Minnesota Ground Water Association
www.mgwa.org

Newsletter

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MGWA President Kelton Barr

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President's Letter

This year marks the 30th anniversary of the Minnesota Ground Water Association. Having been part of the formation of the MGWA, I join the other founders in being amazed and impressed with how the organization has persevered and grown in these three decades. The newsletter has become a major means of disseminating information on new studies, new laws and regulations, and news about our groundwater community. Equally important, our spring and fall conferences are prominent forums for in-depth exploration of many aspects of groundwater science, practice, and policy.

In part because of these conferences, we have seen the science of groundwater mature, going beyond textbook generalizations and delving into the complexities of our state's resources and terrains. In turn, groundwater management has become more nuanced, recognizing more fully its interconnection with surface water resources and ecology and addressing sustainability issues.

Our 2012 conferences will continue these traditions. Our spring conference will be held on Thursday, April 19th with the theme of "Conduits, Karst, and Contamination: Addressing Groundwater Challenges". The conference includes a variety of talks on recent advances in groundwater hydrology, quality, and interconnections. As we expand the poster portion of the conference, we are looking to you for posters on your research or projects pertaining to Minnesota groundwater. This spring the poster session will include several posters on possible changes in the nomenclature of our aquifers, aquitards, and aquitardifers. Look for details about the spring conference on the MGWA website and make your plans to attend!

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MGWA Member Assists Bolivian Cooperativas with Watershed Management

By Jeff Green

Background

This past summer, I had another opportunity to return to Bolivia to work with the local water boards (cooperativas) on watershed management and flow measurement. I previously traveled to Bolivia in 2003 and 2007 to work on similar projects. The MGWA Newsletter published an article about those trips in a previous issue (March 2008). For the most recent trip, I went at the request of LATCOM, a small mission agency that has been working in the country since the 1950s. LATCOM works in partnership with a Bolivian mission organization called EPLABOL, which focuses on leadership and ethics training. EPLABOL operates a retreat center/camp, called Monte Blanco. The purpose of my trip was to develop the water supply for the Monte Blanco retreat center/camp, which is located at the site the former New Tribes Mission School, Tambo.

The Monte Blanco retreat center/camp is located in the foothills of the Andes Mountains.

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— A water supply tank in the San Isidro valley. 'Sin Agua No Hay Vida' means there is no life without water.

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MGWA Web Page

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Newsletter Deadlines

Issue	Due to Editor
June '12	05/04/12
September '12	08/03/12
December '12	11/04/12
March '13	02/01/13

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MEMBER NEWS

Joy Loughry Joins MDH's Drinking Water Protection Program

Joy Loughry recently joined the Minnesota Department of Health (MDH) as a Hydrogeologist in the Drinking Water Protection Section. She is part of a team of planners and hydrogeologists in the Source Water Protection Unit who work with public water suppliers to implement wellhead protection.

Sheila Grow Retires

Sheila Grow started her career as a hydrologist with the MPCA in 1986 after getting her master's degree in geology from the University of Minnesota. In ancient history, she was a stay-at-home mother of two daughters and a former elementary school teacher. Her husband was a sports writer and columnist for the StarTribune and is currently writing for MinnPost. Sheila feels privileged to have worked with the MPCA, MDA, a private consulting firm, and for the last 14 years, for the MDH. As president, president-elect, and past-president, of the MGWA in the early 90's, she worked with Gordie Hess, Bruce Olsen, Bob Beltrame, Larry Johnson, Jennie Leete, Jan Falteisek, Susan Price, Rita O'Connell (all with MGWA), and Mike Convery (president, AIPG) to plan professional conferences and field trips. Sheila feels the hardest part of retiring will be not sharing in the good work state employees provide for the state and missing her coworkers. She looks forward to traveling with her husband to visit friends and families of both daughters, biking, birding, improving her Spanish language skills, gardening, and babysitting twin grandsons in Seattle – and, of course, attending future MGWA conferences.

Christopher Thompson Joins Braun Intertec

Braun Intertec recently announced that MGWA member Christopher Thompson, PE, has joined the firm as a Principal Engineer.

Thompson has 30 years of experience in assessment, alternative analysis, design, permitting, planning, and construction management for the remedial actions and engineered controls associated with contaminated soil, soil vapor, groundwater, surface water, process water, and industrial air emissions. Thompson's duties at Braun Intertec will involve business development, management, and design for projects throughout Minnesota and across the country. Thompson holds Bachelors and Masters degrees in Engineering from the University of Minnesota Institute of Technology.

New Association Officers Elected

Robert Tipping is the newly-elected President-Elect of the MGWA for 2012. Bob is a Senior Scientist at the Minnesota Geological Survey.

Julie Ekman is the newly elected MGWA Secretary. Julie supervises the Water Permits Programs unit in the DNR Division of Ecological and Water Resources.

Next time you see Bob or Julie, congratulate them and thank them for their service to the organization!

FEATURE ARTICLE

Bolivian Watershed Management Assistance, cont.

The area receives about 12-16 inches of rainfall each year. The bedrock here is well-cemented sandstone that was uplifted by the rise of the mountains over the last 70 million years. The San Isidro and the Comarapa Rivers cut through the foothills, creating plains that are used for irrigated agriculture.

The camp historically used the San Isidro River for their water supply. Even though the water was treated, there were still concerns about pesticide contamination and pathogens in the drinking water. We hoped to find a place where a well could be drilled. Any well needed to be relatively productive, since the camp has groups of up to 300 people each week. We concluded in 2007 that groundwater resources were not suitable for a water supply since it is slightly saline and unfit for human consumption.

We determined in 2007 that the best option for Monte Blanco is to work cooperatively with the local water board as they provide clean water to the village of San Isidro and the surrounding area. The village currently gets its water from the river. Their plan is to build a new pipeline to obtain water closer to the river's source, which is upstream of the areas that contribute bacteria, sediment, and pesticides. This water would still need to be treated, but it would be simpler and cheaper.

Preparation

My work priorities in 2011 were set during a meeting with local Bolivian water boards in 2007. The San Isidro and Comarapa Water Boards are responsible for water supply to the local towns in this part of the country. During our meeting, we discussed their water supply and water management issues, their water management needs, and offered our assistance. By the end of the meeting, it became clear that river and watershed management were areas that could use my assistance. We also developed a plan to assist the water boards with streamflow measurements and construct gauging stations in 2011. I also planned to investigate simple water treatment options for the rural people. After much discussion with LATCOM staff, we decided to plan our return trip for late summer 2011.

The upper reaches of the San Isidro River as it cuts through the foothills. Note the farm fields that are irrigated with river water.

I also took a small team from my church to work with the staff at Monte Blanco and assist them with other construction projects. The global economic meltdown did not spare Bolivia. EPLABOL had serious financial issues since our last trip which meant that a lot of maintenance and repair at Monte Blanco was not completed.

You need to have stream gauging equipment in order to measure river flow! I needed a current meter, a counter, a wading rod, and gauge plates. I hoped to find a company that would donate the needed equipment. The first company I called could not donate anything, but did offer free rental. However, the problem with renting is that I would be billed if the equipment did not come back! In a third world country such as Bolivia, there are no guarantees that any equipment will return with you. I then contacted the Rickly Hydrological Company of Columbus, Ohio. This company is a leading manufacturer of stream gauging equipment and supplies the USGS. I spoke with Mike Rickly and, after an amazingly short conversation, he agreed to donate a Price AA current meter, a CMD (current meter digitizer, to count the current meter revolutions and provide a velocity reading), a wading rod, and six gauge plates. It was a wonderful blessing to receive this equipment.

I also hoped to sample the San Isidro River to determine the pesticide concentrations during this

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The primary objectives of the MGWA are:

- Promote and encourage scientific and public policy aspects of ground water as an information provider.
- Protect public health and safety through continuing education for ground water professionals;
- Establish a common forum for scientists, engineers, planners, educators, attorneys, and other persons concerned with ground water;
- Educate the general public regarding ground water resources; and
- Disseminate information on ground water.

MGWA's Corporate Members for 2011

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Links at www.mgwa.org

Abbreviations and Acronyms

- ASTM – American Society for Testing and Materials
- DNR – Minnesota Department of Natural Resources
- MDA – Minnesota Department of Agriculture
- MDH – Minnesota Department of Health
- MGS – Minnesota Geological Survey
- MPCA – Minnesota Pollution Control Agency
- USEPA or EPA – United States Environmental Protection Agency
- USGS – United States Geological Survey

FEATURE ARTICLE

Bolivian Watershed Management Assistance, cont.

year. I met Jerry Balbach of Minnesota Valley Testing Laboratories from New Ulm, Minnesota to discuss my work in Bolivia. Jerry offered to donate free pesticide analysis of the river water samples that I would bring back with me. This also was a real blessing as it would allow us to begin to get a better handle on river water quality.

In-Country

It takes a long time to travel from Minnesota to Monte Blanco. To get to Monte Blanco you fly from Minnesota to Miami and then on to Santa Cruz, Bolivia. We left Rochester at 0230 and arrived in Santa Cruz at 2330. Two days later, we left Santa Cruz and had a 6 hour bus ride to the camp.

The day after we got there, we met with the head of the San Isidro water board. He said our timing was perfect as he needed a flow measurement far up-river. They were working on extending their pipeline into a headwater tributary in the cloud forest. The national government had told them they could only take 19% of the river's flow so they needed a measurement for an up-coming meeting.

A group of six of us (three Americans and three Bolivians) drove to the end of the road through the foothills. We then hiked through the cloud forest a half-hour up-river to the tributary. We had to stay together as there were reports of pumas in the area attacking both cattle and people. I was able to get a flow measurement of 25 cubic feet per second which meant they had plenty of water. We left just as darkness and rain were setting in. Unfortunately, the San Isidro River rose quickly once it started to rain in the cloud forest. Over the next ten days, I was only able to get a few more measurements in the lower reaches of the river. We did locate places for gauging stations and looked more closely at the irrigation canals. The water board is very interested in having irrigation canal measurements so they can get a better handle on water use. They also told me they really needed a hydrologist there all the time. I told them I like Bolivia very much, but I did not think my wife would want to move there. The head of the water board then offered (twice) to find me a wife in San Isidro. I politely declined.

Presenting the Comarapa water board with fiberglass gauge plates

The other water board I worked with was in the city of Comarapa. Comarapa uses water from a headwater tributary of the Comarapa River. Unlike San Isidro, they have already extended their pipeline into a stream in the cloud forest. The Comarapa River and the San Isidro River both have high colloidal sediment loads that create high turbidity levels. The cloud forest tributaries are high enough in the watershed so that the sediment problem is lessened. The Comarapa water board is in the process of purchasing the land in their water supply catchment area and are working with the local farmers who have not sold their property in the catchment. These farmers are being paid to not graze cattle or plant row crops. Instead, the water board is helping them convert cropland and pastures into peach orchards. The return on peaches is about a factor of 10 greater than the return on row crops.

As we met with the officials from the Comarapa water board, they were very happy to learn that my area of particular expertise lies in studying springs and small flows. They told me I needed to come back so I could go to their cloud forest water source and study their springs. The other thing they asked was for my stream gauging equipment. They have stream-gauging equipment (it is used by one of the people we met with, a hydrologic technician with the Santa Cruz provincial

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Bolivian Watershed Management Assistance, cont.

natural resources agency) but the Price AA and CMD would give them readings that are more accurate at lower flows. Though I couldn't leave it with them, I promised to try to come back in a year with equipment for them. I did give them two of the stream gauging plates that Rickly Hydrological Company donated. They were very pleased as the Rickly plates were more accurate than what they had and they are made of fiberglass which does not have the corrosion problems that the Bolivians have with their gauges of metal or wood.

Prior to leaving Bolivia, I took three two-liter samples of San Isidro River water and got some sand samples for sieve analysis. The sand samples were to explore the potential for making simple sand filters so the local people can remove the colloidal sediment from their river water. Minnesota Valley Testing Labs tested the water samples for a whole suite of pesticides; all samples were below the detection limits. It should be noted that the samples were taken during elevated flow conditions, consisting of rain from higher up in the foothills and not from rain falling onto agricultural fields.

What is next?

The staff at Monte Blanco did not want our team to leave. We had a wonderful time working together, and they wanted to know when we were coming back. There were very many opportunities to work with the local people at Comarapa and San Isidro and much maintenance work for our team at Monte Blanco. My plan is to return to Bolivia for three weeks in October 2012, shortly after the Midwest Groundwater Conference in Minneapolis (I agreed to be the karst session chair so I really cannot skip out). My work will be measuring the spring flows in the Comarapa cloud forest, measuring irrigation canal loss, setting up gauging stations, and investigating simple sand filter construction. The sand filter work will be part of our efforts to help the rural people not served by pipelines get cleaner water. We may also work on water treatment system repairs and upgrades at Monte Blanco.

