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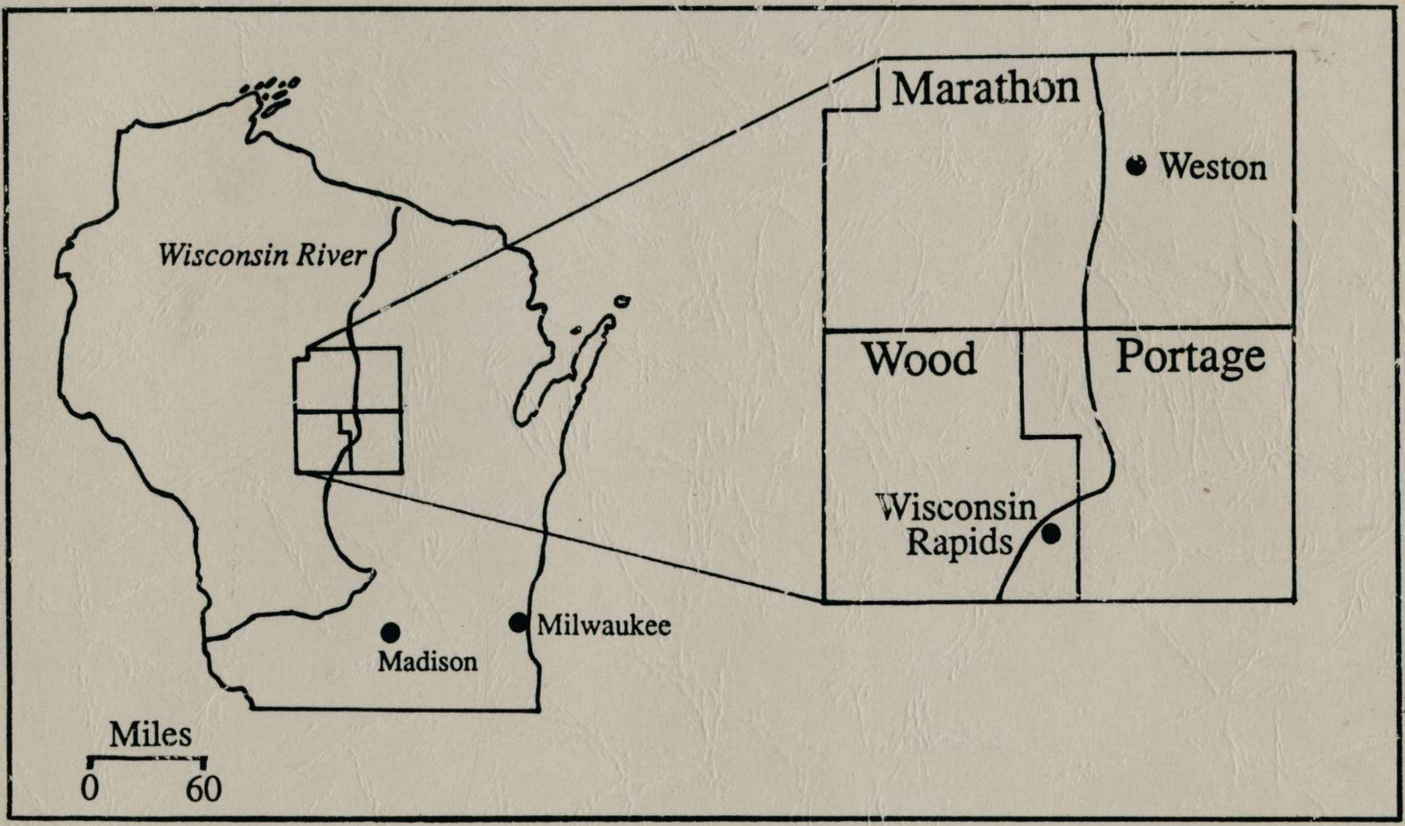

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DESIGNS FOR WELLHEAD PROTECTION IN CENTRAL WISCONSIN

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to

The Wisconsin Department of Natural Resources
Madison, WI

and

The U.S. Environmental Protection Agency
Chicago, IL

PREFACE

This report and project were funded by a grant from the U.S. Environmental Protection Agency, Region V, Chicago, in cooperation with the Wisconsin Department of Natural Resources, Madison. Although the Wellhead Protection Program provided for in the 1986 amendments to the Federal Safe Drinking Water Act has not yet been funded by Congress, these two agencies have supported this study as a pilot project to serve as an example to other municipalities.

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ABSTRACT

This report documents the first wellhead protection area (WHPA) studies in the state of Wisconsin pursuant to the 1986 Safe Drinking Water Act Amendments. Two communities were examined: the city of Wisconsin Rapids in Wood County and the town of Weston in Marathon County. Although hydrogeologic conditions of the study areas are similar, the two community situations contrast significantly. The town of Weston has already experienced contamination problems in its two principal municipal wells and extensive studies have been completed identifying possible sources of contamination and remedial action alternatives. The recharge area of Weston's municipal wells lies entirely within the jurisdiction of the township. Wisconsin Rapids, in contrast, has not yet experienced city well contamination. However, their three existing wells and a fourth proposed well all lie within the adjoining town of Grand Rapids which is experiencing increasing urbanization. This situation has shown the need for the development of innovative management options involving inter-jurisdictional cooperation.

Three main steps were completed: delineation of the zones of contribution, identification and mapping of potential contaminant sources and development of management strategy options to be used in the implementation of a wellhead protection plan. The zones of contribution (ZOCs) for the wellfields were defined using incremental applications of the uniform flow equation, modified by consideration of hydrogeologic boundaries and the balance between municipal pumping rate and natural recharge. Time of travel isochrones for ground water contaminants were presented in frequency diagrams based on Monte Carlo simulations of the average pore water velocity equation.

Potential contaminant sources were identified using existing state and local inventories and field checking. The main sources investigated were point sources such as underground storage tanks, commercial establishments that use hazardous materials or generate hazardous wastes, spills and landfills. Non-point sources of ground water contamination from agriculture were of less concern since neither study area contained significant amounts of this land use type.

Databases were developed to organize and analyze the attributes of the sites and sources of potential point contaminants. Site characteristics include locational data, proximity to municipal wells and soil pollutant attenuation potential. Source information includes underground storage tank characteristics and the quantities of contaminants released and remedial actions taken in spill incidents. Map overlays were digitized for about 20 resource, cultural and contaminant features. These overlays were combined using geographic information system (GIS) software to create various maps including zoning, depth to water table, zone of contribution, land use and potential contaminant site location maps.

Wellhead protection management strategy options were developed for eight potential contaminant types. They include seven educational approaches, 24 administrative and 15 regulatory options for each community. Educational options include distributing information pamphlets and encouraging voluntary removal of underground tanks. Administrative options include incentive programs offering monetary bonuses for the removal of underground tanks, record systems for source inventories and sewer extensions. Regulatory options suggest revising present zoning, establishing a hazardous substance ordinance and enacting overlay zones prohibiting future tank installations in portions of a management zone. Input of local officials was essential to develop workable wellhead protection options.

INTRODUCTION

The 1986 SDWA amendments and the need for wellhead protection

The 1986 amendments to the Federal Safe Drinking Water Act (SDWA) established a new Wellhead Protection (WHP) Program to protect areas surrounding wells and wellfields supplying public water supplies. Unlike previous federal ground water programs which emphasized cleanup of problem sites, the primary goal of the WHP Program is to protect public water supplies from contamination. The Act requires each state to develop a wellhead protection plan which will identify and protect the municipal wells of the state.

The concept of wellhead protection is simple -- protect the land area that contributes surface water runoff or ground water recharge to the water supplies eventually pumped by municipal wells. One of the major elements of the WHP Program is the determination of zones within which contaminant source assessment and management will be addressed by the municipal water supplier. These zones are called wellhead protection areas (WHPAs). The SDWA officially defines a wellhead protection area as "the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield."

The process of implementing wellhead protection under the SDWA involves virtually all levels of government. The role of the U.S. Environmental Protection Agency (EPA) is to administer the requirements of the program through technical assistance and program grants. The states have the lead role in developing statewide WHP plans for all public water supplies. Local governments and municipalities will primarily implement areawide management strategies since they exert the most control over local land use decisions.

Funding for federal support of state WHP plans was authorized for each fiscal year since 1987, however, Congress has not yet appropriated any specific funds (U.S. EPA, 1987). The lack of federal funds means that states and communities that are interested in wellhead protection must find their own sources of funds. The EPA, recognizing this problem, has provided some funds for special pilot WHP projects around the country (Lew and Roy, 1989).

Contract, duties and coordination

Contact among the Central Wisconsin Groundwater Center (CWGC), U.S. EPA Region V office, Chicago, and Wisconsin Department of Natural Resources (DNR) first indicated the possibility of pilot funds for wellhead protection in May 1988. Discussion with central Wisconsin communities interested in sponsoring a WHP study led to the submittal of three proposals. Two proposals, one for the town of Weston in Marathon County and one for the city of Wisconsin Rapids in Wood County, were later combined and funded by EPA through DNR in November 1988. Both communities obtain drinking water from shallow, unconfined sand and gravel aquifers which are ideally suited for application of WHPAs. The town of Weston has existing contamination problems and Wisconsin Rapids plans to add a new well to its water system. A location map for the two communities is shown in figure 1.

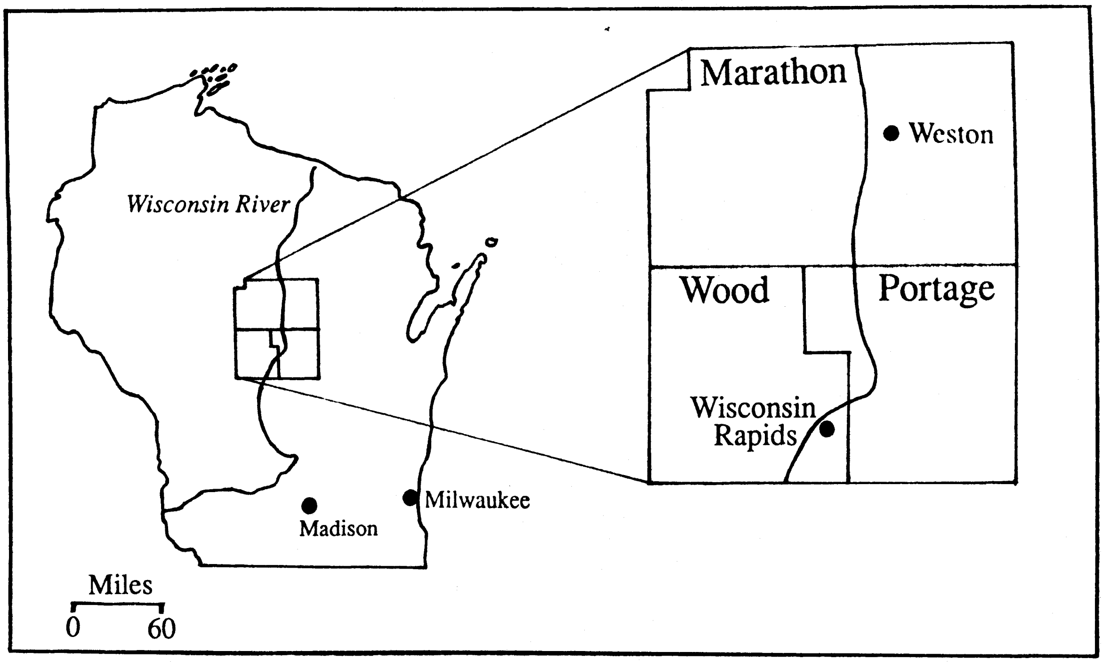


Figure 1. Location map of the two study areas.

The contract between the DNR and CWGC had as its intent the application of wellhead protection techniques and the presentation of a report to DNR, EPA and the municipalities. The town of Weston and city of Wisconsin Rapids were named as cooperators in the contract. This report serves as enabling documentation for actual implementation of wellhead protection plans or ordinances. It also serves as an example to other communities. In addition to this report a separate appendix volume has also been prepared.

The CWGC had primary responsibility for the technical analysis of the study and publication of the final report. Weston and Wisconsin Rapids were responsible for providing all existing information and reports regarding municipal wells, contaminant sources and land and water uses in the study areas. The municipalities provided feedback regarding the implementation methods, regulatory approaches and limitations of the WHP options proposed by the CWGC. Local coordinators facilitated community involvement. In Wisconsin Rapids, the University of Wisconsin-Extension (UWEX) Wood County Resource Agent assumed the lead role, while in Weston, the Director of Public Works took the role.

Hydrogeologic mapping by the CWGC indicated that the recharge area for Weston's municipal wells fell entirely within the jurisdiction of the township. The involvement of other jurisdictions was not necessary in this case. All three of Wisconsin Rapids' existing wells and the proposed new well are located outside city boundaries in the adjoining town of Grand Rapids. From the outset, it was felt imperative that this township and other potentially interested jurisdictions have some mechanism for involvement in the study. To this end, a steering committee was organized by the UWEX Wood County Resource Agent which included representatives from two adjoining townships and one village, as well as the city. Meetings with the steering committee were held three times during the course of the study. Progress reports were presented and feedback received from committee members on WHP materials and initiatives. The committee was seen as essential for inter-jurisdictional cooperation in WHP planning.

WELLHEAD PROTECTION PRINCIPLES AND CONCEPTS

Ground water and wells

Ground water hydrology

Ground water is an unseen resource and liable to be popularized by supposed mystical qualities, exotic points of origin and unusual modes of occurrence. Fictional notions of ground water do nothing, however, to enhance concern about the need to protect ground water at the local level. The logic underlying wellhead protection must be founded on scientific principles of how water occurs on planet earth. Ground water is part of the hydrologic or water cycle; that process whereby the sun's energy powers the transfer of water from the oceans to the land and glaciers where it may evaporate, transpire from plants, run off to rivers or seep through the soil to the ground water system and finally reach the oceans again. One cycle may take from days to many thousands of years.

The soil and rock material beneath the earth's surface is composed of both solid mineral and organic matter and void spaces in the form of pores between grains of sand and gravel, or cracks and fractures in bedrock. Below some depth these voids are permanently saturated with water. Any earth material such as sand and gravel or fractured bedrock which is saturated with water and will transmit water to wells is called an aquifer. The top of the saturated zone is called the water table. The depth to the water table is usually relatively shallow in humid areas, often less than 50 feet, and deeper in arid areas, sometimes hundreds of feet deep.

All ground water we drink originates as rain or snowmelt on the earth's surface. The replenishment of ground water supplies by rain and snowmelt is called ground water recharge. Shallow wells withdraw water which originated as recharge in an area relatively close to the well. Depending on site specific factors, this may mean within a few hundred feet to a few miles of the well. Deeper wells and wells in layered bedrock formations tend to withdraw water which originated many miles distant where that particular rock unit is exposed at the land surface. In addition, the deeper aquifers may be recharged by slow percolation of downward moving recharge water through overlying rocks.

Ground water is not stagnant but moves in response to gravity and pressure potential. The water table is often a subdued replica of the land surface topography and has greater elevation beneath hills and uplands, and lower elevation near rivers, lakes and wetlands. Ground water moves slowly within the aquifers from areas of higher to lower elevation and pressure (figure 2). The final discharge point for ground water is usually a river, lake, wetland or well. Springs are specifically channeled points of ground water discharge.

Contaminants, once they reach the water table, move along with the bulk flow of ground water in a process called advection. Contaminants also get spread out as they move due to dispersion. Dispersion is mainly due to heterogeneities within the aquifer such as grain material, size, shape or position. Ground water moves through many microscopic pathways within the aquifer, imparting varying directions to the contaminant movement. Small scale differences in the velocity of ground water flow occur causing some dissolved contaminant particles to move faster than the average rate of water flow and some to move slower. As it moves then, a

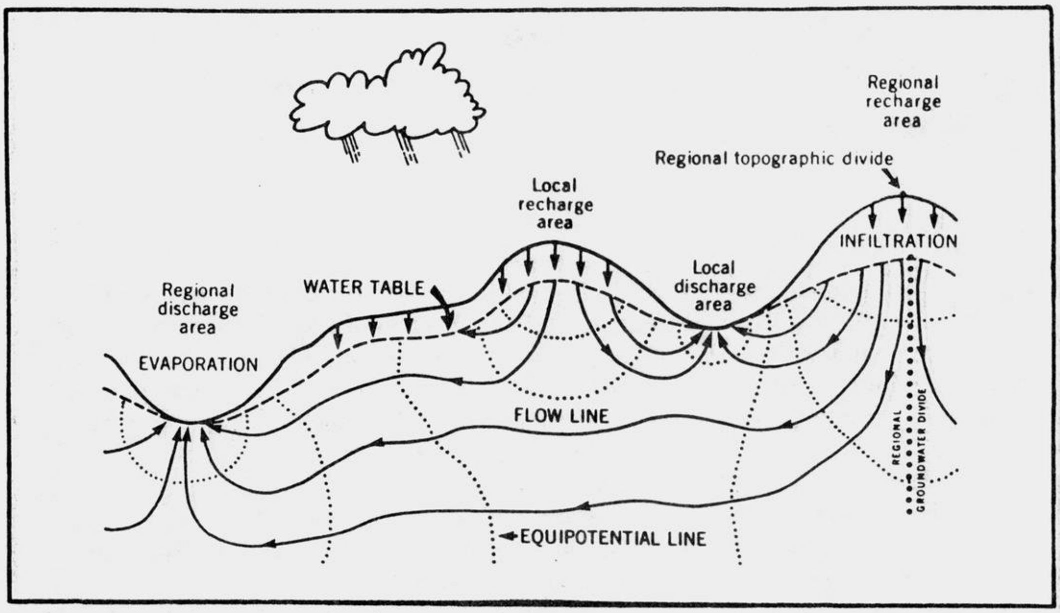


Figure 2. Illustration of ground water movement. (Source: Zaporozec, 1982.)

contaminant plume tends to become elongated, slightly wider and more diffused.

The movement of a contaminant in ground water is also greatly affected by its tendency to adsorb to particles of the aquifer material. Many inorganic anions such as nitrate or chloride have very little tendency to adhere to the aquifer material and hence these substances readily move along with the bulk flow of ground water. Some organic chemicals, on the other hand, have a naturally strong chemical or physical affinity for solids in the aquifer and are substantially slowed or retarded in their movement compared to the bulk flow of ground water.

Other processes may occur in an aquifer which strongly influence any particular natural chemical or contaminant dissolved in ground water. Chemical reactions such as hydrolysis, oxidation-reduction and ion exchange can potentially affect contaminant concentrations and chemical form. Biological degradation by microbes in the ground water system is not as common, but may occur at appreciable rates if the set of conditions favorable for their growth exist. Nutrients and organic substrates are often limiting factors for microbial growth. It usually takes from months to years for a population of microorganisms to develop which are adapted to breaking down a particular contaminant. Aquifer cleanup techniques sometimes employ artificially enhanced biological degradation of organic contaminants.

Ground water flow toward wells

Every water well, from the biggest irrigation well to the smallest sand point well, develops a cone of depression in the water table or potentiometric surface when water is pumped. Both ground water and contaminants within a major portion of the cone of depression of a well will be withdrawn for use as the well is pumped.

The bottoms of most wells in unconsolidated materials are fitted with perforated well screens which allow water to enter the well, but keep out the sand, gravel or rock fragments which make up the aquifer. Filter packs of gravel or sand placed around the screen help exclude silt and clay material from the well. Ground water enters the well around the entire outside of the cylindrical screen. When a pump in a well is turned on, it quickly lowers the water level in the well and creates a zone of lower pressure inside the well casing. Water flows into the well from the aquifer in response to these head and pressure gradients. The water table nearest the well is drawn down the most, with progressively less effect with distance from the well. The end result is a roughly cone shaped depression in the water table centered on the well.

Radii of cones of depression in central Wisconsin sands may range from over one-quarter mile for large irrigation wells to less than 50 feet for small household wells. When pumping stops, the water table in the cone of depression gradually recovers to its previous level as water from higher elevations outside the cone moves in.

The cone of depression of each pumped well expands with time until it intersects a relatively inexhaustible source such as a stream or lake, is balanced by recharge from precipitation or intercepts enough of the natural flow through a region of the aquifer. Along with the ground water, contaminants will also be drawn toward the well within this region.

The length of the paths along which ground water may move to a well is very dependent upon specific conditions, but in the shallow sand aquifers of central Wisconsin it is typically a few thousand feet to a few miles (Faustini, 1985). Since common rates of natural ground water movement in sand and gravel aquifers of this area are one or two feet per day, contaminants could take decades to reach a well if they occur at the edge of the recharge area. If the contaminants occur in the zone of contribution near the well, however, movement to a well may occur within days.

The zone of contribution

The entire area recharging or contributing water to a well or wellfield is defined as the zone of contribution (ZOC). In the hypothetical case of a well in an infinitely large aquifer with a completely flat water table, the ZOC would coincide with the cone of depression and be a circular shaped region centered on the well. The radius of this circle would slowly expand with time if pumping continued. In the real world, however, there is usually a gentle slope to the water table which reflects the natural gradient of the ground water system between its divide and discharge area. When a well is pumped in a sloping water table condition, the ZOC does not coincide with the idealized cone of depression. but rather becomes an elliptically shaped figure with the well in the downgradient side and the upgradient side truncated at the ground water divide (figure 3).

Theoretically, all ground water within a well's ZOC will eventually reach and be pumped by that well. Due to often encountered conditions of partially penetrating well construction, intermittent or variable pumping rate, other pumping wells and other hydrogeologic conditions, it is not likely that the theoretical condition is met. Conversely, due to the same conditions, some ground water outside the calculated ZOC might reach a well or wellfield. Nonetheless, ZOCs calculated by appropriate methods using median or more conservative values that can be justified are the best basis for the designation of a wellhead protection management area. This calculated area will probably be modified using practical physical

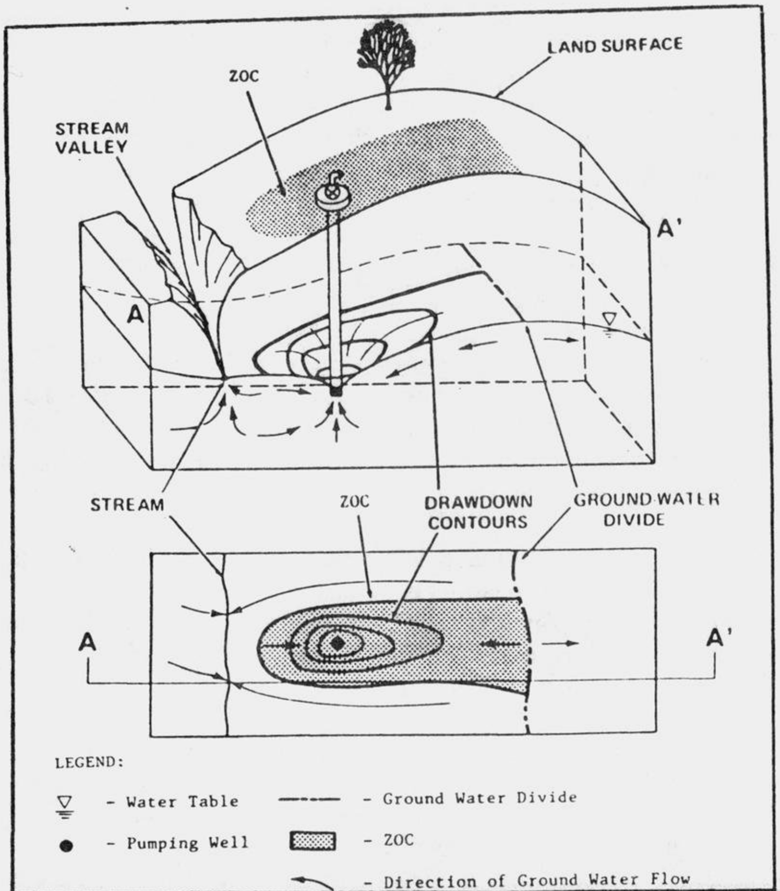


Figure 3. Illustration of a zone of contribution with a sloping water table. (Source: U.S. EPA, 1987.)

or civil boundaries. In this process, some reasonable buffer area should be included to account for the uncertainties inherent in the ZOC calculations.

Zones of contribution for municipal wells and wellfields may be calculated by several different methods. These methods include 1) arbitrary fixed radii, 2) calculated fixed radii, 3) simplified variable shapes, 4) analytical equations, 5) hydrogeologic mapping and 6) numerical computer models (U.S. EPA, 1987). The first three of these were not considered to be sufficiently sensitive or reasonable to use. A combination of analytical equations and hydrogeologic mapping was used for both municipalities' wellfields. Further discussion on the method of ZOC calculation used in this study is contained in the Case Studies Methods section.

Characteristics of contaminant sources

Chemical and physical characteristics

Ground water contaminants have a wide range of chemical and physical characteristics. These characteristics can be important factors in the development of management strategies for WHP. Contaminants may be biological, such as bacteria and viruses, or chemical in nature, such as nitrate, lead or organic material. Major categories of ground water contaminants are classified in table 1.

Table 1. Major categories of ground water contaminants.

Major Category	Sub-Category	Examples
Dissolved Gases	Non-Radioactive	Hydrogen sulfide
	Radioactive	Radon 222
Biological	Coliform Bacteria	Fecal Coliform
	Viruses	Hepatitis Virus A or B
Inorganic Chemicals	Common Constituents	Nitrate, Chloride, Iron
	Trace Elements	
	Metals	Cadmium, Aluminum, Manganese
	Radiological Metals	Radium, Uranium, Thorium
	Non-Metals	Arsenic, Fluoride
Organic Chemicals	Organic Acids	Tannins
	Volatile Hydrocarbons	Trichloroethylene, Benzene,
	Non-Volatile Hydrocarbons	Pentachlorophenol, Naphthalene
	Pesticides	Aldicarb, Atrazine

Some of the contaminants, such as hydrogen sulfide, iron and radium, originate from natural geologic sources or subsurface chemical conditions. In the glacial outwash and alluvial aquifers of the two study areas, the principal natural contamination problems are elevated dissolved iron concentrations and corrosive water. Corrosive water arises from acidic pH and low dissolved mineral content, especially the lack of hardness and alkalinity. The absence of limestone or dolomite minerals in the aquifer is the principal reason for the lack of hardness and alkalinity. This problem may be exacerbated by human activities, such as excessive fertilization, which usually generates acid by-products that deplete alkalinity.

