

1999 Project Abstract

For the Period Ending June 30, 2001

TITLE: W22 Groundwater Flow in the Prairie du Chien Aquifer, Southeastern Minnesota

PROJECT MANAGER: Anthony C. Runkel

ORGANIZATION: University of Minnesota; Minnesota Geological Survey

ADDRESS: 2642 University Avenue W, St Paul, MN 55114-1057

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FUND: Minnesota Environment and Natural Resources Trust Fund

LEGAL CITATION: ML 99, Chap. 231, Sec. 16, Subd. 6(e).

APPROPRIATION AMOUNT: \$110,000

Overall Project Outcome and Results

The goal was to characterize groundwater flow in the Prairie du Chien Group, and underlying Jordan Sandstone of southeastern Minnesota. We documented hydrostratigraphic features in cores and outcrops from 11 counties, collected geophysical logs from nine boreholes in five counties, and conducted comprehensive tests of three scientific boreholes. Groundwater chemistry was analyzed for 28 wells in 10 counties. Data from published investigations were re-evaluated. Our results revealed that the Prairie du Chien and Jordan consist of three hydrogeologic units: 1) An upper Shakopee aquifer in which flow occurs chiefly along a few thin intervals with high conductivity. One such interval in its lower part exists over much of southeastern Minnesota, 2) a lower Oneota confining unit with few cavities, and 3) a lower Jordan Aquifer.

The results have practical value for protecting the Prairie du Chien and Jordan Aquifers, which supply water to over 15,000 wells in southeastern Minnesota. They can be used to model groundwater flow rates and paths, assess vulnerability to contamination, and properly regulate well construction.

Project Results Use and Dissemination

An MGS publication summarizing our results is in preparation. Specific results were presented to local southeastern Minnesota water planners. A formal presentation is scheduled for the October 22 Midwest Groundwater Conference. General summaries for broad audiences include an article in the Summer 2001 issue of IT Magazine of the University of Minnesota, and a segment on the television program Environmental Journal.

The results have or will be used by governmental agencies and private corporations with groundwater concerns in southeastern Minnesota. It will particularly benefit MDH efforts to develop wellhead protection plans for the over 100 communities that use these aquifers, and MPCA staff at sites of contamination. Our scientific techniques are being adopted by the MDNR-Waters, including application to LCMR 2001 project W-22.

Date of Report: July 1, 2001
Date of Next Status Report: None required
Date of Work program approval: June 16, 1999
Project Completion Date: June 30, 2001

LCMR Final Work Program Report

I. PROJECT TITLE: W22 Groundwater Flow in the Prairie du Chien Aquifer, Southeastern Minnesota

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Total Biennial Project Budget:

\$LCMR: \$110,000 **\$Match:** Not applicable

-\$LCMR Amount Spent \$110,000

= \$LCMR Balance \$0

A. Legal Citation: ML 99, Chap. 231, Sec. 16, Subd. 6(e).

W22 Groundwater Flow in the Prairie du Chien Aquifer \$110,000

Appropriation Language: (e) \$55,000 the first year and \$55,000 the second year are from the trust fund to the University of Minnesota to characterize groundwater flow within the Prairie du Chien Formation.

B. Status of Match Requirement: Not applicable.

II. AND III. FINAL PROJECT SUMMARY:

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IV. OUTLINE OF PROJECT RESULTS:

Result 1: Our field investigation of the Prairie du Chien Aquifer provided important new information on the distribution of cavities and how groundwater moves within them. Examination of outcrops and cores in 11 southeastern Minnesota counties allowed us to document marked variability in the abundance, size and connectivity of cavities that provide pathways for groundwater in saturated conditions. Cavities are preferentially developed in the middle to upper part of the Prairie du Chien, whereas its lower part contains relatively few cavities.

