

D. Summary of Professional Contributions and Scholarship

Summary of Professional Contributions and Scholarship

Introduction

I began my appointment as a Hydrogeologist/Geophysicist at the Wisconsin Geological and Natural History Survey (WGNHS) and Assistant Professor in the University of Wisconsin-Extension Department of Environmental Sciences on July 1, 2001. I have served in these positions for four and a half years.

I have two roles at the WGNHS, hydrogeologist and geophysicist. As a hydrogeologist, I have developed research programs and worked with others on groundwater issues, teaching, and research. These efforts have led to better science-based policy and management of groundwater in Wisconsin through an improved understanding of one of Wisconsin's most important natural resources, groundwater. These programs are ongoing.

My other role at the WGNHS is as a geophysicist. Geophysics is the study and use of differences in physical properties of earth materials to study the subsurface. At the WGNHS I have developed research programs that have demonstrated the use and applicability of various geophysical techniques. These techniques have enhanced the geologic and hydrogeologic studies of WGNHS scientists and other researchers across the State of Wisconsin.

In addition, I have contributed to other projects and service needs that help the WGNHS meet its mission statement:

The WGNHS conducts earth-science surveys, field studies, and research. We provide objective scientific information about the geology, mineral resources, water resources, soil and biology of Wisconsin. We collect, interpret, disseminate, and archive natural resource information. We communicate the results of our activities through publications, technical talks, and responses to inquiries for the public. These activities support informed decision-making by government, industry, business, and individual citizens of Wisconsin.

Professional Contributions, Teaching, and Scholarship

The WGNHS and the Department of Environmental Sciences provide excellent opportunities for professional contributions to the sciences of hydrogeology and geophysics. Unlike many science professions, the role of the scientist in the WGNHS and the Department of Environmental Sciences does not end with a completed research project. The results are broadcast to larger audiences so that the scientific knowledge can benefit society. We strive to make our science relevant and applied to practical problems. As a result, teaching is an essential part of my appointment. This research and teaching is embodied in the UW-Extension definition of scholarship.

In the following sections, I discuss programs that illustrate how I have developed professionally and applied the UW-Extension definition of scholarship to earth science studies in Wisconsin. These examples will show how I did creative work that was then reviewed by my peers. The examples demonstrate how I communicated the results of that work and give instances of how that work was valued by my peers, government agencies, planners, and citizens of Wisconsin. I also document my service to the WGNHS and the Department of Environmental Sciences.

1. Groundwater in Southeastern Wisconsin

Groundwater is an important resource for southeastern Wisconsin. Approximately 70 million gallons of groundwater per day are pumped from wells to supply water to more than 300,000 people and the industry and commerce of southeastern Wisconsin. Groundwater use has more than doubled since 1960, primarily driven by the increasing population growth (Exhibit 9). This limited resource cannot sustain this growth indefinitely.

As happens with any resource with limited availability, conflicts arise. These conflicts result from concerns over impacts to the wetlands, lakes, and streams caused by diverting groundwater from them and competition between municipalities for groundwater. Another concern is the dependence of communities outside of the Great Lakes basin—which are not allowed to remove water from the basin—on groundwater (Exhibit 10). These issues and others have made management of this resource a necessity. Policy and management strategies must be based on sound science or it is unlikely that they will succeed. Below I describe my role in projects that are examples of applied and useful science.

Regional Aquifer Model for Southeastern Wisconsin

Computer models of groundwater flow are used to simulate groundwater movement through the earth's subsurface. We created a computer model of groundwater flow in southeastern Wisconsin to provide a tool for understanding and managing groundwater there. This modeling effort was funded by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) to assess the effects of historic and current groundwater withdrawals in southeastern Wisconsin.

I had several roles in this project. The first role was to calibrate the groundwater flow model. A model is calibrated when it accurately produces measured water levels and stream flows. My second role was to compile the groundwater pumping rates (water-use data) for the model. The successful calibration allowed us to make predictions of changes in groundwater levels and flows based on current trends in pumping rates (Exhibit 4). Groundwater pumping drives the changes seen in the flow system and was an important component of the model. It is necessary to know how groundwater pumping altered the water levels in the past to understand how future groundwater pumping rates will affect future water levels. The data includes historic pumping rates from 1864 to 2002 for more than 700 wells in southeastern Wisconsin (Exhibit 4). During compilation and manipulation of the data, it became clear that the collection of water-use data in Wisconsin is incomplete and inadequate for many applications. We wrote a proposal that was subsequently funded to remedy this situation (Exhibit 5). Based on our findings from this research, we will make recommendations to the Wisconsin Department of Natural Resources (WDNR) for their reporting requirements for the new groundwater-use legislation, Act 310.

