POSTERS

It's Time to Talk About 'Till' –
Glacial Sediments and Groundwater

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Characterizing and Mapping the Groundwater Component of Lakes and Wetlands in the Itasca Moraine using GIS Tools and an Analytical Model

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Abstract

Characterizing water budgets is crucial for effectively managing wetlands and protecting their ecological services. The groundwater component of the budget, which often controls water quality and water-level resiliency, is particularly difficult to estimate. We utilized the regionally abundant lakes and wetlands in the Itasca Moraine, central Minnesota, to test a GIS approach using digital elevation models (DEMs), lake levels, stream channels, and hydric soils to delineate groundwatersheds and groundwater flow paths. Coupled with an analytical model for unconfined flow, which permits an estimate of the recharge to hydraulic conductivity ratio (R/K), our method also provides a way to map recharge-discharge rates across the moraine landscape. Although field pH of surface waters varies in the study area, specific conductance increases from 10 to 430 µS/cm down gradient along modeled flow paths. This reveals increased groundwater interaction and verifies our spatial-modeling technique. Based on existing estimates of recharge and the R/K results from the analytical model, hydraulic conductivity varies from 0.5 to 25 m/day in the moraine sediments, corroborating SSURGO data for soil C horizons. Our results indicate that GIS tools together with DEMs and other commonly available data can be used to characterize and map the groundwater component in the Itasca Moraine's lakes and wetlands. Applied elsewhere, this procedure should be helpful to resource managers who need to assess vulnerability of wetlands and lakes to changing land cover and climate.

Drain Tiles and Groundwater Resources: Understanding the Relations

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Abstract

This poster will summarize findings of the MGWA white paper committee on *Drain Tiles and Groundwater Resources: Understanding the Relations*, formed in response to a 2016 request from the Minnesota Ground Water Association (MGWA), which is available at: (http://www.mgwa.org/documents/whitepapers/Drain_Tiles_and_Groundwater_Resources.pdf). The white paper attempted to:

- Summarize the history and review current trends of tiling in Minnesota
- Clarify the regulatory environment for subsurface drainage
- Review the scientific literature related to quantifying or otherwise describing the effect of subsurface drainage on groundwater resources;
- Detail the state of understanding related to tiling and groundwater resources, including the potential changes to recharge of surficial and confined aquifers; and
- Identify knowledge gaps and opportunities for research related to understanding subsurface tiling effects on groundwater resources.

Overall, the findings of the white paper were that Minnesota has a long and complex history as relates to agricultural subsurface drainage; that there are significant regional differences related to hydrogeology and groundwater provinces within the state, with differing implications for how drainage may impact groundwater resources; and that there are significant knowledge gaps regarding the extent and configuration of agricultural subsurface drainage, our understanding of local and regional water budgets and groundwater flow, and therefore potential implications of drainage for underlying

groundwater resources. Closing these gaps would go a long way towards enabling sustainable management of groundwater resources.

Geologic Influence on Stream Temperature and Implications for Future Trout Habitat

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Abstract

The Marengo River headwaters in the Chequamegon-Nicolet National Forest in northern Wisconsin have historically supported populations of brook trout and brown trout. Groundwater influx to the stream provides cool water refuges suitable for trout habitat. However, climate change forecasts make the future of the trout habitat uncertain. We use field measurements and models of groundwater flow and stream temperature to evaluate how climatic changes are likely to impact groundwater discharge and stream temperatures during summer low flow conditions in the Marengo headwaters.

Variations in groundwater discharge and stream temperature in the watershed correlate with the highly varied geology. Cool tributaries, with consistent flow around 10°C, correspond with likely groundwater discharge areas in glacial sand deposits and along bedrock faults and bedding planes. These stream segments also have physical characteristics that keep streams cool: narrow widths, shade, and high gradients. The warmest stream segments, common in flat wetland areas with shallow crystalline bedrock, reach temperatures upwards of 30°C, well above the lethal threshold for trout. We are using groundwater flow and stream temperature models to evaluate the sensitivity of stream temperature to physical characteristics like shade and width, as well as climatic changes in baseflow and air temperature. Impacts to groundwater are simulated by modifying recharge in a steady-state groundwater flow model. Initial results suggest that the upper reaches of the watershed are most sensitive to changes in recharge. Simulated groundwater flows and climate change models of air temperature will be incorporated into a one-dimensional stream temperature network model to further evaluate sensitivity. An improved understanding of stream sensitivity will help the U.S. Forest Service manage the watershed for trout.

