Poster Abstracts

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Relationships between Organic Matter and Mercury in an Ombotrophic Bog

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Recently, studies have shown that dissolved organic matter (DOM) export out of northern wetlands has been increasing, which suggests that toxic metal exports may also be increasing. For example, DOM is known to bind to mercury (Hg) and is a key component controlling metal transport in wetland groundwater. However, the complex and largely unknown character of DOM prevents the construction of reliable models to predict export of toxic metals from wetlands. In this study, relationships between DOM and Hg were examined in the groundwater of the S2 wetland in the Marcell Experimental Forest. This study used various sampling locations in S2 to further understand the complex relationship between and transport of DOM and trace metals. Hg has a high affinity for soil carbon, and higher concentrations of Hg were observed in the subsurface runoff than the weir and lagg porewaters, indicating different binding affinities for soil and/or dissolved organic carbon. This study highlights the complex nature of Hg-DOM interactions and insights that can be gained about the S2 wetland system.

Electrical Resistivity Investigation of Three Agricultural Fields, Fillmore County, Minnesota

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Karst topography and thin soils dominate the landscape of Southeastern Minnesota (SEMN). Agriculture is the predominant land use and presents a unique challenge in controlling agricultural runoff, including nutrients. The karst hydrology of the region provides a shorter path to the susceptible ground and surface water resources through conduits and fractures. This study will contribute to a larger study monitoring the surface, ground and soil water quality to examine the effectiveness of BMPs in the region. This study includes a series electrical resistivity (ERI) surveys that were conducted at three different agricultural fields in SEMN to identify subsurface features that may be affected by accelerated soil and groundwater movement. This project also aims to evaluate the effectiveness of agricultural best management practices (BMP). Subsurface features within the Driftless Area of SEMN are complex and may vary both regionally and locally within the field areas. Compiled ERI images show many of the subsurface features in active karst landscapes are found in the bedrock as enlarged vertical to sub-

vertical fractures rather than enclosed conduits, though both are present. The karst hydrology of the area is likely to yield a lower than expected surface runoff at the gauging station of the study site. The ERI surveys performed in the field areas show that merging the data of the Dipole-Dipole and the Wenner arrays provide the highest resolution, but may not be necessary to identify subsurface features important to the study including fractures, conduits, and soil depth. Results show the Dipole-Dipole array may be more beneficial when trying to constrain vertically oriented features such as enlarged fractures and conduits. Wenner arrays appear to be more useful in constraining the horizontally oriented features, bedding of bedrock and soil depth.

Application of the Generating Analytic Element Approach to Transient Groundwater Modeling in Leaky Aquifer Systems

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We present an application of the Generating Analytic Element Method, (GAEA) introduced by O.D.L. Strack [2009] through modeling: (1) a well with a cosine periodic discharge rate, (2) a well with an exponential based initial step discharge, and (3) a well with a discharge composed of the combination of the first two models. The exponential based initial step discharge, or soft-step used in the second and third applications has been devised to model a well that is turned on at time zero and smoothly increases to the desired discharge rate by use of the exponential function.
The results of application (1), the cosine periodic discharge well, will be compared to those previously published by M. Bakker [2004] using Bessel functions. Similarly, the results for application (2), the soft-step discharge well, will be recreated from results obtained by O.D.L. Strack and R. Barnes [2008] using the same application of the Generating Analytic Element Approach. The final application (3), the combined soft-step and cosine periodic discharge well, is new and offers an expansion to previously published solutions, which require that the discharge representation be consistent in time, by adding the initial behavior of the soft-step function to represent the well being turned on.

