1991

A WELLHEAD PROTECTION PROGRAM NORTH SMITHFIELD, RI

Mark C. Gardella
University of Rhode Island

Richard C. Ribb
University of Rhode Island

A WELLHEAD PROTECTION PROGRAM
NORTH SMITHFIELD, RI

BY

MARK C. GARDELLA
RICHARD C. RIBB

A RESEARCH PROJECT SUBMITTED IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTERS OF
COMMUNITY PLANNING

UNIVERSITY OF RHODE ISLAND
MAY 13, 1991

MASTER OF COMMUNITY PLANNING

RESEARCH PROJECT

OF

MARK C. GARDELLA

AND

RICHARD C. RIBB

Approved:

Major Professor: _____

John J. Kupa

Acknowledged:

Director: _____

Howard H. Foster Jr.

ACKNOWLEDGEMENTS

The authors of this Master's Project document would first of all like to express their gratitude to Ernie Panciera and Sofia Bobiak of the Rhode Island Department of Environmental Management, Groundwater Section, for their assistance and support which was essential to this project. It is hoped that this work will provide a basis for an EPA/RIDEM pilot project, the funding for which application has recently been made. Thanks also to Karen Sherman, North Smithfield's Town Planner, who provided us with encouragement and a valuable contact within the Town governmental structure.

Dr. John J. Kupa, our Major Professor, was instrumental in sparking the authors' interest in environmental planning. Dr. Kupa's lectures, based on his broad knowledge and career experiences, were always stimulating and enjoyable and he certainly deserves his reputation as one of the University's most effective lecturers.

Special thanks to the CPAD graduating class of 1991, particularly those core members who could be counted on to give 100% during the critical periods of Studio and other team projects. We are confident that many of our classmates will become outstanding professional planners.

Lastly we thank outgoing Director Dr. Howard Foster, for his help and guidance, but especially for his contribution of what is likely to be one of the most enduring pieces of CPAD lore - his description of the CPAD facilities as "the airplane hangar that looks like a castle."

Mark C. Gardella
Richard C. Ribb

T A B L E O F C O N T E N T S

L I S T O F T A B L E S

L I S T O F F I G U R E S

CHAPTER I: PROGRAM OVERVIEW

1.1 PROBLEM STATEMENT

Groundwater is an important drinking water resource in the United States, especially in rural areas, unconnected to larger public systems, where it provides 96% of the drinking water supply (Travis and Etnier, 1984). Approximately 50% of all U.S. residents rely on groundwater as their source of drinking water, using 88 billion gallons a day (Patrick et al. 1987). Within the State of Rhode Island, 24% of the population depends on groundwater and 8% utilize private drinking wells (USGS, 1988). Groundwater withdrawals in Rhode Island average 37 million gallons per day and uses include public and private water supply, livestock and irrigation, and industrial uses (USGS 1986).

A recent study of the Rhode Island water supply, conducted by the Arthur D. Little Company, has indicated that the state's increasing reliance on the Scituate Reservoir system may cause future supply problems, forcing water suppliers to look to groundwater as a supplemental source. In most New England states, groundwater is a primary drinking water source.

Groundwater is generally available in good quality throughout the nation, although supplies are gradually becoming more threatened by human activity. The duration, type, and intensity of human activities will determine the

degree of risk that is posed to both ground water quality and quantity. As further development takes place, additional pollutants are introduced into the groundwater, significantly impacting water quality. Rhode Island's twenty-one major groundwater aquifers are extremely susceptible to contamination due to high aquifer permeability and minimal depth (usually less than 20 feet) to the water table (USGS, 1986). Since 1975, the water from 9 public supply wells and 250 private wells has become unsuitable for human use due to contamination by hazardous chemicals (USGS, 1986).

Groundwater contamination occurs as a result of three main mechanisms: by natural processes, by man's waste disposal practices (sanitary, industrial, solid, and hazardous wastes), and by spill (and illegal dumping), leaks, and agricultural activities and other sources unrelated to disposal. Non-point sources of groundwater pollution include nutrient loading from septic systems, erosion and sedimentation from construction sites, stormwater runoff carrying nutrients, heavy metals and hydrocarbons, road de-icing practices with heavy salt concentrations, and the use of pesticides and fertilizers. Past land uses may yet cause groundwater contamination. Many of the known 16,000 hazardous waste sites nationwide that are now closed will eventually leach contaminants into the ground, as will the 2 million underground storage tanks

containing petroleum and chemical products (Page, 1987).

It is difficult to assess the overall threat to groundwater from a particular land use. The actual threat presented by a land use depends upon several factors including; (1) the type and quantity of chemicals used or wastes generated, (2) storage and disposal methods, (3) soils and aquifer characteristics of the site, (4) distance from the contamination source to the wellfield, and (5) the attenuation of the pollutant in the soils and ground water. These factors all contribute to the complexity of adequately protecting ground water quality.

1.2 GROUNDWATER PROTECTION: North Smithfield, RI

The Town of North Smithfield, Rhode Island, uses four separate water supply systems, which serve one-third of the Town's residents (Weston and Sampson 1990). One of the systems, the Slatersville Water Company, consists of a series of five wells, three of which are tapped into a groundwater aquifer and two others that draw water from bedrock fractures. This system currently serves approximately 445 residences and 12 non-residential users (Weston and Sampson 1990). In addition to this system, most residents and many businesses depend on private wells for water supply. The RIDEM Division of Groundwater and Freshwater Wetlands, Groundwater Section has identified major aquifers capable of supporting public well systems

throughout the State. One of these large aquifers underlies a section of North Smithfield. Due to a projected increase in demand and the availability of an accessible aquifer source, it is possible that the Town will increase its dependence on groundwater reserves.

Local groundwater protection programs are still uncommon in rural communities like North Smithfield. Smaller communities often lack sufficient staff and economic resources to undertake the hydrogeological and management studies that underlie ground water protection planning. Like most rural communities, North Smithfield is experiencing increased development, leaving its groundwater supplies vulnerable to contamination from point source as well as non-point source pollution. Groundwater protection has long been a concern to water suppliers, public health officials and Town residents. It is also an issue of growing importance for planners because of the long-term problems associated with groundwater contamination. Consequently, the most effective groundwater protection measures are preventive, and prevention requires planning. In terms of policy issues, this program helps with the clarification of state, local, and water supplier responsibilities. Contingency planning, often neglected in local government, is given a new focus.

1.3 PURPOSE OF THE PROJECT

The primary purpose of this project is to fulfill the requirements for a Master's Degree from the Graduate Curriculum in Community Planning from the University of Rhode Island. A secondary purpose of this project is to assist the Town of North Smithfield in establishing a WellHead Protection (WHP) Program (as mandated by the 1986 amendments to the Safe Drinking Water Act (SDWA) to protect its wellhead areas from the threat of contamination. An effort to obtain available EPA WHPA pilot project funding, initiated by the authors, has been met with enthusiasm by the Town of North Smithfield and RIDEM. An application has been made to the EPA and it is currently under consideration. Throughout the project, the authors of the study will be working closely with the RIDEM, Town officials and residents. A document will be drafted that will incorporate the requirements of the WHP Program with local groundwater concerns and efforts. In addition, this project will benefit RIDEM by providing a pilot project that will allow the Department to critique existing WHP Program guidelines as applied in a practical planning exercise.

1.4 RELEVANT CURRENT LITERATURE

As the demand for water has increased, a great deal of research has been conducted that focuses on groundwater protection issues. This documentation takes the form of:

* EPA documents relating to groundwater protection and management;
* State documents;
* Books and articles from planning literature;
* Scientific research studies;
* Computer generated maps and analysis;
* Symposium reports;
* Groundwater related periodicals;
* University Research;
* Water resource management studies.

These documents describe policy issues related to groundwater management, sources and chemical properties of contaminants, computer modeling techniques, mitigation measures, results of scientific studies of groundwater movement, local government responsibilities and limitations, financing of programs, legal tools and techniques for groundwater protection, soil properties, and data needs for groundwater protection programs. This literature is available through government and University sources.

The RIDEM Wellhead Protection Program

In 1986, amendments to the Federal SDWA established a WHP Program in order to enable states to "protect wellhead areas within their jurisdiction from contaminants which may have an adverse effect on the health of persons." Under the WHP amendments, section 1428 of the SDWA, each State must prepare a WHP Program and submit it to the Environmental

Protection Agency (EPA). The Rhode Island Department of Environmental Management (RIDEM) has undertaken the responsibility for developing and implementing the WHP Program for the State. The WHP Program is an attempt by federal and state officials to curtail or minimize the effects of development on groundwater quality. Groundwater protection planning encompasses several stages including the identification of contamination sources relative to wells and wellfields and the ranking of existing and potential threats. These steps will establish a framework for identifying problems facing the community and will aid in the development of the individual components of management plans. Once identified in the management plan, a series of Best Management Practices (BMPs) will be analyzed to determine which will be the most effective in minimizing the effects of development within the wellhead area identified by RIDEM.

RIDEM has developed a wellhead protection program in accordance with the EPA requirements. The agency given responsibility for this program is the Groundwater Section of the Division of Groundwater and Freshwater Wetlands. The WHP Program is part of an ongoing comprehensive effort by RIDEM to protect the state's groundwater supply. Elements of the WHP Program will be integrated into other agency programs. The program is focused on (1) placing a high priority on pollutant source control and remedial efforts in

the designated wellhead areas, and (2) providing local governments and water suppliers with technical information and administrative tools that are necessary to accomplish protection objectives. Success of the program is dependent on local initiative.

The WHP Program applies to all public water systems that are dependent on groundwater. These systems consist of community wells (supplying municipal systems, nursing homes and trailer parks and serving at least 25 individuals at least 60 days out of the year) and non-community wells (which are seasonal systems, or those serving schools, hotels, and restaurants). In Rhode Island there are seventy community water systems using 170 community wells and 375 non-community wells (RIDEM, 1990).

Local governments have the responsibility to see that the protection plans are completed and submitted to RIDEM for review. This program was developed with an understanding of the limited resources of local governments and suppliers. By integrating the program elements with other state and federal planning requirements, a minimal additional burden will be placed on municipalities and suppliers. In addition, RIDEM will provide technical assistance for all aspects of the program.

1.5 ELEMENTS OF THE WHP PROGRAM

A. Delineation of the Wellhead Protection Areas (WHPA).

Preliminary delineation of the WHPA is the responsibility of the RIDEM. The delineation for community wells is based on existing information (RIDEM maps, USGS maps, supplier's information, RIGIS maps, private and public testing, and EPA/RIDEM groundwater computer modeling processes). For non-community wells, a WHPA consisting of all land within a circle with a radius of 1750 feet will be used.

B. Identification of Contamination Sources in WHPA's.

Many land activities have the potential to contaminate groundwater. The degree of threat varies depending on the nature of the activities at the site, the materials used, and the safety practices in use. Local governments or suppliers are responsible for the inventory of existing and abandoned/inactive sources. The RIDEM will provide guidance on inventory procedures, standards, and forms for data collection.

C. Development of Management Strategies.

Over the past several decades, engineers and planners have combined their expertise and have developed a number of BMPs to mitigate some of the adverse impacts on groundwater associated with human activity. Through trial

and error, it has been shown that each BMP option has both unique capabilities and limitations which must be balanced with the overall management objectives and the physical constraints within the WHPA.

Municipalities have many tools other than physical design standards at their disposal to protect local groundwater resources. These tools include both zoning and non-zoning measures, some traditional, some innovative. They range from land-use controls to public education programs. These can be tailored to fit the nature of the community's water supply, the threats to surface and groundwater, the location of the wellheads, the degree of protection desired, and the structure of local government. Strategies developed for WHPA's should be implementable and administrable by local authorities.

The RIDEM guidelines require that management plans include a discussion of:

1. Past efforts to protect groundwater;
2. An assessment of groundwater quality;
3. Selection of the most appropriate management strategies;
4. Implementation strategies for management options.

D. Preparation of Contingency Plans.

These plans will describe the steps to be taken by a supplier in the event of a well being contaminated or threatened with contamination. This process will augment

existing state emergency plans. It will define responsibilities, equipment inventories, and alternatives for short-term and long-term provision of water. Technical, logistical, and financial resources will be identified.

1.6 PROCEDURES AND METHODS OF ANALYSIS

A. Wellhead Delineation

As stated before, the preliminary delineations will be prepared by the Groundwater Section of the RIDEM Division of Groundwater and Freshwater Wetlands based on site information and hydrogeological computer modeling. A detailed description of this process is included in Chapter II.

