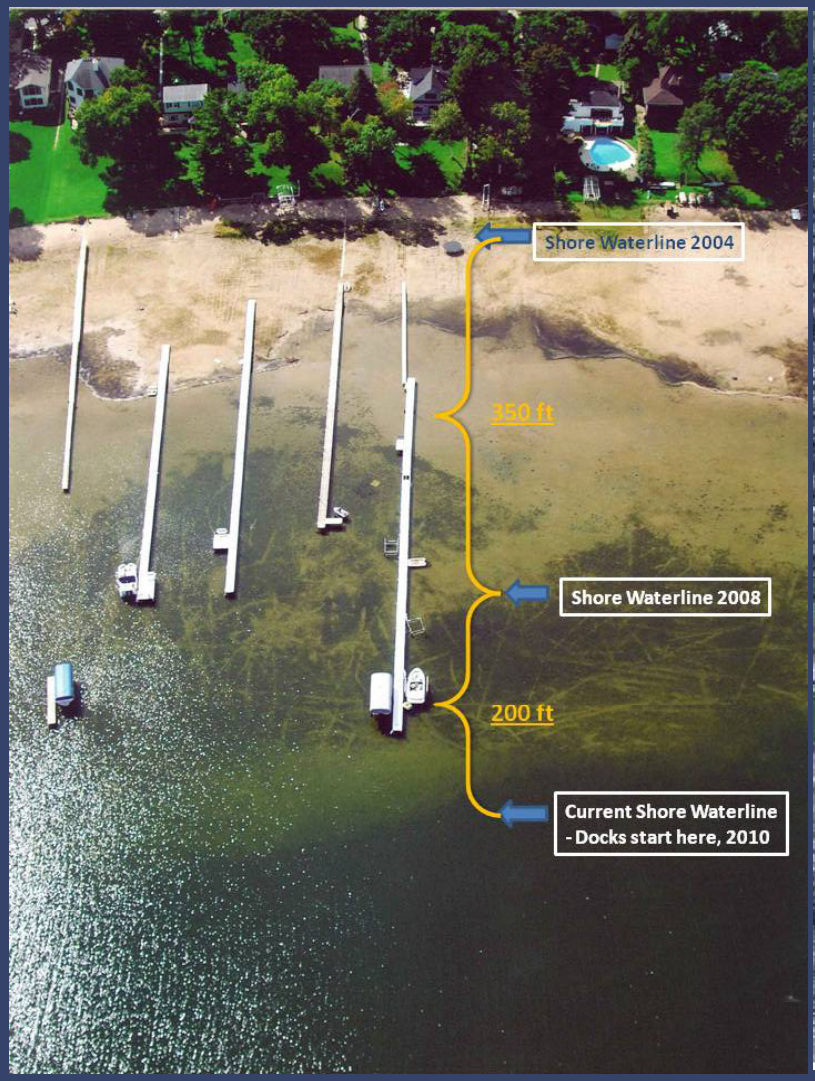
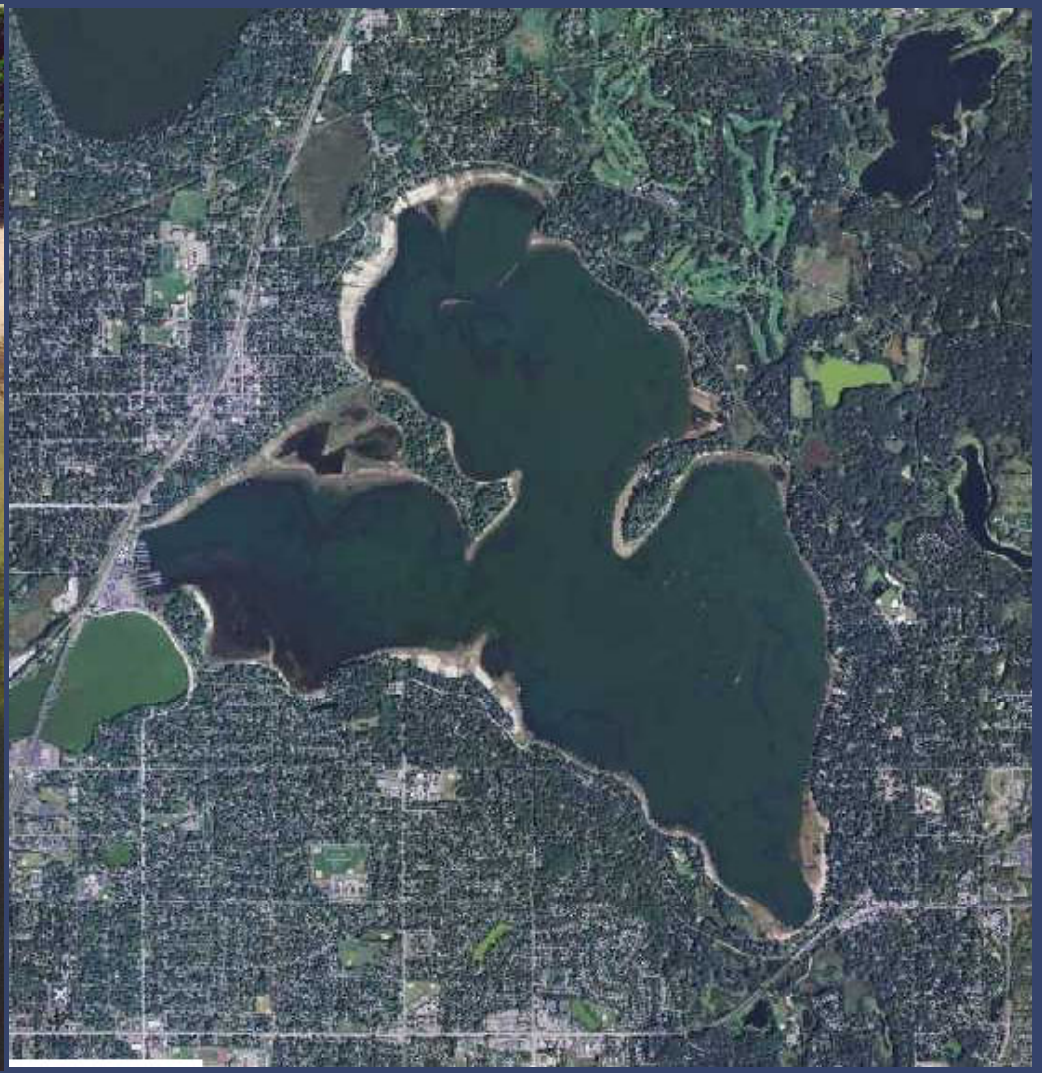
White Bear Lake Groundwater and Surface-water Interaction Study

Perry Jones, Jared Trost, and Don Rosenberry, U.S. Geological Survey





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

Thank You, Local Residents!

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

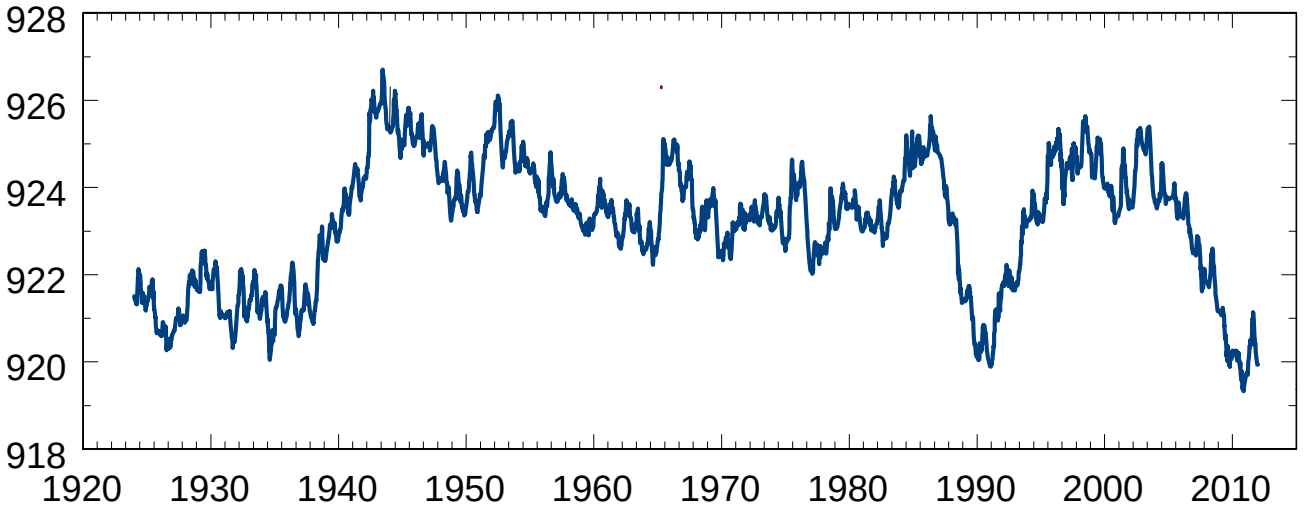
Watershed Organizations

Rice Creek Watershed District

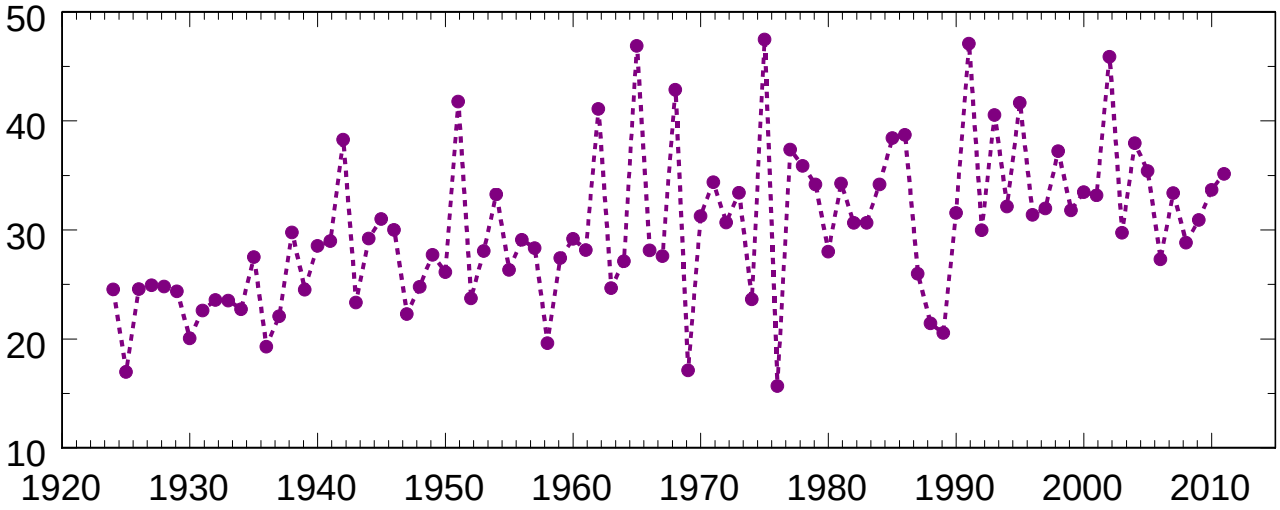
Vadnais Lakes Area Water Management Organization

White Bear Lake Water Elevation and Precipitation
1924 - 2011

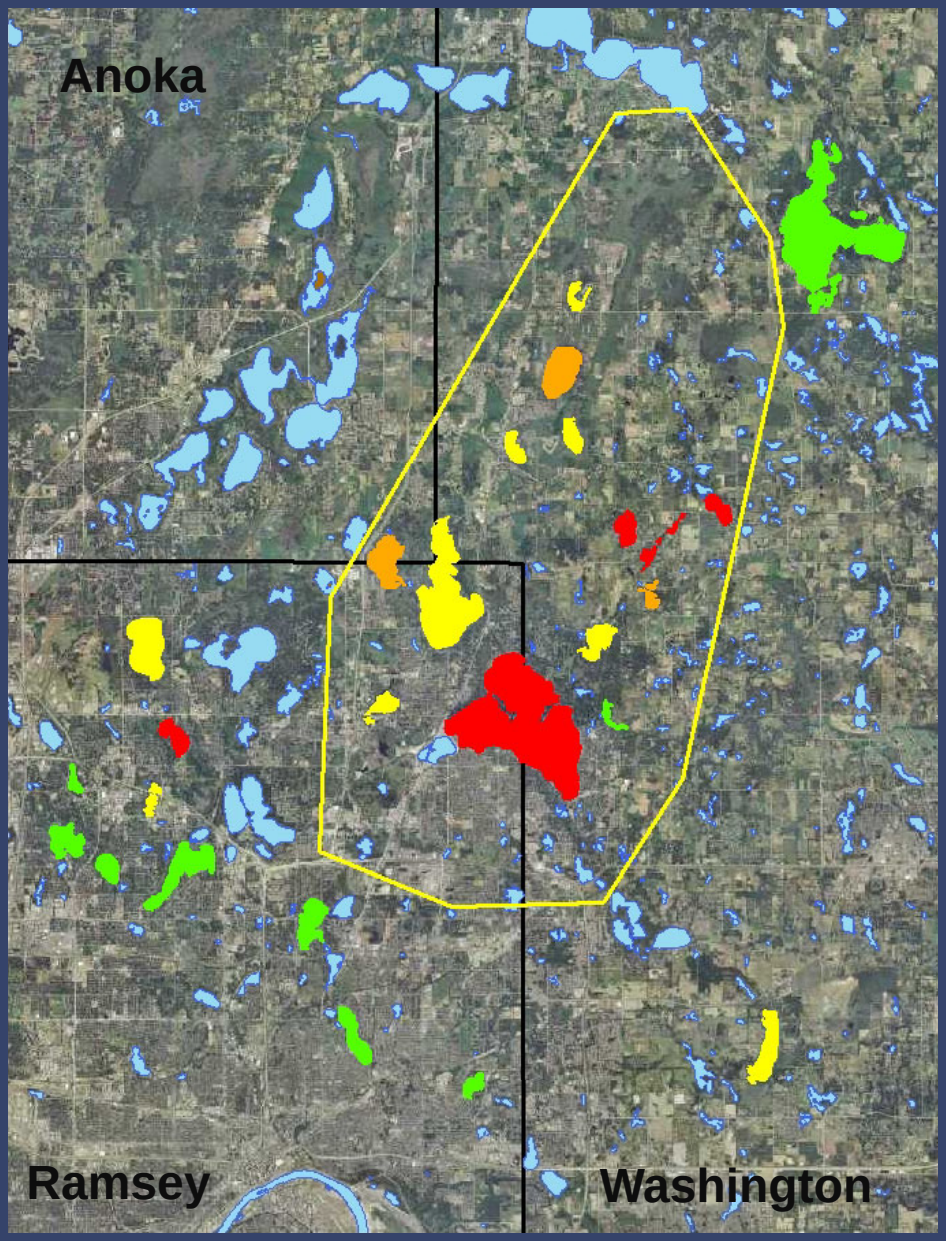
Water Elevation (ft AMSL)