Most ground water contamination, however, is due to intentional or unintentional disposal of contaminants on or beneath the land surface. Contaminant movement may be slow, through granular pore spaces, or rapid in some bedrock types, through fractures and cavities. The more rapidly a contaminant moves through the soil zone, the less opportunity for degradation and remedial action. Much of the Central Sands area, alluvial river valleys, and karst regions in Wisconsin have soils which are low in pollutant attenuation capacity (WDNR et al., 1987).

The fate of contaminants is dictated by a number of physical, chemical and biological processes which are characteristic of the contaminant and conditions within the aquifer. Some chemical processes such as volatilization or photolysis become relatively unimportant once the contaminant moves beneath the soil surface. In ground water, the processes of sorption-desorption, hydrolysis, ion-exchange, biodegradation, oxidation-reduction, precipitation-dissolution and dilution are most important.

When a chemical is known to degrade by some of these processes at a repeatable rate, a half-life for it can be estimated. A half-life is the time required for one-half of the original mass of chemical to be reduced to simpler compounds. For some substances, the intermediate breakdown products are also hazardous. When the breakdown products are benign and half-life can be reasonably estimated, WHP zones based on half life and ground water travel times can be proposed.

Table 2 lists important characteristics of contaminants expected from sources like underground fuel storage tanks, industries, septic systems and agricultural land. Figure 4, based on a study of contaminant plume movement in a sand aquifer, shows the importance of adsorption in retarding the movement of an organic substance like carbon tetrachloride compared to chloride, an inorganic chemical which shows very little tendency to adsorb to the aquifer material. The leading edge of the chloride plume has traveled about 2.2 times farther during 21 months than the organic contaminant. Organic contaminants differ appreciably in the degree to which they are adsorbed within the aquifer.

Recent research indicates that some hydrophobic organic contaminants such as dioxin, PCBs, and polynuclear aromatic hydrocarbons, plus heavy metals, may be much more mobile than first believed, due to a process called facilitated transport (Huling, 1989). Some organic solvents and dissolved colloidal material (less than 10 micrometers) are believed to be agents enhancing the mobility of these chemicals.

Once the contaminants are dissolved in the solvent or attached to the colloids, adsorption to aquifer solids is decreased and they move more readily with ground water flow. For wellhead protection purposes, contaminant sources which generate mixtures of organic solvents, metals, soluble organic carbon compounds or colloidal materials bear special consideration.

In the practical application of wellhead protection, usually one or two characteristics of a contaminant are important. For the gasoline component benzene, for example, sorption is an important factor which slows its movement relative to the ground water, but hydrolysis and natural biodegradation usually are not. Nitrate,

Table 2. Characteristics of contaminants found in ground water in Wisconsin.

Source	Contaminant	Wisconsin Enforcement Standard	Important Characteristics
Gasoline	Benzene	.67 ppb	Lighter than water, vaporizes, adsorbs to soil.
Industrial Solvent	Tetrachloro-ethylene	1.0 ppb	Heavier than water, vaporizes, slow biodegradation.
Septic Systems	Viruses	none	Smaller than bacteria, may travel over 1000 feet.[1]
Fertilizer	Nitrate (as N)	10.0 ppm	Very soluble, no degradation in ground water.

[1] Yates and Yates, 1989.

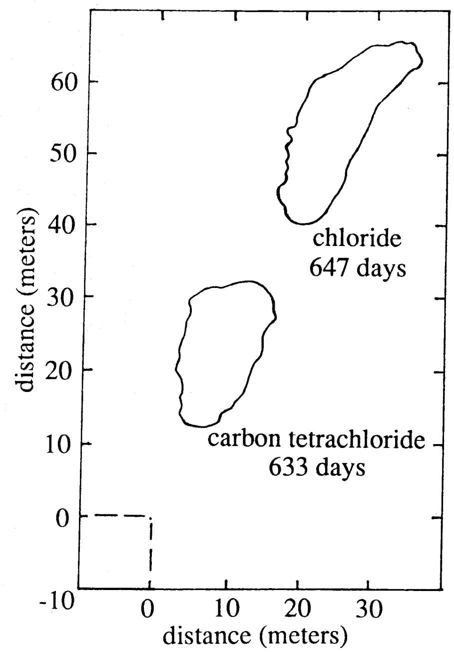


Figure 4. Contaminant movement of chloride and carbon tetrachloride in a sand aquifer. (Source: modified from Mackay et al., 1986.)

on the other hand, does not adsorb to aquifer particles and travels along at the same velocity as ground water. It usually travels unaltered in the ground water system unless organic carbon added from some source promotes denitrification by bacteria (Starr and Gillham, 1989).

For wellhead protection, the characteristics of benzene indicate that a buffer zone restricting potential sources from part of the ZOC may be a practical approach because of the retardation effects of adsorption. For nitrate, however, its addition to the ground water system anywhere in the ZOC contributes to the overall nitrate concentration and will eventually reach a municipal well. Nitrogen management practices targeted to non-point sources in the entire ZOC, instead of a buffer zone, will better limit long-term nitrate concentrations in the aquifer.

Regulatory considerations

Very small quantities of hazardous organic contaminants, such as volatile organic chemicals (VOCs), non-volatile organic chemicals and pesticides, can contaminate large volumes of ground water. Wisconsin's Ground Water Management Law, 1983 Wisconsin Act 410, requires that most of these types of contaminants be cleaned up or managed so as to eliminate further contamination. Regulations such as Chapter Ag 29, Wis. Adm. Code, which governs pesticide contamination, or proposed Chapter ILHR 10, Wis. Adm. Code, governing underground storage tanks, provide a measure of confidence that if contamination from these sources is found, the responsible parties will be required to mitigate the problem. In applying WHP practices for these compounds, the key is to prevent ground water contamination. It is also important to discover any problem at an early date so that cleanup efforts begin soon enough to prevent contamination of municipal wells. Use of special management zones to regulate or exclude potential hazardous organic contaminant sources within the 10 year time of travel is an example of possible WHP measures.

Contaminants such as nitrate, road salt, organic acids and metals are accepted or incidental ground water contamination from sources such as septic systems, farm fields, feedlots, highways, dry wells or other urban runoff. Most of these compounds do not normally degrade in the ground water system and may travel with the ground water flow for miles from any point in the ZOC to the municipal wells. Moreover, since most of these contaminants come from non-point sources, regulatory agencies do not have the means to identify and control all sources.

For these contaminants, local units of government must monitor the overall mix of land uses such as unsewered residential areas and farm land in the ZOC. Conversion of undeveloped property anywhere in the ZOC to residential areas or farm land will always result in some additional nitrate contamination. Wellhead protection for these types of contaminants must rely more on local land use planning and education than on state or federal regulation, at least at the present time.

Wellhead protection area management approaches

European, national and Wisconsin experiences

Western European countries have faced ground water contamination problems due to high population densities for many years. For example, the population density of West Germany may average ten times greater than that of the mid-western United States. Ground water is the major source of drinking water in Western Europe and wellhead protection programs have been in place since 1953 (Pfannkuch, 1989).

West Germany has land use controls in place for 14,000 wellheads throughout the country. Sixty-eight hundred of these plans were enacted in 1988 alone. France passed legislation in 1964 requiring 20,000 to 30,000 wellhead protection plans. Due to the intensive land use and population densities, countries like Holland have very few private wells and 99 percent of the people are served by public water supplies (Pfannkuch, 1989).

Wellhead protection programs in West Germany employ three to four zones around each well. Zone I is at least a 10 by 10 meter fenced area around the well. The outer edge of zone II corresponds to the 50 day time of travel to the well. This zone can contain no underground or surface tanks holding contaminating materials, radioactive facilities, campgrounds, cemeteries or military maneuvers. Only organic fertilizer can be used. Zone IIIA is a two kilometer distance from the well and can have no nuclear plants, landfills, pipelines or transport of hazardous materials. Zone IIIB extends to the drainage area boundary but does not contain siting restrictions (Pfannkuch, 1989).

Other European countries such as France have different approaches, but it is clear that these programs exact their economic toll. Pfannkuch (1989) reports that water bills in France, where wellhead protection is often in private hands, are four times higher than in Minnesota.

Although wellhead protection has not been extensively implemented in the United States, there are some notable case examples. Intensive efforts have been made by Dade County, Florida to protect the county's only public water source, the Biscayne aquifer, a shallow, highly productive unconfined limestone and sand aquifer. In

March of 1981, the Dade County Commission adopted the Potable Water Supply Well Protection Ordinance (Section 24-12.1, Dade County Code) which restricts the intensity of development which can occur around wellfields and does not allow for new development involving hazardous materials. This ordinance supplements other countywide environmental regulations such as an underground storage tank ordinance and a waste transport ordinance (DERM, 1984).

A county wellhead protection plan, called the Northwest Wellfield Protection Plan, was adopted by the Board of County Commissioners in November 1985. Its purpose is to help preserve the public water supply of those served by the Northwest Wellfield, a regional wellfield in a relatively undeveloped portion of Dade County. The wells of the Northwest Wellfield are not contaminated by VOCs as are some of the older urbanized wellfields. Outlined in the plan is a set of recommendations to be implemented in the future. Expansion of the countywide monitoring network, connection of existing industrial development within all wellfield protection areas to sanitary sewers, prohibition of underground storage tanks within wellfield protection areas, implementation of educational programs increasing public awareness and increased promotion of the county's present recycling program are just a few of the many recommendations (DERM, 1985).

Portland, Oregon's municipal wellfield area has recently been considered for industrial development and transportation improvement. Realizing the potential threat posed by development, the city has adopted a water quality protection plan. Prohibition or control of high risk activities, land use and building regulations, treatment and containment of runoff, ground water and surface water monitoring and emergency response and cleanup programs are some of the management options included in the plan (U.S. EPA, 1989).

Many more plans have been written than have actually been implemented. One plan is a statewide ground water management strategy developed for Connecticut. Present state management programs and possible additions to these programs are described along with new management options such as an aquifer acquisition program in which the state would purchase potential wellfield sites and critical drawdown areas to be sold later to a utility when a wellfield is needed (CT Dept. of Envir. Prot., 1987). A similar plan was produced for New Castle County, Delaware. Four water resource protection areas were defined and a short management plan describing restricted and conditional land uses in each area was given (Water Resources Agency, 1987).

Wellhead protection has already been implemented in Wisconsin in a rather abbreviated but effective manner. The town of Rib Mountain and city of Mosinee have enacted overlay zones surrounding their city wellfields (Marathon Co., 1988). A copy of the Rib Mountain Well Recharge Area Overlay District may be found in Appendix 3. These zones define prohibited and conditional land uses based upon their potential threat to ground water quality. Restriction is most intense nearest the wells and less farther from the wells. To date, the definitions of these overlay zones have not been legally contested.

Several Wisconsin counties have examined ground water protection at the county level. Marathon and Portage counties have written county ground water plans outlining specific recommendations for ground water protection and management. The Portage County plan lists 39 recommendations and details how each would be implemented (Portage Co., 1987). The Marathon County plan lists 19 recommendations, quoting estimated costs and lead departments and agencies involved in implementation (Marathon Co., 1988). Each report also describes present ground water conditions of the county.

A similar report was prepared for Rock County (Zaporozec, ed., 1985). It includes detailed inventorying and mapping of potential sources and an assessment of potential contaminant sources. An environmental assessment of the county, including a thorough description of soils and their pollution attenuation potentials, surficial and bedrock geology and ground water flow is also given. The report details findings for each source and lists both regulatory and non-regulatory options the county can use to control each type of potential ground water contaminant source. Based on the findings of this report, it was determined that underground storage tanks are the number one potential contaminant source in the county presently and a follow-up report was written concerning only this issue (Banwell and Holman, 1988).

Regulatory and non-regulatory tools

Two basic management approaches can be used separately or concurrently by local government to protect ground water: regulatory and non-regulatory approaches. Some laws presently exist in Wisconsin which directly or indirectly protect ground water. A partial listing of these laws, the regulatory agency involved and the extent of regulation can be found in Appendix 2.

The following information regarding regulatory and non-regulatory tools for ground water protection available to municipalities and counties was condensed from two Wisconsin Geological and Natural History Survey (WGNHS) publications, "A Guide to Groundwater Quality Planning and Management for Local Governments" (1987) and "Groundwater Protection Through Local Land Use Controls" (1984).

Regulatory tools

Potential and actual threats to ground water can be effectively regulated through the enabling powers of local government. Counties are much more limited than cities, villages, and towns with village powers (hereafter collectively referred to as municipalities) in the range of powers they possess. A county (and town without village powers) must be authorized by statute to adopt regulations, whereas municipalities have broad statutory home rule powers.

Local regulatory protection of ground water has not been extensively tested in state courts. There may be grey areas in which the legal extent of regulation is questionable although the power to regulate is clearly authorized. For a more detailed discussion of this issue and techniques which may be used to avoid constitutional invalidity of local ground water ordinances, refer to Yanggen and Amrhein's 1989 publication, "Groundwater Quality Regulation: Existing Governmental Authority and Recommended Roles." A summary of regulatory options for ground water protection available to municipalities is listed below:

1) Municipal zoning

Zoning is an important tool for regulating new land uses and has a variety of applications to wellhead protection. Three basic approaches that can be used either separately or in combination are discussed here:

Revise existing zoning ordinance

Review and revise zoning district boundaries to make sure the wells and WHP areas are within districts compatible with ground water protection.

Enact overlay zoning

Overlay zoning districts set additional requirements over those of the underlying zoning districts. This approach allows municipalities to avoid overly broad regulations by limiting the most restrictive controls to areas with the greatest need for protection.

Define conditional uses within the zoning ordinance

This approach offers flexibility because it is not strictly prohibitive. Certain uses are still allowed as long as they meet specifically defined requirements.

Zoning and subdivision ordinances can be amended to require developers to install monitoring wells in areas of known abandoned waste sites. The developer must prove that ground water in the area is not polluted. A major limitation with zoning: uses in existence before the passage of new zoning regulations are permitted to continue as nonconforming uses.

2) Municipal extraterritorial zoning

This type of zoning may be useful when a municipal well or its zone of contribution is beyond municipal boundaries. Extraterritorial authority for a first, second or third class city extends up to three miles beyond city limits; fourth class cities and villages can regulate up to 1.5 miles beyond their boundaries.

Interim zoning by the city or village can be adopted for a maximum of two years without the consent of the affected town. Present zoning in the affected area is frozen while a comprehensive zoning plan is prepared. For the extraterritorial zoning to become permanent after two years, it must be approved by a majority vote of a six-member committee composed of three town and three city (or village) representatives.

Extraterritorial zoning enables cities and villages to take emergency action to control land uses affecting their ground water quality. This power has not been widely used in Wisconsin.

3) Municipal subdivision ordinances

These ordinances regulate how larger tracts of land are subdivided for sale or development. Subdivision regulation has traditionally focused on residential development, but it can also apply to commercial and industrial development.

State subdivision regulations are described in Chapter 236, Wisconsin Statutes. Municipalities with a planning agency may enact subdivision ordinances which are more restrictive than these statutory provisions.

4) Municipal extraterritorial subdivision regulations

Extraterritorial authority is the same as for extraterritorial zoning.

5) Municipal hazardous substance ordinance

Such an ordinance could do some or all of the following: identify hazardous substances, require reporting by new and existing businesses, establish standards for storage and handling, require contingency plans in case of spills and provide for inspection and enforcement. Automobile salvage yards could be regulated under this ordinance or under a separate ordinance authorized by Sec. 175.25, Wis. Statutes.

Limitations of such an ordinance: self-reporting by existing facilities may be ineffective and identifying substances to be regulated, setting storage and handling requirements and inspection all require technical expertise and can be expensive.

6) Municipal underground storage tank ordinance

Such an ordinance would supplement non-technical aspects of the Department of Industry Labor and Human Relation's (DILHR) regulations.

7) Municipal hazardous waste ordinance

Such an ordinance would regulate small quantity generators not covered by state and federal regulations.

Counties have some powers of regulation regarding ground water not authorized to municipalities, such as a county well code. Following is a summary of the enabling powers of counties to help protect ground water:

1) County zoning

Such zoning covers all areas of a county except for those municipalities which have enacted their own zoning ordinances.

2) County subdivision ordinance

Such an ordinance would be similar to that described for municipalities.

3) County well code ordinance

Counties may adopt and enforce a county well code which must conform to DNR rules in Chapter NR 112, Wis. Adm. Code. Four levels of county involvement are described in Chapter NR 145, Wis. Adm. Code:

1. Private well location and well abandonment
2. Well location and pump installation permits
3. Existing private and noncommunity water systems
4. Private well construction

Counties may be authorized to administer level 1, levels 1 and 2, levels 1 and 3 or levels 1 to 4. For the first 18 months of the program county operations are limited to level 1. Two limitations of this ordinance: inspection would probably require additional staff and special training and the ordinance must be applied countywide - cities, villages and towns cannot adopt well codes.

4) <u>County septage ordinance</u>

Counties may adopt an ordinance regulating the land disposal of septage. Site criteria and disposal procedures must be identical to DNR rules in Chapter NR 113, Wis. Adm. Code. The ordinance must require a soil test and annual license for each site and the county must maintain records of soil tests, site licenses, inspections, and enforcement actions. If the county does not adopt a septage ordinance, cities, villages and towns may do so.

5) <u>County animal waste storage facility ordinance</u>

Counties may adopt an ordinance that requires all earthen animal-waste storage facilities to meet minimum design and siting criteria. Standards for land application of livestock waste could also be specified.

6) <u>County hazardous substance ordinance</u>

Such an ordinance would be similar to that described for municipalities. Counties could regulate automobile salvage yards under this ordinance or under a separate ordinance specified by Sec. 59.07(38), Wis. Statutes.

Non-regulatory tools

Local governments can also protect ground water through non-regulatory approaches. Listed here are some suggestions of administrative and educational programs which can be implemented. Programs must be tailored to fit the specific needs of a particular locality.

<u>Administrative programs</u>:

1) Countywide Operation Clean Sweep program to facilitate the disposal of hazardous wastes for homeowners.

2) Provide a depository for hazardous wastes from local small quantity generators. Municipality would need a funding mechanism for permanent disposal of wastes.

3) Ground water monitoring of sites in sensitive areas such as underground storage tanks close to a well or monitoring for road salt near wells.

4) Reduction of salt usage on roads near wells.

5) Establish inventories and record systems of underground storage tanks, above ground storage tanks and abandoned and improperly constructed wells.

6) Incentive programs providing monetary bonuses for the removal of underground storage tanks or proper sealing of abandoned wells.

Educational programs on:

1) Proper septic tank maintenance and the dangers of dumping hazardous materials into septic systems.

2) Proper storage and handling of hazardous materials by businesses and proper disposal of hazardous wastes by both businesses and households.

3) Leaking underground storage tanks, how they pollute ground water and endanger drinking water supplies and methods of leak prevention.

4) Proper abandonment of wells.

5) Agricultural best management practices and the proper storage, handling and use of pesticides and fertilizers.

6) Proper use and application of lawn fertilizers and pesticides.

7) Drinking water quality in conjunction with areawide water testing programs.

Evaluating effectiveness and costs of WHP programs

The range of regulatory, administrative and educational WHP management options available is very wide and certainly varies with respect to probable effectiveness and costs. On one extreme, a hazardous waste pickup program sponsored by a municipality will undoubtedly be very effective in eliminating potential contaminants. Alternatively, a leafleting campaign targeted to hazardous waste users is simple, but proves more difficult to demonstrate positive results. The first of these options is quite expensive, perhaps tens of thousands of dollars per program, while the second is very low in cost. The challenge to the professionals and local officials implementing WHP programs is to strike a balance between effectiveness and costs.

The bottom line of a WHP program's effectiveness is to create a low risk environment for contamination within the zone of contribution. An example of how a community might rank the relative effectiveness of seven WHP management programs (number one being most effective) is given in table 3. Detailed descriptions of these programs are given in the Case Studies WHPA Management Options sections for each study area.

The ranking of options is somewhat arbitrary and the effectiveness of WHP programs will depend heavily upon the specific method and approach used in implementation. One of the key issues of WHP program effectiveness is verification.

Table 3. Example of a hypothetical community's ranking of wellhead protection management programs.

Rank	WHP Program
1.	Prohibitions and phase out of sources through zoning.
2.	Regulation of sources through permits and inspection.
3.	Testing and monitoring at key locations.
4.	Record system for sources.
5.	Financial incentives for voluntary removal of USTs.
6.	Targeted educational programs.
7.	Information and leafleting campaigns.

With an information system which maintains and updates records of the location, characteristics and status of all potential contaminant sources, the effectiveness of even a voluntary compliance or educational program could be verified.

All WHP options have a broad band of potential effectiveness, and none should be regarded as wholly superior or inferior. Figure 5 is a schematic representation of the relative effectiveness of the WHP programs listed in table 3. The wide band indicates the degree to which verification techniques might enhance programs like education or incentives.

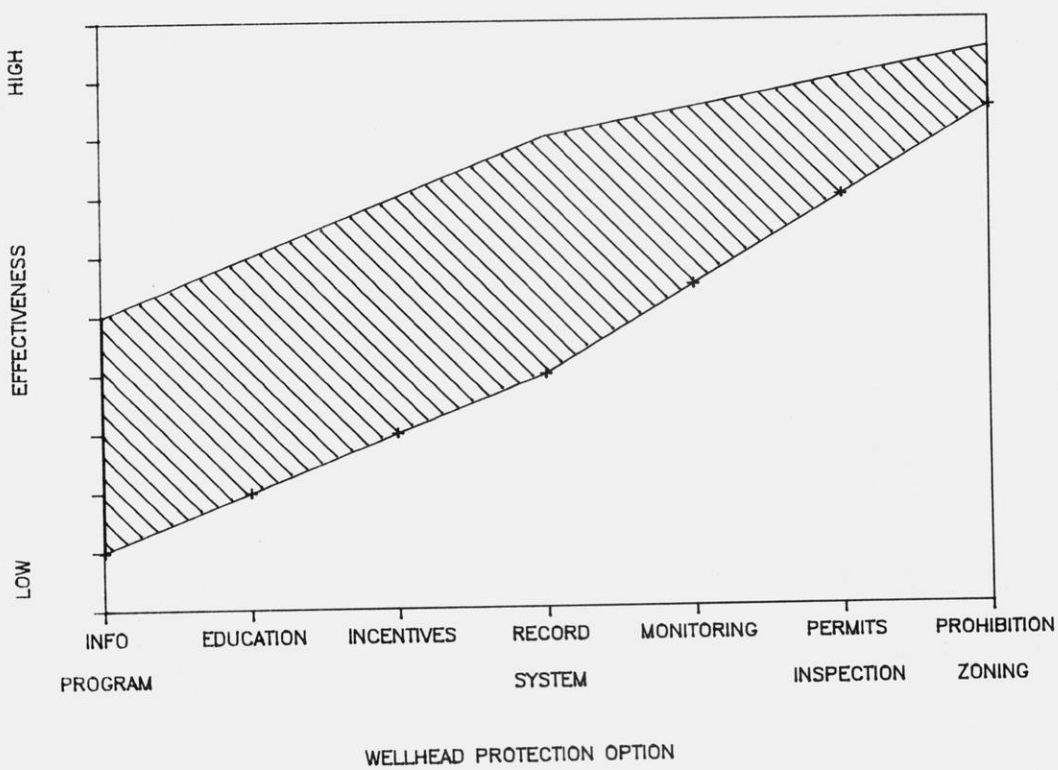


Figure 5. Hypothetical wellhead protection effectiveness rating.

Cost assessment for WHP programs is highly dependent on specific situations. To many citizens, the value of a WHP program may not become apparent until compared to the cost of remediating actual ground water contamination. A single underground storage tank leak may easily cost in excess of $100,000 for ground water studies and cleanup.

Determining the costs of WHP programs is problematic in a generic sense, but they can be reasonably estimated in any specific case. A worksheet approach can be taken (table 4). The case depicted in table 4 might be that of a small to mid-sized community with a single wellfield or zone of contribution.

The cost estimates can also be shown in graphical form (figure 6). Cases will likely arise where an effective, relatively low cost alternative is not adopted due to negative public opinion or hardships to certain segments of the community. Decisions related to effectiveness and costs should include consultation with specialists such as planners, attorneys, educators and hydrogeologists. Each community's WHP program ranking for effectiveness and costs will be somewhat unique, but a systematic approach will assist local officials and citizens in decision-making and supporting appropriate courses of action.

Table 4. Worksheet for wellhead protection program cost estimates.

WHP Program Ranking From Table 3	**Costs Per Year (in $)**		
Assumptions	**Operation**	**Capital**	**Total**
1. 0.25 person-year + 10%.	8,250		8,250
2. 0.5 person-year + 20%.	18,000		18,000
3. 8 well nests, 800 ft @ $25/ft; 16 samples quarterly @ $150 each.	3,840	20,000/10 yr	5,840
4. PC computer + database software 0.25 person-years + 10%.	8,250	4,500/5 yr	9,150
5. Estimate 12 tanks/yr @ $100 bonus each + 10% each.	2,840		2,840
6. Existing state/local specialists, materials, mail, phone, travel.	1,500		1,500
7. Printing, duplication, mailing.	300		300

Note: Capital costs amortized linearly over estimated life.

