WELLHEAD PROTECTION WORKBOOK*

United States Environment Protection Agency Region III
January 1993

(Please check with state agencies for current information on wellhead protection activity)

CONTENTS

INTRODUCTION

This workbook provides a step-by-step approach to understanding ground water principles so that resource managers and residents can develop water resource protection programs for their local and regional aquifers. The following four steps of a successful protection program are discussed:

1) Organization of a local committee;
2) Mapping of ground water protection areas;
3) Identification of existing and potential contamination sources; and
4) Development and implementation of protection strategies.

Ground water throughout US EPA Region III occurs in several types of aquifers, or water-bearing formations, which are vulnerable in varying degrees to contamination from land uses such as agriculture, residential and commercial/industrial development. The states and territories served by US EPA Region III include: The District of Columbia, Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. Aquifers throughout Region III are located in the following distinct physiographic provinces: the Atlantic Coastal Plain, Piedmont and Blue Ridge, Nonglaciated Central Region, and the Glaciated Central region (Heath, 1984).

This workbook focuses on the protection of ground water and can be used in conjunction with the video, "The Power To Protect", a 30-minute presentation of successful case studies of ground water protection in three communities. The protection techniques described in the video can be utilized by local governments throughout EPA Region III. Information, interpretations, and graphics on ground water protection are presented with follow-up exercises, to reinforce the reader's understanding of its terminology, issues, and applications.

Local government officials will benefit from learning how land use activities controlled and permitted at the county, city, town, borough, and township levels can result in ground water contamination. Developing a ground water protection program according to the four steps listed here, will ensure the protection of a valuable natural resource - ground water.

STEP ONE: ORGANIZE A LOCAL COMMITTEE

In EPA Region III, ground water is a major source of water for domestic use, industry, and irrigation. Although major population centers such as Philadelphia, Baltimore, and Washington, D.C., rely upon surface water, almost all of the rural areas rely on ground water. For example, in the video, "The Power To Protect", the key to the success of the first town was local involvement in ground water protection issues. Local community members such as farmers, teachers, citizens, business people, and public officials joined together to develop a ground water protection program and to resolve the pesticide contamination problem. The second example shows the importance of involving local businesses in ground water protection. Businesses are often excluded from the process, which can lead to divisions in the community and, in some instances, the failure to adopt the ground water protection plan. The third example on the video deals with regional ground water management issues. In this case, an aquifer crosses town boundaries and coordination is required between the local officials of both towns. Because aquifers and wellhead protection areas frequently cross political boundaries, the cooperation of neighboring municipalities will be important to the protection of these areas.

Rural areas that rely completely on ground water can use this document to help organize and conduct a local wellhead protection program. It is in these small towns, villages, and communities that protection of ground water quality is most important.

1. Identify Key Individuals - In order to establish a successful ground water protection committee, first identify (hose individuals who should be active participants in the development and implementation of the plan. These key individuals may be public officials, representatives of agriculture and industry, special interest group leaders, and representatives from other communities in the region. They may include any of the following:

• Local Public Officials
• Board or department of water supply representatives
• Planning commissioners
• Wetlands commissioners
• Soil and erosion control officials
• Chief elected official
• Environmental commissioners
• Fire officials, emergency management officials
• Special Interests
• Private Water suppliers
• Agricultural representatives
• Chambers of commerce
• Developers
• Industry representatives
• Watershed associations
• Representatives of local military installations
• Schools and universities
• Community Groups
• Senior citizens/retired persons
• League of Women Voters
• Neighborhood associations

• Outside Groups

2. Goal Setting - Ground water protection should be one of the highest priorities for a local community. It is important for a community to prioritize threats to ground water, from most critical to least significant, in order to make the best use of limited funding and staff. More comprehensive protection program elements may always be added in the future as resources allow. Setting priorities should be completed by the protection committee early in its agenda, to focus action where it is most needed. Most ground water quality protection programs include the following criteria:

• Officials of neighboring towns
• County planning officials
• State water resource management representatives
• State land use representatives
• State Department of Health representatives
• Environmental organizations such as The Nature
    Conservancy, Audubon, Sierra Club, etc.
• Federal water resource management representatives
• Health hazards posed by the activity and the materials handled;
• Proximity of the site to the water supply well, or spring, or the aquifer;
• Number of people likely to be affected by ground water contamination and;
• Geologic conditions making the aquifer sensitive to con lamination.

Making a list of ground water priorities will help identify ground water controls and management approaches that are necessary. A well documented goal-setting process may eliminate possible challenges from the public as to why certain activities must be regulated and others not.

3. Coordination with State and Federal Agencies - While local governments may have control over land uses throughmechanisms such as zoning and health regulations, a successful local ground water protection program must coordinate with relevant county, state, and federal agencies. Each state in EPA Region III has designated an agency with the primary role of protecting and regulating ground water quality. Each state manages ground water a little bit differently. For example, in Virginia Department of Environmental Quality issues ground water withdrawal permits in certain areas of the state and issues pollution abatement permits to facilities that may discharge pollutants to ground water from pits, ponds, or lagoons. The Virginia Department of Waste Management regulates the siting and operation of landfills. The Virginia Department of Health enforces the Safe Drinking Water Act requirements on public water suppliers.

For additional information on wellhead and source water protection at state agencies in EPA Region III see Appendix A.

4. Develop a Protection Plan - After the protection committee has set its priorities, a protection plan should be developed. Early committee meetings should identify existing local ground water protection programs and review the community's land use authorities. The community should develop strategies to ensure implementation of the protection program and to ensure adequate financial support.

The committee should review the activities, effectiveness, and enforcement of current programs (local, county, state, federal) that operate to protect ground water. State and local program managers should be invited to provide a brief summary presentation of how their program works to protect ground water quality, and to make any suggestions they would have for the community. This approach helps to generate support and interest in the committee's efforts and to eliminate concerns over program responsibilities.

Local regulatory powers must also be reviewed early in the process. The committee must clearly understand which agencies have the authority to regulate potential contamination sources or the siting of water supplies. For example, it would be useful to determine who has the authority to limit the number and/or density of septic systems in delineated ground water or wellhead protection areas. One way to organize this review is to list local land uses and note which agency currently controls each category in your community. The authority may currently exist to regulate many of the land use activities of concern, but specific regulations may not have been developed to exercise this authority.

Recently, some states in EPA Region III have proposed or enacted legislation that will enhance ground water protection in their states. West Virginia enacted a comprehensive law in 1991 called *"The West Virginia Ground Water Protection Act"*. Delaware has proposed specific wellhead protection legislation. Pennsylvania is considering a new law that would establish nitrogen loading limits in wellhead protection areas.

How the local ground water protection plan will be implemented is also an important initial issue for the committee to consider. A budget should be developed with resources (dollars and staff time) devoted to each task, such as mapping, contamination source inventories, development of specific control measures, and implementation. A properly designed ground water protection plan should have financial support to ensure that the plan is implemented. A phased approach might be necessary because of resource constraints. Therefore, implementation should be considered as a strategic, long-term effort.

STEP TWO: MAP THE GROUND WATER PROTECTION AREAS

As part of ground water protection plan development, the area to be protected must be identified. This requires collection and analysis of general and technical information about the aquifer and water resource system. The information is also used to determine which policies and goals will be selected in the community. The following section provides an introduction to ground water terminology and an overview of ground water mapping techniques.

Ground Water Terminology

<u>Ground water</u> is the water that fills (or saturates) the pore spaces between sand, silt, or clay particles, or in bedrock fractures below the water.

The rocks and sediments through which ground water moves, and from which usable quantities of ground water can be extracted, are called <u>aquifers</u>, Aquifers can exist under either unconfined or confined conditions. Unconfined (or water table) aquifers exist where the ground water is in contact with atmospheric pressure.