Annual Precipitation (in)

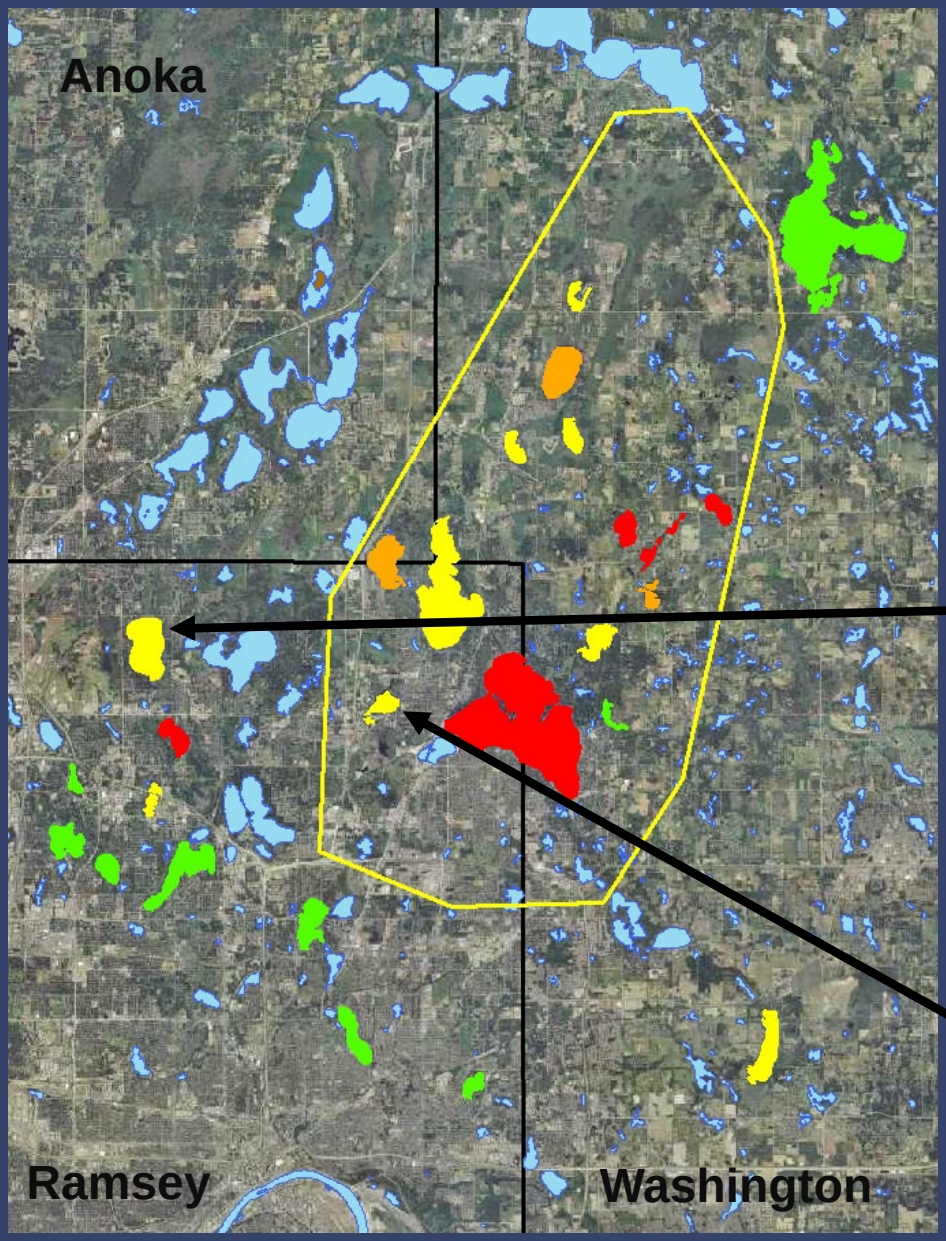


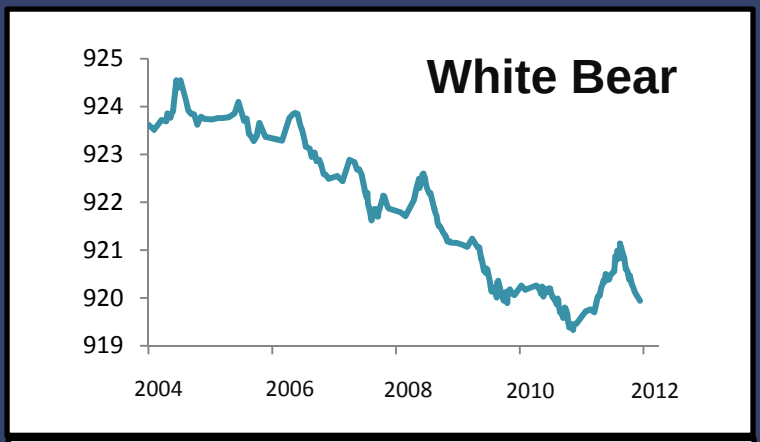
Lakes with Lower Water Levels – 2004-2011

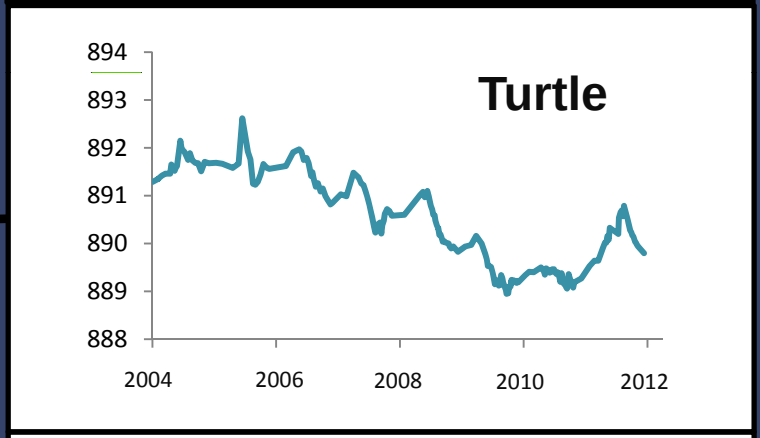


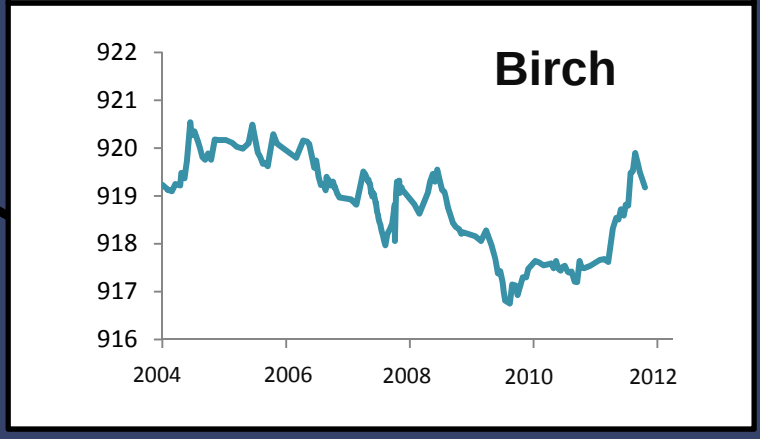
- Little change
- Minor decrease (1 foot or less)
- Moderate decrease (2-3 feet)
- Substantial decrease (4 or more feet)

