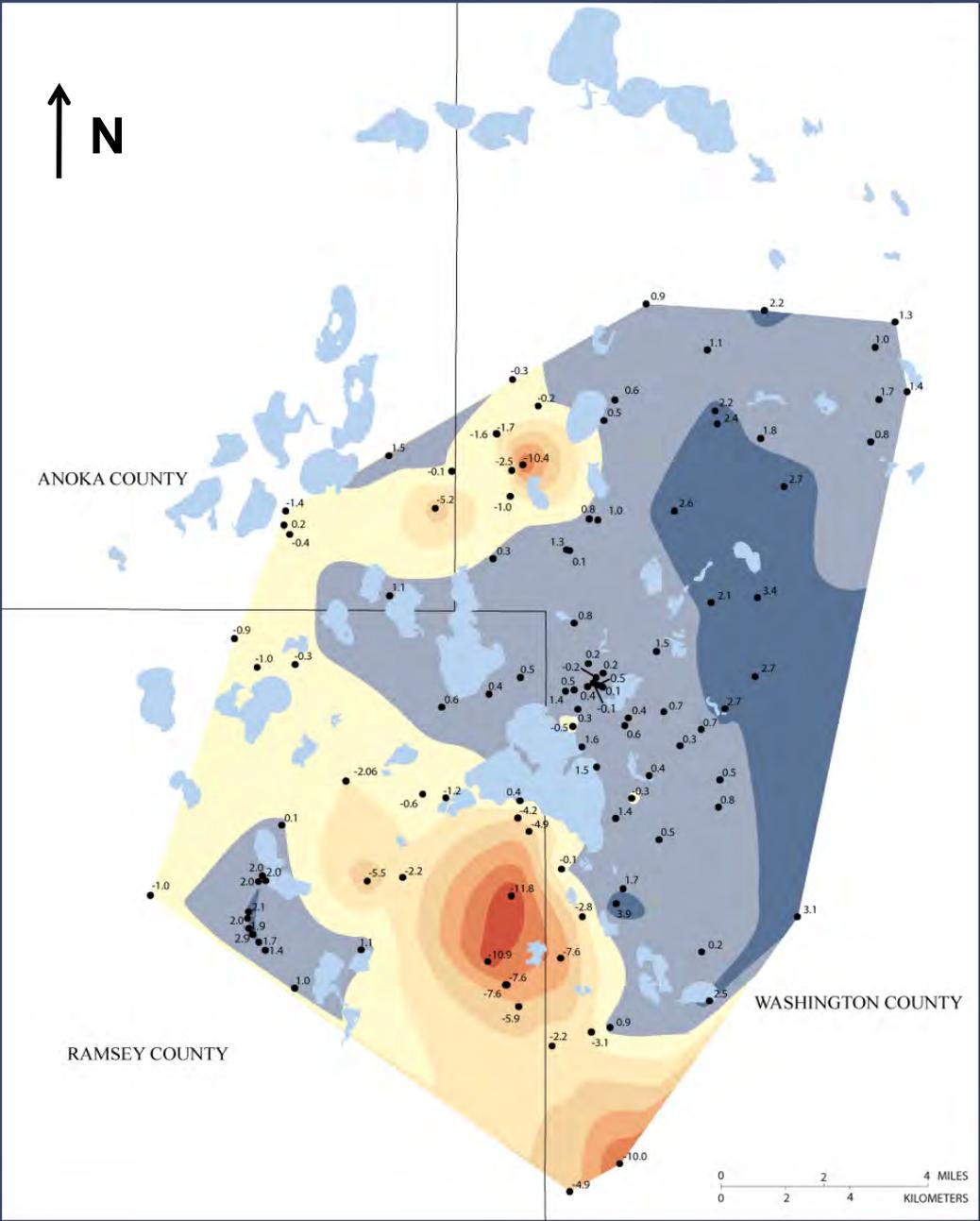
March 2011
113 wells

- Well – water level measurement
- Potentiometric (Groundwater Elevation) Contour
- - - Estimated Potentiometric Contour
- ← Direction of Groundwater Flow



Groundwater Elevation Change in Prairie Du Chien/Jordan Aquifer

Between March 2011 and August



- Well – water level change
- 10 – 12 foot Decline
- 8 – 10 foot Decline
- 6 – 8 foot Decline
- 4 – 6 foot Decline
- 2 – 4 foot Decline
- 0 – 2 foot Decline
- 0 – 2 foot Rise
- 2 – 4 foot Rise

Stable Isotopes – Lake Hydrology

What are stable isotopes?

Isotopes – “heavy” and “light” forms of the same chemical element, i.e. hydrogen, oxygen

Hydrology

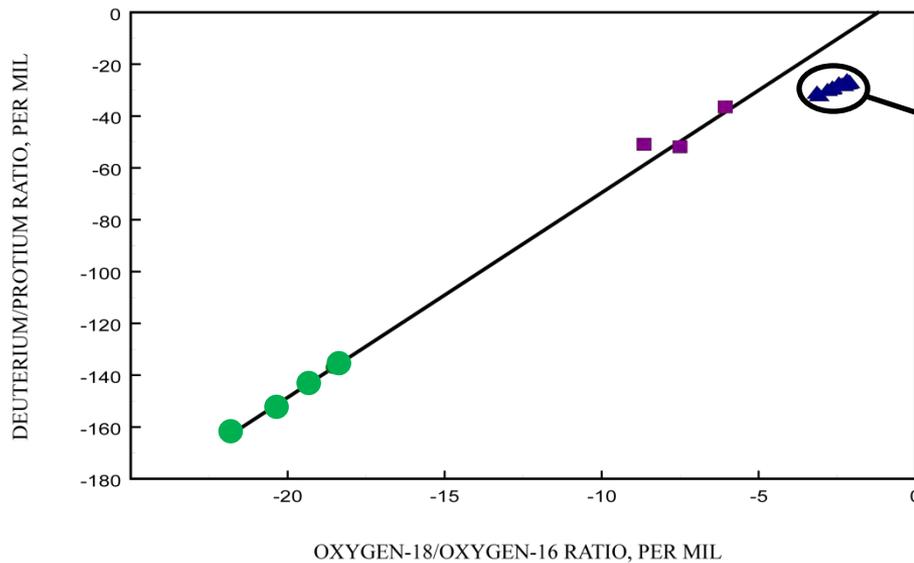
Use isotopic ratios similar to “DNA” fingerprinting
identify sources and mixtures of waters

