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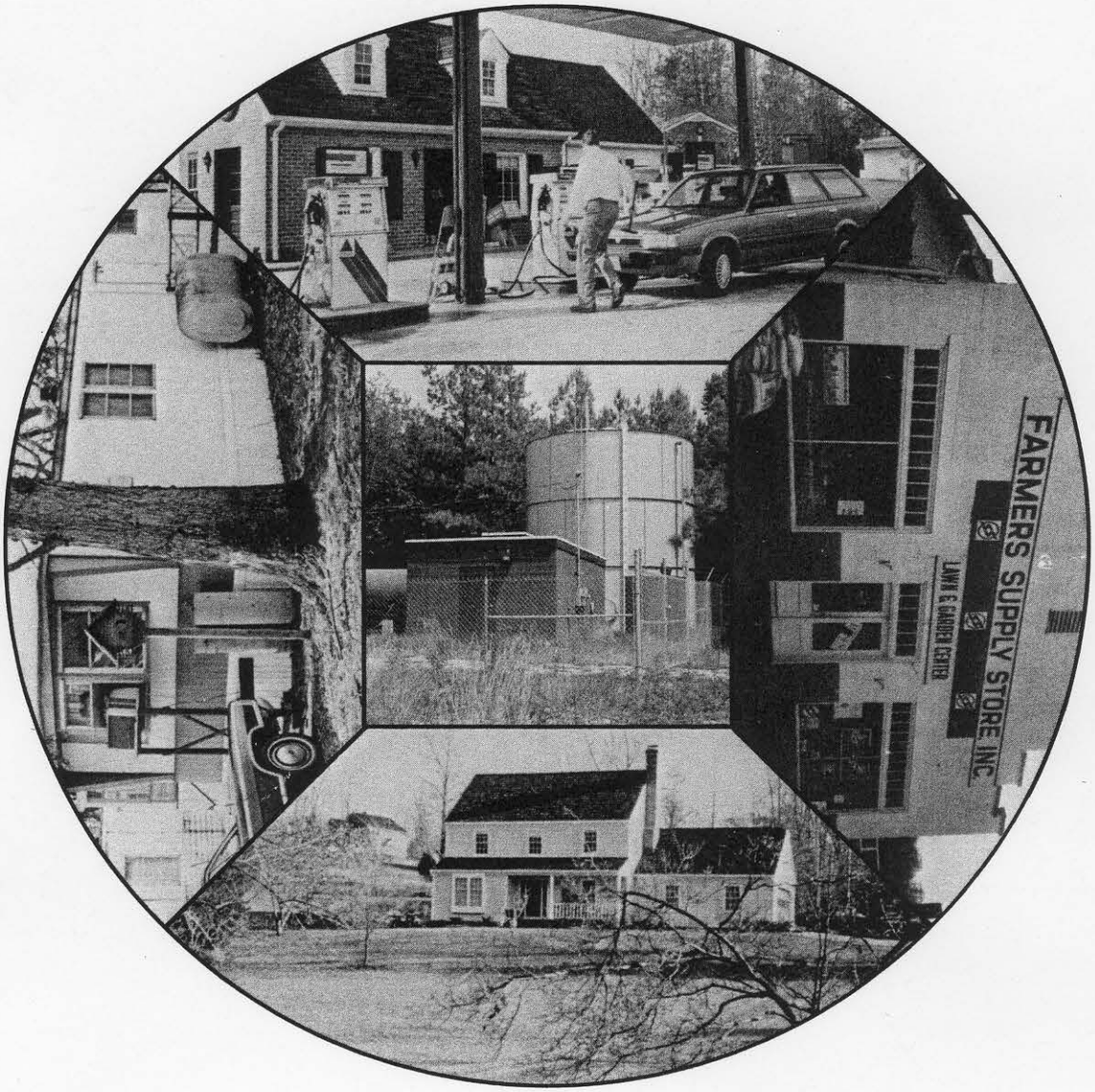
WELLHEAD PROTECTION

A Handbook for Local Governments in Virginia



Virginia Ground Water Protection Steering Committee

This publication is part of a series of documents prepared by the Virginia Ground Water Protection Steering Committee aimed at increasing awareness of ground water, the need to protect and conserve this essential resource, and strategies and methods for accomplishing these goals. Others in the series include:

- *A Groundwater Protection Strategy for Virginia*, May 1987
- *Virginia's Groundwater Protection Strategy: A Summary Report*, May 1987
- *Groundwater Protection in Virginia: First Annual Report of the Groundwater Protection Steering Committee*, 1988
- *Virginia Groundwater Management Handbook: State Agency Programs for Groundwater Protection*, 1988
- *Groundwater Protection in Virginia: Second Annual Report of the Groundwater Protection Steering Committee*, 1989
- *1990 Supplement to a Groundwater Protection Strategy for Virginia*, 1990
- *Groundwater Protection in Virginia: Fourth Annual Report of the Groundwater Protection Steering Committee*, 1991
- *Groundwater Protection in Virginia: Fifth Annual Report of the Groundwater Protection Steering Committee*, 1992

Copies of these reports and additional copies of this Handbook can be obtained from the Virginia Water Control Board, P. O. Box 11143, Richmond, Virginia 23230 or 804/527-5201.

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A Handbook for Local Governments in Virginia

Virginia Ground Water Protection Steering Committee

prepared by

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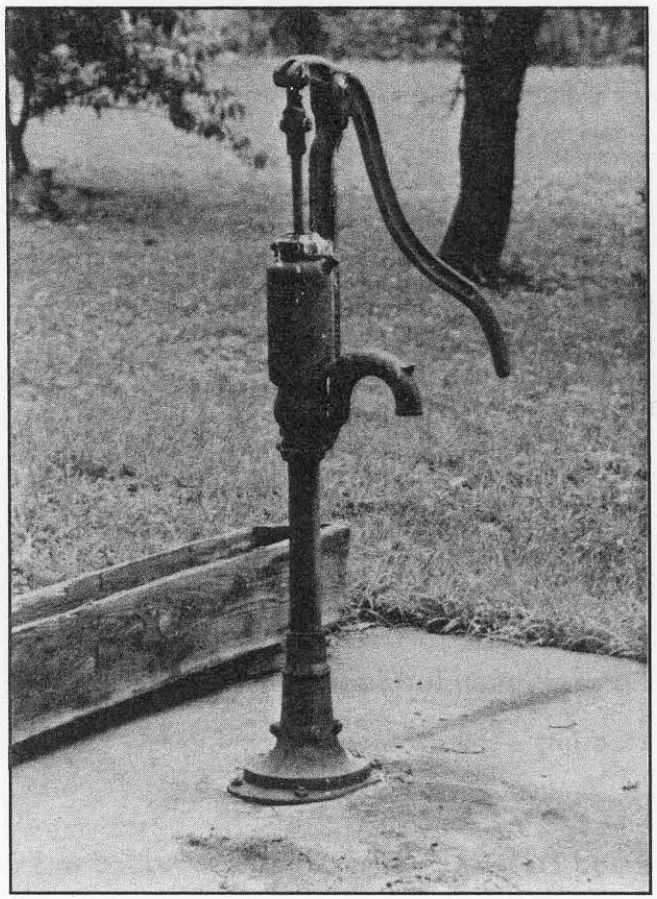


Chapter 1

THE NEED FOR WELLHEAD PROTECTION

Purpose

This Handbook has been prepared for local government officials, public water supply managers, citizens and anyone in Virginia concerned with maintaining and protecting the quality of public drinking water pumped from wells.

"Wellhead protection" is the term applied by EPA and others to describe a process for assessing potential threats to ground water, for managing land uses and activities in the area near public wells, and for planning to prevent problems before they arise. This Handbook sets out a series of steps aimed specifically at jurisdictions in Virginia to help these localities get started with wellhead protection. This Handbook outlines a range of options that allow decision makers to tailor specific wellhead protection programs to their particular situation and to reflect local land use patterns, hydrogeology, staff skills and the availability of alternative water supplies.

This Handbook follows the recommendations of the Ad Hoc Wellhead Protection Advisory Committee made up of local government representatives and a selection of state agencies. The state's Ground Water Protection Steering Committee has reviewed the Ad Hoc Committee's report and endorses the following findings:

- **There is a need for wellhead protection in Virginia.** Many public water supplies in Virginia depend wholly or in significant part on ground water wells. Replacement supplies or treatment would in most cases prove very expensive or impractical.*
- **Local governments in Virginia have the land use authority needed for wellhead protection.** The state code was specifically modified in 1988 and in 1990 to give localities clear authority to use their planning and zoning powers to protect ground water and public water supplies. Since wellhead protection is based on land use management, it is essential that local governments be involved.
- **Overlay zoning is one of a number of tools available to Virginia's local governments for wellhead protection.** This technique is already in use for a variety of purposes such as protecting surface water supplies in the Commonwealth. Overlay zoning does not change the basic

* Private wells serving individual homes or businesses, while extremely important in Virginia, are not part of the federal wellhead protection program covered by the Safe Drinking Water Act.

Figure 1

WELLHEAD PROTECTION AREA: A BRIEF DEFINITION

A wellhead protection area consists of land in the vicinity of a public water supply well chosen for special protection to prevent pollution of the ground water by nearby surface and sub-surface activities. Public wells include community wells - both those owned by governments and those owned privately - serving residential customers and a variety of wells serving the public in locations such as restaurants, schools and industry.

The size of the protection area can be a function of the hydrogeology in the vicinity of the well, its daily withdrawal rate, land use activities existing or likely in the area, and assessment of replacement or other options if the well were to become polluted. The area could range from a few acres to several square miles or more.

The special protection measures which could be applied to a wellhead protection area include zoning limitations on the types of land uses allowed, performance standards to contain and manage potential pollutants, contingency plans for accidents, and coordination among local, state, and federal governments and private property owners.

A Safe Drinking Water Act amendment of 1986 (Section 1428) establishes a federal program for wellhead protection under the Environmental Protection Agency and calls on states to develop programs that respond both to the federal guidelines and to local conditions which can be highly diverse. Local governments are essential participants because of their authority over land use and because of local government's role as a utility supplying public water needs. Wellhead protection is an important part of an overall ground water resource protection strategy.

Report of the Ad Hoc Wellhead Protection Advisory Committee, June 1991

underlying zoning upon which property owners have relied and adds protective provisions only in those area where needed. The technique is flexible and can be tailored to the desired degree and type of protection sought by a locality.

The Virginia Ground Water Protection Steering Committee finds that the need for wellhead protection exists, that the means for localities to protect wellhead areas exist, and now has prepared this Handbook to encourage local governments to take the next step.

Is There a Problem in Virginia?

Before starting a new program like wellhead protection, local leaders and citizens are correct in asking whether there is a problem in Virginia. If they personally have not experienced a problem in the past, should they be considering wellhead protection now for the future? Several responses are in order.

- **First, a number of Virginia localities have, in fact, had experience with pollution problems that affected their public wells.** For instance, in 1985, Prince William County found that one of its public wells contained perchloroethylene. The IBM plant at Manassas, approximately a mile away, was detecting the same chemical in their underlying groundwater. This public water supply well was temporarily taken off line, and IBM and the County initiated a "pump and treat" system to prevent the contamination from spreading further. The contaminated ground water was pumped from many specially drilled recovery wells. This water was treated through carbon filtration and discharged as waste water into the municipal sanitary sewer system. Fortunately, other water sources were available during this time to serve the area that had been served by this public well. Now, the well is back in use, but all water drawn from it is treated before entering the water supply.

The Town of Berryville in Clarke County lost its main public water supply well when it was found that the water contained excessive levels of nitrates. The town, at an expense of $1.3 million, took that well out of service and constructed a water treatment facility using the Shenandoah River. Agricultural practices were believed to be the source of the problem.

The Town of Fincastle also found that it could no longer rely on ground water within the town for its public water supply due to contamination from residential septic tanks and hydrocarbons from leaking underground storage tanks. The Town has subsequently drilled two new wells located outside the town limits in Botetourt County and is now working with the county to develop a wellhead protection program that can prevent future problems with the town's new wells.

- **Second, stricter Safe Drinking Water Act testing requirements may reveal additional problems.** Under the 1986 amendments to the Safe Drinking Water Act, public water supplies will soon be phasing in more extensive monitoring and testing programs and these tests may uncover previously unknown problems. In Virginia, the Virginia Department of Health administers the provisions of the Safe Drinking Water Act including permitting of public wells, monitoring of the testing program and enforcing compliance with the Act's requirements.

Some of this initial data has been placed on a computerized data base at the Virginia Department of Health regarding volatile organic chemicals (VOCs) - chemicals such as toluene, benzene, trichloroethylene, and perchloroethylene. This early data shows that approximately two dozen systems - including public schools, city systems, and a variety of public/private public water facilities - have turned up detectable levels of VOCs. Typically, this is the result of leaking underground storage tanks and poor well construction. The levels detected to date, however, are below established maximum allowed contaminant levels established by the Environmental Protection Agency. Consequently, the Virginia Department of Health does not view these detections as violations or as immediate health concerns. Fortunately, these measurements are at this time within allowed maximum contaminant levels. Even low levels of these chemicals, however, indicate that a pathway has been found to the ground water that is being pumped for public consumption.

If we look for a moment at underground storage tanks, such as those involved in these VOCs leaks, there are approximately 66,000 regulated underground storage tanks (USTs) at 24,000 facilities throughout the Commonwealth. Over the past two years the number of reported leaking UST sites has increased dramatically to 3,300. Since October 1990, replacement sources of drinking water to homes and businesses have been necessary at 87 different locations - 34 sites have been provided with a new well or an extension of an existing public water supply and the other sites have to install continuous carbon filtration. None of these alternatives is cheap, either for individuals or for the taxpayer, or is very reassuring to the public.

- **Third, there is also growing evidence that ground water not currently used as drinking water is becoming polluted by surface and sub-surface activity.** For instance, the Pickett Road Tank Farm case in the City of Fairfax has been receiving a great deal of attention. Star Enterprises, Texaco, and other oil companies op-

erate a tank farm at this location. An oil leak occurred which migrated beneath homes in a nearby neighborhood. While no public or private water supplies have been impacted, a number of lawsuits have recently been settled regarding damages to homes in the adjoining subdivision and a number of families were forced to move because of the fire and safety threat from fumes. Fortunately, these homes didn't rely on wells and fortunately no public water supply wells were nearby.

Any time that there are septic systems, underground storage tanks, agricultural activities, tank farms, transportation centers or a host of other activities, there could be ground water pollution as a result. Wellhead protection is aimed at preventing such occurrences, along with the costs and disruption that would result if contamination occurred. Ground water pollution has occurred in Virginia but can be prevented through careful management actions which include local wellhead protection programs.

Ground Water and Public Supply Wells in Virginia

How important is it that ground water be protected? Few people are aware that in Virginia there are 38 counties - 40% of the counties in the state - where public water supply systems depend entirely on ground water. These counties are found in every region of the state and include the following:

Counties 100% Reliant on Ground Water For Public Water Supplies*

Accomack	Frederick	Mathews
Amelia	Giles	Middlesex
Appomattox	Gloucester	New Kent
Bath	Greensville	Northampton
Bedford	Henrico	Northumberland
Botetourt	Highland	Page
Buchanan	Isle of Wight	Powhatan
Charles City	James City	Prince George
Craig	King & Queen	Rappahannock
Cumberland	King George	Richmond
Dinwiddie	King William	Southampton
Essex	Lancaster	Surry
Floyd		Westmoreland

* Several of these counties purchase water from other systems which include water from surface sources. In these instances, the 100% figure refers only to sources within the county.

Within these counties there can be little disagreement about the importance of maintaining ground water as a pure source of water. These counties do not have their own developed surface water sources that could be turned to in the event that a public well was impacted by ground water pollution.

The list of ground water dependent jurisdictions grows to 54 counties when those which draw less than 100% but more than half of their public water from ground water are included. These additional counties include:

Counties Drawing 50-99% From Ground Water For Public Water Supplies

Augusta	Nelson
Caroline	Roanoke
Charlotte	Rockingham
Fauquier	Russell
Fluvanna	Shenandoah
Grayson	Smyth
Louisa	Sussex
Madison	Washington

At the other end of the spectrum, only 18 counties in Virginia draw as little as 10% or less of their water from wells.

With figures such as these, it is clear that ground water is a crucial source of public water supply in Virginia. Local officials should feel concern and should be interested in learning more about how to get started in protecting this valuable resource. This Handbook shows how a locality can begin.

Getting Started

A) Ask youself, how prepared is your community?

- Do you know how many public wells are located in your community, where they are and who they serve?
- Do you use this knowledge when land use and development decisions are made?

These are the types of questions that a community should start to ask itself, especially if the majority of its public water supply comes from ground water. Even if 10% or less comes from ground water, this portion may not be easy or economical to replace if it becomes contaminated.

A "preparedness" questionnaire was prepared by the Ad Hoc Wellhead Protection Advisory Committee as a way for communities to easily assess their current situation, potential vulnerability and possible next steps. Fill out the questionnaire and discuss the results and their significance with your Planning Commission, the Board of Supervisors, or those involved in managing or using the public wells in your locality. Think of wellhead protection not just as a technical matter of concern to professionals but also see this as an opportunity to educate citizens, groundwater consumers, waterworks investors, businesses, and all who are concerned about ground water. Unless an answer of "yes" is given to most questions, there is room for improvement.

B) Next, read on in this Handbook in order to become familiar with your options. The following chapters are:

- Chapter 2 - The Land Use/Ground Water Connection
- Chapter 3 - Assessing Your Local Situation
- Chapter 4 - Wellhead Protection Tools
- Chapter 5 - Choosing Among Delineation Methods
- Chapter 6 - The Decision Making Process

We have attempted to be brief and to the point in this Handbook, but in Chapter 7 you will find an extensive list of the reference materials on delineation methods, finance and other topics discussed in this Handbook.

C) Locate and map the public wells in your community. You will find that there are many types of public wells serving different types of customers and users. The Virginia Department of Health regulates, permits, and monitors each public well in Virginia. They can provide a listing of wells along with descriptions which can help a locality plot these wells on a map.

D) With this map, you are ready to survey current and potential land uses and to assess potential risks. A study area should be drawn around each well and a field study of land use activities within the area conducted. A circular area around the well with a half-mile radius would be a good start. What you are looking for is activities currently in place - or which could develop under current zoning - which might pose a threat to ground water. Chapter 3 discusses what these land uses might be in urban, suburban, and rural situations.

E) Where you go next depends on what you find when you assess the results of your field study. **Overlay zoning could be the method you would choose** to apply special precautions in the vicinity of the wells that have been surveyed. Some uses might be prohibited in close proximity to a well while others might be allowed but only with special operating features to prevent contamination.

F) It is also necessary to delineate the area to be protected. The field investigations conducted earlier may suggest where overlay zoning boundaries should be placed, or you may wish simply to continue the half-mile radius boundary used for the field study. Alternatively, various technical calculations based on the type of well and the local hydrogeology can be performed to calculate a delineation area for protection.

G) Finally, plan for the future. Many localities will want to protect the sites of future wells in a manner comparable to what they have done for existing wells. This means planning ahead, assessing land use trends and public facility and service needs, and applying appropriate protective methods.

• • • • • •

As you can see, wellhead protection is a common sense way to employ land use controls to protect public water supply wells.
Wellhead protection protects the public investment and ensures that high quality water will continue to be available to meet the needs of residents, business and public institutions. It is time that local governments begin to adopt wellhead protection as one part of their local planning and zoning actions. This Handbook shows how this can be done.

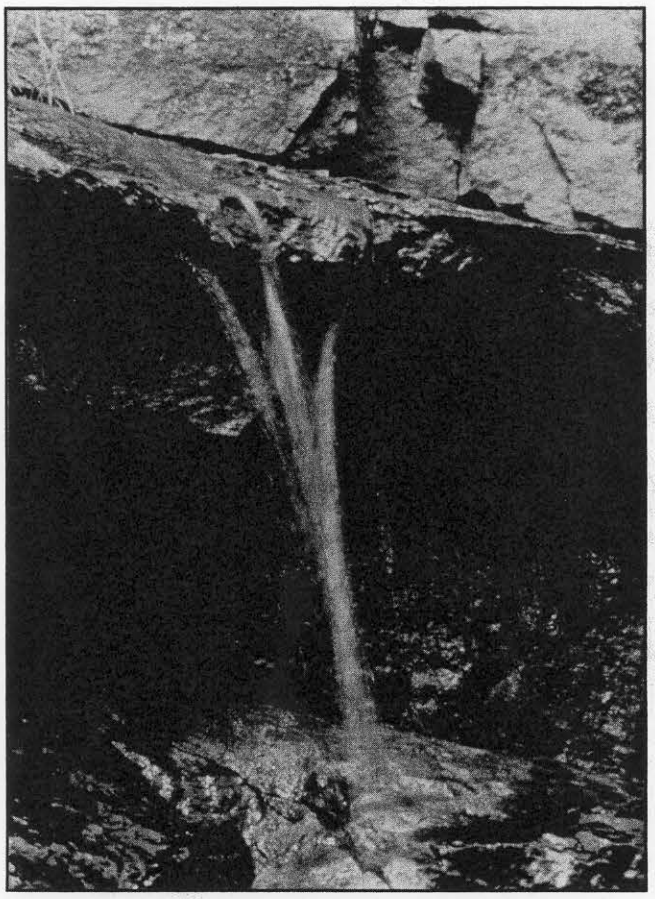
Figure 2

TEST YOUR KNOWLEDGE: A SELF ASSESSMENT QUESTIONNAIRE

"Out of Sight - Out of Mind" is a phrase often used to describe people's attitudes toward ground water. The goal of wellhead protection, however, is to bring public water supply wells into sharper focus so that they can be protected for continued beneficial use. Chapter 15.1 Article 4 of the Virginia Code indicates that localities shall study or survey ground water, geology, and other factors in preparing and amending their comprehensive plan. In beginning that process, the following questions can help you decide how well informed you are and how well prepared your community is to protect its public ground water supplies.