Lakes with Lower Water Levels – 2004-2011

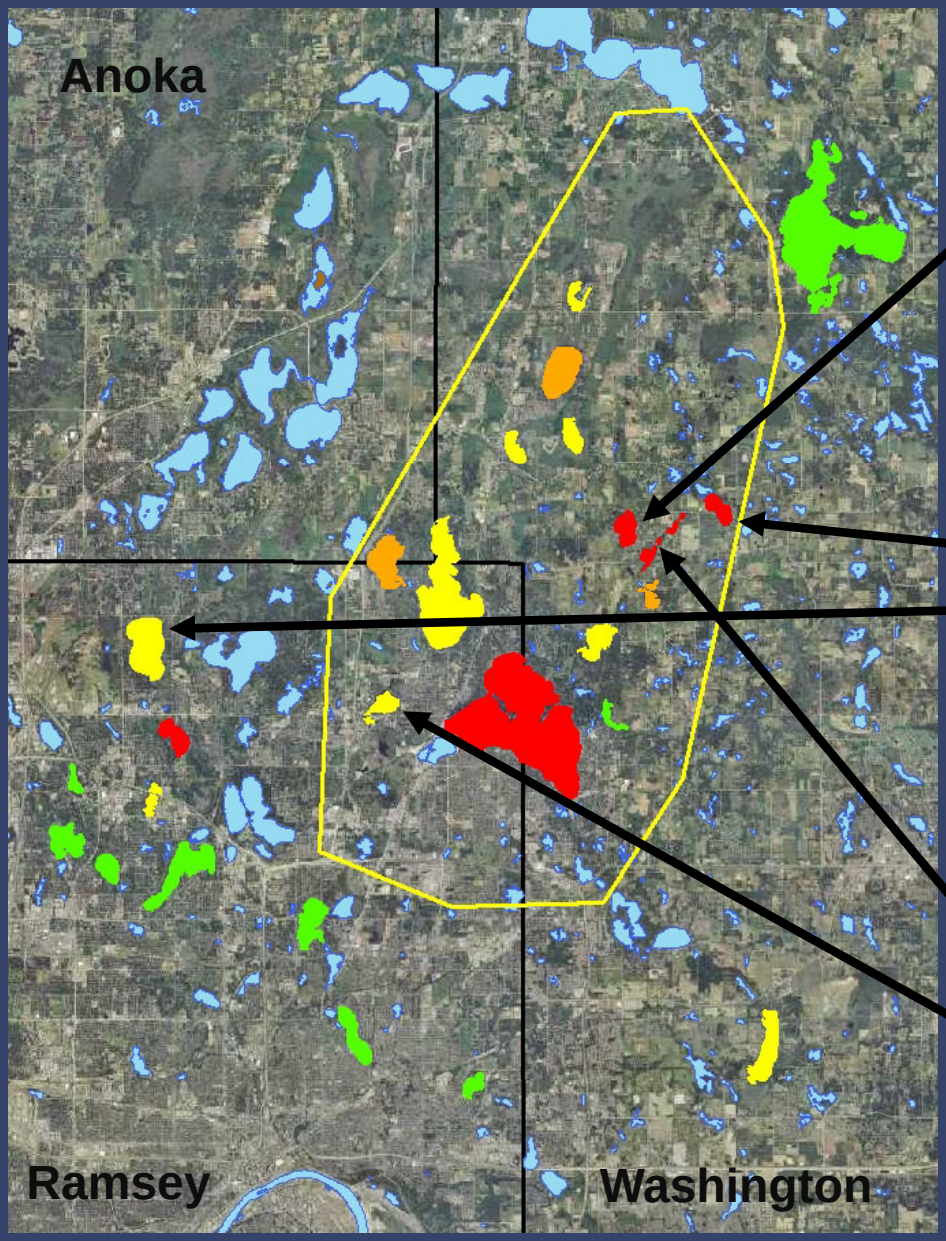


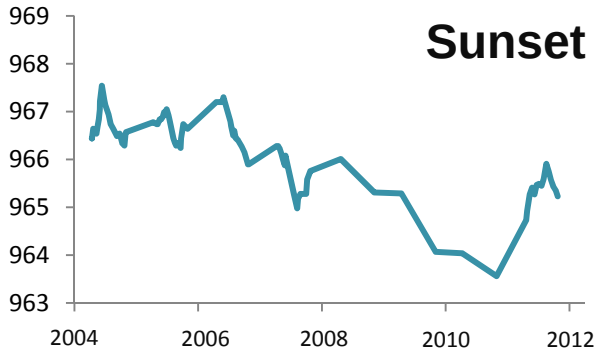


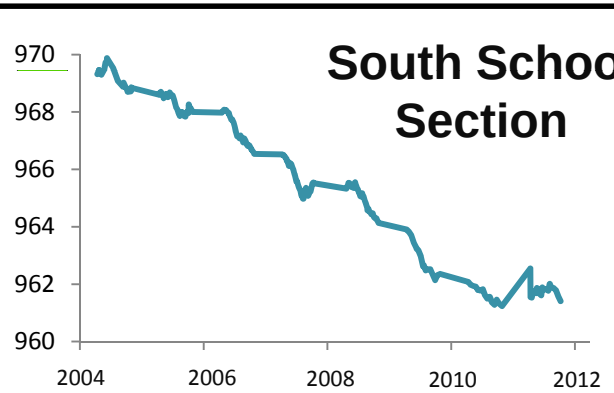


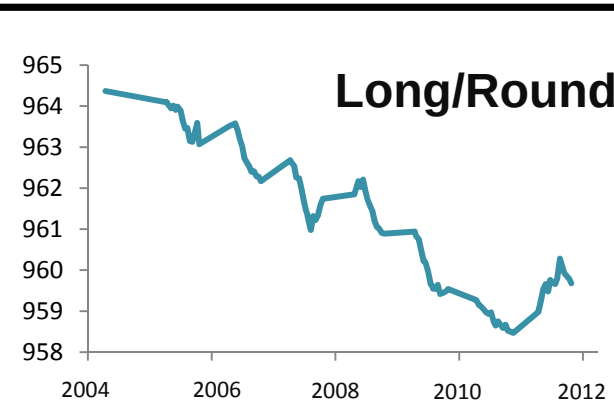


Lakes with Lower Water Levels – 2004-2011

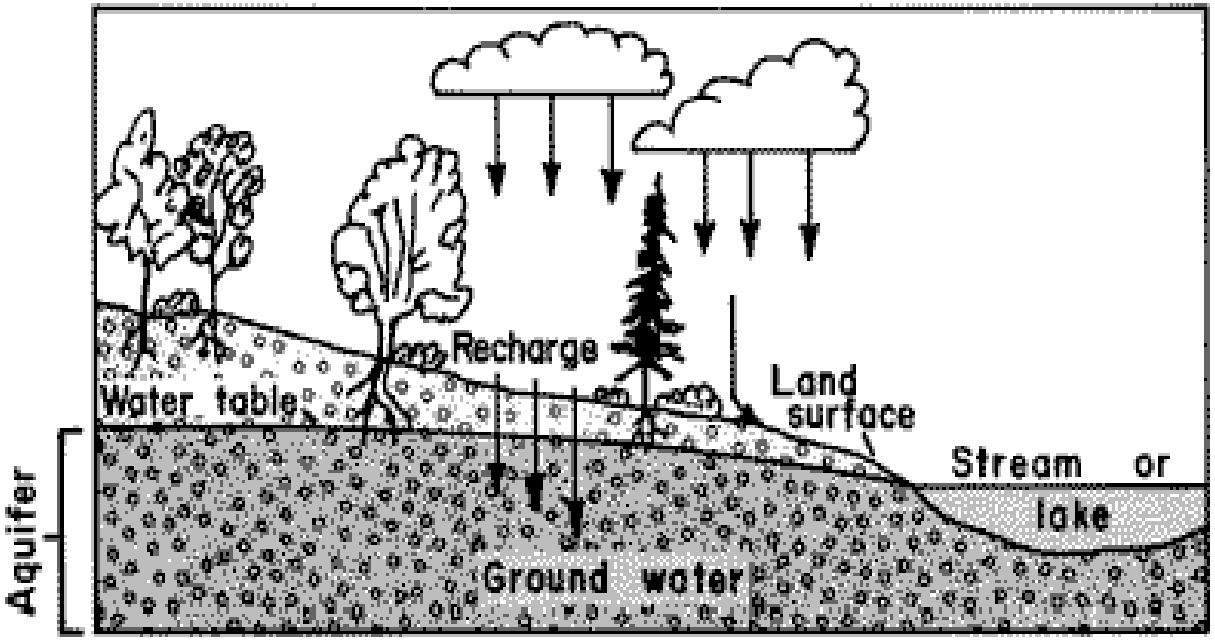








What is Groundwater?



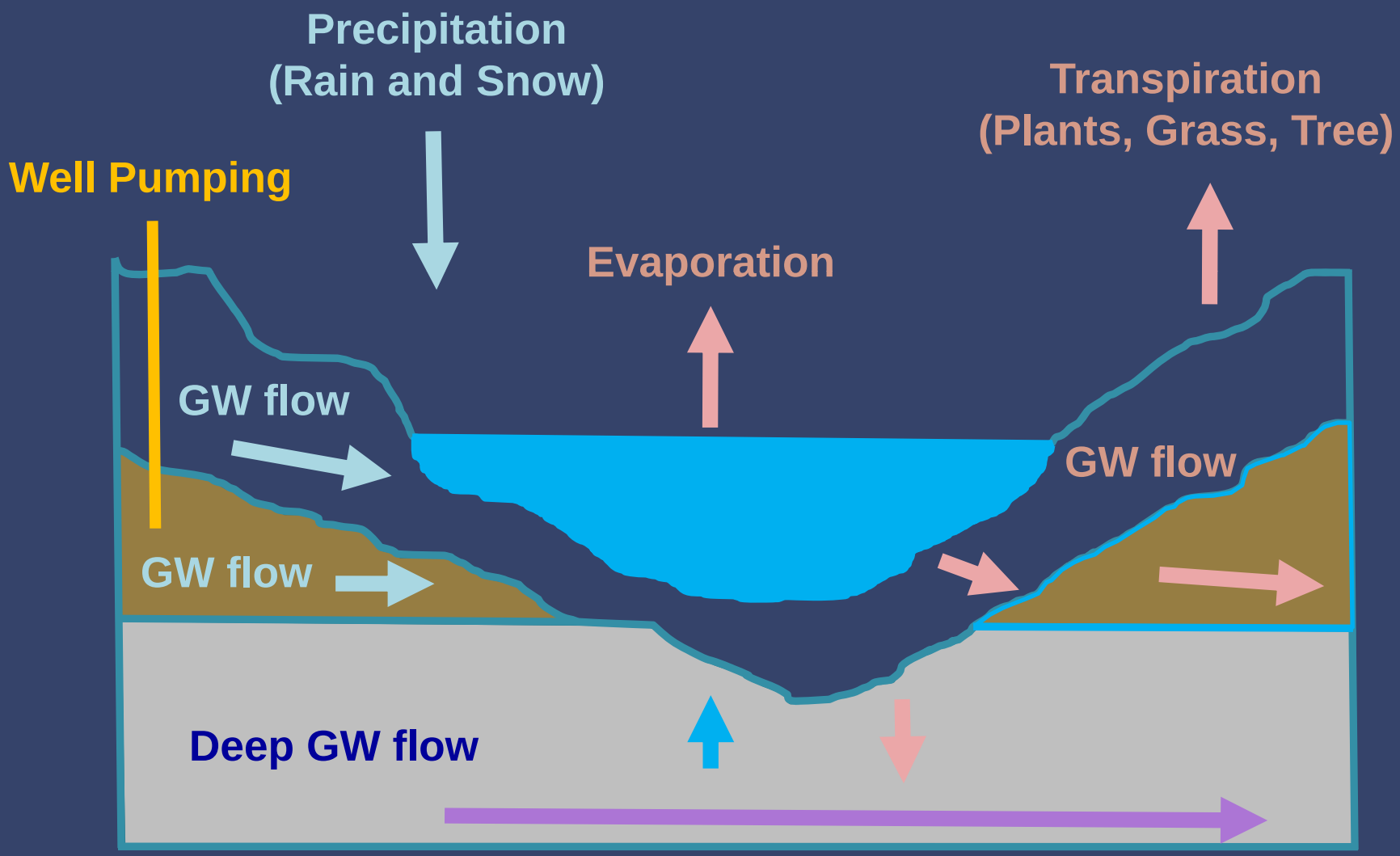
From U.S. Geological Survey Open-File Report 93-643

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

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

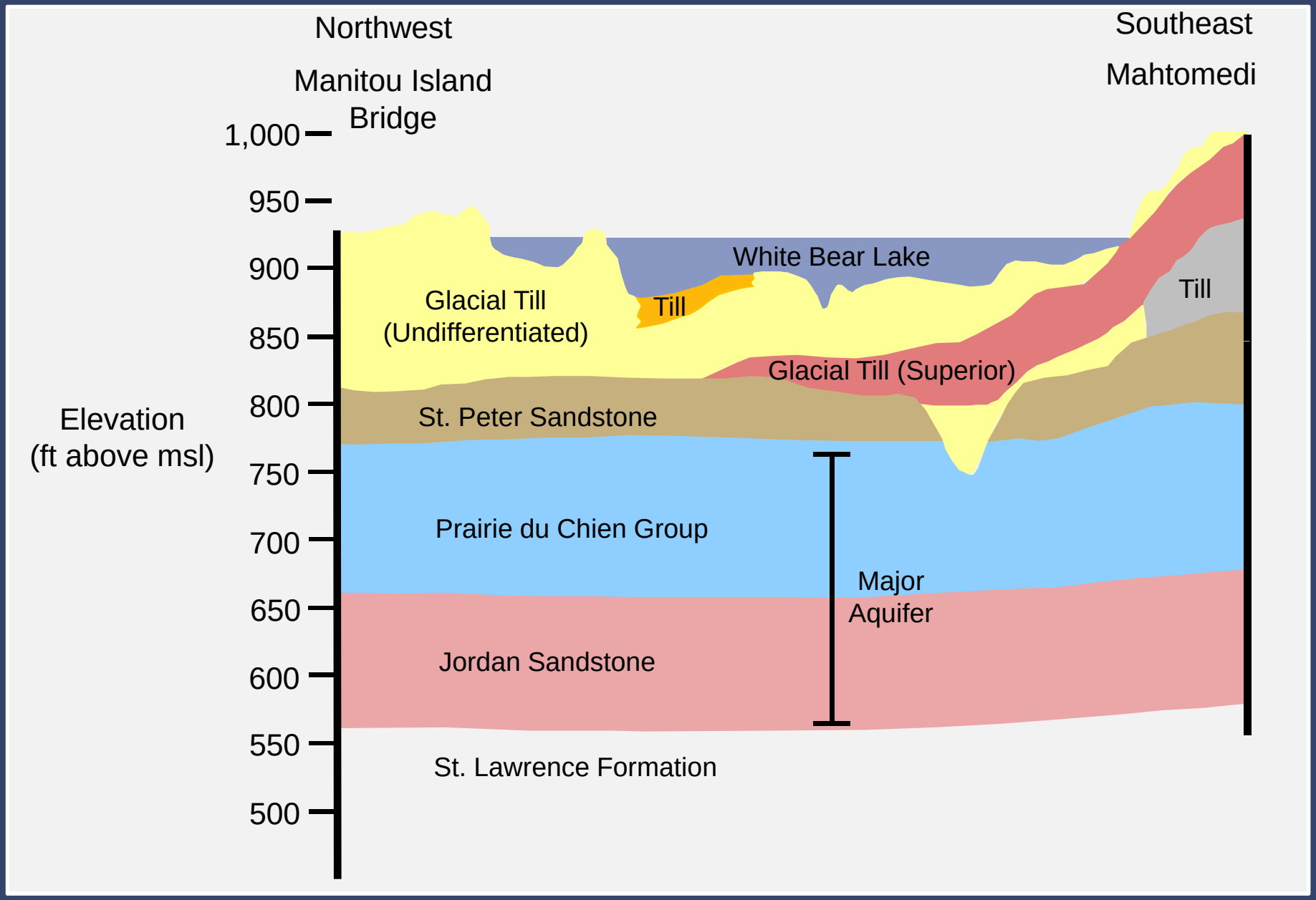
Aquifer - underground rocks and sediments containing groundwater for water supplies

General Cross-section Showing Water Balance for a Closed Basin Lake



Geologic cross-section – White Bear Lake

Geologic cross-section – White Bear Lake



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

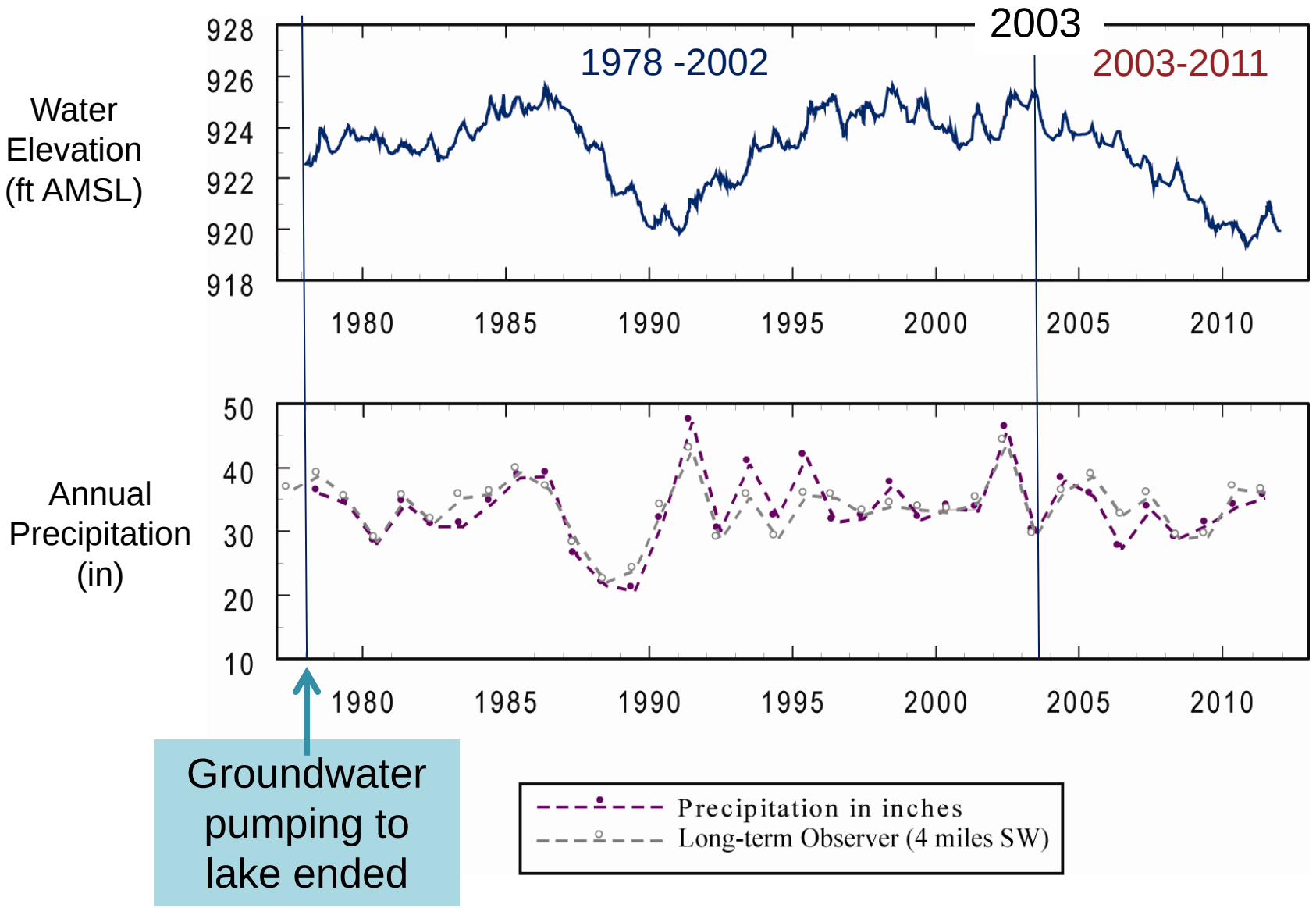
Low lake levels can be explained by higher regional pumping and lower precipitation