B. Inventory Procedures

Once the WHPA's are delineated, field surveys will be conducted in order to identify existing and potential contamination sources. On-site investigations, along with information from RIDEM files, local government files, directories of local industrial companies, and examination of aerial photographs, will be used in creating inventories of land use and contamination sources.

C. Management Strategies

A review of state and local protection measures including ordinances, regulations, policies, and existing

management plans will be conducted to assess current protection. A review of the current literature will provide a selection of innovative protection strategies which can be applied on a site-specific basis. Coordination and consultation with the Town, RIDEM, and water suppliers will assist in the identification of the preferred alternatives.

D. Implementation Plan

Once a range of appropriate management strategies have been determined, the strategies will be prioritized according to staffing capabilities, health risks, funding sources, and community support. An implementation plan will be developed that reflects these priorities and identifies possible initiating parties. This plan will effectively preserve groundwater quality within the WHPA.

1.7 SPECIFICATIONS OF DATA

Data collection tasks will include the compilation of existing information from state agencies, local officials, published materials, aerial photographs, and maps related to the Town and its water resources. The Department of Health (DOH) will provide water samples containing detailed information on water quality as the need is indicated. Attributes will be mapped at a scale suitable for analysis (1 inch equals 2,000 feet) as appropriated by the WHP Program.

A considerable amount of data concerning geology, topography, and soils is available through published reports and maps (e.g., USGS topographic maps, USDA *Soil Survey*). Information concerning land use, vegetative cover, wetlands, roads, drainage, and infrastructure will be obtained from federal, state, and municipal sources. This will be supplemented by aerial photograph interpretation. Point source wastewater generators will be inventoried using state discharge permits. Additional on-site investigation will verify and add to the data gathered, where necessary. This data will be combined with climatic information to determine rain runoff, flooding, and surface and groundwater relationships.

CHAPTER II: GEOHYDROLOGY

2.1 GROUNDWATER

Groundwater is water beneath the surface of the ground in the zone of saturation where every pore space between rock and soil particles is saturated with water (Dunne and Leopold 1978). Above the zone of saturation is an area where both air and moisture are found in the spaces between soil and rock particles. This is called the zone of aeration. Water percolates through this zone until it reaches the zone of saturation, the top of which is termed the water table.

2.2 THE HYDROLOGIC CYCLE

Before analyzing different methods and strategies to manage local groundwater resources, it is important to first describe groundwater characteristics in order to understand how groundwater pollution occurs. Basic concepts, principles, and hydrogeologic terminology will be briefly examined. Acquiring an understanding of groundwater dynamics will enable the water resource planner to adopt the proper design and regulatory guidelines on a site-specific basis which is crucial for the successful implementation of a WHP program.

The hydrologic cycle, as illustrated in Figure 1, involves the continual movement or exchange of water between the atmosphere, the oceans, and other surface water bodies

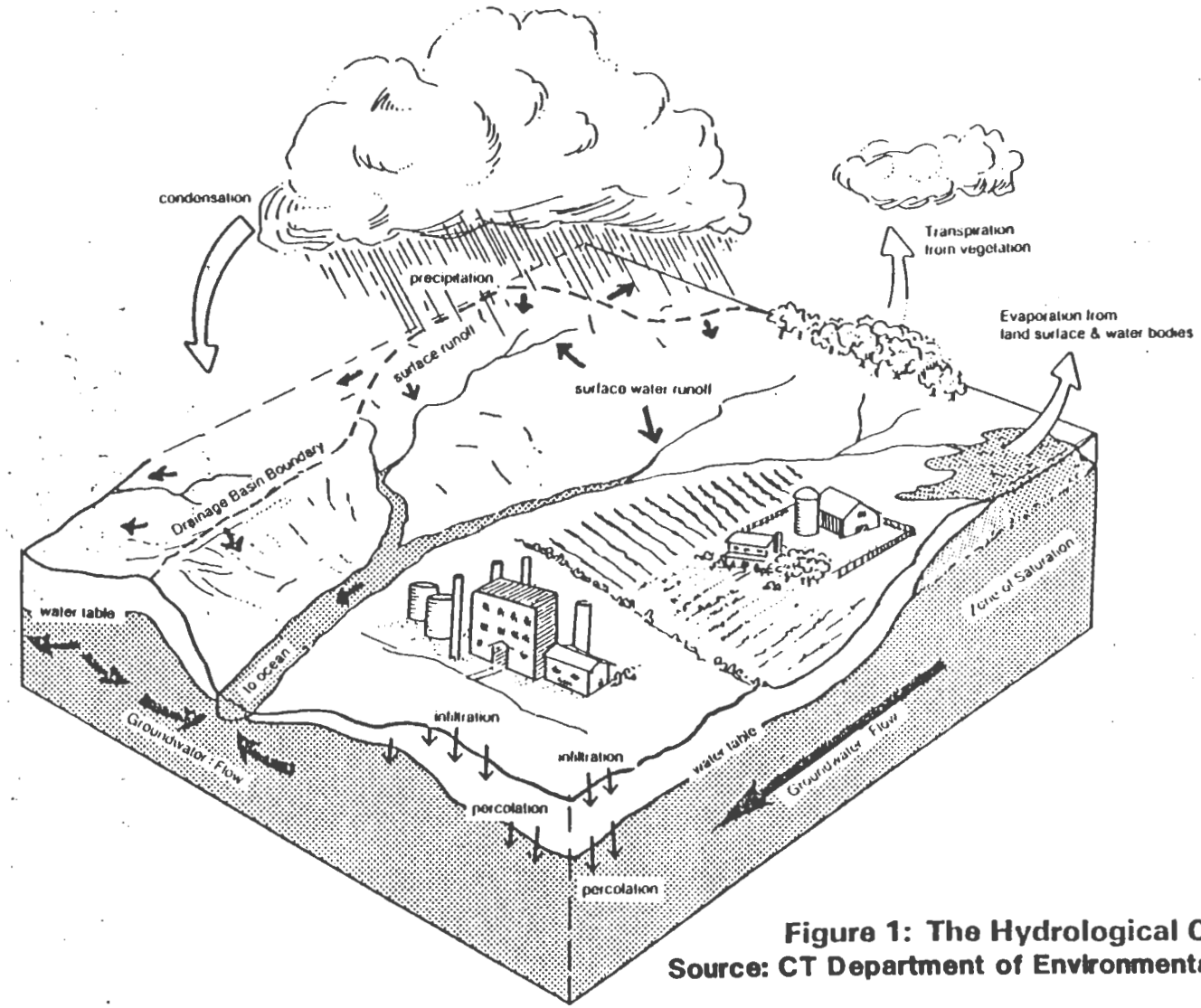


Figure 1: The Hydrological Cycle
Source: CT Department of Environmental Protection

and the land. During this endless circulation, the water is stored temporarily in streams, lakes, the soil, or groundwater and becomes available for use. In this cycle, when atmospheric conditions are favorable, a portion of the water is precipitated as rain or snow. There are several processes that water can undergo at this stage. The water will either evaporate or transpire through vegetation back into the atmosphere, be absorbed into the soil by the process of infiltration where it is held there as soil moisture by capillary forces, or remain on the surface and travel overland to streams or lakes. Water that is absorbed into the soil will gradually percolate down through the zone of aeration (or unsaturated zone), the upper layer of soil where all available pore spaces between rock and soil particles contain air as well as water. When the soil moisture content is raised, infiltrating water will percolate vertically to the zone of saturation where all available pore spaces are completely filled with water. From this zone water moves slowly into streams, swamps, or lakes, providing surface runoff during dry weather.

2.3 GROUNDWATER RESOURCE AREAS

Groundwater is always present at some depth below the land surface, which can be found in saturated rock and soil formations. These formations may be consolidated bedrock, or unconsolidated deposits of sand and gravel (stratified

drift). Water is stored in void spaces within the sand and gravel. The ability of a specific geologic material to hold groundwater is known as its porosity. Unconsolidated deposits generally contain a larger proportion of void space to total volume thus enabling them to hold larger amounts of water than consolidated deposits.

Permeability refers to the size and interconnectedness of the voids and describes the capacity of a material to transmit water or the availability of stored groundwater. There are three important characteristics of unconsolidated materials that influence permeability: (1) the size and shape of rock particles, (2) the degree of uniformity in the size and shape of the particles (sorting) and (3) the pattern in which the particles are packed (CCAMP 1988). Permeability, or the ability of a material to transmit water, is an important parameter, since a geologic unit containing a large volume of groundwater will be of little value to a community if water flow in the formation is impeded and consequently trapped. In consolidated rock, such as granite bedrock, permeability depends on how well the fractures in the rock are interconnected. A detailed study on a site specific basis is needed to determine the yield of a well drilled into bedrock. Unconsolidated deposits such as sand and gravel on the other hand, are examples of highly porous, permeable aquifer materials.

Aquifers occur where such formations will yield usable

amounts of water to a well. An aquifer's capacity to hold water is due to spaces and cracks between particles of rock and soil, which become saturated with water below the water table. The uppermost surface of the zone of saturation is known as the water table. The movement of water is a function of elevation and water along the water table surface will always move from higher to lower elevations. Therefore, the water table (in Rhode Island) generally follows the contours of the overlying terrain (S. Bobiak, pers comm. 1991).

2.4 CHARACTERISTICS OF AQUIFERS

Without going into specific detail regarding the types of aquifers, for the purposes of this introduction it can be generally stated that there exists two types of aquifers. Unconfined or surficial aquifers occur where only unsaturated porous material overlies the saturated formation (Jaffe and Dinovo 1987). The top of this aquifer is defined by the water table. Precipitation recharges the groundwater by soaking into the ground and percolating down to the water table. These aquifers contain little or no pressure and withdrawal of water from these formations requires pumping. Confined aquifers, also known as artesian aquifers, are bounded at the top and bottom by relatively impermeable formations called confining beds, typically of clay or rock. These artesian aquifers may be under greater than

atmospheric pressure thereby raising water levels in wells above the top of the aquifer or water table. The pressure of the groundwater determines the elevation to which the water will rise. This pressure causes the water to flow from wells without requiring pumping. Both the water table and the potentiometric surface, or height of water under pressure, determine the characteristics of the hydrologic system and the rate and direction of groundwater flow.

Each type of aquifer has unique characteristics that determines its susceptibility to contamination. Groundwater management programs must take into account these variable characteristics in order to develop an effective local groundwater protection plan.

2.5 TYPES OF AQUIFERS

Aquifers are generally divided into two classes, characterized by different water-storage properties. The first class is surficial deposits. These unconsolidated aquifers appear as formations of sand and gravel deposited by glacial ice, water, or sometimes wind. Unconsolidated aquifers often occupy the buried valleys of preglacial streams to form highly productive groundwater sources that may be hundreds of feet deep. The surficial sediments overlying bedrock were deposited as the last glacier melted over 10,000 to 15,000 years ago (CCAMP 1988). Permeabilities vary among these deposits depending on the

characteristics of the particles as well the heterogeneity and the degree to which it has been sorted. Sediment deposited by glaciers is called drift and can be classified into two categories, till and stratified drift (See Figure 2).

Till is an unsorted mixture of debris that was deposited directly by glacial ice either frozen within or pushed beneath the ice sheet. As the glacier melted, it compacted the till directly onto the surface of the bedrock creating a dense layer called hardpan. Till deposits generally provide small amounts of water normally yielding only a few hundred gallons of water a day. Till is usually of low porosity and are relatively impermeable. Predicting the result of contamination within these formations is difficult because contaminants can rapidly enter underlying bedrock fractures.

