Black swans, disappearing lakes, and the societal value of integrated modeling and monitoring

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Investigate the spatial and temporal variability of groundwater-surface-water exchange in response to changes in the geometry and hydrogeologic properties at the sediment-water interface that are driven by episodic and sustained fluvial and hydrologic events. Develop new methods.

Substantial relevance to scientific pursuits . . .
But how is this relevant to the public, to the taxpayer?

We need to demonstrate not just scientific relevance but also societal relevance.
Two examples of completely unexpected black-swan events; drastic decreases in lake stage and how USGS was able to help the problem.

Black swan event: “An unpredictable event that is beyond what is normally expected of a situation and has potentially severe consequences.”

White Bear Lake, MN

Long Lake, MI
1. Long Lake near Kalamazoo, MI

The definition of bucolic

2.3 km²
But what happens when your lake abandons you?

Dale Bothwell, 8939 Waruf, walks in the former lakebed from the direction of Long Lake. He is standing approximately half way between the current shoreline and the former shoreline.

3-6-00
Long Lake residents sink hopes in new well

Unit will pump two-plus million gallons of groundwater into lake daily.

BY TOM HAROLDSON
KALAMAZOO GAZETTE

A steel tower that could be ready to pump in a couple of weeks offers hope for hundreds of Long Lake residents living on the shrinking lake or trying to sell their homes there.

It's a deep water well with a pump that will run constantly, paid for by the lake property owners with help from Pavilion Township and the city of Portage. When fully operational, it will draw more than two million gallons of groundwater into the lake each day.

Now five feet lower than normal, the parched, muck-rimmed lake is a victim of weeks of dry conditions and the fact it's a bit higher than other area lakes so it cannot gain from their water runoff.

All that could change, but it may take some time.

Meanwhile, homes are selling for thousands of dollars less than when the lake level was normal.

Long Lake's low water level is dramatically indicated in this aerial photo taken Friday from the south end of the lake. The lake is located in the city of Portage and Pavilion Township.

"We can maintain and improve it this year; and next year we may have it stabilized," said Julie Ellis, a Long Lake resident and head of the Long Lake Board who has been working diligently on the lake-level dilemma for more than three years.

"We figure the pump takes 82 days to gain a foot, but that's not taking into consideration evaporation. It's up to evaporation and rainfall—and we're not expected to have a good rainfall year. It will probably be a year before it's close to normal. And that's just a guess," Ellis said.

The water from a deep aquifer comes none too soon for residents who have dry docks or a lake that is hundreds of feet away from its normal shoreline. The pump is also pumping hope into anyone offering a home for sale that either goes unsold or sells at a lower-than-normal price.

Todd Overbeek, a Long Lake resident and Realtor for ReMax, has studied home sales on Long Lake the past 10 years and finds a disturbing trend traced to the low lake level since 1997.

In 1997, when the lake level was about three feet below normal, the average size of a Long Lake home sold was about 1,137 square feet and its average sale price was $121,000. In 1998, that same-size home sold for $112,000.

In 1999, when the lake again was drained by a drought and a record
Seepage meters

Instrumented wells

2500 gpm

Very small lake-stage rise
Area of rapid downward seepage

A simple model could have saved a lot of money

GW inflow everywhere, except . . .

Drilling the well deeper or moving it farther from the lake would have reduced the chance of recirculation of lake water.
2. White Bear Lake, MN

- 3rd largest lake in MSP metro area
- Mesotrophic with good water quality
- Very popular recreation lake
- Many expensive homes
- 780 (31 in) ppt/yr
- Big concerns when lake stage dropped 1.5 m

9.8 km²
(2400 acres)

4.3 km
What does really low lake stage look like?
Difficult to get the boat in the lake

A few images from Google
Difficult to get the boat in the lake

Public beach closed 5 summers in a row

A few images from Google
Difficult to get the boat in the lake

Public beach closed 5 summers in a row

Can't drive the boat to the marina for evening happy hour

A few images from Google
Ever-expanding dock!
Lake stage closely follows changes in precipitation

Precipitation cumulative departure from normal
1970 to 2012

Lake elevation, in feet (1929 datum)
Precipitation cumulative departure from normal 1970 to 2012

Lake stage closely follows changes in precipitation

... and then something else
Eighteen different entities partnered with USGS to study the problem

“GW-SW Interaction partners”

- White Bear Lake Conservation District
- Minnesota Department of Natural Resources
- Minnesota Pollution Control Agency
- Minnesota Board of Water and Soil Resources
- Metropolitan Council
- Washington County Public Health and Environment
- Ramsey County Public Works
- City of White Bear Lake
- City of Mahtomedi
- City of Birchwood Village
- City of Dellwood
- White Bear Township
- Rice Creek Watershed District
- Vadnais Lake Area Water Management Organization
- White Bear Lake Home Owners Association
- Veterans of Foreign Wars of White Bear Lake, Post 1782.


