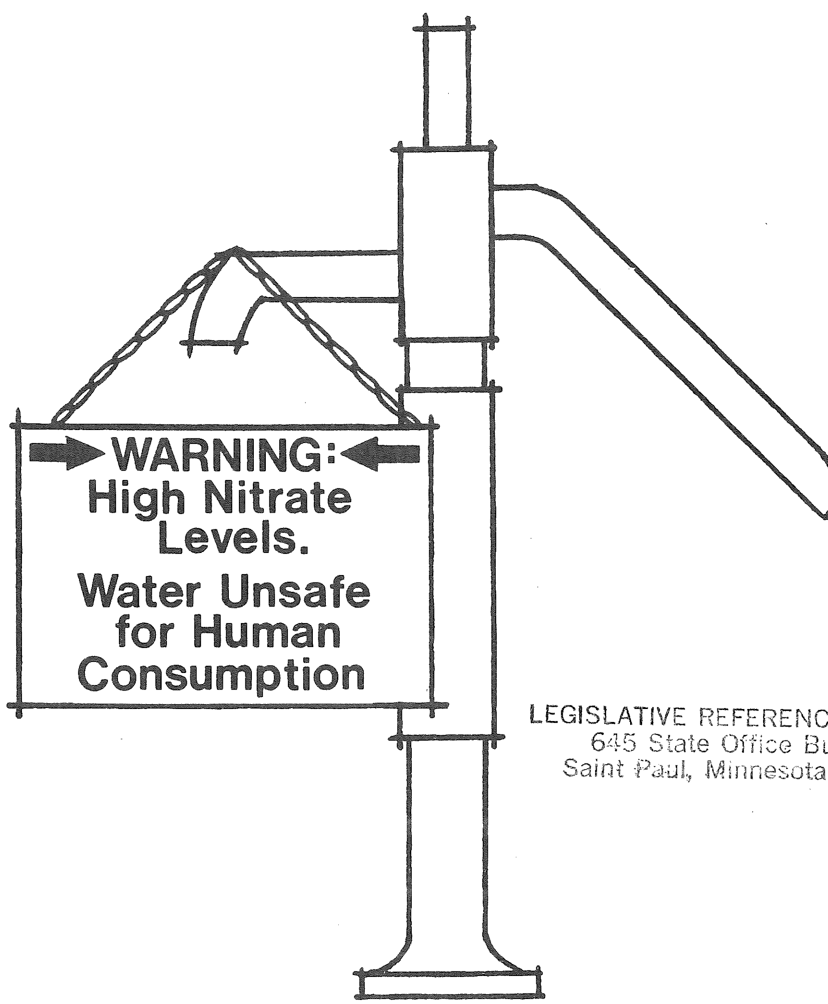
LAND USE AND YOUR WELL

From the Field to the Faucet in Minnesota's Central Sandplain Region



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From the Field to the Faucet
in Minnesota's Central Sand-Plain Region

June 1986

A Cooperative Publication of the
Minnesota Pollution Control Agency
and the
Minnesota Department of Natural Resources, Division of Waters

MINNESOTA
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Division of Waters

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Fun Facts:

More than 90% of Minnesota communities rely on ground water for their public supply.

Two-thirds of the State's population use ground water for drinking.

Over 10,000 wells are constructed annually.

Projections suggest that by 1990, ground water use could increase by 75%.

Acknowledgements:

Staff wish to thank the graphic artists from both agencies whose work has made this report much more interesting to read. James Zicopula from the Minnesota Department of Natural Resources prepared the cover and the hydrographs for the publication, and Len Nelson from the Minnesota Pollution Control Agency prepared the centerfold.

Thanks are also extended to the staff of the United States Geological Survey, St. Paul office for the information concerning water quality they provided from ongoing, unpublished work.

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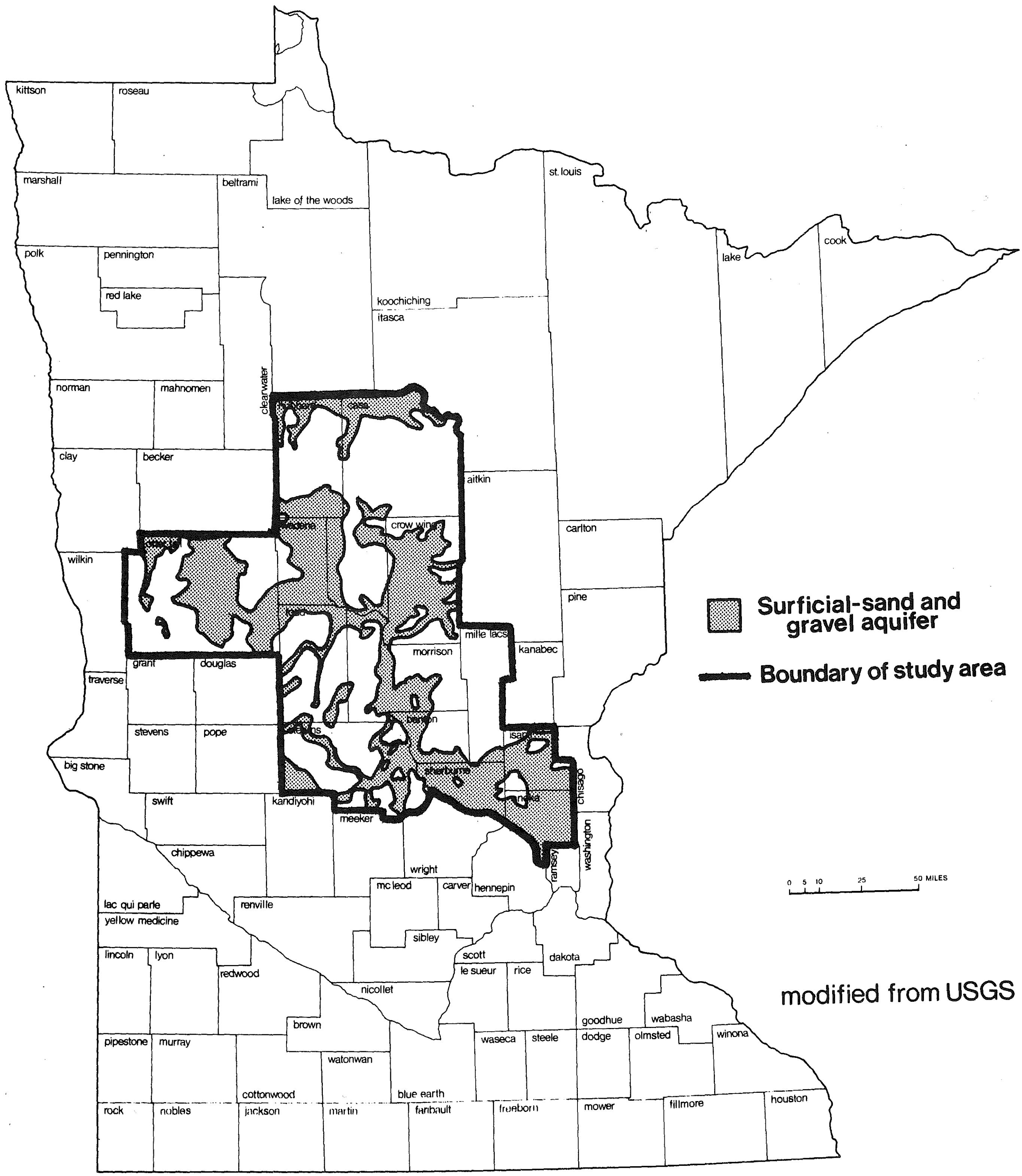