Soil Characteristics and Groundwater Supply in Little Rock Creek Watershed Area

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Abstract

This research focuses on the soil characteristics, groundwater supply, and watershed in the Little Rock Creek area. The original aim was to collect data on soil properties to better understand infiltration in the watershed. The recent impairment of the creek has led to research on the water quality and quantity within the Anoka Sand-Plain aquifer. Sustainability of the aquifer is critical for the citizens that rely on it for irrigation. The results are based on data and samples from two 1 meter deep soil profiles. Each profile exhibits 3 distinct horizons. The Ap horizon is 0.28 meters thick, the Bt1 horizon is 0.33 meters thick, the Bt2 horizon is 0.18 meters thick. The soil is all categorized as sand based on hydrometer tests. The percentage of clay decreases with depth while the amount of silt increases with depth. The particle size ranges from medium to fine sand. Infiltration tests were not conducted because of heavy precipitation and all calculations are done based on grain size distribution. The low percentage of clay in all horizons along with a high porosity suggests that the infiltration rate is high which reduces the water retention.

Synthesis of Geothermal Borehole Results at Carleton College: A Hydrogeological Perspective

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Abstract

Ground source heat pumps are an becoming an increasingly popular alternative to conventional systems, exchanging energy to provide a sustainable source of heat and cooling to population centers such as at Carleton College. Several geologic factors influence the performance of geothermal fields, including thermal properties, groundwater movement, and temperature. While the stratigraphic sequence across the Carleton College campus is generally consistent, localized divergence from the assumed homogeneity of underlying rock units, such as karstic features within the Prairie du Chien aquifer, cause discrepancies that affect groundwater flow. Geophysical logs, formation thermal test results, and drill cuttings provide a detailed basis of thermodynamic properties of geologic formations to provide an overall foundation for future hydrogeologic studies of Carleton College geothermal fields.

Evidence of Anthropogenic Contamination in Till Aquitards at the Hydrogeology Field Camp and Olivia Sites in Minnesota

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Abstract

As part of a study of confined aquifer sustainability, the U.S. Geological Survey, Iowa State University, and Minnesota agencies have investigated vertical leakage through till aquitards deposited by glacial advances in Minnesota. Although estimating leakage involves assessment of aquitard hydraulic properties, previous studies show that groundwater geochemistry data in till aquitards can corroborate estimated vertical travel times. In Phase II (2017) of the study, a rotary-sonic rig was used to install 12 small-diameter piezometers in nests at Olivia (depths from 13 to 175 ft) and at the MN Hydrogeology Field Camp (HFC; depths from 115 to 200 ft) near Akeley. Hydraulic data at both sites suggest that groundwater flow is vertically downward. Geometric mean hydraulic conductivity (K) values were 7E-03 ft/d in till at Olivia and 5E-02 ft/d in till at HFC. Vertical profiles of major anions and Piper and Stiff plots show anomalous Cl, Na, and O_2 concentrations suggestive of contamination. Examples include: 1) Na-HCO_3 type water; 2) high Cl/Br ratios in groundwater not duplicated in pore water; 3) above-background Cl concentrations in groundwater older than the 1963 tritium bomb peak; and 4) presence of dissolved O_2 in groundwater with dissolved Fe^{2+} concentrations up to 1.84 mg/L. Studies elsewhere have suggested a decline in contaminants connected to drilling activities and a return to the pre-drilling groundwater geochemistry after two years. To verify the original geochemical data, we plan to resample the groundwater at both sites in spring 2019 and compare the results statistically to the 2017 samples.

An Integrated Framework for Quantifying Scale-Dependent Groundwater Flow and Solute Transport in Fractured Till Using Field Data and Numerical Modeling

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Abstract

Previous work characterizing till in Iowa has identified the extensive fracture networks that can reach depths of 30 m. Preferential flow in those fractures can result in groundwater velocities that are 1-4 orders of magnitude higher than those in the matrix and facilitate rapid advective transport. The effects of till fractures have been quantified by column tracer tests in the laboratory, but their effects on flow and transport at larger scales (e.g., field, watershed) are unknown, primarily due to the lack of data on fracture properties and a computationally-feasible method for including fractures in large-scale models. This research provides a methodology to address this problem and allow fractures to be incorporated into models at larger scales. Field fracture measurements, quantification of the Representative Elementary Volume, development of a hydraulic conductivity (K) tensor estimation program (FracKFinder) and numerical modeling with the dual-continuum (D-C) model in HydroGeoSphere (HGS) were used to characterize the hydraulic properties of the matrix and fractures of the late Wisconsin Dows Formation till in central Iowa.