The biggest hurdle for my return trip is the need for more equipment. I need a Pygmy meter, current meter digitizer, a metric wading rod and more gauge plates. The idea is to give the Price AA meter, current meter digitizer and the metric wading rod to the Comarapa water board. The hydrologic technician they work with measures both Comarapa and San Isidro Rivers so the equipment would help both areas. I would use the Pygmy meter for the smaller flow measurements they asked me to do. I also need to leave them additional gauge plates. Those that I left are graduated from 0-1 meter. They need the next two plates above that for accurate high-flow stage measurements. The Comarapa water board also asked me to bring them four recording rain gauges to help with hydrologic monitoring. I really hope to be able to get this equipment.

The 2011 Bolivia trip was my fifth overseas water mission's adventure. Between the good contacts we made with the water boards, their interest in my returning to assist them, the local needs, and the wonderful relationships we made with the Monte Blanco staff, I struggled more than I ever had when it came time to leave. I am very eager to return!

If you are interested in more information or are interested in assisting with this effort, you can contact me at jagreen@uwalumni.co. I am available to talk to groups, companies, or individuals who might be interested in helping with procuring the needed equipment.

President's Letter, cont.

website and make your plans to attend!

Like last year, our fall conference is subsumed by a larger entity as the MGWA hosts the 57th Annual Midwest Ground Water Conference. This conference will have two days of talks on Monday and Tuesday, October 1st and 2nd, with a field trip on Wednesday, October 3rd. The conference draws attendees from the Dakotas to Kentucky and Ohio to Arkansas, a region that has similar problems as Minnesota but are usually approaching them differently – ample opportunities for cross fertilization of ideas! Sessions on a variety of subjects are already in the works, and you are all encouraged to submit abstracts for talks or posters. This is a chance for the results of your project or research to be presented to and discussed with a broader collection of our colleagues. Although you'll be receiving information in the near future, please check out the link to the Midwest Ground Water Conference on our website.

In addition to these conferences, we are laying the groundwork for the organization's next decade, expanding the content of the newsletter, the funding of the MGWA Foundation and its scholarships, and – hopefully – the profile of groundwater as a resource and a legacy to the future. As always, this work depends on members volunteering to help out. I encourage you – yes, you – to volunteer. An email to the address on the newsletter will start the ball rolling. And if someone calls you for assistance, answer "yes"!

See you April 19th at the spring conference!

National Groundwater Awareness Week

National Groundwater Awareness Week is March 11-17. To find out more and learn how you can get involved, visit the web site: www.ngwa.org/Events-education/awareness/Pages/default.aspx

Crude Oil at the Bemidji Site: 25 Years of Monitoring, Modeling, and Understanding

Excerpted by Mindy L. Erickson from Essaid, H.I., B.A. Bekins, W.N. Herkelrath, G.N. Delin, 2011, Crude Oil at the Bemidji Site: 25 Years of Monitoring, Modeling, and Understanding, Ground Water, DOI: 10.1111/j.1745-6584.2009.00654.x.

The fate of hydrocarbons in the subsurface near Bemidji, Minnesota, has been investigated by a multidisciplinary group of scientists for over a quarter century. Essaid et al. (2011), as summarized in the excerpts below, have presented an overview of studies conducted at the crude-oil spill research site. These studies have contributed to understanding the fate of hydrocarbons in the natural field setting. The approaches developed and processes studied at Bemidji are universal and can be adapted and used to evaluate other hydrocarbon spill sites. Work is continuing at the site and in 2009 a four-party collaborative agreement was signed by Enbridge Energy, Limited Partnership, the Minnesota Pollution Control Agency, Beltrami County, and the US Geological Survey (USGS) Minnesota Water Science Center. The purpose of the collaborative agreement is to support the advancement of science, research, and education on the fate, transport, and natural attenuation of crude-oil contamination in the subsurface. The Agreement provides funding that augments the long-term funding provided by the USGS Toxic Substances Hydrology Program. A Request for Proposals (RFP), in place since 2010, has been inviting funding requests for proposed work at the site. Funding is likely to be available to continue the RFP and proposal funding process for several more years.

Monday, June 11, 2012, is the date of a symposium titled "Terrestrial crude oil spills: decades of science from the Bemidji, Minnesota Research Site." The symposium will focus on sharing research results from the National Crude Oil Spill Fate and Natural Attenuation Site, Bemidji, Minnesota, and will be held at the University of St. Thomas, St. Paul campus. The symposium will be followed by a site tour on June 12, starting at 1:00 p.m.

On August 20, 1979, approximately 16 km northwest of Bemidji, an 86-cm diameter crude-oil pipeline burst along a seam weld, spilling about 1.7 × 106 L (10,700 barrels) of crude oil onto glacial outwash deposits (Figure 1) (Pfannkuch 1979; Hult 1984; Enbridge Energy 2008). The oil sprayed over an area of about 6500 m2 (the spray zone) and collected in a wetland and topographic depressions where crude oil infiltrated through the unsaturated zone to the water table resulting in three subsurface oil bodies (termed the north, middle, and south oil pools, Figure 1). An estimated 1.1 × 106 L (6800 barrels) of the spilled oil was removed by pumping from surface pools and trenches, and an additional 0.2 × 106 L (1300 barrels) was removed by burning and excavation of soil. After cleanup efforts were completed in 1979 to 1980, about 0.4 × 106 L (2600 barrels) of crude oil remained in the subsurface. The NAPL oil trapped in the unsaturated zone and floating on the water table has provided a continuous source of hydrocarbon contamination. Hydrocarbon compounds have volatilized and dissolved from the oil at varying rates, changing the source composition and forming soil vapor and groundwater plumes within physically and chemically heterogeneous subsurface sediments (Figure 2). The compounds have been transported mainly by diffusion (with some advection) in the unsaturated zone, and by advection and dispersion in the saturated zone. Reactions and biodegradation have transformed the hydrocarbons to less toxic compounds, modified the subsurface redox conditions, and resulted in changes in mineral characteristics.

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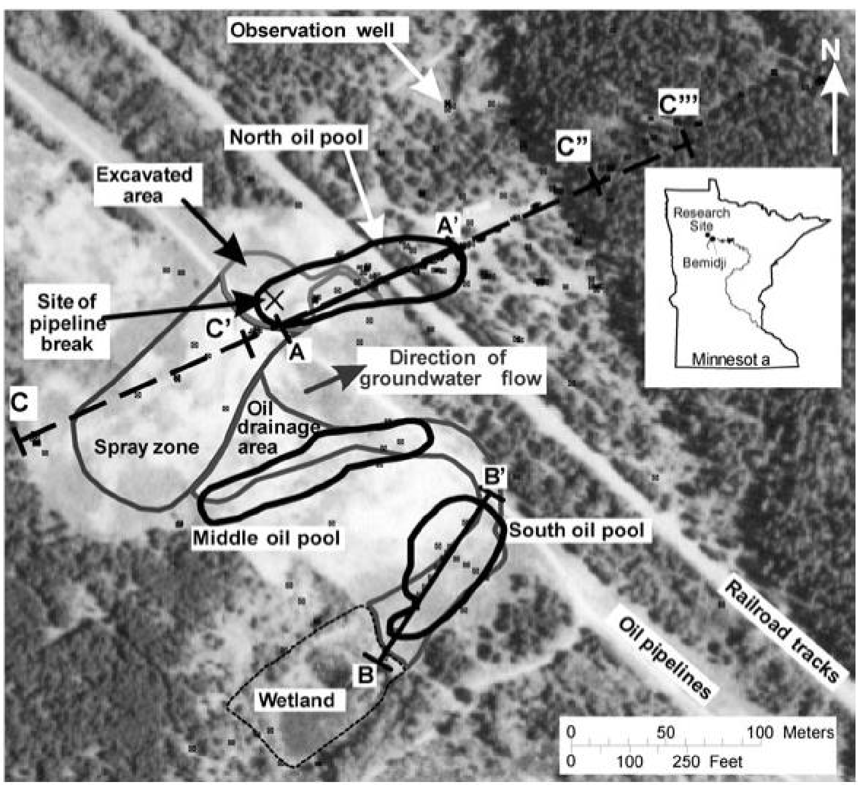

Figure 1. Aerial view of the Bemidji, Minnesota, crude-oil spill research site showing the site of the pipeline break, surface area impacted by oil spill, approximate extent of north, middle, and south oil pools floating on the water table, general direction of groundwater flow, and locations of cross sections shown in subsequent figures.

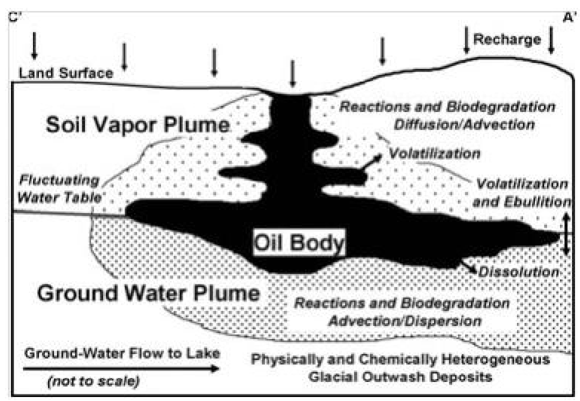

Figure 2. Generalized vertical cross section illustrating the fate and transport of spilled hydrocarbons in the subsurface. Hydrocarbons infiltrate the subsurface as a separate oil phase, resulting in a residual oil source in the unsaturated zone and an oil body floating on the water table. Volatilization and dissolution of hydrocarbons from the oil phase produce vapor and groundwater plumes. The extent of these plumes is moderated by biodegradation and geochemical reactions that take place in a heterogeneous porous medium.

Research at the Bemidji Site, cont.

A long-term, interdisciplinary research project sponsored by the U.S. Geological Survey Toxic Substances Hydrology Program was established at the Bemidji site in 1983 in response to the research community's need for in situ field-scale studies of hydrocarbon fate to complement ongoing experimental and modeling efforts (Delin et al. 1998). An overview of the project with site maps and data is available at http://toxics.usgs.gov/sites/bemidji_page.html and http://mn.water.usgs.gov/projects/bemidji/. Research at this site has been oriented toward characterizing and quantifying the physical, chemical, and biological processes controlling the fate of hydrocarbons in the subsurface. From 1983 to 1999, scientists working at the site were able to study and document the extent and progression of hydrocarbon contamination under natural, undisturbed conditions. In 1999, a 4-year remediation effort focused on removing the NAPL oil source was initiated by the pipeline company in response to a mandate from the Minnesota Pollution Control Agency.

Twenty-nine years of comprehensive, interdisciplinary research has made Bemidji one of the best-characterized hydrocarbon spill sites in the world and has resulted in over 200 publications (complete list available at http://toxics.usgs.gov/bib/bib-bemidji.html). Research efforts at Bemidji have focused on developing and applying methods for measuring and investigating in situ properties and processes. Work at the site has ranged from characterization of microscopic-scale water-mineral interactions to plume-scale geochemical and microbial evolution, and has included testing of complex models of multiphase flow, reactive transport, and biodegradation.

Investigations have involved the collection and analysis of more than 5000 samples of crude oil, water, soil, vapor, sediment, and microbes. The NAPL oil distribution and composition have been characterized and modeled to provide an understanding of the nature of the continuous hydrocarbon source. Monitoring and modeling of the geochemistry of the contaminated aquifer have revealed the chemical and biological processes controlling the evolution and extent of the groundwater and soil vapor hydrocarbon plumes. Simulation has been used to test conceptual models, quantify properties and rates, and evaluate hydrocarbon mass balance.

Site Hydrogeology

The Bemidji oil spill is located in a pitted and dissected outwash plain composed of moderately calcareous, moderately to poorly sorted sandy gravel, gravelly sand and sand with thin interbeds of silt (Franzi 1988). The average organic carbon content of these sediments was 0.09% (Baedecker et al. 1993), and the mean porosity was 0.38 (Dillard et al. 1997). At a depth of 18 to 27 m the outwash sediments are underlain by a low-permeability till layer. Local groundwater flow is to the northeast and discharges to an unnamed lake 300-m downgradient from the point of the pipeline rupture (Figure 1). Depth to the water table ranges between 0 (near the wetland) and 11 m, and water levels fluctuate as much as 0.5 m seasonally. The observed average water-table gradient was 0.0035 m/m (Essaid et al. 2003). Estimates of mean hydraulic conductivity at the north oil pool site ranged from 5.6×10^{-6} m/s (estimated from particle-size distributions, Dillard et al. 1997) to 7.0×10^{-5} m/s (calibrated model estimate, Essaid et al. 2003). Mean porosity, conductivity, and gradient estimates yield average velocity estimates that range between 0.004 and 0.056 m/day. A small-scale natural-gradient bromide tracer test con-

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ducted within the hydrocarbon plume, along a 1.6-m long flow path 57-m downgradient from the center of the oil body, yielded a mean flow velocity of 0.06 m/day and longitudinal dispersivity of 0.15 m (Essaid et al. 2003).

Mean annual temperature and precipitation at the site are 3◦C and 0.58 m, respectively (National Oceanic and Atmospheric Administration 1983). Recharge rates at the site have been estimated using a water-table fluctuation method and an unsaturated zone water balance method based on time-domain-reflectometry measured soil moisture (Delin and Herkelrath 1999, 2005; Herkelrath and Delin 2001). Estimated values range from 0.1 to 0.3 m/year. The greatest recharge rates have been observed below areas of topographic lows, primarily as a result of accumulation of surface runoff in these depressions—the same depressions where spilled crude oil infiltrated to the water table.