The portion of the subsurface which is saturated with ground water is known as the <u>zone of saturation</u>. The top of the zone of saturation (at atmospheric pressure) is the water table. The soils or rock formations above the water table contain both water and air. This layer is therefore known as the <u>zone of aeration</u>.

Ground Water levels usually fluctuate with seasonal changes in recharge (Figure 2). During the winter months and early spring, transpiration rates are low and a larger portion of precipitation reaches the water table as recharge. Heavy withdrawals (pumping) and high evapotranspiration during the summer lower the water table to its lowest point, which usually occurs in the fall.

Water table elevations can fluctuate in response to changes in precipitation, evaporation, uptake by plants (transpiration), and withdrawals for public water supplies, industrial use, and irrigation.

Water Table Fluctuations

Confined aquifers exist where the ground water system is overlain or crossed by a confining bed, made up of a low-permeability geologic deposit such as silts and clays. In these settings, the ground water in the confined aquifer is commonly under pressure. An aquifer is defined as confined, or artesian, if water (as in a well) rises above the level at which it is first encountered in the aquifer. The artesian pressure is the elevation to which water rises within the well. This elevation to which water would rise above an aquifer is known as the Potentiometric surface. When wells are constructed in confined aquifers which are under great pressure, water will rise to the top of the well and flaw out at the land surface. These wells are called flowing artesian wells.

Aquifer Types

Many aquifers in EPA Region III are confined in the Atlantic Coastal Plain where accumulated layers of marine clay sediments form confining layers of low permeability (See Appendix A). Many communities use bedrock wells which may also be confined.

The source of ground water can be precipitation or surface water, which percolates downward into the aquifer. Precipitation can vary widely due to local conditions across the area. The annual average precipitation in Region III ranges from 42-44 inches. From Pennsylvania to Virginia, approximately 40% of the precipitation that occurs is returned to the atmosphere via evapotranspiration, 20% becomes surface runoff, and 40% recharges the aquifers.

Ground Water Movement

The surface of the water table can be measured with the installation of monitoring wells. These elevations are used to produce a water table map which shows the slope of the water table (see Figure 4). Such a map is a series of contours of equal elevation below the ground level, similar to a topographic map of the land surface. Ground water flaws perpendicular to the water table contours and moves downgradient to areas of lower water table elevations.

The need for an aquifer protection area versus a wellhead protection area is determined by local hydrogeology, water use, and potential sources of contamination. A community must also determine whether private water wells are to be included in the protection program along with the public water sources.

Both existing and future water supply sources should be considered in the protection planning process. If local zoning allows further development, increased water supplies will also be necessary. Water supply demand continues to grow in most areas of EPA Region III. This demand will require the identification and development of new public water supply wells. If potential new well sites have not been identified, an aquifer protection area may be required to ensure good quality water for the future.

Wellhead Protection Areas

Wellhead protection areas (WHPAs) are defined in the 1986 Safe Drinking Water Act as: "the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield."
The wellhead protection areas are also commonly referred to as zones of contribution, zones of influence, or recharge areas.

Wellhead protection areas are identified from analysis of both natural ground water flow conditions and the impacts of pumping wells. Pumping causes a drawdown of the water table, the extent of which is termed the "zone of influence". That portion of the zone of influence that flows to the pumping well, and other ground water which naturally flows to the well, comprise the wellhead protection area or zone of contribution.

The protection zones or WHPAs may be delineated using various criteria such as setback distances from drinking water sources to prevent contamination, time of travel for contaminants to move to a wellhead, the extent of drawdown, assimilative capacity, or flow boundaries.

Wellhead Protection Area

conservative, or largest, setback distance should be used for the WHPA if a combination of contaminant threats are to be addressed.

Time of travel (TOT) is a more frequently used measurement. Using a time of travel criterion, the protection zone is defined in terms of time required for a contaminant or water to reach the well (e.g. 30, 60, 90 days, or 1, 3, S years). Once a time measure is established, then the corresponding distance from the well can be calculated and plotted on a map. For example, if ground water travels at 10 feet per day, in 1 year it will travel 3,650 feet. If 1 year is selected as the threshold, the WHPA would extend 3,650 feet in all directions from the well.

Setback distances are the most elementary protection measures and are effective only for direct physical threats to a well or for prevention of microbial contamination. For example, a circular fence around a wellhead at a distance of 400 feet may keep out vandals and prevent spills of chemicals near the well. Also, since bacteria and viruses are usually attenuated in unsaturated soil, a setback distance between the well and septic systems or other sewage treatment facilities may prevent microbial degradation of the water quality. Clearly, the most

Other methods require the measurement of the zone of influence or drawdown area in the field with the installation of monitoring wells. Analytical models or computer models can also be used to predict the drawdown.

WHPAs can also be delineated using the criterion of assimilative capacity: the WHPA is delineated to include sufficient land area and associated ground water for neutralization of potential contaminants by natural assimilative processes including dilution, decomposition, adsorption, and volatilization. Since the fate and transport processes for various contaminants may not be definitively known, use of this criterion may be risky. Using this criterion also assumes that low levels of contaminants are acceptable, which may not be true politically or scientifically, especially for newer contaminants where health effects at various concentrations are not well documented. This process may work best for contamination sources such as septic systems, where loading rates can be calculated for septic system effluent.

Lastly, flow boundaries may be used as a delineation criterion. Such boundaries may be natural hydrogeological divides (e.g. topographical), or ground water divides induced by pumping.

Delineation methods range from drawing a circle of fixed radius around the wellhead to development of variously shaped areas using computer modelling. The type of ground water system, and the availability of hydrologic data, funding, and time influence the choice of delineation method. Assistance is available from the state and regional EPA offices.

Maryland Wellhead Protection Delineations

Maryland provides a very good example of haw a state in EPA Region III can address very complex geologic conditions in developing wellhead protection efforts. The State of Maryland extends across five physiographic provinces. The result is highly variable hydrogeologic settings. The Maryland Department of the Environment (MDE) has conducted several delineation demonstration projects throughout the state in these different aquifer settings. The MDE established that a semi-analytical approach using an EPA ground water flow computer model called "WHPA" is the best approach for most settings in Maryland. In addition, an analytical method used in Florida to calculate recharge areas to wells was compared. One-year and ten-year time of travel (TOT) zones were calculated using both methods. The MDE recommended a 10-year TOT criterion for delineation. Hydrogeologic mapping helped to identify boundary conditions at each of the sites.

Delaware Wellhead Protection Delineations

Delaware has a two-phase delineation process. The first is a preliminary (notice of boundaries) and the second is a more accurate and enforceable zone. The Delaware Department of Natural Resources and Environmental Control (DNREC) will use the WHPA code and the simplified variable shape method to delineate a S-year TOT. More detailed site-specific information will be used for the phase II delineations. Non-community public water supply wells will have a default radius of ISO feet, which corresponds with current water well regulations requiring 150 feet between wells and any source of contamination. DNREC is planning to input all of the delineations into a state computer mapping system called MAIS. Phase I maps will be distributed to the communities to allow public input and use of the delineations in planning.

EXAMPLE OF MAPPING THE GROUND WATER PROTECTION AREAS.

The following figure shows an example of mapping ground water protection areas in a semi-confined Coastal Plain aquifer in Pocomoke City, Maryland. The water supply wells for the City tap the Pocomoke Aquifer which is approximately 46 feet thick. Above the aquifer are layers of silts and clays that act as a confining layer. These confining units serve to provide a natural barrier that retards the movement of contaminants down to the Pakomoke Aquifer. Estimates of the TOT through this material will be determined from more detailed studies.

Pocomoke City Wellhead Protection Area

Water in a perched aquifer is derived from recharge through the land that directly overlies the impermeable perching layer, a map of the perching layer can serve also as the ground water protection area.

