# FOR BOARD ACTION

**Agenda Item #** 6 **Meeting Date:** 1/27/04

**SUBJECT:** PROJECT REPORT
U.S. Geological Survey Groundwater Investigation – Year 2

**PREPARED BY:** Doug Rovang, Senior Civil Engineer

ITEM DESCRIPTION:

From the mid-1980's to the present, the Utility Board has maintained an unwritten policy of financially supporting various hydrogeologic studies which have significantly expanded information available on the Prairie du Chien-Jordan groundwater aquifer which serves as the source of water for the City of Rochester's municipal water system. A listing of technical reports resulting from those studies is provided on the next page.

The Board has approved approximately $50,000 in each year's Water Utility Budget for the groundwater source studies. From the mid-1980's through the end of 2003, related Water Utility expenditures have totaled approximately $650,000. During that time, matching funds from the U.S. Geological Survey, the Minnesota Geological Survey and the Minnesota DNR have provided an additional $450,000, making approximately $1.1 million available for these worthwhile studies.

Funding of the most recently approved multi-year U.S. Geological Survey groundwater study "Evaluating the Effects of Vegetative Buffers Along the Edge of the Decorah Shale, Rochester, Minnesota" began in 2002. With the completion of the second year of this study, Geoffrey Delin and Perry Jones of the U.S. Geological Survey, will be attending the 1/24/04 Utility Board meeting to review the status of the study. A copy of the original Project Proposal is also attached for the Board's information.

UTILITY BOARD ACTION REQUESTED:

This item is being brought forward for Utility Board information only.

Larry Kasha — General Manager

1/22/04 — Date

**ROCHESTER PUBLIC UTILITIES**

# FOR BOARD ACTION

**Agenda Item #** **Meeting Date:**

## Studies of Rochester's Municipal Groundwater Supply Source Financially Supported by Rochester Public Utilities

1. Hydrogeology and Simulation of Ground-Water Flow in the Rochester Area, Southeastern, Minnesota, 1987-88 (U.S. Geological Survey Water-Resources Investigations Report 90-4081, 1991, Geoffrey N. Delin).

2. Computer Hydraulic Model of the St. Peter-Prairie du Chien-Jordan Aquifer, Rochester, Minnesota, (Unpublished MODFLOW computer program developed for Rochester Public Utilities by U.S. Geological Survey following 1987-88 Groundwater Study, 1990, Geoffrey N. Delin).

3. Delineation of Recharge Areas for Selected Wells in the St. Peter-Prairie du Chien-Jordan Aquifer, Rochester, Minnesota (U.S. Geological Survey Open-File Report 90-397, 1991, G.N. Delin and J.E. Almendinger).

4. Geologic Investigations Applicable to Ground-Water Management, Rochester Metropolitan Area, Minnesota (University of Minnesota, Minnesota Geological Survey Open-File Report 96-1, January 19, 1996, Anthony C. Runkel).

5. Hydraulic Properties and Ground-Water Flow in the St. Peter-Prairie du Chien-Jordan Aquifer, Mochester Area, Southeastern Minnesota (U.S. Geological Survey Water-Resources Investigations Report 97-4015,1997, Richard J. Lindgren).

6. Ground-Water Recharge and Flowpaths Near the Edge of the Decorah-Platteville-Glenwood Confining Unit, Rochester, Minnesota (U.S. Geological Survey Water-Resources Investigations Report 00-4215, 2001, Richard J. Lindren).

