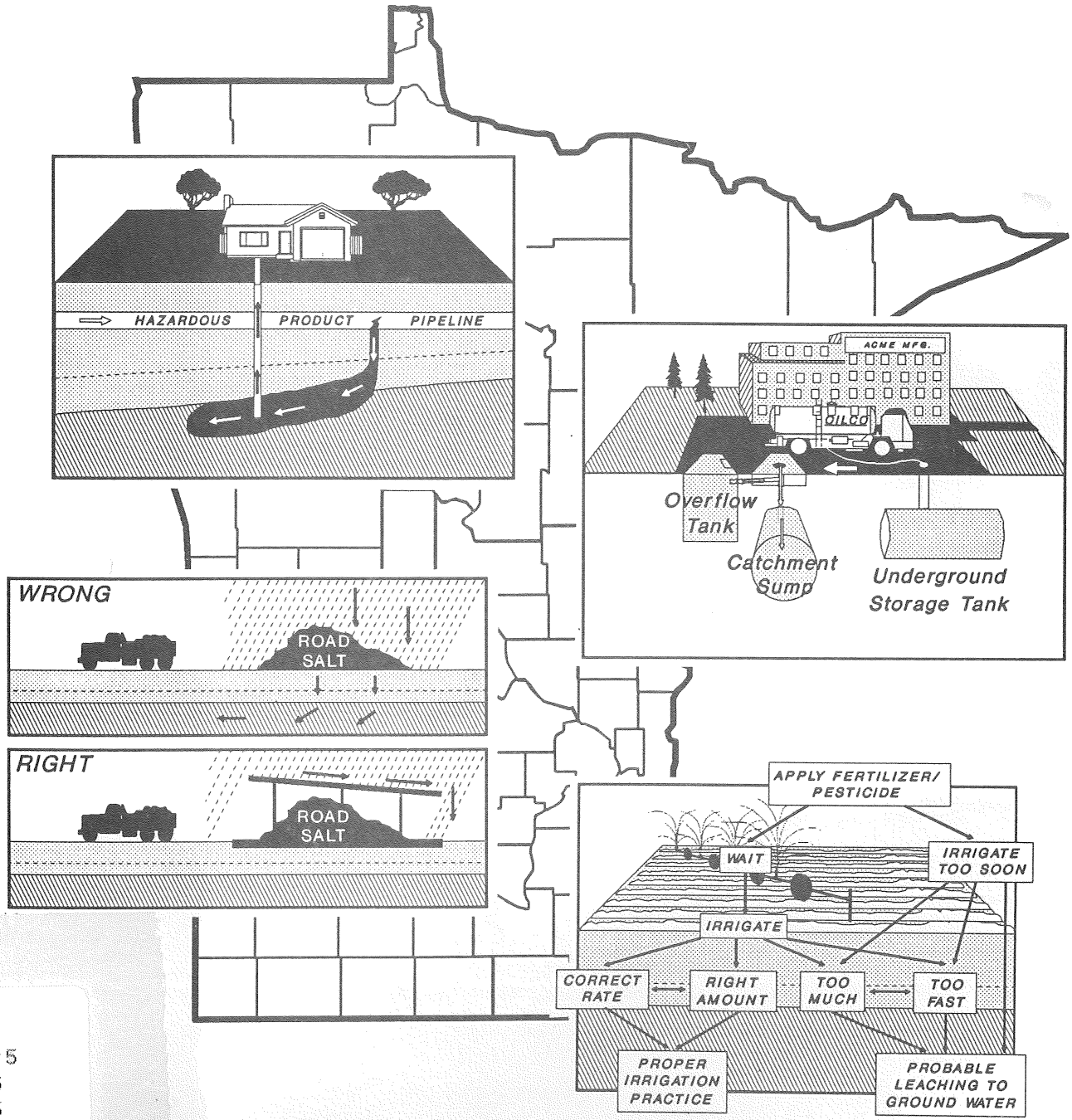
debook for Local Ground Water Protection in Minnesota



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SECTION 1 - INTRODUCTION

Three-quarters of Minnesotans depend on a safe and clean supply of ground water for their drinking water. Included in this portion of the state's citizens are more than 1.8 million people served by community water supply systems and virtually all of the rural population served by private wells. More than 90 percent of the state's municipal water supply systems rely on ground water.

In addition to drinking water, Minnesota relies on ground water to support its economy. Ground water is used for agricultural irrigation, food and beverage processing, industrial processing and livestock production. All of these activities are affected by the quality of the resource.

Minnesotans have become increasingly aware that they can no longer assume their ground water is safe or protected. Across Minnesota, in both urban and rural areas, the quality of ground water is being affected by land use activities at or near the surface. Recent state-wide surveys of community and non-community (motels, service stations and schools) water supply systems detected low levels of organic chemicals (volatile organic compounds, or VOCs) in many of the wells (Minnesota Department of Health, 1985 and 1988). These organic chemicals are synthetically produced and are commonly associated with agricultural, industrial, commercial and residential uses, in products such as dyes, pesticides, paint thinners, degreasers and drying agents.

Other state-wide studies have detected generally low levels of one or more pesticides in a significant number of community, irrigation and observation wells (Minnesota Departments of Agriculture and Health, 1989). The same studies detected the presence of nitrate-nitrogen at many of those same sites, with some levels exceeding the federal drinking water standards.

Although the levels detected are very low in most instances, there are continuing concerns about the long-term effect of these contaminants. For many of the chemicals, there are no federal standards and little is known about their impact on public health. Some are known carcinogens.

At the same time, the state's updated list of Superfund Permanent List of Priorities has grown to 188 identified hazardous waste sites. These are sites where further investigation and cleanup are necessary, activities leading to cleanup are in process or cleanup is complete and long-term monitoring, if required, is underway.

The purpose of this guidebook is to assist local governments in developing their plan for protection of ground water. Emphasis is placed on the prevention of ground water contamination to avoid the economic costs and impacts of after-the-fact cleanup. The handbook contains basic information about ground water systems, potential land use activities which may use, produce or handle contaminants, and the programs and areas of responsibility that are currently managed by federal, state and local authorities. Sources of available information regarding local ground water resources, technical assistance, related research and financial assistance are also summarized. Potential strategies available to local governments as part of an overall strategy to protect ground water are then discussed. Finally, a planning process is presented to guide local governments in the task of developing a plan or strategy for protection.

ECONOMIC IMPACT OF GROUND WATER CONTAMINATION

While public awareness of ground water contamination is growing, there is also an increasing realization of the costs and economic impacts of contamination and after-the-fact cleanup. These costs suggest that preventative programs may be less costly.

A recent report (Freshwater Foundation, 1989) shows that the costs of ground water contamination in Minnesota impact both private industry and local governments. Twenty-one Minnesota cities and 18 private companies indicated the estimated costs to date totaled more than $67 million. Costs included administration, cleanup and remediation of the site, new equipment and water treatment, consultant services, legal fees and the construction of new wells. Indirect costs included reduced tax revenues due to real estate devaluation and lost economic development opportunities, such as when a company chooses another location to avoid the potential liability of developing at the contaminated site.

LAND USE AND GROUND WATER QUALITY

With the growing public awareness of the problems of ground water contamination has come the realization that the source of the problem is almost always human activity on or near the surface of the earth. Pesticides are detected in ground water in intensive agricultural areas. Nitrates are detected in ground water where there is extensive use of nitrogen-based fertilizers, feedlots and manure application, and septic tanks. Industrial chemicals, gasoline and other contaminants are detected near leaking underground storage tanks, former dumps, airports, sanitary landfills, industry, businesses and government facilities such as military ordinance plants.

SENSITIVE AREAS

Ground water in some parts of the state is known to be more sensitive to contamination. In these areas the thickness, permeability, mineralogy, and number and type of geological layers or materials overlying the ground water allow potential contaminants to move easily downward from the surface to the aquifer. These conditions leave little chance for the physical, chemical and biological processes that occur in the soils and surficial geological materials to completely degrade or change the contaminant into a less hazardous substance; neither do state and local agencies have sufficient time to act to contain or clean up the contamination before its effects are widespread. Two examples of such situations are the high nitrate concentrations frequently found in the more susceptible karst areas in southeastern Minnesota and the near-surface glacial outwash sand and gravel aquifers in the east-central part of the state.

LOCAL GOVERNMENT AND GROUND WATER QUALITY

Many state programs have been established in response to federal laws and local initiatives to control or regulate potential sources of contamination. These programs address sources such as landfills, wastewater treatment facilities, hazardous waste disposal, and underground storage tanks which have the potential to discharge or release hazardous materials at or near the surface and infiltrate the ground water, affecting public and private water supplies.

Many other land use decisions involving potential sources of contamination are made by local governments or heavily influenced by citizens in local communities. These decisions include the location and standards for residential, business and industrial development, the siting and management of central wastewater treatment plants and on-site sanitary waste disposal systems, solid and household hazardous waste management, and the location, design and operation of public service and maintenance facilities. Local governments manage these activities through a variety of existing responsibilities and programs such as comprehensive planning, zoning, subdivision approvals, capital improvement programming and adoption of health and sanitary regulations. While such programs were established for other purposes, they may in many instances be adapted or expanded to address ground water protection.

The Minnesota Legislature recognized the importance of local governments in protecting ground water and other water resources in the mid-1980s. Several bills were passed authorizing or directing counties, watershed management organizations and local governments to develop long-range plans for managing water resources. In the Twin Cities Metropolitan Area, county plans include goals and policies for ground water protection and standards and guidelines for the implementation of the plan by watershed management organizations and local governments. In Greater Minnesota, comprehensive county water plans contain objectives for ground water quality and related land use conditions. Local governments amend existing water and related land resource plans and land use controls to conform to their county plan.

SUMMARY OF CONTENTS

This guidebook is organized into six sections. The following section, Section 2, provides a basic understanding of ground water systems. The section also includes general information describing ground water occurrence, movement, recharge and discharge and how this affects the potential for contamination. An overview of the occurrence of ground water resources in Minnesota is included in Appendix A.

Section 3 discusses land use and the associated potential contaminants which might affect ground water quality. In addition, the section describes the ways in which contaminants move from the surface and near-surface environment into ground water and the natural processes occurring in the underlying soils and geologic materials. Most of the chapter is an overview of general classifications of contaminants, their potential risks and the types of land use activities with which they are associated. Appendix B includes lists of contaminants found in ground water as well as the toxic or hazardous components of common household products.

Section 4 summarizes the current legislative and governmental framework for ground water protection beginning with major federal laws and programs which affect state and, ultimately, local protection efforts. Next, the influence of the Minnesota Ground Water Protection Act of 1989 and other state legislation and agency programs for ground water protection are discussed. A summary of the general responsibilities of local governments which might be used as part of a local strategy to protect ground water is then presented. Examples are given of local policies affecting ground water quality including water resource planning, comprehensive planning, adopting and administering land use controls, and solid and household hazardous waste planning. Appendices C and D summarize the major federal laws and state agency programs that influence ground water protection at the state and local levels. Appendix E lists federal and state agency acronyms used in the text.

Section 5 presents an overview of the potential strategies introduced in Section 4 that local governments might use to protect ground water quality. This section addresses both nonregulatory and regulatory strategies to manage site-specific land use activities that pose potential risks to ground water, such as septic tanks and feedlots. Also included is a discussion of resource-based strategies to manage special protection areas such as wellhead, ground water recharge, and geologically sensitive areas. Resource-based strategies require the integration of multiple strategies to protect critical resource areas from contaminants associated with certain land use activities.

Section 6 describes the various steps local governments can follow to develop a protection plan for managing local ground water resources.

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Rita O'Connell and Eric Porcher, Minnesota Pollution Control Agency; and
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SECTION 2 - GROUND WATER BASICS

Developing a plan to protect ground water first requires a basic understanding of ground water. The occurrence and movement of ground water is often difficult to visualize or understand because it is hidden underground in the cracks and pores of rock and soil materials. This section presents an overview of ground water concepts including its occurrence, movement, recharge and discharge, and how each of these affect the potential for contamination. A brief summary of the geography of ground water resources in Minnesota is presented in Appendix A.

HYDROLOGIC CYCLE

Water moves continuously, transported throughout the environment in an ongoing process called the hydrologic cycle (Figure 1). The major parts of the cycle are:

- Solar evaporation of surface water and transpiration from plants resulting in the movement of water vapor to the atmosphere;
- Condensation of water vapor into water;
- Precipitation released as rain, snow, and hail back to the earth, resulting in runoff to lakes, streams and rivers, or infiltration into the soil; and,
- Percolation of water through the soil layers to recharge aquifers, some of which discharge into lakes, streams and other surface waters.

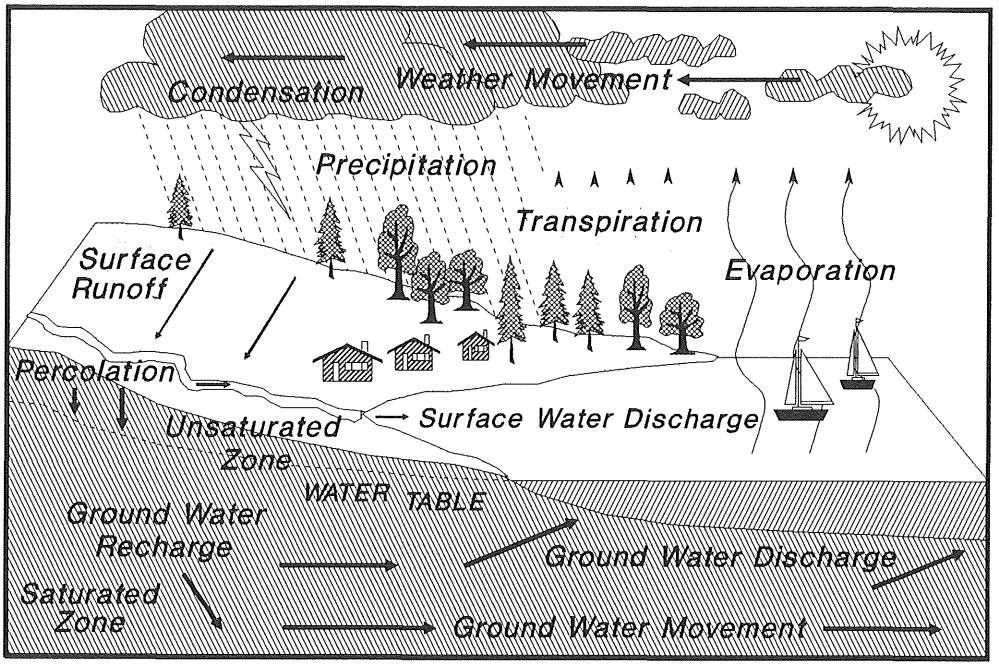
The interconnections between surface and ground water are important considerations when developing a plan to protect the ground water. For example, precipitation replenishes the ground water which can then resupply streams and lakes. Contaminants released on or near the surface may move into the ground water and eventually discharge to surface waters. Contaminants released in lakes or streams may ultimately seep into ground waters. These interconnections point out the importance of coordinating the development of local plans and programs for protecting both surface and ground water quality.

As water moves down through soil and underlying materials, some is retained in the unsaturated or vadose zone where the voids between the soil particles or cracks in the rock are filled with some combination of water and air (Figure 1). The unsaturated zone includes the soil layer and the underlying consolidated (rock) or unconsolidated geological material. This zone may range in thickness from zero feet, where the water table is at the surface, to hundreds of feet where the water table is quite deep.

Water percolates downward through the unsaturated zone into the saturated zone where all the voids and spaces between soil and rock particles are completely filled with water. The water table is the boundary or surface separating the unsaturated and saturated zones. The water stored in the saturated zone is called ground water. The water table roughly parallels that of the land surface. In many parts of Minnesota, the water table is close to the surface and may be exposed in low-lying lakes, streams, and wetlands. Springs are points of ground water discharge.

As water moves from the surface through the unsaturated zone to the saturated zone and, ultimately, to discharge back to the surface, water may encounter different materials. In Minnesota, which was once covered by glaciers, these materials can include not only unconsolidated clay, sand and gravel, but also consolidated materials such as sandstone, limestone and fractured crystalline rocks.

FIGURE 1. SIMPLIFIED HYDROLOGIC CYCLE



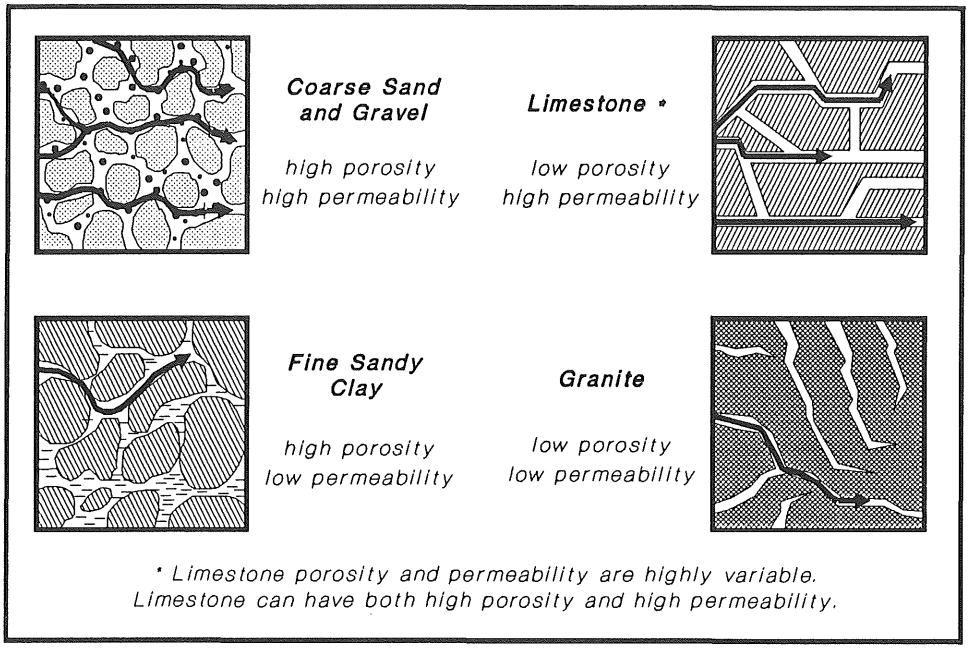
OCCURRENCE OF GROUND WATER

Ground water occurs underground in saturated geologic materials. Rock or other materials, such as sand, yielding a usable quantity of water are called aquifers. The water occupies the spaces or voids such as intergranular pores between sand grains or cracks and cavities in rock layers. For a geologic material to be a productive source of water, it must be both porous and permeable. Porosity is the percentage of the geologic unit's volume that is occupied by openings or spaces.

Permeability is the measure of the relative ease with which water can move or flow freely through a material (Figure 2). An aquifer's permeability is determined by its composition and the degree to which its pore spaces are interconnected. Aquifers consisting of primarily gravel and coarse sand are both porous and permeable due to the large well-connected spaces between the grains. When the aquifer material is fine sand or includes significant amounts of silt and clay, the permeability is likely to be lower. A fine-grained deposit like silt or clay may have a high porosity and contain a large amount of water when saturated, but the pores are so small that most of the water is held by molecular attraction, limiting its movement. In fractured rock aquifers, such as limestone or granite, the permeability is determined by the number and size of fractures and the degree to which they are interconnected. Similarly, pore spaces in sandstone aquifers must be interconnected to allow effective ground water movement.

There is no clear definition of the minimal yield required to designate a geologic material an aquifer. In some areas of Minnesota, wells are supplied by water table aquifers that yield less than one gallon per minute to continuous pumping. An aquifer with insufficient yield to supply a large city may be adequate to supply a small rural community.

FIGURE 2. GENERALIZED GROUND WATER AVAILABILITY



TYPES OF AQUIFERS

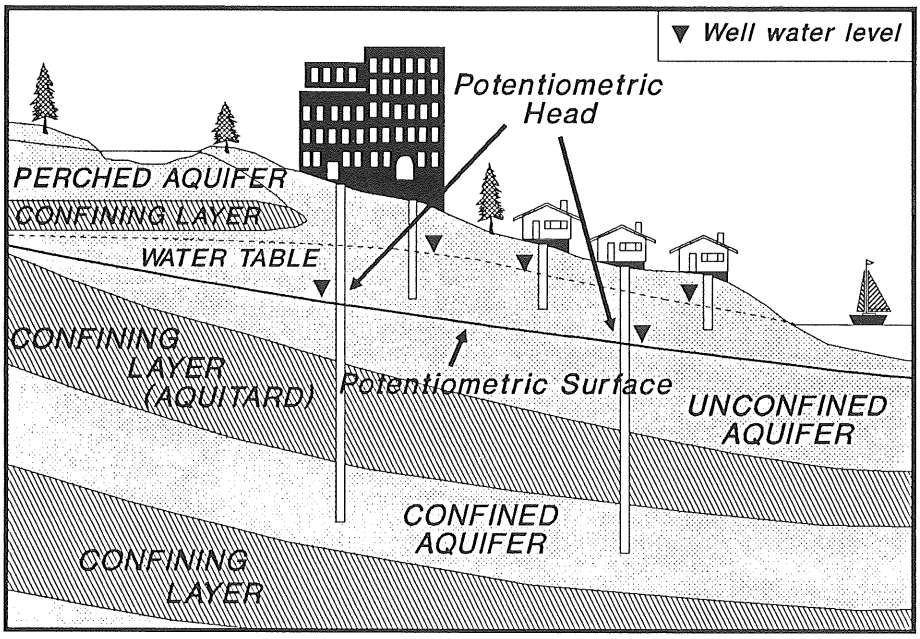
The characteristics and physical relationships of soils and geologic materials at and under the earth's surface create different types of aquifers. Aquifers may occur at or just under the surface or hundreds of feet beneath the land surface. Aquifer thickness may range from a few feet to hundreds of feet The lateral extent also varies; some aquifers underlie many counties while others may occur in only part of a county.

Water occurs in aquifers under two different conditions, unconfined and confined. Unconfined aquifers are usually close to the land surface, typically in sand and gravel deposits, but also in consolidated materials such as sandstone and limestone. Unconfined aquifers are exposed to the atmosphere through pores in the overlying material, thus they are at atmospheric pressure. The water level in an unconfined aquifer is referred to as the water table (Figure 3). The water table aquifer is the uppermost aquifer with unconfined conditions.

In some instances, perched water may form in limited areas above the water table. Water percolating downward through the unsaturated zone creates a saturated condition above a less permeable layer such as clay or shale. Site-specific data are needed to define the extent and depth of this condition.

In general, a confined or artesian aquifer is completely saturated and bounded above and below by confining beds or aquitards. Confining beds are units of relatively less permeable material than that of the aquifer. For example, in the Twin Cities Metropolitan Area, the Mount Simon - Hinckley Aquifer is confined by the overlying Eau Claire (sandstone and siltstone) formation. The silt-sized particles in the Eau Claire formation fill the pores between the larger sand-sized particles and reduces the permeability. Confining layers that sandwich aquifers are not totally impermeable; water can move slowly into and out of aquifers through the confining layers.

FIGURE 3. TYPES OF AQUIFERS



In instances where there is more than one confined aquifer, water may move between them slowly through the pores or fractures in the aquitards that separate them. Contaminants reaching the one aquifer may eventually affect the other aquifer.

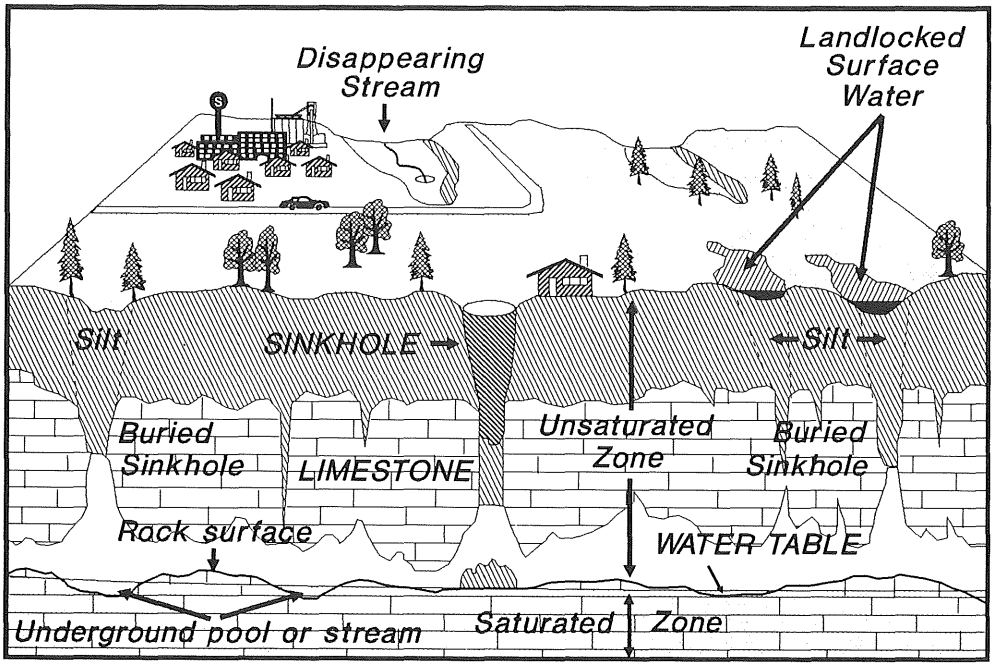
The elevation level to which water rises in a stand pipe or unpumped well (the static water level) in a confined aquifer is called the potentiometric head. Since confined aquifers are under pressure, the water level in a confined aquifer always rises above the top of the aquifer. In some cases the pressure is so great the water level is above the ground surface and the well is a flowing well. Static water levels are mapped to define the potentiometric surface of an aquifer.

In southeastern Minnesota, another type of aquifer is present in karstic limestone (Figure 4). The nature of this type of bedrock affects both the topography and the hydrology of the area. As a result of millions of years of erosion and dissolution, the limestone formations have developed a network of fissures and cavities, that, in some cases, form underground caverns and caves that look something like Swiss cheese.

As water percolates slowly through the soil and moves down into the bedrock, it may dissolve the limestone rock along some of the fractures and joints, slowly enlarging them. The enlarged fractures eventually carry most of the ground water, which speeds the development of further karst features. The ground water flowing through these widened paths can be as rapid as flow through a pipe. If the soil mantle is thin or absent in karst areas, the aquifers may be readily contaminated by pollutants introduced to the ground surface above them. In some instances, sinkholes form at the surface where the underlying material collapses, providing easy conduits for the infiltration of precipitation and contaminants.

Appendix A presents a short summary of the geology and geography of the major ground water aquifers in Minnesota.

FIGURE 4. KARST HYDROGEOLOGIC FEATURES



GROUND WATER RECHARGE AND MOVEMENT

Aquifers are resupplied principally from melting snow or rain that infiltrates the overlying soil and percolates downward through the unsaturated zone; however, seepage can also occur from lakes and other surface waters. The resupply process is called aquifer recharge. Water table or surficial aquifers are recharged from precipitation which percolates downward through the unsaturated zone. Confined aquifers are recharged by seepage of water through the overlying confining layer or layers, but at a slow rate. Confined aquifers may also be recharged from a long distance where the confining layer is absent and the aquifer is exposed at or near the surface (Figure 5). These recharge areas may be located outside the community where the ground water is used.

Ground water flow systems may occur over large regions as well as locally. The regional movement of water in a surficial aquifer typically reflects the general topography. Ground water is usually recharged in upland areas and moves deeper in the aquifer toward low points in a drainage basin where it discharges to a major stream, river or other surface water body (Figure 6). Regional movement may include an extensive area, such as several counties. As an example, seepage from regional aquifers in the state supply water to the Minnesota and Mississippi Rivers from their headwaters on through the Twin Cities Metropolitan Area. Local ground water flow systems generally follow local topography. A good example is the beach ridge aquifers bordering former Lake Agassiz in northwest Minnesota. The primary difference between the two movements is that local flow is restricted to a relatively smaller surface area, such as a watershed or one of its sub-basins.

Ground water can discharge to surface water or be recharged by surface water, depending on the geologic setting. Under normal water table conditions, for example, ground water will discharge to the lake or stream (Figure 7). Under drought conditions, the water table may fall below the base of a water body. Water will seep through the river or lake bottom and act as a temporary

FIGURE 5. LOCAL AND DISTANT RECHARGE AREAS

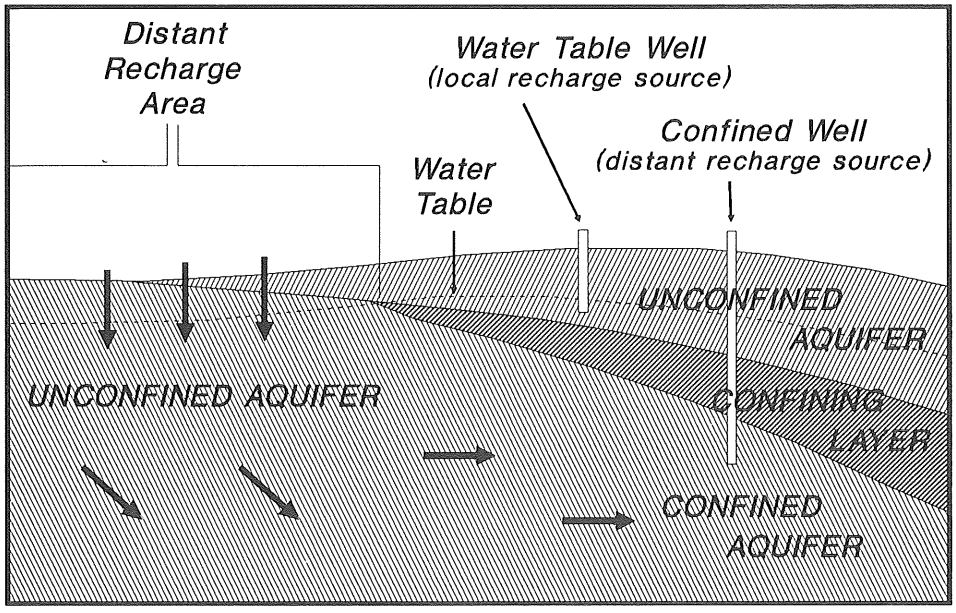
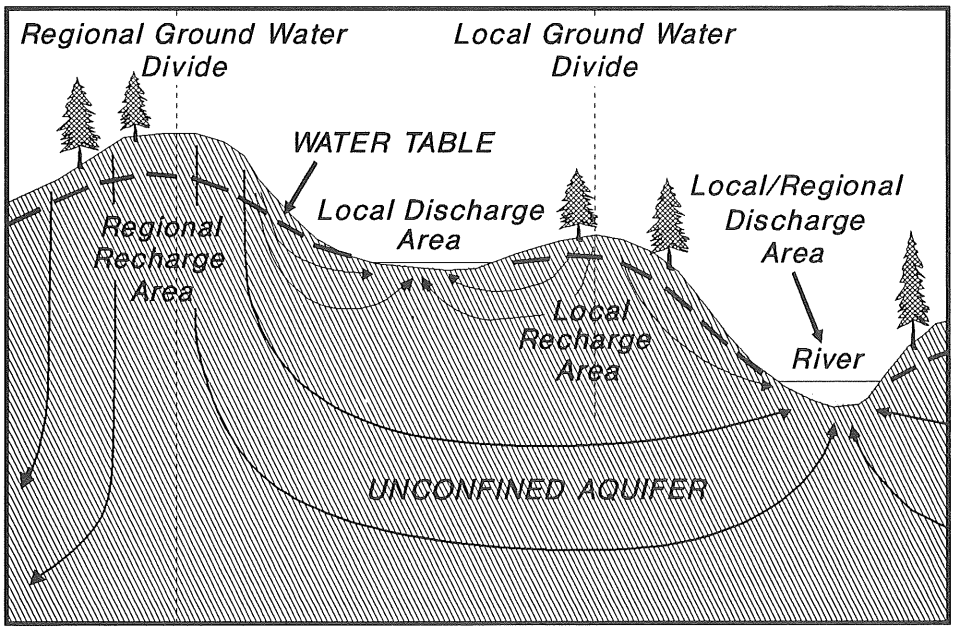


FIGURE 6. LOCAL AND REGIONAL GROUND WATER FLOW PATTERNS



recharge source for the water table aquifer. After drought conditions have eased and the water table has returned to normal, ground water will again discharge to surface water.

The construction and use of a well or wells in an aquifer affects the movement of ground water. When a well is pumped in a water table aquifer (Figure 8), flow is induced toward the well, and the aquifer surrounding the well is dewatered. In a confined aquifer, a pumping well lowers the pressure near the well, but the aquifer remains saturated.

FIGURE 7. GROUND WATER AND SURFACE WATER INTERACTION DURING NORMAL AND DROUGHT CONDITIONS

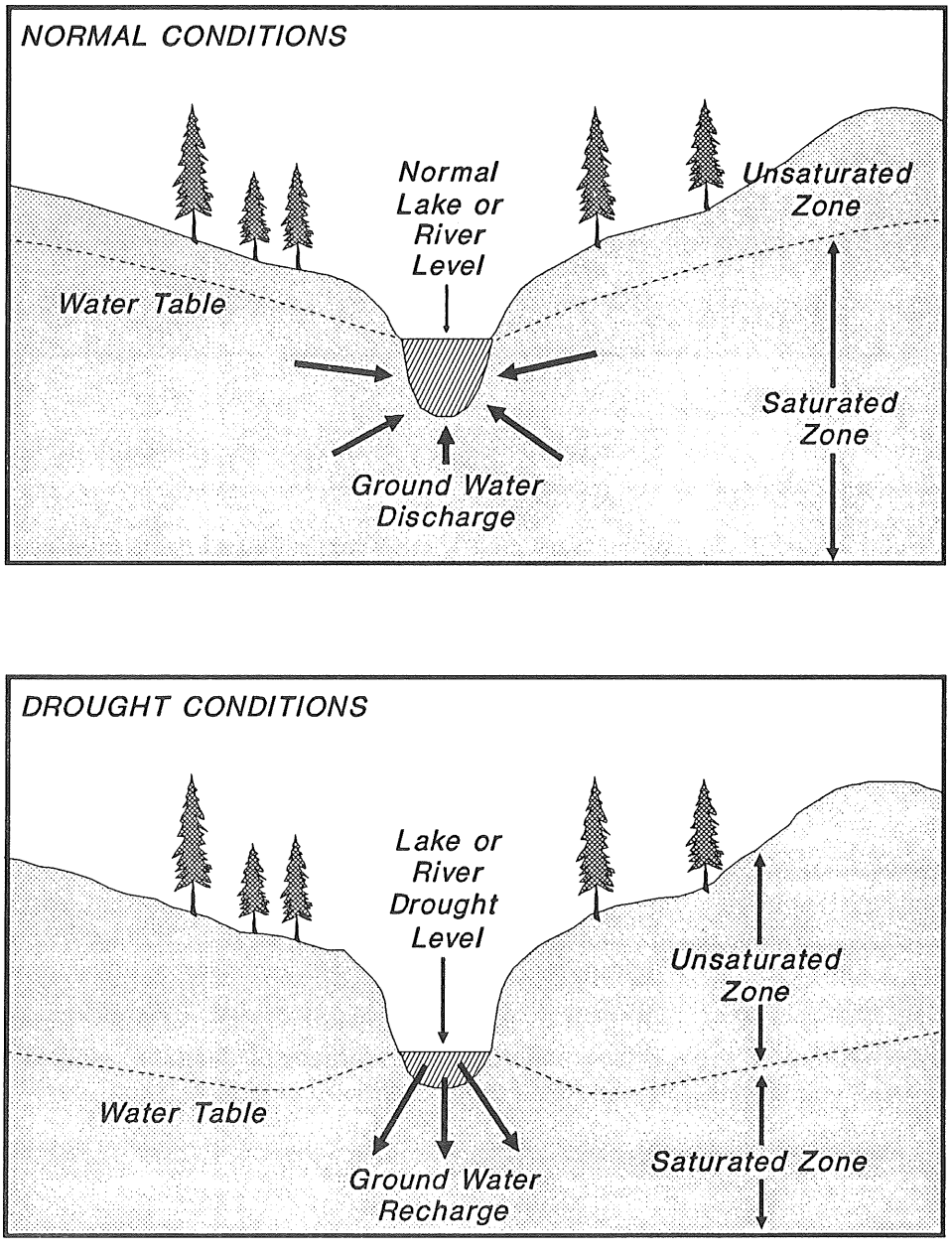
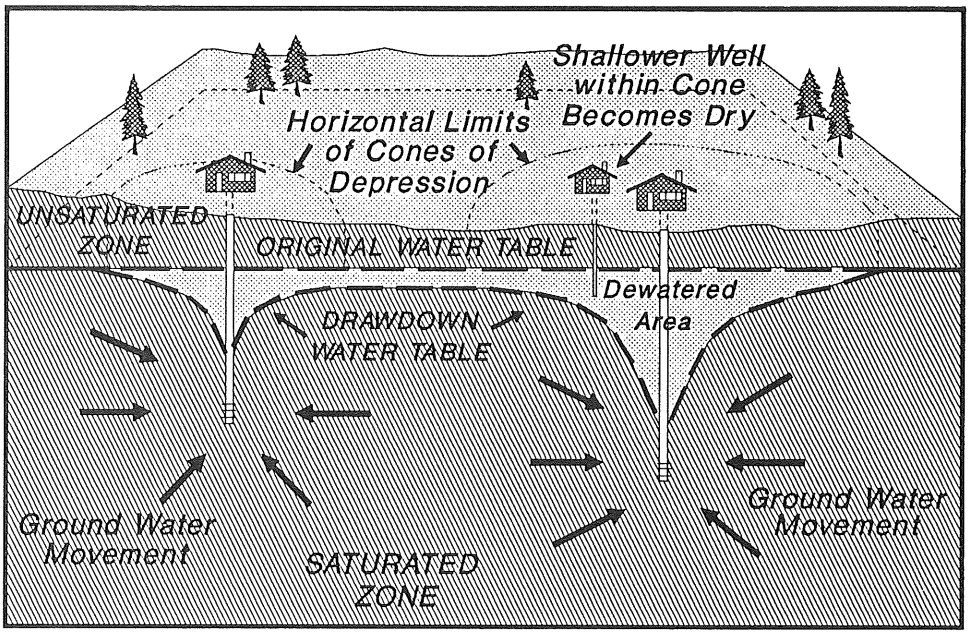


FIGURE 8. WATER TABLE DRAWDOWN DUE TO PUMPING



Rates of ground water movement can vary greatly both vertically and horizontally. Movement in an aquifer varies from the imperceptible to many hundreds of meters per year, but more typically about 10 to 100 meters per year. By comparison, water in a stream moves rapidly and can travel many miles per day. The length of time for a contaminant to reach a well or a surface water body is determined primarily by the rate of movement of the ground water it affects, although other factors such as the type of contaminant also influence how fast contaminants travel.

POTENTIAL FOR GROUND WATER CONTAMINATION

All ground water in Minnesota is at some risk of contamination but this risk is highly variable. The potential for contamination is a combination of 1) the properties of the soil and other geological materials overlying the aquifer and the aquifer itself, 2) the physical, chemical and biological characteristics of the contaminants, 3) the possibility of their release into the environment, and 4) the timely and appropriate response and management to control a release.

A variety of terms have been used or proposed to describe the potential for ground water contamination. Although there is no standardized terminology at this time, sensitivity, susceptibility and vulnerability are the three terms used most often.

Geologic or intrinsic ground water sensitivity is the relative ease with which a contaminant released at or near the land surface can migrate to the particular aquifer. The less time it takes for the contaminant to reach the aquifer, the less time there is for a response to prevent or minimize contamination or for natural processes to convert the contaminant to another substance that may be less of a problem. Natural processes such as dilution, adsorption (chemical

attachment of molecules to soil particles), absorption (physical attachment), oxidation, and biological breakdown of the substance can reduce contaminant concentration, particularly in the unsaturated zone.

The key characteristics of the unsaturated materials that influence the ease of contaminant movement are the permeability, composition and thickness of the materials between the source of the contaminant and the aquifer. For example, an aquifer may be overlain by material hundreds of feet thick but the material could be entirely composed of permeable sand and gravel. Thin or highly permeable unsaturated zones provide significantly less time for adsorption, biological breakdown and other processes to occur, resulting in a greater likelihood of ground water contamination. Section 6 provides a more detailed discussion of the characteristics and criteria for assessing ground water sensitivity.

Ground water susceptibility is often used to describe the relative ease with which a particular contaminant applied at or near the surface can migrate to the aquifer of interest. Evaluation of susceptibility includes the intrinsic sensitivity of the aquifer plus additional factors relating to the nature of the contaminant. Not all chemicals behave similarly in the same soil and geologic environment. While some contaminants are captured quickly by soil particles, the movement of others is not much affected by the material in which it travels. In some instances, separate evaluations for each contaminant or type of contaminant, such as "surficial aquifer nitrate susceptibility" or "surficial aquifer atrazine (or triazine family) susceptibility," may be needed when selecting priorities for ground water protection and specific protection strategies.

Ground water vulnerability typically includes the element of risk of release in addition to contaminant susceptibility and intrinsic sensitivity. The term vulnerability addresses land use activities and pollutant presence and handling. For example, a near-surface sandy aquifer may occur in an area with no development or potential sources of contaminants. In this instance, while the aquifer is intrinsically sensitive, it is not particularly vulnerable at this time. Planning for ground water protection would require reevaluation of the aquifer vulnerability as land use changes occur.

SECTION 3 -
GROUND WATER CONTAMINANTS AND LAND USE

INTRODUCTION

When planning for ground water protection, one of the first tasks for a local government is to assess and inventory existing and potential sources of contamination in the area and then develop strategies to manage them. To accomplish this, the local government must first understand the various chemicals and other substances that are considered contaminants and possible sources of ground water contamination. This section summarizes the types of potential contaminants which affect ground water quality, some of the risks associated with them, and some of the more common land uses and activities that are potential sources of these substances.

Pathways for Contaminant Movement

Whether or not ground water contamination occurs in a specific instance depends greatly on the nature of the land use activities at or near the land surface and the ability of the contaminant to reach the aquifer. Once a contaminant is released, there are four ways by which ground water contamination occurs: infiltration, direct migration, inter-aquifer exchange, and recharge from surface water (Figure 9).

Infiltration occurs when a liquid or solid contaminant dissolved by precipitation filters through the soil and moves downward to the aquifer. Infiltration is probably the most common ground water contamination mechanism.

Direct migration occurs when a contaminant flows directly from an at- or below-ground level source, such as an underground storage tank and pipeline, into the aquifer. This frequently occurs where the water table is at or near the surface.

Inter-aquifer exchange is the spreading of contaminants from a contaminated aquifer to an uncontaminated aquifer. This usually occurs in aquifers that are hydraulically linked or where an improperly constructed or sealed well penetrates more than one water-bearing formation.

Recharge from surface water can be a source of contamination. Some surface waters are constantly losing water to the ground water system. For example, organic compounds which are present in a "losing" river can contaminate the aquifer below. In other instances, pumping or drought can lower the water table to the point where, instead of ground water contributing to surface water, this relationship reverses and surface waters recharge ground water.

When ground water is contaminated, it usually affects only that part of the aquifer down-gradient of the site. Ground water typically has a laminar flow pattern which could be thought of as thin sheets, one on top of the other, that slide past one another. A particle in one sheet tends to stay in that sheet. This means that ground water is generally subject to little mixing and follows predictable, trackable paths. In contrast, contaminants released in surface water often become mixed throughout the water body due to the turbulent nature of the flow. Pollutants from point sources such as landfills travel in masses called plumes, which look like clouds or fingers (Figure 10). Fortunately, the laminar flow of ground water tends to retard the lateral spreading of contaminants. The shape and concentration of the plume depends primarily on local geology, physical and chemical properties of the contaminant, rate of pollution by the contaminant source, dispersal of ground water flow, and modifications in flow from wells or pumping.

FIGURE 9. SOURCES OF GROUND WATER CONTAMINATION

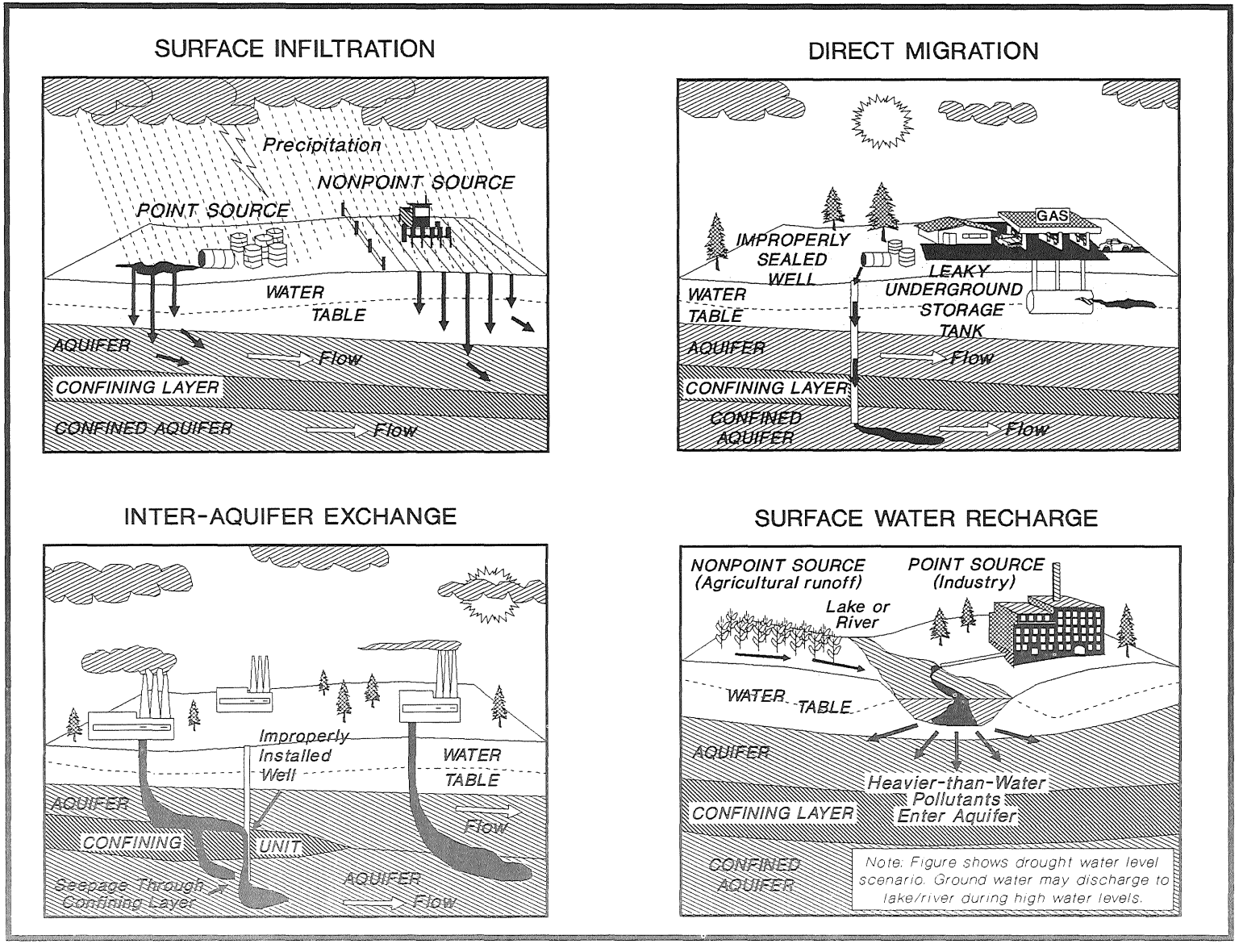
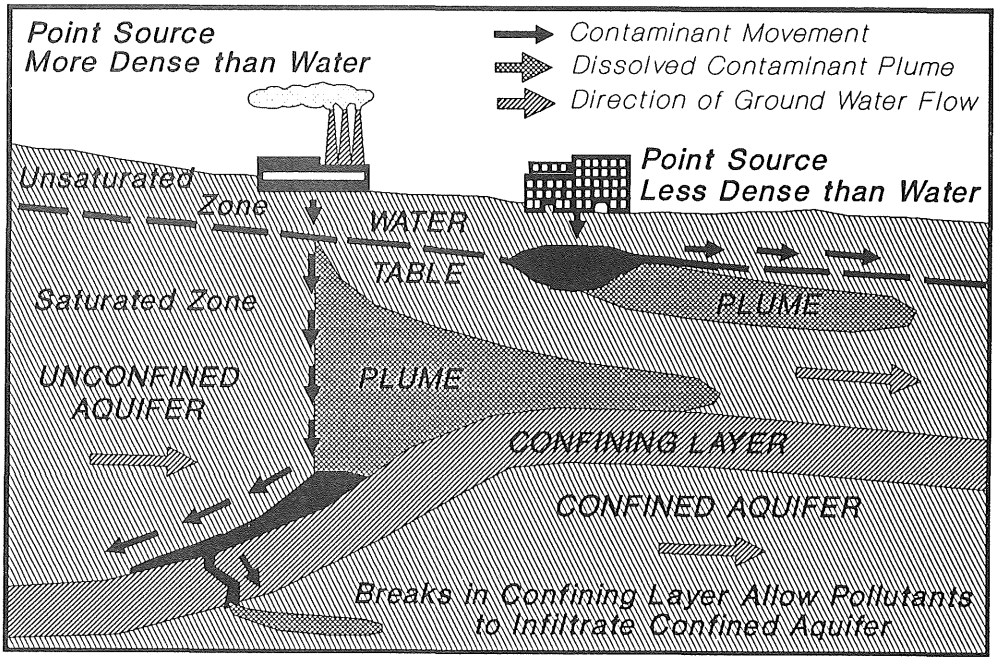


FIGURE 10. GENERALIZED MOVEMENT OF GROUND WATER CONTAMINATION FROM POINT SOURCES



Natural Defense Mechanisms

Natural physical, chemical or biological processes which occur in the soil and other geological materials underlying the contaminant source can affect the risk of ground water contamination. These processes can reduce the concentration or alter the form of the contaminant, thereby mitigating its effect. The effect is further influenced by time: the longer it takes for a contaminant to reach ground water, the more opportunity there is for these processes to occur. Conversely, the shorter the time, the less these processes can act. However, the effects of the processes may be temporary or incomplete, and some degradation of the ground water may occur.

The most common physical mechanism or process that can attenuate contamination is dilution. Contaminants may be diluted by mixing with surface water runoff as it infiltrates the soil. Some mixing also occurs by diffusion in the unsaturated zone, which consists of mixing on a molecular level as ions move from points of higher to lower concentrations. Contaminants may also be diluted within the saturated zone due to dispersion resulting from molecular diffusion and mechanical mixing. Plumes are formed as the dissolved contaminants flow with the ground water away from the source. Contaminants are much less concentrated at the edges of the plume than near the source. Depending on the percolation rate, some contaminants may simply evaporate in the subsurface before they reach the aquifer.

Chemical processes in the subsurface which may mitigate the effect of a contaminant source include chemical precipitation, adsorption, and hydrolysis. These processes remove chemicals from the contaminant solution at least temporarily.

Precipitation within the subsurface results in the formation of a crystalline substance within the porous material. The substance may be redissolved if the chemical conditions change.

Adsorption refers to the removal of a chemical from solution by fixation onto the subsurface material, such as clay particles. Rather than the contaminant crystallizing as it does in the precipitation process, individual molecules "stick" to the surrounding filtering material.

Hydrolysis refers to the chemical reaction of a compound with water. This process uses water to break the contaminant down into different products. Sometimes it takes more than one breakdown, i.e., more than one hydrolysis reaction, to change the contaminant into a less toxic or non-toxic product, although sometimes breakdown products are more toxic.

Biological mechanisms are driven primarily by bacteria, which play an important part in the chemical reactions that naturally clean up hazardous material in ground water. They are relatively abundant in the ground water zone, and can permanently remove or alter chemical compounds within the contaminant solution. However, not all contaminants are affected by bacteria, and the potential impact is determined by the specific geological and chemical conditions at the site.

TYPES OF CONTAMINANTS

All ground water contains some natural impurities, mostly dissolved from the rock or sediment through which it travels. Examples of this are calcium, iron, sodium and carbonate. The types and concentrations of natural impurities vary depending upon the geology and soil in the area. In addition to these natural variations, ground water may contain contaminants from the many different activities occurring on the land's surface.

There are four general types of contaminants that have been detected in studies of ground water at various locations in the United States: biological contaminants, organic and inorganic substances, and radionuclides. When concentrations of these contaminants exceed toxic limits, they can be a hazard to the health of the public consuming the ground water as drinking water. In addition to the potential public health concerns, ground water contaminants may also make water unsuitable for industrial and agricultural use.

The potential health effects of ground water contaminants are typically divided into two classes: acute and chronic effects. Acute effects occur as a result of contact with high levels of a contaminant over a short period of time. Symptoms include nausea, skin irritation, central nervous system damage and, in some cases, death. They usually occur shortly after exposure.

Chronic effects are those that occur as a result of long-term exposure to contaminants at levels lower than those which would cause an acute attack. Chronic effects, which include cancer, mutations, immunological changes, birth defects and other reproductive problems, are much more difficult to diagnose than acute effects.

Biological Contaminants

Biological contamination is the most common form of ground water contamination affecting human health. Bacteria, viruses, parasites and other microbiological agents that can cause illness fall into this category. Common types of bacteria found when testing ground water include *Escherichia coli*, a type of bacteria that is not necessarily harmful, but exists readily in human and animal wastes and may indicate the presence of other more harmful bacteria. Microbiological organisms are the cause of many illnesses such as typhoid, tuberculosis, cholera and hepatitis.