	Yes	No
1. Do you know how many public wells are located in your community?	____	____
2. Could you locate them on a map?	____	____
3. Do you know how many are owned by local government and how many are owned by investors or others?	____	____
4. Do you know which wells pump the greatest quantity of water?	____	____
5. Do you know how many people they serve?	____	____
6. Do you know how many businesses or industries depend on public wells?	____	____
7. Are there contingency plans in place for use in the event that any of these wells might become polluted?	____	____
8. Have any public wells required treatment as a result of testing under the new Safe Drinking Water Act amendments?	____	____
9. Have any public wells in the past been closed due to contamination?	____	____
10. Do any public wells have activities within 1/2 mile that might pose a threat (e.g., landfills, abandoned wells, underground tanks, waste lagoons, chemical businesses, septic tanks)?	____	____
11. Under current zoning, could such activities locate there in the future?	____	____
12. Does the planning commission have knowledge of the existence of public wells when making zoning decisions?	____	____
13. Do you have knowledge of the underlying geology and feel confident that the flow of contaminated ground water would not be in the direction of a public well?	____	____
14. Are you familiar with the authority under chapter 15.1 of the Virginia Code for localities to adopt measures to protect ground water?	____	____
15. Are you confident that a problem with any of the public wells in your locality would not have a negative impact on economic development?	____	____

If more than a few questions are answered "No," then your jurisdiction should consider further studies of its public wells and consider adopting wellhead protection measures.



Chapter 2

THE LAND USE/GROUND WATER CONNECTION

Note: This Chapter sets out the logic behind wellhead protection and introduces some basic terminology about ground water. The reader who is familiar with these concepts may wish to skip ahead to Chapter 3 which describes an action plan for a locality beginning wellhead protection.

The Logic of Wellhead Protection

Many land uses and human activities in urban, suburban, and rural areas can pose potential threats to ground water. Home septic tanks, disposal of liquid and solid waste, leaking underground storage tanks, or a fire at a paint store, for example, could all act as possible sources of pollutants which could reach ground water.

Figure 3 diagrams the many ways land use discharges can eventually reach ground water. This picture shows both surface and near surface land use activities, and it shows wells constructed to withdraw ground water. This picture is useful because under normal circumstances, ground water is "out of sight, out of mind." The familiarity and daily contact we have with many of these surface activities gives us a false sense of security about ground water. Also, because ground water in many geologic formations moves slowly, contaminated water can remain undiscovered for many years, even for decades. As a result, pollution often goes undetected until it reaches an outlet where it is discovered, such as a well or spring, at which point it could already be creating a serious problem. Remediation may not be economically or practically feasible or may require a very long time. Since the loss of a crucial drinking water supply could be disastrous and because treating contaminated ground water can be difficult and expensive, preventing contaminants from reaching ground water is an essential.

Figure 3

GROUND WATER AND LAND USE IN THE WATER CYCLE

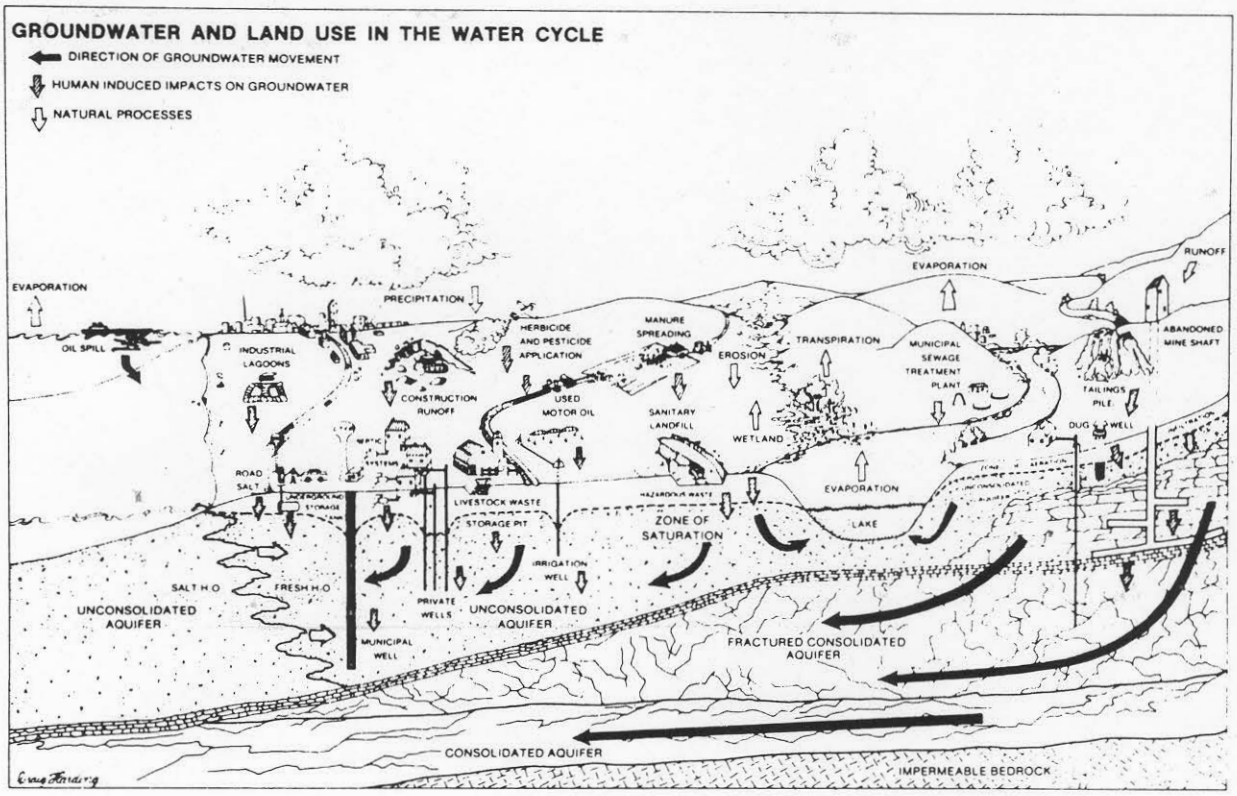


Figure 4

SAFE DRINKING WATER ACT: MONITORING AND PUBLIC NOTICE REQUIREMENTS

The 1986 Amendments to the Safe Drinking Water Act and Virginia's Waterworks Regulations include requirements that owners of public water systems, or "waterworks," periodically test for 83 substances which will be fully regulated by 1993, and an additional 40 "unregulated" contaminants.

When tests reveal that a Primary Maximum Contaminant Level (PMCL) for a substance has been exceeded, the system owner is required to notify the public of the violation in the following ways according to section 2.19 of the Waterworks Regulations.

1. **Newspaper - by publication in a daily newspaper of general circulation in the area served by the system as soon as possible, but in no case later than 14 days after the violation or failure. If the area served by a waterworks is not served by a daily newspaper of general circulation, notice shall instead be given by publication in a weekly newspaper of general circulation serving the area; and**
2. **Mail or hand delivery - by mail delivery (by direct mail or with the water bill), or by hand delivery, not later than 45 days after the violation or failure. The Division may waive mail or hand delivery if it determines that the owner of the waterworks in violation has corrected the violation or failure within the 45-day period. The Division must make the waiver in writing and within the 45-day period; and**
3. **Imminent Health Threats - for violations of the PMCLs of contaminants that may pose an acute risk to human health, by furnishing a copy of the notice to the radio and television stations serving the area served by the waterworks as soon as possible but in no case later than 72 hours after the violation. The following violations are acute violations:**
   a. **Violation of the Bacteriological PMCL**
   b. **Violation of the nitrate PMCL**
   c. **Other violations as determined by the Division**
4. **Long term violations - following 2.19B1, or 2, of this section, the owner must give notice at least once every three months by mail delivery (by direct mail or with the water bill) or by hand delivery, for as long as the violation or failure exists.**

In an area where there is no daily or weekly newspaper, exceptions and alternative means are provided.

The contents of such notices must meet the following requirements according to Section 2.19 E of the regulations.

General content of public notice - Each notice required by this section must provide clear and readily understandable explanation of the violation, any potential adverse health effects, the population at risk, the steps that the waterworks is taking to correct such violation, the necessity for seeking alternative water supplies, if any, and any prevention measures the consumer should take until the violation is corrected. Each notice shall be conspicuous and shall not contain unduly technical language, unduly small print, or similar problems that frustrate the purpose of the notice. Each notice shall include the telephone number of the owner, operator, or designee of the waterworks as a source of additional information concerning the notice. Where appropriate, the notice shall be multilingual.

Wellhead protection offers a means to prevent contamination from occurring. This can save localities time and money, as well as the difficulty of dealing with a fearful consuming public. Additionally, by demonstrating to the State Department of Health that protection measures have served to reduce sources of contamination to ground water, monitoring requirements may actually be lessened for certain wells. This, too, can save valuable time and money.

There are a number of ways that these various surface and near surface activities can impact ground water. Most people think primarily of accidental spills or unplanned discharges, such as when a landfill leaks, or storage tanks fail or a pipeline ruptures. Some facilities, however, are intended to discharge substances (e.g., septic tanks). Sometimes substances are discharged as a consequence of other activities (e.g., pesticide applications, urban run-off), and in other cases, pollution results from a conduit for potential contaminants (e.g., improperly abandoned wells). Wellhead protection seeks to deal with all these potential sources of pollution by managing the land around public wells to prevent potential "dischargers" from locating nearby or by requiring special protections.

While it is not possible or desirable for a locality to prohibit all activities which could be potential ground water contamination sources, it is important to minimize negative impacts. Localities need to be aware of the existence of such potential polluters in their communities, and must understand the threat they can pose to their water supply. The Safe Drinking Water Act requires that a public water supplier notify his/her customers when water quality violations occur. Wellhead protection seeks to prevent such problems from occurring.

Basic Concepts in Wellhead Protection

A few basic concepts are important for a general understanding of the ground water resource, how it is tapped through public drinking water wells, and how wellhead protection can help prevent problems.

Ground water and surface water are closely related through the **hydrologic cycle,** with water from the atmosphere moving to the earth's surface, into the ground, and eventually back into the atmosphere. The base flow of many streams comes from ground water. Many wetlands and wildlife habitats they support are maintained by ground water during dry periods.

Water located underground occurs in two zones, the **unsaturated** and the **saturated zones.** The unsaturated zone, also known as the zone of aeration or percolation, is the uppermost zone located directly beneath the surface of the land. It is into this unsaturated zone that facilities such as septic tanks discharge and where underground tanks and pipelines are buried. Below this is the saturated zone where all interconnections, voids, and cracks are filled with water, and this water is what can properly be called **ground water.** It is from this zone that potable water is drawn through public wells. Wells are cased and grouted to a certain depth in order to prevent pollutants from the surface from finding their way into the ground water that is pumped for human use.

Many types of underground geologic formations contain sufficient saturated permeable material to yield significant quantities of ground water. These formations, known as **aquifers,** can be composed of either **consolidated** or **unconsolidated** materials. Consolidated aquifers are solid rock formations, while unconsolidated aquifers are uncemented formations with interspersed layers of silt, sand, and gravel. The storage and flow of water through a consolidated aquifer depends on the cracks, fissures, and channels in rock masses which are created by shifts and movements within the earth, and by chemical actions which create solution features. In an unconsolidated aquifer, ground water fills the open spaces that exist between particles of silt, sand, and gravel. The storage capability of an aquifer, determined by the relative volume of pores and cracks available, is known as its **porosity.** The size of the pores and cracks and the extent to which they are connected determine the aquifer's capacity to transmit water, its **hydraulic conductivity.** In delineating a surface area for wellhead protection, key assumptions about the porosity/permeability of the aquifer and other characteristics are made in order to calculate a potential protection area.

Aquifers are also characterized as **confined** or **unconfined** depending on the presence of restrictions on the movement of ground water into or out of adjacent aquifers. Overlying impermable units, known as confining beds or **aquitards,** can restrict the flow of ground water into underlying aquifers. When aquifers are completely filled with water and surrounded on all sides by aquitards, they are called confined - or artesian - aquifers. This ground water is under pressure, so water levels in wells completed in such aquifers will rise to a level some height above the confining bed, called the **potentiometric surface.** An unconfined aquifer is not overlaid by low permeability geologic formations, but rather has the water table as its upper surface, which rises and falls as the amount of water in the aquifer fluctuates. The level of water in a well drilled in an unconfined or water table aquifer reflects the depth of the water table in the surrounding aquifer. Generally speaking, confined aquifers are less vulnerable to surface pollutants than shallow water table aquifers where surface activities can have a fairly rapid and direct impact.

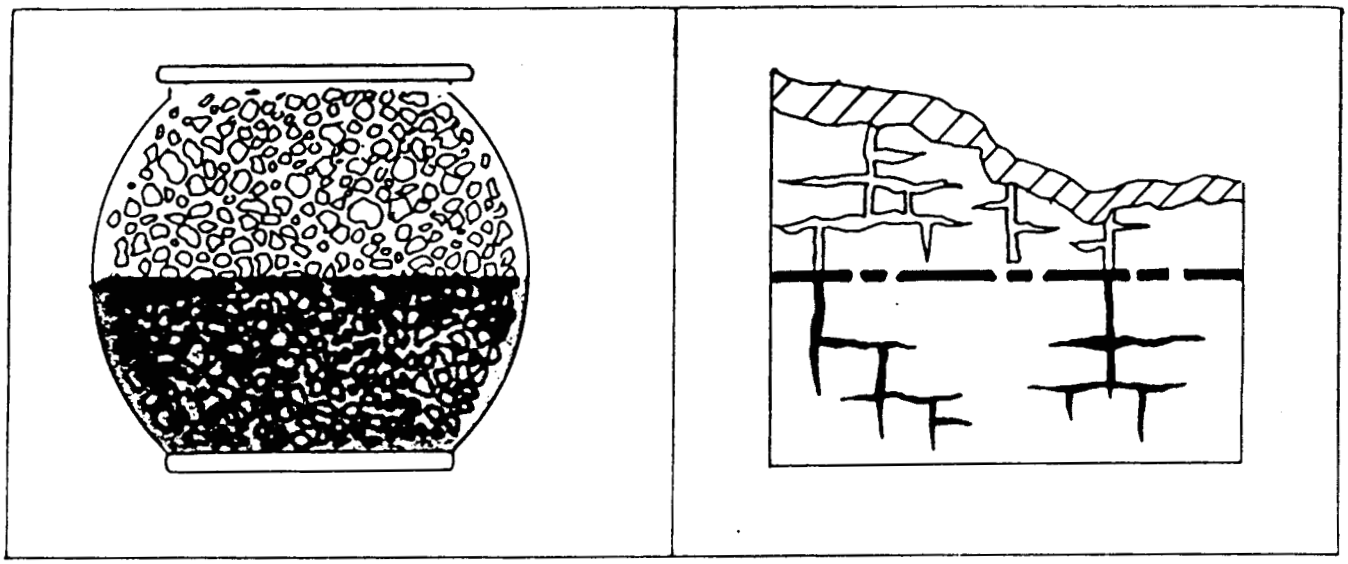
The use of ground water as a source of drinking water involves the installation and operation of a well that taps either a confined or unconfined aquifer. Withdrawal of water by a well causes a lowering (drawdown) of water levels in the area around the well, causing the formation of **cones of depression** in the aquifer. The decline in water level in the vicinity of a well may extend for several hundred feet or for miles, depending on the amount of

Figure 5

CONSOLIDATED AND UNCONSOLIDATED DEPOSITS

Groundwater in an unconsolidated deposit, represented by a half-filled fishbowl, occupies all the spaces between gravel particles. Groundwater in a consolidated deposit fills cracks and channels in the rock.

Source: *A Groundwater Primer for Virginians*



ground water that is withdrawn and the characteristics of the aquifer. This surface area affected by drawdown is known as the **zone of influence.**

Recharge areas are the regions which are hydrogeologically connected to an aquifer and which contribute significant amounts of water to it. If pollution sources exist in this area, the ground water in the aquifer is in danger of being contaminated also. Wellhead protection seeks to prevent the contamination of public supply wells from activities in the zone of influence or more distant recharge areas.

All areas or features supplying ground water recharge to a pumped well are known as the **zone of contribution.** If the water table is perfectly level, the zone of contribution and the zone of influence are identical, however, this is rarely the case and the two areas usually only coincide near the well. These zones may constitute only a fraction of an aquifer's area, or go beyond an individual aquifer to inter-connected aquifers. If the zone of contribution to a well could be known exactly, that zone of contribution would be precisely the area which should ideally be protected by a wellhead protection area. Since we can only estimate this zone based on reasonable assumptions, absolute boundaries are never possible.

In summary, the susceptibility to contamination varies according to factors such as the porosity and permeability of the aquifer. Sand and gravel aquifers, for example, are the main source of water for wells in many parts of the United States but they are also highly vulnerable because they are permeable and thus transmit polluted water readily. Each aquifer type presents its own challenges. The types of existing aquifers and their potential for ground water pollution vary across Virginia. Information on regional ground water characteristics follows.

Ground Water in Virginia

The naturally occurring quantity and quality of ground water in an area depends on the underlying geologic conditions. Five regions, called physiographic provinces, are recognized in Virginia. From East to West the provinces are known as the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Cumberland Plateau. Understanding the relation of each of these physiographic regions to the occurrence of ground water helps in assessing the nature of the threat to a locality's public water supply and indicates how a wellhead protection program might be shaped to fit local conditions.

Coastal Plain: The Coastal Plain in Virginia extends inland from the coast about 110 miles to

the fall line and passes roughly through Fairfax County, Fredericksburg, Richmond, Petersburg, and Emporia. The Eastern Shore is part of this region and the two counties there have for several years been conducting studies to develop a more detailed understanding of their ground water situation. The Coastal Plain region is the only one in Virginia that is composed mostly of unconsolidated deposits, primarily alternating layers of sand, gravel, shell rock, silt, and clay. More ground water is withdrawn from these very permeable materials than in any other province in the state. The pollution potential in the uppermost unconfined aquifer here is high, however, because of the permeability coupled with the high population density and agricultural activities in the area.

A large portion of the state's ground water use occurs in the Coastal Plain, which has two separate ground water systems, one shallow and one deep. In many places, a shallow unconfined aquifer system lies above relatively impermeable clay beds and is the source of water for hundreds of domestic and other small capacity wells. The principal source of major ground water withdrawals is a deeper system of confined aquifers. The recharge area to these aquifers occurs miles away where the formations outcrop but infiltration from the water table and shallower confined aquifer also recharge the deeper confined aquifers and could carry pollutants into these deeper reaches. The coastal plain presents a complex wellhead protection problem where the deep confined aquifers are concerned. The shallower aquifer, however, may have a more direct interaction with the surface and present a relatively straightforward challenge.

Except for areas where saltwater, iron, and hydrogen sulfide occur, the natural water quality in the Coastal Plain aquifers is good. In aquifers near a salt water interface, salt water may migrate west as aquifers are pumped. As a result, water from the deep aquifers on much of the lower York-James Peninsula and the Norfolk-Virginia Beach area generally contains high chloride concentrations, rendering the water too salty for domestic use. Also, high salt concentrations make Eastern Shore ground water unpotable below a depth of about 300 feet.