Science Education Inclusion Strategies for Students with Cerebral Palsy and Autism Spectrum Disorder

Katherine Hickman, Atmospheric & Hydrologic Sciences Department, Saint Cloud State University

Abstract

Students with disabilities are becoming rapidly included in general education and are expected to understand core content, including science. This study focuses on Cerebral Palsy (CP) and Autism Spectrum Disorder (ASD), the development of scientific thinking, literacy, and content knowledge. These are all topics emphasized in current legislation along with the Next Generation Science Standards (NGSS). Participating in science class is often a challenge for students with CP or ASD, given difficulties with academic language, communication, or overall physical skills. A lack of resources for adaptations for inclusion strategies in the field of science education creates a sizeable learning gap. This study reviews labs from three different courses in the Atmospheric and Hydrologic Sciences Department at Saint Cloud State University. It highlights inclusion weaknesses and suggests different methods for improvement. The methods include introducing variations in style and format of instruction, differentiated instruction and Universal Design for Learning, as well as the use of communication and physical limitation devices that can improve lab performances for students with CP and ASD. The included methods can be modified for any general science classroom.

Isn’t the water level supposed to go down? Poroelastic Effects in Northwestern Minnesota

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Abstract

Unexpected water level changes were observed during an aquifer test conducted in Northwestern Minnesota. The unconsolidated glacial aquifer system consisted of multiple confined aquifers separated by clay till aquitards. Water levels were monitored in two observation wells; one well in the pumped aquifer and the other in a shallower aquifer. The unexpected water level changes occurred at the beginning and end of the pumping phase in the shallow confined aquifer. Water levels rose when the pump started and then began to decrease. Conversely when the pump stopped, water levels dropped and then rose. These unexpected water level changes were found to be due to poroelastic effects that result from the three-dimensional deformation of the aquifer system; the solids within porous media deform due to fluid flow.

Care must be taken when analyzing these datasets as this deformation can impact calculations of transmissivity and storativity. Poroelastic effects are often ignored as they are small and occur over a short timeframe. In this case, water level changes were pronounced. Following a recent paper, a multilayered leaky confined analytical solution was fit to the drawdown data after poroelastic effects had dissipated (after early time). This solution was found to fit both the pumped and shallower confined aquifer responses showing that when deformation-induced effects are observed and accounted for, hydraulic parameters can be estimated using traditional groundwater theory.

Numerical Modeling of Convective Heat Transfer for the Ground Source Heat Pump System at Carleton College

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Abstract

This study investigates the thermal impact of groundwater flow on the borehole field of Ground Source Heat Pump (GSHP) system during cooling cycles. To simulate the temperature distribution in a borehole field at various depths, a series of 2D finite-element forward models are constructed based on the advection-diffusion equation. The forward models are then used to assess the temperature distributions underneath the Bald Spot at Carleton College, where a GSHP system has been recently installed. Preliminary results have shown that, differential thermal and hydraulic properties of near flat-lying formations will result in varied thermal responses at various depths underneath the Bald Spot. Counterintuitively, slow groundwater flow may result in a borehole field that is hotter than without groundwater, rendering the borehole field less efficient as a heat exchanger. Fast groundwater flow undoubtedly makes the borehole field cooler than without groundwater. The correlation between groundwater velocity and borehole field temperature is therefore nonlinear. The direction of groundwater flow relative to the geometric configuration of the borehole array may significantly control the threshold groundwater velocity needed to increase the efficiency of the borehole array. The simulation results indicate that it is unlikely to detect temperature disturbance in water bodies near the Bald Spot. This study demonstrates that 2D numerical modeling can give insight into the temperature distribution in the GSHP borehole field underneath the Bald Spot. Subsurface temperature distributions can, in turn, be used as a proxy for inferring the performance of the system.