The likelihood that microbiological organisms will cause ground water-related illness depends on their ability to survive and migrate through soils and aquifers. The two most important factors in

an organism's ability to survive are temperature and soil moisture. They survive best in low temperatures and saturated conditions. Time is also a factor. Over time, the organisms may starve, be eaten by other organisms or die. Survival time will affect how far the organisms will travel from the source of contamination and the potential risks to local wells.

Inorganic Contaminants

Inorganic substances include metals, salts and other chemical compounds which do not contain carbon. A study by the United States Office of Technology Assessment (OTA), 1984, identified 37 inorganic substances in ground water supplies at various locations around the United States, including 27 metals (Appendix B, Table B-1). The most common substances exceeding EPA primary drinking water standards were fluoride and nitrate, as well as the toxic metals of cadmium, selenium, mercury, lead and silver (The Conservation Foundation, 1987).

Nitrates (compounds with oxidized forms of nitrogen) may be the most common form of ground water contaminant in the United States. Low levels of nitrates (less than ten milligrams per liter) may be natural due to nitrate release by decomposing vegetation. High levels (greater than ten milligrams per liter) may indicate contamination is occurring from sources other than natural decomposition, such as fertilizer application, animal waste, septic tank leakage or landfills.

The ingestion of high concentrations of nitrates has been linked to methemoglobinemia, or "blue baby's disease". The nitrate is reduced to nitrite (NO_2) in the infant's stomach and ultimately inhibits the release of oxygen from the infant's blood (Minnesota Pollution Control Agency and Minnesota Department of Agriculture, August 1991).

The health effects of the many chemical compounds found in ground water are not fully understood. For a large number of the chemical compounds found in ground water, there are little or no toxicity data available. However, information that is available indicates some of these chemicals can cause serious health problems, conditions that range from skin irritation to cancer and birth defects. Health and environmental protection agencies have not yet established standards or safe limits for drinking water for many of the substances.

The health effects from exposure to the metals detected in ground water vary. Some, such as iron and manganese, are not known to have any toxic effects. Others, such as arsenic, lead, mercury and selenium, are known to produce acute and chronic health problems at high doses. Even at low doses, toxic metals generally tend to accumulate in the body because they do not break down. It is usually this gradual build up of toxics that leads to health problems.

High levels of inorganic salts may also cause adverse health effects. The most common form of salt, sodium chloride, is thought to be the cause of hypertension, which in turn contributes to strokes and heart disease. Salts also have the potential to cause abnormal swelling of the blood vessels and kidney damage.

Organic Contaminants

Although organic (carbon-containing) compounds occur naturally, tens of thousands of synthetic organic compounds have been developed in laboratories over the past several decades. Organic compounds, which contain carbon, are ingredients in a variety of widely used products such as dyes, food additives, detergents, plastics, solvents and pesticides. Some of the more common natural and synthetic organic compounds are listed in Appendix B, Table B-1. The recent discovery of synthetic and natural organic compounds in ground water in various parts of the U.S. and Minnesota is a cause for concern. Many organic compounds, especially volatile organic

compounds (VOCs), are more mobile because they readily dissolve in water. Also, some are less susceptible to degradation and breakdown through the natural biological and chemical mechanisms discussed earlier in this section.

Information on the acute and chronic effects of many organic chemicals is limited. But it is known that exposure to certain organic chemicals in high or low doses can result in health problems. Some of the symptoms related to this contamination are nausea, dizziness, rashes, and liver and kidney damage. Evidence of reproductive problems has been linked to exposure to high doses of DBCP, vinyl chloride, EDB, benzene, toluene, and xylene. Exposure to low concentrations of these chemicals may lead to impairment of the central nervous system and skin eruptions. Some organic chemicals that have been detected in drinking wells are confirmed human or animal carcinogens. The U.S. Environmental Protection Agency, Office of Water, maintains an assessment of the carcinogenicity of individual contaminants found in drinking water. This information can be obtained by calling the "Safe Drinking Water Hotline" in Washington, D.C. (1-800-426-4791).

Exposure to organic pesticides is also of concern to health experts. Long-term exposure to certain pesticides can cause liver damage, reproductive impairment, birth defects and cancer.

Radionuclides

Almost all ground water contains some amount of naturally occurring radionuclides or radioactive materials, such as radium. The types and levels of these substances vary geographically, depending on the local geology. Approximately 20 radionuclides are known to occur in ground water, originating from both natural radiation and radioactive substances produced by human activity. Activities associated with the radionuclides include the production of nuclear power and scientific research. Radionuclides are a special concern because of their longevity, ability to migrate with ground water, and potential health impacts. In general, human exposure to radiation can cause a wide range of carcinogenic, mutagenic, teratogenic, and reproductive effects. Appendix B, Table B-2 contains a list of known and potential radionuclides.

LAND USE AND CONTAMINANTS

Potential contaminant sources are numerous. They are found in urban and rural locations, and in industrial, agricultural, commercial and residential settings. Potential contaminants may be released in a variety of ways, such as onto the ground surface via fertilizer application, under the surface but above the water table from landfills, or below the water table as a result of unsealed or improperly constructed wells.

A source of ground water contamination can be either point or non-point. A point source is a discrete, identifiable source where the contaminant flows in a fairly distinct plume, such as from an underground tank for bulk gasoline storage. Because they are identifiable, they are easier to manage for the purpose of ground water protection.

A non-point source is widespread and relatively difficult to trace to its precise origin. An example of a non-point source is the application of commercial nitrogen fertilizer onto farmland. The nitrogen cannot often be traced to one specific point because it is most likely that nearly all of the farmers in the area are applying nitrogen fertilizers. Residences in rural areas may also be served by septic tanks, another source. Because of their diffuse origin, these types of contaminants are more difficult to manage.

The following discussion identifies the major potential sources of ground water contamination and the contaminants associated with them. This information is summarized in Table 1. The list,

while not intended to be comprehensive, does indicate the more common sources of contaminants. Local governments will want to identify all potential sources when developing their ground water protection plan, particularly those that are unique to their area. The sources are organized around four groups: agricultural, industrial and commercial, municipal, and other miscellaneous sources, although some overlap does exist.

Agricultural Land Uses

The land uses and activities below are generally associated with agricultural activities but may be present in urban or other rural settings, for example, the use of fertilizers and pesticides on residential or commercial lawns and gardens.

Animal Feedlots and Waste Storage and Application

The raising of livestock and poultry on farms and feedlots is a potential source of ground water contamination because of the production, storage and disposal of large volumes of animal wastes. Feedlots are generally defined as outdoor areas where animals are concentrated for feeding and other management purposes. The storage of animal waste occurs in concentrated areas on the ground, or in concrete or earthen pits. Animal waste is also land spread as fertilizer.

The potential contaminants associated with animal waste are nitrogen, chloride, and bacterial or viral pathogens. The contaminants enter the ground water by infiltrating through the soil beneath the site or as runoff to nearby low areas. Land spreading of the waste can lead to increased levels of nitrogen in the ground water when the amount of waste applied or concentration of nitrogen in the waste is greater than what crops can efficiently use. The excess nitrogen leaches through the underlying soil into the ground water.

Fertilizer Application

Large amounts of commercial fertilizers are used on farms to increase productivity and in urban areas on residential and commercial lawns, golf courses, recreation areas, gardens and other areas. Commercial fertilizers include a variety of types and concentrations of nitrogen, phosphorus, potassium, and trace elements. Nitrogen is the major concern for ground water pollution. When an excessive amount of nitrogen-based fertilizer is applied, the excess leaches through the soil. Even normal application necessary for economic yields can result in some leaching of nitrate, particularly in sandy or thin soils. Because nitrogen is relatively soluble in water and is not generally attracted to soil particles, it can seep readily through the soil and into the ground water.

The phosphorus in fertilizer is also a concern. Because of the amounts applied, it is a potential contaminant. However, while nitrogen is readily dissolved in water and passes through the ground easily, phosphorus is less soluble and tends to attach to soil particles. Therefore, less phosphorus is carried down into the ground water.

Irrigation and Chemigation

Irrigation can contribute to ground water pollution in two ways. Irrigation water may leach potential pollutants (land-applied fertilizers and pesticides) into the ground water. Over-irrigation may worsen this problem. In addition, chemicals may also be applied through irrigation systems, often referred to as chemigation. If the required back-flow prevention mechanisms are not installed and maintained properly, these chemicals may flow back into the well and ground water.

Table 1
POTENTIAL CONTAMINANTS ASSOCIATED WITH VARIOUS LAND USES

Sources	Inorganic Substance	Organic Substance	Radio-Nuclide	Bio-logical
Agricultural Land Use				
Animal feedlots and waste storage and application*	X	X		X
Fertilizer application	X			
Irrigation and chemigation	X	X		
Pesticide application	X	X		
Industrial/Commercial Land Uses				
Hazardous materials use, storage and handling	X	X	X	X
Hazardous waste disposal*	X	X	X	X
Mining wastes*	X	Poss. minor	Poss. minor	
Salvage and junk yards*	X	X		
Storage tank and pipeline leaks*	Possible	X		
Municipal Land Uses				
Incinerator ash*	X	X		
Public service and maintenance facilities*	X	X		
Road salt, storage and use of*	X			
Sewage and industrial effluent*	X	X		X
Sewage sludge*	X	X		X
Sewer (sanitary) leakage	X	X		X
Solid waste landfills*	X	X		X
Urban runoff	X	X		X
Other Sources				
Accidental spills*	X	X	Poss. minor	X
Cemeteries*		X		X
Infiltration of polluted precipitation and surface water	X	X		X
Injection wells*	X	X		X
Military facilities*	X	X	X	X
On-site sewage treatment systems (individual)	X	X		X
Well construction and abandonment	X	X	Poss. minor	X

* Indicates the source of pollution may be a "point source", depending on the use or facility and current federal and state regulations.

Pesticide Application

Pesticides are applied to extensive areas in agriculture and urban areas (golf courses, lawns and gardens) for insect and weed control. There are hundreds of pesticide ingredients in active use, and many new formulations reach commercial production annually. Most consist of synthetic organic compounds. If applied properly, most approved pesticides are generally taken up by plants or are broken down to harmless substances by soil organisms, sunlight or chemical reactions; however, sometimes the by-products resulting from the breakdown are more toxic.

The risk of ground water contamination is affected by the leaching potential of the pesticide and the composition and physical properties, such as porosity, of the soil. The tendency of the pesticide to dissolve in water, adhere to soil particles, disperse in the air or dissipate in the soil will influence its potential for leaching. The greatest potential for pollution from pesticides exists in irrigated sandy soils or in areas where thin soils overlay fractured or karst bedrock. Infiltration rates are rapid in sandy soils, resulting in insufficient time for certain pesticides to be naturally inactivated before reaching the ground water table. The pesticides and herbicides may flow directly into the ground water through the cracks in the bedrock. Accidents, improper storage, mishandling during mixing, loading or transport of these substances, can all be a source of significant localized ground water contamination.

Industrial and Commercial Land Uses

These uses are generally concentrated in urban areas but may also be located in rural towns and agricultural areas.

Hazardous Materials Use, Storage and Handling

A wide range of hazardous materials are used, transported, stored or distributed by business and industry. Hazardous materials pose a substantial present or potential hazard to human health or the environment. The use of hazardous materials is not as broadly regulated as the disposal of hazardous wastes. Although there are some requirements for their labeling and transporting, there are no regulations for the use and storage of many hazardous materials.

Improper storage, handling or disposal of the many hazardous materials which are used every day in agricultural, commercial, industrial and domestic instances can lead to serious pollution problems if they infiltrate and reach the ground water supply. Every warehouse, manufacturing facility or retail outlet that contains paints, fertilizers, industrial cleaners and other chemicals is a potential source. If proper care is not given to these materials while they are being stored, used or handled, unnecessary spills or leakage could occur. Explosions, fires and other catastrophic events can also release these substances. A prominent example of one industry that uses hazardous materials daily is the dry cleaning business. Cleaning chemicals can become a ground water contaminant if handled improperly.

Hazardous Waste Disposal

According to the Minnesota Office of Waste Management (OWM), state industries annually produce approximately 100,000 tons of hazardous waste. This waste must be stored, transported, treated and disposed of in a manner that will prevent the release of any contaminant into the ground water.

Hazardous wastes are those wastes "which, because of their quantity, concentration, or physical, chemical or infectious characteristics may: a) cause, or significantly contribute to an increase in mortality, or an increase in serious, irreversible, or incapacitating reversible illness; or b) pose a

substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed." (The Resources Conservation and Recovery Act, 42 U.S.C., Sections 6901-6987).

A waste may be subject to regulation because federal regulations specifically list it as a hazard, or because it exhibits a hazardous characteristic described by the law (i.e. ignitable, corrosive, reactive, or toxic). The specific requirements for its treatment, storage, disposal, transport and documentation vary depending upon how much waste is generated. Generators of smaller quantities are regulated less stringently then large-quantity generators.

Many household products used in various home cleaning and maintenance tasks contain smaller quantities of toxic or hazardous substances. These are frequently disposed with other sanitary waste. In general these wastes are not regulated, but counties are establishing voluntary programs to manage their disposal. Appendix B, Table B-3 contains a list of household products and their toxic or hazardous components.

Mining Wastes

Ground water contamination can occur from the mining of metallic ores such as iron ore. Mining wastes can contain such dissolved toxic materials as arsenic, sulfuric acid, copper, selenium, and molybdenum, as well as radioactive materials. Sometimes the physical disruption of the mined material in the mining process will release potential contaminants that are normally bound within the rock. Mining for materials such as sand, gravel, clay, and stone may contribute suspended solids to ground water, but their wastes are generally less hazardous because they are usually chemically inert.

Salvage and Junk Yards

The grease, oil, solvents, battery acid and other hazardous materials associated with automobiles, trucks and other salvage materials are potential contaminants. If the materials are improperly stored or not removed, the harmful chemicals can be spilled or leached into the ground.

Storage Tank and Pipeline Leaks

Above- and below-ground storage and transmission of a wide variety of fuels and chemicals are part of many agricultural, industrial, commercial and individual activities. The large volume and high concentration of hazardous materials stored in a small area creates a significant on-site pollution risk.

Petroleum and its products are the most common potential pollutants. Underground gasoline and oil storage tanks that were installed in the 1950s and 1960s have now reached or surpassed their 20 to 30 year life span. Some have begun to leak because they were not built of corrosion-resistant materials. Leaks in buried tanks and pipelines may go unnoticed until a large amount of chemical has been released. The fumes may penetrate basements, sewers, wells, and springs, rendering drinking water unsafe and creating explosion and fire hazards.

The Minnesota Pollution Control Agency, which is charged with the responsibility of implementing a tank cleanup program, estimates there will be more than 40,000 tanks registered statewide when their inventory is completed.

Municipal Land Uses

The numerous and varied activities operated by or serving local communities are another potential source of ground water contaminants. Some of the major activities are described below.

Incinerator Ash

Solid waste incinerators are becoming more widely used to reduce the volume of solid waste and the need for landfill sites. However, the bottom and fly ash produced by incinerators must be disposed of in an environmentally safe manner. Often this ash contains concentrated amounts of metals, such as lead and cadmium, and other harmful compounds, such as chlorinated organics and polyaromatic hydrocarbons (PAHs). Without proper management, disposal of ash can lead to ground water contamination.

Public Service and Maintenance Facilities

All levels of government operate facilities where vehicles and equipment are stored and maintained. Gasoline, industrial cleaners, paint and other chemicals are used or stored in these facilities. Improper use, handling or disposal of these substances can result in ground water contamination.

Road Salt Storage and Use

Salt storage and road salting may result in high salt concentrations in both ground and surface water. Salt stored in uncovered piles is dissolved by precipitation which infiltrates the soil and eventually reaches the aquifer, while salt applied to streets and highways in the winter is carried by the snowmelt into roadside ditches and low areas where it leaches into the ground water.

Sewage and Industrial Wastewater

Municipal and industrial waste waters are collected and treated in treatment plants before the effluent is discharged. Some treatment plants are designed to use seepage cells (absorption ponds), which allow the treated wastewater to filter into the ground rather than discharging to a stream or river. If not properly located, designed, constructed, operated and maintained, these seepage cells can cause ground water pollution. The retention time in seepage lagoons is usually sufficient to ensure low levels of bacteria and viruses. Occasionally, however, nitrate, ammonia, sulfate, and metals (which pose a long term environmental hazard) are released from the seepage cells in significant concentrations. Also, municipal sewage and industrial ponds may contain hazardous chemicals not removed in the lagoons.

In some instances the effluent is discharged to the land surface by spray irrigation and land spreading, which allows wastewater effluent from treatment operations to filter into the ground. If these land application sites are properly located and proper application rates are adhered to, contaminants in the discharge will be attenuated in the soil.

Sewage Sludge

Sludge, an organic byproduct of municipal and industrial wastewater treatment, is composed mostly of water (up to 99 percent of its weight) and organic matter but may contain hazardous chemicals and metals. Metals frequently detected in sludge include arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. The type and concentration of metals found in sludge depend upon the source of the wastewater. Other components of sludge which may be harmful to ground water are nitrogen compounds, chloride, and pathogenic bacteria and viruses.

Pollution from land application of municipal sludge depends on the concentration of the contaminants in the sludge, the application rate, the physical and chemical soil properties, amount of precipitation, and distance to the water table. Coarse-textured soils, a high water table and high rates of precipitation increase the chances of ground water contamination.

Sewer (Sanitary) Leakage

The leakage of sanitary sewers is not recognized as a significant ground water contaminant, probably because the problem is not highly visible, the loss of flow is difficult and costly to pinpoint, and the potential sources are widely dispersed. From a ground water pollution standpoint, however, exfiltration (or contamination caused by the leakage of sanitary sewer lines) can be a problem. Contaminants from this source may include nitrate or other forms of nitrogen, bacteria and any hazardous materials that have been introduced into the sewer.

Solid Waste Landfills

Landfills are a major source of ground water pollution because of the volume and diversity of the potential contaminants they contain. Landfills are also generally located at least partially below the ground surface and may be close to the water table. Continuous or intermittent contact between refuse and water from runoff and precipitation produces leachate. Leachate is a liquid characterized by high concentrations of dissolved chemicals, high chemical and biological oxygen demand and hardness. Its composition is extremely variable and may also contain substances leached out from hazardous materials at the site.

Urban Runoff

Although urban runoff has traditionally been considered a surface water contaminant, it is now also considered a potential source of ground water contamination because in many areas much of it will eventually infiltrate the soil and other material overlying the ground water or seep from surface waters into the aquifer. Potential contaminants carried in storm water come from automobiles, residential and commercial lawns, road oiling and salting operations, pets, industrial activities, and construction sites. Bacteria and pathogens from pet and animal waste, metals from vehicles, organic and inorganic compounds from lawn fertilizers and pesticides, and road salt are commonly found in urban runoff. As local governments and state agencies require the construction of storm water detention ponds to protect lakes and streams from contaminants in urban runoff, there will be increasing concern for potential ground water impacts.

Other Sources of Contamination

Accidental Spills

As trucks and trains carry an increasing volume of petroleum and chemicals, the potential for hazardous material spills increases. Truck accidents most commonly result in petroleum and other chemicals spills. Train derailments can release a wide spectrum of substances and chemicals such as diesel fuel, anhydrous ammonia, sulfuric acid, chlorine, propane and other toxics. If the spill is contained and cleaned up promptly, the ground water may not be affected. If the ground water is affected, cleanup may be expensive.

Cemeteries

Cemeteries have been found to cause contamination, contributing biologic and organic contaminants to the ground water.

Infiltration of Polluted Precipitation and Surface Water

Atmospheric pollutants are a potential source of ground water contamination, although their other environmental effects may be of greater concern. Pollutants such as nitrogen compounds, asbestos, organic contaminants and heavy metals are released into the atmosphere by urban,

industrial and agricultural activities, and can then be transported hundreds of kilometers from where they are discharged. Sulfur and nitrogen compounds react with moisture in the atmosphere to form dilute sulfuric and nitric acids which then return to the earth as acid precipitation.

The potential for ground water contamination from atmospheric sources depends upon the buffering capacity (ability to neutralize through natural alkalinity) of the soils or water where the acid rain falls.

Injection Wells

Injection wells are not currently allowed in Minnesota, with the exception of injection of fresh water which requires legislative or state agency approval. However, they are used in other parts of the U.S. to deposit wastes into deep geological strata below the depth of usable ground water supplies. The depth to which the waste is injected depends upon the hydrogeology of the injection site and the characteristics of the waste. Injection wells have been constructed in the past in rural portions of Minnesota as a means of draining agricultural land. If improperly constructed, or abandoned without sealing, agricultural drainage wells can become easy conduits for the transport of chemical fertilizers and pesticides from the surface to ground water aquifers.

Military Facilities

Within the U.S., the military is one the largest potential generators of hazardous waste, producing over 1 billion pounds a year. The military produces and utilizes an abundance of toxic and hazardous substances, not only in its munitions operations but also as part of on-going maintenance and other activities. Military facilities use significant amounts of fuel, oils, solvents, paint thinners and strippers, heavy metals, and acids to operate and maintain equipment.

On-site Sewage Treatment Systems (Individual)

Individual on-site sewage treatment (septic) systems are used in rural and urban areas to dispose of the wastewater from individual homes, recreational developments, small industries and businesses. On-site septic systems typically consist of a water-tight tank placed underground and an associated soil absorption field. In some instances, several residences or businesses are served by a common or community drainfield. Waste is discharged from the house or business to the tank, where most solids (called sludge) settle to the bottom and are partially digested by bacteria. In a properly operating system, the liquid waste or effluent flows from the tank to the soil absorption field where harmful microbiological pathogens are removed by the natural mechanisms as the effluent moves through the soil as discussed earlier in this section. However, not all pathogens and hazardous substances may be eliminated by these mechanisms. If the system is located in shallow or porous soil (sand and gravel) or a high water table, is not maintained, or is poorly constructed allowing effluent to reach the ground water virtually untreated, ground water pollution is more likely to occur. In some communities where there is inadequate inspection of these systems, the tanks have been connected to drain tiles rather than an absorption field and discharge directly to surface waters.

The pollutants most commonly associated with these systems are nitrates, bacteria, viruses and hazardous substances. Certain household products which are disposed of by pouring them down the drain contain hazardous substances including organic and inorganic chemicals (Appendix B, Table B-3). Since they break down very slowly, they tend to accumulate but not as significantly as from an industrial or manufacturing facility.

Well Construction and Abandonment

Wells are not a source of contaminants, but they may serve as a conduit for the transport of contaminants from the surface to ground water or between aquifers. This most often occurs when wells are improperly constructed. Improper construction includes inadequate casing or grouting, or failure to properly seal the opening when the well is abandoned. Contaminants are then free to move from the surface to the water table or from an upper to a lower aquifer. Urban and agricultural runoff containing pesticides, fertilizers, bacteria, metals and other chemicals can then be channeled into the ground water through the well.

SECTION 4 - EXISTING GOVERNMENTAL FRAMEWORK

INTRODUCTION

This section summarizes existing federal and state laws and programs which affect the local management and protection of ground water. The information presented is intended to assist localities as they develop plans, policies and programs for ground water protection, as well as direct them to appropriate agencies and programs for more information.

FEDERAL LAWS AND PROGRAMS

The federal government does not directly regulate the quality of ground water, but a variety of federal laws have been enacted which indirectly result in the protection of ground water quality. Some of the laws and programs pertain to potential sources of contamination and the use of specific contaminants while others indirectly protect ground water.

For example, the National Pollution Discharge Elimination System (NPDES), which was established under the Clean Water Act, regulates pollutants being discharged from public and private treatment plants to surface waters. This regulation also protects ground water where the surface waters recharge the ground water.

The most significant ground water-related laws and programs administered by the federal government are authorized by:

- The Clean Water Act;
- Safe Drinking Water Act;
- Resource Conservation and Recovery Act;
- Comprehensive Environmental Response, Compensation and Liability Act ("Superfund");
- Energy Planning and Community Right-to-Know Act;
- Toxic Substance Control Act; and
- The Federal Insecticide, Fungicide and Rodenticide Act.

Table 2 summarizes the primary focus of each of the laws and associated programs that are intended to support them. In some instances, the laws allow the responsible federal agency to delegate primary responsibility for enforcing the law and program to a state agency. This authority to delegate is called primacy and is indicated in Table 2. A more detailed summary of each of the major federal laws and other agency programs is presented in Appendix C.

The federal government has shifted its focus from the cleanup and control of sources or specific contaminants to a preventative strategy in which ground water protection is also emphasized. States are encouraged or in some cases required to take the lead role in this effort. For example, the U.S. Environmental Protection Agency (EPA) now requires and assists states in establishing ground water protection programs such as wellhead protection.

Table 2

EXISTING FEDERAL LAWS AND AGENCIES REGULATING GROUND WATER PROTECTION

Federal Law	Program Focus	Responsible State Agency
Clean Water Act of 1972, as amended (CWA)	National permit system and standards for the discharge of wastewater and sludge from public and private treatment plants.	Minnesota Pollution Control Agency
	Funding for new, expanded or improved public wastewater treatment plants.	Minnesota Pollution Control Agency
	Funding for state and local activities affecting ground water quality (monitoring, research, planning and technical assistance.)	Minnesota Pollution Control Agency
Safe Drinking Water Act, 1974, as amended (SDWA)	Standards for public water supply systems.	Minnesota Department of Health
	EPA designation of sole-source aquifers.	—
	Requirements and authorization for funding assistance for the establishment of state wellhead protection program. (Funds to date have come from Section 106 of Clean Water Act).	Minnesota Department of Health
	Regulation of waste disposal by underground injection wells, including agricultural and storm drainage.	—
Resource Conservation and Recovery Act (RCRA)	Establishes "cradle to grave" management system for hazardous waste and standards for treatment, storage and disposal facilities (TSDFs). EPA permit required for TSDFs. Small generators (between 100 and 1000 kilograms per month) were included by amendment in 1984. Transportation of hazardous waste and materials is also regulated.	Minnesota Pollution Control Agency and Minnesota Department of Transportation
	Provides for management of solid (nonhazardous) waste, including development by EPA of minimum criteria for landfilling. Granting of permits left to states; EPA has non-direct management responsibility. Requires states to develop solid waste plans, including assessment of needs for additional facilities and monitoring of all disposal facilities.	Minnesota Pollution Control Agency

Table 2 (continued)

EXISTING FEDERAL LAWS AND AGENCIES REGULATING GROUND WATER PROTECTION

Federal Law	Program Focus	Responsible State Agency
Resource Conservation and Recovery Act (RCRA), cont.	Regulations for the management of leaking underground storage tanks (10% or more of volume underground).	Minnesota Pollution Control Agency
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or "Superfund Law"	Provides authorization and funding (Superfund) for ground water cleanup at existing or closed waste disposal sites. Places liability on operators, generators and transporters. EPA, with state assistance, maintains national list of priority sites.	Minnesota Pollution Control Agency and Department of Agriculture where agricultural chemicals are involved.
Emergency Planning and Community Right-to-Know	Provides for local planning for hazardous chemical accidents, and allows citizens right-to-know about hazardous chemicals in their community. Requires annual reporting of hazardous and toxic chemicals in storage or used at facilities and released or spilled.	Minnesota Department of Public Safety and Emergency Response Commission
Toxic Substances Control Act of 1976 (TSCA)	Authorizes EPA to require testing of chemicals which are a risk to the environment, and requires manufacturers to notify EPA of new chemicals or significant new uses.	—
Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)	Authorizes EPA to regulate hazardous pesticides, including procedures for classification, registration, sales, use, monitoring and disposal.	Minnesota Department of Agriculture

STATE GROUND WATER LAW AND PROGRAMS

Ground Water Protection Act of 1989

The most comprehensive legislation for protecting ground water in Minnesota is the Ground Water Protection Act (GWPA) of 1989, Minn. Stat. ch. 103H and 103I (1990). The law establishes a comprehensive strategy for protecting the state's ground water resources. It also instituted a state policy that ground water be maintained in its natural condition, free from degradation caused by human activities. Where the policy is not currently practicable, it encourages the development of methods and technology that will make prevention practicable.

The act also provides for the following activities:

- Improved monitoring of ground water and management of information;
- Better control of potential contaminant sources;
- Stronger protection of drinking water and water supply wells (wellhead protection);
- Enhanced management of well construction, maintenance and sealing;
- Increased control of pesticides and fertilizers;
- Cleanup of agricultural chemical contamination incidents; and
- State funding for local water planning and plan implementation.

To implement these activities, the act directs various state agencies to undertake specific regulatory, research, program development and other tasks.

State and University of Minnesota Programs

Sixteen state agencies and boards administer over 80 water-related programs directly or indirectly affecting ground water protection in Minnesota. Most of the regulatory and management programs for ground water are administered by four agencies: Departments of Agriculture (MDAg), Natural Resources (MDNR), and Health (MDH), and the Minnesota Pollution Control Agency (MPCA).

The University of Minnesota, through the Extension Service and Minnesota Geological Survey, provides information and technical assistance to local governments and individuals.

The following section summarizes the major program responsibilities of the state of Minnesota in ground water protection. State agency involvement in ground water protection includes coordination, regulation and management, financial assistance, monitoring and data management, planning and research, technical assistance, and public information and education. Table 3 indicates the responsibilities of each agency under the Ground Water Protection Act and related on-going activities. Table 4, which summarizes the major regulatory programs by the type of source, lists each agency and their general responsibilities as well as a reference to the rules or statutes which guide the agency. Appendix D contains a more detailed discussion of the responsibilities and programs of state agencies and the University of Minnesota. More extensive listings of programs and information are noted in the bibliography. Local governments preparing plans for ground water protection should contact the agencies directly to determine what types of information are available for regulated sources such as landfills, feedlots and underground storage tanks in their jurisdiction. Additional program information can be obtained by contacting the responsible agency at the nearest office. Many of the state agencies have regional offices.

Table 3

STATE AGENCY GROUND WATER MANAGEMENT RESPONSIBILITIES

Minnesota Planning (Office of Strategic and Long-Range Planning • Staff for Environmental Quality Board • Environmental Policy Planning • Land Management Information System • Ground Water Data Clearinghouse • Systems for Water Information Management (SWIM) • Data Compatibility Standards	**Environmental Quality Board** • Water Resources Committee • Interagency Water Policy Development • State Water Plan and Priorities • Water Monitoring Plan • Water Information and Education Plan • Water Research Needs • Quality & Quantity Trends Report (biennial) • Enforcement of Data Compatibility Standards	**Department of Natural Resources** • Water Appropriation Permits • Ground Water Sensitive Areas - Criteria and Mapping • County Geologic Atlases and Regional Hydrogeologic Assessments (with Minnesota Geological Survey) • MDNR and U.S. Geological Survey Cooperative Programs • Ground Water Investigations • Hydrologic Data Collection and Analysis
Pollution Control Agency • Ground Water Monitoring and Assessment • Ground Water Data Management • Water Quality Standards • Pollution Discharge Permits • Nonpoint Pollution Programs • Clean Water Partnership Grants • Agricultural Waste Systems • Solid and Hazardous Waste Management • Tanks and Spills Program • Contaminated Site Response/State Superfund	**Board of Water and Soil Resources** • Local Water Resource Protection Grants • Local Water Resource Plan Review and Approval • Erosion Control and Water Quality Grants • RIM Reserve Program • Well Sealing Grants • Oversight of Soil and Water Conservation Districts and Watershed Districts	**Department of Agriculture** • Agricultural Best Management Practices Development • Fertilizer Regulation • Water Monitoring for Pesticides and Fertilizer • Pesticide Use Survey • Pesticide Registration, Application and Certification • Agricultural Chemical Incident Response and Cleanup • Waste Pesticide Collection • Superfund for Agricultural Chemicals • Sustainable Agriculture and Integrated Pest Management
Department of Health • Well Management • Wellhead Protection • Public Water Supply Program • Health Risk Limits • Community Health Services Grants	**Department of Education** • Environmental Education Advisory Board • Office of Environmental Education (joint responsibility of the Departments of Education and Natural Resources)	

Table 4

STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity or Source	Agency	Program Emphasis
Agricultural chemical incidents and spills	MDAg	Requires immediate reporting of agricultural chemical spills and provides for the investigation and cleanup of incidents, including disasters. Minn. Stat., §§ 18D.103 and 18D.105
Chemigation	MDAg	Requires a permit for fertilizer and pesticide application to land or crops through irrigation systems. Requires the use of devices to prevent the backflow of fertilizers and pesticides into surface and ground waters. Minn. Rules, 1505.2000 and 1505.2100.
Contaminated site response/Superfund (uncontrolled disposal of hazardous substances)	MPCA	Investigates former industrial and municipal dumpsites for ground water and other forms of pollution, establishes their priority, determines need for remedial action, and finds responsible parties. State and federal "Superfunds" are used to pay the costs where responsible parties cannot be determined, or are unwilling or unable to pay. Minn. Rules, ch. 7044
Feedlot and manure management	MPCA	Permits and regulates animal feedlots containing 10 or more animal units (10 beef steers, 1,000 chickens, etc.) including construction, location and operation; may also require an NPDES permit. Allows delegation to county to enforce. Minn. Rules, ch. 7020
Fertilizer (liquid & dry) storage and handling facilities	MDAg	Approves construction and alteration of facilities for the storage, mixing, handling and blending of liquid and dry commercial fertilizers; facilities must protect ground water. Minn. Rules, pts. 1510.0370 & 1510.0400 (new rules being developed)
Hazardous waste facilities (includes toxics, corrosives, ignitables, flammables, poisons, explosives and reactives)	MPCA	Permits and regulates facilities for the storage, treatment and disposal of hazardous wastes, including the construction, operation, closure and ground water monitoring. Also, establishes procedures for the transport of hazardous waste originating or terminating in Minnesota, including the recovery and cleanup of spills and leaks. Minn. Rules, chs. 7001 and 7045

Table 4 (continued)
STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity/Source	Agency	Program Emphasis
Individual on-site sewage treatment system (ISTS) (serving a dwelling or other establishment which utilizes subsurface soil treatment and disposal)	MPCA	Provides minimum standards and criteria for the design, location, installation, operation and maintenance of ISTS. Required permits for ISTS designed to treat an average daily flow of 10,000 gallons per day or a maximum average daily flow of 15,000 gallons per day or more. Standards are mandatory only in shoreland, scenic river land use districts, floodplain areas and for permitted systems. Minn. Rules, ch. 7080
On-site treatment systems serving public establishments	MDH	Enforces MPCA standards for large on-site treatment systems and public establishments licensed by the department: camps, food/beverage lodging facilities and mobile home parks. Minn. Rules, chs. 4635 and 4630
Pesticide (bulk) storage	MDAg	Permits and regulates the construction and operation of sites at which bulk pesticides are stored for distribution or repackaging. Minn. Rules, ch. 1505
Pesticides use	MDAg	Oversees compliance with Federal Insecticide, Fungicide and Rodenticide Act. Registers all pesticides. May impose stricter requirements or restrict use. Minn. Stat. § 18.53
Pipelines	EQB	Administers the Pipeline Routing Program which provides for the review of pipelines six inches or greater in diameter designed to carry hazardous liquids or operated at more than 275 lbs. per square inch designed to carry natural gas. Approves routing permit. Minn. Rules, ch. 4415
	DPS - Office of Pipeline Safety	Administers federal/state standards for the design, construction, testing, operation and maintenance of intra-state and interstate pipelines carrying natural gas and hazardous liquids. The emergency response center receives notice of emergency releases from pipelines and notifies appropriate state agencies and local governments. Minn. Stat. ch. 299J

Table 4 (continued)
STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity/Source	Agency	Program Emphasis
Public water supplies	MDH	Administers federal (EPA) drinking water standards and monitoring requirements for public water supply systems. Minn. Rules, ch. 4720
Sanitary sewers	MPCA	Requires an extension permit for the construction of new sanitary sewers.
Sensitive ground water areas (geographic areas defined by natural features where there is a significant risk of ground water contamination from land use activities)	MDNR	Provides for the development of criteria for identifying sensitive areas and then adoption by rule. Sensitive areas are identified in cooperation with the MGS and local planning and zoning authorities. Minn. Stat. §§ 103H.101-103H.151
Septage (pumpings from septic tanks)	MPCA	Certifies septage pumpers. There are no state regulations for managing septage.
Sewage sludge from municipal wastewater treatment plants (solid and associated liquids in municipal wastewater that are concentrated by municipal wastewater treatment plants)	MPCA	Permits and regulates the disposal and use of sewage sludge, including standards for the design, location and management of landspreading sites and facilities. Minn. Rules, chs. 7001 and 7040
Solid waste disposal sites (Includes garbage, refuse and other discarded material from industrial, commercial, agricultural and community activities.)	MPCA	Permits and regulates all solid waste management and land disposal facilities, such as mixed municipal solid waste, solid waste transfer facilities and demolition debris, including standards for their design, operation, monitoring and closure. Minn. Rules, chs. 7001 and 7035
Spills (acute environmental releases such as train or truck wrecks, pipeline breaks, dumped barrels)	MPCA	Requires the reporting of spills that may cause pollution of the waters of the state and oversees cleanup. Minn. Rules, pt. 7045.0275, subp.2

Table 4 (continued)
STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity/Source	Agency	Program Emphasis
Spills (continued)	MDAg, MPCA, MDPS, MDNR	Requires handlers of oil and hazardous substances to take reasonable steps to prevent the discharge of materials that might cause pollution of land, water or air, or threaten public health or safety, including their rapid and thorough recovery. Handlers of large quantities exceeding minimum thresholds must prepare a prevention and response plan. Minn. Stat., ch. 115E
Storage tanks: underground (UST)	MPCA	Regulates and registers USTs containing 1,100 gallons or more of petroleum or a regulated substance. Exceptions include farm or residential tanks containing 1,100 gallons or less used for storing fuel for noncommercial use and tanks of 1,100 gallons or less used for heating on the premises where stored. Sets standards for construction of new tanks. Standards govern the construction, installation and cleanup of tank spills and leaks. Maintains information on location and characteristics of tanks. Minn. Rules, Chs. 7105 and 7150.
Storage tanks: above ground (AST) (includes any liquid that might cause pollution of the waters of the state)	MPCA	Requires a permit for all ASTs. No standards have been adopted to date. Owners required to report size and contents within 30 days after new installation. Minn. Rules, ch. 7100
Transporters of hazardous waste	MnDOT	Requires the licensing and inspection of hazardous waste transporters (trucks). Provides assistance in the investigation of spills. Minn. Stat. § 221.035
Underground gas & liquid storage	MDNR	Requires that a permit be obtained from the DNR for underground storage in natural formations. Monitoring of the activity may be required. Minn. Rules, pt. 6115.0130

Table 4 (continued)
STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity/Source	Agency	Program Emphasis
Underground injection wells	MPCA	Prohibits the direct discharge of sewage or other wastes into the saturation zone via injection wells. Minn. Rules, pt. 7060.0400
	MDH	Prohibits wells for disposal of industrial waste, surface water, ground water or any liquid, chemical or gas. Minn. Rules, pt. 4725.2300
Used battery disposal	MPCA	Regulates the disposal of dry cell batteries containing mercuric oxide electrode, silver oxide electrode, nickel-cadmium or sealed lead-acid. Manufacturers of these batteries must ensure that a system for the collection, transportation and processing of waste batteries exists for purchasers in Minnesota. Minn. Stat. § 115A.9155 Retailers and wholesalers of automotive (lead acid) batteries must accept used batteries from customers for recycling. Minn. Stat. §§ 325E.115 and 325E.1151 Prohibits the placement of automotive (lead acid) and dry cell batteries in mixed municipal solid waste. Minn. Stat.§ 115A.915 and 115A.9155
Used motor oil	MDPS	Requires retail outlets selling motor oil to provide tanks for the collection of used motor oil or post notice stating where it can be returned for recycling. Minn. Stat. § 325E.11
	MPCA	Prohibits the placement of used oil in mixed municipal solid waste or on the land unless approved by the agency. Minn. Stat. 115A.91

Table 4 (continued)
STATE REGULATORY PROGRAMS FOR GROUND WATER PROTECTION

Activity/Source	Agency	Program Emphasis
Wastewater disposal: municipal and industrial	MPCA	Permits and regulates wastewater treatment facilities including seepage and destabilization ponds and spray irrigation. Issues State Disposal Systems (SDS) permits for discharge to surface waters, land and subsurfaces, and National Pollution Discharge Elimination System (NPDES) permits for discharges to surface water. Minn. Rules, ch. 7050
Water appropriation	MDNR	Requires a permit for any appropriation of surface or ground water for usage greater than 10,000 gallons per day or 1 million gallons per year or serving 25 or more households. Minn. Rules, ch. 6115
Water quality standards	MPCA	Regulates surface and ground water quality. Standards and limits for surface water quality are based on their use. Minn. Rules 7050. A nondegradation policy applies to ground water. Minn. Rules, ch. 7060
Well construction, repair and abandonment (well sealing)	MDH	Regulates the construction and repair of wells and sealing of abandoned wells. Departmental notification is required for new wells. May delegate inspection and enforcement to local board of health. Minn. Rules, ch. 4725
Wellhead protection (surface or subsurface area surrounding a public well or wellfield through which contaminants are likely to pass to reach the well.	MDH	Regulates the establishment of local programs to protect the wellhead areas of public wells. The MDH is currently developing rules to implement this program in mid 1994 consistent with the federal Safe Drinking Water Act amendments. Minn. Stat. § 103I.101

LOCAL GOVERNMENT

Local governments in Minnesota play an important role in protecting ground water because of the broad authority conferred on them by the state. This authority includes planning and regulating land use, acquiring and developing property for public purposes, enacting health ordinances, building and operating sanitary sewer systems, and implementing solid waste management programs (Table 5). More recently, the legislature directed local governments to prepare surface water plans and authorized the seven counties in the Twin Cities Metropolitan Area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington) to prepare ground water plans. The legislature also authorized county governments in Greater Minnesota to prepare comprehensive water resource plans, including ground water protection.

Following is a summary of the major responsibilities of local governments in Minnesota which affect ground water protection. Local governments include counties, cities, towns, watershed districts, watershed management organizations, and soil and water conservation districts.

Water Resource Planning

During the 1980s, the legislature passed several major water resource planning bills authorizing or directing local governments to undertake water resource planning to guide the use, cleanup and protection of the resource. All of the laws recognize the potential impact of land use decisions on water quality and require local water resource planning to address the connection between land use plans and controls, such as zoning and subdivision regulations, and water quality.

Water Planning - Greater Minnesota

In 1985, the legislature enacted the Comprehensive Local Water Management Act. The act authorizes each county in Greater Minnesota to develop and implement a long-range, comprehensive water plan (Minn. Stat. § 103B.311). Counties are authorized to review water and related land resource plans and official controls submitted by local governments for consistency with the plan, and to exercise any and all powers necessary to assure implementation of the plan. The Minnesota Board of Water and Soil Resources (BWSR) reviews and approves the plan. The county plans are to address water problems in the context of watersheds and ground water systems, and be based on sound principles of hydrologic management and environmental protection. The plans must address ground water quality and land use and are to include:

- Description of existing and expected changes to the physical environment, land use and development;
- Available information about surface and ground water, and related land resources, including water use and quality;
- Objectives for surface and ground water, and related land use resources, including use, supply and quality;
- Objectives for future development, use and conservation of water and land resources, including water quality and quantity, sensitive areas, wellhead protection and land use;
- Potential changes in state programs and policies and requirements that affect local water management;
- Proposed actions to achieve the objectives;
- A statement of the conflicts with the plans of other county water plans in the affected ground water systems; and
- An implementation program. The program is to include a schedule for amending official (land use) controls and the water and related land resource plans of local governments to conform with the comprehensive water plan.

Table 5

SUMMARY OF LOCAL GOVERNMENT AUTHORITIES RELATED TO GROUND WATER PROTECTION*

I. Counties
Greater Minnesota Only • Prepare, adopt and implement a comprehensive water plan and implementation program (surface and ground water) • Must review related local land and water plans and official (land use) controls for consistency with water plan and recommend amendments • Acquire real property by eminent domain to implement the water plan • Prepare and adopt comprehensive plan and official (land use) controls such as zoning and subdivision regulations • Must prepare and adopt solid waste management plan, including the management of household hazardous waste • Regulate the disposal of sewage
Twin Cities Metro Area Only • Prepare, adopt and implement ground water plan, including standards and guidelines for implementation by watershed management organization and local governmental units • Must prepare and adopt comprehensive plan and land use controls (except Hennepin, Ramsey) • Must prepare a solid waste master plan, including the management of household hazardous waste • Must establish rules, regulations and standards for solid waste facilities relating to location, operation, inspection and monitoring • Must establish rules, regulations and standards for the labeling and classification, collection, storage, transportation, processing and disposal of hazardous waste, and require permits or license for the same
All Counties • Acquire by eminent domain real property for solid waste management, redevelopment and other specific purposes • Must establish health board, or act as one, with authority to adopt ordinances and regulations • Conduct a solid waste management program • Establish rules, regulations and standards for solid waste and sewage sludge disposal facilities relating to their location, operation, maintenance and then collection, processing and disposal, and issue permits for solid waste disposal facilities • Establish regulations and standards for classification and collection, storage, transportation, processing and disposal of hazardous waste, and issue permits for generators

** Most authorities are at the option of the local government except where it says must.*

Table 5 (continued)
SUMMARY OF LOCAL GOVERNMENT AUTHORITIES
RELATED TO GROUND WATER PROTECTION*

II. Cities
Twin Cities Metro Area Only • Must prepare local water management plan, capital improvement program and official controls to bring local water management into conformance with watershed plan • Must prepare and adopt comprehensive plan and official (land use) controls • Regulate the disposal of sewage subject to approvals of Metropolitan Council and Metropolitan Waste Control Commission • With the approval of the Metropolitan Council, may impose reasonable conditions on the construction, operation, inspection, monitoring and maintenance of a solid waste disposal facility
Greater Minnesota Only • Prepare and adopt comprehensive plan and zoning ordinance, subdivision regulations and other land use controls to effectuate the plan • Regulate the disposal of sewage
All Cities • Acquire real property by eminent domain • Must establish or act as a health board with the authority to adopt ordinances/regulations
III. Towns
Twin Cities Metro Area Only • Must prepare local water management plan, capital improvement program and official controls to bring local water management into conformance with watershed plan • Must prepare and adopt comprehensive plan and official (land use) controls • Regulate the disposal of sewage subject to approval of Metropolitan Council and Metropolitan Waste Control Commission • Towns with 1200 or more persons, or towns with a platted area within 20 miles of a city of the first class (Minneapolis and St. Paul) with more than 200,000 persons, have the power of eminent domain • With the approval of the Metropolitan Council, may impose reasonable conditions on the construction, operation, inspection, monitoring and maintenance of a solid waste disposal facility

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Table 5 (continued)
SUMMARY OF LOCAL GOVERNMENT AUTHORITIES
RELATED TO GROUND WATER PROTECTION

III. Towns
Greater Minnesota Only • Prepare and adopt comprehensive plan and zoning ordinance, subdivision regulations and other official controls to effectuate the plan • Town (with 1000 population or more) may elect to acquire real property by the power or eminent domain • Regulate the disposal of sewage
IV. Watershed Management Organizations - Twin Cities Metropolitan Area
• Must prepare, adopt and implement a long-range watershed plan for each minor watershed • Must review and approve local water management plans, capital improvement programs and official controls
V. Watershed Districts - Statewide
• Must prepare a comprehensive plan to achieve the purposes for which it was established, such as regulation of surface water and protection of ground water. (In the Twin Cities Metropolitan Area, districts may function as watershed management organizations).
VI. Soil and Water Conservation Districts
• Prepare a comprehensive plan indicating the practices to implement state soil and water conservation policy including structural measures, methods of cultivation, cropping practices and changes in the use of land. • Implement any necessary practice with the consent of land occupier and provide financial aid, equipment or materials. • Accept the delegation of authority from a city or county to administer official (land use) controls for the purpose of soil and water conservation.

**Most authorities are at the option of the local government except where it says must.*

Local governments must amend existing water and related land resource plans and official controls such as zoning and subdivision regulations to conform with the approved comprehensive water plan. The county board will review these plans and recommend changes (Minn. Stat. § 103B.311). Following the adoption of the county water plan, the county board shall review new or amended local water and related land resource plans. Plans are to be updated periodically.

Water Planning - Twin Cities Metropolitan Area

In 1982, the legislature enacted the Metropolitan Surface Water Management Act. The act requires the preparation and adoption of a long-range watershed plan for all minor watersheds in

the seven-county Twin Cities Metropolitan Area (Minn. Stat. § 103B.231). The plans are to be prepared by a watershed management organization (WMO). Local governments may form a joint powers entity established by intergovernmental agreement to undertake the planning or a watershed district may act as a WMO. If local officials fail to act, the responsibility for planning goes to the county. The plans are to be reviewed and approved by the Minnesota Board of Water and Soil Resources.

The plan content requirements emphasize the management of surface water (flooding, erosion and quality) and the impact of land use decisions on surface water quality. The plans are to describe existing and proposed land use and development. Each plan is to include an implementation program consistent with the plan. A capital improvement program, standards and schedules for amending local (city and town) comprehensive plans, and official controls to achieve conformance are typical components of the implementation plan. Official controls include a variety of land use controls such as zoning, subdivision controls, site plan regulations, sanitary codes, building codes and official maps. The watershed plan is to indicate any inconsistencies with, or adverse impacts on, the county ground water plan and must be modified to conform to the county plan.

After the watershed plan is approved or amended, local governments in the watershed that have land use planning and regulatory responsibility are to prepare a local water management plan, capital improvement program and official controls to bring local water management into conformance with the watershed plan. Local water plans are then reviewed by the WMO for consistency with the watershed plan and approved or rejected. The plans are to include:

- A description of the proposed physical environment and land use;
- A description of drainage areas, volumes, rates and patterns;
- An identification of areas and elevations for stormwater storage consistent with the watershed plan performance standards;
- A definition of water quality and protection methods consistent with the watershed plan standard;
- An identification of regulated areas; and
- A description of the implementation program, including official controls and a capital improvement program.

In 1987, the legislature amended the Metropolitan Surface Water Management Act to authorize each of the seven counties in the Twin Cities Metropolitan Area to prepare and adopt a ground water plan (Minn. Stat. § 103B.255). (The act is now referred to as the Metropolitan Water Management Act.) The law recognizes the importance of local land use decisions and ground water protection. If the county chooses to prepare a plan, it must:

- Describe existing and expected land use changes;
- Summarize ground water information, including quality, use and availability;
- State goals, objectives and priorities for ground water protection;
- Contain standards, criteria and guidelines for the protection of ground water from pollution and for various land uses in environmentally sensitive areas, critical areas or previously contaminated areas;
- Indicate the relationship and any conflicts between the ground water plan and other county, local government and watershed plans; and
- Describe standards and guidelines for implementation of the plan by watershed management organizations and local government units.

As part of their review of the ground water plan, local governments and WMOs must indicate the changes they expect will be necessary to bring their plans into conformity with the county ground water plan.

Watershed Districts (WD)

Watershed districts are also subdivisions of the state established for diverse purposes ranging from providing for sanitation and public health; regulating the use of streams, ditches or water courses used to dispose of waste; and protecting and regulating ground water (Minn. Stat. § 103D.201). WDs must prepare a comprehensive plan for any or all of the purposes for which they are established. The plan must describe existing water and related problems, possible solutions and the general objectives of the district. Specific powers of the watershed districts as to land use controls vary depending on the authorities assumed when they were formed. The plans are reviewed by the director of the Minnesota Department of Natural Resources Division of Water and approved by BWSR. In Twin Cities Metropolitan Area districts, plans and activities are subject to the requirements of the statutes for watershed planning and county ground water planning (Minn. Stat. §§ 103D and 103B.201 to 103B.255).

Soil and Water Conservation Districts (SWCD)

SWCDs are political subdivisions of the state. Districts are authorized to develop a comprehensive plan specifying practices that implement state soil and water conservation policy. This plan may include structural measures, methods of cultivation, use of vegetation, cropping programs and other agricultural practices, mechanical practices, changes in the use of land, and related technical standards. It also must include a classification of soil types and identify areas most in need of control methods. The SWCD's board may acquire property and property interests to carry out its duties, and the district may accept the delegation of authority from a city or county to administer official (land use) controls to conserve soil and water resources (Minn. Stat. § 103C.331). SWCDs also monitor the state-wide observation well network for the MDNR and implement well-sealing programs with the financial assistance of BWSR.

Land Use Planning and Zoning

Cities, towns and counties have the express legislative authority to engage in land use planning and zoning activities. While their authority can be used to help implement the water resource plans discussed above, cities, towns and counties can also use land use planning and zoning as an independent source of authority to help protect ground water. Comprehensive planning is mandatory for cities, towns and counties located in the seven county Twin Cities Metropolitan Area. Comprehensive planning is discretionary for cities, towns and counties outside the area.

Cities

Cities may undertake comprehensive planning activities for guiding the future development and improvement of the city (Minn. Stat. § 462.353, subd. 1). This usually involves preparing a comprehensive plan stating policies, goals and standards, accompanied by maps which will indicate the physical, social and economic (public and private) development of the city. A comprehensive plan typically includes a land use plan, a community facilities plan, a transportation plan, and recommendations for plan execution. It may also include a ground water protection element with policies, standards, and goals for the protection of ground water in the city.