Extent of surficial sand and gravel aquifers in study area.

Figure 1

Minnesota has been blessed with a legacy of abundant water supplies. Our surface waters include more than 12,000 lakes, 92,000 miles of streams, and 7,000,000 acres of wetlands. Our ground water supplies are developed from various extensive aquifers which underlie most of Minnesota, providing ample high-quality water for most needs. (For more information, see the accompanying discussion, Who Uses Ground Water in Minnesota?) But is this abundance of water real? Are supplies really adequate where they are needed? In the process of using water are we affecting its quality and quantity, thus reducing the supply of water for future generations? Are our land use practices affecting our water? Are we affecting surface water when we pump and use ground water?

Sculpted by Glaciers.........

Thousands of years ago, the advance and wasting of vast glaciers sculpted the face of Minnesota which we know today. Lakes and stream beds were formed; and thick deposits of sand, gravel and clay were left behind. Boulders carried by the ice from far-off places littered the landscape.

In some areas, the sand and gravel deposits which were left cover many square miles of land surface. This is the case with the Anoka sand plain, which covers most of Anoka and Sherburne Counties and parts of Isanti County. Extensive sand deposits also are present along the central Minnesota portion of the Mississippi River basin and along the Crow Wing and Leaf Rivers. These areas are highlighted in Figure 1.

A great amount of ground water is stored in these sand and gravel deposits, forming aquifers which can yield to wells sustained flows of more than 100 gallons per minute. Where present, these aquifers are frequently tapped to supply domestic and municipal wells along with the demands of industry and irrigated agriculture. The ground water flows from the aquifers into streams and rivers, providing base flow even in times of drought. Lake levels are maintained in a similar fashion.

Water is replenished in the aquifers by precipitation infiltrating through the soil. In areas of surficial sand and gravel, this type of replenishment (or "recharge") is rapid due to the soil's poor moisture-holding capacity. Sandy soils also are very poor "attenuators", which means that contaminants such as pesticide residues, highway runoff and wastewater percolate through relatively unchanged. In this situation, ground water is extremely vulnerable to widespread contamination which may ultimately affect the potability (drinkability) of the water.

Who Uses Ground Water in Minnesota?

In 1980, 224 billion gallons of ground water were withdrawn in Minnesota. This represents 22% of the total water use in the State.

Categories of Ground Water Users

Public Water Supply

Public water supplies account for 37% of ground water withdrawn. Generally the public water supplies are almost evenly split between ground water and surface water sources. The use of ground water for public water supply has increased by nearly one-third since 1975. Many municipalities switched to ground water sources because they experienced unreliable surface water supplies during the drought of the 1970s.

Rural Water Use

At 29%, rural water use is the second largest category of ground water use. Most farms in Minnesota get their domestic water from wells. Quantities used are estimated at 50 gallons/day/person. In western Minnesota, rural water systems are being constructed to deliver water to several farms from a single well field. These systems replace individual farm wells in areas where farmers have experienced problems with supply, quality of water or with the longevity of individual wells.

Irrigation

22% of the ground water withdrawn is used for irrigation. The use of water for irrigation has increased dramatically. In 1960, farmers irrigated only about 20,000 acres, mostly in Sherburne and Dakota Counties, close to major farm-produce markets. Over the years, however, techniques for farming sandy soils in central Minnesota have developed. By 1980, irrigation was used on 462,000 acres, better than a 2000% increase.

Self-Supplied Industrial

Industries use 12% of the ground water withdrawn. These industries use this ground water for processing, heating and cooling.

Table 1. County Summaries of Ground Water Use, 1983 - Based upon data reported to DNR by appropriation permit holders. Does not include rural water use.

County	Reported Ground Water Use for Irrigation (MGY)*	Reported Acres Irrigated	Reported Ground Water Use for Public Supply (MGY)	Population Served	Percent of Total Water Withdrawn Supplied by Ground Water
Anoka	168.10	1,207	5,618.1	102,584	7%
Benton	1,110.8	4,343	373.6	11,325	11%
Cass	106.5	1,078	176.9	3,503	60%
Crow Wing	164.7	504	829.7	13,105	25%
Hubbard	1,527.4	8,315	199.1	3,308	70%
Isanti	123.8	995	266.7	5,160	99%
Mille Lacs	0	0	301.1	4,378	97%
Morrison	1,336.0	6,181	543.3	9,899	97%
Ottertail	4,432.0	24,116	626.2	19,193	31%
Sherburne	4,710.3	17,895	342.8	10,936	49%
Stearns	2,704.4	18,428	1,490.0	17,665	44%
Todd	767.8	4,775	639.1	5,656	84%
Wadena	608.3	3,427	261.4	5,203	74%

*Million Gallons per Year

How Good is the Water?