Stratified drift is glacial debris that was carried away by torrents of water that flowed off the melting ice in meltwater streams. These materials dropped out of the meltwater into layered deposits with the larger stones and boulders being deposited closest to the glacier and the smaller lighter materials carried further away. Thus, as they moved away from the glacier, the meltwater streams sorted the rock fragments they carried into separate layers of gravel, sand, and fine sand. Coarse-grained stratified drift contains space between the gravel and sand particles

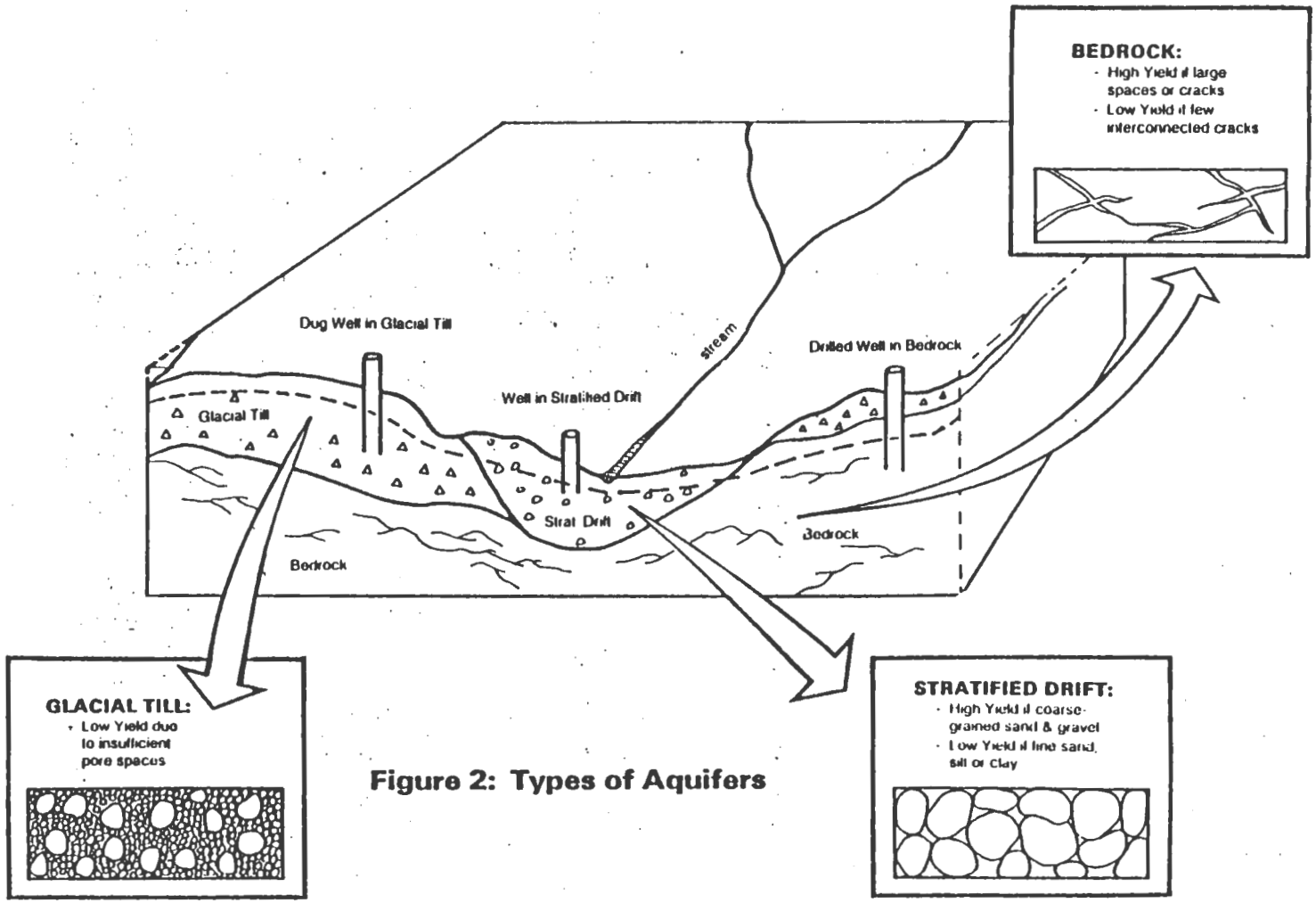


Figure 2: Types of Aquifers

Source: CT Department of Environmental Protection

which can hold large amounts of water without restricting its flow. The thicker the deposit the more likely the chance of yielding large quantities of water.

The second class of aquifer is known as a bedrock aquifer. This consolidated material can only store water in cracks, fractures, or in channels created when water enlarges the fractures in certain carbonate rocks. If there is an abundance of fractures and cracks that are interconnected, then bedrock may provide significant quantities of groundwater as much as 200,000 to 400,000 gallons per day (CCAMP 1988). Although the yield of groundwater from bedrock aquifers is reliable, the path of groundwater as it moves through the bedrock is very difficult to predict. Large fractures serve as conduits transmitting contaminants over large distances, with no attenuation or filtration. Due to the difficulty in predicting groundwater flow through bedrock, a larger wellhead protection area is needed to effectively protect the groundwater resources within this type of aquifer.

2.6 GROUNDWATER MOVEMENT

Groundwater is always moving from the higher recharge areas to the lower discharge areas. The speed at which groundwater moves is determined by the types of material through which it flows and the steepness of the gradient from recharge area to discharge area. The larger the pores

between soil particles, the more easily the water will move through the soil. Groundwater movement is measured in feet per day, or in feet per year. Examples of recharge areas are land surfaces that allow a significant amount of precipitation to infiltrate the soil. Examples of discharge areas are streams, lakes, rivers, springs, wetlands and the oceans.

Once water infiltrates the ground and forms an aquifer, it is not simply stored there but moves by gravity toward areas where it discharges to a surface water body. The water table generally follows the shape of the topography or surface elevation of the ground. The water table is at the top of the zone of saturation but does not remain at one level all year long. The level rises and falls seasonally as a result of natural processes. Melting snow, evaporation, transpiration, and rainfall all contribute to a fluctuating water table. The water level is generally higher during winter and spring and usually falls during the summer and fall months. The water table also responds to cyclical periods of drought and heavy rain.

2.7 PUBLIC SUPPLY WELLS

When a public supply well is pumping, the well creates an artificial discharge area by changing the direction of groundwater flow within the influence of the well. Instead of moving toward the natural discharge area, the groundwater

within the influence of the pump flows toward the well from every direction. Pumping depresses the water table in the vicinity of the well and causes water to flow towards the well, creating a cone of depression which outlines the area of drawdown. Figure 3 illustrates a typical cross-section of a well. The cone of depression varies in size depending on the duration and rate of pumping, the aquifer characteristics, and the availability of recharge. This cone of depression is termed the area of influence. Wellhead delineations are based on these areas.

Land use within the area of influence can change the size and shape of the cone. Impermeable surfaces redirect the flow of water that normally recharges the groundwater by creating runoff that flows to streams instead of recharging the groundwater. The cone of depression will then expand to compensate for the loss of water. This creates a larger area of influence that will have to be protected, placing an additional burden on municipalities. Corrective measures should be implemented to ensure that land uses do not degrade or impact the quality or quantity of groundwater resources in the vicinity of the well.

Induced recharge is a process where wells draw surface water from a stream or surface water body. This occurs when the cone of depression reaches as far as a stream and lowers the water table beneath it. Instead of discharging water into the stream, this cone reverses the direction of flow

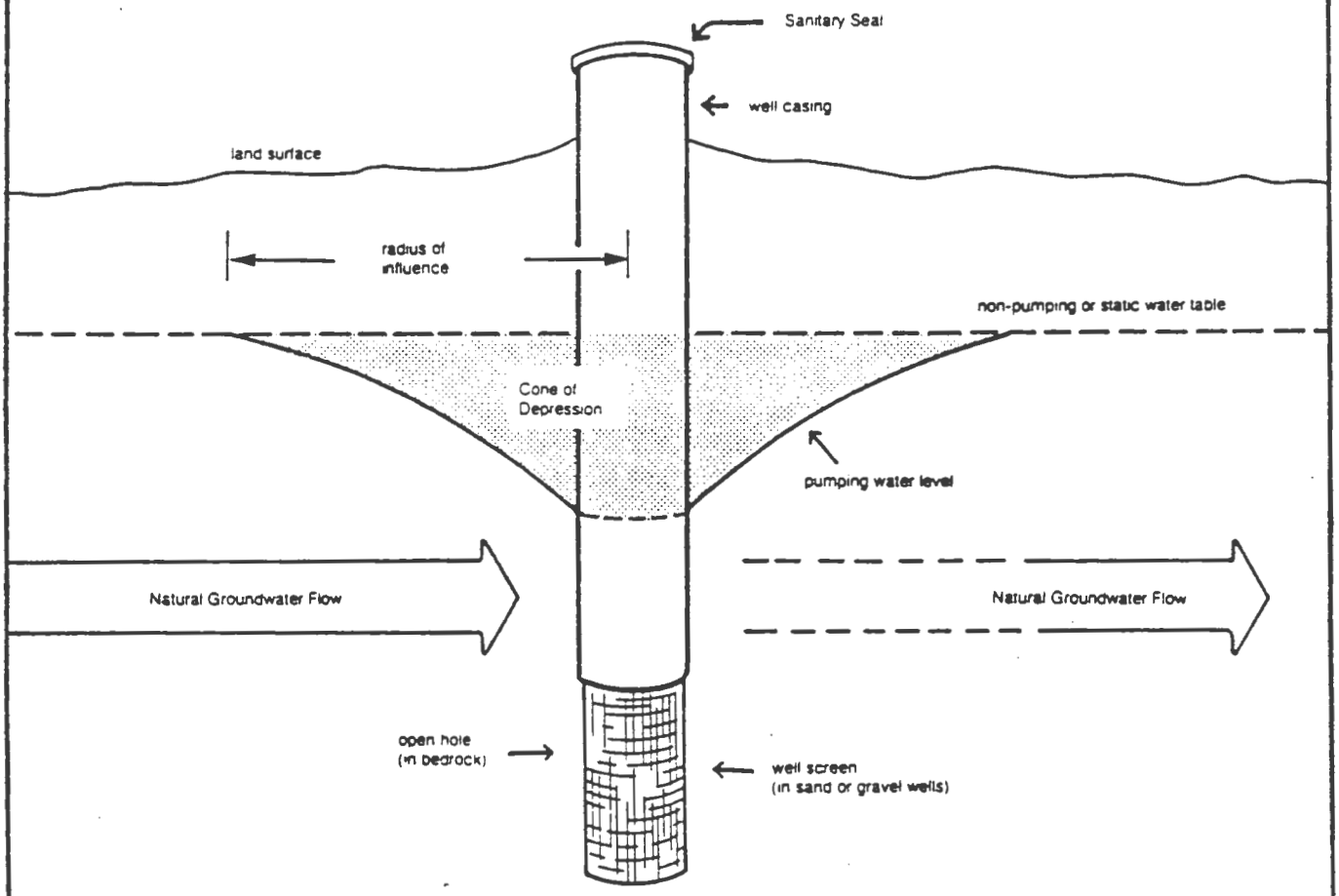


Figure 3: Cross-Section of a Well
Source: CT Department of Environmental Protection

and draws water from the stream. The pump will then pull water from the stream down through the aquifer and into the well. Under these conditions, polluted surface water can enter the well and degrade the quality of water. Two of North Smithfield's stratified drift wells are in close proximity to the Slatersville Reservoir and may be subject to induced recharge.

There are four areas significant to groundwater supplies that must be identified and protected to prevent contamination. These four areas are (1) aquifers where groundwater can be found, (2) cone of depression or area of influence, (3) recharge areas by limiting development, and (4) surface water since groundwater and surface water are interconnected.