Piedmont: The largest physiographic province in Virginia is the Piedmont, extending from the fall line on the east to the Blue Ridge Mountains in the center of the state. Hard, crystalline igneous and metamorphic formations dominate this region with some areas of sedimentary rocks, with sapprolite deposits overlying the bedrock. The size and number of fractures and faults in the bedrock which store and transmit ground water decrease with depth, so most significant water supplies are found within a few hundred feet of the surface. Fairly large yields

Figure 6

CONFINED AND UNCONFINED AQUIFERS

Source: *Threats to Virginia's Groundwater*

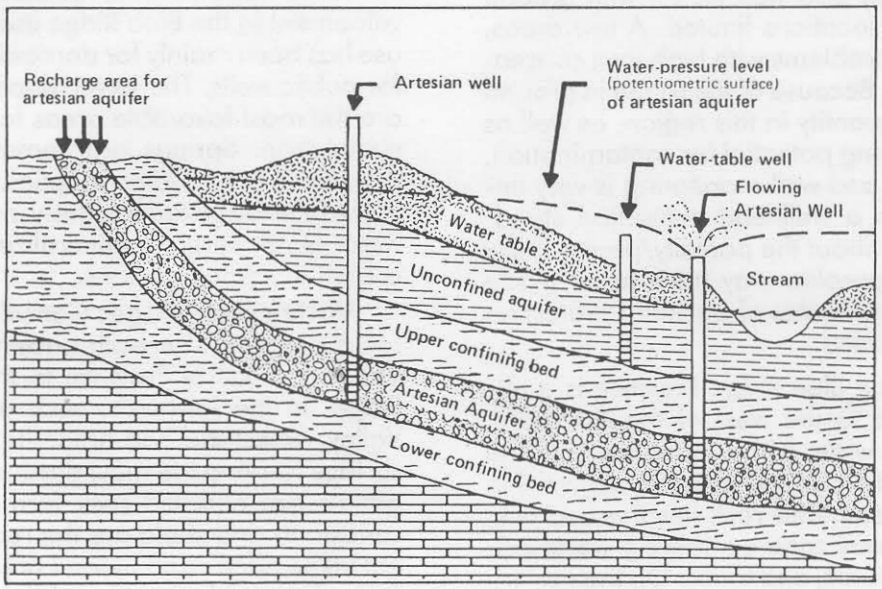
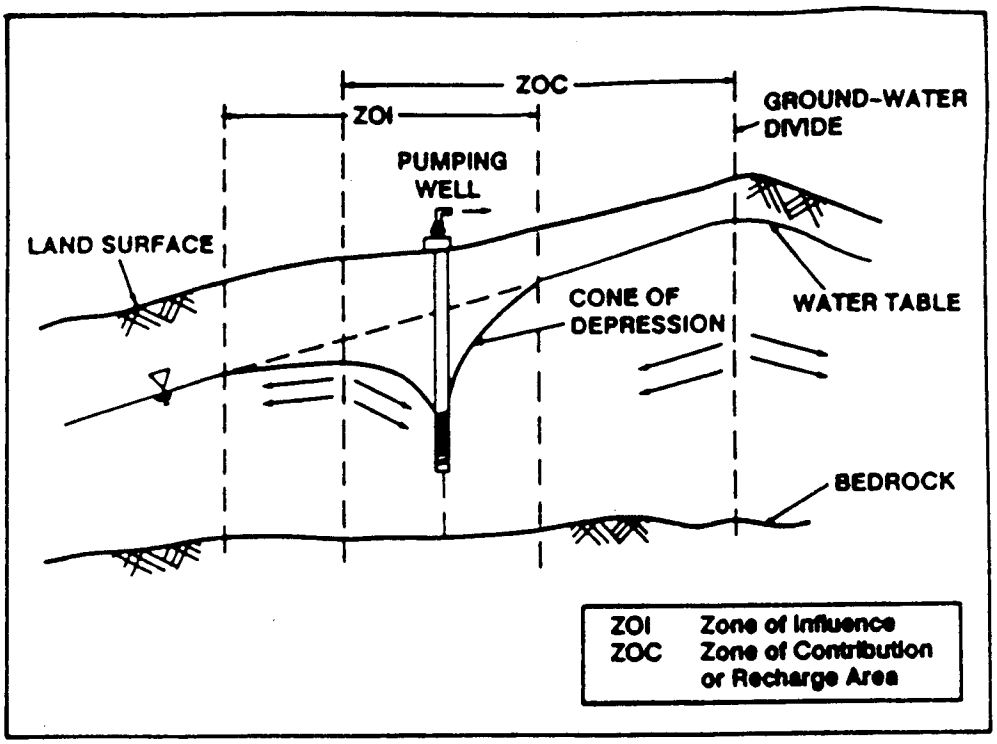


Figure 7

ZONES OF INFLUENCES AND CONTRIBUTION

Source: *Wellhead Protection Programs: Tools for Local Governments*



of water can be obtained where fracture and fault systems are extensive, as in the Western Piedmont along the base of the Blue Ridge Mountains.

The diversity of the subsurface geology of the Piedmont Province results in wide variations in ground water quality and well yields, with ground water use at many locations limited. A few areas, for example, have problems with high iron concentrations and acidity. Because of the range in ground water quality and quantity in this region, as well as the subsequent varying potential for contamination, well site evaluation and well monitoring is very important here. From a wellhead protection standpoint, assumptions about the porosity/permeability of the overlying sapprolite may have to be made so that reasonable estimates of wellhead protection areas can be calculated.

Blue Ridge: The Blue Ridge Province is a relatively narrow zone to the west of the Piedmont, from 4 to 25 miles wide, with mountains of some of the highest elevations in the state. Beneath a thin layer of soil and weathered rock lies the bedrock, a relatively impervious zone containing water primarily in joints, fractures, and faults. On the eastern flank of the Blue Ridge, ingeneous and metamorphic rocks are most common; sedimentary rocks are more common on the western flank. Steep terrain and thin soil covering result in rapid surface runoff and low ground water recharge.

There has been little residential or industrial development in the Blue Ridge itself, so ground water use has been mainly for domestic needs rather than for public wells. The lower slopes of the mountains are the most favorable areas for ground water accumulation. Springs are common and are often used for private water supplies. Because the rocks in the Blue Ridge are relatively insoluble, the ground water is not severely mineralized, but iron content is high in some locations.

Valley and Ridge: Consolidated sedimentary rocks deposited beneath ancient seas underlie the Valley and Ridge Province to the west of the Blue Ridge. In the lowlands, such as the Shenandoah Valley, limestone and dolomite occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. In contrast, sandstone and shale are the rock types often present in the ridges and upland areas, which yield only enough water for rural and domestic supplies.

The connection between ground water and surface water plays a major role in ground water recharge in the Valley and Ridge, where streams often cross fault zones recharging aquifers. Wells in the fault zones have the greatest yields. Recharge also occurs through surface run-off into limestone sinkholes, bypassing filtration through the soil. This can cause serious water quality problems since polluted surface water may be introduced directly into the ground water system. Ground water quality can also be adversely affected by private trash dumps located in sinkholes that receive surface run-off. In addition, carbonate formations contribute to the "hardness" of the ground water.

The karst limestone type of terrain in the valley poses difficult problems for wellhead protection area delineation since underground conduits may act much like surface rivers. Some studies have suggested that surface water drainage patterns may be the best way to delineate wellhead protection areas in such circumstances.

Cumberland Plateau: The Cumberland Plateau province, encompassing the Southwestern tip of Virginia, is underlain by sedimentary rocks, principally sandstone, shale, and coal. Ground water quality here varies with depth. The ground water contained in the first 100 feet of rock below stream level is often of poor quality, tending to be sulfurous and iron-rich, and naturally saline waters occur at depths greater than 300 feet. Better quality water can be found at depths of 150 to 300 feet below stream level, however. In coal mining areas, some ground water has become acidic due to mine drainage and is usually unsuitable for most uses.

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For the reader wanting a better understanding of ground water and conditions in Virginia, several sources are suggested in Chapter 7.

Figure 8

PHYSIOGRAPHIC PROVINCES OF VIRGINIA

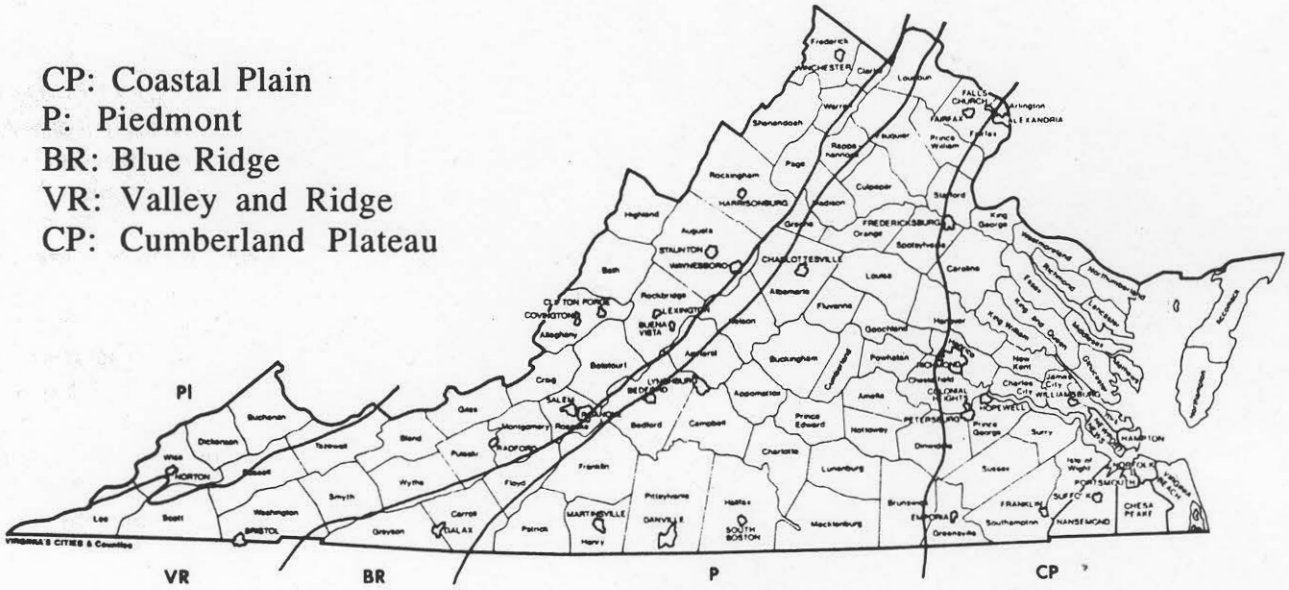


Figure 9

ACCOMACK-NORTHAMPTON: GETTING TO KNOW THEIR GROUND WATER RESOURCE

The Ground Water Supply Protection and Management Plan for the Eastern Shore of Virginia was developed in 1992 by the counties of Accomack and Northampton for the purpose of assisting local governments and residents of the Eastern Shore in understanding and safeguarding their ground water resource. The project, prepared by consultants in water resources and land planning, was guided and funded by the Eastern Shore of Virginia Ground Water Study Committee. This group consists of two members from each county's Board of Supervisors, one citizen appointee by each Board, the County Administrator from each county, and the Executive Director of the Accomack-Northampton Planning District Commission.

Ground water is considered an essential water resource on the Eastern Shore since it is the only source of drinking water. The Ground Water Plan, therefore, recognizes the importance of understanding the water system as a whole in order to make future land use and development decisions designed to protect water supplies. Before attempting to develop a management approach or to delineate wellhead protection areas, the plan collected valuable information necessary to understand the nature of local ground water. The study addresses the hydrogeology of the aquifers on the peninsula which influence ground water quality and quantity, as well as the flow and recharge patterns. Topography and soil types are also described because of their role in water purification as it moves through the ground.

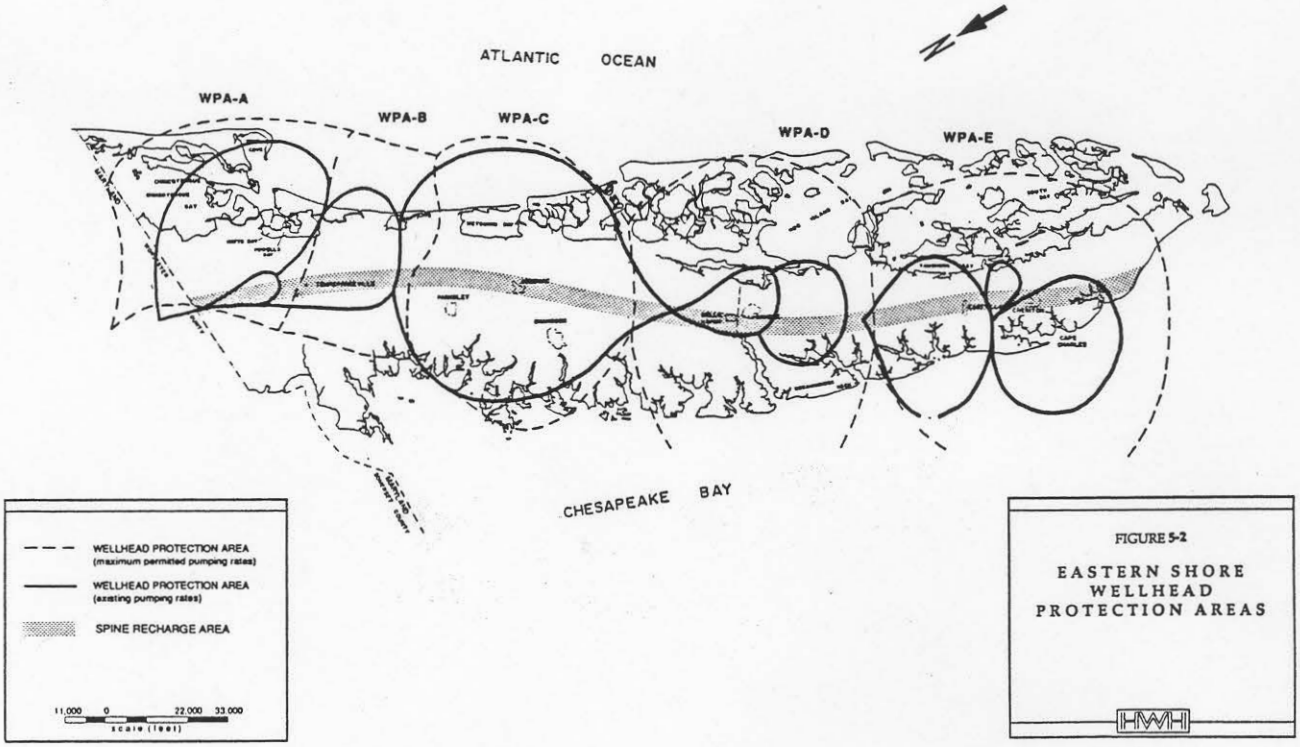
The aquifers on the Eastern Shore are strongly influenced by the physical character of the rock in the area. The upper aquifer, called the Columbia Aquifer, is unconfined and between 80 and 100 feet thick. It is used primarily for private on-site domestic wells, and agricultural irrigation. Water quality in the Columbia Aquifer is threatened by the many land uses that discharge, leach or dispose of contaminants to the ground water, including septic systems, agricultural fertilizers, manure storage and animal waste disposal, septage lagoons, and landfills.

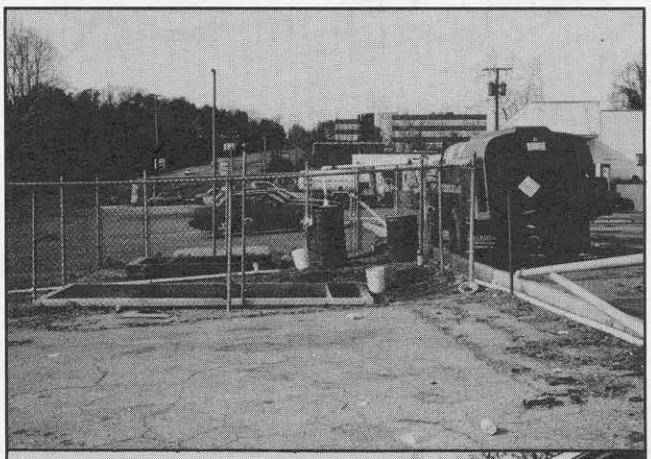
The next water bearing zone is the Yorktown-Eastover formation, a confined aquifer consisting of coarse shelly sands found in three layers separated by clay confining units. These confining units serve to protect the aquifer from many water quality threats, but they also act to impede the amount and rate of recharge to the aquifer. Industrial withdrawals and public water supply wells are drawn from the Yorktown-Eastover Aquifer. Problems of well interferences and salt water intrusion, already observed near the largest industrial water users, will be greatly enhanced if the amount of withdrawal increases substantially as some forecasts would suggest.

Based upon the analyses and the review of existing information, the study proposed several recommendations for water quality protection. These recommendations included regulatory techniques such as creating an overlay protection zoning district to protect the spine recharge area to the Yorktown-Eastover aquifer, restricting the siting of new mass drainfields in the spine recharge area, and requiring the registration of currently unregulated underground storage tanks. Non-regulatory suggestions were also given, including pursuing water conservation measures with major industrial users and supporting the implementation of agricultural nutrient management plans. Protection of the water quality and quantity in the Eastern Shore will require the implementation of many actions designed to prevent ground water contamination, prevent over use of the aquifer, and provide for future needs to accommodate growth in the two counties.

Not all localities will be able to be as thorough as the Eastern Shore nor will they necessarily need to do so in order to begin a basic wellhead protection program. The more background information available, however, the better the ensuing plan and practices will be tailored to the local situation. Accomack and Northampton Counties stand out as leaders in the state for their far-sighted efforts to protect valuable ground water resources.

Figure 9 (continued)





Chapter 3

ASSESSING YOUR LOCAL SITUATION

Chapter 1 gave a brief overview of the general approach which a locality might follow in considering and developing a wellhead protection program. This Chapter identifies a series of steps which can serve as an action plan for localities interested in pursuing wellhead protection. It is assumed that the self assessment questionnaire from Chapter 1 has been completed and that enough unknowns - "no's" on the questionnaire - have been encountered that a decision has been made to consider the next steps. A twelve step plan is described.

Step 1 - Obtain a List of Public Wells

There are many more types of "public" wells than most people are aware. Typically the term "public well" brings to mind a municipally owned and operated well that serves a nearby community area. It is important to remember that there are also privately owned public wells. Both can be called "community waterworks" in official parlance. Public wells also, however, serve freestanding schools, industry and various transient facilities such as roadside rest areas. The following public well definitions are used by the Virginia Department of Health and by the federal government.

Community Waterworks - means one that has 15 or more service connections or that serves 25 or more year-round residents. Examples would be municipalities, subdivisions, mobile home parks, or institutions such as nursing homes and correctional facilities.

Transient or Non-community Waterworks - means one that serves a transient populationof at least 25 people for at least 60 days each year. Examples include campgrounds, motels, restaurants, and highway rest areas with their own water supplies.

Other (Non-transient Non-community) Waterworks - means one that serves a fairly consistent non-residential population of at least 25 of the same people for at least 6 months per year. Examples here would include schools and factories with their own water supply.

Across the State of Virginia, community waterworks are the most numerous category making up over half of the systems coming under the authority of the Virginia Department of Health. It is important to note again that waterworks that are considered "public" wells or "community" wells may not be publicly owned. In Virginia, in fact, nearly 3 times as many community systems are owned by "investors" as local governments. Virtually all of the investor systems are small (serving fewer than 3,300 people) while publicly owned systems range all the way from the very small to the very large serving more than 10,000 customers.

Because of the diversity of wells falling into one category or other of "public," it is advisable that a listing be obtained from the Virginia Department of Health. A local utility, for instance, may only be familiar with its own wells and not be aware of investor owned small systems or other categories of public wells in the area.

Step 2 - Locate Each Well on a Map

Virginia Department of Health records frequently do not contain precise locations for each well in terms of latitude or longitude or other definitive locators. Records typically give the name of the owner and the name of the facility (e.g., John B. Smith, Smith's Mobile Home Park or Smithville Service Authority, Shady Hollow Service Area).

To locate a well on the map, it may be necessary to seek advice from Health officials or to contact the owner or other locally knowledgeable sources and/or a field confirmation. County property records can also be useful when a well is located on a designated "well lot" and recorded as part of the subdivision approval process. For initial location purposes, USGS 1:24,000 maps may be useful - they strike a compromise between too much and too little detail for general location and pattern purposes. These maps can be assembled to view the county as a whole if that is desirable. For later field study, more detailed maps showing individual property lines will be needed.

(Optional Step 3 - Prioritize Wells for Protection Activities)

For a variety of reasons, it may be necessary to prioritize wells before moving on to subsequent steps. Priorities could be based on factors such as the following:

- those municipally owned
- those serving the greatest number of customers
- those located in areas suspected of being more vulnerable
- those for which no alternate supplies are evident
- those investor owned systems where the owner has requested further study

There could be a variety of ways to set priorities when it is not possible to proceed simultaneously to study all the public wells in the locality.

Step 4 - Establish Study Areas

Sophisticated delineation is not necessary in order to begin to study land uses and management practices in the vicinity of public wells. A balance needs to be struck between available resources and the desire to be as inclusive as possible. The greater the number of wells being studied and the larger the area to be studied around each well, the greater will be the strain on resources.

A starting point might be to draw a 1/2 mile radius around each well. (This delineation technique is called "fixed radius" and is explained in more detail in Chapter 5.) This could then be modified through field investigations if it were felt to be too small (e.g., just beyond is an industry or a farm facility or a subdivision on septic tanks or an abandoned gas station). The 1/2 mile radius starting point might also be expanded if the well in question is a major well serving many customers - all other factors equal, the greater the number of gallons withdrawn, the larger would be the well's zone of contribution. It is also possible to do some relatively simple calculations (see Chapter 5) to estimate the zone of contribution. It might also be that the shape of the study area would be modified based on actual conditions. If a ridge line runs through the area indicating a surface water divide, and an unconfined aquifer was the source of ground water withdrawal, the portion on the far side of the ridge/divide might be deleted from further study and time instead devoted to expanding the study area within the watershed. Regardless of the shape or size of the study area, field personnel should be instructed to make note of any conditions beyond or about the study area which could be significant factors for the well under study.

Whatever the size and shape of the study area at the outset, it should also be noted that this may or may not eventually become a regulatory boundary. The designated area or wellhead protection area and its boundaries are topics that can be revisited later, so a precise delineation is not necessary at this time.

