

**PROVIDING COMMUNITIES WITH THE GROUND  
WATER INFORMATION NEEDED FOR  
COMPREHENSIVE PLANNING**

**Douglas S. Cherkauer**

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**Providing Communities with the Ground Water Information  
Needed for Comprehensive Planning**

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## Project Summary

### **Title: Providing Communities with the Ground Water Information Needed for Comprehensive Planning**

**Project ID:** WR03R0007

**Investigators:**

PI: Douglas S. Cherkauer, Professor, Department of Geosciences, University of Wisconsin-Milwaukee

PAs: Daniel Alessi, Alison Coulson, both formerly of University of Wisconsin-Milwaukee

**Period of Contract:** July 1, 2003 to June 30, 2005

**Background/Need:** Communities which rely on ground water as their sole source of water need to factor the magnitude and limits of their resource and ways to protect it into their development plans. Most of these communities do not, partly because they don't understand their ground water supply and don't know what information they need or where to obtain it.

Wisconsin now requires that communities adopt a comprehensive plan. The rules make passing reference to water resources and ground water supply, but typically the plans only include very cursory reference to them. Land use plans are primarily driven by economics and transportation; rarely does water supply influence the end result.

**Objective:** The primary purpose of this study was to assess the water resources of a ground water using community and then to work with that community so that it could design a comprehensive land use plan that protects its water supply. An outcome from the process is development of the procedure needed to get the right ground-water information to the community.

**Methods:** The study was structured as a complete analysis of the quantity of the ground water resource in the study area. During the project, information was shared with Town officials in order for them to incorporate it into their planning and administrative processes. Once the state-funded project was completed, an assessment was made to determine which information was most relevant and usable from the community's perspective.

Richfield was openly receptive to the idea of the study and willing to consider incorporation of the information into their comprehensive land use plan. That planning process began shortly after the ground water project started. The Town instituted a 12 month moratorium on new developments to coincide with its planning process and, coincidentally, the first half of this project's study period.

This study determined the underlying hydrogeology and the main sources and sinks of ground water within the Town. It developed a full ground-water budget using a calibrated, steady state flow model. The PI then worked with the community to provide them the information, to interpret it for them, to aid in its incorporation into their planning, and to establish a mechanism to protect their resource into the future.

**Results:** Richfield's ground water is primarily recharged by rainfall and snowmelt within the Town. It discharges mainly to the Town's surface waters and surrounding communities. As a consequence, Richfield is in control of its own water supply and the impacts that human actions will have on its lakes, streams and wetlands.

Town leaders decided that they wanted to protect its supply and surface waters. With input from this project, they decided to do so by:

1. developing a land use plan which protects sensitive ground-water area (both sources and baselevels),
2. limiting population density so that the combined human and environmental demand for water would never exceed the lowest expected recharge inputs, and
3. adopting an ordinance that requires determination of both the water demand and anticipated drawdowns resulting from new developments beforehand and then rejects projects which do not meet prescribed, acceptable drawdowns.

Population density is limited within the community's land use zoning by requiring a relatively large individual lot size for residences and that new developments cluster structures in such a way that a minimum of 30% of the total development remains as green space. Water intensive commercial or industrial development is discouraged. A development which fails to meet drawdown limits (< 1 foot at any property boundary and < 0.5 feet at any perennial surface waterway) must be redesigned to augment natural recharge or reduce water demand before it will be accepted.

Communication with townspeople and their leaders is key to getting them to understand their water system and how best to manage it. In this project, we used articles in the town newsletter, presentations before the general public and at official town meetings and annual reports to get our concepts out. Discussions with the volunteer well owners was also a major factor, because they spread information among their neighbors. The project's final report is attached in Appendix II and is designed to provide information in simple verbiage and US measures. It is also posted on the Town's website.

**Implications and Recommendations:** The most important information needed by a ground-water community is a good understanding of the geology, sources, sinks and water balance of their aquifer system. Presentation and interpretation of this basic information helped residents and their leaders understand where their water comes from. Interaction with the users at all levels was also crucial in developing the awareness that led this community to create a long term plan and supporting laws to sustain their water supply for most, is not all, future conditions.