Oil Phase Distribution

Characterizing the subsurface oil-phase distribution is a necessary step for understanding the influence of the NAPL oil source on the vapor and groundwater plumes. Often, the only information available at a field site is the thickness of oil floating on water in an observation well, a measurement that does not correlate well with the thickness of oil in the adjacent sediments (Kemblowski and Chiang 1990). Methods to determine the subsurface distribution of oil saturation, the fraction of the pore space occupied by oil (volume of oil/volume of pore space), were developed and applied at the Bemidji site. In 1989 and 1990, cores were collected at the south and north oil pools (Figure 3) using a sampling tech-

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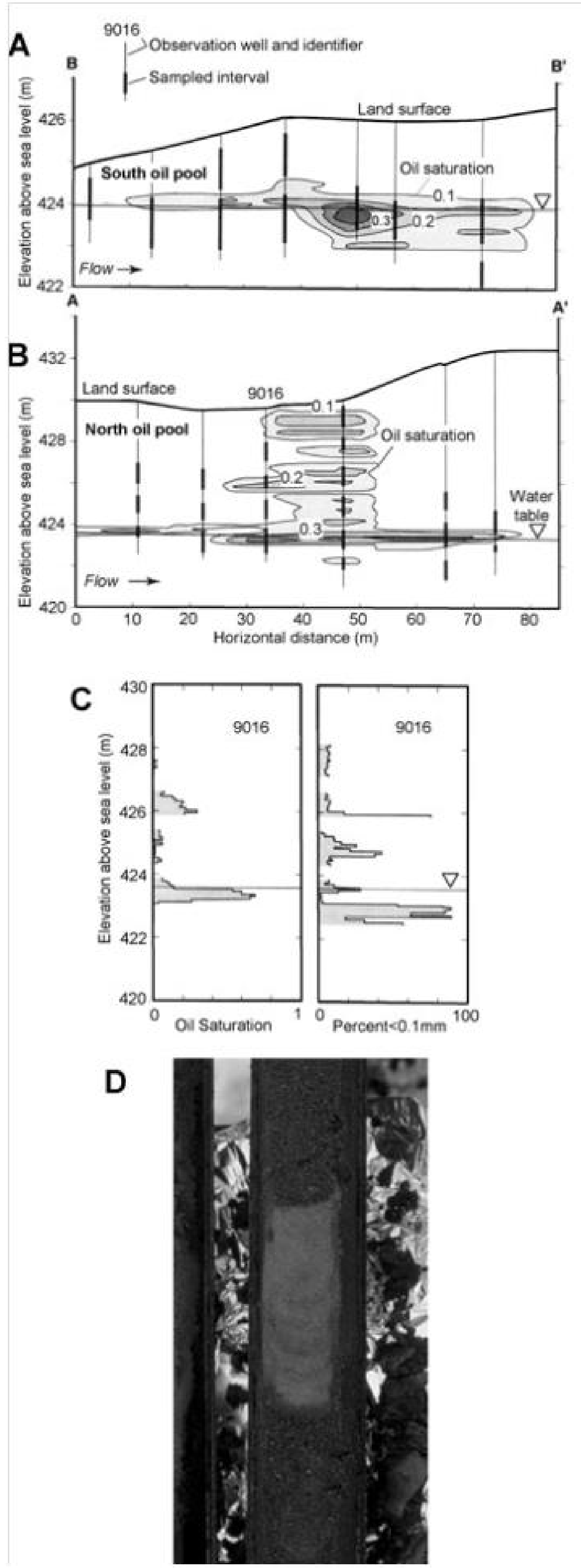

Figure 3. Oil-phase distribution at the Bemidji site (modified from Essaid et al. 1993; Dillard et al. 1997): (A) oil saturation (volume of oil/volume of pore space) distribution at the south pool; (B) oil-saturation distribution at the north pool; (C) oil saturation and percent grain size smaller than 0.1 mm at borehole 9016 showing the influence of heterogeneity on oil-phase distribution; (D) photograph of an oil core crossing the water table showing oil exclusion from a finer grained horizon.

Research at the Bemidji Site, cont.

nique that could recover relatively undisturbed core samples from both the unsaturated and saturated zones while maintaining the in situ pore-fluid distribution (Hess et al. 1992). Oil and water saturations, porosity, and particle-size distribution were determined for core sections aligned along a 120-m transect at the south pool (Hess et al. 1992), and core sections aligned along a 90-m transect at the north pool (Dillard et al. 1997). Both transects were approximately parallel to the direction of groundwater flow.

The observed south pool oil body (Figure 3A) was more than 70 m long with, the greatest oil saturation (0.62) measured near its center in a localized zone of high oil saturations. Outside this zone there was a large area with oil saturations less than 0.20. The oil body was asymmetric and it appeared that there may have been some downgradient lateral migration of oil below the water table, possibly through zones of high permeability. The thickness of oil measured in three wells at the time of core collection did not correspond to the oil-saturation distribution in the adjacent sediments (Hess et al. 1992), illustrating that accumulated thickness in wells is a poor indicator of the actual distribution of oil in the subsurface. The distribution of oil at the north pool site was more complex than that at the south pool site (Figure 3B). A considerable amount of oil remained in the unsaturated zone where oil infiltrated following the spill. The body of oil floating on the water table was not lens shaped, but rather consisted of zones of high and low oil saturation distributed along the general direction of groundwater flow. The maximum oil saturation of 0.74 was measured in the downgradient part of the oil body. Figure 3C shows profiles of oil saturation and particle size for borehole 9016 and illustrates the influence of fine-grained layers on oil-saturation distribution. A layer containing almost 80% fines occurred in the unsaturated zone at an elevation of about 426 m. Oil saturations above this layer were greater than 0.3, even though it was more than 2 m above the water table. Apparently the fine-grained layers impeded the infiltration and redistribution of oil. The peak oil saturation was below the water table within a zone that was lacking in fines, rather than at or above the water table as buoyancy would predict. Fine-grained layers occurred above and below the zone of high oil saturation, suggesting that migration of oil near the water table was controlled by heterogeneous layering. Figure 3D is a photograph of a core collected at the water table, which illustrates the effect of grain size on oil saturation. The gray zone in the center has smaller grain size and is free of oil, whereas the coarser overlying and underlying zones are heavily saturated with oil. These field data illustrate the importance of heterogeneity and capillary effects on the distribution and movement of the oil phase.

Remediation at oil spill sites often targets removal of the NAPL oil phase in order to minimize the hydrocarbon source. The Bemidji remediation effort initiated in 1999 focused on removing sufficient NAPL oil so that it would only occur as a sheen on the water-table surface. Oil was recovered by inducing depressions in the water table by pumping from beneath the north, middle, and south oil pools, with removal of inflowing oil by skimming. Efficacy of oil removal by pump-and-skim remediation depends on oil mobility and flow to the pumped well. Herkelrath (1999) made a prediction of oil removal at the north pool based on oil saturations measured in cores. His analysis indicated that about 25% of the oil was recoverable assuming a residual oil satura-

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Research at the Bemidji Site, cont.

tion of 0.2 based on observed oil-saturation distributions (Figure 3). The remediation from 1999 to 2003 resulted in the removal of about 1.14 × 105 L of crude oil from the north, middle, and south oil pools (Enbridge Energy 2008), or about 27% of the oil that remained following the initial remediation in 1979 to 1980. Although the renewed remediation decreased oil thickness in the immediate vicinity of remediation wells, average oil thicknesses measured in wells at the north pool (0.6 m) and south pool (0.3 m) were unaffected. In one observation well located about 5 m from a remediation well at the north pool, oil thickness decreased twice briefly but rebounded to pre-remediation levels shortly thereafter. These results, together with ongoing analyses, suggest that oil-phase recovery is challenging, and that considerable volumes of mobile and entrapped oil remain in the subsurface at spill sites in spite of significant remediation efforts.

Oil Phase Composition

The numerous studies of the NAPL oil source at Bemidji have shown that the oil phase is slowly evolving with time as hydrocarbon components are lost through mass transfer to water and soil gas, and biodegradation (Eganhouse et al. 1993, 1996). The oil-phase loss of relatively soluble components (e.g., BTEX) is sensitive to factors controlling dissolution, such as water concentrations and flow rates. Relatively volatile components (e.g., short chain-length alkanes) can be rapidly lost through volatilization under favorable conditions. Alkanes are also lost from the oil body by methanogenic degradation. Bekins et al. (2005a) pointed out that hydrologic conditions at a site can control oil degradation rates, and that techniques for dating a spill on the basis of the degree of degradation may yield very different results depending on where the sample was collected. In addition, techniques to identify spilled product based on fingerprinting may provide misleading results when methanogenic conditions are present, because the fingerprint of the degraded product in such cases differs from the expected pattern under aerobic conditions (Hostettler et al. 2007, 2008).

Geochemical Evolution of the Hydrocarbon Plume

By the mid-1980s it was recognized that hydrocarbons could be effectively degraded by naturally occurring indigenous microbial populations (Wilson et al. 1986). Aerobic degradation of BTEX was accepted as an effective biodegradation process, and the potential of anaerobic degradation was just being documented (Wilson and Rees 1985). Studies initiated at Bemidji since 1984 have provided concrete evidence of the importance of anaerobic degradation for limiting the extent of hydrocarbon plumes, and significant insight into the succession of redox processes, microbial populations, and geochemical interactions. Hydrocarbon components dissolving from the oil phase have undergone different rates of transport and biodegradation. Within the plume, biologically mediated geochemical reactions have resulted in mineral alteration.

Early characterization of the groundwater hydrocarbon plume (Baedecker et al. 1989, 1993; Bennett et al. 1993) identified five distinct geochemical zones below the water table (Figure 4). Zone 1 consisted of oxygenated uncontaminated native groundwater very low in nitrate, ammonia, and sulfate. Zone 2, below the spray zone, was characterized by reduced oxygen concentrations and the presence of refractory high-molecular-weight hydrocarbons transported from oil residues on the land surface. Zone 3, beneath and immediately downgradient from the separate phase oil body, was anoxic with high concentrations of hydrocarbons, dissolved manganese and iron, and methane. In addition, nitrate and ammonia concentrations were slightly higher than in background water possibly because of nitrogen-containing compounds in the oil and/or infiltration of fertilizer used at the land surface to promote tree growth following the spill. In Zone 4, there was a transition from anoxic conditions to fully oxygenated conditions, with a corresponding rapid decrease in hydrocarbon concentrations as a result of aerobic biodegradation. Zone 5 consisted of oxygenated water downgradient from the oil body with slightly elevated concentrations of dissolved inorganic and organic constituents. The relatively stable extent of the plume, when compared to groundwater flow rates, led to the conclusion that migration of the plume was being limited by natural attenuation processes, including both aerobic and anaerobic biodegradation.

Long-term monitoring of plume-scale hydrocarbon concentrations and aqueous geochemistry has provided a well-documented field example of the evolution of natural attenuation processes (Cozzarelli et al. 1990, 1994, 2001; Bekins et al. 2001). The Bemidji findings have influenced recommended approaches and protocols for evaluating natural attenuation at hydrocarbon spill sites (National Research Council 2000). Approaches developed at Bemidji for characterization of small-scale variations in chemistry have shown that shifts in biodegradation processes that impact the future extent of the plume may occur before changes can be detected in observation well concentrations.

Microbiology of the Hydrocarbon Plume

Concurrent with studies documenting geochemical evidence of biodegradation were efforts to characterize the microbial populations and processes responsible for aerobic and anaerobic biodegradation of hydrocarbons, as well as enhanced mineral-water interactions. Studies at Bemidji have documented bacterial colonization on rock surfaces resulting in enhanced quartz (SiO2) dissolution, identified bacteria responsible for iron reduction, and characterized the spatial and temporal distributions of microbial populations.

Studies at Bemidji were among the first field efforts that documented microbial evidence of anaerobic degradation of hydrocarbon compounds (Chapelle 1999; Cozzarelli and Baehr 2003). Bekins et al. (1999) used the most probable

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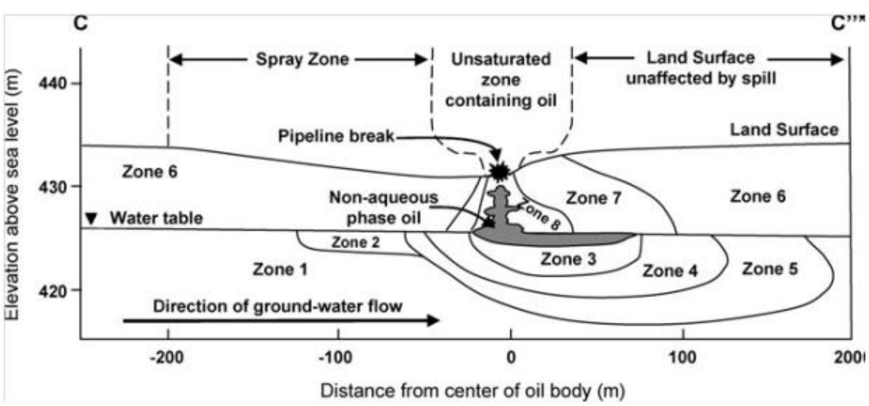

Figure 4. Subsurface geochemical zones identified at the north oil pool site (modified from Baedecker et al. 1993 and Delin et al. 1998). Zones are described in the accompanying text.

number (MPN) method to characterize the spatial distribution (in water and sediment) of six physiologic types in the anaerobic portion of the hydrocarbon plume: aerobes, denitrifiers, iron reducers, heterotrophic fermenters, sulfatereducers, and methanogens (Figure 5). Iron reducers formed the bulk of the microbial population in the anoxic zone of the plume. Areas evolving from iron reducing to methanogenic conditions were clearly delineated based on microbial populations, and generally occupied 25% to 50% of the plume thickness. Lower microbial numbers were observed below the water table than in the unsaturated zone, suggesting that nutrient limitations may be limiting growth in the saturated zone. Finally, the data indicated that an average of 15% of the total population was suspended, rather than attached to the solid substrate.