Given the vulnerability of the surficial sand and gravel aquifers, what quality of water is usually found? The natural quality of the water is generally good. Like most Minnesota ground water, it is "hard," meaning that the levels of calcium and magnesium are relatively high. Water which is hard can contribute to the formation of "scale build-up" in plumbing as well as lessening the efficiency of soaps and non-detergent cleaners. These problems are easily remedied with home water softeners.

Iron and manganese concentrations in ground water are also relatively high statewide, including the surficial sand and gravel aquifers. These high levels affect the aesthetic quality of the water, but do not present a health hazard to the water user (see accompanying discussion, Iron and Manganese in Ground Water). Of greater concern are the elevated levels of nitrates which are being found in the surficial sand and gravel aquifers. There is a long-established standard for the allowable concentration of nitrate in drinking water, and nitrate may also indicate contamination from wastewater (septic tanks), animal wastes, or fertilizers. Naturally-occurring levels of nitrate are generally low.

Nitrate can present a health hazard when present in concentrations greater than the drinking water standard of 10 mg/l (parts per million or ppm) nitrate as nitrogen (N). The hazard associated with high nitrates is mainly of concern to parents of infants under six months old whose formula is prepared with the nitrate-contaminated water. That is because the babies' immature bodies lack the systems needed to handle high levels of nitrate, and a disease called "methemoglobinemia" may result, impairing the ability of the babies' blood to carry oxygen throughout their bodies. It has been a very rare disease in this country in recent years.

The other problem with high nitrates is that their presence may indicate that other contaminants are reaching the aquifer. For example, Minnesota farmers used pesticides at least once each year on over 96% of their corn acreage. Information from the 1984 Pesticide Survey conducted by the Minnesota Agricultural Statistics Service shows that the following pesticides were used on corn acreage in Minnesota (the first word is the chemical name of the pesticides, and the word in parentheses is a typical trade name):

Alachlor(Lasso)	2,4-D; 2,4-D amine and esters
Atrazine (Aatrex)	Dicamba (Banvel)
Cyanazine (Bladex)	Terbofos (Counter)
Metolachlor (Dual)	Fonofos (Dyfonate)
Propachlor (Ramrod)	Carbofuran (Furadan)
EPTC and protectant (Eradicane)	
Butylate and protectant (Sutan plus)	

If the nitrate found in the ground water was due to fertilizers on corn crops, it is likely that pesticide residues could be present as well. Ongoing studies in Iowa have shown that nitrate and some pesticides are leaching from the soil, into shallow ground water and are now found in many of Iowa's aquifers. University of Minnesota research in Southeastern Minnesota, where sinkholes and caverns provide ready conduits for contaminants to reach the ground water, show similar findings. There is no reason to think that this could not occur in Minnesota as well.

Current programs of the Minnesota Department of Health and the Minnesota Department of Agriculture involve testing for pesticides in wells near fields where pesticide treatment has taken place. No data have been reported yet from these, but a similar study in the surficial sand aquifers of central Wisconsin documented wide-spread contamination from Aldicarb, an insecticide use on potato crops. Tests showed the presence of Aldicarb in about 80 of the 500 wells tested. The state, as a precautionary measure, adopted emergency rules temporarily limiting the use of the pesticide in some areas. Further studies showed that Aldicarb did break down in the ground water and that by properly managing timing and rate of application the problem can be controlled.