Groundwater flows into the lake from glacial sediments

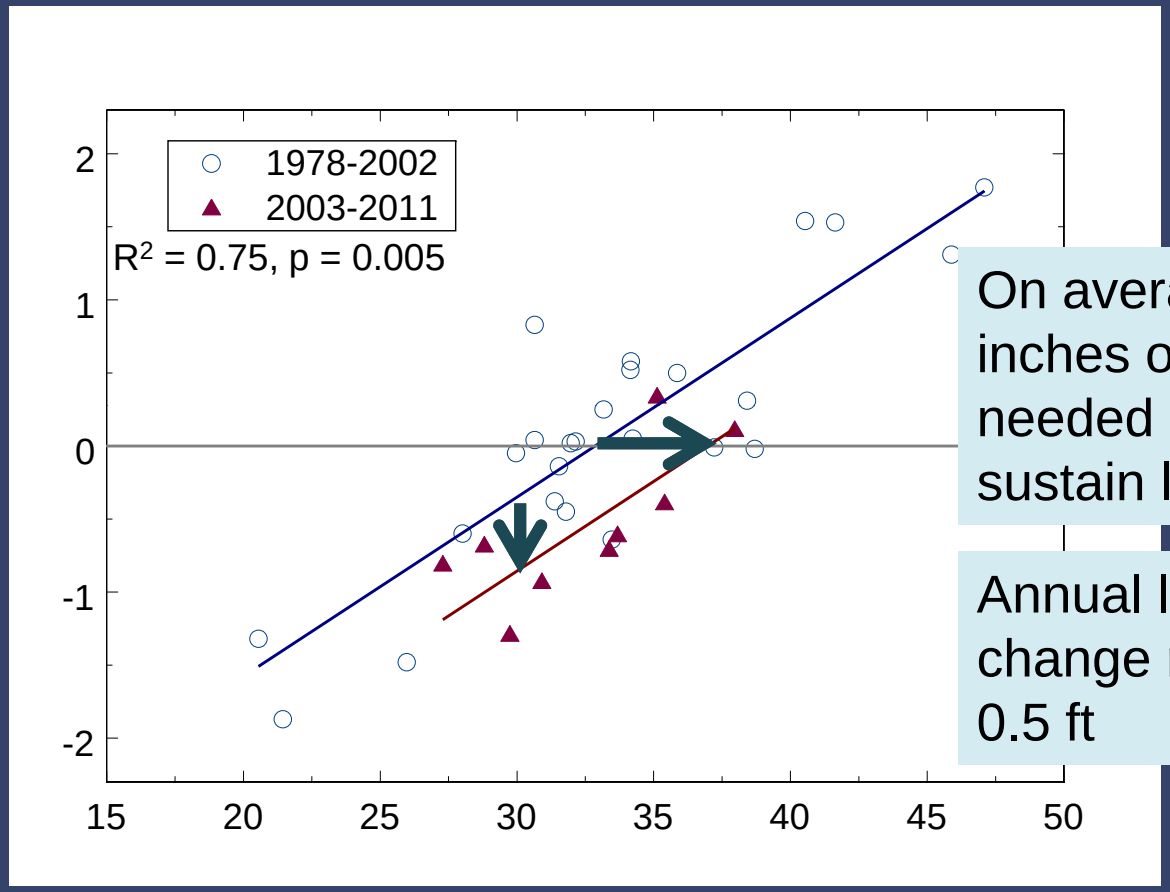
Lake water flows out and reaches wells in Prairie du Chien/Jordan and glacial aquifers

USGS

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



White Bear Lake Annual Lake Level Change versus Precipitation



Annual Lake Level Change (feet)

Annual Precipitation (inches)

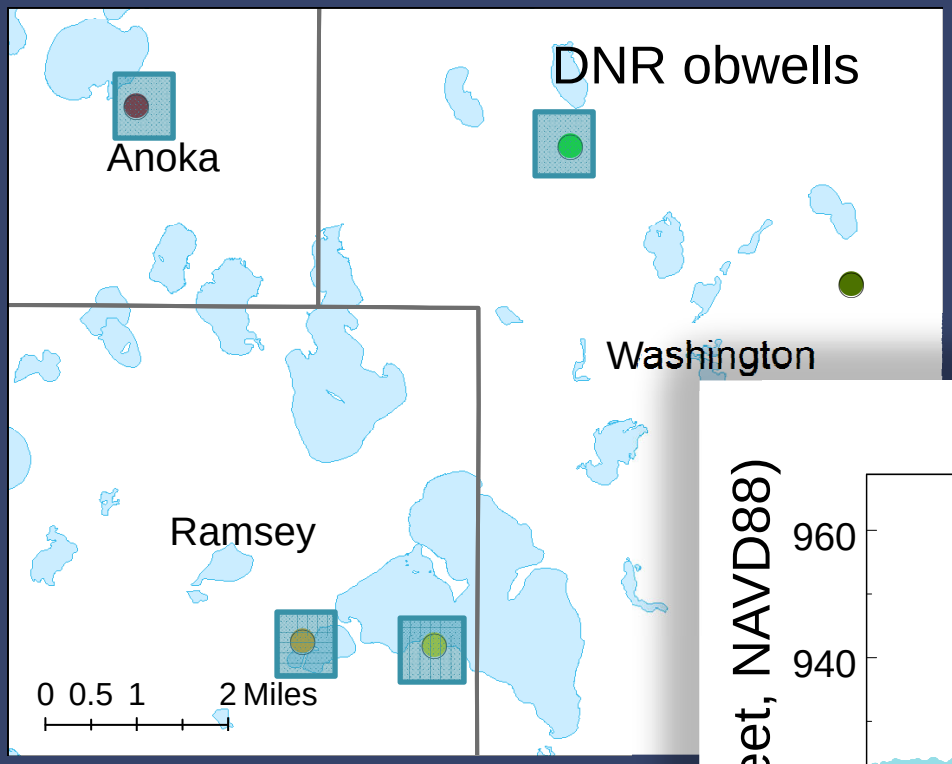
On average, 4 more inches of precip needed per year to sustain lake level

Annual lake level change reduced by 0.5 ft

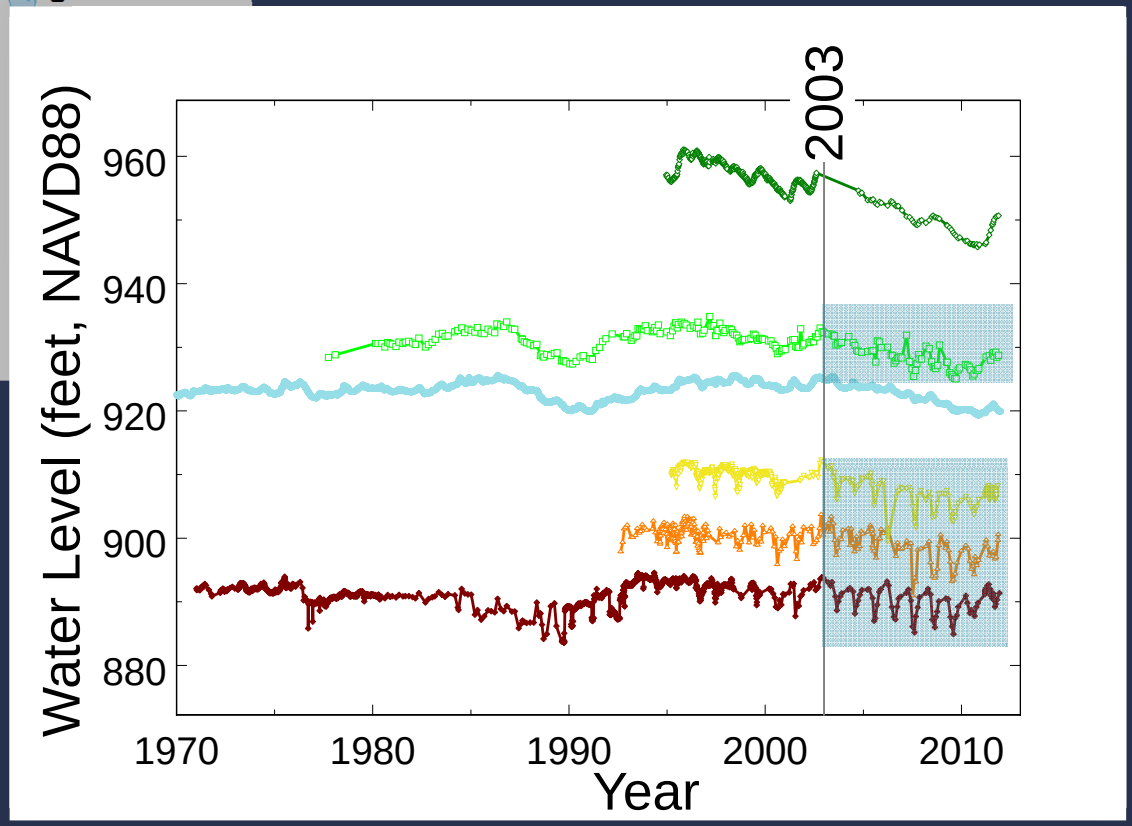
Significant in the summer (June, July, and August)

USGS

White Bear Lake and Prairie Du Chien Jordan Water Levels



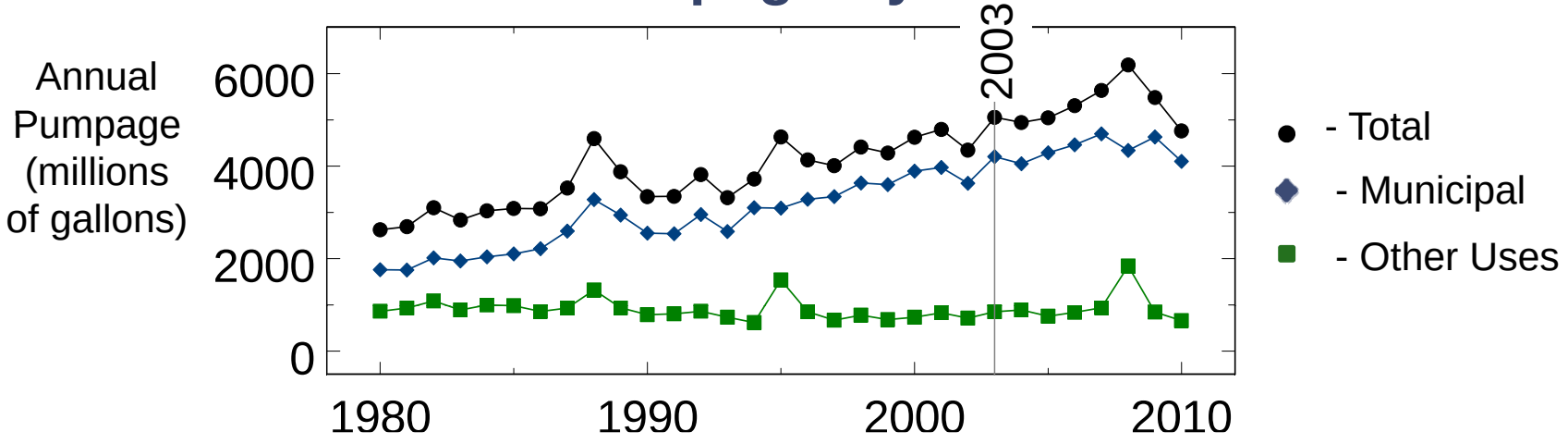
- Lake level follows PDCJ levels
- Increasing annual PDCJ variability



- 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

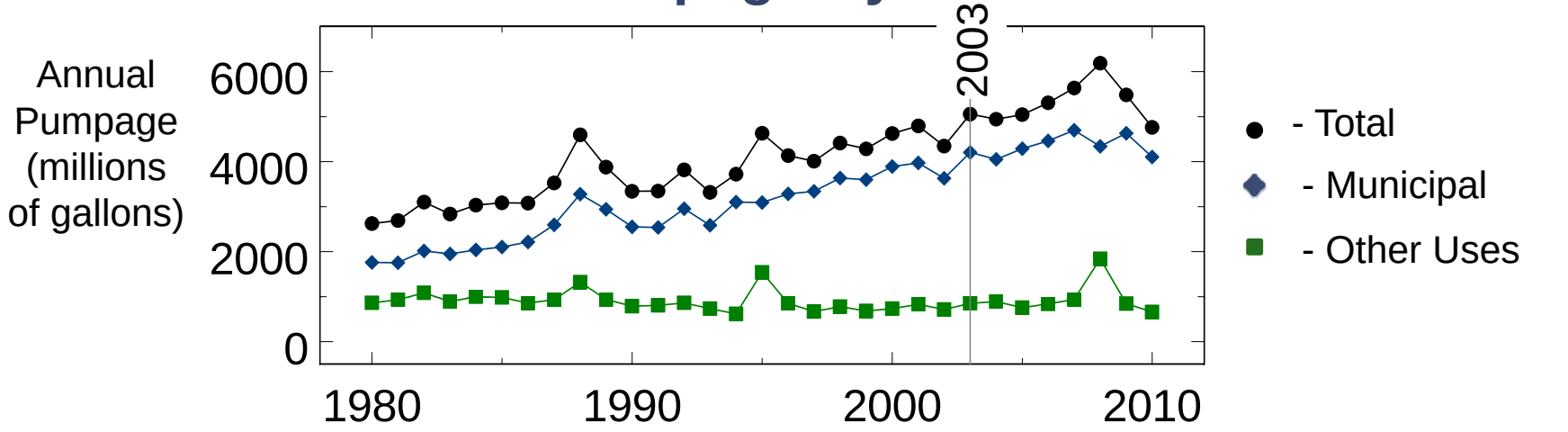


Municipalities included:

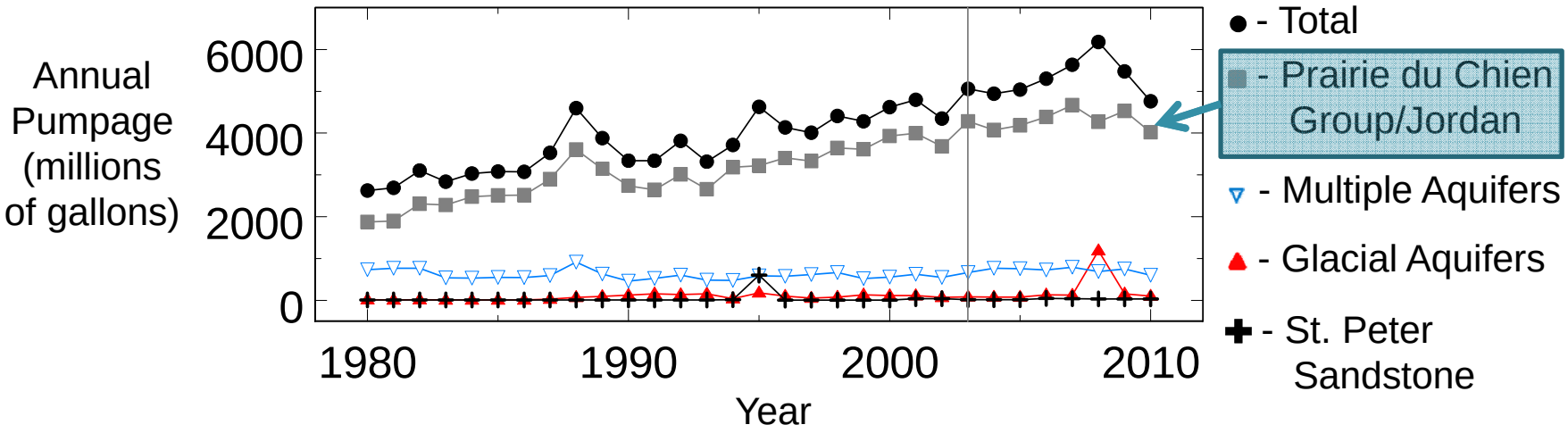
- Centerville
- Hugo
- Lino Lakes
- Mahtomedi
- North St. Paul
- Vadnais Heights
- White Bear Lake
- White Bear Township

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

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

Pumping explains more of the recent decline.

USGS

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

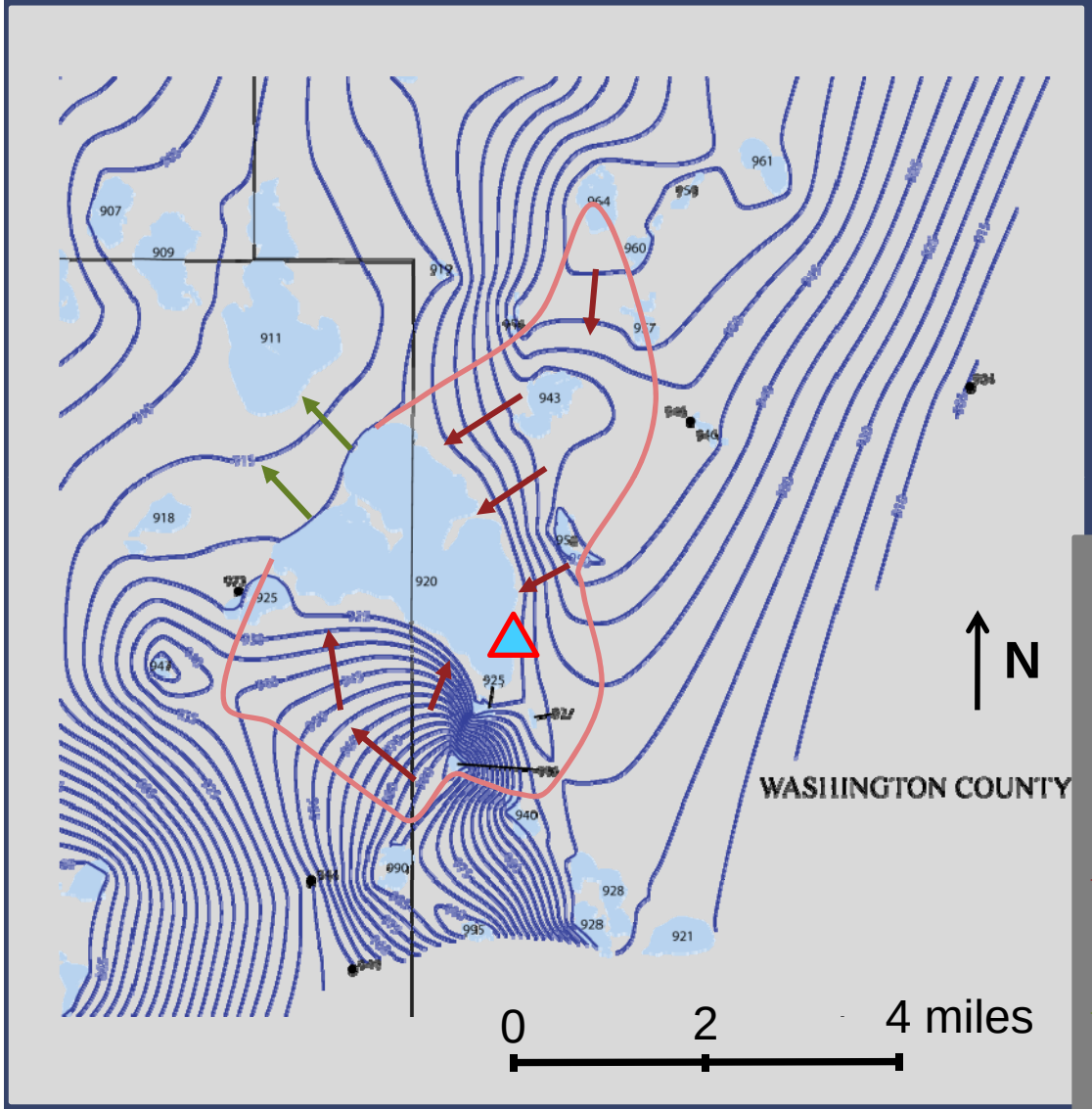
Results

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

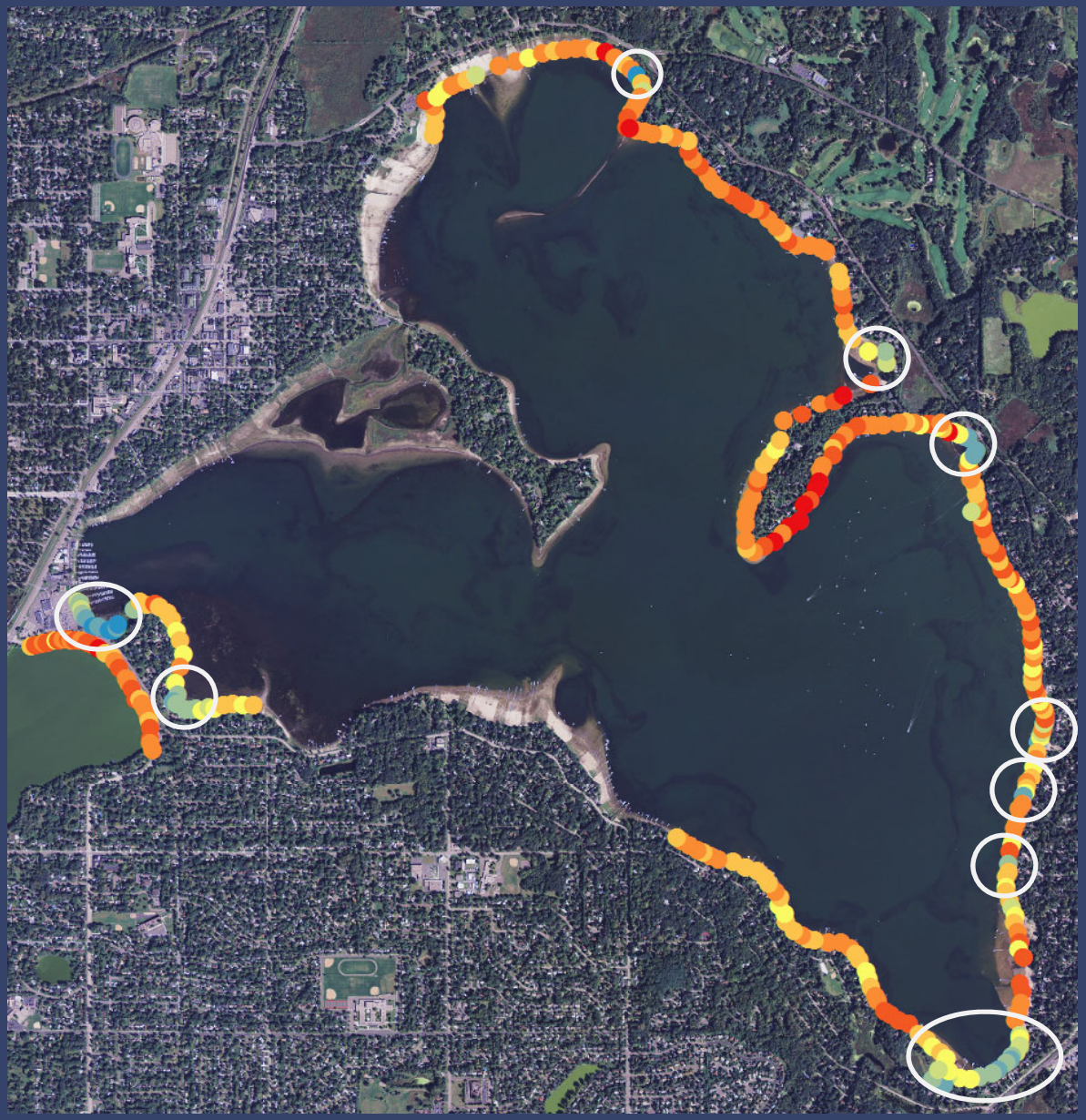
USGS

Iron Seeps forming at Mahtomedi Public Beach

Groundwater inflow to White Bear Lake

USGS

Water Temperatures in Nearshore Lake Sediments



July – September, 2011

Cooler Temperatures – Groundwater Inflow (springs)

Collected Water Samples

- 28 - 30 °
- 26 - 28 °
- 24 - 26 °
- 22 - 24 °
- 20 - 22 °
- 18 - 20 °
- 16 - 18 °
- 14 -16 °
- 12 -14

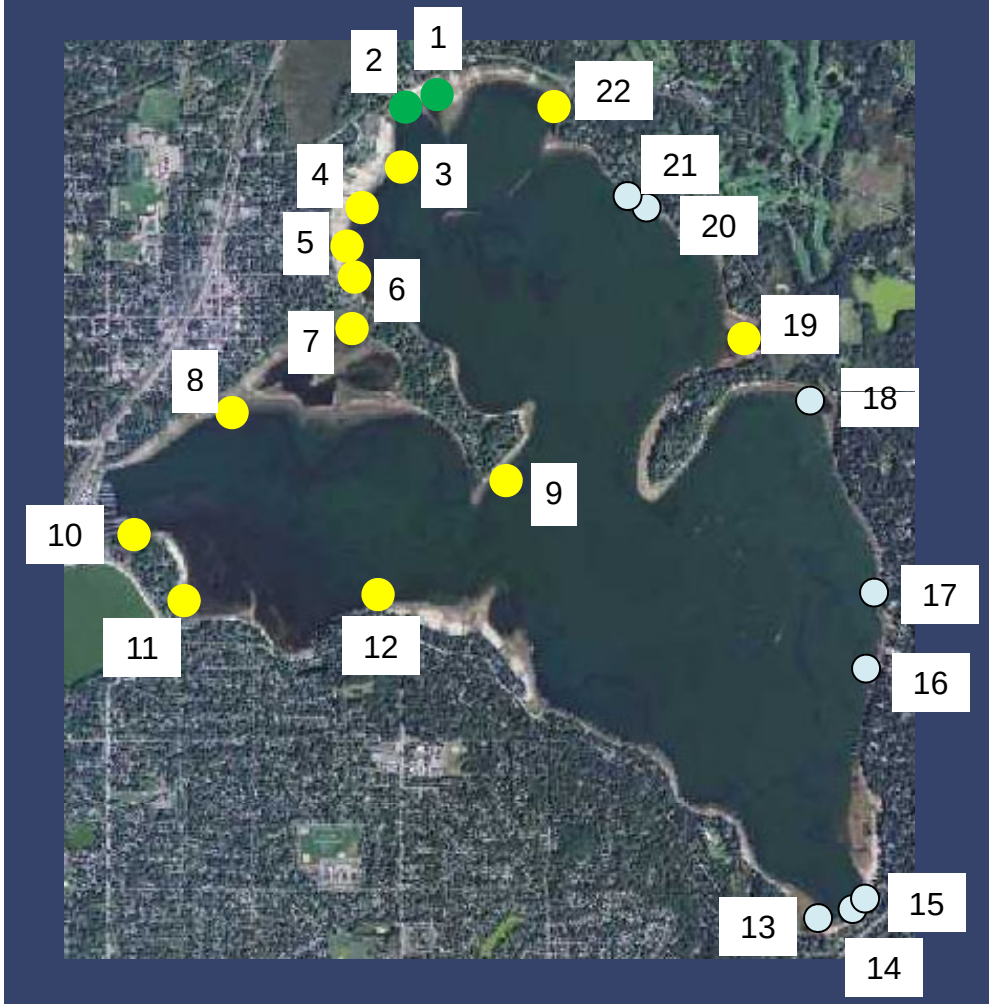
Cool Water Sediment Temperatures and Iron Stains