Our experience was that the ground water model was probably not necessary in the process and tended to be misunderstood by the public – as having greater predictive resolution than is actually possible. The next step in this process will be to convince other communities to repeat this study.

**Related Publications:** D. Alessi won best student poster presentation at Wisconsin Water Resources Assoc. March, 2005

**Key Words:** Ground Water Resources, Community Planning, Water Budget, Recharge

**Funding:** University of Wisconsin System

## **Introduction**

The residents of the Town of Richfield, Washington County, Wisconsin rely entirely on ground water as their source of water supply. That water comes from private wells. At this time, there are no community water supply wells in the community. All wastewater is disposed of through onsite wastewater treatment systems (septic and mound systems), a process which recycles most of the water back into the subsurface.

Development in Richfield has been rapid over the last several years. Over 300 wells were drilled in the Town during the period from 2000 to 2003. Citizens and Town leaders alike needed to know what impacts that past development and different types of future development would have on the Town's water supply. As part of its Smart Growth Planning, the Town of Richfield entered into a cooperative agreement with the University of Wisconsin-Milwaukee to obtain that information. Funding was obtained from the Wisconsin Ground Water Research Coordinating Council to support a two year study (July, 2003 through June, 2005) designed to provide the needed ground water information.

## **Objective**

The primary purpose of this study was to assess the water resources of a ground water using community and then to work with that community so that it could design a comprehensive land use plan that protects its water supply. An outcome from the process is development of the procedure needed to get the right ground-water information to the community.

## **Methods**

The study was structured as a complete analysis of the quantity of the ground water resource in the study area. During the project, information was shared with Town officials in order for them to incorporate it into their planning and administrative processes. Once the state-funded project was completed, an assessment was made to determine which information was most relevant and usable from the community's perspective.

The following steps were undertaken:

1. Identify a ground water using community which is receptive to the study and willing to incorporate water resource information into its planning.
2. Ascertain the hydrogeology underlying the study area.
3. Define the ground water flow system to determine where the sources and sinks (discharges) of ground water occur
4. Quantify the community's full ground water budget, and
5. Work with the community to provide them the information, interpret it for them, aid in its incorporation into their planning, and to establish a mechanism to protect their resource into the future.

Richfield was openly receptive to the idea of the study and willing to consider incorporation of the information into their comprehensive land use plan. That planning process began shortly after the ground

water project started. The Town instituted a 12 month moratorium on new developments to coincide with its planning process and, coincidentally, the first half of this project's study period.

The distribution of the underlying geologic materials was determined from well construction reports on file with the Wisconsin Department of Natural Resources (WDNR, 2004). Within unconsolidated sediments, correlation of both clays and coarser materials (anything in which sand or gravel was the dominant grain size) was made between these logs.

A first step in assessing a shallow ground water system is to map the water table. The project identified 35 residents who volunteered access to their wells. Ground-water levels were measured there and coupled with measurements of streams and lake levels at 18 other locations. It should be noted that water levels in the wells are measured when they are not impacted by pumping.

Prior to the start of monitoring, each cooperating well was tested for bacteria. Three had unsafe levels of *E. coli* and were treated before they were monitored. After 18 months of monitoring, they were tested again. As expected, at that time all were certified as bacteriologically safe. The electric tape used to measure the depth to the water in a well is sterilized with bleach solution before and after it enters each well. As a result, the monitoring process has not caused any contamination problems.

Streamflows have been gauged measured at 7 road crossings. The measurements have been used to construct hydrographs plotting streamflow through time. Baseflow separation (Linsley, et al, 1982) has then been used to determine the contribution of ground water to the total streamflow at each site. These baseflows serve as ground water discharge targets for the ground water flow model. Ground water recharge throughout the study area has been mapped using the method presented in Cherkauer and Ansari (2005).

The geology, water levels and water fluxes have been incorporated into a ground water flow model designed to allow integration of the water budget across the entire Town. The model is also available as a tool to test the impact of different development scenarios.

Interim results and reports have been presented to the Town Board, the Town Administrator and participating citizens. Occasional ground water articles about the project or ground water, in general, have been circulated in Richfield's semi-annual newsletter. Ground water information from the study was also incorporated into the Town's development of comprehensive, long-range land use plans.