The differential distribution of cavities within the Prairie du Chien is reflected by karstic attributes at the land surface, and by groundwater hydraulics and chemistry. A collaborative project sponsored by Wabasha County demonstrated that sinkholes, potential pathways for the rapid introduction of contaminants, are preferentially developed where the middle to upper Prairie du Chien lies directly beneath a thin cover of glacial drift. Borehole geophysical tests of nine water wells in five counties showed that ambient groundwater flow is relatively strong in the cavity-riddled middle to upper Prairie du Chien, and markedly more subdued in the lower part that contains relatively few cavities. Groundwater chemistry data compiled from previous work, and collected from 28 wells in 10 counties as part of this project, demonstrated that the lower Prairie du Chien commonly separates distinct hydrochemical facies: For example, groundwater above it is commonly strongly impacted by anthropogenic constituents such as nitrate, chloride, and tritium whereas water below it is not. Exceptions typically occur where the lower part of the Prairie du Chien lies near the bedrock surface and relatively recent water travels downward through vertical fractures into the underlying Jordan aquifer.

LCMR Budget: \$23,475
Balance: \$0

Match: \$0
Match Balance: \$0

Completion Date: April 15, 2000

Result 2: Hydraulic tests of three scientific boreholes drilled in Washington, Rice, and Olmsted counties allowed us to collect detailed hydraulic measurements of the Prairie du Chien Aquifer. Natural gamma, electric, caliper, EM flowmeter and video logs were collected at all three boreholes, and temperature and conductivity logs were also collected at two of the boreholes. Discrete interval packer tests (10 ft intervals) indicated that hydraulic conductivity ranges over at least four orders of magnitude: intervals with few secondary pores have a conductivity of 10^{-1} ft/day or less, whereas intervals with well developed secondary pores can have a conductivity of 10^3 ft/day or greater. The low conductivity intervals behave as aquitards that separate discrete aquifers with potentiometric levels that differ by as much as 9 ft.

The results of our tests at all three sites indicate that the middle to upper part of the Prairie du Chien is characterized by a relatively dynamic flow system in which groundwater travels chiefly along a few thin intervals of very high hydraulic conductivity, separated by aquitards of low conductivity. The middle of the Prairie du Chien contains a zone of particularly high conductivity, greater than the measuring limits of standard hydraulic tests. At one hole, near Northfield Minnesota, an individual conduit system less than five feet thick in the middle of the Prairie du Chien accommodated water travelling under ambient conditions at rates greater than 12 gallons/minute. The lower Prairie du Chien at all sites tested served as a low conductivity confining unit.

The only changes made to our original workplan were related to Result 2. One change reduced the number of scientific boreholes from four to three. This reduction was required because of an unanticipated increase in the cost of borehole drilling between 1998, when our LCMR proposal was first written, and 2001, when the holes were eventually drilled. Additionally, our schedule for drilling was significantly altered because a key borehole geophysical instrument, an EM Flowmeter, unexpectedly developed an electrical malfunction. The company that provides this instrument to us required months to fix the problem, and as a result we were forced to postpone our borehole drilling for months. A workprogram amendment approved on February 8, 2001 reflects this modification to the schedule. Nevertheless we were able to complete all Result 2 tasks with great success prior to June 30, 2001

LCMR Budget: \$74,425

Match: \$0

Balance: \$0

Match Balance: \$0

Completion Date: ~~November 15, 2000~~ June 30, 2001

Result 3: Interpretation and synthesis of data, and compilation of maps, cross-sections, and reports

Synthesis and interpretation of the data we collected together with a re-evaluation of previous geologic mapping, dye tracing, stream gauging, pump tests, chemical studies, and the distribution of springs and sinkholes demonstrate that the Prairie du Chien is hydrogeologically more complex than commonly believed, yet has attributes that are generally predictable across much of southeastern Minnesota. The upper part of the Prairie du Chien is best considered a karstic aquifer, which we call the Shakopee Aquifer. It is characterized by abundant cavities that accommodate a relatively dynamic groundwater system in which flow occurs predominantly along a few discrete intervals of high conductivity that are separated from one another by aquitards. The lower part of the Shakopee Aquifer has a particularly well developed system of high conductivity conduits and therefore is a regionally important pathway for groundwater. In contrast the lower part of Prairie du Chien is best considered a low conductivity unit, the Oneota

confining unit, that has the ability to hydraulically separate the underlying Jordan aquifer from the Shakopee aquifer