The studies of microbial populations at Bemidji helped confirm that microbially mediated reactions and anaerobic biodegradation were responsible for the natural attenuation of hydrocarbons and observed plume geochemistry. The distribution and evolution of populations in the hydrocarbon plume were influenced by sediment properties, hydrologic conditions, and availability of electron acceptors and growth nutrients.

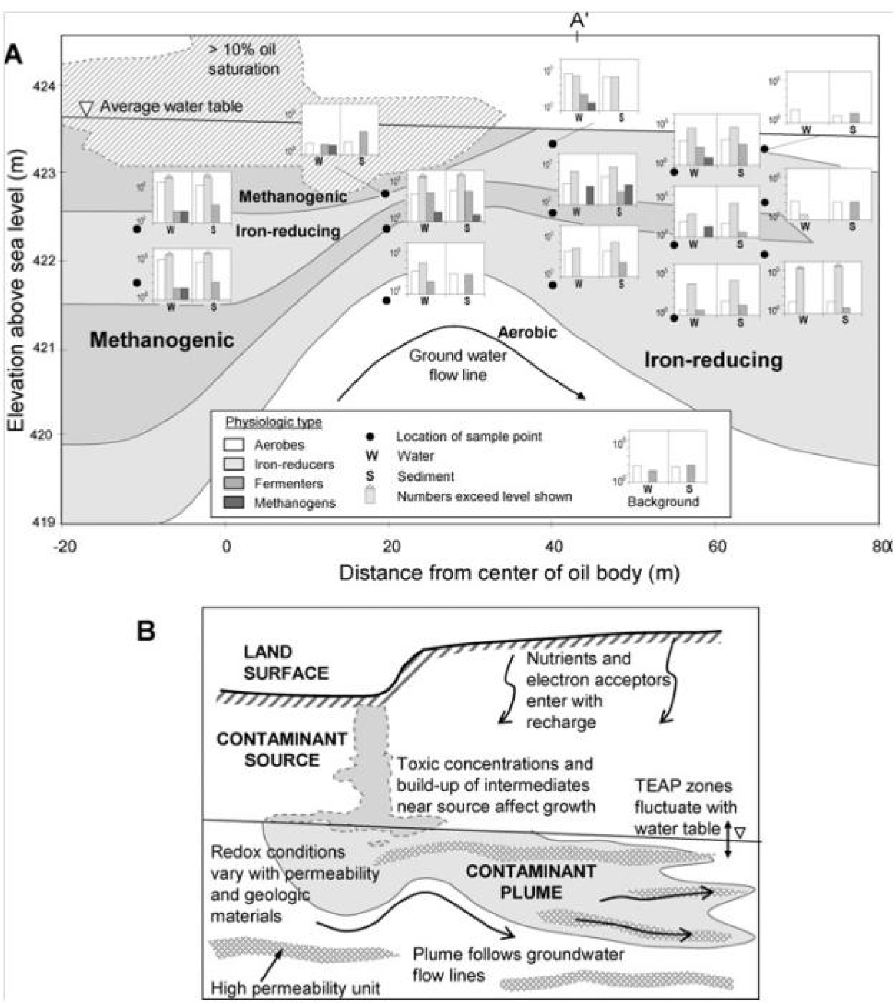

Figure 5. The influence of subsurface hydrologic and geochemical conditions on microbial populations in the hydrocarbon plume: (A) distributions of aerobes, iron reducers, methanogens, and heterotrophic fermenters in water and sediment within the north pool anaerobic plume (from Bekins et al. 1999); (B) conceptual model illustrating the complex interactions of recharge, water-table fluctuations, sediment heterogeneity, and geochemistry that influence microbial population growth (from Haack and Bekins 2000).

The Unsaturated Zone Vapor Plume

Volatile hydrocarbon compounds and biodegradation end-products are transferred from the NAPL oil and groundwater plume to the gas phase in the unsaturated zone (Hult and Grabbe 1998). Understanding the factors controlling gas phase hydrocarbon transport is important for evaluating mass loss during natural attenuation and has relevance to the use of soil gas analysis as a field screening tool for NAPL contamination.

Observation of unsaturated zone gas concentrations (hydrocarbon, oxygen [O2], CO2, and CH4) at the north oil pool in 1997 was used to identify three geochemical zones shown in Figure 4 (Delin et al. 1998). The outer Zone 6 had near atmospheric concentrations of O2. Zone 7, a transition zone, was defined by lower concentrations of O2 (10% to 20%), hydrocarbon concentrations less than 1 part per million (ppm), and higher concentrations of CO2 (0% to 10%) and CH4 (0% to 10%). The inner Zone 8, immediately above the oil body, had the lowest concentrations of O2 (0% to 2%) and contained the highest concentrations of CO2 (>10%), CH4 (>10%), and hydrocarbon (>1 ppm). Thus, the unsaturated zone vapor plume mirrored the saturated zone groundwater plume, suggesting a similar core of anaerobic degradation near the NAPL oil source.

Hydrocarbon Fate Modeling

Geochemical and transport models are effective tools for integrating field observations, testing hypotheses, determining the relative importance of simultaneously occurring processes, as well as quantifying reaction rates and system mass balance. The comprehensive, long-term field data set collected at Bemidji has provided an opportunity to test and refine modeling approaches. Efforts to model the fate of hydrocarbons in the Bemidji plume have become progressively more complex, providing increased insight into processes affecting the long-term fate of the groundwater and vapor plumes.

In the first modeling effort at the Bemidji site, Baedecker et al. (1993) used the geochemical mass-balance model NETPATH (Plummer et al. 1991) to deduce geochemical reactions occurring as groundwater flowed along a 40-m path in the anaerobic zone. Essaid et al. (1995) modeled the evolution of the groundwater hydrocarbon plume and sequential use of terminal electron acceptors using the multispecies solute transport and biodegradation model BIOMOC (Essaid and Bekins 1997). In a subsequent modeling study, Essaid et al. (2003) considered dissolution from the oil body, transport, and biodegradation of BTEX compounds in the saturated zone and examined the evolution of BTEX composition in the NAPL oil source. Essaid et al. (2003) also explored an alternative iron-reduction conceptual model that modified the first-order anaerobic biodegradation process for benzene to be dependent on solid phase Fe3+ concentration, decreasing as ferric iron was depleted. Curtis (2003) developed a thermodynamically based reactive transport model with mineral dissolution and precipitation for

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geochemical conditions similar to those observed at Bemidji. Chaplin et al. (2002) determined unsaturated zone biodegradation mass removal rates by calibrating the gas transport model R-UNSAT (Lahvis and Bear 1997), using UCODE (Poeter and Hill 1998), to the observed O_2, CO_2, and CH_4 gas-concentration data. Amos et al. (2005) provided field evidence that CH_4 and CO_2 production in the hydrocarbon plume formed gas bubbles, affecting groundwater chemistry and potentially solute transport. Amos and Mayer (2006) modified the unsaturated/saturated zone reactive transport code MIN3P (Mayer et al. 2002) to include the formation and collapse of gas bubbles in addition to kinetically controlled redox and mineral dissolution/precipitation reactions, equilibrium hydrolysis, aqueous complexation, ion exchange and surface complexation reactions.

Model development and application has been an important complement to the field analysis at Bemidji, affirming conceptual models developed from field and experimental observations. Models have progressively incorporated more complex processes and have provided a means to quantify mass removal and biodegradation rates. These modeling approaches have universal application to studies at other hydrocarbon contaminated sites.

Conclusions and Lessons Learned

Research at Bemidji has involved extensive investigations of multiphase flow and transport, volatilization, dissolution, geochemical interactions, microbial populations, and biodegradation with the goal of providing an improved understanding of the natural processes limiting the extent of hydrocarbon contamination. A considerable volume of oil remains in the subsurface today despite 30 years of natural attenuation and 5 years of pump-and-skim remediation. Studies at Bemidji were among the first to document the importance of anaerobic biodegradation processes for hydrocarbon removal and remediation by natural attenuation. Spatial variability of hydraulic properties was observed to influence subsurface oil and water flow, vapor diffusion, and the progression of biodegradation. Pore-scale capillary pressure-saturation hysteresis and the presence of fine-grained sediments impeded oil flow, causing entrapment and relatively large residual oil saturations. Hydrocarbon attenuation and plume extent was a function of groundwater flow, compound-specific volatilization, dissolution and biodegradation rates, and availability of electron acceptors. Simulation of hydrocarbon fate and transport affirmed concepts developed from field observations, and provided estimates of field-scale reaction rates and hydrocarbon mass balance.

Long-term field studies at Bemidji have illustrated that the removal processes evolve with time, and estimates of removal rates made early in the life of a hydrocarbon plume may not be representative of future removal rates due to exhaustion of electron acceptors and/or nutrients. This must be kept in mind when evaluating the efficacy of natural attenuation as a remediation alternative at contaminated sites (Bekins et al. 2005b). A snapshot study of a hydrocarbon plume may not provide information that is of relevance to the long-term behavior of the plume during natural attenuation.

Natural attenuation has been demonstrated to be an effective remediation strategy for many spills (Wiedemeier et al. 1999). However, transport and fate of hydrocarbons in the subsurface is a spatially and temporally complex problem. The persistent nature of the oil-phase hydrocarbon source and the long time frame for natural attenuation observed at Bemidji is not unique. Long-term field monitoring and process-oriented modeling at Bemidji

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has illustrated that hydrocarbon fate is compound specific and continually evolving with time. Ongoing research at the Bemidji crude oil spill site continues to focus on providing insights and methods that will help us to understand and predict the evolution and fate of subsurface hydrocarbon plumes.

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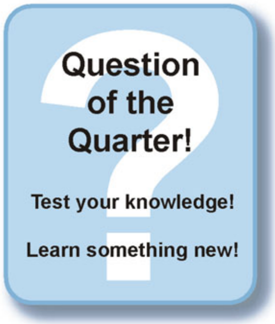

Question of the Quarter

The Question of the Quarter is an occasional feature of your newsletter in which a question is posed , and all members are invited to respond. Last quarter's question was a little tricky, especially since there was no Minnesota connection:

> *"What legendary hydrogeologic feature did popular American magician David Copperfield claim he had discovered in a cluster of four small islands in the Exuma chain of the Bahamas?"*

Mindy Erickson answered the question correctly with praise to Google.

ANSWER: The fountain of youth.

This feature or area was thought of as the mythical Shangri-La of Bimini by the Caribbean tribe, the Arawaks--but they really were probably referring to the Yucutan. Although Ponce de Leon traveled to the Bahamas, there's no evidence in his writings that he was searching for the fountain of youth— later on, the legend developed that he had been searching. St. Augustine, FL has capitalized on this misnomer with an entire fabricated narrative for unsuspecting tourists.

www.st-augustine-travel-guide.com/fountain-of-youth-st-augustine.html

Send your ideas for 'Question of the Quarter' to: editor@MGWA.org

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The First Annual Report of the Minnesota Geological Survey

The MGS scanning project has made many historic reports and maps readily available for download. These documents are not only educational but are a wonderful written history of the study of geology in the State of Minnesota. One of these documents is The first annual report for the year 1872 by the Geological and Natural History Survey of Minnesota. This report was written by Newton Horace Winchell, State Geologist. Below is an excerpt from the address to Hon J.S. Pillsbury, president of the board of regents of the University of Minnesota in the preface of the report. The full report can be accessed at http://purl.umn.edu/56232

"Dear SIR: I have the honor herewith to present the first annual report of progress on the geological and natural history survey of the state, required by the provisions of the law creating the same. The field work covered by this report is that performed by myself alone between the first of September and the closing of the season, on the 12th day of November, by the first fall of snow. The means at my disposal not admitting of the employment of assistants, it has only been possible to make a general reconnaissance of the state by visiting those parts accessible by railroad. In that way I have succeeded in making a connected section of observed strata from the trap and granite rocks, which lie at the base of our geological system, to the Galena limestone, in the Lower Silurian, including also about forty feet of the latter. Between the Galena and the Cretaceous no intervening rocks have been seen, but it is probable that the remainder of the Lower Silurian, including the Maquoketa shales and the Niagara limestone, which in the Northwest seems to constitute the Upper Silurian, as well as the lower portions of the Devonian, are in place in some parts of the southern portion of the state. A few sections have also been taken in the Cretaceous clays and sandstones in the southern part of the state. Developments of considerable interest and economical importance have already been made in connection with this series of rocks, as detailed in the accompanying report; and it is believed that they will afford in the future progress of the survey some of the best exemplifications, not only of the scientific value, but also of the practical usefulness of our investigations.