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Surface Water-Groundwater Interaction, Groundwater Residence Time, and Anthropogenic Geochemical Signatures in the Chisago Lakes Area, Chisago County, Minnesota, USA

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Preliminary results of the Minnesota Department of Natural Resources (MnDNR) Chisago County Geologic Atlas Part B document the interaction of lake and groundwater in southeastern Chisago County and the movement of recent waters to depths exceeding 200 feet below ground surface. The groundwater flow system of Chisago County, Minnesota was investigated using the geologic framework

developed for Part A of the Chisago County Geologic Atlas published by the Minnesota Geological Survey and the results of water chemistry samples collected for this study by the MnDNR and by other agencies. Stable isotope data from 107 wells, 5 springs, and 25 surface water samples collected county wide suggests that surface waters in the Chisago Lakes area are a source of recharge to the groundwater system. Groundwater samples in Chisago County with lake water isotopic signatures ranging from 50% to 100% of the maximum evaporative signature were all collected from wells located in, or east/southeast, of the Chisago Lakes region. The Chisago Lakes region is underlain by a sequence of multiple buried sand and gravel aquifers. The till units in this area are high in sand content, permitting groundwater movement from upper to lower aquifers. Equipotential contours derived from static water levels show downward and easterly groundwater flow in this vicinity. Tritium samples collected in the vicinity show that "recent" age water, water that infiltrated the land surface since 1953, has migrated through the sequence of aquifers and till units into the underlying Tunnel City group. Slightly elevated chloride and chloride to bromide ratios in these aquifers are consistent with recent-aged anthropogenically influenced waters. Transmissive till units coupled with steep groundwater gradients, possibly from high volume pumping of nearby municipal waterworks wells, appears to be bringing recent waters to depths not seen elsewhere in the county.

Interaction of Groundwater and Surface Water in the Williston and Powder River Structural Basins

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Groundwater availability in the Lower Tertiary and Upper Cretaceous aquifer systems in the Williston and Powder River structural basins is currently being assessed by the U.S. Geological Survey (USGS). The Williston basin is located in parts of North Dakota, South Dakota, and Montana in the United States and Manitoba and Saskatchewan in Canada. The Powder River basin is located in parts of Montana and Wyoming. Both structural basins are in the forefront of energy development, with an increased demand for both surface water and groundwater uses. As part of this study, the interaction between groundwater and surface water is being quantified. Estimates of base flow, gaining streams, sinking streams, and reservoir interactions have all been computed. Streamflow records from more than 300 streamgages available in the USGS National Water Information System database were used in conjunction with the hydrograph separation software, PART, developed by the USGS. To eliminate interference from natural and anthropogenic processes associated with measuring streamflow, only fall estimates of base flow were used in the study. A net balance approach was used along stream reaches where streamgages were located. Base-flow estimates from PART were compared to actual streamflow measurements. The streamflow estimates were used in the final quantification of the interactions. A water budget for each mainstem reservoir along the Missouri River was completed using data from the U.S. Army Corps of Engineers. Most of the streams in the study area are gaining flow from the aquifers, whereas the main-stem reservoirs are recharging or contributing water to the underlying aquifers.

Human Enteric Viruses in the Ames Aquifer: Induced River Infiltration or Leaky Sewers?

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Recent epidemiological studies suggest that groundwater containing human enteric viruses can affect human health. In this study, we hypothesized that human enteric viruses enter the Ames aquifer by induced infiltration from the South Skunk River (SSR) and move in groundwater through the alluvial/buried valley aquifer (Ames aquifer) to the Downtown well field. Previous field studies and groundwater modeling have suggested that the area of River Valley Park hosts a losing reach of the SSR caused by pumping in the Downtown well field. To test this hypothesis, we used enteric viruses, stable isotopes, and temperature, as tracers of groundwater flow in the aquifers. Piezometers adjacent to the river at depths from 14 to 42 ft below ground surface indicate temperature and stable isotope fluctuations, mirroring the adjacent surface water and suggesting a hydraulic connection. Seven virus sampling events, from eight piezometers/wells along the flow path, were conducted between October 2011 and October 2012. Composite 24-hour sewage samples were also taken twice during the period from the Ames Wastewater Treatment Plant to investigate the possibility of virus transport from leaky sewers adjacent to the sampling sites. A total of 52 samples were analyzed for a suite of viruses by fluorescence-based, reverse-transcription quantitative polymerase chain reaction (RT-qPCR) in the Marshfield, Wisconsin USDA-ARS laboratory. Of the 50 water samples collected, 19 (38%) were positive for enteric viruses. Viruses detected included Adenovirus, Enterovirus, and Hepatitis E. Adenovirus and Hepatitis E were then subjected to sequencing analysis to identify their Serotypes. Results from qPCR and sequencing analyses showed that although Adenovirus Serotype 31 appears in both river and sewage samples, Hepatitis E was only found in the river and not in the sewage. Furthermore, the Hepatitis E is of swine origin, consistent with upstream activities in the SSR (and inconsistent with human sewage). Because the locations of virus detections in groundwater are also consistent with estimated groundwater travel times of two years from the river, we conclude that human (and swine) enteric viruses originate from the SSR and are transported by groundwater to the Downtown well field.