COLLECTING INFORMATION

Ground water information useful for delineation may be available from a variety of sources. Useful information may include the following:

- U.S. Geological Survey reports
- Pumping test data
- U.S. Geological Survey topographic maps
- Water table maps
- Geologic maps
- Saturated thickness and transmissivity maps
- Hydraulic connection between surface water and aquifers
- Areas of discharge, recharge, and retention
- Locations of wells, construction details, and pumping rates
- Precipitation data
- Surface and ground water quality (laboratory test results)
- Land uses
- Contamination threats
- Water budgets

Information Sources

Local, state, county, and federal agencies such as the Department of Health, the Department or Board of Water Supply, the Department of Land and Natural Resources, the U.S. Geological Survey, the U.S. Soil Conservation Service, River Basin Commissions, and the National Park Service may be able to provide useful information. Private sources such as environmental advocate organizations, industrial or agricultural water users, and developers may also be information sources. This is another reason to ensure all sectors of the local economy are represented in the ground water protection program (see Step 1, above). Collection of hydrogeological information can be costly; time and money may be saved by locating existing reports rather than commissioning new studies.

Test yourself on your knowledge of ground water concepts and protection area mapping (answers are found in Appendix B).

1. Water that completely saturates between gravel, sand, slit or clay particles, or in bedrock fractures, !n the subsurface environment, is called____.

2. The upper elevation of the saturated zone is referred to ____________________________.

3. Ground water elevations may fluctuate with or with ________________________________.

4. Ground water flows relative to water table contours _________________________________.

5. A geologic formation capable of yielding a usable amount of water is called an ______________.

6. Coastal Plain aquifers may be confined by _______________________________________.

7. A "zone of influence" is created when a well is _________________________________.

8. A wellhead protection area may be based on criteria such ______________________.

9. The pressure surface measured from wells located in confined aquifers is called a _________________surface.

STEP THREE: CONTAMINATION THREATS

Once ground water protection areas have been identified, threats to water quality should be inventoried. (Threats to water quantity may also be a concern, but are not discussed here). This inventory should identify past, present, and potential future sources of contamination. Many activity on the land surface that disposes of, produces, stores, uses, treats, or transports chemicals has the potential to contaminate ground water. Whether a potential threat becomes an actual one is determined in part by the type of activity and its duration.

Precipitation falling on the land may infiltrate and carry contaminants into the saturated zone, where they move with the ground water flow system. Figure 11 shows how a landfill can contaminate ground water as it is drawn toward a pumping well. In some cases, injection wells and abandoned wells may serve as conduits for contaminant movement from the land's surface into the underlying ground water.

How these contaminants react in ground water may influence the severity of its threat to water quality. Contaminants behave differently in the ground water environment due to their chemistry.

Contaminants can be generally classified into floaters, mixers, or sinkers. Floaters are compounds less dense than water, such as petroleum hydrocarbons, that tend to float on the surface of the water table. Mixers are compounds, such as salts or nitrate-nitrogen, that readily dissolve in ground water. Sinkers, such as chlorinated hydrocarbons, are more dense than waterand tend to sink to the bottom of the aquifer.

Ground Water Contamination in Wellhead Protection Area

The following is a list of common sources of groundwater contamination, organized by the following activity categories: agricultural, commercial, industrial, residential, and waste management. Some of these activities directly discharge into the ground water system.

COMMON SOURCES OE SOURCE WATER CONTAMINATION

AGRICULTURAL

•Animal burial areas
•Animal feedlots
•Chemical storage areas
• Irrigation
• Manure spreading and pesticides
• Pesticides and fertilizers

COMMERCIAL

• Airport
• Auto repair shops
• Boat yard
• Construction Areas
• Car Washes
• Cemeteries
• Dry cleaning establishments
• Gas stations
• Golf courses (chemical application)
• Jewelry and metal plating
• Laundromats
• Medical institutions
• Paint shops
• Photography establishments/printers
• Railroad tracks and yard/maintenance Research laboratories
• Road deicing operations (e.g. road salt)
• Scrap and junkyards
• Storage tanks and pipe (i.e. above-ground, below-ground, underground)

INDUSTRIAL

• Asphalt plants
• Chemical manufacture, warehousing, and distribution activities
• Electrical and electronic products and manufacturing
• Electroplaters and metal fabricators
• Foundries
• Fire training facilities
• Machine and metal working shops
• Manufacturing and distribution for cleaning supplies
• Mining (surface and underground) and mine drainage
• Petroleum products production, storage and distribution centers
• Pipelines (e.g. oil, gas, coal, slurry)
• Septage lagoons and sludge
• Storage tanks (i.e. above ground, below-ground, underground)
• Toxic and hazardous spills
• Wells - Operating and abandoned (e.g. oil, gas, water supply, injection, monitoring, and exploration)
• Wood Preserving facilities

RESIDENTIAL

• Fuel storage systems
• Furniture and wood strippers and finishers
• Household hazardous products
• Residential lawns (chemical application)
• Septic systems, cesspools, water softeners
• Sewer lines
• Swimming Pools

WASTE MANAGEMENT

• Hazardous waste management units (e.g., landfills, land treatment areas, surface impoundment's, waste piles, incinerators, treatment tanks)
• Municipal incinerators
• Municipal landfills
•Municipal wastewater and sewer lines
•Open burning sites
•Recycling and reduction facilities
•Stormwater drains, retention basins, transfer stations

Other contaminants occur on the land surface, where normal infiltration of precipitation or runoff can move contaminants to ground water (e.g. land application of sludge, landfills, pesticide applications). Other activities discharge to the land surface or subsurface only if an accident occurs, but are a threat in protection areas because of the type of chemicals involved (e.g. pipelines and underground storage tanks).

Water Quality Threats in EPA Region III

EPA Region III not only has varied hydrogeologic settings, but also a wide range of contamination sources that have the potential to impact ground water quality. Agriculture is a very important industry for the states of Delaware, Pennsylvania, Maryland, and Virginia. Much of the land area in these states is in agriculture. The use of agricultural chemicals (pesticides and fertilizers) can have a major influence on ground water quality. For example, the Lancaster area of Pennsylvania has been documented as having serious nitrogen contamination in ground water as a result of agricultural operations.

The poultry industry is very important in Delaware and Virginia. Thedisposal of animal wastes can cause ground water contamination problems if done improperly. New methods of composting and reusing animal wastes and animal carcasses are becoming the accepted practice, replacing mass burial pits and waste stockpiles.

Coal mining in West Virginia and Pennsylvania has resulted in ground water contamination from mine wastes and mine drainage. Highly acidic mine waste water can be discharged to surface streams or ground water and cause considerable amounts of contamination. Abandoned oil wells in Pennsylvania have been known to act as pathways for contaminants to move into aquifers.

Conducting an inventory of potential contamination sources within protection areas requires an examination of land uses. The first step is to obtain or develop a base map for the area; assessor's maps or maps from a geographic information system (if available, see below) are appropriate. Land use information may be obtained from the local planning department or tax assessor. Other types of relevant information may be available from state and local agencies. This information may include the following:

- Ground water discharge permits
- Industrial or agricultural chemical surveys: locations of continuous usage, handling, and storage of industrial and toxic chemicals
- Underground injection well data
- Emergency management and response data, Superfund Amendments Reauthorization Act (SARA) Title III data
- Solid waste facility locations

- Hazardous waste generators, storage and transport practices
- Petroleum storage locations
- Petroleum and chemical spill or leak locations
- Hazardous substance storage locations
- Radioactive waste storage locations

All of the above information may be available, provided one can identify the officials able to supply the information in a usable format.