The small geological map of the state accompanying this report is intended to embody all that is known concerning the geographical outlines of the various formations embraced within the state. With the exception of the southeastern part of the state, the outlines of the geology of which have been more minutely laid out by Mr. W. D. Hurlbut, of Rochester, Minn., this map is to be regarded as only an approximation to the actual bearing of the strata, the boundaries of which are marked by tortuosities which it will be the future work of the survey to carefully trace out."

— MGWA Newsletter Team

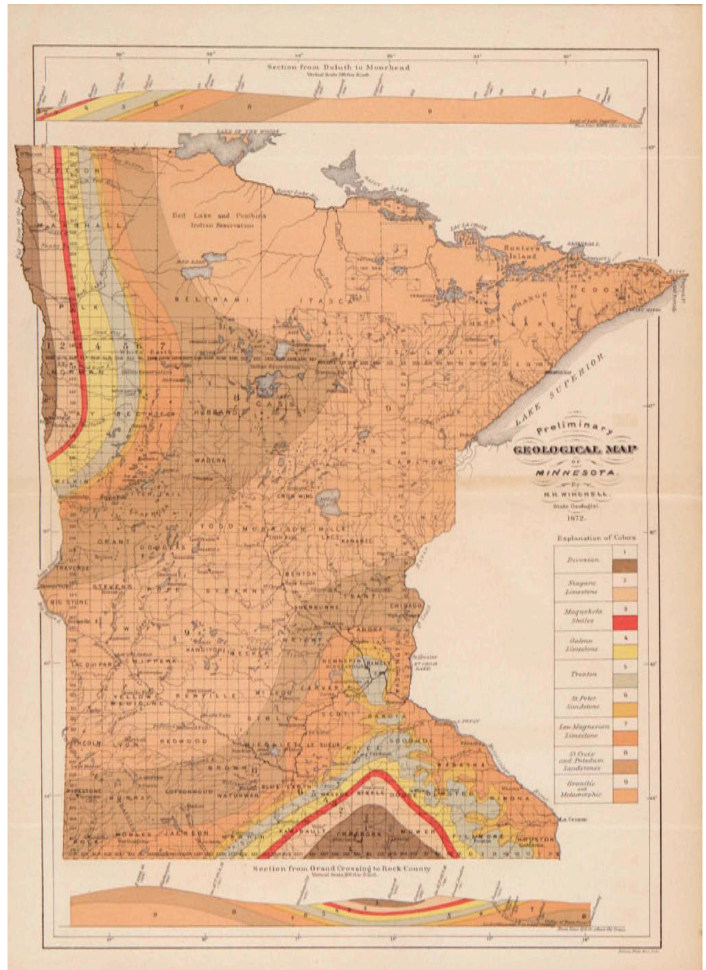

Figure 1. Image of 1872 Preliminary Geological Map of Minnesota published by The Geological and Natural History Survey of Minnesota.

New from the USGS

The USGS has published the following articles of interest to the groundwater community:

Erickson, M.L., 2012, Steroidal hormones and other endocrine active compounds in shallow groundwater in nonagricultural areas of Minnesota—Study design, methods, and data, 2009–10: U.S. Geological Survey Data Series 663, 9 p. The URL for this publication is http://pubs.usgs.gov/ds/663/

Lee, K.E., Langer, S.K., Barber, L.B., Writer, J.H., Ferrey, M.L., Schoenfuss, H.L., Furlong, E.T., William T. Foreman, Gray, J.L., ReVello, R.C., Martinovic, D., Woodruff, O.P., Keefe, S.H., Brown, G.K., Taylor, H.E., Ferrer, I., and Thurman, E.M., 2011, Endocrine active chemicals, pharmaceuticals, and other chemicals of concern in surface water, wastewater-treatment plant effluent, and bed sediment, and biological characteristics in selected streams, Minnesota—design, methods, and data, 2009: U.S. Geological Survey Data Series 575, 54 p., with appendixes. The URL for this publication is http://pubs.usgs.gov/ds/575/

Nystrom, E.A. and Burns, D.A. (2011) (2011) TOPMODEL Simulations of Streamflow and Depth to Water Table in Fishing Brook Watershed, New York, 2007–09, U.S. Geological Survey Scientific Investigations Report 2011–5190, 54 p.

Riva-Murray, K., Chasar, L.C., Bradley, P.M., Burns, D.A., Brigham, M.E., Smith, M.J., Abrahamsen, T.A. (2011) Spatial patterns of mercury in macroinvertebrates and fishes from streams of two contrasting forested landscapes in the eastern United States, Ecotoxicology, vol. 20, p. 1530–1542.

Writer, Jeffrey H., Joseph N. Ryan, Steffanie H. Keefe, and Larry B. Barber, 2012, Fate of 4-Nonylphenol and 17β-Estradiol in the Redwood River of Minnesota, Environ. Sci. Technol., 2012, 46 (2), pp 860–868. The URL for this publication is http://pubs.acs.org/doi/abs/10.1021/es2031664

White Bear Lake Project Update

Perry Jones, US Geological Survey

The USGS is working with the White Bear Lake Conservation District, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and several other state, county, and city agencies, watershed organizations and private organizations to characterize groundwater and surface-water interactions in White Bear Lake and the response of lake water levels to changes in precipitation and groundwater flow conditions. Results from a historical precipitation/lake level analysis for the White Bear Lake indicate that the relation between precipitation and lake levels for White Bear Lake changed after 2002. The new relation means that more precipitation is needed to reach similar lake levels than in the past. Possible explanations for this change could be an increase in groundwater outflow from the lake, a decrease in groundwater inflow to the lake, or a decrease in surface water inflow to the lake. A groundwater level analysis using existing data from the Minnesota Department of Natural Resources was used to assess relations between groundwater level, lake level, and precipitation and any changes in these relations after 2002.

Total groundwater extraction rates increased from high-capacity wells in the White Bear Lake area from 1980 to 1990 but have fluctuated since 1990. Over the past 30 years, municipal water use accounts for 87 percent of the total groundwater extraction in the area, with 90 percent of the total groundwater extraction occurring from the Prairie du Chien/Jordan aquifer. The largest groundwater extraction rates occur in the cities of White Bear Lake and Oakdale, with annual extraction rates in Oakdale gradually increasing from 375 million gallons in 1980 to 887 million gallons in 2010. Over the past nine years, groundwater extraction rates have increased in some municipalities north of White Bear Lake, with a substantial increase in total groundwater extraction north of the lake. This increase correlates in time with the change in the relation between precipitation and lake levels for White Bear Lake.

Potentiometric contours for glacial and bedrock (St. Peter Sandstone and Prairie du Chien Group) aquifers were created using groundwater level data collected from the two synoptic studies. These synoptic studies were conducted during low-stress (March/April - low pumping) and high-stress (August - high pumping) conditions. Between March and August 2011, the largest water-level declines (up to 10 feet) occurred in the Prairie du Chien/Jordan aquifer in the cities of White Bear Lake and North St. Paul, which is south of White Bear Lake, and in Hugo, which is north of the lake. Results from these analyses were presented at the White Bear Lake Conservation February Meeting on February 21 in White Bear Lake.

The major ion chemistry for White Bear Lake in summer 2011 was more similar to the water chemistry of larger lakes in the area (Turtle, Bald Eagle) than smaller lakes (Long, Sunset, Mann, Pine Tree, Echo). The larger lakes had high specific conductance and major ion concentrations. The smaller lakes are located at higher elevations with smaller watersheds, where lower-conductive precipitation and shallow groundwater may be more important components of the lake's water budget. Water samples collected from Goose, Birch, and Lost Lakes had high sodium and chloride concentrations relative to the other lakes sampled in the study. Major roadways run along the shore or through these lakes, so winter road salt is a likely source of sodium and chloride. Specific conductance values and dissolved iron concentrations were higher in groundwater and pore-water samples compared to surface water sampled from White Bear Lake.

USGS staff measure a well in the White Bear Lake area.

Isotope data for surface-water, precipitation, well water, and lake-sediment pore water samples were analyzed. Isotopic ratios were calculated for water sampled from residential, monitoring, and municipal wells near White Bear Lake. Isotopic ratios indicate that water in wells located to the south and west of White Bear Lake is composed of a mixture of surface water and ground water. Water in wells located to the east of White Bear Lake is composed of solely groundwater.

A draft report summarizing study results will be completed by March 2012; the final report will be completed later in 2012.

MPCA Releases Report on Contaminants of Emerging Concern in Groundwater

The MPCA recently released a report describing the results from the first round of sampling of contaminants of emerging concern in groundwater. The sampling was conducted cooperatively with the USGS from 2009-2010. Twenty different chemicals were detected in the groundwater at concentrations that generally were less than 1 microgram per liter. The data from this sampling will help the State to better understand the occurrence and distribution of these chemicals in the groundwater and will assist in work currently being done to determine the human-health effects from drinking water containing these chemicals. The report can be found here:
www.pca.state.mn.us/index.php/water/water-types-and-programs/groundwater/groundwater.html

MGWA members Sharon Kroening and Steve Thompson were interviewed by Minnesota Public Radio shortly after the report was released. The story can be found here:
http://minnesota.publicradio.org/display/web/2012/02/13/minnesota-groundwater-contamination-study/

Bioretention: A Sustainable Approach to Removing Stormwater Hydrocarbons and Protecting Groundwater

Gregory H. LeFevre, Graduate Research Fellow, Dept. of Civil Eng., University of Minnesota; Advised by: Professors Raymond M. Hozalski and Paige J. Novak

Introduction and Background

Nationwide, non-point sources of water pollution including stormwater from urban runoff present one of the greatest water quality challenges of the coming century (National Research Council 2008). Stormwater contains pollutants such as nutrients, heavy metals, and petroleum hydrocarbons at levels of concern—typically at higher concentrations than treated wastewater (U.S. EPA. 2000). Clearly, stormwater quality is an issue of concern in protecting our lakes, rivers, and groundwater resources.

Standard stormwater mitigation practices, i.e. retention ponds, appear ineffective at mitigating certain pollutants (Kamalakkannan *et al.* 2004; Weinstein *et al.* 2010). Discovery of polycyclic aromatic hydrocarbon (PAH) accumulations in retention pond sediments have demonstrated the inability of stormwater ponds to attenuate important pollutants (Kamalakkannan *et al.* 2004; Weinstein *et al.* 2010). Low impact development (LID) is an alternative approach to stormwater management which uses infiltration to mimic the native hydrology and has been proven to reduce negative impacts in the watershed (National Research Council 2008). One best management practice (BMP) in use is bioretention (Figure 1). Bioretention, also called raingarden or bioinfiltration practices, are shallow vegetated depressions with an engineered soil media into which stormwater from impervious surfaces is directed for infiltration. Current research indicates that

Figure 1: Bioretention cell in residential area. Note curb-cut where stormwater enters from street. (Photo: LeFevre)

properly designed and installed raingardens are effective at infiltrating the majority of small rainfall events (Davis *et al.* 2009; LeFevre *et al.* 2010). Nevertheless, concerns have been expressed about the potential for contaminating groundwater resources due to intentional infiltration of contaminated stormwater (Weiss *et al.* 2008; Pitt *et al.* 1999).

Little research overall has been conducted on the fate of stormwater petroleum hydrocarbons in bioretention areas, despite abundance of these pollutants in stormwater within urban catchments (Figure 2). Sources may include leaky storage tanks, park-

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Geologic Atlas of Carlton County, Part B

Jim Berg, Minnesota Department of Natural Resources, Division of Ecological and Water Resources

Introduction

The Geologic Atlas of Carlton County, Part B was published in July 2011. This atlas is designed for units of government and citizens to use in planning for land use, water supply, and pollution prevention. The data and maps in this atlas show the distribution and physical characteristics of the most important aquifers in the study area. They also describe the groundwater flow patterns, flow directions, aquifer connections, and important groundwater chemical characteristics. The atlas is comprised of four plates including: Hydrogeology of the Surficial Aquifer, Hydrogeologic Cross Sections, Hydrogeology of the Buried Aquifers, and Sensitivity of Groundwater Systems to Pollution.

Hydrogeology of the Surficial Aquifer

This plate includes maps of the surficial sand aquifer thickness, water table elevation, and water table depth. This aquifer covers a large portion of the eastern part of the study area and is highly variable in thickness. A simplified version of this aquifer showing only the extent in the study area is shown in Figure 1. A detailed portion of the thickness map is shown on Figure 2. Most of the surficial sand and gravel in the mapped area were from outwash deposits of several phases of advance and retreat of the Superior ice lobe, which advanced into the area from the present day area of Lake Superior. This aquifer is a relatively minor, direct source of water supply for domestic and municipal wells. Only eight percent of the approximately 3,500 wells in the mapped area draw water from this aquifer; with the remainder of the wells drawing from buried sand and gravel and bedrock aquifers. The surficial sand aquifer is, however, a vital water source to most aquatic habitats (e.g., river, lake, and wetlands) within the extent of this aquifer. Furthermore, this aquifer is the most important recharge source for the underlying buried sand and gravel and bedrock aquifers.