Areal Photography April 1, 2006

Seepage Meter Surveys – May and August/September 2011

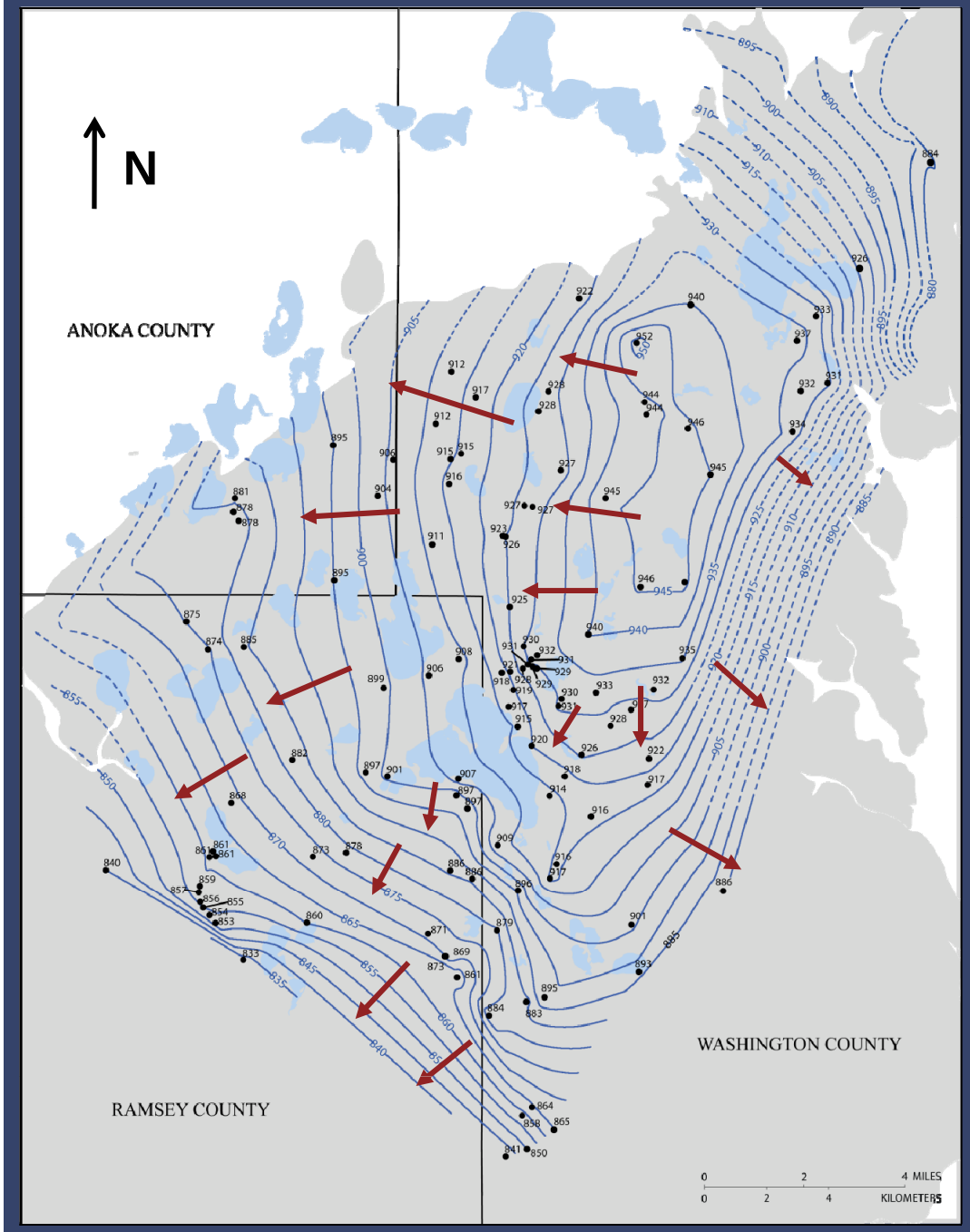
- May - 9 nearshore transects - measured groundwater flux (inflow to lake or outflow to aquifer)
- August/September – 22 nearshore transects/single meters

Nearshore Seepage Meter Surveys – August 2011



USGS

Site	Average Flux (cm/day)
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



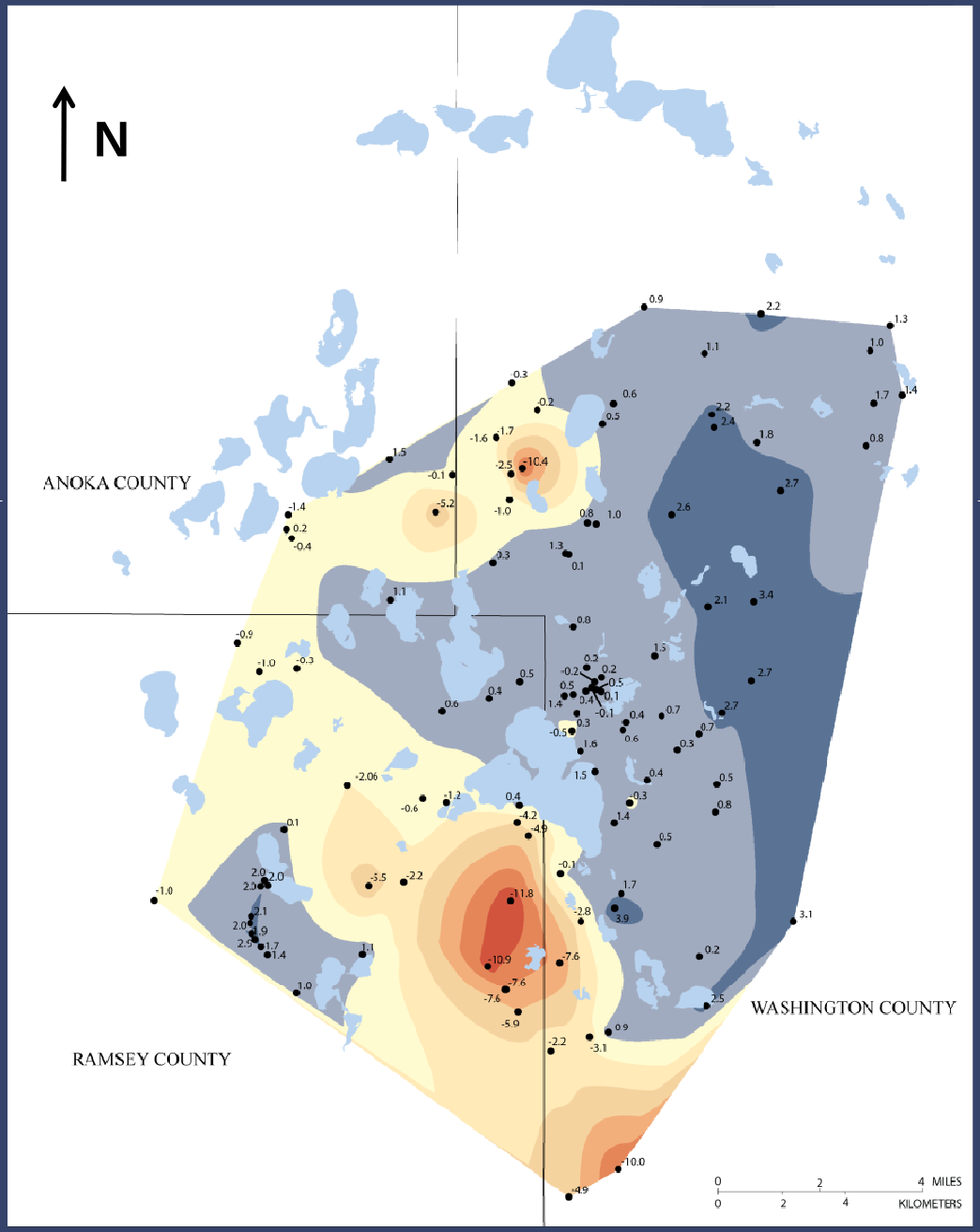
Potentiometric Surface for Prairie Du Chien/Jordan Aquifer