Many states and some local governments are developing computerized mapping systems called geographic information systems (GIS). The GIS technology allows the collection and graphical display of large volumes of data. Information from a GIS system can be layered on maps of wellhead protection areas showing various contamination threats. Information on the contamination source, such as its age, discharge volume, and owner, can be easily accessed and displayed. U.S. EPA Region III Ground Water Office has a GIS system that can be accessed for ground water protection projects. New Castle County, Delaware, has an active GIS program that allows the County to map ground water resource areas and assess potential ground water quality threats. Carroll County, Maryland, is also using a GIS approach to implement a comprehensive water resource protection program. Project reviews are also made easier by viewing many data sources on one graphical display system.

In addition to the above information sources, local governments often maintain records on many different contamination sources. Health departments may maintain records of the locations of septic systems and private wells. The town may also maintain maps of the sewer and water distribution systems.

If computerized overlay maps are not available, the combination of the above types of information can be displayed on clear plastic overlays that fit over the base map. This procedure provides an easy way to visualize the many threats to ground water quality and to plan management approaches.

Site specific information may have to be collected. If sufficient informational detail is not available, a survey of residents or field inspections may be required to document the likelihood of contamination. Some communities have effectively used volunteers to conduct contamination source inventories. For example, the City of El Paso, Texas, used retired senior citizen volunteers to canvas neighborhoods, interview residents, and record potential sources of contamination. (The volunteers were located through the Retired Senior Volunteers Program, RSVP, a nationwide program with local branches.) In the video, "The Power to Protect", the Whatley Protection Committee distributed a questionnaire asking residents to list hazards to ground water quality, such as underground stage tanks.

Potential Future Contamination Threats

After existing contamination sources are identified, future threats to ground water quality should also be addressed. The community master plan or zoning regulations should be analyzed to determine likely future development and associated impacts. The zoning map should be viewed as the "blueprint" by which the community will develop and grow. The maximum amount of facilities that can be built according to the zoning is also important to consider. Far example, septic systems may become a threat when the density of systems exceeds the land's capacity to assimilate the waste.

Mapping allows for identification of incompatible zoning within wellhead or aquifer protection areas. For example, areas zoned for industrial development within protection areas may be shown. If major industrial facilities are allowed to be located in ground water resource areas, then contamination of the ground water in the future may be very likely. Changes in zoning to eliminate future land use threats or the development of other management controls such as performance standards can provide appropriate protection for public water supply wells and springs.

Step Three Questions

1. Would the type of product (gasoline, solvents, heating oil) In the tank have any effect on the decision as to which well would be affected? It yes, how so?

2. Agricultural operations are likely to contaminate groundwater from______and___________.

3. Nitrogen contamination In ground water is most likely to float, mix or sink in an aquifer.

4. Poultry waste products (manure and dead animals) can best be managed by___________and then land application.

5. Mining activities in Pennsylvania and W. Virginia can impact ground water quality from the disposal of__________.

6. Zoning maps and ordinances act as the ___________ by which a community eventually grows.

7. Zoning can/cannot be changed to eliminate a potential land use conflict with water resource protection.

8. Conducting contamination source inventories require the collection of information from many different agencies and organizations. The computerized graphical display of this information is called______.

STEP FOUR: TOOLS FOR GROUND WATER PROTECTION; DEVELOPMENT AND IMPLEMENTATION OF PROTECTION STRATEGIES

Which Management Approach?

Once local goals and objectives for ground water protection have been defined, protection areas delineated, sources of contamination inventoried and assessed, then management and protection techniques can be developed. Local and county governments in EPA Region III have many options available to manage existing sources of contamination and to ensure that future land use activities do not pose a threat to ground water quality.

Selection of appropriate management technique should be based upon the hydrogeologic and socio-political situation. Health, zoning, arid subdivision regulations, and voluntary controls are the possible management options which may be selected. Health regulations can address both proposed and existing development and their impacts on ground water quality. Zoning controls are limited in that they only apply to future development and not to existing activities which are exempt or "grandfathered". Voluntary (or non-regulatory) controls may include educational efforts, monitoring, the adoption of certain best management practices, and land acquisition.

The strategy selected will also determine which local agency should bear responsibility. For example, if underground petroleum storage tanks are considered a threat, then the local fire official should be involved in the planning of any regulatory measures. It would also be valuable to gather support from local businesses that may be affected by new underground tank controls.

Historically, county and local governments in EPA Region III have used zoning to protect water resources from both point source (direct discharges such as sewage outfalls) and non-point source (septic systems) contamination. Large lot zoning, prohibition of various noxious uses such as landfills, and overlay districts are three of the more common tools that communities have used to protect ground water. For example, the Littleton, Massachusetts example in the video, showed how an aquifer zoning overlay district was developed to maintain the existing high quality of the local water supply.

In Pennsylvania, several local governments (Dover Township, Elizabethtown, Cranberry Township, and State College) are developing overlay zoning approaches for ground water protection. However, a comprehensive approach to the protection and management of the ground water resource is more effective than the use of individual zoning techniques. Counties must develop comprehensive land and water resource protection programs that go beyond simple zoning approaches. A broad range of regulatory and non-regulatory techniques is usually required. The following pages present a summary of each of the tools that are available.

REGULATORY

Some Guidelines for Writing Ground Water Protection Regulations

The most difficult part of the ground water protection process is developing regulations--ordinances and bylaws-designed to correlate with mapped ground water or wellhead protection areas. With increasing attention focused on the extent to which government can regulate private property, it is important that planners and regulators in Region III develop regulations that will sustain court scrutiny. The following are key questions regarding the defensibility of a ground- water protection regulation.

1. Does your government (either local or county) have the authority to regulate for ground water protection?

While governments generally have the ability to protect ground water resources, the power to regulate land uses, issue permits or assess fines for violations may be limited to specific boards or agencies. Make sure you have identified the enabling statute that your proposed regulation is working under and the appropriate board or agency that will assume each new ground water protection regulation(s).

2. Does your regulation(s) directly address the problem to be solved?

This question is best addressed by including a purpose or intent statement in the ordinance and then ensuring that all aspects of the regulation are focused on the overall purpose or intention. For example, "It is the purpose and intent of this Ordinance to protect the ground waters of _____ by regulating land use and development within areas identified as wellhead protection zones more fully described....."

3. Is your regulation in compliance with procedural requirements specified by the enabling legislation?

State statutes set forth procedural guidelines for the adoption and amendment of regulations, holding of public hearings, public notice requirements and so on. Unfortunately, too often these requirements are not taken seriously. And while regulations that are invalidated by courts on procedural grounds rarely make the news, they far outnumber the regulations thrown out due to substantive reasons.

4. Is the regulation based on defensible technical data including delineation of ground water protection areas and contaminant source?

Protecting ground water requires the "marriage" of science, planning, and law. The most logical plans and well drafted ordinances may still fail if the delineation is inaccurate, arbitrary, or inconsistent with known facts. If your regulation is based on an interim delineation the ordinance should reflect this and allow for more refined delineations at some point in the future.

5. Does your regulation limit itself to the protection of known ground and/or surface water resources?

Remember, the regulations should apply only to those areas of the community that lie within the delineated or mapped areas. Even if the entire community overlies a productive aquifer, be careful that the regulation is not overly broad, so broad that the regulation can be successfully challenged.

6. Does your regulation contain a severability clause?

Severability clauses allow the court to sever individual sections of the ordinance from the body of the regulation, usually without invalidating the whole. These clauses don't always work, but are a good idea, particularly for long, cumbersome regulations.

7. Does the regulation provide for enforcement and penalties?

What good is the regulation if it cannot be enforced or if penalties cannot be assessed? Make sure the board or agency assigned to enforce the regulation has the power to do so. Similarly, make sure the penalties the board can levy are within the allowable limits established by the enabling legislation.