Hydrogeology of Buried Aquifers

The potentiometric surfaces and groundwater flow directions of all the mapped buried sand and gravel aquifers (8 units on five figures) and the bedrock aquifers are shown on this plate. Simplified versions showing only the extent of mapped buried sand and gravel and bedrock aquifers are shown on Figure 1. The plate also includes an interpretation of 90 groundwater samples that were collected across the study area and analyzed for the stable isotopes 18O and deuterium. The data show four lakes or lake areas (Figure 1) where leakage of surface water to the underlying aquifers occurs. Finally, this plate includes information illustrating groundwater use and monitoring in the study area.

Hydrogeologic Cross Sections and Sensitivity of Groundwater Systems to Pollution

The Hydrogeologic Cross Section plate includes nine hydrogeologic cross sections (Figure 1) that illustrate the horizontal and vertical extent of hydrogeologic units such as aquifers and aquitards, groundwater residence time, and general directions of groundwater flow. These cross sections were selected from a set of 53 regularly spaced, west-to-east cross sections created by the Minnesota Geological Survey to help map the area aquifers. The Sensitivity of Groundwater Systems to Pollution plate illustrates the pollution sensitivity of eight buried sand and gravel aquifers (shown on five figures), the bedrock aquifers, and the near surface materials.

Although presented separately in the atlas, the eastern portion of cross section E-E' and selected pollution sensitivity maps are shown together in Figure 2 to illustrate hydrogeologic conditions typical of the study area. This cross section and those included in the atlas are shown with aquifers colored according to known or assumed tritium ages, also known as the groundwater residence time. This is the estimated time that has elapsed since the water infiltrated the land surface to when it was pumped from the aquifer for this investigation. In general, short residence times suggest high pollution sensitivity, whereas long residence time suggests low sensitivity. Tritium (3H) is a naturally occurring isotope of hydrogen. Concentrations of this isotope in the atmosphere were greatly increased from 1953 through 1963 by the above-ground detonation of hydrogen bombs (Alexander and Alexander, 1989). This isotope decays at a known rate with a half-life of 12.43 years. Water samples with tritium concentrations of 10 or more tritium units (TU) are considered recent water since the tritium concentrations indicate that the aquifers have been mostly recharged during the past 50 years (shown in pink). Concentrations of 1 TU or less were recharged prior to 1953 and are considered vintage water (shown in blue). Water samples with tritium concentrations greater than 1 TU and less than 10 TU are considered a mixture of recent and vintage and are referred to as mixed water (shown in green).

The associated pollution sensitivity maps are shown with colors that represent pollution sensitivity conditions (red, orange, yellow, light green and dark green). The calculated elevation surfaces of geologic layers created by the MGS were used in a series of ArcMap spatial analyst map calculations to generate pollution sensitivity maps for each buried aquifer (Berg, J.A., 2006). In the final step of the sensitivity evaluation, the thickness of the protective till or aquitard that covers each aquifer is calculated and a sensitivity rating is applied. The sensitivity of the aquifer is inversely proportional to the thickness of that protective layer. The protective layer thickness is calculated by subtracting the elevation of the top of the aquifer from the elevation of the adjacent overlying recharge surface.

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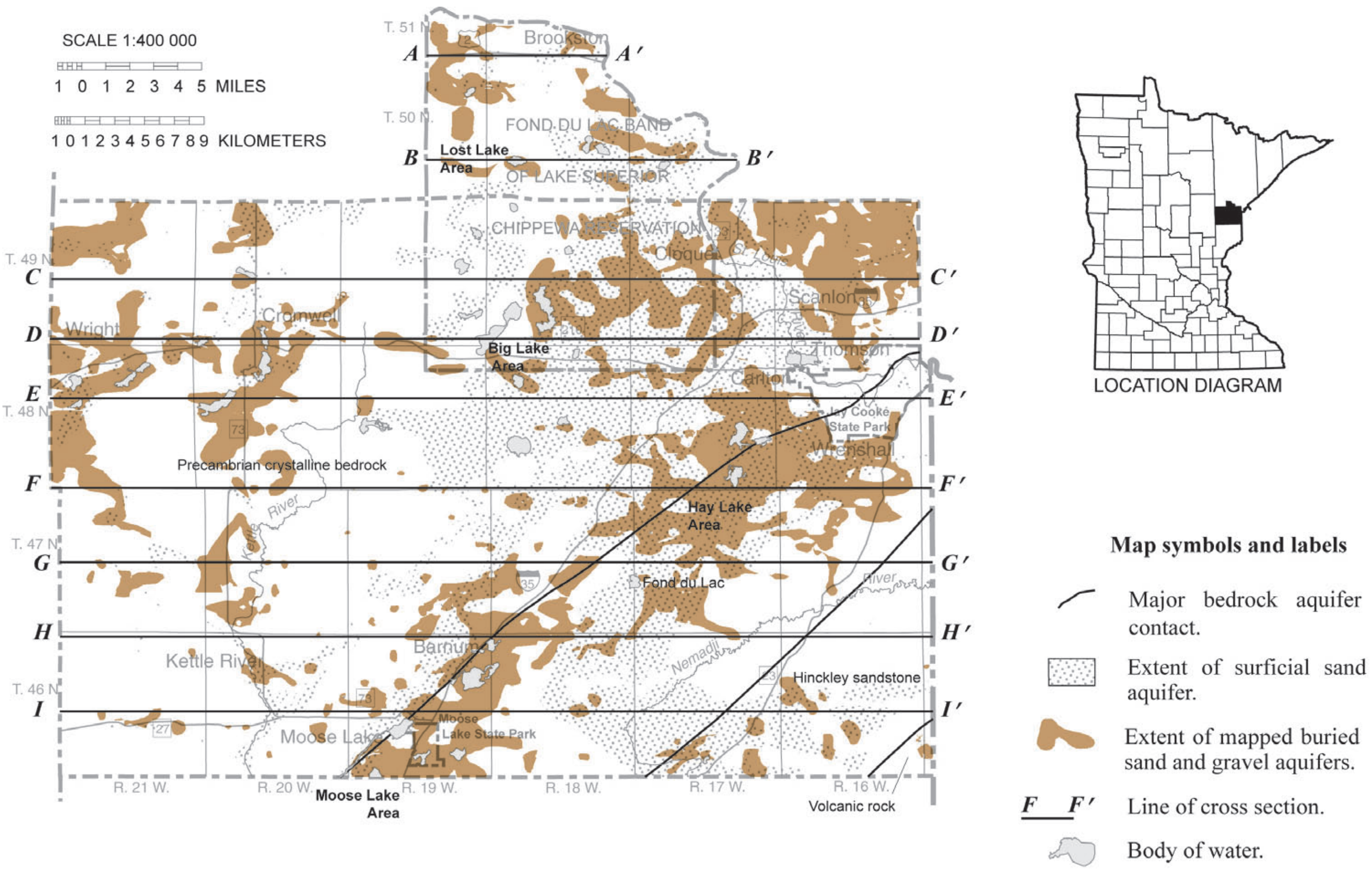

Figure 1. Extent of aquifers in the study area

Specifically, Figure 2 (see pages 20-21) illustrates the complexity of the surficial sand aquifer connections with the buried sand and gravel aquifers, and the highly variable nature of bedrock aquifer pollution sensitivity. Figure 2 focuses on an area south of the city of Carlton where one of the most extensive buried sand and gravel aquifers in the study area, the SC aquifer, is also commonly the shallowest buried aquifer. On cross section E-E' the SC aquifer is shown as the green layer (representing mixed tritium age) with a diagonal pattern. This aquifer layer has a locally moderate to high pollution sensitivity due to the generally thin overlying clayey aquitard.

Figures2 also illustrates two examples typical of bedrock aquifer pollution sensitivity: the Fond du Lac aquifer and the Precambrian crystalline bedrock in the southeastern and central portions of the study area, respectively (Figure 1). The shallow crystalline bedrock conditions on the western portion of this cross section segment are typical of a five to ten mile zone that bisects the county from the southwest to the northeast. Recent and mixed tritium conditions in the shallow portions of the bedrock are common in this zone.

The very western portion of this cross section segment shows the Fond du Lac Formation is overlain by thick layers of fine-grained glacial sediment that may contain little or no interbedded sand and gravel. This situation is typical of the south-central portion of the county east of Barnum. Domestic wells in this area are commonly completed with long uncased boreholes to maximize fracture flow into the well bore from this arkosic sandstone with interbedded fine grained layers. With the very thick overlying layer of fine-grained glacial sediment the pollution sensitivity of this aquifer is typically very low.

This atlas was funded in part by the Minnesota Environment and Natural Resources Trust Fund and the Clean Water, Land and Legacy Amendment. Electronic files of the Part B Atlas are available online at http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/carlcga.html.

The Carlton County Geologic Atlases, Part A and B can be purchased at the Minnesota Geological Survey, Publications Office, 2642 University Avenue, St. Paul, Minnesota 55114, (612) 627-4782. PDF images and data of part A of the atlas can be downloaded from the MGS website at http://www.mngs.umn.edu/county_atlas/countyatlas.htm. We can also be contacted by telephone: Jim Berg (651) 259-5680, Jan Falteisek (651) 259-5665, or Dale Setterholm (612) 627-4780.

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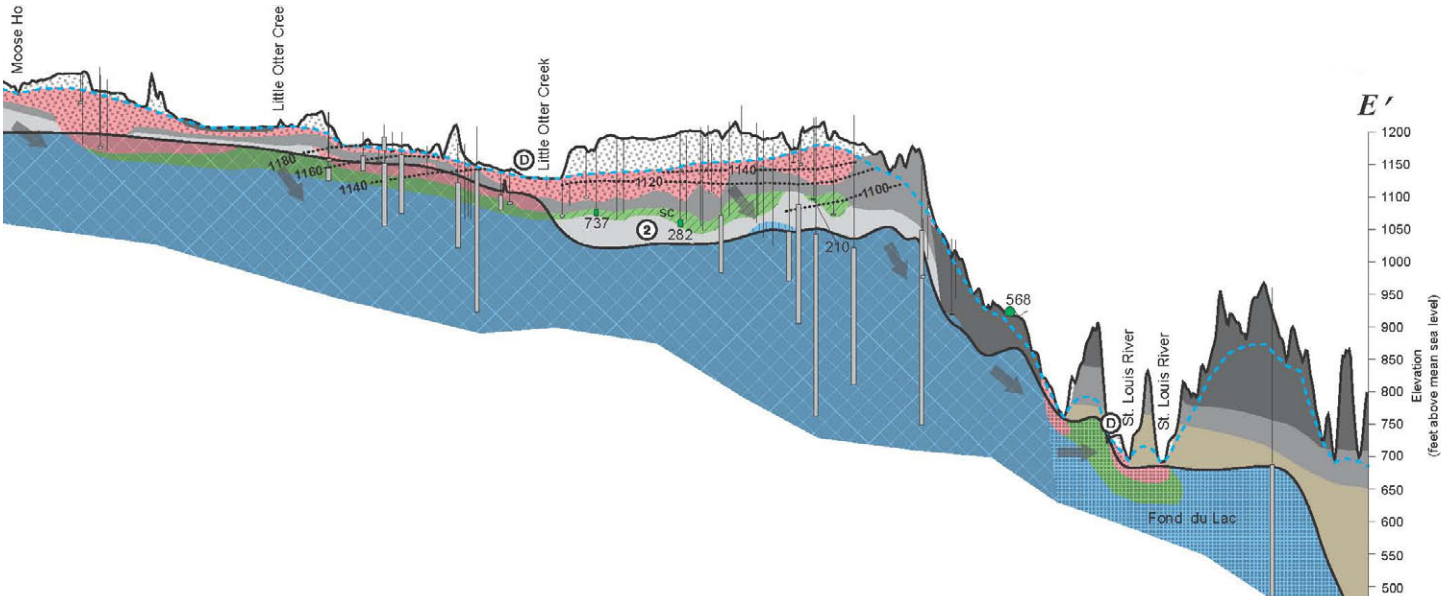
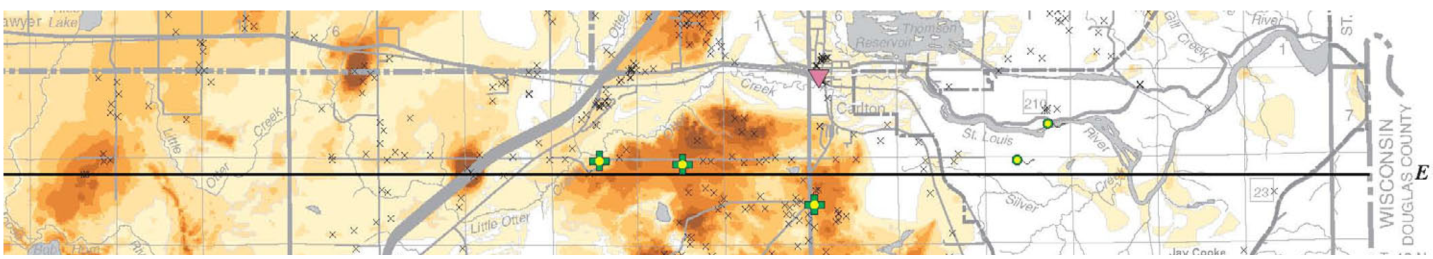
Natural Resources County Atlas Series C-15, Part B, 4 pls., scale 1:100,000.