A city may put the plan into effect through zoning regulations, regulations for the subdivision of land, an official map, a program for coordination of the normal public improvements and services of the municipality, urban renewal and a capital improvements program (Minn. Stat. § 462.356,

subd. 1). Under the legislature's broad delegation of authority to cities in the zoning enabling law, cities should be able to use zoning to protect ground water. The zoning enabling law provides that:

> For the purpose of promoting the public health, safety, morals, and general welfare, a [city] may by ordinance regulate on the earth's surface...and in subsurface areas, the location...type of foundation,...size of buildings and other structures, the percentage of lot which may be occupied, the size of yards and other open spaces, the density and distribution of population, the uses of buildings and structures..., and the uses of land for...water supply conservation,...flood control or other purposes, and may establish standards and procedures regulating such uses (Minn. Stat. § 462.357, subd. 1).

In addition, a city may implement its comprehensive plan or otherwise protect ground water under the legislature's broad delegation of authority to cities for subdivision regulations. Subdivision regulations may be used to address issues such as water supply, storm drainage, sewers, "and the protection and conservation of flood plains, shorelands, soils, water vegetation, energy, air quality, and geologic and ecologic features" (Minn. Stat. § 462.358, subd. 2a).

Towns

If a town has adopted zoning authority, the town must exercise that authority consistent with the planning and zoning enabling legislation for cities (Minn. Stat. §§ 462.351 - 462.365) and with the specific town laws contained in Minn. Stat. § 366.10 - 366.19). Like cities, towns may use their zoning authority to protect ground water. In particular, towns may regulate land to promote "a distribution of population and classification of land uses and distribution of land development and utilization that will facilitate and conserve provisions for...water flowage, water supply, drainage, sanitation, educational opportunities,...soil fertility, food supplies, and protection of urban and non-urban development" (Minn. Stat. § 366.14). A town's zoning regulations must be made in accordance with a comprehensive plan.

Counties

Any county in Minnesota (excluding Hennepin and Ramsey Counties) may engage in county planning and zoning activities (Minn. Stat. § 394.21, subd. 1). A county may prepare and adopt a comprehensive plan. The comprehensive plan becomes the basis for official controls adopted by the county (Minn. Stat. § 394.23). The official controls may include zoning ordinances, subdivision controls, site plan rules, sanitary codes, building codes, housing codes, and official maps (Minn. Stat. § 394.22, subd. 6). Counties may include in their comprehensive plan and adopt official controls for "wetlands preservation, open space, parks, sewage disposal, protection of ground water, protection of floodplains..., protection of wild scenic or recreational rivers..., [and the] protection of slope soils, unconsolidated materials or bedrock from potentially damaging development" (Minn. Stat. § 394.25, subd. 2). Towns must adopt official controls consistent with the county's comprehensive plan but may choose to adopt controls which are more restrictive than provided in controls adopted by the county (Minn. Stat. § 394.33, subd. 1).

The Twin Cities Metropolitan Area

Cities, towns and counties (except Hennepin and Ramsey Counties) located within the Twin Cities Metropolitan Area are required to have comprehensive plans pursuant to the Metropolitan Land Planning Act (Minn. Stat. §§ 473.175, and 473.851 to 473.871). These comprehensive plans must be reviewed by the Metropolitan Council which has the general authority to plan for the development of the Metropolitan Area.

In particular, the Metropolitan Council prepares plans for metropolitan systems, including the airports, highways, transit, sewers and regional recreation open space. The comprehensive plans of cities, towns and counties within the metropolitan area must be consistent with the metropolitan system plans. The comprehensive plans must also contain objectives, policies, standards and programs to guide public and private land use and development, redevelopment, and preservation for land and waters. The metropolitan cities, towns, and counties must adopt official controls which are consistent with their comprehensive plans.

Other Local Government Powers

Eminent Domain

Local governments in Minnesota have other powers that also might be used to manage or protect ground water. One of these is the power of eminent domain. Local governments may exercise the power of eminent domain provided the local government is authorized to exercise the power of eminent domain, the acquired property is used for a public purpose, and the property owner is provided adequate compensation.

All cities are explicitly granted the right to acquire property by eminent domain. Counties and towns may exercise the power of eminent domain in certain cases. Towns with 1200 or more persons and towns with a platted area within 20 miles of the city hall of a first class city of over 200,000 persons have the power of eminent domain. Towns with 1,000 or more persons may elect to exercise the power of eminent domain (Minn. Stat. § 368.01). Counties have the power of eminent domain to acquire property for specific purposes such as solid waste management, and housing development. Counties in Greater Minnesota can use eminent domain to acquire property necessary for implementation of an approved comprehensive water plan (Minn. Stat. § 103B.331, subd. 3).

Health Boards

Cities and counties are required by the Local Public Health Act, Minn. Stat. ch. 145A (1990) to undertake the responsibilities or establish health boards. Health boards have the authority to remove public nuisances, acquire property and issue injunctions. They may adopt ordinances to prevent the disposal of unwholesome substances, regulate the disposal of sewage, garbage and other refuse, and to provide for the "cleaning and removal of obstruction from waters in the county and to prevent their obstruction and pollution." The health board also has the right to regulate offensive trades or one that is harmful to inhabitants, dangerous to public health, injurious to neighboring property or from which offensive odors arise.

Cities and towns within a county health board's jurisdiction may also adopt ordinances, but they cannot conflict with or be less restrictive than county ordinances. In contrast to zoning controls, health codes may be applied retroactively and may be used if there is only a threat of contamination. Local health codes may not conflict with state regulations.

Sewage Treatment

Local governments are also given broad powers to control sewage treatment, although the MPCA has the ultimate authority over sewage control. Municipalities, towns and counties in Greater Minnesota have the power to regulate the disposal of sewage and to prevent pollution to protect public health. Cities and towns in the Twin Cities Metropolitan Area have the same authority, but their plans are subject to the approval of the Metropolitan Council and Metropolitan Waste Control Commission.

Although the MPCA has promulgated minimum standards and criteria for individual septic systems, all local governments may adopt ordinances that provide more stringent requirements for sewage treatment.

Solid and Hazardous Waste Management

In Greater Minnesota, counties are authorized to conduct solid waste management programs to promote the public safety, health, welfare and productive capacity of the state's population (Minn. Stat. § 400.01). Counties may establish rules, regulations and standards relating to the location, operation and maintenance of solid waste and sewage sludge disposal facilities by the county, any municipality or private operators; the collection, processing and disposal of solid waste and sewage sludge; and the control of salvage operations, and water, air or land pollution at such facilities. The county may issue permits or licenses for solid waste facilities, and adopt ordinances and make provisions for permitting mixed municipal solid waste facilities.

Greater Minnesota counties are authorized to establish rules, regulations and standards for the identification, labelling and classification, collection, transportation, processing, disposal and storage of hazardous waste and other matters necessary to protect the public health (Minn. Stat. § 400.161). Greater Minnesota counties must also prepare a solid waste management plan which must include recycling and household hazardous waste management.

In the Twin Cities Metropolitan Area, the Metropolitan Council must prepare a long-range policy plan for solid waste management, including recycling and household hazardous waste management. Each of the seven counties is then required to prepare a solid waste master plan to implement the Council's policy plan. The plans are to include a land disposal abatement element to reduce, to the greatest feasible and prudent extent, the need for land disposal of mixed municipal solid waste. Master plans are also to include mechanisms for the management of household hazardous waste. Counties may also adopt rules, regulations and standards for solid waste facilities within the county, including their location, operation, inspection and monitoring. Counties are also authorized to regulate hazardous waste, including the generation, collection, processing and disposal of hazardous waste, and must require permits or licenses for these activities (Minn. Stat. § 473.803).

SECTION 5 - PROTECTION STRATEGIES FOR CONTAMINANT SOURCE MANAGEMENT AND RESOURCE PROTECTION

INTRODUCTION

Because so many variations exist in land uses, local land use conditions and ground water resources within communities, local governments need to consider a variety of protection strategies. This section gives an overview of alternative strategies and their value in protecting ground water. The information is not intended to be exhaustive. Local governments may also develop other alternatives as they evaluate their situation.

SOURCE- AND RESOURCE-BASED MANAGEMENT

The strategies available to local governments to protect ground water are two general types: source controls or resource-based. Source controls are community- or area-wide strategies aimed at managing or controlling potential contaminants from an individual or specific type of land use, such as storage tanks or animal feedlots. Specific strategies such as zoning controls are adopted by the local government to manage or control the particular source. A source-based strategy may be easier to implement than a resource-based approach because of the time and complexity of the geology and hydrogeology data required to delineate resource areas.

Using a resource-based strategy, a local government focuses on protecting the resource. The entire hydrologic system is defined, including the surface water system and the geographic area which affects the resource, and a broad strategy is adopted to protect the resource from all potentially harmful land use activities. There are four resource-based strategies: recharge areas, wellhead protection areas, sensitive ground water areas and entire aquifers. The geographic area overlying the resource may include a portion or all of the community, or extend beyond its boundaries, depending on the extent of the resource to be protected. It may be more effective for a local government to integrate several management strategies including source- and resource-based approaches depending on the types of existing or potential land uses and contaminants involved.

PROTECTION STRATEGIES

Specific protection strategies are of two types: non-regulatory and regulatory (Table 6). Non-regulatory strategies involve the use of financial incentives, education and other means to encourage voluntary private and public efforts to protect ground water. Regulatory strategies are based on the general authorities of local governments in Minnesota to enact land use controls, adopt ordinances under their police powers and establish health codes. (See previous discussion in Section 4.)

Non-regulatory Strategies

Many planning and management strategies that are used for other purposes can be adapted as part of a local ground water protection strategy. These are non-regulatory in nature, but many of them may be more effective when combined with regulatory approaches. Non-regulatory strategies may be attractive to local decision-makers because they do not force land owners, developers or other affected persons to modify their building, and facilities or other current practices to protect ground water. Regulatory strategies will be discussed later in this section.

Table 6
GROUND WATER PROTECTION STRATEGIES

Non-regulatory Strategies	Regulatory Strategies
• Growth management • Comprehensive planning • Acquisition of land, development rights • Best management practices (BMPs) • Public information and education • Solid and hazardous waste planning • Financial incentives • Program coordination and government operations • Monitoring • Spill contingency planning	• Zoning and rezoning • Overlay zoning • Conditional zoning • Floating zone • Cluster and planned unit development (PUD) • Transferable development rights (TDR) • Site plan approval • Subdivision regulations • Health and sanitary codes

Growth Management

Growth management integrates the non-regulatory functions of local government, such as comprehensive planning and capital improvement programming, and traditional land use controls such as zoning and subdivision controls. The purpose of growth management is to manage the location, timing, density and type of development or redevelopment to ensure that the supporting public facilities and services can be provided in an economical and timely manner consistent with the financial resources of the community. The protection of unique, sensitive and valuable natural resources such as wetlands and agricultural lands may be part of the strategy.

Local governments coordinate long-range planning for land use, programming of public capital improvements and the administration of zoning and subdivision controls to ensure that development occurs in specific areas where highways, sewers, parks and other public facilities and services are available or planned. For example, land is not planned for dense urban development unless sewer service will be available. Premature development is discouraged by planning and designating land for low density, rural uses. Similarly, the extension or provision of public services such as sewers is not planned or programmed for areas not planned for development. The local government's capital improvement program should indicate the construction, timing, costs, financing and location of planned public services for the same planning period. At the same time, agricultural lands and areas of sensitive natural resources are delineated and controlled to protect them or minimize the effects of development. A municipality may establish urban and rural service districts by ordinance for separate taxation purposes to support its growth management policies (Minn. Stat. § 272.67).

Ground water protection may be incorporated in the local growth management scheme. For example, after recharge, wellhead or sensitive areas have been delineated, they may be protected by discouraging commercial and industrial development in these areas until sewers, emergency services for spill cleanup, and other services are available and an adequate protection program of land use controls is adopted.

Comprehensive Planning

The local comprehensive plan is one of the least recognized strategies for protecting ground water. It consists of the local government's adopted goals, objectives, policies and plans for future development and provision of public services and facilities to serve the expected growth. Specific plans for the type, location and density of future land uses and public facilities such as sanitary sewers, roadways, storm drainage, parks and emergency services may also be included in the comprehensive plan (see Section 4, Local Government). Protection of the environment and natural resources such as wetlands, lakes, streams and ground water can also be addressed in the plan.

One of the purposes of the comprehensive plan is to provide a basis or rationale for the community's zoning, subdivision regulations and other local land use controls, all of them being important tools for implementing the land use recommendations in the plan. The plan is used to guide the preparation of a zoning map and ordinance, and to review proposed rezonings. It can be designed to guide development and future land use in newly developing areas and proposed redevelopment of older, fully developed areas.

The plan is based on a variety of environmental and natural resource data. Soils, geology, hydrogeological and particularly ground water sensitivity data can be an important part of the information used in developing the land use recommendations in the plan (see a discussion of this subject later in this section). Ground water sensitivity data could be used to evaluate potential areas for future industrial and commercial development, and identify areas where the use of on-site sanitary systems should be discouraged. The availability and use of ground water information should result in a plan which is more responsive to ground water protection concerns.

Because of its emphasis on land use and the provision of public facilities, the comprehensive plan plays an important role in protecting ground water. The plan may include explicit community-wide goals and policies for ground water protection, discourage land uses and densities in critical areas which represent a threat to ground water quality and recommend design and operating standards for land uses to protect ground water. Including goals, policies and standards for the type, location and design of public facilities to be provided will ensure that they will be designed, operated and located to protect ground water resources.

The comprehensive plan may also be part of a resource-based protection strategy for recharge, wellhead and sensitive areas. Maps delineating the area(s) and appropriate land use policies for the development of the area to ensure its long-term protection may be incorporated in the plan. Land use policies define the appropriate type and density of residential, commercial, industrial and other land uses that are to be encouraged or discouraged, and the protection standards to be incorporated in their development. The zoning ordinance and other land use controls would be amended to incorporate specific provisions to implement these policies and standards. Policies and standards for the development and operation of public facilities (i.e., sewers, maintenance facilities, sewage treatment and stormwater ponds)in these areas may also be contained in the plan. These would be used to review proposed public facilities proposals as they come before the local planning body.

Many local governments have established a planning commission consisting of local citizens that reviews both private and public development proposals. Proposals should be reviewed for consistency with the community's comprehensive plan. To be effective, the comprehensive plan should be adopted by the governing body as the official development policy of the community.

Acquisition of Land and Development Rights

Local governments may acquire land or other property through negotiation or condemnation (see Section 4). The purchase of fee title provides the most absolute protection of ground water because local government will have the power to determine land use. Acquisition of fee title for large land areas may be very costly, particularly in urban areas where land and property values are high. If the land can be used for another public purpose, such as a community park, the cost of acquisition may be easier to justify. To mitigate the cost issue, the land may be purchased and then sold or leased back with limits placed on the use. The local government could, for example, lease the land for agricultural activities but limit or prohibit the use of pesticides on the land as a condition of the lease.

Purchase of land development rights or an easement over the land may be less costly and leave the land in private ownership and use. The easement allows uses compatible with the protection of the resource.

Acquisition may be more feasible if it is limited to key parcels of land, such as areas immediately adjoining a proposed community well, where there is a direct threat of a spill or other release, or land uses such as an existing industry that represents a significant threat to a public well.

State funds may be available through the Board of Water and Soil Resources (BWSR) and the Reinvest in Minnesota (RIM) program to acquire easements in sensitive ground water areas (see Section 4 and Appendix D).

Best Management Practices

Best Management Practices (BMPs) are defined in Minn. Stat. ch. 103H as:

> ....Practicable voluntary practices that are capable of preventing and minimizing degradation of ground water, considering economic factors, availability, technical feasibility, implementability, effectiveness, and environmental effects. BMPs apply to schedules of activities, design and operation standards, restrictions of practices, maintenance procedures, management plans, practices to prevent site releases, spillage or leaks, application and use of chemicals, drainage from raw material storage, operating procedures, treatment requirements, and other activities causing ground water degradation.

BMPs are typically thought of as something applied to agricultural uses such as pesticide or fertilizer application, but the concept can be readily applied to urban, commercial and industrial, and public land uses. The risks from excessive fertilizer and pesticide use in urban areas, the release of toxic and hazardous materials associated with industrial or commercial activity, and the accidental discharge of chemicals used by government agencies can be minimized or avoided by incorporating better design standards into these facilities or improving operating procedures.

Ideally, BMPs are adopted voluntarily by citizens, operators, land owners, developers and other individuals or organizations, but their use may also be required by local regulations. Local land use controls can require that proposed land uses incorporate design and operating standards to prevent the release of contaminants as a prerequisite for local approval.

BMPs may also be incorporated with other management strategies which encourage their use. For example, financial incentives such as cost-sharing may be used to overcome the economic barriers to the use of a practice, or a public information and education program can be organized to ensure that potential users receive accurate information about the costs and benefits of management practices.

BMPs are generally of two types. "Soft" techniques involve changes in procedures, operations and activities such as testing soil nutrient levels prior to applying lawn fertilizer. "Hard" techniques involve the use of structures and other physical improvements and the incorporation of design features or devices to prevent the spilling or release of contaminants from the source, such as the placement of containment structures around chemical storage tanks.

Public Information and Education

Local governments can plan and undertake a variety of organized activities using various media to inform local officials and citizens about the importance of ground water protection. Programs could include information regarding the importance of ground water resources to the health and growth of the community, potential impacts of individual and community land use decisions on ground water quality, potential exposure to liability, costs and impact of after-the-fact pollution cleanup, and potential methods for protecting ground water. These activities may be an attractive "first step" protection strategy in those situations where monitoring data indicates contaminants are non-existent or present at very low levels and there is no pressure to regulate sources.

The goal is to increase public consciousness of how public and private decisions affect ground water and encourage them to take voluntary action. In seeking to build support for local government programs, information campaigns can be designed for all citizens or targeted at special groups. Homeowners, for example, can be encouraged to dispose of household hazardous waste in a safe manner. Similarly, business organizations can be informed of the risks of contamination and how their facilities can be improved to avoid these.

Many local, state and federal agencies provide information on ground water quality and managing specific sources of contaminants which could be incorporated in a local public information program (see Section 4).

Solid and Hazardous Waste Planning

Counties in Minnesota are responsible for solid and household hazardous waste planning and management. This authority includes assessing the need for disposal, siting solid waste disposal facilities and developing programs to reduce the volume of waste by recycling and other means. (see Section 4, Local Governments). Counties are required by state law to include recycling and household hazardous waste management elements in their solid waste management plans. One objective of solid waste planning should be the removal of potential ground water contaminants from the waste stream, thereby minimizing the amounts which are discarded or landfilled and eventually affect ground water quality. Local solid waste management planning may be coordinated with the development of a ground water protection plan to focus the goals and priorities of the former on the removal or safe recycling or disposal of contaminants in the waste stream.

Financial Incentives

Financial incentives may be useful or necessary to encourage or support ground water protection. Two common forms of financial incentives are differential assessments and tax credits. Differential assessments may be used in areas where land use is highly restricted or controlled to protect ground water and to reflect any reduction in the value of the land. Tax credits are given to land owners and applied against local taxes or state income taxes to balance the land use restrictions placed on their property to protect ground water.

Both of these approaches would be applicable as part of an overall resource-based strategy to protect the area overlying the ground water. Before implementing this strategy, the legality of the

approach should be reviewed. Currently, Minnesota state law allows differential assessments for the purpose of preserving agricultural land.

Another financial incentive involves cost-sharing. In this instance, the cost of installing or using best management practices which provide better protection for ground water is shared by federal or state programs. This method is frequently used to encourage farmers to adopt soil and water conservation methods.

Loans and grants are available in some instances to encourage ground water protection planning, or to implement protection activities. For example, loans and grants are available through the Minnesota Department of Agriculture to encourage farmers to reduce the unnecessary use of nitrogen fertilizers and pesticides (see Appendix D).

Program Coordination and Government Operations

As part of their day-to-day operations, local governments are directly involved or responsible for a number of activities which may affect ground water quality (see also Solid and Hazardous Waste Planning, above). Included are activities that involve the use or storage of potential contaminants such as petroleum products, paint, roadway deicing chemicals, cleaning chemicals, hazardous wastes, fertilizers and pesticides. Maintenance of buildings, parks, roads, right-of-ways and vehicles may involve one or more of these potential contaminants.

Local governments are also responsible for the location, design and construction of a wide variety of public facilities which could affect ground water quality. These facilities include storm water management, landfills, sanitary sewers, wastewater treatment plants, water supply wells and maintenance buildings. Local government can set a good example for the rest of the community by first assessing how its operations and program responsibilities affect ground water quality. The next step is to adopt design and operating standards to guide the use, handling and storage of contaminants and the construction and operation of public facilities.

In Greater Minnesota, county governments are responsible for developing a comprehensive water resource plan for surface and ground water. In the Twin Cities Metropolitan Area, surface water plans are prepared by watershed management organizations and ground water plans by the counties. Surface water quality problems may affect ground water quality where surface water bodies recharge ground water or runoff infiltrates surficial geological materials and eventually enters the ground water system. Local goals, policies, strategies and standards for managing surface water should be coordinated with local ground water quality protection plans to ensure consistency and compatibility between the programs. For example, locating of stormwater detention ponds in wellhead zones or sensitive areas may conflict with the protection goals and strategies in the local ground water plan.

One approach for improving state-local government coordination is for local government to assume responsibility for some state regulatory programs where state law provides for this. Counties may, for example, administer portions of the state's feedlot regulations and well construction code.

Monitoring

Ground water quality monitoring is not a preventive strategy. It can, however, be an important part of an overall strategy to protect ground water. The purpose should be considered in designing a monitoring program since monitoring can be designed to evaluate ambient ground water quality throughout an area, a single land use or group of such uses, or a critical area such as a wellhead area.

Ongoing monitoring of ambient ground water quality allows a community to establish the current status of ground water quality and evaluate the trends in quality over time and space. Monitoring data also enables the community to assess the effectiveness of its protection plan over a long period of time. The information provides an early warning system to assist the community in identifying emerging contaminant problems and specific areas or uses that may require further study. The monitoring of specific land uses or sites, such as a landfill, would assist in delineating the area, population and land uses affected by a contaminant release and give the community time to respond to the problem.

The design of a new or expanded monitoring program should be based on the goals and priorities established in the local ground water plan. For example, the plan may indicate that continued use of a surficial aquifer rather than the future use of a deeper, confined aquifer is the community's principle concern. The monitoring program could be designed to reflect this priority.

A ground water monitoring program may be expensive because of the number of sites involved, the number or different types of contaminants (parameters) to be tested for and the cost of laboratory tests. In particular, laboratory tests for organic chemicals are extremely costly. Before undertaking a monitoring program, the local government should contact state agencies (see Section 4) to avoid costly duplication and ensure data acquisition quality and integrity. Also, a local government could consider requiring long-term monitoring requirements as a condition of its approval of new industrial or research developments which store or use hazardous materials. This requirement would defray public costs and allow the community to monitor the effectiveness of preventive measures incorporated in the development.

Spill Contingency Planning

A local government contingency plan for managing and cleaning up spills, leaks and catastrophes on public or private property provides another means for preventing or minimizing ground water contamination. Since speed and effectiveness of the response will affect the extent of contamination, the plan should include information regarding the types and location of contaminant sources and procedures for the reporting of incidences to appropriate state and local authorities. This precaution ensures that adequate personnel and equipment are available and determines the roles of various local and state emergency response agencies.

Regulatory Strategies

Several regulatory strategies can be adapted to serve ground water protection needs. Some can be adapted to the management or control of both contaminant source management as well as resource protection. Specific applications or uses of individual strategies will be discussed later in this section. The purpose here is to introduce the basic concepts.

Zoning and Rezoning

Traditional zoning is the most common form of land use control used by local governments. An area is divided into districts that are designated as industrial, commercial or residential, and permitted land uses and standards are determined for each district. Zoning is also used to control the size of lots or density of development, the size and height of structures, percent of lot coverage and population density (number of dwellings per acre).

In an undeveloped or newly-developing community, zoning or rezoning may be used to preclude new potential contaminant sources in the community, such as industries using or storing hazardous materials. Zoning district boundaries may be redrawn to prohibit these uses in a more limited protection area, or district standards may be amended to restrict such uses in the future.

Traditional zoning and rezoning is more limited as a protection device in developed areas. It is not always feasible or sufficient to rezone an area to restrict the development of contaminant sources. Existing non-conforming land uses are "grandfathered in" and would continue to operate until private or public actions remove them. This limits local government's ability to manage or control potential sources of contamination which exist in the area.

The problem of controlling existing land uses can be managed to some extent by requiring an occupancy permit for new businesses and industries moving into existing buildings. Prior to securing the occupancy permit, the firm is required to meet the local government's building and operating standards to protect ground water. For example, this would allow a new industrial use in an existing building but ensure that any hazardous materials are handled, used or stored in a manner that meets the local government's ground water protection requirements.

Traditional zoning has been adapted in several different ways to make it a more flexible and sophisticated land use control technique. New approaches include overlay zoning, conditional zoning, floating zones, cluster zoning, planned unit development (PUD), transferable development rights (TDR) and site plan review. Each of these approaches can be adapted for ground water protection purposes.

Overlay Zoning

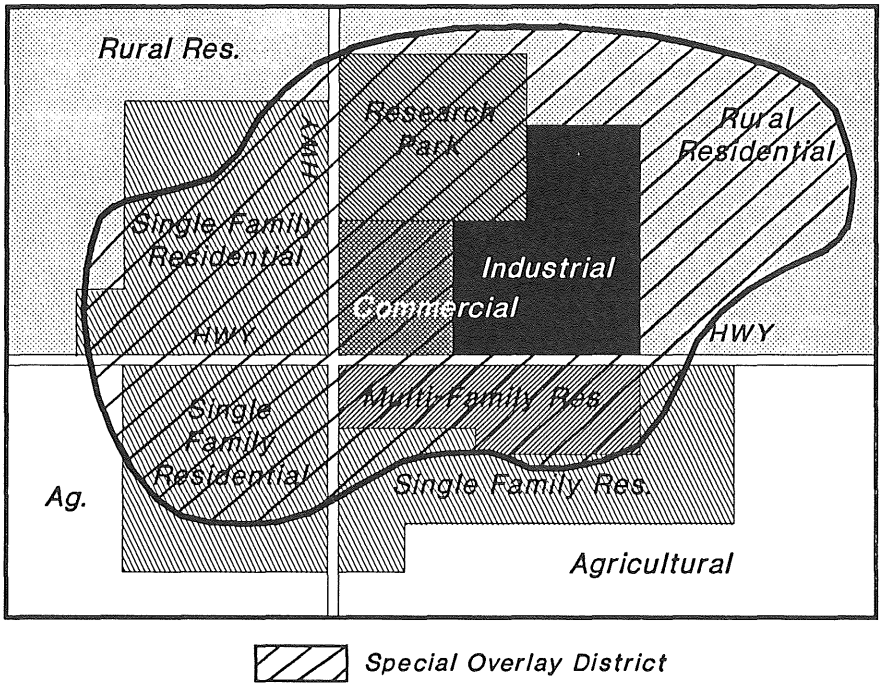
In this approach, another zoning district which establishes additional and more restrictive requirements is "laid over" the existing zoning districts. It may include part or all of one or more existing districts. Industrial, commercial and residential land uses allowed by the underlying zoning are permitted if they satisfy the additional standards required by the overlay zone. This approach is frequently used as part of a resource-protection plan for wellhead and ground water recharge areas (Figure 11).

The overlay district may include additional standards for building design, site plans and operating procedures for uses within the district to protect ground water quality, such as special requirements for the containment of hazardous materials stored on the site. The local government may require the submittal of a site plan for the proposed development indicating the specific measures proposed to protect ground water. Overlay zoning works best when applied to a single, relatively compact geographic area. If there are many separate areas throughout the community involving many different types of land uses affected by the issue, it may be better to create an entirely new but separate zoning classification, such as a conservation district (American Planning Association, 1991).

Conditional Zoning

Under this approach, residential, commercial and industrial uses which represent no risk to ground water quality are allowed by the zoning ordinance as permitted uses. Other such uses or expansions which are associated with potential sources of contamination are only allowed by a special use or conditional use permit if they meet certain conditions to protect ground water. For example, commercial land uses involved in the processing, storage or handling of hazardous materials would not be permitted in industrial or commercial zones unless specific standards to prevent the release of these substances are incorporated in their design and operation. The applicant may be required to submit detailed information regarding the geology of the site, a site plan indicating proposed design specifications for facilities, an operations plan and other information showing how ground water will be protected. Conditional zoning may be applied to individual sources of potential contaminants such as salvage and junk yards, cemeteries and feedlots.

FIGURE 11. GROUND WATER RECHARGE PROTECTION ZONE



Special Overlay District Requirements:

- *Submittal of site plan for proposed subdivisions and development*
- *Special design, operating standards and occupancy permits for industrial and commercial development*
- *Prohibition of municipal and industrial wastewater discharges and solid and hazardous waste disposal*
- *Management standards for on-site sewage disposal systems*
- *Required hook-up to municipal sewers where and when available*

Floating Zone

Floating zones are applied to areas in which certain specified land conditions exist that are to be protected because of their unique role in the ground water system. Local government may, for example, prohibit land uses which involve the use, handling or storage of hazardous chemicals in recharge areas. The areas may not be precisely mapped, and it is the applicant's responsibility to show that the proposed development is not located in an area subject to these conditions or that the development complies with the protection standards imposed by the local government. The applicant may submit the necessary hydrogeological data to substantiate the location of the proposed use outside the zone or submit a site plan satisfying the local government's standards.

Cluster Zoning and Planned Unit Development (PUD)

Specific land areas or districts that are zoned to permit cluster development allow development to be concentrated or clustered on one portion of a land parcel while retaining the overall density standard. This approach is typically applied to residential land uses where there is a need for greater flexibility in the arrangement and design of housing (Sanders, 1980). For example, if local zoning allows a maximum of 4 dwelling units per acre on a ten-acre site, then rather than requiring a subdivision to be platted with each house on a quarter-acre lot with its own street frontage, cluster zoning permits clustering the residences on part of the parcel at a higher density designating the rest of the site for open space uses. In some areas, the open space could be set aside to protect the wellhead area of the municipal well. The local planning and zoning authority will require the submittal of a clustering site plan for its review and approval.

Planned unit development is also designed to allow greater flexibility, particularly for mixed-use developments such as shopping centers and office-retail development (So, 1973) and permits the setting aside of open space areas. Clustering and PUDs are frequently allowed by establishing an overlay district(s) in those areas where greater flexibility is to be encouraged.

Transferable Development Rights (TDR)

TDR is based on the concept that land ownership consists of several rights, including development, mining and air rights. Each of these can be transferred separately to another owner. In order to protect ground water, the local government may restrict development in a critical area such as a wellhead area. TDR allows the transfer of the landowner's right to develop from the restricted zone to a "receiving zone" located elsewhere in the community and designated by the local government as suitable for development at a higher density than allowed by the existing zoning. There must be a landowner in the receiving zone who is willing to purchase the development rights from the original landowner (Bangs, 1975).

Site Plan Approval

Local governments often require the submittal of a site plan to evaluate the effect of a proposed development on surrounding land uses and capacity of public facilities and services. Submittal of a site plan may also be required as part of the overlay district and conditional zoning permit application. The ordinance may require that detailed information about the proposed development be provided including characteristics of the underlying soils and geology, depth to the water table and types of hazardous materials which will be handled or stored on site. The site plan may also indicate the proposed standards for the design and construction of facilities and operations to promote ground water protection. The local planning board and government reviews the site plan against the site plan ordinance requirements and approves or rejects the plan, or accepts it with the condition that certain changes will be made to protect ground water.

Subdivision Regulations

Subdivision regulations are a common form of land use control used by local governments when parcels of land are subdivided into lots for sale or development. The purpose of the regulations is to ensure that streets, sanitary sewers, storm drainage, parks, schools and other public service facilities will serve the new development and are designed and constructed to meet appropriate engineering and other community standards. Typically, the developer must submit for review and approval preliminary and final plats (plans) of the design layout and standards, proposed facilities, and other provisions to confirm their compliance with local government objectives.

Subdivision regulations can be adapted for the purpose of ground water protection by incorporating special design and construction standards. This may include standards for low leakage sewers, stormwater storage ponds, septic system design and installation, well construction, the dedication of public open space and lot sizes. Like traditional zoning, subdivision regulations are more valuable in controlling future land use in undeveloped or developing areas. They apply only when a new lot is created. Once an area is developed, further subdivision activity will be limited until the area is redeveloped and replatted.

Health and Sanitary Codes

Traditionally, local health and sanitary codes administered by local health agencies have not been applied to land use-related problems. One of the advantages to local governments in using health and sanitary codes is that codes can be applied to existing sources of contamination whereas traditional zoning and subdivision regulations are generally more effective in controlling new development. Health codes are most readily applied to the control of specific land use activities which have been identified as potential sources of contamination: septic systems; storage tanks; the use, storage and handling of hazardous materials; and the construction, repair or sealing of abandoned wells. The code may incorporate permit, monitoring, reporting, inspection, design and operating requirements for each source. When a potential source of contamination is replaced or expanded, the ownership changes or problems occur, the code requirements can be applied by the local government.

CONTAMINANT SOURCE MANAGEMENT

Many of the specific strategies discussed previously can be adapted to control or manage individual sources or land use activities for the purpose of ground water protection. Selected examples of the major contaminant sources presented in Section 3, and the application of the specific control strategies to each are discussed in this subsection. A variety of point and nonpoint, agricultural, commercial and industrial, municipal and other types of sources were selected to show how the specific strategies could be applied in each case. Not all of the sources discussed in Section 3 are covered because many exhibit the same type of control or management problems. Tables 7a and 7b include most of the sources discussed in Section 3 and the types of strategies that might be applied to them. Examples presented below provide sufficient information for developing control strategies for the other sources discussed in Section 3 plus other land use activities that local governments may identify as a concern in their areas.

Animal Feedlots and Waste Management

The major concern regarding feedlots is the potential impact from the storage and disposal or land application of animal manure (Figure 12). The MPCA regulates the construction of new feedlots and proposed expansions for facilities involving ten animal units or more. (Ten units is equal to ten beef steers or 1000 chickens). Applications to the MPCA must include a proposed manure management plan which addresses storage, disposal and land application of manure as a fertilizer (see Section 4 and Appendix D for additional information). Local governments will be concerned where the activities are located and whether state standards are sufficient to protect ground water resources.

Prior to evaluating or implementing any of the following strategies, local government could undertake an assessment of existing feedlots, including their location, current design and operating standards and the geologic sensitivity of the groundwater. To assist local governments in inventorying and evaluating feedlots, the MPCA and BWSR have produced a guidebook (*Feedlot Inventory Guidebook*, 1991).

Table 7a

NON-REGULATORY SOURCE CONTROL STRATEGIES

Sources	Growth Management	Comprehensive Planning	Acquisition of Land & Dev. Rights	Best Management Practices	Public Information & Education	Solid & Hazardous Waste Planning	Financial Incentives	Program Coord. & Gov't. Operation	Monitoring	Spill Contingency Planning
Accidental spills				o	o			o	o	o
Animal feed- lots & waste management		●	o	●	●		o	o	o	
Cemeteries		o		o	o				o	
Fertilizer application			●	●	●		o	●	●	o
Hazardous waste disposal	o	o		o	o	o		o	o	o
Hazardous substance use, storage & handling	●	●	●	●	●		o	o	●	o
Incinerator ash		o		o	o	o		o	o	
Irrigation				●	●			o	o	
Military facilities				●	●			●	o	●
Mining wastes		o		o	o			o	o	
On-site sewage treatment systems & septage disposal	●	●		o	●	●		●	●	
Pesticide application			●	●	●		o	●	●	o

● **Discussed in the text**

o **Not covered in the text**

Table 7a (continued)

NON-REGULATORY SOURCE CONTROL STRATEGIES

Sources	Growth Management	Comprehensive Planning	Acquisition of Land & Dev. Rights	Best Management Practices	Public Information & Education	Solid & Hazardous Waste Planning	Financial Incentives	Program Coord. & Gov't. Operation	Monitoring	Spill Contingency Planning
Pipeline leaks								●		●
Public service & maintenance facilities		●		o	o	o		●	o	o
Road salt storage		●		●	o			●	●	
Salvage & junk yards	o	●	●	●	●	o		o	●	o
Sewage & industrial wastewater		●			o		o	●	o	
Sewage sludge		o		o		o		o	o	
Sewer leakage (sanitary)		●			o			●	o	o
Solid waste landfills		●			o	●		●	o	
Storage tanks (under- & above-ground)		●		o	●		●	●	o	●
Urban runoff		o		o	o			o	o	

● **Discussed in the text** o **Not covered in the text**

Table 7b

REGULATORY SOURCE CONTROL STRATEGIES

Sources	Zoning & Rezoning	Overlay Zoning	Condi-tional Zoning	Planned Unit Develop.	Cluster	Transfer of Devel. Rights	Site Plan Review	Subdiv-ision Reg.	Health & Sanitary Codes
Accidental spills		o	o				o		o
Animal feedlots & waste management	●	o	●				o		●
Cemeteries	o	o	o					o	
Fertilizer application		●[1]	o[1]						●
Hazardous waste disposal	o	o	o				o		o
Hazardous materials use, storage & handling	●	●	o	o		o	o		●
Incinerator ash	o	o	o				o		
Irrigation		●	●						
Military facilities									
Mining wastes	o	o	o				o		
On-site sewage treatment systems & septage disposal	●	●	●	o	o	o		o	●

● **Discussed in the text** o **Not covered in the text**

Table 7b (continued)

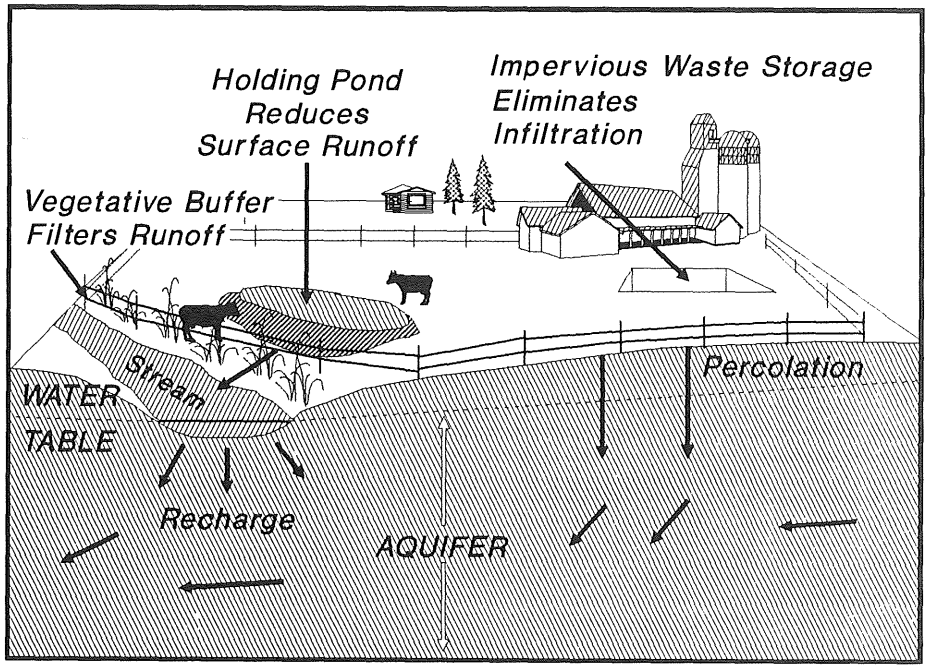
REGULATORY SOURCE CONTROL STRATEGIES

Sources	Zoning & Rezoning	Overlay Zoning	Condi-tional Zoning	Planned Unit Develop.	Cluster	Transfer of Devel. Rights	Site Plan Review	Subdiv-ision Reg.	Health & Sanitary Code
Pesticide application		●[1]	o[1]				o[2]		●
Pipeline leaks									
Public service & maintenance facilities	●	●	●				o		
Road salt storage	●	●	●				o		
Salvage & junk yards	●		●				●		o
Sewage & industrial wastewater	●	o	●						●
Sewage sludge	o	o	o				o		o
Sewer (sanitary) leakage								●	●
Solid waste landfills	●	●	●						●
Storage tanks, (under- & above-ground)	●	o	●				●		●
Urban runoff							o	o	
Well construction & abandonment							o	●	●

[1]Assuming legal issues can be resolved [2]For urban development only

● Discussed in the text o Not covered in the text

FIGURE 12. ANIMAL FEEDLOTS AND WASTE MANAGEMENT



Non-regulatory Strategies

Comprehensive Planning Land use goals, policies and criteria may be incorporated in the local comprehensive plan addressing the location, design and operation of feedlots and waste storage to protect ground water. A policy that feedlots and related activities be located, designed and operated to protect ground water quality and public health would discourage the location of these activities in critical areas such as wellhead, recharge, and highly sensitive ground water areas. Or, the comprehensive plan may allow the location of these facilities in such areas if they are designed and operated in accordance with state regulations and local standards. Appropriate zoning or other land use controls would be adopted to implement the policies.

Public Information and Education Local governments could develop a public information and education program encouraging the voluntary adoption of best management practices (BMPs) for existing feedlots. Existing feedlots are not affected by state regulations unless there is a change in ownership, an expansion or a pollution problem. Information and education programs would explain the benefits of BMPs to ground water quality and the costs and impact of cleaning up ground water pollution. Local USDA-SCS, Minnesota Extension Service and SWCD offices provide technical assistance on the design and location of facilities. Information on state and federal cost-sharing funds is also available from these agencies, ASCS and BWSR. The MPCA also provides technical assistance and information regarding the design, construction, location, management and regulation of feedlots.

Regulatory Strategies

Zoning Local governments may choose to treat feedlots as a specific land use and prohibit or allow new facilities only in specific zones depending on their compatibility with other land uses.

A more flexible approach would be to allow new feedlots only as a conditional use. The ordinance would incorporate MPCA standards and any additional or more stringent local standards as a condition for approval. The applicant would be required to submit a plan for the proposed feedlot or expansion that indicates how the facility will be designed and operated to prevent or minimize the contaminants reaching the ground water.

Jefferson County, Wis., has adopted a zoning ordinance that requires a conditional use permit for feedlots (American Planning Association, 1987). Conditions for approval address the location, surface and ground water protection, and animal manure management. The ordinance incorporates USDA-SCS standards for nutrient application as a means for determining the land area requirements for manure spreading.

If wellhead, recharge or sensitive geological areas have been defined, the local government may consider prohibiting or restricting feedlots and the application of manure in these areas.

The Minnesota Project, a non-profit public interest organization located in the karst area in southeastern Minnesota, developed a model ordinance that addresses the management of livestock waste from feedlots and manure storage facilities (Minnesota Project, 1984). The ordinance includes standards for the siting, design and operation of feedlots and manure storage facilities to protect sinkholes, water supply wells, and surface waters, and also regulates the land application of manure as a fertilizer.

Health and Sanitary Code Another option for local governments is to adopt a comprehensive health or sanitary code governing the construction and operation of feedlots as part of the local sanitary codes to protect public and private water supplies. The code establishes standards for the design and operation of feedlots including the disposal or land application of waste. The code could incorporate MPCA standards and its requirements would be applied to new facilities and existing feedlots when a threat to public health or water supply is detected, a change in ownership takes place, or the facility is expanded.

As an alternative to the adoption of local controls, the county may choose by resolution to administer the state rules locally to ensure that all feedlots are managed consistently, effectively and in a timely manner.

Fertilizer and Pesticide Application

The chief concern is that fertilizers including animal manure and pesticides are frequently applied in excess of plant needs or in geologically sensitive areas where chemicals leach readily into the ground water. The latter case might occur due to high recharge rates in irrigation areas.

Minnesota law does not currently limit the role of local governments in regulating the application of fertilizer for the purpose of protecting ground water quality. The situation with regard to state regulation of pesticides application is less clear. State law preempts local ordinances that "prohibit or regulate any matter relating to the registration, labeling, distribution, sale, handling, use, application or disposal of pesticides" (Minn. Stat. § 18B.02). The law also states that "it is not the intent of this section to preempt local responsibilities for zoning, fire codes, or hazardous waste disposal." However, zoning is used in many areas to control activities and contaminants that are a risk to ground water. The use of the word "zoning" confuses rather than clarifies the limits of the previous provision.

The statute also authorizes the Commissioner of Agriculture to delegate by a joint powers agreement specific inspection, enforcement and other regulatory duties to officials of approved agencies including county, municipal or other political subdivisions (Minn. § Stat. 18B.03). Rules

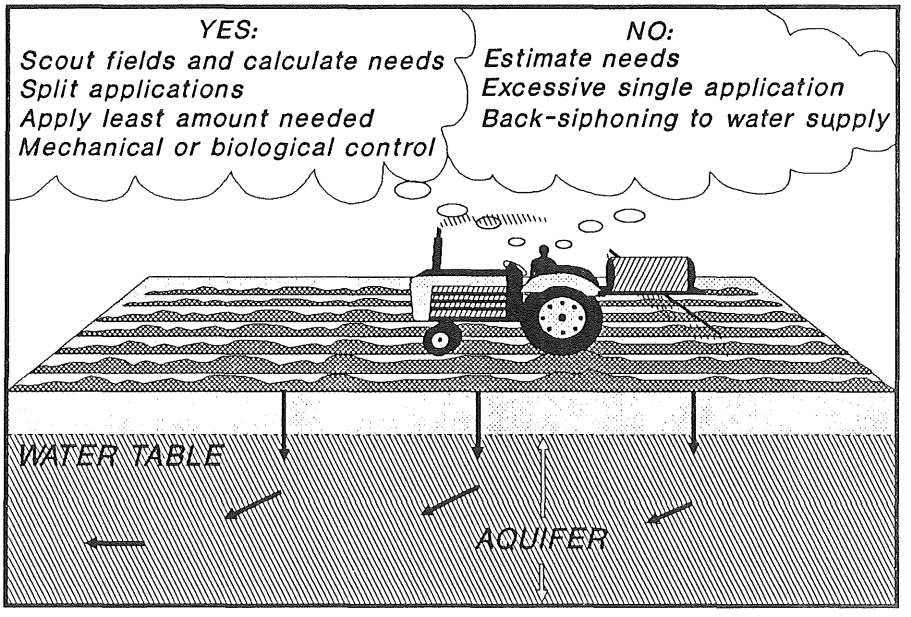
to implement and enforce this provision, including procedures addressing local control of pesticide regulation, have not yet been developed. This might present a mechanism for local governments to regulate pesticide use, particularly in wellhead, recharge or sensitive ground water areas.

In Minnesota, the primary emphasis is being placed on developing best management practices (BMPs) and educating farmers, businesses and residents to voluntarily limit the application of nitrogen and pesticides in urban and agricultural settings. (The Ground Water Protection Act of 1989 directs the Minnesota Department of Agriculture (MDAg) and MPCA to develop specific BMPs.) The goal is to reduce excessive use of these substances while maintaining the profitability of farming and the viability of other activities.

Integrated Pest Management (IPM) is a comprehensive management strategy for pest control. IPM uses a variety of methods to control and keep pest populations below economically damaging levels. IPM is based on three principles: 1) chemical and nonchemical control methods play a role in pest control; 2) a certain level of pest activity can exist without causing economic loss; and 3) pest control can affect the environment and therefore control methods which reduce these impacts are to be promoted (Environmental Quality Board Water Resources Committee, 1988).

IPM substitutes nonchemical methods and encourages the judicious use of pesticides to reduce their use (Figure 13). Nonchemical practices include crop rotation, use of resistant varieties, modification of cultural practices such as planting and harvesting, and use of biological controls such as natural enemies. Judicious use of pesticides includes applying them at the right time and proper rate. IPM relies on information regarding the biology of the crop and pest, the environment and control methods, the weather, the crop and the pest population. Scouting fields to determine the pest types and population levels present is an integral part of the strategy. Pesticides may be used, but only after monitoring of pests and consideration of other controls indicate it is necessary (University of Wisconsin Extension, 1987).

FIGURE 13. MANAGEMENT OF PESTICIDE APPLICATION



Nitrogen is a basic nutrient used in agricultural crop production and maintaining urban lawns and golf courses. For agricultural purposes, adequate amounts of nitrogen must be available from sources in the soil, commercial fertilizer, crop residue, atmospheric sources or animal manure to produce a sufficient and profitable yield. If nitrogen is applied in excess of what the crop or turf requires, the surplus may leach into the ground water in the form of nitrate.

The goal of best management practices is to avoid the excessive application of nitrogen, whether that involves the application of animal manure, commercial fertilizers or both. BMPs for nitrogen management are based on several basic principles: the rate of application should be based on soil needs determined by soil testing; timing of application should be related to when the crops can most efficiently use the nutrients; and placement of nitrogen should maximize uptake and reduce the potential of leaching (Figure 14). The application of commercial fertilizer should also take into account previous applications of nitrogen in the form of manure or the amount of nitrogen available in the residue of previous soybean and alfalfa crops (Minnesota Project, 1989).

Some farmers and other agricultural interest groups are advocating the concept of "sustainable agriculture." In part this philosophy involves reducing the use of commercial fertilizers and pesticides to reduce production costs and increase profit margins while developing and using farming methods which are more compatible with the environment over the long term. Implementation of sustainable agriculture will also provide increased protection for ground water quality.

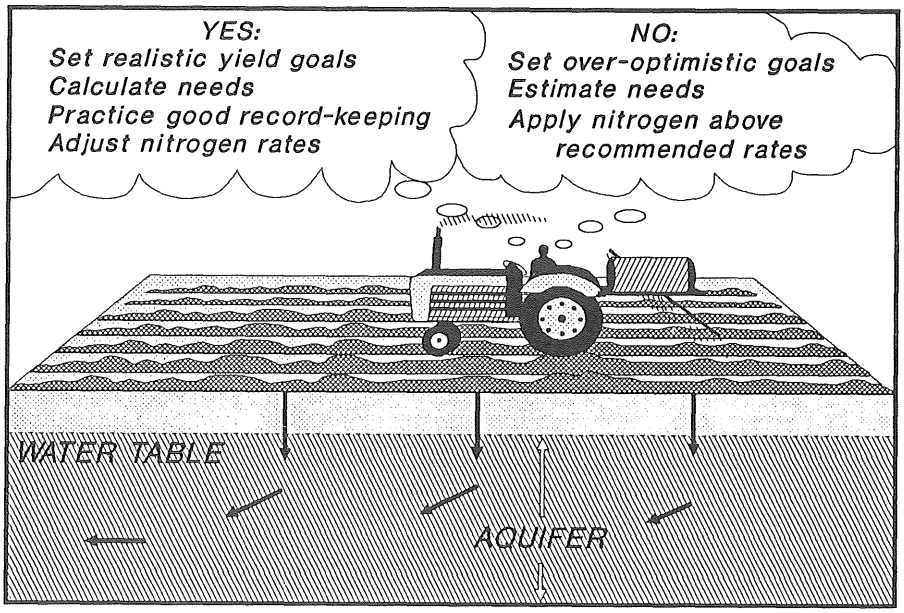
A primary goal of sustainable agriculture is to reduce the need for agricultural chemicals and replace them with an integrated system to control weeds, insects and fertility. Primary objectives include crop rotation, building soil fertility, recycling livestock manure, non-chemical management of weeds, use of integrated pest management, and soil conservation. Crop rotation, for example,is encouraged to disrupt the life-cycle of certain pests and diseases while putting nitrogen back into the soil. A publication is available, *Protecting Groundwater through Sustainable Agriculture* (Minnesota Project, 1989), which introduces concepts of sustainable agriculture. It provides a summary of the basic concepts underlying this approach and lists other sources of information.

Non-regulatory Strategies

Acquisition Acquiring fee title to land is not likely to be used extensively to limit chemical use because of the cost. However, it might be used in special situations, for example to protect a wellhead area. Acquiring a long term easement would be less expensive and allow the removal of the land from production. The easement eliminates the application of agricultural chemicals but allows other lower risk uses. The area may eligible for funding from the state RIM program (see Appendix D - Board of Water and Soil Resources).

Public Information and Education Encouraging farmers, businesses, home owners, property managers and other groups to voluntarily adopt BMPs to reduce the excessive application of nitrogen and pesticides is one strategy available to local governments. This is the easiest approach to implement because it does not force anyone to change their current practices. Also, a growing body of technical information on BMPs is available from federal and state agencies, universities, and local water and agriculture related organizations. Grants, loans and technical assistance may also be available to encourage individuals to adopt BMPs. Local governmental units can develop a communications plan and organize support; identify target groups such as property managers, commercial applicators, residents or farmers; obtain funding; coordinate the federal, state and local sources of information; and organize workshops and other educational forums.

FIGURE 14. MANAGEMENT OF FERTILIZER APPLICATION



Information on BMPs to limit pesticide and nitrogen use is available from numerous sources. The GWPA of 1989 directed the Commissioner of Agriculture to develop BMPs for agricultural chemicals commonly found in ground water and develop pesticide management and nitrogen fertilizer management plans. The latter report is available from the department. The final draft of the pesticide management plan is awaiting publishing of final EPA guidelines and EPA approval. In the meantime, MDAg is drafting a state plan which will include a broader strategy.