Our results have significant practical applications for citizens across much of southeastern Minnesota, where over 15,000 domestic, municipal, and commercial wells draw water from the Prairie du Chien and Jordan, making them the most widely used sources of groundwater in that part of the state. Over 100 communities rely entirely or in part on the Prairie du Chien or Jordan aquifers, and the information provided by this study can be used for the development of wellhead protection plans required by the Minnesota Department of Health (MDH). Our characterization of the distribution and magnitude of conductivity can also be used by groundwater investigators at the United States Geological Survey (USGS) Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Natural Resources (MDNR)-Division of Waters to more accurately model travel times, assess vulnerability to contaminants and regulate the construction of water wells for the purpose of aquifer protection. Our characterization can also be used as a general framework from which site specific studies of contamination can be conducted. In addition, the techniques we used to study the aquifer are already currently scheduled to be adapted by the MDNR as part of a groundwater monitoring project, and as part of an in-progress 2001 LCMR project (W-22) in which the effects of high volume pumping at quarries is investigated.

Our results have or will be disseminated in a variety of fashions. Some results were presented to the Southeastern Minnesota Water Resources Board on Sept 5, 2001 and are scheduled to be presented to the Board of Commissioners of the same group on Nov 19, 2001. A presentation will be made at the Midwest Groundwater Conference in Madison, Wisconsin on Oct 22, 2001 and an abstract summarizing our results will be published as part of the proceedings from that meeting. A general article written for a broad audience was published in the Summer, 2001 issue of Inventing Tomorrow (IT) Magazine of the University of Minnesota. An on-site video of our borehole testing and a summary of the project was shown on the television program Environmental Journal. A scientific report published by the Minnesota Geological Survey that includes a comprehensive description of our data, interpretations, and discussion of the practical value to the citizens of Minnesota is in preparation.

LCMR Budget: \$12,100
Balance: \$0

Match: \$0
Match Balance: \$0

Completion Date: June 30, 2001

V. DISSEMINATION: The results will be published in print form in the Report of Investigations (RI) Series of the Minnesota Geological Survey. They will be in the form of text, digital maps, cross-sections, and block diagrams that depict groundwater flow within the aquifer at various scales. RIs are distributed widely to state and local units of government, state agencies, and libraries. They are available to the general public, and are covered by major scientific abstracting services.

VI. CONTEXT:

A. Significance: The Prairie du Chien Aquifer is a widely used groundwater source that is under a well-documented threat of degradation. Nitrate levels exceed the safe drinking water standards in several rural areas as a result of infiltration of fertilizers. The aquifer is also highly susceptible to contamination in urban areas, including much of the Rochester and Twin Cities metropolitan areas. Specific sites where the Prairie du Chien Aquifer is known to be contaminated include a landfill in northern Olmsted County, at the former Twin Cities Army Ammunition Plant in Ramsey County, and beneath sewage treatment ponds in Goodhue and Winona Counties. Sites

under active investigation by the MPCA include the City of Faribault (Rice County) where municipal wells draw contaminated water from the aquifer, and at Koch Refinery in Dakota County where petroleum products have traveled through the Prairie du Chien Aquifer toward the Mississippi River. A common problem to investigators at each of these sites is the difficulty encountered in predicting the paths of groundwater flow through the Prairie du Chien.

Despite the well-documented susceptibility of the Prairie du Chien to contamination and the widespread use of this unit as an aquifer, prior to our investigation there had been no comprehensive characterization of groundwater flow. The occurrence and frequency of fracture flow paths, nature of recharge, and internal hydraulic variability were virtually unknown. As a result, groundwater managers did not have the fundamental information necessary to develop aquifer protection strategies.

The results of this project have these practical applications:

- 1) For delineation of hydrogeologic setting and wellhead vulnerability of municipal water supplies as mandated by State Wellhead Protection Rules written by the Minnesota Department of Health.
- 2) To improve on-going bedrock hydrogeologic studies by DNR, USGS, and MGS which currently suffer from inadequate understanding of fracture flow. Such studies include pollution sensitivity maps and recharge delineation investigations of the most widely used aquifer system in southeastern Minnesota.
- 3) To provide accurate hydraulic parameters of fractured aquifers for use in computerized groundwater models such as those currently being produced for the City of Rochester (by the USGS), and for the metro area (by MPCA). These range from city-scale (e.g. Rochester) to regional-scale (e.g. Twin Cities Metro) models.
- 4) To provide information necessary for proper regulatory guidelines for the construction and abandonment of water wells.
- 5) To provide a framework for site-specific investigations including sewage treatment lagoons, feedlot sites, tank spills, and hazardous waste disposal sites.