The full final report to the Town is included as Appendix II of this report. Both reports are presented exclusively in American units of measure because they are intended for dissemination to the public. Experience at community meetings has shown that a sure way to anger and lose the attention of the citizenry is to present results in metric units.

## **Results of the Ground Water Resource Study**

### **Richfield's Geology and Hydrogeology**

Over 500 well construction reports (WCRs or drillers logs) from private wells throughout Richfield and surrounding areas were examined in order to determine what lies beneath the surface. An example east-west cross-section is provided in Figure 1. Thirteen others are included in Appendix II. The local geology consists of interwoven glacial till aquitards and outwash aquifers (clay and sand/gravel, respectively, on Figure 1) overlying a dolomite aquifer. A shale aquitard is the effective base of the Town's

ground-water system. Where present, the clays limit the flow between the sands, resulting in areas where there are actually several separate aquifers. However, where the clays are not continuous and the sand layers are interconnected, ground water can flow readily from one to another. Across the community as a whole, there are enough interconnections that water does flow among all the sands and gravels. The areas which have the greatest abundance of ground water are usually those overlying the deep valleys carved in the bedrock. Toward the east in Richfield, the glacial sediments thin and sands and gravels become relatively scarce (Figure 1). In these areas, the primary aquifer then becomes the dolomite bedrock.

### Water Levels

Water levels have been measured since November, 2003. Well head and culvert elevations were surveyed to 0.01 feet using GPS and laser theodolite and tying into SEWRPC's elevation monuments ([www.SEWRPC.org/regionallandinfo/survey.shtm](http://www.SEWRPC.org/regionallandinfo/survey.shtm)). The March, 2004, water table is representative of the flow pattern at low ground water levels (Figure 2). The map shows that ground water is flowing into Richfield from the northwest and then flows out mostly to the east, but also to the south. Within the Town, a water table high occurs east of Friess Lake (Figure 19). From it flow radiates outward to discharge into most of the surface water bodies, but especially the Oconomowoc River (Figure 1). Ground water in most of the Town discharges toward the Mississippi River, although all that is discharging to Cedar Creek goes to Lake Michigan and the St. Lawrence. Hence Richfield is bisected by a ground water divide between the Mississippi and St. Lawrence basins. The ground water divide does not exactly coincide with the surface water divide (Figure 2). Hydrographs of the water table elevation through time for each well are presented in Appendix II

### Ground Water Recharge

The empirical relation presented in Cherkauer and Ansari (2005) was used to estimate the 2004 recharge in 30 subwatersheds within Richfield and in another 240 in the surrounding 8 towns. The rates have been confirmed using the spring water level rises in each observation well for the same period. Details of both methods are provided in Appendix II.

In Richfield, normal recharge ranges from a little about 1.5 in/yr to just under 9 in/yr. It averages about 5 in/yr for years with average precipitation. Lower recharge rates tend to be toward the east and north, where clay-rich glacial till is the dominant surficial material. The highest rates occur toward the southwestern part where surface sediments are predominantly glacial outwash (sands and gravels) associated with meltwater channels. Heavy rainfall Richfield received in May, 2004, resulted in recharge rates about 40% higher than normal for this first year of the study.

### Ground Water Discharge

Ground water flows from Richfield's aquifers to three primary types of sinks: surface water bodies, subsurface flow to the east and south, and net withdrawals due to wells. Stream baseflows (total flow less surface runoff) were determined at the seven gauging sites. Outflows to surrounding communities were quantified with the ground-water model.

The amount of water pumped from wells has not been measured directly. Two assumptions have been made to estimate it. First, for domestic wells, it has been assumed that average pumping is 100 gallons per day per capita (gpd), and that 80% of that amount is returned to the aquifers via onsite

wastewater treatment systems. Second, it was assumed that high capacity wells (those capable of pumping in excess of 70 gpm) are being pumped at half their rated pump capacity when they are active.

The 100 gpd/c is based on the average per capita amount that Brookfield/Elm Grove municipal water system provides their customers (WGNHS, 2000). This community has a similar array of housing to Richfield, although it does have somewhat more commercial and industrial land use. The 80% return is what Solly, et al (1993) report as the average for the US. The distribution of domestic pumpage in the Town has been estimated by taking the 2000 census population within each quarter section served by private wells and multiplying it by 20 gpd/c. In Richfield, this amounts to nearly 208,000 gallons per day (resulting from a population of 10,373).