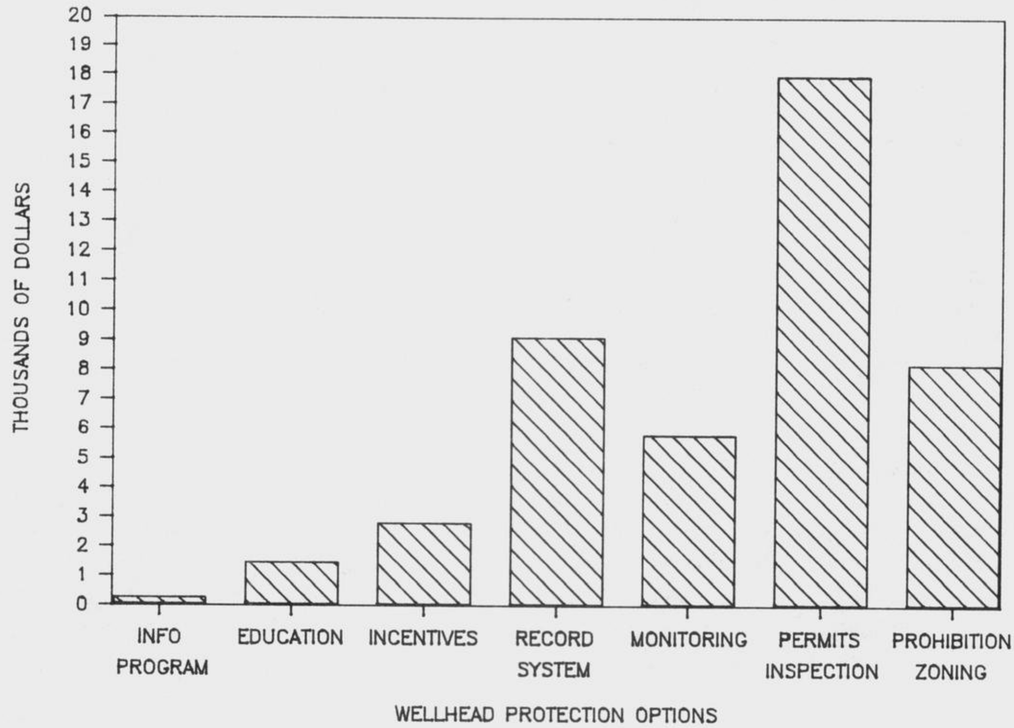


Figure 6. Estimated costs for wellhead protection program example.

CASE STUDIES

Methods

Format of studies

The general work plan for this report consisted of three main steps: delineation of the zones of contribution using hydrogeologic and well data, identification and mapping of potential contaminant sources within the study area and development of management strategy options to be used in the implementation of a wellhead protection program. Background on the hydrogeology of each study area and specific wellfield characteristics was obtained from consulting reports, published and unpublished literature and personal contacts with city and town officials.

Potential contaminant sources were identified using existing inventories from state agencies, consulting reports, unpublished information and maps from the municipalities involved, aerial photo slides, correspondence with key state and local officials and field checking. Mapping was initially done on mylar overlays using street maps and topographic maps as base maps, and then digitized. The potential contaminant source and site databases were originally created using dBASE III software and then later converted to R:BASE and combined with pcARC/INFO to enable further manipulation of the data.

Ideas for management strategy options came from federal and state publications on ground water and wellhead protection, ordinances from around the country related to wellhead protection, existing city and town zoning ordinances, discussions with city and town officials, university faculty and county staff and brainstorming.

In addition to the final report, an appendix has also been compiled in a separate volume. The appendix includes a summary of laws in Wisconsin that help to protect groundwater, ZOC calculations, potential contaminant site and source databases, additional maps and other pertinent information. Appendix material has been referenced individually in the text where appropriate.

Zone of contribution

Delineation of the zone of contribution was based on an integration of three approaches: 1) the uniform flow analytical model, 2) a balance of pumping rate with needed recharge area and 3) hydrogeologic boundaries. The best available well and hydrogeologic data were used to delineate the flow system to each well or wellfield. No new field hydrogeologic studies were conducted.

The uniform flow analytical model (Todd, 1980) assumes a homogeneous isotropic aquifer and estimates a zone of contribution based on steady state conditions. It was developed for confined aquifer conditions, but may be applied to unconfined aquifers as long as the drawdown is small relative to the aquifer thickness. Input into the equation includes hydraulic conductivity (K), aquifer thickness (b), hydraulic gradient (i) and design discharge rate (Q).

Hydraulic conductivity (K) is a measure of the permeability of an aquifer. It may vary several orders of magnitude within a small area due to changes in aquifer material. However, in the glacial outwash aquifers encountered in this study, uniformity was assumed and a single K value assigned to each aquifer.

Aquifer thickness (b) in the uniform flow model defines the saturated thickness contributing ground water to the well. In the Central Sands of Wisconsin the unconfined sand aquifer is underlain by granite or sandstone bedrock. Undulations in the bedrock surface cause variability in aquifer thickness.

Hydraulic gradient (i) is the change in head with a change in distance, measured perpendicular to the ground water contours. This was calculated from ground water contour maps for both study areas.

There were no guidelines found in the literature for the value of the pumping rate (Q) to be used in delineating a ZOC. Because wellhead protection is critical during extended periods of heavy pumping, a simple average pumping rate may not result in protecting a sufficient area at all times. The average pumping rate during the month of maximum withdrawals was judged to be a reasonable design basis. It represents a time period sufficient to permit a larger than normal cone of depression to form and, in many cases, become semi-stabilized.

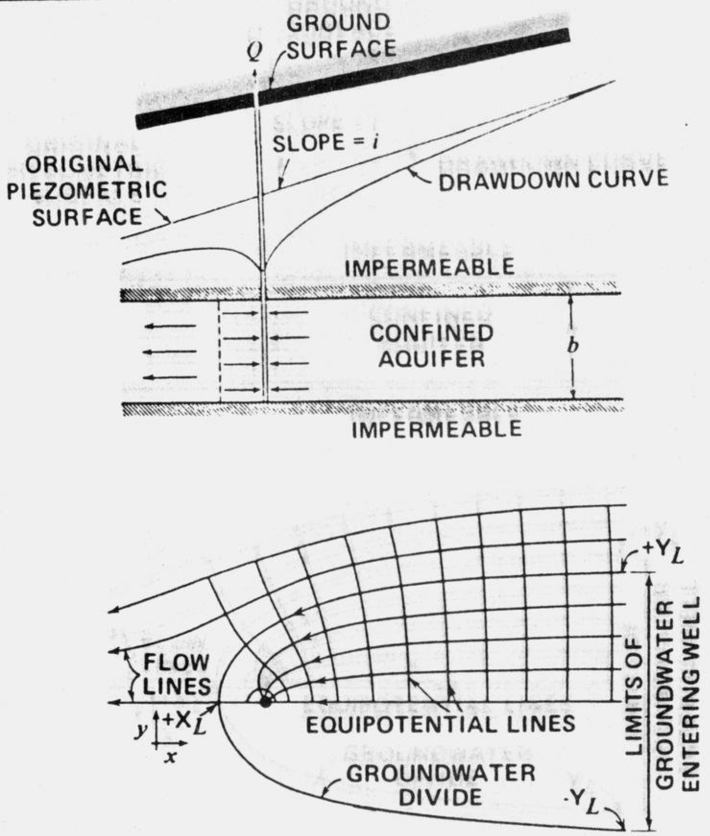
Future population growth and attendant pumping increases are another factor bearing on selection of the design discharge. The preventative nature of WHP strongly implies use of a design discharge based on future rates, if population and water use is growing.

Both the maximum monthly discharge and future projections were incorporated into the methodology to derive the design discharge. First, total or average monthly discharge rates were tabulated for the past 10 years or so. The average maximum monthly pumping rate was calculated along with the standard deviation and 90 percent confidence limits via the Student T-test. The maximum monthly rate was divided by the average annual rate for each year to obtain a maximum month to average annual ratio. The mean ratio and its standard deviation were then calculated. Next, the 90 percent confidence interval for the mean was calculated using the Student T-test. The 90 percent upper confidence limit of the mean was used as the monthly ratio factor.

Water demand forecasts had been made by consultants to the communities in previous studies for the year 2000 in Weston and 2005 in Wisconsin Rapids. The forecasts in both cases gave an estimate of the average annual demand rate. The forecasted mean annual rate was scaled upward by the 90 percent upper confidence limit for the historic mean previously calculated. The design discharge was then calculated by multiplying the scaled-up forecasted mean rate by the monthly ratio factor.

The uniform flow model consists of three equations (figure 7). The first calculates the maximum downgradient distance from which water is drawn into the well (downgradient null point). This distance separates water that will be extracted by the well from that which will continue to flow downgradient. The second equation estimates the width of the ZOC in both directions perpendicular to the flow path center at its greatest distance, theoretically infinity. This maximum width and the downgradient null point distance are then used in a third equation to determine the distance from the well at which the ZOC has an arbitrarily specified width less than Y_L.

The calculated ZOC at each well was custom fit according to the local ground water hydrology. The uniform flow model was applied incrementally in one or more uniform portions of the aquifer, based on variation in flow direction, hydraulic gradient and aquifer depth. The ZOC was measured in both directions perpendicular



Uniform Flow Equation

$X = - Y/\tan(Y/-X_L)$

Distance To Downgradient Null Point

$X_L = - Q/2K(\pi)bi$

Boundary Limit

$Y_L = \pm Q/2Kbi$

Where:

X_L = downgradient null point (ft)
Q = daily pumping rate (ft^3/day)
K = hydraulic conductivity (ft/day)
b = aquifer thickness (ft)
i = hydraulic gradient
Y_L = maximum width of the zone of contribution measured from the flow path center
X = distance from the well at which the zone of contribution width is + or - Y
Y = a specified distance less than Y_L
π = 3.1416

LEGEND

• pumping well

Figure 7. Illustration of the uniform flow equation. (Source: modified from Todd, 1980.)

to a curvilinear flow path which led directly to the well. Plotting of each ZOC was a graphical integration of the various sub-model outputs in order to best represent the zone as a function of the changes in aquifer characteristics along the flow path upgradient from the well.

A balance of pumping rate with needed recharge area was one means by which to evaluate the plotted ZOC. An average recharge rate of 10 inches/year was reported in the literature review for the sandy soils of the Wisconsin Rapids and Weston aquifer recharge areas (Holt, 1965; Karnauskas, 1977; Kendy and Bradbury, 1988). An 8 inches/year rate represents a more conservative estimate. Both were included in the calculations for comparison. The pumping rates for each community are discussed in the Case Studies Zone of Contribution sections for each study area.

A ZOC must extend over a large enough area to accept recharge that will balance the annual discharge from the well. Reconsideration of the ZOC boundaries may be needed if the recharge area is inadequate. At the Wisconsin Rapids study site the delineated ZOC provided adequate recharge area. At the town of Weston site the small, relatively isolated aquifer suggested a need for additional influx, possibly from the river during heavy pumpage and/or runoff from surrounding shallow bedrock areas to the aquifer.

Two main hydrogeologic boundaries were encountered in the delineation of the ZOCs. At Wisconsin Rapids the presence of a ground water divide provided a no-flow boundary along the northern extent of the ZOC. Mapping of the divide was based on water table and contour maps (Karnauskas, 1977; Lippelt, 1981). At Weston, the river valley aquifer is flanked by a bedrock valley wall, creating a narrow outwash aquifer approximately 1.5 miles wide in the vicinity of the Sternberg and Mesker wells. The ZOC no-flow boundaries led to the bedrock valley walls where the sand and gravel aquifer was truncated. The upgradient surface watershed in the bedrock region tributary to the unconsolidated aquifer ZOC was included in the final map of the ZOC for the wellfield.

Since the Weston wellfield discharge was not balanced by recharge rates of 8 to 10 inches over the unconsolidated aquifer portion of the ZOC plus estimated runoff rates of 9 to 11 inches from the bedrock portion, an adjusted ZOC was also drawn which extended the boundaries to the Eau Claire River (Devaul and Green, 1971). The Eau Claire River is the closest hydrogeologic boundary capable of supplying a source of water needed to balance the design discharge rate. Use of the adjusted ZOC for wellhead protection planning can be justified as a reasonable first approach unless future hydrogeologic studies suggest otherwise.

Time of travel calculations

Within the ZOC, various time of travel (TOT) zones were calculated which show the distance from the well to lines from which ground water and contaminants take an average of a certain number of years to travel. Time of travel calculations are based on aquifer values for hydraulic conductivity (K), hydraulic gradient (i) and effective porosity (n). The average distance (D) a contaminant would move, due to advection alone, can be calculated by the formula: $D = Kit/n$ where the time (t) is expressed in units that are consistent with K.

Various time of travel criteria can be used in wellhead protection to allow for early warning of contamination, time-dependent degradation of pollutants, dilution of contaminants or as reasonable setback distances for various contaminant sources.

The breakdown rates of many bacteria, viruses and organic contaminants may be estimated from research studies and are usually expressed in half-lives. Knowing the average velocity of ground water, it is then possible to determine the separating distance required for a specified average concentration limit to be met in the aquifer. It is crucial to note, however, that intermediate breakdown products of some organic contaminants are as toxic or more toxic than parent compounds. If known, the intermediate half-lives should be used in time of travel calculations. There is considerable uncertainty surrounding the values of parameters used in the time of travel calculations. These are due to both actual variations of parameter values from place to place and over various depths (heterogeneities) and errors in measurement of the values in the field. Typically, large aquifer areas are assumed to be homogeneous due to a lack of detailed data.

Because of these uncertainties, a probabilistic approach was used in this study to calculate average travel distances for a given number of years. The steps followed in calculating time of travel lines are outlined in Appendix 4. A simulation was done in which many calculations were made using a random variable approach instead of a single average calculation. Each of the three variables K, i and n, in the calculation, was assumed to have a statistical distribution. Hydraulic conductivity (K) was assumed to be log-normally distributed while porosity (n) and hydraulic gradient (i) were assumed to be normally distributed. The log-mean and standard deviation for hydraulic conductivity were calculated using the formulas described by Naylor et al., 1965. Sources of data came from consulting reports containing field data from the two sites. Standard deviations for porosity and hydraulic gradient were assumed to be one-fourth the total range of observed values. Over 100 simulations were run for each well and the results displayed in cumulative frequency graphs in the Case Studies Assessment of Potential Contaminant Sources sections for each study area.

The graphs indicate that a wide range of travel distances for any given time is possible given the likely range of the values for K, i and n. The 50 percentile distance is usually close to that calculated by using single average values in the average linear velocity equation. The graphical results allow selection of a percentile which might be judged to include an appropriate margin of safety. In this study, the authors chose the 70 percentile distance as the value for maps and management options.

Inventory of potential contaminant sources

Potential contaminant sources were identified for each study area using existing state inventories and other available resources to identify, quantify and assess sources that may affect ground water quality. This information aided in the development of management strategy options by indicating which potential sources were of most concern.

All point sources for which information was found were mapped on mylar overlays using street maps (1:1,000) and topographic maps (1:24,000) as base maps. Some inventory sources only provided addresses, not legal descriptions, making locating sites an often tedious process. Almost all point sources in the ZOCs have been field checked. Because non-point sources such as agriculture and residential areas are difficult to map as point locations, land use maps were developed for each study area. These maps were based on Agricultural Stabilization and Conservation Service (ASCS) aerial photo slides and U.S.G.S. topographic maps. The aerial photos used for

Weston were from 1987 and from 1988 for Wisconsin Rapids.

Although data collection and mapping was done to the most thorough extent possible, the point source inventory is not 100 percent accurate because the information available was not complete. Existing state inventory lists may have incorrect data and may not be up to date. There are also potential sources which have never been inventoried and therefore there is no record of their existence. Field checking was also limited. Address locations of sources were verified in the field for mapping purposes but the sources themselves were not checked. A list of potential contaminant sources investigated in this study is given in table 5. Potential sources with locational data are those sources which were able to be mapped; those without locational data could not be mapped because information was not available.

Underground storage tank locations were mapped DILHR's Report of Underground Storage Tanks, June 1989. Tank material, capacity, age, contents, owner, type of use (residential, commercial, industrial) and status of tank (abandoned, in use) are also included in the inventory. Because the list was six months behind in the updating process, some information such as tank removals was out of date.

Businesses were mapped using several sources - telephone directories, the Grand Rapids business directory obtained from the Grand Rapids Planning and Zoning Department, Weston Hazardous Waste Survey (DNR, 1987), List of Wisconsin Facilities Having U.S. EPA Hazardous Waste I.D. Numbers (U.S. EPA, 1989), businesses listed on

Table 5. Potential contaminant sources.

With locational data	Without locational data
Point sources	
1. Underground storage tanks	1. Hazardous materials
2. Commercial establishments	2. Animal feedlots
3. Landfills	3. Livestock waste storage
4. Salvage yards	4. On farm fertilizer and pesticide storage
5. Spills	5. Above ground storage tanks
6. Regulated hazardous wastes	6. Abandoned and improperly constructed wells
7. Deicing salt piling	7. Class V injection wells
8. Fertilizer and pesticide storage at distributor sites	
Non-point sources	
1. Storm and sanitary sewers	1. Sludge and wastewater spreading
2. Irrigation	2. Road salting
3. Transmission pipelines	3. Livestock waste spreading
4. Hazardous materials transport by truck or rail	4. Fertilizer application
	5. Pesticide application

DILHR's tank inventory list and field checking. Businesses were mapped in order to identify potential or known hazardous waste generators and places of hazardous materials storage. No material safety data sheets (MSDS) and emergency and hazardous chemical inventory forms required under sections 311 and 312 of the Emergency Planning and Community Right-To-Know Act of 1986 have been submitted for the town of Grand Rapids. These forms were not obtained for the Weston area.

Landfills were located using the April 1988 updated list of Active and Abandoned Landfills of Wisconsin, obtained from the DNR's Bureau of Solid and Hazardous Waste. Salvage yards were located using the DNR's last Active Salvage Yards List, dated 1982. Although this list is outdated, it was the only list available since DNR's authority to license salvage yards was removed by the Wisconsin Legislature in May 1981.

Spills were mapped using the DNR's List of the North Central District Spill, LUST and Groundwater Contamination Cases (June 1989). Address, legal description and the type and quantity of substance spilled is given. A description on the background of each spill and remedial actions taken is also given.

Road salt piling locations were found through correspondence with local officials. It was also found through phone correspondence that no bulk fertilizer and pesticide storage sites are located in the study areas (Hyer, pers. comm., 1989). DNR has a list of approved sludge spreading sites (DNR, 1989). One site was found in the study areas - Alexander Field in Grand Rapids where municipal sludge is spread.

Many potential contaminant sources were not able to be mapped because information was unavailable. There are no inventories available for above ground storage tanks, hazardous materials transported by truck or rail, wastewater spreading sites, private wastewater systems, road salting, animal feedlots, livestock waste storage and spreading sites, fertilizer and pesticide application sites, class V injection wells and abandoned and improperly constructed wells. The above ground tanks which were inventoried were found while in the field. Although no inventory is available for private wastewater systems, a housing density map of the town of Grand Rapids may be used to indirectly estimate the number of septic systems. No housing density map was available for the town of Weston.

Data management and digitization

The inventory of potential contaminant sources was computerized using dBASEIII database management software. The large volume of compiled data and availability of computer software made computerization the most practical method of data manipulation. It is important to note that computerization of the database is not necessarily the only method of data manipulation. This is especially true for a management area with fewer potential contaminant sites. A simple record system may be adequate in such a case.

Site and source databases of potential point sources of contamination were developed for each study area. Source types listed include underground and above ground storage tanks, commercial users/generators of hazardous materials, spills and landfills.

The site database contains general information on sites, each of which may have one or more potential contaminant sources. Site information includes owner's name, site address and legal description, distance to the nearest well and name of well, whether the site is in the ZOC, whether the site is on sewer, land surface and water table elevations and static water level depth. The source database contains specific information for each potential contaminant source identified. Such information includes source type, underground storage tank characteristics, soil pollutant attenuation potential and quantities of contaminants released and remedial actions taken in spill incidents.

Each entry in the source database is related to one entry in the site database by a field containing a unique site identification number. In this way locational information is not repeated unnecessarily for multiple sources at the same site. Corrections or changes of site information can also be made more easily. Information in the databases was compiled using available inventorys and resources described previously.

A third database was developed which relates to the source databases of each study area (Appendix 6). It lists general categories of commercial establishments found in the communities and their potential for using or generating hazardous materials (ranked either medium or high). The categories are arranged in alphabetical order and are numbered accordingly. The source and business category databases are related through this numbering system. Six different contaminant types are itemized in the source database and contain a true or false presence indicator for each category. Each business type has been defined as to which of these six contaminant types may or may not be used or generated by the business. For example, vehicle service and auto body shops are categorized as vehicle maintenance services and are ranked as high potential users/generators of hazardous materials. Potential contaminant types are volatile and non-volatile organic compounds, total dissolved solids, trace elements and acids, bases or oxidants.

The purpose of this database of business types is to provide a means of ranking businesses found in the study areas. It was designed to complement the site and source databases and is not a complete inventory. Information was compiled using an EPA publication describing businesses and the types of hazardous materials they use or produce (U.S. EPA, 1985) and through consultation with a groundwater specialist (A. Wilson, pers. comm., August 28, 1989).

The site and source databases can be queried to provide information on various contaminant source types and contamination potentials relative to management needs. For example, the databases can be used to determine the number of underground storage tanks within 1000 feet of a particular well that are constructed out of bare steel and have an age of installation greater than 10 years. Such information can help in deciding which wellhead protection management options are most needed.

With the assistance of the Wisconsin Geological and Natural History Survey (WGNHS), pcARC/INFO geographic information system (GIS) software was used with the wellhead protection study. A geographic information system is a method of using computer hardware and software to store, manipulate, retrieve and analyze information about the distribution of spatial information or characteristics. Road networks derived from 1:100,000 scale digital line graph (DLG) files obtained from the Wisconsin Department of Transportation (DOT) were used as a base layer in the GIS. Potential contaminant site locations, well locations, zones of contribution, time of travel lines, sanitary and storm sewer boundaries, land uses, zoning, water table contours and depth to water table contours are examples of other data layers digitized in the GIS.

Spatial analysis tools in pcARC/INFO were used to compute infomation to complete the site and source databases. Locations of wells and potential contaminant sites were recorded in the state plane coordinate system and the distances from sites to the wells were determined. Within the GIS, the potential contaminant sites were overlaid with sewer service boundaries, ZOC boundaries and the soil contaminant attenuation potential maps to determine which sites are serviced by sewer, which are within the ZOC and the contaminant attenuation potential of soils underlying the sites. These data were then fed back into the dBASEIII source and site databases. GIS data layers were also combined to determine the acreages and percentages of different land uses and sewer service areas in the study areas and in the ZOCs. These analyses facilitate the identification of problem areas and management options. The mapping and presentation tools in pcARC/INFO were used to graphically display the information.

Literature available on wellhead protection

Wellhead protection management options were developed primarily through review of related literature and discussion of ideas among the authors, University of Wisconsin faculty and community members from the town of Weston, city of Wisconsin Rapids and town of Grand Rapids.

In order to develop feasible options it was necessary to understand what state, county, and local laws and regulations already exist or may be implemented. Wisconsin Statutes, Wisconsin Administrative Codes, and county, city and town zoning ordinances were reviewed. Three publications which offer good descriptions of present state laws are "Groundwater Protection Through Local Land Use Controls" (Yanggen and Webendorfer, in prep.), "Wisconsin's Groundwater Management Plan Report No. 6 - Assessment of Groundwater Management Programs in Wisconsin" (Lohr, 1988) and the Wisconsin Geological and Natural History Survey publication "A Guide to Groundwater Quality Planning and Management for Local Governments" (Born et al., 1987).

Two excellent references which outline wellhead protection management options for local governments and were of great assistance are "Wellhead Protection Programs: Tools for Local Governments" (U.S. EPA, 1989) and "A Guide to Groundwater Quality Planning and Management for Local Governments".

Specific references describing where ground water protection or wellhead protection has been recommended or implemented in the state of Wisconsin include "Groundwater Protection Principles and Alternatives for Rock County, Wisconsin" (Zaporozec, ed., 1985), "Marathon County Groundwater Plan" (Marathon Co., 1988), "Portage County Groundwater Management Plan", volumes I and II (Portage Co., 1987), "Wellhead-Protection Districts in Wisconsin: An Analysis and Test Application" (Born et al., 1988) and the Rib Mountain Municipal Well Recharge Area Overlay District (Rib Mountain Sanitary District, 1985). Out of state references describing the application of ground water and wellhead protection are listed in the references.

Summary of WHPA management options

The zone of contribution is a physically defined boundary based upon known hydrogeologic information. While it defines the recharge area for a well or wellfield, the ZOC may need adjustment for management purposes. For example, the

ZOC boundary may cross roads, property lines or civil boundaries at inconvenient points. The size of the area may also depend on the characteristics of potential sources and management techniques used. The adjusted management zone, called the wellhead protection area (WHPA), takes these factors into consideration.

The Rib Mountain Municipal Well Recharge Area Overlay District is an example of how a ZOC can be translated into wellhead protection area management districts (Rib Mountain Sanitary District, 1985). Two management zones covering the recharge area are defined. Zone A, the zone closest to the wellfield, encompasses the land area most likely to transmit ground water contaminants to the municipal wells. Due to its sensitive nature, this zone has more land use restrictions than Zone B. Thirty-four land uses, including landfills, underground petroleum storage tanks and several types of manufacturing or processing plants are prohibited. Zone B is defined as an area where contaminants are less likely to reach the municipal wellfield. Within this zone, only underground tanks are prohibited. In both zones, existing sources remain as nonconforming uses.

In this report ZOCs have been defined for both communities. The delineation of wellhead protection areas is the next step to be completed by the municipalities. A management plan can then be decided upon and implemented. Wellhead protection area management options have been developed for each community and are described in detail in the Case Studies.

Options were developed for eight potential contaminant sources (table 6). Several areawide techniques are also discussed. The options for each source are divided into three categories - educational, administrative and regulatory. Both the educational and administrative options are non-regulatory.

Table 6. Summary of management options for potential contaminant sources in both study areas.

Potential Sources	Number of Options Presented: Educational	Administrative	Regulatory	Total
USTs[1]	2	3	2	7
Commercial2	2	2	4	8
Spills	0	3	2	5
Landfills	0	2	0	2
Salvage yards	0	1	2	3
Deicing salts	0	2	0	2
Residential areas	1	2	4	7
Agricultural areas	1	5	0	6
Areawide techniques	1	4	1	6
Total	7	24	15	46

[1] Underground storage tanks
[2] Commercial users/generators of hazardous materials

Town of Weston

Water supply situation

The town of Weston (figure 8) is a high growth-rate community in the Wausau, Wisconsin metropolitan area. Neighboring cities and villages are currently hemmed in by physical or political boundaries. The recent lifting of a sewer extension moratorium has accelerated residential and commercial development in the town.

The Weston Water Utility supplies water to the primary service area of the town from three wells. A fourth well serves an isolated corner of the township. The original primary service area well, the Alta-Verde well, was constructed in 1963. The Mesker and Sternberg wells, constructed in 1983 and 1984, are higher capacity wells designed to meet the needs of the growing community. The Mesker and Sternberg wells are located 1,600 feet apart about two miles east of the Alta-Verde well. These two wells are the subject of this WHP study.