B. Time: The project was completed within the standard two-year LCMR limit.

C. Budget Context: Specific, on-going work related to this project:

- 1) Wabasha County geologic atlas investigation by MGS scheduled for 1999-2001. Funded by Wabasha County and the Minnesota DNR, Division of Waters. Wabasha County contribution is \$55,128 and \$175,000 from the DNR Division of Waters projected over the next 3 years.
- 2) Goodhue County geologic atlas investigation, Part B, Hydrogeology of Goodhue County by the Minnesota DNR, Division of Waters. Expenditures by DNR are unknown. No direct support for MGS at present time. MGS portion of project (part A) completed in 1999.
- 3) MPCA investigation of contaminants in the Prairie du Chien Aquifer. Active investigations are underway at the City of Faribault, Minnesota, and Koch Refinery in Dakota County. Amount of expenditure unknown. No direct support for MGS.

Earlier Work: In addition to the above, several earlier projects have dealt with different aspects of the geology and hydrogeology of the Prairie du Chien Aquifer at various levels of detail and sophistication. These include County Geologic Atlases for Fillmore, Olmsted, Winona, Rice, Dakota, Washington, Ramsey, and Hennepin Counties, regional and local studies by the U.S. Geological Survey, local studies of the Rochester area funded by Rochester Public Utilities, and various topical investigations conducted by the University of Minnesota (Professor Calvin Alexander) and Winona State University. The Prairie du Chien Aquifer was also studied as part of the Groundwater Sensitivity Project funded by LCMR in the late 1980s. The total sum expended on the Prairie du Chien from these varied, multi-objective projects is difficult to quantify, but probably is in the \$250,000-\$500,000 range summed over a 10-year period.

1. BUDGET:

Personnel \$31,200
 Equipment
 Geophysical logging
 equipment upgrade ~~10,000~~ 16940
 Downhole pump equipment ~~1,500~~ 1100
 Geophysical tool rental ~~8,000~~ 4000
 Acquisition 0
 Development 0
 Other:
 Borehole drilling ~~40,000~~ 37,460
 Water chemistry analyses 6,500
 Communications 180
 Travel 12,570
 Misc. supplies 50

 Total \$110,000

2. BUDGET DETAIL

Attachment A Deliverable Products and Related Budget				
LCMR Project Biennial Budget	Objective/Result			
	Result 1	Result 2	Result 3	
Budget Item	Field investigations of Karst features	Borehole drilling and hydraulic testing	Synthesis/interpretation Map and report construction	ROW TOTAL
Wages, salary and benefits	\$10,000	\$9200	\$12,000	\$31,200
Communications, telephone/mail, etc.	\$50	\$80	\$50	\$180
Contracts				
Water chemistry analyses	\$4420	\$2080	-----	\$6500
Borehole drilling and abandonment	-----	\$40,000 \$37,460	-----	\$40,000 \$37,460
Travel				
Vehicle rental	\$1575	\$525	-----	\$2100
Mileage in Minnesota	\$2760	\$690	-----	\$3450
Field lodging/sustenance	\$4670	\$2350	-----	\$7020
Office/computer supplies	-----	-----	\$50	\$50
Tools and equipment				
Purchase	-----	\$11,500 \$18040	-----	\$11,500 \$18040
Rental	-----	\$8000 \$4000	-----	\$8000 \$4000
COLUMN TOTAL	\$23,475	\$74,425	\$12,100	\$110,000

VII. COOPERATION: The boreholes were drilled and abandoned to code by a contractor licensed to construct boreholes in Minnesota. The driller was chosen through an open bidding process according to the procedures required by the University of Minnesota.

VIII. LOCATION: Southeastern Minnesota, in a north-south belt between Hennepin County on the north and Houston County on the south. The investigation will have results applicable to parts of Washington, Ramsey, Hennepin, Dakota, Goodhue, Rice, Scott, Carver, Wabasha, Olmsted, Fillmore, Winona, and Houston Counties. (See attached map.)

IX. REPORTING: Periodic work program progress reports will be submitted not later than January, 2000 and January, 2001. A final work program report and associated products will be submitted by June 30, 2001.