Step 5 - Establish a Study Team

The task of the study team is to identify and describe existing land use activity within the study area and to describe potential future uses. Team members need to be conversant with land use classification terminology as well as careful and systematic recorders of information. They need not be professional planners. Interns who are studying urban and environmental planning or students who might undertake this work as part of a class or field study could also conduct the field investigations. Planning Commission members in some cases have been a part of a field investigation team as volunteers - the advantage of this being that they gain first hand knowledge of the conditions which they will subsequently be called on to address from a management or regulatory perspective. At least one locality has reported the use of retired citizens as field investigation team members - the advantage being that they had memories of former activities (e.g., abandoned gas station where tanks might remain or an old house site where a well might still exist that had not been properly sealed).

Step 6 - Develop Protocols and Fields Record Sheets

If the locality has had a previous land use survey or if there is a GIS or other computerized system of land use information, a starting point would be to make this information available to the study team. It can both familiarize the members with the area and allow them to update this portion of the locality's inventory.

Team members should also be provided copies of the zoning map and comprehensive plans for this area. Work using these particular maps will take place in the office before and after the field work, however it is advisable to bring these maps along in case they are needed for reference in the field. Illegal or non-conforming uses can be noted as a result.

Before going to the field, a decision must be made about the approach to the land use and activity inventory. The locality's choices range from a generalized approach to a "special purpose" study approach. The special purpose in this case being wellhead protection from specific pre-identified potentially polluting land uses. Only those properties containing this type of use - or which would be allowed to have these uses under the zoning - would be noted and recorded in the special purpose study approach.

In the generalized approach all parcels and land uses are surveyed and recorded. This is a much more time consuming and labor intensive process both in the field and in terms of handling and processing the data once the researchers return to the office. The land use categories typically included in generalized land use maps are more inclusive than would be the case in a specialized survey. The generalized survey map might have one or only a few categories for commercial activities while a specialized survey would distinguish between dry cleaning establishments, chemical retailers, paint shops, etc. Accessory facilities such as septic tanks, underground storage tanks or pipelines would not necessarily be noted in a generalized land use survey. These broad categories and omissions would make a generalized study less than desirable from a wellhead protection standpoint.

For many localities, the best approach may be a hybrid in which more detailed information needed

Figure 10

LAND USES IMPACTING GROUND WATER QUALITY - WHAT TO LOOK FOR

Residential

Threats to ground water from residential uses are normally less acute on a case-by-case basis than those from other more intensive land uses. The cumulative effect from many residents in an area can prove disastrous, however, especially if they are unaware of the numerous potential contaminants that can be found in the home and yard and the proper methods for their use and disposal. These potential contaminants include:

- on-site septic systems, cesspools
- sewer lines
- fuel storage systems
- household, lawn, automotive, and pool chemicals
- urban run-off
- abandoned wells

Septic systems and underground storage tanks are major contributors to the total volume of waste discharged directly into the ground, and inappropriate siting and poor design, construction, and maintenance can cause pollution of underlying ground water. According to the 1987 *Groundwater Protection Strategy for Virginia,* the management and regulation of septic and storage tanks should be a top priority to prevent contamination from occurring.

Gasoline and other toxic fluids also pose a threat to ground water if they run off paved surfaces into the soil. Driveways, parking lots, and streets contribute to the problem of urban run-off. Another significant threat to ground water and to public safety is abandoned wells. If improperly sealed, abandoned wells can provide a direct conduit for surface run-off carrying pollutants, and are sometimes illegally used to dispose of wastes. A similar problem exists with sink holes in areas of karst topography.

Industrial

Industrial operations also commonly use toxic substances as part of manufacturing, warehousing, and/or distribution. Materials such as chemicals, petroleum, cleaning supplies, machinery, metals, electronic products, asphalt, and others pose a potential threat and must be managed. Other possible sources of contamination associated with industrial land uses include:

- mining (surface and underground)
- pipelines
- storage tanks (above and underground)
- operating and abandoned wells (e.g., gas, oil, water supply, injections, monitoring and exploration)
- septage lagoons and sludge
- land application of sludge

Mining, which is common in parts of Southwestern Virginia, can cause many types of environmental problems. The creation of toxic products, lowering of the water table, disruption of aquifers, effects on movement and recharge of ground water, and the causing of land subsidence can completely alter the landscape and seriously affect wellhead areas.

The liquid wastes produced by coal-fired plants, rendering plants, fertilizer production operations, and other industrial activities are often placed in shallow holding ponds and lagoons. These liquids can easily contaminate ground water, especially if the lagoons are constructed with insufficient lining, and thus should not be located over aquifers supplying drinking water. For persons wanting additional information on industrial activity, an EPA Technical Assistance Document, "A Review of Sources of Ground Water Contamination From Light Industry" is cited in Chapter 7.

Figure 10 (continued)

Commercial

Many commercial operations use toxic and hazardous materials in their processes. Examples include:

- auto repair shops, gas stations
- road maintenance depots, de-icing operations
- boat yards, railroad tracks and yards, airports
- construction areas
- dry cleaners, laundromats
- medical institutions, research laboratories
- photography establishments, printers

The storage, use and disposal of chemicals required by these operations can pose a potential threat to ground water, since even small amounts of the hazardous materials can contaminate large amounts of ground water. Storing quantities of the materials can also create a serious problem if they are not contained and stored properly. Leaks and spills from storage tanks and pipes can contaminate ground water, rendering the water unfit for drinking.

Agricultural

Chemical usage associated with farming activities can present a contamination threat to underlying ground water. Pesticides, fungicides, and fertilizers can leach through the soil to the water below when applied improperly in the field. They also have the potential to leak from any storage containers into the ground.

Animal feedlots and livestock operations can create excessive nitrate/nitrite and bacteriological problems if animal waste loads are high and ground water is shallow or the soil is permeable. Ground water contamination from livestock operations can best be prevented by siting operations in areas with sufficient soil attenuation capacity and by controlling animal densities.

Waste Management

Disposal of wastes must be handled carefully to prevent contamination of ground water. Older landfills in particular can significantly threaten ground water. Leachate is produced from precipitation or other moisture seeping through waste to the base of the landfill, taking with it soluble materials. In unlined landfills, substances in the leachate can percolate through the soil and contaminate aquifers below the landfill. Hazardous waste management is an even touchier problem since the materials to be handled pose a greater threat. In lined landfills reliance is placed on the liner not failing after a number of years.

The need to manage stormwater is created by most development - residential, commercial and industrial - since impervious surfaces prevent rain from soaking into the soil. This allows an accumulation of pollutants. Stormwater management, which has only been a subject of concern for the past ten to fifteen years, focuses on controlling the volume and peak discharge rate which increases dramatically when impervious surfaces cover an area. Concern also needs to be given to potential impacts on the ground water.

for wellhead protection purposes is collected in addition to generalized information. In any case, before the field investigation team sets out they must be clear on what they are to record, how and on what forms or maps.

The best guidance for conducting a land use survey continues to be the classic *Urban Land Use Planning* by Chapin and Kaiser, most recently updated in 1979. Chapter 8 discusses preparation of base maps, land use coding systems, advance preparations, field procedures and gives examples of coding forms and annotated working maps. This book is available in most planning offices or the personal collections of planning officials. U.S. EPA's *Guide for Conducting Contaminant Source Inventories For Public Drinking Water Supplies* is another useful source.

Step 7 - Conduct the Survey

When all the preparations have been made, conducting the field survey should primarily be a matter of implementing these preparations.

One thing that can be anticipated is that the appearance of the study team, perhaps in an official car and carrying maps and clipboards, will arouse curiosity and perhaps apprehension on the part of land owners and others in the study area. This can be converted to an opportunity to educate the public about wellhead protection. In all likelihood the land owner is served by ground water from the area being surveyed and will have an interest in maintaining that water supply. There may also be apprehension about possible new regulations or other changes which may constrain the use of property. Field personnel should be instructed in how to respond to such reactions. Statements about how decisions will be made and when will be appreciated by curious landowners who may want to become involved in the wellhead protection process.

A portion of the work for the study areas is best done in the office. This applies particularly to vacant land which has not yet developed and developed land where the occupant or activity might change. In these cases, someone knowledgeable and familiar with the local zoning ordinance should make a determination about which of the land uses, activities and facilities of concern would be allowed to be developed in the future under the current zoning provisions. Likewise, if there is a discrepancy between what the long term plan shows and what the zoning ordinance allows or what currently exists, these discrepancies should be noted.

Step 8 - Compile the Land Use Data

Data should be compiled separately for each study area. Both tabular and map presentations will prove useful. Maps will allow geographic and distance factors to be assessed and help to identify emerging development patterns. Tables summarizing the acreage of uses of concern - perhaps broken down by high, medium, and low pollution potential - will facilitate assessment of degree of risk and allow for comparisons between wells. Figure 11 can be referenced for examples of potential pollution sources categorized by level of risk.

In each case, special note should be made of observations from the field which will enrich the tabulated or mapped data. For instance, if in the course of conducting the field work, a property owner indicated a particular concern or a willingness to participate in the wellhead protection effort, this should not be lost in field notes but should be carried forward for follow-up. Additional special notes should be carried forward about suspected abandoned wells or underground tanks.

Other useful information which should be compiled for each wellhead area would be property maps and owner/address lists. Surface drainage patterns and soils could also prove useful in assessing the potential direction of flow and the permeability characteristics of materials which might transmit pollutants. If the locality has a DRASTIC map showing pollution potential based on topographic, and other factors, that information should also be assembled. Another useful piece of information would be the presence (or absence) of nearby existing or planned water lines which would help in assessing alternative water supplies.

Step 9 - Assess Vulnerability, Replaceability, and Impact of Alternative Strategies

This step may be one of the most complex in the wellhead protection process. It involves combining the compiled data, weighing the significance of what has been found and assessing various options. Considerable judgement is required and for that reason, it may be desirable to take a team approach involving various county staff. It may be desirable to establish an advisory committee consisting of community members and county staff to better assess impacts and educate various sectors of the community. In some communities, it is expected that a committee will be appointed to give advice and reactions on almost any significant planning issue. Elsewhere, the Planning Commission itself fills this role. Whether to complete the vulnerability assessment, etc., of step 9 and then to report the results along with proposed actions or whether to involve others at the beginning of step 9 - or earlier - is a choice that each locality should make.

No formula can be offered for weighing the information which has been compiled. This is much like any other planning or zoning decision process

Figure 11

The following list is from the Rhode Island wellhead protection program. It groups activities by their degree of risk.

LIST OF CATEGORIES OF POTENTIAL SOURCES OF GROUND WATER CONTAMINATION

Higher Risk

Airports-Commercial (maintenance repair, fuel storage)
Automotive Repair Shops
Automotive Body Shops
Boat Builders & Refinishers
Bus & Truck Terminals
Chemical Manufacturers
Dry Cleaners
Dumps
Fuel Oil Distributors (product storage, equipment maintenance & storage)
Furniture Strippers, Refinishers
Industrial Manufacturers
Junkyards & Salvage Yards
Landfills
Machine Shops
Metal & Drum Cleaning/Reconditioning
Paint Shops
Photographic Processors
Printers, Blueprint Shops
Railroad Yards
Repair Shops (engines, appliances, etc.)
Rust Proofers
Service Stations (gas stations)
Waste Storage, Treatment, & Recycling (hazardous & non-hazardous waste)

Moderate Risk

Agricultural Related Activities* (pesticide & fertilizer storage & application, machinery maintenance & fueling)
Asphalt, Coal, Tar & Concrete Companies
Car Dealers
Dredge Disposal Sites
Medical Facilities (hospitals, clinics, laboratories)
Military Facilities (past & present)
Nursing Homes
Pipelines (oil & sewer)
Prisons
Research Laboratories
Road Salt Storage
Schools, Colleges & Trade Centers
Wastewater Treatment Plants (past or present sludge disposal)
Wood Preservers

* Not all agricultural applications of pesticides and fertilizers represent a moderate risk to ground water. A number of factors are involved in determining the risk to ground water, and many pesticide and fertilizer applications can be considered to represent a lower risk.

Lower Risk

Animal Care & Holding Areas (stables, kennels, pet shops)
Auto Parts Stores
Beauty Salons
Construction Sites
Food Processors (meat packers, dairies, bakeries)
Funeral Homes & Cemeteries
Golf Courses
Hotels & Motels
Land Application of Sewage Sludge
Laundromats
Nurseries
Residential Development (lawn care, septic systems)
Restaurants & Taverns
Retail Shopping Centers, Malls
Sand & Gravel Mining Operations
Sawmills
Stormwater Management Facilities
Transmission Line Rights of Way
Transportation Corridors (road de-icing, materials transport)
Utility Substations/Transformers
Waste Transfer Stations

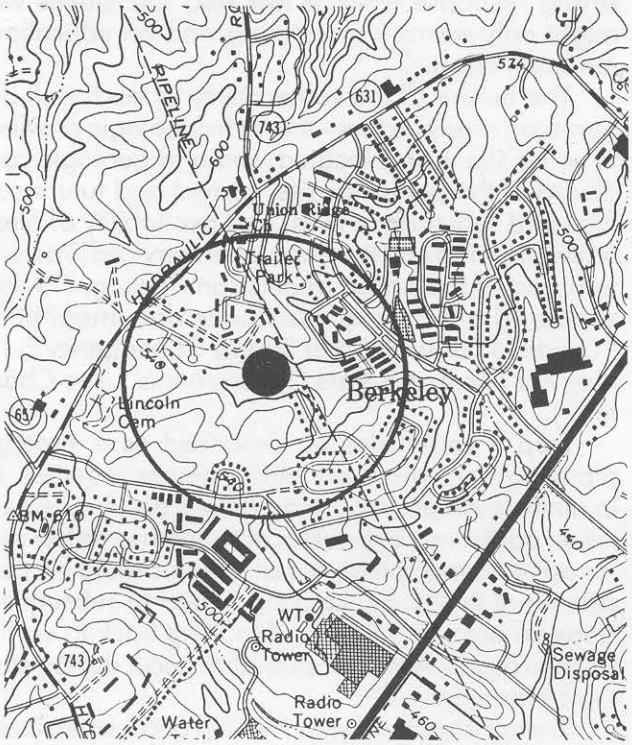
Notes

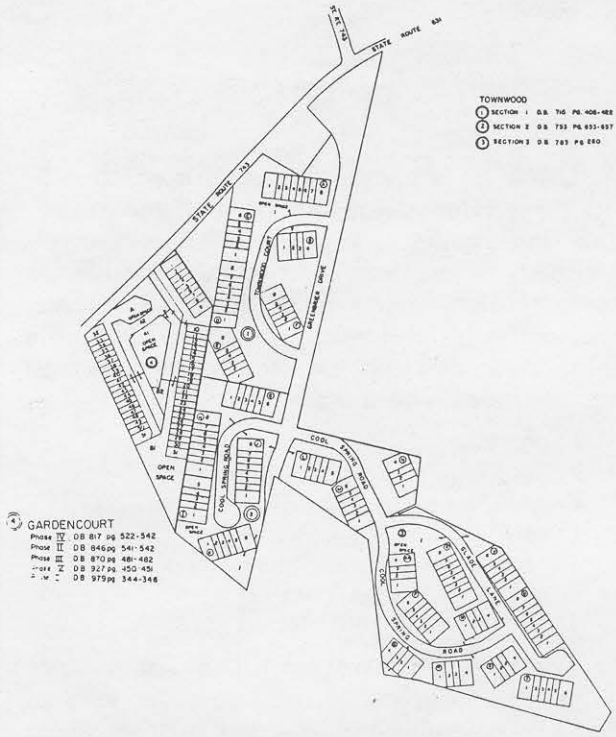
1. This list is not a substitute for investigating a specific source in order to determine its threat to ground water, which may be higher or lower than indicated on this list.
2. The level of risk to ground water associated with each category is based on the assumption that the sources are not utilizing and/or releasing any potential contaminants that are not normally associated with the activity. In addition, the threat posed by facilities within a category varies depending on the safeguards or best management practices that are utilized to prevent contamination.
3. It is assumed that none of the categories in this table are being served by sewer systems. Consequently, if sewer lines were brought into an area, the risk posed by certain categories could potentially be reduced.
4. Low risk is not to be confused with no risk. Sources in this category can and have caused ground water contamination.
5. This list is subject to change as more information becomes available about the threats posed to ground water from these categories.

Source: *State of Rhode Island 305B Report,* 1990, Ground Water Section.

Figure 12

EXAMPLES OF FIELD STUDY MAPS AND MATERIALS





Land Use Field Sheet
(portion)

Tax Map #	Parcel #	Address	General Land Use	Special Features
61	26	2252 Rose Lane	Church	Under Construction
61	30	318 Jefferson Hway	Hway Commercial	Gas Station
61	31	319 Jefferson Hway	Res.-Mobile Home	Adjacent to Well #2
61	32	321 Jeff. Hway	Res.-M.H.	
61	33	324 Jeff. Hway	Res.-M.H.	Leaking Heating Oil Tank
62	1-14	1290 Pine St. thru 1322 Pine St.	Res-Townhouse	New
62	20	1400 Pine St.	Public	Elem. School

in that it is a matter of judgement and balancing of factors.

One approach would be to develop what could be called a "Risk/Response Matrix." Along one axis might be risk factors broken into high, medium and low. The other axis might reflect an assessment of the stakes or an evaluation of what is at risk. A public water supply system serving a large number of customers for which there was no feasible alternative supply might be considered high stakes. A well classified as high stakes and high risk would warrant a strong response while a low risk, low stakes well might only warrant monitoring and an education/outreach effort.

The nature of the vulnerability of each well depends on many factors - the hydrogeologic province in which the well is located, soil and geologic conditions at the particular site, current and future surface and sub-surface uses, and availability of alternative supplies and the population serviced. To assist with part of this phase of decision making, EPA has prepared a technical assistance document titled "Guide to Ground Water Supply Contingency Planning For Local and State Governments" (see Chapter 7).

Step 9 could also be described as a strategic planning step where everything comes together. As in other strategies, planning details and implementation particulars are not focal concerns - rather major options and categories of action should be considered at this stage. Looking ahead to subsequent steps (in broad outline) and looking back to earlier steps to assess various inputs both occur during strategic planning.

The conclusion of step 9 would occur when it was possible to summarize and report what has been found and what strategic next steps are proposed along with their justification. A generic outline of such a report might look something like the following:

I. Public Wells in County X
   a) number
   b) locations
   c) withdrawal rates and service areas
   d) ownership
   e) role of wells in the overall public water supply system

II. Results of Study Area Surveys
   a) methodology
   b) field study findings
   c) plans, zoning and other findings
   d) replaceability findings

III. Proposed Strategy
   a) proposal and rationale
   b) other strategies considered but not recommended
      1) do nothing
      2) others

IV. Next Steps
   a) regulatory measures
   b) voluntary measures
   c) dealing with existing land uses
   d) anticipating future allowed uses
   e) technical assistance
   f) financing
   g) work plan for next steps

Figure 13

DRASTIC

DRASTIC is a mapping system which provides a systematic way for planners, administrators, and managers to address the relative vulnerability of an area's water table aquifer to contamination when making decisions that may impact the ground water resource. The name DRASTIC derives from the seven factors which go into the maps. These are:

- **D**epth to water
- **R**echarge
- **A**quifer Media
- **S**oils
- **T**opography
- **I**mpact of Vadose Zones
- (Hydraulic) **C**onductivity

The system consists of two major components: the mapping of hydrogeologic settings and the assignment of an index number which helps the user evaluate the relative ground water pollution potential of these settings. This information can be used for preventative purposes through the priortization of areas where ground water protection is critical and can identify areas where special attention is warranted.

DRASTIC was developed by the U.S. EPA and the National Water Well Association. Interest has been growing in Virginia since DRASTIC map training workshops were initiated by the Virginia Ground Water Protection Steering Committee. The following Virginia counties now have DRASTIC maps and are using them for various purposes:

Amherst	Nelson
Augusta	Prince William
Botetourt	Rappahannock
Carroll	Rockbridge
Greene	Rockingham
Henrico	Shenandoah
Louisa	Southampton
Middlesex	Warren

Six of these communities were part of an original pilot program undertaken by the Virginia Ground Water Protection Steering Committee. The others have been undertaken by local governments, PDCs, or other organizations.

Chapter 4 discusses a variety of tools and measures which would be the basis for considering "next steps." Chapter 5 discusses the advantages and disadvantages of various delineation techniques which can be used to estimate the area which might be established as the official wellhead protection area.

Step 10 - Discuss Results With the Planning Commission and Board/Council

It is frequently said that ground water is "out of sight and, therefore, out of mind." To the extent that this is true, it is a problem.

This stage in the wellhead protection process can be viewed as an opportunity to promote ground water and wellhead awareness and to build community support for wellhead protection. If wellhead protection can be seen as a means of protecting a valuable public investment in water supply, maintaining the community's reputation and attractiveness for development, protecting private investment and property values and as beneficial and necessary for the community, this would be desirable and would likely provide a basis for taking further steps. If, on the other hand, the community's first encounter with wellhead protection is in the form of more restrictions and more government control, it may prove difficult to gain the community support necessary for a program. The key factors in the community seeing wellhead protection as worthwhile are: early and consistent information; encouraging a partnership attitude between water customers, well owners, property owners and local government; and protection measures that are appropriate and justifiable in terms of both allowing for beneficial uses of property and protection of ground water to serve community needs. This approach is no different than in other zoning situations but it may be that wellhead protection can be explained with a clearer rationale than other less focused area-wide forms of planning and zoning.