REGULATORY MANAGEMENT APPROACHES

A. Zoning

1. Overlay Water Resource Protection Districts
2. Prohibition of Various Land Uses
3. Special Permitting
4. Large Lot Zoning
5. Transfer of Development Rights
6. Cluster/Planned Unit Developments
7. Growth Controls/Timing
8. Performance Standards

A. Zoning regulation has been used in many communities in EPA Region III to segregate potentially conflicting activities into different areas of a community. Zoning can be limited in its effectiveness for ground water protection, however, because state statutes provide "grandfather" protection-protection for pre-existing uses and structures from newly enacted zoning regulations. Because zoning can be changed, current zoning may not necessarily dictate future land use. In each of the states within EPA Region III, zoning is adopted at the county or community level. In Pennsylvania, municipalities have the authority to zone, while Maryland and Virginia zone at the county levels. Pennsylvania also allows joint municipal zoning ordinances that could be used for regional ground water management. Several examples of the use of joint municipal zoning ordinances for ground water protection are under way in Pennsylvania.

1. Overlay Water Resource/Aquifer Protection Districts

These ordinances and bylaws, while varying in their approach toward resource protection, are similar in their goals of defining the resource by mapping zones of contribution boundaries and enacting specific legislation for land uses and development within these boundaries (see Figures 14 and 15). For example, Salisbury, Maryland, has an overlay zoning protection district to restrict and control certain land use activities that could impact ground water quality. Accomack and Northampton Counties, Virginia, are also developing overlay zoning regulations.

2. Prohibition of Various Land Uses

Once an overlay district is established, governments have the authority to proceed with the prohibition of known ground water threats within the overlay mapped areas. Most county governments can prohibit various structures and land uses that could threaten ground water quality. While not the most creative nor effective approach toward resource protection, prohibition of land uses such as gas stations, sewage treatment plants, landfills, or others involving the use, storage, and disposal of toxic and/or hazardous materials represents an important step toward the development of a comprehensive ground water protection strategy.

3. Special Permitting

Special permits can be used to protect for water quality by regulating uses and structures that may be desirable, but that may also contaminate water. In coral districts, for example, a special permit can be required for all land uses other than low density residential uses, agricultural uses and public or quasi-public facilities. The special permit process is designed to allow certain uses only when the applicant can show that the proposed land use is in keeping with the overall intent of the zoning regulations governing the district. Clearly one intention of the regulations is that development should not negatively impact drinking water resources.

4. Large Lot Zoning

Large lot zoning, as the title implies, seeks to limit ground water resource degradation by reducing the number of buildings and, therefore, septic systems within a ground water protection area (see Figure 16). When used as part of an overall ground water protection strategy, large lot zoning within appropriate areas (wellhead protection areas or zones of contribution to public supply wells) can be an effective tool against water contamination. County and local zoning regulations define minimum lot size within development districts.

5. Transfer of Development Rights

The idea of transfer of development rights (TDR) is based on the concept that a parcel of land has a bundle of different rights associated with it. A TDR program allows a landowner to separate his or her right to develop the land, as permitted by zoning, from the other rights associated with the land, and sell those development rights.

To implement a TDR program, the local government prepares a plan designating the parcels or districts from which development rights could be transferred (a "sending" or "donor" parcel), and the parcels or districts which would receive those development rights and develop at a higher density than allowed by the underlying zoning district (a "receiving parcel"). Typically, a sending parcel or district might be perceived by the community as having importance as recharge to a public water supply or as a buffer area for a public supply well. A Development Rights receiving parcel is able, both from a physical standpoint and in terms of the community's growth program, to accommodate additional development beyond that allowed as-of-right by zoning. In selling his or her development rights, a landowner gains the cash value of whatever development rights the market associates with the land, keeps the land in a less intensive use and, presumably, continues to enjoy lower property taxes. A perpetual easement or some other development restriction would be recorded with the deed of the sending or donor parcel. The purchaser of the development rights gains the ability to develop the receiving parcel at a higher density than allowed as-of-right and can recapture the cost of the purchased development rights through the more intensive use of the receiving parcel.

The State of Maryland Agricultural Preservation Program is an excellent example of TDR use. Under a state law, counties are able to develop programs to protect prime agricultural lands from development through the use of TDRs.

6. Cluster Design

Development Rights

Standard Grid Development

Cluster Grid Development

6. Cluster Grid Development

Cluster zoning is an alternative to the standard grid-style subdivision which may allow placement of lots (and associated septic systems) outside of a mapped wellhead protection area (see Figure 18). In a cluster development, smaller building lots are allowed, with resulting land savings set aside in contiguous areas of open space. Clustering can be done at the same density that could be obtained in a grid system, or with greater density bonuses. Typically, cluster development allows shorter streets, reducing construction and maintenance costs. It provides tremendous flexibility for both the developer and community, and often allows for greater creativity in the division of large land parcels.

7. Performance Standards

Performance standards set design, engineering, or discharge requirements on facilities. Performance controls assume that most uses are allowable within a designated area, provided that the use or uses will not overload the resources. Carroll County, Maryland, is currently implementing a performance-based ground water protection program that sets nitrogen loading limitations for developments, requires setbacks between wells and potential contaminant sources, and requires industries to properly manage wastes. Activities, such as septic systems, are regulated mainly through the establishment of numerical ground water quality standards that the land developer must comply with. In addition, design standards for underground storage tanks, stonnwater drainage basins, etc., are also part of the Carroll County Ground Water Protection Program.

8. Health Regulations

a. Underground Fuel Storage Systems
b. Privately-Owned Wastewater Treatment Plants (Small
c. Sewage Treatment Plants)
d. Septic System Maintenance

The development of health regulations is an extremely effective method of rounding out a county's regulatory protection program.

a. Underground Fuel Storage System

Leaking underground fuel storage systems may be the single largest source of ground water contamination in the nation. A recent study by the Environmental Protection Agency estimates that 35% of the tanks in the ground are leaking. It is estimated that there are four million tanks in the United States. Specifically, the larger underground gasoline storage tanks associated with automotive service stations have caused numerous ground wafer contamination incidents. Pennsylvania has identified leaking underground storage tanks as the number one ground water threat.

b. Small Sewage Treatment Plants (SSTPs)

Privately-owned small sewage treatment plants, formerly referred to as "package treatment plants", have been used as a technological solution for wastewater disposal. This technology has allowed development in areas which exceed the carrying capacity of the land when using proven, conventional, wastewater disposal technologies. The effectiveness of SSTPs is more dependent on the proper functioning of more technological components than in a conventional system. SSTPs also depend on a much greater level of supervised operation and maintenance. For these reasons, SSTPs are subject to a degree of uncertainty and malfunctioning. Some communities have banned or prohibited the development of SSTPs in order to eliminate risks in critical ground water resource areas.

c. Septic System Maintenance

The maintenance of on-site septic systems is frequently overlooked. The result is typically an overloading of solids moving to the leaching compartment and subsequent clogging. When this occurs, the system needs to be rehabilitated. This is commonly done with the use of strong acids or organic solvents. These chemicals are ground water contaminants and can degrade water quality in downgradient wells. To minimize the use of such chemicals and to ensure proper maintenance of septic systems, health departments can develop voluntary septic system maintenance programs. These programs can be designed to encourage the homeowner to pump his/her septic tank and perform other maintenance that will result in a reduced risk of ground water contamination.

9. Regional Ground Water Management

Regional ground water management strategies are usually those created by individual state legislative bodies. Such regional strategies can provide a more comprehensive approach to resource protection issues, as opposed to separate local approaches. For example, three communities sharing a common aquifer for drinking water supplies may find that methods of protecting the various wellhead areas from contamination vary from community to community (see Figure 19). One town may have enacted stringent land use controls within the wellhead protection area. Another town, however, facing an economic decline, may be encouraging commercial growth in the wellhead area, particularly if it has easy access to the highway.

Because of the large aquifers found within EPA Region III, a regional approach to protection can be very beneficial. In Pennsylvania, the Municipalities Planning Code authorize joint-municipal zoning ordinances. These ordinances must be based on a joint municipal comprehensive plan.