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General Manager Date

**ROCHESTER PUBLIC UTILITIES**

# EVALUATING THE REDUCTION IN NITRATE CONCENTRATIONS ALONG THE EDGE OF THE DECORAH SHALE, ROCHESTER, MN

Preliminary Project Proposal by the
Minnesota District, U.S. Geological Survey
June 2001
Revised February 2002

## SUMMARY

Water managers are concerned that nitrate-contaminated ground water from the Upper Carbonate aquifer may eventually reach water supply wells in the City of Rochester. Ground water in the Upper Carbonate is known to have nitrate levels that exceed the U.S. Environmental Protection Agency recommended maximum contaminant level of 10 mg/L. Water from the Upper Carbonate discharges along hill slopes over the edge of the Decorah-Platteville-Glenwood confining unit and into the underlying St. Peter-Prairie du Chien-Jordan aquifer. Soils and vegetation along the 200- to 600-foot long subcrop of the Decorah Shale apparently function as a physical and chemical buffer between the two aquifers, potentially removing nitrate from water flowing over the edge. Objectives of the study are (1) to evaluate the causes for the loss or removal in nitrate-nitrogen in the buffer area along the edge of the Decorah Shale and (2) to evaluate the effects of changing land use on water quality along the Decorah edge. The 5-year study will begin with installation of 3 to 7 observation wells in formations overlying (upgradient of) and underlying (downgradient from) the Decorah edge. Following well installation, about 20 samples will be collected along the transect of springs, interflow water, and newly installed wells. The water samples will be analyzed to quantify the concentrations of field parameters, nitrate-nitrogen, chloride, sulfate, and dissolved gases. The nitrogen ($N_2$) and argon dissolved gas concentrations will be used to estimate the excess $N_2$ that was formed by denitrification. Seasonal water sampling from the wells/springs will be conducted at selected sites beginning in FY2002 to evaluate the effects of land-use changes on water quality of the Decorah edge area over time as upland sites are developed and housing developments are installed. During succeeding years of the study, a tracer test will be conducted to evaluate the continuity of the Upper Carbonate aquifer through the Decorah edge area and into the underlying St. Peter-Prairie du Chien-Jordan aquifer. Tracers such as fluorescene and bromide will be applied at land surface, sampled at approximately daily intervals, and analyzed for the relevant constituents. Pending results of the initial sampling, we also may collect samples of sap water extracted from tree leaves and branches for analysis of $\delta D$ values during succeeding years of the study.

## PROBLEM AND BACKGROUND

Water managers are concerned that nitrate-contaminated ground water from the Upper Carbonate aquifer (Prosser-Cummingsville, figure 1) may eventually reach water supply wells in Rochester. Ground water in the Upper Carbonate is known to have nitrate levels that exceed the U.S. Environmental Protection Agency recommended maximum contaminant level of 10 mg/L (Balaban, 1988). Ground water from the Upper Carbonate discharges over the edge of the Decorah-Platteville-Glenwood confining unit and into the underlying St. Peter-Prairie du Chien-Jordan aquifer. About half of the water supply for the City of Rochester is obtained from this focused recharge along the edge of the confining unit (Delin, 1990).