## Richfield's Ground Water Budget

A ground-water flow model has been developed for Richfield in order to assess the Town's water budget and potential changes in it. A full description of the model, its design and calibration is provided in Appendix II. Under normal conditions, about 1.5 million ft<sup>3</sup>/day (11.3 million gallons/day) circulate through the community. Among inflows inflow to the Town's ground water system 82% occurs as recharge from rainfall and snowmelt. Inflow from surrounding communities and recharge from surface waters each account for another 9%. Outflow goes mainly to surface water bodies (37% to rivers and lakes, 31% to wetlands). Another 27% leaves the Town as ground water flowing to surrounding communities. The net loss to wells is 3%, and quarries account for the remaining 2%.

Richfield is entirely self-sufficient in terms of its water supply. Average recharge varies annually from an expected low of 3.2 in/yr to a high of 7.3 in/yr. These annual changes also effect the distribution within the total budget. The biggest effects of low recharge are reductions in the ground water flow to surface waters, reductions in stream baseflows and lake/wetland levels. Long term planning intended to minimize impacts to both ground and surface waters, therefore, should be based on the lowest expected annual recharge.

## **Inclusion of Ground Water Information in Richfield's Planning Process**

A primary goal of this project was to provide the study community with adequate information to allow its leaders to steer development so as to stay within the natural limits of their water supply. Richfield was selected as the test community because it:

1. is dependent on ground water,
2. is under development pressure (and therefore needed the information),
3. has many wells which provide geologic information and monitoring locations, and
4. has responsive leadership.

Comprehensive planning in Wisconsin is guided by Section 66.1001 of the Wisconsin Statutes (Wisconsin Assembly Bill 872). Communities are required to complete their plans within the next few years. While inclusion of water resources information is "required", it is only as a small part of a background section on agricultural and natural resources. There is no requirement that the material about ground water be any more than a descriptive narrative about the local aquifers. Richfield's Town Board and Planning Commission actively sought information beyond this.

The study initially provided them two forms of input to process:

1. identification of areas where land use control is important to protecting ground water
2. information on the population density which can be comfortably supported with ground water.

Ground water quantity in the Richfield system is controlled by how much recharge occurs and the water levels maintained at discharge points. Recharge occurs everywhere within the Town, but the northwest corner and central parts of the Town function as significant source areas (Figure 3). Subsurface flow radiates throughout the Town from those two headwater areas. They were identified to the Town as locations which should be protected from commercial or industrial development that could produce undesirable contaminants.

The surface water bodies throughout Richfield are the primary ground water discharge points. Steady state ground water simulations show that if wetland levels, in particular, are caused to drop, ground water levels in the areas draining to them will also drop. It was recommended that areas of extensive wetlands (called base level buffer zones) be protected from development in order to prevent their being drained (Figure 3).

The 20-year land use plan which Richfield adopted incorporated both of these recommendations (Figure 4). Source areas are intended to remain either agricultural or to convert to residential. The wetland areas have all been identified as environmental corridors (Figure 4) to remain undeveloped.

Within a ground-water dependent community, it is also important to control the demand for water so it doesn't exceed the available supply. This can be achieved by a variety of tactics which limit demand or enhance recirculation. Demand can be constrained by limiting total growth, controlling populations density, or educating residents to reduce water consumption, among others. The recirculation of treated wastewater is already taking place in Richfield through the use of onsite wastewater treatment systems. It can be enhanced by collecting rainwater and allowing it to infiltrate to augment recharge.

Richfield has recognized that it cannot stop development; landowners may choose to develop their land within the constraints of approved zoning. Instead the Town has chosen to keep the water demand far below natural recharge's ability to replenish it and also to encourage recharge augmentation through rainwater infiltration.