Both the Mesker and Sternberg wells were tested for volatile organic chemicals by the DNR when they were constructed. No compounds exceeded the limits of detection at that time. The two wells are located in an area surrounded by light industrial and commercial development.

VOCs were first discovered in the Sternberg well during July and August 1985, in response to taste and odor complaints from utility customers. The town initiated testing of the municipal wells to identify the source of the problem. Benzene, toluene, m-xylene, o&p xylene and ethylbenzene were identified in the Sternberg well (DNR, 1986). Concentrations of VOCs exceeded the health advisory limits and the Sternberg well was removed from service in August 1985.

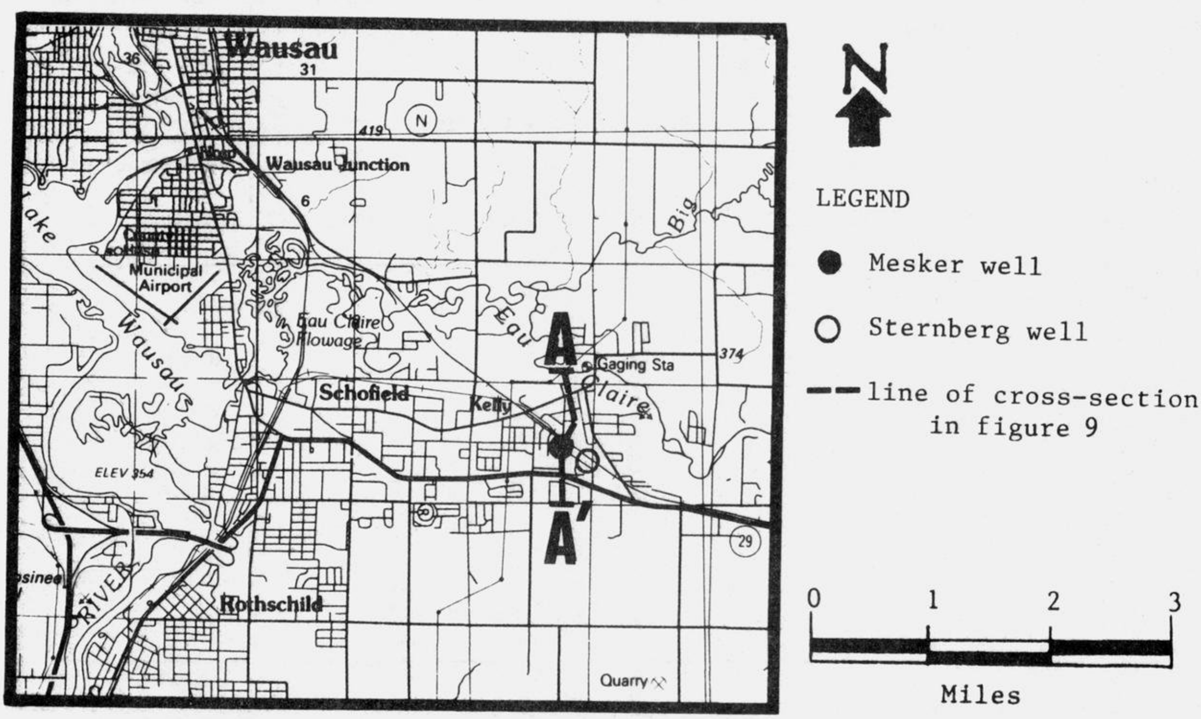


Figure 8. Location map showing the town of Weston study area. (Map source: U.S.G.S., 1984.)

In the same month, a water sample from the Mesker well indicated that perchloroethylene (PCE) was present slightly above the detection limit of 1 ppb (STS, 1988). Subsequent sampling showed evidence of an increasing trend of PCE, which reached 38 ppb in January 1986. The health advisory level is 20 ppb and the well was shut down at that time. Appendix 7.1. is a map of known spill plumes in the study area.

The Mesker and Sternberg wells were designed to operate on 12 hour cycles. Since 1985, when VOCs were discovered in both these wells, the Sternberg well has not been used at all for public consumption. Mesker well water is now treated at a VOC air stripping facility after which it is blended with water from the Alta Verde well in a community water tower.

Several ground water contaminant extraction wells are also operating within the Weston wellfield. Two extraction wells have been operating to remove a gasoline plume which contaminated the Sternberg well. These two are pumped at rates of 60 and 150 gallons per minute (gpm) and run through a small air stripping tower prior to being discharged to a storm sewer which empties into the Eau Claire River. A third extraction well was under construction in September 1989 and is expected to be pumped at 200 gpm for withdrawal of PCE contaminated ground water.

Since 1980, total water pumped by the Weston Water Utility has ranged from about 192 million gallons per year (mgy) in 1982 to 307 mgy in 1988. The maximum daily pumping rate occurred during 1988 and was 1.69 million gallons per day (mgd).

Hydrogeologic description of area

The town of Weston is situated near the southern edge of the exposed Precambrian Shield in north central Wisconsin. The Precambrian in this area is composed of Early Proterozoic metavolcanic and granitic rock which was intruded by Middle Proterozoic syenite and other granitic rock (LaBerge and Myers, 1983). Much of the hilly topography of the area, including Rib Mountain near Wausau, is formed from these rocks. The Wisconsin River runs along the eastern margin of the intruded rock bodies, and along with other tributaries such as the Eau Claire River, may occupy valleys associated with Precambrian fault zones (Kendy and Bradbury, 1988). A clayey residuum called grus, weathered from the granitic rock, usually overlies surficial bedrock and sometimes underlies the sand and gravel aquifers in the river valleys. The bedrock and grus are much less permeable than the sand and gravel and are considered to be the lower boundary of the unconsolidated aquifer.

Melting of the last continental ice sheet which halted just north and east of the Weston area caused huge amounts of sand and gravel and igneous and metamorphic cobbles to be deposited in the Wisconsin and Eau Claire River valleys. These deposits have collectively been called the Wausau Aquifer by Kendy and Bradbury (1988). Ground water from this aquifer supplies the municipal wells for the town of Weston. It is the only aquifer in the region capable of supplying large quantities of water.

The thickness of the sand and gravel deposits varies considerably, with depths exceeding 100 feet in certain areas. The thickness is controlled by the contour of the underlying bedrock, which is quite variable. In the Eau Claire River Valley of the town of Weston, well constructor's reports indicate that the Mesker and Sternberg wells penetrate 92 and 83 feet of sand and gravel, respectively, and terminate just above the bedrock in a buried bedrock valley. Figure 9 is a

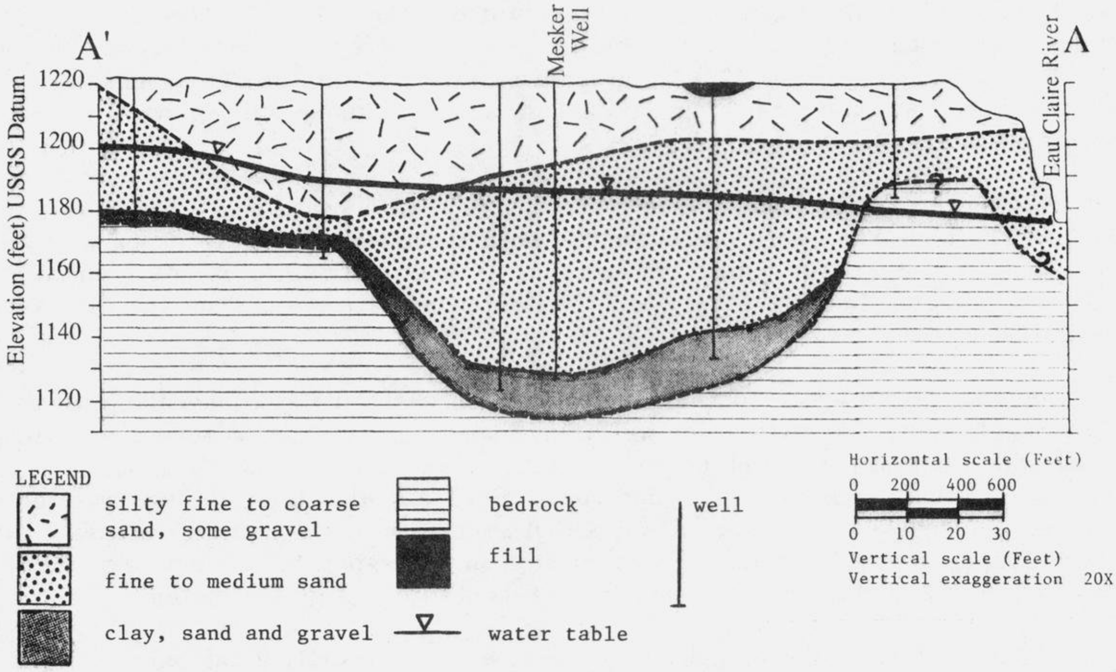


Figure 9. Hydrogeologic cross-section through the Weston main wellfield. (Source: modified from STS Consultants, Ltd., 1988.)

hydrogeologic cross-section through the wellfield area. The average saturated thickness of the aquifer in the wellfield vicinity was estimated to be 40 feet.

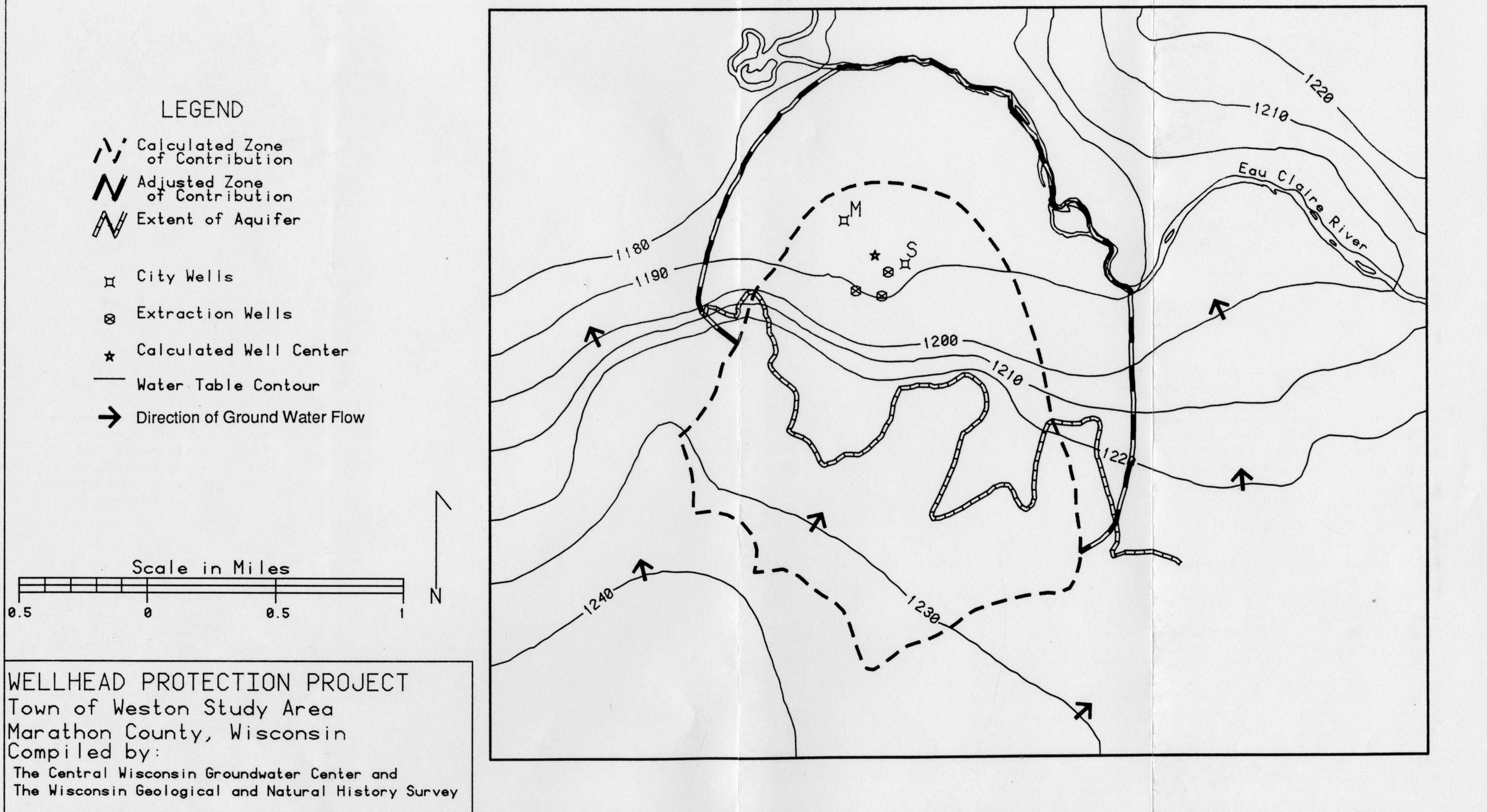
The majority of ground water recharge to the shallow sand and gravel aquifer originates locally as a result of precipitation and infiltration of surface runoff along the margins of the valley. Ground water occurring in the shallow sand and gravel deposits generally moves toward the Eau Claire River, where it discharges as base flow. Annual or seasonal changes in precipitation and river levels can cause fluctuations in ground water levels and gradients. Figure 10 is a water table elevation map of the study area.

Zone of contribution

The town of Weston's maximum monthly pumpage occurred in May of 1985 when 39,676,000 gallons were pumped, averaging 1.28 mgd. The town and its consultants estimated that design pumping rates would increase about 20 percent by the year 2000 (Grutzik, pers. comm., 1989). In addition to municipal pumpage, three extraction wells for contaminant plume cleanup will discharge an estimated 410 gpm from the wellfield. The additional extraction well withdrawals are more than twice as large as the 10 year projected increased pumping rate. For this reason the historically high monthly rate plus the extraction well discharge was used as the design rate. A total pumping rate of 1,300 gpm (1.87 mgd) was assigned to a hypothetical well located centrally between the two municipal wells and the extraction wells for the model calculations. Calculation of the design discharge rate for the Sternberg and Mesker wells and three extraction wells is shown in Appendix 7.e.

The horizontal hydraulic conductivity (K) in the Weston recharge area was es-

Figure 10. Water table elevation map of the Weston study area.



timated to be 345 ft/day by the geometric mean of several available sources of data (Markart, pers. comm., 1989; Giraud, pers. comm., 1989; Kendy and Bradbury, 1988; STS, 1988). The Weston wells are placed within a local depression of the bedrock underlying the river valley, with approximately 50 to 60 feet of saturated sand and gravel. Aquifer thickness decreases farther from the well. Based on several maps (Kendy and Bradbury, 1988; STS, 1988; Donohue, 1986), an average aquifer thickness of 40 feet was used in the uniform flow model for this site.

Hydraulic head and gradient data was integrated from a combination of general maps and site specific consulting reports (Lippelt, 1981; STS, 1988). Because of the small aquifer and relatively short flow paths encountered at the Weston site, a single hydraulic gradient value of 0.002 was used.

The zone of contribution was delineated and plotted (figure 11). Uniform flow equation calculations are shown in Appendix 7.d. The five year travel distance probability graph is shown in figure 12. The five year time of travel was not mapped for Weston because at the distance of the 70 percentile most of the alluvial aquifer in the ZOC was already included.

Eight to ten inches of recharge per year over the calculated ZOC was insufficient to balance the total annual pumping by the town (Appendix 7.f.). The small ZOC indicated the need for additional recharge from greater recharge rates, more movement of water from the outwash aquifer upgradient of the Weston wells or infiltration of water from the river into the aquifer during times of high pumpage or low water table. A combination of these factors most likely contributes the rest of the recharge. In consideration of these conditions, a larger adjusted ZOC was drawn which theoretically allows for a balance between the design discharge and recharge sources (figure 11). The adjusted area extends the calculated ZOC so that it reaches the Eau Claire River.

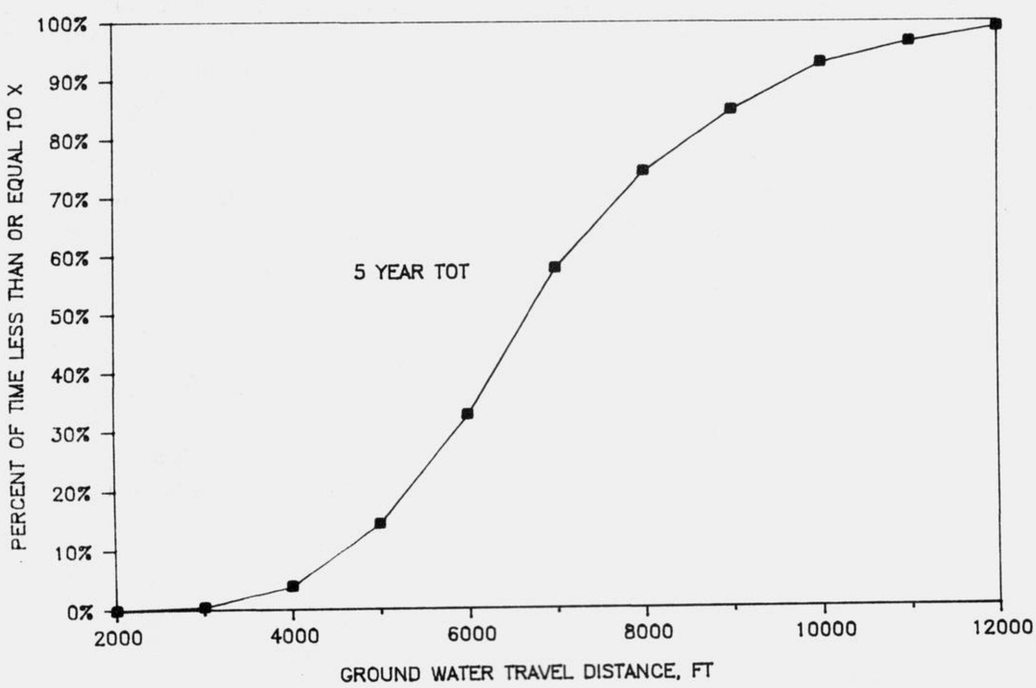


Figure 12. Five year time of travel for the Weston main wellfield.

Assessment of potential contaminant sources

Point sources such as underground storage tanks (USTs) and spills of hazardous materials have resulted in extensive contamination of ground water supplies serving the town of Weston. The sites of potential ground water contamination in the site database inventory (Appendix 7.a.) are mapped (figure 13). The Weston source database may be found in Appendix 7.b. Underground storage tanks and commercial users/generators of hazardous materials present the greatest threat to ground water quality. There have been 16 reported spills in the study area.

Potential point sources of contamination are mapped at 30 locations in the ZOC for the Mesker and Sternberg wellfield. Some locations have more than one potential source of contamination, such as multiple underground tanks or a tank plus on-site hazardous materials. Of the 71 potential contaminant sources in the calculated ZOC, 41 are underground storage tanks and 18 are commercial establishments likely to use hazardous materials or generate hazardous wastes (table 7). Five above ground storage tanks were discovered incidentally while field checking. While they are included in the database, they are not included in this discussion because a comprehensive inventory indicative of the actual number of above ground tanks in the study area was not completed.

Most of the potential point sources are underground fuel storage tanks containing leaded, unleaded or diesel fuels, or home heating oil. The tank inventory by DILHR contained some information on tank characteristics such as size, fuel type, tank material and age. The age and material of a tank offer some indication of its susceptibility to leakage. Of the 103 underground tanks in the entire Weston study area, 17 are bare steel and 48 are greater than 20 years old or are of unknown age. These types of tanks are at a high risk of leaking and should be checked as part of a wellhead protection program. More typically, tanks in the Weston area are made of coated steel and are 1 to 20 years old. Only one tank in the inventory was cathodically protected to prevent corrosion. All tanks in the ZOC should probably be of concern due to the relatively high rate of failure of tanks or piping. The ability of some of the soils in the study area to attenuate contaminants is low based on the soil contaminant attenuation potential map for the Weston study area (Appendix 7.n.) and is also a factor to be considered.

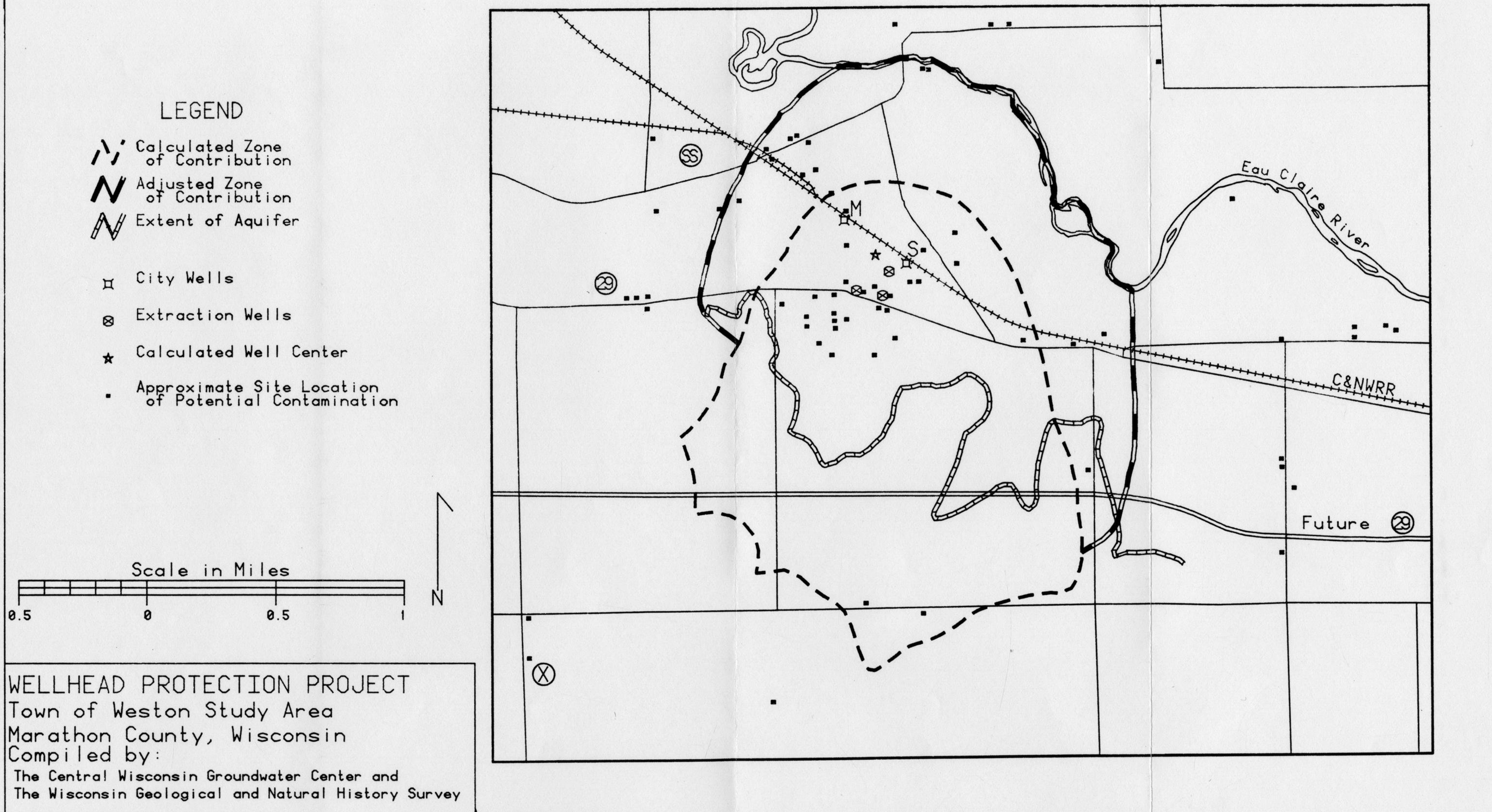
All but two of the 71 point sources in the calculated ZOC are located in the alluvial sand and gravel aquifer which serves the municipal wells. Figure 14 indicates that over 30 point sources are within the five year time of travel of the

Table 7. Potential point sources in the town of Weston study area.

Point Sources	**Total Inventory**	**Total In Calculated ZOC**	**Total In Adjusted ZOC**
USTs	103	41	62
Commercial	26	18	22
Landfills	1	1	0
Spills	16	11	13
Total	146	71	97

Figure 11. Weston zone of contribution.

Figure 13. Potential contaminant sites in the Weston study area.



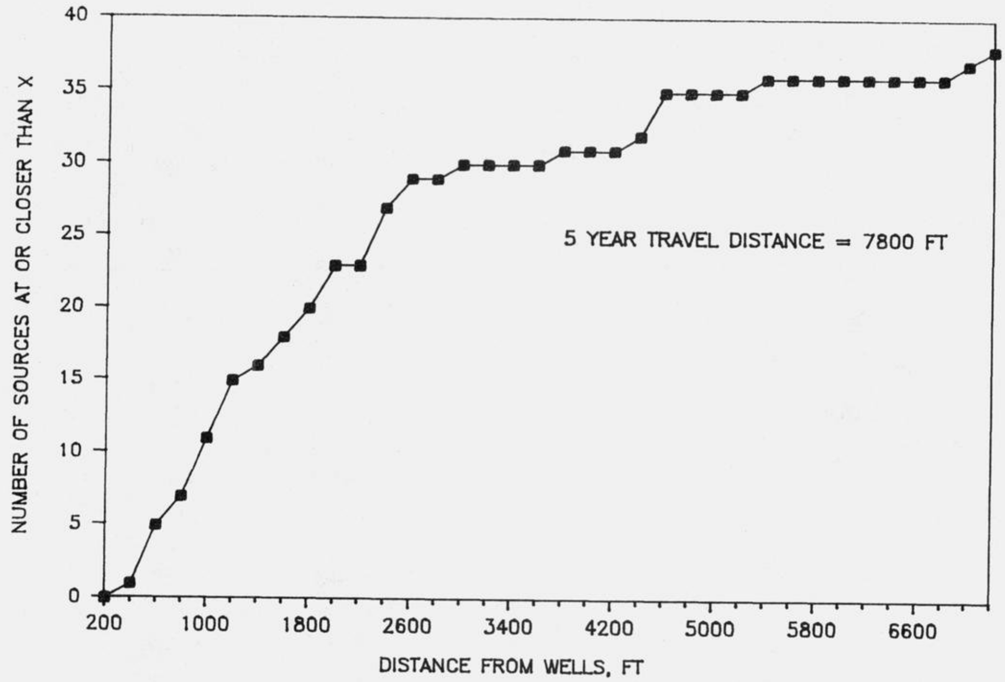


Figure 14. Distance of sources to the Weston wells.

municipal wells. This analysis indicates that the town of Weston faces a challenging job in controlling the numerous potential point sources already in the ZOC. There are possibly other unknown point sources such as forgotten tanks and old spills which may also threaten future water quality.