Calibrating Modified Philip Pump Dunne Infiltrometer

Farzana Ahmed

The modified Philip Dunne (MPD) Infiltrometer is a new technique to estimate the saturated hydraulic conductivity (K_{sat}) of the soil surface and the soil suction (ψ) of the wetting front. The advantage to this infiltrometer is that multiple infiltration measurements can be taken simultaneously, determining and ultimately reducing the uncertainty of measurement. The MPD infiltrometer has been calibrated by solving Richards equation with the infiltrometer in place for known K_{sat} and ψ, determining the falling head over time, putting the head versus time results into the MPD software, and calculating K_{sat} and ψ with the software. A calibration coefficient (β) was determined to be close to 1 for both for uniform soil and layered soil. In this presentation the application of calibration coefficient and MPD infiltrometer will be discussed.

Groundwater/Surface Water Exchange: Hydraulic Gradient Mapping Along a Shallow Lake Bottom

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This study in progress documents temporal and spatial change in hydraulic gradient (HG) across a shallow lake bottom during an extended drought. The lake is in the north central, Minnesota region, located down-gradient of a USGS research field station (since '83) where a terrestrial crude oil spill took place. Hence, a secondary goal is to help create a more complete picture of the potential impact of surface water contamination.
Piezometers, or two or more wells with openings at different depths, are used, and designed to facilitate the calculation of HG at various lake water depths. The result is determination of net upward or downward flow into/out of the lake (positive: upward and negative: downward). Approximately 48 piezometer data-points are used, each with both a deep and a shallow tube made of ½ inch PVC. Transect and grid-pattern deployments are used to produce greater coverage, and a "high-data-density" area on a portion of the lake is used to create interpolations of the HG conditions for that area using GIS. Results tend to agree with our current understanding. The west side of the lake has more positive HG on average, and receives localized groundwater discharge. The lake mud layer shows magnitudes as low as -0.218, while the overall average for all points is -0.011— consistent with the dramatic lake stage decrease, and evaporative conditions. Considerable spatial heterogeneity, and varying degrees of response to precipitation appear to effect the interpolated area. In conclusion, this study works to further the understanding of groundwater/surface water exchange in surface water bodies as a factor of climate and time, and will provide insight into proper management of shallow lakes in drought conditions.

Customized and Standard Investigation Techniques Were Implemented to Define the Source of Contaminants within a Capped Landfill and the Extent and Magnitude of the Groundwater Plume

Gary Gilbert

Additional investigation and possible Corrective Action (CA) measures appeared warranted as a result of volatile organic compounds (VOC) concentrations exceeding regulatory standards in groundwater at the property lines of a County owned landfill in central Minnesota. It appeared that the potential source area of the VOC originated from a 23 acre unlined section of the landfill. Landfill records indicate that a significant volume of paint waste may have been disposed of within the unlined section of the landfill from between 1970 to 1980. The unlined section was capped from 1989 to 1995.
Preliminary CA discussions involved complete excavation of the waste material within the unlined section and relocating it to a lined section of the landfill. Initial cost estimates ranged from 3 to 4 million dollars to complete the relocation of the waste. The relocation plan would possibly be coupled with additional groundwater remediation techniques to address VOC in the groundwater on and downgradient of the landfill property. Based on review of available project information, the size of the unlined area, and the cost associated with the relocation process, it appeared that the most cost-effective approach would be to determine the location of the VOC within the unlined section of the

landfill, and to fully define the horizontal and vertical extent and magnitude of the VOC groundwater plume.