Compare

“Light/Heavy” Hydrogen ratio vs “Light/Heavy” Oxygen ratio

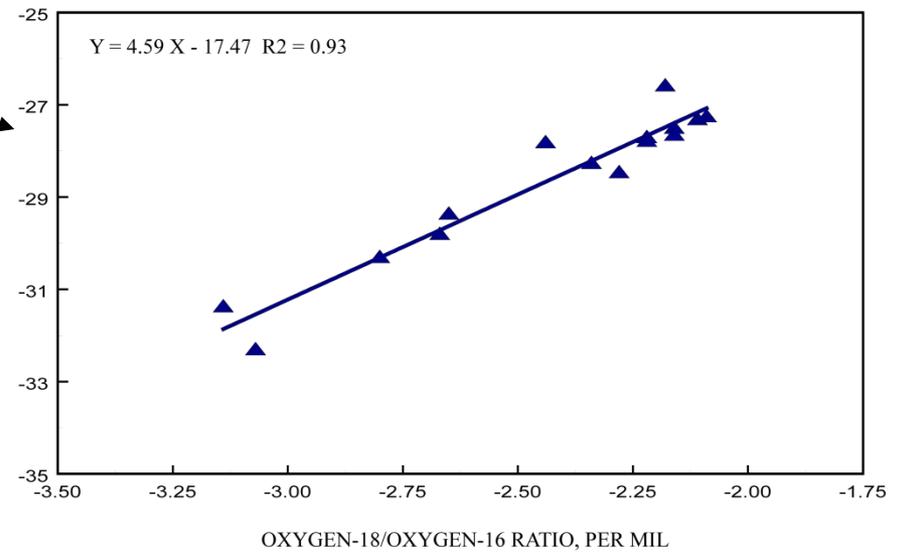
Stable Isotopes – White Bear Lake

Snow, Rain, and Lake Water



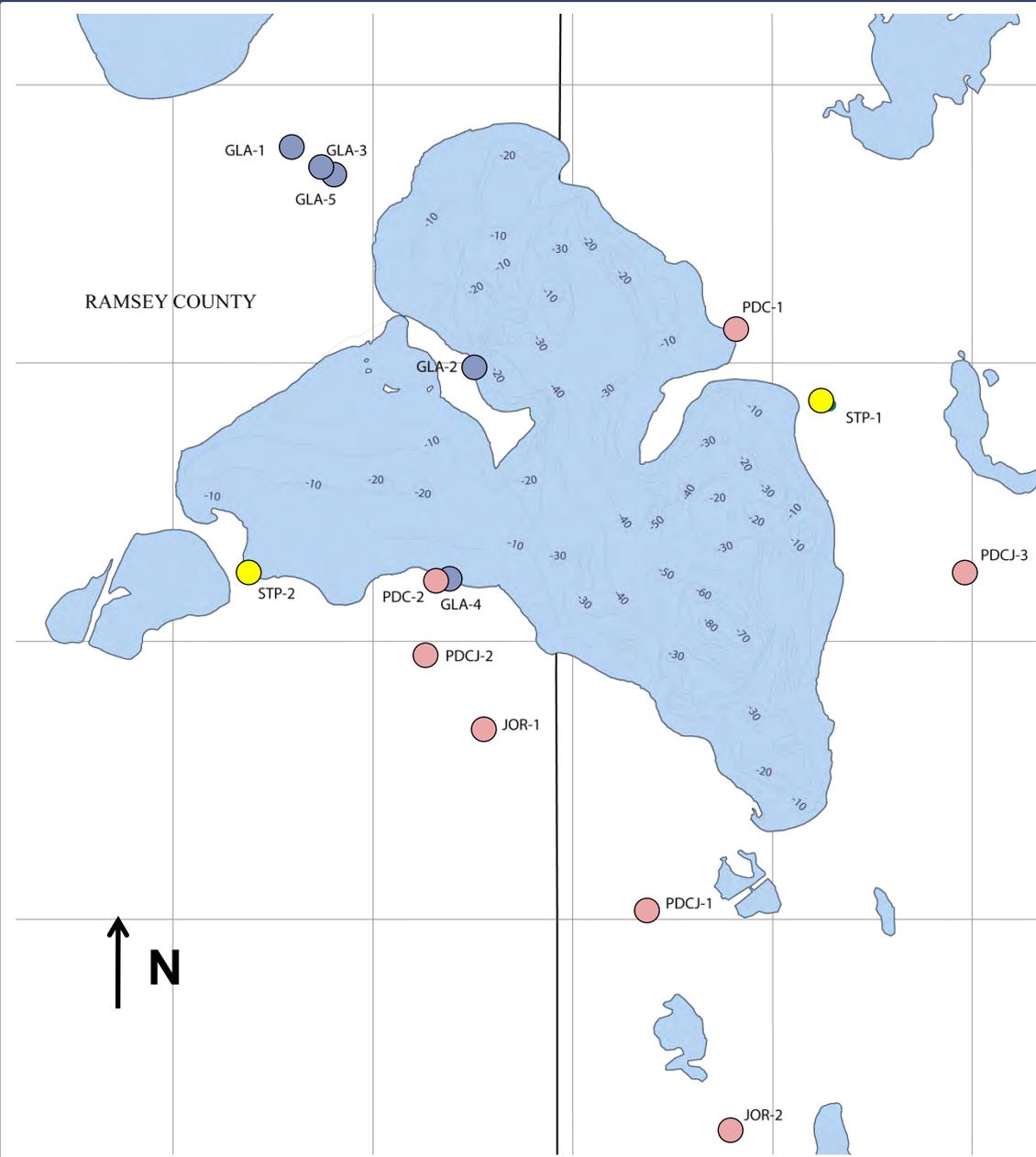
- EXPLANATION
- Snow samples
 - Bulk precipitation (rain) samples
 - ▲ White Bear Lake surface-water samples
 - Princeton Minnesota meteoric waterline (Landon and others, 1999)