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

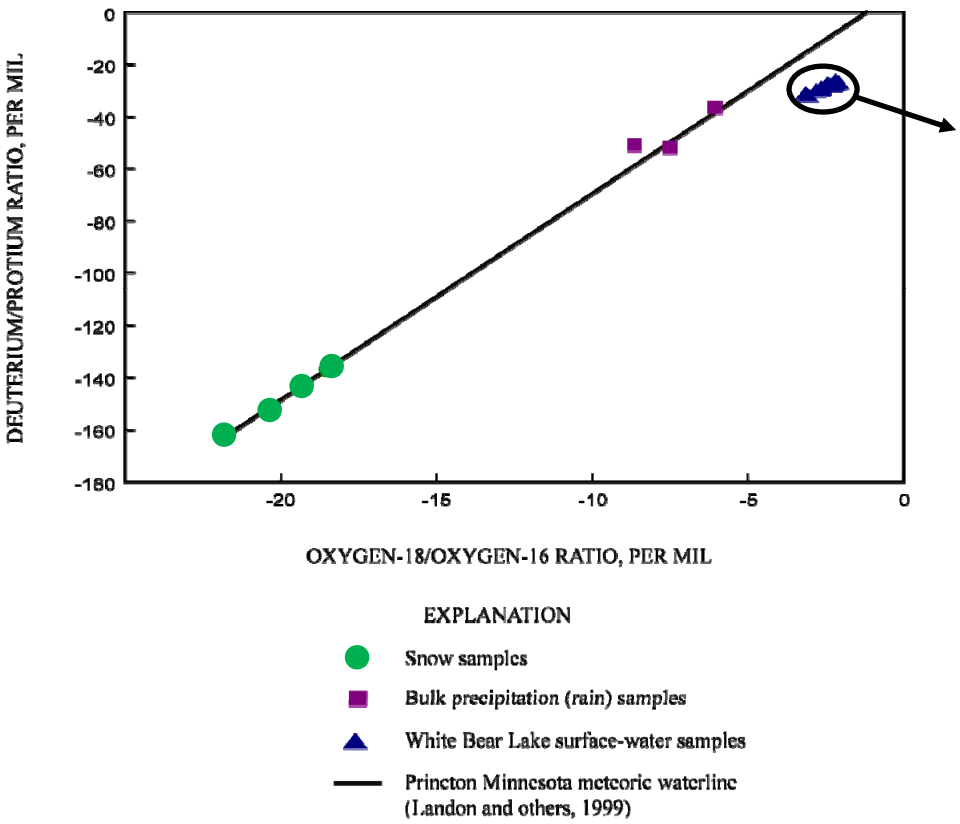
Compare

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

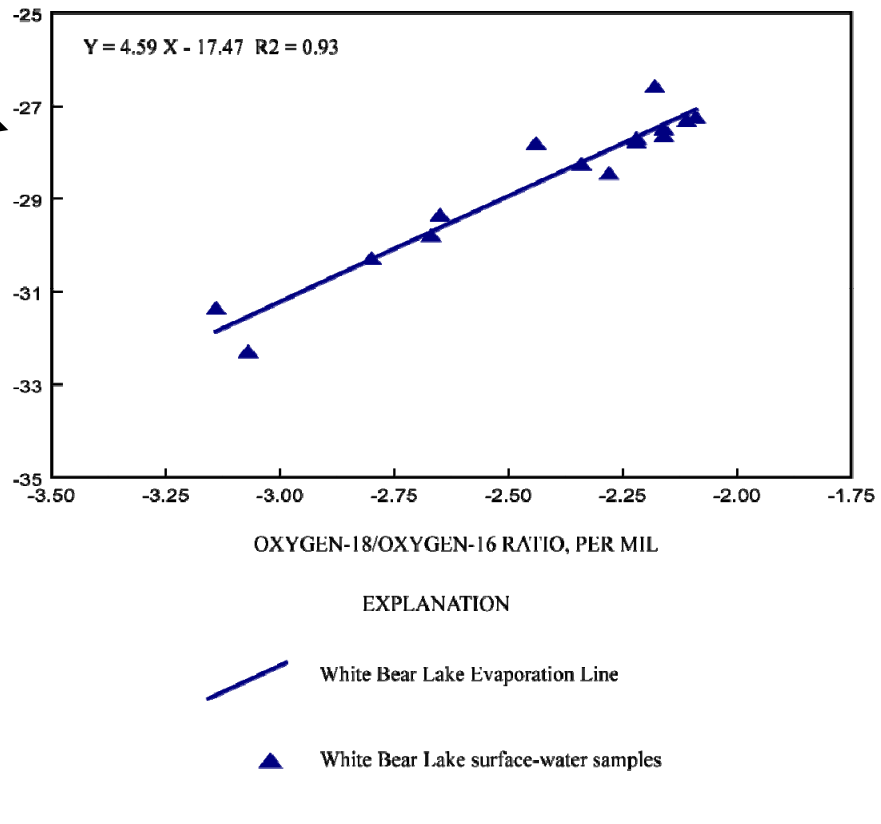
USGS

Stable Isotopes – White Bear Lake

Snow, Rain, and Lake Water

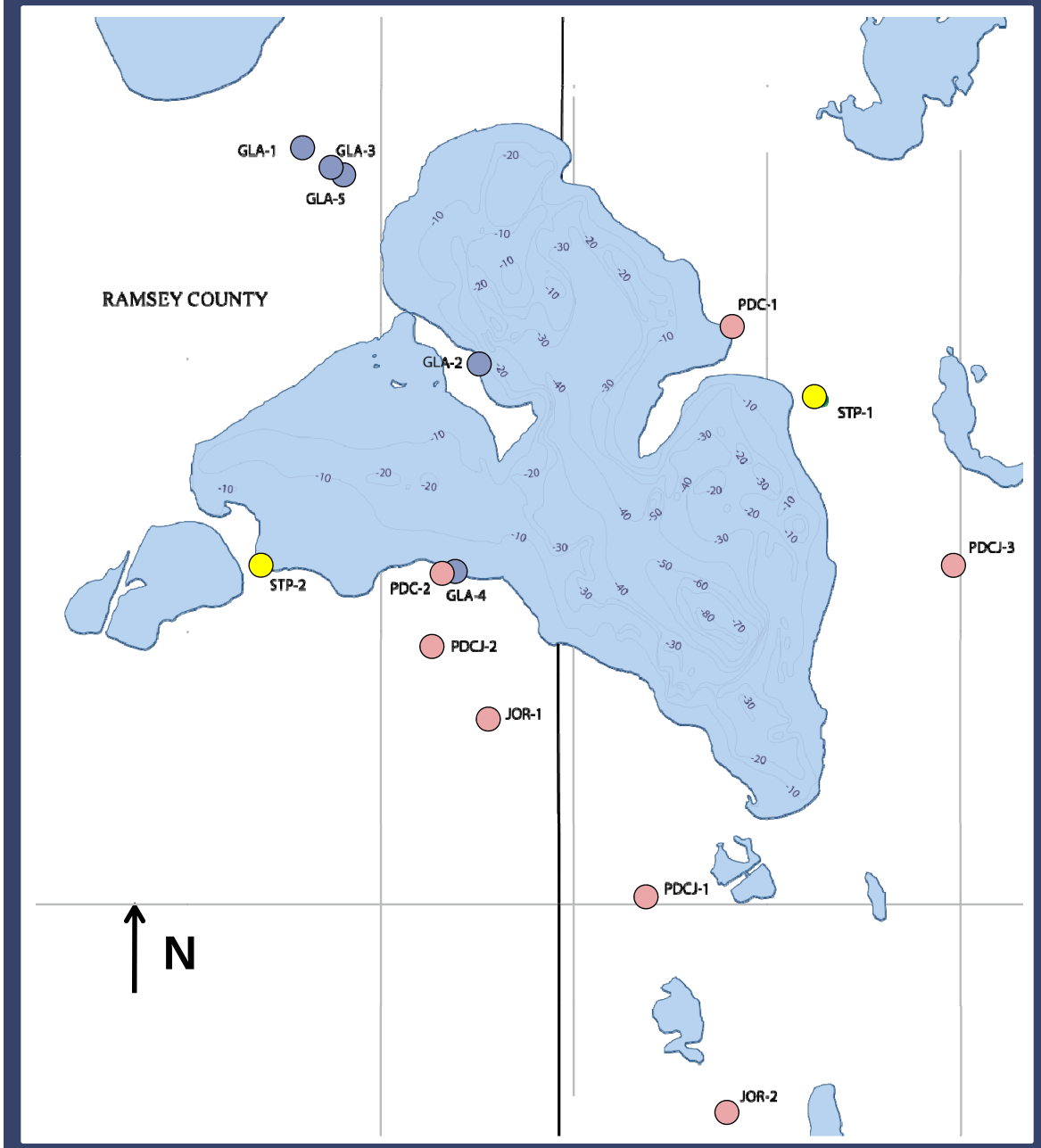


Lake Water



USGS

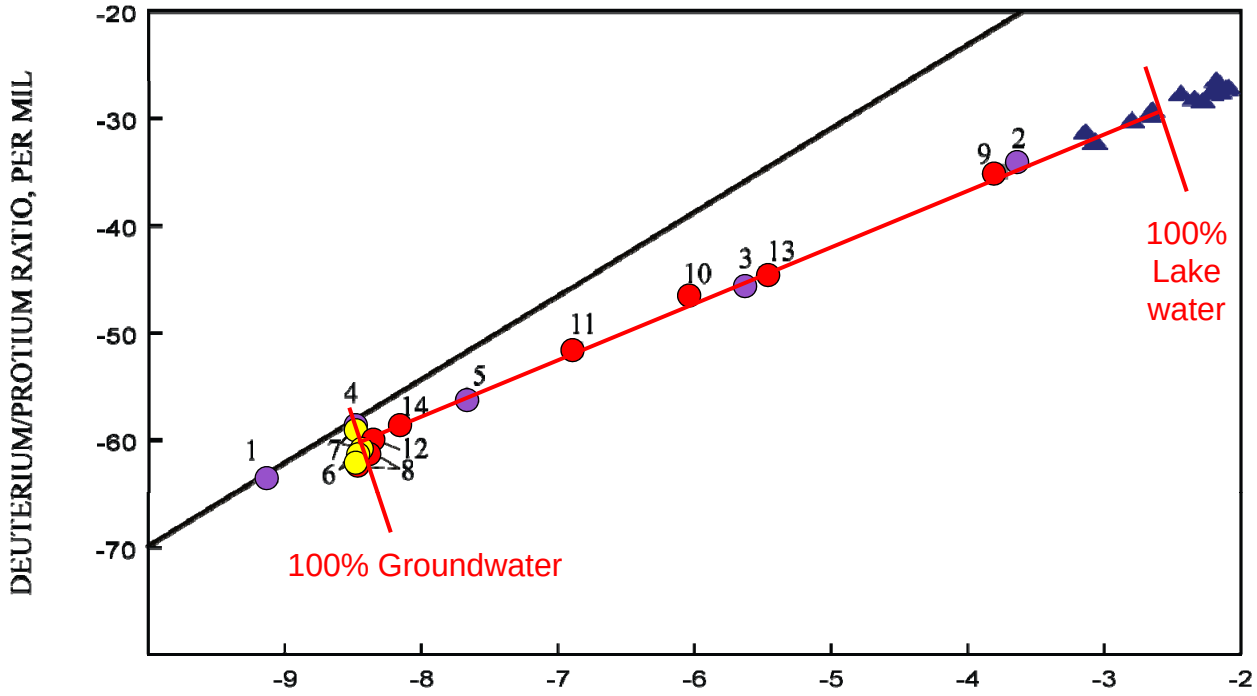
Water Quality 2011 - Wells



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

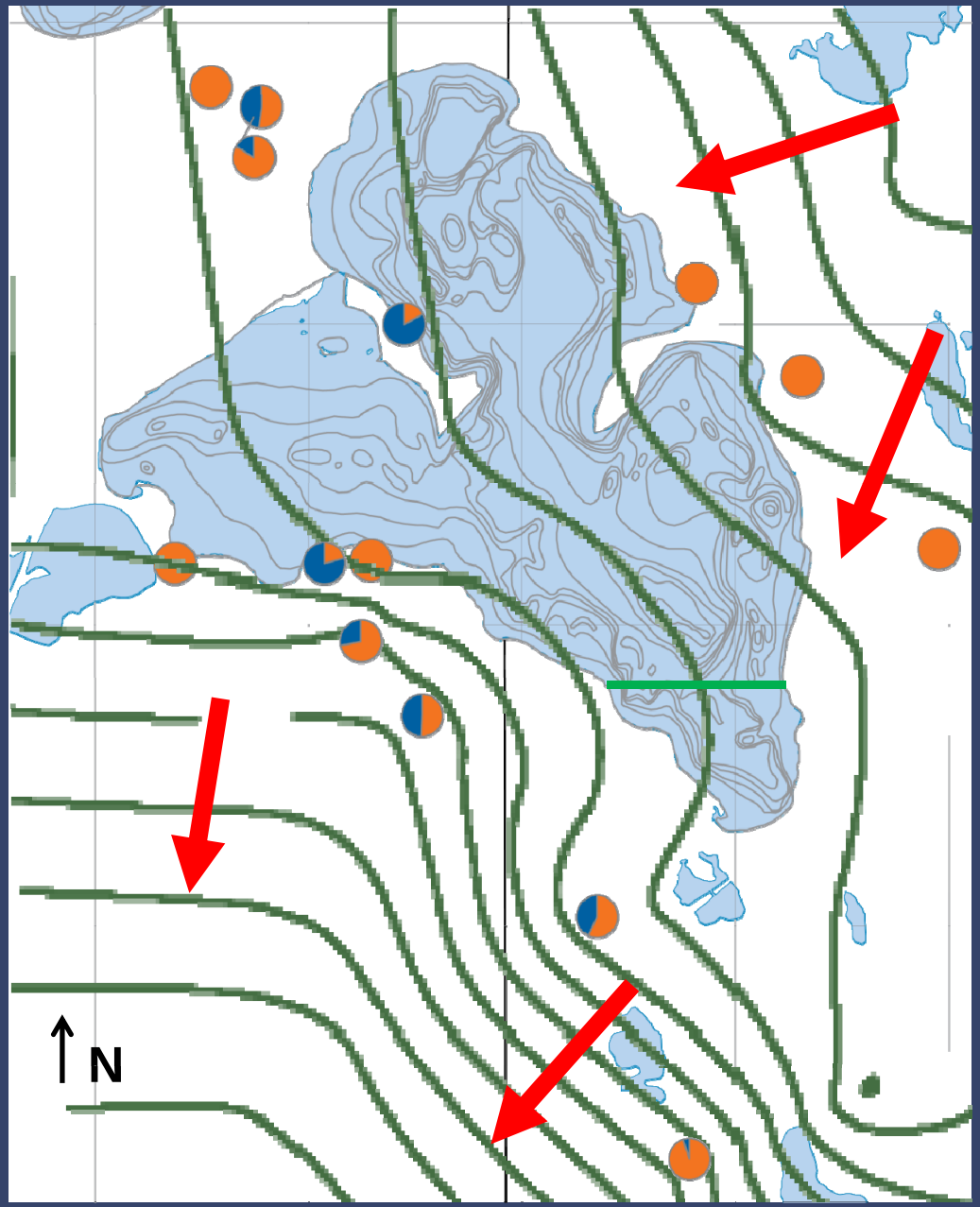
Groundwater Samples

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

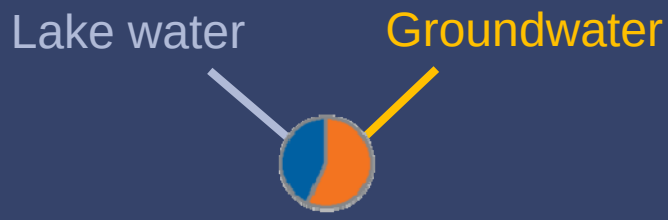
Groundwater sample sites - Numbers are site identifiers (values in parentheses are number of samples collected from the well)

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



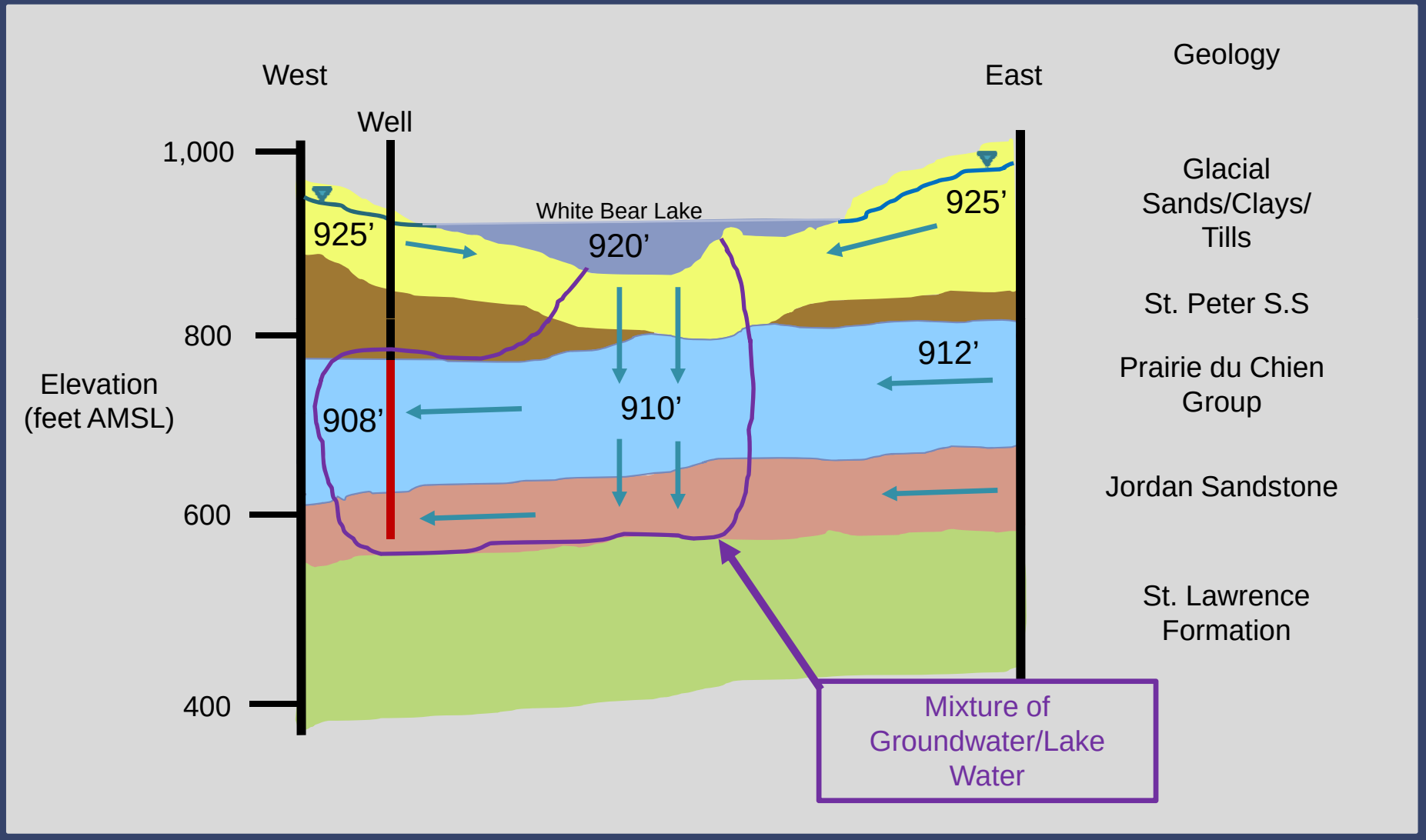
Glacial

St. Peter Sandstone

Prairie du Chien Group /
Jordan Sandstone (PDCJ)