Most of the ground water protection efforts in Virginia, Maryland, and Delaware have been at the county level. The Eastern Shore of Virginia, a two-county area, has recently completed a comprehensive groundwater protection program which includes a regional aquifer protection approach. Nationally, there are many examples of regional groundwater protection approaches requiring multi-jurisdictional cooperation, as in the Kingston, Rhode Island, example in the video.

NON-REGULATORY TECHNIQUES

Most communities across the country have relied upon traditional regulatory tools to protect water quality: zoning, subdivision, and, to some extent, health regulations. While these regulatory tools can be effective, over-reliance upon regulatory tools merely programs a municipality for development and allows little flexibility. If the original program was inaccurate, or if better information has been made available since the program was devised, the original regulations need to be amended to incorporate the new data.

Non-regulatory approaches to ground water protection have traditionally included:

1. Purchase of Land
2. Donations of Land
3. Conservation Easements
4. Public Education
5. Ground Water Monitoring

1. Purchase of Land

Many communities are committed to the acquisition of selected parcels deemed so significant to their future that they may be willing to purchase them outright, at market prices. These acquisition priorities include land within defined ground water protection areas.

Four types of land acquisition are shown below:

a. Sale at fair market value: The price a buyer is willing to pay a seller to purchase a piece of property.

b. Bargain sale: The sale of property below fair market value to a conservation organization or municipality. The difference between fair market value and the reduced price may qualify as a charitable deduction from income taxes.

c. Installment sale: The sale of property over a period of years. Installment sales allow the seller to spread the income from the sale over a several year period, thus deferring, and in some cases, reducing income taxes.

d. Sale with a reservedlife estate: The transfer of property upon the death of the individual land owner. This option allows landowners to sell or donate now, but continue to use their property during their lifetime and/or the lifetimes of other members of their immediate family. Despite the high costs of acquiring land, there are many instances where public acquisition of private property for the protection of ground water resources is the most cost-effective way to protect groundwater resources.

2. Donations

Land owners are often able to donate a piece of land (as part of a development project or an entire developable parcel) to either the community or a non-profit organization such as a local land trust. If so, they will find that giving the land for preservation costs them far less than they might think. Such a donation can yield a variety of substantial tax breaks for the land donor. The donor's initial tax benefit is the elimination of estate or capital gains taxes. In addition, the donor ceases responsibility for the real estate taxes, insurance and maintenance costs for the property. Also, the entire value of the donation can be deducted over time from federal and in many cases state income tax obligations.

3. Conservation Easements

An easement is a limited right to use or restrict land owned by someone else. Easements are either positive (rights-of-way) or negative (conservation, scenic) and may take a variety of forms. Easements can effectively assist a community in protecting land from development by restricting all or a portion of the property to open space or limited development uses. The granting of a conservation easement does not involve the transfer of ownership of the land; instead it means giving up certain development rights of the property. For example, a conservation restriction may limit the number of houses to be built upon a parcel, limit that parcel to specified types of developments, or specify that portions of the parcel within ground water protection areas remain undeveloped in perpetuity.

4. Public Education

Public education and community support are vital to any community's ground water protection effort. The

Wellhead Protection Areas

Step Four Questions

1. What non-regulatory or other approaches would you recommend to protect a well from impacts from the landfill?

2. List three land uses you would recommend prohibiting in an aquifer protection overlay district.

3. In order to manage existing (future land uses which could harm ground water, which is more appropriate - zoning or health regulations? Why?

4. Suggest two techniques you could use to manage pesticide use on a farm located partially within the wellhead protection area to the town's main water supply well.

SUMMARY: PUTTING THE PROTECTION PLAN TOGETHER

Development and implementation of a ground water protection program requires a community to gather technical and land use information from many different sources. A comprehensive program should be the ultimate goal of the community that relies upon ground water for public supply.

A comprehensive community ground water protection program can be developed by following the steps outlined in this workbook. A simplified program would consist of the following elements:

• Organize local officials, industry representatives, state officials, others
• Set goals and objectives
• Collect background information on geology, land use, and water supply
• Delineate the protection areas to public water supply wells
• Inventory contamination sources (historical, existing, and future)
• Develop protection approaches
• Adopt and implement the program.

Once a ground water protection program is developed into a written document and the protection approaches (regulatory, non-regulatory) have been prepared, public support must be generated for the implementation of the program. It is important that residents be kept abreast of progress during program development, to ensure support by all sectors and to receive additional information and suggestions.

Public education is a critical component of the program. This can include public meetings to discuss findings; local newspaper and media coverage; newsletters; water bill inserts; volunteer groups; and participation in local meetings. In addition, working with local schools can ensure that the next generation of water users will understand and value the importance of ground water protection.

Funding for local ground water protection projects can come from many sources. EPA Region III has funded six local governments with Wellhead Protection Demonstration Grants. This funding will help local governments implement wellhead protection. Projects have been funded in: Northampton - Lehigh Joint Planning Commission, PA; Baltimore County, MD; Walkersville, MD; Accomack - Northampton Counties, VA; Fincastle, VA; and Eastern Panhandle Regional District Planning Commission, WV; among other communities in the Region. Your state environmental agency may also have funding for ground water protection projects. Other agencies may also be able to provide funding assistance.

REFERENCES

American Planning Association. 1987. Local Groundwater Protection, APA, Chicago, Il,.
Cornell University. 1986. Chemical Hazards in our Groundwater, Options for Community Action, Center for Environmental Research, Cornell University, Ithaca, NY.

Delaware Department of Natural Resources and Environmental Control. 1990. Wellhead Protection Program.

Fetter, C.W. 1980. Applied Hydrogeology, Charles E. Merrill Publishing Company, Columbus, OH.

Heath, R. C.1982, Classification of Ground-Water Systems of the United States, Ground Water, v. 20, no. 4, pp 393-401.

LeGrand, H. E.,1988, Region 24, Piedmont and Blue Ridge, in W. Back, J. S. Rosenshein and P. R. Seaber, Eds., Hydrology, Geological Society of America, the Geology of North America, v. 0-2, Chapter 24, pp. 201-208.

Maryland Department of the Environment. 1991. Wellhead Protection Training Manual.

Meisler, Harold, Miller, J. A., Knobel, L. L. and Wait, R. L.1988, Region 22, Atlantic and eastern Gulf Coastal Plain, in W. Back, J. S. Rosenshein and P. R. Seaber, Eds., Hydrology, Geological Society of America, the Geology of N. America, v. 0-2, Chapter 25, pp.209-218.

National Resource Council.. 1986. Ground Water Quality Protection, State and Local Strategies, National Academy Press, Washington, DC.

Rosenshein, J. 5.1988, Region 18, Alluvial valleys, in W. Back, J. S. Rosenshein and P. R. Seaber, Eds., Hydrology, Geological Society of America, the Geology of N. America, v. 0-2, Chapter 21, pp.165-176.

Seaber, P. R., Brahana, J. V. and Hollyday, E. F.,1988, Region 23, Appalachian Plateaus and Valley and Ridge, in W. Back, J. S. Rosenshein and P. R. Seaber, Eds., Hydrology, Geological Society of America, the Geology of North America, v. 0-2, Chapter 23, pp.189200.

Todd, D.K. 1980. Groundwater Hydrogeology, 2nd Ed., Wiley and Sons, New York, NY.

* USEPA. 1990. Citizen's Guide to Ground-Water Protection, EPA 440/6-90-004.

* USEPA. 1988. Guide to Contamination Sources for Wellhead Protection, EPA 901/3-88-004, Washington, DC.

* USEPA, Office of Ground-Water Protection. 1990. A Review of Sources of Ground Water Contamination from Light Industry. EPA, Washington, DC.

* USEPA, Office of Ground-Water Protection. 1990. Guide to Ground Water Supply Contingency Planning for Local and State Governments, EPA, Washington, DC.