Step 11 - Implement Management Practices and Delineate Wellhead Protection Areas

At this point the Planning Commission and Board would need to authorize proceeding to implement particular protection measures. The local planning staff or the PDC is familiar with preparing zoning and other regulatory proposals and should handle the wellhead protection measures according to local practice.

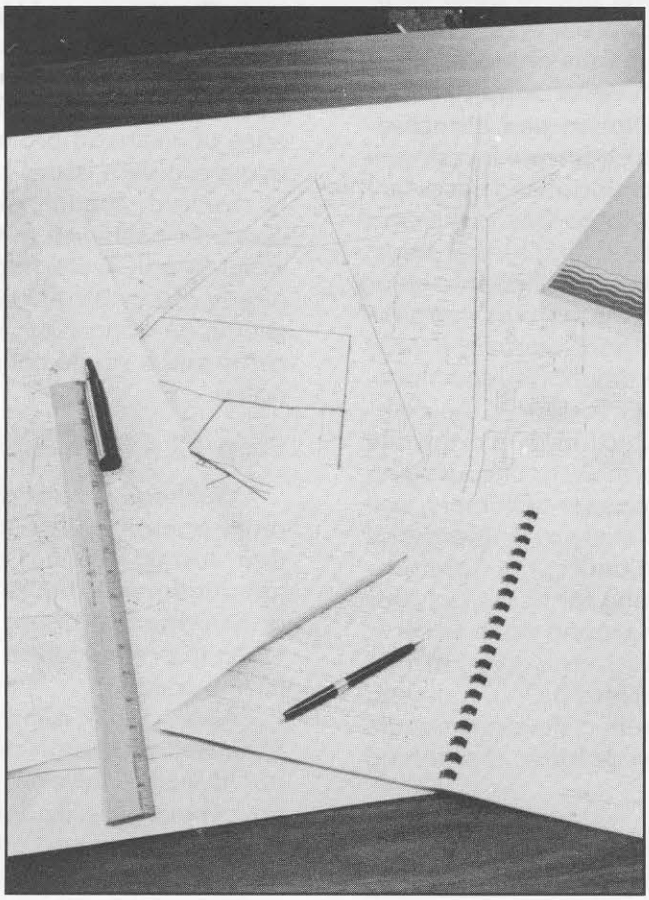
Other aspects of implementation also deserve mention. Once wellhead protection areas have been adopted, it is suggested that copies of these maps be incorporated into the comprehensive plan and all other development and property related maps so that "one hand knows what the other is doing." It would also be advisable to file a copy of a map showing the protection areas with other local and state agencies who might conceivably take action in the vicinity of the wellhead areas. These might include: fire and police departments, neighboring localities, the Planning District Commission, Virginia Department of Transportation, Virginia Department of Waste Management, Virginia Department of General Services, Virginia Water Control Board, Virginia Department of Health, and the County Extension agent. Many state agencies make it a practice to contact local governments prior to their own action, however, attempting to alert them to the existence of wellhead protection areas in advance may avoid problem issues before they occur.

Second, a contingency plan should be developed for each well in the event that an alternative water supply were necessary. Both the immediate needs of customers and long-term replacement should be addressed. A plan for easing public concerns and a single contact person should be designated.

Step 12 - Plan for the Future

Wellhead protection should extend beyond currently operating wells to include planning for the future. Just as localities consider future surface water impoundment sites and take steps to protect these in anticipation of need, so should similar steps be taken to protect future well sites and wellhead protection areas.

Also, keep in mind that the Safe Drinking Water Act's wellhead protection program addresses only public wells. However, in many localities individual household wells, if added up, serve many more people. Public wellhead protection is justified as a starting point based on the number of people served, on protecting the public investment and in educating the community, and on the need for more inclusive ground water protection. Public wells may be addressed as a first step but many more wells exist as part of an area-wide pattern of private use withdrawal. These private wells also need to be protected.



Chapter 4

WELLHEAD PROTECTION TOOLS

Local governments in Virginia have the authority to employ a range of planning, regulatory, and other techniques in order to achieve wellhead protection goals. Tools, such as overlay zoning or easements, for example, are well suited to achieving land use and source controls to protect wellhead areas.

A locality's decision about which methods to employ is really two decisions. One has to do with the size and extent of the area to be protected. The other has to do with the degree of restrictiveness of the protections. If the wellhead protection area is to be of minimal size and limited to the immediate vicinity of the well, the controls may need to be relatively stringent. The protection approach for a large wellhead protection area, however, may include tiers where the restrictions reflect progressively reduced levels of control. The most restrictive controls might be placed near the wellhead, with graduated zones phasing to less restrictive provisions further from the well.

Since the choice of tools is related to the size of the wellhead protection area, it is suggested that Chapters 4 and 5 be read together. In the following chapter,Chapter 5, methods for delineating protection areas are described and compared. The meshing of protection techniques and delineation methods into a workable wellhead protection scheme will require, like any other land use planning decision, a sensitivity to local political and economic factors as well as legal and environmental considerations.

In the following sections, tools are grouped based on their general method or approach.

Planning Approaches

Comprehensive Planning. The comprehensive plan is a logical starting point for wellhead protection since it provides the foundation for all programs and land use management tools at the local level. It sets forth goals and policies to guide future land use and development policies of a community. In the event that a community's wellhead protection program is ever challenged, one of the best defenses will be a well formulated comprehensive plan which provides the basis and rationale for the challenged action.

Virginia law requires that local governments prepare comprehensive plans and update them at least once every five years. Provisions were added to the code in 1988 and 1990 to indicate that jurisdictions shall study matters such as ground water and geology in preparing their plan and may subsequently adopt provisions to protect the ground water resource. These provisions apply both to private wells serving individual households and businesses, and to the various types of public wells which are the focus of the Handbook.

Area-wide planning studies for public wells might examine land use types and densities in relation to ground water vulnerability, and result in designating areas where conservation and protective measures are needed. Techniques such as DRASTIC mapping could be employed to assess vulnerability. This evaluation process can help localities to understand the nature of any potential threats to their drinking water supply, and provide an impetus for establishing goals to protect these valuable resources.

Site specific studies around individual public wells can provide the basis for planning and goal-setting on a site by site basis. In some cases, the individual results may suggest that the community revisit its development concepts and policies in order to address recurrent issues or problems.

Localities that fall under the Chesapeake Bay Preservation Act are already familiar with using comprehensive plans to evaluate development patterns and their impact on water quality protection. In order to comply with the Act, Chesapeake Bay jurisdictions must prepare comprehensive plans which identify the relationships between water quality protection and other land use considerations. The Chesapeake Bay Local Assistance Department's *Local Assistance Manual* includes a section on wellhead and ground water protection and provides useful guidance for all localities regardless of location.

Capital Improvements Planning. Often included as an element in a comprehensive plan, a capital improvements program - or CIP - provides a schedule for financing, constructing, repairing, or replacing major public facilities needed by a locality. Section 15.1-464 of the Code of Virginia permits a locality to prepare a capital improvements program based upon its comprehensive plan, but does not make it mandatory. It states that:

> "...Such capital improvement program shall include the commission's recommendations, and estimates of cost of such facilities and the means of financing them, to be undertaken in the ensuing fiscal year and in a period not to exceed the next four years, as the basis of the capital budget for the county or municipality...."

Figure 14

ENABLING LEGISLATION FOR COMPREHENSIVE PLANNING IN VIRGINIA

In 1988, following the completion of *A Groundwater Protection Strategy for Virginia,* the Virginia Code was amended to include provisions for localities to survey and study matters such as ground water and geology in preparing their plan. This section of the code now reads as follows:

PLANNING, SUBDIVISION OF LAND AND ZONING -
ARTICLE 4:

The Comprehensive Plan

15.1-446.1. Such plan, with the accompanying maps, plats, charts, and descriptive matter, shall show the commission's long-range recommendations for the general development of the territory covered by the plan, including the location of existing or proposed recycling centers. It may include, but need not be limited to:

1. The designation of areas for various types of public and privatedevelopment and use, such as different kinds of residential, business,industrial, agricultural, conservation, recreation, public service, floodplain and drainage, and other areas.
2. The designation of a system of transportation facilities such as streets,roads, highways, parkways, railways, bridges, viaducts, waterways, airports, ports, terminals, and other like facilities.
3. The designation of a system of community service facilities such as parks, forests, schools, playgrounds, public buildings and institutions, hospitals, community centers, waterworks, sewage disposal or waste disposal areas, and the like.
4. The designation of historical areas and areas for urban renewal or other treatment.
5. **The designation of areas for the implementation of reasonable ground water protection measures.**

15.1-447. Surveys and studies to be made in preparation of plan; implementation of plan—(1) In the preparation of a comprehensive plan, the local commission shall survey and study such matters as the following: (a) Use of land, preservation of agricultural and forestal land, production of food and fiber, characteristics and conditions of existing development, trends of growth or changes, natural resources, **ground water,** surface water, **geologic factors,** population factors, employment and economic factors, existing public facilities, drainage, flood control and flood damage prevention measures, transportation facilities, the need for affordable housing, and any other matters relating to the subject matter and general purposes of the comprehensive plan.....

Capital improvements planning is an important component of a wellhead protection program, given the role that local government infrastructure plays in fostering development. In planning areas for future development, local governments must ensure that there will be adequate potable water supplies. If ground water is to be relied on as the primary source of drinking water, this means considering the need for and the location of new wellfields. In addition, furnishing infrastructure to a region, or not doing so, can act as a means of locating future development in areas away from wellheads in order to lower vulnerability to ground water contamination. The CIP also plays a role in contingency planning. In the event that a public well needed to be phased out, replacement supplies - either from surface or ground water sources - would need to be identified, planned and linked to a source of funding.

Contingency Planning. In deciding how big an area to protect and what protections should be applied, a locality must evaluate how dependent it is on the current supply from a given water well. A contingency plan deals with this issue, identifying how a jurisdiction would deal with a water supply disruption, as well as addressing prevention methods and mitigation measures to avert threats.

In developing a contingency plan, potential threats to ground water should be classified along with appropriate response and remediation actions. This should include specific information on the individuals responsible for coordinating and taking

response actions. Plans for obtaining replacement water sources should be determined and means of funding identified in the event that a problem occurs. Thinking seriously about contingency planning may be what motivates a locality to undertake wellhead protection as a way of decreasing the need to implement its contingency plan.

Regulatory Techniques

General Zoning. The ability of a locality to control land uses through zoning can provide a strong basis for a successful ground water protection program. Along with the part of the code dealing with the comprehensive plan, Section 15.1-489 of Virginia's zoning law was also amended to incorporate language allowing localities to include "reasonable" zoning provisions to protect ground water. Wellhead protection is a prime example of the type of program envisioned when the state enabling laws were expanded. While the term "reasonable" is not defined in the statute, it can be assumed that a reasonableness standard applies to all zoning and, therefore, that ground water protection measures must be no less reasonable than other zoning measures.

Zoning can be used as a tool to protect wellhead areas from contamination in a number of ways, depending on the level of development surrounding the wellfields. It is most effective for directing future development in a planned fashion - it is much less effective once an area is developed. This is a good reason to take a preventive and anticipatory approach in dealing with wellhead areas.

If a wellhead area is currently undeveloped, the most direct approach for protecting it would be to zone the wellhead area for uses compatible with ground water protection. Other uses, those on the "Land Uses Impacting Ground Water Quality - What to Look For" lists discussed in Chapter 3, such as certain commercial or industrial activities, could be directed to other locations where the ground water and surface water resources may be less vulnerable.

In addition, the following sections discuss specific types of zoning controls that are especially applicable for wellhead protection, although others may be appropriate as well. The techniques that will be discussed here are: overlay zones, density restrictions and cluster development, setback and buffer requirements, conditional zoning and special

Figure 15

ENABLING LEGISLATION FOR ZONING IN VIRGINIA

The Virginia enabling legislation for zoning was also amended in 1988 to allow localities to adopt reasonable provisions in their zoning ordinances to protect the ground water resource. This section of the code now reads as follows:

PLANNING, SUBDIVISION OF LAND AND
ZONING - ARTICLE 8:

Zoning

15.1-489. Purpose of zoning ordinances—Zoning ordinances shall be for the general purpose of promoting the health, safety or general welfare of the 15.1-427. To these ends, such ordinances shall be designed to give reasonable consideration to each of the following purposes, where applicable: (1) to provide for adequate light, air, convenience of access, and safety from fire, flood and other dangers; (2) to reduce or prevent congestion in the public streets; (3) to facilitate the creation of a convenient, attractive and harmonious community; (4) to facilitate the provision of adequate police and fire protection, disaster evacuation, civil defense, transportation, water, sewerage, flood protection, schools, parks, forests, playgrounds, recreational facilities, airports and other public requirements; (5) to protect against destruction of or encroachment upon historic areas; (6) to protect against one or more of the following: overcrowding of land, undue density of population in relation to the community facilities existing or available, obstruction of light and air, danger and congestion in travel and transportation, or loss of life, health, or property from fire, flood, panic, or other dangers; (7) to encourage economic development activities that provide desirable employment and enlarge the tax base; **(8) to provide for the preservation of agricultural and forestal lands and other lands of significance for the protection of the natural environment;** (9) to protect approach slopes and other safety areas of licensed airports, including United States government and military air facilities; and (10) to promote affordable housing. **Such ordinance may also include reasonable provisions, not inconsistent with applicable state water quality standards, to protect surface water and ground water as defined in §62.1-44.85 (8).**

Figure 16

CLARKE COUNTY'S USE OF OVERLAY ZONING

Prospect Hill Spring is a major source of drinking water for the communities of Boyce and Millwood in Clarke County, Virginia. Concern had arisen that future growth and development near the spring might result in its contamination. In 1983 Clarke County hired a contractor to perform a hydrogeologic and engineering study of the spring. As a result of that study, the County implemented an overlay zoning district to protect the recharge area surrounding the spring.

The Natural Resource Conservation (RC) Overlay District was designed as part of the Clarke County Zoning Ordinance to "apply special regulations to the ground water recharge area of the Prospect Hill Spring" with a purpose of protecting "those water resources in Clarke County which are necessary to serve adequately and efficiently the public need, health and welfare..." The area included in the RC boundary extends approximately 3,000 feet from the spring. It covers a previously zoned area and allows development and land uses permitted by the underlying zoning if they are compatible with the intent of the RC District. However, the following uses or development of land within the district are strictly prohibited:

- Mining, and/or extraction of natural resources;
- Drilling, other than for private, on-site source of potable water;
- Sanitary land filling, application, depositing, spreading or spraying of any hazardous or toxic chemical and/or biological materials or substances;
- Underground storage of any chemical or petroleum products for commercial or industrial purposes;
- Storage, disposal, and/or land application of sludge, residue and/or effluent resulting from treatment, storage, disposal or reclamation of sewage and industrial wastes; and
- Animal confinement operations (feedlots).

Clarke County also mandates that residential dwellings be built on a minimum lot area of two acres and a maximum lot area of four acres, and that the lot coverage by all impervious surfaces not exceed twenty percent. Detailed regulations for septic systems are also laid out, but the County plans to update the ordinance by the end of 1992 to increase the septic requirements. New district boundaries will be established through the update of the Comprehensive Plan, and additional restrictions will be implemented. The intent in the new ordinance will be to keep the strictest provisions in the currently protected area, and to add new, less stringent, requirements for areas further out from the spring.

permits, and subdivision requirements.

Overlay Zones. Overlay zoning involves placing additional requirements for environmental or other purposes on portions of existing zoning districts. The standards for the overlay zone are then added to the standards of the original zone. This technique is also appropriate in protecting environmentally sensitive areas with geographic boundaries that do not coincide with the underlying zoning district.

Floodplain overlay zones are a common use of this type of zoning, where the overlain restrictions in flood areas cover portions of the community's residential, commercial, and industrial districts but not all. Within the floodplain zone, standards for floodproofing of buildings, erosion control, and other purposes are added to the existing requirements. This overlay technique can also be used to protect reservoirs and historic areas, and for controlling building heights near airports.

At the recommendation of the 1991 report of the Ad Hoc Wellhead Protection Advisory Committee, the Virginia Ground Water Protection Steering Committee endorses overlay zoning as an appropriate approach for wellhead protection. Overlay zoning enables a municipality that already has a standard zoning ordinance to add wellhead protection zones and regulations.

A wellhead protection overlay zone might include requirements such as:

- prohibition of certain uses;
- reduced densities;
- limits on amounts of impervious surface;
- special requirements for septic systems;
- strict control of hazardous and toxic materials storage and management; or
- special stormwater and waste disposal provisions

In addition, several of the land management tools which will be discussed below, such as site plan review, design and operating standards, and source prohibitions, might be especially effective when applied within wellhead area overlay zones.

Density Restrictions. Reducing the allowable density of structures can be useful in protecting a

wellhead area since it lessens the potential impacts of development by reducing the total number of buildings,-amounts of impervious surface, or numbers of septic systems within the zone. Since large-lot zoning tends to leave more open land, it can also help maintain natural vegetation and landscape contours which contribute to the filtration of runoff and recharge water. The down side of large lot zoning is that it uses more land and almost guarantees that private septic systems rather than a common waste water collection system will be used, in which case there would actually be more discharge to the ground than if densities were higher. If, however, there is no chance of a public sewer system, then larger lots would result in fewer septic systems and fewer failures than smaller lots.

Cluster Zoning and Planned Unit Developments (PUD) are another strategy to reduce densities near wellheads. These methods increase densities within portions of parcels while the remaining areas are left in open space and that open space could be established near the well to be protected. This technique offers flexibility in designing and locating development in wellhead protection areas so that the more sensitive portions of a site can remain in a natural unaffected state.

Setback and Buffer Requirements. Zoning ordinances normally include requirements that buildings be set back a certain minimum distance from the boundaries of a lot. The setback requirement could also be used to ensure that structures are kept away from the most sensitive areas of the lot or from features or facilities near the lot. Buffer strips of natural vegetation can also be required between structures and the lot boundaries to allow for better water filtration and erosion control. Given the inflexibility of a lot by lot approach, however, a cluster or PUD approach to an entire development may be a preferred approach.