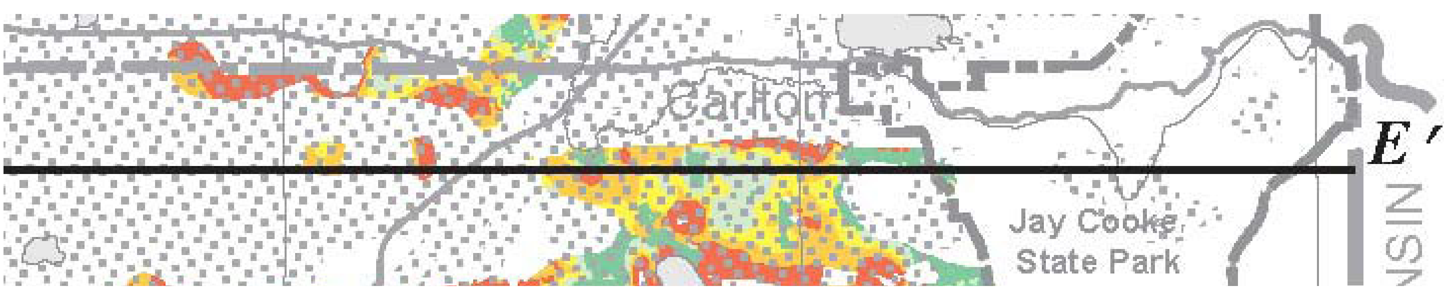
Geologic Atlas of Carlton County, Part B cont..



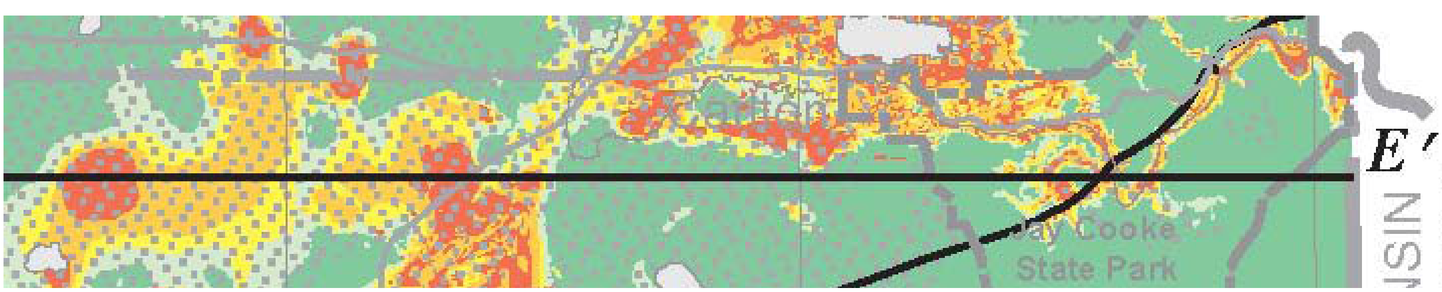
Cross section E-E'. *City of Carlton (center upland) and Jay Cooke State Park area (eastern lowland)*



Surficial sand thickness. *Black x symbols show well lcoations. Green cross symbols show SC aquifer samples*



Pollution sensitivity SC aquifer. *Stippled pattern shows extent of overlying surficial sand*



Pollution sensitivity bedrock aquifers. *Precambrian crystalline bedrock west, Fond du Lac Fm east*

Figure 2. Eastern portion of cross section E-E' and comparison with corresponding surficial sand thickness and pollution sensitivity for the SC buried sand aquifer and bedrock aquifers.

Tritium age

Darker color in small vertical rectangle (well screen symbol) indicates tritium age of water sampled in well. Lighter color indicates tritium age of water in aquifer.

- Recent—Water entered the ground since about 1953 (10 or more tritium units [TU]).
- Mixed—Water is a mixture of recent and vintage waters (greater than 1 TU to less than 10 TU).
- Vintage—Water entered the ground before 1953 (less than or equal to 1 TU).
- Well not sampled for tritium.

Symbols and labels

- Groundwater sample from spring collected for chemical analysis; color indicates tritium age.
- 300 If shown, chloride to bromide ratio greater than 190.
- 2000 If shown, groundwater age in years, estimated by carbon-14 (^{14}C) isotope analysis.
- General direction of groundwater flow.
- ····1250···· Approximate equipotential contour. Contour interval 20 feet.
- Water table.
- Land or bedrock surface.

Cross section explanation

Estimated surficial sand aquifer thickness (feet)

- Surficial sand not present or no data available.
- 0 to 20
- > 20 to 40
- > 40 to 60
- > 60 to 80
- > 80 to 100
- > 100 to 120
- > 120

Sampled well and aquifer symbols

- ▼ Surficial sand aquifer.

Buried sand and gravel aquifers.*

- sm (Moose Lake till).
- sc (Cromwell till).
- sc1 (Cromwell till).
- sic (Independence till).
- sts (Old Red till units).
- stw (W sequence till).
- su undifferentiated.

Bedrock aquifers.

- ▲ Hinckley sandstone.
- ■ Fond du Lac.
- ● Precambrian crystalline bedrock.

* Buried sand and gravel aquifers are listed with their associated underlying till layer (Plate 5, Part A).

Surficial sand aquifer map explanation

Pollution sensitivity rating

Estimated vertical travel time for water-borne contaminants to enter an aquifer (pollution sensitivity target).

- VH Very High—Hours to months.
- H High—Weeks to years.
- M Moderate—Years to decades.
- L Low—Decades to a century.
- VL Very Low—A century or more.

Pollution sensitivity map explanation

Bioretention, cont.

ing lot and street runoff, automotive emissions, illicit dumping, spills, and tire particles (Davis and McCuen 2005). Urban runoff also contributes PAHs to aquatic environments (Menzie *et al.* 2002). Coal-tar based seal coats, primarily used in the eastern and central portions of the United States, contain substantial quantities of PAHs (Van Metre *et al.* 2009). Therefore, determining the fate of stormwater petroleum hydrocarbons in bioretention is vital to protecting groundwater resources and ensuring the sustainability of these systems. In recent research undertaken, we examined the accumulation of petroleum hydrocarbons in bioretention field sites as well as determined the fate of a representative hydrocarbon in a laboratory simulated system.

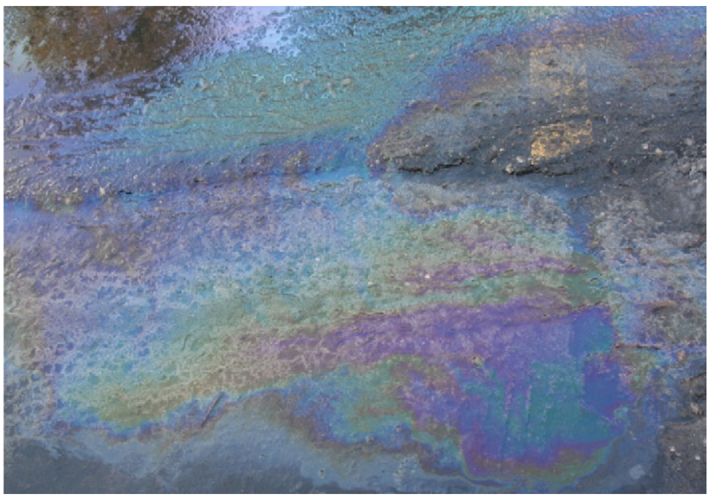


Figure 2: Petroleum Hydrocarbons are common stormwater pollutants. (Photo: LeFevre)

Research Approach and Findings

Over 70 soil samples from over 50 bioretention areas in the Twin Cities metropolitan area were collected and analyzed for petroleum hydrocarbon residual (LeFevre *et al.* 2012a). Different catchment land uses were specifically examined, including parking lots, roof runoff, and streets. The hydrocarbon residual was statistically greater in bioretention soils than at background sites, but was several orders of magnitude below expected levels if no loss mechanisms were occurring (LeFevre *et al.* 2012a). More importantly, the concentrations observed were all well below regulatory action levels (LeFevre *et al.* 2012a). Thus, petroleum hydrocarbons are not accumulating in bioretention soils as they have been found to in retention ponds (LeFevre et al. 2012a). In addition, land use does not appear to influence residual levels for bioretention soils (which are degraded to extremely low uniform concentrations) (LeFevre *et al.* 2012a), whereas land use has been shown to impact residual concentrations in stormwater pond sediments (Weinstein *et al.* 2010).

Understanding the loss mechanisms for petroleum hydrocarbons and their relative importance also is vital to optimizing bioretention design. In the laboratory, column bioretention cells were constructed wherein all fluxes of naphthalene, a representative hydrocarbon, could be determined (LeFevre *et al.* 2012b). Adsorption to soil, plant uptake, biodegradation, volatilization, and leaching were measured. The experiment was run for five months, with repeated pollutant spiking. Overall, pollutant adsorption to soil was the single largest loss mechanism. Biodegradation was substantial and some plant uptake occurred. Volatilization was minimal, as was leaching following the first-flush. Biodegradation was further examined in the laboratory (Figure 3). Field soils were capable of fully degrading naphthalene (LeFevre *et al.* 2012a), and the biodegradation kinetics were enhanced following exposure to the pollutant (LeFevre *et al.* 2012b). The presence of vegetation significantly improved the biodegradation kinetics (LeFevre *et al.* 2012b). Substantial enrichment of an important biodegradation gene was also observed in bacteria present in bioretention soils following contact with the hydrocarbon (LeFevre *et al.* 2012b). This research represents the first comprehensive examination of hydrocarbon fate in bioretention cells and is the first to study biodegradation in bioretention media (Roy-Poirier *et al.* 2010).

Figure 3: Batch tests were used to determine biodegradation kinetics. (Photo: LeFevre)

Implications of Research

Overall, our research suggests that bioretention is an effective means to protect the groundwater resources from petroleum hydrocarbon pollution in stormwater. One can envision hydrocarbon removal largely as a two-stage process. First, hydrocarbons are removed from the infiltrate via adsorption to organic matter in the bioretention media (a very fast process). Secondly, the subsequent biodegradation between keeps the petroleum hydrocarbons in the bioretention cell from accumulating slowly, between storm events. The findings in this research (LeFevre *et al.* 2012a; LeFevre *et al.* 2012b) are in distinct contrast to stormwater retention ponds, where PAH accumulation in the bottom sediments is known to occur to harmful levels (Kamalakkannan *et al.* 2004; Weinstein *et al.* 2010). One reason bioretention performed so differently with respect to petroleum hydrocarbons is because bioretention soils are well-drained and maintain aerobic conditions, whereas stormwater pond sediments typically are devoid of oxygen (Kamalakkannan *et al.* 2004). Although anaerobic biodegradation of hydrocarbons occurs, the kinetics are much slower.

This research suggests three important design parameters can improve bioretention performance for stormwater petroleum hydrocarbon removal. First, a bioretention area must not become clogged and waterlogged, or anoxic conditions will prevail and substantially reduce opportunity for biodegradation. Second, planting bioretention with deep-rooted vegetation creates an enhanced environment for hydrocarbon-degrading bacteria and increases the biodegradation kinetics. Lastly, bioretention media should contain some organic matter (not pure sand) to allow adsorption of hydrocarbon pollutants (and future biodegradation) while protecting the underlying groundwater.

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Bioretention, cont.

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Mark your Calendars - Upcoming Conferences and Symposium

April 19, 2012: **Conduits, Karst and Contamination – Addressing Groundwater Challenges**.
MGWA's spring conference will be held at the University of Minnesota Saint Paul campus. Check the MGWA website for details: www.mgwa.org

June 11, 2012: **Terrestrial Crude Oil Spills: Decades of Science from the Bemidji, Minnesota Research Site.**
The symposium will focus on sharing research results from the National Crude Oil Spill Fate and Natural Attenuation Site, Bemidji, Minnesota, and will be held at the University of St. Thomas, St. Paul campus. The symposium will be followed by a site tour on June 12, starting at 1:00 p.m. The symposium hosts are the U.S. Geological Survey, Minnesota Pollution Control Agency, Enbridge Energy, and Beltrami County, with financial sponsorship from the American Petroleum Institute.

October 1st through 3rd, 2012: **57th Midwest Ground Water Conference and the MGWA 30th Anniversary Conference.**
Potential session topics are:

- Groundwater and Energy Production
- Geothermal
- Karst
- The Groundwater Surface-water Interface
- Groundwater Modeling
- Groundwater Quality
- Groundwater sustainability
- Aquifer Characterization
- Urban Hydrogeology

A field trip is being planned.

Deploying a geophysical array at the Bemidji site.

MGWA's 57th Midwest Ground Water Conference will be held at the Earle Brown Heritage Center.