* USEPA, Office of Ground-Water Protection. 1986. Guidelines for Delineating Wellhead Protection Areas, EPA, Washington, DC.

* USEPA, Office of Ground-Water Protection. 1989. Local Financing for Wellhead Protection, EPA 440/6-89-001, Washington, DC.

* USEPA. 1988. Protecting Ground Water: Pesticides and Agricultural Practices, EPA 440/6-88-001, Washington, DC.

*USEPA. 1991. Protecting Local Ground-Water Supplies Through Wellhead Protection, EPA 570/9-91-007.

* USEPA. 1991. Protecting the Nation's Ground Water: EPA's Strategy for the 1990s, EPA 21Z-1020.

* USEPA, Office of Ground-Water Protection. 1986. Septic Systems and Ground Water Contamination, EPA, Washington, DC.

* USEPA, Office of Ground-Water Protection. 1989. Wellhead Protection Programs: Tools for Local Governments, EPA 440/6-89002, Washington, DC.

*USEPA. 1991. Why Do Wellhead Protection? EPA 570/9-91-014.

US Geological Survey. 1987. National Water Summary, USGS Water Supply Paper 2350, USGS, Washington, DC.

US Geological Survey. 1985. National Water Summary, USGS Water Supply Paper, USGS, Washington, DC.

Virginia Ground Water Protection Steering Committee. 1992. "Wellhead Protection: A Handbook for Local Governments in Virginia."

Virginia State Water Control Board. 1991. Report of the Ad Hoc Wellhead Protection Advisory Committee.

Wisconsin Geological and Natural History Survey. 1987, A Guide to Groundwater Quality Planning and Management for Local Governments., WGNHS, Madison, WI.

* EPA Documents can be ordered by calling (202) 260-7779.

APPENDIX A
Aquifers In EPA Region III

The states of Delaware, Maryland and the District of Columbia, Pennsylvania, Virginia, and West Virginia (U.S. Environmental Protection Agency Region III) have been divided into five distinct hydrogeologic regions for the description of ground water resources (Heath, 1982). Four of these regions form bands which roughly parallel the Atlantic coast and are from east to west, the Atlantic Coastal Plain, the Piedmont and Blue Ridge, the Appalachian Valley and Ridge, and the Appalachian Plateaus. The fifth region, the Central Glaciated Plains occurs in northern Pennsylvania.

<u>The Atlantic Coastal Plain</u>

The Atlantic Coastal Plain is a flat to gently rolling lowland region extending along the Atlantic coast from New York to Florida and around the Gulf coast to Mississippi (Figure 21). Almost all of Delaware, the eastern one third of Maryland, eastern one fifth of Virginia and a very small sliver of southeastern Pennsylvania are located in the Atlantic Coastal Plain region. The geology of this region consists of a wedge of unconsolidated and semiconsolidated beds of poorly permeable silt and clay interlayered with permeable beds of sand, gravel, and limestone of Cretaceous and Tertiary age (Meisler and others, 1988). It lies between the Atlantic shoreline and the Fall Line, where it forms a feather edge against the crystalline rocks of the Piedmont. This wedge of aquifers and confining wits deepens and thickens toward the shoreline and extends offshore beneath the continental shelf. Ground water flow through these aquifers is generally from the Fall Line in the west toward the shores of Delaware Bay, Chesapeake Bay, and the Atlantic Ocean, or west from the Delmarva Peninsula to Chesapeake Bay.

Atlantic Coastal Plain Cross Section

<u>Atlantic Coastal Plain Cross Section</u>

The aquifers receive recharge from their strips of outcrop areas on the plain or from leakage through the confining layers and become progressively deeper to the east of their outcrop (recharge) areas. The Columbia aquifer is an unconfined aquifer near the shore in eastern Virginia, Maryland and Delaware. The Chickahominy-Piney Point aquifer is an artesian aquifer in Virginia, Maryland, and Delaware with no surface outcrop or recharge area. The Magothy-Potomac aquifer crops out near the Fall Line and extends from near the Delaware River in Pennsylvania and New Jersey southward through Delaware, Maryland, and Virginia. This aquifer is unconfined in it's outcrop area and artesian to the east of the outcrop area where it is overlain by confining layers of clay and silt of low permeability. Wells in these aquifers commonly yield 100 gpm (gallons per minute) or more, and some yields may exceed 2,000 gpm (USGS,1985). Ground water is the major source of water supply for this region. Generally, as the aquifers become closer to the shoreline the water in them becomes more saline and overpumping can cause salt water intrusion .

The Piedmont and Blue Ridge

The Piedmont and Blue Ridge region lies immediately west of the Atlantic Coastal Plain region and occupies southeastern Pennsylvania, the most northern part of Delaware, central Maryland, and central Virginia (Figure 22). The region is primarily underlain by crystalline igneous and metamorphic rocks covered by a mantle of saprolite which is derived from weathering of the underlying rocks. In addition, there are several Mesozoic sedimentary basins within this region (Le Grand, 1988).

Ground water for the most part, occurs in fractures in the upper few hundred feet of the crystalline rocks which possess little intergranular porosity, and recharge of water to the fractures is transmitted through the overlying mantle of saprolite (LeGrand,1988). Precipitation infiltrates the saprnlite and is stored and gradually recharges the fractures in consolidated rock with water. In Region III, well yields are generally low, commonly in the 5-25 gpm range and suitable for individual home supplies (USGS,1985). Unlike the extensive multistate aquifer systems of the Atlantic Coastal Plain, recharge and discharge through the aquifers of the Piedmont and Blue Ridge region is within shallow, local systems which very nearly coincide with the topographic drainage basins of the numerous streams. Ground water flow is from the hills toward and into the local streams (LeGrand, 1988).

The Mesozoic age sedimentary basins in Pennsylvania, Maryland and Virginia are distinct, both in lithology and water yielding capacity from the other parts of the Piedmont and Blue Ridge region. The rocks of these basins are characteristically, but not exclusively, red in color, and they consist of layers of consolidated arkosic sandstone and conglomerate, and shale with interspersed layers (lava flows) and dikes of basalt and diabase igneous rock. The redbeds are, typically, gently inclined toward the flanks of the elongate basins which trend northeast to southwest. The red colored soils that develop over these rocks make the basins easy to recognize and differentiate from other areas of the Piedmont. Although the intergranular porosity of the sandstones has commonly been filled by rock cementing mineralization, these sediments yield more water than other rocks of the Piedmont. The common range of yields is 10-100 gpm, but some wells yield more than 1,000 gpm (USGS,1985). The major water bearing zones are bedding plane joints where vertical fracturing facilitates *flow* between the bedding plane joints and recharge from the surface. Both water table and artesian conditions are common and water from deeper zones is usually hard.

The Appalachian Vallev and Ridge

The Appalachian Valley and Ridge region lies between the Piedmont and Blue Ridge region and the Appalachian Plateaus region. It extends from eastern Pennsylvania through western Maryland, along the border between Virginia and West Virginia, and through southwestern Virginia into Tennessee. As it's name somewhat implies this region is characterized by a series of parallel valleys and ridges that trend northeast to southwest (Seaber, Brahana, and Hollyday,1988). The valleys overlie easily eroded layers of rock and the ridges are composed of resistant rock layers. Because of compressional crustal forces from the southeast and the northwest, the originally flat lying layers of limestone, dolomite shale, siltstone, sandstone, and conglomerate were folded and faulted about 250 million years ago so that the sedimentary beds are steeply inclined and their outcrop areas trend northeast to southwest. As the result of differential, valleys were formed in the outcrops of soft layers and the hard and resistant rocks comprise the ridges. This sequence of layered rocks spans the Paleozoic Epoch from the Cambrian Period to the Pennsylvanian Period.