Iron and Manganese in Ground Water

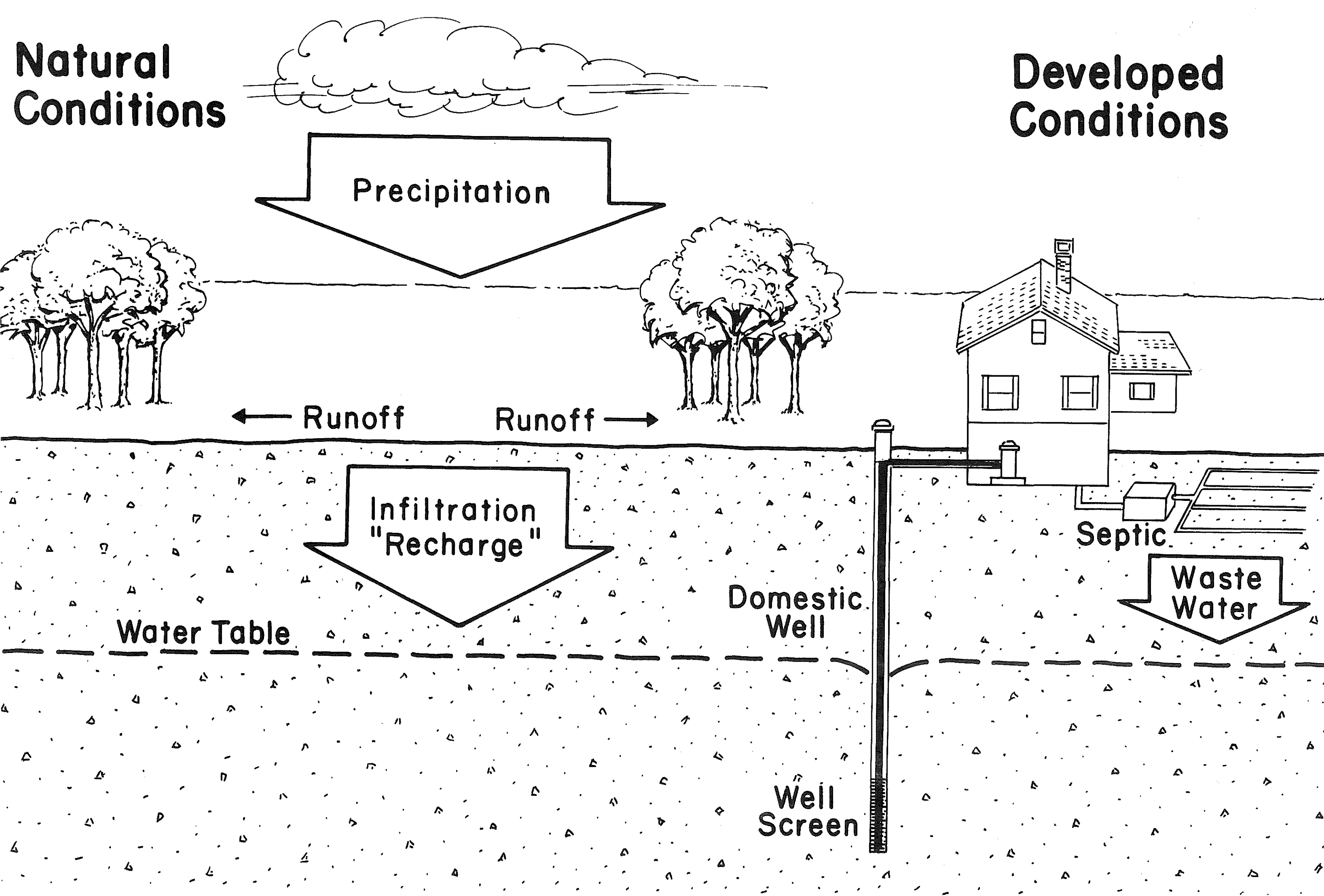
Iron in ground water occurs naturally in the soluble (ferrous) State and cannot be seen. However, when the water is exposed to air, the iron becomes oxidized to the ferric state and forms reddish-brown particles that may settle to the bottom of the container. The drinking water standard (recommended upper limit of concentration for water used for human consumption) has been set at 0.3 ppm (parts per million), however, water containing iron in excess of that amount does not constitute a health hazard to the water consumer. Rather, it can cause reddish-brown stains on porcelain fixtures and laundry, and support the growth of "iron bacteria", usually noted as a slimy red, brown or black substance which may accumulate in and eventually clog the well, treatment units, and distribution pipes. The statewide average value found in the Minnesota Pollution Control Agency's ground water quality monitoring program is 1.3 ppm. The iron standard is the most frequently exceeded standard in that program, with 53% of the samples tested failing to meet the standard.

Manganese in ground water occurs in the soluble state, and when exposed to air, oxidizes causing brownish or black stains on porcelain fixtures and laundry. The stains caused by manganese generally are harder to remove than those caused by iron. The drinking water standard for manganese was set at 0.05 ppm, based upon these aesthetic concerns. Consumption of water containing manganese in excess of 0.05 ppm does not constitute a health hazard. The statewide average value for manganese is 0.15 ppm. The manganese standard is the second most frequently exceeded standard, with 46% of the samples tested falling above the limit.

How Land Use Affects Ground Water

Ground water quality can be polluted by concentrated sources of contaminants such as leaking sanitary landfills, spills or leaks of petroleum and other products, and illegal disposal of hazardous wastes, to name a few. These concentrated contaminant sources can affect a large quantity of ground water and severely affect many people. The Minnesota Pollution Control Agency has programs which regulate these types of contaminant sources and oversee the cleanup of the sites where problems have occurred.

A more insidious threat to ground water is posed by "non-point source" pollution, which is that which does not have a single, concentrated source of contaminants. Non-point source pollution is typified by wide-spread, low level contamination from a multitude of diverse sources, such as agricultural practices and increasing urbanization. Anything which is applied or disposed on or below the surface of the land can affect ground water quality in the shallow sand and gravel aquifers of Minnesota. Deicing chemicals used on road surfaces in the winter infiltrate through the soil in the spring, increasing the salinity of the ground water near roads. Liquids from home septic systems, may contain any of the chemicals which home owners flush down their drains, such as cleaners, paint thinners or waste oil along with the nitrate typically found in waste water. Sewer lines, too, leak these same sorts of contaminants at an



alarming rate which increases proportionately with the age of the lines.

Many common agricultural practices can damage ground water as well. Uncontained, contaminated runoff from animal feedlots may seep into ground water or pollute surface water. Over-fertilization of crops can cause the leaching of the unused nutrients into the ground water. A recent study in Iowa showed that 1/3 to 1/2 of the nitrogen applied to corn crops was not used by the plants. This excess nitrogen is then lost and may damage the environment and certainly wastes the farmer's money. The Iowa study indicates that the amount of nitrogen applied can be decreased substantially without damaging yield, if the timing is geared to the crop's needs. Pesticide application, too, can be made more economical by similar means. Conservation tillage, while reducing runoff into surface waters, may impair ground waters more than traditional tillage methods since greater quantities of pesticides are required which may subsequently leach into ground water supplies. Tillage methods are currently being studied for a better idea of their effect on ground water quality.

Studies conducted by the United States Geological Survey in recent years have indicated that ground water in surficial sand aquifers is very susceptible to contamination by nitrates. Table II shows some of the median nitrate values they have found in ground water present under various types of land use. It is obvious from this data that man's activities can have a profound affect on ground water quality.