2.8 GROUNDWATER POLLUTION

There are many types and sources of groundwater contamination, both natural and man-made. Figure 4 illustrates the results of contamination in the ground and its effects on the groundwater. Man-made pollutants such as sanitary waste and landfills are the most serious sources. Contamination from hazardous waste spills and leaks as well as the application of pesticides and fertilizers and road salting procedures all contribute to the pollution of groundwater. Once groundwater is contaminated, its use as a drinking water supply may be ended because restoration is

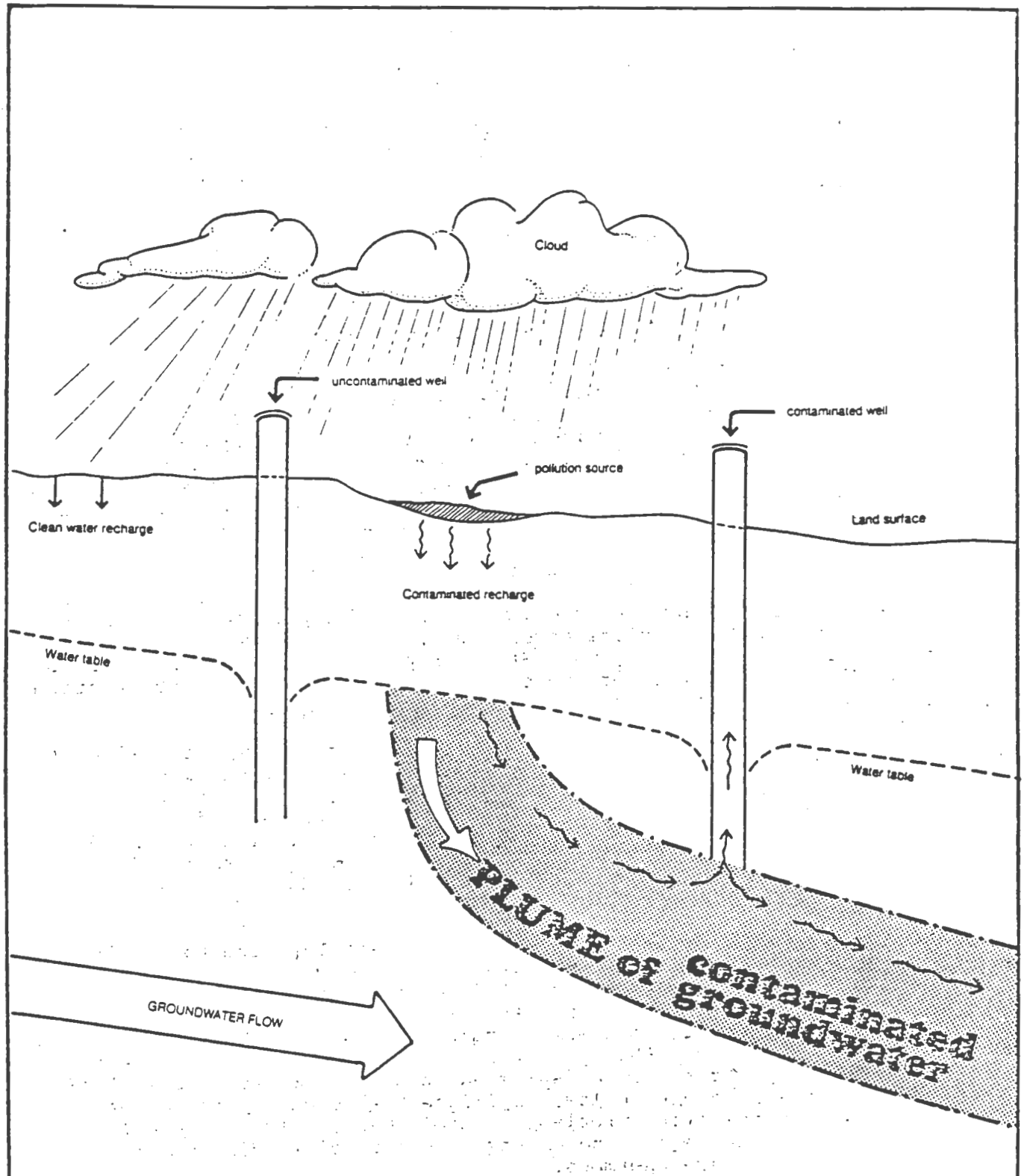


Figure 4: Contaminant Plume
Source: CT Department of Environmental Protection

often either technologically impractical or prohibitively expensive.

Groundwater pollution usually results from some activity on or just below the land surface. As the water infiltrating the ground comes into contact with pollutants, some may be dissolved and move with the water down to the groundwater. Many of the harmful contaminants are removed as the water moves through the soil. Other contaminants such as synthetic organic chemicals, however, travel unaltered through the ground. Once pollutants enter groundwater, they flow according to the same hydrologic principle: from recharge areas toward discharge areas.

Contaminants in groundwater usually form a concentrated plume of pollution that moves with the groundwater as a contamination plume. The porosity, permeability, and chemical composition of the geologic formation as well as the chemical properties of the contaminants all affect the way contamination moves once it reaches the groundwater.

CHAPTER III: WHPA DELINEATIONS

3.1 WELLHEAD PROTECTION AREA DELINEATION

This chapter is based on information from the US EPA's publication, "Developing a State Wellhead Protection Program", Rhode Island Wellhead Protection Program documentation and from interviews with RIDEM hydrogeologist, Sofia Bobiak.

3.2 EPA GUIDELINES

EPA guidelines for wellhead protection require that delineation methods protect wells from three general categories of threats:

* direct introduction of contaminants in areas immediately contiguous to wells;
* microbial contaminants;
* chemical contaminants.

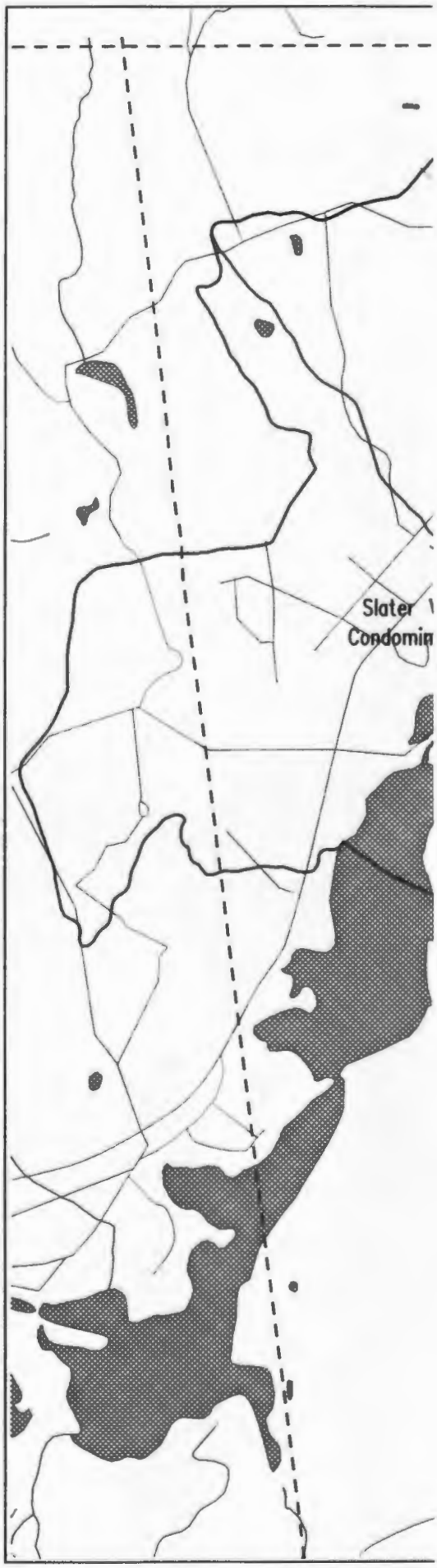
The EPA authorizes states to make initial delineations using simplified procedures to ensure early implementation and then to later refine these delineations. States are also instructed to prioritize the delineation of wellhead protection areas (targeting larger WHPA's initially) according to factors such as well yield, hydrogeologic setting, vulnerability, or contamination risk so that phased protective measures can be developed. Also required of the states was a comparison of alternative delineation criteria, thresholds, and methodologies to ensure cost-effectiveness

and a statement of rationale for the methods chosen. Delineation criteria considerations include: protectiveness, ease of understanding, economy of development, economy of application, defensibility, application for phasing, and relevance to goals.

3.3 RIDEM DELINEATION METHODOLOGY

For the purposes of this report, the delineation methods developed by geohydrologists from the Groundwater Section of the Division of Groundwater and Freshwater Wetlands, RI Department of Environmental Management, were used. It should be noted that, in order to provide a measure of wellhead protection at the earliest date possible, a two-stage process was used. Delineations used in this report are considered draft initial delineations; final delineations derived from further refinements in the methods will be forthcoming (see Figures 5 and 6 for mapped delineations). Local wellhead protection programs developed at this time will be updated using the refined delineations as those refinements become available. The EPA's framework for selecting criteria and criteria thresholds was utilized in the RI DEM delineations. The delineations produced for this project are some of the first examples of delineations that will be part of the RI Department of Environmental Management's Wellhead Protection Program.

In order to develop effective wellhead delineations,



DRAFT

Wellhead Protection Areas for Slatersville Wells

- Bedrock Wells
- Stratified Drift Wells
- Wellhead Protection Areas for Wells in Bedrock
- Wellhead Protection Areas for Wells in Stratified Drift
- Streams
- Lakes and Ponds
- Town Boundaries
- Roads

Area Location

Scale 1 : 18,000

FIGURE 5.

DRAFT
Wellhead Protection Area for Woodland Convalescent Home Well

+ Bedrock Well Location
Wellhead Protection Area
Streams
Town Boundaries
Lakes and Ponds
Roads

Area Location

N

Scale 1 : 10,000

FIGURE 6.

RIGIS
(c) RIGIS 1991

the staff of the Groundwater Section worked with a wellhead protection delineation committee. Recommendations of the committee members were incorporated into the delineation program. Representatives of the following organizations participated in this process: the US Environmental Protection Agency, the US Geological Survey, the University of RI, the RI Water Resources Board, the RI Department of Health, the League of Women Voters, the RI Department of Environmental Management, and members of the private sector.

In order to prioritize wellheads in terms of needed protection, public wells were divided into three groups:

1. Community wells in stratified drift deposits, and non-community stratified drift wells with maximum yields known to be greater that 10 gallons per minute (gpm);

2. Community wells drilled into bedrock, and those non-community bedrock wells that are capable of yielding greater than 10 gpm;

3. Non-community wells with maximum yields of less than 10 gpm.

3.4 THE DELINEATION PROCESS

Data used in the initial WHPA delineation process included one or more of the following: published reports, well driller completion reports, pump test data, and RI Department of Health records. Information from the Rhode Island Geographic Information System (RIGIS) was used in processing information from the U.S. Geological Survey regarding average transmissivities (the ability of an

aquifer to transmit a fluid, i.e. water) and hydraulic gradients (the slope of water tables). USGS and RI Department of Health (DOH) records, as well as local municipalities and water suppliers, provided pump capacities and rates. Well locations are mapped by the use of aerial photographs and site visits and this information is entered into the RIGIS. Non-community wells have been mapped by the RI DOH.

Several options for delineation methods were examined and evaluated by the Groundwater Section. A basic method is to set an arbitrary fixed radius around a wellhead. This method was considered too simplistic given the available data. Another method, numerical modeling, was deemed too complex given the available data. A method combining analytical modeling and hydrogeological mapping was devised for use with the larger wells and a calculated fixed radius was used for smaller wells.

DELINEATION TECHNIQUES RECOMMENDED BY THE EPA (listed in order of increasing sophistication (US EPA, 1990)):

* Arbitrary fixed radii
* Calculated fixed radii
* Simplified variable shapes
* Analytical methods
* Hydrogeological mapping
* Numerical flow/transport models

3.5 CATEGORY 1 METHOD - Stratified Drift Community and Non-Community Wells.

For these wells, two methods were combined: the uniform flow equation model downgradient of the well, and

hydrogeological mapping upgradient of the well (delineation information can be seen in Appendix A). Although the decision to utilize hydrogeological mapping was straightforward, the choice of an analytical model was more complicated. The Theis, Theim, and uniform flow equations were considered and it was determined that the uniform flow equation's ability to incorporate a gradient component made it the most appropriate model. The former equations would cause overprotective delineations (on the downgradient side of a wellhead) due to the fact that Theis and Theim equations assume a flat water table; the latter would require more specific site information but would provide a more accurate delineation of the surface and subsurface area.

When using the uniform flow equation (an EPA groundwater modular flow mode, WHPA - module MWCAP, was used) there is a point downgradient of a stratified drift well at which groundwater no longer flows toward the well (the null point) and this constitutes the downgradient limit of a WHPA. This location of this point is determined by aquifer transmissivity, well pumping rate, and water table gradient. Some values for these parameters may be estimated from available data. The drainage basin upgradient of the wellhead is considered the upgradient limit of the WHPA. However, if the well is located in a major stream valley where the stream affects the configuration of the water

table, a distance of one mile from the well is the criterion and threshold (this is consistent with RIDEM's GAA groundwater classification delineation method). In valleys where no stream exists to affect water table configuration, the criterion is time of travel and a threshold of 10 years was selected.

3.6 CATEGORY 2 METHOD - Bedrock Community and Large Non-Community Wells.

WHPA delineation for these wells was achieved by using the Theis equation in conjunction with a drainage basin (or portion thereof) that is situated in the uphill glacial drift. Other equations considered for this delineation method (uniform flow equation, volumetric flow equations for cylinder and cone shaped zones of influence) were considered but rejected because necessary information regarding groundwater flow direction in major bedrock fractures is not readily available (extensive mapping of fractures and a pump test to determine the location of water-bearing fractures would be required). It was determined that the safest method for delineation of a bedrock well would create a WHPA in the shape of a circle. This shape would best protect the unknown extent of the drawdown area contributing water to the well. As mentioned above, this circular shape was modified by the addition of the uphill glacial drift area from which water seeps into bedrock areas in the vicinity of the well. These delineations are subject to a threshold

value of a one-foot drawdown for the Theis-equation generated circle.