The sandstone, limestone and dolomite aquifers have relatively large yields while the other less permeable rock layers form poor aquifers or aquitards, which in some instances act as confining layers. Because of the geologic structure of this region, the lithology and water bearing properties of the rock varies greatly across the grain of the valleys and ridges, but is relatively consistent along a valley or ridge. The shale and siltstone aquifers have yields similar to the crystalline rock of the Piedmont region (5-25 gpm). The limestone and dolomite aquifers yield 5-500 gpm, but the sandstones commonly yield 1-SO gpm (USGS, 1985). Solution enlargement has increased the secondary porosity of the limestone and dolomite in many localities accounting for the higher yields from these soluble rock aquifers. Some intergranular or primary porosity and a high degree of fracturing in the brittle sandstone and quartzite layers accounts for larger yields from these rocks, even though they occur mostly as ridges. Some of the most productive aquifers in the region are the Knox Beekmantown and Helderberg limestone and dolomite aquifers and the Oriskany sandstone.

Shallow ground water flow patterns are similar to the patterns dictated by the shape of the land surface (topography), and ground water divides commonly conform to topographic divides. As a consequence, ground water flow is usually from the ridges into the streams on the valley floors.

<u>The Appalachian Plateaus</u>

The Appalachian Plateaus region underlies western Pennsylvania, most of West Virginia and westernmost Maryland. The plateau region is underlain by a thick sequence of Paleozoic sedimentary rock layers, some of which are the westward continuation of the sedimentary layers exposed in the Valley and Ridge region. These sediments are not folded and faulted, but are nearly flat lying Seaber, Brahana, and Hollyday, 1988). Topographically the region consists of relatively flat topped plateaus, deeply dissected by the streams that drain the region. The valleys are typically V-shaped with steep walls and very narrow floodplains, which makes for rugged terrain. The tops of the plateaus are largely composed of resistant sandstone of Pennsylvanian and Permian age. This sequence of Pennsylvanian sediments is thicker than to the east and contains sandstone, shale and coal. Slopes are steep and the soil cover is thin providing little ground water storage and consequently, runoff is rapid. The original intergranular porosity of the sandstones has been eliminated by the processes which cemented and consolidated the sediments and ground water is conducted through rock fractures. In West Virginia, the Pennsylvanian and Mississippian sandstone aquifers are typically unconfined in the hilltop and hillside areas, but confined in the valleys, and yield 1-100 gpm (USGS,1985). Aquifers are named after geologic formation names such as Monongahela, Allegheny, Pottsville, Mauch Chunk and Pocono. The ground water flow system is concentrated in the upper 300 feet and is reported to rarely active below about 600 feet in depth (Seaber, Brahana, and Hollyday,1988). The limestone and dolomite aquifers, so important in the Appalachian Valley and Ridge region, are deeply buried in the Appalachian Plateaus region and little is known about them. Because the nearly flat lying layers of aquifers and aquitards are deeply dissected by the surface drainage system, contact spring are very common on the steep sides of the valleys where the permeable sandstone (and coal) aquifers overlie poorly permeable layers of shale.

<u>The Central Glaciated Plains</u>

The Central Glaciated Plains region represents the boundary of Wisconsin age continental glaciation which reached into northern Pennsylvania. It overlies areas that are geologic and hydrologic extensions of the Appalachian regions. The glaciated Valley and Ridge area forms a narrow belt along the west side of the Delaware River from the Delaware Gap to near Milford, Pennsylvania where the river turns northwestward at the New York state line. The remaining part of the Central Glaciated Plains region covers areas that are geologically and hydrologically similar to the Appalachian Plateaus. The glacial deposits in Pennsylvania are thin and of little hydrologic consequence except for the major outwash or valley train deposits in the Susquehanna and Allegheny River valleys, where they form both confined and unconfined aquifers capable of yielding 100-1,000 gpm to wells (USGS,1985).

Alluvial Valley

Alluvium aquifers in the stream valleys throughout EPA Region III are generally productive aquifers. These are generally unconfined aquifers (Figure 23) which depend on induced infiltration from the streams to sustain high yield wells with yields of 50-500 gpm. Alluvium aquifers along the banks of the Ohio and Kanawha Rivers in West Virginia yield approximately 50-1,500 gpm to wells (USGS,1985).

State Agencies:

Delaware
Ground Water Management Section
DE Department of Natural Resources and Environmental Control
P.O. Box 1401
Dover, DE 19903
http://www.dnrec.state.de.us
(302) 739-4793

District of Columbia
District of Columbia Department of Health
Environmental health Administration, WQD
2100 Martin Luther King, Jr. Ave. SE, Suite 203
Washington, DC 20020
(202) 404-1120

Maryland
Special Water Supply Program Division
Maryland Department of the Environment
2500 Broening Highway
Baltimore, MD 21224
http://www.mde.state.md.us/
(301) 631-3713

Pennsylvania
Bureau of Water Supply Management
Pennsylvania Department of Environmental Protection
P.O. Box 8467, RCSOB-11th Flr.
Harrisburg, PA 17105-8467
http://www.dep.state.pa.us/
(717) 772-4018

Virginia
Virginia Department of Health (Source Water Assessment Program)
P.O. Box 2448
Richmond, VA 23218
http://www.vdh.state.va.us/
(804)786-5568

Virginia Department of Environmental Quality (Wellhead Protection Program)
Ground Water Program
P.O. Box 10009
Richmond, VA 23240-0009
http://www.deq.state.va.us/
(804)698-4043

West Virginia
West Virginia Bureau of Public Health
815 Quarrier St., Suite 418
Charleston, WV 25301
http://www.wvdhhr.org/
(304) 558-2981

ANSWERS TO QUESTIONS/APPENDIX B

Step Two Answers

1. Water that completely saturates the pore spaces between gravel, sand, silt or clay particles, or in bedrock fractures, in the subsurface environment, is called groundwater.

2. The upper elevation of the saturated zone is referred to as the water table.

3. Ground water elevations may fluctuate with evaporation, plant uptake, or withdrawals by humans.

4. Ground water flows perpendicular relative to water table contours.

5. A geologic formation capable of yielding a usable amount of water is called an aquifer

6. Coastal Plain aquifers may be confined by silts or by clays.

7. A "zone of Influence" is created when a well is pumped such that the water table is lowered.

8. A wellhead protection area may be delineated based on criteria such as time of travel, setback distances, drawdown, flow boundaries, or assimilative capacity.

Step Three Answers

1) Agricultural Operations are likely to contaminate ground water from pesticides and nitrates.

2) Nitrogen contamination in ground water is most likely to mix in an aquifer.

3) Poultry waste products (manure and dead animals) can best by managed by composting and then land application.

7) Mining activities in Pennsylvania and West Virginia can impact ground water quality from the disposal of mine wastes.

8) Zoning maps and ordinances act as the blueprint by which a community eventually grows.

9) Zoning can be changed to eliminate a potential land use conflict with water resource protection.

10) Conducting contamination source inventories require the collection of information from many different agencies and organizations. The computerized graphical display of this information is called GIS.

Step Four Answers

1. While there are several possible answers, two options are as follows: limit development in the WHPA to maintain water demands at existing levels, so that actual pumping rates will not increase; and monitor goundwater to track any possible impacts from the landfill..

2. Such land uses could include storage of hazardous chemicals, application of pesticides in quantities greater

than typical residential uses, dry-cleaning facilities, automobile repair stations, etc.

3. Health regulations (existing uses are grandfathered under zoning).

4. There are many possible answers. You could adopt an ordinance that requires users of pesticides to register their use with the local Board of Health. You could specify the type of storage facility required to house pesticides within the WHPA through a local ordinance.

Aquifer Types

ACKNOWEDGEMENTS

This document was prepared for the United States Environmental Protection Agency, Region III Water Management Division. Dale Long served as Project Manager for this document, with assistance from Barbara Smith, Peter Weber, and Virginia Thompson.