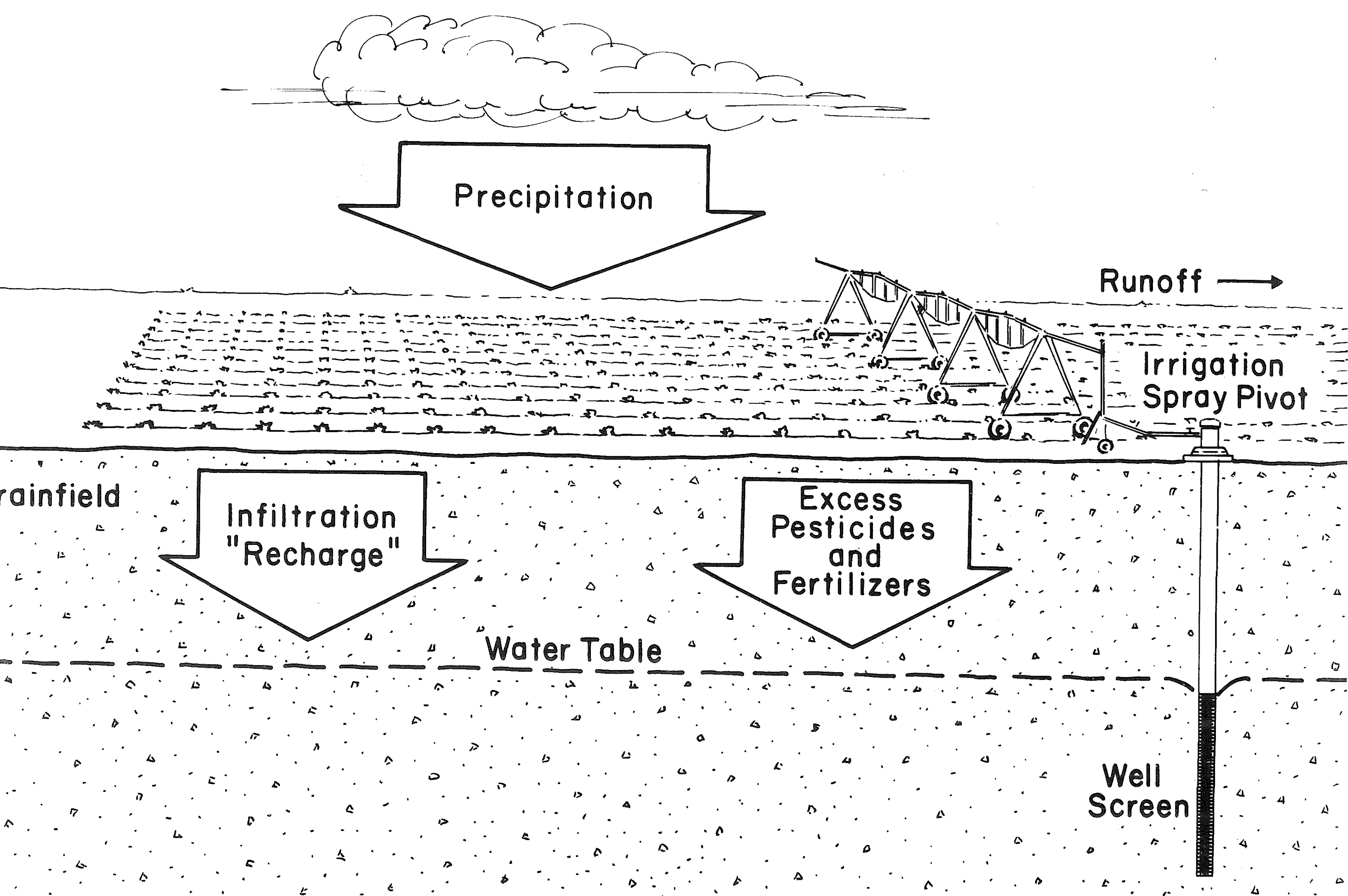


Table II. Nitrates in Shallow Ground Water.

	Uncultivated	Cultivated	Irrigated	Residential
West Central Minnesota	2.5 mg/l	3.4 mg/l	14.0 mg/l	not avail.
Anoka Sand Plain	0.15 mg/l	1.8 mg/l	5.6 mg/l	2.8 mg/l

(Uncultivated means apparently natural and undisturbed, Cultivated is non-irrigated row crops, Irrigated is irrigated row crops, and Residential means homes with septic tanks.)

As the population of an area grows, so does the stress placed on the environment in that area. More people mean more roads and more deicing chemicals, more sewer lines and septic tanks to leak, more low levels of contaminants seeping into ground water. (See below for a brief discussion of population trends.) The impact of this growth is not only likely to be degradation of the shallow ground water, but it also will lead to increasing withdrawals of ground water for public and domestic water supply. Withdrawal of water from the lower aquifers could cause the contaminated upper waters to sink into the lower aquifers being used for water supply.

The ground water in the shallow aquifers is usually not very old, which is to say that it has not been in the ground for a very long time. The deeper aquifers may contain water which is tens, hundreds or even thousands of years old. Due to man's increasing surface and subsurface activities, the quality of the recharge water going into our aquifers is not as good as that of earlier ages. Withdrawing the older, higher quality water will lead to its eventual replacement with newer, lower quality water, causing a general decline in the water quality over much of the aquifer systems. This is a serious concern which must be addressed.

Population Growth

Population forecasts for Minnesota see the greatest increase in number of persons in the counties surrounding the Twin Cities and extending up to St. Cloud. Much of this area is underlain by the shallow sand and gravel aquifers which are the focus of this report. Anoka County has the greatest population density in the study area. The population density of Anoka County was 365 persons per square mile in 1970, and it has increased to an approximated 497 persons per square mile in 1984. Projections place the population density by the year 2000 at 604 persons per square mile, a 65% increase in 30 years. The greatest anticipated growth in population density is expected in Sherburne County, where the population density is projected to increase 288% between 1970 and the year 2000.