3.7 CATEGORY 3 METHOD - Non-Community Wells with Maximum Yields of Less Than 10 gpm or Unknown.

Through the use of the Theis equation, a WHPA consisting of a circle with a radius of 1750 feet was determined for these wells. The choice of this simpler method was due to lack of site-specific information about these wells and the time and staff limitations of RIDEM. This lack of data has caused conservative delineations which may possibly be overprotective on the downgradient sides and underprotective on the upgradient sides.

3.8 DELINEATION DEVELOPMENT

RIDEM provides initial delineations in order to accelerate the WHP Program and to ensure protection of groundwater supplies at the earliest date possible. It is intended that more refined delineations will be developed and that local WHP Programs will update their programs with this more detailed information. However, due to resource limitations at the state and local level, "no determination has been made with respect to responsibility for or scheduling of this refined delineation process" (RIDEM WHP Program, 1990). RIDEM will be providing guidance regarding methods for refining WHPA delineations which will likely require more sophisticated numerical modeling and the

gathering of new data. It is recognized, however, that the costs involved in this second stage may delay any refinement programs until the state or communities feel that they can afford to initiate such a program. Initial delineations provided by the RIDEM may be the basis for local WHP Programs for the foreseeable future. However, in response to comments presented at a WHP Program public hearing in February 1990 that inquired about the accuracy of the delineations and their legal defensibility, RIDEM expressed confidence that these delineations are suitable for local planning purposes.

CHAPTER IV: INVENTORY OF CONTAMINATION SOURCES

4.1 OVERVIEW OF RI GROUNDWATER CONTAMINATION

Contamination has forced the closure of 17 community wells (those wells serving 25 people or more) since 1979 (RIDEM 305 (b) report). In over half the cases, volatile organic compounds (VOCs), specifically TCE and tetrachlorethylene, were identified as the contaminants. Two of the closed wells were in North Smithfield (Forestdale Water Association and N.S. Air National Guard). Other contaminants forcing closures were bacteria, metals, pesticides, hydrocarbons, and radionuclides. Of these 17 wells, only one has been returned to service. Over the last four years, eight non-transient non-community wells (those serving at least 25 people for more than six months of the year) have been closed to contamination by VOCs. Remediation efforts have allowed four of the NTNC wells to be operated again.

DOH Private Well Testing Data-Public Water Supply Wells

Testing of public water supply wells conducted by the DOH over the last four years showed that VOCs were detected in low concentrations in approximately 15-20% of the wells tested (a complete listing of contaminants detected in RI groundwater can be found in Appendix B). Of the twelve VOCs detected, the most commonly occurring compounds were 1,1,1-

trichloroethane and chloroform, found in 15 wells in 1987 (RIDEM 305 (b) report). The levels found were below the EPA MCL (maximum contaminant levels) standards, where such standards were available. The only instance of an excedance of an MCL standard was at the North Smithfield Air National Guard facility, where TCE (MCL of 5 ppb) was detected at a level of 6 parts per billion (ppb). This site is within one of the North Smithfield WHPAs.

Up until January of 1988, the EPA had produced standards for only eight VOCs. At this point, the DOH began testing for an additional 51 VOCs, as required by the SWDA amendments of 1986 (Swallow, pers. comm. 1991) Up until mid-1989, although VOC contamination had been detected, MCLs for these substances had not been exceeded. The greatest incidence of VOC contamination occurred in systems serving over 10,000 people (RIDEM 305 (b) Report). The DOH remains very concerned over the management of VOCs due to the relative ease with which they travel in groundwater, their persistence in the environment, and the serious threat these substances present to public health.

The US EPA, in January 1991, added 14 other inorganic and organic compounds to the list of regulated substances. Inorganic chemicals are metals, salts, and other compounds that do not contain carbon and organic chemicals are natural or synthetic compounds that do contain carbon (US EPA 1991). Initially, the EPA was required to develop standards for a

total of 83 contaminants by 1989 (US EPA, 1991). However, that deadline has not been met and has been the subject of recent lawsuits. 25 other contaminants are slated to become regulated after standards for the initial 83 are determined.

Elevated levels of other pollutants have been detected in public water supply wells. DOH sampling (over a seven-year period, 1981-88) revealed elevated levels of sodium and nitrates as well as iron and manganese. Contamination by nitrates is the result of multiple non-point source inputs from land use activities. The highest level of nitrates detected was 7.6 mg/l which is still below the EPA standard of 10 mg/l. Road salting practices have resulted in increased levels of sodium and chloride. 21% of the public wells had sodium levels that exceeded 20 mg/l which is the DOH Alert Level, designed to protect citizens who are on salt-sensitive diets and two wells showed levels over 100 mg/l (RIDEM 305 (b) Report, 1990). Iron and manganese are metals that naturally occur in groundwater and the EPA has established secondary drinking water standards for them based on aesthetic considerations rather than health reasons.

Private Well Testing

The DOH has monitored a total of 3,060 private wells, usually those in close proximity to hazardous waste landfills, industrial sites, and leaking underground storage

tanks. This monitoring indicates that VOCs are the most frequently detected contaminants (usually in low concentrations), occurring in 27% of the wells tested. Other detected contaminants include: gasoline, MBTE (a gasoline additive), fuel oil, arsenic, cadmium, chromium, lead, pesticides (aldicarb and carbofuran), salt, and nitrates (RIDEM 305 (b) Report, 1990).

4.2 EXISTING WATER SYSTEM WITHIN THE WHPAS

This section will describe the existing wells that fall within the initial draft WHPA delineations supplied by RIDEM for the Town of North Smithfield. Information in this section was derived from the Weston and Sampson Water System Master Plan and from records on file at the DOH. This study has focused on these delineations as being the primary wells of concern. There are a total of five bedrock and three stratified drift public wells. These comprise the public wells both community and non-community as described in the first section of this report.

The Slatersville Water Company (SWC) operates the original Slatersville water system which was constructed to supply the Slater's Mills. The SWC currently serves about 445 residences and 12 non-residential users. Available records from the town and the DOH indicate that water is supplied from five well sites within the system. The SWC operates five of the eight wells that this study addresses.

Table 1 illustrates a summary of the eight well sites that are addressed in this study.

EXISTING SWC SUPPLY WELLS/COMMUNITY SYSTEMS

Well	Type	Pumping (gpm)	Depth (Feet)	Year Built	Well House
Main St. Pump House No. 1	Dug	90	28	1800's	8'* 8' Brick
Main St. Pump House No. 2	6 Well Points	100	16-21	—	8'* 8" Brick
Pacheco Park Well	Drilled Bedrock	40	>300	1979	None
Halliwell School No. 5	Drilled Bedrock	10	580	1959	None
Halliwell School No. 6	Gravel Packed	100	43	1986	None
Slater Village Condominium Well	Drilled Bedrock	40	N/A	N/A	N/A
Coast Guard Housing Well	Drilled Bedrock	30	300	N/A	N/A
Woodland Convalescent Center	Drilled Bedrock	3	860	1968	N/A

Source: RIDEM/DOH/SWC

Table 1

There are two well pumping stations located on Main Street in Slatersville. Pump House No. 1 houses a 28 foot deep dug well that was installed in the late 1800's. The well is located adjacent to the Slatersville Reservoir approximately 300 feet north. Figure 5 illustrates the wells and the delineations supplied by the RIDEM. Studies have shown that induced recharge occurs along the southwest corner of the well. Due to excessive drawdown as a result of the pumping operation, the well is intermittently shut down to allow the well to recover. This gravel packed well

under optimum conditions has a pumping rate of 90 gallons per minute (gpm).

Main Street Pump House No. 2 houses a manifold and vacuum system which joins two sets of three well points, the combined total of which can be safely pumped at 100 gpm. The maximum depth of these well points is 16-21 feet.

The Pacheco Park Well is a 300 foot deep, drilled bedrock well with no well housing structure and has a 1 horsepower pump with a pumping capacity of 9 gpm.

Halliwell School Well No. 5 is a drilled bedrock well that was originally installed to supply the Halliwell school with water. The well began operation in 1959 and pumps at a rate of 10 gpm.

Halliwell School Well No. 6 is a gravel packed, 43 foot well with a pumping capacity of 100 gpm. Past pumping rates achieved a rate of 135 gpm but this rate was reduced to prevent excessive drawdown of the water table.

The Slater Village Condominium Well is a drilled bedrock well with a pumping capacity of 40 gpm. This system serves a condominium complex located off Victory highway. The WHPA extends westard across the town line into Burrillville. Adequate protection within this particular wellhead area will require a combined effort between the towns of North Smithfield and Burrillville.

The Coast Guard Housing Well is a 300 foot drilled bedrock well with a pumping capacity of 30 gpm. This well

serves approximately 85 persons located on the NIKE site. The RIDEM has documented contamination sources in the vicinity of this well. Pumping rates within this system should be carefully monitored to prevent excessive drawdown that might induce recharge in the direction of the contamination sources.

The Woodland Convalescent Well was installed in 1968 to provide drinking water for 60-80 residents of the center. This bedrock well has a pumping capacity of 3 gpm. Extensive drilling was required to a depth of 860 feet in order to provide the center and fulfill their water needs.

SWC Water Quality

Since 1989 the RIDOH has monitored RI water systems for a total of 59 solvents and organic chemicals as required under the SDWA Amendments of 1986. At present only 22 of these substances are regulated (J. Swallow pers. comm., 1991). Test results for the 22 regulated substances revealed that water from the Halliwell School Well No. 6 contained 1-2 parts per billion (ppb) of trichloroethene. This does not exceed EPA limits. None of the 58 other substances were detectable. The DOH advised the town (March 1990) that none of these chemicals are present in amounts that would pose a threat to the health of the consumer. Refer to Appendix C for the DOH sampling report.

4.3 CONTAMINANT DESCRIPTIONS AND EFFECTS

Information in the following section is derived from the folowing publications: CCAMP, 1988, Special Legislative Commission on Water Supply, 1986.

1. Acids and Bases

Acids and bases occur as a result of industrial wastes, wastewater from jewelry shops, machine shops, furniture stripping, leachate from landfills, junkyards and industrial pits/lagoons. The most common acids and bases found in the wastestream include hydrochloric acid, sulfuric acid, and ammonia. The harmful effects of acids occur when the positive charged ions remove heavy metals from soil particles. Consequently, the metals remain in solution and can move through the soil into the groundwater. High concentrations of acids and bases in wastewater will kill the bacteria that decompose the waste and reduce the effectiveness of a septic system.

2. Chloride

One of the major contributing sources of chloride in the soil stems from the road salt used to deice roads and parking lots. Road salt enters the groundwater as runoff from roads and uncovered salt piles. Septic systems and water softening agents also contribute chloride to groundwater. Elevated chloride levels in drinking water results in an aesthetically displeasing sample. The

presence of excessive chloride concentrations may be linked to the same elevated levels in sodium concentrations which can have adverse health effects on the general population (See Sodium).

3. Fluoride

Fluoride occurs naturally in the soil. Wastes generated from various manufacturing practices contain fluoride. It is also an additive to drinking water, toothpaste and other dentifrices. The ingestion of excess fluoride causes fluorosis, a disease which results in brittle and sensitive teeth and bones.

4. Heavy Metals

Heavy metals are not generally found in concentrated form in natural constituents. Metals are soluble in water and are more mobile in acidic, reduced conditions. The health threats associated with heavy metals are many depending on which one is of concern. Typical health threats associated with metals include: high blood pressure, kidney damage, toxicity, nervous disorders, and blue-gray discoloration of the skin, eyes and mucus membranes.

5. Iron and Manganese

Iron is one of the most abundant elements and can be found in high concentrations in natural constituents.

Industrial waste and drainage water contain an abundance of iron. Manganese is common in salts and minerals. Water with elevated iron concentrations will develop a brownish appearance which colors laundry and porcelain fixtures. High manganese levels have a similar aesthetic problem. Iron and manganese particles will collect in joints and valves and has a tendency to clog pipes and decrease their life expectancy.

