Can stream baseflow be augmented through stormwater infiltration? The case of Minnehaha Creek

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Minnehaha Creek: a valued urban resource

Coursing nearly 21 miles from its origin at Lake Minnetonka to its confluence with the Mississippi River, Minnehaha Creek is among the most valued surface water features of the Twin Cities area. Over half a million visitors flock to the creek's park areas and cascading falls annually, and have included high-profile figures such as President Lyndon B. Johnson (Fig. 1). Flow in the creek is heavily dependent on discharge from Lake Minnetonka (Fig. 2), the outlet of which is controlled to manage water elevations in the lake. Streamflow records indicate groundwater-fed baseflow is not consistently sufficient to sustain flow in Minnehaha Creek during periods when Lake Minnetonka's outlet is closed (Fig. 3), and the creek has experienced dry periods in 8 of the last 12 years. In light of the value of this urban resource, there is interest in enhancing ecosystem service provision by the stream by increasing baseflow.

Figure 1. President Lyndon B. Johnson smiles as he views Minnehaha Falls. The President's June 1964 visit coincided with a drought during which flow in the creek had ceased. To provide the President with a view of the falls, the City released 6 million gallons of water from Minneapolis fire hydrants.[1]

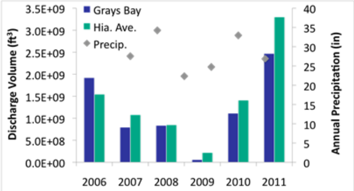

Figure 2. Annual discharge volumes from Lake Minnetonka's outlet at Grays Bay dam and near Minnehaha Creek's confluence with the Mississippi River at Hiawatha Avenue. Flow in the creek and discharge from Lake Minnetonka are highly correlated; the effects of outflow restrictions from the lake on streamflow in 2009 are clear.

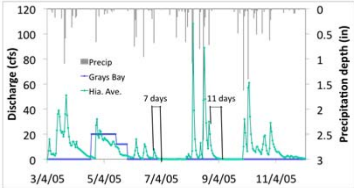

Figure 3. Outflow from Lake Minnetonka at Grays Bay and 20 miles downstream at a USGS gauging station (Hia. Ave.) during 2009. Apart from Lake Minnetonka discharge to moderate flows, the time from the hydrograph peak to 0 flow can be as short as 7 days. Extremes in flow conditions are exacerbated by expedient stormwater drainage throughout the creek's urbanized watershed.

Understanding stream-shallow groundwater interactions and potential for baseflow augmentation

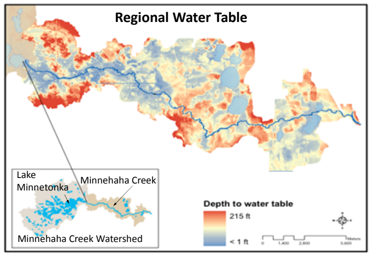

Figure 4. Depth to the regional water table. Though this mapping does not reflect perched water table conditions, it does give an indication of areas where upward fluxes of groundwater to Minnehaha Creek are most likely to occur.

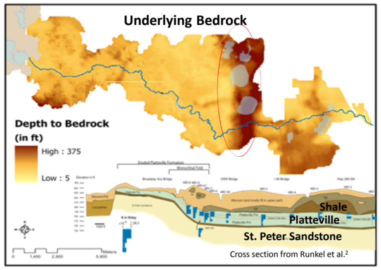

Figure 5. The lower Minnehaha Creek watershed is underlain by a series of bedrock units. The carbonate dominated Platteville formation is the uppermost unit throughout much of the watershed and, while it is typically classified as an aquitard, non-uniform erosion of this unit may permit leakage from the surficial aquifer. Though not specific to the Minnehaha Creek watershed, the cross section above illustrates non-uniform erosion of the Platteville in the region, including its complete erosion as is the case in the bedrock valley underlying the watershed's "Chain of Lakes" outlined in red.

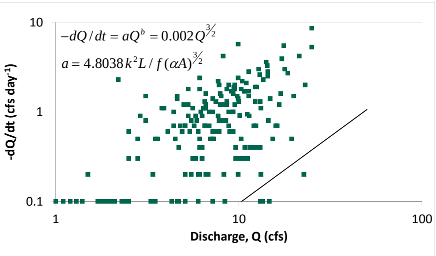

Figure 6. The method of Brutsaert and Nieber[3] has been applied to the lower envelope of stream discharge data collected near the mouth of the creek from 2000 – 2011 to infer properties of the shallow aquifer (hydraulic conductivity *k*, porosity *f*, and the fraction of the watershed underlain by stream-feeding aquifers, α) according to the nonlinear solution of the *Boussinesq* equation. Based on expected values of *k* and f from existing surficial mappings, the contributing aquifer must be quite small (< 0.1% of the total watershed area) to satisfy the condition a = 0.002 $ft^{-1.5}$- $sec^{-0.5}$.

We hypothesize that stream baseflow in Minnehaha creek can be augmented through strategic infiltration and storage of urban stormwater runoff in the shallow aquifer. To test this hypothesis, we must develop an understanding of current interactions between the stream and shallow groundwater. Several methods have been applied to estimate watershed-wide recharge and groundwater contributions to streamflow (Table 1). These estimates are being evaluated in combination with existing surficial geology datasets (Fig. 4 and 5), characterization of aquifer properties based on the method of Brutsaert and Nieber[3] (Fig. 6), modeling of sw/gw interaction, well observations, seepage measurements, and temperature and stable isotope analysis to better understand the potential to augment baseflow through storage of infiltrated stormwater in the shallow aquifer.

Method	Estimate of groundwater recharge or discharge (in yr^{-1})
SWB Soil Water Balance model[4]	5.1 (est. available recharge, 1977-2011)
PART baseflow separation model[5]	1.35 (mean annual discharge, 2006-2011)
RORA recession index model[6]	1.7 (mean annual discharge, 2006-2011)
Prior seepage measurements[7]	1.5 (extrapolated from Sept. 2003 data)

Table 1. Estimates of groundwater recharge, as estimated from a watershed-wide water balance method[4]; discharge, as estimated from two streamflow-based methods[5,6]; and groundwater seepage measurements from a 550-ft reach of the stream[7].

Conclusions

- Sustained baseflow during drought periods in Minnehaha Creek is likely limited by rapid vertical transit of groundwater through the shallow aquifer to underlying bedrock units, the median travel time of which is on the order of 0.5 years.
- Accordingly, and in concordance with results from the Brutsaert and Nieber method, it is likely that only a small portion of the shallow aquifer (< 0.1%) contributes baseflow to the creek. This would be equivalent to a 15-ft wide buffer on either side of the creek.
- Field measurements of stream and porewater temperatures, groundwater seepage, and O-18 and deuterium isotopes will be used to provide further insight to the Minnehaha Creek aquifer system and the potential to augment flow during drought periods through improved stormwater management.

Acknowledgments

The authors thank the Minnehaha Creek Watershed District and Mississippi Watershed Management Organization for funding this work.

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