Richfield's long-term average recharge rate of about 5 inches/year could support a little over 18 people per acre using 20 gpcd as the net consumption. However, such a density of people on septic systems raises concerns about water quality. In Wisconsin, communities are encouraged to install collective wastewater treatment systems, usually before their overall density reaches 1 person/acre. These systems are commonly designed to discharge the treated wastewater to a surface water body. Consequently, it is possible that Richfield may need to adopt community wastewater treatment in the future. This process has the unfortunate side effect of transferring about 100 gpcd out of the local ground water system with no planned replenishment.

Therefore, it is prudent for a ground water community to base land use plans on the highest potential per capita demand (as well as the lowest anticipated natural recharge, as mentioned above). Once developed infrastructure is in place, there is no way to reverse it and reduce its density. For a net ground water demand of 100 gpcd, Richfield's recharge rate can support an absolute maximum of about 4 (3.7) people per acre. While there would be enough recharge to support roughly 1 residence per acre, this would be at the expense of all environmental systems dependent on ground water discharge. All the available recharge would be pumped by humans and then discharged to a river. Ground water discharge to all other

rivers, wetlands and lakes would be severely impacted. Some streams would cease to be perennial, and lake and wetland levels would drop noticeably.

Recognizing this as an undesirable outcome, Richfield decided to build in a safety factor by adopting an average lot size for future development of 3 acres per residence. Effectively this means that humans will consume no more than about 750 ft<sup>3</sup> per year per acre (5500 gallons per year per acre) when using septics and no more than about 3700 ft<sup>3</sup> per year per acre (27,000 gallons per year per acre) if the Town went to offsite wastewater treatment. These amounts are 4% and 20% of the average available recharge for the respective wastewater systems.

Furthermore, Richfield's zoning ordinances require cluster development, which reduces the amount of impervious surfaces and maximizes green space. The latter will enhance protection of recharge rates. Developers are also encouraged to design developments to minimize runoff and to collect what occurs and allow it to infiltrate.

The Town has also adopted a ground water ordinance (Included in Appendix II) to foster the protection of ground water quantity. Developers must now submit a water study which defines a priori the net changes their development will make to the site's water budget and quantifies the impacts the net increase of ground water withdrawal will be. Developments which cause more than one foot of drawdown at any of their boundaries or more than one half foot at any perennial surface water body will not be accepted. Plans would then need to be redesigned to assure that the development will meet those constraints. The intent is to limit the cumulative drawdown of multiple developments to less than 2 feet at any given shared boundary and less than 1 foot at any location along a stream, lake or wetland.

The end result of Richfield's response is a land use plan that maintains a very low development density (averaging less than 1 residence per 3 acres). This will probably be assailed as contributing to "urban sprawl". Another perspective is that it defines a mechanism by which human development lives within the constraints of the available water supply. Under the greatest ground water demand scenario (offsite wastewater treatment with no return to ground water), the Richfield plan will consume less than 20% of the baseflow discharges to surface waters. Richfield's plan allows humans to coexist with streams, lakes and wetlands receiving a healthy and sustainable amount of water in dry seasons.

### **Assessing the Protocol Used**

The study has shown that it is crucial to make a ground water using community aware of the intimate interrelation of their water supply and their land use decisions. In retrospect, the analysis of Richfield's ground water system was probably more extensive than it ultimately needed to be. Some procedures could have been simplified, while others were not really necessary for inclusion in the planning process.

For communities with onsite wastewater treatment, a bare-bones analysis of the ground water supply would use well construction reports to define the underlying geology, the position of the water table and the conductivity of the primary aquifers. From that, a hydrogeologist could calculate reasonable approximations of the flow through community boundaries and ground water discharges to surface waters. The assumptions made in this study for the net discharge of domestic and high capacity wells proved to be very reasonable and could be applied elsewhere. If it is further assumed that there is no long term change in aquifer storage (because the community is recycling most of its pumpage back into the aquifer), then recharge can be estimated as the residual term in the water budget.

Such a study would be enhanced tremendously by measuring water levels in domestic wells. This gets residents involved, is visible activity and provides actual data which can be used to show community leaders what is actually happening. With monthly (or probably even well-conceived bimonthly) monitoring, the well hydrographs provide an independent means to assess recharge. This does require some knowledge of reasonable ranges of porosity of aquifer materials. In this study, the ground water model was very valuable in refining estimates of hydraulic conductivity and recharge, and of testing the continuity of aquifers and defining a community-wide water budget. A hydrogeologist could, however, understand these items without building a flow model.