The value of the southeastern Wisconsin groundwater project has been recognized nationally. It is cited as being the case study that initiated the current U.S. Geological Survey (USGS) effort to model the groundwater of the entire Great Lakes Basin. It is also valued locally. We have used this model to determine zones of contribution (ZOCs) for 33 water supply wells for the WDNR's source water assessment program. A ZOC is the area of land surface over which precipitation and snowmelt enters a groundwater

system and eventually flows to a well. The ZOCs were relayed to the WDNR and then to municipalities for planning purposes so they can better protect their drinking water.

In addition to its use as a policy and management tool, the model has also been an excellent teaching tool. As part of the teaching effort, I created a PowerPoint “movie” of groundwater-pumping rates and water-level decreases in southeastern Wisconsin (Exhibit 3). This simple presentation demonstrates the link between increased water use and the decrease in water levels. This movie has been used in at least seven presentations by me, by WGNHS personnel in local, state, regional, and national conferences, and by others with permission. For example, Jansen and others from the consulting firm, Ruekert and Mielke presented it at the North Central Geological Society of America Meeting, 2005. It is part of a USGS Web page on groundwater and the Great Lakes and can be seen at the following web address, (<http://wi.water.usgs.gov/glpf/images/stptw12.avi>).

Water-Use Project

I was a co-author of a proposal with colleagues at the WGNHS and the USGS (Exhibit 5) to study water use in Wisconsin. We were awarded \$69,246 through the USGS; the project has just begun its second and final year. As part of this project, I am supervising a graduate student in the University of Wisconsin-Madison Civil Engineering Department.

This project was an outgrowth of the groundwater pumping rates data compilation for the regional aquifer model of southeastern Wisconsin. In that compilation I found that historical water use was doubling approximately every 50 years. Model simulations showed that this increase is not sustainable (Exhibit 4). It is unclear what is driving the increased groundwater use: increased industry, population, changing lifestyles, or some other unknown factor.

We seek to understand how water is used in Wisconsin so that programs can be designed to conserve and manage water. For example, it would not be useful to regulate industrial users if they only account for five percent of the total water use. It might be more effective to limit watering of lawns by residential users. We also hope this study can be used by planners so that they can predict how groundwater use might change as population increases or as an area goes from primarily agricultural to urban or suburban land use. The WDNR will use the results of this study to design their reporting requirement rules for Act 310. Finally, this research will result in more accurate groundwater-use estimates to improve our model predictions of groundwater flow and levels in southeastern Wisconsin. The results will be presented to municipalities and planning organizations like SEWRPC to aid them in their planning activities.

Mechanisms of Flow Across an Aquitard

Aquitards are rock units that slow groundwater flow. They prevent groundwater from entering underlying aquifers but also protect those underlying aquifers from contamination. Aquitards are composed of low permeability materials such as shale or clay. A large regional aquitard, the Maquoketa shale, is present in southeastern Wisconsin. Groundwater levels are dramatically decreasing in the aquifer beneath this aquitard because the aquitard limits flow to the underlying aquifer (Exhibit 3).

In southeastern Wisconsin, our computer model predicts that eight million gallons of groundwater flow each day from the upper aquifer across the Maquoketa shale into the

lower aquifer. This amount of water is much larger than expected for this shale. I authored a paper suggesting two potential mechanisms that explain how this quantity of water is moving across the Maquoketa shale (Exhibit 7). The first mechanism is wells that allow groundwater to flow from the upper aquifer downward through the well and then into the lower aquifer. The second mechanism is flow through natural geologic faults and fractures. Although this might seem to be an esoteric study, it has profound real-world implications. If the mechanism of flow across the shale layer is through wells, then plugging those wells will result in accelerated drawdowns in that already depleted lower aquifer.