Lake Water



- EXPLANATION
- White Bear Lake Evaporation Line
 - ▲ White Bear Lake surface-water samples

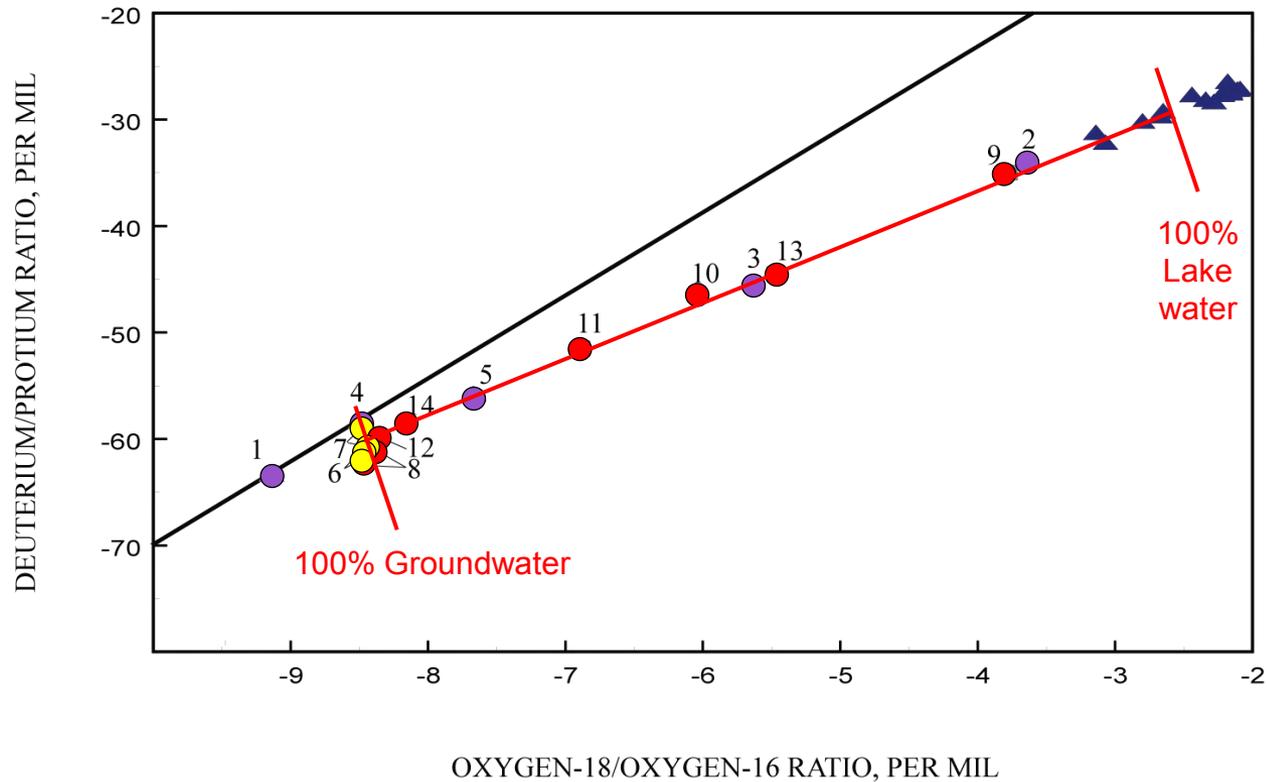
Water Quality 2011 - Wells



Aquifers

- - Glacial (GLA)
- - St. Peter Sandstone (STP)
- - Prairie du Chien Group / Jordan Sandstone (PDCJ)