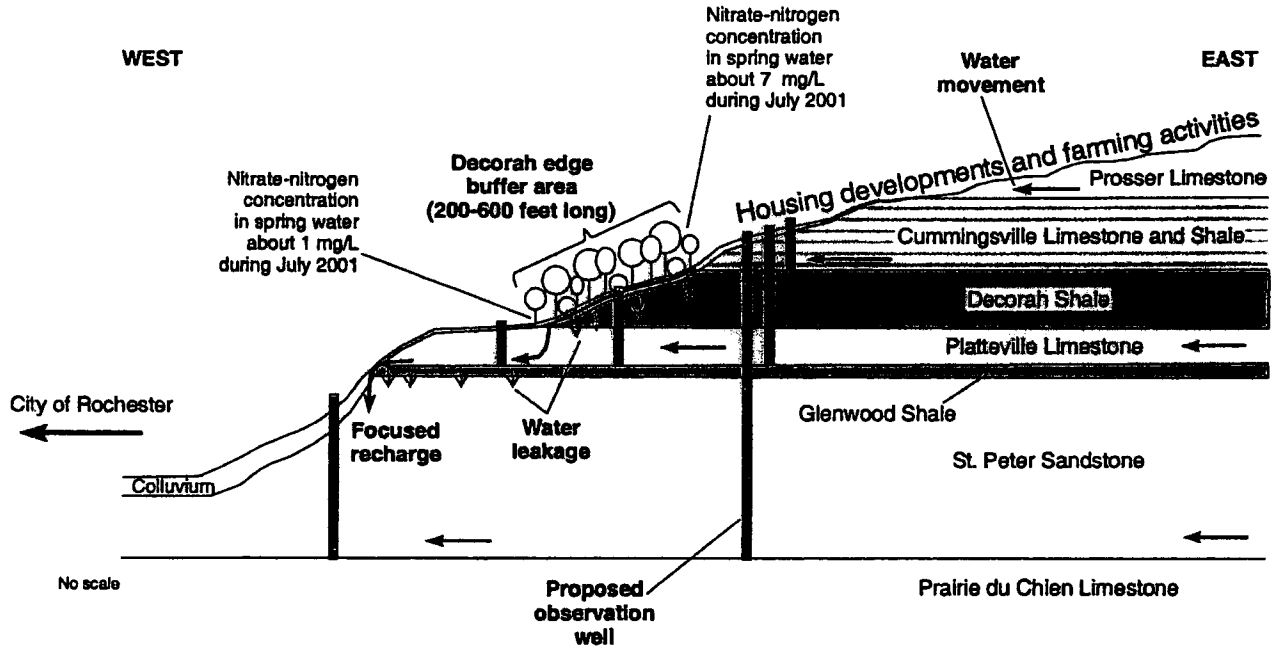


**Figure 1.--Hydrogeologic setting near the Decorah edge vegetative buffer. (Modified from the Minnesota Geological Survey, 1998).**

Soils and vegetation along the 200- to 600-foot long subcrop of the Decorah Shale apparently function as a physical and chemical buffer between the Upper Carbonate and St. Peter-Prairie du Chien-Jordan aquifers (figure 1), potentially removing nitrate from water flowing over the edge. Focused recharge water passes through the soils and colluvium along wooded slopes overlying the Decorah Shale as interflow before entering the underlying aquifer (Lindgren, 2000). A 1990-94 nitrate budget found that only about 41 percent of nitrogen applied each year in upland agricultural areas could be accounted for by agricultural harvests (Terry Lee, Olmsted County Health Dept., written commun., 1995). Much of the applied nitrogen may be entering the local ground water system. Ground water in the Upper Carbonate aquifer has nitrate-nitrogen concentrations greater than 10 mg/L whereas concentrations decrease to less than 1 mg/L on the downgradient end of the Decorah Shale

(Terry Lee, Olmsted County Health Dept., oral commun., 2001). Ground-water transport models alone could not account for this decrease in nitrate concentrations.

In the summer of 2001, Olmsted County personnel sampled water and soil at about 50-foot horizontal intervals (about 10-foot vertical intervals) along a transect overlying a 200-foot wide subcrop area of the Decorah Shale. Results of the study indicated that nitrate concentrations in the interflow water within the colluvium were less than 0.5 mg/L along the entire subcrop area of the Decorah shale (Terry Lee, Olmsted County, electronic commun., 2002). Conversely, chloride concentrations in the colluvium decreased from about 28 mg/L at the top of the Decorah subcrop area (upper contact) to less than 10 mg/L at the bottom of the Decorah subcrop area (lower contact). Sulfate concentrations remained fairly constant (about 12-14 mg/L) in the colluvium. In water emanating from springs along the subcrop area of the Decorah shale, nitrate concentrations decreased from about 7 to 1 mg/L, chloride decreased from 21 to 14 mg/L, and sulfate decreased from 16 to 12 mg/L from the top to the bottom of the subcrop area, respectively.