To better understand the implications of cross-connecting wells and fractures and faults, I wrote and received funding for a proposal to investigate these mechanisms (Exhibit 8). This one-year project was awarded \$37,615 by the WDNR. In this project we have found more than 133 wells that provide flow to the lower aquifer across the Maquoketa aquitard. We have also completed a literature review of the Waukesha fault in Wisconsin. The final report to the WDNR will show the implications to the lower aquifer of sealing the wells and provide some data on the location of the Waukesha fault system.

2. Application of Near-Surface Geophysics to Geotechnical and Archeological Issues

The WGNHS is responsible for collecting and providing information about the subsurface to the citizens, municipalities, and the State of Wisconsin. The WGNHS management realized that geophysical tools would help it conduct its mission and that a geophysicist was needed on staff. I was hired in July 2001 to fill that gap.

My approach to building a geophysics program at the WGNHS has been to assemble a suite, or toolkit, of geophysical techniques and then educate geologists and other users of geophysics on the limitations and proper applications of the methods. As a result of my program, we currently have the capability of conducting the following geophysical surveys: ground-penetrating radar, seismic, time and frequency domain electromagnetics, gravity, magnetics, and direct current resistivity. I have conducted geophysical surveys that were used to determine depth to bedrock and the water table, the presence of an aquitard, the presence of graves, the internal structure of sand dunes and beach deposits, the presence of caves and fractures, and the locations of buried utilities. I consider this program to be successful because geologists and hydrogeologists here at the WGNHS and other users of geophysics now consider using these methods as routine as drilling a well in a study of the subsurface. Examples of geophysical surveys and education that illustrate the progression of geophysics at the WGNHS are discussed below.

Education on Geophysical Techniques

One of the main hindrances to the application of geophysics is that users often lack knowledge about when geophysics has some chance of success. I have developed a lecture titled What's in the Box (Exhibit 15), that I've delivered to Beloit College geology students, the Groundwater Coordinating Council, an introductory University of Wisconsin-Madison geologic engineering class, and WGNHS staff. This lecture draws analogies between what children do when shaking wrapped presents and what we do with geophysics to make educated guesses about what we can't see. For example, children

Deleted: ¶

can guess, by shaking it, that a package contains clothes, but won't know the color of the clothes; we can guess, using geophysics, that the subsurface contains sand, not clay. Another education effort was teaching the Introduction to Geophysics Class, lecture and field components at the University of Wisconsin-Madison. I was able to use many local examples in my lectures so that students were introduced to Wisconsin geology. The student reviews were favorable; one student noted that it was "The best class I have taken to date." (Exhibit 12).

Deleted: ¶

Groundwater Studies

One of the most important questions about groundwater flow systems is whether or not an aquitard is present. Aquitards, often layers of clay or shale, slow groundwater flow. An aquitard can protect an underlying aquifer from contamination and prevent recharge from entering the underlying aquifer. In collaboration with David Alumbaugh, a professor at the University of Wisconsin-Madison, I received funding (\$26,546) from the University of Wisconsin System for a project that used time-domain electromagnetics to delineate the edge and thickness of the Eau Claire shale aquitard (Exhibit 11). This major aquitard covers much of southern Wisconsin and is an important part of the groundwater flow system there. The limitations of the method were determined so that the Eau Claire shale could be better delineated and the method could be properly applied in the future (Exhibit 13). The results of the delineation were used to strengthen the conclusions of a groundwater flow model for Sauk County developed here at the WGNHS and to improve our understanding of the geology in southern Wisconsin (Exhibit 16). We are continuing to use this method in a study of geology and groundwater in St. Croix County.

In another example, the WDNR requested our assistance in an investigation of how liquid manure contaminated rural private wells in Dodge County. I used an EM-31, a geophysical electromagnetics instrument, to determine the depth to bedrock along several 100-yard transects in the field where the liquid manure was applied. Based on the geophysical results, we excavated some locations where depths to bedrock were shallow and some locations where it is deep. Working with a WGNHS Pleistocene geologist, the WDNR, and University of Wisconsin-Madison soil scientists, we were then able to determine the location where the liquid manure penetrated. Surprisingly, the liquid manure penetrated the overburden and entered the groundwater system where the depth to bedrock was deepest, around 20 feet, rather than where the depth to bedrock was shallow, around 4 feet. The results of the survey are being used by the WDNR and the Wisconsin Department of Agriculture, Trade, and Consumer Protection (WDATCP) to write rules concerning liquid manure application (Exhibit 21).