The nitrogen fertilizer plan contains recommended BMPs for state-wide use, individual regions and special situations including turfgrass application (Minnesota Department of Agriculture, 1990). In 1991 the department adopted the voluntary BMPs for the use of nitrogen fertilizers and a specific BMP for the use of atrazine (Minnesota Department of Agriculture, 1991). In addition, the Department's Energy and Sustainable Agriculture Program (ESAP) provides information, education and technical assistance on sustainable agriculture and IPM (see Section 4 for additional information). A private organization, the Land Stewardship Project, Stillwater, Minn., will also provide information about sustainable agricultural practices. A summary of agricultural BMPs to protect ground and surface water quality *Agriculture and Water Quality* is available from the Minnesota Pollution Control Agency.

To foster the use of IPM practices, the Minnesota Extension Service administers several programs in rural and urban areas involving demonstration and education activities and produces various publications containing technical information on nitrogen management in agricultural and urban settings. The Extension Service and USDA-SCS also provide information regarding the leaching rating of various pesticides and soils for the state. These publications and guides can be used by farmers and other land managers to make better decisions regarding the use of pesticides and the protection of ground water (Becker, et al., 1989).

The MDAg and MPCA completed a comprehensive report on nitrogen in ground water in 1991. The report reviews nitrogen-related trends, sources, ground water impacts, BMPs, policy and research needs (Minnesota Pollution Control Agency and Department of Agriculture, December 1991).

Local soil and water conservation districts (SWCD) and USDA-SCS offices are other resources for developing information programs and providing technical assistance to organizations, land owners and renters.

In urban areas, a public information program may also encourage the use of BMPs by residents and businesses. A task force established by the city of St. Paul recommended a major public education program to reduce use of pesticides and fertilizers by homeowners on lawns and gardens (City Council Investigation and Research Center, 1990). The Minnesota Extension Service in cooperation with Iowa State University Extension has produced a report and other information for homeowners on turf grass management to protect surface and ground water quality (Minnesota Extension Service and Iowa State University, 1992). The city of Minneapolis Environmental Commission produced and distributed an informational brochure to all homeowners regarding the proper use and disposal of pesticides (Minneapolis Environmental Commission, no date).

Information on ground water sensitivity, wellhead and recharge areas could be used to set priorities for developing and implementing education and information programs. These areas would be a high priority for information, education programs and materials.

Program Coordination and Governmental Operations It is equally important for governmental units to assess and manage their use of pesticides and fertilizer. As a first step, all governmental agencies and administrative units can be encouraged to assess their use of these chemicals, their potential impact on ground water and the adoption of BMPs. For example, governmental agencies would be encouraged to evaluate and limit the application of nitrogen and pesticides to golf courses, roadway rights-of-way, parks and other public property. Information regarding the impacts of the chemicals, the location of wellheads and recharge areas, and evaluation of ground water sensitivity and appropriate BMPs could be provided to each agency. City councils and county and town boards could require the development and approval of staff plans for managing nitrogen and pesticide application on public lands and review them periodically. St. Paul requires that pesticide applications on city property be approved by the city council (City Council Investigation and Research Center, 1990).

Monitoring The establishment of a monitoring program to detect the presence and levels of nitrates and pesticides in ground water may be part of a local strategy to protect ground water. The information provides a means for assessing the long term impact of these chemicals on local aquifers, private and public wells, and the effect of current management efforts to control these. The application of chemicals should also be monitored to evaluate the relationship between changes in chemical use and ground water quality.

Regulatory Strategies

The GWPA of 1989 establishes a new state-wide mechanism for protecting ground water from agricultural chemicals which could achieve local objectives for limiting the use of these substances (Minn. Stat. §§ 103H.251-.275). The MDAg is designated to monitor and evaluate the pollution of ground water from agricultural chemicals. In areas where pollution is detected, the agency or political subdivision regulating the activity contributing to the pollution must promote the implementation of BMPs to prevent or minimize the source of pollution to whatever extent

practicable. Pollutants are substances for which a health risk limit has been established by the Health Department (see Appendix D). If the voluntary implementation of BMPs proves to be ineffective, the commissioner may adopt "water resource protection requirements" to prevent the pollution from exceeding the health risk limits. The water resource protection requirements are adopted by rule and include design criteria, standards, operation and maintenance procedures, practices to prevent releases, spills, leaks and incidents, restrictions on use, and practices and treatment requirements. Requirements may apply state-wide or to a limited area.

Although this new mechanism is a state-administered program, local governments could play an important role in its implementation. Local governments may request the establishment of the program and provide monitoring data and other information to the MDAg to assist in defining the area to be managed, the sources (land use data) and the extent of the problem. They can also support the voluntary adoption of BMPs by organizing, coordinating and implementing technical assistance and public information programs to inform individual land owners of the concerns and solutions. Local governments may continue to play this role if mandatory water resource requirements are adopted by MDAg and could also review their local land use plans and controls to determine how they contribute to the problem and what needs exist for stronger controls such as local septic tank regulation. Since they are close to affected residents, businesses and landowners, local governments could also assist in monitoring the effectiveness of BMPs.

Although there are many issues which must be resolved regarding local regulation of pesticide application, there is no state or federal prohibition of local control of fertilizers. There is some precedent for regulating fertilizers in Minnesota to protect water quality. The city of Shoreview in Ramsey County adopted a general ordinance in 1985 limiting the use of fertilizers to protect surface water quality. The ordinance requires a license for commercial applicators and establishes standards for application by property owners. Other communities are considering similar action.

In rural areas where ground water nitrate levels are of particular concern, local governments could take the initiative and adopt an overlay ordinance to protect ground water, perhaps beginning with critical areas such as wellhead, recharge and sensitive ground water areas. The ordinance would require farmers to develop a management plan for the use of fertilizers. Because of the technical nature of the issues involved, the farmer would be required to work with and submit the plan to the local SWCD for review. The ordinance would indicate the requirements contained in the plan such as the need for soils nitrate testing, the amount of fertilizer to be applied, the timing and proposed BMPs to be followed. Local agricultural agencies could be asked to assist local governments in developing the plan content requirements .

To participate in federal commodity support programs, farmers are already required by the U.S. Food Security Act of 1985 to develop and submit a "conservation farm plan" emphasizing erosion control and surface water quality protection. A fertilizer management plan could be incorporated into the conservation farm plan for local review.

Assuming that legal issues can be resolved, local governments could adopt a similar approach with regard to the use of pesticides in agricultural areas. Farmers would be required to work with local agricultural agencies and develop a management plan for the application of pesticides, focusing first on critical areas such as wellhead and recharge areas.

In urban areas, because of the large number of individual land owners, local governments might take a different regulatory approach. Local governments may adopt area-wide codes to require commercial applicators to perform soil tests and manage the application of fertilizer based on the test results. Or area-wide ordinances could require the incorporation of a chemical management plan in the site plans for proposed office centers, industrial parks and other major developments.

The plan would indicate the proposed use of fertilizers based on soil testing, the leaching rate of the soils on the site, risks associated with other chemicals to be used and proposed BMPs to minimize the use of chemicals. The report of the City of St. Paul Toxic Chemical Task Force contains many ideas on managing the use of pesticides and fertilizer in urban areas (City Council Investigation and Research Center, 1990).

Hazardous Materials Use, Storage and Handling

Hazardous materials are associated with a variety of businesses and industries, large and small, in city, suburban, and rural areas, and are found in raw materials and finished products. They are stored, processed, distributed and utilized in a variety of settings including industrial parks, office centers, commercial districts, research parks and individual establishments. Ground water contamination can result from leaking storage and distribution facilities, spills during loading and unloading, leaching of exposed materials, cleaning of tanks and equipment, and improper disposal. A review of 182 case studies of ground water contamination at light industries by the U.S. Environmental Protection Agency indicates that contamination occurred most frequently during the management and disposal and storage of materials (U.S. Environmental Protection Agency, 1990). Major catastrophes such as fires or explosions may also release large quantities of these substances to the environment. Dry-cleaning, auto repair, electro-plating, warehousing, furniture refinishing and wood treating are a few examples of the uses where these materials may be found.

In general, most hazardous materials and potential sources are not directly regulated by existing state and federal programs unless the disposal and storage of hazardous waste is involved. However, the potential for local governments to manage and control these materials is significant because of their authority to plan and to adopt land use controls and health and sanitary codes (see Section 4).

Non-regulatory Strategies

One approach for local government is to prohibit land uses associated with these materials or locate them away from critical areas such as wellhead, recharge areas and geologically sensitive ground water areas. If this is not possible, two other general approaches to prevent ground water contamination from hazardous materials are 1) designing or engineering buildings and facilities to prevent spills, leaks or other releases, and from reaching the earth's surface, or 2) adopting or revising internal operations and procedures to prevent spills or releases of these materials during handling, loading or unloading, processing or other phases of their use.

The first approach would include a wide variety of design requirements such as the installation of catchment basins and holding tanks in loading or unloading areas (Figure 15) and outdoor storage of those materials in covered areas or on impervious surfaces or pads. The second approach could involve the adoption of new internal procedures to guide the handling and use of hazardous materials to minimize the risk of spills, to ensure the proper disposal of waste materials or to provide a faster response to spills. Employees would be trained in these procedures to ensure that they are implemented properly.

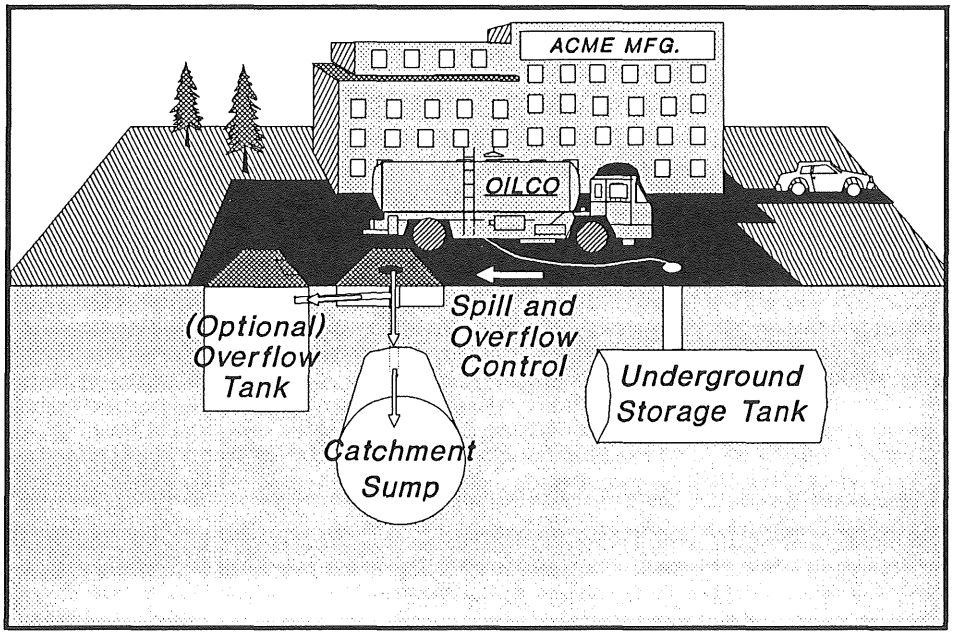
Growth Management and Comprehensive Planning Both a local growth management strategy and a comprehensive plan may be used to protect ground water from hazardous materials. A local growth management program may be adopted to encourage the location of new industry and commercial development associated with hazardous materials in areas where the necessary public services are available or planned to protect ground water. This would include areas where sanitary sewer services are available or planned to collect and treat wastewater, emergency services are available to respond to spills and leaks and land use management programs and

controls have been adopted to protect ground water quality. Strong policies discouraging the use of on-site sanitary systems to serve commercial and industrial development in unsewered areas would also be adopted.

Land use and public facilities (sanitary sewers) policies and criteria in the local comprehensive plan would designate appropriate areas for the location of industrial and commercial development based on the availability of services and soils and geological information. The plan would indicate the type of standards to be incorporated in this development to prevent hazardous material spills or releases from reaching the ground. If wellhead, recharge and sensitive ground water areas are defined, the plan can establish specific land use policies and criteria to protect these critical areas from uses involving hazardous materials. The plan policies and criteria will provide a basis for the adoption of detailed land use controls to implement the policies.

The Spokane County, Wash., comprehensive plan contains water quality policies governing the location, design and operation of uses involving "critical materials" located in the area above the aquifer which is the city's sole source of drinking water (Spokane County, 1990). The aquifer had been previously delineated by a special study undertaken by the United States Geological Survey. Major commercial and industrial developments within the designated "aquifer sensitive area" are to be located in the county's priority sewer service area where service is planned within ten years. Outside the service area, these developments may be approved if "nonground" wastewater disposal techniques are used consistent with county performance criteria, such as the use of sealed lagoons or holding tanks.

FIGURE 15. HAZARDOUS MATERIALS HANDLING



Acquisition Existing industrial and commercial uses located in wellhead and other critical areas which represent a high risk could be acquired and redeveloped for other low risk uses. Dayton, Ohio, established a Well Field Protection Fund which provides funds for emergency response andremedial actions including acquisition of property interests to reduce the risk to the water supply. The fund is financed by a fee charged to water utility users (Hall, et al., no date).

Public Information and Education Where existing land uses involving hazardous materials will not be phased out soon, local governments may develop an information program to encourage these firms to improve their facilities and operations voluntarily. Businesses may make improvements once they are aware of the liabilities and financial costs of ground water contamination and cleanup. Firms would be provided with technical information on proper facilities, equipment specifications and operating practices to prevent and clean up releases of hazardous materials. Spokane County developed a critical materials handbook to help local businesses comply with the standards of its aquifer protection ordinance (Spokane County, 1989).

Monitoring Ground water quality monitoring in industrial and commercial areas, particularly downgradient of existing districts, may be integrated into the local government's overall strategy to determine the effect of past practices in these areas and evaluate the long-term effect of the local strategy. The establishment of a monitoring program could be required as a condition of the local government's approval for new commercial and industrial development. Monitoring priorities could be based on defined wellhead, groundwater recharge and geologically sensitive areas.

Regulatory Strategies

Zoning Zoning and other regulatory techniques may be adapted to protect ground water from land use activities involving hazardous materials. Some possible approaches include rezoning the entire area to restrict these uses, redefining the permitted uses in commercial and industrial districts to prohibit such uses, or prohibiting them in critical areas such as wellhead, ground water recharge and geologically sensitive areas. The potential impact on local economic development, particularly if the affected area is extensive, may be a concern.

A strategy of conditional zoning includes more limited approaches that may be attractive to the local government. Examples are adoption of an overlay district for a critical area such as a recharge area or an ordinance which treats hazardous material uses as a conditional use. The overlay district establishes specific design and operating standards for commercial and industrial uses within the area to be protected. The conditional use approach requires the applicant to submit a plan indicating how the proposed use would incorporate adequate design and operating measures to protect ground water from potential spills and other releases. The ordinances may also require periodic reporting of the types and amounts of substances on the site and submittal of an operations plan including the reporting and cleanup of spills, leaks and other discharges.

In some cases, a strategy of overlay zoning may be appropriate. Dayton, Ohio, adopted an overlay ordinance to protect its wellhead areas from hazardous materials (Hall, et al, no date). Rather than the traditional approach of zoning out all industry in the district, the city regulates the use of hazardous materials or "regulated substances." New uses involving quantities of regulated substances above stated minimum thresholds are prohibited. Expansions are allowed if the city determines that it will not increase the risk or that it will be offset. New, nonconforming industries may replace existing ones if the risk from the use of regulated substances is equal or less than the previous use. Owners or occupants must file periodic inventories of regulated substances. New owners or occupants of existing structures must obtain a certificate of occupancy and file an inventory as a condition.

Spokane County also adopted an overlay zone to protect the aquifer supplying its water (Spokane County, 1990). The ordinance establishes procedural and design standards for businesses and industries involving "critical materials". The county maintains a list of these materials, and the ordinance designates specific activities which are automatically classified as "critical materials activities". The department that issues the permit asks the applicant to submit information regarding the types and amounts of materials to be used. If the department determines that the activity comes under the ordinance, the department has the authority to ensure that the activity complies with the ordinance standards (see discussion of Wellhead Recharge Areas later in this section for additional information).

Health and Sanitary Codes The adoption of a local health or sanitary code governing hazardous materials is another potential regulatory approach. The purpose is to regulate the use of the materials rather than specific land uses. Suffolk County, N.Y., adopted a comprehensive regulatory program, administered by the health department as part of its county sanitary code (Portage County Planning Department, 1988). The regulations prohibit the discharge of toxic or hazardous materials in the county unless it is under a state or federal permit. A discharge includes leaks, spills during transport or transfer, disposal or storage of contaminated soil, disposal to a drainage or leaching system, burial, landspreading or dumping, or the abandonment of tanks and pipes involving these materials. Construction and operating permits are required for storage and handling facilities. The regulations also include standards for the design of facilities such as underground storage facilities, outdoor above-ground facilities, portable containers and tanks, indoor storage facilities and bulk storage. In some instances, existing facilities must be brought up to standard, and deadlines are provided for achieving this.

The Cape Cod, Mass., Planning and Economic Development Commission, developed a model ordinance and health regulation to control toxic and hazardous materials (National Research Council, 1986) for adoption by local towns under their local police powers. The regulation prohibits the discharge of toxic and hazardous materials in the town. Discharges include accidental spilling, leaking, dumping and emitting on land or waters in the town, and disposal in on-site sanitary disposal systems. The application of fertilizers and pesticides are excluded if applied according to state regulations and label directions. Outdoor storage is prohibited except in product-tight containers protected from the weather, leakage, accidents and vandalism. Types and quantities (above minimum amounts) of products and their location and method of storage must be registered with the local board of health. The board may require that the containers of materials be stored on an appropriate impervious surface and may inspect the site for compliance. Spills and leaks must be reported immediately. A certificate of compliance must be obtained prior to the issuance of construction and occupancy permits. The town of Barnstable, Mass., a commercial and industrial area, has adopted the regulations.

Irrigation

Excessive irrigation will increase the leaching of nitrates, pesticides and mineral salts from the soil into the ground water. If used where the ground water is already sensitive because of the characteristics of the overlying geological materials, irrigation greatly increases potential for leaching. Agricultural irrigation in Minnesota is widely practiced on highly permeable, sandy soils which drain too rapidly to hold adequate moisture to support intensive cropping, particularly during dry weather or drought conditions. If additional water is applied before pesticides can be taken up by the plants, adsorbed to the soil particles or break down, the chemicals may leach into the ground water.

The potential for leaching can be minimized by managing the rate, timing and amount of irrigation (see Figure 16). Timing of irrigation is important so water is not applied when conditions are likely to result in chemical leaching. The rate and the amount or volume of application should be adjusted to the water-holding capacity of the soil in the root zone. The timing and volume of application should also be based on crop needs and soil conditions. Soil moisture should be monitored continuously as a guide to determine when irrigation is necessary.

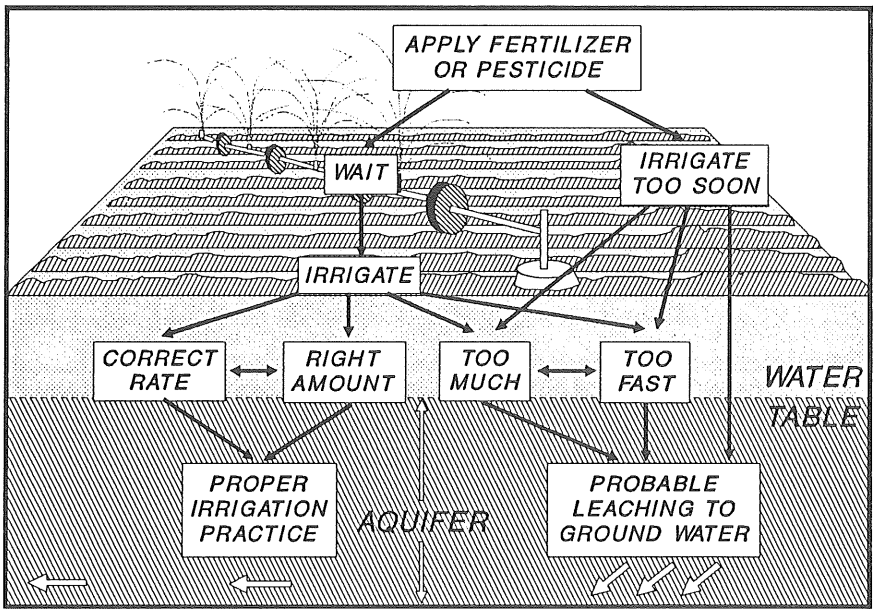
There are currently no state rules or standards which directly limit or require the management of water applied for irrigation purposes. The Minnesota Department of Agriculture administers rules that regulate chemigation or the application of pesticides and fertilizers with the irrigation water, but not the water application itself. Irrigators must apply to the Minnesota Department of Natural Resources for an appropriation permit, which limits the rate at which water can be withdrawn, but not application of the water (see Appendix D).

Non-regulatory Strategies

Development of a local public information and education program to assist and advise farmers and other irrigators in adopting BMPs is one approach to discourage excessive use of irrigation. Information may be provided as a service to all current irrigators and at the time of application for a new MDNR water appropriation permit. The latter approach would require coordination of MDNR permitting procedures with implementation of the local information program. The MDNR may require all new permit applicants to have a soil and water conservation plan approved by the local SWCD (Minn. Stat. § 103G.295). The plan must address irrigation.

Information regarding irrigation management practices is available from the local USDA-SCS, Minnesota Extension Service and SWCD offices. The USDA-SCS has developed a guide for

FIGURE 16. IRRIGATION MANAGEMENT



irrigation practices in Minnesota (U.S. Department of Agriculture, Soil Conservation Service, 1976). The guide takes into account such factors as the type of crop and its water requirements, soil uptake rates and permeability, sprinkler system design and irrigation methods. A moisture accounting data sheet can be used to assist in monitoring soil moisture conditions over the growing season. The Minnesota Extension Service has developed two recent publications to assist users in managing irrigation. The first of these outlines best soil management practices and monitoring techniques for irrigation of sandy soils in Minnesota (Wright, 1989). The second publication explains the scheduling or planning of irrigation to make efficient use of water and minimize the leaching of nitrates (Wright and Bergsrud, 1991).

Information regarding wellhead, ground water recharge areas and geologically sensitive areas may be incorporated in the program to define priority areas and inform irrigators regarding the potential risks in these areas. Ground water monitoring in the areas of intensive irrigation can be used to assess the impacts of irrigation activity and the effect of voluntary management programs.

Regulatory Strategies

Local governments may require irrigators to develop a management plan to limit the application of water where nitrate levels and pesticides are a concern. The plan would be developed with the assistance of and reviewed by the local SWCD. Other regulatory options include prohibiting irrigation in priority critical areas through an overlay ordinance for wellhead, ground water recharge and geologically sensitive areas, or requiring each irrigator in those areas to develop a management plan. Irrigation could be treated as a conditional use subject to the review and approval of a management plan. The plans would indicate the proposed timing, rate and amount of irrigation and the monitoring of soil moisture.

Military Facilities

Military facilities, whether they are involved in munitions production or provide fixed base facilities for a branch of the military, are potential sources of ground water contaminants. Because they are federal facilities, local governments generally have no regulatory or other direct authority over the management of these facilities (see Section 3).

The best strategies for local governments may be voluntary approaches that encourage coordination of local and federal efforts to assess the potential risks to ground water and the local water supply:

- Providing information about local ground water resources to the facility officials including the hydrogeology of the area, the direction and rate of ground water movement, the location of public and private wells and an assessment of ground water sensitivity;
- Encouraging facility officials to inventory or provide an inventory of the types and location of sources and contaminants present at the facility and evaluate potential measures to mitigate the risks to ground water;
- Providing the information on the best management practice to local businesses and industries regarding building design standards and operating procedures to prevent the release of contaminants to the facility officials to guide their internal evaluation and planning;
- Establishing a monitoring program for wells around the facility with federal support where possible if local officials suspect there may be a problem; and
- Appointing a representative of the facility to the local advisory committee if one is formed to assist in preparing the ground water protection plan.

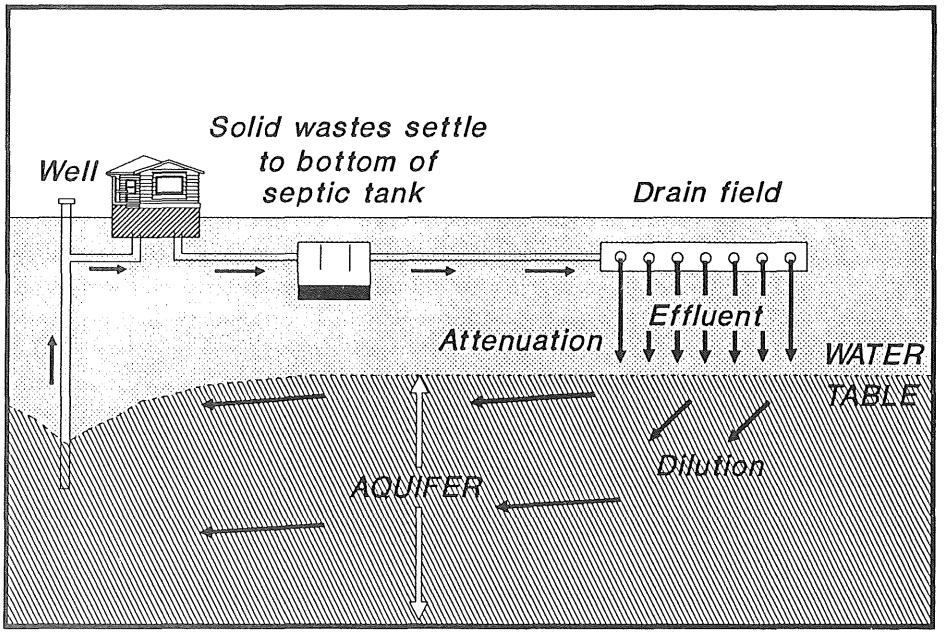
The ultimate objective is the development of a management plan for the federal facility if potential contaminants are present. The plan would include the improvement of facilities and operations at the facility. Ground water monitoring and the development of a spill contingency plan may be included in the plan.

On-Site Sewage Treatment Systems and Septage Disposal

Protection of ground water requires on-site sewage treatment systems be located in appropriate soil conditions, and designed and installed to allow for adequate attenuation of contaminants in the effluent (Figure 17). Adequate long-term maintenance of the systems is also necessary to ensure that they will operate effectively over the design life. In addition to concerns for individual systems design, the siting of too many systems in a small area may represent a risk to ground water quality. Many systems in a small area may result in the concentration of contaminants such as nitrate in ground water. On-site systems are not designed to treat hazardous materials or waste. These substances tend pass through the system and soils into the ground water. For example, volatile organic compounds from household and industrial solvents are poorly bound in the soil. State rules prohibit the disposal of industrial hazardous waste in these systems but allow normal amounts of household products and cleaners. Also, MPCA rules (Minn. Rules ch. 7080) for on-site disposal systems are advisory, except in state-wide shoreland, floodplain and wild and scenic river districts or where adopted by the local government.

Septage, the waste material held in the septic tank, must be disposed of properly or ground water may be contaminated. The MPCA does not currently regulate septage disposal, and this task is left to the discretion of local governments. The two options for septage disposal as currently practiced in Minnesota are land application or discharge to a municipal treatment plant.

FIGURE 17. ON-SITE SEWAGE DISPOSAL SYSTEM



Non-regulatory Strategies

Growth Management and Comprehensive Planning In urbanizing areas, a local growth management strategy may play a key role in minimizing the potential impact of concentrated areas of on-site systems. A coordinated strategy involving sewer planning, land use planning and land use controls can ensure that dense urban development is served by sewers and not on-site systems. The local comprehensive plan designates areas for future urban development and the public facilities or sewer plan of the plan indicates the timing and staging for the extension of sewers to these areas. Sewers are extended to avoid the use of on-site systems and divert municipal sewage and industrial wastes to treatment plants. Areas not planned for sewers are designated and zoned for low density residential and rural land uses to discourage urban development and the concentration of systems in relatively small areas.

The public facilities or sewer element of the comprehensive plan may be amended to include the local policies for the management of on-site systems. Maps could indicate areas suitable or unsuitable for on-site systems, based on soils and geological information. If wellhead, ground water recharge or geologically sensitive areas have been defined, this information can be used to evaluate the siting of on-site systems. The plan also states the precautions that must be taken in these critical areas regarding the proper management of these systems, such as the frequency of inspection and pumping. Minn. Rules ch. 7080 may be referenced as local policy.

Local governments in urbanizing areas within the Twin Cities Metropolitan Area are required to adopt local growth management strategies similar to the approach described above. Local governments must also limit the number of residential units served by on-site systems in rural areas. The local comprehensive plans are also required to designate areas suitable and unsuitable for on-site systems based on soils and geological data, and adopt comprehensive programs for managing the systems including inspection.

Local comprehensive plan policies may also address the location and management of septage disposal. A septage policy may encourage disposal at a convenient municipal treatment plant, where feasible, or at approved sites. Plan policies may encourage disposal sites where the risks to ground water resources are minimal, for example, outside of wellhead and recharge areas. Criteria may be incorporated in the plan policy to guide the review and selection of proposed disposal sites.

Public Information and Education Informing residents, businesses and other property owners of the potential risks to ground water from on-site treatment systems, particularly if they are used for hazardous waste disposal will encourage their proper use and maintenance. Local education programs can also target system pumpers to inform them of the proper disposal of septage to protect ground water.

Solid and Hazardous Waste Planning Planning and implementing programs for the collection and safe disposal of household hazardous waste assist in minimizing the use of on-site systems for this purpose. Even small amounts of these materials can affect ground water, particularly where many systems are concentrated. All Minnesota counties are required to include recycling and management of household hazardous waste in their solid waste management plans (see Section 4).

Program Coordination Local governments may work with other communities that operate municipal treatment plants to determine the feasibility of using these facilities for septage disposal. In the Twin Cities Metropolitan Area, the Metropolitan Waste Control Commission has designated specific locations in its system where septage can be discharged and has developed procedures for managing this activity.

Monitoring Local governments may want to consider establishing a ground water monitoring program in areas where there are existing concentrations of on-site disposal systems, or encourage homeowners to check their wells periodically. Priorities for establishing these activities could reflect wellhead, recharge area and sensitive area information. Monitoring septage disposal sites would assure local governments that the conditions placed on the use and operations of these areas are effective over the long term.

Regulatory Strategies

Zoning Areas served by on-site systems can be zoned or rezoned to require a larger minimum lot size to avoid the concentration of many systems in a limited area or limit residential density. Many local governments have adopted these approaches as part of their local protection strategy (American Planning Association, 1986). The lot size standard varies from community to community, depending on the land use situation, soil and geological conditions, depth to the water table and the techniques applied in the decision-making process. Some communities, such as Acton, Mass., (Jaffe and Dinovo, 1987) have used analytical models to predict the concentration of nitrates resulting from the density of systems. The number or density of systems is limited to keep the predicted concentration below the federal drinking water standard for nitrates. Wellhead or recharge areas could be selected as the first priority for implementing this strategy.

Septage disposal can be managed by prohibiting it in critical areas such as wellhead or ground water recharge areas as part of an overlay zone, and allowing the activity in other areas by conditional use permit. Permit applications would be required to include information on ground water sensitivity, hydrogeological conditions, septage characteristics, soil suitability, application rates and other data necessary to evaluate the impacts.

Health and Sanitary Codes Local governments may adopt a local ordinance or health code to regulate existing and new on-site systems. The ordinance would require a permit and include standards for their design, siting, installation and post-installation inspection and maintenance. The ordinance could incorporate the MPCA regulations (Minn. Rules ch. 7080) or more restrictive local standards, depending on local concerns.

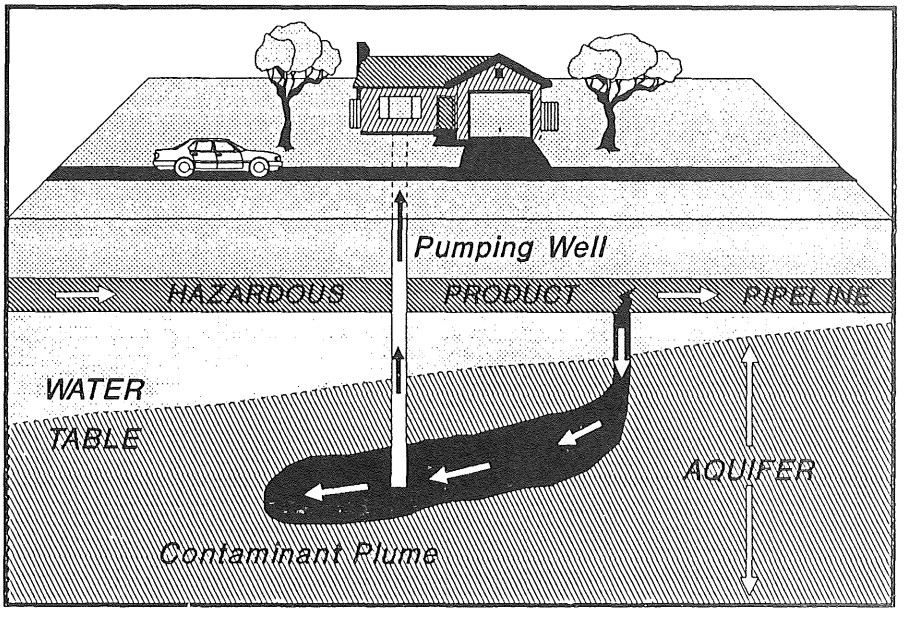
The code may also require that site evaluators, inspectors, installers and pumpers be certified. The MPCA periodically administers training programs for that purpose. To ensure systems are inspected regularly and maintained, the local government may establish a record-keeping system. Local governments in the Twin Cities Metropolitan Area are required to establish such a program as part of their local sewer plans. Requiring the inspection of the system when the property is sold or at the time of application for a building permit are other strategies to ensure existing systems are working properly.

Local codes may be amended to control septage disposal by prohibiting dumping and requiring a permit for land disposal. The permit applications would require the necessary information for assessing the impact of the proposed activity on ground water and other water resources (see related discussion above regarding zoning).

Pipeline Leaks

Catastrophic failure of pipelines have heightened concern that pipelines may be inadequately designed, constructed or inspected and will eventually leak, contaminating ground water and wells before it is detected (Figure 18). Local governments have no authority under existing federal and state legislation to manage or regulate pipelines. State agencies exercise some authority regarding the routing of pipelines carrying hazardous liquids and the administration and enforcement of

FIGURE 18. PIPELINE LEAKS



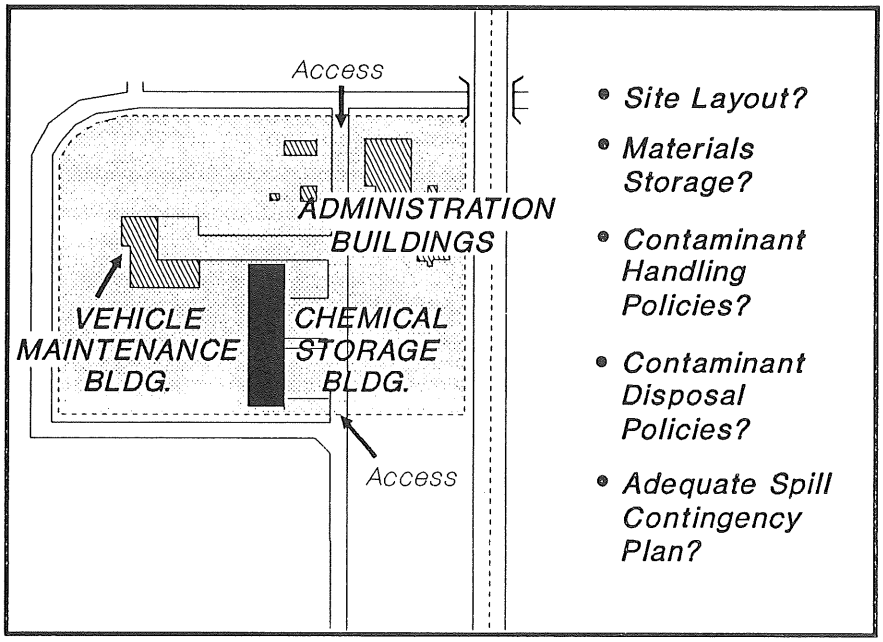
state and federal standards for pipeline design, construction and inspection. (see Section 4 and Appendix D for more information). Local planning and zoning authorities are specifically preempted by state legislation.

To ensure ground water is protected, local governments must take the initiative to coordinate with state and federal permitting agencies. Local governments are generally notified of proposed pipelines, and opportunities are provided for public comment. This is the time to bring ground water related concerns to the permitting agencies and pipeline owner and operator. Local governments may review proposed pipelines for potential ground water impacts. They may also provide state and federal agencies with information regarding the location of wellheads, ground water recharge areas and sensitive areas and encourage the agencies to use the data in evaluating the potential risks to ground water quality. Federal and state agencies should be encouraged to enforce design, testing, construction and maintenance standards for new and existing pipelines. Spill contingency planning should address the risks of pipeline leaks and the response of the appropriate local government agencies to protect ground water. Local governments should determine that the pipeline operator or owner and appropriate state and federal agencies have adequate contingency plans for reporting, controlling and cleaning up leaks. These measures require local governments to establish long-term communication with appropriate agencies and the company.

Public Service and Maintenance Facilities

Counties, cities, townships and state agencies maintain a variety of highway maintenance, public safety and other service facilities for the storage and servicing of vehicles and equipment and the storage of other supplies (Figure 19). These facilities may involve the use, storage and disposal of a variety of potential contaminants such as paints, pesticides and petroleum related products (see

FIGURE 19. PUBLIC SERVICE AND MAINTENANCE FACILITIES



Section 3). Because they are part of governmental operations, the proper management of these facilities is guided by the "internal policies" of the government rather than zoning and other land use controls. By emphasizing the proper management of its own facilities, a local government will indicate its concern and leadership in protecting the community's ground water resources.

Non-regulatory Strategies

Comprehensive Planning The public facilities element of the local comprehensive plan may incorporate goals, policies and criteria to ensure all proposed public facilities that involve potential contaminants such as service and maintenance facilities are located, designed and operated in a manner that will protect ground water. The policies would encourage the incorporation of specifications in site and building plans that prevent the discharge or accidental release of contaminants from reaching the earth's surface. The plan may also require the submittal of an operating plan for each new facility emphasizing the proper handling, storage, use and disposal of contaminants. A spill contingency plan would be required with the site and building plans for each facility submitted for review. The policies may also discourage the location of higher risk public facilities involving large amounts of potential contaminants in wellhead, ground water recharge and geologically sensitive areas. When new or expanded service and maintenance and other facilities are proposed, the local government would review the facility plans for consistency with the plan policies.

Program Coordination and Governmental Operations The location, design and operation of public service and maintenance is the responsibility of many different state agencies and local

governmental units. There are several measures a local government can use to protect ground water. These include:

- Developing and establishing intergovernmental review procedures and agreements to ensure existing and proposed facilities are located, designed and operated to protect ground water;
- Providing information to other governmental units about the local ground water system, the potential risks associated with the substances associated with service and maintenance facilities and proper site, building and operating standards to mitigate the risks;
- Auditing existing service and maintenance and other public facilities to determine what contaminants are used, how they are handled, stored or disposed, and what measures have been implemented to avoid ground water contamination;
- Adopting the specifications and standards applied to commercial and industrial development for public facilities to prevent leaks and spills from reaching the earth's surface;
- Adopting administrative operating procedures or a plan for each public facility involved with contaminants to ensure that materials are stored, handled and disposed of properly including a spill contingency plan; and
- Informing and educating employees regarding the risks to ground water and the goals of the operating plan for each facility to protect ground water.

Regulatory Strategies

If a wellhead or recharge area protection program is being considered, the local government may consider prohibiting in specific areas any public facilities that handle contaminants. Restricted areas may be defined as part of an overlay zone or, as an alternate strategy, applying conditional use zoning. Site plans, building and operating standards (BMPs) governing industrial and commercial uses can also be applied to public facilities in these areas.

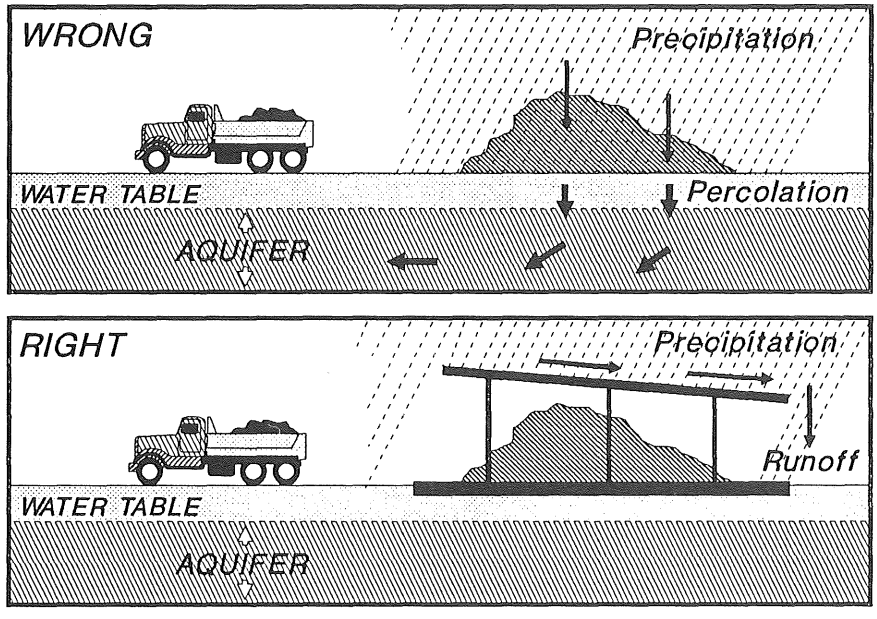
Road Salt Storage

Salt (sodium chloride and calcium chloride) are important chemicals used in maintaining the safety of highways and city streets during Minnesota winters. The primary management goal is to prevent or minimize the infiltration of runoff from storage sites into the land surface on and off the site (Figure 20). Since most sites are owned by a state or local governmental unit, this activity has not been controlled by zoning or other land use controls.

Non-regulatory Strategies

Salt storage sites can best be controlled with the adoption by the appropriate governmental unit or agency of BMPs to prevent surface and ground water contamination due to leaching and runoff. The Minnesota Department of Transportation (MnDOT) has developed and adopted a chemical storage policy for all its storage sites as part of its maintenance manual which local governments could adopt or adapt for their purposes (Minnesota Department of Transportation, 1986). The policy incorporates several BMPs. The policy gives priority to indoor storage of chemicals during the summer, requires covering the material outdoors to prevent moisture contact, and requires storage on an impervious surface, and it also recommends construction of a containment system to avoid runoff. Local highway and street maintenance agencies could be informed of the potential for ground water contamination from salt storage and encouraged to adopt the MnDOT policy.

FIGURE 20. MANAGEMENT OF ROAD SALT STORAGE



Some of the other non-regulatory strategies discussed previously for other sources, such as incorporating policies in the local comprehensive plan to manage the location, design and operation of public facilities, may be applied to salt storage facilities. Chemical storage areas are frequently located in conjunction with service and maintenance facilities which were discussed previously. Existing sites where there has been no effort to prevent infiltration can be monitored and evaluated to determine whether any contamination has occurred, and whether preventative or cleanup measures are needed. Priorities may be based on the proximity to wells, ground water recharge areas and geologically sensitive areas.

Regulatory Strategies

An overlay zone in wellhead, ground water recharge and geologically sensitive areas may prohibit salt storage facilities within these areas or allow them only as a conditional use. The facilities would be allowed only where BMPs are incorporated in the facility design.

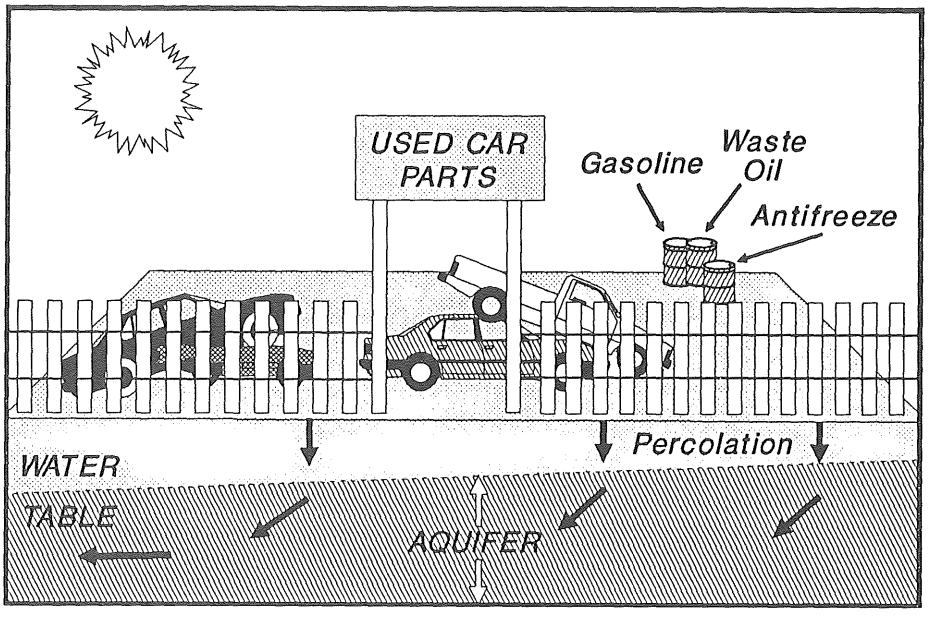
Salvage and Junk Yards

Salvage and junk yards are potential sources of contamination because of the type of substances associated with the vehicles and other materials they handle (Figure 21). There are currently no state regulations with regard to the siting, design and operation of these facilities. Any regulatory action is left to the discretion of local governments.

Non-regulatory Strategies

Non-regulatory strategies include those discussed previously for similar land uses, such as those involving the use, storage and handling of hazardous materials. The strategies include:

FIGURE 21. SALVAGE AND JUNK YARDS



- Incorporating land use policies in the local comprehensive plan that address the location, site planning, facilities design and operations of these facilities;
- Acquisition of existing uses in high risk areas such as in wellhead areas;
- Monitoring of nearby wells;
- Developing and implementing a public information and education program for owners and operators informing them of potential risks to ground water quality and their liabilities;
- Encouraging owners and operators to adopt BMPs addressing the proper storage and disposal of potential contaminants; and
- Inventorying existing facilities to develop information about the types and volumes of contaminants handled, storage practices, disposal methods and the need for local government intervention to solve these problems. Information about ground water sensitivity would assist in evaluating the risks of contamination at existing sites and establishing program priorities.

Regulatory Strategies

Potential regulatory strategies are similar to those discussed earlier for other industrial and commercial uses. New salvage facilities may be prohibited entirely by the local government or excluded only in critical areas such as wellhead and ground water recharge areas. Another zoning approach is to allow these uses only as a conditional use and treat them as similar uses involving hazardous materials. Conditions for local review and approval would include submittal of a site plan that indicates how potential contaminants such as waste gasoline and antifreeze are to be stored and disposed of properly. Discharge or release of contaminant materials on-site may also be prohibited by the ordinance. Ground water monitoring and periodic reporting of the types and volumes of waste materials handled and disposed may also be conditions for the permit. Ground

water sensitivity information may be used to evaluate the location of proposed facilities and potential risk to ground water quality (see this section, Sensitive Ground Water Areas). Similar conditions may be incorporated in an overlay zone ordinance for wellhead and recharge areas.

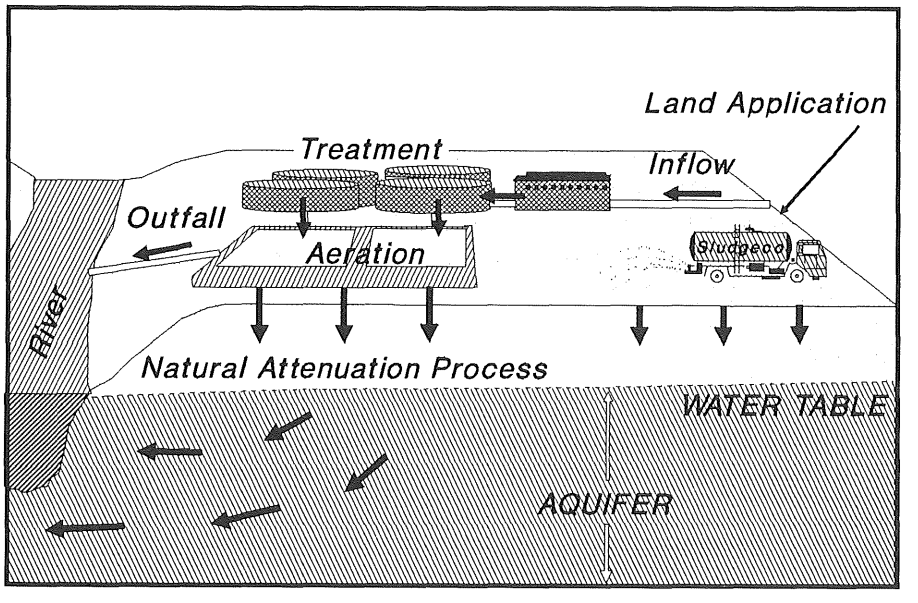
If the local government adopts a local health or sanitary code amendment governing the handling of hazardous materials, these provisions may be applied to junk and salvage yards to ensure that waste oil, antifreeze and other materials are properly disposed of and not dumped on or off the site. Existing sites may be inspected periodically in accordance with the code provisions.

Sewage and Industrial Wastewater

Municipal sewage and industrial wastewater treatment systems use surface impoundments or land application to dispose of wastewater and related by-products such as sludge. These systems are designed to allow wastewater and contaminants to infiltrate the underlying soil. (Sludge is the solid by-product produced by the wastewater treatment process.) If the natural attenuation occurring in the underlying soils and other geological materials does not remove or break down contaminants in the effluent, they may reach the ground water (Figure 22) (see Section 3).

The MPCA is charged with the responsibility of regulating the discharge of sewage, industrial and other wastes to all waters of the state. (See Section 4 and Appendix D - Minnesota Pollution Control Agency for additional information). The waters of the state include both surface and underground waters. The agency's responsibilities include the authority to establish effluent limitations for discharges and issue state and federal discharge permits for the installation or operation of wastewater disposal systems.

FIGURE 22. MUNICIPAL AND INDUSTRIAL WASTEWATER TREATMENT AND DISPOSAL



Non-regulatory Strategies

Comprehensive Planning Local governments, particularly municipalities, are generally responsible for planning new and expanded wastewater treatment facilities, including their location and design specifications. Local governments may incorporate policies and criteria in the public facilities orsewer element of their comprehensive plan to ensure that new or expanded facilities are located and designed to protect ground water. For example, the plan may incorporate a policy to avoid siting these facilities in wellhead, ground water recharge and geologically sensitive areas. If this is not possible, more stringent design standards may be required to provide increased ground water protection, such as more stringent specifications for surface impoundments to prevent infiltration of contaminants. New or expanded facilities would be reviewed for consistency with the policy.

As a matter of local or internal policy, planning and engineering studies for new or expanded wastewater treatment facilities may be required to assess the potential risks to ground water quality including an evaluation of the geological sensitivity of the ground water at proposed sites and the potential impacts on public and private wells and recharge areas. Local governments may also establish ground water monitoring at new and existing treatment facilities as a means for evaluating the long-term effect of the facility.

Regulatory Strategies

Local governments may choose to regulate the discharge of wastewater and land application of by-products, particularly sludge. One alternative is to prohibit all discharges or land application throughout the area or specifically in wellhead, ground water recharge and sensitive areas under the provisions of an overlay district. Another alternative is to require a conditional use permit for these types of facilities under the local zoning ordinance. A condition of the permit would require the applicant to submit a plan for the facility or activity including assessment of potential impacts on ground water quality and proposed specific measures to mitigate them. Applicants may be required to assess specific risks to wellhead, ground water recharge and sensitive areas.

Another alternative is the adoption of provisions for regulating activities such as part of the local health or sanitary code. If there is an existing code for the management of on-site sanitary disposal systems, the regulations could be incorporated. A permit would be required for the proposed application or discharges of wastewater. The requirements for the permit application may be the same as those for the conditional use permit.

If the local government is considering a regulatory strategy, it should contact the MPCA to avoid any conflicts with state regulations.

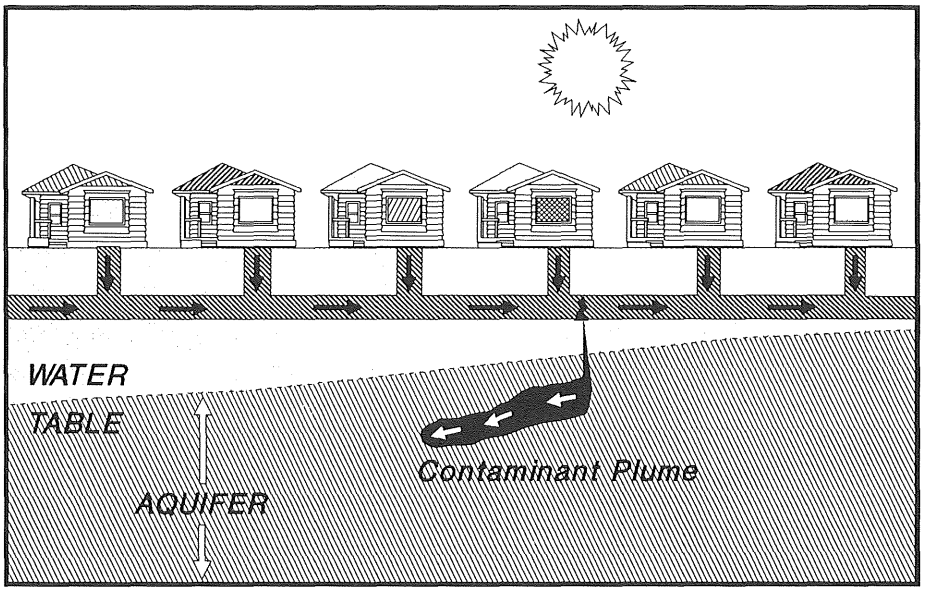
Sewer (Sanitary) Leakage

Deteriorating or poorly constructed sanitary sewers will leak, resulting in the leaching of nitrates, solids, microbes and organic chemicals into ground water (see Figure 23). The MPCA must approve construction of new public and some private sanitary sewers in the state. Sanitary sewers must be designed in accord with the agency's specifications to limit the infiltration of ground water. Limiting infiltration will also limit the amount of sewage that will leak out of the sewer.