Non-point sources of ground water contamination include such chemicals as pesticides, nitrate from fertilizer and septic systems and chloride from road salt. Overall, non-point sources are not considered to constitute a major threat to ground water quality in the ZOC. Non-point sources are best depicted with the land use map (figure 15). Superposition of the ZOC on this map shows that most of the ZOC close to the municipal wells is in commercial and residential uses. Table 8 lists the land use types in the ZOC in percent total area and in acres. As of September 1989 approximately 45 percent of the commercial and residential area in the calculated ZOC was on municipal sewer and water service. This is a rough estimate calculated from the Weston storm and sanitary sewer map (Appendix 7.k.). Lawn fertilizers and pesticides still remain potential sources of nitrate and pesticide contamination in sewered areas. Available data on nitrate concentrations in private wells in the wellfield vicinity do not indicate a significant nitrate problem (Marathon Co. Health Dept., 1989).

Mostly agricultural and forest lands are found on the outer extent of the ZOC. A significant block of forest land east of the Sternberg well along the Eau Claire River undoubtedly has a very beneficial effect by contributing a local source of good quality recharge water to the aquifer. Preservation and enhancement of this area will benefit water quality and WHP efforts. The agricultural land in the ZOC is primarily in dairy production and located on heavier silt loam soils. These soils are derived from granitic bedrock south of the alluvial aquifer which supplies the

Table 8. Areas of land use types in the Weston study area and calculated zone of contribution in acres and percent total area.

	Area of Each Land Use			
	Entire Study Area		Calculated ZOC	
Land Use Type	Acres	Percent (%)	Acres	Percent (%)
Agriculture	1673.2	24.4	459.3	23.9
Forest	2858.5	41.8	710.1	37.0
Grassland/Brush/ Undeveloped Space	648.0	9.5	104.5	5.4
Lake/River/Stream	71.0	1.0	13.7	0.7
Residential	1089.3	15.9	308.5	16.1
Commercial	354.5	5.2	274.7	14.3
Public Facility	26.8	0.4	0.0	0.0
Trailer Court	112.3	1.6	34.8	1.8
Landfill	13.4	0.2	13.4	0.7
Total	6847.0	100.0	1919.0	100.0

municipal wells. None of the agricultural land is under irrigation.

WHPA management options for Weston

The ZOC physically defines the recharge area of a well or wellfield. For management purposes, the ZOC is adjusted to accommodate for roads, property lines, civil boundaries and characteristics of potential sources. This adjusted ZOC is called a wellhead protection area (WHPA) and is defined by those implementing WHP management plans. The WHPA can include all or parts of the ZOC and one or more WHPAs can be defined.

Options are presented rather than recommendations so the town can design its own management plan based upon the potential contaminant source assessment and views of local officials and community members. Options also illustrate the range of management levels available. Both non-regulatory and regulatory options are presented and the costs and effectiveness of the options vary. Three types of options are described: educational, administrative and regulatory. The educational options are directed at informing the public on WHP and related issues, while administrative options may require more management by local government.

Management options are described here for eight potential contaminant source types: underground storage tanks, commercial users/generators of hazardous materials, spills, landfills, salvage yards, deicing salts, residential areas and agricultural areas. Several areawide management techniques are also given. A description of each option is given and alternatives, questions, limitations, examples and implementation methods are listed when appropriate.

Additional maps useful to WHP management planning not already mentioned may be found in the Appendix, including a zoning map (Appendix 7.i.), depth to water table map (Appendix 7.j.) and map of monitoring well locations (Appendix 7.m.).

Underground storage tanks

Underground storage tanks (USTs) are the most ubiquitous potential point source in the Weston study area. They are also the source of most concern. A gasoline tank leak from a local gas station has already decommissioned the Sternberg well indefinitely. Efforts have been made by the town to persuade some businesses to voluntarily remove tanks close to the Mesker and Sternberg wells, but many still remain.

1. Information option *(educational)*

Send a leaflet out to all addresses in the WHPA discussing principles of WHP in general, WHP for Weston, the threat of leaking USTs to ground water, methods of leak prevention and tank registration procedures.

Alternatives:

Seminars sponsored by the town, county or University of Wisconsin-Extension (UWEX).

Programs coordinated with trade/business associations.

Questions/Limitations:

Uncertain as to effectiveness.

Lack of direct feedback from all tank owners.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

2. Information plus voluntary removal of tanks option *(educational)*

Contact people in the WHPA known to have UST(s). Present educational material regarding WHP and USTs. Encourage voluntary removal of tanks, especially if tank is abandoned, not used regularly or unneeded.

Questions/Limitations:

Uncertain as to effectiveness.

Lack of direct feedback from all tank owners.

May miss unlisted UST owners.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

3. Fire department involvement option *(administrative)*

Increase volunteer fire department's involvement with tank approval, inspection, inventory and removal.

Alternative:

Ally with city of Wausau fire department or organize a metrowide effort.

Questions/Limitations:

Unclear about fire department's present and future potential for involvemnent.
Personnel of volunteer department may not be available to implement this fully.
People in fire department may not be trained at tank inspection, inventory and removal.

Implementation:

By the Weston volunteer fire department.

4. Incentive program option *(administrative)*

Contact people known to have USTs in the WHPA. Present educational material regarding WHP and USTs and offer a monetary bonus for the removal of their tank(s).

Alternative:

Town pay for part or all of the cost of tank removal in addition to a monetary bonus.

Questions/Limitations:

Where will money for this program come from?

Implementation:

By existing town and county staff, Weston fire department or contracted staff.

5. Inventory USTs/set up UST database option *(administrative)*

Contact people in the WHPA to verify they are on the DILHR tank inventory list. If they are on the list, recheck tank data; otherwise fill out tank registration form. Set up a database for USTs in the town and continually update to keep information current.

Alternative:

Coordinate inventorying with bulk sales/delivery companies.

Implementation:

By existing town staff, county staff or hire a limited term employee.

6. UST ordinance option *(regulatory)*

Implement an UST ordinance supplementing the nontechnical aspects of DILHR regulations. Such an ordinance could require more frequent inspection, removal of abandoned tanks and/or take over the administration of DILHR rules such as inspection.

The ordinance could also require that a tank check be completed when property is sold. Tanks in use would be required to be on the DILHR tank inventory list. If not in use, tanks would have to be properly abandoned and any contamination associated with them would be recorded.

Questions/Limitations:

Cost of increased inspection or the administration of DILHR rules is unknown.
No precedent exists in Wisconsin for such an ordinance. However, in theory an

UST ordinance would not conflict with either the purpose or spirit of state law (Amrhein and Yanggen, 1989).

Implementation:
By existing town staff.

7. Overlay zoning option *(regulatory)*

Implement an overlay zone in the WHPA prohibiting the installation of USTs.

Alternative:
Degree of regulation could decrease as time of travel of contaminants to wells increases.

Questions/Limitations:
Existing tanks would remain as nonconforming uses.
Extent of zoning power to require the amortization of nonconforming uses is unclear.

Example:
Overlay zoning is being used in the town of Rib Mountain to prohibit the installation of USTs. To date, this ordinance has not been challenged.

Implementation:
By existing town staff.

Commercial users/generators of hazardous materials

Commercial establishments are a significant potential source of contamination in Weston. Commercial development surrounding the wells has been minimally regulated. Over 20 businesses, including gas stations, auto body shops, trucking companies, bulk fuel storage companies and window manufacturers, are now located in the study area. Most are small quantity hazardous waste generators that are not required to report waste quantities and disposal methods.

Until recently, many business locations were not on storm and sanitary sewer. The potential for improper waste disposal in the past and present is high. The Mesker well has already been contaminated with the industrial solvent perchloroethylene. The source of this contaminant has yet to be confirmed after several years of ground water investigation by the DNR and private consulting firms.

1. Information option *(educational)*

Send a leaflet to businesses in the WHPA describing WHP, the business' potential threats to ground water (spills, improper waste disposal, septic systems) and proper methods of waste storage and disposal.

Alternative:
Seminars sponsored by the town, county or UWEX.

Questions/Limitations:

Uncertain as to effectiveness.

Lack of direct feedback from people contacted.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

2. Information plus voluntary inventory option *(educational)*

Contact all businesses in the WHPA with educational information and provide a form asking owners to describe the hazardous materials they use, store and dispose of and quantities and methods of disposal. This would strictly be voluntary and would serve as an inventory for local government.

Alternative:

Coordinate programs with trade/business associations.

Questions/Limitations:

Uncertain as to effectiveness.

Lack of direct feedback from all business owners.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

3. Hazardous waste cooperative option *(administrative)*

Distribute information to businesses regarding the Marathon County Health Department Small Generators Hazardous Waste Cooperative. Costs for transport and disposal of wastes is reduced for members. The cooperative is managed by business members and has been in existence since 1987. About 100 businesses have joined. For more information, contact the Groundwater and Hazardous Materials Coordinator at the Marathon County Health Department.

Implementation:

By businesses who choose to join the cooperative. There is no cost to join. Payment is based on the types and quantities of wastes to be disposed. To join, a business must obtain an EPA hazardous waste I.D. number and fill out a disclaimer form.

4. Sewer extension option *(administrative)*

Hazardous waste disposal into septic systems or dry wells may occur when municipal storm and sanitary sewers are not available. Use this study to determine what businesses in the WHPA are not on sewer, their potential threat to ground water and where it would be best to have sewer extended.

Alternative:

Have businesses share directly in the costs of the extensions.

Encourage the Marathon County Zoning Department to do visual inspections of septic systems in the WHPA and to issue noncompliance orders.

Questions/Limitations:
Additional costs of sewering are high.

Implementation:
By existing town staff.

***5. Holding tank option** (regulatory)*

Require businesses a set distance from a well and not on storm and sanitary sewer to use above ground holding tanks for waste disposal instead of septic systems. Records would be kept by the town of quantities pumped and frequency of pumping. Tanks could also be inspected periodically.

Implementation:
By existing town staff or hire a limited term employee.

***6. Hazardous substance ordinance** (regulatory)*

This ordinance could do some or all of the following: identify hazardous substances, require initial and periodic reporting by new and existing businesses that store, handle and use these substances, establish standards for storage and handling, require contingency plans in case of spills and provide for inspection and enforcement.

Alternative:
Encourage the county to establish a countywide hazardous substance ordinance.

Questions/Limitations:
Identifying the substances to be regulated and setting standards requires technical expertise which can be costly.
Inspection can be time-consuming and expensive.

Implementation:
By the town or county (if implement a county hazardous substance ordinance).

***7. Review and revise present zoning option** (regulatory)*

Review present zoning in the WHPA and change to preserve open areas and to reduce the amount of land zoned commercial or industrial near the wells. For example, change commercially zoned areas which are undeveloped to residential to stop further commercial development near the wells.

Questions/Limitations:
Option applies primarily to new land uses.

Implementation:
By existing town staff.

***8. Overlay zoning option** (regulatory)*

Implement an overlay zone prohibiting certain types of businesses in the WHPA.

Alternatives:

Implement an overlay zone which would require new businesses to meet certain established criteria. Each new business would be evaluated before being given approval to locate in the WHPA.

Incorporate the consideration of hazardous material storage and handling facilities into a site plan review ordinance.

Questions/Limitations:

Existing businesses would remain as nonconforming uses.

Extent of zoning power to require the amortization of nonconforming uses is unclear.

Implementation:

By existing town staff.

Spills

The issue of spills is closely related to other potential contaminant sources such as USTs and businesses. Therefore management to prevent spills or implement remedial action ties in with other management options already suggested.

1. Town spill contingency plan *(administrative)*

Town work with Emergency Government and DNR to establish a contingency plan so immediate action can be taken when a spill occurs.

Questions/Limitations:

Option does nothing to prevent spills.

Implementation:

By town staff or Weston volunteer fire department.

2. Hazardous waste cooperative option *(administrative)*

Option same as that described for commercial users/generators of hazardous materials.

3. Sewer extension option *(administrative)*

Option same as that described for commercial users/generators of hazardous materials.

4. Hazardous substance ordinance *(regulatory)*

Businesses establish contingency plans for spills under a hazardous substance ordinance as described for commercial users/generators of hazardous materials.

*5. **UST ordinance option** (regulatory)*

Option same as that described for underground storage tanks.

Landfills

One landfill is located in the study area. It is about 1,500 feet from the Sternberg well and 2,800 feet from the Mesker well. The landfill is now closed but it was the town landfill for about 20 years. It does not have a clay lining although it will have a clay top when covering is completed.

*1. **DNR assistance option** (administrative)*

Request DNR not to approve future landfills in the WHPA.

Implementation:
By existing town staff.

*2. **Monitoring/set up database option** (administrative)*

Supplement present DNR monitoring of the landfill by having the Marathon County Health Department test homeowner's wells within 1,200 feet of the landfill and wells downgradient of the landfill. Test for VOCs, chloride, nitrate and chemical oxygen demand one to four times per year. This information could then be compiled in a database.

Implementation:
By existing town staff and the county health department.

Salvage yards

A permit must be obtained to establish a salvage yard in the town. The town no longer issues such permits (D. Grutzik, pers. comm., 1989). Therefore, only the three existing salvage yards in the town require management. Salvage yards are a minor potential contaminant source in the study area.

*1. **Monitoring/set up database option** (administrative)*

Monitor wells within 1,200 feet of each salvage yard, testing for VOCs one to four times per year. Set up a database for this information and update regularly.

Implementation:
By existing town staff.

*2. **Zoning ordinance option** (regulatory)*

Enact a zoning ordinance prohibiting the establishment of salvage yards in the WHPA.

Questions/Limitations:
Existing salvage yards remain as nonconforming uses.
Extent of zoning power to require the amortization of nonconforming uses is unclear.

Implementation:
By existing town staff.

3. Hazardous substance ordinance *(regulatory)*

Salvage yards can be regulated under a hazardous substance ordinance as described for commercial users/generators of hazardous materials or under a separate ordinance as authorized by Sec. 175.25, Wisconsin Statutes.

Alternative:
Encourage the county to regulate salvage yards under a county hazardous substance ordinance or under a separate ordinance authorized by Sec. 59.07(38), Wisconsin Statutes.

Implementation:
By existing town or county staff.

Deicing salts

Deicing salts are of concern for two reasons: 1) salt is stored at the Weston Municipal Center which is within 800 feet of the Sternberg well and 2) Hwy 29, a heavily salted state road, runs no less than 1,500 feet from both the Sternberg and Mesker wells.

1. Upgrade facilities option *(administrative)*

Upgrade storage facilities for salt mixtures to insure runoff from storage areas does not enter ground water.

Implementation:
By existing town staff.

2. Salt reduction option *(administrative)*

Control usage amounts on certain roads near wells and in the WHPA.

Questions/Limitations:
Salting of Hwy 29 is not controlled by the town.

Implementation:
By existing town staff.

Residential areas

Residential areas are not presently a serious threat to ground water in the study area. Homes with septic systems are of more concern than those with storm and sanitary sewer. In unsewered areas nitrates and hazardous wastes that are improperly disposed of are of concern.

1. Information option *(educational)*

Send a leaflet to homes in the WHPA that are not on storm and sanitary sewer discussing proper septic system maintenance, the dangers of disposing of hazardous materials in a septic system and proper methods of hazardous waste disposal.

Alternatives:
Seminars sponsored by the town, county or UWEX.

Questions/Limitations:
Uncertain as to effectiveness.
Lack of direct feedback from septic system owners.

Implementation:
Assistance by existing local and state specialists; hire or contract services.

2. Publicize Marathon County Clean Sweep option *(administrative)*

Further publicize county Clean Sweep program, especially in WHPA.

Implementation:
By existing town staff.

3. Sewer extension option *(administrative)*

Extend storm and sanitary sewers to subdivisions in the WHPA with lot sizes less than two acres as described for commercial users\generators of hazardous materials.

4. Holding tank option *(regulatory)*

Require homes a set distance from a well and not on storm and sanitary sewer to use above ground holding tanks as described for commercial users/generators of hazardous materials.

5. Revise present zoning option *(regulatory)*

Add another large lot residential category to the zoning classifications to be used in key undeveloped areas in the WHPA. For example, require a minimum lot size of two acres to limit housing densities in undeveloped areas.

Alternative:
Require a designated portion of each new lot to be left in a natural state.
Size of the undisturbed area could be a certain portion of the total lot size.

Implementation:
By existing town staff.

6. Amend Valley Plain District in zoning ordinance option *(regulatory)*

Amend the Valley Plain District to include ground water protection purposes.

Alternative:
Add a new section to the zoning ordinance establishing a WHPA zoning district.

Implementation:
By existing town staff.

7. Subdivision ordinance option *(regulatory)*

Implement a subdivision ordinance in the WHPA. Such an ordinance applies only to subdivided property and could control the number of lots being created, lot density standards and the timing of development (i.e., limited number of parcels developed each year). The ordinance may also require the use of low leakage sewers and advanced water treatment facilities.

Alternative:
Combine a subdivision ordinance with a site plan review ordinance for more comprehensive protection.

Questions/Limitations:
Option applies primarily to new land uses.

Example:
Austin, Texas adopted a subdivision ordinance that defines three zones within the city's WHPA. Development is staggered so that the density of development is most controlled near the wells and becomes less controlled farther from the wells (U.S. EPA, 1989).

Implementation:
By existing town staff.

Agricultural areas

Only a small portion of the study area is being used for agriculture and it is therefore a potential contaminant source of lesser concern.

1. Information option *(educational)*

Achieve general reductions in agricultural and technical assessment inputs of fertilizer and pesticides through farmer education and adoption of best management practices (BMPs). These practices are developed through scientific research by leading universities and are designed to replace surplus inputs with more intensive management as a means of risk minimization on the farm.

Implementation:
By farmers, with assistance from agencies such as UWEX, Soil Conservation Service (SCS) and Land Conservation Committee (LCC).

2. Record keeping option *(administrative)*

Initiate record keeping of principal nitrogen and pesticide inputs in the WHPA on a continuing basis. Review inputs relative to yield goals, residual soil nitrogen, leaching potentials and other farm specific factors.

Questions/Limitations:
Program is entirely voluntary.

Implementation:
By farmers, existing town staff and/or agricultural agencies.

3. Monitoring option *(administrative)*

Wisconsin's Ground Water Law now regulates 12 commonly used pesticides by setting enforcement standards and preventative action limits. A key element in bringing about enforcement of these standards is to discover detectable levels of these pesticides. Monitoring in or near fields where pesticide use is reasonably known will greatly aid in corrective action. Conduct monitoring on fields where pesticides are applied and at key private wells in the WHPA one to four times per year for nitrate and selected pesticides.

Alternatives:
Cost share with cooperative farmers.
Request assistance from DNR.

Implementation:
By existing town staff or hire a limited term employee.

4. Land purchase option *(administrative)*

Purchase parcels of agricultural land close (within 1 mile) to the wells in the WHPA. These parcels could be retired from production or leased back to farmers with specific instructions as to permissible amounts of fertilizer or pesticides used per year per acre.

Example:
This is done by the city of Waupaca, Wisconsin.

Implementation:
By existing town staff.

5. Land easement option *(administrative)*

Negotiate with key farmers in the WHPA for purchase of easements which restrict agricultural chemical use in return for cash or other benefits.

Example:
Purchase of scenic easements is underway by the state of Wisconsin along the Lower Wisconsin River.

Implementation:
By existing town staff.

6. Legislative option *(administrative)*

Encourage state legislation to enforce the 10 mg/l NO_3-N ground water standard or seek incentives such as the pilot Wind Erosion Control Tax Credit Program passed in 1989 by the Wisconsin State Legislature. State enabling legislation similar to that enacted in Nebraska in 1986 could also be encouraged. This legislation allows Natural Resource Districts to create special protection areas based on ambient nitrate levels in ground water. Special fertilizer management practices are required based on the severity of nitrate contamination in the area (U.S. EPA, 1989).

Implementation:
By existing town staff.

Areawide techniques

Previous options target specific potential sources. Some options, listed here, manage several or all sources concurrently.

1. Information option *(educational)*

Send a leaflet to all addresses in the WHPA discussing WHP and ground water protection, types of potential contaminant sources and actions people can take to prevent future contamination.

Alternative:
Seminars sponsored by the town, county or UWEX.

Questions/Limitations:
Uncertain as to effectiveness.

Implementation:
By existing town or county staff or with assistance by local and state specialists.

2. Land purchase option *(administrative)*

Purchase land in the WHPA to protect selected key parcels from potentially polluting uses. Purchased land can be use for parks, airports, hay fields or leased for other uses with restrictions.

Implementation:
By existing town staff.

*3. **Sign option** (administrative)*

Erect WHPA notification signs along major thoroughfares at the boundaries of the WHPA. These signs will serve an educational function and as continual reminders of the special nature of the area.

Implementation:
By existing town staff.

*4. **Monitoring well network option** (administrative)*

Establish a regional monitoring well network. These networks would help in early detection of contaminants and provide a basis for requesting enforcement of water quality standard violations by the DNR and Wisconsin Department of Agriculture Trade and Consumer Protection (DATCP).

Alternative:
Obtain grant monies to help pay for monitoring.

Implementation:
By existing town staff or hire a limited term employee.

*5. **Environmental audit option** (administrative)*

Attempt to locate properties in the WHPA upon which suspect activities have occurred such as locations of former businesses that improperly disposed of wastes or illegal dumping sites. The search can include all the ZOC or be limited to a certain distance from the wells. Surface geophysical methods such as resistivity or electromagnetic surveys could also be used to investigate suspect properties. Resistivity may be used to detect contaminant plumes if it has mineralized and electromagnetic surveys may be used to detect old drums. Conduct environmental audits of suspect properties. Such audits may include a site history description, soil borings and soil or ground water sampling and analysis for a broad spectrum of inorganic and organic compounds.

Implementation:
Contract for services.

*6. **Zoning option** (regulatory)*

Enact zoning on a broad scale in the WHPA to restrict future potential contaminant sources, establish conditional uses and declare nonconforming uses.

Implementation:
By existing town staff.

Implementation guidance for Weston

Following are suggestions of actions the town may take to begin the process of approving and implementing a WHP plan. Completion of this report is only the beginning step, providing information on the ZOC, potential contaminant sources and management choices. Local government and the community may now decide what level of WHP is desired and how it will be achieved.

* Review, comment on study report and modify existing plan if needed.
  - Present local government committees with the plan for their review. They can provide comments and modifications and recommend further actions to be taken.
  - Solicit public comments and/or hold a public hearing.
  - Obtain legal assistance from a municipal attorney, UWEX and/or other agencies.
  - Revise plan if needed and submit it for official governmental approval, adoption and/or action.
* Establish WHPA management zones.
  - Establish one or more WHPA management zones based on the ZOC, TOTs, potential contaminant source characteristics, roads, civil boundaries and natural barriers.
* Designate a lead person or department to implement the WHP plan.
  - Rely on local resource personnel in various agencies such as UWEX, Marathon County Health Department, County Planning and Zoning, SCS, LCC and DNR.
  - Hire or contract with a ground water specialist.
* Prioritize management options and potential contaminant sources.
  - Review options and select one or more for implementation. Refer suggestions to the appropriate personnel or agencies.
* Conduct further investigative studies.
  - Install monitoring wells and/or use existing wells to conduct ground water studies. For example, monitoring can be used to help better define the ZOC or TOT lines.
  - Conduct monitoring as an early warning system to monitor for indicator parameters (such as nitrate) and to help identify the source of a contaminant.
  - Conduct more detailed inventories of potential sources to better estimate their numbers in the ZOC.

* Examine other Wisconsin ground water plans as models for methods of approaches or actions that may be taken.

  - Examples are the "Portage County Groundwater Plan" (Portage Co., 1987), "Marathon County Groundwater Plan" (Marathon Co., 1988), "Groundwater Protection Principles and Alternatives for Rock County, Wisconsin" (Zaporozec, ed., 1985) and the Rib Mountain Municipal Well Recharge Area Overlay District (Rib Mountain Sanitary District, 1985).

Alternative water supplies

The town of Weston has already faced serious water supply problems beginning in 1985 when VOCs were discovered in both the Mesker and Sternberg wells. At that time the town responded by heavier pumping of their only other well serving the main service area, the Alta Verde well. This well is 26 years old and has a design pumping rate of only 500 gpm (Donohue, 1986). A temporary granular activated carbon adsorption facility was installed on the Mesker well in July 1986 to allow consumption of water from that well.

The town of Weston water mains are interconnected with both the adjoining village of Rothschild and city of Schofield. The town sold water to Rothschild for a period of one year when that community experienced VOC contamination problems with its wells. Weston purchased water from Schofield for two days during a construction project. Weston has a written agreement covering water sales with Rothschild, but only an informal agreement with Schofield.

Alternative water supply options for Weston in the event of future contamination of the Mesker or Sternberg wells would include relying on the other one or two uncontaminated wells, water conservation, purchasing water from Rothschild or Schofield and installing temporary water treatment facilities.

City of Wisconsin Rapids

Water supply situation

Wisconsin Rapids (figure 16) is a city of 18,700 people in central Wisconsin. With its surrounding urban areas of Grand Rapids, Port Edwards, Nekoosa and Saratoga, the area includes approximately 40,000 people.

The city is served by a municipal water utility which presently owns and operates three wells in the adjoining town of Grand Rapids. These three wells, installed in 1953 and 1959, are the collector well type, consisting of a vertical casing and 10 horizontal laterals extending into the aquifer. The city has had difficulty meeting maximum water demands during summer months and has plans prepared to construct a fourth well at a new site also in Grand Rapids.

Land use surrounding the first three wells has changed significantly since they were built thirty years ago. Residential development has continued to displace rural land and Grand Rapids is considered to be some of the prime growth area for the metropolitan area. These changes in land use have increased concerns about contaminants affecting city well water. The proposed fourth well site is farther away from potential contamination sources, but some forested land near the site is available for development.