Several processes could be contributing to the reduction of nitrate concentrations in the Decorah Shale buffer area. Previous studies have established that denitrification (microbial reduction of nitrate to nitrogen ($N_2$) gas) can be an important mechanism for nitrate removal from ground waters containing reducing substrates such as organic carbon (e.g. - Vogel et al., 1981). Other studies have indicated that removal of nitrate from shallow ground waters by denitrification and(or) biologic assimilation may be especially active near the water table in riparian zones that are overlain by forests or wetlands (e.g. - Lowrance et al., 1984). Dissimilatory nitrate reduction, ammonification, and nitrification are other process that may be contributing to the observed nitrate losses. Progressive denitrification or dissimilatory nitrate reduction along water flow paths should cause decreases in nitrate concentrations and increases in $\delta^{15}N_{NO3}$ stable isotope values.

Uptake of nitrate by trees and shrubs in buffer areas could be important components of the overall nitrate pathway (Simmons and others, 1992; Komor and Magner, 1996). Hydrogen isotope ($\delta D$) values in sap water reflect the water sources used by the plants and could be very useful in evaluating spatial and temporal changes in nitrate uptake by the plants.

Another process that may be contributing to the decrease in nitrate concentrations across the Decorah Shale is leakage of water from the Upper Carbonate aquifer through fractures in the Decorah-Platteville-Glenwood confining unit (fig. 1). Although fractures are known to occur in the confining unit, the extent and continuity of these fractures are unknown. The effect of the fracturing likely would be two-fold. Firstly, the volume of interflow water in the colluvium overlying the Decorah Shale would become progressively reduced down hill as water leaks downward through the fractures.

Thus, a lesser volume of water likely discharges as interflow over the downgradient edge of the Decorah than discharges from the Upper Carbonate aquifer onto the upgradient edge of the Decorah. Secondly, water leaking through fractures in the Decorah Shale will be diluted as it enters the underlying Platteville Formation, which presumably has much lower nitrate concentrations. Concentrations would be further diluted by the time these same waters are transported to the edge of the Glenwood Shale and into the underlying St. Peter-Prairie du Chien-Jordan aquifer.

Many of the areas that contribute contaminants to the Decorah edge are in transition from agricultural to residential land use. It is unknown how this change in source-area land use will affect the chemistry of waters passing through the Decorah edge into the underlying St. Peter-Prairie du Chien-Jordan aquifer. Information from long-term water-quality data collection is needed to evaluate the effects of changing land use on nitrate distribution and pathways through the focused recharge system and buffer along the Decorah edge.

## OBJECTIVES

(1) To evaluate causes for the loss or removal in nitrate-nitrogen in the buffer area along the edge of the Decorah Shale near Rochester, Minnesota in waters that recharge the underlying St. Peter-Prairie du Chien-Jordan aquifer and (2) to evaluate the effects of changing land use on water quality along the Decorah edge.

## RELEVANCE AND BENEFITS

Study results will provide managers with information needed to assess the impact of various land-use changes on the subcrop area of the Decorah Shale. By being able to make more educated management decisions, mangers can help to ensure greater protection of water quality in the St. Peter-Prairie du Chien-Jordan aquifer. Improved knowledge of the sources of nitrate and the processes controlling nitrate concentrations in waters discharging to the Decorah edge buffer area will result from this study. Results will provide managers with information on the effects of land-use changes on water quality over time along the Decorah edge as upland sites are developed and housing developments are installed. An understanding of the processes controlling nitrate reduction in these vegetative buffers may provide insight into the fate of other contaminants introduced by upland land-use changes. This project is relevant to the USGS mission by advancing scientific knowledge on application of innovative geochemical tools to aid in solving complex water resource management problems. This project will help USGS refine the application and accuracy of these techniques.