There are several non-regulatory and regulatory strategies for improving the protection of ground water from leaking sewers. These include:

- Incorporating a policy in the public facilities or sewer element of the local comprehensive plan that includes more restrictive standards for sewer design to minimize leakage throughout the area or in wellhead, ground water recharge and sensitive areas;

FIGURE 23. SANITARY SEWER LEAKAGE



- Establishing or expanding a systematic inspection and maintenance program to reduce leakage in the existing sanitary sewers and giving a high priority to the sewers in wellhead, ground water recharge and sensitive areas;
- Providing residents, businesses and other system users with information to discourage the use of the sanitary sewer system for the disposal of hazardous materials or waste;
- Prohibiting disposal of hazardous materials and wastes in the sewer system by ordinance;
- Amending the local subdivision ordinance to include a more restrictive design standard for limiting infiltration and requiring testing of new sewers to ensure the new standard is met.

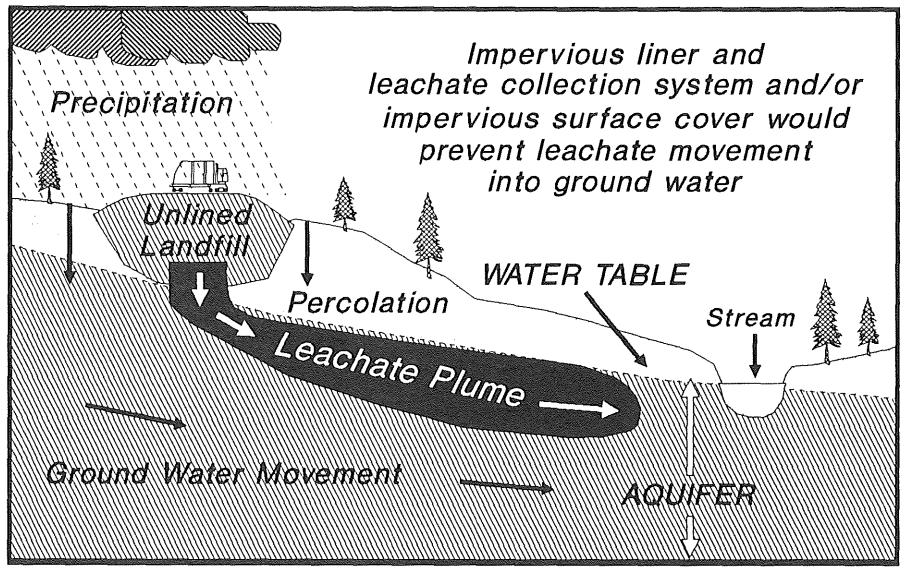
Local governments should seek technical expertise when establishing more restrictive standards for sewer systems.

Solid Waste Landfills

Protecting ground water from landfill leachate requires strategies to locate, design, construct, operate, and maintain them according to criteria that will prevent the contaminants from reaching ground water (see section 3). The MPCA plays the most important role in protecting ground water from the variety of contaminants typically found in the leachate from landfills (see Figure 24). The agency has the authority to approve landfills or expansions, and establish standards and conditions for their design and operation. Many of its regulatory requirements, such as standards for liners, intermediate and final cover systems, and leachate collection systems, are intended to protect ground water quality.

Counties may also play important roles in planning for new or expanded landfills as part of their solid waste management responsibilities including the location and design of landfills. They may

FIGURE 24. SOLID WASTE LANDFILL IMPACTS



also establish rules and regulations and issue permits or licenses for landfills. Counties, townships and cities can address other local land use or ground water concerns through their traditional landuse planning and zoning authorities. (see Section 4 for additional information regarding their responsibilities). Because of the complexity of solid waste management issues, local governments should coordinate with the MPCA, Minnesota Office of Waste Management (OWM) and other appropriate local solid waste planning agencies in developing a protection strategy.

Non-regulatory Strategies

Local governments may use several non-regulatory strategies to manage landfills:

- Adopting local comprehensive (land use) plan policies and criteria based on local ground water information that emphasize the protection of ground water in locating and expanding landfills and other solid waste disposal facilities;
- Supporting county and other local solid and household hazardous waste management activities such as waste reduction and recycling programs to reduce the need for landfills and remove contaminants from the waste stream that would end up in landfills;
- Using or urging counties to use wellhead, ground water recharge areas, sensitive area and other ground water information for identifying and evaluating search areas and potential sites within those areas for new or expanded landfills and selecting a final site; preparing an environmental assessment or a more detailed environmental impact statement (EIS) for the proposed facility and developing design, operating and other requirements for the proposed facility including the location of monitoring wells; and
- Evaluating the ground water impacts at existing solid waste disposal facilities, including landfills and abandoned dumps and the need for establishing or improving ground water monitoring.

Regulatory Strategies

Several regulatory strategies are available with which local governments can protect ground water from landfill contaminants. Zoning ordinances may be adopted or amended to prohibit landfills in certain zoning districts where they are incompatible with surrounding land uses, for example, residential. This would also protect residential wells. A more comprehensive approach would be to delineate wellhead, ground water recharge and geologically sensitive areas and adopt an overlay ordinance prohibiting landfills in these critical areas or allowing them under a special use permit if specific conditions are met. Landfills might be allowed subject to obtaining the necessary state, county and local (special use) permits. One condition for obtaining a local permit might be submitting an evaluation of ground water sensitivity and the risks of ground water pollution.

Another approach which is currently used by many local governments is to allow sanitary landfills only as a conditional use in specific zoning districts where they are compatible with the surrounding land uses, such as in industrial zones. This would give local governments an opportunity to review the proposed facility design in detail, particularly with regard to the potential ground water impacts and proposed protection measures. State and county permits would be obtained before a local conditional use permit is approved.

State law provides counties with broad authority to adopt rules, regulations and standards for the location, operation, inspection, monitoring, termination or abandonment of solid waste facilities, and the power to enforce these. Under this authority, counties could evaluate current state agency requirements for ground water protection and adopt more stringent location, design and operating standards for landfills under the local health or sanitary code.

In some instances, local ordinances may be overridden by state law and policy. County ordinances in Greater Minnesota must include the minimum standards and requirements of the MPCA. In the Twin Cities Metropolitan Area, county ordinances must incorporate the plans, policies, rules and standards of any state agency authorized to manage, plan or regulate solid waste. The ordinances must also include Metropolitan Council waste management plans and county solid waste master plans approved by the Council (Minn. Stat. § 473.811, subd. 4a.).

Storage Tanks - Above- and Below-Ground

Storage tanks contain a variety of materials that are potential ground water contaminants. These include home heating oil, gasoline, pesticides, and industrial chemicals. Tanks are located on farms and in service stations, schools, residences and industrial sites. The major concern, particularly for underground tanks, is that tanks will leak and contaminate the ground water before the leak is discovered. Older underground tanks are typically constructed of single-walled steel which is subject to interior and exterior corrosion. In addition, the integrity of piping used for loading and unloading the tanks is subject to breaking as the tank or surrounding soil settles. Although leaks at above-ground tanks are more easily detected, the potential risks to ground water quality are just as serious where the tanks are not designed, monitored, maintained and operated to minimize the potential for spills, leaks and other releases of fluids.

Several state agency programs regulate the design and construction of storage tanks. Much of the regulation has been adopted in response to federal law and regulations. The MPCA regulates underground storage tanks used for hazardous materials and petroleum. Smaller commercial tanks (110 gallons or less) and residential or farm tanks (1100 gallons or less) used for storing motor fuel or heating oil for non-commercial on-site use are also exempt from regulation. The agency also regulates above ground tanks including commercial tanks and larger tanks (more than

1100 gallons) for farm or residential use. The MDAg has regulatory authority over the storage of pesticides (more than 500 gallons over ten days) and the bulk storage of fertilizers and soil or plant amendments. The Minnesota Department of Health (MDH) has established setback requirements for wells to protect them from hazardous substances. For example, a well must be setback twenty feet from a petroleum tank. In addition, the state fire marshall must certify tanks containing flammable and combustible materials. All leaking tanks must be reported to the MPCA. Section 4 and Appendix D provide more information about existing state regulatory programs. Detailed information is available from these agencies.

Although the specific requirements vary depending on the size, type or contents of the tank, the state's current regulatory strategy:

- Requires tank owners and operators to register underground and above ground tanks;
- Sets performance standards for new and existing underground tanks such as protection from corrosion and the use of release detection and spill and overflow prevention systems;
- Requires inspection, monitoring and testing of underground tanks;
- Establishes cleanup procedures and responsibilities;
- Prescribes an enforcement mechanism and penalties;
- Establishes schedules for upgrading existing underground tanks; and
- Sets standards for the temporary or permanent closure of underground tanks.

Although these requirements do not apply to small, on-site farm and residential tanks, these facilities are a potential source of ground water contamination. A leak from one of these tanks, if not detected early, can contaminate wells and a substantial volume of ground water. As an example, one gallon of gasoline, if not detected, can contaminate a million gallons of ground water.

Current state regulations establish standards for the design and construction of larger above and below ground tanks to minimize leaks and spills and ensure the detection of leaks. The regulations do not specify standards or criteria for the location of storage tanks. This is left to the discretion of local government.

Prior to developing a protection strategy, the local government may undertake an inventory of existing tanks to determine the extent and nature of the problem. Tank locations, sizes, type of construction, types of materials stored, age and other tank features are some of the data that should be collected. The Minnesota Board of Water and Soil Resources and the MPCA have produced the *Above and Below Ground Storage Tank Inventory Guidebook* (1991) which will assist in developing an inventory of tanks. The guidebook, one of a series of related source inventory guidebooks, provides background information on current state regulations, sources of information and data collection methods.

Non-regulatory Strategies

Local comprehensive plans may be amended to incorporate policies on storage tanks, particularly large industrial and commercial tanks which are a major land use and significant risk to ground water. In addition to incorporating or referencing state regulations to ensure that new tanks conform to regulatory requirements, policies could include location and performance criteria to protect ground water. For example, the plan may recommend ground water monitoring and reporting for large tank sites and the inspection of small farm and residential tanks. As an alternative, the local government may choose to focus the plan policies on the protection of wellhead, ground water recharge and geologically sensitive areas. The policies may elect to

discourage the location of all tanks in these areas or allow only those tanks that meet state standards and any additional local management standards such as the establishment of ground water monitoring at the site and reporting of spills and leaks to local agencies and the inspection of small residential and farm tanks. The policies would support the adoption of local regulations.

The development and implementation of a local public information and education program would assist in minimizing the risk of contamination from storage tanks. The program could target local businesses, farms, residents and other tank owners and operators. Targeted groups would be informed about the potential risks of existing tanks, the financial liabilities, state regulations for new and upgraded tanks, and the availability of technical and financial assistance and other information. The owners and operators of unregulated small farm and residential tanks may be included in the program. This last group could be encouraged to periodically inspect and test older tanks and replace those in poor condition. Owners of abandoned tanks would be encouraged to report their presence, remove them, clean up the site if necessary or properly close them according to regulation. Local government could develop financial incentives to encourage the removal or upgrade of older tanks with the assistance of local water utilities, particularly in wellhead areas.

Local governments could also review and assess the condition of all the tanks connected with their own operations and those of other governmental units within their jurisdiction to ensure that they conform to state regulations, are in good condition and are operated in a way that prevents and detects leaks and spills.

Local spill contingency planning should take into consideration the location of tanks and their contents. This will ensure that the risks of contamination from spills and leaks or catastrophic events involving tanks are minimized.

Regulatory Strategies

There are several regulatory approaches local governments can adopt to manage storage tanks. One alternative is to prohibit these tanks outright by zoning, particularly large above-ground commercial tanks. However, storage tanks are a necessary part of the economy and support the operations of industries and businesses.

A more reasonable alternative is to allow storage tanks in specific industrial and commercial zones as a conditional use, particularly the larger commercial variety which are a major land use. One of the conditions for approval would be the submittal of a site plan to the local government indicating how the design and construction of the tanks will comply with state regulations and incorporate other measures to protect ground water.

A local government may also adopt a storage tank code requiring a permit for all new and existing tanks containing petroleum and hazardous materials including small residential and farm tanks not covered by state regulations. A local ordinance would allow closer supervision of the installation, upgrading and management of all tanks. State requirements and any additional local requirements for construction, inspection, monitoring and reporting of spills or leaks could be incorporated in the regulation. Suffolk County, N.Y., has adopted a comprehensive code for most storage tanks including the upgrade or replacement of many large underground tanks (National Research Council, 1986). Owners of heating oil tanks over 1100 gallons, who are often schools, are required to have the tanks tested every five years. Permitting of small farm and residential tanks provides a means of developing an accurate inventory of the location and use of these facilities and ensures these tanks are routinely inspected and maintained. Owners could be required to test

and inspect the tanks periodically. The ordinance could also require removal or proper closure of unused tanks by a certain date. The code could encourage use of above-ground tanks or prohibit below ground tanks where feasible. A model health regulation developed for the Cape Cod, Mass., Planning and Economic Development Commission prohibits use of underground tanks on single-family and two-family residential sites (National Research Council, 1986).

If an overlay ordinance is adopted by the local government to protect a wellhead, ground water recharge or geologically sensitive area, performance standards for the construction, design, operation, maintenance, inspection, reporting of spills and leaks, and closure of storage tanks could be included with requirements for other potential sources of contamination. State and local requirements may be incorporated.

Well Construction and Abandonment

Improperly constructed wells, wells in disrepair, or abandoned wells without proper sealing are potential conduits for the movement of contaminants from the earth's surface into the underlying ground water, or from a contaminated aquifer to a deeper aquifer. The contaminants may eventually be drawn into other private or public wells (Figure 25). The MDH has adopted standards and regulations for the proper construction, repair and sealing of wells, including the licensing of well contractors (Minn. Rules, ch. 4725) (see Section 3 and Appendix D).

Non-regulatory Strategies

Local governments may undertake a number of non-regulatory activities to protect ground water and local water supplies from improperly constructed, poorly maintained or abandoned wells.

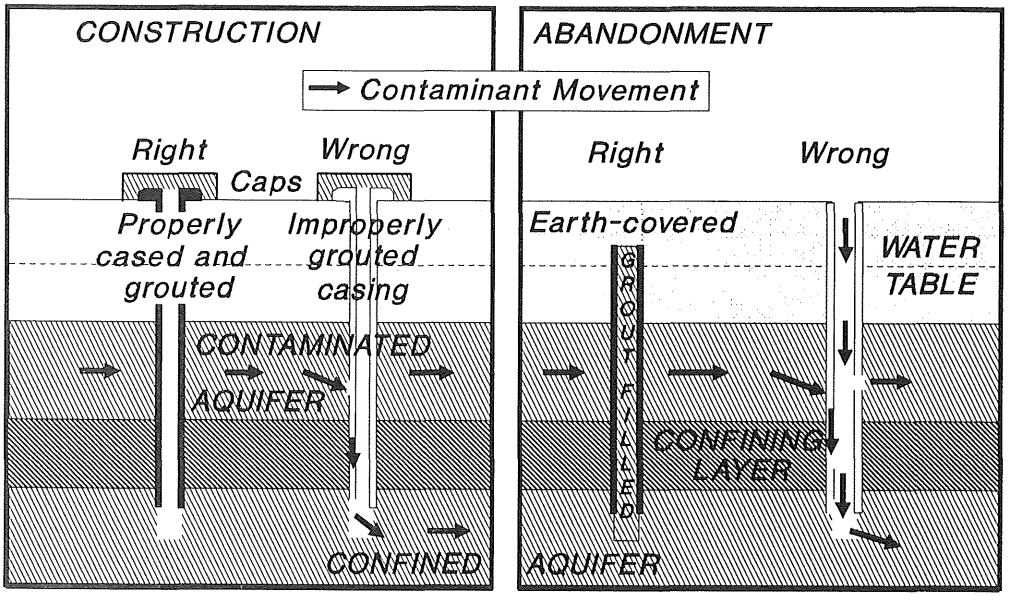
If the local government suspects that improperly abandoned wells represent a significant risk to ground water quality, it may want to undertake a special study to locate them, evaluate the risks, and analyze the feasibility of a sealing program. There are a variety of techniques for identifying abandoned wells, such as field surveys, inspection of land records and interpretation of aerial photos. Other more sophisticated techniques may require the use of special expertise. A number of state agencies have cooperated to produce a guidebook, *Abandoned Well Inventory,* (Minnesota Board of Water and Soil Resources, 1991). Sources of information and techniques for locating wells are discussed. Once the data have been compiled, the potential risks and alternative solutions can be evaluated. Priorities can be established based on well depth, construction and condition; proximity to wellhead and recharge areas; proximity to private and public wells; and the ground water sensitivity rating of the area and aquifers affected.

State law requires property owners to provide a formal disclosure statement to buyers indicating the status and location of any known wells on the property prior to its sale or transfer (Minn. Stat. § 103I.235). Otherwise, the deed or other instrument must certify that the owner is unaware of any well on the property. The MDH receives a copy of this information. The data developed by this program is another source of planning information for local governments.

A local information program informing residents, businesses, farmers, land owners and other target groups about the potential impacts of these wells may encourage some to voluntarily seal wells no longer in use or upgrade wells in need of repair. These groups may also be encouraged to have their well water checked periodically and avoid hazardous activities near their wells.

State funds to implement a local sealing program may be available. The Minnesota Board of Water and Soil Resources (BWSR) has provided funding to counties to conduct inventories of

FIGURE 25. WELL CONSTRUCTION AND ABANDONMENT PRACTICES



abandoned wells. The legislature has also provided special funds to BWSR to provide grants to counties for the purpose of sealing abandoned wells. The costs are shared with the well-owner. It may be feasible to provide local funds to cover a portion of the costs, particularly as part of a wellhead protection program.

Regulatory Strategies

Local governments can adopt several regulatory strategies to prevent contaminants from reaching ground water from new wells, wells in disrepair and abandoned wells. The governing bodies can:

- Incorporate state well code regulations by reference as part of the local subdivision regulations to ensure that new wells comply with MDH standards prior to the approval of the final plat by the local government;
- Require disclosure of all pre-existing, active or abandoned wells on the property as part of the local subdivision regulations and indicate what steps have been taken to comply with state regulations;
- Have the county health board assume responsibility under an agreement with the state commissioner of health for inspection, reporting and enforcement of the state well code;
- Require sealing of abandoned wells whenever the demolition of property is proposed; and
- Adopt a county well code as part of its health and sanitary regulations, incorporating state standards and special or more restrictive standards that reflect local concerns and the hydrogeology.

For example, Olmsted County, Minn., adopted additional standards to provide wells with a higher degree of protection due to the pollution risks associated with the karst geology (Jaffe and Dinovo, 1987). The additional county requirements address the location of wells relative to

pollutant sources, temporary and permanent abandonment, the use or prohibition of specific aquifers and the licensing of well contractors.

When pursuing any regulatory strategy, local governments or health boards should consult with the MDH to ensure the proposed standards and requirements are consistent with state laws and regulations.

RESOURCE PROTECTION STRATEGIES

Rather than focusing on one or more specific sources of contamination, such as feedlots or landfills, local governments may pursue a broader and more comprehensive protection strategy that is focused on a critical resource. The choice will depend on federal and state policy, existing and potential uses of ground water, existing and potential land use activities in the area and the information available on the local hydrogeology. A local government may choose one or more of four approaches (each involving a different geographic area, although they may overlap): wellhead areas, ground water recharge areas, sensitive areas or entire aquifers. Each approach involves managing the land use activities in the geographic area which affects the critical resource. Before such a strategy can be developed, the local government must undertake a study to delineate the geographical limits of the resource.

Wellhead and Ground Water Recharge Areas

Local governments may focus their protection strategies either or both wellhead or ground water recharge areas. In general, the wellhead area is the area around and upgradient of a pumping well that includes the portion of the aquifer that supplies water to the well. Contaminants released or spilled in this area may eventually be drawn into the well with the ground water.

Ground water recharge occurs where water passes through the soil and underlying geological materials to replenish surficial and deeper aquifers, and where the hydraulic head has a downward component. Some areas perform more effectively because of the higher porosity and permeability of the underlying geological materials, such as surface or near-surface sand and gravel deposits. Much of the land surface of Minnesota functions as a recharge area, including some wetlands, lakes and streams. The potential for contamination from land use activities is great in recharge areas. If recharge water is contaminated, it may carry the contamination into one or several aquifers. (See Section 2, Ground Water Recharge and Movement, for more information regarding recharge areas.)

Wellhead Areas

The Minnesota GWPA of 1989 and the federal Safe Drinking Water Act (SDWA) define a wellhead protection area as the surface and subsurface areas surrounding a public well or wellfield through which contaminants are likely to move toward and reach the well or wellfield. To protect a wellhead area, the local government must define and map the wellhead protection area and develop a strategy to prevent contaminants from reaching the well or wellfield.

The wellhead protection area includes the well capture zone (Figure 26). This is the area or volume of the aquifer which contributes water to the well when it is pumping. (As the well is pumped, a cone-shaped depression is created in the potentiometric surface or water table around it as the water is drawn towards the well). The actual shape of the zone will depend on the withdrawal or pumping rate, the permeability of the aquifer, recharge rates in the area, the location of ground water basin boundaries and the pumping rates of nearby wells. The zone of contribution may change in the future because of increased pumping and changing aquifer conditions, and these must be taken into consideration in delineating a wellhead protection area.

There are several techniques for defining wellhead protection areas involving the use of hydrogeological and nonhydrogeological factors. The Minnesota Department of Health has been directed by the legislature to develop rules for implementing a wellhead protection program for public wells. The department will be recommending specific criteria for delineating protection areas and other requirements in late 1993 (Minnesota Department of Health, 1992).

Wellhead protection can be applied to all public wells whether they are located in a surficial or deeper confined aquifer. In a surficial aquifer the materials overlying the aquifer may be highly permeable such as sand and gravel, and recharge occurs directly in a short time period in the area around the well. In this instance, wellhead protection would emphasize the management of surface land uses to prevent or minimize the release of potential contaminants in this area. When the well is located in a deep, confined aquifer that is recharged many miles from the well as part of a regional flow system, perhaps in a different community, the protection strategy may take a different approach. In this case, the strategy would focus on the proper construction of new wells and sealing of abandoned wells located in the confined aquifer that are upgradient from the well. (See Section 2 for more information about flow systems). Another alternative would be to develop a strategy to protect the entire recharge area.

A shortcoming of the wellhead protection strategy is that it is designed to protect only existing wells or wellfields unless future locations have been identified. Where all or much of the wellhead area is located in another community it will be difficult to develop a protection strategy unless there is inter-governmental cooperation. Also, protecting only the wellhead area leaves the remainder of the aquifer unprotected, which may serve many private wells. In larger urban and metropolitan areas where there are many public wells serving different communities with overlapping wellhead areas, the delineation of protection areas will be more difficult and costly, and protection will be more complex. In these situations, a broader strategy to protect the whole aquifer may be more appropriate. This approach is discussed later in this section.

Ground Water Recharge Areas

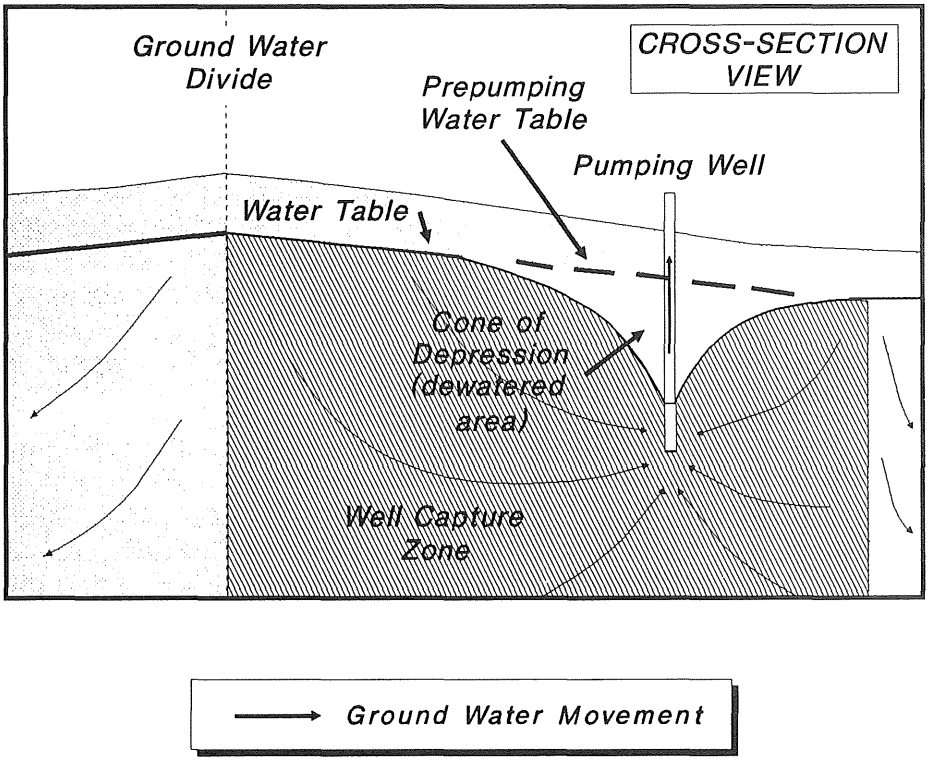
A ground water recharge area that is part of a regional flow system may encompass a large geographical area, such as one or more counties. The recharge area for a confined aquifer may be located quite a distance outside the boundaries of the local government. The recharge area for a surficial water table aquifer may also be quite extensive and underlie the entire community and adjoining communities. A joint or coordinated approach to aquifer protection would be appropriate in both instances.

Delineating recharge areas can be time consuming and costly for local governments because of the large amount of hydrogeological data required to define flow systems. The movement of ground water from recharge areas to discharge areas may be quite complex, particularly within the glacial deposits that cover much of Minnesota.

Wellhead and Ground Water Recharge Area Protection Strategies

Wellhead and ground water recharge area protection will be discussed together because the protection strategies are similar. Wellhead protection is the management of land use in the well capture zone of the public well to avoid or minimize the risks to the water supply. Any private wells within the public well wellhead protection zone would be protected as an additional benefit. A ground water recharge area usually requires a protection area much larger than a wellhead protection zone. A recharge protection area would be delineated to include both public and private wells, existing and future. Similar to wellhead protection, management of land use activities is also emphasized in ground water recharge protection.

FIGURE 26. CAPTURE ZONE FOR WATER TABLE WELL



Note: Figure does not represent well in confined aquifer.

Many local governments across the U.S. are developing comprehensive programs to protect wellhead and ground water recharge areas. A regulatory strategy involving some form of land use controls is a major component of these programs. This approach will have a strong impact on private land use, but it may not be sufficient to manage all the land use activities. Some activities such as agricultural practices or governmental actions (e.g., the siting and design of governmental maintenance and service facilities) may not lend themselves to traditional land use controls. Also, if the area is already intensely developed, land use controls may have little immediate affect on existing uses. A broader strategy that integrates land use controls and non-regulatory strategies such as planning, public information and education, land acquisition and best management practices may be the most effective approach.

Tables 8a and 8b summarize the specific non-regulatory and regulatory strategies that may be used to protect wellhead and ground water recharge areas. Individual strategies are classified as primary or secondary based on the extent to which they would be important in protecting the resource. Secondary strategies are less effective because they are costly or not applicable to all types of land uses or potential contaminant sources. However, secondary strategies such as land acquisition that are too costly to apply over a wide area may be valuable in protecting small but strategic portions of a resource protection area.

In the near future, all local governments in Minnesota may be required to protect public wellhead areas. The MDH is directed by the legislature in the Ground Water Protection Act of 1989 to develop rules for implementing wellhead protection measures for public wells. These rules will define the program responsibilities of local governments for developing and implementing wellhead protection. This guidebook will be limited to general discussion of how some of the various strategies discussed earlier in this section may be adapted to wellhead protection. These and other approaches will have to be adapted to the program rules which the MDH adopts.

After the wellhead or recharge area is delineated, the next step is to assess the risk to ground water water quality from existing and potential land uses based on the current zoning, local comprehensive plan and other available information. The individual source protection strategies discussed earlier may be incorporated as part of the overall protection strategy, depending on the types of land uses that are present or expected in the area.

Non-regulatory Strategies

Several non-regulatory strategies may be necessary to implement a comprehensive protection strategy for wellhead or recharge areas. Identifying these areas in the local government's growth management program would ensure that sewers and other public services are available or planned when higher risk commercial and industrial developments occur in these critical areas. In addition, the location of higher risk land uses may be discouraged in these areas until sewers and other services are available. Information regarding the location of wellhead and recharge areas would assist the local government in determining the timing, priority and level of services needed for future development areas.

The local comprehensive plan may also be amended to protect wellhead or ground water recharge areas with maps delineating the areas included in the plan. The plan would include protection of the area as a goal, and the land use element of the plan would establish policies and criteria for the type of uses, density, and standards for development or redevelopment. The policies would support revisions to the local zoning, subdivision regulations and other land use controls to implement the plan. The public facilities element of the plan would incorporate policies to guide the development of these services in the protected area, such as types of services to be provided and how they will be designed or operated to protect ground water. For example, location of

Table 8a

POTENTIAL NON-REGULATORY RESOURCE PROTECTION STRATEGIES

Strategy	Wellhead Areas	Ground Water Recharge Areas	Sensitive Areas	Aquifers
Growth management	P	P	P	P
Comprehensive planning	P	P	P	P
Acquisition of land & development rights	P/s*	s	s	s
Best management practices	P	P	P	P
Public information & education	P	P	P	P
Solid & hazardous waste planning	P/s*	P/s	P/s*	s
Financial incentives	P/s	s	s	s
Program coordination & government operations	P/s*	P/s*	P/s*	P
Monitoring	P/s*	P/s*	P/s*	P/s*

P = primary strategy s = secondary strategy * = depends on existing land uses, area size and cost

Table 8b

POTENTIAL REGULATORY RESOURCE PROTECTION STRATEGIES

Strategy	Wellhead Areas	Ground Water Recharge Areas	Sensitive Areas	Aquifers
Zoning & rezoning	P	P	P	P
Overlay zoning	P	P	P	P
Conditional zoning	P	P	P	P
Planned unit development	P/s*	s	s	s
Cluster	P/s*	s	s	s
Transferable development rights	P/s*	s	s	s
Site plan review	P	P	P	P
Subdivision regulations	s	s	s	s
Health & sanitary codes	P/s*	P/s*	P/s*	P/s*

P = primary strategy s = secondary strategy * = depends on existing land uses, area size, and cost

municipal wastewater treatment facilities in protection areas may be discouraged, and policies for development of sanitary sewers may support more stringent specifications to minimize leakage.

Acquisition of property or development rights in wellhead and ground water recharge areas may be the most certain method of protection, but may be limited because of the potential costs of acquiring large areas of undeveloped or developed land. However, it may be necessary to acquire an existing use or parcel that cannot be controlled by regulations or represents a significant risk to the wellhead or recharge area because of its location or the type of use and contaminants involved. The city of Dayton, Ohio, has established a fund financed by user fees for this purpose as part of the city's overall protection program (Hall et al, no date). Before acquiring property or development rights, the local government should determine what, if any, existing liabilities there are due to spills or releases of contaminants.

A combined strategy utilizing public information and education techniques to encourage the voluntary application of BMPs may be a valuable strategy where the area is substantially developed or regulation is not feasible. An organized program informing farmers, businesses or homeowners located in wellhead and recharge areas of the potential impacts of their activities on ground water, the risks involved and alternative BMPs which they could implement to reduce the risks may encourage individuals to change their current operations or improve their facilities. Information regarding sources of local, state and federal technical and financial assistance should be made available as part of the program to give further encouragement (see the discussion of specific sources in Section 4 and Appendix D).

Other governmental programs, such as solid and hazardous waste and surface water planning should be reviewed to ensure their goals, policies and programs contribute to the protection of wellhead and ground water recharge areas. For example, surface water plans may encourage the location of stormwater storage ponds in wellhead or recharge areas resulting in the possible infiltration of contaminants in the runoff.

A local government may wish to establish a financial incentive program of its own to assist businesses, homeowners and others in achieving wellhead and ground water recharge area protection. For example, a program of low interest loans or grants might encourage land owners to seal abandoned wells or replace older underground storage tanks. The establishment of these programs would require an inventory of the number and types of sources as a basis for estimating the potential costs.

Because of the critical nature of wellhead and ground water recharge areas, the local government should consider the development of a spill contingency plan so action can be taken immediately when an incident (or catastrophe such as a chemical-releasing explosion) occurs. This would involve local and state emergency response agencies and the Minnesota Department of Agriculture (agricultural chemical spills) or the Minnesota Pollution Control Agency (for all other spills). Spills may occur at local industries and businesses, but they often occur along highways and railroads.

The establishment of an adequate monitoring program for wellhead and ground water recharge areas may be a crucial part of the strategy. (The Safe Drinking Water Act currently requires monitoring as part of a wellhead protection program for public water supplies). Identifying potential contaminants before they reach public and private wells will enable local governments and other agencies to take effective action to protect wells. Tracking the ground water quality changes in these areas will allow local officials to assess the effect of protection strategies, build support for stronger programs to protect the public health, and target the sources or types of sources which contribute to the problem, but not currently under control.

Regulatory Strategies

Several of the zoning strategies discussed earlier in this section may be applicable for wellhead and ground water recharge area protection. If the area is relatively undeveloped, the more simple approach may be to rezone the area to restrict potential sources of contaminants. For example, businesses, industry, and other activities which use or produce hazardous materials or generate hazardous wastes may be prohibited. These uses would be allowed outside the wellhead or recharge areas. However, depending on the size of the protected area this approach may result in all or large areas of the community being zoned to restrict industrial or commercial development.

The most widely used zoning technique to protect wellhead and recharge areas is the overlay zone, particularly where the land is substantially developed or zoned for commercial and industrial uses. After the wellhead or recharge area is delineated, an overlay zone conforming to the boundaries of the protection area is established over the existing zoning pattern. New uses allowed by the existing or underlying zoning are permitted, subject to requirements imposed by the overlay zone.

The overlay zone may comprise several management elements. These include the prohibition of certain high-risk land use activities, submittal of a site plan for review, the establishment of design and operating standards for uses, and other elements. The overlay ordinance will often prohibit certain high-risk uses in the overlay zone, such as municipal and industrial wastewater treatment facilities and the land application of sewage sludge. The ordinance may also specify permitted uses or those which represent no potential risk to ground water quality, particularly if the area is largely undeveloped. These typically have no or minimal involvement with the use, storage, handling or discharge of any contaminants.

One of the most important elements is the standards under which permitted or conditional uses are allowed in the overlay zone. These can consist of several components, but generally include design and operating standards to prevent contaminants from reaching the earth's surface. These standards are to be incorporated into any proposed plan for property development or use, and followed once the use is approved and operating. Design and operating standards can include such items as:

- Standards for underground storage tanks to prevent corrosion and overflow, and monitoring for leaks;
- Requirements for wastewater treatment such as the connection to a centralized treatment system;
- Proper disposal of hazardous waste according to state regulations;
- Specifications for the design of facilities in which hazardous materials are used, stored or handled, to prevent leaks and spills from reaching the earth's surface;
- Establishment of an operating plan for businesses and industries including procedures for the reporting and cleanup of spills and leaks;
- In-house tracking systems to monitor or account for the use of hazardous materials; and
- Monitoring of ground water to ensure the design and operating standards are effective for the long-term.

An overlay ordinance may require the submittal of a detailed site plan for any proposed conditional use as part of the permit application. The ordinance specifies what information is to be included with the plan, such as proposed designs and specifications for hazardous materials storage, the type and quantities of hazardous materials present on the site, the geology and hydrogeology beneath the site, proposed surface drainage, and other information necessary to evaluate the risks to ground water quality and how these will be mitigated. Some ordinances also

require periodic reports on the use, storage and handling of hazardous materials. All of the information is reviewed in determining whether a permit will be approved. Depending on the technical level of the information, the community could ask other local and state agencies for assistance during its review.

There are a number of applications in the United States of the overlay district concept to protect wellhead and recharge areas . Dayton, Ohio, adopted an overlay district as a key element in a comprehensive program to protect its wellfields (Hall, et al., no date). Following a thorough assessment of the hydrogeology of its wellfields and potential pollution sources, the city enacted an overlay district for each wellhead. Rather than regulating according to traditional land use categories such as "heavy industry," the ordinance regulates the use of harmful or "regulated substances" identified under the Federal Emergency Planning and Community Right-to-Know Act (see Section 4). New uses in excess of minimum quantities of regulated substances are prohibited.

Dayton's ordinance also establishes threshold capacity limits for regulated substances by existing nonconforming uses. Businesses using in excess of excluded amounts are required to notify the city periodically of the use of regulated substances. Thresholds may be exceeded if it is determined that the proposed expansion will not increase the risk or the risk will be offset by other measures. New owners or occupants of land in the district apply for an occupancy certificate and must submit a inventory of regulated substances.

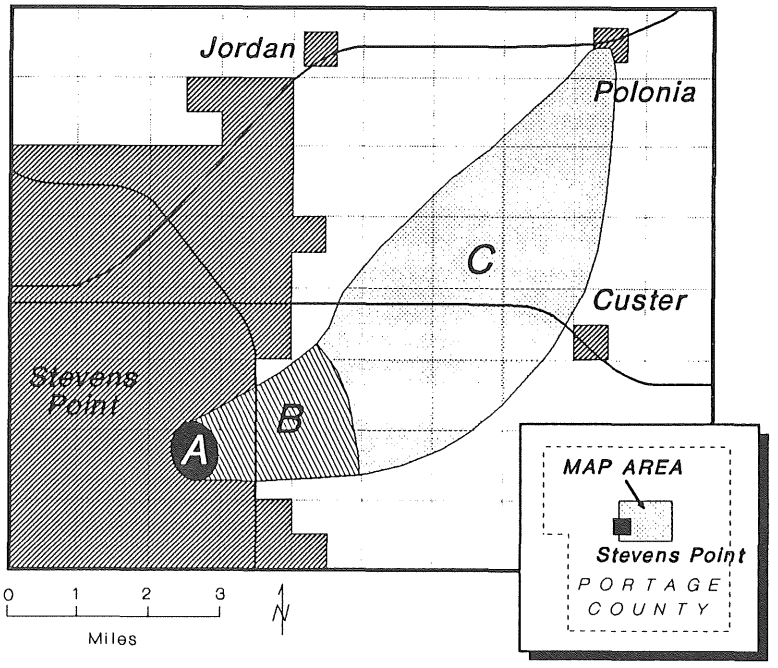
A proposed overlay ordinance included in the Portage County, Wisc., ground water plan (Portage County, 1988) takes a slightly different approach to wellhead protection. The wellhead area is divided into three zones (Figure 27) based on the travel-time distances of ground water, the risk of wellfield contamination by land use activities, and the level of protection required.

Zone A, the innermost zone with a radius of 1500 feet, is the area commonly known as the cone of depression in which the ground water elevations are drawn down by pumping. This is considered to be the area of highest risk to the wellfield, and land use activity is highly restricted. Zone B is the recharge area upgradient of Zone A. The boundary of this zone is based on a five year travel time, which is the minimum criteria recommended by the U.S. EPA. It would take a contaminant five years or less to reach the well. Because of the longer travel time and greater opportunity to take action to protect the well from contaminants, the land use restrictions are less restrictive than those for Zone A. Zone C includes the remaining recharge area upgradient of Zone B, but also includes surface water basins that potentially contribute to well recharge. Protection measures are the least restrictive in this zone. Potential sources of contamination are allowed subject to review, but their size, design, reporting of activity and monitoring of ground water are regulated.

The town of Rib Mountain, Wisc., adopted a two-zone land use control ordinance (Born, et al., 1988). Zone A approximates the extent of a sand and gravel aquifer and Zone B includes the outer limits of the wellhead area. Industrial and commercial uses are prohibited in Zone A but allowed in Zone B if they satisfy certain standards to protect ground water. Broward and Dade counties in Florida have both adopted time-related wellhead protection programs (Jaffe and Dinovo, 1987).

The Cape Cod, Mass., Planning and Economic Development Commission (National Research Council, 1986) developed a model "water resource district" overlay ordinance for adoption by local town governments that could be used for wellhead protection. The ordinance bans higher risk land uses, such as landfills, junkyards, municipal wastewater treatment facilities and any other use involving the manufacturing, storage, use, transporting or disposing of toxic or hazardous materials except as allowed by a special permit. Applicants for a permit are required to submit information

FIGURE 27. PROPOSED PORTAGE COUNTY, WISCONSIN WELLHEAD PROTECTION ZONES



Generalized extent of urban area

Rural area

Whiting Field Wellhead Protection Zones

A Cone of depression

B Five-year travel time

C Remaining recharge area

that indicates the types and amounts of chemicals used on the site, the proposed measures to prevent spills and leaks and control spills, and the toxic or hazardous wastes to be generated, including storage and disposal. The design and operating guidelines contain general standards for safeguards against spills, leaks, the location of on-site pollution sources and hazardous waste disposal.

Local governments have also adapted the overlay zone concept to the protection of ground water recharge zones. Spokane County, Wash., established an "aquifer sensitive area" which includes the geographic area overlaying the aquifer serving the Spokane urban area and a major portion of the recharge area (Spokane County, 1990). The ordinance allows the use, handling and storage of critical (hazardous) materials where aquifer protection is assured. The ordinance establishes performance standards for facilities utilizing critical materials and development standards, particularly for residential, consistent with the availability of sewer services. The county provides

a critical materials handbook containing suggested management and design solutions to achieve the performance standards. New commercial and industrial occupants or proposed expansions must obtain a certificate of occupancy. An initial screening process determines whether the activity uses any critical materials. Prior to issuing the certificate, the county building department must determine that all critical materials associated with the activity are stored or used in conformance with the performance criteria. Hook-ups to central sewer systems are required where these are available, and larger minimum lot sizes are required where sewers are not available or planned.

Other regulatory measures may be combined with the overlay district to protect the wellhead or ground water recharge areas depending on the size of the area. Zoning all or key portions of the overlay district for large scale planned unit development (PUD) and cluster development would allow land owners and developers to concentrate or cluster higher risk uses in the portion of their property that is located outside the wellhead or recharge overlay district. Land inside the overlay district would be designated for lower risk uses. Incorporating provisions for transferable development rights (TDR) in critical portions of the overlay zone where land use or density is highly restricted would enable the land owner to transfer the right to develop to receiving zone(s) designated by the local government outside the overlay district.

Local subdivision regulations may also be amended to establish higher design standards for new development within wellhead or recharge overlay districts, such as the use of sanitary sewers where these are available, more restrictive standards for sanitary sewers to limit leakage, location of stormwater ponds outside the district where feasible, proper construction of new wells and proper abandonment of wells no longer in use.

Sensitive Areas

The third resource protection approach is the protection of geologically sensitive areas. The approach is based on the premise that the sensitivity of ground water to contamination depends on how long it takes a contaminant, from the time it is released on or near the surface, to reach ground water. The longer it takes, the greater the potential for the chemical, biological and physical mechanisms present in the soils and overlying geological materials mechanisms to reduce the effect of the contaminant and decrease the risk of ground water contamination. (See Section 3 for a more detailed explanation of these mechanisms.) Also, the shorter the time of travel, the less time there is to detect and prevent ground water contamination.

As discussed in Section 2, the characteristics of the soil and geological materials overlying an aquifer determines the sensitivity of the aquifer to pollution. Such characteristics include the permeability, mineralogy, thickness, and the number and type of geologic materials overlying the ground water. These characteristics, and others, affect the downward time of travel for a contaminant at the land surface to reach an aquifer, and thus its sensitivity to pollution. For example, if the overlying material consists of highly permeable sand and gravel deposits, the downward time of travel for contaminants will generally be short. In this case the aquifer will be sensitive. In contrast, clay and shale deposits of the same thickness can retard or perhaps completely prevent the downward movement of contaminants. Aquifers in this environment will tend to be less sensitive to pollution. Typically, aquifers which underlie materials that are less able to retard downward movement will be more sensitive to pollution.

Assessing Ground Water Sensitivity

The Minnesota Ground Water Protection Act of 1989 includes the protection of sensitive ground water areas statewide as one of the state's strategies for protecting ground water (Minn. Stat.

§103H.101). The act defines a sensitive ground water area as a "geographic area defined by natural features where there is a significant risk of ground water degradation from activities conducted at or near the surface."

The GWPA directs the Minnesota Department of Natural Resources to develop criteria for identifying sensitive ground water areas with advice from other state agencies and local governments. The MDNR maps the areas with the advice of those organizations, indicates the type of risk from land use, and provides this information to local planning and zoning authorities.

The MDNR, with the financial assistance of the Legislative Commission on Minnesota's Resources (LCMR) and technical assistance of other state agencies and local governments, has developed general criteria and guidelines for applying the criteria for assessing the geologic sensitivity of ground water (Minnesota Department of Natural Resources, 1991). The criteria are based on the properties of the surficial and deeper geologic materials overlying the ground water and their effect on the "time of travel," or the time it takes for a water-borne contaminant to move vertically from its source at or near the surface to the ground water of concern. Table 9 indicates the sensitivity rating and the corresponding time of travel developed for the project. The times overlap because of the uncertainty of travel time estimates.

The sensitivity criteria are based on the physical and geologic characteristics of an area, and do not include other factors that may affect the travel time or the contaminant, such as the presence of poorly constructed or improperly abandoned wells, the physical or chemical properties of the contaminants, or the chemical and biological nature of the soils and underlying geologic materials.

The guidelines for applying the criteria consist of three options--Levels 1, 2 and 3. The selection depends on the amount and type of data available to characterize the underlying geological materials and hydrogeology of the area, and the purpose of the assessment (Table 10).

Levels 1 and 2 assess the relative sensitivity of the surficial or water table aquifer. Level 1 is a preliminary assessment based on the permeability characteristics of the surface and near surface materials, basically, the texture and parent materials of the soil layer or upper six feet as described in a soil survey of the area. This level assumes the near surface materials represent the entire unsaturated zone. In both Level 1 and 2 assessments, water table depth is a critical factor in evaluating sensitivity. If the depth is less than six feet, the sensitivity is increased by one rating, such as from moderate to high.

Level 2 represents a more detailed assessment of the entire unsaturated zone above the water table aquifer. In Minnesota the depth of the unsaturated zone can range from zero, where the water table is at the surface, to more than 100 feet. The unsaturated zone may consist of unconsolidated materials, such as sand, gravel and clay, or consolidated material, such as sandstone or limestone. A Level 2 assessment focuses on the presence and thickness of any low or moderate permeability units.

Since the depth and characteristics of the entire unsaturated zone are evaluated in a Level 2 assessment, more information is required and the person doing the assessment must be more experienced and familiar with geologic and hydrogeologic principles and processes.

A Level 3 assessment evaluates the relative sensitivity of deeper aquifers below and hydrologically separated from the water table or surficial aquifer (see Section 2). The assessment is based on the presence, characteristics and cumulative thickness of confining layers that retard vertical movement of water and contaminants into the deeper aquifers. Ratings reflect the thickness of

Table 9

GEOLOGIC SENSITIVITY RATINGS BASED ON TIME OF TRAVEL

Geologic Sensitivity Rating	Estimated Travel Time
Very high	Water moving vertically will reach the aquifer within hours to months;
High	Water moving vertically will reach the aquifer within weeks to years;
Moderate	Water moving vertically will reach the aquifer in years to decades;
Low	Water moving vertically will reach the aquifer within several decades to a century;
Very low	More than a century will be required before water moving vertically will reach the aquifer. This rating should only be used in deeper aquifer assessments unless age-dating or other studies confirm such conditions in water table aquifers.

Note: Entire sensitivity assessment area is initially assumed to be a ground water recharge area. A detailed hydrogeological study may be required to fully define recharge and discharge areas.

Table 10

OPTIONS FOR ASSESSING GEOLOGIC SENSITIVITY

Assessment Level	Zone	General Information Needed	Major Benefits	Major Limitations
1 (preliminary)	Surface or near-surface materials (maximum six feet in depth)	Soil texture/parent materials; depth to water (county soil surveys)	No new data or geologic interpretation necessary; relatively easy	Ignores variations in lower unsaturated zone, not site specific
2	Entire unsaturated or vadose zone	Depth to water; type and permeability of materials throughout zone (presence and cumulative thickness of low permeability materials)	More complete assessment of water table aquifer sensitivity	Does not evaluate complex vadose zone processes and is not site specific; does not differentiate recharge vs. discharge
3	Deeper aquifers (below water table aquifer)	Permeability of confining layers and aquifers (cumulative thickness of low permeability layers)	Assesses multiple aquifers below water table	Does not assess lateral movement of contaminants or thin (less than ten feet) lower permeability units

potential confining layers of clay, clayey till or shale. More, and thicker, confining layers add to the degree of protection.

A Level 3 assessment requires more detailed information describing subsurface geologic conditions, including water level data. This data may not be available in many areas. The assessment also requires the skills of a highly experienced and trained person to complete.

A portion of the sensitivity assessment for Washington County prepared by the Minnesota Geological Survey is shown in Figure 28. The figures indicate results of separate sensitivity assessments for both the water table or surficial aquifer and the deeper Prairie Du Chien aquifer in the city of Woodbury. The figure shows how the sensitivity of the deeper aquifer may differ from that of the overlying water table aquifer, emphasizing the importance of developing a separate assessment for each aquifer. This assessment uses seven classes rather than the five-class rating system in the DNR project but, in general, is consistent with the five-class system.

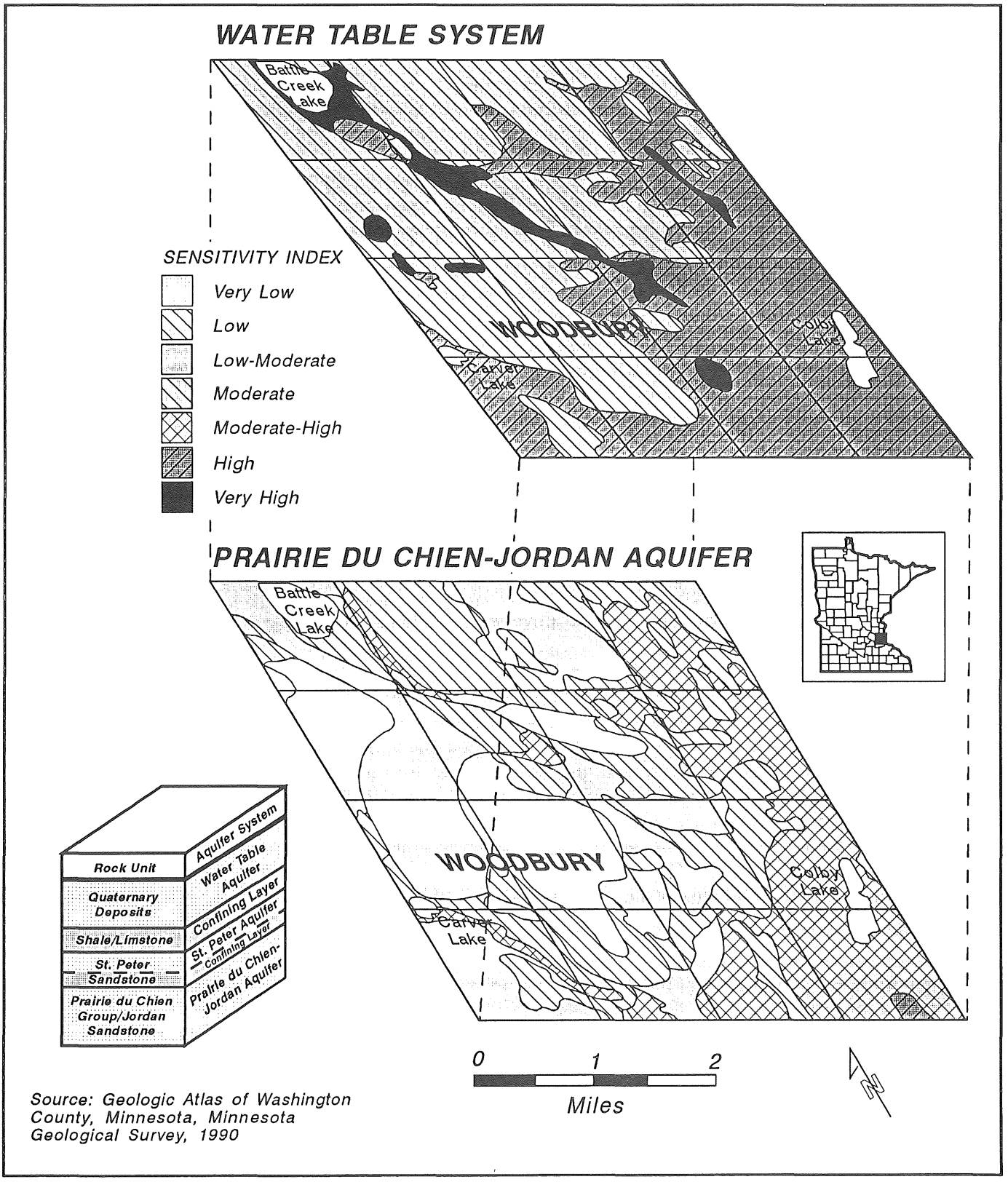
Other sensitivity assessment techniques are available. The suitability of any of these will depend on the purpose for which they were designed, the information they require, and the scale of the area involved. An overview of these techniques is provided in Appendix D of the final MDNR Geologic Sensitivity Project report (Department of Natural Resources, 1991). Another recent comprehensive review *Guide to Ground Water Sensitivity Rating Techniques* has been published by the Water Resources Research Center, University of Minnesota (Geier and Perry, 1992).