6. Nitrates

The most commonly occurring source of contamination is excess nitrates. Sources of nitrate pollution include: leachate from septic systems, runoff, discharges from municipal sanitary waters, and runoff from agricultural lands, and landfills. At concentrations exceeding federal standards, nitrates can cause a disease called methemoglobinemia or "blue-baby disease" which can be fatal in infants under three months of age.. This occurs as a result of too much nitrite in the blood which inhibits the blood's ability to transport oxygen.

7. Pathogens/Viruses

The presence of Escherichia coli (E. coli), more commonly known as coliform, results from contamination by human and animal wastes. Too much coliform indicates the presence of viruses and parthenogenic bacteria. The harmful

effects of this type of contamination are generally gastrointestinal diseases. Bacteria, viruses, and parasites are all parthenogenic organisms. Diseases such as typhoid, dysentery, cholera, hepatitis and tuberculosis are common in contaminated conditions.

8. Pesticides

Pesticides refer to a wide range of chemicals including herbicides and insecticides. Application and storage of these products are process that can threaten groundwater quality. Farmers use pesticides to kill unwanted pests such as insects and weeds that threaten cops. Pesticides contaminate groundwater by percolation through the soil. A common pesticide used locally to control the Colorado potato beetle was aldicarb or more commonly called temik. The use and application of these chemicals must be closely monitored to insure the quality of the groundwater.

9. Petroleum Products

Petroleum products such as gasoline, diesel fuel, kerosene, heating oil, motor oil, and grease are commonly used everyday. The presence of these products in groundwater can be attributed to leaking UST and pipelines. Benzene is a component of fuels and is often the only name constituent in cases of fuel contamination. Toluene xylene, and butyl ether are also found. These products will degrade

in the presence of nutrients and oxygen. Concentrated plumes of these products will cause problems in drinking water that are costly and timely to rectify. Low level exposure produces dizziness, weakness, euphoria, headaches, nausea, tightness in the chest, and staggering. At high concentrations benzene blurs the vision, tremors paralysis and unconsciousness. Excessive exposure has resulted in death due to leukemia and aplastic anemia.

10. Sodium

Salt is a naturally occurring constituent of water. Elevated levels of sodium is commonly a result of runoff from de-icing operations. High sodium concentrations pose dangerous health threats to certain segments of the population. It is believed to be related to the development of hypertension and has also been connected as a factor in Sudden Infant Death Syndrome.

11. Solvents

Typically, solvents are used as a cleaning agent (degreasing) in automobile repair shops. Dry cleaning and furniture stripping businesses rely on solvents for cleaning purposes. Common household products contain solvents including, nail polish remover, drain openers, detergents, thinners and septic tank cleaners. The cumulative impact of toxic organic solvents by households into domestic septic

systems may have a significant effect on groundwater quality. Common solvents used in industrial manufacturing include toluene, naphthalene, benzene and trichloroethylene (TCE) which has been detected at the Stamina Mills Site in North Smithfield. The health threats are similar to those of petroleum products and should be carefully monitored to ensure the protection of drinking water supplies.

Non-point Sources of Groundwater Contamination in Rhode Island (See Appendix D for Land Use Impacts)

1. Pesticides

Instances of pesticide contamination in groundwater have been on the rise. Most pesticides are very soluble in water and therefore have the ability to be transported long distances in groundwater. In the RIDEM's Private Well Survey, 28 or the 256 wells tested had detectable levels of pesticides (all were below drinking water standards). The most frequently detected pesticide was Aldicarb (also known as Temik), a compound designed to kill soil insects. It is often applied to potato fields.

2. Fertilizers

The most serious contamination problem resulting from agricultural and homeowner use of fertilizer is the introduction of nitrogen into groundwater. Nitrogen, in the form of nitrate, is very soluble in water and can become concentrated in the earth. It then can leach into and

travel quickly through groundwater. Homeowners have a tendency to overfertilize lawns thus allowing excess nitrate to contaminate groundwater.

3. Septic Systems

One of the most serious threats to groundwater is nitrates and contaminants that leach from septic systems. There are currently about 144,000 individual septic disposal systems (ISDS) in operation in Rhode Island today (RIDEM 305 (b) Report, 1990). Existing regulatory setbacks and separation distances cannot prevent effluent from properly designed ISDS from reaching groundwater (Myers, 1988, Horsley, 1990). This is problem is compounded by leachate from systems that have failed due to poor design or old age.

Bacteria, viruses, nitrates, and volatile organic compounds (VOC) are the main contaminants that leach from septic systems. It has been shown that although bacteria can be attenuated within the soil within a short distance of a septic system, viruses can survive as long as 120 days and can travel as far as 218 feet (Myers, 1988) in groundwater. High nitrate concentrations in groundwater drinking supplies are considered a health hazard. Nitrates can be converted to nitrites in the human body which can cause infant cyanosis (blue baby), a condition in which nitrogen rather than oxygen is transported by the blood and produces oxygen starvation (US EPA, 1976,). Groundwater nitrate levels

above 10 mg/l are considered a health hazard. Elevated concentrations of nitrates have been found as far as 330 feet from a septic system leachfield (State of State's Waters 305 (b) Report). Many organic chemical pollutants are commonly found in septic systems. Household cleaners, paint thinner, drain and oven cleaners, and solvents are often flushed into septic systems. Many of these substances are very mobile in groundwater and are persistent in the environment. Septic system cleaners contain organic chemicals which present a serious threat to groundwater quality. The most common of these chemicals are methylene chloride and 1,1,1 - trichloroethane. The State has banned the use of cleaners containing these chemicals but enforcement of this ban is difficult. Little research has been conducted on the impacts of these compounds and the EPA has yet to determine acceptable levels for many organic chemicals.

4. Road Salt

In an effort to provide safe winter road conditions, RI communities apply a mixture of sand and salt as a deicing measure. Salt is applied at a rate of up to 300 pounds per lane mile of road (RIDEM 305 (b) report). Municipal and private wells are often located near major roads and some wells have been contaminated by road salt. High sodium concentrations in drinking water are considered a public

health threat, particularly to those on salt-restricted diets. Alternative deicing materials have been tried (calcium chloride mixed with sodium chloride) but high costs and complaints regarding road conditions have meant a return to the standard salt/sand mixtures.

5. Radon

Radon is a colorless, odorless radioactive gas which occurs naturally in bedrock in Rhode Island. The federal government has stated that an estimated 5,000 to 20,000 people may die each year from radon-induced lung cancer (Lowry, 1987). Because radon is 60 times more soluble in water than is oxygen, it accumulates in greater concentrations in water than air (Lowry, 1987). The EPA recommended mitigation level for airborne radon is 4 picocuries per liter (pCi/l) and as low as 20 pCi/l for waterborne radon. The EPA is considering setting an MCL for radon at about 500 pCi/l (RIDEM 305 (b) Report). However, the magnitude of the problem is evidenced by the fact that national average radon concentrations in groundwater are about 500 pCi/l (Lowry, 1987). Radon in groundwater used for domestic water supply can be released into the air through dishwashing, showers, and other water-using activities. It is known that breathing radon is more dangerous than drinking it, although it has been concluded that drinking radon-contaminated water will increase the

risk of contracting stomach cancer (Univ. of ME, 1986). Water supplies that are drawn from sand and gravel aquifers have lower radon levels than water drawn from bedrock wells. Some radon decay takes place when water stands while in storage before distribution (Univ.of ME, 1986).

The RIDEM Private Well Survey tested 303 wells and included radon as one of the test parameters. Groundwater radon concentrations ranged from 140 to 49,080 pCi/l. 291 of the RI private wells tested registered radon levels exceeding 500 pCi/l. No state action is anticipated until EPA standards are set.

6. Petroleum Spills

RIDEM Emergency Response personnel respond to over 200 spills of petroleum products every year (RIDEM 305 (b) Report). Many unreported spills result in groundwater contamination that is later discovered. Other sources of petroleum contamination are parking and transfer areas (with above ground tanks) for oil trucks and sand and gravel operation vehicles.

4.4 CONTAMINATION SOURCES IN NORTH SMITHFIELD

This section describes the existing and potential sources of contamination based on on-site investigation, aerial photographs, land use surveys and file reviews at the RIDEM Groundwater Section. There are primarily two sources

of contamination, natural and man-made. It is the purpose of this project to identify the man-made sources of pollution which will be broken into point and non-point pollution.

Point sources of contamination are attributed to a particular point of discharge such as end of pipe discharge, or any contaminant that can be traced back to its origin. Examples of point sources include but are not limited to: hazardous materials storage and disposal, leaking underground storage tanks, salt piles, oil and gas pipelines, and junkyards.

Non-point sources of pollution cannot be located at a particular point and are difficult to quantify. Examples of this type of pollution include: septic system failure, runoff from highways, pesticides and fertilizers, farms and animal waste just to name a few. Because of the difficulty in assessing the non-point sources of contamination, potential sources of contamination are included within this classification. The following section includes a brief discussion of various non-point sources of pollution.

4.5 SUPERFUND/CERCLIS SITES IN NORTH SMITHFIELD

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) established the Superfund - a funding source used to clean up existing or closed high priority toxic waste sites. There are three such sites in

the Town of North Smithfield. Toxins disposed of or stored at waste sites have been found to leach into groundwater. This act created a funding mechanism for clean-up actions. The broad powers this act grants of assigning liability for cleanup of such sites to hazardous waste transporters, generators, and landfill owners acts as a deterrent to continued toxic dumping practices. CERCLA sets forth a cost-sharing formula in which the states must contribute 10 to 50 percent of the cost of clean-up, depending on whether the site in question was publicly or privately owned. The high costs associated with toxic waste removal or remediation has hampered the effectiveness of this act as many states currently do not have the financial resources to allocate funds for CERCLA actions. Sites on the CERCLA Information List are potential contamination sources where it has been established that presently or in the past there occurred releases of hazardous substances. Locations deemed to represent an immediate threat to the public health and safety are elevated to the National Priority list called Superfund. When investigated and fond not to be a potential hazard, it gets removed from the list.

Superfund Sites in North Smithfield

1. Stamina Mills, Main St., Forestdale section of N. Smithfield

This five-acre site was in operation from 1969 to 1975 as a textile mill in which solvents were used in a scouring

system. In the early 1970s, an 800 gallon trichloroethylene spill occurred. The mill was closed in 1974 and storage tanks were abandoned still containing 600-700 gallons of solvents. The mill was destroyed by fire in 1979 and the tanks could not be found in the remains. Surface water (the Branch River), groundwater, and soil were contaminated. The RI Water Resources Board and the EPA provided funds for a new water supply. The EPA monitored the site until 1986 and remedial measures are still in the process of development. The contaminant plume is currently receding toward the site.

2. Landfill and Resource Recovery Site (L&RR)

This 28-acre site is located off of the Oxford Turnpike, northwest of Pound Hill Road. Industrial wastes were received at the site from 1927 until a court-ordered closure in 1985. The length of the time period in which hazardous wastes were received is not known. The site is located within the Slatersville Aquifer recharge area and on the perimeter of the groundwater reservoir. The EPA estimated the clean-up costs to be between 8 and 11 million dollars.

3. Western Sand and Gravel

Western Sand and Gravel, a gravel quarry operation, is located on the Burrillville, North Smithfield town line,

east of Douglas Turnpike. Disposal of septage and industrial wastewater occurred in the mid 1970's on a portion of the site. This site was closed in 1980 and at present, there is little information available on the potential ability of this landfill to contaminate the Slatersville Reservoir or the aquifer. It is located between Douglas Pike (Rte. 7) and the reservoir. Approximately 4700,000 gallons of liquid hazardous wastes were disposed at the site between 1975 and 1977. Tarklin Brook, which eventually drains to the Slatersville Reservoir, passes within 300 feet of the site. Groundwater movement in the area of the site was determined to be in a northwest direction, closely following the Tarklin Brook channel. Remediation measures have included capping and a groundwater recycling system and further measures are still being developed.

The following table lists non-Superfund CERCLIS sites in North Smithfield.

NORTH SMITHFIELD SITES ON USEPA'S CERCLIS LIST

SITE	ADDRESS
Glas-Kraft/Halliwell Blvd.	Railroad Street
Poly-Top Corp/Halliwell Blvd.	Graham Drive
Halliwell Blvd. Property	Halliwell Blvd.
DODF, Army, N. Smith Nike	Poundhill Road
DODF/Air-RI Air Nat. Guard	Old Oxford Road

Source: USEPA CERCLIS List

Table 2

The Superfund Amendments and Re-authorization Act (SARA) Title III requires businesses to notify governments (Right-to-Know) of potentially hazardous substances stored or used on-site. SARA records for the State of Rhode Island are managed by the RI Department of Labor. Table 3 list the sites that fall within the WHPAs that have registered with the RI Department of Labor. Of these sites only 13 have submitted annual substance inventory lists (T. DiCicco, pers. comm.).