Geological Studies

Geophysics has begun to be routinely incorporated into geologic studies conducted by the WGNHS. These studies support land-use planning and resource management efforts in the State of Wisconsin. I completed a gravity survey in Fond du Lac County to determine the depth to bedrock where no wells were deep enough to encounter bedrock; the project geologist was able to use the results in his depth to bedrock map of Fond du Lac County. I conducted a ground-penetrating radar study over sand dunes in Shawano County. The internal structure of the dunes was determined by

the radar survey (Exhibit 17); the results of the study were used by the project geologist in a proposal to further study the area. I also conducted a magnetometer survey in St. Croix County to better identify the location of faulting. The geologist working there will use those results to place the faulting in a broader geologic context. The USGS will incorporate his geologic maps into a groundwater flow model for west-central Wisconsin.

As a result of these studies, WGNHS geologists now include geophysics in the proposals to the State Geologic Mapping (STATEMAP) Program administered by the USGS. In the next year alone, these proposals contain approximately \$30,000 applied to geophysical investigations. When I first started at the WGNHS, no near-surface geophysics was included in the STATEMAP proposals.

Archeological Studies

Archeological studies are conducted to better preserve and understand Wisconsin's cultural heritage. I have conducted ground-penetrating radar studies of 150-year-old cemeteries for the cemetery manager, Native American burial mounds, and sites occupied by Native Americans for Dodge County Parks and the Ho Chunk Nation archeologists. These studies have been particularly satisfying to me. In two studies, I was able to identify previously unmarked graves. The first study was conducted in a 150-year-old cemetery in Attica, Wisconsin. The northwest corner of this cemetery appeared empty but questions remained as to whether any graves existed there. The curator thought that part of the cemetery had been used to bury paupers. The ground-penetrating radar survey identified several likely unmarked graves there (Exhibit 18).

The second study was at Nitschke Mounds Park in Dodge County. I conducted a ground-penetrating radar survey of a mound and found, as had been documented, that it had been previously excavated. Near this mound was a pile of rocks. According to one of the Nitschke Mounds volunteers, Native Americans occasionally buried their dead near these much older mound structures around the 1900s. A ground-penetrating radar survey showed that the depth of the rock pile and disturbed earth was more than 5 feet below ground surface, making it more likely that the rock pile was a grave monument and not just placed there by a landowner clearing land. These two examples show an application of geophysics that goes beyond pure science to a broader societal issues.

Karst, Cave, and Fracture Studies

Planners and developers have an increasing need to identify and map features such as sinkholes, caves, and fractures as more land is developed. In addition, water supplies must be protected from surface contaminants that can easily enter the groundwater through these features. I have applied geophysics at several locations in Wisconsin to improve our ability to understand these features. These studies have been valuable, from showing that sinkholes can occur even when the depth to bedrock is greater than 80 feet (Exhibit 14) to identifying highly disturbed areas near a retention pond that has periodically drained without warning through sinkholes and fractures near Madison (Exhibit 20).

3. Application of Mathematics and Physics to Geological Investigations

Although geology is traditionally a descriptive science, there is often a need to apply more quantitative methods. My training in geophysics and laboratory

experimentation has given me a background to approach science from a physical perspective that often complements the geologist's approach.

I have conducted several investigations that make use of my quantitative approach and skills. The first investigation involved testing and reviewing a new method of computer modeling groundwater flow. At the request of the WDNR I tested this method and wrote a review (Exhibit 23). I also completed an investigation of the connection between indoor radon and Wisconsin geology. A letter report to the Wisconsin Department of Health and Family Services (Exhibit 25) documented the variation in home radon values due to geology in Wisconsin. This work will be used to further public understanding and mitigation of this naturally occurring and preventable health risk. Another investigation involved determination of hydraulic flow parameters for sediment from glacial Lake Oshkosh using consolidation testing and extraction of pore fluids from that sediment. I utilized this test during a previous investigation of undersea serpentine muds from the Ocean Drilling Program (Exhibit 22).

These investigations are examples of how my skill set has broadened the capabilities of the WGNHS and enhanced its science programs. I have found that my quantitative approach to science works well with the geologist's observational qualitative approach. The two approaches complement each other and strengthen the end result.