For communities which do not return treated wastewater to the ground water system, the process will be somewhat different. In this case, it is essential to know how much water is being pumped (and therefore removed from the aquifers) and what the effect of that removal is on water levels. Thus an accurate accounting of water use by the water utility is needed, plus good records of static (unpumped) water levels through time in the community wells and as many others as exist. It may be necessary to install some monitoring wells if the array of community wells is too sparse to allow definition of ground water levels throughout the community.

A low density of wells will also make it more difficult to accurately define the geology underlying such communities. In addition, development of an accurate water budget will be more complex, because water levels may show a persistent reduction through time. Thus it will be necessary to include the long term change of ground water storage in the budget, something that is inconsequential in communities recycling their water. Furthermore, community pumping without return to the aquifer probably will cause changes in the interactions between aquifers and surface water bodies that will be difficult to quantify. It seems likely that a transient flow model would play a much more significant role in these communities.

## **Conclusions and Implications**

In the case of Richfield, the study objectives have been met. This community is truly interested in protecting ground water, its sole source of supply. They have succeeded in developing a long-term plan which recognizes that some development is inevitable, but provides direction driven by the Town's intent that future water demands will fit within the capacity of their aquifers.

The information needed to achieve this was: 1. a thorough understanding of the hydrogeology, 2. determination of the ground water flow pattern (recharge and discharge areas), and 3. quantification of the community's ground water budget. It was then absolutely necessary to present this information in understandable fashion to policymakers and the public alike, to be available to answer questions and dispel misunderstandings during construction of the comprehensive plan. Any such plan is a dynamic concept, subject to future change and reinterpretation. By itself, it is not a guarantee that the ground water resources will remain protected.

To that end, three additional steps were recommended:

1. The regular monitoring of water levels throughout the Town should be continued,
2. The Town should move away from reliance on volunteered domestic wells (which are active and subject to pumping effects) and change to passive, dedicated monitoring wells, and
3. The Board should require future developments to quantify how they will modify the hydrologic system and demonstrate that their ground water impacts will fall within defined constraints.

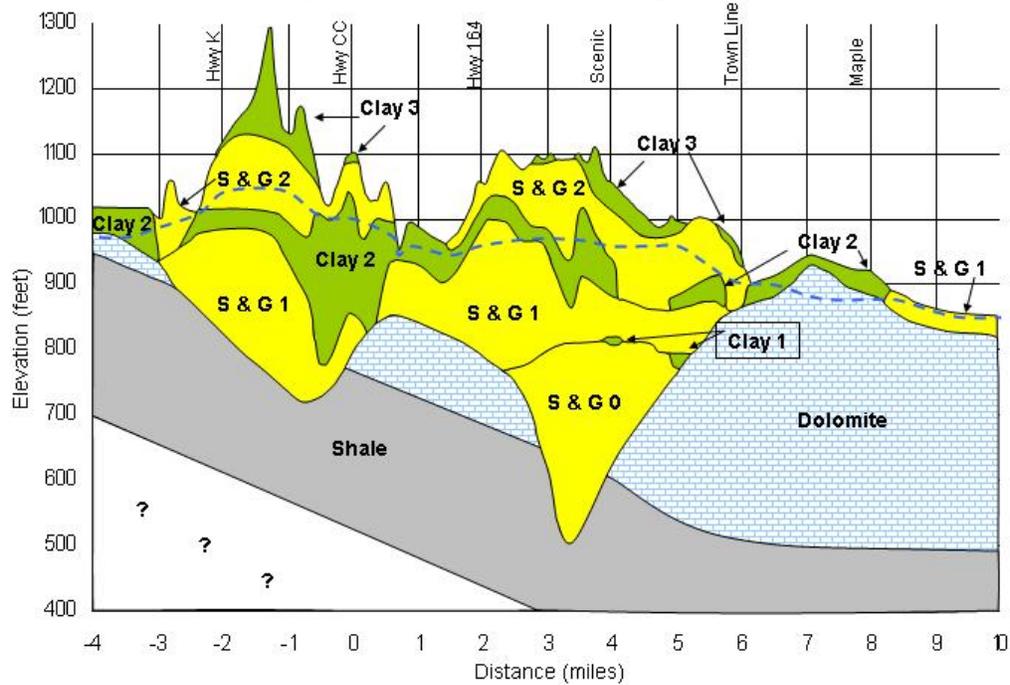
Richfield is already doing the first step, initially contracting with the University of Wisconsin-Milwaukee to continue the monitoring. Ultimately the task should be transferred to Town personnel. A recommendation that new developments each be required to install one monitoring well proved too controversial among area builders. The Town is now considering building its own monitoring wells on an as needed basis. It remains to be seen how well that works.