SARA TITLE III SITES

COMPANY NAME	ADDRESS
A & J Well Co. Inc.	77 North Main Street
C & C Service Inc.	Victory Highway
Dumais Plumbing & Heating Inc.	905 Victory Highway
Farrell Construction Co. Inc.	468 Sayles Hill Road
G. Bouchard - Masonry	12 Willerval Avenue
Holliston Sand Co. Inc. *	Tifft Road
L & L Dozer Service Co. Inc.	115 Mount Pleasant Road
Marcantonio & Sons *	31 Georgianna Avenue
Norman J. Langelier Co. Inc.	1435 Victory Highway
Northern RI Animal Hospital	152 School Street
Poly-Top Corp. *	Graham Drive
Precision Auto Repair Inc. *	550 Iron Mine Hill Road
The Homestead *	P.O. Box 543
The Pines	Poundhill Road
The Villa Capri Inc.	North Main Street
Village-Haven Restaurant Inc.	90 School Street
Woodland Convalescent Center *	70 Woodland Road
Yard King Inc.	1087 Eddy Dowling Highway

* Submits Substance List Annually

Source: RI Department of Labor

Table 3

RCRA Facilities within the WHPAs

This federal statute provides standards for treatment, storage, and disposal facilities for hazardous wastes (See Table 4) all aimed at preventing contamination of surface and groundwater and at public safety. Hazardous wastes are tracked from "cradle-to-grave" (point of generation to point of ultimate disposal). The Act was amended in 1984 to address groundwater contamination from leaking underground storage tanks which are subject to RCRA regulation if 10 percent of a tank's volume is beneath the ground surface and if the tank contains a material regulated under RCRA or CERCLA.

RCRA FACILITIES

REG. #	FACILTIY NAME	ADDRESS
801192488	Glas-Kraft Inc.	Railroad Street
081889305	Menard Subaru	Eddy Dowling Highway
082766891	Menard Subaru	Eddy Dowling Highway
082192676	Precision Auto Repair	Greenville Road
910522105	RI Air National Guard	N.S. Air National S
000843755	Sunoco Service Station	1047 Eddy Dowling Hgwy
082755506	Yard King	1087 Eddy Dowling Hgwy

Source: RIDEM

Table 4

The US EPA has not added to the list of RCRA-regulated materials since 1980 although several states have requested that the list be expanded (Jaffe and DiNovo, 1987). Four

factors are used to classify hazardous wastes under RCRA: ignitability, corrosivity, reactivity, and toxicity. Substances not regulated under RCRA are those that are carcinogenic, infectious, and cause birth defects (teratogenic) although there are provisions in the 1986 amendments to add such substances.

RIDEM Registered Underground Storage Tanks (UST)

The State of Rhode Island regulates USTs that hold 1100 gallons or more. A majority of these tanks store petroleum products such as home heating oil and gasoline which comprise 39% and 35% of the total, respectively. Table 5 illustrates a list of USTs within the WHPAs.

RIDEM REGISTERED UNDERGROUND STORAGE TANKS

REG. #	FACILITY NAME	ADDRESS
02375	C & C Service	Great Road
00883	Citgo/Slatersville Plaza	Victory Highway
00292	DB Mart	Eddy Dowling Highway
01599	Don Schmor Excavating Co.	Main Street
01557	Edgecomb Metals	Industrial Park
02725	Menard Subaru	1401 Eddy Dowling Hgwy
01473	North Smithfield Armory	Pound Hill Road
00580	Pike Mobil	1148 Eddy Dowling Hgwy
00401	Ryder Student Trans.	Old Providence Pike
00633	Sunoco #0002-4976	Eddy Dowling Hgwy
00367	Town Hall	Main Street
02229	U.S. Post Office	1 Main Street

Source: RIDEM

Table 5

There have been 125 incidents of UST leakage discovered in Rhode Island in the last few years (RIDEM 1989). 83% of the registered USTs are constructed of steel which deteriorates at a higher rate in humid climates.

Two incidents of groundwater contamination have occurred as a result of leaking underground storage tanks. The first leak occurred at the Sunoco station located at 1047 Eddie Dowling Highway when a neighbor complained of water quality problems in their well. After deliberation and careful studies, the Sun Refining and Marketing Company entered into agreement with the RIDEM to initiate a clean up program to restore the drinking water quality in a well located at 29 Woodland Road. Sun agreed to install a two-tiered recovery system to remove MTBE, a gas additive found in halos around the well. The first step in this procedure required aeration to volatize and release the additive into the air. Then to pass it through a charcoal filtration system, and finally discharge the water into a DOT storm drain. In the mean time the RIDEM would provide fresh drinking to the residents.

The second incident that resulted in groundwater contamination occurred in the same area as the first. The DB Mart located at 80 Eddie Dowling Highway owned by Deblois Oil Company was issued a permit for wastewater discharge following a clean up procedure of the contaminated groundwater. This problem began in 1989 after a complaint

by a local resident was filed with the RIDEM. High levels of MBTE and aromatics were found in a nearby well. The parties involved are in the process of working out an agreement to determine the responsibilities of each. Refer to Appendix E for Sun Oil/DB Mart documentation.

Potential Threats

Other potential sources of contamination that pose a threat to groundwater quality exist in North Smithfield. Of primary concern is an underground mobile pipeline bisecting Sayles Hill Road adjacent to the North Smithfield and Lincoln Town Line. This multi-product pipeline transports various petroleum products consisting of No. 2 and No. 6 bunker fuel. The 6 inch pipeline is buried at a depth of 37 feet. Although no record of leaks or contamination are on file at the RIDEM, the risk of contamination remains.

The final threat to groundwater quality found in this study occurs at the RI Air National Guard (NIKE) site located on Pound Hill road. The threat exists as an underground injection well which pumps wastes deep into the ground. This site is registered with the RIDEM.

CHAPTER IV: CURRENT PROTECTION/MANAGEMENT STRATEGIES

5.1. REGULATORY PROTECTION

The development of surface water reservoirs has become politically difficult and extremely costly in recent times. Opposition from environmental groups (and sometimes the EPA as in the case of the proposed Big River project) combined with fiscal limitations has forced states and communities to take a closer look at groundwater sources of drinking water. Drought conditions in the Western United States have drawn attention to problems involving the allocation of water rights and withdrawal rates from groundwater aquifers (National Public Radio broadcast, May 1991). Because effective regulations aimed at the protection of groundwater did not exist until recent times, some reserves were contaminated and others are at risk. The RIDEM State of the State's Waters 305 (b) Report estimates that 9% of the state's groundwater has been impacted by contaminants and that 80% is threatened.

Federal, state, and local regulations address different aspects of the protection of groundwater reserves but existing regulations do not provide comprehensive protection. Rhode Island's antiquated zoning enabling act did not provide the authority necessary for communities to adopt groundwater protection ordinances until recent amendments made that possible. The addition of aquifer

overlay districts to zoning ordinances has been beneficial but there are still gaps in protection.

Analysis of the existing regulatory groundwater protection measures prevents overlaps, duplications of effort, and conflicts with existing groundwater programs. Using these programs as a basis, communities can craft groundwater protection strategies that are specific to their circumstances. Gaps in existing authority can be identified and any needs for intergovernmental cooperation become apparent (as in the case of designing protection for aquifers that underlie several communities).

Federal and state efforts regarding groundwater protection are in a state of flux (Patrick et al. 1987). As the issue has recently become the focus of political concern and as communities realize the extent of the risk of contamination of groundwater drinking water supplies, there have been many legislative actions aimed at groundwater protection (primarily on the local level).

5.2 FEDERAL GROUNDWATER PROTECTION

There are no federal statutes that specifically target the protection of groundwater. When combined, different parts of existing programs provide a certain degree of groundwater protection (Refer to Appendix F for a descriptive listing of federal and state regulations that affect groundwater quality). These existing programs are

often amended to include aspects of groundwater protection (i.e. RCRA and SDWA) and are focused on activities or practices that are likely to threaten the environment with groundwater being one of the environmental factors warranting protection (Patrick et al 1987).

It is likely that federal responsibility for groundwater protection will be legislatively expanded in the future (Jaffe and DiNovo, 1987) . Comprehensive groundwater legislation was offered in both Houses of the Congress in 1986 and 1987; no acts were passed but support is growing as legislators and their constituents recognize the vulnerability of water supply systems in the United States.

One of the groundwater issues being debated in Congress is the question of whether the federal government or state governments should have primary control over groundwater protection. Also being discussed are legislative methods that will ensure that states develop and implement programs to address their own unique groundwater problems (Patrick et al. 1987).

In 1984, the EPA established the Office of Groundwater which was given the responsibility for developing an overall federal groundwater strategy. This effort is in competition with other environmental regulatory initiatives (i.e. air quality, surface water quality) that have been part of the regulatory scheme for more than a decade and that have established a certain momentum. Additionally, the process

is slowed by technical issues more complex than those encountered in other environmental protection efforts (Patrick et al. 1986).

The federal acts that are provide groundwater protection are:

The Clean Water Act (CWA) as amended by the Water Quality Act of 1987

The Safe Drinking Water Act (SWDA)

Resource Conservation and Recovery Act (RCRA)

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Superfund Amendments and Reauthorization Act (SARA)

Toxic Substances Control Act

Federal Insecticide, Fungicide, and Rodenticide Act

National Environmental Policy Act (NEPA)

These acts grant authority to governments to take action against threats to public health or the environment and so they can be applied to groundwater. State governments are given authority by Congress to administer and enforce these federal regulations. In some instances, states have developed programs that are more stringent than required by federal law.

5.3 STATE GROUNDWATER PROTECTION

RI Groundwater Strategy

In 1983, the State of Rhode Island's Water Pollution Control Act was amended to include groundwaters under the

definition of the State's waters. In doing so, the RIDEM was given authority to regulate the prevention of groundwater contamination and to restore groundwater quality to acceptable levels. The State enacted the Groundwater Protection Act in 1985 which was designed to provide for the development of a comprehensive groundwater protection program. Policies established by the Act provided measures to restore, protect, and maintain the quality of the State's groundwaters. These measures included aquifer, recharge area, and watershed protection. Degradation of groundwater was prohibited unless the state chose to allow "lower quality as a result of essential, desirable, and justifiable economic, commercial, industrial, or social development" (RI Groundwater Protection Strategy, RIDEM 1989). This act also directed the RIDEM to identify and classify groundwater aquifers and to establish standards for the four classes of groundwater. These classes are (from RIDEM's RI Groundwater Protection Strategy, 1989):

GAA - groundwater sources suitable for public drinking water use without treatment;

GA - groundwater sources which may be suitable for public or private drinking water without treatment;

GB - groundwater sources which may not be suitable for public or private drinking water without treatment due to known or presumed degradation;

GC - groundwater sources which may be suitable for certain waste disposal practices because past or present conditions have rendered these sources more suitable for receiving permitted discharges than for development as a public or private

drinking water supply.

Analysis of State Regulatory Protection

State programs provide protection in terms of setbacks and separation distances (ISDS regulations) and control of substances and practices that pose a threat to groundwater quality (refer to Appendix F for a listing of State regulations). It has been scientifically documented that existing setbacks and separation distances may not be sufficient to attenuate certain contaminants (viruses, nitrates, VOCs) especially in the highly permeable outwash soils in which the state's significant aquifers are located (RI State Plan Guide Overview - Element 010, 1984, Myers, 1988, Horsley, 1990).

Although regulations aimed at control of hazardous wastes are effective, hazardous materials, in raw form, are not regulated and pose a threat to groundwater quality due to spills or leaks that could occur as these materials are stored or transported. Another gap in groundwater protection from hazardous materials is the fact that federal and state statutes only regulate USTs with capacities of over 1100 gallons. Although a few communities have enacted more stringent UST regulations or bans (as encouraged by the RIDEM WHP Program), the majority of domestic and small commercial tanks are unregulated. Small volumes of contaminants can cause significant groundwater contamination.