The existing wells are normally rested only several hours per 24 hour period and are probably pumped at higher than desired rates (Donohue, 1988). The heavy pumping has contributed to scale problems and reduced yields. Well 3 has the greatest average daily pumpage at 1.21 million gallons per day (mgd). Wells 1 and 2 have average daily rates of 0.82 and 0.79 mgd respectively (Donohue, 1988). Follow-

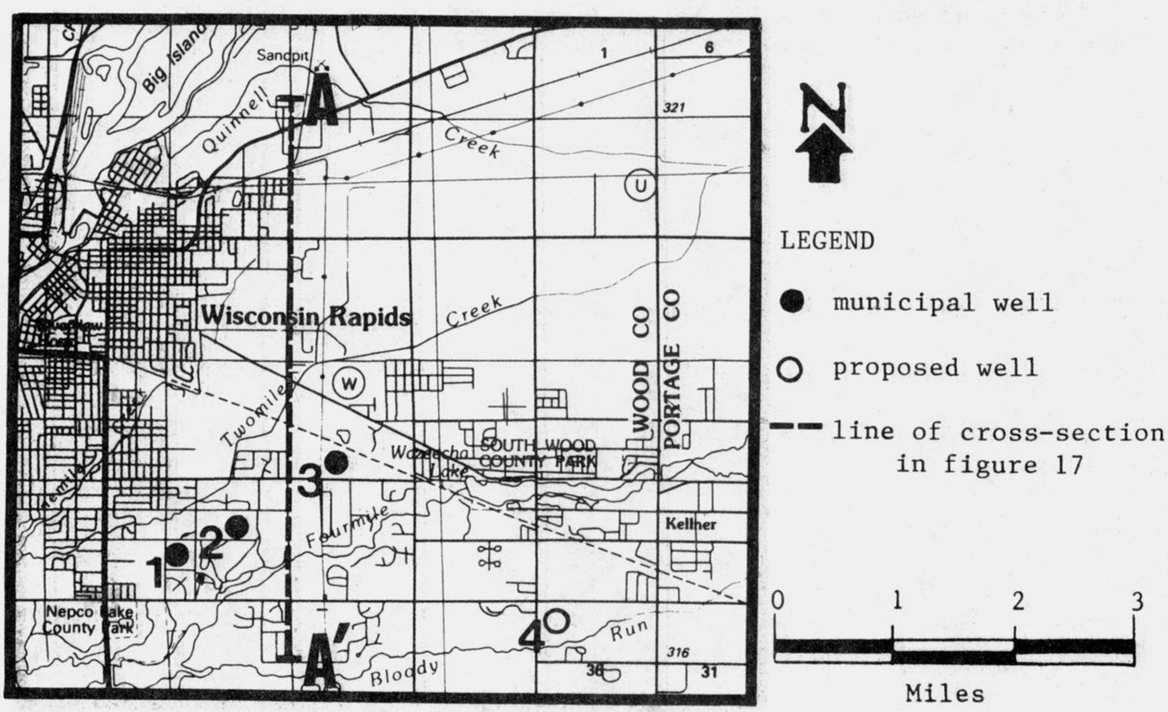


Figure 16. Location map showing the city of Wisconsin Rapids study area. (Map source: U.S.G.S., 1985.)

ing construction of the fourth well, the average pumping rates for wells 1, 2 and 3 would probably decrease by 20 to 50 percent.

A consultant to the city (Donohue, 1988) estimated that wells 1, 2 and 3 impact ground water levels within radii of 1,600, 1,600 and 1,000 feet respectively when operated at their rated capacities, although no specific drawdown limit was given. The extent of the cone of depression for well 4 was estimated to reach about 2,200 feet at a pumping rate of 1.5 mgd and about 4,500 feet at 3.0 mgd. The calculated drawdowns assumed steady state conditions and an idealized aquifer setting.

Residents in the town of Grand Rapids are concerned that the drawdown from the new well might cause some private wells to go dry, and that if they deepen their wells very high dissolved iron levels will be encountered. The town and the city are attempting to negotiate a remediation and compensation plan if water level or water quality problems are encountered.

Hydrogeologic description of area

Wisconsin Rapids lies on the southern edge of the Precambrian Shield which is at or near the earth's surface over much of eastern Canada and the north central United States. The rocks were formed from volcanic activity, the intrusion of granite rock bodies and the melting and recrystallization of older rocks (Batten, 1989). Precambrian rock types include granite, gneiss, schist and quartzite. In some places Cambrian sandstone overlies the Precambrian rock, but preglacial erosion stripped most of it away. The Precambrian bedrock is fractured and is frequently covered with a layer of clayey residuum called grus, weathered from the granitic bedrock. Granite is used for domestic water supplies only where unconsolidated deposits are too thin or absent, as on the west side of the Wisconsin River. It yields only small quantities of water to wells and frequently has high iron content.

The bedrock of the Wisconsin Rapids wellfield area is overlain by Pleistocene outwash and lacustrine deposits of sand, gravel and silt. Large quantities of sandy outwash were deposited by braided streams flowing from the continental ice sheet terminus located to the east. A large glacial lake, fed by meltwater, covered much of this region about 15,000 years ago (Batten, 1989). The lake deposits are primarily medium to coarse grained sand which becomes finer in a westward direction. One or more thin silt beds often occur within the sandy deposits.

The sand and gravel deposits, which are the principal aquifer, generally thicken from north to south through the wellfield area. The saturated thickness over this region varies from almost nothing in the north to 60 feet in the south. In the existing wellfield vicinity it is typically about 40 feet thick. Figure 17 is a hydrogeologic cross-section through the wellfield area.

Ground water flow is generally from east to west with discharge to numerous ditches, marshes and larger features like Fourmile Creek, Lake Wazeecha and the Wisconsin River. Ground water flow paths from recharge to discharge are of short to moderate lengths, from less than one mile to several miles. Estimates of the amount of average recharge in the area were made by Weeks and Stangland (1971) at 11 to 12 inches per year, by Holt (1965) at 6.8 to 10.3 inches per year and by Stoertz (1985) at 6.7 inches per year. A detailed study of the hydrogeology of the area was done by Karnauskas (1977). Figure 18 is a water table elevation map of the study area.

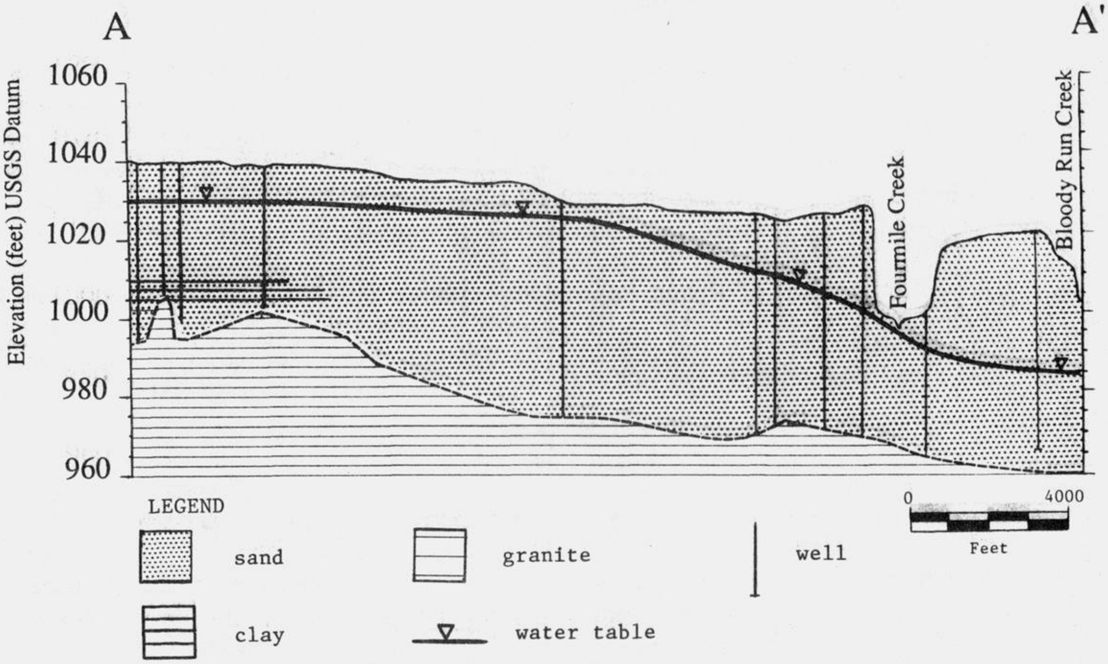


Figure 17. Hydrogeologic cross-section through the Wisconsin Rapids wellfield area. (Source: modified from Donohue, 1988; water table interpolated from Karnauskas, 1977.)

The depth to the water table is usually less than 20 feet. The average hydraulic gradient ranges from 10 to 20 feet per mile. Natural ground water velocities within the sand and gravel aquifer are 1 to 2 feet per day.

Uncontaminated ground water is of generally good quality with low mineralization. However, the ground water is low in pH and has high corrosive tendencies (CWGC, 1989). High dissolved iron concentrations of 3 to 4 milligrams per liter (mg/l) are also common (Batten, 1989).

Zones of contribution

A statistical analysis (t-test) of pumping rates since 1978 was conducted to determine the ratio of maximum monthly rate to average rate. The average ratio was 1.36 with an upper 90 percent confidence limit of 1.42. The average and 90 percent confidence interval for the maximum monthly pumping rate were 3.35 and 3.48 mgd respectively. A consulting report (Donohue, 1988) estimated the mean annual pumping rate for the city in the year 2005 at 2.94 mgd. This rate was multiplied by the ratio factor (using the 90 percent upper confidence limit) and scaled upward by the upper confidence limit for the maximum monthly rate to obtain the design discharge rate. The resulting design rate of 4.35 mgd was divided among the three existing wells and one proposed well based on their rated capacity. Calculation of the design discharge rate is shown in Appendix 8.h.

Based on several studies (Karnauskas, 1977; Holt, 1965; Weeks and Stangland, 1971; Donohue, 1988) a K value of 200 ft/day was used in the ZOC calculations for wells 1, 2 and 3. A consultants study by Klaer and Associates (Donohue, 1988)

Figure 15. Weston land use map.

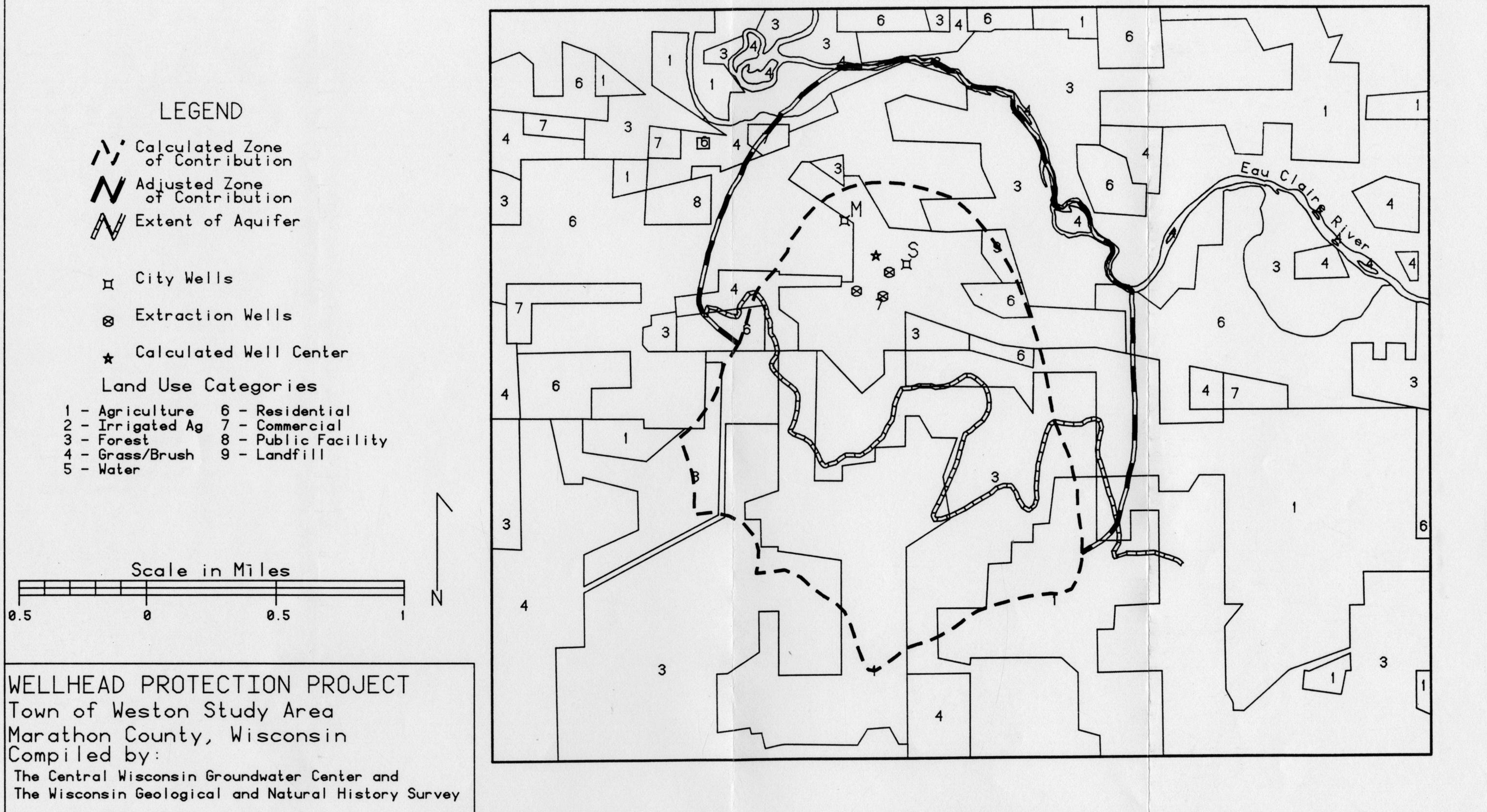


Figure 19. Wisconsin Rapids zones of contribution.

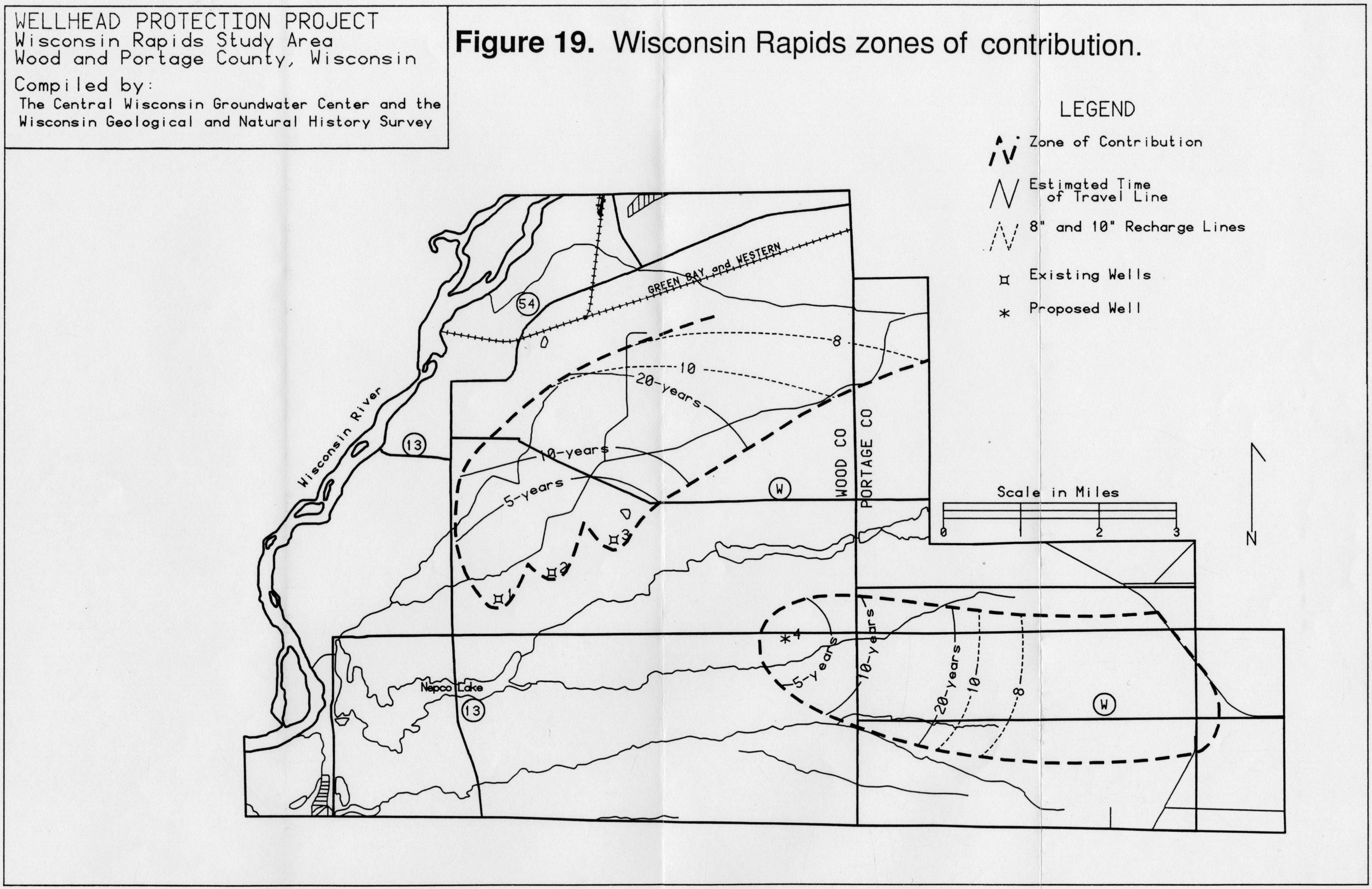
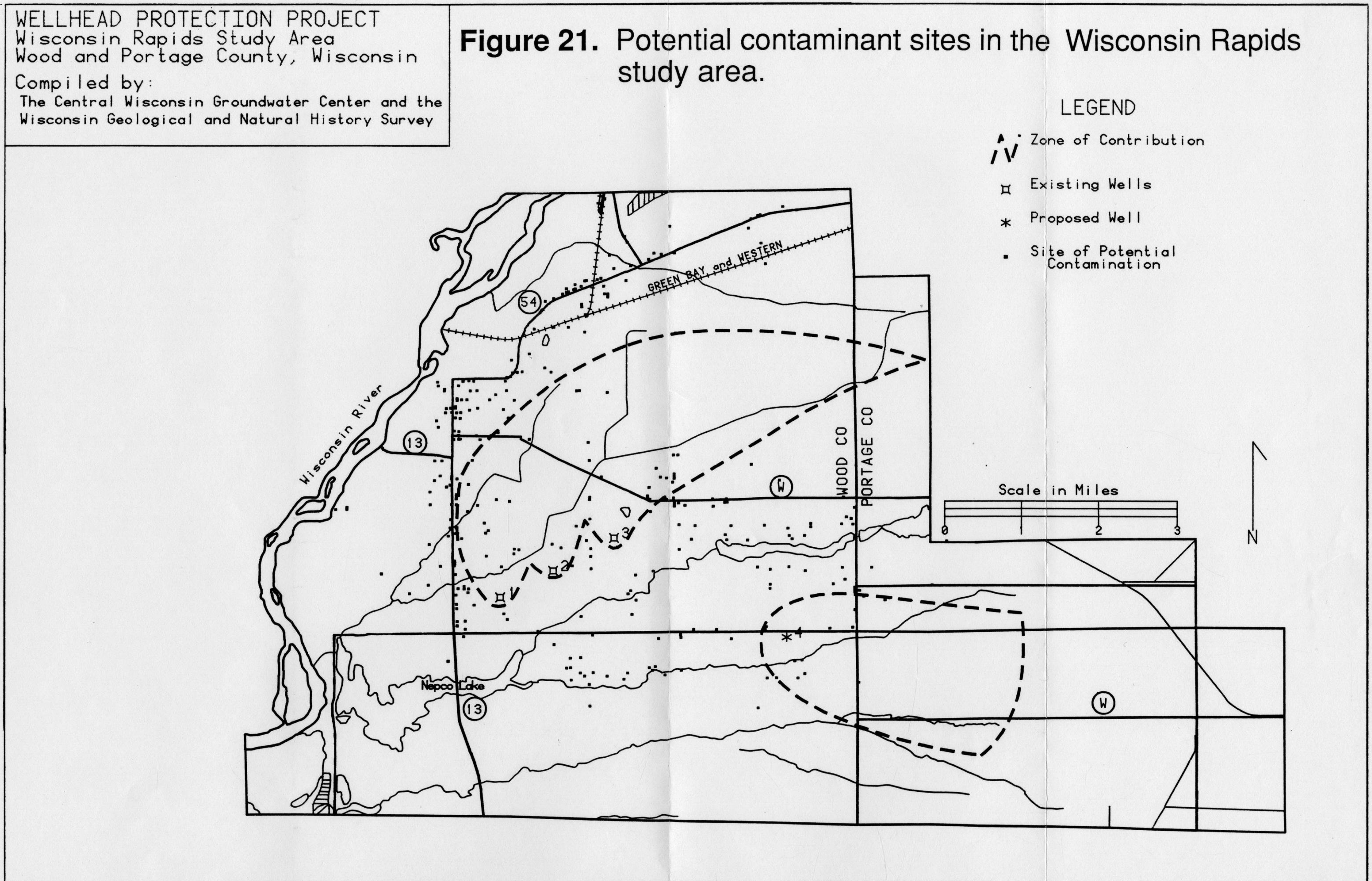


Figure 21. Potential contaminant sites in the Wisconsin Rapids study area.



reported a K value of 184 ft/day from their study of the well 4 site. This value was used for the ZOC delineation of proposed well 4.

The saturated thickness varies from around 50 feet in the vicinity of wells 1, 2 and 3 to less than 5 feet in parts of its recharge area to the north and east (Donohue, 1988). An average aquifer depth of 30 feet was used in the flow model for wells 1, 2 and 3. The presence of a ground water divide provided a no-flow boundary along the northern extent of the ZOC. Mapping of the divide was based on ground water head and watershed basin maps (Karnauskas, 1977; Lippelt, 1981).

Hydraulic gradient changes along the flow path were incorporated into the model to calculate the ZOC width at a particular location. Calculations of hydraulic gradient for the Wisconsin Rapids sites are found in Appendix 8.i.

Figure 19 represents the delineation of the zones of contribution for wells 1, 2 and 3 and proposed well 4. The five, ten and twenty year time of travel isochrones are also depicted. Appendix 8.f. is the uniform flow equation calculations. Appendix 8.g. shows the flow paths to the city wells and the hydraulic gradient segments used in the uniform flow equation. The delineated area was adequate to account for municipal wellfield discharge at eight inches of recharge per year (Appendix 8.j.). The travel time isochrones are based on the 70 percentile distances as discussed in the Case Studies Methods section. Table 9 lists the 50 and 70 percentile travel distances for all Wisconsin Rapids' wells. A travel distance probability graph, used to construct table 9 is shown in figure 20 for well 1.

Table 9. Distance of ground water travel over time for the city wells of Wisconsin Rapids.

		Distance in Feet			
Year of TOT	**Percentile***	**Well 1**	**Well 2**	**Well 3**	**Well 4**
1	50	1100	1300	1225	675
1	70	1170	1360	1335	755
5	50	3385	5200	3225	2550
5	70	4200	5335	3445	2750
10	50	7005	6600	5050	4650
10	70	7445	6900	5500	5150
20	50	13200	9200	8500	9100
20	70	14000	10400	9700	10100

* Percent of time the travel distance is less than or equal to the value in the table as calculated in approximately 100 simulation calculations.

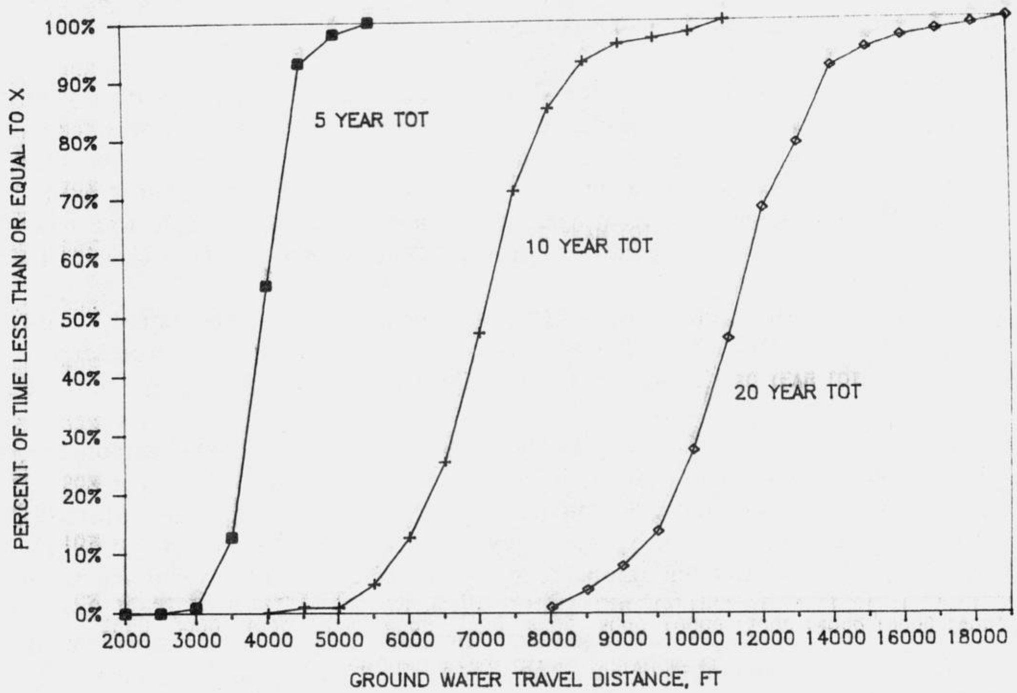


Figure 20. Times of travel for well 1.

Assessment of potential contaminant sources

Point sources of contamination such as spills and leaky underground storage tanks have already contaminated ground water in the town of Grand Rapids in the vicinity of the municipal wells. The potential sites of ground water contamination in the site database inventory (Appendix 8.a.) are mapped (figure 21). The Wisconsin Rapids source database may be found in Appendix 8.b. Underground storage tanks and businesses utilizing or generating hazardous materials present the greatest threat to ground water quality. Unsewered residential development within the five year time of travel presents the second most important potential source of concern to wellhead protection.