Perhaps the biggest success of the project has been Richfield's development of an ordinance which requires that a ground water analysis be completed before a project is approved (very much like a traffic study). Developers must specify how the project will alter recharge and surface runoff, what the project's pumping demand will be, and then project the long-term drawdowns. A project which causes drawdown in excess of prescribed limits must be redesigned or it will be rejected.

## References

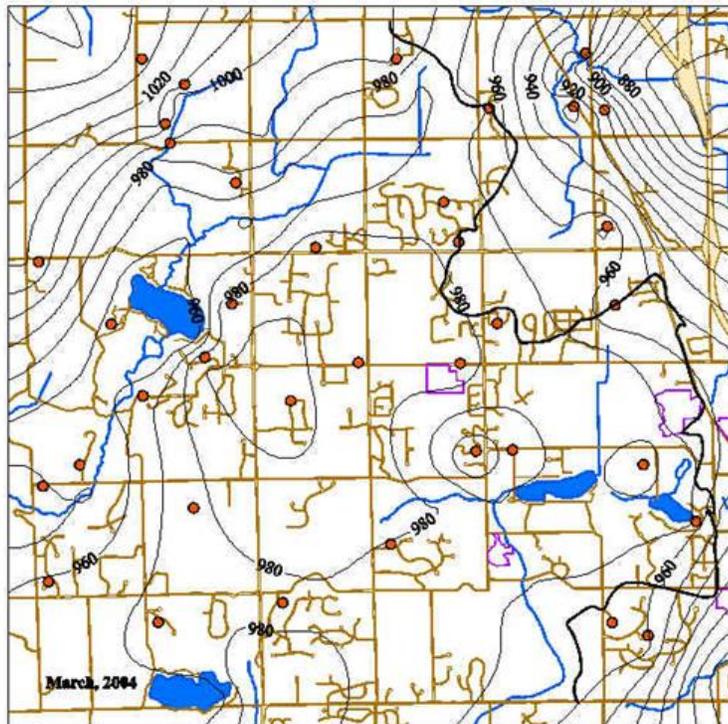
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**Figure 1: Cross Section along Holy Hill Road**

