The importance of groundwater to lakes, wetlands, and streams: New methods, new understanding, and the societal relevance of research at the sediment-water interface

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Hydrogeology of lakes, wetlands, and streams

Investigates 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

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Rapidly advancing research

• Water budgets, water management
• Estimates of GW recharge
• Constrain estimates of GW discharge for flow models (streambed, lakebed conductance)
• Spawning redds
• Constructed wetlands
• Augmentation lakes, reservoirs
• Sub-marine GW discharge and coral reefs
• Nutrient and chemical fluxes
• Hyporheic processes
But how is this relevant to the public, to the taxpayer?

Could I sell this to my dad?
Drought

Latest News

White Bear Lake’s Water Levels Linked To Tap Water?

Study proposes well pumping to raise lake level

DNR inspects lake hole

by Mark Nicklaveske
Regional Editor
Precip cumulative departure from normal 1970 to 2012
Pumping has doubled in St. Peter - Prairie du Chien Aquifer
Ever-expanding dock!
It could be even worse

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.
Nearby, at Austin Lake, it’s fun as normal
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 years 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 Overbeck, 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
Pumping well

Area of rapid downward seepage
Flooding

But how is groundwater relevant?
1997
2.7 m stage rise
(0.3 m higher yet in 1998)

Winter and Rosenberry, 1998 Climatic Change
The deluge continues

1453.83
What is groundwater’s role?
Ave ppt. = 440 mm
Ave ET = 810 mm

Not much.
GW not very important based on P1 water budget

Winter et al., 2001
Figure 13. Total over-winter precipitation and total spring rise of Wetland P1 stage, 1981-1992. Values at top of columns are ratios of stage rise to precipitation.
During wet times groundwater is very close to land surface and near-surface $K$ is large.
During drought water-table troughs accelerate wetland stage decline
Positive feedback related to hydrology enhances wetland sensitivity and response to changes in climate.
Strange field results + modeling = new understanding the Lake Belle Taine story

Rosenberry, 2000, WRR
• Ten lakes drain into Belle Taine
• Average flow into lake = 1 m$^3$/s
• No outlet
• $P = E$
• Where does all the water go?
• Lakes as close as 0.5 km away are 15 m lower in stage
• Drillers report unusually warm ground water in wells drilled along the south shore of the lake
  • Geothermal activity?
• GW-SW training class found strange things going on
Leech Lake
45,000 ha

Belle Taine
480 ha

7th Crow Wing

6th Crow Wing

5th Crow Wing

South shoreline
435.5

421
Seepage through 8.7 km south shore should be ~30 to 90 cm/d
Measured seepage ranged from 0.1 to 263 and averaged 37 cm/d

Rosenberry, 2000, WRR
Hand-augering a 7-m deep well

Rosenberry, 2000, WRR
USGS model VS2DH

Seepage limited by a 20-30 cm thick clogging layer

Best match for wedge thickness

$K_O/K_L = 70$

Best match for lakebed and outwash geology

$K_O/K_L = 20$

Lowest $K_O/K_L$ to create UZ beneath lake

$K_O/K_L = 15$
A very nice place to live and play

. . . Until the climate changes
High water is countered by loss to ground water, but it’s not enough.
• Jetted in 30 cm dia. pvc pipe ~30 cm through the lakebed
• Connected seepage cylinder to an inverted floating seepage tub with 5.5 cm dia hose
• Measured seepage rates up to 20,000 cm/d!
• Seepage rates were back to normal after 2 months (10 to 100 cm/d)

The rest of the story

Rosenberry et al., 2010, WRR
Solutions to high water
Requested by county commissioners

- Create channel from Belle Taine to Crow Wing lake
- Route water to infiltration lagoons
- Pump water to irrigation sites
- Manipulate lakebed to get faster seepage
Time heals all wounds and all floods

Lake Belle Taine stage, m

Ordinary high-water stage

GW exchange is particularly important during extreme conditions
Water supply
Sonoma County Water Agency
Ranney wells induce a lot of recharge 78 mgd for the northern San Francisco Bay area
Seepage meters

Sonoma County Water Agency Collector Well 1 (C1) transect

C1RB

-400

C1C

ET tower

+10

ESM

+15

C1LB

-22

C1 Collector well

Russian River

100 m
• Seepage is highly localized
  – The bed is not clogged everywhere
• Some of the clogging layers are transient

More water is always better, right?
78 mgd = 120 cfs
That's 40% of 300 cfs
Not better for these people
GW – SW exchange is relevant to public water supply and public recreation.
Water and chemical budgets of Mirror Lake, New Hampshire
300 kg per lane per km

½ ton per lane per mile
What person on the street will ever read this?

NH DOT read our paper
Problem solved . . .

. . . we hope

Continued monitoring will tell
Are you SURE this is groundwater?

- GW was the link that brought salt to the lake
- Flushing out that GW may take many years
Ecosystem health – birds

Great Salt Lake, UT
Selenium in the Great Salt Lake

“... One of the Western Hemisphere’s most important migratory bird habitats.”
Utah DWQ
Very little groundwater discharge most of the time.
Lake seiche – water pushed around by a thunderstorm
There were 13 seiches larger than this one during 2010
Ecosystem health – fish

- Moir et al. 2002. *Geomorphology*
- Morrison et al. 2002. *Journal of Hydrology*
- Baxter and Hauer. 2000. *Journal of Fisheries and Aquatic Science*
- Garrett et al. 1998. *Journal of Fisheries Management*
- Pitlick and Van Steeter. 1998. *Water Resources Research*
- Ridgway and Blanchfield. 1998. *Ecology of Freshwater Fish*

Ecosystem health – fish
If sediments are contaminated, can discharging groundwater expose fry to contaminants?
Seepage is small and downward. No problem for fry hanging out in the gravel.
Until nighttime when river stage drops and seepage becomes upward
The concern is that as we use more groundwater to supply our homes and infrastructure, there may be less groundwater discharging to the river. So at times when the river temperature is very warm, the fish and the animals that live in the substrate may become stressed.
So who cares?

Plants
Benthic invertebrates
Endangered species
Fish
Ecologists
Geochemists
Geomorphologists
Hydrologists and hydrogeologists
Resource managers
The PUBLIC!
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- Bill Simonds, Steve Cox, Rich Sheibley, USGS Washington WSC
- Perry Jones, USGS Minnesota WSC
- Dave Mushet, Chip Euliss, USGS Northern Prairie, Jamestown
• Direct measurement of flux
• Measure flows from ~0.1 to ~500 cm/d  \((10^{-8} \text{ to } 5 \times 10^{-5} \text{ m/s})\)
• Modified versions can measure down to ~0.00001 cm/d or up to 5000 cm/d or more

The original half-barrel seepage meter
David Lee, 1977, Limnology and Oceanography
Great Salt Lake, UT