Conditional Zoning and Special Use Permits. Conditional zoning and special use permitting provide ways to add flexibility and to respond to the particular features of each site as applications are submitted for its development. Uses, which might be inappropriate to a district if permitted without limitation, can be allowed under certain specified conditions. Rezoning which allows an applicant to voluntarily propose (proffer) conditions that limit or qualify how property may be used can address many of the concerns that might arise in a wellhead protection area. The acceptability of different land uses can thereby be evaluated on a case by case

Figure 17

WATER RESOURCES OVERLAY ZONING DISTRICTS

Source: *Wellhead Protection Programs: Tools for Governments*

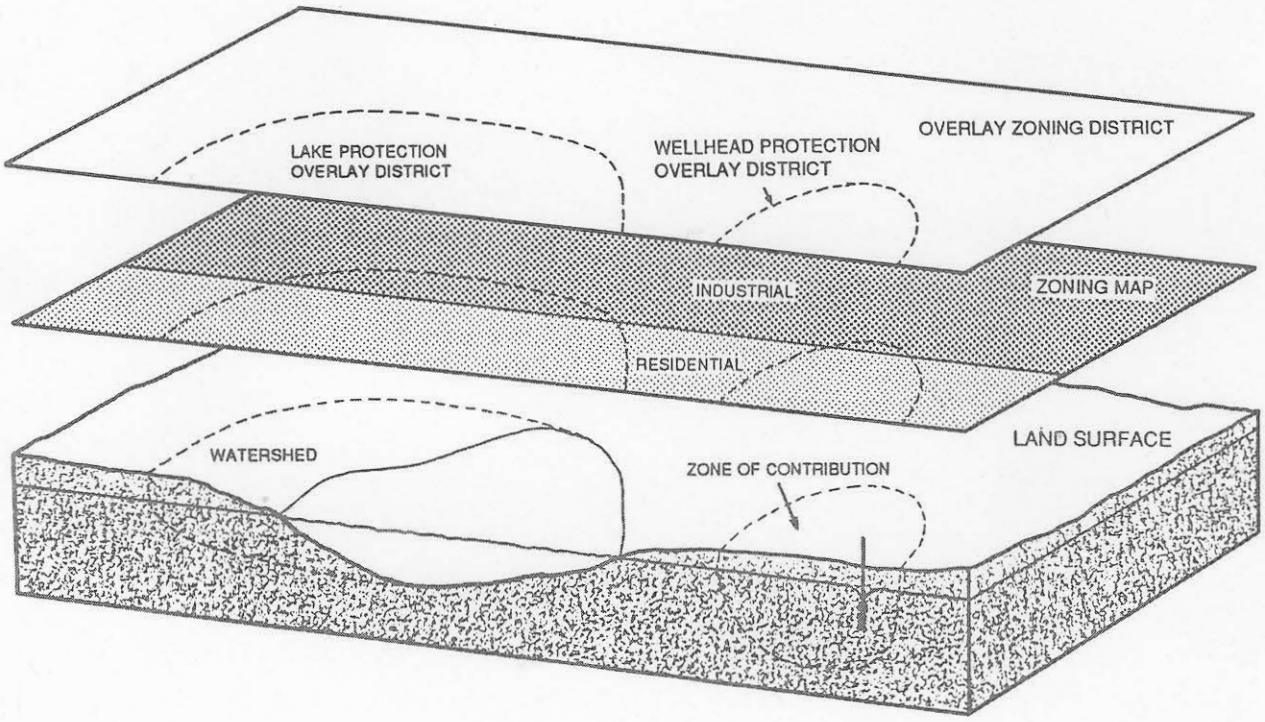
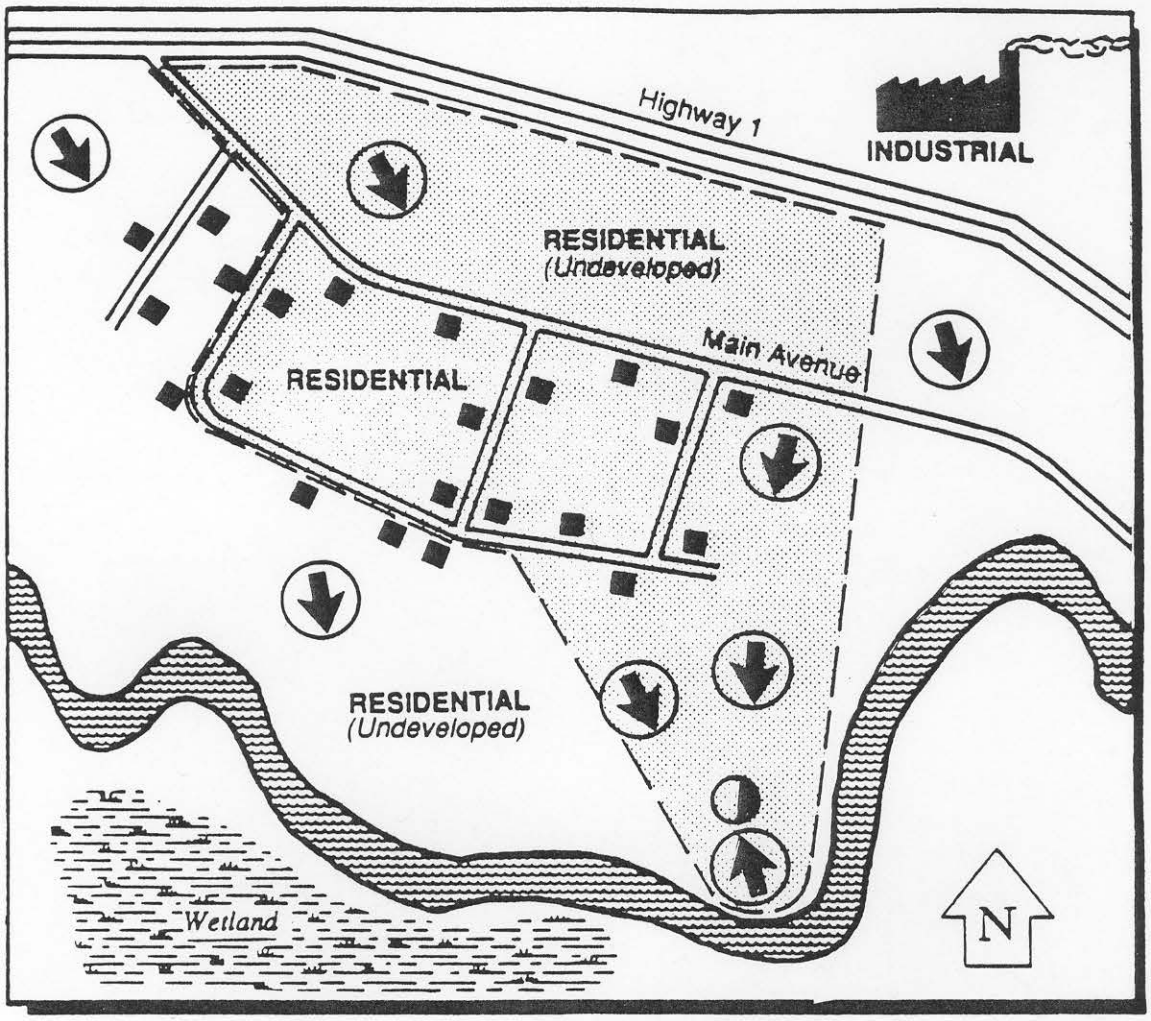


Figure 18

A WELLHEAD PROTECTION OVERLAY ZONE IS ADDED TO EXISTING ZONING

Source: *Wellhead Protection Programs: Tools for Local Governments*



Scale: 1" = 1mile

Legend:

- Municipal Water Supply Well
- Ground-Water Flow
- Overlay District
- *Wetland*

basis to ensure that potentially harmful activities are adequately addressed.

In terms of wellhead protection, these techniques can be used so that certain land uses, such as single family housing, are allowed while other more intensive uses, such as apartment complexes, are permitted only under specified conditions which would minimize impact to the aquifer, including septic tank or mass drainfield limits, impervious surface restrictions, or vegetation planting requirements. This tool is probably most effective if used in combination with site plan review, which is discussed below.

Subdivision Ordinances. Subdivision ordinances are local regulations that establish requirements for streets, utilities, property platting, and procedures for dedicating land for rights-of-way and easements. Their primary focus is on what might be termed engineering concerns and ensuring that the basic site and public facility needs are met. Roads, lot drainage and water supply are among the concerns to be addressed. If the subdivision involves property in the vicinity of a current or a planned public well, the subdivision should be designed and laid out in a way that would minimize any impacts upon the wellhead protection area. The Code of Virginia Section 15.1-466 outlines the provisions of subdivision ordinances and while it does not specifically mention wellhead protection areas, how a subdivision is designed can have an influence on preventing ground water contamination and promoting beneficial aquifer recharge. If a new subdivision is to be served by their own community water supply and the locality has wellhead protection overlay district provisions on the books, approval of the subdivision should ideally be coordinated with a rezoning to add the overlay district provisions around the new well site. Consideration should also be given to preparing a contingency plan in the event that supplies were to fail or become contaminated.

Site Plan Review. The purpose of a site plan review is to assure that a proposed development is laid out to be compatible with existing land uses in the surrounding area and existing or planned infrastructure. A site plan review requirement can be a very useful tool for implementing a wellhead protection program because it offers a mechanism for reviewing and enforcing other requirements, such as design and operating standards or source prohibitions. The more sophisticated and complex a wellhead protection ordinance, the more useful a comprehensive review process will be for ensuring that all aspects of the regulations are being addressed. Localities need to keep in mind, though, that the more technically complex the site plan review requirements, the more time and expertise reviewers must have.

Design and Operating Standards. Design and operating standards are used to regulate the design, construction, and ongoing operation of various land-use activities. Design standards include physical requirements such as double-walled underground storage tanks, runoff collection systems, stream or ditch channels, and road-salt storage areas. Operating standards are procedures to prevent pollution during the normal activities of a land use. When used in coordination with site plan review, special use permits or proffered zoning, design and operating standards can be an effective technique in preventing ground water contamination in wellhead areas.

A hazardous materials containment structure or area is one example of an activity that could have a significant impact on ground water and could be controlled by design standards with requirements for a back-up containment system or adequate protection from adverse weather to prevent an accidental release of materials. Design standards to limit the size of large impervious surfaces, such as parking lots or buildings, could also be useful to ensure a wellhead area has adequate aquifer recharge.

Operating standards designed to protect wellhead areas would be a set of procedures that can be used in a particular industry or commercial activity to limit the threat to the environment posed by ongoing processes, such as pesticide application or the management of hazardous substances. As a locality develops its wellhead protection program, it should review the ongoing activities within wellhead areas to determine their contamination threats. As is discussed later, it is often difficult to impose new operating standards retroactively so it may be that a voluntary approach should be encouraged. "Working with" land owners may achieve the desired result as quickly and less painfully than a "command and control" effort.

Localities should keep in mind that some potential sources of ground water contamination are already regulated under Federal or State design and operating standards which may preempt certain local actions. These sources include:

- underground storage tanks containing petroleum products or hazardous substances
- underground injection wells
- hazardous and nuclear waste facilities and generators
- use of pesticides
- municipal and industrial solid waste landfills
- wastewater treatment plants
- PCB storage, treatment, and disposal facilities
- Superfund sites
- surface mines

Source Prohibitions. Prohibiting the storage or use of specific hazardous materials in a wellhead

protection area can help remove a serious threat to ground water supplies. Where a wellhead areas is so vulnerable that design and operating standards would not be fully protective, or where there is no development in the wellhead area, source prohibitions can be considered.

These regulations generally take the form of either restrictions on the use of specific hazardous materials or prohibitions against certain kinds of activities that typically require the use of dangerous materials. Specific materials of concern that might be prohibited within the wellhead area include heavy metals, solvents, petroleum products, and radioactive materials. Examples of activities that can pose a threat are described in Chapter 3. Communities that take a material based approach rather than a land use approach should be aware that greater staff expertise and careful monitoring and inspection will be necessary to make the program fully effective.

Local Septic Tank Requirements. Septic systems can be a major source of ground water contamination due to inappropriate siting, unfavorable soil or water conditions, poor design, construction, or lack of maintenance. While Virginia has statewide septic regulations, the state Code also allows localities to adopt more stringent regulations. Chesterfield County, Virginia is an example of one locality which has adopted stricter standards than the general statewide standards by requiring that septic systems be pumped at least once every five years. If implemented within the wellhead protection zone, stricter septic tank requirements could help to avoid pollution of underlying ground water from this potential source.

Dealing With Existing Non-Conforming Uses. If a wellhead area is completely undeveloped, most of the regulatory techniques described above would be useful and easily implemented. However, since this is not often the case, localities must be prepared to deal with the existing uses which are not fully compatible with wellhead protection but which have vested rights. Existing legal uses have certain rights to continue even after changes in zoning or other regulations deem them non-conforming. A recent amendment to the Virginia Code, Section 15.1-475P, immunizes approved final site plans and recorded subdivision plots from local ordinance changes for five years from the date of approval or recordation. Amortization or discontinuance of a use after a reasonable period of time is theoretically possible but both politically and legally difficult. A subtle combination of persuasion, negotiation, and agreements to come into compliance over time may be the best approach in such situations. If a special use permit or other authorization has a requirement for renewal, that occasion may provide an opportunity to bring a use into compliance.

Phasing-in protective measures may take some time to be implemented fully, but this approach does offer the advantage of allowing the community to initiate wellhead protection in developed, undeveloped, or partially developed locations. The cliche "better late than never" does apply in such situations.

Non-Regulatory Techniques

Acquisition of Property or Development Rights. Ownership of land is sometimes described of as a "bundle of rights" - surface use rights, mineral rights, and the right to control access to the land, etc. A fee-simple title conveys full ownership of the entire bundle of rights, while a partial interest can be obtained for a more limited set of rights, such as the right to develop or subdivide the land. The surest means for a locality to provide for protection of wellhead protection areas would be through acquisition of fee-simple titles or development rights of a property. The downside of this statement is that if rights must be purchased, this can be time consuming and costly if the area involved is large or of high assessed value. A critical piece might be purchased around a crucial municipal well but widespread purchase may not be feasible - especially for non-community or investor owned public wells.

In some cases, acquisition might be justified by uses in addition to wellhead protection. These might include using the land for park or recreation facilities or other community-oriented land uses. If the land is extremely sensitive, though, the property might best be set aside for conservation purposes, with public access restricted. Parks and golf courses can themselves threaten ground water if they are heavily fertilized or involve the use of pesticides.

Localities can also protect ground water resources by purchasing partial interests in a parcel of land, which can have advantages over fee-simple interest. Lower acquisition costs allow the community to obtain interest in more parcels without being burdened with maintaining the property, and the property remains part of the taxable base. The more controlling the interests the locality acquires in property, though, the closer the price becomes to the fee-simple cost.

Partial interests in land in Virginia are most often acquired through either conservation easements or restrictive covenants. Sometimes referred to as "purchase of development rights," and sometimes offered as gifts, conservation easements allow the easement holder the right to prevent landowners from taking specified actions on the property covered by the easement, while at the same time al-

lowing landowners to continue many other productive uses of their land. Easements could be used to protect ground water by prohibiting certain kinds or densities of development or restricting human activities such as the use of hazardous materials or septic systems for sewage disposal. Easements apply to all subsequent landowners for the full term of the easement, which may be either a finite number of years or permanent. The advantage to the landowner is in the form of tax benefits on their income tax as a deduction for a gift and on their real property taxes because the land has a reduced value for development as a result of the easement.

Restrictive covenants are another device that can also be used to place permanent restrictions on the use of properties. Whereas easements must be held and enforced by a state agency or a charitable organization under provisions of the *Virginia Conservation Easement Act,* convenants can be enforced by other property owners or service authorities. For properties in wellhead areas, convenants could be imposed to prohibit specific land uses, densities, or threatening activities.

Use Value Taxation. Using property tax incentives to encourage landowners to keep their land undeveloped is a way localities can seek to protect wellhead protection areas. In 1971, the Virginia General Assembly passed enabling legislation allowing localities to give agriculture and forest uses preferential assessment for property taxation. This means that undeveloped land is assessed at its value as currently used, rather than at its full market value. More recently, a provision was added to the Virginia Code Section 58.1-3230 to allow "real estate devoted to open-space use" to also obtain this special classification if it is:

> "provided or preserved for park or recreational purposes, conservation of land or other resources, floodways, historic or scenic purposes, or assisting in the shaping of the character, direction, and timing of community development or for the public interest..."

The "conservation of land or other resources" provision would appear to include wellhead areas. This provision would make keeping large areas of land undeveloped or in less intensive uses more affordable to the landowner, and thus may provide an additional incentive for owners of property in a wellhead area to voluntarily do so.

Water Conservation. Water conservation can help a community to protect its water supply by reducing the total quantity of water withdrawn from aquifers. This reduces the zone of contribution at the surface and thus reduces the area of wellhead vulnerability. Reduced intake also protects against contamination from saltwater intrusion.

Implementing a water conservation effort requires educating the public, elected officials, and the media in order to garner interest and support. Citizens could be encouraged to join voluntary conservation efforts in order to prevent mandatory requirements later.

Hazardous Waste Collection. Household wastes contain materials that are a potential source of contamination for water wells. These include:

- Pesticides and herbicides
- Cleaning chemicals
- Batteries
- Pool chemicals
- Septic system chemicals
- Paints and art supplies
- Motor oil

These waste materials often go unrecognized by the household and are disposed of in regular trash pickups, in local landfills, onto the ground, or into sewers or septic systems. They may then get into local ground water aquifers posing a serious threat to drinking supplies.

Periodic hazardous waste collection days is a way to alleviate the threat of contamination from household sources. A locality could receive wastes at an announced central location and dispose of them through a licensed hazardous waste disposal firm. Interested groups and individuals can help in publicizing such events. Informing the community members of the importance of keeping hazardous waste out of their water supply and encouraging the people to get involved will help increase the awareness of ground water issues and reduce the potential for contamination of aquifers.

Best Management Practices. Voluntary efforts by private citizens and organizations can play a significant role in preventing groundwater contamination. Implementing Best Management Practices (BMPs) which reflect a concern about and commitment to ground water protection can help reduce threats posed by agricultural and industrial uses as well as others.

BMPs are practical design and operational standards that can prevent degredation of ground water while considering economic factors, technical feasibility, ease of implementation, and environmental effects. These standards can apply to schedules of activities, restrictions of practices, maintenance procedures, application and use of chemicals, and other activities which reduce the threat of contamination.

The following list provides examples of some BMPs which could be adopted by agricultural or

industrial operations in the vicinity of public wells:

- Determine the susceptibility of the ground water in the area of the well by knowing the soil type, depth to bedrock, type of bedrock, depth to water table, and characteristics of surface deposits. This type of information can be obtained from the Soil Conservation Service county soil surveys, where available.
- Carefully read and follow the directions on chemical labels which refer to water supplies.
- Mix and store chemicals in a safe place outside the wellhead protection area and as far away from wells as possible.
- Be especially careful to properly calibrate mixing and application equipment when wells are nearby.
- Allow a safe buffer zone between the application area and any water supply wells.
- Properly dispose of chemical containers outside the wellhead protection area.
- Keep especially detailed and accurate records, including all material safety data sheets.
- Develop an alternate water supply plan to implement in case of emergencies that could contaminate a well.
- Follow up immediately to remedy any problems occurring near water supply wells and report the situation to the well owner.

Local governments, Soil and Water Conservation Districts and Soil Conservation Service field offices, as well as extension agents, can help to inform the public about the importance of BMPs and about tax or other cost-share incentives to encourage their implementation.

Cost Share/Matching Funds. As an incentive to implement practices advocated through outreach and education, seed money/cost share/matching funds can make a difference in the degree to which deserved practices are adopted. Since many public wells are small investor owned, financial encouragement to take steps to acquire additional land around a wellhead or to assist low income tenants to replace old underground oil tanks or septic tanks, might provide the necessary stimulus to desired action. In agricultural areas, working with county extension agents to fund a Farm-A-Syst Program to protect farm wells could make an important difference in the rate of adoption of various voluntary programs in the agricultural sector.

Public Education. Last but not least is public education. Perhaps the biggest impediment to more adequate ground water protection is a general lack of public awareness. Chapter 3 outlined a number of steps that a locality could follow in assessing its situation and potential vulnerability. The results of these studies need to be communicated to the public. Chapter 1 provided a self-assessment questionnaire for community leaders which can help such people realize just how much or how little they know.

Localities will have a much better chance to succeed in a wellhead protection program if the community supports the regulatory programs being implemented as well as takes part in voluntary protection efforts. Innovative public education programs on ground water topics can be used to develop interest and backing. Some approaches which could be taken include press releases and conferences, newsletters, and presentations to local schools and community organizations. The content of the materials will depend on local conditions and the audience, but should focus on the role of ground water in meeting community needs, methods for preventing ground water contamination, and what individual residents, property owners, and business managers can do to contribute to the community need.

To assure that someone takes responsibility for public education and outreach in behalf of wellhead protection, localities may want to consider designating one staff member as that locality's "Wellhead Protection Officer". That way, all questions can come to a single person who can take the lead on promoting the program in a variety of ways including visiting with landowners in the protection areas.

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These are examples of tools which local governments in Virginia can consider as part of a local wellhead protection program. These examples do not exhaust the possibilities, however. Localities should innovate and experiment with various approaches and then share the results of their experience with others. In the future, the Virginia Ground Water Protection Steering Committee expects to develop a series of case studies about the efforts of several Virginia localities.

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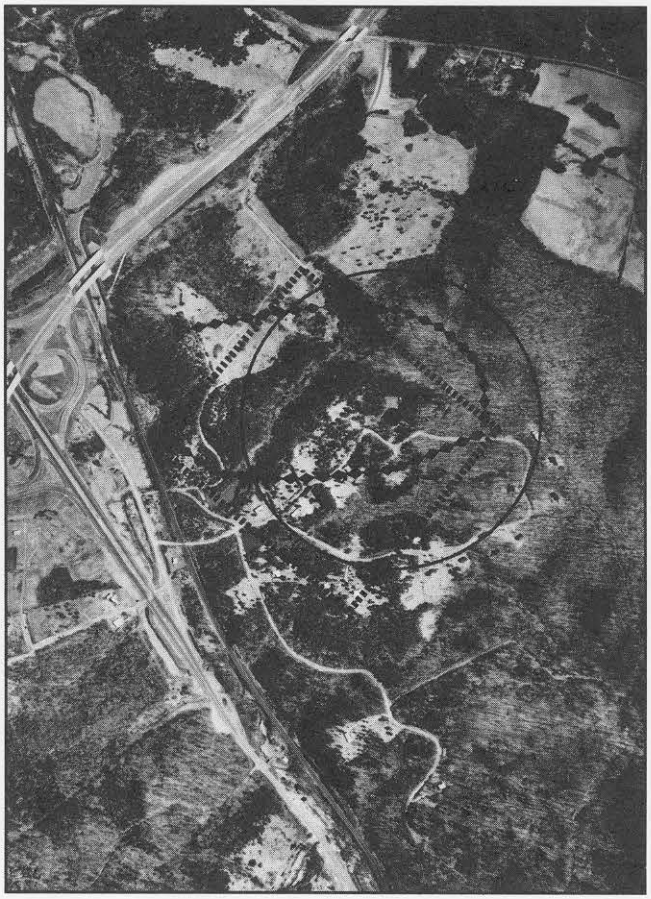


Chapter 5

CHOOSING AMONG DELINEATION METHODS

Along with choosing the most acceptable planning, regulatory, or voluntary approaches, a locality must also make decisions about the area to be protected, the area to be called the "wellhead protection area." A variety of factors enter into such decisions but ultimately they are a matter of policy choice. While there is a wealth of technical writing about the topic of delineating zones of contribution, it is a policy choice whether a locality feels it desirable, or even feasible, to protect that whole area or only its central portion, and to what degree and how.

This chapter will explain several of the methods available for delineating the wellhead protection area. Advantages and disadvantages of each delineation method will be discussed with the intent of helping localities choose which would be the most appropriate for their situation. For those who have been following the steps outlined in Chapter 3, a 1/2 mile fixed radius study area was delineated. What are the advantages and disadvantages of such a fixed radius and what are the alternatives?