4. Groundwater Education

Most of Wisconsin's residents depend on groundwater for drinking, washing dishes and clothes, and other home uses. Industry, agriculture, and commercial users also depend on groundwater, making it an essential part of Wisconsin's economy. Many groundwater users do not realize how much they depend on groundwater and do not understand groundwater basics. The result is a degraded resource and the need for costly solutions to fix the problems created by that lack of knowledge.

I believe one of my most effective teaching approaches has been the use of a groundwater sand-tank model that was developed by James O. Peterson of the University of Wisconsin-Extension and Ron Hennings of the WGNHS. The sand-tank model has a proven record as a tool for teaching groundwater basics. It allows for a hands-on experience and observation of groundwater. The sand-tank model is a narrow rectangular box filled with sand and clay to represent aquifers and aquitards, respectively, with plexiglass sides and an open top. It has a "river" in the middle, "septic system" at the surface, and multiple wells that can be used to pump water and see the impact on water levels. Food coloring can be added to represent contaminants; this allows students to see how water moves through the various materials and how a pumping well can intercept a contaminant.

Since 2001, the WDNR, in cooperation with the UW -Extension Wisconsin Groundwater Center and the WGNHS, has funded workshops for junior high and high school teachers. Working with David Lindorff of the WDNR and Kevin Masarik of the Wisconsin Groundwater Center, I have helped lead those workshops for the last two years (Exhibit 26). In those one-day workshops, we give the teachers an introduction to groundwater in Wisconsin, hands-on training on use of the model, and a choice of classroom groundwater lessons based on the model. The training is greatly enhanced by pairing the teachers with an expert in groundwater from the WDNR or University of Wisconsin-Extension. At the end of the day, the teachers take the model home to their

schools. To obtain reimbursement for the substitute teaching required by their absence, the teachers submit a report to the Wisconsin Groundwater Center on how the model was used in their curriculum and how it impacted their students and the broader community.

In the two years I have been part of this program, we have provided 46 sand-tank groundwater models to 46 schools across Wisconsin. The workshops have been held in Madison, Eau Claire, Green Bay, Waukesha, Spooner, and Tomahawk. We plan to distribute another 22 models in the coming year in another set of workshops. I have found these workshops to be one of the most rewarding parts of my job. The response of the teachers to the workshop and the model is excellent (Exhibit 27).

I also demonstrate and lend a WGNHS sand-tank model to schools and other agencies. The WDNR personnel and local teachers have used the model and have found it to be very useful for demonstrating basic groundwater concepts. (Exhibit 28).

Committee Service and WGNHS Responsibilities

As a scientist working for the WGNHS and a faculty member in the Department of Environmental Sciences, I have responsibilities to the State of Wisconsin and its citizens beyond producing sound applied science and conveying those results to stakeholders. I also have a service component. I fulfill that commitment through service on statewide committees and working on administrative issues within the WGNHS and the Department of Environmental Sciences.

I have served and continue to serve on a wide range of statewide committees. These include the Education Subcommittee of the Wisconsin Groundwater Coordinating Council, the Wisconsin Highway Research Program, the University of Wisconsin-Madison Geology Consortium, the WDNR Source Water Assessment Program modeling group, and as Director at Large for the Wisconsin Chapter of American Water Resources Association.

I have served as the secretary of the Department of Environmental Sciences for the last two years. I was part of the Ad Hoc Committee to review bylaws of the Department of Environmental Sciences in 2003. I also had the opportunity to serve on the hiring committee for the geographical information system (GIS) specialist in 2004.

Summary Statement

The Department of Environmental Sciences in University of Wisconsin-Extension and the WGNHS have given me opportunities not afforded to all scientists. I am allowed and expected to be both a researcher and a teacher. One of the greatest pleasures of this job is conducting good science and applying and communicating it to various stakeholders. The fact that the WDNR will use my work to create sound policy and rules makes the science worth doing even on cold windy days in January. Another pleasure is teaching wide and varied audiences. Few teachers get to speak one day to elementary school children about Wisconsin's geological heritage and then the next day to an audience of PhDs about groundbreaking research in hydrogeology. I look forward to continued improvement of our science programs and advancing of earth-science education in Wisconsin.