Sensitive Area Protection Strategies

State laws provide some direction for the local management of sensitive areas. State law requires county comprehensive water plans in Greater Minnesota to include "objectives for future development, use and conservation of water and related land resources, including objectives that concern water quality and quantity and sensitive areas...and related land use conditions..." (Minn. Stat. § 103B.311, subd. 6). County ground water plans in the Twin Cities Metropolitan Area are to contain "standards, criteria and guidelines for the protection of ground water and for various types of land uses in environmentally sensitive areas..." (Minn. Stat. § 103B255, subd.7). County ground water plans may respond by indicating the objectives for development in sensitive areas including the level of protection to be achieved in these areas, the types of land use activities that may be permitted, and the criteria or standards under which land uses would be allowed. This would provide direction to local governments for revising their comprehensive plans and land use controls to ensure local land use decisions are compatible with the county's ground water plan. County ground water plans may also provide guidelines for the development and implementation of special programs to influence decisions which are not or cannot be affected by land use controls. This involves such programs as public information and education, solid and hazardous waste planning, use of best management practices, and coordination of related government programs and operations. The county plan guidelines would also be used to influence the siting or design of public facilities at the federal, state or local levels or the permitting of facilities or land uses at other governmental levels. These are described in more detail below.

When choosing or implementing a strategy to manage or protect sensitive areas, local governments should keep in mind the amount of information concerning ground water sensitivity that is available. A ground water sensitivity assessment is an approximation. The amount of data used to prepare an assessment may be sufficient in some areas, but limited in others. The data may be insufficient for site specific land use decisions. For example, a Level 1 assessment which evaluates only the surface or near surface material (to a depth of six feet) may have limited utility in evaluating proposed land use activities located below that, such as landfills and underground storage tanks. However, a Level 1 assessment may be suitable for land use decisions at a very

FIGURE 28. SENSITIVITY OF THE GROUND WATER SYSTEM TO POLLUTION
(City of Woodbury, Washington County, Minnesota)



Source: Geologic Atlas of Washington County, Minnesota, Minnesota Geological Survey, 1990

general level such as comprehensive planning, planning for sanitary sewers or defining search areas for the siting of hazardous waste disposal facilities. It may be necessary in some instances to obtain more data about a specific area. Table 11 indicates some typical local government activities and the level of sensitivity assessment that may be suitable for these activities. Once an assessment is completed, it may be used to identify potential areas where more data should be obtained through a more detailed study of the geological materials and the ground water system.

As in the case of wellhead and ground water recharge area protection, the management of sensitive areas may require the integration of several specific strategies, depending on the type of existing and future land uses (Tables 8a and 8b). Land use controls can be adopted to manage private development, but a blend of other regulatory and non-regulatory strategies may be required to manage public land use activities and other private land use activities. For example, a local government might adopt an overlay ordinance requiring new commercial and industrial development in sensitive areas to incorporate certain design specifications, and concurrently implement a public information and education program to encourage existing businesses to incorporate these requirements voluntarily. Since a ground water sensitivity assessment may be too general, particularly for site specific applications, the local government may choose to encourage the submittal of site specific sensitivity data with plans for proposed development.

Non-regulatory Strategies

Growth Management Local growth management programs may be used to protect sensitive areas. Information on ground water sensitivity would be used as criteria in determining priorities for future development areas and evaluating the type of public services needed to serve them.

Undeveloped, highly sensitive areas may receive a high priority for future development along with the provision of public services such as sanitary sewers, rather than development utilizing on-site sewage disposal systems. In addition, the development could include establishing protection programs to protect ground water before development occurs. For example, the local government could adopt suitable land use standards to ensure the the design of commercial and industrial development incorporates features that contain spills. Conversely, sensitive areas could be protected by assigning them a low development priority until the necessary public services and protection programs are planned or available. This would require local land use plans and controls to discourage development in the interim, such as limiting the type and density of land uses.

Comprehensive Planning The local comprehensive plan is another potential strategy for protecting ground water in geologically sensitive areas. Sensitivity information is valuable for revising or developing plan goals and policies to protect ground water. Maps indicating ground water sensitivity may be included in the plan document. The goals and policies would indicate how sensitive areas are to be protected and how the information will be used in the community's planning and decision-making process. For example, the plan may incorporate a policy that certain types of proposed developments or land use decisions in sensitive areas will be reviewed by the local government to evaluate the risks to ground water quality and how these will be mitigated. Local land use controls would be amended to integrate the process into the local government's development review process.

Information on ground water sensitivity may be used specifically to revise the land use element of the plan. The information would be used to develop goals, policies, standards and criteria as to the type, density and design of land uses that would be encouraged or discouraged in these areas. For example, the land use plan may discourage the location within sensitive areas of land uses that are designed to discharge hazardous and other wastes, such as landfills. Other activities that

Table 11
LOCAL APPLICATION OF GROUND WATER SENSITIVITY INFORMATION

Typical Activity	Suggested Assessment Levels 1	2	3
1. Planning			
a. Growth management and comprehensive planning	M	P	-
b. Neighborhood and project planning	M	P	-
c. Systems planning (sanitary sewers, highways, stormwater management)	M/P*	-	-
d. Identification of search areas for various waste disposal facilities such as landfills	M	P	+
e. Identification and evaluation of sites for waste disposal facilities	M*	M*	+
f. County-wide water resource and ground water planning (watershed planning in the Twin Cities Metropolitan Area)	M	P	+
g. Local (city and township) water management planning	M	P	-
2. Regulation and Management			
a. Zoning and subdivision regulations (subdivision and site plan reviews)	M	P	-
b. Conditional or special use permits	M	P	-
c. Health and sanitary codes, for example requirements for storage tanks	-	M	-
d. Management and design standards, for example storm water pond design specifications	M	P	-
e. Best management practices, for example management of roadway salt application	M	P*	-

M Minimum assessment level
P Preferred assessment level
* Depending on specific planning needs and contaminants involved
+ Suggest completion of Level 3 assessment for this activity
- Completion of Level 3 assessment may not be needed

Source: Minnesota Department of Natural Resources, 1991 and Metropolitan Council

use, produce or handle contaminants may be allowed to locate within sensitive areas if they incorporate special design specifications that prevent or minimize the risk of a spill or other release.

Ground water sensitivity information can also be incorporated in the public facilities element of the comprehensive plan. The information may be used in developing goals, policies, standards and criteria for locating, designing and operating public facilities such as sanitary sewers, storm water drainage facilities, maintenance garages and wastewater treatment plants in sensitive areas. The plan would be used by the local government in making decisions about proposed public facilities in sensitive areas. The policy could also be used in reviewing facilities proposed by other governments and agencies.

Public Information and Education A local public information and education program to protect ground water may be designed to use sensitivity information. The purpose would be to inform residents, businesses, public officials, farmers, developers, and other groups about the location and extent of sensitive areas and the implications and risks of locating and operating in these areas. The information and education program would advocate the adoption of appropriate best management practices (BMPs) for minimizing the risks. Information about appropriate BMPs for agricultural, commercial, industrial and other land uses could be provided to each group of users. The BMPs would include suggested designs for buildings and storage facilities, operating procedures to prevent or minimize spills and leaks, and suggested practices for the use of fertilizer and pesticides in agricultural and urban areas. Sources of this information have been discussed elsewhere in this section. Ground water sensitivity maps may be laid over existing land use maps to determine priority areas and target groups or uses.

Governmental Operations A variety of local governments and state agencies are active in planning, permitting, locating, designing and operating public facilities and other administrative programs which may affect sensitive areas. After ground water sensitivity is mapped, the local government can provide this information to other governmental units and officials. The information must be accompanied by an explanation of its significance, how the local government intends to use it and how the other governmental agencies or units might use it in their programs. Listed below are some examples of how this information could be used. A more comprehensive list of potential uses and related activities is presented in Table 11.

- Counties, watershed management organizations (Twin Cities Metropolitan Area), watershed districts and local governments that are responsible for water resource planning, including the location and design of storage ponds may use the information to locate and design detention ponds to avoid or minimize the infiltration of contaminants associated with stormwater into the geologic materials above ground water aquifers.
- Counties may use the sensitivity information to plan for proposed solid waste disposal facilities including the delineation of search areas, evaluation of potential sites within these areas and developing design specifications for these facilities.
- City, county and townships that are responsible for administering zoning and other land use controls may use the information in reviewing subdivisions and projects such as industrial parks and bulk pesticide and fertilizer distribution facilities to assess the risks to ground water and the need for measures to mitigate the risk.

The same information may be provided to state agencies that are involved in permitting, regulating, siting and designing potential sources of contaminants, overseeing the clean-up of spills and Superfund sites, preparing or overseeing the preparation of environmental review documents (EAWs and EISs), developing BMPs and other decisions affecting ground water. The purpose is

to encourage them to integrate this information into their decision-making processes. For example, the information could be used to place conditions on permits for facilities involving potential contaminants. Section 4 and Appendix D identify many of the state activities that could benefit from the use of this information.

Monitoring Ground water sensitivity information may be valuable in defining or modifying a local ground water monitoring program. Overlaying the sensitive area information on maps of existing land use, potential sources of contamination and other information would assist in defining areas to monitor.

Regulatory Strategies

Zoning Several zoning techniques may be adapted by local governments to protect sensitive ground water areas. If the concern is limited to the location of one or more specific uses, such as the disposal of sanitary, solid or hazardous waste, the local government may adopt an ordinance requiring a conditional use permit for certain activities in the most sensitive areas. The ordinance could require the submittal of a detailed plan for review and approval indicating the proposed use and design and other control measures to protect ground water. The ordinance would allow the local government to require the incorporation of additional conditions if necessary to mitigate the risk of contamination.

An overlay ordinance may also be adapted to protect geologically sensitive areas. The ordinance could incorporate the sensitivity classification scheme and establish the requirements or standards for each class. The standards or restrictions would vary with the level of sensitivity. The ordinance could indicate the prohibited uses for each class, the conditional uses and the conditions under which other uses might be allowed, monitoring requirements, and the other information to be submitted by the applicant to assist the local government in evaluating the proposed use. Site plans would be required for proposed conditional uses, indicating the proposed design specifications intended to protect ground water.

Prohibited uses in the most sensitive areas might include those which are planned or designed to discharge or apply waste materials, such as septage, sludge or wastewater to the land, or uses where there is a high risk of releasing or discharging contaminants, such as landfills. Where it is not feasible to prohibit these uses, the overlay ordinance may require the submittal of a risk assessment that includes an evaluation of proposed mitigation measures to reduce the risk.

Lower risk activities involving potential contaminants might be allowed in the most sensitive areas, depending on the volume and type of contaminants. For example, small on-site sanitary disposal systems might be permitted for low density residential development under a comprehensive, local management system. Large volume on-site systems serving commercial or institutional uses may be prohibited.

Agricultural activities involving the application of fertilizers and pesticides would be required to develop BMP plans indicating what practices would be followed, depending on the sensitivity of the area. Information on the leaching characteristics of certain agricultural contaminants is already available from the Minnesota Extension Service and USDA-SCS offices. Other agriculture-related uses, such as feedlots and commercial establishments using, handling or storing agricultural chemicals, would be required to meet appropriate state standards and additional local design and operating standards to protect ground water.

A local government may choose to require or allow a more detailed, site specific assessment of sensitivity be submitted as part of its regulatory strategy. For example, if the sensitivity assessment is based on a county soils survey and limited or no surficial geological data, the local

government may encourage the applicant to provide more site specific data. The government would consider this additional data in determining the sensitivity of the site and the need for additional protection requirements. This may avoid the problem of enforcing restrictive land use and imposing additional costs where they may not be necessary.

PUD and TDR The use of Planned Unit Development (PUD) and Transferable Development Rights (TDR) could also be incorporated in the local land use controls to provide some flexibility for the local government, land owners and developers. For example, in the most sensitive areas where land use controls are the most restrictive, the use of PUD zoning would allow developers to cluster development on the portion of their land outside the sensitive area and reduce the risk to ground water. Or, the landowner or developer could be allowed to transfer the development rights from a restricted sensitive area to a "receiving" area designated by the local government in less sensitive areas.

Health and Sanitary Codes Health and sanitary codes for specific sources of contaminants such as storage tanks and on-site sanitary disposal systems may also be amended to tailor the standards and requirements to the level of ground water sensitivity. For example, local regulations for the design, construction, siting, inspection and maintenance of on-site sanitary disposal systems, including small residential systems and larger systems serving free-standing restaurants and motels could be amended to protect sensitive areas. Larger commercial systems (based on effluent volume) might be prohibited and tighter management requirements set for residential systems, such as larger minimum lot sizes, as well as tighter inspection and maintenance requirements in the most sensitive areas.

In moderately sensitive areas, larger commercial systems would be allowed where the applicant can demonstrate that wells will not be contaminated. The code could require ground water monitoring for larger systems, and periodic renewal of the permit. The minimum lot size would be reduced for residential systems. In each case, the controls and management system is designed to fit the sensitivity of the area and the risk involved.

Aquifer Management

In urban and metropolitan areas, many communities and large populations may depend on the same aquifer for their water supply. In these areas, communities are in such close proximity that local land use decisions, ground water development and ground water protection programs are affected by, or affect the ground water resources of other communities. For example, individual wellhead protection areas may overlap or extend outside the community. As a result, the land use decisions of one community may conflict with the protection of the adjoining community's water supply. For example, one community may fail to consider the potential for contamination of the adjoining community's wells in approving the development of new industry upgradient of those wells.

An alternative protection strategy in these situations is to manage or protect the aquifer as a single unit. After the aquifer protection area is delineated, common goals, objectives, policies and standards are adopted for the entire aquifer and implemented by all the affected communities through new and ongoing local programs. Priorities for implementing the strategy may also be established including specific programs to manage or control land use. This would protect the resource and the interests of all the communities, businesses and citizens who are dependent on the resource. This approach would require the affected local governments to establish a coordinating mechanism. Coordination could be achieved by a formal or informal organization, depending on the needs of the area. There are many examples of cooperative management

efforts in Minnesota, including watershed districts, lake conservation districts and multi-county joint-powers organizations that have been formed to protect a specific water resource. Regardless of the form of the coordination, the purpose is to ensure a consistent and effective protection strategy among all the local governments affecting the aquifer.

There are also many national examples of this approach. In San Antonio, Texas, the Edwards Underground Water District was established over a five-county area for the purpose of conserving, protecting and recharging the Edwards Aquifer, the city's only source of water (Brereton, 1988). Although the major concern was to assure the city of adequate water supply to meet its future needs, the city and district have adopted a nondegradation policy to protect the aquifer. The district is authorized to develop comprehensive plans for the use and prevention of pollution of underground water.

The state of Washington approved legislation in 1985 that allows local governments or the Department of Ecology to propose the designation of ground water management areas when there is concern for the quality or quantity of water (Washington State Department of Ecology, 1988). These are specific geographic areas that contain one or more aquifers. An advisory committee that includes local governments, water users and other interests is appointed by the department for the purpose of developing a management program. The program is to include the proposed management strategies and an implementation section including proposed model ordinances, amendments to comprehensive plans, inter-agency agreements and legislative changes.

Another protection strategy for local governments under the Safe Drinking Water Act of 1974 is to petition the EPA to designate a sole-source aquifer. Under a sole-source designation, the EPA must review all federally funded projects in the area to ensure ground water is protected. However, the designation provides limited protection because the review process does not apply to private development and state or local government projects. More information concerning sole-source designation is provided in Appendix C.

Non-regulatory Strategies

The use of non-regulatory strategies to protect the aquifer is essential if the management or coordinating organization's implementing authority is limited. For example, the coordinating organization may have only the authority to recommend but not require local governments to adopt compatible comprehensive plans. In this instance, plan implementation would be the responsibility of each affected local government on a voluntary basis.

After common goals, objectives, policies and standards are established by the coordinating or management organization, local governments would voluntarily incorporate these into local growth management strategies and comprehensive plans to ensure local land use decisions are compatible with the goals for aquifer protection. The coordinating organization could develop model provisions and standards for land use to assist local governments in revising their growth management schemes and land use plans. Public information and education programs could be designed and implemented by the coordinating organization to educate all governmental organizations and agencies as well as residents, businesses and industries about the importance of the area's aquifers and the impact of public and private decisions on aquifer protection. Local solid and hazardous waste planning could also be evaluated to ensure these programs are consistent with the aquifer protection goals and objectives and determine the need for new programs. If the affected local governments are not prepared to give the coordinating organization approval power over local plans and programs, they may be willing to allow the organization to review and make advisory comments as to the consistency of local plans and programs with the overall aquifer protection goals and objectives.

Long-term monitoring of the aquifer would be an important part of the protection strategy. The information would enable local governments to understand any changes and trends in the water quality and evaluate the effectiveness of the protection program. It would be more efficient for the coordinating organization to develop and implement a single monitoring plan for the entire aquifer rather than each local government attempt to develop its own.

Regulatory Strategies

The regulatory strategies utilized to protect well head, ground water recharge and sensitive areas could also be adopted to protect aquifers, including overlay zoning, conditional zoning, and health and sanitary codes. This could be achieved in two different ways depending on the authority granted to the coordinating organization. If the coordinating organization has the authority, it could adopt appropriate zoning code requirements and standards for land uses to protect the aquifer. If the organization is not authorized to adopt these controls, it could develop model requirements and standards, and local governments would amend their existing codes voluntarily to incorporate the new requirements and standards.

SECTION 6 - PLANNING FOR GROUND WATER PROTECTION

INTRODUCTION

This section is designed to assist local governments in developing a plan for ground water quality protection as part of an overall plan for ground water or water resource management, or as a "free-standing" protection plan. Incorporating the material and information presented in the other sections of the guidebook, this section is intended for use by local planners, consultants, soil and water conservation districts and other local officials who are responsible for ground water planning.

In Greater Minnesota, counties are responsible for preparing a comprehensive water plan which addresses ground water and surface water resources. In the Twin Cities Metropolitan Area, the seven counties are authorized to prepare a separate ground water plan which addresses both quantity and quality issues. An individual city or township may also choose to prepare a plan to protect ground water resources unilaterally or in response to a county protection plan.

Counties have been granted the authority under state law to undertake general ground water planning, but they may not regulate related land resources in every instance. Counties, with the exception of Ramsey and Hennepin, are authorized by state law to adopt a comprehensive plan and land use controls to guide their physical development, but not all counties have chosen to do so. (Hennepin and Ramsey counties are specifically prohibited by state law from undertaking land use planning and zoning.) In some counties, the townships have adopted a comprehensive plan and land use controls rather than the county; the townships in Anoka and Dakota counties in the Twin Cities Metropolitan Area are in this category. In addition, counties may not adopt land use controls for an incorporated area unless officially requested. Many municipalities have adopted comprehensive plans and land use controls to manage land use within their borders. In Greater Minnesota, counties may regulate land resources in incorporated areas only under certain conditions (Minn. Stat. § 103B.311), such as in the case where a municipal plan is inconsistent with the county's comprehensive water plan. As a result, counties will have to work closely with cities and townships in the development and implementation of a county-wide protection plan.

Cities and townships may be asked to develop individual local ground water plans that address specific parts of the overall county plan. For example, a city may develop a wellhead protection strategy to protect its municipal well or wellfield in order to implement the goals, policies and priorities of the county plan. (See Section 4 for a discussion of local government planning responsibilities).

Legislative and Regulatory Requirements for Planning

The legal requirements for county ground water planning in the Twin Cities Metropolitan Area and Greater Minnesota are very similar (Table 12). The plans must include an inventory of the geological, land use and other conditions that affect ground water resources; goals, objectives and policies for ground water protection; standards, criteria and guidelines for special areas of concern, such as sensitive ground water and wellhead protection areas; and an implementation strategy. Greater Minnesota county plans must specifically address objectives for sensitive areas (see Section 5). Twin Cities metropolitan county plans are to incorporate land use standards and criteria for "environmentally sensitive areas" which could include sensitive areas.

Table 12
PLAN CONTENT REQUIREMENTS FOR GROUND WATER PROTECTION*

Twin Cities Metropolitan Area (Seven Counties)	Greater Minnesota Counties
1. Description of existing and expected changes in the physical environment, land use and development	1. Description of existing and expected changes in the physical environment, land use and development
2. Presentation of available information about ground water and related resources	2. Presentation of available information about ground water and related resources
3. Statement of goals and objectives, scope, and priorities for protection	3. Statement of objectives for future development, use and conservation, including quality
4. Statement of standards, criteria, and guidelines for ground water protection from pollution and for various types of land uses in environmentally sensitive areas, critical areas or previously contaminated areas	4. Statement of objectives for sensitive areas, wellhead protection areas and related land use conditions
5. Indication of conflicts between county plan and other local plans	5. Indication of conflicts between county plan and other local plans
6. Description of standards and guidelines for implementing the plan by local governments and watershed management organizations	6. Description of implementation program, including schedules for amending official controls and related local plans (water and land use) to conform

* Minn. Stat. §§ 103B.255 and 103B.311

In addition, the Minnesota Board of Water and Soil Resources has adopted rules that specify the minimum data and information to be included, plan contents and the procedures to be followed in developing a comprehensive water plan for a Greater Minnesota county (Minn. Rules ch. 9300). Although these rules do not apply to metropolitan counties, the rules do provide guidance as to what should be included in a ground water protection plan. When preparing a protection plan, local governments should review and follow state requirements for plan contents and process.

To assist counties in Greater Minnesota with the preparation of a comprehensive water plan in accordance with state requirements, the State Planning Agency (now Minnesota Planning) prepared *The Handbook for Comprehensive Local Water Planning, 1987.* The handbook provides assistance in addressing a broad range of surface and ground water resource problems and also gives many useful examples and ideas on planning for ground water quality protection.

PLAN DEVELOPMENT AND CONTENTS

Developing a ground water protection plan requires five major steps or phases:

- An inventory of the ground water system, ground water uses, water quality conditions, potential contaminant sources and existing federal, state and local protection programs;
- An assessment of problems and issues;
- The establishment of goals, objectives and a protection strategy;
- The development of an implementation program; and
- Monitoring and evaluation of progress.

As listed in Table 13, each of the five major planning steps includes a number of sub-tasks, such as inventorying resources, defining issues and concerns, and evaluating long-term progress toward protection goals. The planning process can be applied to the preparation of a county, city or township ground water protection plan, or a specific resource such as a wellhead or ground water recharge area. For example, one of the necessary steps in preparing a local wellhead protection plan after the area has been delineated is to inventory existing and potential land uses or contaminant sources in the area.

The inventory phase provides the basic data and information for preparing a protection plan. The inventory should provide basic information about the nature of the ground water system, the influence of the surrounding geology on the potential for contamination, current ground water quality conditions and trends, ground water users that might be affected by contamination, existing and future land uses that are potential contaminant sources and the extent to which current management programs protect the resource.

The next step in the planning process is assessing or defining the problems and issues that should be addressed by the plan. The information gathered in the inventory phase will indicate whether there any existing problems or potential risks to ground water quality and related issues. Issues are those aspects of problems that require the local government to select the overall direction or response. Issues frequently require elected officials to choose among alternative courses of action. For example, the local government may have a choice between pursuing the alternatives of educating businesses, residents and other groups about ways to protect ground water or regulating potential sources of contaminants.

After problems and issues have been defined, local governments are to choose policies to guide preparation of the plan. Policies are the directions or courses of action the plan will recommend in responding to individual problems and issues. Policies include the development of goals and objectives, establishing priorities, and selecting protection strategies. Goals are the broad, long term purposes the local government seeks to achieve through the adoption and implementation of the plan. Objectives are more specific, focusing on specific problems, actions and outcomes.

Selecting priorities among the various problems and issues identified in the inventory and assessment is an important part of the planning process. Assuming there are never adequate resources (funding, time and personnel) to address all the problems at once, local governments will have to decide which should be addressed first.

Once goals, objectives and priorities are established, local governments will formulate and evaluate alternative strategies for achieving the objectives. These are potential program choices or activities that the local government can adopt or implement to achieve the specific objectives in the plan. Examples of regulatory and non-regulatory strategies have been discussed in detail in Section 5. Others may be developed in examining the alternatives.

Table 13

DEVELOPMENT OF A GROUND WATER PROTECTION PLAN

Inventory of Physical Environment, Land Use and Ground Water Use	
• geology of ground water system	• ground water use
• assessment of ground water sensitivity	• ground water quality
• existing and future land use	• existing protection policy and regulations
• known and potential contaminant sources	

⇓

Assessment of Problems and Issues	
• current water quality problems	• resource related concerns (wellhead, recharge and sensitive areas)
• health concerns	• adequacy of existing protection programs
• existing and potential land use related risks	• other public concerns

⇓

Development of Goals, Objectives and Plan of Action	
• issue identification and policy development	• alternative strategies and policies
• priorities	• plan of action or program strategy
• goals for ground water quality and land use	• recommended changes in state programs
• objectives (measurable)	• resolution of conflicts with other local plans

⇓

Development of Implementation Program
• proposed activities or tasks (research, education, adoption of land use controls, capital improvements) • proposed schedule and costs

⇓

Monitoring and Evaluation of Progress
• monitoring of ground water quality • status of implementation program and activities • revise plan if necessary

The development of an implementation program is a critical part of a protection plan. The implementation program is a statement of specific activities or actions such as the adoption of land use controls or the initiation of an education program. The program also includes a schedule for the completion of the activities, their estimated cost and funding sources. These items represent the local government's commitment of resources to achieve the goals and objectives it has established in the plan.

Monitoring and evaluation of progress in achieving the goals and objectives of the plan is the final and most often overlooked element in the planning process. These are the methods the local government will use for monitoring progress in implementing the plan and the effect of the plan. This information may be used to revise the plan.

Inventory of Physical Environment and Ground Water Resources

Several types of basic data and information should be inventoried when developing a ground water protection plan. Local governments will need to obtain data on the geology and hydrology of the area. In addition, data will need to be collected on the ground water system, including its current quality, current users, existing and potential sources of contamination and current governmental programs to protect ground water.

For the purpose of developing an inventory, emphasis should be placed on the use of available data from existing state or local sources, particularly if this is the first ground water protection plan. Although adequate information is important for a thorough understanding of the ground water system and problems, it may not be necessary for initial development of the plan. Undertaking a lengthy, technical study to collect the data would delay completion of the plan. Completing the plan to establish some protection of the resource while incorporating a specific recommendation in the plan to collect the information as a special study would be a more useful solution. For example, if the current information regarding ambient ground water quality is limited, the plan may recommend that one of the priorities is to establish or expand a monitoring program.

State agencies and other organizations have developed guidebooks and other information to assist local governments in inventorying potential sources of contamination, such as landfills, improperly sealed wells and dumps. Some of these materials are referenced by source in Section 5.

Data Collection and Storage

Before the inventorying process is begun, planning officials should give some thought to designing the system for collecting and recording ground water planning data. Several objectives should be kept in mind in designing such a system. The system should be easy to update as additional data is collected. Data should be readily available not only to local staff but to potential outside users. It should be recorded in a manner that will make it easy to compare or analyze information concerning related phenomena or activities such as the location of abandoned wells and the location of potential sources of contamination. Finally, the growing availability of computers and their increasing efficiency in storing and processing large amounts of data suggests that data be capable of computerization now or in the future.

The traditional means for recording and displaying planning data are maps supplemented by paper files or records. Maps are still a valuable tool for displaying and analyzing data, particularly for public presentations. State agencies and local governments increasingly look to the development of computerized geographical information systems (GIS) to store and readily access information. One of the main features of GIS is its capacity to integrate data.

Any data that can be tied or referenced to a point on the surface of the earth can be stored in a GIS with similarly referenced data. Once it is encoded by a proper geographic reference, a GIS is a valuable system for storing ground water resources, ground water quality, land use, contaminant sources and other ground water planning data. If the local ground water planning body intends to develop a GIS system in the future, all data should be collected so that it can eventually be coded as GIS data.

The state of Minnesota is developing a GIS data base to facilitate state agency and local government use. The Land Management and Information Center, Minnesota Planning and the Environmental Quality Board are charged with the task of developing and implementing procedures and standards for collecting and recording water resource-related data (see Section 4 and Appendix D). A draft of this document, *Data Compatibility Guidelines for Water-Related Data Collection and Automation* (1991) is available from the Center. The guidelines cover base mapping, data identification and classification, and water-data repositories.

Currently, local governments which accept or use state funds to generate or collect water resource or related data of value to the state are required to collect it in a format that is compatible with state systems and standards. These guidelines are incorporated into *Spatial Data Integration Guidelines for Legislative Commission on Minnesota Resources Inventory Programs* (1991) and are also available from the Center. Currently, these guidelines require local governments accepting or using state funds to plot data on 7.5 minute U.S.G.S. quadrangle sheets. This would make the data capable of being encoded later as part of a local or state GIS system. The state-produced guidebooks for inventorying potential contaminant sources such as feedlots, abandoned wells, storage tanks and landfills were mentioned in Section 5. They provide detailed information on standardized procedures for the collection and recording of planning data.

Physical Data

Data describing the physical environment provides an understanding of the nature of the local ground water system, specifically the location, extent, type (water table or confined), permeability and flow characteristics, particularly the direction of flow, and any confining layers. The concepts discussed in Section 2 provide a guide to the types of information which should be collected. Table 14 indicates the basic data a community should consider collecting. An existing study which was developed for another purpose or a county geologic atlas may provide much of the information.

If the data is not available, the preparation of a special study of the ground water system may be necessary and recommended in the plan. Data that may be used to map the location of surficial and confined aquifers may be available from soil borings and well logs. For example, borings and logs may indicate water table elevations and the character of the overlying geological materials for surficial aquifers. The University of Minnesota and Minnesota Geological Survey have produced a guidebook for obtaining ground water data for planning purposes. The guide provides information on the sources of data, mapping, data bases and use of the data (Olsen, et al., 1987). Before preparing this part of the inventory, local planners should contact the state agencies indicated in Section 4, local colleges and universities and other local governmental agencies to determine what information or studies are already available. Local government planners should be certain that the data is detailed enough for their needs.

Table 14
INFORMATION FOR GROUND WATER PROTECTION PLANNING

Information	Sources**	Purpose
A. Physical Environment		
1. Topographical data and land forms (maps)	USGS (7.5 minute - quadrangle maps), local government planning offices, MGS	Provide data for determining the general direction of surface and ground water flow, recharge and discharge areas, and depth to water table.
2. Surface water movement - boundaries of watersheds and sub-watersheds, direction of surface runoff (map).*	USGS, MGS, MDNR, local watershed plans, local government planning offices, special studies	Provide data for determining the direction of ground water movement and recharge/discharge areas.
3. Soils data - relative infiltration characteristics (map)*	USDA-SCS (county soil maps)	Provide partial data for evaluating potential recharge areas, general attenuation value of soil layer and depth to water table.
4. Hydrogeological data - extent, location, thickness, permeability of aquifers, confining layers and flow characteristics,* specifically, the direction, rate and quantity of flow. Maps of water table evaluations and potentiometric surface of confined aquifers. Geologic profile showing relationship of aquifers and confining areas. Map of wellhead and recharge areas.	MGS, MDNR, USGS, USDA-SCS, county geologic atlases, special studies, well log data	Provide data to evaluate the location and movement (direction) of ground water and the physical movement of contaminants released on or near the surface from land use activities. Provide data for assessment of ground water sensitivity.

Table 14 (continued)
INFORMATION FOR GROUND WATER PROTECTION PLANNING

Information	Sources**	Purpose
5. Assessment of ground water sensitivity - relative geologic sensitivity within planning area (map). Preliminary assessment of parent materials in the soil zone and ultimately complete assessment of geologic characteristics of materials above the water table aquifer and confined layers above deeper aquifers.	MGS, MDNR, county geologic atlases, USDA-SCS county soil surveys, special studies, well log data	Provide data for evaluation of the relative risk of ground water contamination based on the time of travel for contaminants between surface and aquifers.
6. Special geologic features such as buried valleys, karst areas and sand plains (map).	MGS, county geologic atlases, special studies, well log data	Provide data for assessment of geological features which affect the risk of ground water contamination.
B. Ground Water Use and Quality		
1. Location and description of wells (active and abandoned) including aquifer sources by use or purpose (public water supply, industrial and commercial, private, irrigation).* Areas served by public water supplies (current and future).	DNR, MDH, local governments	Provide an understanding of uses affecting ground water movement and affected by ground water contamination.
2. Location and description of known ground water quality contamination, risks, and aquifer and areas affected.	Various state agencies, such as the MPCA and MDH, local health department.	Assessment of current ground water quality and changes.

Table 14 (continued)
INFORMATION FOR GROUND WATER PROTECTION PLANNING

Information	Sources**	Purpose
C. Potential Sources of Contamination		
1. Existing and future land use (map) - residential (sewered and unsewered), commercial, industrial and agricultural; federal, state and other public lands, American Indian tribal lands.*	Local land use maps, zoning ordinances and comprehensive plans	Provide information on the location of potential sources of ground water contamination, the general type and amounts of contaminants and release mechanisms involved
2. Current and future sanitary sewer service areas, private treatment plants, public treatment plants, on-site sanitary disposal systems (map).	MPCA, local health departments, local planning agencies and public works departments	Same as above.
3. Location and description of permitted and regulated sources of contaminants, such as landfills, dumps, underground storage tanks, waste water (treatment plant) discharges, feedlots, and state Superfund sites and dumps.*	Various state agency programs (see Section 4)	Same as above.
4. Location and description of facilities that have hazardous waste generator identification numbers.*	MPCA	Same as above.

Table 14 (continued)
INFORMATION FOR GROUND WATER PROTECTION PLANNING

Information	Sources**	Purpose
5. Location and description of existing commercial/industrial land uses involving the use, storage or handling of hazardous materials (not waste) and other potential contaminants.	State-wide industrial directories, local libraries, local planning offices, Minnesota Dept. of Public Safety and Emergency Response Commission.	Same as above.
6. Location and description of existing and planned public facilities and property having potential contaminants such as road salt storage sites (federal, state and local).	Local, state and federal agencies such as the county highway agency and city department of public works.	Same as above.
D. Current Management Activities		
1. Federal regulatory and other ground water management programs.	See Section 4, various federal agencies.	Assess the adequacy or deficiencies in current programs to protect ground water and evaluate the need for improved management.
2. State regulatory and other ground water management programs.	See Section 4, various state agencies.	
3. Local policies, regulations and other programs affecting ground water protection.	Local comprehensive plans, land use controls, watershed plans, and agency or departmental operating guidelines and programs.	

* Minimum information to be included in Greater Minnesota county water plans.
** See Section 4 for more details on sources of information.

Ground Water Flow Maps

Information about the movement and direction of ground water is important in assessing potential risks to the ground water. This information enables local planners to assess the potential effect of contaminants should they reach the ground water, particularly what "downstream" or downgradient ground water users could be affected. Ground water flow maps are a valuable tool for evaluating the movement and direction of released contaminants and identifying potential problems and issues. Flow maps will also assist in defining recharge and discharge areas.

The accuracy of a flow map will depend on the amount and accuracy of well log data available. Section 4 lists the agencies that are potential sources of well log data and the data bases that may contain information for the planning area. The agencies should be contacted to determine what data is available and how to access the data.

Flow maps can be prepared for both water table and confined aquifers. A flow map for the water table or first unconfined aquifer is based on the elevation of the water table. Water table elevation data is plotted on a base map of the area. Contours are drawn to connect points of equal water table elevation. Finally, arrows are drawn perpendicular to the contour lines representing the direction of ground water movement from higher to lower water table elevations (Figure 29).

A similar map may be drawn for confined aquifers, however, since there is no water table in a confined aquifer, contours are drawn to connect points of equal head along the potentiometric surface (see Section 2 for more detail on these concepts). Arrows are again drawn perpendicular to the contours, indicating ground water movement from areas of high to lower head.

A series of cross-section diagrams indicating the potentiometric relationship of the water table and the deeper aquifers would allow an assessment of the vertical movement of ground water.

Information on the rate of ground water movement, the effect of pumping or seasonal changes, and other aquifer characteristics will provide the basis for a more detailed assessment of the potential impact of contaminants on the resource and affected land use activities. The development of this information typically requires the assistance of a ground water professional.

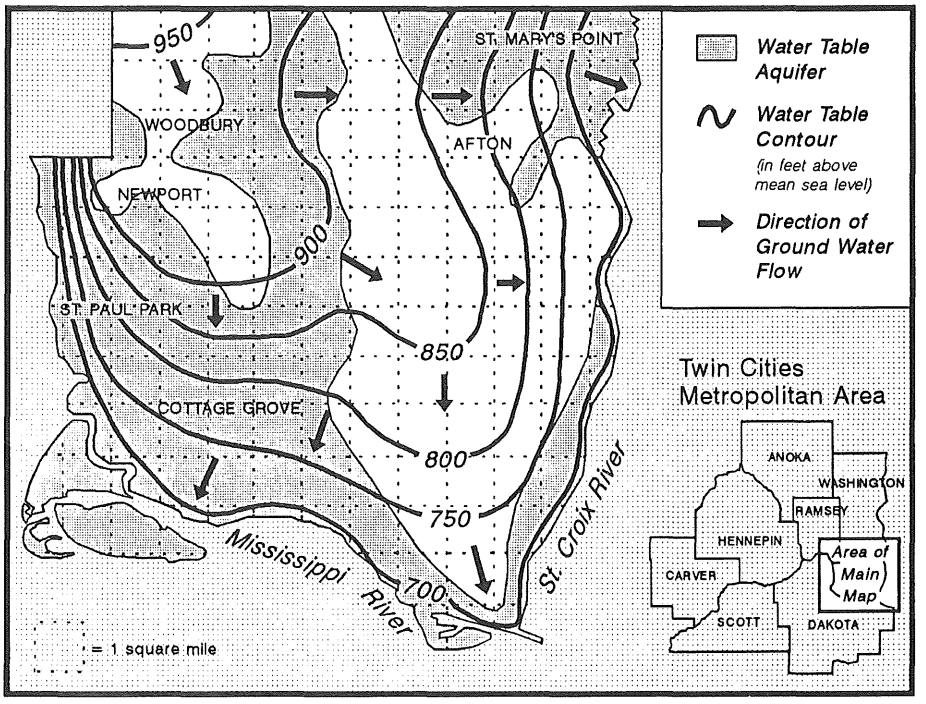
Ground Water Sensitivity

The inventory of the ground water system may also include an assessment of ground water sensitivity to pollution (see Section 5). If the available time and information do not allow a more complete assessment of both the water table and any deeper aquifers, a preliminary geologic sensitivity or Level 1 assessment should be prepared if a soil survey is available. A Level 1 assessment is based on the parent material descriptions in the local county soil survey. A Level 1 assessment is suitable for general ground water planning purposes at the township, city, county or larger scale and will indicate the general pattern and extent of sensitivity and the implications for protection strategies, such as land use controls. (The DNR suggests that Level 1 assessments done at the local level be reviewed by the DNR for accuracy and consistency, and to avoid duplication of effort since many Level 1 assessments have already been completed or are underway.)

Ground Water Use and Quality

The inventory should also include ground water use and quality data. The tasks in this phase involve: 1) identifying, locating and mapping current and planned uses of ground water; and 2) identifying the existing ground water quality and any changes occurring in the quality, either geographically or temporally within the planning area.

FIGURE 29. WATER TABLE SURFACE AND MOVEMENT IN SOUTHERN WASHINGTON COUNTY, MINNESOTA



Source: Minnesota Geological Survey, 1990.

The initial purpose is to provide information which would enable water planners to assess what users (industrial or commercial, irrigation, public water supplies, irrigation, or private) and other activities might be affected if contamination occurs. The most important task is to locate and map these uses so it can be determined later in the planning process whether they might be affected by potential contaminants moving from upgradient land use activities.

If the information is available or time permits, it is valuable to delineate and map critical ground water areas, specifically wellhead and ground water recharge areas (see Section 5). The development of flow maps as described earlier will assist in defining recharge areas if sufficient data is available to evaluate vertical flows.

The second task is to develop an assessment of existing or emerging water quality problems in the planning area. It should include data on the area and aquifers affected, the types of contaminants involved, contaminant characteristics and any trends, if historical data is available. A variety of state agencies that collect information about existing ground water quality problems were identified in Section 4. Data can be compared to federal drinking water standards or health advisories administered by the Minnesota Department of Health (MDH) to determine if a cause for concern exists (see Section 4). Although current data may indicate that ground water quality is within federal standards, a comparison to historical data may indicate that ground water quality is deteriorating. Comparisons might also be made with the health risk limits (HRLs) being developed by the MDH (see Appendix D).

Potential Contaminant Sources

Potential or known sources of contaminants should be included in the inventory, including data on existing or future land use activities which involve one or more potential contaminants. The state

agencies listed in Section 4 maintain inventories of potential sources of contaminants that are currently being regulated or permitted by them, such as landfills, dumps, feedlots, spills, underground storage tanks, pipelines and state Superfund sites, and related activities such as abandoned wells. (Table 4 in Section 4 shows potential sources and the agency that regulates them.) Once the appropriate agency has been contacted to determine what data they can provide on regulated land uses in the planning area, the location and type of facility can then be included on local planning maps and a description of the source and contaminants developed.

Agency records may not be sufficient for local planning needs. For example, because only sources which meet minimum thresholds or criteria are regulated, small feedlots would not be included in agency records. Local information sources or field surveys may be needed to supplement agency records. Once the plan is completed, more detailed data about each source can be collected as part of a specific study.

Data describing other unregulated land uses that are potential contaminant sources can be inventoried at various levels of detail, depending on the time and information available. Local government maps of existing land uses, zoning ordinances and comprehensive plans can be used to locate and map potential sources such as industries, commercial establishments and development served by on-site sewage disposal systems. Maps of existing land use and sewered areas will provide an estimate of the areas potentially affected by septic systems if local records for these systems are insufficient. MDH records will indicate the location of commercial establishments such as restaurants served by large, on-site systems. While this information provides a general overview of the types and location of land uses that are potential sources of ground water contaminants, it may not identify specific industries or firms, their location and the specific sources or contaminants involved. However, it is reasonable to assume that industries or firms using, storing or handling substances that are potential contaminants are now or may be located in these areas in the future.

A second approach that requires more time but provides more detail is to identify and locate specific industries or firms and the potential contaminants in the planning area. Several public information sources are available to assemble this data. Firms that store certain chemicals at their facilities are required to report the types and amounts of chemicals to the Minnesota Department of Safety and Emergency Response Commission which maintains county-by-county lists (see Section 4) and to local emergency planning committees and fire departments. Businesses handling substantial amounts of toxic chemicals must report annually any accidental or routine releases of the chemicals into the environment. The MPCA's inventory of hazardous waste generators is another source. Additional data may be requested from the businesses on the specific chemicals, amounts, manner of storage and the location.

Other resources for information on these potential contaminant sources include local and state-wide business directories, telephone directories, planning agencies, local libraries and chambers of commerce. One such state-wide directory, the Minnesota Directory of Manufacturers, identifies individual manufacturing firms for each county and community by Standard Industrial Classification (SIC) group. The services and products description for each SIC group provides a general indication of the presence of potential contaminants at the site. Each information source is limited as to the types of contaminant sources included. Local governments should be aware of these limitations when using this data. A local survey of businesses may be necessary to develop a complete inventory of all potential sources.

Potential contaminant sources also exist in facilities maintained by government agencies and departments. Local, state and federal offices should be contacted and surveyed to identify sources

such as road salt storage areas, maintenance garages, and underground storage tanks, and then quantify the types and amounts of contaminants involved.

The development of an inventory will most likely be done in phases because of the costs and time involved. As time allows, detailed information about new sources can be combined with existing information to establish a current data base on potential sources of contaminants suitable for detailed program planning as part of the implementation program. The dollars and time necessary to update or expand the inventory should be included as part of the implementation program.

Existing Management Programs

After existing and potential contaminant sources have been inventoried, the next step is to evaluate the extent to which current local, state and federal programs manage these sources. In this step, detailed information is gathered on the local impact of the individual federal and state programs outlined in Table 3 and Appendices C and D. Each program should be analyzed to determine how it protects ground water from contamination from a specific source. Section 5 gives some examples of how various sources are regulated by certain of these programs. Local land use controls, health codes and other local management programs should also be evaluated as to the extent of the protection they provide. Some of the requirements and standards discussed in Section 5 may already be incorporated in local zoning ordinances and subdivision regulations. A chart may be incorporated in the plan which describes each source and how it is managed by existing federal, state and local programs. This chart would suggest what role the local government should play in providing additional protection. For example, state regulations control the design and operations of feedlots; however, they do not regulate their location. If local governments conclude that feedlots should be restricted in critical ground water protection areas such as recharge and wellhead areas, local land use controls may be enacted to achieve this protection objective.

Assessment of Problems and Issues

This section of the ground water protection plan evaluates the implications of the information and data assembled in the inventory phase and defines the problems and issues to be addressed in the plan. Defining problems requires understanding how the geology and hydrogeology of the ground water system and local land uses influence the risk of contamination to ground water users.

One approach to defining ground water problems and issues is to formulate a series of questions that will focus the assessment. These are some examples to guide local planners:

- Who are the current ground water users and what is their significance to the area?
- What is known about the characteristics of the ground water system, specifically the location of aquifers, the direction of flow and the geology (permeability) of the aquifers, overlying materials and confining layer(s)? What are the implications of special natural conditions such as karst areas, sand plains and bedrock valleys? (If current information is insufficient for planning purposes, this is a problem which the plan should address. A study of the ground water system might be identified as a high priority in the plan.)
- What is known about the current quality of ground water and the changes occurring? (If there is little data, this may indicate the need for an expanded monitoring program.) Which aquifers and geographic areas are affected? How does the quality compare to federal drinking water standards? Are any current, planned or potential uses of the ground water affected? What are the health implications or risks of these contaminants? What public and private costs are associated with cleaning up contamination if it occurs?

- What types of land uses or potential sources of contaminants are or could be located in the planning area due to existing land use controls or encouraged by the local comprehensive plan? What is known about the characteristics of the contaminants and potential impacts and risks? Is there adequate information about existing sources?
- Where are existing or potential contaminant sources located relative to the location of recharge areas, the direction of ground water flow, wellhead areas, public and private wells, and other ground water users? Are current and potential users located downgradient of contaminant sources?
- What is the sensitivity to pollution of surficial and deep, confined aquifers relative to where the sources of contaminants are located or proposed?
- Which local land use activities or potential sources of contaminants are currently regulated by federal, state or local management programs? What aspects are not included in existing programs--their design, operations, or location? What local programs, such as land use controls, influence the location of these sources? Are public facilities reviewed by agencies and local governments for their potential impact on ground water quality by operating agencies?
- How do the land use and water resource plans and policies of local governments in adjoining the planning area affect ground water protection?

Preparing a series of maps and overlays showing the relationship of the ground water system and potential sources will aid in assessing problems and issues and help local residents understand the problems and issues. The base map indicates the location, extent and characteristics of the aquifers such as the direction of flow and recharge areas. The first overlay map in the series may indicate the pattern and extent of ground water sensitivity and other special conditions such as karst areas. A second overlay map may show the location of current or planned ground water uses such as public water supply wells or wellfields, private wells, irrigation wells and wellhead areas if they have been delineated.

Next, one or more overlay maps can be developed indicating the location and potential types of contaminant sources of contaminants. The areas for future industry, commercial activity and other potential sources could be indicated based on zoning and local land use plans. Mapping this information simplifies evaluating their relationship to aquifers, ground water users, ground water sensitivity to potential sources of contaminants, and the potential risks to ground water quality. A summary map may be prepared showing the potential problems and issues by geographic area and by source.

Public meetings and the use of diverse advisory committees representing various ground water users are other sources of information for defining problems and issues. The results of the problem and issue assessment could be presented at a public meeting as a means of encouraging public discussion of other ground water quality issues. Informal meetings with other local governmental bodies and agencies such as watershed districts and management organizations are another source. A community survey is another method of assessing the public's concerns for ground water quality and their support for additional protection measures.

Issue Identification and Policy Development

After the problems and issues have been defined and before the goals, objectives and other plan elements are developed, the policies that will guide and shape the plan should be developed. Policies are developed in response to the problems and issues raised by the problem assessment phase. Issues are the major decisions that elected officials will have to make in response to the problems. Policies set the overall direction for the plan. Potential policies involve decisions

about the level of ground water protection to be provided, the role of local government in addressing the problems, priorities for action, methods for financing solutions or programs, and the general protection strategy to be pursued, be it regulation, education, inter-agency coordination, research, or a combination of several strategies.

Policy issues will be raised at various points in the planning process. The purpose of addressing them early in the planning process is to develop a consensus among the decision-makers as to the problems, priorities and the general course of action they wish to pursue before planners begin to draft the details of the plan. After a consensus has been reached, planners can proceed to draft the detailed elements of the plan for discussion. This will minimize the risk of having elected officials reject the completed plan later or delay implementation because it is inconsistent with their thinking and values.

One approach to facilitating issue and policy development is to prepare one or more issue papers outlining each problem, the issues, alternative goals, objectives, and courses of action that respond to the issues. Each paper may also outline the possible impacts of each alternative. These papers would be reviewed and discussed by the appropriate policy-making bodies. The following are some of the policy issues that should be addressed in this process:

- How important or significant is ground water quality to the future of the area?
- What are the current problems or potential risks to ground water quality?
- Should the plan emphasize prevention or wait until problems occur before recommending action?
- What should be the priorities in developing a strategy to protect ground water?
- What should be the role of the local government in protecting ground water? Educating residents, businesses, farmers and governmental agencies as to how they can protect the resource unless there is an existing problem? Regulating land use activities to prevent a problem before it happens? Coordinating the efforts of other local governments and public agencies? Undertaking a more detailed assessment of potential sources to understand the risks more clearly?
- Should the same level of protection be adopted throughout the area or only for critical areas such as wellhead, ground water recharge or sensitive areas?
- Should private users be provided with the same level of protection as public users?
- What level of protection should be provided for ground water quality? Should potential contaminant sources be prohibited in the area? Or should land uses be allowed if they incorporate certain design and operating standards and other requirements to protect ground water?
- Should existing potential contaminant sources be treated the same as new development?
- How or with what revenue sources should ground water protection programs be funded? Does everyone who benefits pay or only certain classes of users such as water utility users? Should only the potential "polluter" pay?

The results of this process provide the basic direction for developing the contents of the plan, including the proposed goals, priorities, objectives, protection strategies and implementation program.

Goals for Protection

Goals are the long-term and broader purposes, ends or conditions that the local government seeks to achieve in managing ground water quality. It is an important step in developing a local plan

for ground water protection. The information, problems, issues and policies developed in the previous planning phases will help shape the goals, and later, the more specific objectives under each goal.

The goals should be developed with regard for other local government goals. Goal-setting for ground water protection must recognize the potential conflicts among community goals that will be raised at some point in the planning process. For example, ground water protection goals may impact the community's goals for economic development. Planners should be prepared to address these policy conflicts in formulating the goals, rather than waiting until the specific strategies or implementation programs are being formulated, or until the elected body is asked to adopt the plan. If goal conflicts are not addressed early in the planning process, support for the plan may ultimately fail.

Goals may be organized in different ways. Goals may address what is to be protected, such as all ground water resources or specific resources such as public water supplies. Goals may also address the level of protection or the means for achieving protection such as increased public understanding of the need for protection. The focus or emphasis of ground water protection goals will be affected by local priorities, land use conditions, water quality problems and the value of the resource. Table 15 presents selected goals from the Beltrami County comprehensive water plan that address ground water quality. One of the goals emphasizes community education as a way of protecting the resource and preventing contamination.

In the written plan, the policies developed in the previous phase of planning may be stated as part of the goals presentation. Stating the policies at this point will indicate the reasons for the basic direction taken by the plan and provide a framework for the specific objectives and protection strategies contained in the plan.

Establishment of Priorities

At an early point in the planning process, it will be necessary to establish priorities. As discussed above, state rules for Greater Minnesota county water plans require the establishment of priorities for water quality and land use conditions that affect water quality. The latter may include wellhead, sensitive areas and karst areas. Some problems will be more important or represent a greater risk to ground water quality, and it is unlikely that there will be adequate resources, either staff, financial or both, to address every problem at the same time. When developing, evaluating and establishing priorities, several factors should be considered. These are:

- The nature of the land use(s) or source(s) and the contaminants typically associated with them;
- The inherent hazards or risks to public health of the contaminant, if known;
- The characteristics of the contaminant involved, such as the concentration and amount involved;
- The area of land use involved (current and future);
- Presence of a contaminant in ground water;
- Natural characteristics of site or area, for example, the ground water sensitivity, presence of recharge areas, or special conditions such as karst;
- Location and number of private and public wells in affected area and proximity to well head areas;
- Number of persons in affected area dependent on ground water for drinking water; and
- Extent to which existing federal, state or local management programs provide protection.