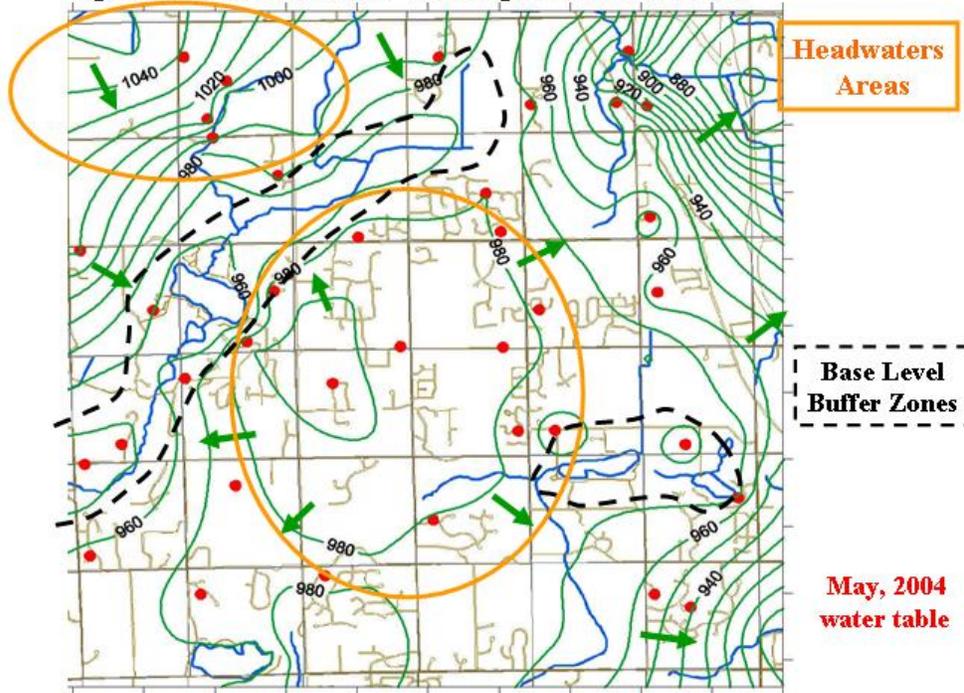


S & G is sand and gravel; dashed line is the water table

**Figure 2: Richfield Water Table Map for March 2004**



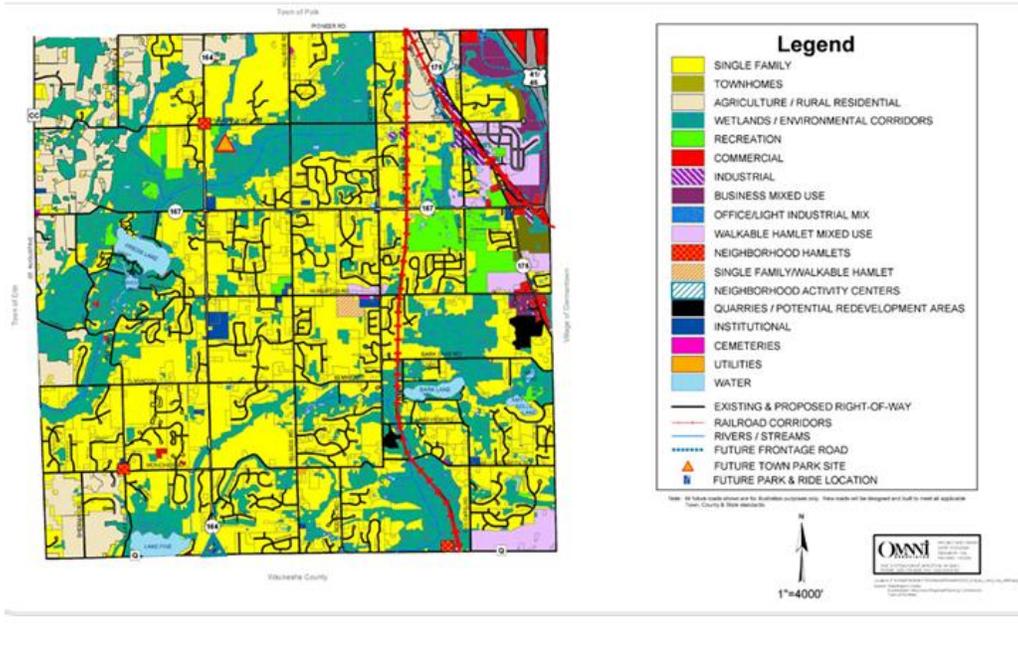
**Figure 3: Identification of critical ground water areas**



**Figure 4:**

**20-YEAR FUTURE LAND USE**

**TOWN OF RICHFIELD**



## **APPENDIX A: Awards, Publications, Reports and Presentations**

### **Presentations:**

Alessi, D.S. and D. S. Cherkauer. 2005. Insights from a ground water model of a rural township: Richfield, Washington County, Wisconsin. Presentation at Wisconsin Chapter, American Water Resources Association, March, 2005, Delavan Lake, WI

Cherkauer, D. S. 2005. Incorporating ground water sustainability into the comprehensive planning process. Presentation at Wisconsin Chapter, American Water Resources Association, March, 2005, Delavan Lake, WI

### **Awards:**

Dan Alessi's poster paper above was awarded Best Student Poster at the AWRA meeting of 2005.

### **Reports:**

The Final Report to the Richfield Town Board and Richfield residents is included in Appendix B. It is also currently on the Town of Richfield website ([www.Town-Richfield.com](http://www.Town-Richfield.com)).