Groundwater sampled from wells and surface waters sampled from White Bear Lake



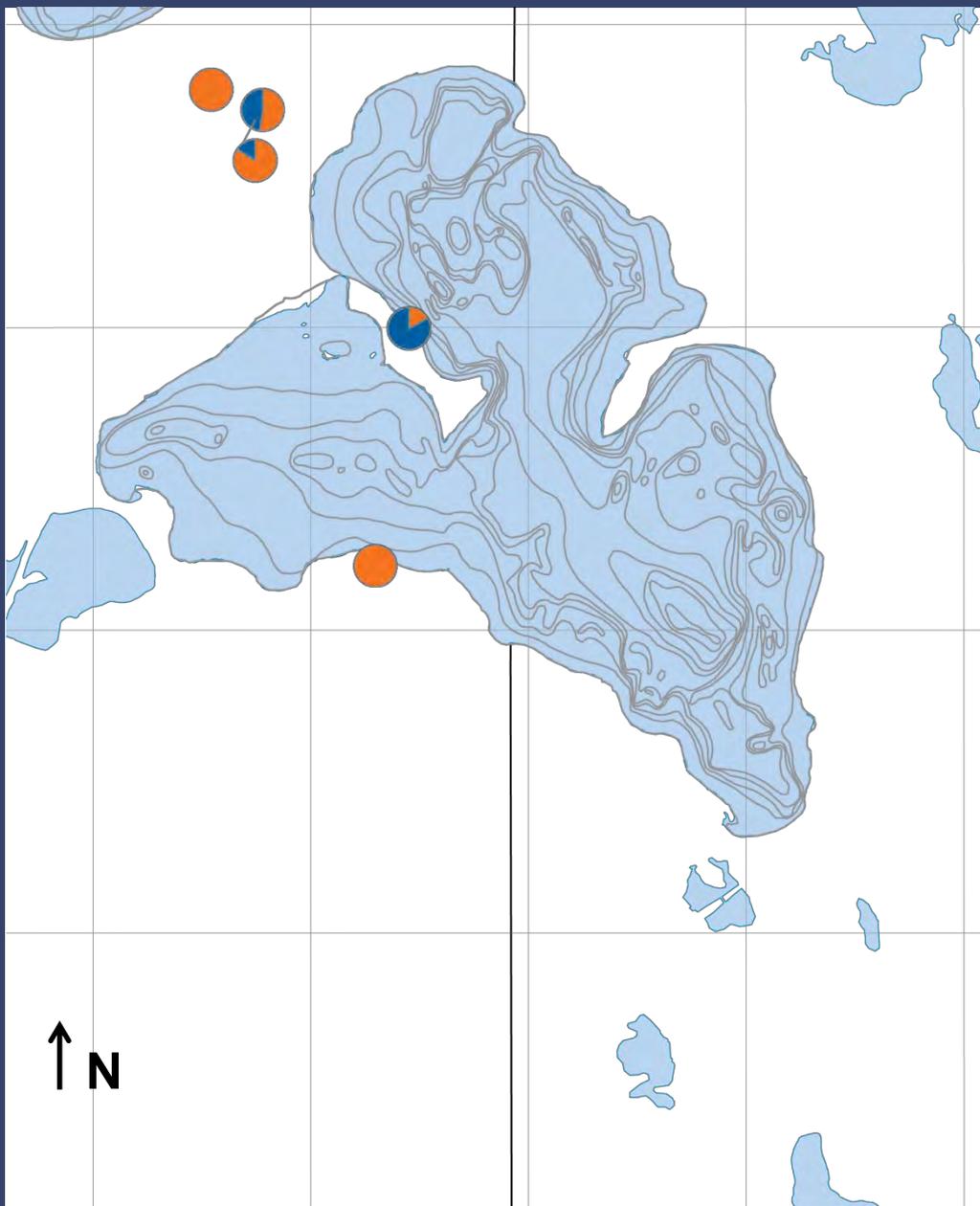
EXPLANATION

- Groundwater Samples
- Glacial Aquifers
- St. Peter Sandstone Aquifer
- Prairie du Chien/Jordan Aquifer
- ▲ White Bear Lake surface-water samples
- Princeton Minnesota meteoric waterline (Landon and others, 1999)

Groundwater sample sites - Numbers are site identifiers (values in parentheses are number of samples collected from the well)

- | | |
|---------------|-----------------|
| 1 - GLA-1 (1) | 8 - PDC-1 (2) |
| 2 - GLA-2 (1) | 9 - PDC-2 (1) |
| 3 - GLA-3 (1) | 10 - PDCJ-1 (1) |
| 4 - GLA-4 (1) | 11 - PDCJ-2 (1) |
| 5 - GLA-5 (1) | 12 - PDCJ-3 (1) |
| 6 - STP-1 (2) | 13 - JOR-1 (1) |
| 7 - STP-2 (2) | 14 - JOR-2 (1) |

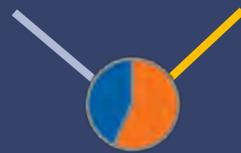
Results of Stable Isotope Model 2011 - Wells