Jones et al, 2017
White Bear Lake settlement pushes plan to divert water from Mississippi
By Jim Anderson Star Tribune
December 1, 2014

White Bear Lake’s Water Levels Linked To Tap Water?
By Bill Hudson WCCO-TV

The lowdown on lake water levels
Public invited to special forum
by Mark Nicklawske
Regional Editor

Research in the spotlight
White Bear forum draws big crowd; discusses drought

Study proposes well pumping to raise lake level
Low stage in 1990 was caused by decreased $P$ and increased $E$. But that wasn’t the case in 2010.

No SW exchange. More $P$ than $E$. Net GW must be negative; flow from the lake to GW.
A few simple tools to see where the lake is losing water

Hydraulic potentiomanometer (Winter et al., 1989)

Half-barrel seepage meter (Lee, 1977)
Nearshore seepage – August 2011
GW is flowing to, not from the lake as expected

Average Flux (cm/day)
- Outflow – less than 0.15
- Small Inflow (0.02 – 1.1)
- High Inflow (3.0 – 28)
Hypothesis based on conceptual diagrams in Winter et al. Circular

1. What if flow was normally to the lake.
2. A nearby pumping well could reverse the flow direction and induce flow from the lake.
3. But what if that pumping well was much deeper and was pulling water from an underlying aquifer?
4. The well could be pulling water from the deeper parts of the lake while GW is still flowing from the shallow aquifer to the lake margins.
Combination of hydraulic gradients and water isotopes indicates lake water is flowing to at least some of the municipal wells.
6 of 11 municipal wells indicated SW was present. Of those, percent SW ranged from 16 to 83%.

But specifically where is the lake leaking to the underlying aquifers?
Four deep-water sites, P1-P4, selected based on geophysics and lake sediment cores.

EXPLANATION

- P4: Lake-sediment core collected/piezometer nests/deep seepage meter measurement and identifier
- 9: Seepage-meter and hydraulic-head measurement site and identifier

Seepage-meter flux for each site, in feet per day between August 20 to 23, 2014:
- 0.01 to 0.03
- 0.13 to 0.47
- 0.04 to 0.12
- 0.48 to 0.94
Installed a remotely operated seepage meter at each deep-water site

Automated seepage meter (Rosenberry & Morin, 2004)
In the middle of the lake, seepage and hydraulic gradients were both downward! Also installed piezometer nests in the middle of the lake. Deepest piezometer was 10 m below lakebed. Piezometers were monitored for 1 year with pressure transducers.
Went back in the summer with a better seepage meter to measure seepage when municipal wells are meeting a much larger demand.

However, by then, $P$ was substantially larger than normal and lake stage had risen more than 0.5 m.
• Even during the wet summer of 2016 seepage was still downward.

• But how much water are we talking about?
MODFLOW results

- Used the calibrated model to determine GW-SW exchange for four lakes
- Vertical downward seepage on the order of 5.5 mgd
- $E$ is 4.5 mgd, so $Q_{GWout}$ is a big term
- Lake level lowers 1.5 feet if GW pumping increases by 30%
- Lake level lowers 3 feet if $P$ decreases by 5%
- White Bear Lake is particularly sensitive to changes compared to three other simulated lakes
- Results are being contested in MN Supreme Court
Both sides in MN Supreme Court case are presenting USGS data.

“Win or lose, I believe our efforts have brought awareness of water conservation to the table.”

Attorneys in White Bear Lake level case argue before Supreme Court

By Debra Neutkens/Staff Writer Jan 15, 2020

Plaintiffs and legal counsel posed for a group photo after the Supreme Court hearing Jan 6 at the Capitol. From left, attorney Heather McElroy, Greg McNeely, Katie Crosby Lehmann, Jim Markoe, Brian McGoldrick and attorney Byron Starns.
Integrated modeling and monitoring is smart, cost-effective, and directly relevant to public needs.

Studies of these black-swan events provide context and understanding that serves both science and management objectives.

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