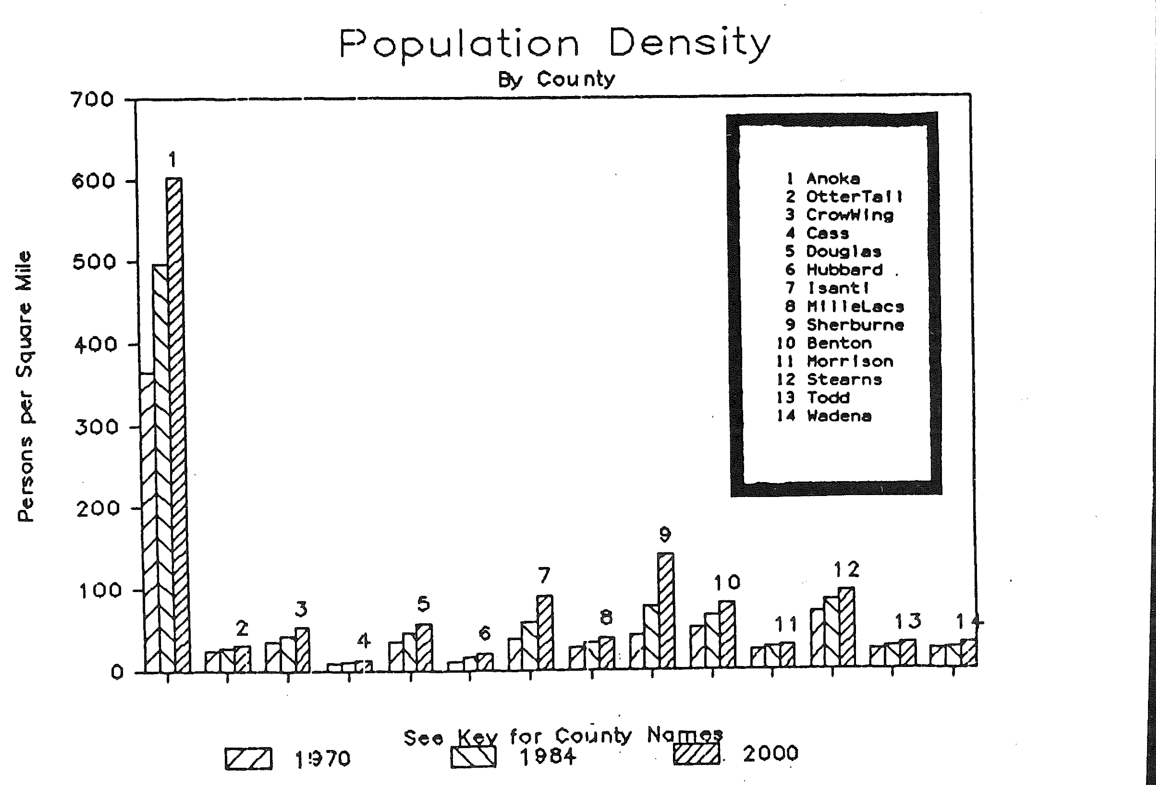
This graph shows the population density, by county, of the counties in central Minnesota which are underlain by surficial sand and gravel deposits. Data shown in from the 1970 census and projections of the population in the years 1984 and 2000.

Factors Affecting Ground Water Levels

Ground water levels in sand plain aquifers fluctuate in response to ground water recharge (infiltration to the water table) and ground water discharge (seepage to the surface and pumping). The measurement of water level fluctuations in wells is an important facet of many ground water studies. The plot of these ground water levels through time is called a hydrograph. Two main trends can be noted from a hydrograph: seasonal trends and marked water levels changes due to sudden events such as a specific rainfall event. Seasonal trends produce a roughly cyclic pattern in a hydrograph. Isolated trends in water levels occur when the yearly average recharge or discharge deviates from the norm for a prolonged period of time. By studying a hydrograph, water resource researchers can monitor the impact of droughts or ground water pumpage and determine the best management strategy for maintaining ground water supplies for both present and future users.

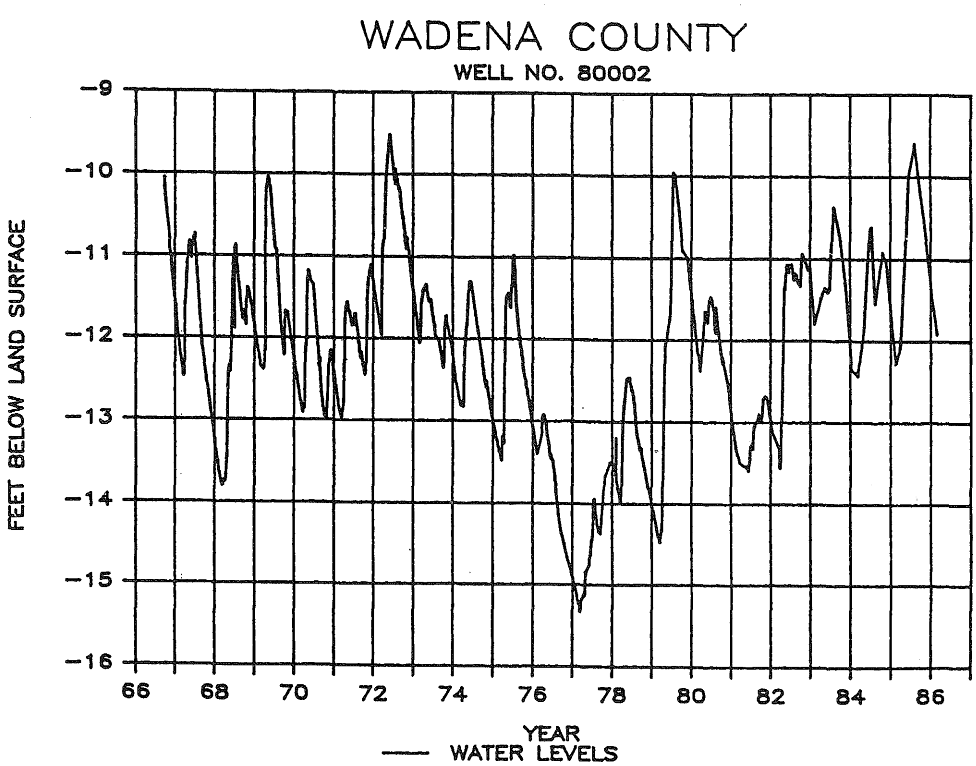
Water level declines may create major environmental and economic consequences long before an aquifer is depleted. As the water level drops, shallower wells dry up and must be replaced with deeper, more costly wells. In extreme cases, land subsidence or collapse of the material overlying the aquifer can occur due to loss of bouyant support. Ground water flow patterns can be altered thus affecting the amount of water flowing into a lake or river harming wildlife and impairing water recreation. (See the accompanying discussion of Ground Water and Trout.) Lower ground water levels also, lead to reduced soil moisture within the rooting zone of many crops, impairing crop production.