There are 52 potential point sources of contamination at 47 locations in the ZOC for municipal wells 1, 2 and 3 (table 10) and 24 potential sources at 13 locations in the ZOC for proposed well 4 (table 11). Some locations have more than one potential source such as multiple underground tanks or a tank plus on-site hazardous materials.

Most of the potential point sources are underground fuel storage tanks containing leaded, unleaded or diesel fuels, or home heating oil. The 1989 tank inventory by DILHR contained some information on tank characteristics such as size, fuel type, tank material and age. The age and material of a tank offer some indication of its susceptibility to leakage. Of the 428 underground tanks mapped in the Wisconsin Rapids study area, 61 are bare steel and 229 are greater than 20 years old or are of unknown age. These types of tanks are at a high risk of leaking and should be checked as part of a wellhead protection program. More typically, tanks in the Wisconsin Rapids study area are made of coated steel and are 1 to 20 years old. Only 17 tanks in the inventory were cathodically protected to prevent corrosion. All

WELLHEAD PROTECTION PROJECT
Wisconsin Rapids Study Area
Wood and Portage County, Wisconsin

Compiled by:
The Central Wisconsin Groundwater Center and the
Wisconsin Geological and Natural History Survey

Figure 18. Water table elevation map of the Wisconsin Rapids study area.

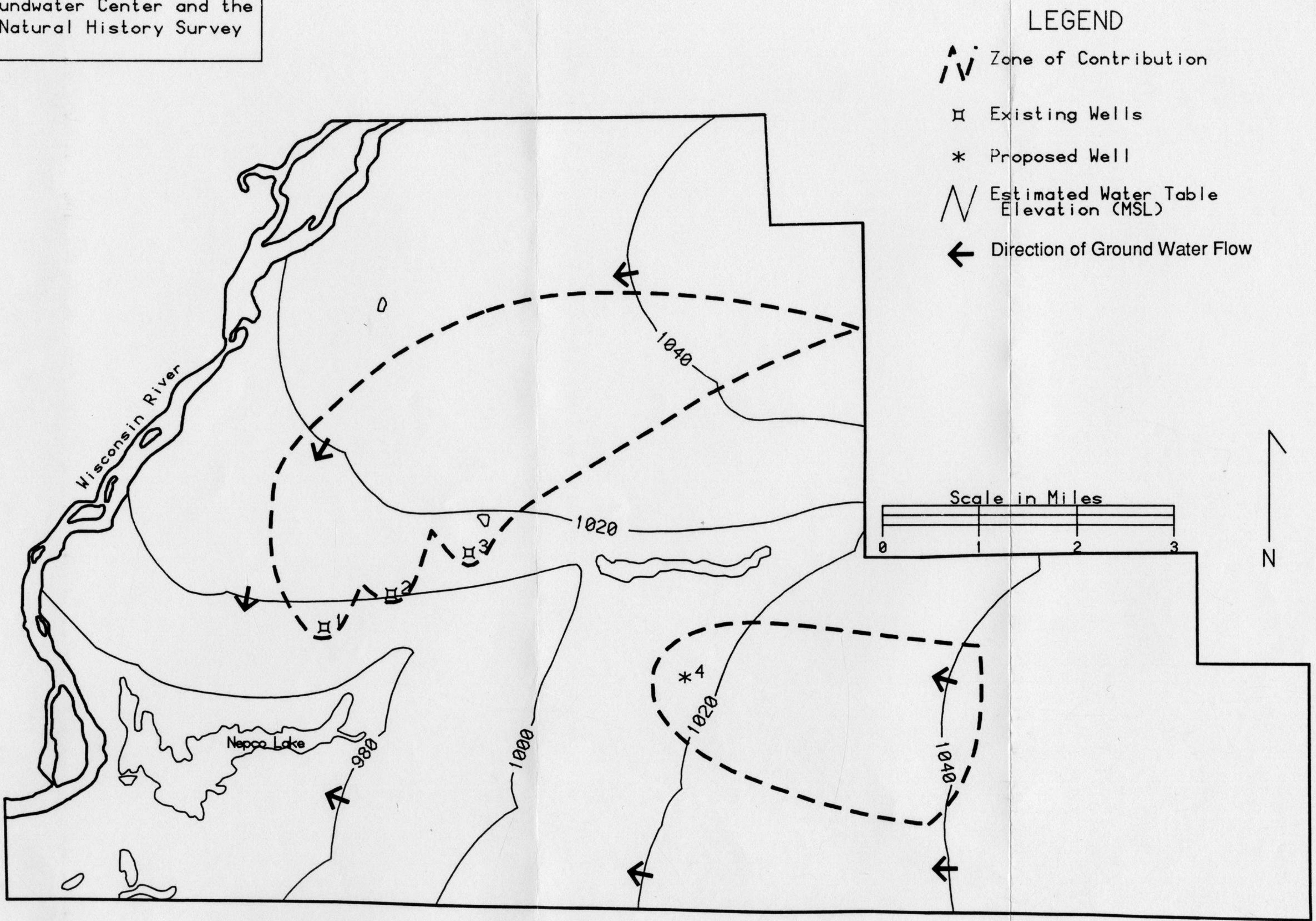


Table 10. Types and numbers of potential point sources for wells 1, 2 and 3 and the entire study area.

Point Sources	Entire Study Area	In ZOC	In 5 Yr TOT	In 10 Yr TOT	In 20 Yr TOT
USTs	428	32	17	26	32
Businesses	92	15	5	10	15
Landfills	3	2	2	2	2
Spills	16	3	2	2	3
Total	539	52	26	40	52

Table 11. Types and numbers of potential point sources for proposed well 4.

Point Sources	In ZOC	In 5 Yr TOT	In 10 Yr TOT	In 20 Yr TOT
Tanks	20	8	18	20
Businesses	3	1	3	3
Landfills	1	0	0	1
Spills	0	0	0	0
Total	24	9	21	24

tanks in the ZOC should probably be of concern due to the relatively high rate of failure of tanks or piping. The ability of the soils in the study area to attenuate contaminants is low and is also a factor to be considered (Good and Madison, 1987).

Approximately 26 potential contaminant sources were located within the five year time of travel of wells 1, 2 and 3, and nine sources were located within the five year time of travel of proposed well 4 (figures 22 and 23). There may be other possible unknown contaminant sources such as forgotten tanks and old spills which could also threaten future water quality.

Non-point sources of ground water contamination include such chemicals as pesticides, nitrate from fertilizers and septic systems and chloride from road salt. Non-point sources are best depicted with the land use map (figure 24). Superposition of the ZOC on this map shows that forest and unsewered residential land uses predominate in the five year time of travel from wells 1, 2, 3 and proposed well 4. Table 12 lists the land use types in the ZOCs in percent total area and in acres. Areas of land use types in the ZOC time of travel zones are listed in Appendix 8.d. for wells 1, 2 and 3 and in Appendix 8.e. for proposed well 4. As of September 1989 approximately 33.4 % of the commercial and residential area in the ZOC for wells 1, 2 and 3 was on municipal sewer and water service. This is a rough estimate calculated from the Wisconsin Rapids storm and sanitary sewer map (Appendix 8.m.). No portion of the ZOC for proposed well 4 receives municipal water and sewer service.

Each well, however, has some other nearby land use which may be of concern for

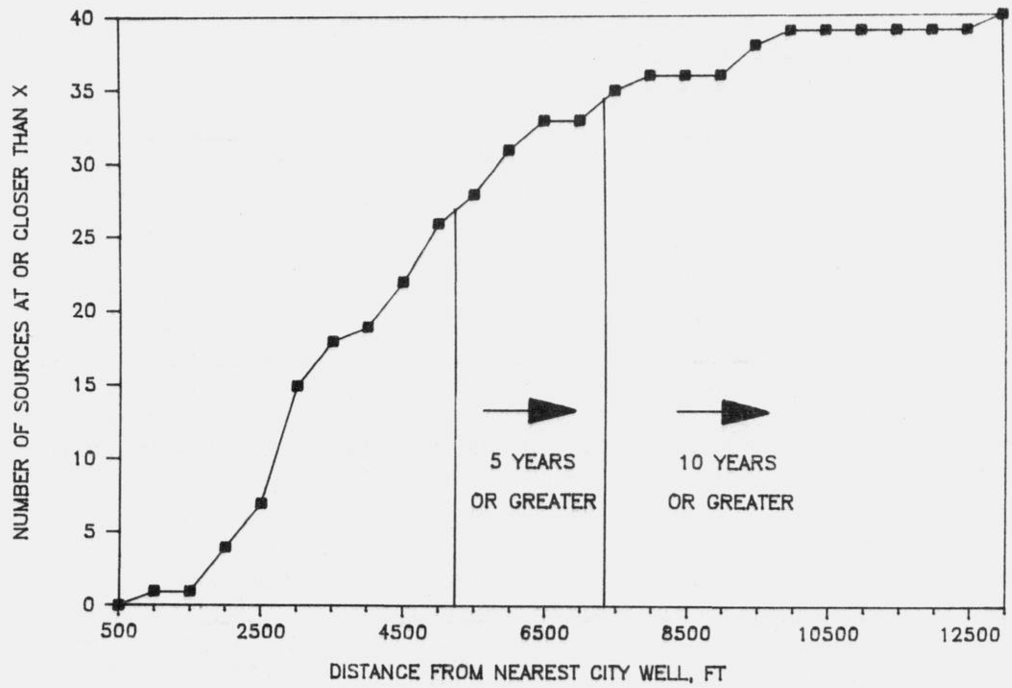


Figure 22. Distance of sources to wells 1, 2 and 3.

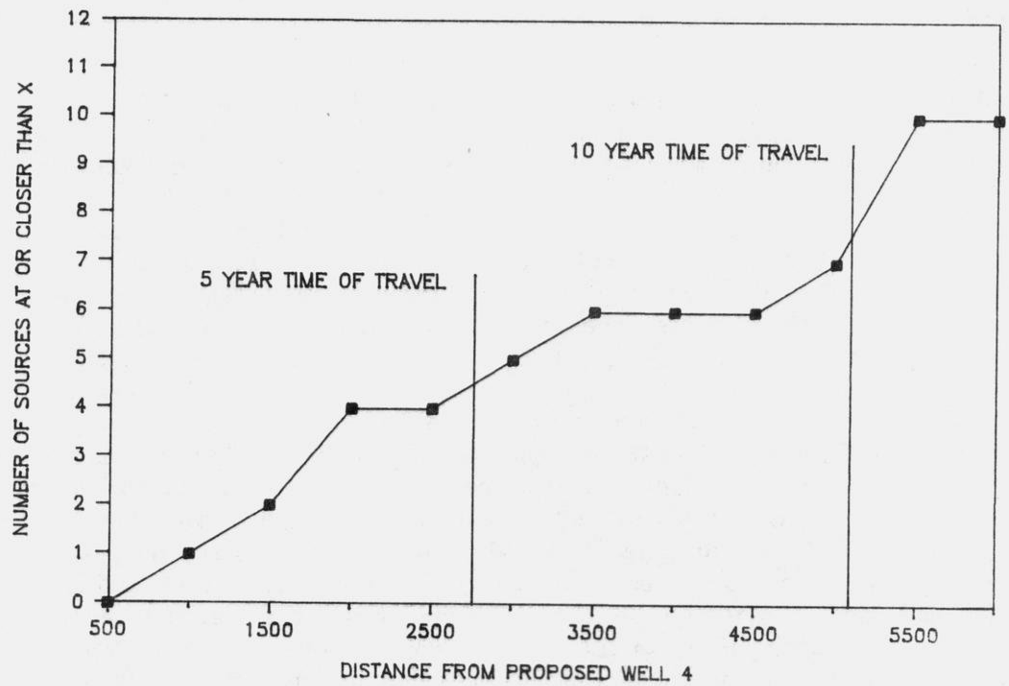


Figure 23. Distance of sources to proposed well 4.

WELLHEAD PROTECTION PROJECT
Wisconsin Rapids Study Area
Wood and Portage County, Wisconsin

Compiled by:
The Central Wisconsin Groundwater Center and the
Wisconsin Geological and Natural History Survey

Figure 24. Wisconsin Rapids land use map.

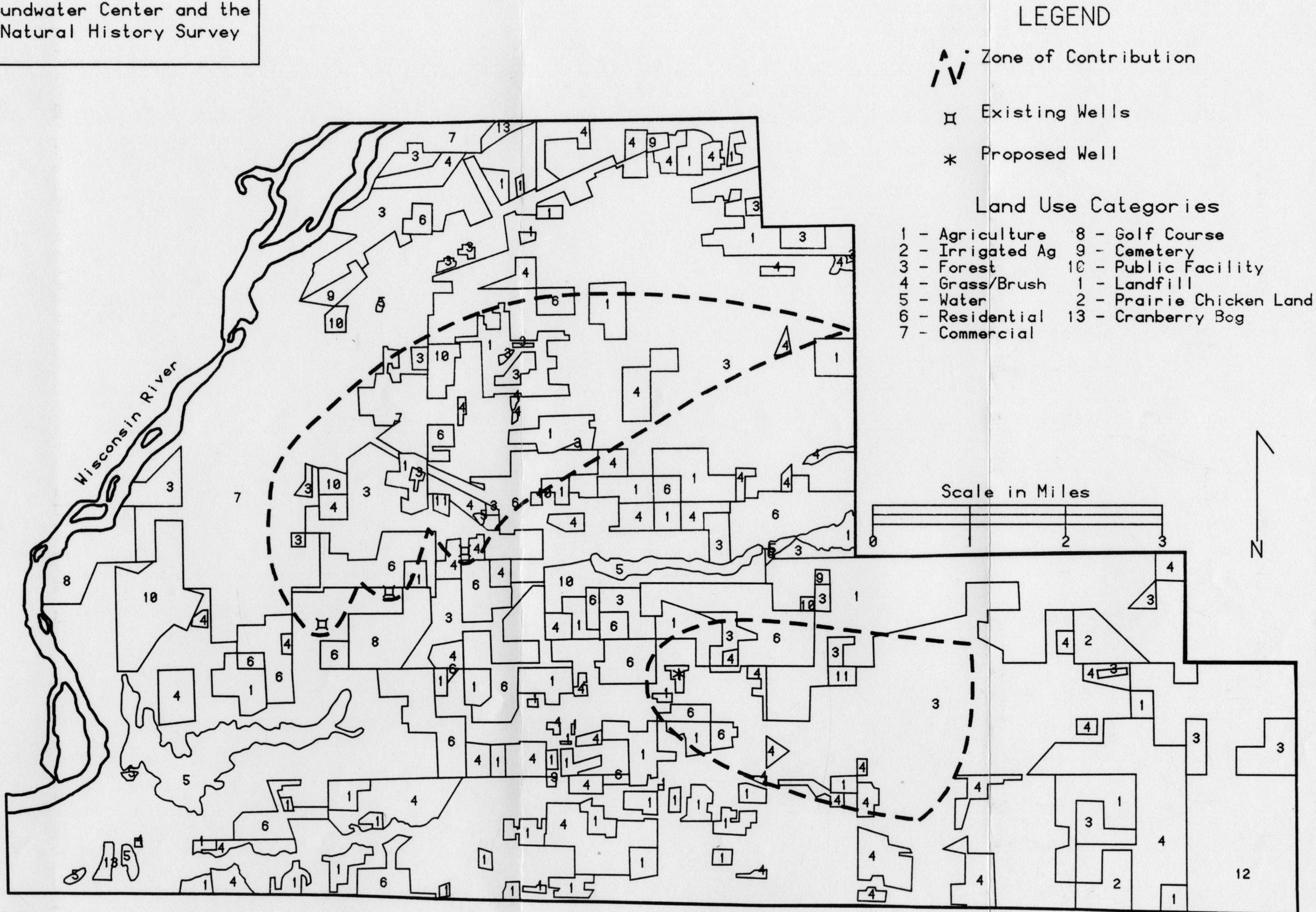


Table 12. Areas of land use types in the Wisconsin Rapids study area and zones of contribution in acres and percent total area.

	Area of Each Land Use					
	Entire Study Area		ZOC Wells 1,2&3		ZOC Proposed Well 4	
	Acres	Percent(%)	Acres	Percent(%)	Acres	Percent(%)
Agriculture	4793.4	13.3	508.1	10.8	392.7	15.0
Irrigated Ag	273.2	0.8	0.0	0.0	0.0	0.0
Forest	17340.7	48.0	2676.6	56.8	1793.3	68.6
Grassland/Brush/ Undeveloped Land	3227.3	8.9	279.1	5.9	131.0	5.0
Lake/River/Stream	678.1	1.9	4.8	0.1	0.0	0.0
Residential	3203.2	8.9	535.2	11.4	268.7	10.3
Built-up Area	3647.9	10.1	564.1	12.0	0.0	0.0
Golf Course	493.7	1.4	0.0	0.0	0.0	0.0
Cemetery	94.2	0.3	0.0	0.0	0.0	0.0
Public Park	379.6	1.1	114.4	2.4	0.0	0.0
Trailer Court	64.3	0.2	0.0	0.0	0.0	0.0
Landfill	76.3	0.2	29.7	0.6	28.2	1.1
Airport	391.5	1.1	0.0	0.0	0.0	0.0
Prairie Chicken Land	1414.8	3.9	0.0	0.0	0.0	0.0
Cranberry Bog	59.1	0.2	0.0	0.0	0.0	0.0
Total	36137.3	100.0	4712.9	100.0	2613.9	100.0

wellhead protection. Built-up residential and commercial property occurs within 2,000 feet of well 1. Most of the immediate ZOC for well 2 is in unsewered residential use and a former landfill lies 1,300 feet east of the well. Well 3 also has an abandoned waste disposal area about 1,800 feet upgradient. Proposed well 4 has tracts of agricultural land within the five year time of travel.

With the exception of the ZOC for well 1 within the city limits, all of the residential dwellings and commercial establishments in the ZOCs are on septic systems. Private well water testing (CWGC, 1989) indicated that three percent of 193 samples exceeded the nitrate maximum contaminant level of 10 mg/l NO_3-N. Eighty percent of the samples are less than 5 mg/l. Due to the sandy soils and shallow water table, concern over potential contamination is high.

The outlying areas of the ZOCs, beyond the 10 year time of travel, are mostly in forested and undeveloped land uses. This undoubtedly contributes high quality ground water recharge to the aquifer. Some agricultural land also occurs in these areas. Careful attention should be given to conversion of undeveloped land to more intensive, possibly contaminating, land uses in the ZOCs.

WHPA management options for Wisconsin Rapids and town of Grand Rapids

The ZOC physically defines the recharge area of a well or wellfield. For management purposes, the ZOC is adjusted to accommodate for roads, property lines, civil boundaries and characteristics of potential sources. This adjusted ZOC is called a wellhead protection area (WHPA) and is defined by those implementing WHP management plans. The WHPA can include all or parts of the ZOC and one or more WHPAs can be defined. For example, WHPA zones or districts can be drawn based on time of travel lines.

Wellhead protection management is more difficult to plan and implement in a situation such as that which exists for Wisconsin Rapids where the city wells and recharge areas are located outside city boundaries. Inter-jurisdictional cooperation is essential in this case. Management choices will need to be decided and implemented jointly. For wellhead protection to be effective, both communities will need to consider making concessions such as funding of management options by Wisconsin Rapids and acceptance of land use restrictions in Grand Rapids.

Options are presented rather than recommendations so the town and city can design their own management plan based upon the potential contaminant source assessment and views of local officials and community members. Most options are described with the idea of joint implementation, but some can be implemented by communities separately if cooperation is not achieved.

These options also illustrate the range of management levels available. Both non-regulatory and regulatory options are presented and the costs and effectiveness of the options vary. Three types are described: educational, administrative and regulatory. The educational options are directed at informing the public on WHP and related issues, while administrative options may require more management by local governments.

Management options are described here for eight potential contaminant source types: underground storage tanks, commercial users/generators of hazardous materials, spills, landfills, salvage yards, deicing salts, residential areas and agricultural areas. Several areawide techniques are also given. A description of each option is given and alternatives, questions, limitations, examples and implementation methods are listed when appropriate. The option of extraterritorial zoning by Wisconsin Rapids is not described in the following section. A general description of extraterritorial zoning is given in the section Wellhead Protection Area Management Tools - Regulatory Tools.

Additional maps useful to WHP management planning not already mentioned may be found in the Appendix, including a zoning map (Appendix 8.k.), depth to water table map (Appendix 8.l.), map of spill locations (Appendix 8.n.) and a housing density map for the town of Grand Rapids (Appendix 8.o.).

Underground storage tanks

Underground storage tanks (USTs) are the most ubiquitous potential point source in the study area. They are also one of the sources of most concern. Gasoline spills have occurred in the study area, but none have yet affected municipal water supplies. A spill from a commercial leaking UST in 1983 affected seven private wells about 4,000 feet northeast of city well 3 (Bailey, pers. comm., May 26, 1989).

1. ***Information option*** *(educational)*

Send a leaflet out to all addresses in the WHPAs discussing principles of WHP and ground water protection in general, WHP for Wisconsin Rapids' wells, the threat of leaking USTs to ground water, methods of leak prevention and tank registration procedures.

Alternatives:

Seminars sponsored by the city and town, county, or University of Wisconsin-Extension (UWEX).
Programs coordinated with trade/business associations.

Questions/Limitations:

Uncertain as to effectiveness.
Lack of direct feedback from all tank owners.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

2. ***Information plus voluntary removal of tanks option*** *(educational)*

Contact people in WHPAs who are known to have UST(s). Present educational material regarding ground water protection, WHP and USTs. Encourage voluntary removal of tanks, especially if tank is abandoned, not used regularly or unneeded.

Questions/Limitations:

Uncertain as to effectiveness.
Lack of direct feedback from all tank owners.
May miss unlisted UST owners.

Implementation:

Assistance by existing local and state specialists; hire or contract services.

3. ***Fire department involvement option*** *(administrative)*

The city and town fire departments work together to develop and implement a program increasing the fire departments' involvement with tank approval, inspection, inventory and removal.

Alternative:

City and town fire departments work independently.

Questions/Limitations:

Unclear about fire departments' present and future potential for involvement.
Personnel in the departments may not be fully trained in tank inspection, inventory, and removal.

Implementation:

By the Grand Rapids volunteer fire department and Wisconsin Rapids fire department.

4. *Incentive program option* (administrative)

Contact people known to have USTs in the WHPAs. Present educational material regarding WHP and USTs. Town and/or city offer a monetary bonus for the removal of their tank(s).

Alternative:

Town and/or city pay for part or all of the cost of tank removal in addition to a monetary bonus.

Questions/Limitations:

Where will money for this program come from?

Implementation:

By existing town and city staff, county staff, local fire departments or contracted staff.

5. *Inventory of USTs/set up UST database option* (administrative)

Contact people in the WHPAs to verify they are on the DILHR tank inventory list. If they are on the list, recheck tank data; otherwise fill out tank registration form. Set up a database for USTs in the town and city and continually update to keep information current.

Alternative:

Coordinate surveying with bulk sales/delivery companies.

Implementation:

By existing town and/or city staff, county staff or hire a limited term employee.

6. *UST ordinance option* (regulatory)

Both Wisconsin Rapids and the town of Grand Rapids implement UST ordinances in all or part of the WHPAs which supplement the nontechnical aspects of DILHR regulations. Such an ordinance could require more frequent inspection, removal of abandoned tanks and/or take over the administration of DILHR rules such as inspection.

The ordinance could also require that a tank check be completed when property is sold. Tanks in use would be required to be on the DILHR tank inventory list. If not in use, tanks would have to be properly abandoned and any contamination associated with them would be recorded.

Questions/Limitations:

Cost of increased inspection or the administration of DILHR rules is unknown.
No precedent exists in Wisconsin for such an ordinance. However, in theory an UST ordinance would not conflict with either the purpose or spirit of state law (Amrhein and Yanggen, 1989).

Implementation:

By existing town and city staff.

7. Overlay zoning option *(regulatory)*

Both the city and town implement overlay zones in the WHPAs prohibiting the installation of USTs.

Alternative:
Degree of regulation could decrease as time of travel of contaminants to wells increases.

Questions/Limitations:
Existing tanks would remain as nonconforming uses.
Extent of zoning power to require the amortization of nonconforming uses is unclear.

Example:
Overlay zoning is being used in the town of Rib Mountain to prohibit the installation of USTs. To date, this ordinance has not been challenged.

Implementation:
By existing town and city staff.

Commercial users/generators of hazardous materials

Commercial establishments are a significant potential source of contamination in the study area because many are not connected to storm and sanitary sewer. Only those businesses within the city boundaries have sewer services. The potential for improper waste disposal in the past and present is high. Most businesses in the study area are small quantity waste generators that are not required to report waste quantities and disposal methods.

1. Information option *(educational)*

Send a leaflet to businesses in the WHPAs describing WHP, the business' potential threats to ground water (spills, improper waste disposal, septic systems) and proper methods of waste storage and disposal.

Alternative:
Seminars sponsored by the town, county or UWEX.

Questions/Limitations:
Uncertain as to effectiveness.
Lack of direct feedback from people contacted.

Implementation:
Assistance by existing local and state specialists; hire or contract services.

2. Information plus voluntary inventory option *(educational)*

Contact all businesses in the WHPAs with educational information and provide a form asking owners to describe the hazardous materials they use, store and dispose of and quantities and methods of disposal. This would strictly be voluntary and would serve as an inventory for local governments.

Alternative:
Coordinate programs with trade/business associations.

Questions/Limitations:
Uncertain as to effectiveness.
Lack of direct feedback from all business owners.

Implementation:
Assistance by existing local and state specialists; hire or contract services.

3. Hazardous waste cooperative option *(administrative)*

Work with the Wood County Health Department to develop a Small Generators Hazardous Waste Cooperative for businesses like the cooperative which has been formed in Marathon County. Costs for transport and disposal of wastes would be reduced for members. For more information, contact the Marathon County Health Department.

Implementation:
Local businesses and Wood County Health Department work together in the formation of a cooperative.

4. Sewer extension option *(administrative)*

Hazardous waste disposal into septic systems or dry wells may occur when municipal storm and sanitary sewers are not available. Use this study to determine what businesses in the WHPAs are not on sewer, their potential threat to ground water and where it would be feasible to have sewer extended.

Alternative:
Have businesses share directly in the costs of the extensions.
Encourage the Wood County Planning and Zoning Department to do visual inspections of septic systems in the WHPAs and to issue noncompliance orders.

Questions/Limitations:
Additional costs of sewering and question of who will pay for it.
Presently, city policy is that no sewering will be extended without annexation.