Table 15
EXCERPTS FROM THE BELTRAMI COUNTY COMPREHENSIVE WATER PLAN

Goal I	Increase understanding of the nature and value of the county's water resources, the relationship between the county's land and water resources and the actual and potential water quality and quantity problems in the county.	
Goal II	Prevent the county's surface and ground water resources from being degraded and, if need be, mitigate any problems that now exist.	
Objective:	Implement a comprehensive program to prevent ground water contamination by the effluent of individual septic systems.	
	Strategy 1	Adopt a countywide waste water treatment ordinance that protects ground water while minimizing costs to the individual household, and target enforcement to those areas with permeable soils and higher population densities.
	Strategy 2	Adopt and enforce septage disposal regulations.
	Strategy 3	Implement proactive enforcement of county shoreland ordinance.
Objective:	Develop and implement a program to monitor ground water quality and quantity and to identify areas where quality is being degraded.	
	Strategy 1	Continue ground water monitoring in the Bemidji-Bagley Sand Plain Aquifer.
	Strategy 2	Enter ground water study data into computerized geographic information system.
	Strategy 3	Implement water well inventory data system.
	Strategy 4	Develop a geologic atlas for the county.
	Strategy 5	Collect ground water data in northern Beltrami County to supplement geologic atlas information.
Objective:	Prevent contamination by new and abandoned wells.	
	Strategy 1	Develop and implement a public information program concerning abandoned wells.
	Strategy 2	Conduct an abandoned well inventory.
	Strategy 3	Implement a cost-shared pilot project to seal abandoned wells.
	Strategy 4	Enforce the state well code at the county level.
Objective:	Identify underground storage tank locations; prevent ground water contamination by these tanks.	
	Strategy 1	Assist the MPCA in completion and verification of underground storage tank inventory, including the identification of small tanks.
	Strategy 2	Develop a targeted information program to owners of small underground storage tanks.
Objective:	Improve the understanding of staff, elected officials and the general public of the nature of the pesticide and nutrient contamination problem.	
	Strategy 1	Develop information and an education campaign concerning sound nutrient and pesticide management.
	Strategy 2	Form a partnership with the state in implementing the State Pesticide and Nutrient Management Strategy.

Source: *Beltrami County's Water Resources: A Plan for Action (Summary)*, 1989

There have been attempts by some local planning agencies to make the priority setting process more objective. Rating schemes which assign points to such factors as the land use, type of contaminants, size of population affected, proximity to water resources and area involved have been developed to evaluate the potential hazard or risks for the planning area. (Jaffe and Di Novo, 1987). These systems may take additional time to prepare, but they do provide a different way of looking at the problem of setting the priorities.

Establishing priorities prior to developing objectives would help focus this next phase of the planning on the most significant problems. Lower priorities may not be addressed by the objectives or the plan may rank the objectives according to the priorities.

Objectives

After broad, long-term goals for ground water protection are established, objectives to achieve each of the goals should be defined. Objectives are more specific and should address the problems, issues and priorities identified earlier in the process. For example, if the lack of basic information about the local ground water system has been identified as a problem, one of the objectives would be to undertake a hydrogeologic study for the county or city.

Objectives should be measurable. (State rules require measurable objectives for Greater Minnesota county water plans). Measurable objectives will assist local governments in determining whether progress is being made toward achieving each objective and whether the staff, financial or other resources being expended are achieving their purpose. Measurable objectives may be product-oriented, such as completing a specific technical study, outcome-oriented, such as reducing the level of a specific contaminant in the ground water, or time-oriented, such as bringing all feedlots into conformance with state regulations by a certain year. Recognizing that it may take many years to accomplish some objectives, the plan may establish short and long term objectives.

In some cases, objectives may focus on a specific land use or group of potential contaminant sources such as fertilizer application or a specific land resource, such as environmentally sensitive ground water recharge areas, karst or other sensitive areas (see Sections 2 and 5). For instance, an objective could be to protect public water supplies by establishing a wellhead protection program.

The Beltrami County water plan establishes general long-term goals for ground water protection and specific objectives to achieve them. For example, to achieve the goal of preventing ground water degradation the plan objectives include identifying underground storage tanks and preventing contamination from these sources. The plan does not include a time frame for achieving these objectives, but a time element can be inserted later in the implementation section.

Protection Strategies

After the objectives have been established, potential strategies to achieve each objective are formulated and evaluated. In some cases, this may involve evaluating alternative strategies. (Examples of various regulatory and non-regulatory strategies for contaminant source and resource management are discussed in Section 5). The types of strategies that may be considered and evaluated will depend on the policies established earlier. For example, if local officials decide that the protection role of government should be limited, at least initially, the strategies may focus on activities such as the collection and analysis of additional data or the development of public information programs to encourage private and individual protection efforts. The Beltrami County plan contains several strategies to achieve each of the objectives in the plan. The

individual strategies include developing public education programs, completing technical studies, emphasizing the enforcement of existing regulations and adopting new regulations.

Local governments may find it necessary or helpful to develop and incorporate more specific policies as part of the strategies for a particular issue and objective. The policies indicate the position of the local government regarding a specific ground water concern and are intended to guide future administrative actions when responding to groundwater issues. Carver County in the Twin Cities Metropolitan Area established one or more specific policies for each of the objectives in its ground water plan (Carver County Board of Commissioners, 1992). Specific policies in the plan for managing on-site sewage treatment systems in the county include: 1) All units of government that have or permit on-site sewers within their jurisdiction shall adopt and enforce at a minimum the state standards for their installation and maintenance; and, 2) Units of government are encouraged to initiate programs to identify and correct failing on-site systems. Correction of systems identified in this plan as high impact should be given priority.

In evaluating a proposed strategy, local governments should consider a number of factors, including:

- The severity of the problem or risk being addressed;
- The degree to which existing management programs (federal, state and local) address the problem;
- The effectiveness of the strategy in achieving the objective;
- Capital and operating costs required to implement the strategy;
- The availability of financial resources to support the strategy;
- Impacts on other community goals;
- The legal authority of local government to implement the strategy;
- Who or what unit would have administrative responsibility; and
- Community support.

At the conclusion of this phase, the plan contains a statement of the problems and issues in the planning area and proposed goals, policies, objectives and protection strategies for addressing them.

Implementation Program

An implementation program is a list providing details of the proposed activities and actions the local government or governmental units will undertake to implement the plan. Ideally, an implementation program should indicate:

- Proposed activities (programs and projects);
- Recommended priorities;
- The time frame for activities (start-up to completion);
- Estimated costs;
- Funding sources (state or local); and
- Agency or department that will be responsible.

The types of proposed activities that could be included in an implementation program may include: preparation of a technical study such as a county-wide hydrogeological study; development and adoption of various land use controls or other local ordinances, such as a feedlot management ordinance; development of a public information and education program for all residents or a target group, such as septic tank owners; initiation of a ground water monitoring program; and hiring of staff to administer the programs.

Capital improvements may be included in the development program. (The legislation and rules for Greater Minnesota water plans specify that these improvements may be included in the development program). Capital improvements will not usually be a significant part of a protection plan or the implementation program. (See Section 5 for examples). In most instances, protection strategies will focus on management programs which do not involve capital items, such as amending the local zoning ordinance. Two examples of capital improvements which could be included in the implementation program are the construction of a central wastewater treatment and sewer system to replace, or avoid the use of, individual on-site sanitary disposal systems and land acquisition. Land acquisition may be necessary in specific instances to protect ground water, such as the area surrounding a public well where there is a high risk of a spill. If capital improvements are proposed, the implementation program should specify their location, physical characteristics, purpose in relation to the plan objectives, schedule and financing sources.

State rules for Greater Minnesota county water plans specify that the implementation program also indicate any agreements made with other local governments to implement a portion of the plan and their responsibilities. For example, one or more local governments may agree to develop and adopt jointly a well head protection program or adopt a land use ordinance designed to protect a recharge area. These cooperative agreements should be included in the implementation section of the comprehensive water plan.

State rules also require Greater Minnesota water plans to include schedules for amending official controls and water and related land resource plans of local governments. State law requires local units of government to amend plans and controls to conform to the water plan. (Minn. Stat. 103B.325, subd. 1). This includes the plans of municipalities, towns, counties, soil and water conservation districts, watershed districts and other special districts with authority in water and related land resources management at the local level. If the county ground water protection plan recommends that local governments adopt or amend local land use controls incorporating standards that protect ground water, local governments would have to act. The development program could contain the time schedule for accomplishing this task.

State law does not require that Twin Cities Metropolitan Area county ground water plans include an implementation program, but they must provide standards and guidelines for implementing the plan by local governments and watershed management organizations. (Minn. Stat. 103B.255 subd. 7.) The content or subject of the guidelines will depend on the problems, priorities and strategies contained in the plan. The standards and guidelines will provide guidance for the development or revision of local programs or activities to protect ground water. For example, a county plan may contain specific guidelines and standards for requirements to be incorporated in local zoning ordinances, health codes and other regulations. This might include design and operating standards for commercial and industrial uses that store or handle hazardous materials, feedlots, underground storage tanks, and on-site sewage treatment systems. Or a plan might include guidelines for the content of local solid waste management plans and programs to ensure that these activities encourage the removal of hazardous waste from the waste stream before it reaches the landfill. Examples of these specific strategies are discussed in Section 5.

Although Metropolitan Area counties in most instances lack land use planning and zoning authority, they can play an important role in implementing a protection plan. County-level activities can be included in an implementation program. The program may contain the following types of activities:

- Development of appropriate public information and education programs to increase the awareness among local governments, officials and citizens of priority concerns;
- Studies of local ground water resources and problems such as county-wide hydrogeological studies and source inventories;
- Funding and establishment of a ground water monitoring program; and
- Development of model codes or ordinances for the use of local governments and provision of other types of technical assistance.

Monitoring and Evaluation of Progress

Establishing monitoring and evaluation mechanisms is an important but often overlooked step in the planning process. After the plan is adopted, monitoring and evaluation provides a way of tracking the progress of plan implementation and evaluating the effect on ground water quality. Monitoring and evaluation may also indicate the need to amend the plan as new problems or better solutions emerge.

There are two approaches local governments may use: 1) monitoring changes in ground water quality; and, 2) tracking the progress in implementing activities recommended in the plan. Establishing or expanding ground water monitoring is the most direct method for evaluating the results of the plan. Over the long term, monitoring data will indicate whether ground water quality is improving or deteriorating. If properly designed, a monitoring program may also indicate the development of new problems, particularly as the land use changes. However, as changes in quality may occur very slowly, it will not always be easy to link changes in quality to a specific land use or protection strategy. Depending on the goals and objectives of the plan, land use diversity and size of the planning area, monitoring may prove expensive and require a long time period to in order establish an adequate program.

In the short term, it may be easier to monitor the progress or accomplishments in implementing the plan. This type of monitoring includes tracking and reporting on the administrative progress in implementing each of the specific tasks and activities contained in the plan. Progress tracking may include monitoring and reporting on progress in initiating, developing and completing technical studies; developing and adopting new land use controls and other ordinances; organizing public information and education programs and executing the variety of other activities called for in the plan. For example, the plan may recommend the preparation of an assessment of abandoned wells and the risk to ground water quality to be completed within two years. The progress monitoring and evaluation element of the plan would indicate the department or agency responsible for the study, the expected date of completion, the expected interval for progress reports, the information to be provided such as the number of wells located, their condition and the local official or administrative office that is to receive this information.

The plan should establish the method or approach for monitoring and evaluation. The monitoring mechanism, the agency responsible for the activity and reporting progress, the method and frequency of reporting, the information to be reported, the reporting frequency or interval, who is to receive the reports and target dates for completion of the activity should be stated in the plan. Incorporating the monitoring and evaluation element in the plan provides a means for holding administrative units accountable and determining whether plan implementation is moving ahead according to schedule.

RECOMMENDED CHANGES IN STATE PROGRAMS

State rules require Greater Minnesota county comprehensive water plans to recommend changes in state programs. The plans are to indicate the specific program, policy or requirement to be changed, and indicate the proposed change and the reasons for the recommendations. Local governments may want to make suggestions in a number of areas such as the following:

- Methods for making state-collected ground water and land use or contaminant source data more accessible to local governments;
- Ways to improve coordination of state programs, local ground water planning and implementation to achieve local goals and objectives;
- Providing additional state technical assistance to local governments; and
- Improving state management of specific contaminant sources.

CONFLICTS WITH OTHER LOCAL PLANS

State law requires that county ground water plans in the Twin Cities Metropolitan Area and county comprehensive water plans in Greater Minnesota address existing or potential conflicts between the plan and the plans of other local governments, including counties, local governments, watershed districts and watershed management organizations (Minn. Stat. §§ 103B.255 and 103B.311). Comprehensive water plans in Greater Minnesota are to indicate the type of conflict, recommended changes and whether there is a process underway to resolve the conflict or if any attempts to do so have been unsuccessful. In the Twin Cities Metropolitan Area, differences that exist among local governmental agencies regarding the plan must be mediated.

Assessment of conflicts and differences should examine local comprehensive land use and public facilities plans, local land use controls, such as zoning ordinances and subdivision regulations and other regulations such health codes. Planned or permitted land uses and development standards should be evaluated as to the potential impact or risks to ground water quality. Local specifications or design standards for public facilities or improvements should also be reviewed. The evaluation should emphasize the potential risks to sensitive ground water, recharge and wellhead areas or in special conditions such as karst areas. For example, if the adjoining county or city has planned or zoned large areas for industrial development with no controls to prevent spills or other releases, or the area is used for intensive farming with fertilizer or pesticide application, local wells may be at risk. Conflicts with local watershed plans should also be noted, particularly location and standards for proposed stormwater ponds, which may receive heavy loadings of metals, toxins and other contaminants relative to wellhead, ground water recharge and sensitive areas. The evaluation results should be incorporated in the problem assessment section of the plan. Appropriate objectives and strategies for resolving these issues would be included in other sections of the plan as part of the proposed program to implement the plan.

PLAN UPDATING

Updating a ground water protection plan is as important as preparing the initial plan. If the plan is to be a useful guide to local officials, the information, goals, objectives, priorities and other recommendations should be kept current as new needs and issues emerge. It may be necessary when preparing the plan to establish a mechanism or process for reviewing the plan periodically to evaluate the need for revisions. For example, local officials could be required to annually review the priorities and program recommendations in the plan. The review could coincide with the preparation of the local operating and capital improvement budgets since these might be affected by new priorities and programs.

APPENDIX A

MINNESOTA GROUND WATER RESOURCES

MINNESOTA GROUND WATER RESOURCES

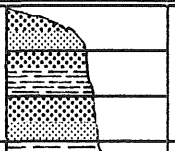
In Minnesota, there are 14 major aquifers that are the principal sources of ground water. These aquifers range in geologic age from the most recent--the Quaternary or glacial period--to the oldest or Precambrian, which is represented by the volcanic, crystalline rocks along the North Shore of Lake Superior (Figure A-1). The aquifers consist of two types of geologic material--glacial deposits and bedrock. In general, glacial aquifers consist of unconsolidated fine-to-coarse sand and gravel deposits left by glaciers or deposited later by the meltwater from glaciers. They can be unconfined or confined. Glacial aquifers occur as surficial deposits or as buried deposits. The latter are overlain by less permeable layers of clay or silt and are confined (or semi-confined) to a greater or lesser degree depending on the overlying material (Figure A-2).

Both buried and surficial unconsolidated deposits are important sources of water for many areas of the state. Surficial aquifers, which are generally unconfined, occupy approximately one-third of the state (Figure A-3). Surficial aquifers in central Minnesota are a significant source of water, particularly for irrigation. Buried sand and gravel aquifers, which are confined, occur throughout much of Minnesota, except where the glacial drift is thin or nonexistent as in the northeastern and southeastern parts of the state (Figure A-3). These buried confined aquifers typically consist of discontinuous lenses of sand and gravel isolated by the glacial till, but they can be quite extensive. Several counties in the glacial sand plains area of east-central and central Minnesota are underlain by buried confined aquifers. Buried aquifers are also an important source of water in the southwestern areas of the state. In the Twin Cities Metropolitan Area, surficial and buried aquifers provide water for many suburban water supply systems and private, individual wells.

Bedrock aquifers consist of sedimentary formations and crystalline rocks, laid down over millions of years. The sedimentary formations include sandstone, dolomite and limestone, and contain some of the most significant ground water resources in the state (Figure A-4). The crystalline rocks contain ground water in fractures, cracks and joints in the solid rock. The latter are found everywhere in the state at some depth, but they are not widely used because of the availability of ground water in the overlying glacial till and sedimentary formations and the difficulty of locating the productive fractures. In northeastern Minnesota, crystalline aquifers are important because of the absence of other aquifers.

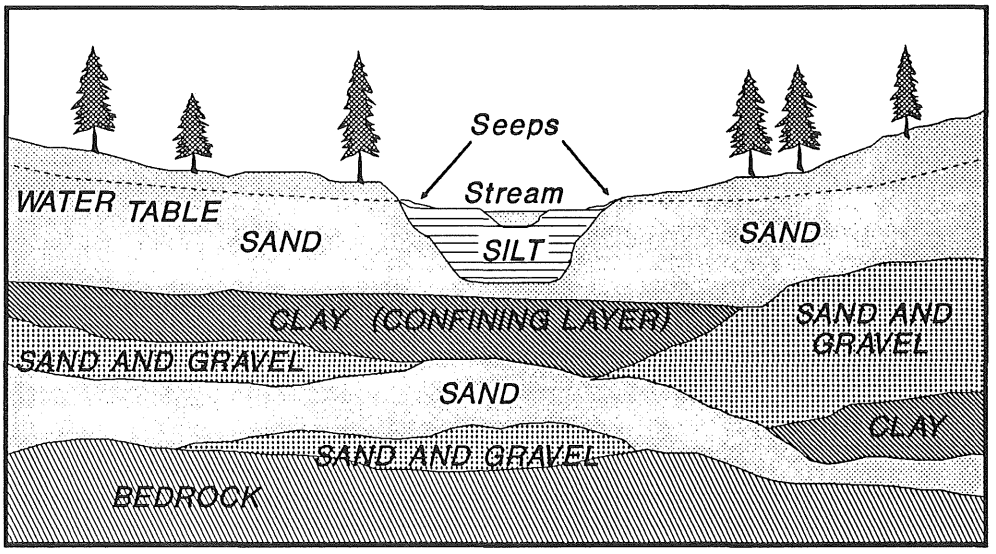
The sedimentary aquifers include seven major aquifers consisting generally of sandstone, dolomite and limestone deposits. The Cretaceous Age rocks, which are located generally throughout the western half of Minnesota, consist of soft, gray shale containing sand beds (Figure A-4). The Red River-Winnipeg Aquifer is located in northwestern Minnesota, and is overlain by several hundred feet of till and sediments deposited by glacial Lake Agassiz. A complex system of five different bedrock aquifers comprises the Hollandale Embayment, which is the major source of water for much of southeastern Minnesota, including the Twin Cities Metropolitan Area (Figure A-4). The system includes (from the youngest to the oldest) the Upper Carbonate, St. Peter, Prairie du Chien-Jordan, Franconia-Ironton-Galesville and Mount Simon-Hinckley-Fond du Lac Aquifers. The use and importance of these aquifers are dependent on their yield and presence of other sources. For example, the St. Peter Aquifer is not generally used for public water supplies because of the higher yields which are obtained from the Prairie du Chien-Jordan and Mount Simon-Hinckley Aquifers.

FIGURE A-1. GENERALIZED HYDROGEOLOGIC PROFILE FOR MINNESOTA

ERA	PERIOD	GROUP OR FORMATION	GRAPHIC COLUMN	MAXIMUM THICKNESS (Feet)	HYDROGEOLOGIC UNITS
Cenozoic	Quaternary	Drift		500	Surficial sand and gravel aquifer Clay-rich till confining beds Buried sand and gravel aquifers
Mesozoic	Cretaceous	Cretaceous beds		550	Cretaceous confining beds - shale Cretaceous aquifer - sandstone lenses in shale
Paleozoic	Devonian	Cedar Valley Limestone		300	Upper Carbonate aquifer - limestone, dolomite and dolomitic limestone
	Ordovician	Maquoketa Shale		70+	
		Dubuque Formation		35	
		Galena Formation		230	
		Decorah Shale		95	Confining bed - shale, dolomitic limestone and limestone
		Platteville Limestone		35	
		Glenwood Shale		18	
		St. Peter Sandstone		155	St. Peter aquifer - sandstone St. Peter confining bed - siltstone and shale
		Prairie du Chien Group		360	Prairie du Chien-Jordan aquifer - dolomite and sandstone
	Cambrian	Jordan Sandstone		115	
		St. Lawrence Formation		65	St. Lawrence confining bed - dolomite
		Franconia Formation		200+	Franconia-Ironton-Galesville aquifer - sandstone interbedded with shale, siltstone and dolomite
		Ironton Sandstone		45	
		Galesville Sandstone		95	
		Eau Claire Sandstone		195	Eau Claire confining bed - sandstone, siltstone
		Mount Simon Sandstone		315	Mt. Simon-Hinckley aquifer - sandstone, siltstone and shale
Precambrian	Proterozoic and older.	Hinckley Sandstone		500	
		Fond du Lac		2000+	Sandstone and sandy shale
		Sedimentary, metamophic and igneous rocks[1]			

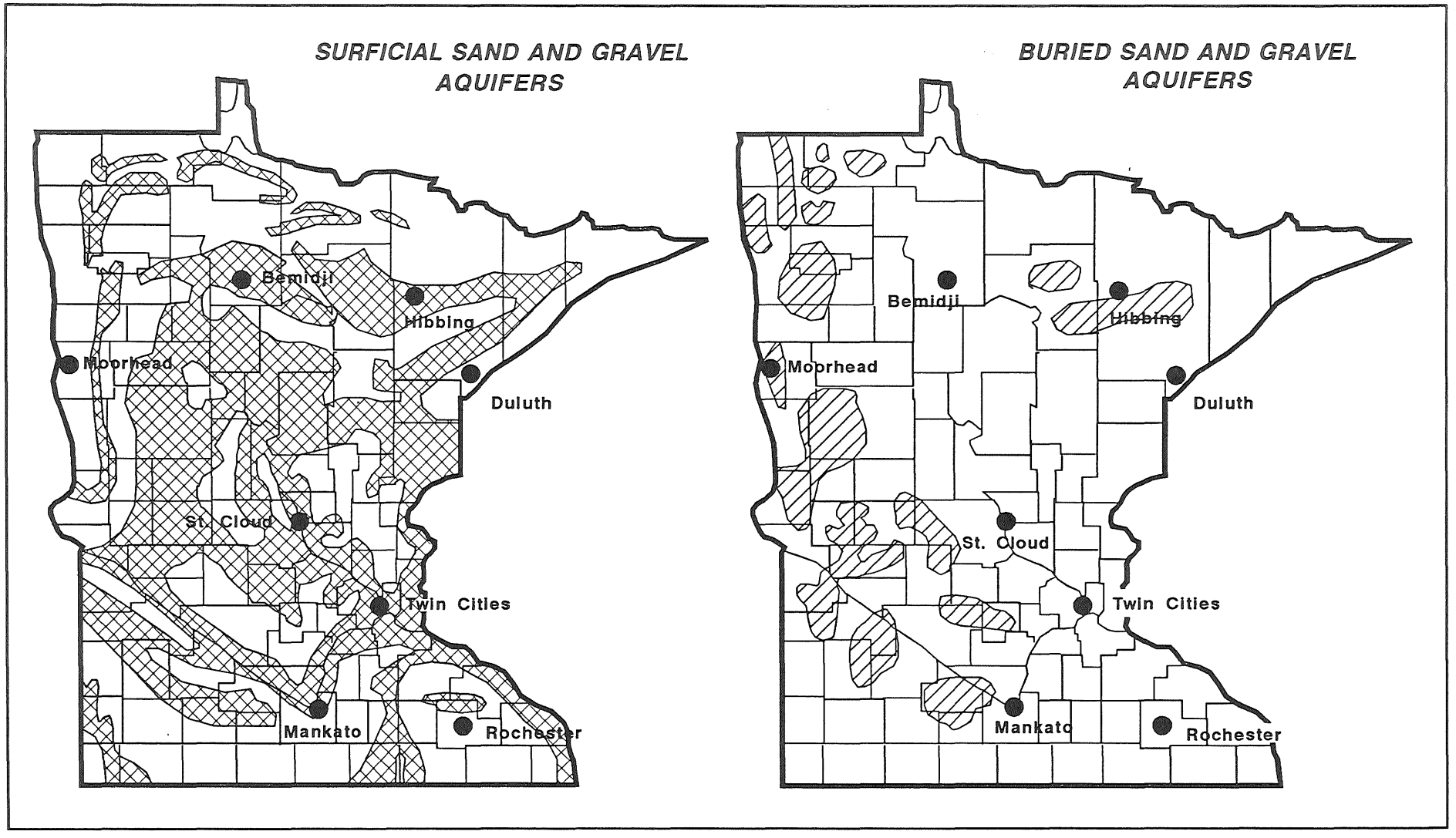
[1] This includes the North Shore Volcanic Group, the Biwabik Iron Formation, Sioux Quartzite and Precambrian Undifferentiated.

FIGURE A-2. AQUIFERS IN GLACIAL DEPOSITS



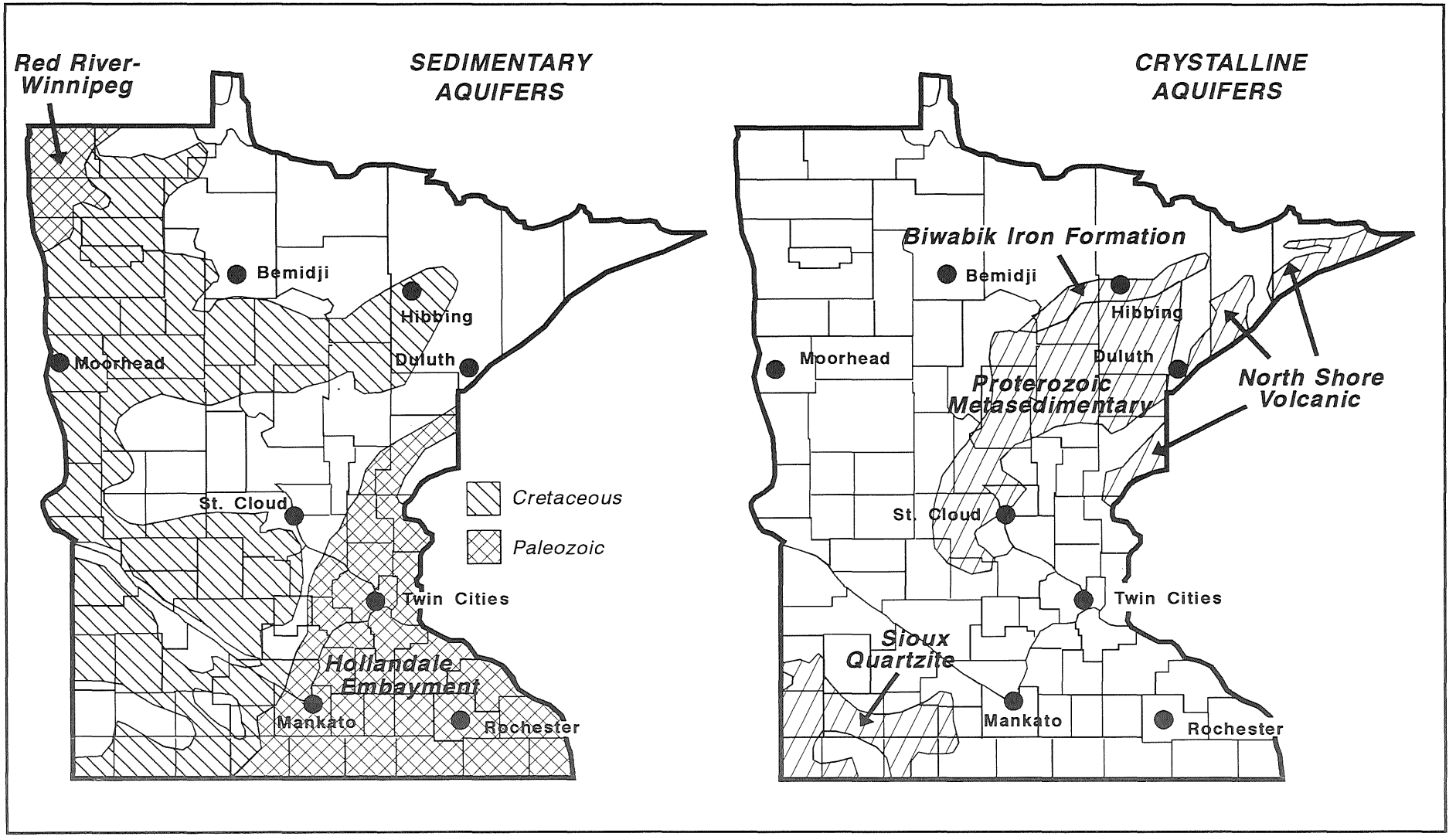
The crystalline rock aquifers include five major aquifers: North Shore Volcanic Group, Sioux Quartzite, Proterozoic Meta-Sedimentary rocks, which includes the Biwabik Iron-Formation and undifferentiated Precambrian rocks. These aquifers are located primarily in southwestern and northeastern Minnesota (Figure A-4).

FIGURE A-3. GENERALIZED EXTENT OF MINNESOTA GROUND WATER RESOURCES: GLACIAL AQUIFERS



Sources: Designation of Principal Water Supply Aquifers in Minnesota. St. Paul: U.S. Geological Survey and U.S. Environmental Protection Agency, August, 1981; and Understanding Ground Water Local Trends: A Key to Managing Water Use. St. Paul: Division of Waters, Minnesota Dept. of Natural Resources, June, 1989

FIGURE A-4. GENERALIZED EXTENT OF MINNESOTA GROUND WATER RESOURCES: BEDROCK AQUIFERS



Sources: Designation of Principal Water Supply Aquifers in Minnesota. St. Paul: U.S. Geological Survey and U.S. Environmental Protection Agency, August, 1981; and Understanding Ground Water Local Trends: A Key to Managing Water Use. St. Paul: Division of Waters, Minnesota Dept. of Natural Resources, June, 1989

APPENDIX B

GROUND WATER CONTAMINANTS AND LAND USE

Table B-1
POTENTIAL CONTAMINANTS PREVIOUSLY IDENTIFIED IN GROUND WATER

Inorganic	Organic
Aluminum (M)	Acetone
Ammonia	Alpha-BHC
Antimony (M)	Benzene
Arsenic (M)	Bis (2-ethylhexyl) phthalate
Barium (M)	Bromoform
Beryllium (M)	Butyl benzyl-phthalate
Boron (M)	Carbon tetrachloride
Cadmium (M)	Chloroform
Calcium (M)	Chloromethane
Chlorides	Cyclohexane
Chromium (M)	DBCP (1,2-dibromo-3-chloropropane)
Cobalt (M)	Delta BHC
Copper (M)	Di-n-butyl-phthalate
Cyanides	Dibromochloromethane
Fluorides	Dioxane
Iron (M)	Ethyl benzene
Lead (M)	Ethylene dibromide (EDB)
Lithium (M)	Gamma-BHC (Lindane)
Magnesium	Isopropyl benzene
Manganese (M)	Methylene chloride
Mercury (M)	Parathion
Molybdenum (M)	Tetrachloroethylene
Nickel (M)	Toluene
Nitrates	Trichloroethylene
Nitrites	Triflourotrichloroethane
Palladium (M)	Vinyl chloride
Potassium (M)	Xylene
Phosphates	1,1-Dichloroethane
Selenium (M)	1,1,1-Trichloroethane
Silver (M)	1,1,2-Trichloroethane
Sodium (M)	1,1-Dichloroethylene
Sulfates	1,2-Dichloroethane
Sulfites	1,2-Dichloroethylene
Thallium (M)	
Titanium (M)	
Vanadium (M)	
Zinc (M)	

M = Metal

Source: Office of Technology Assessment, U.S. Congress, *Protecting the Nation's Groundwater from Contamination*, Volumes 1 and 2, 1984.

Table B-2

KNOWN AND POTENTIAL RADIONUCLIDES IN GROUND WATER

Antimony-125	Radium-226*
Barium-140	Radium-228*
Cesium-134	Ruthenium-103
Cesium-137*	Ruthenium-106*
Chromium-51*	Scandium-46*
Cobalt-60*	Strontium-89
Iodine-129	Strontium-90*
Iodine-131*	Strontium-131
Iron-59*	Thorium-270*
Lead-210*	Tritium*
Phosphorus-32*	Uranium-230
Plutonium-238*	Uranium-238*
Plutonium-243*	Zinc-65*
	Zirconium-95*

* radionuclides known to have contaminated ground water

Source: Office of Technology Assessment, U.S. Congress, *Protecting the Nation's Groundwater from Contamination*, Volumes 1 and 2, 1984.

Table B-3
HOUSEHOLD PRODUCTS AND HAZARDOUS COMPONENTS

Product	Toxic or Hazardous Components
Automotive Products	
Antifreeze (gasoline or coolant systems)	methanol, ethylene glycol
Automatic transmission fluid	petroleum distillates, xylene
Battery acid (electrolyte)	sulfuric acid
Car wash detergents	alkyl benzene sulfonates
Car waxes and polishers	petroleum distillates, hydrocarbons
Degreasers for engines and metal	chlorinated hydrocarbons, toluene, phenols, dichloroperchloroethylene
Diesel fuel, kerosene, #2 heating oil	hydrocarbons
Engine and radiator flushes	petroleum solvents, ketones, butanol, glycol ether
Gasoline and jet fuel	hydrocarbons
Grease, lubes	hydrocarbons
Hydraulic fluid (brake fluid)	hydrocarbons, fluorocarbons
Motor oils and waste oils	hydrocarbons
Rustproofers	phenols, heavy metals
Home Maintenance Supplies	
Asphalt and roofing tar	hydrocarbons
Cesspool cleaners	tetrachloroethylene, dichlorobenzene, methylene chloride
Degreasers for driveways and garages	petroleum solvents, alcohols, glycol ether
Floor and furniture strippers	xylene
Metal polishes	petroleum distillates, isopropanol, petroleum naphtha
Other solvents	acetone, benzene
Paint brush cleaners	hydrocarbons, toluene, acetone, methanol, glycol ethers, methyl ethyl ketones
Paint and lacquer thinner	acetone, benzene, toluene, butyl, acetate, methyl ketones
Paint and varnish removers, deglossers	methylene chloride, toluene, acetone, xylene, ethanol, benzene, methanol
Paints, varnishes, stains, dyes	heavy metals, toluene
Refrigerants	1, 1, 2 trichloro - 1, 2, 2 trifluoroethane
Rock salt (Halite)	sodium concentration
Swimming pool chlorine	sodium hypochlorite
Household Cleaners	
Bug and tar removers	xylene, petroleum distillates
Disinfectants	cresol, xylenols
Drain cleaners	1, 1, 1 trichloroethane
Household cleaners, oven cleaners	xylenols, glycol ethers, isopropanol
Jewelry cleaners	sodium cyanide
Laundry soil and stain removers	petroleum distillates, tetracholoethylene
Spot removers and dry cleaning fluid	hydrocarbons, benzene, trichloroethylene
Toilet cleaners	xylene, sulfonates, chlorinated phenols
Pesticides/Fertilizers	
Pesticides (all types)	naphthalene, phosphorus, xylene, chloroform, heavy metals, chlorinated hydrocarbons
Miscellaneous	
Lye or caustic soda	sodium hydroxide
Photochemicals	phenols, sodium sulfite, cyanine, silver halide, potassium bromide
Printing ink	heavy metals, phenol-formaldehyde
Wood preservatives	
• CCA	copper, chrome, arsenic
• creosote	polynuclear aromatic hydrocarbons (PAHs)
• penta	pentachlorophenols (PCPs)

Source: Department of Natural Science, University of Rhode Island, "Natural Resources Facts: Household Hazardous Wastes", Fact Sheet No. 88-3, 1988.

APPENDIX C

FEDERAL LAWS AND GROUND WATER PROTECTION

FEDERAL LAWS AND GROUND WATER PROTECTION

Clean Water Act of 1972 (CWA), as amended - The primary emphasis of the CWA has historically been on the cleanup and protection of surface waters and, indirectly, the protection of ground water. The act requires the EPA to set ambient water quality standards for surface waters and effluent standards for public and private treatment plants (National Pollutant Discharge Elimination System) which discharge wastewater to United States waters. The disposal of sludge, the solid material which settles out during the treatment process, is also regulated by EPA under the act. The law also provides funds to each state to assist local governments in upgrading and expanding public treatment plants.

Many states and local governments have undertaken research and planning activities related to ground water protection as provided for under sections 205 and 208 of the act. The 1987 amendments make funds available to states and local governments for a variety of ground water protection activities including monitoring, research, planning and technical assistance. Section 319 directs states to prepare an assessment and management strategy for addressing nonpoint source pollution (urban and agricultural) that, if not controlled, may also reach the ground water. Funds are authorized for state programs and assistance to local governments. The Minnesota Pollution Control Agency (MPCA) administers the programs under this act.

Safe Drinking Water Act of 1974 (SDWA), as amended 1986 - The purpose of the SDWA is to protect public health through the regulation of public water supply systems. The act gives EPA the authority to set primary and secondary water quality standards for public water systems. Primary standards are called maximum contaminant levels (MCLs). MCLs are established at a level which balances the potential health risks against the considerations of available analytical methods, available treatment technology, economic imapct (costs) and regulatory impact. Secondary standards are aesthetic-based and include such things as taste, color or odor and are non-enforceable. Currently, the EPA regulates contaminants in drinking water (see Table C-1). The EPA has developed less formal health advisories for other chemicals that are not currently regulated. Public water systems affected by these standards include systems with a minimum of 15 service connections or those which regularly serve at least 25 people for 60 days a year. In Minnesota, the SDWA is administered by the state Department of Health. If an MCL is exceeded, the agency requires corrective action such as additional treatment or a new source.

Sole-source aquifer designation - EPA has the authority to designate sole-source aquifers in areas where an aquifer provides 50 percent or more of the area water supply. Individuals, organizations or communities may petition the EPA for designation. Sole-source designation requires EPA review of federally-funded projects in the area to ensure the ground water will not be degraded. Federal financial assistance may be withheld if the project may contaminate the aquifer. Private and state/local financed projects would not be affected. Currently, the only designated sole-source aquifer in the states is around the Lake Mille Lacs area, which serves the Mille Lacs Indian Reservation and the towns of Onamia and Isle.

Wellhead protection - The 1986 amendment to the SDWA requires states to adopt programs to protect public wellhead areas from contaminants which may have an adverse effect on human health. The wellhead protection area refers to the surface and subsurface area surrounding a well or wellfield through which contaminants are likely to move toward and reach the well or well

Table C-1
PRIMARY DRINKING WATER STANDARDS

Contaminants	MCL[1]
MICROBIOLOGICAL	
Coliforms (Total coliform and fecal coliform bacteria)	Presence
Giardia Lamblia	Minimum of 3 log removal (99.9%)
Viruses	Minimum of 4 log removal (99.99%)
INORGANIC CHEMICALS	
Antimony	.006
Arsenic	.05
Asbestos	7MFL[5]
Barium	2
Berylium	.004
Cadmium	.005
Chromium	.1
Copper	1.3
Cyanide	.2
Fluoride	4 and 2[6]
Lead	.015
Mercury	.002
Nickel	.1
Total nitrate/nitrite	10
Nitrate	10
Nitrite	1
Selenium	.05
Sulfate	.5
Thallium	.002

Contaminants	MCL[1]
TURBIDITY	Filtered water must not exceed 5 NTU[2] ≤0.5 NTU[2] in 95% of monthly measurements[3] ≤1 NTU[2] in 5% of monthly measurements[3] ≤1 NTU[2] in 95% of monthly measurements[4]
ORGANIC CHEMICALS	
Volatile Organic Chemicals	
Benzene	.005
Carbon Tetrachloride	.005
o-Dichlorobenzene	.6
para-Dichlorobenzene	.075
1,2-Dichloroethane	.005
1,1-Dichloroethylene	.007
cis-1,2 Dichloroethylene	.07
trans-1,2 Dichloroethylene	.1
Dichloromethane	.005
1,2-Dichloropropane	.005
Ethylbenzene	.7
Monochlorobenzene	.1
Styrene	.1
Tetrachloroethylene	.005
Toluene	1
Trichloroethylene	.005
1,1,2-Trichloroethane	.005
1,1,1-Trichloroethane	.2
1,2,4-Trichlorobenzene	.009
Vinyl chloride	.002
Xylenes	10

Contaminants	MCL[1]	Contaminants	MCL[1]	
ORGANIC CHEMICALS (continued)				
Pesticides		**Synthetic Organic Chemicals**		
Alachlor	.002	Polychlorinated biphenyls (PCB's)	.0005	
Aldicarb	.003	Benzo(a)pyrene	.0002	
Aldicarb sulfone	.002	Di-(ethylhexyl)adipate	.4	
Aldicarb sulfoxide	.004	Di-(ethylhexyl)phthalate	.004	
Atrazine	.003	Hexachlorobenzene	.001	
Carbofuran	.04	Hexachlorocyclopentadiene	.05	
Chlordane	.002	2,3,7,8-TCDD (Dioxin)	$3x10^{-11}$	
Dalapon	.200			
Dibromochloropropane (DBCP)	.0002	**Treatment Techniques**		
Dinoseb	.007			
Diquat	.02	Acrylamide	0.005% dosed at 1mg/l	
2,4-D	.07	Epichlorohydrin	0.01% dosed at 20 mg/l	
Endothall	.1			
Endrin	.002	**DISINFECTION BY-PRODUCTS**		
Ethylene dibromide (EDB)	.00005			
Glyphosate	.7	Total Trihalomethanes (TTHM's)	.1	
Heptachlor (banned)	.0004			
Heptachlor epoxide	.0002	**RADIONUCLIDES**		
Lindane	.0002			
Methoxychlor	.04	Gross alpha particle activity	15 pCi/L	
Oxamyl (Vydate)	.2	Gross beta particle activity	4mrem/yr	
Pentachlorophenol	.001	Radium 226 & 228 (total)	5 pCi/L	(20 pCi/L)[7]
Picloram	.5	Radon 222	--	(300pCi/L)[7]
Simazine	.0004	Uranium	--	(30 pCi/L)[7]
Toxaphene	.003			
2,4,5-TP Silvex	.05			

[1] Currently enforceable maximum contaminant levels in Minnesota, in milligrams per liter, unless otherwise noted.
[2] NTU - Nephelometric turbidity unit (unit of measurement for turbidity)
[3] Systems using conventional treatment or direct filtration.
[4] Systems using slow sand filtration or diatomaceous earth (DE) filtration.
[5] Million fibers per liter longer than 10 microns.
[6] The primary standard is 4; the non-enforceable, secondary standard is 2. Between 2 and 4 public notice must be given.
[7] Effective January 1996.

Source: Minnesota Department of Health

field. The program in each state must specify state and local government roles, delineate wellhead protection areas, identify potential sources of contaminants, develop management approaches to protect the water supply in the wellhead, develop contingency plans for each water supply in case of contamination, locate new wells properly to minimize contamination, and ensure public participation in program development. The Minnesota Department of Health (MDH) is responsible for developing this program.

Underground injection control program - The SDWA authorizes the EPA to regulate this waste management disposal technique as part of a consolidated permit program to protect present and future sources of drinking water. Underground injection wells have been used in some parts of the U.S. to dispose of various liquid wastes and assist in the extraction of minerals and hydrocarbon resources. Wells used in rural areas for agricultural and storm drainage purposes are included. Minnesota does not currently allow the underground injection or discharge of sewage, industrial wastes or other wastes into the saturated zone. Heating and cooling water may be reinjected if certain conditions are met. The state of Minnesota has not assumed responsibility for the program. Therefore, the EPA administers the program in the state.

Resource Conservation and Recovery Act of 1976 (RCRA) - The act provides for the management of three potential sources of ground water contamination--hazardous waste, solid waste and underground storage tanks. Under the act, the EPA has established performance standards for treatment, storage and disposal facilities (TSDs), and monitoring requirements for new and existing facilities. The program includes procedures applicable to generators and transporters of hazardous waste and requirements for EPA permits. EPA maintains a list of hazardous wastes.

Transportation of hazardous waste is regulated under RCRA and the Hazardous Materials Transportation Act. The U.S. Department of Transportation also regulates transportation of the materials and has established rules for packaging, notification and emergency response actions for spills.

Under RCRA, the EPA also establishes criteria for nonhazardous solid waste disposal (landfills). States are required to develop a solid waste management plan. It is the state's responsibility to grant permits for the facilities and enforce the solid waste provisions.

The 1984 amendments to RCRA emphasize that land disposal (landfills and surface impoundments) should be the least favored method for managing hazardous waste. The amendments also ban the disposal of hazardous waste by underground injection into or above a potential underground source of drinking water. The only enforcement the EPA has is the power to withhold grants and funding to states who have not complied with these policies. The Minnesota Pollution Control Agency (MPCA) is responsible for the permitting of solid and hazardous waste facilities in the state.

The 1984 amendments also establish a regulatory mechanism for leaking underground storage tanks. The states are to inventory these tanks, and the EPA is to develop management standards for them. Storage tanks which have 10% of their volume underground and contain substances regulated under RCRA and CERCLA are included. The MPCA administers the provisions of the law and program in Minnesota.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Federal Superfund) - The act, widely known as the "Superfund Law", authorizes the EPA to respond to releases of chemicals and hazardous materials into the environment, and to act immediately to prevent the spread of ground water contamination from existing or closed disposal activities.

The act creates two trust funds to pay for cleanups: the Hazardous Substance Response Fund which pays for remedial actions, and the Post Closure Liability Fund which pays for damages caused by release of hazardous waste and the post closure costs.

The law places financial liability for costs associated with cleanup on the generators and transporters of the waste as well as the facility owners and operators. Under the act, a national priority list for sites is established by the EPA with the assistance of states. A determination is made on a site-by-site basis as to whether EPA or a state agency will administer the provisions of the law.

The Emergency Planning and Right-to-Know Act of 1986 - The act provides for local planning for hazardous chemical emergencies or accidents and allows citizens the right to know about hazardous chemicals in use or storage in their communities. Owners and operators are required to file periodic reports on hazardous chemicals stored or used at their facilities, to provide notice when an accidental chemical release occurs, and, in some cases to file annual reports on routine and accidental releases of toxic chemicals to the environment. The Minnesota Department of Public Safety and Emergency Response Commission have the responsibility for administering the act locally.

Toxic Substances Control Act of 1976 (TSCA) - The act addresses ground water protection indirectly by controlling potential contaminants. The EPA may require testing of chemical substances to determine whether they represent unreasonable risks to human health and the environment. Chemical manufacturers must first notify the EPA of all new chemicals prior to production or chemicals to be produced for a significant new use. The agency may take a variety of actions regarding a chemical which represents an unreasonable risk to the environment, including: restricting its use; requiring warning labels; mandating application procedures for users; and requiring special disposal plans. To date, it appears the EPA has rarely used this authority to protect ground water.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) - FIFRA gives the EPA the authority to regulate pesticides. All pesticides are classified as restricted use or general use. Special user training is required for restricted pesticides due to their acute toxicity and potential for leaching. The law allows the EPA to restrict, suspend or prohibit the use of hazardous pesticides. The agency has developed guidelines for the registration and testing of pesticides to determine the potential for these substances to leach into the ground water as a result of normal use. The EPA has delegated the authority to administer the act to the Minnesota Department of Agriculture.

OTHER FEDERAL PROGRAMS

Several other federal agencies are involved in research, technical assistance, monitoring or management activities.

Department of Agriculture (USDA)

The USDA has several programs which directly and indirectly benefit ground water quality.

Soil Conservation Service (SCS) - The SCS has produced a soil survey for most of the counties in Minnesota. The survey data will assist local governments in defining geologically sensitive areas, or areas which are more susceptible to ground water contamination. The SCS has an office in most counties, usually in conjunction with the local soil and water conservation district, where information can be obtained regarding the availability of technical and financial assistance. SCS provides technical assistance to land users in planning, designing and instilling conservation practices. Some of these practices will assist in the protection of ground water.

Agricultural Stabilization and Conservation Service (ASCS) - The ASCS administers federal financial assistance for agricultural conservation cost-share programs. Cost-sharing is provided for conservation practices through the Agricultural Conservation Program (ACP), which can be used to assist in controlling the movement of nitrogen and pesticides to surface and ground water, such as the installation of animal waste control facilities. The Conservation Reserve Program (CRP), which is administered by ASCS with technical assistance from the SCS, provides funds for land set aside. Marginal cropland is taken out of production for a ten year period, reducing potential ground water contamination since the land won't be receiving agricultural chemicals. ASCS also administers Special Project 53 Integrated Pest Management (IPM) monies. This program is currently limited to a single project in Minnesota: the Anoka Sand Plain. This is a cost-share assistance program to encourage producers to adopt IPM and other measures to minimize the amount of pesticides and nutrients used on farms while maintaining farm income.

Cooperative State Research Service (CSRS) - Administers the Low In-put Sustainable Agriculture (LISA) program. This is a research and demonstration grant program involving educators, farmers and scientists. Its purpose is to evaluate the effects of alternative farming systems on the structure of agriculture, rural communities, human health and the environment.

Cooperative Extension Service (CES) - Administers IPM monies and programs. Their purpose is to educate farmers and other land owners as to other viable approaches to pest management. CES works through the professionals that deal directly with farmers, such as county extension agents and crop consultants.

Farmers Home Administration - Provides loans which may be used by land owners to improve confined animal facilities such as adding or modifying water pollution control practices.

Water Quality Demonstration Project - Projects were selected in eight states to demonstrate new ways of minimizing the effect of agricultural nonpoint pollution on water quality, especially ground water. The SCS and the Extension Service work with individual farmers to implement on-farm demonstration projects. ASCS provides cost-share assistance to eligible farmers for the practices. The Anoka Sand Plain Project was selected in Minnesota as part of the larger project to demonstrate the results on sandy soil. Many of the state agencies described later in this chapter are cooperating with the ASCS in this project.

Hydrologic Unit Areas

Thirty-seven agricultural watersheds across the U.S. were selected by the USDA and SCS in 1990 and 1991. Individual farmers in each area are assisted in voluntarily applying management practices that will help achieve water quality goals. Cost-share funds (federal and state) are provided for installing practices such as animal waste control facilities and integrated crop management. The St. Peter-Prairie du Chien-Jordan Hydrologic Unit Project in the Rochester-Olmsted County area is one of the units selected for this project. It is being carried out jointly with the Olmsted County ground water and wellhead protection project, a MPCA Clean Water Partnership-funded project .

Department of Interior

United States Geological Survey (USGS) - The USGS is an agency of the U.S. Department of the Interior. It's major responsibility is to undertake research regarding the status of ground water quality and quantity. It is involved in ground water monitoring and data gathering. The USGS frequently produces detailed assessments of ground water concerns in cooperation with state and local governments. Information regarding published reports and information, and all other available data can be obtained from the agency's St. Paul office.

Department of Defense

The DOD has undertaken a Nationwide Environmental Restoration Program to assess the presence and extent of hazardous or toxic contaminants at former department facilities. Ground water at the sites is sampled to determine whether continuing monitoring is necessary. Some 50 sites nationally will be included in the program.

APPENDIX D

RESPONSIBILITIES AND PROGRAMS OF STATE AGENCIES AND THE UNIVERSITY OF MINNESOTA

RESPONSIBILITIES AND PROGRAMS OF STATE AGENCIES

Board of Water and Soil Resources (BWSR)

The Board's primary responsibility is to coordinate the local water resources planning and management activities of counties, soil and water conservation districts, watershed districts, watershed management organizations (Twin Cities Metropolitan Area), and other local units of government. BWSR is also to facilitate communication and coordination among state agencies.

Coordination and Plan Approvals

- Local water plan review and approval

BWSR reviews and approves county ground water plans and surface water (watershed) management plans in the Twin Cities Metropolitan Area, and comprehensive county water plans for Greater Minnesota.

Source Management and Regulation

- Reinvest in Minnesota (RIM) reserve program

This program takes marginal cropland out of production for 20 years or perpetually through up-front payments to farmers for easements. A perennial vegetative cover must be established to reduce erosion, improve water quality, and develop and enhance habitat for fish and wildlife. Removing the lands from production will also eliminate the application of farm chemicals in these areas. The criteria were expanded by the GWPA of 1989 to include lands with a high sensitivity to ground water contamination due to their geological characteristics.

Financial Assistance

- Cost-share grants

Provides funds for cost-share grants to local units of government and land owners for various surface and ground and water improvement projects such as feedlot agricultural waste systems.

- Erosion control cost-sharing

Funds are provided to cost-share the cost of implementing conservation practices to control soil erosion and protect water quality. Includes practices which divert run-off from sinkholes.

- Local water planning grants

The Local Water Resource Protection and Management Program provides grants to local governments for use in planning or implementing already approved local water management plans. The grants are of two types: base level, which are available to all; or challenge grants, which are competitive and based on the merit of proposals.

- Well sealing grants

Limited funds are made available for local cost-share programs to seal abandoned wells. The program was established to provide funds to targeted counties for sealing high priority abandoned wells.