Elevated ground water levels can cause severe flooding problems along lake shores and agricultural land. This can wreak havoc in lake shore communities such as is currently happening in the area surrounding Lake Pulaski in Wright County. Flooding of agricultural lands leads to delayed planting and possibly a reduction in the amount of tillable land.



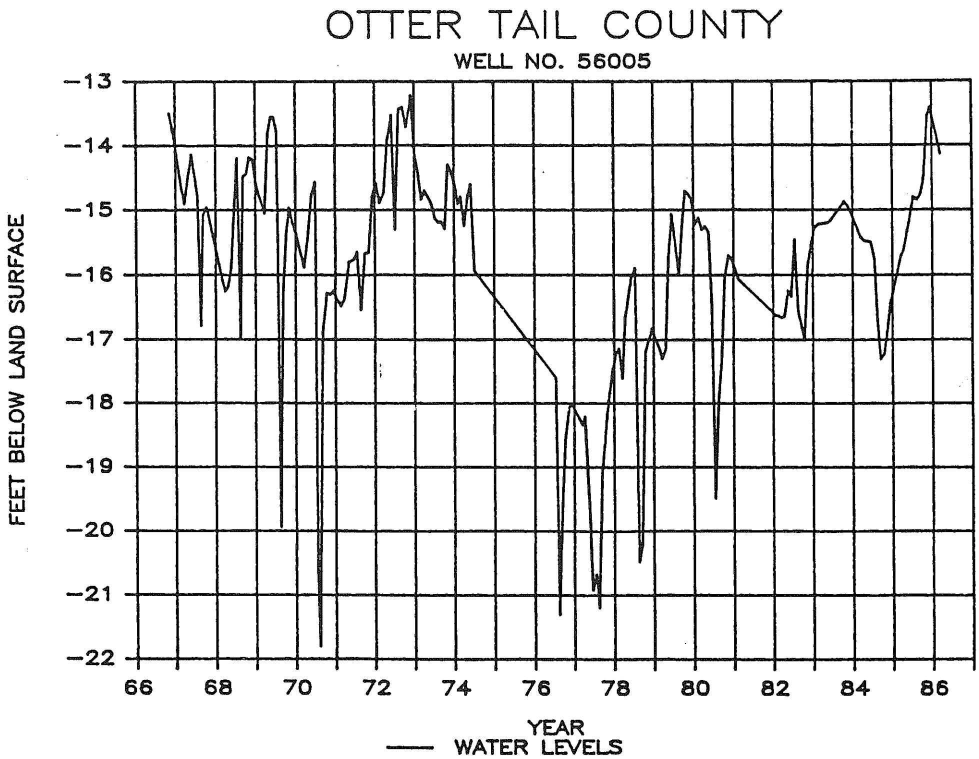
Seasonal trends for two sand plain wells are illustrated on Hydrograph #1 and #2. The first hydrograph shows a seasonal water level pattern for a sand plain aquifer that has not been influenced significantly by pumping. The effects of pumping are illustrated on the second hydrograph. Hydrograph #3 illustrates an isolated trend due to prolonged drought.

Hydrograph #1 shows that water levels are generally at highest levels in spring and at lowest levels in late winter just before the ground was thawed. Water levels are shown to decline at a rather uniform rate through the summer, fall and winter months except for sporadic rises in response to recharge from rain storms. Ground water levels generally reach their peak in spring due to precipitation replenishing surface water and recharge basins such as streams, lakes and wetlands which are at high levels following snow melt. Water levels decline through the summer and fall since ground water levels are now above lake and stream levels and seep into these systems. Water levels continue to decline through the winter since frozen conditions curtail recharge and ground water continues to discharge into streams and lakes.