Balancing Policy and Technical Considerations

Many localities who are considering wellhead protection for the first time will place priority on getting started more than on technical refinements. Once a start is made and some experience is gained, they may, at a later date, refine the protection areas. Their logic might be that it is better to get some tools in place in the immediate vicinity of the well than to delay while refinements to the outer boundary of the zone are more precisely studied. Smaller communities with less technical staff or financial resources will also favor some of the more basic approaches. All communities regardless of size, should adopt the attitude that when better data and methods become available, the boundaries of the protection area will be adjusted to reflect the new information.

A related and important consideration for a locality is the ease with which the delineation methodology can be used and understood. While some methods are relatively straightforward and simple to apply, others can be quite technically complex. The easiest methods can be implemented without technical hydrologic training because they place relatively little emphasis on hydrogeologic properties associated with each well. Other methods, however, are dependent on a full understanding of hydrogeologic properties and using these methods may require a staff member with a strong scientific background or a consultant. Technical sophistication translates fairly directly into costs, of course.

The ability of a delineation method to incorporate different hydrogeologic settings and physical processes has another important side in addition to costs - that is, defensibility. The more restrictive the regulation, the more substantial must be the relation between the objective of protecting the public drinking water and the area delineated. All zoning decisions, of course, need to be defensible in certain ways (e.g., they are for a legitimate purpose, the means bear a relation to the ends, etc.). No calculation, however, can determine a zoning policy or boundary. How often, for instance, can a strictly technical basis be provided for a height limit of 35 feet (why not 36?), or a density of 10 units per acre (why not 9 or 11?) or 100 acres set aside for industry (rather than 90 or 110?)? The point is that all zoning decision are "judgement calls" within some limits. To the extent that a community has the ability to use some of the more complex methods discussed below, they can better back up their judgement. All of the methods discussed below, however, are accepted methods and have been succesfully used. All are, in varying degrees, defensible and none is more than an estimate.

Each of the delineation methods to be described in the following pages has its inherent strengths and weaknesses. They range from simple, inexpensive methods to quite complex and costly ones. More than one method can be used to delineate alternative protection areas for a single well or wellfield. In fact, comparative studies of different methods have shown that methods can diverge quite significantly in their estimates of the shape and extent of outer boundaries. It is important to point out, though, that near the well, all methods tend to overlap to a significant degree.

Available Methods: Their Advantages and Disadvantages

For more detailed assessments and technical guidance on any of these methods, the reader should consult the U.S. EPA manual *Guidelines for Delineation of Wellhead Protection Areas.*

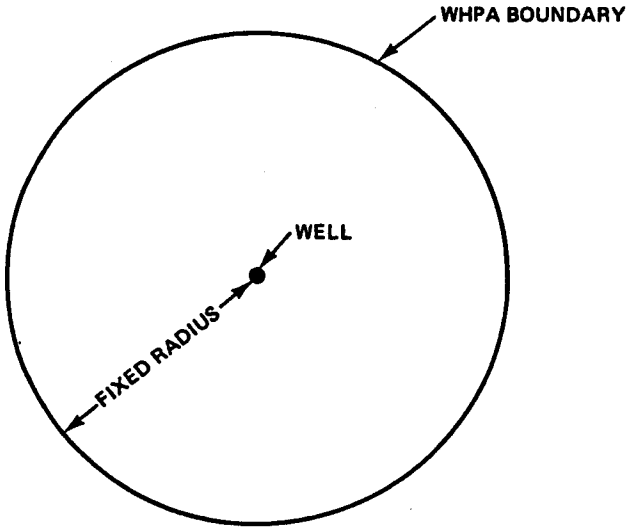
Fixed Radius. Delineation of a wellhead protection area using the fixed radius method involves drawing a circle of a specified radius around a well which is to be protected. The length of the radius in this approach will not necessarily have a specific hy-

drologic or scientific basis and thus it is not known how accurately the area corresponds to the actual zone of contribution. It could, however, be based on generalized hydrogeological considerations and professional judgement, or some average of the distances associated with adopted zones for similar hydrogeologic settings in other jurisdictions. The U.S. EPA suggests a minimum radius of 2 miles as an initial guideline for wellhead protection areas, although many existing programs in other states use shorter radii. For instance, Rhode Island uses 1,750 feet for small wells. Arkansas uses 1,000 feet, while Vermont uses as little as 200 feet. In Chapter 3, a study area of 1/2 mile or 2,640 feet was suggested as a starting point that could be modified based on observed conditions.

Figure 19

USING THE FIXED RADIUS METHOD

Source: *Guidelines for Delineation of Wellhead Protection Areas*



The fixed radius method is an easy technique for a locality beginning their first wellhead protection efforts. It is inexpensive, and requires relatively little technical expertise. However, due to the lack of specific scientific basis for the delineated area, this method can over-protect or under-protect actual well contribution areas. This could add to overall costs by controlling land use in areas that aren't needed if the radius is excessively large. Conversely, portions of areas of contribution that should be protected may lie outside of the fixed radius if it is kept too small.

When using a fixed radius some policy analysts suggest using a conservatively large area which could later be refined, and possibly reduced, if a more scientific method is later adopted. A locality could also choose to start with a small radius in order to put some primary measures of protection in place in the area closest to the well and once the program gained acceptance in the community and more data were available, a larger protection area could be delineated. For communities starting out, this later approach may prove most acceptable. This would also lessen the likelihood of challenge wheras a large fixed radius would raise more issues and potential challenges.

Calculated Radius. The calculated radius methods are also used to delineate a circular wellhead protection zone around a well, but the radius is computed using one of several formulas. The input data required by the radius equations include the pumping rate of the well and hydrogeologic parameters such as porosity and hydraulic conductivity of the surrounding area. Thus, a calculated radius for a protection area may change as the variables in the equations are changed to reflect conditions in the hydrologic system. Three different methods are commonly used for calculating the radius: the radius-of-influence, rate-of-recharge, and volumetric methods.

The radius-of-influence method can be used to delineate the area around a well where a specified drawdown could be expected to occur. The drawdown criterion defines a zone in terms of the degree to which the normal, unaffected water table (for unconfined aquifers) or potentiometric surface (for confined aquifers) is lowered or drawn down as a result of the water withdrawals in an area. In other words, the formula calculates how far away from the well you would expect to find the water table lowered by 15 feet, 10 feet, 5 feet or 0 feet, etc. The no drawdown point would be the estimate of the extent of the zone of influence.

The rate-of-recharge method is applicable to unconfined aquifers and is based on the assumption that all water pumped from a well comes from a direct natural recharge. The radius for the wellhead protection zone is computed using the rates of pumpage and recharge, and the delineated area will correspond to a zone of contribution necessary to recharge the well.

Volumetric formulas for delineating wellhead protection areas are based on the volume of water that will be drawn into a well in a specified period of time. This period of time is known as the time-of-travel and represents the amount of time it would take a contaminant discharged to the land surface to reach the well. The time required would be affected not only by the distance to the well but also by

Figure 20

USING THE CALCULATED RADIUS METHOD BASED ON DRAWDOWN CONTOURS

Source: *Guidelines for Delineation of Wellhead Protection Areas*

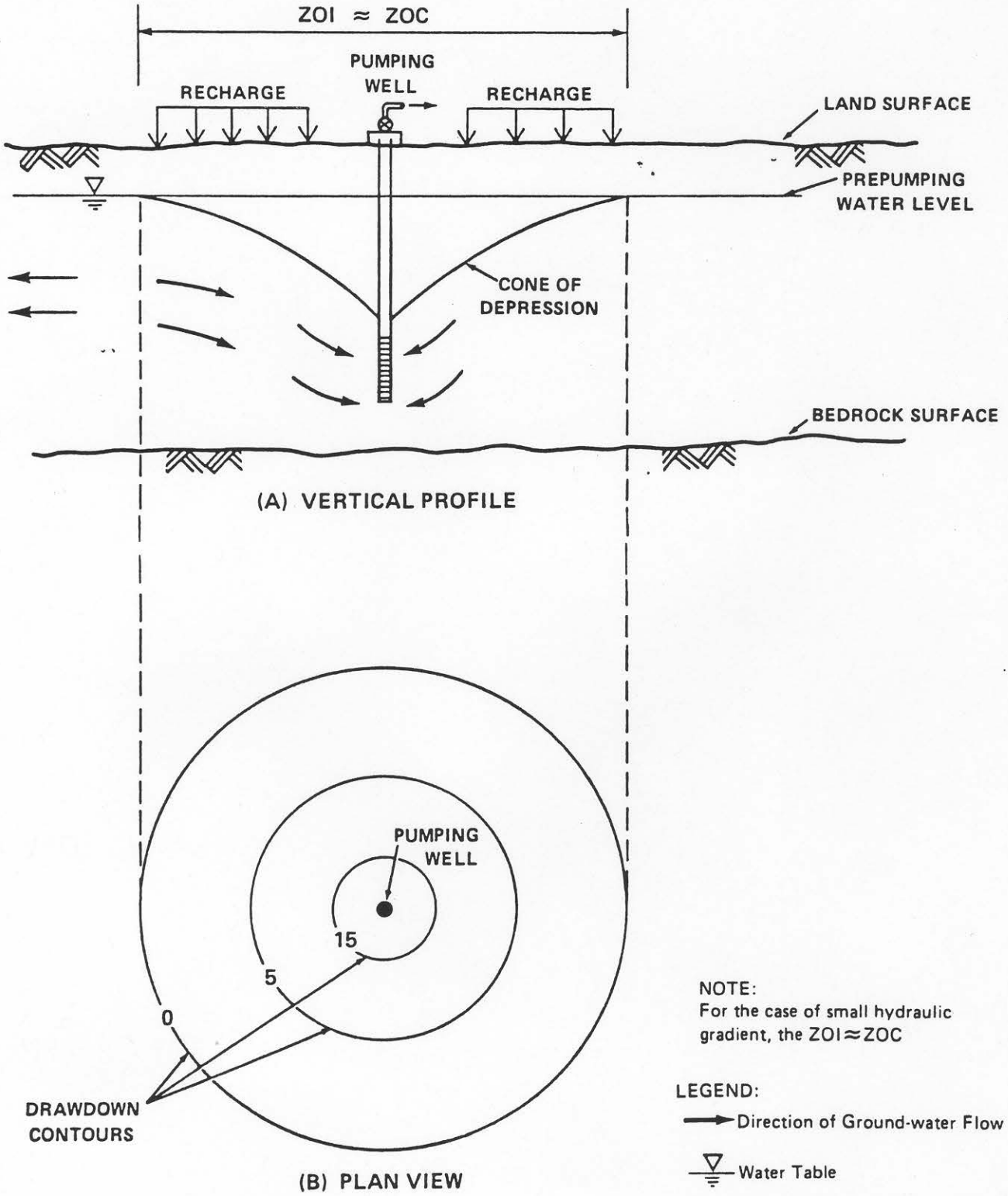


Figure 21

USING THE CALCULATED RADIUS METHOD BASED ON ZONES OF TRANSPORT

Source: *Description and Evaluation of Selected Methods Used to Delineate Wellhead Protection Areas Around Public-Supply Wells Near Mt. Hope, Kansas*

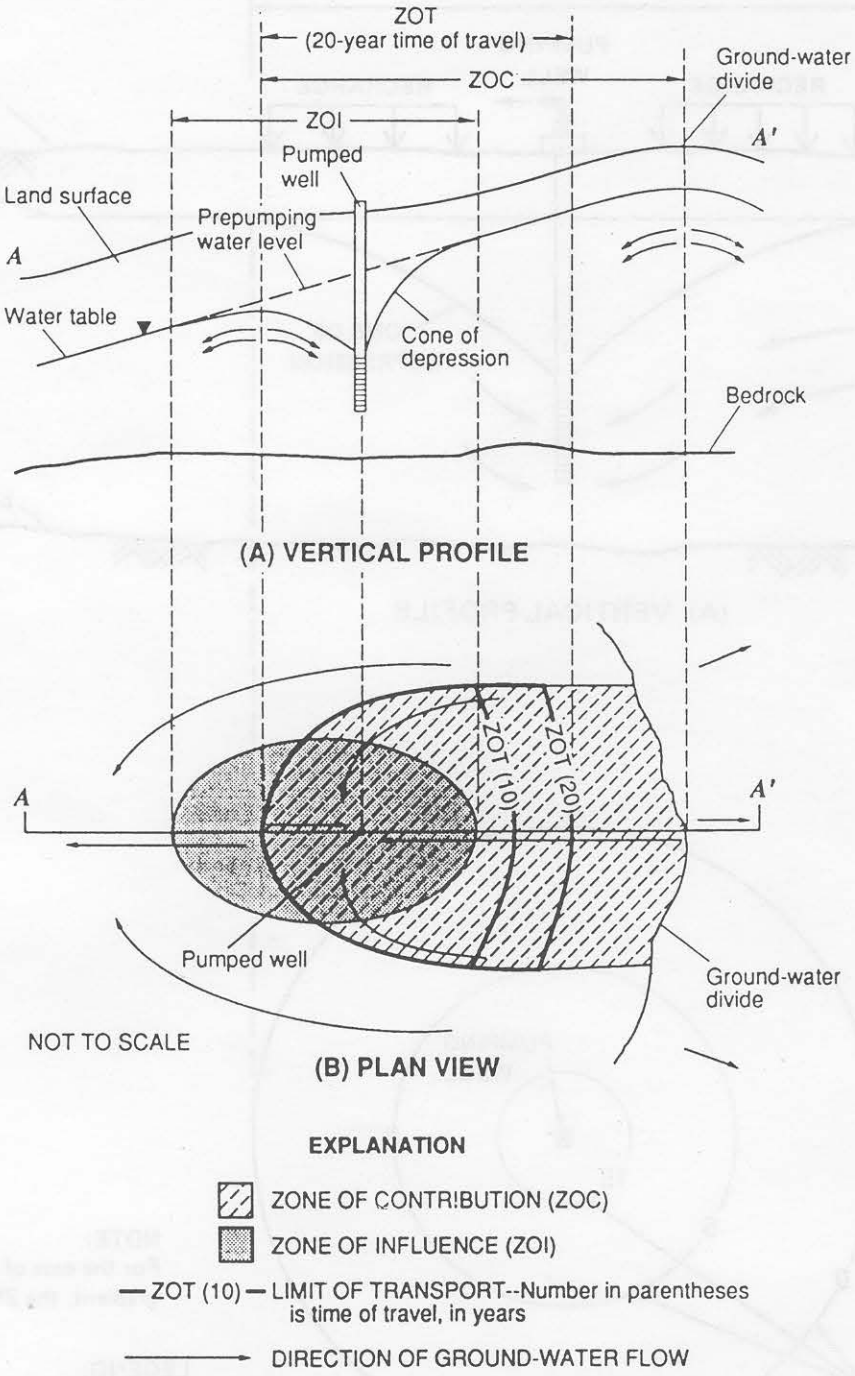


Figure 1. Zones of contribution, influence, and transport under sloping water-table conditions.

the increase in hydraulic gradient near the well. The volumetric method allows for wellhead protection areas of different sizes, depending on the length of the time-of-travel factor. The resulting areas correspond to the zones of transport, the parts of the zone of contribution from which water would flow to the well during a particular time-of-travel. Times used by various communities range from a number of days to 20 years. Choosing the travel time is a matter of policy and could reflect a judgement call about the length of warning time a community would need in order to provide a replacement water supply or to install treatment equipment in the event that there was a known accident.

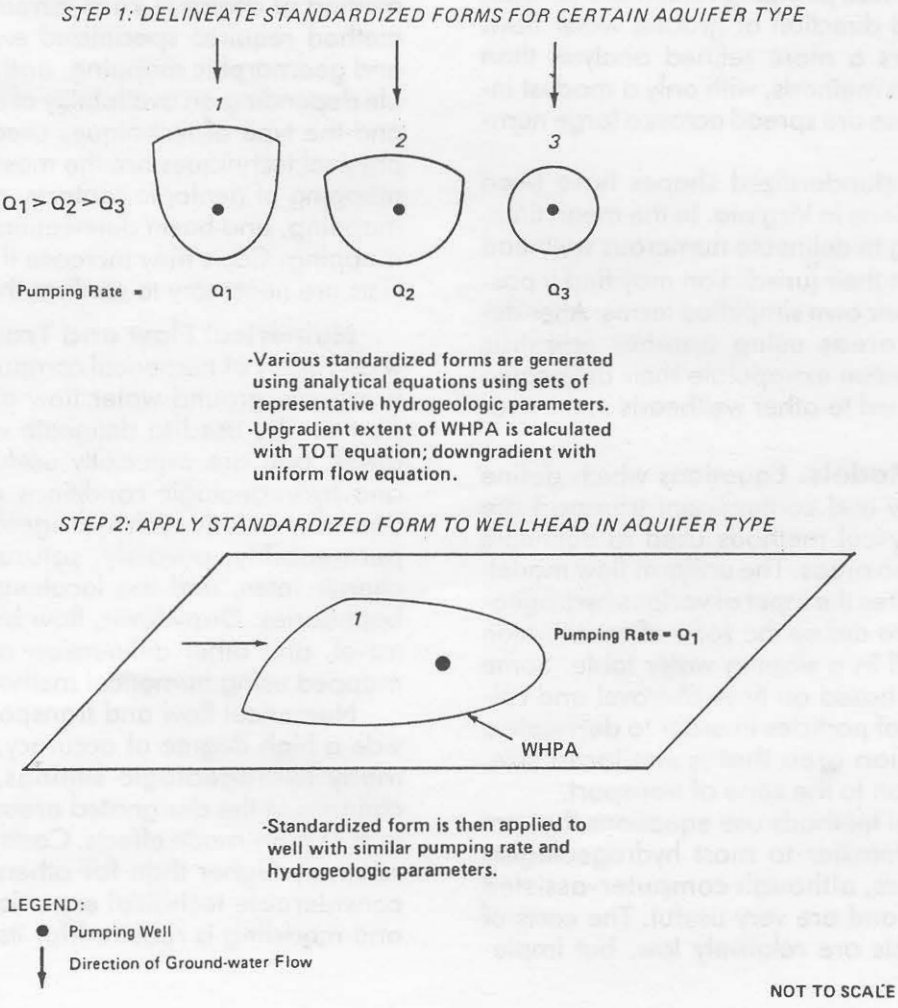
Calculated radii methods are relatively easy to apply and inexpensive, but do require some experience and comfort with equations. They do require more commitment than the fixed radius method because time may be involved in developing the data or assumptions to define the parameters used in the equation. Information needed for the volumetric method is more easily obtained than for the other calculated radius methods. Determining the values for the radius-of-influence and the rate-of-recharge equations can require some hydrologic training. However, all of the calculated radius methods offer a significant increase in accuracy over the fixed radius method, and have the ability to reflect some variability in actual conditions.

Simplified Variable Shapes. The simplified variable shapes method utilizes a set of standardized prototype shapes for the wellhead protection area which are based on pilot studies using an analytical model to delineate zones of transport for the types

Figure 22

USING THE SIMPLIFIED VARIABLE SHAPES METHOD

Source: *Guidelines for Delineation of Wellhead Protection Areas*



of well and aquifer systems found in the region. The model to develop the standard forms might be based primarily on the time-of-travel factor, as well as on information for each aquifer in the region. The delineated zones are grouped by sets of well and aquifer properties and then generalized into groups of simplified shapes.

Using these established forms can simplify implementation for local officials. The appropriate form can be selected based on the pumping conditions found at the particular well and the general hydrogeologic properties of the aquifer it penetrates. The form is then oriented around the well according to the location of the well and estimated ground water flow patterns. The wellhead protection area is delineated by applying the prototype shape.

Costs of initially developing the standardized forms for a state or locality can vary from low to moderate, depending on how much data collection is required in order to obtain the representative set of hydrogeologic parameters needed to calculate the shapes. Once the standardized shapes have been calculated, however, the simplified variable shapes method requires a relatively small amount of field data and can be easily implemented. The only information required to apply the shapes to a particular well are the well pumping rate, material type, and the estimated direction of ground water flow. This method offers a more refined analysis than either of the radius methods, with only a modest increase in cost if these are spread across a large number of wells.

Currently, no standardized shapes have been developed for regions in Virginia. In the mean time, localities intending to delineate numerous wellhead protection areas in their jurisdiction may find it possible to develop their own simplified forms. After delineating a few areas using another scientific method, a locality can extrapolate their delineated shapes to be applied to other wellheads in their region.

Analytical Models. Equations which define ground water flow and contaminant transport are the basis of analytical methods used to delineate wellhead protection areas. The uniform flow model, for example, requires the input of various hydrogeologic parameters to define the zone of contribution to a pumping well in a sloping water table. Some other models are based on time-of-travel and calculate the motion of particles in order to delineate a wellhead protection area that is similar in size, shape, and location to the zone of transport.

Most analytical methods use equations that are understood and familiar to most hydrogeologists and civil engineers, although computer-assisted models also exist and are very useful. The costs of using these models are relatively low, but implementation costs can be high if site-specific hydrogeologic data must be developed for each wellhead protection area.

Hydrogeologic Mapping. Designation of protection areas can be based on mapping as an alternative to the various mathematical techniques discussed above. In hydrogeologic mappings, flow boundaries, including ridges, rivers, canals, and lakes, can be mapped and used to delineate wellhead protection areas. Aquifer and ground water drainage divides are examples of subsurface boundaries which can be defined by changes in permeability within an aquifer or variations in the character of the underlying rock.