Percentage of Contribution

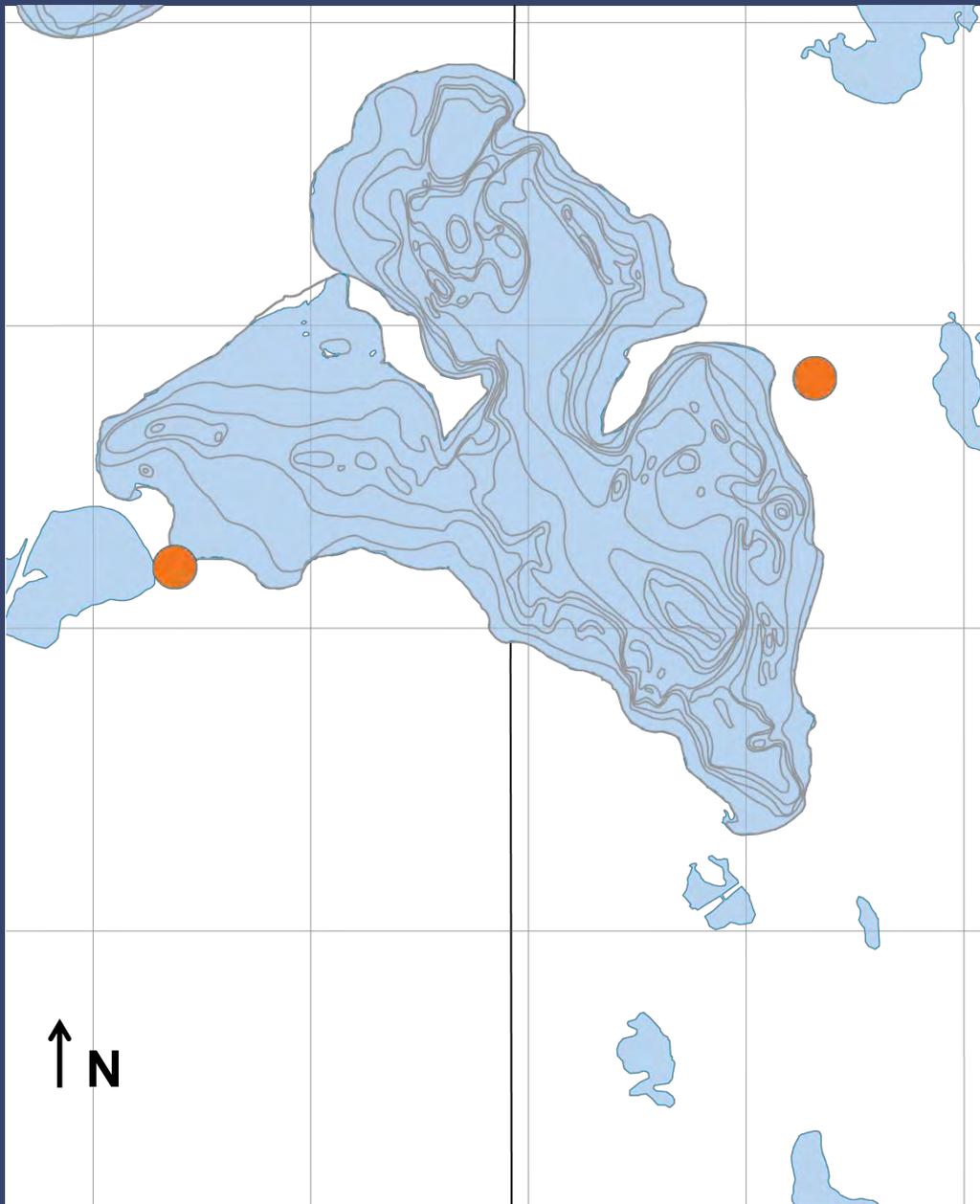
Lake water

Groundwater



Glacial

Results of Stable Isotope Model 2011 - Wells



Percentage of Contribution

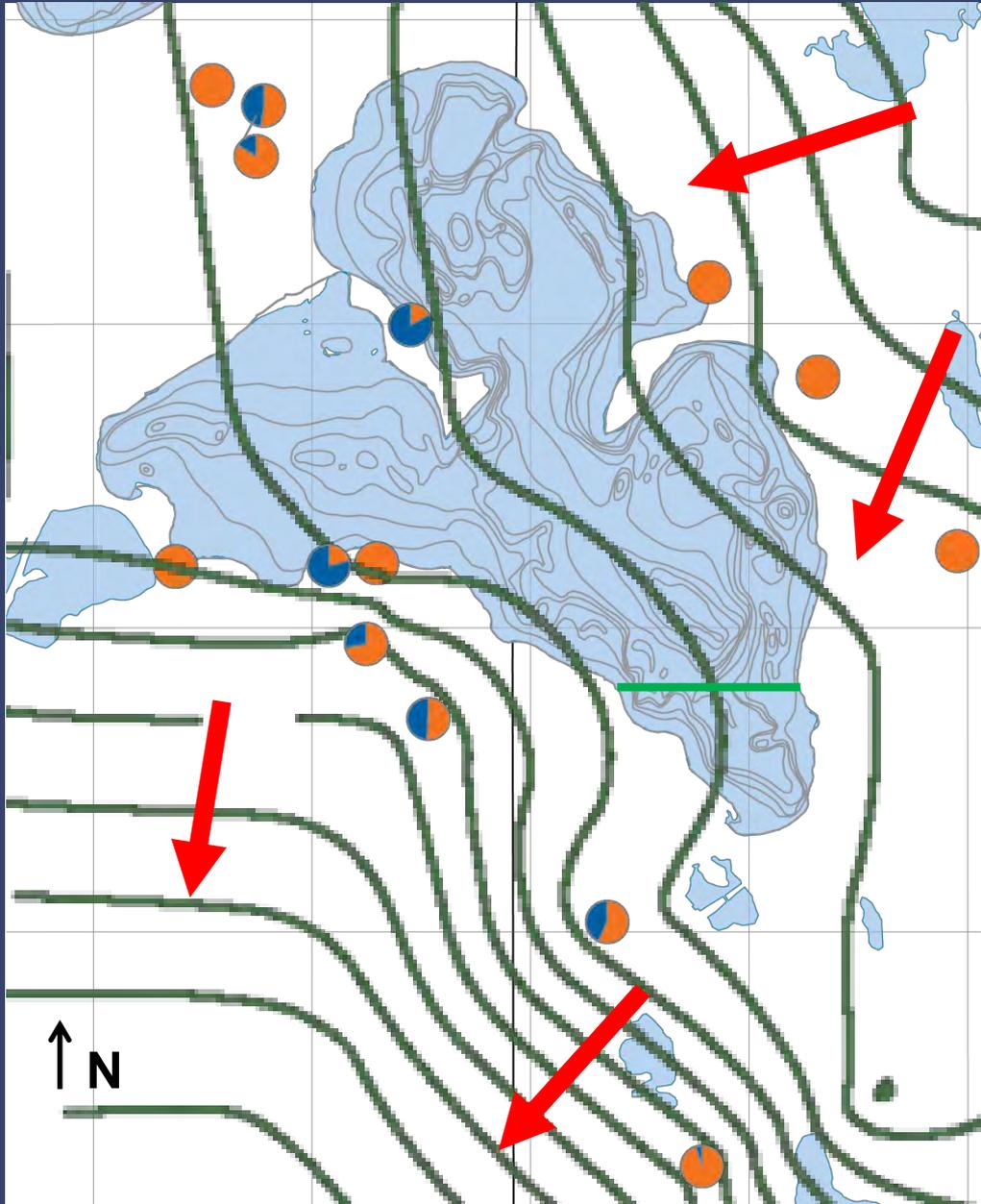
Lake water

Groundwater