The source area investigation, which was mainly completed within the unlined section of the landfill involved collecting air samples from existing vertical vents using active gas sampling equipment, and completing soil borings to collect soil and ground water samples using mud rotary, hollow stem auger, and geoprobe sampling techniques. The primary goal of this work was to identify any main areas of contamination or "hot spots" of VOC concentrations within the old scale/paint storage area, landfill waste material, soil between the bottom of the landfill waste material and top of water table, and on the water table directly beneath the landfill waste material.

The downgradient investigation involved completing 25 Rotosonic Borings (RS) over a 3 year period. Representative in-situ groundwater samples were collected at 5 foot vertical intervals from each RS boring and analyzed on-site by a mobile lab. The aquifer was semi-confined, non-homogenous and ranged in thickness from approximately 90 feet near the source area to approximately 20 feet near the leading edge of the plume. The goal of the RS borings was to determine the hydrogeologic characteristics and to geochemically profile the VOC groundwater plume vertically as well as horizontally downgradient from the landfill.

A summary of the investigation is as follows:

- There were two main areas of waste material identified within the unlined section of the landfill that contained elevated concentrations of VOC.
- There were relatively low concentrations of VOC on the water table beneath the unlined section.
- The highest levels of VOC detected within the groundwater had migrated away from the landfill and was currently approximately 2,000 feet downgradient.
- The leading edge of the VOC groundwater plume had migrated approximately 1 mile from the landfill.
- The results of the work allowed the owner to obtain a new permit in 2011 without having to dig up and relocate the waste material from the unlined section.
- Twelve additional groundwater monitoring wells (MW) can now be installed in the proper locations to monitor and track VOC concentrations over time.

The success of the project was driven by a cooperative effort between the regulators, the owner, and consultant. The project required meticulous planning, data collection and effective regulatory communications during dynamic conditions to expedite the project in a cost-effective manner.

Evidence for the Natural Attenuation of PAH

Acenaphthalene: the Last PAH Standing

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PAH compounds are biodegradable, and several researchers have published the mechanisms, rates, and other details of PAH biodegradation in groundwater (Fraser, et al. 2008, Zamfirescu and Grathwohl, 2001). The researchers have shown that aerobic degradation removes most of the lighter, two-ring and three-ring PAH compounds. Heavier PAH compounds, especially carcinogenic PAH, are more generally resistant to biodegradation and are less mobile in the environment.

The pattern of groundwater PAH concentrations at the Reilly Site is similar to the biodegradation pattern described in the literature. This is illustrated by naphthalene and acenaphthene concentrations in groundwater samples. Near the source areas at the Reilly Site, naphthalene is the dominant PAH compound found in the groundwater and is the primary energy (food) source for biodegrading

microorganisms. The mass of acenaphthene becomes greater than the mass of other PAH compounds downgradient from the source due to acenaphthene's relative resistance to biodegradation compared to naphthalene, and its greater mobility compared to heavier PAH compounds.

Isoconcentration maps and other data presentations illustrate that acenaphthene represents 80% or more of the total PAH present in groundwater samples collected downgradient from the Reilly Site.

Adsorption of Food Color with Kaolin, Bentonite, Egg Shells, and Activated Carbon

Nichole Lowey, Christina Schultz, Jaryd Marks

Conventional remediation technologies for removal of pollutants are not economical and are, often, associated with production of toxic sludge. Low-cost adsorbents could replace the conventional remediation technologies in the removal of pollutants from waters and wastewaters. Adsorption is also an important environmental and industrial process. Parameters such as pH, concentrations of adsorbent and adsorbate, contact time affect the adsorption; we used Langmuir isotherm to analyze experimental data and to compare four adsorbents: activated carbon, bentonite, kaolin, and egg shells. Adsorption of yellow, blue, and red food coloring on the adsorbents was studied at different pH and ionic strength and also in presence and absence of detergent (SDS) and biopolymer (xanthan). Bentonite and activated carbon adsorb more dyes than egg shell and kaolin. This project was made possible through funding by Minnesota Space Grant Consortium and Center for Environmental, Earth, and Space Studies.