## APPROACH AND WORK PLAN

The proposed 5-year study will build upon results of Olmsted County Health Department water sampling from springs, wells, and seeps conducted during the summer of 2001 and planned sampling during 2002 along the edge of the Decorah Shale. During the first year of the study we propose the installation of a series of observation wells along one of the transects established by Olmsted County in 2001-02, or perhaps along a transect established during an earlier USGS study (Lindgren, 2000). Site selection for the well installation is critical to achieving the project objectives. We intend to work closely with the cooperator as well as Olmsted County officials to ensure proper site selection. Selection of the Decorah edge subcrop drilling sites will be based on the following information or criteria: (1) topography mapped at 2-foot contour intervals; (2) drilling rig accessibility, (3) agricultural land use upgradient than will be transitioning to domestic land use in the near future; (4) previous hydrologic data upon which to base this investigation, and (5) a relatively flat exposure of the Decorah Shale. At least one well will be installed in the Upper Carbonate aquifer upgradient of the Decorah edge to facilitate quantification of nitrate concentrations in the source water for the transect (figure 1). An additional well may be installed in the Upper Carbonate aquifer upgradient of the other well to improve the quantification of source area nitrate concentrations. At least two wells will be installed in the Platteville Formation: one well upgradient of the Decorah edge (in the vicinity of the newly-installed Upper Carbonate well) and one downgradient of the Decorah edge. If funding is available, another well will be installed in the Platteville through the subcrop of the Decorah Shale. These wells will be used to quantify background concentrations of chemical constituents in the Platteville Formation and to evaluate the effects of leakage through the Decorah Shale. Finally, one well will be installed in the St. Peter-Prairie du Chien-Jordan aquifer near the downgradient edge of the Glenwood Shale (figure 1) to allow quantification of the concentrations of chemical constituents recharged into the drinking water aquifer. An additional well may be installed in the St. Peter Sandstone in an upgradient location, probably near the Upper Carbonate well, to quantify background concentrations of chemical constituents in the drinking water aquifer. Water-level measurements in these new wells will allow us to better evaluate focused recharge rates along the Decorah edge. Data loggers will be used with pressure transducers and rain gages to measure water level changes in selected wells and precipitation.

In FY2002, continuing into FY2003 if necessary, we propose collecting about 20 samples along the transect of springs, interflow water, and newly installed wells. Field parameters (pH, specific conductance, temperature, and dissolved oxygen) will be measured and water samples will be collected to quantify concentrations of nitrate-nitrogen, chloride, sulfate, and dissolved gases. Nitrogen ($N_2$) and argon dissolved gas concentrations will be used to estimate the excess $N_2$ that was

formed by denitrification. These analyses will allow us to determine what the original nitrate concentration was prior to denitrification.

Seasonal sampling from wells/springs will be conducted at selected sites to evaluate the effects of land-use changes over time as upland sites are developed and housing developments are installed. This sampling will begin as soon as possible, preferably in the summer of 2002, to establish background concentrations prior to the anticipated changes in land use. Seasonal sampling will also allow us to account for seasonal variability in vegetation growth and nutrient uptake along the Decorah edge. Nitrate utilization by vegetation, as well as denitrification rates, should vary seasonally and likely will be greatest in August and least in April-May.

During the second or third year of the study, a tracer test will be conducted to evaluate the continuity of the Upper Carbonate aquifer through the Decorah edge area and into the underlying St. Peter-Prairie du Chien-Jordan aquifer. Tracers such as fluorescene and bromide will be applied at land surface in the adjacent field, upgradient of the transect of wells and springs. The wells, springs, and interflow water along the transect will be sampled at approximately daily intervals and analyzed for the relevant constituents to track water flow from the Upper Carbonate aquifer through the Decorah edge area and into the underlying St. Peter-Prairie du Chien-Jordan aquifer. Other tracers such as isotopically-labeled nitrate may also be used during future tracer tests to evaluate nitrate attenuation in the Decorah edge. Isotopically labeled nitrate is a very expensive tracer to use and analyze for, however, and thus we will not employ this approach if the flow system is not very well defined. Any tracer test that is conducted will coordinated with local experts Dr. Calvin Alexander (University of Minnesota) and Jeff Green (Minnesota Department of Natural Resources).

Based on results of the sampling during the first and second years of the study, analyses for $\delta^{15}N_{NO3}$, $\delta^{15}N_{NH4}$, and $\delta D$ isotopes may be completed in succeeding years. These analyses would provide information about nitrogen sources and transformations from the source area, through the buffer area, and into the underlying St. Peter-Prairie du Chien-Jordan aquifer.