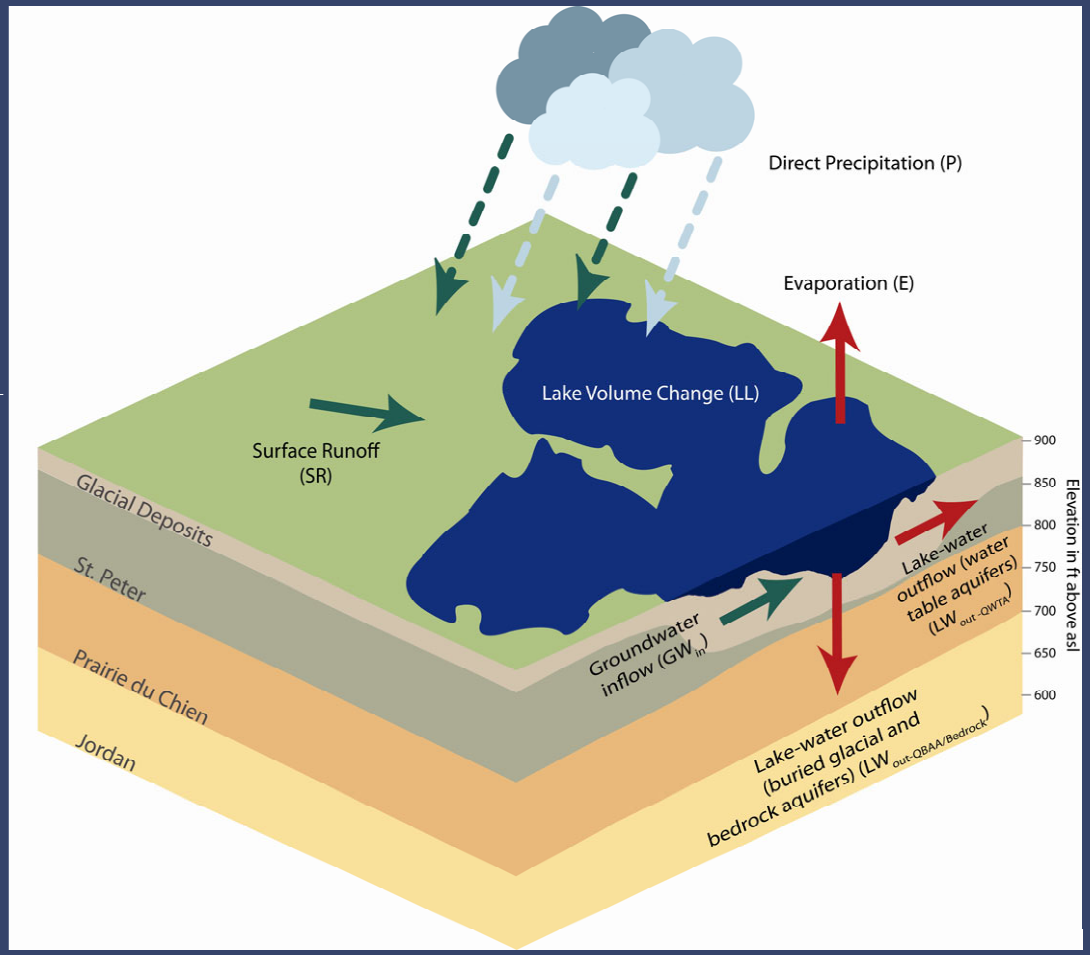
General Groundwater
Flow Direction – PDCJ
August 2011

General Hydrogeology – White Bear Lake



(modified from Mossler and Bloomgren, 1990)

2011 Monthly Water Balance for White Bear Lake

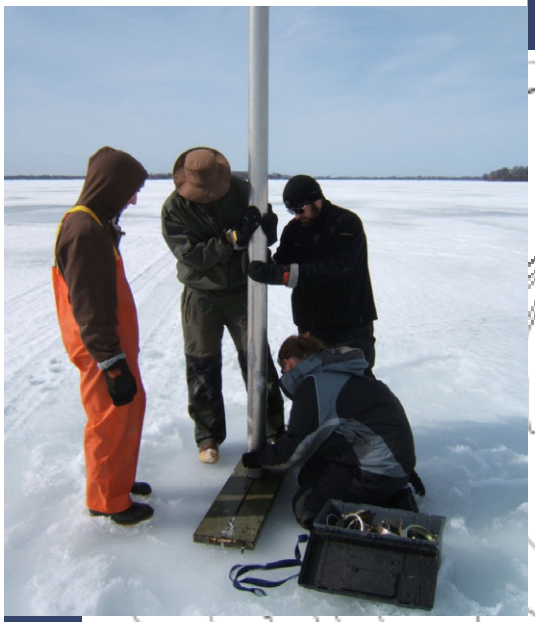


	In inches	
	March	August
LL	1.8	-0.3
P	0	5.8
SR	0	1.5
GW_{in}	2.1	1.8
E	0	4.9
$LW_{out - QWTA}$	0.1	0.1
$LW_{out - QBAA/Bedrock}$ + Errors	0.2	4.4

USGS

Lake area = 2,401 acres

U of MN, LaCore Facility



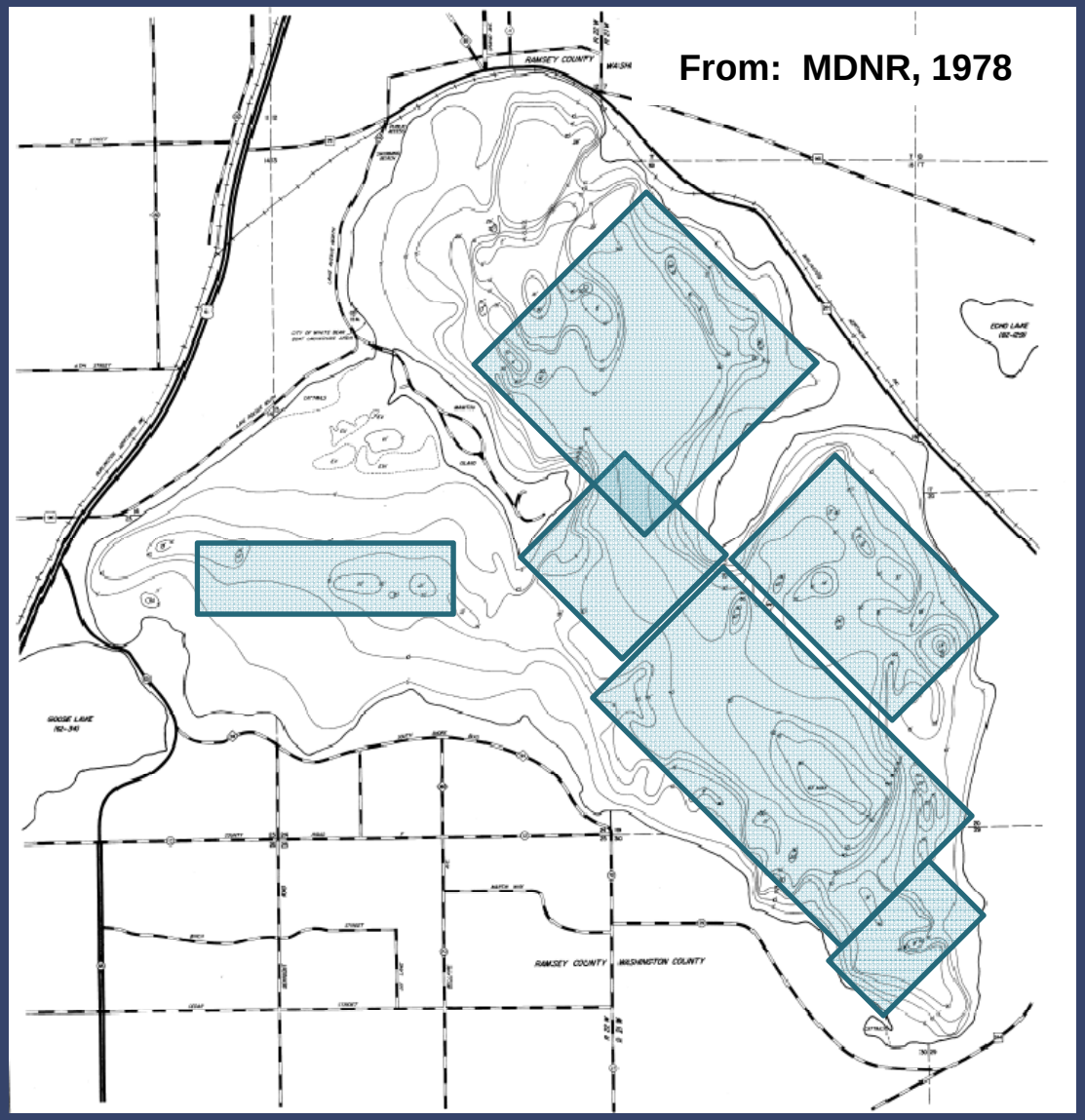
Lake Sediment Coring

- Probe Measurement
- Core/Probe Measurement

Site	Water Depth (ft)	Organic Sediment Thickness (ft)
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

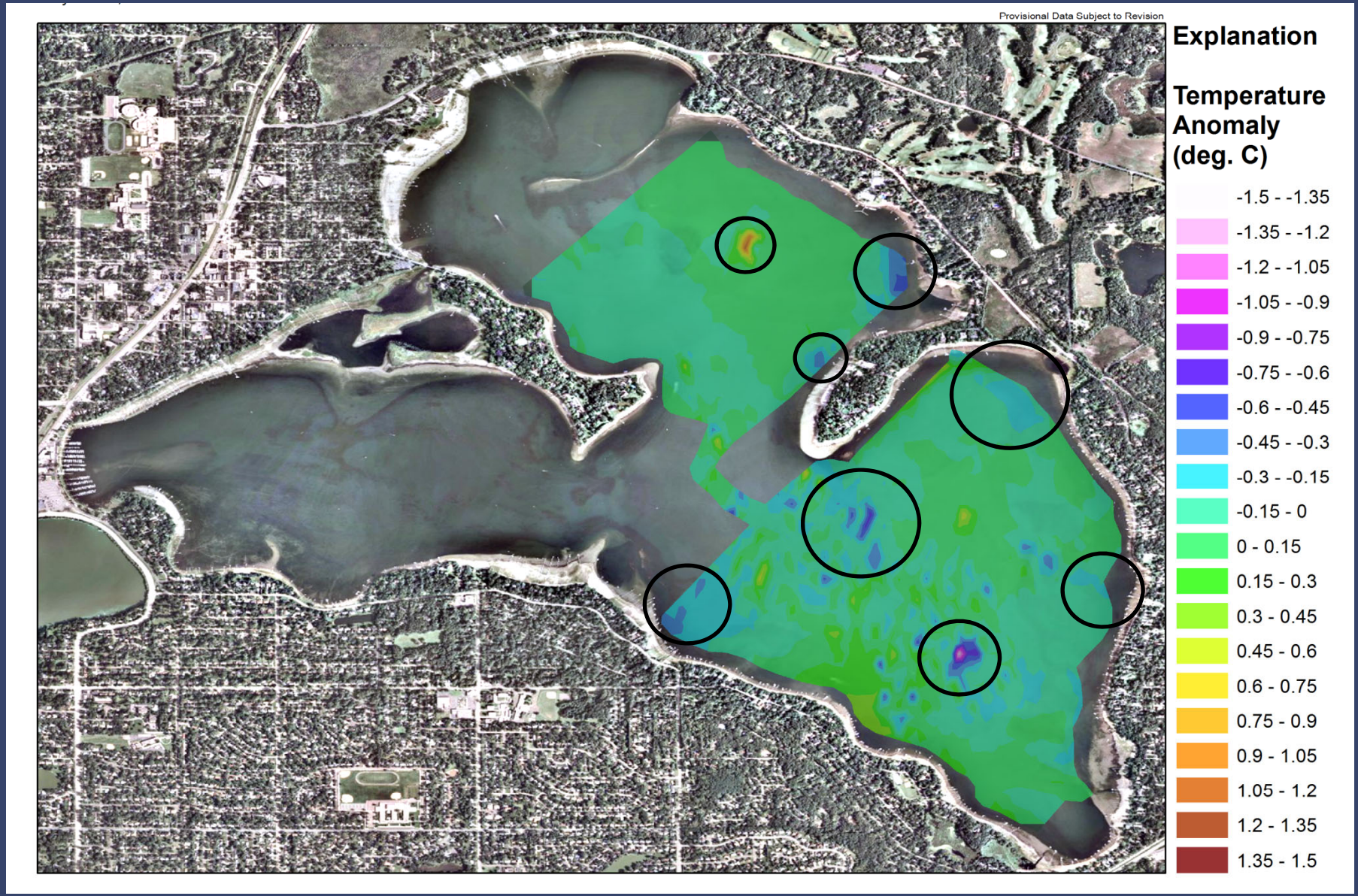
Turbidity

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

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/Jordan aquifer 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)

USGS

Any Questions?