Photo-Catalytic Degradation of Blue Food Color with Nano-TiO_2/Magnetite

Alexandra Miller, Nichole Lowery, and Christina Shultz

Faculty sponsor: Dr. D. Bilanovic

Photo-catalytic degradation of organic compounds is an expanding technology in wastewater and water treatment industries. Literature review shows that various materials were tested as photo-catalysts; in this study we used locally made nano-size TiO_2/magnetite particles to degrade blue food coloring (BFC). The rate of BFC degradation was determined under both visible and UV light; the experiments were conducted at five concentrations of TiO_2, four BFC concentrations, with and without pH control. This project was made possible through funding by Minnesota Space Grant Consortium and Center for Environmental, Earth, and Space Studies.

Investigating peak flow effects of tile drainage in the Beaver Creek watershed using a physically based, coupled, surface water/groundwater model

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Recent large-scale flood events in Iowa demonstrate a need to understand how drainage alteration, specifically through tile drainage and ditches related to intensive agriculture, affect peak flow events and streamflow hydrology. We are investigating these relationships in the South Fork watershed in north-central Iowa using the physically based, coupled surface water/groundwater model, HydroGeoSphere. The goal of this research is to describe, through modeling of the watershed pre- and post-alteration of drainage, how the hydrologic behavior of the South Fork watershed has been altered by drainage systems. The South Fork watershed (78,000 ha) was chosen for this research due to its lengthy and ongoing data record (15+ years) and its extensive subsurface tile drainage (80%). The

HydroGeoSphere model represents all flow partitioning mechanisms, and will quantify spatial and temporal heterogeneous water fluxes by simultaneously solving flow equations and calculating exchanged fluxes in surface, tile drain, and groundwater flow pathways. In addition to more standard calibration techniques (i.e., hydraulic head, streamflow), stable isotopes of water (δ^2H and $\delta^{18}O$) will be used to estimate the contributions of tile drainage and groundwater to streamflow under varying flow conditions. Contributions to peak flow by tile drainage will be estimated by hydrograph separation using the simulated hydrographs produced by the model. Models are being constructed for two subwatersheds of the South Fork watershed, one of which is the Beaver Creek subwatershed (18,200 ha) that is highlighted in this presentation. The predominant surficial material is till of the Dows Formation of late Wisconsinan age. Subsurface geologic data from well logs and coreholes are being compiled, along with hydrologic parameters and data from previous research in the watershed. The results of this research will help guide water resource and land management practices and may suggest potential control measures for future peak flow events.

A Multilevel Monitoring System Provides New Insights into a Bedrock Aquitard in Southeastern Minnesota

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Aquitards are an important control on recharge and contaminant transport, yet are relatively poorly understood compared to aquifers, particularly in fractured rock such as that of the Cambrian St. Lawrence bedrock aquitard of southeastern Minnesota. To better understand the properties of bedrock aquitards, we initiated a project that included the construction of a multilevel system (MLS) with numerous ports for monitoring a borehole that spans the St Lawrence Formation in the eastern Twin Cities Metropolitan Area.

The open borehole penetrated about 100 ft of bedrock and ambient flow conditions prior to MLS installation were dominated by strong downflow (~60 gal/min) from the lower Jordan Sandstone to the upper Tunnel City Group, bypassing the intervening St Lawrence Formation. Information from an extensive suite of borehole geophysical logs and packer tests guided construction of the MLS, which includes 14 ports for discrete interval fluid pressure measurements and water sampling, and six ports for higher capacity pumping. Hydraulic head measurements collected since installation of the MLS in November, 2012 reveal that a head difference of ~50 ft between the top and bottom of the open hole is mostly expressed as distinct, large deflections across four thin (<10ft) intervals in the lower Jordan Sandstone and St Lawrence Formations. Meyer et al. (2008) documented similarly abrupt shifts in the Paleozoic bedrock of Wisconsin, and suggested they may reflect poor vertical connectivity of fracture sets in adjacent geomechanical and (by definition) hydrogeologic units. Our outcrop observations of fractures in bedrock of southeastern Minnesota are consistent with such an interpretation: vertical fractures commonly are stratabound within discrete mechanical units. Analysis of water chemistry from our Minnesota MLS is ongoing, but initial results show variability between units defined by head deflections. Additionally, there is some evidence that water from discrete fractures may differ in some chemical parameters from water sampled largely from matrix.