MGWA to Host the 57th Midwest Ground Water Conference

Planning is underway, the location has been chosen — the Earle Brown Heritage Center — and our web designer at Red Kite Creative has prepared the graphics we will use to promote the conference.

The image below is the banner that will be the header on the web site, the image to the right is a 'badge' that will be used in the newsletter and on the brochures.

Minnesota Ground Water Association Board Meeting Minutes

Meeting Date: December 12, 2011

Location:	Fresh Grounds Café 1362 West 7th Street, St. Paul, MN
Attendance:	Mindy Erickson, President; Steve Robertson, Past President; Jill Trescott, Secretary; Kelton Barr, President-elect; Jeanette Leete, WRI; Sean Hunt, WRI; Audrey Van Cleve, Treasurer
Past Minutes:	November minutes approved as amended.
Treasury:	Cash on hand is approximately $36,900.
Newsletter:	December issue ready for production.
Web Page:	"Give to the Max" and membership information has been updated.
WRI Report:	Dues renewal notices were sent out. A "Give to the Max" report was prepared. Members will be sent a reminder that the match is in effect for the rest of the year.
Foundation:	There was a discussion of how to configure the "Give to the Max" match, but this was tabled until after the first of the year.
Old Business:	GSA 2011: DONE! Midwest Groundwater Conference (presented by MGWA, October 1-3, 2012). Kelton distributed a list of potential topics. The planning schedule was also reviewed.
New Business:	New Officers: Bob Tipping is the candidate for president elect. Julie Ekman is the candidate for secretary. Group Membership: The idea of an "Agency Group Membership" was discussed. The idea was not necessarily to discount memberships for government agencies, but to consolidate them to expedite renewals and record-keeping. Spring Conference: The date will be April 19, 2012

Meeting Date: January 13, 2012

Location:	Fresh Grounds Café, 1362 West 7th Street, St. Paul, MN
Attendance:	Kelton Barr, President; Mindy Erickson, Past President; Audrey Van Cleve, Treasurer; Julie Ekman, Secretary; Sean Hunt, WRI; Jeanette Leete, WRI; Tedd Ronning, Newsletter Editor; Bob Tipping, President-Elect; Jill Trescott, outgoing Secretary
Past Minutes:	December minutes approved as amended.
Treasury:	Cash on hand is approximately $38,800. Total expenses for 2011: $57,394. Net income for 2011: -$5,231.30, this was down due to no fall MGWA conference.
Newsletter:	Ronning asked that we talk to colleagues about submitting articles for the newsletter. The news team meets once per month. Barr has talked to professors from Minnesota and neighboring states about encouraging their students to submit articles for a separate student section in the newsletter. We discussed posting digital content of graphics from articles on the server so that higher quality graphics can be available. Leete suggested that we create a special 30th Anniversary logo to include in the newsletter throughout this year; MGWA's web designer could design this. Leete pointed out that a couple of advertisers did not notify us of a change in address and consequently their ads contained incorrect information.
Web Page:	A Survey Monkey account was purchased for election of officers; this account will be available for a year. An email was sent to the membership on the end of year Foundation donation and the need for science fair judges. Membership and officers information has been updated. The web domain for the Midwest Ground Water Conference (mwgwc.org) could be maintained after the conference for historical purposes for about $10/year. Hunt will get a cost estimate for setting up graphics and a framework for this website. Motion: give pre-approval for Hunt to decide on the design and to work directly with Debbie Campbell on this so it can be ready by the end of January. Motion seconded and carried.
WRI Report:	Leete handed out a table explaining the differences between the MGWA Foundation [a 501(c)(3)] and the MGWA [a 501(c)(4)]. When MGWA has a profit it goes into the Foundation; the end of year fund drive raised $2051. WRI contract is multi-year and no changes are anticipated at this time. Liability insurance type has changed; information will be brought to the Board as it develops.
Membership:	Hunt will follow up with past members who haven't paid dues for this year, yet. Kelton suggested creating a list of attendees at the GSA Conference who are not MGWA members and contacting them about membership.
Foundation:	Chris Elvrum resigned from the Foundation. No Foundation meeting has been set; the first will probably be in February. Expecting to have 2 meetings this year. Gil Gabanski is working on this.
Old Business:	• Barr: MGWA will host 2 conferences in 2012; one is the MGWA Spring Conference and the other is the 57th Midwest Ground Water Association conference in October. An application has been sent to the GSA to bring the Birdsell-Dreiss lecture here. • Conversation ensued on ideas for the conferences: No themes or titles have been

The MGWA Board of Directors meets once a month.

All members are welcome to attend and observe.

MGWA Minutes, cont.

determined for either conference. We have received volunteers to speak on karst and on MPCA landfill regulations. Perhaps someone from MDH could talk on wellhead protection. Leete suggested a presentation on what the Clean Water Fund is doing for ground water. Tipping offered to present on the distribution of vertical recharge to upper bedrock aquifers. The USGS might be asked to report on their White Bear Lake study. Another possible topic is aquifer naming.

- A replacement is needed for Chris Elvrum who retired from the MGWA Foundation. Elvrum's contribution is appreciated and an article on this should be written for the next newsletter.
- We need ideas for celebrating MGWA's 30th anniversary.
- It was reported that there are a number of session co-chairs developing topics for the Midwest Ground Water Conference. We discussed the intended site for the conference and the potential risk in paying up front for many out of state attendees that might not show due to the current economic situation. It was decided that we will go forward with planning based on our normal conference attendance and not count on many attendees from out of state.
- Motion: Move $2,051 to the Foundation fund; motion was seconded and carried.

Meeting Date: February 9, 2012

Location: Fresh Grounds Café, 1362 West 7th Street, St. Paul, MN

Attendance: Kelton Barr, President; Mindy Erickson, Past President; Bob Tipping, President-elect; Julie Ekman, Secretary; Audrey Van Cleve, Treasurer; Jill Trescott, Outgoing Secretary; Jeanette Leete, WRI; Sean Hunt, WRI;

Past Minutes: January minutes approved.

Treasury: Van Cleve handed out a budget summary. MGWA income to date is $13,765.96. Donations to the MGWA Foundation totals $3,373.05. Cash on hand: $38,588.36.

Newsletter: March newsletter deadline is February 24th. Sharon Kroening is issue editor.

Web Page: Hunt reported he is working with Debbie Campbell of Red Kite Creative; we have received and accepted a quote. The MWGWC web page is being developed in Word Press; Hunt will learn how to use it so we can have a template for next year and can archive past conference information. The 30th Anniversary logo is ready for the next newsletter. Emails were sent to about 400 members reminding them to renew their memberships.

WRI Report: Leete reported that the state's financial software (SWIFT) makes it difficult to get information about Electronic Funds Transfers (EFTs). MGWA's business records are avilable for audit. Leete will meet with Van Cleve to start the internal audit.

Foundation: Next meeting February 28th at USGS. Will discuss fundraising.

Old Business:

- Barr distributed a handout summarizing potential topics for the 57th Midwest Ground Water Conference. All the sessions are chaired and the field trip is staffed. Additional co-chairs are needed. Another conference on frac sand is being planned by UMD's PreCambrian Institute and the Society for Mining Engineers (SME). Discussion ensued on the possibility that these two conferences could coincide. Planning will go forward to hold both conferences together, possibly keeping session tracks separate. Websites for the conferences could be separate but linked. Leete is meeting with the Earle Brown Conference Center on February 15th along with someone from the frac sand conference planning group.
- Barr distributed a handout of draft speakers and topics for the 2012 MGWA Spring Conference to be held on April 19th. Nearly all of the speaker time slots are filled and confirmed. Still need someone to speak on what the Clean Water Fund is doing for Groundwater. Early registration deadline will be April 6th. Hunt will send out an email call for posters. Discussed whether or not to hold a session on aquifer renaming.

Next Meeting: Friday March 2nd, 11:30 at Fresh Grounds Café, 1362 West 7th Street St. Paul.

MGWA 2012 Membership Dues

Professional Rate:	$35
Full-time Student Rate:	$15
Newsletter (printed and mailed)	$20
Directory	$7

Membership dues rates were revised at the October 1, 2010 meeting of the MGWA Board. The Board intends to balance the membership services budget.

Thank You Chris Elvrum

By Gil Gabanski

I have said this many times before…one the best rewards from volunteering your time with an organization is the opportunity to meet and work with colleagues, and (here's the best part) to simply get to know them. I and the other Minnesota Ground Water Association Foundation (MGWAF) Board directors have been most fortunate to have had the pleasure of working with and getting to know Chris Elvrum, who last year stepped down as the a director for the MGWAF Board. Chris served as president of the MGWA in 2004 and as past-president in 2005 became a MGWAF director. In 2004 and 2005 Chris also was also a major contributor to developing and designing the Big Back Yard groundwater display at the Science Museum of Minnesota. At the end of 2005, we needed a new Foundation Board director and I asked Chris to stay on. Chris had served three years as an officer of the MGWA and could have easily said no and argued that he had given the organization plenty of his time. Yet, he agreed to stay on with the Foundation board. Chris has been a reliable Foundation Board member and one who brought ideas and a willingness to debate and listen. As Foundation Board president my role was easier with Chris there, I knew he would take on any task if asked. I did not know Chris that well when he was President of MGWA but now, after all these years, he is now more a friend than a colleague. This, as I said, is one of the benefits of volunteering in an organization.

If you know Chris, or if you see him at a conference, please join me, take a moment, and thank him for his dedication, and for giving back to his profession.

Chris, you have set the standard for excellence during your years of service. Your work and fundraising efforts are much appreciated. Thank you.

From the Archives: Chris Elvrum receives an MGWA Service award from Laurel Reeves for his service as President

FOUNDATION MINUTES

Meeting Date: February 28, 2012

Attending: Gilbert Gabanski, Mindy Erickson, Cathy von Euw and Cathy Villas-Horns. MGWA Management Present: Jennie Leete and Sean Hunt

Review of Minutes: The meeting minutes for the August 3, 2011 meeting were approved on December 7, 2011. The minutes were provided via e-mail to the MGWAF Board and the MGWA Newsletter staff.

Treasurer's Report: MGWA Foundation balance as of February 27, 2012 is $117,639.70. Interest in the amount of $1,432.41 was accrued since 08/02/2011 and was swept into the endowment. Donations of $7327 to the MGWA Foundation endowment and $3358 to the MGWA Foundation general fund were received during this period. Total debits of $500 were deducted during this period for a $500 grant to Dr. Kerry Keen of the University of Wisconsin River Falls for expenses from a spring 2011 student field trip.

The HO Pfannkuch Fund balance as of February 27, 2012 is $19,438.11. Interest in the amount of $110.06 was accrued since 08/02/2011and was swept into the fund. Total donations of $5717 were received during this period.

The Foundation Wahoo Certificate of Deposit (Wahoo CD) will be coming due in August 2012. Gil asked Cathy to do some research on investing these funds and to send a recommendation on a new investment vehicle about 60 days before the Wahoo CD matures.

Old Business: MGWA Board Meeting report: The spring 2012 MGWA conference will be held on April 19 at the Continuing Education and Conference Center at the U of MN in St. Paul. The title of the conference is "Conduits, Karst and Contamination – Addressing Ground Water Challenges."

The fall 2012 MGWA conference will be held jointly with the Midwest Ground Water Conference at the Earle Brown Heritage Center in Brooklyn Center from October 1-3. There will be two days of conferences and a one day field trip.

There are two new officers to the MGWA Board: Bob Tipping is the President Elect and Julie Ekman is the Secretary.

Fundraising: Approximately $1000 was raised through donations on Give to the Max Day for the MGWA Foundation; this was reduced by about $30 for credit card fees., but MGWA paid those fees Another $1050 was donated outside of this event. The Give to the Max event could be better utilized by advertising the MGWA to the beneficiaries of past MGWA Foundation donations such as the Children's Water Festival, the Headwaters Science Center in Bemidji and the Science Museum of Minnesota. People who give to these organizations may be more likely to donate to the MGWA Foundation.

Gil and Kelton Barr met to discuss fundraising. A separate committee should be set up to perform fundraising activities.

Scholarship: There was some discussion of how to structure a scholarship now that the endowment is large enough to generate interest to support a meaningful scholarship. One person on the scholarship committee should be a member of the MGWAF Board. Jennie mentioned that some of the criteria for the scholarship were established with the Internal Revenue Service filing in 2000. This information is available on the MGWA website. The goal is to be able to present a scholarship to a student at the fall MGWA conference.

The interest generated from endowment investments will be used to fund the scholarship. Right now all the interest generated is swept back into the endowment fund. The MGWAF Board agreed that we will stop putting the endowment interest into the endowment account and will instead set up another account, a general unrestricted type account, that will receive interest generated from endowment investments and can be used for issuing the scholarship.

New Business: Stu Grubb volunteered to be a director on the MGWA Foundation Board. Mindy moved that Stu be accepted; Cathy Villas-Horns seconded the motion. Motion passed.

Next Meeting: The next meeting will be in May, either May 15 or 22.

The MGWA Foundation is a 501(c)3 charitable organization. Donations to the Foundation are deductible on your state and federal income tax returns.