White Bear Lake Groundwater and Surface-water Interaction Study

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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

- **Sunset**
  - Little change
- **South School**
  - Minor decrease (1 foot or less)
- **Lake Turtle**
  - Moderate decrease (2-3 feet)
  - Substantial decrease (4 or more feet)
- **Mann Long/Round**

Locations:
- Anoka
- Ramsey
- Washington

Graphs show water levels from 2004 to 2012 for each lake.
What is Groundwater?

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

- Precipitation (Rain and Snow)
- Transpiration (Plants, Grass, Tree)
- Well Pumping
- Evaporation
- GW flow
- Deep GW flow
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.

Water Elevation (ft AMSL)

Annual Precipitation (in)

1978 - 2002

2003

2003-2011

Groundwater pumping to lake ended

- - - Precipitation in inches
- - - Long-term Observer (4 miles SW)
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)

R² = 0.75, p = 0.005

1978-2002

2003-2011

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

Annual Pumpage (millions of gallons)

Pumpage By Aquifer

Annual Pumpage (millions of gallons)

* 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.

Water Elevation ft AMSL (1912 datum)

Observed Lake Level: Predicted Values Actual 2003 - 2010 Pumping Conditions
Predicted Values at 1980-2002 Average Pumping Rates
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

- 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

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<tr>
<th>Site</th>
<th>Average Flux (cm/day)</th>
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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

Lake Water

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

**Equation**
\[ Y = 4.59 \times 17.47 \] 
\[ R^2 = 0.93 \]
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

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

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

Landon and others, 1999
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)
### 2011 Monthly Water Balance for White Bear Lake

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<tr>
<td>Lw\text{out} - QBA\text{A}/Bedrock + Errors</td>
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Lake area = 2,401 acres
Lake Sediment Coring

U of MN, LaCore Facility

From: MDNR, 1978

<table>
<thead>
<tr>
<th>Site</th>
<th>Water Depth (ft)</th>
<th>Organic Sediment Thickness (ft)</th>
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<td>2.89</td>
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Water-quality survey - Ecomapper
July 11-14, 2011    White Bear Lake

From: MDNR, 1978

- 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/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)