Implementation:
Coordination between the city and town.

5. Holding tank option *(regulatory)*

Require businesses a set distance from a well and not on storm and sanitary sewer to use above ground holding tanks for waste disposal instead of septic systems. Records would be kept by the town and city of quantities pumped and frequency of pumping. Tanks could also be inspected periodically.

Implementation:
By existing town staff or hire a limited term employee. City could pay for initial costs of tank purchasing and installation in exchange for needed protection.

*6. **Hazardous substance ordinance** (regulatory)*

This ordinance could do some or all of the following: identify hazardous substances, require initial and periodic reporting by new and existing businesses that store, handle, and use these substances, establish standards for storage and handling, require contingency plans in case of spills and provide for inspection and enforcement. The town and city each implement an ordinance in appropriate parts of the WHPAs.

Alternative:

Encourage the county to establish a countywide hazardous substance ordinance.

Questions/Limitations:

Identifying the substances to be regulated and setting standards requires technical expertise which can be costly.

Inspection can be time-consuming and expensive.

Implementation:

By the town and city or county (if implement a county hazardous substance ordinance).

*7. **Review and revise present zoning option** (regulatory)*

Review present zoning in the WHPAs and change to preserve open areas and to reduce the amount of land zoned commercial or industrial near the wells. Zoning review could be done by a joint committee so the needs of both communities would be addressed.

Alternative:

Zoning review and revisions could be made separately by each community.

Questions/Limitations:

Option applies primarily to new land uses.

Implementation:

By existing town and city staff.

*8. **Overlay zoning option** (regulatory)*

Town and city implement overlay zones in the WHPAs prohibiting certain types of businesses in the WHPAs.

Alternative:

Implement overlay zones requiring new businesses to meet certain established criteria. Each new business would be evaluated before being given approval to locate in the WHPA or portion of the WHPA being zoned.

Incorporate the consideration of hazardous material storage and handling facilities into a site plan review ordinance.

Questions/Limitations:

Existing businesses would remain as nonconforming uses.

Extent of zoning power to require the amortization of nonconforming uses is unclear.

Implementation:
By existing town and city staff.

Spills

The issue of spills is closely related to other potential contaminant sources such as USTs and businesses. Therefore management to prevent spills or implement remedial action ties in with other management options already suggested.

1. Spill contingency plan option *(administrative)*

City and town work with Emergency Government and DNR to establish a contingency plan so immediate action can be taken when a spill occurs.

Questions/Limitations:
Option does nothing to prevent spills.

Implementation:
By city and town staff or local fire departments.

2. Hazardous waste cooperative option *(administrative)*

Option same as that described for commercial users/generators of hazardous materials.

3. Sewer extension option *(administrative)*

Option same as that described for commercial users/generators of hazardous materials.

4. Hazardous substance ordinance *(regulatory)*

Businesses establish contingency plans for spills under a hazardous substance ordinance as described for commercial users/generators of hazardous materials.

5. UST ordinance option *(regulatory)*

Option same as that described for underground storage tanks.

Landfills

Three landfills are located within the study area - two are located within the ZOC for wells 1, 2 and 3 and a third is located within the ZOC for proposed well 4. No contamination of private wells has been reported due to these landfills, but they are of some concern because of their proximity to the city wells.

1. DNR assistance option *(administrative)*

The town request DNR not to approve future landfills in the WHPA.

Implementation:
By existing town staff.

2. Monitoring option *(administrative)*

Supplement present DNR monitoring of landfills by having the Wood County Health Department test homeowner's wells within 1,200 feet of the landfills and wells downgradient of the landfills. Test for VOCs, chloride, nitrate and chemical oxygen demand one to four times per year. This information could then be compiled in a database.

Implementation:
By town and city staff and the Wood County Health Department. Costs for such monitoring could be shared by both the town and city.

Salvage yards

Salvage yards are considered a potential source of lesser concern in the study area. None are located within the immediate vicinity of the city wells and proposed well 4. Some consideration should be given to regulating salvage yards, however, since they are no longer regulated by the DNR or any other state agency.

1. Monitoring/set up database option *(administrative)*

Monitor wells within 1,200 feet of each salvage yard, testing for VOCs one to four times per year. Set up a database for this information and update regularly.

Imlementation:
By existing town and city staff. Costs for such monitoring could be shared by both the town and city.

2. Zoning ordinance option *(regulatory)*

City and town each enact zoning ordinances in appropriate parts of the WHPAs prohibiting the establishment of salvage yards.

Questions/Limitations:
Existing salvage yards remain as nonconforming uses.
Extent of zoning power to require the amortization of nonconforming uses is unclear.

Implementation:
By existing town and city staff.

3. Hazardous substance ordinance option *(regulatory)*

Salvage yards can be regulated under a hazardous substance ordinance as described for commercial users/generators of hazardous materials or under a separate ordinance authorized by Sec. 175.25, Wis. Statutes.

Alternative:

Encourage the county to regulate salvage yards under a county hazardous substance ordinance or under a separate ordinance authorized by Sec. 59.07(38), Wis. Statutes.

Implementation:

By existing town and city staff or county staff.

Deicing salts

Salt mixtures for the town of Grand Rapids are stored at the Grand Rapids Town Landfill located about 1,500 feet from city well 2.

1. Upgrade facilities option *(administrative)*

Upgrade storage facilities for salt mixtures to insure runoff from storage area does not enter ground water.

Implementation:

By existing town staff.

2. Salt reduction option *(administrative)*

Control usage amounts on some roads near the wells and in the WHPA.

Imlementation:

By existing town staff.

Residential areas

Residential areas are a potential point source of concern in the study areas. Grand Rapids is considered a prime growth area for subdivision development because of its proximity to the city and available space. In these unsewered areas nitrates and hazardous wastes that are improperly disposed of are of concern.

1. Information option *(educational)*

Send a leaflet to homes in the WHPAs that are not on storm and sanitary sewer discussing proper septic system maintenance, the dangers of disposing of hazardous materials in a septic system and proper methods of hazardous waste disposal.

Alternatives:

Seminars sponsored by the town and city, county or UWEX.

Questions/Limitations:
Uncertain as to effectiveness.
Lack of direct feedback from septic system owners.

Implementation:
Assistance by existing local and state specialists; hire or contract services.

2. County Clean Sweep option *(administrative)*

Work with the county to establish a county Clean Sweep Program. Such a program aids in the proper disposal of household hazardous wastes.

Questions/Limitations:
Cost of program is high and is really economically feasible only at the county level presently.

Implementation:
By county staff and existing city and town staff.

3. Sewer extension option *(administrative)*

Extend storm and sanitary sewer to subdivisions in the WHPA with lot sizes less than two acres. Subdivisions closest to the wells and closest to city boundaries will be considered first.

Questions/Limitations:
Additional costs of sewering are high.
Negotiations regarding annexation and costs must be conducted by the city and town.

Implementation:
By the city in collaboration with the town. Cost sharing of sewer extensions by the city and town may be considered.

4. Holding tank option *(regulatory)*

Require homes a set distance from the city wells and not on storm and sanitary sewer to use above ground holding tanks as described for commercial users/generators of hazardous materials.

5. Revise present zoning option *(regulatory)*

Add another large lot residential category to the zoning classifications to be used in key undeveloped areas in the WHPAs. For example, require a minimum lot size of two acres to limit housing densities in undeveloped areas of the WHPAs.

Alternative:
Require a designated portion of each new lot to be left in a natural state. Size of the undisturbed area could be a certain portion of the total lot size.

Implementation:
By existing town staff.

6. New zoning option (regulatory)

Add a new section to the town zoning ordinance establishing a WHPA zoning district.

Implementation:
By existing town staff, in coordination with city staff.

7. Subdivision ordinance option (regulatory)

Implement subdivision ordinances in the WHPAs. Such an ordinance applies only to subdivided property and could control the number of lots being created, lot density standards and the timing of development (i.e., limited number of parcels developed each year). The ordinance may also require the use of low leakage sewers and advanced water treatment facilities and control lot density standards.

Alternative:
Combine a subdivision ordinance with a site plan review ordinance for more comprehensive protection.

Questions/Limitations:
Option applies primarily to new land uses.

Example:
Austin, Texas adopted a subdivision ordinance that defines three zones within the city's WHPA. Development is staggered so that the density of development is most controlled near the wells and becomes less controlled farther from the wells.

Implementation:
By existing town staff.

Agricultural areas

Only a small portion of the ZOC for city wells 1, 2 and 3 is being used for agricultural purposes and it is therefore a potential contaminant of lesser concern. The ZOC of proposed well 4 contains more agricultural land use, most of which is in Portage County.

1. Information option (educational)

Achieve general reductions in agricultural and technical assessment inputs of fertilizers and pesticides through farmer education and adoption of best management practices (BMPs). These practices are developed through scientific research by leading universities and are designed to replace surplus inputs with more intensive management as a means of risk minimization on the farm.

Implementation:
By farmers, with assistance from agencies such as UWEX, Soil Conservation Service (SCS) and Land Conservation Committee (LCC).

2. Record keeping option *(administrative)*

Initiate record keeping of principal nitrogen and pesticide inputs in the WHPA on a continuing basis. Review inputs relative to yield goals, residual soil nitrogen, leaching potential and other farm specific factors.

Questions/Limitations:
Program is entirely voluntary.

Implementation:
By farmers, existing town and city staff and/or agricultural agencies.

3. Monitoring option *(administrative)*

Wisconsin's Ground Water Law now regulates 12 commonly used pesticides by setting enforcement standards and preventative action limits. A key element in bringing about enforcement of these standards is to discover detectable levels of these pesticides. Monitoring in or near fields where pesticide use is reasonably known will greatly aid in corrective action. Conduct monitoring on fields where pesticides are applied and at key private wells in the WHPAs one to four times per year for nitrate and selected pesticides.

Alternatives:
Cost share with cooperative farmers.
Request assistance from DNR.

Implementation:
By existing town and county staff. Costs for such monitoring could be shared by both the town and city.

4. Land purchase option *(administrative)*

City purchase parcels of agricultural land close (within 1 mile) to the wells within the WHPAs. These parcels could be retired from production or leased back to farmers with specific instructions as to permissible amounts of fertilizer or pesticides used per year per acre.

Example:
This is done by the city of Waupaca, Wisconsin.

Implementation:
By existing city staff.

5. Land easement option *(administrative)*

City negotiate with key farmers in the WHPA for purchase of easements which restrict agricultural chemical use in return for cash or other benefits.

Example:
Purchase of scenic easements is underway by the state of Wisconsin along the Lower Wisconsin River.

Implementation:
By existing city staff.

6. Legislative option (administrative)

The city and town encourage state legislation to enforce the 10 mg/l NO_3-N ground water standard or seek incentives such as the pilot Wind Erosion Control Tax Credit Program passed in 1989 by the Wisconsin State Legislature. State enabling legislation similar to that enacted in Nebraska in 1986 could also be encouraged. This legislation allows Natural Resource Districts to create special protection areas based on ambient nitrate levels in ground water. Special fertilizer management practices are required based on the severity of nitrate contamination in the area (U.S. EPA, 1989).

Implementation:
By existing city and town staff.

Areawide techniques

Previous options target specific types of potential sources. Some options, listed here, manage several or all sources concurrently.

1. Information option (educational)

Send a leaflet to all addresses in the WHPA discussing WHP and ground water protection, types of potential contaminant sources and actions people can take to prevent future contamination.

Alternative:
Seminars sponsored by the town and city, county or UWEX.

Questions/Limitations:
Uncertain as to effectiveness.

Implementation:
By existing town and city staff, county staff or assistance by local and state specialists.

2. Land purchase option (administrative)

City purchase land in the WHPA to protect selected key parcels from potentially polluting uses. Purchased land can be use for parks, airports, hay fields or leased for other uses with restrictions.

Implementation:
By existing city staff.

*3. **Sign option** (administrative)*

Erect WHPA notification signs along major thoroughfares at the boundaries of the WHPAs. These signs will serve an educational function and as continual reminders of the special nature of the area.

Implementation:
By city and town staff. City could pay for purchase and installation of the signs.

*4. **Monitoring well network option** (administrative)*

Establish a regional monitoring network. These networks would help in early detection of contaminants and provide a basis for requesting enforcement of water quality standard violations by the DNR and Department of Agriculture Trade and Consumer Protection (DATCP).

Implementation:
By existing city and town staff. The city could pay costs of monitoring well installations and sampling and data could be shared by the city and town.

*5. **Environmental audits option** (administrative)*

Attempt to locate properties in the WHPAs upon which suspect activities have occurred such as businesses which have improperly disposed of wastes or illegal dumping sites. The search can include all the ZOC or be limited to a certain distance from the wells. Surface geophysical methods such as resistivity or electromagnetic surveys could also be used to investigate suspect properties. Resistivity may be used to detect a contaminant plume or electromagnetic surveys may be used to detect old buried drums. Conduct environmental audits of suspect properties. Such audits may include a site history description, soil borings and soil or ground water sampling and analysis for a broad spectrum of inorganic and organic compounds.

Implementation:
City contract for services.

*6. **Zoning Option** (regulatory)*

Enact zoning on a broad scale in the WHPA to restrict future potential contaminant sources, establish conditional uses and declare nonconforming uses.

Implementation:
By existing town staff cooperating with city staff.

Implementation guidance for Wisconsin Rapids and town of Grand Rapids

Following are suggestions of actions Wisconsin Rapids, the town of Grand Rapids and the county may take to begin the process of approving and implementing a WHP plan. Completion of this report is only the beginning step, providing information on the ZOC, potential contaminant sources and management choices. Local governments and the communities may decide what level of WHP is desired and how it will be achieved.

Joint implementation by the city and town:

* Establish a joint study committee composed of government officials and interested citizens.

  - Review, comment on the report and suggest modifications and further actions to be taken.

  - Solicit public comment and/or hold a public hearing.

  - Examine other ground water plans. Examples are the "Portage County Groundwater Plan" (Portage Co., 1987), "Marathon County Groundwater Plan"

    (Marathon Co., 1988), "Groundwater Protection Principles and Alternatives for Rock County" (Zaporozec, ed., 1985) and the Rib Mountain Municipal Well Recharge Area Overlay District (Rib Mountain Sanitary District, 1985).

* Jointly establish WHPA management zones.

  - Establish WHPA management zones based on the ZOCs, TOTs, potential contaminant source characteristics, major roads and civil boundaries.

* Jointly prioritize management options and potential contaminant sources.

  - Review options and select one or more for implementation. Refer suggestions to the appropriate personnel or agencies for further modifications.

* Designate a joint committee to implement selected management options or a comprehensive management plan.

  - Rely on local officials, interested citizens and local resource personnel in various agencies such as UWEX, Wood County Health Department, Wood County Planning and Zoning, SCS, LCC and DNR.

  - Hire or contract with a ground water specialist for additional assistance.

Implementation with county involvement:

* The city and town request the county to assist the implementation of ground water protection measures for both city and private wells.

* The city and town cooperate with the county in the development of a countywide groundwater protection plan or ordinances.

Implementation by each community:

* Any suggestion discussed above may also be implemented by either community separately.

* Obtain legal assistance from a municipal attorney, UWEX and/or other agencies.

* Revise plan if needed and submit it for official governmental approval, adoption and/or action.

* Conduct further investigative studies.

  - Install monitoring wells and/or use existing wells to conduct ground water studies. For example, monitoring can be used to help better define the ZOC or TOT lines.

  - Conduct monitoring as an early warning system, to monitor for indicator parameters (such as nitrate) and to help identify the source of a potential contaminant.

  - Conduct more detailed inventories of sources to better estimate their numbers in the ZOC.

Alternative water supplies

The city of Wisconsin Rapids currently operates three collector wells spaced about 3,500 to 5,000 ft apart. The ZOCs for the three wells overlap a short distance upgradient from the wells. The city has difficulty meeting recent high demand periods even with all three wells operating at higher than desired rates. Studies contracted by the city for installation of a fourth well are complete but construction is awaiting completion of permitting and legal review. The proposed new site would be unaffected by contamination of ground water at the current wellfield.

Although use of water from the Wisconsin River may be possible, additional treatment would be required and costs would be very high (Wilson, pers. comm., 1989). Water supply options for Wisconsin Rapids include water conservation, temporary water treatment facilities such as an air stripper and installation of one or more new wells.

CONCLUSIONS

This study provided actual applications of Federal Safe Drinking Water Act wellhead protection guidelines for two communities obtaining drinking water from vulnerable sand and gravel aquifers. Both areas have numerous potential point sources of contamination in the zones of contribution for their municipal wells. The town of Weston's ZOC is entirely within township boundaries. The city of Wisconsin Rapids' ZOCs are almost entirely beyond city limits in the neighboring town of Grand Rapids.

Zone of contribution calculations were performed using the simplest method consistent with the aquifer conditions and limitations of the data. In spite of previous detailed hydrogeologic studies at both sites, the available hydraulic head data was a major limitation in attempting to use more sophisticated models. Most previous studies lacked data in the region upgradient of the wellfield and out to logical hydrogeologic boundaries. In some situations, additional field study may be necessary before sufficient confidence can be placed in the location of ZOC boundaries.

The design of WHP areas or management zones should recognize the inherent uncertainties of the available data and modeling assumptions. The use of prudent safety factors, buffer zones or nested management zones should be part of the policy decisions made by the municipalities, with the help of technical advice, prior to implementation.

Contaminant source inventories are tedious work and require frequent updating. Although much information already exists, it is often inadequate. The diverse array of information from state and federal agencies dictates that a methodical and persistent search be conducted. A database framework for input and collation of the myriad source attributes greatly assists the effort. Field checking of data is required to establish a credible and usable inventory at the local level.

A computerized mapping approach greatly aids the overlay process needed to evaluate the contaminant sources relative to the ZOCs. The ability to integrate a geographic information system with this project was a major asset. The computerized approach provided exceptional output products which enhanced communication of WHP concepts and scenarios.

Many WHP management options have been identified which appear legally and technically feasible at the local level, but few have been actually tried. Municipalities have broad home rule powers to adopt and implement plans and ordinances to protect the public health and welfare. Wisconsin municipalities need to see some examples of successful WHP implementation. Simple WHP ideas should be tried first. Approaches such as the town of Rib Mountain overlay district, signs erected at WHPA boundaries and educational programs are examples of relatively simple, low cost strategies.

Wellhead protection areas which cross political jurisdictions present major challenges for implementation. Mechanisms and prototypes of multi-jurisdictional planning exist and can be adopted if the parties have the will to try. Councils of governments and interlocking zoning review boards are examples of informal and formal mechanisms. The town of Grand Rapids continued to actively participate in this study because they saw the potential to adopt wellhead protection concepts for ground water protection generally in their jurisdiction, which would benefit their citizens using private wells. Wellhead protection planning must be flexible enough to accommodate the varied interests of the key participants and produce options by which both jurisdictions benefit.

Wellhead protection can be used for existing wells or new wells. If a proposed well is specifically located in an undeveloped area, the job of contaminant source inventory will be easier, but most of the other studies and management options will be similar. Rarely are new well sites located in pristine regions where development pressures will remain low. New sites do offer increased opportunity for land purchase or easement options. Existing wells within the jurisdiction of a municipality may present easier implementation of WHP than new wells located in more remote areas in an adjoining township's jurisdiction.

The municipalities involved were very supportive of the study due to an awareness of ground water contamination from actual experience. However, there was concern by officials that this plan might lead to state policies which could pre-empt local control over water planning. Comparisons to the 208 Water Quality Management Plan were made.

The involvement of local staff and citizens throughout the study allowed for a period of growth in understanding the concepts and methods of WHP planning. Municipal officials and citizens were presented with a list of management options for review similar to materials presented in the report and these options were discussed at a meeting. Initial reaction was positive. Some options were readily accepted for possible implementation such as further database development and educational programs, while other options were considered unlikely to be accepted.

adsorption (from solution) - The process of removing a solute molecule from solution and attaching it to the surface of a solid.

advection - The process by which solutes are transported by the motion of flowing ground water.

alkalinity - Capacity to neutralize acid; related primarily to the amount of hydroxide (OH^-), bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) in water.

alluvial aquifer - An aquifer composed of alluvium.

alluvium - A general term for clay, silt, and sand, gravel or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

aquifer - Any earth material such as sand and gravel or fractured bedrock which is saturated with water and will transmit water to wells.

aquifer thickness (b) - The vertical distance over which an aquifer is saturated with water under ambient conditions.

aquifer, unconfined - An aquifer in which there are no confining beds between the zone of saturation and the land surface. There will be a water table in an unconfined aquifer.

attenuate (contaminants) - To reduce the severity of contamination; to lessen the amount of contaminants.

Cambrian - The oldest period of the Paleozoic Era, from about 500 to 600 million years ago.

cone of depression - A cone shaped depression in the ground water table or potentiometric surface that develops around a well from which water is being withdrawn.

dBASEIII - A database management system marketed by Ashton-Tate. Data is stored in files (in table form) for defined fields (attributes). These files can be related through common fields.

desorption - The process of removing an adsorbed material from the solid on which it is adsorbed.

dispersion - The spreading out of contaminants which are dissolved in ground water as they move along with ground water flow. Dispersion is due to molecular diffusion, mechanical mixing on the microscopic scale and variations in directions and velocities of ground water flow resulting from macroscopic variations in hydraulic conductivity.

dissolution - The act or process of dissolving.

downgradient null point (X_L) - The maximum downgradient distance from which water is drawn into a pumping well. Also referred to as stagnation point.

drawdown -- A decline in the water table or potentiometric surface of an aquifer caused by the pumping of ground water from wells.

effective porosity (n) - The amount of interconnected pore space through which fluids can pass, measured as a volume of pore space per unit volume of aquifer.

facilitated transport - The enhanced mobility of contaminants in ground water thought to be caused by the effects of organic cosolvents or colloidal attachment.

geographic information system (GIS) - An interacting system of computer hardware and software that stores, manipulates, retrieves and analyzes information about the geographic distribution of any spatial information or characteristics.

ground water divide - A boundary within an aquifer across which there is no flow.

ground water recharge - The replenishment of ground water supplies by rain and snowmelt.

grus - A clayey residuum which is weathered material from granitic rock.

half-life - The time required for one-half of the original mass of contaminant to be degraded to simpler compounds.

hardness - A measure of the amount of calcium, magnesium and iron dissolved in water.

hydraulic conductivity (K) - A coefficient of proportionality describing the rate at which water can move through a permeable medium under a unit hydraulic gradient. Hydraulic conductivity varies with the density and viscosity of the fluid.

hydraulic gradient (i) - The change in total head with a change in distance.

hydraulic head - Height above a datum plane (such as mean sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a ground water system. Equal to the distance between the water level in a well and the datum plane.

hydrogeologic boundary - Any geologic or hydraulic condition which serves to define a logical region of ground water flow.

hydrogeology - A science dealing with the interrelationships of geologic materials, geologic processes and subsurface water.

hydrolysis - A chemical reaction in which water reacts with another substance to form two or more new substances. This involves ionization of the water molecule as well as splitting of the compound hydrolyzed.

ion exchange -- A reversible chemical reaction between a solid (ion exchanger) and a fluid (usually a water solution) by means of which ions may be interchanged from one substance to another.

isochrone - Plotted line graphically connecting all points having the same time of travel for contaminants to move through the saturated zone and reach a well.

isotropy - The condition in which properties of the aquifer are equal in all directions.

metavolcanic rock - Volcanic rock that shows evidence of having been subjected to metamorphism.

non-volatile organic compound (NVOC) - An organic compound which is not easily vaporized under normal environmental conditions.

oxidation-reduction - Two simultaneously occurring reactions during which the oxidizing agent gains electrons and the reducing agent releases electrons.

pcARC/INFO - A geographic information system software package marketed by Environmental Systems Research Institute.

Pleistocene - The earlier of the two most recent geologic epochs, in which glacial activity was very frequent; about 10,000 to 1 million years ago.

potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells, assuming the wells are screened at the same depth in a single, confined aquifer.

ppb (for aqueous solution) - Parts per billion; one gram contaminant per billion grams of solution.

ppm (for aqueous solution) - Parts per million; one gram contaminant per million grams of solution.

Precambrian - The earliest unit of geologic time; older than 600 million years.

precipitation - 1. In chemistry: The process of separating mineral constituents from a solution to form a solid phase. 2. In meteorology: the deposition of rain, sleet, hail and snow.

preventative action limit (PAL) - One of two types of ground water standards required under Wisconsin's Ground Water Law, 1983 Wisconsin Act 410. PALs have been established for 46 substances and are set at a percentage of the enforcement standards.

Proterozoic - The more recent of the two great divisions of the Precambrian.

recharge area - That portion of a ground water basin in which the net saturated flow of ground water is directed away from the water table. There are downward components of ground water flow in the aquifer in a recharge area. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

sorption - A surface phenomenon which may be either absorption or adsorption, or a combination of the two.

specific capacity - A measure of the effectiveness of a well. It is calculated from the discharge of a pumping well (pumping rate) divided by the drawdown of the well.

steady state conditions - Conditions in which ground water levels or hydraulic head do not change over time.

syenite - A group of plutonic rocks (rocks formed at considerable depth by crystallization of magma and/or by chemical alteration).

time of travel (TOT) - The time required for a contaminant to move in the saturated zone from a specific point to a well.

total dissolved solids - The total amount or mass of dissolved mineral material in a given quantity of water, usually reported as milligrams of solids per liter of water.

trace element (in water) - An element dissolved in very small concentrations (generally less than 50 ppb) in water. Examples are aluminum, arsenic, selenium, boron and lead.

volatile organic compound (VOC) - An organic compound which easily vaporizes under normal environmental conditions.

water table - The surface in an unconfined aquifer or confining bed at which the pore water pressure equals atmospheric pressure.

wellfield - An area containing two or more wells supplying a public water supply system.

wellhead - The physical structure, facility or device at the land surface from or through which ground water flows or is pumped from subsurface, water-bearing formations.

wellhead protection - Protection of the land area which contributes surface water runoff or ground water recharge to the water supplies eventually pumped by municipal wells.

wellhead protection area (WHPA) - The surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are likely to move toward and reach such water well or well field. Term may also be used to define a designated management area based on the ZOC and physical and civil boundaries.

zone of contribution (ZOC) - The area surrounding a pumping well that encompasses all areas or features that supply ground water recharge to the well. Term is synonymous with the physical definition of WHPA.

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