There are many techniques involved in the process of hydrogeologic mapping. Geological observations may provide surface indications of changes in rock type, while geophysical data can be used to map the surface area or thickness of unconfined aquifers. Topographic analysis and mapping of ground water levels may also be included in order to identify drainage divides.

Hydrogeologic mapping is best suited to settings dominated by near-surface flow boundaries, but is less useful for delineating wellhead protection areas in large or deep aquifers. Mapping is sometimes the method of choice in karst terrain, for instance. This method requires specialized expertise in geologic and geomorphic mapping, and costs can be variable depending on availability of existing information and the type of techniques used. In general, geophysical techniques are the most costly, followed by mapping of geologic contacts, regional water level mapping, and basin delineation using topographic mapping. Costs may increase if test holes or pump tests are necessary to confirm the mapping.

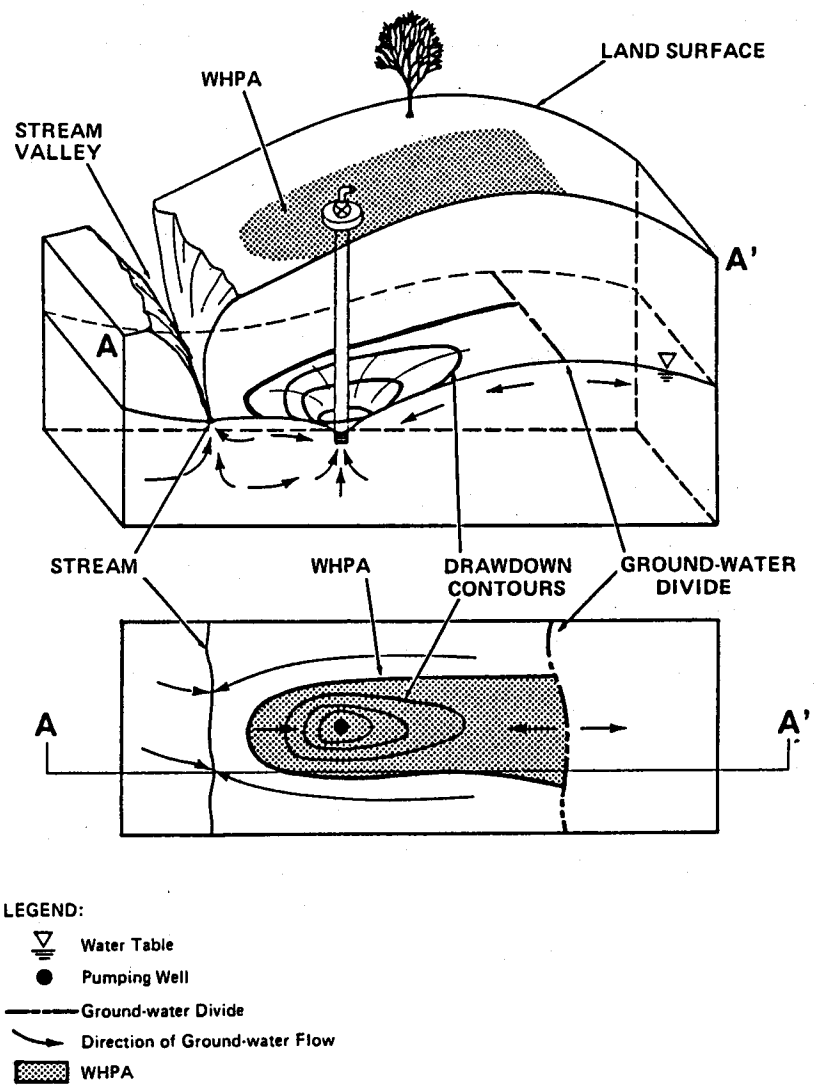
Numerical Flow and Transport Models. A wide variety of numerical computer models that approximate ground water flow and/or solute transport can be used to delineate wellhead protection areas, and are especially useful where boundary and hydrogeologic conditions are complex. Input data may include such hydrogeologic parameters as permeability, porosity, saturated thickness, recharge rates, and the locations of hydrogeologic boundaries. Drawdown, flow boundaries, time-of-travel, and other delineation criteria can also be mapped using numerical methods.

Numerical flow and transport models can provide a high degree of accuracy, can be applied to many hydrogeologic settings, and can predict changes in the designated areas as a result of natural or man-made effects. Costs for this method are relatively higher than for others, though, because considerable technical expertise in hydrogeology and modeling is required for its use. However, the

Figure 23

USING THE HYDROGEOLOGIC MAPPING METHOD

Source: *Guidelines for Delineation of Wellhead Protection Areas*



cost may be warranted in areas where a high degree of accuracy is desired.

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To sum up this discussion of delineation methods, the following points should be made:

- The fixed radius, or some of the other less technical methods, may be most appropriate for communities beginning wellhead protection.
- Whatever the method chosen, the attitude should be that when better data or methods become available, the boundaries of the protection area will be modified.
- Several pilot study communities in Virginia are now experimenting with different delineation methods and the results of these as well as a variety of publications, will be available next year from the Virginia Ground Water Protection Steering Committee.

Figure 24

VIRGINIA COMMUNITIES BEGIN WELLHEAD PROTECTION

The Virginia State Water Control Board and two local governments in Virginia are coordinating pilot wellhead protection projects to be completed by the end of 1992. These projects, undertaken in Roanoke and Henrico County, are intended to increase public awareness of wellhead protection issues, evaluate approaches to delineating wellhead protection areas, and examine various protection strategies and policies for implementation. A report on the results of the pilot studies will be issued by the Virginia Ground Water Protection Steering Committee after the completion of the studies. The findings could be of great use to other localities in Virginia.

Roanoke County has selected three wells for their wellhead protection pilot study which are vital components of the county's water distribution system. The goal of their wellhead protection project is to develop wellhead protection overlay districts for these three wells. The fixed radius method will be used initially to delineate the protection area, with primary and secondary protection zones moving outward from the well. This delineation method was selected because of limits in available data and limited technical expertise of the county staff. The radius lengths will be based on observations about land use patterns and the relative importance of the wells rather than a pre-set figure.

Once areas are delineated, Roanoke's initial wellhead study areas will be overlain onto a map depicting land use information. This baseline data will be presented to county officials and the public. Brochures will also be developed to educate the county about wellhead protection and about the ongoing efforts. A draft wellhead protection ordinance will be prepared and presented to county officials for action, and will be implemented if approved by the Planning Commission and Board of Supervisors.

There are 30 to 40 wells in Henrico County that are classified as public water supplies. These supply water to individual subdivisions, to county park and recreation facilities, and twelve deep wells pump directly into the county distribution system. Delineation of wellhead protection areas is being undertaken in Henrico's pilot project through the use of a package of mathematical models distributed by the U.S. EPA. This package, known as the WHPA code, consists of four independent mathematical models, three of which are semi-analytical and one which is also numerical. These models are able to delineate pathlines and/or time-related zones of transport. As part of this study, the county will collect the available data and will then delineate areas around those wells for which the necessary information exists.

Henrico County also intends to examine their zoning maps and planning documents to assess the risks posed to the wells by the existing land uses. The areas with potentially contaminating land uses will be surveyed and examined in more detail. The planning staff will determine the most appropriate method of protection for the wellhead areas, and will develop informational brochures for public education.

While the above two counties obtained state funding to implement wellhead protection measures, Botetourt County received a direct federal grant from the U.S. EPA. In the fall of 1991, Botetourt applied to EPA Region 3 for a grant under the Safe Drinking Water Act in order to study the Town of Fincastle's two wells. They used the grant funding to hire a hydrogeologist to delineate wellhead protection areas around the wells. The areas were delineated by a 500 foot radius in combination with the aquifer recharge zone branching out from the well.

No changes to the existing zoning ordinances are anticipated by Botetourt County, but rather the wellhead study will be used to guide future zoning changes and other development decisions. If a landowner within the wellhead protection area wishes to obtain various permits or requests a rezoning, appropriate recommendations will be made by the planning staff to the Planning Commission and the Board of Supervisors based on the results of the wellhead study. While uses may not be disallowed, certain conditions may be requested or the implementation of Best Management Practices (for agricultural uses) may be suggested. If additional staffing and funding became available, Botetourt County would eventually like to begin an educational program to inform landowners in the wellhead protection areas of voluntary measures they can undertake to aid in the protection of their water supply.

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Sleepy Hollow
Soil Types & Drainage Patterns

Chapter 6

THE DECISION-MAKING PROCESS

When a community has gone through the process outlined in this Handbook and has completed the steps described in Chapter 3, it will be in a much stronger position to respond positively that it:

- is informed about the number and location of public wells in the community.
- is aware, not only of wells owned by the municipality, but also those owned by investors and others.
- knows who is served by each well - residences, businesses, industry.
- has contingency plans on the shelf in the event that any of these wells needs to be taken off line.
- monitors these public wells and has encountered no water quality problems.
- has developed controls to guide potentially polluting activities to locations outside wellhead protection areas.
- is working with activities already located in wellhead protection areas to assure that their operations are conducted according to safe guidelines.
- has modified its comprehensive plan and zoning to establish goals for and means of wellhead protection.
- has included the Planning Commission and other groups in the wellhead protection process and feels confident that the community at large is becoming more knowledgable about the ground water supplying its public wells.
- now has confidence that the community water supply will continue to be an asset to serve existing residents and activities as well as those who might move to the community in the future.

Despite the considerable attractiveness of wanting to be able to respond with statements like those above, a community may still find that it has several hurdles remaining before it can begin and effectively carry out a program of wellhead protection. To get beyond the hurdles the following advice is offered.

Start Small

If it seems too much to undertake wellhead protection for 30 or 40 or more wells, concentrate on only the three or four wells that are most vital to the community. Adopt a multiple year work plan that would take care of the rest of the wells over several years. This will ease the workload burden and focus attention on the most vital wells where community support for wellhead protection might be strongest. You can later use the success of the program for these initial wells as a selling point for a more inclusive program. If the local government does not have staff that can take on the studies or develop alternative protection strategies, assistance could be sought from the Planning District Commission. Involving the PDC has the added advantage of enabling issues to be addressed that might involve several localities within the region. Perhaps a pooling of efforts would allow economies of scale and sharing of study and management costs as well.

Pull Together a Management Team

It may be useful to assemble two groups to approach the development and implementation of a wellhead protection program, a management team and a technical advisory group. Planning staff having experience with land management tools will know best which management and administrative techniques are most suited for the local program. They will also be able to set realistic goals and their knowledge will aid in developing enforcement and oversight methods. The management team might also include staff from the utility department, public works, finance or the county extension agent.

A technical advisory group can also help strengthen personnel resources by guiding the process through technical issues concerning hydrogeological information gathering and evaluation, and by helping to develop appropriate protection standards. Local resource people might be found at universities or community colleges or they might be residents with professional training and experience who are employed in business or industry.

The knowledge of local staff can be increased by sending people to training workshops and conferences about ground water and wellhead protection and by purchasing books and materials on the topic.

The jobs of the management team and the technical team would be to oversee the fledging wellhead protection program to make sure that it gets off to a good start.

Communicate Often and Widely

Successful communication with and involvement of the local community is essential to an effective wellhead protection program. Public awareness and understanding of the program can be increased by providing people who might be regulated by the program, as well as people who might participate in monitoring and enforcement, with clear and concise material on their responsibilities and on the rationale for the program. Education and publicity techniques, such as community meetings, mailings, newspaper articles, and advertisements, can be used to both inform the public and to build support. Contact with the public throughout the decision making process will provide an opportunity to answer questions and to respond to complaints or requests. Communication could be a function assigned the management team. This way a single source is giving out information and builds confidence through competence and consistency. Communication between the locality and other localities in the area and the PDC can also foster more effective regional coordination.

Check How You Are Doing

An essential step in the process of creating a successful new program is to ensure that monitoring is performed and evaluated on a regular basis. Ground water monitoring at public wells serves as an important feedback mechanism, aids in program evaluation and refinement, and provides early warning of problems such as contamination, saltwater intrusion, or declining water levels. The management team should receive such information regularly.

An active oversight program will also ensure that the resources invested in wellhead protection are used efficiently. Establishing any new program means changing some old habits. Building permit staff need to be alerted to any new wellhead requirements and various land users need to be informed and educated. Keeping an eye open for problems and for opportunities to educate is crucial with a new program.

Don't Be Afraid to Ask

Once a locality has looked into the process of developing a wellhead protection program, there are several places to turn to if a stumbling block is reached. State and federal agencies, as well as local sources, can often provide useful guidance.

The Virginia Water Control Board keeps a library of reference documents available for use by localities learning about wellhead protection. These include the materials listed in Chapter 7 in addition to other useful information. Technical questions regarding wellhead area delineation can also be discussed with the Virginia Water Control Board. Contact Terry Wagner for information at (804)-527-5203.

Data on the locations of public wells in the state are kept by the Virginia Department of Health. In cases where wells have been constructed during the past ten years, data on pump tests and other useful information is also available about each public well. This data can be obtained through Alan Hammer in the Office of Water Programs at (804)-786-5566 or by contacting the field office in the region where your jurisdiction is located.

Topographic maps, aerial photographs and geologic information are also very helpful when locating and assessing community wells. The Virginia Department of Mines, Minerals, and Energy's Division of Mineral Resources has these resources available for purchase and can be reached at (804)-293-5121. The Earth Science Information Center of the United States Geological Survey, (703)-648-6044, also sells these resources.

The United States Environmental Protection Agency has published a substantial amount of material about wellhead protection, much of which is available through the Virginia Water Control Board. Information about these documents, insight on the wellhead protection efforts being undertaken in this region (Region III), and some technical assistance can be obtained by calling Virginia Thompson at their Office of Ground Water Management at (215)-597-2786.

Local sources can also help provide background information on what is being done in Virginia. Localities with experience in wellhead protection, such as Clarke, Henrico, Roanoke, and Botetourt can be contacted for valuable suggestions. In addition, several Planning District Commissions have also begun to be involved with ground water issues, including Accomack-Northampton, Lord Fairfax, and Thomas Jefferson.

Spend a Little, Save a Lot!

Wellhead protection need not be an expensive program if it is thought of as part of the planning and zoning budget of the locality. Suggestions were made in Chapter 3 about how various groups might contribute time to conducting the field surveys. In some states, such as Florida, where wellhead protection is a major program, a special purpose staff is dedicated to the program and supported by water

customer user charges. The program is substantially self-supporting. Other ways to finance local programs are discussed in a Technical Assistance Document published by EPA titled *Local Financing For Wellhead Protection* (see Chapter 7).

Nonetheless, it may be that some additional financial support is necessary. In that case, it can be reported that several state agencies receive federal funds which can be used for ground water protection purposes, some of which can go to PDCs and/or to local governments. Many of these funds are limited in amount and require local matching money. They can sometimes support planning and development of new ground water protection approaches as seed money though generally they cannot support on-going operational costs. The best advice would be to contact the agency in question and inquire about the availability of any funding for the purpose you have in mind.

Virginia Agency	**Grant Type**
VA Water Control Board	Clean Water Act: Sections 106 and 205J/604B
VA Department of Conservation and Recreation	Clean Water Act: Section 319
Chesapeake Bay Local Assistance Department	Planning Assistance Grants
Housing and Community Development	Community Development Block Grants
Council on the Environment	Coastal Zone Management Act Funds

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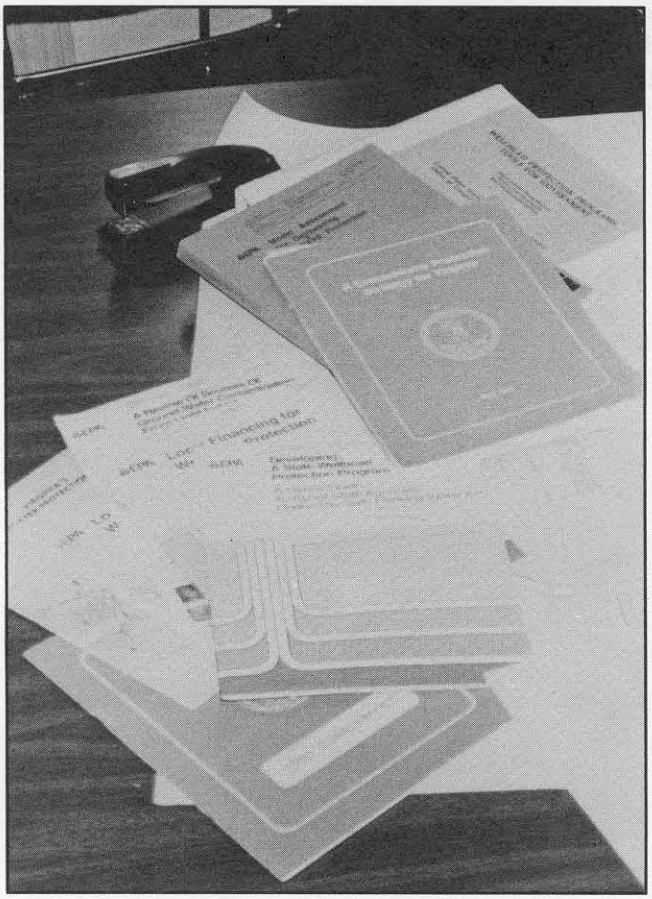
At this point it is hoped that enough has been described and explained that local governments in Virginia will begin to see wellhead protection as an idea whose time has come.


Financing for
Protection

Chapter 7

REFERENCE MATERIALS

The documents mentioned in this Handbook, plus some others, provide more detailed information on certain aspects of wellhead protection. Information on obtaining the following materials is available to localities by calling Mary Ann Sykes at the Virginia Water Control Board at (804)-527-5201:

- *Capital Improvement Programming: A How-To Manual for Virginia's Local Governments;* VA Dept. of Housing and Community Development, Office of Local Development Programs, January 1986.
- *Description and Evaluation of Selected Methods Used to Delineate Wellhead-Protection Areas Around Public-Supply Wells Near Mt. Hope, Kansas;* U.S. EPA and U.S.G.S. 1991.
- *A Groundwater Primer for Virginians;* Torsten D. Sponenberg and Jacob H. Kahn, Virginia Polytechnic Institute and State University, Virginia Water Resources Research Center, 1984.
- *A Groundwater Protection Strategy for Virginia;* Virginia Ground Water Protection Steering Committee, May 1987.
- *Guide for Conducting Contaminant Source Inventories for Public Drinking Water Supplies* (Technical Assistance Document); U.S. EPA Office of Water, December 1991.
- *Guide to Ground Water Supply Contingency Planning for Local and State Governments* (Technical Assistance Document); U.S. EPA Office of Water, May 1990.
- *Guidelines for Delineation of Wellhead Protection Areas;* U.S. EPA Office of Ground Water Protection, June 1987.
- *Local Financing for Wellhead Protection;* U.S. EPA Office of Water, June 1987.
- *Local Assistance Manual;* Chesapeake Bay Local Assistance Department, November 1989.
- *Model Assessment for Delineating Wellhead Protection Areas;* U.S. EPA Office of Ground Water Protection, May 1988.
- *Protecting Ground Water From the Bottom Up: Local Responses to Wellhead Protections* (Conference Proceedings); U.S. EPA Region I, October 1989.
- *Protecting Local Ground Water Supplies Through Wellhead Protection;* U.S. EPA Office of Water, May 1991.
- *Protecting Virginia's Ground Water: A Handbook for Local Government Officials;* Margaret Hrezo and Pat Nickerson, Virginia Water Resources Research Center, 1986.
- *The Protection of Groundwater Resources: Action at the Local Level;* Waldon R. Kerns, Virginia Cooperative Extension, 1990.
- *Report of the Ad Hoc Wellhead Protection Advisory Committee;* June 1991.
- *A Review of Sources of Ground Water Contamination From Light Industry* (Technical Assistance Document); U.S. EPA, May 1990.
- *Threats to Virginia's Groundwater;* Diana L. Weigman and Carolyn J. Kroehler, Virginia Polytechnic Institute and State University, Virginia Water Resources Research Center.
- *Urban Land Use Planning;* F. Stuart Chapin, Jr., and Edward S. Faiser, Third Edition, University of Illinois Press, 1979.
- *Wellhead Protection Programs: Tools for Government* (Proceedings of Workshop on Management Options for Wellhead Protection Area); U.S. EPA Office of Ground Water and Drinking Water, June 1991.
- *Wellhead Protection Programs: Tools for Local Governments;* U.S. EPA Office of Water, April 1989.

In addition, the following books serve as basic reference materials on ground water and hydrogeology and are available through the publishers or through libraries around the state.

- *Applied Hydrogeology;* C. W. Fetter, Jr., Charles E. Merrill Publishing Company.

- *Basic Ground-Water Hydrology;* Ralph C. Heath, U.S. Geological Survey Water Supply Paper 2220.

- *Groundwater;* R. Allan Freeze and John A. Cherry, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

In addition, a large variety of computer software packages are available with wellhead protection applications. One example is:

- *WHPA: A Modular Semi-Analytical Model for the Delineation of Wellhead Protection Areas;* T. Neil Blandford, Peter S. Huyak, Hydrogeologic, Inc., Herndon, VA; Report prepared for U.S. EPA Office of Ground Water Protection, September 1990.

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