St. Peter Sandstone

Results of Stable Isotope Model 2011 - Wells



Percentage of Contribution

Lake water

Groundwater



Glacial

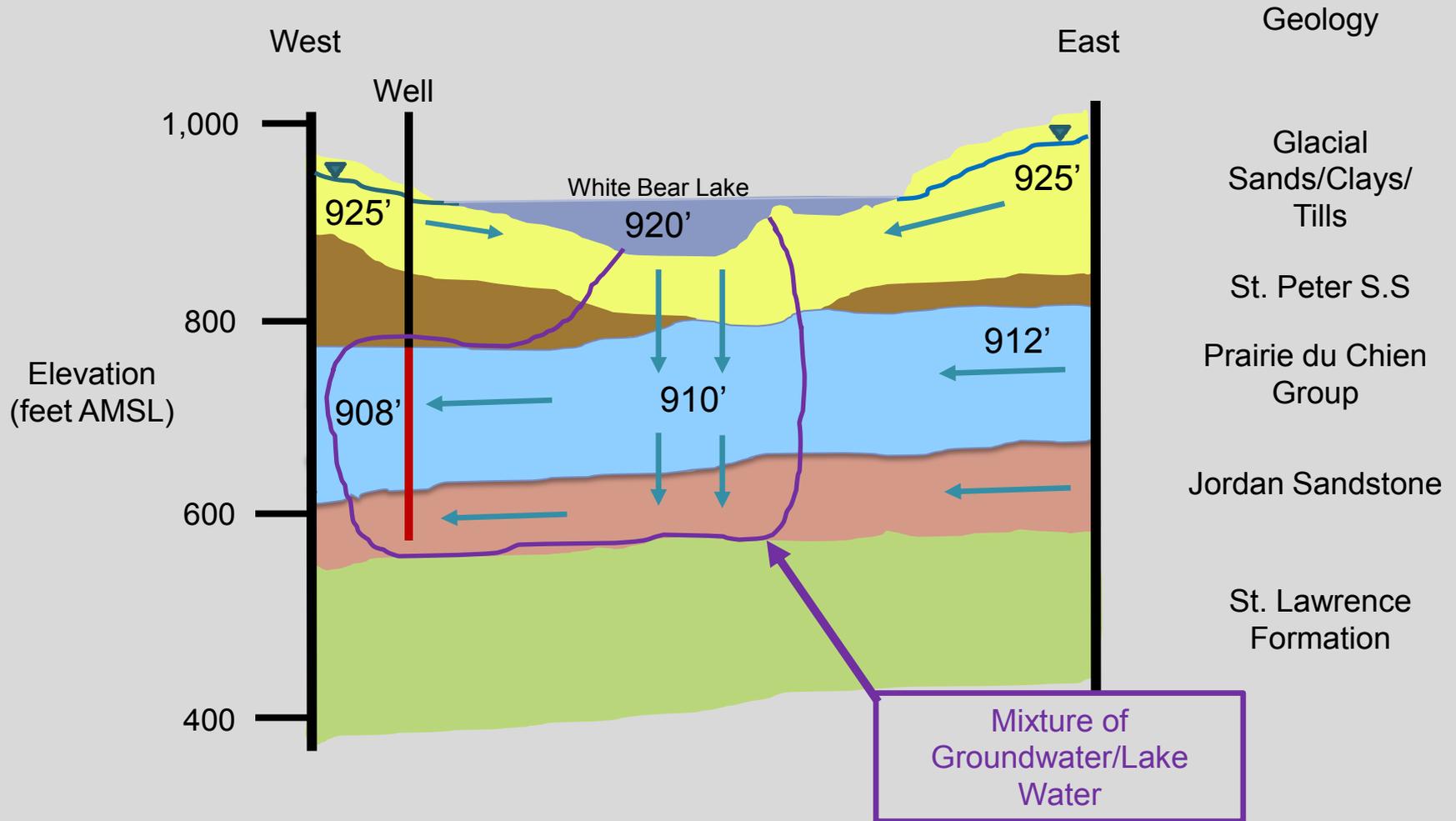
St. Peter Sandstone

Prairie du Chien Group /
Jordan Sandstone (PDCJ)