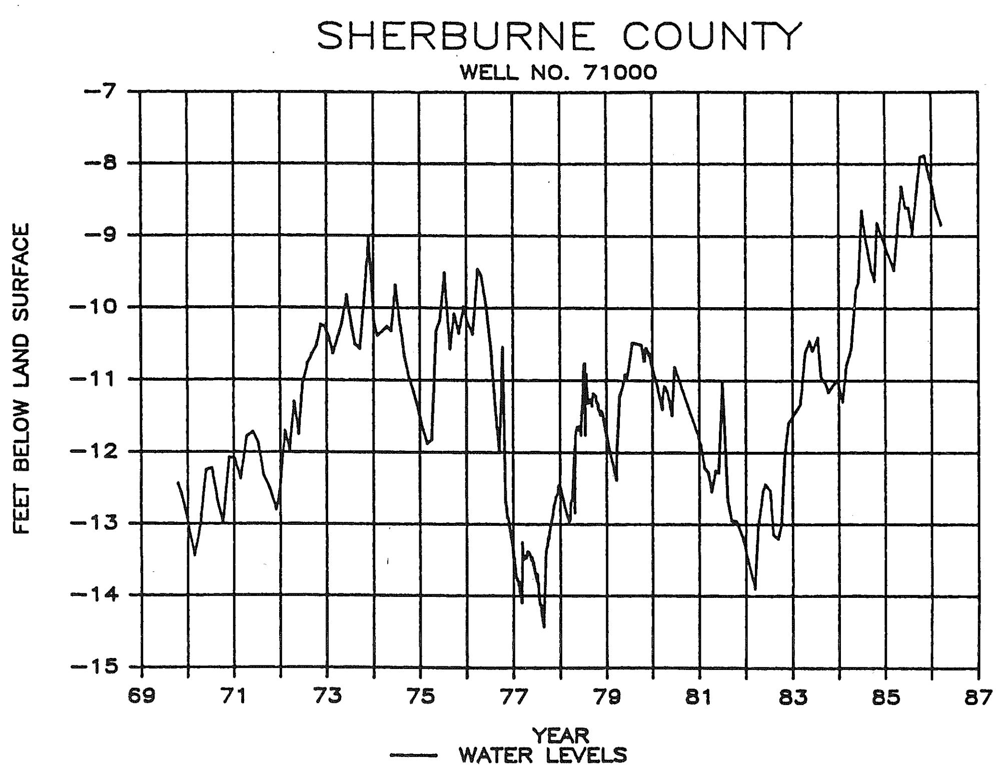
HYDROGRAPH No.1

The effects of pumping are illustrated in Hydrograph #2. Water levels gradually decline following the spring recharge. The decline becomes steep during the summer months. This results from an increasing water withdrawal for irrigation as well as use of ground water by vegetation. The water level begins to recover after irrigation has stopped and generally returns to seasonal levels by mid-fall if adequate precipitation is available for recharge.



HYDROGRAPH No. 2

Hydrograph #3 show isolated downward trends in water levels which occur when discharge exceeds recharge for a prolonged period of time. This loss in water levels can occur due to large pumping withdrawals or drought. Water levels will rise for the opposite reasons. A decline in water levels occurred during the drought of 1976 and continued into 1977. Water levels are observed to slowly recover following the drought years. A second, less severe drought occurred over a two-year period beginning in 1980. Water levels have since risen due to above-average precipitation. The present ground water levels are high and are a major contributing factor for the high water levels in many of the area's lakes.



HYDROGRAPH No. 3

Ground Water and Trout

The Straight River in Hubbard and Becker Counties is a designated trout stream. Trout streams typically have cold, high quality water, most of which comes from ground water. Because designated trout streams are highly valued resources, the State does not permit the direct withdrawal of water from these streams. This to protect the stream from either quantity or quality losses.

In the past few years, certain physical characteristics of the water of the Straight River have changed for the worse. The river water is slightly warmer than it used to be and there are concerns about the potential for higher nitrate concentrations and possible pesticide contamination, as well as reduced oxygen-carrying capacity due to higher temperatures. What has happened in the Straight River Watershed that is affecting the river?

The most obvious change in the watershed has been a change in land use from dryland farming to intensive crop irrigation. Currently, 17% of the 80 square mile watershed is being irrigated. In 1974, there were only five irrigators; now there are 66. The heaviest irrigation takes place within two miles of either side of the Straight River. In addition, the city of Park Rapids has four wells in use for municipal supply.

Our understanding of the details of the interaction between the flow of the Straight River and ground water withdrawal is uncertain at best. We do know that ground water provides the base flow of this stream and we also know that 1,491.1 million gallons of ground water was withdrawn for irrigation in 1984. We do not yet have the capability to quantify the details of the ground water withdrawals on the quality or quantity of the flow of the river. A major area of interest is the relationship between the timing of ground water withdrawal and the subsequent impact on river flow.

Funding is being sought to collect data and develop computer models to predict the impacts of ground water use on the river. When the results of the modeling studies are available, it will be possible to develop innovative water-use management techniques so that we can balance the need for ground water use with the need to maintain the Straight River as a prized recreational resource for future generations.

What Can be Done?

Water quality is slowly and subtly being degraded, and increasing withdrawals of ground water are changing natural flow patterns, influencing both surface and ground water supplies. The imperative is upon the people of the sandplains to manage their ground water resource wisely, with an eye to the future.

Residents must be certain that septic tanks are working properly, without overloading their systems. Solvent-type septic tank cleaners should be used sparingly, if at all, and care should be taken when disposing of other types of cleaners or waste materials into the septic tanks. Lawn fertilizers and herbicides should be used sparingly, to prevent their leaching into the ground water. Waste oil should be recycled, not poured into drains or onto the ground.

Farmers, too, must be aware of potential ground water impacts from many common practices. Feedlots should be constructed and maintained in a manner which does not allow the contaminated runoff to seep into ground water. Application of fertilizers and pesticides should be timed so that the crops receive the maximum benefit and a minimum of environmental damage is done. This is especially important in irrigated agriculture, where additional water flushes more contaminants into the ground water. Care must be taken to avoid back-siphonage of chemicals into the irrigation well. Chemical mixing and storage areas should imperviously-lined to contain spillage wherever possible.

All well owners should periodically check their water for nitrate and coliform bacteria. These tests can be arranged by the county community health services throughout the State.

Everyone must remember that protecting the ground water of the surficial sand and gravel aquifers requires awareness of potential effects and a personal commitment to reduce these effects wherever possible. As Pogo said in a comic strip years ago, "We have met the enemy, and he is us." People create this sort of environmental degradation, and people can solve the problem as well. It is only through a well-informed and concerned public that we can protect our ground water resource, so do not hesitate to contact public officials who make decisions that directly or indirectly affect ground water quality and quantity. Make sure that they know and respond to your concerns.

For Further Reading:

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Who to Contact with Problems or Questions

Well Construction and Abandonment

Ground Water Quality Unit, Division of Environmental Health
Minnesota Department of Health
717 Delaware Street S.E.
Minneapolis, Minnesota 55440
612-623-5339

Private Well Water Testing

Your Local County Community Health Service

Septic Tank Construction and Maintenance

Your Local Ag Extension Office

Suspected Ground Water Contamination

Ground Water Unit, Solid and Hazardous Waste Division
Minnesota Pollution Control Agency
1935 West County Road B-2
Roseville, Minnesota 55113
612-296-7330

Water Appropriation or Water Level Problems

Minnesota Department of Natural Resources
Division of Waters
500 Lafayette Road
St. Paul, Minnesota 55101
612-296-4800