Pending results of the initial sampling, samples of sap water may be extracted from tree leaves and branches for analysis of $\delta D$ values during the second and third years of the study. Lower $\delta D$ values are consistent with larger portions of soil water whereas greater values are consistent with ground water (Komor and Magner, 1996). Isotopically lighter values reflect infiltration from snowmelt and spring. The data will be analyzed to provide a mass balance of nitrate-nitrogen along the Decorah edge and to estimate the flux of nitrate being utilized by vegetation in the vegetative buffer along the Decorah edge.

## QUALITY-ASSURANCE PLAN

At least fifteen percent of all water-quality samples will be collected for quality assurance / quality control (duplicates, blanks, splits). All project water-quality samples will be collected and analyzed using accepted and well-documented USGS quality assurance protocols (http://wwwmn.cr.usgs.gov/mnlocal/qw.qaqc.97.pdf and http://wwwrcolka.cr.usgs.gov/uo/proposals/Tables1&2DQOs.pdf). Coding of water quality samples will follow procedures documented on the following web site: http://ar.water.usgs.gov/nawqa/sample-coding/outline.html. Ground-water quality data collection will also follow standard procedures documented in the following web site: http://wwwmn.cr.usgs.gov/mnlocal/gw.qa.plan.01/MN%20Dist.%20GW%20QA%20Plan.htm.

## PERSONNEL

A hydrologist (GS-12) will be required about one-quarter to one-half time for the planned project duration of five years.

## PLANNED PRODUCTS

An interpretive report(s) will be prepared during the final two years summarizing significant findings of the study.

## FUNDING

A cooperative funding agreement will be developed between USGS and the City of Rochester for FY2002. Funding requirements from The City of Rochester are $20,000, fully matched by USGS Federal/State coop dollars, for a grand total of $40,000. Project funding requirements for FY2002 - FY2006 will be re-evaluated following completion of each year of the study.

The Minnesota District has requested funding from the USGS Office of Ground Water (OGW) to assist with the project during FY2002. OGW is very interested in the results of this study with respect to ground-water recharge. If received, the funds will be used for the installation of observation wells. The FY2002 budget shown below does not include the OGW dollars per se but reflects the assumption that the wells will be installed using funds received from OGW. Should the OGW funding be unavailable, however, most of the project funds for FY2002 and FY2003 will be dedicated to well installation, and much less water water-quality sampling will be completed. The FY2003 budget reflects the need for drilling, should the OGW funding be unavailable or insufficient. Should we receive sufficient funding from OGW to cover the drilling costs, this line item can be removed from the FY2003 budget.

| ITEM | FY2002 | FY2003 | FY2004 | FY2005 | FY2006 |
|---|---|---|---|---|---|
| Salaries | $16,482 | $36,293 | $38,126 | $39,859 | $16,330 |
| Travel | $440 | $1,000 | $1,000 | $1,000 | ---- |
| Vehicle | ---- | $2,520 | $2,520 | $2,520 | ---- |
| Drilling | ---- | $17,000 | ---- | ---- | ---- |
| Supplies | ---- | $1,050 | $500 | $500 | ---- |
| Equipment | ---- | $2,000 | $1,000 | $1,000 | ---- |
| Lab analyses | $3,170 | $10,000 | $10,000 | $10,000 | ---- |
| Technical support and overhead | $19,908 | $65,649 | $49,700 | $50,720 | $15,760 |
| Total: | $40,000 | $135,512 | $102,846 | $105,599 | $32,090 |

## REFERENCES


Balaban, N.H., ed., 1988, Geologic atlas of Olmsted County, Minnesota: Minnesota Geological Survey County Atlas Series, Atlas C-3, 9 sheets.

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Vogel, J.C., Talma, A.S., and Heaton, T.H.E., 1981, Gaseous nitrogen as evidence for denitrification in groundwater. Journal of Hydrology, v. 50, p. 191-200.