Research

BWSR is administering an abandoned well inventory pilot project for a statewide abandoned well inventory. Funds are provided to selected counties to develop an inventory.

Technical Assistance

BWSR provides technical assistance to all local governments related to the development of model ordinances, geographic information systems (GIS) and training for local governments in the areas of erosion control, water management and administration.

Department of Agriculture (MDAg)

Historically, the MDAg is the major farm food regulatory and protection agency in the state. It has established statewide programs to monitor water supply wells on dairy farms and related plants, and food and beverage processors. The Ground Water Protection Act expanded the agency's role in water resource protection, and the MDAg is undertaking a variety of programs or projects to manage and regulate agriculture related contaminants and sources.

Monitoring and Data Management

MDAg administers several ground water monitoring programs. The GWPA of 1989 provided additional funding to expand the existing programs throughout the state, including urban areas, to assess the trends and inputs of routine pesticide and fertilizer use on ground water quality. This is in addition to monitoring data gathered as part of its dairy and food inspection activities. The data are in paper and automated files.

Source Management and Regulation

•Liquid and Dry Fertilizer Storage and Handling

The MDAg regulates facilities for the storage, mixing, blending, weighing and handling of liquid and dry fertilizers. Any person constructing a new facility or substantially altering an existing facility must obtain the approval of the Commissioner. Proposed facilities must include safeguards to protect ground and surface waters. Existing facilities were also approved by the Commissioner (Minn. Rules, pts. 1510.0370 to 1510.407).

•Agricultural Chemical Incidents-Response and Cleanup Program

The MDAg is the lead agency for overseeing the investigation and cleanup of agricultural chemical incidents including disasters such as tornados, fires, accidents, leaks or spills. Costs may be eligible for reimbursement through the Agricultural Chemical Response and Reimbursement Account (ACRRA). State Superfund monies may also be used in certain cases (see MPCA discussion below).

•Chemigation Regulations

MDAg regulates the application of pesticides and fertilizers through irrigation systems. (The rules for the application of fertilizers will be upgraded in 1994 to a management level comparable to that for pesticide application). Permits are required for these systems, and must be renewed annually. MDAg rules include requirements to prevent the back-siphoning of these chemicals into ground and surface waters, contain spills and protect the water supply or well head (Minn. Rules, pt. 1505.2000).

•Pesticide Regulations

The MDAg is also charged with assuring state compliance with the Federal Insecticide, Fungicide and Rodenticide Act. All pesticides must be registered with the department including farm and lawn chemicals. The 1987 Minnesota Pesticide Law authorizes MDAg to levy fines, impose

stricter requirements, cancel a pesticide or change it from general to restricted use. (Minn. Stat., ch. 18B, 1990)

•Bulk Pesticide Storage

The construction or operation of a new bulk pesticide storage facility (56 U.S. gallons or more or 100 pounds or more net dry weight) requires a permit from the Commissioner. Operators of existing storage facilities must also obtain a permit and comply with the requirements of the rules by mid-1991 unless an extension is granted. The rules include requirements for storage; loading areas; secondary containment areas; recovery, use and disposal of releases; inspection and maintenance; and record keeping. Underground storage is prohibited (Minn. Rules ch. 1505).

•Waste Pesticide Collection Program

MDAg implements the collection and disposal of unused and unwanted pesticides, including suspended or canceled substances, with the cooperation of local governments, principally with counties.

Planning and Research

•Pesticide Container Collection & Recycling Pilot Project

The project is evaluating the feasibility of collecting and recycling empty pesticide containers.

•Pesticide Management Plan

The GWPA directs MDAg to develop a plan to address prevention, evaluation and mitigation of ground and surface water contamination from pesticides and breakdown products. A final draft of the plan is waiting for EPA review.

•Best Management Practices (BMPs) for Agricultural Chemicals

The GWPA directs the department to develop voluntary BMPs for agricultural chemicals that are commonly found in ground water. The MDAg is to evaluate the effectiveness of the BMPs, and if they prove ineffective, propose and adopt "water resource protection requirements". The latter will be adopted by rule. Voluntary BMPs for the pesticide atrazine and nitrogen fertilizers have been adopted by MDAg.

•Nitrogen Fertilizer Task Force

The GWPA of 1989 directed the formation of this group. The Task Force has developed recommendations for nitrogen fertilizer best management practices and prepared a nitrogen fertilizer management plan. The report *Nitrogen Fertilizer Management Plan* (1990) is available from the department. The nitrogen fertilizer management plan promotes the prevention of contamination of water resources by inorganic nitrogen fertilizer and develop appropriate responses to the detection of inorganic fertilizers in surface and ground water.

•Nitrogen Compounds in Ground Water Study

This broader joint study with the MPCA of all nitrogen compounds in ground water includes sources such as septic tanks, feedlots and fertilizers, prepared with recommendations from the MDAg's Nitrogen Fertilizer Task Force in cooperation with other state agencies. Goals include compiling a computer data file of ground water nitrate data, assessing sources of nitrates, evaluating current policy and programs, and identifying mitigation measures for reducing the various sources of nitrate contamination. The report, *Nitrogen in Minnesota Ground Water,* 1991, is completed.

Public Information and Education

•Information Clearinghouse

The GWPA of 1989 directs the MDAg to establish an information clearinghouse and provide other assistance to promote sustainable agriculture or alternative practices which are more energy efficient, environmentally sound and profitable. This includes information regarding practices which encourage the use of non-chemical pest controls or integrated pest management (IPM) and farm-produced nutrients, rather than petrochemical-based nitrogen.

The MDAg's Energy and Sustainable Agriculture Program (ESAP) provides information, demonstrates sustainable agricultural practices and assists farmers in adopting these practices through a grants and loans program. ESAP includes the IPM program, the On-Farm Research and Demonstration program, the Sustainable Agriculture Grants and Loans program, the Sustainable Agriculture Information program, the Energy Audit program, and the Sustainable Agriculture Farm Communication program. The IPM program promotes and facilitates the use of IPM through education, financial or technical assistance, research and information to farmers, state agencies, the public and others.

•Pesticide Education and Training

The MDAg, with the assistance of the Minnesota Extension Service, educates and trains pesticide applicators through the pesticide applicator certification process. Pesticide applicators who use restricted use products must be certified.

Department of Health (MDH)

MDH programs emphasize the protection of public drinking water supplies and well management.

Monitoring and Data Management

The department has information in paper and automated files regarding well sealing and construction. The department also maintains data regarding drinking water quality statewide and selected private and public wells near landfills or dumps which have received mixed municipal solid waste in the Twin Cities Metropolitan Area.

Source Management and Control

•Public Water Supplies

The MDH is responsible for administering EPA drinking water standards and monitoring requirements for public water supply systems. Public water supplies are water systems serving 25 or more persons on a regular basis or a system with 15 or more service connection. This involves the enforcement of maximum contaminant levels (MCL). These are enforceable federal standards for public water supplies (not private) promulgated by the EPA and adopted by MDH. The EPA has also developed Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals. Public water supply systems including community and non-community systems (such as, schools and highway rest stops) must be monitored periodically. If a contaminant level exceeds the MCL, the water utility must take remedial action or take the water supply out of service until the problem is corrected.

•Water Well Construction and Abandonment

The department regulates the proper construction of new wells and the sealing of abandoned wells. All new wells are sampled for nitrates and coliform bacteria. Departmental notification

and a fee are required for the construction of all new wells. The notification system is a potential source of valuable subsurface information that will be useful to local ground water planning purposes. The Commissioner may delegate all or part of the inspection, reporting and enforcement duties pertaining to permitting, construction, repair and sealing of wells to a local board of health.

Property owners must provide a formal disclosure statement to prospective buyers indicating the location of any type of water well on the property, or the deed must certify that the seller does not know of any well on the real property. Property owners are responsible for all wells and must obtain a maintenance permit from MDH for keeping an unused well unsealed.

•Health Risk Limits and Drinking Water Advisory Program

The MDH conducts risk assessments, including assessments of private water wells. The private well assessments are based on sample data collected by or for other state programs. If the contaminant level exceeds a recommended allowable limit (RAL) or other criteria established by the department, an advisory regarding the suitability (drinking or other purposes) of the water supply is issued to the well owner and user. This is a non-regulatory activity.

The GWPA authorizes the MDH to adopt health risk limits (HRLs) or maximum allowable concentrations for contaminants in ground water. These are the levels of contaminants that are considered safe to people to drink. The HRL rule will not supersede other federal or state drinking water resource regulations. The GWPA specifies that HRLs are to be used as one criteria for initiating Water Resource Protection Requirements. These are to be put in effect when best management practices for a commonly detected pollutant fail to control its spread or increase. HRLs may be incorporated eventually in other state ground water protection programs. MDH will use HRLs to issue drinking water advisories and perhaps to regulate the construction of new wells and well sealing. The HRL rules will be final or official Nov. 22, 1993, and include a total of 89 substances.

•Management of Certain Individual On-site Sewage Treatment Systems (ISTS)

MDH enforces the MPCA standards for on-site sewage treatment systems (less than 10,000 gallons/day) that serve public establishments such as resorts, food/beverage, lodging facilities, convenience stores and small businesses.

•Wellhead Protection

The GWPA authorizes the department to develop a wellhead protection program consistent with the requirements of the federal Safe Drinking Water Act. This is a preventative strategy to protect public water supplies from contamination. A wellhead protection area is defined as the surface and subsurface area surrounding a well or wellfield supplying a public water system through which contaminants are likely to pass and reach the well or wellfield. The department is currently developing rules for implementing the program by mid-1994.

Financial Assistance

•Community Health Service Grants

State funds are provided to county, multi-county and selected city health boards for public health activities. Funds can be used for environmental health programs such as well inspection.

Department of Natural Resources (MDNR)

Management of ground water quantity is the primary responsibility of the MDNR. This includes such activities as regulating the appropriation of surface and ground water resources, addressing the availability of surface and ground water supplies, maintaining a system of water level monitoring wells and managing a data base of aquifer information. The GWPA authorized the agency to develop a program for the protection of sensitive ground water areas.

Monitoring and Data Management

•Precipitation Monitoring Network

The State Climatology Office is the repository for statewide precipitation data from a collection network consisting of hundreds of individuals and organizations such as the U.S. Weather Service. Much of the data is computerized.

•Stream Gauge Network

To monitor water availability, the MDNR maintains a network of continuous record flow gauges and varying number of partial flow gauges depending on rainfall and flow condition. The data provides a measure of base flow or the portion of stream flow due to ground water discharge.

•Water Level Observation Wells Network

This program consists of a statewide network of 650 observation wells monitored for the MDNR by local Soil and Water Conservation Districts and the U.S. Geological Survey. The network provides water level data for evaluating existing and future impact on ground water use.

Source Management and Control

•Abandoned Well Sealing

MDNR is responsible for sealing abandoned wells on its property and developing a plan for sealing wells on the property of other state agencies.

•Water Appropriation Regulations

Minnesota rules require that a permit be obtained for the MDNR for any appropriation of surface or ground water for 10,000 gallons per day or 1,000,000 gallons per year or more. Permits are issued for users that exceed the threshold such as community water suppliers, irrigation and manufacturing or industrial users. Water use data are available for each permit.

•Underground Gas and Liquid Storage Permits

State law requires that a permit be obtained from the MDNR for the underground storage of gas and liquids. There is currently one site near Waseca under permit.

Planning and Research

•Ground Water Sensitivity Criteria and Mapping

The GWPA of 1989 directs the MDNR to develop criteria for defining geologically sensitive ground water areas and incorporate them into rules (see Section 5). In addition, the GWPA requires the MDNR to map sensitive areas with the assistance of the Minnesota Geological Survey, and provide this information to local planning and zoning authorities.

• County Geologic Atlases

The mapping program of the DNR provides ground water information at two levels. The DNR and Minnesota Geological Survey work jointly on preparing county geologic atlases (see discussion of Minnesota Geological Survey). The atlases contain detailed systematic summaries of the geologic and hydrologic conditions of a county. Seven atlases have been prepared, each including a map of geologically sensitive areas.

• Regional Assessments

The regional assessment provides a less detailed assessment of a multi-county area. The MGS and MDNR work jointly to develop geologic maps, hydrologic maps, vulnerability maps and data summaries for the surficial geology and shallow ground water conditions. One regional hydrologic assessment is completed.

• Regional Aquifer Studies

The MDNR also participates in special regional aquifer studies with local governments and the USGS. These technical investigations examine a multi-county area or the entire area where the aquifer is present beneath the surface. The studies involve flow modeling and a prediction of yield capability in addition to ground water quality information.

Department of Public Safety

• Emergency Planning and Community Right-to-Know

The Department and Emergency Response Commission supervise and coordinate state and local activities that carry out the federal Emergency Planning and Community Right-to-Know Act of 1986. The law requires planning for hazardous chemical emergencies and allowing citizens the right to know about hazardous chemicals in their communities. Under the law, all regulated facilities must report the presence of hazardous chemicals exceeding minimum thresholds to the Commission, local emergency planning committees and local fire departments. Manufacturing facilities must file annual reports on routine and accidental releases of toxic chemicals to the air, land and water. Although not all facilities are covered (small facilities and non-manufacturing facilities are excluded), the data is one source of information for local governments preparing an inventory of potential sources of contaminants.

• Pipeline Safety

The Office of Pipeline Safety administers federal and state standards for the design, construction, testing, operation and maintenance of intra-state and interstate pipelines carrying hazardous liquids and natural gas. The standards directly and indirectly address environmental protection. The agency will be authorized by the federal government to inspect interstate pipelines. Emergency pipeline releases are to be reported to the agency's emergency response center. Releases are also reported to the appropriate state agencies, such as the MPCA, and local governmental units.

Department of Transportation (MnDOT)

Several of Mn/DOT's programs affect ground water quality. MnDOT's primary role is to oversee the construction and maintenance of highway facilities. The concern for ground water contamination is related to the maintenance of highways, including the storage and use of road deicing chemicals, pesticides for right-of-way maintenance, gasoline and other petroleum products for maintenance vehicles, and other potential contaminants.

In several instances, MnDOT has developed policies and programs to minimize or research the impact of these activities on ground water. This involves managing maintenance garages where these chemicals are stored, monitoring for hydrocarbons and chlorides at its storage facilities and a special investigation of the impact of highway runoff on ground water quality. The department follows a policy for salt, and salt and sand storage that was developed to prevent ground and surface water contamination. The policy includes the containment of runoff from stockpiles, covering the material in storage, and placement on a sloped bituminous pad to prevent the infiltration of surface water.

•Licensing of Transporters of Hazardous Waste Products

The department is responsible for the licensing and inspections of hazardous waste transporters (trucks); informs carriers, shippers and manufacturers of federal/state hazardous material regulations, audits the operations of hazardous material carriers and shippers and assists the MPCA in the investigation of spills.

Under the Hazardous Materials Transportation Uniform Safety Act of 1990, the federal government sets the standards for designating or limiting highway routes for shipments of hazardous materials and the states designate or limit routes consistent with those standards. Local governments can designate or limit routes only with state approval.

•Monitoring and Data Management

MnDOT collects ground water data as an integral part of several on-going programs. These include the collection of water level data at construction sites, water quality and level data at contaminated sites acquired by the agency and ground water samples at water supply and waste water systems owned by MnDOT, such as rest areas.

Legislative Commission on Minnesota Resources (LCMR)

The LCMR reviews and recommends funding to the legislature for proposed projects for preserving, developing and maintaining the natural resources of the state. If projects are approved by the legislature, the LCMR oversees them. Public, private or non-profit organizations may apply to the LCMR for funds. Projects are funded by a tax on cigarettes and monies from the state Environmental and Natural Resources Fund. The latter is funded by proceeds from the state lottery. Monies in the fund are to be used to supplement, not substitute for, traditional sources of funding for environmental and natural resources activities in such areas as research, data collection and analysis, public education, capital projects for preservation and protection of unique natural resources and activities that preserve or enhance wildlife, land, air, water and other natural resources.

Minnesota Planning (Office of Strategic and Long Range Planning) and Environmental Quality Board (EQB)

Formerly the state planning agency, Minnesota Planning is primarily responsible for the development of statewide environmental policy, particularly for water resources management. It provides some direct staff support to the EQB.

The Land Management Information Center (LMIC) which is part of the state planning agency, manages a statewide geographic information system, or GIS. The system stores computerized maps of environmental, demographic and other physical information. It operates as a fee-based service for state and local governments.

Monitoring and Data Management

•Ground Water Data Clearinghouse

The GWPA directed the Land Management Information Center (LMIC) to support the development of a single access point for ground water data currently collected and stored at various state and federal agencies. The various data bases include information on well attributes, stratigraphy, ground water use, water levels and ground water quality. Data from the MDNR, MGS, MDH, MDAg and MPCA will be linked. The staff is also developing standards for the collection and automation of new data.

•Systems for Water Information Management (SWIM)

This is an ongoing inter-agency advisory group working with LMIC to identify needs for water resource information and promote data compatibility and sharing.

•Data Compatibility Standards

LMIC is responsible for developing standards to achieve compatibility for the data collected and managed by state agencies. The EQB will be responsible for enforcing the standards once they are accepted.

The EQB Water Resource Committee is the state's principal forum for discussing water resource and other environmental issues, and developing interagency policy to resolve these. Both agencies administer several programs which will have long-range impact on ground water quality.

Monitoring and Data Management

•Enforcement of Data Compatibility Standards

The GWPA provisions call for improved monitoring and data management to provide better information for water resource management decision-making. Once a mechanism is developed to coordinate agency data gathering and management, the EQB will ensure that the data compatibility standards are enforced.

Source Management and Regulation

•Pipeline Routing Permits

EQB regulates the location of certain pipelines under the Pipeline Routing Program. Minn. Stat. § 116I.015 authorizes the Board to designate the location of pipelines with a diameter of six inches or more that are designed to carry hazardous liquids. The pipeline routing permits issued by EQB imposes conditions for right-of-way preparation, construction, cleanup and restoration. These permits supersede and preempt local zoning and land use planning.

Planning and Research

•State Water Plan

The GWPA directed the EQB to develop a new statewide water plan and update this plan every five years to guide state water policy, programs and priorities through the 1990s. The plan was completed in 1990, and is available from EQB.

•Water Resource Monitoring

EQB is charged with the responsibility of developing a plan for monitoring the state's water resources, including coordinating all monitoring. The plan will include water quantity and quality, and specific problem sites.

•Assessments of Water Resource Research Needs and Trends

The GWPA directed EQB to assess state water research needs and priorities, and to evaluate water quality and ground water degradation trends and future water needs, including efforts to reduce, prevent, minimize and eliminate degradation of water quality. The EQB shall report these to the legislative water commission in odd-numbered years. The first assessment *1991 Minnesota Water Research Needs Assessment* was published in 1992 and is available from EQB.

Minnesota Pollution Control Agency (MPCA)

The MPCA has a major role in ground water protection by virtue of its regulatory authority. MPCA has been given broad authority under federal and state statutes to protect surface and ground water quality. This includes the authority to classify state waters, set limits for the contaminants found in water and regulate major sources, such as municipal and industrial treatment facilities, feedlots and solid and hazardous waste disposal facilities. In addition, a number of programs were transferred to the agency from the Office of Waste Management which gives the MPCA additional responsibilities in solid waste management. These are summarized below.

Monitoring and Data Management

•Integrated Ground Water Information System (IGWIS)

MPCA is automating the ground water data collected by many of its programs for greater access in a central computer database. The ten programs below are included in the system. The location of sampling points, well logs, sampling information and water quality data will be included.

•Water Quality Monitoring

Many MPCA programs require some water quality monitoring. The results must be reported to the MPCA. The programs that require such monitoring include:

- Clean Water Partnership (part of the nonpoint program does not require monitoring);
- Hazardous Waste Program;
- Property Transfer Technical Assistance (if contamination if found);
- Site Assessment Program (provides early screening of potential Superfund sites when contamination is suspected);
- Superfund Program;
- Wastewater Discharge Permits (NPDES/SDS Permit Program);
- Solid Waste Program;
- Ground Water Monitoring and Assessment Program;
- Underground Storage Tank Program; and
- Emergency Spill/Leak Program (if ground water contamination is suspected).

•STORET (EPA Storage and Retrieval) Database Data Management

This EPA-managed computer database contains data on surface water quality for lakes and rivers,

ground water quality, permit discharge quality information, and compliance monitoring data. MPCA is responsible for maintaining the data base in Minnesota. The data is available to state agencies and local governments for water resource planning purposes.

Source Management and Regulation

•Wastewater Disposal Municipal and Industrial

MPCA issues permits and regulates discharges from municipal, commercial and industrial wastewater treatment facilities to surface waters under the National Pollution Discharge Elimination System program (NPDES), and issues a State Disposal System (SDS) permit for facilities discharging on land, to surface waters or subsurfaces. These include seepage ponds, rapid infiltration basins, stabilization ponds, spray irrigation and land application of sludge. Each permit sets limits for effluent quantity, quality and monitoring requirements. The rules contain provisions for the location, design and operation of the facilities (Minn. Rules, pts. 7001.1000 to 7001.1100 and ch. 7040).

•Solid Waste Program

MPCA permits, monitors and inspects all solid waste disposal facilities, including mixed municipal solid waste, demolition debris, industrial solid waste disposal compost, refuse derived fuel, recycling facilities and solid waste transfer. The permit establishes standards for facility design, operation, monitoring and closure (Minn. Rules, ch. 7035). The agency has developed rules for mixed municipal incinerator ash disposal facilities.

•Hazardous Waste Program

MPCA permits and regulates hazardous waste facilities, including their design, ground water monitoring, waste analysis and annual reporting requirements. Hazardous waste includes any waste which may be explosive, flammable, poisonous, corrosive, oxidizing or an irritant. Generators, transporters, and treatment, storage and disposal facilities are required to obtain an EPA identification number for wastes and facilities (Minn. Rules, ch. 7045). The transporter must carry a manifest indicating the type and amounts of waste carried.

•Contaminated Sites "Superfund" Program

Under the Superfund program, MPCA has the authority to require responsible parties to undertake cleanup of hazardous waste sites where contamination threatens public health or the environment, or to use Superfund monies if responsible parties cannot or will not undertake cleanup. State Superfund monies are used when federal Superfund monies are not available or must be matched by state funds. Sites are investigated and ranked before they are placed on the state Superfund list, known as the Permanent List of Priorities (PLP). The list indicates the problem, actions taken at the site and the Hazard Ranking System (HRS) score. The agency maintains a list of federal and state priority sites. The Minnesota Department of Agriculture exercises all the same authorities where contamination involves agricultural chemicals.

•Agricultural Waste Systems (Feedlots)

MPCA regulates animal feedlots (buildings and/or lots but not pastures) containing more than ten animal units where manure can accumulate (Minn. Rules, ch. 7020) and issues a permit or certificate of compliance. A permit is required if a new feedlot is proposed, a change in ownership occurs, an operational change occurs or a feedlot is creating a pollution hazard. Counties may choose to adopt and administer the feedlot rules. MPCA maintains a computerized inventory of permitted feedlots.

•Sanitary Sewer Extension Permits

MPCA must approve the construction, replacement and relocation of public and some private sanitary sewers. Sewers must comply with engineering specifications to minimize infiltration of ground water and leakage, Minn. Stat. 115.07.

•Storage Tanks, Above-Ground (AST) and Underground (UST)

An above-ground storage tank is any container or vessel that either dispenses or stores regulated substances. A permit is required for new tanks. Owners of existing tanks must submit a notification form for each tank by June 1, 1990 or within 30 days of installation. Some farm or residential tanks are exempt (Minn. Rules, ch. 7100). An underground tank is one with at least ten percent of its volume underground. Most tanks larger than 1100 gallons must be registered. New underground storage tanks must satisfy construction, installation and leak detection systems requirements. Tank installers and removers must be certified. The MPCA is currently developing rules governing underground storage tanks. The MPCA maintains inventories of known tanks. The agency works with tank owners and operators to secure the cleanup of contaminants from leaking storage tanks. State funds may be available to pay for part of the costs. (See discussion of Petrofund on following page).

•Household Hazardous Waste Management

The purpose of this program is to reduce the amount of hazardous waste and find alternative methods for the safe disposal of the small amounts of hazardous wastes generally found in homes that formerly were deposited in landfills. MPCA is charged with developing a statewide program including collection sites, technical assistance, and public education and information regarding the proper management of the material.

•Individual On-Site Sewage Treatment Systems (ISTS)

MPCA has adopted minimum standards for the design, location, installation, use and maintenance of individual treatment systems, including septic tanks that serve residential and commercial uses. Unless a local unit of government adopts the standards, they are only advisory. The MDNR requires these standards to be incorporated in local floodplain and shoreland regulations, as well as state wild and scenic river land use districts. The Metropolitan Council of the Twin Cities recommends that local governments adopt the rules as part of a comprehensive management program for on-site sewage treatment system. In addition, an NPDES or SDS permit may be required for systems generating more than 10,000 gallons per day, or a maximum average daily flow greater than 15,000 gallons per day (Minn. Rules, ch. 7080).

•Emergency Spill and Leak Response

Persons or parties responsible for a leak or spill are required to report it to the MPCA and take prompt action to clean it up. This could involve train or truck accidents, pipeline breaks or dumped barrels. The agency oversees the cleanup and may take legal action to recover costs. The agency works with local emergency response personnel.

•Voluntary Investigation and Clean Up Program

The MPCA provides assistance to property owners and buyers in determining the existence or potential contamination of a parcel. If the parties decide to do a site investigation or clean-up of minor contamination, the MPCA will provide technical review and oversight on a fee basis.

•Agricultural and Storm Water Drainage Wells

State rules prohibit the discharge of sewage, industrial waste or other wastes into the saturated zone via injection wells (Minn. Rules, pt. 7060.0600). Any applications are referred to the EPA, which is the federal agency administering the regulatory program. The Minnesota Department of Health enforces rules that prohibit drainage wells for the disposal of surface water, ground water or any liquid, chemical or gas (Minn. Rules, pt. 4725.2300).

•Water Quality Standards

MPCA is authorized to regulate surface and ground water quality. In the former instance, the state and EPA authorize the agency to classify surface waters based on their use and establish limits for contaminants in these waters (Minn. Rules, ch. 7050). Minn. Rules, Ch. 7060, establishes general standards and requirements for the protection of ground water. Currently, a non-degradation policy applies to all ground waters in the state.

Planning and Research

As part of the reorganization of the Office of Waste Management, MPCA now oversees the development of county solid waste management plans. Counties must prepare a ten-year plan to receive certain types of financial assistance for program implementation. MPCA will review the county plans.

Financial Assistance

•Clean Water Partnership Program

The MPCA provides state grants on a 50/50 matching basis, and technical assistance for those local units of government who wish to protect or improve lakes, streams and ground water affected by nonpoint source pollution. Funding is made available for two phases. The first is for a diagnostic study, including data gathering, identification of problems, development of goals and objectives and development of a plan. The second phase involves implementation of the plan (Minn. Rules, ch. 7076).

•Petroleum Tank Release Cleanup Fund (Petrofund)

The purpose of the fund is to assist in the cleanup of pollution resulting from leaking petroleum storage tanks. Tank owners are reimbursed for up to 90 percent of leak cleanup costs as high as $250,000. Petrofund monies are administered by the Minnesota Department of Commerce.

•State Superfund

See Contaminated Sites "Superfund" Program above.

•Assistance for New, Expanded, or Improved Wastewater Treatment Facilities

State and federal capital funds are provided through the State Revolving Fund to assist local governments in constructing and improving wastewater treatment plants. The Minnesota Public Facilities Authority (through the Department of Trade and Economic Development and MPCA) administers the revolving loan program.

•Assistance for Solid and Hazardous Waste Facilities

The MPCA now administers several programs providing financial and technical assistance to local governments and businesses that were formerly administered by the Office of Waste Management.

Research

•Nitrogen Compounds in Ground Water Study

The GWPA authorized a joint study with the MDAg to study the impact of nitrogen on ground water from a variety of sources, such as fertilizer, feedlots and septic systems. The report, which addresses trends, sources, best management practices policy and research needs, is now available.

•Development of Best Management Practices

The GWPA directed the agency to develop voluntary best management practices (BMPs) to protect ground water. With the assistance of MDAg and MDNR, the agency has produced catalogs describing BMPs for agriculture, urban areas and forest management. These are available from the agencies.

Public Information and Education

MPCA provides technical assistance to local governments in the areas of water resource planning, financial assistance and program development.

Office of Waste Management (OWM)

The agency provides technical and financial assistance to business, industry and local governments to assist them in managing solid and hazardous waste. Some of its responsibilities have been transferred to the MPCA.

Planning and Research

OWM prepares a biennial solid waste policy report for the Legislative Commission on Waste Management and an annual SCORE (Select Committee on Recycling and Environment) report that indicates statewide and county progress in meeting waste reduction goals.

Technical and Financial Assistance

The agency also administers the state Toxic Pollution Prevention Act (Minn. Stat. ch. 115D). The law requires manufacturing facilities that must file annual reports on toxic chemical emissions to develop plans to reduce or eliminate the generation or release of toxic pollutants (see Department of Public Safety). Progress reports are to be submitted to the MPCA. Technical assistance and grants for research and development are available from OWM. Pollution prevention fees, based on the number and amount of pollutants released by a given facility, are paid to OWM. In addition, fees are imposed on the state's largest generators of hazardous waste.

The OWM also provides technical and financial assistance in the areas of recycling, waste generation reduction, pollution prevention, and industrial waste reduction and management. For example, the agency provides assistance to local governments to help them reduce the generation of solid waste and to school districts to make more information on waste management available and to assist them in improving their management of solid waste. The Waste Education Clearinghouse provides information and materials on a variety of environmentally sound waste management options.

PROGRAMS OF THE UNIVERSITY OF MINNESOTA

Extension Service

The Service has offices in every county in Minnesota. Its purpose is to provide educational programs and materials on a variety of community interests, including agriculture and water quality. The Service has developed educational materials on pesticide and nutrient management, animal waste management and other ground water quality concerns. The Extension Service received funds under the GWPA to develop an urban integrated pest management program (IPM) and expand agricultural IPM activities. These will include promotional and educational materials.

Minnesota Geological Survey (MGS)

The MGS conducts investigations, mapping and interpretations of Minnesota's geology and hydrogeology, and also works on special projects with various state agencies and local governments throughout the state.

Research and Data Management

There are currently two major programs with a ground water focus: county geologic atlases and regional assessments. The county geologic atlases are detailed, systematic summaries of geologic and hydrologic conditions in an individual county. The seven atlases prepared to date include a map of areas geologically sensitive to ground water pollution. The MDNR and MGS work jointly on these projects. The MDNR provides hydrogeological data and an evaluation of geologically sensitive ground water areas, and the MGS concentrates on geologic studies and data. (See MDNR).

The regional assessment is similar to the county geologic atlases, but provide a less detailed assessment of the geology, hydrology and other information for multi-county areas. MGS has completed regional geologic and ground water sensitivity maps for the Anoka Sand Plain aquifer (Anoka, Chisago, Isanti and Sherburne counties) (see MDNR discussion). Similar studies for the Red River Valley and southwestern counties are underway in cooperation with the MDNR.

•Monitoring and Data Management

The MGS maintains geological, water level and well construction data in records and automated data bases. For example, County Well Index is a PC-based database containing up-to-date water well information such as the location, depth and static water level. The agency provides training to the public and local officials in the use of MGS files of well logs, soil borings, geological test logs, and published maps. The agency also provides geological interpretations assistance to local agencies.

APPENDIX E

GLOSSARY OF ACRONYMS

GLOSSARY OF ACRONYMS

ACCRA	Agricultural Chemical Response and Reimbursement Account
ACP	Agricultural Conservation Program
ASCS	United States Agricultural Stabilization and Conservation Service
AST	above ground storage tank
BMPs	best management practices
BWSR	Minnesota Board of Water and Soil Resources
CERCLA	U.S. Comprehensive Environmental Response, Compensation and Liability Act
CES	Cooperative Extension Service
CRP	Conservation Reserve Program
CSRS	Cooperative State Research Service
CWA	U.S. Clean Water Act of 1972
DOD	United States Department of Defense
EPA	United States Environmental Protection Agency
EQB	Minnesota Environmental Quality Board
ESAP	Minnesota Energy and Sustainable Agriculture Program
FIFRA	U.S. Federal Insecticide, Fungicide and Rodenticide Act
GIS	geographic information systems
GWPA	U.S. Ground Water Protection Act of 1989
HRL	health risk limit
HRS	hazardous ranking system
IGWIS	integrated ground water information system
IPM	integrated pest management
ISTS	individual sewage treatment system
LCMR	Legislative Commission on Minnesota Resources
LMIC	Land Management Information Center
MCLG	maximum contaminant level goals
MCLs	maximum contaminant levels
MDAg	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MDPS	Minnesota Department of Public Safety
MDPSer	Minnesota Department of Public Service
MGS	Minnesota Geological Survey
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
NPDES	National Pollution Discharge Elimination System
OTA	United States Office of Technology Assessment
OWM	Minnesota Office of Waste Management
PLP	permanent list of priorities
PUD	planned unit development
RAL	recommended allowable limit
RCRA	U.S. Resource Conservation and Recovery Act
RIM	Reinvest in Minnesota
SDS	State Disposal System

SDWA	U.S. Safe Drinking Water Act of 1974
SWCD	soil and water conservation district
SWIM	systems for water information management
TDR	transferable development rights
TSCA	U.S. Toxic Substances Control Act of 1976
TSDF	treatment, storage and disposal facilities
USDA	United States Department of Agriculture
USDA-SCS	U.S. Department of Agriculture Soil Conservation Service
USGS	United States Geological Survey
UST	underground storage tank
VOCs	volatile organic compounds
WD	watershed district
WMO	watershed management organization

BIBLIOGRAPHY

Most of the following items are referred to in the text or were used in developing the contents of the guidebook. Other items are included because they contain background information that may be useful to guidebook users.

Section 1

Freshwater Foundation, 1989. *Economic Implications of Groundwater Contamination to Companies and Cities*. Navarre, MN.

Minnesota Department of Agriculture and Department of Health, 1988. *Pesticides and Groundwater: Surveys of Selected Minnesota Wells*. St. Paul.

Minnesota Department of Health, 1988. *Noncommunity Public Water Supply Survey for Volatile Organic Chemicals*. St. Paul.

Minnesota Department of Health, 1985. *Volatile Organic Survey of Community Water Supplies*. St. Paul.

Section 2

Anderson, Mary, 1987. "Hydrogeologic Framework for Groundwater Protection," *Planning for Ground Water Protection*. ed. William Page. Department of Urban Planning and Center for Great Lakes Studies. University of Wisconsin-Milwaukee: Orlando Academic Press, Inc.

The Conservation Foundation, 1987. *Groundwater Protection*. Washington, D.C.

Heath, Ralph C., 1982. *Basic Ground Water Hydrology*. Water Supply Paper 2220. U.S. Geological Survey. Prepared in cooperation with the North Carolina Department of Natural Resources & Community Development. Alexandria, Virginia: U.S. Government Printing Office.

Jaffe, Martin and Frank Dinovo, 1987. *Local Ground Water Protection*. Chicago: American Planning Association.

Jorgensen, Eric P., 1989. *New Strategies for Ground Water Protection: The Poisoned Well*. Sierra Club and The Legal Defense Fund. Washington, D.C.: Island Press.

Minnesota Pollution Control Agency, 1989. *Protecting Minnesota's Ground Water, Non Point Source Ground Water Strategy: Issues and Recommendations*. St. Paul: Minnesota Pollution Control Agency.

Minnesota Pollution Control Agency & State Planning Agency, 1984. *Ground Water in Minnesota: A User's Guide to Understanding Minnesota's Ground Water Resource*. St. Paul.

Minnesota Department of Natural Resources, State Planning Agency and The Freshwater Foundation, 1985. *Groundwater: Understanding our Hidden Resource*. St. Paul.

Office of Research and Development, U.S. Environmental Protection Agency, 1987. *Ground Water Handbook*. Washington, D.C.

Pfannkuch, Hans-Olaf, (no date). *Basic Hydrogeology and Groundwater: A Primer*. Minneapolis: University of Minnesota.

U.S. Geological Survey & U.S. Environmental Protection Agency, 1981. *Designation of Principal Water Supply Aquifers in Minnesota*. St. Paul.

U.S. Geological Survey, U.S. Environmental Protection Agency and the Metropolitan Council of the Twin Cities, 1973. *Water Resources Outlook for the Minneapolis-St.Paul Metro Area*. St. Paul.

Wheeler, Betsy, E. Calvin Alexander, Jr. and Russell S. Adams, Jr., 1990. "Groundwater in Southeastern Minnesota Karst Country." *Center for Urban and Regional Affairs Reporter*. St. Paul: University of Minnesota.

Section 3

Agricultural Law and Policy Institute, Inc., 1988. *Farming and Groundwater: An Introduction*. Agricultural Law and Policy Institute Issues Booklet No. 1. Minneapolis.

Anderson, Mary. Op. cit.

Born, Stephen M., Douglas A. Yanggen and Alexander Zaporozec, 1987. *A Guide to Groundwater Quality Planning and Management for Local Governments.* Wisconsin Geological and Natural History Survey and Wisconsin Department of Natural Resources. Madison: Wisconsin Geological and Natural History Survey.

The Conservation Foundation. Op. cit.

Freshwater Foundation, 1988. "Nitrates and Groundwater: A Public Health Concern" (pamphlet). Navarre, Minnesota.

Jaffe, Martin and Frank Dinovo. Op. cit.

Jorgensen, Eric P. Op. cit.

Minnesota Departments of Health and Agriculture and the Freshwater Foundation, 1986. "Pesticides and Groundwater: A Health Concern for the Midwest" (pamphlet). St. Paul.

Minnesota Pollution Control Agency and Minnesota Department of Agriculture, 1991. *Nitrogen in Minnesota Ground Water*. Prepared for the Legislative Water Commission. St. Paul.

Office of Ground Water Protection, U.S. Environmental Protection Agency. February 1988. *Protecting Ground Water: Pesticides and Agricultural Practices*. Washington, D.C.

Page, G. William, 1987. "Drinking Water and Health," *Planning for Groundwater Protection.* ed. William Page. Department of Urban Planning and Center for Great Lakes Studies, University of Wisconsin-Milwaukee. Orlando: Academic Press, Inc.

U.S. Congressional Office of Technology Assessment, 1984. *Protecting the Nation's Groundwater From Contamination*. Volumes 1 and 2. Washington D.C.: U.S. Government Printing Office.

Section 4

Belgea, Lynn and Eila Sevela, 1990. *Local Protection of Ground Water.* Unpublished research paper. St. Paul: Metropolitan Council.

Bruemmer, Linda B., and Thomas P. Clark, 1984. *Ground Water in Minnesota - A User's Guide to Understanding Minnesota's Ground Water Resource*. St. Paul: Minnesota Pollution Control Agency and State Planning Agency.

Izaak Walton League of America, 1990. *A Citizen's Guide to Clean Water.* Arlington.

Jaffe, Martin, and Frank Dinovo, 1987. Op. cit.

Minnesota Board of Water and Soil Resources, 1989-91 (various issues) *Water Billboard.* In cooperation with the Minnesota Department of Health, the Minnesota State Planning Agency, the Minnesota Department of Agriculture and the Minnesota Pollution Control Agency. St. Paul.

Minnesota Department of Public Safety and Emergency Response Commission. 1990. *1989 Toxic Chemical Release Inventory - State of Minnesota.* St. Paul

Minnesota Environmental Quality Board, Water Resources Committee, 1991. *Minnesota Water Plan.* St. Paul.

Minnesota Pollution Control Agency, 1990. *1990 Catalog of Ground Water Monitoring Programs and Projects in Minnesota.* St. Paul.

Minnesota Pollution Control Agency, 1990. *Minnesota Pollution Control Agency Issue Statement.* (Unpublished) St. Paul.

Minnesota Pollution Control Agency, 1988. *Minnesota Ground Water Protection Strategy.* St. Paul.

Minnesota State Planning Agency, 1989. *The Minnesota Ground Water Protection Act of 1989 - A Summary.* St. Paul.

Office of Drinking Water, U.S. Environmental Protection Agency, 1990. "Drinking Water Regulations Under the Safe Drinking Water Act." (fact sheet) Washington, D.C.

Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency, 1989. *Status of Contaminants Regulated Under the Safe Drinking Water Act.* Washington, D.C.

Office of Ground Water Protection, U.S. Environmental Protection Agency, 1987. *EPA Activities Related to Sources of Ground Water Contamination.* Washington, D.C.

Office of Ground Water Protection, U.S. Environmental Protection Agency, 1987. *Improved Protection of Water Resources from Long-Term and Cumulative Pollution: Prevention of Ground Water Contamination in the United States.* Washington, D.C. Prepared for the Organization for Economic Co-operation and Development.

Office of Ground Water Protection, U.S. Environmental Protection Agency, 1984. *Ground Water Protection Strategy.* Washington, D.C.

Office of the Revisor of Statutes, State of Minnesota, 1991. *Minnesota Rules.* St. Paul.

Office of the Revisor of Statutes, State of Minnesota, 1990. *Minnesota Statutes.* St. Paul.

Office of Water and Ground Water Protection, U.S. Environmental Protection Agency, 1989. *Funding Ground Water Protection: A Quick Reference to Grants Available Under the Clean Water Act.* Washington, D.C.

Office of Water, U. S. Environmental Protection Agency, 1987. *Progress in Ground Water Protection and Restoration.* Washington, D.C.

Water Planning Division and Office of Solid Waste, U.S. Environmental Protection Agency, 1980. *Ground Water Protection.* A Water Quality Management Report. Washington, D.C.

Section 5

American Planning Association, April 1986. "Residential Density and Ground Water Contamination." *Zoning News.* Chicago.

American Planning Association. August, 1991. "Standards for Overlay Districts." *Zoning News.* Chicago.

Bangs., Frank S., Jr., and Conrad Bagne, eds. March 1975. *Transferable Development Rights.* Planning Advisory Service, Report No. 304. Chicago: American Planning Association.

Becker, R.L., D. Herzfeld, K.R. Ostlie, and E. J. Stamm-Katovich, 1989. *Pesticides: Surface Runoff, Leaching and Exposure Concerns.* St. Paul: Minnesota Extension Service, University of Minnesota.

Born, Stephen M., Douglas A. Youngen, Allen R. Czecholinski, Raymond J. Tierney, and Ronald G. Hennings, 1988. *Wellhead Protection Districts in Wisconsin: An Analysis and Test Applications.* Madison: University of Wisconsin Extension and Wisconsin Geological and Natural History Survey.

Brach, John, 1990. *Agriculture and Water Quality.* St. Paul: Minnesota Pollution Control Agency.

Brereton, Thomas F., 1988. "Liquid Gold." *Planning.* Chicago: American Planning Association.

Clinton River Watershed Council, 1988. *Local Government Regulations for Groundwater Protection - A Guidebook for the Control of Hazardous Substances at Business Sites.* Utica, Mich.

Dane County Regional Planning Commission, 1987. *Groundwater Protection Plan Dane County, Wisconsin.* Madison.

Dayton, City of. *Revised Code of General Ordinance.* Sections 53.01-53.06, 53.99, 150.03824-150.0383, 150.600-150.604, 150.610-150.613 and 150.620. Dayton.

Hall, Douglas L., William B. Zilli, and John M. Becker, (no date). *An Approach to Pollution Source Control.* Dayton.

Hamill, Samuel M., Jr., John C. Keene, David Kinsey and Roger K. Lewis, 1989. *The Growth Management Handbook--A Primer for Citizen and Government Planners.* Princeton: The Middlesex Somerset Mercer Regional Council.

Hanson, Mark E., and Harvey M. Jacobs, 1989. "Private Sewage System Impacts in Wisconsin--Implications for Planning and Policy." *American Planning Association Journal.* Chicago.

Harrison, Ellen Z., and Mary Ann Dickinson, (no date). *Protecting Connecticut's Groundwater - A Guide to Groundwater Protection for Local Officials.* Hartford: Connecticut Department of Environmental Protection.

Jaffe, Martin and Frank Di Novo. Op. cit.

Jackson, Gary, Dennis Keeney, David Gurren and Bruce Webendorfer, 1987. *Agricultural Management Practices to Minimize Groundwater Contamination.* Environmental Resources Center, University of Wisconsin-Extension. Madison.

Local Government Commission, 1987. *Land Use Planning for Prevention: Getting Started. Communities Controlling Toxics Project.* Sacramento.

Marathon County Planning Department, 1988. *Marathon County Groundwater Plan.* Wausau.

Metzger, Philip C., Edwin H. Clark and Geraldine Bachman, April 1986. "The Developer's Stake in Groundwater Protection," *Urban Land.*

Michigan Department of Natural Resources, 1992. *Community Planning and Zoning for Groundwater Protection in Michigan: A Guidebook for Local Officials.* Lansing.

Minneapolis Environmental Commission, (no date). *Pesticides, the Environment and You.* Minneapolis.

Minnesota Board of Water and Soil Resources, 1991. *Abandoned Well Inventory Guidebook.* St. Paul.

Minnesota Board of Water and Soil Resources, 1991. *Above and Below Ground Storage Tank Inventory Guidebook.* St. Paul.

Minnesota Board of Water and Soil Resources, 1991. *Dump and Landfill Inventory Guidebook.* St. Paul.

Minnesota Board of Water and Soil Resources, 1991. *Feedlot Inventory Guidebook.* St. Paul.

Minnesota Department of Agriculture, (no date). *Voluntary Atrazine Best Management Practices.* St. Paul.

Minnesota Department of Health, 1992. *Wellhead Protection in Minnesota. A Report of Recommendations by the Ad Hoc Wellhead Protection Policy Workgroup.* St. Paul.

Minnesota Department of Natural Resources, 1991. *Criteria and Guidelines for Assessing Geologic Sensitivity of Ground Water Resources in Minnesota.* St. Paul.

Minnesota Department of Transportation, September 14, 1986. *Maintenance Manual (5-791.330 Materials).* St. Paul.

Minnesota Environmental Quality Board, Water Resources Committee, 1988. *A Strategy for the Wise Use of Pesticides and Nutrients.* St. Paul.

Minnesota Pollution Control Agency, (no date). *Agriculture and Water Quality - Best Management Practices for Minnesota.* St. Paul.

Minnesota Pollution Control Agency, 1989. *Ground Water Contamination Susceptibility in Minnesota (Revised edition).* St. Paul.

Minnesota Pollution Control Agency, 1989. *Nonpoint Source Ground Water Strategy: Issues and Recommendations.* St. Paul.

Minnesota Pollution Control Agency and Minnesota Department of Agriculture, Dec. 1991. *Nitrogen in Minnesota Ground Water.* Prepared for the Legislative Water Commission.

The Minnesota Project, 1989. *Protecting Groundwater Through Sustainable Agriculture.* Minneapolis.

National Research Council, 1986. *Ground Water Quality Protection - State and Local Strategies.* Washington, D.C.: National Academy Press.

Nitrogen Fertilizer Task Force, 1990. *Nitrogen Fertilizer Management Plan.* St. Paul: Minnesota Department of Agriculture.

Northeast Michigan Council of Governments, 1981. *Local Strategies for Groundwater Management Project Area: Briley Township, Montgomery County, Michigan.* Gaylord, Mich.

Office of Engineering Standards-Research and Standards Division, Minnesota Department of Transportation, 1972. *Salt Brine Runoff Control at Stockpile Sites.* St. Paul.

Office of Research and Development, U.S. Environmental Protection Agency, 1983. *Ground Water Management in the Southeastern United States.* Washington, D.C.

Office of Water, U.S. Environmental Protection Agency, 1990. *A Review of Sources of Ground Water Contamination from Light Industry.* Washington, D.C.

Office of Water, U.S. Environmental Protection Agency, 1988. *Protecting Ground Water: Pesticide and Agricultural Practices.* Washington, DC.

Office of Water and Office of Groundwater Protection, U.S. Environmental Protection Agency, 1989. *Wellhead Protection Programs: Tools for Local Government.* Washington, D.C.

Office of Water and Office of Groundwater Protection, U.S. Environmental Protection Agency, 1989. *Local Financing for Wellhead Protection.* Washington, D.C.

Office of Water Research and Technology, U.S. Environmental Protection Agency, 1981. *Management Options for Ground Water in Urbanizing Areas.* Washington, D.C.

Olmsted County Water Policy Advisory Committee and Rochester/Olmsted Department of Planning and Housing, 1989. *Comprehensive Water Management Plan, Vols. I-III.* Rochester.

Osborne, Thomas J., Jenifer L. Sorenson, Mark R. Kraack, David J. Mecherich, and Michael J. Travis, 1989. *Designs for Wellhead Protection in Central Wisconsin.* Stevens Point: Central Groundwater Center, University of Wisconsin-Extension and University of Wisconsin-Stevens Point.

Portage County Planning Department, 1988. *Portage County Groundwater Management Plan, Vols. I and II.* Stevens Point.

Sanders, Welford, Dec. 1980. *The Cluster Subdivision, A Cost-effective Approach.* Planning Advisory Service 356. Chicago: American Planning Association.

Schenectady County Planning Department, (no date). *Groundwater Supply Source Protection - A Guide for Localities in Upstate New York.* Prepared for the Capital District Regional Planning Commission and the New York State Department of Environmental Conservation. Schnectady.

Shoreview, Minn., *Municipal Code, Chapter 919.*

So., Frank S., David R. Masena and Frank S. Bangs, Jr., May 1973. *Planned Unit Development Ordinances.* Planning Advisory Service 291. Chicago: American Planning Association.

Soil Conservation Service, U.S. Department of Agriculture, 1976. *Irrigation Guide.* St. Paul.

Spokane County, 1990. "Water Quality Section 10." *Spokane County Comprehensive Plan.* Spokane.

Spokane County, Wash., *Spokane County Zoning Code, Chapter 14.706.*

Spokane County Engineers Office, 1989. *Critical Materials Handbook.* Spokane: Water Quality Management Program-Coordination Office and Technical Advisory Committee.

State of Washington Department of Ecology, 1988. *Guidelines for Development of Ground Water Management Areas and Programs.* Chapter 173-100 WAC. Spokane.

Toxic Chemical Taskforce, 1990. *Pesticide and Fertilizer Use in Saint Paul.* St. Paul: City Council Investigation & Research Center.

U.S. Environmental Protection Agency, Region 1; U.S. Geological Survey, Massachusetts District Office; Massachusetts Department of Environmental Quality Engineering; Cape Cod Planning and Economic Development Commission; Town of Barnstable and Town of Eastham; 1988. *Guide to Contamination Sources for Wellhead Protection. The Cape Cod Aquifer Management Project.* Boston.

University of Minnesota Extension and Iowa State University Extension, 1991. *Turfgrass Management for Protecting Surface Water Quality.* St. Paul.

Wisconsin Geological and Natural History Survey, Rock County Health Department, University of Wisconsin-Extension and Wisconsin Department of Natural Resources, ed. A. Zaporozec, 1985. *Groundwater Protection Principles and Alternatives for Rock County, Wisconsin.* Madison: Wisconsin Geological and Natural History Survey.

White, Bernard, 1989. Septic Tank Density and Groundwater Contamination: An Annotated Bibliography. *CPL Bibliography No. 234.* Chicago: Council of Planning Librarians, American Planning Association.

Wright, Jerry, 1989. *Water Management Considerations for Sandy Soils in Minnesota*. St. Paul: Minnesota Extension Service and the University of Minnesota.

Wright, Jerry and Fred Bergsrud, 1991. *Irrigation Scheduling Checkbook Method*. St. Paul: Minnesota Extension Service and the University of Minnesota.

Yates, Marylynn, 1987. *Septic Tank Siting to Minimize Contamination of Ground Water by Microorganisms.* Washington, D.C.: Office of Groundwater Protection, U.S. Environmental Protection Agency.

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Carver County Board of Commissioners, 1992. *Carver County, Minn., Groundwater Protection Plan.* Chaska.

Geier, Theodore W., and James A. Perry, 1992. *Guide to Groundwater Sensitivity Rating Techniques.* St. Paul: Water Resources Research Center, University of Minnesota.

Headwaters Regional Development Commission and Beltrami Soil and Water Conservation District, 1989. *Beltrami County's Water Resources: A Plan for Action (Summary)*. Bemidji.

Jaffe, Martin, and Frank Di Novo. Op. cit.

Jaffe, Martin, 1987. "Data and Organizational Requirements for Local Planning." *Planning for Groundwater Protection*. William Page, ed. Orlando: Academic Press.

Jorgenson, Eric P. Op. cit.

Land Management Information Center, Department of Administration, 1991. *Spatial Data Integration Guidelines for Legislative Commission on Minnesota Resources Inventory Program.* St. Paul.

Land Management Information Center, Department of Administration, Sept. 1991. *Data Compatibility Guidelines for Water-Related Data Collection (Draft).* St. Paul.

Minnesota State Planning Agency, 1987. *The Handbook for Comprehensive Local Water Planning.* St. Paul.

Murphy, James, 1987. "Ground Water Protection - A Planning Process for Local Government." *Connecticut Government.* Storrs: University of Connecticut Institute of Public Service, Vol. 38, No. 1.

National Computer Systems-National Information Services, 1990. *Minnesota Directory of Manufacturers.* Burnsville.

Olsen, Bruce M., Eric H. Mohring and Patricia A. Bloomgren, 1987. *Using Ground Water Data for Water Planning.* Minnesota Geological Survey Series - Vol 8. St. Paul: University of Minnesota.