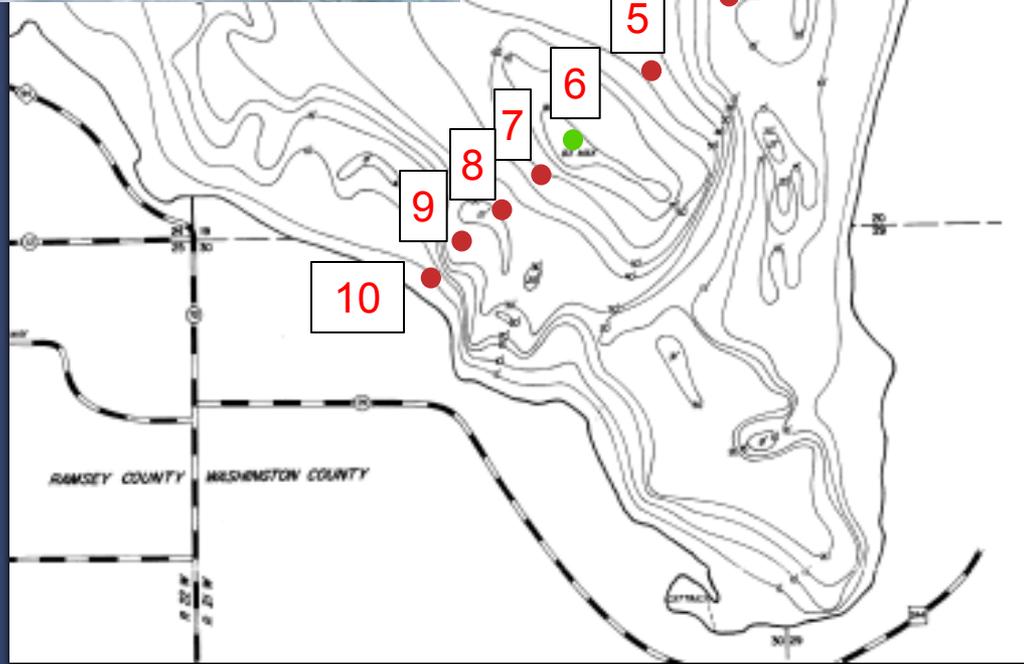
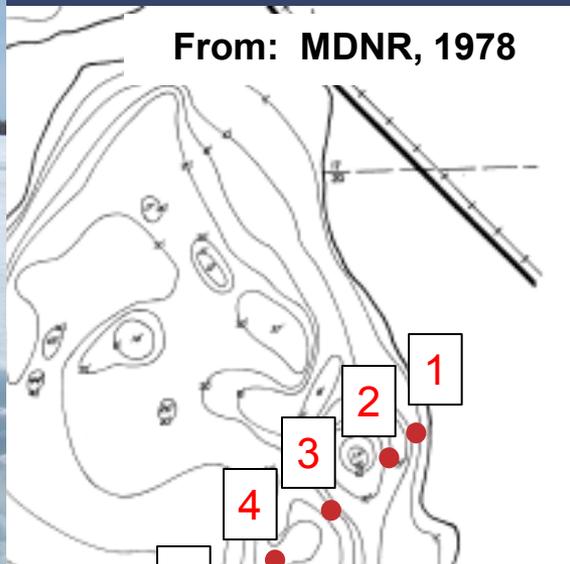
General Groundwater
Flow Direction – PDCJ
August 2011



General Hydrogeology – White Bear Lake



(modified from Mossler and Bloomgren, 1990)



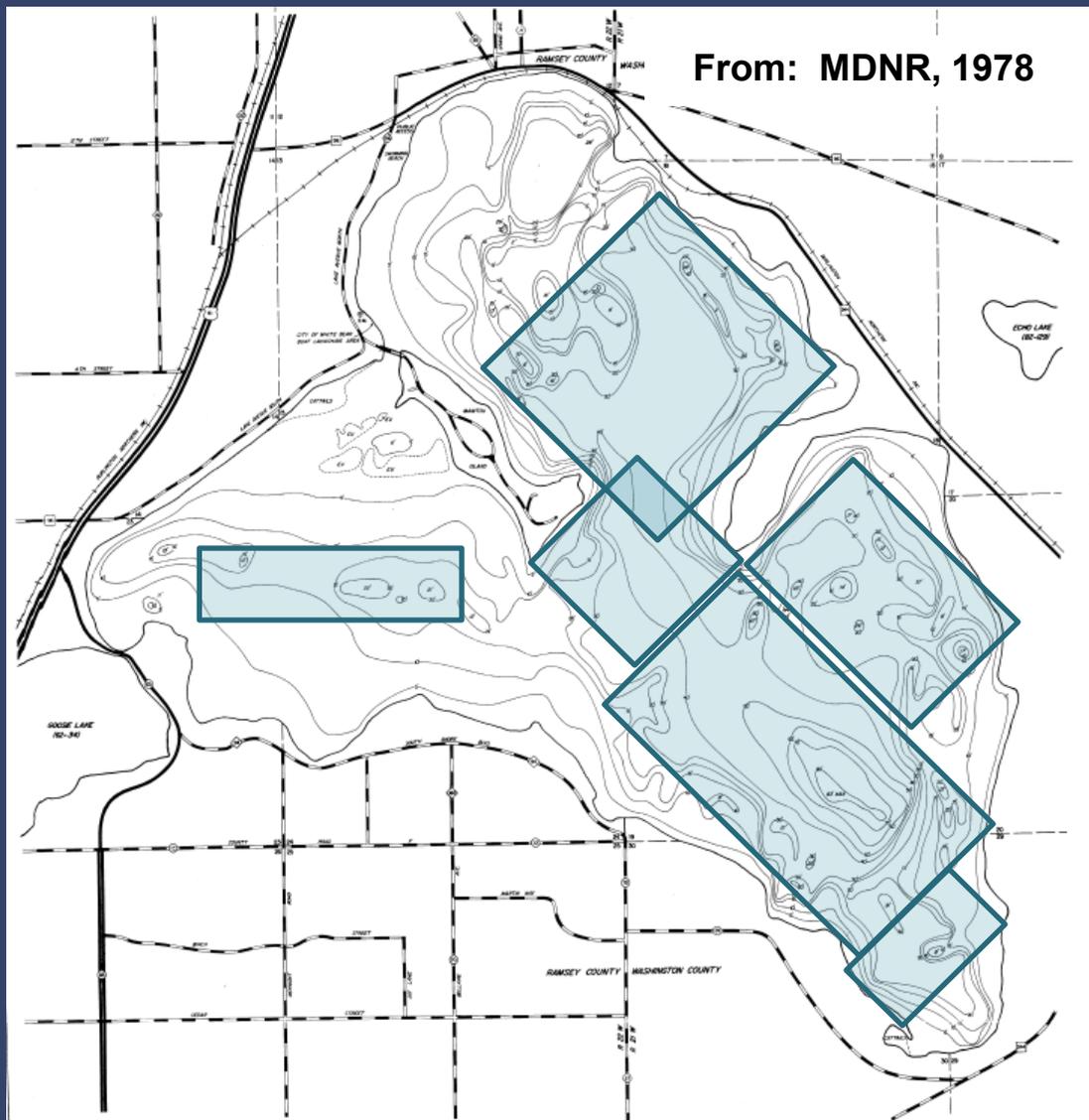
Lake Sediment Coring

- Probe Measurement
- Core/Probe Measurement

<u>Site</u>	<u>Water Depth (ft)</u>	<u>Organic Sediment Thickness (ft)</u>
1	10.66	0.20
2	10.30	4.20
3	17.98	4.30
4	11.81	1.51
5	39.70	6.76
6	75.62	7.02
7	44.29	11.38
8	32.48	10.66
9	30.18	14.86
10	7.48	2.89

Water-quality survey - Ecomapper

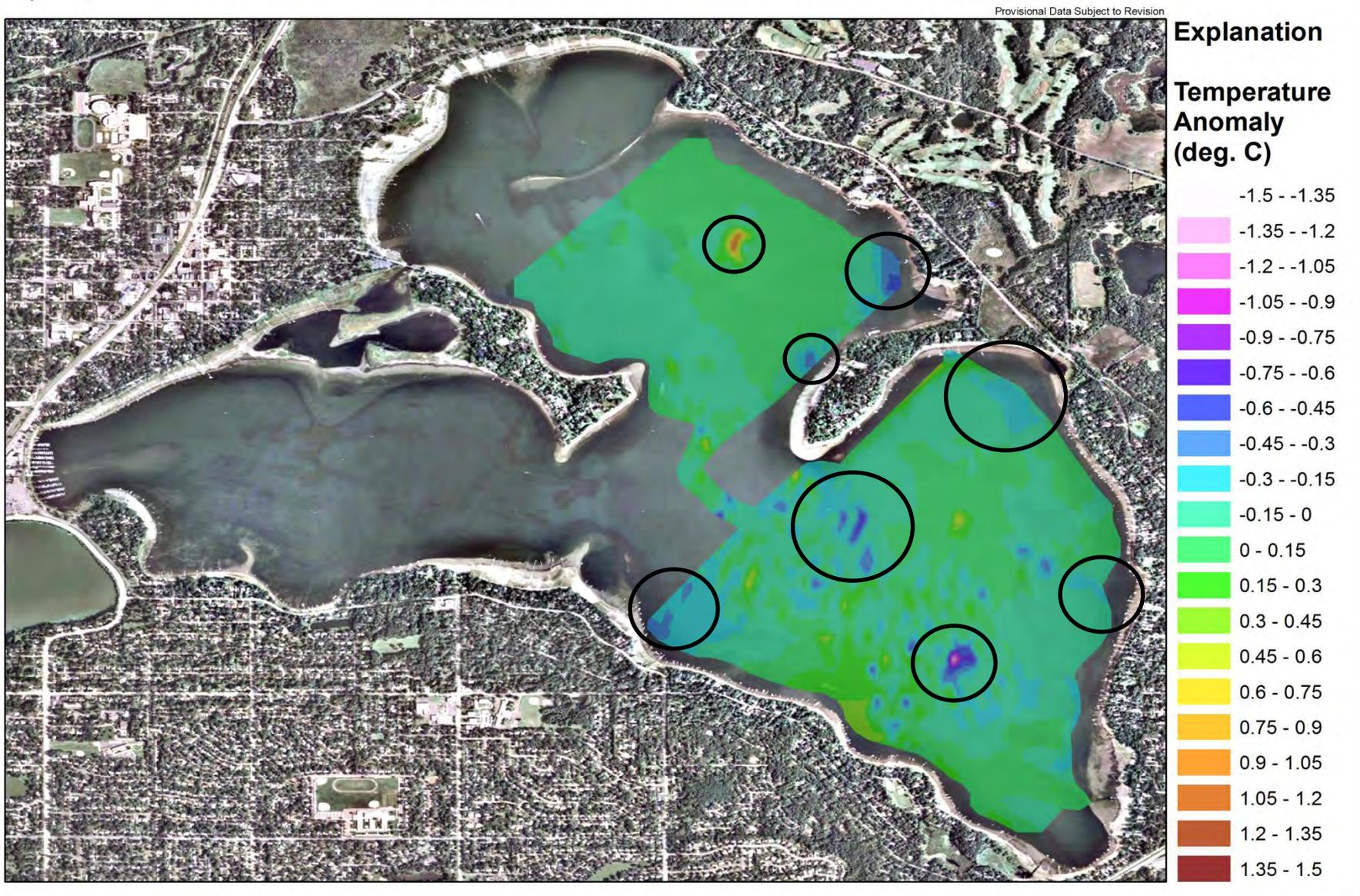
July 11-14, 2011 White Bear Lake



Water temperature
Dissolved Oxygen
Specific Conductance
Turbidity
pH
Blue-green Algae
Chlorophyll



Ecomapper – Water Temperature Survey



Conclusions on White Bear Lake

Low lake levels can be explained by higher regional pumping and lower precipitation

Groundwater flows into the lake from glacial sediments

Lake water flows out and reaches wells in Prairie du Chien/Jordan and glacial aquifers

USGS Potential Activities - Address the Low Water Levels

work with State (MDNR, MPCA, MDH, Met Council), counties, and cities to address:

How much water can we pump from the Prairie du Chien with

- a) minimal impact on lake levels?
- b) minimal lake water entering the wells?

Which wells are impacting the lake levels?

Groundwater level monitoring

Groundwater-flow models

Water quality (stable isotopes)

Any Questions?