The injection of waste products into the ground, while strictly regulated, creates a potential for future groundwater contamination problems due to the lack of knowledge of subsurface geological conditions. Contaminants can be transported great distances along bedrock fractures, threatening drinking water wells and aquifers (S. Bobiak, pers. comm. 1991).

There exist in RI many smaller, abandoned private landfills that could contain substances capable of contaminating water supplies. No state program exists that would identify and monitor such landfills that are located within watershed or aquifer recharge areas. Given current budgetary conditions, the establishment of new programs to address this problem would strain existing staff and funding capabilities.

Road salting practices are responsible for water quality degradation throughout the state. In an effort to provide safe winter road conditions, communities apply sand/salt mixtures that have been shown to contaminate water supplies (RIDEM 305(b) Report, 1990). Salt application practices are not currently regulated.

Some communities have identified watershed or aquifer recharge areas as areas targeted for public land acquisition programs, with funding from RIDEM or the federal government or through the surcharge created by the RI Public Drinking Water Protection Act. RIDEM programs such as Household

Hazardous Waste Days and the Waste Oil Recycling Program remove potential sources of groundwater contamination. Towns can request that an Environmental Review Team (ERT) from the Resource Conservation and Development Area review specific site plans to determine the environmental impacts of projects, in particular those affecting groundwater quality.

5.4 LOCAL GROUNDWATER PROTECTION

Until recently, RI (and other state's) communities considered groundwater protection a function of state government but local municipalities are now starting to address this issue (Jaffe and DiNovo, 1987). Despite a shortage of staff and funding resources, local efforts are being made to protect groundwater. Several communities (Exeter, Richmond, North Kingstown, South Kingstown, Middletown, Jamestown, Tiverton, Smithfield, and Warwick) have passed groundwater protection measures which take the form of aquifer protection districts, nutrient loading provisions, hazardous material ordinances, underground storage tank registration programs (or even bans on USTs), and septic system repair funds. The establishment of Waste Water Management Districts (under 1987 State enabling legislation) is under consideration in several RI communities.

The Comprehensive Planning process provides an

opportunity for communities to address the protection of natural resources and provides a basis for changes in zoning ordinances that will effect such protection. The process requires that towns identify natural resource areas in need of protection.

Regulatory Protection in North Smithfield

1. Zoning Ordinance

The development pattern of the Slatersville area consists of areas of relatively dense residential, and industrial development with some commercial areas. Most of these areas overlie the aquifer reservoir or recharge zone and fall into the delineated wellhead protection areas. It is impossible to rezone these areas for low-density uses (i.e. REA-120 3-acre zoning) that would afford aquifer protection. Many substandard lots are "grandfathered" and, due to the lack of sewers in most of the aquifer area, could be the sites of new septic systems and thus potential contamination sources.

2. Subdivision Ordinance

North Smithfield's Subdivision Ordinance has a also procedural focus that focuses on design specifications in terms of public safety and developer responsibility, not water quality or environmental protection issues. Groundwater is afforded some protection by the Ordinance's requirements regarding the safe operation of ISDS. As

mentioned before, many communities have added a zero-net runoff provision to their subdivision ordinances as a water quality protection measure. There are no provisions for the use of vegetated buffers and other BMPs.

3. Groundwater Protection Overlay District

Section 6.16.1 of the North Smithfield Zoning Ordinance describes the Groundwater Protection Overlay District. This ordinance is designed to protect the public health and safety, to protect drinking water supplies, and to protect the integrity of natural systems within the Town. Permitted uses include all those allowed in the underlying zone with the exception of those activities that use hazardous material and those that could pollute the groundwater aquifer. Uses prohibited in the Overlay District are management facilities involving septic wastes, hazardous materials, and solid waste materials. Also prohibited are hazardous waste disposal facilities and use that generate hazardous wastes. Exemptions include agricultural uses and permitted ISDS.

Unaccounted for in the requirements of this ordinance are specific controls designed to protect groundwater from existing uses (industrial and commercial, septic systems and other nonpoint sources). The broad definition of non-permitted uses that "pollute the aquifer" grants great discretion to the Town official responsible for enforcement. The lack of specific regulations and standards often leads

to weak enforcement (EPA, 1988).

4. Site Plan Review

The recently enacted Site Plan Review Ordinance (Section 19.1) is a positive step toward controlling the impacts of commercial, industrial, and large residential development. It specifically states as one of its goals the intent to "protect and enhance the ecology and physical characteristics of the community." Its impact analysis requirement can expose possible threats to groundwater and allows a means to modify projects or to negotiate the use of BMPs. Connection to sewer and water systems can be required and the adequacy of disposal of liquid and solid wastes can be a limitation on developments. Again, great discretion is granted to the official responsible for development review and the lack of specific standards can be a positive or negative aspect, depending on the skill and political influence of the parties involved.

5.5 MANAGEMENT APPROACH

Local municipalities often cite the following constraints to efforts to initiate new environmental protection programs: insufficient staffing resources, lack of funding, reluctance of governments to add new regulations to an increasingly regulated way of life, and lack of political and community support. The approach taken in developing these strategies was one emphasizing low funding

requirements, use of existing staff, integration with or modification of existing regulations and programs, and the use of expertise available from State institutions and agencies. New regulations are recommended only where needed to fill significant gaps in protection.

The effective implementation of a WHP Program will to some degree, increase the burden on Town administration, at least initially. However, through the use of community volunteer organizations, coordination with existing State and federal programs, and available outside technological expertise, this additional burden can be kept manageable. Certain aspects of a WHP Program (i.e. source identification and inventory, newsletter production, meeting scheduling, etc.) are well-suited to volunteer capabilities. State and federal agencies (i.e. RIDEM, SCS, EPA, URI) offer many technical services and materials at little or no cost. Drawing on these resources, a local WHP Program Coordinator can provide an effective level of wellhead and aquifer protection.

An effective WHP Program uses information and education to build support for wellhead protection measures. In lieu of developing a whole new regulatory scheme, modification of existing programs and regulations is, in general, more politically acceptable, particularly in a recession economy. Also, the RI Zoning Enabling Act, unchanged since the 1920s, does not afford much legal protection for bold and

innovative land-use regulations. Fear of expensive lawsuits often limits municipalities to a traditional, conservative interpretation of the enabling act authority (EPA, 1989).

The development of an effective WHP Program often requires changes to a community's zoning and subdivision ordinances. It is essential that appropriate and thorough legal research be conducted in order to establish the nexus between the regulatory action and the protection goal to be achieved. This usually can be done by the Town Solicitor. However, as environmental protection efforts have become increasingly technical, it may be desirable to consult with outside authorities such as RIDEM, or a legal consultant.

5.6 MANAGEMENT STRATEGIES - Regulatory

As previously stated, there are ways in which groundwater protection can be enhanced by modification of the Town's Zoning Ordinance. Due to fact that much of the WHPAs and the aquifer reservoir and recharge areas are intensely developed (mostly 1 to 1.5 acre lots), an approach that emphasizes source controls rather than land use controls is recommended. Any effort to remove or phase out industrial uses that are potential contamination sources would not be economically and politically feasible at this time.

Modifications and additions to the Zoning Ordinance include:

Waste Water Management District

The problems identified regarding septic systems should be addressed in a comprehensive manner. One way of doing this is to establish a Wastewater Management District. In 1987, the legislature of the State of Rhode Island passed enabling legislation allowing towns and cities to establish these districts (RIDEM, 1987). The purpose of this legislation is to prevent contamination of state waters caused by the malfunctioning of individual septic disposal systems through the implementation of inspection and maintenance plans.

Wastewater Management District provisions allow:

* The passage of local officials onto private property to periodically inspect ISDS.
* The ability to raise funds
* The ability to raise funds for the administration of the WWMD by assessing property owners for taxes or annual fees, borrowing or issuing bonds, or setting rates for pumping.
* Establishment of administrative, financial, technical, enforcement, maintenance, and legal structures to effectively implement and conduct WWMD programs.
* Establishment of a public education program.
* Grants to be received and the establishment of a revolving fund for low-interest loans to correct failed septic systems.
* The levying of fines for non-compliance not to exceed $500 for each day of non-compliance.

Adoption of a WWMD can be accomplished in the same manner as the adoption of other municipal ordinances. The program could be administered by the existing sewer authorities or by the creation of a new WWMD Commission appointed by the Town Council.

Hazardous Materials Ordinance

Provisions of this ordinance include registration for the storage of more than a certain amount (for example, 25 pounds dry weight) of hazardous materials, design standards, and housekeeping requirements (logs, inventories, labeling) for the above and below ground storage of hazardous materials, a broader category which includes hazardous wastes (refer to Appendix G, the Charlestown, RI Hazardous Material Ordinance). Design standards are determined for hazardous material transport and loading facilities and for contaminant containment structures. Methods and procedures for a Spill Prevention Control and Cleanup Plan (CCAMP, 1988) should be listed. Hazardous material users should be required to provide Emergency Facility Plans (and updates) in a timely manner to the RI Emergency Response Commission and to the Town. At present only three North Smithfield companies have complied with this regulation (K. Sherman, pers comm. 1991).

Underground Storage Tank Registration and/or Ordinance

An EPA survey determined that there were 12,444 incidents of releases from USTs as of 1984. The U.S. Congress, Office of Technical Assistance estimates that 25 billion gallons of petroleum products are stored in USTs and that 13.8 billion gallons of hazardous materials (solvents, organic chemicals) are also stored in this manner. Many of the existing tanks are constructed of steel which deteriorate faster in a humid climate (Jaffe and DiNovo).

Many existing tanks are old and are potential sources of groundwater contamination. Federal and State underground storage tank regulations are directed at industrial and commercial tanks larger than 1100 gallons. Several communities (Jamestown, Tiverton, Glocester) have adopted more stringent measures that more effectively address local UST problems.

Protection strategies include:

* Creation of a local registry and map of existing underground storage tanks.

* Creation of a tank tagging program that would require tank owners to attach a tag to tanks specifying age and contents. Non-compliance would result in fines or tank removal at owner's expense.

* The petitioning of RIDEM for more stringent monitoring and for an early leak detection program.

A ban on the installation of new tanks in the WHPAs would provide a higher level of long term protection and would have a limiting effect on land uses within these areas. If the community is committed to maintaining and

upgrading the current water system, a ban on USTs would be politically acceptable and would enjoy public support.

Modification of the Groundwater Protection Overlay District

The existing Groundwater Overlay Protection District includes a provision that permitted uses are those that do not pollute groundwater or utilize hazardous materials. There currently exist many uses in this area that can definitely cause groundwater pollution. ISDS that have received DEM approval and agricultural uses are allowed in the District. Existing and potential ISDS in the sensitive WHPAs and aquifer reservoir areas pose a significant threat due to the transport of ISDS-derived contaminants through excessively permeable soils and to the inadequate regulation of ISDS (setbacks and siting procedures) (Myers, 1988). According to the draft North Smithfield Comprehensive Plan, 2,900 acres of the available developable land in the Town are environmentally constrained. Industrial and commercial users of hazardous material operate within designated groundwater protection areas. The authority granted by this ordinance is essentially unused because of political and economic impracticability.

Application of the provisions of a WWMD, a Hazardous Materials Ordinance, and a modified Groundwater Aquifer Protection District would dramatically raise the level of protection afforded to groundwater reserves. Modification

of this ordinance could initiate performance controls (i.e. number of septic tank fields per acre, septic tank construction standards, limits on impervious or built area per parcel, limits on the volume of discharge to septic systems) for new development and could require BMPs for the many existing uses and practices that threaten groundwater quality. The inclusion of a specific list of prohibited uses would make the ordinance more legally defensible (refer to Appendix G, Model Ordinances).

Pesticide and herbicide use for commercial agriculture in the WHPAs is limited due to the small amount of land in agricultural use. However, many homeowners use these substances liberally without regard (or knowledge, in many cases) for the impacts on groundwater quality. A specific list of those substances banned for the purposes of this ordinance should be developed.

Although politically difficult, the lowering of densities where appropriate (on undeveloped land that will not be serviced by sewers), will result in a reduced groundwater contamination threat. This "down zoning" action requires a rational connection between the minimum lot size and resource protection goals (Horsley et al., 1990). Again, this is a step that requires strong community support.

Septic System Cleaner Ban

Septic system cleaners contain solvent compounds (e.g. 1,1,1-trichloroethane) that travel easily through groundwater, are persistent in the environment, and pose significant health risks. The effectiveness of these compounds is questionable and they are capable of destroying bacteria that are an important part of the waste treatment cycle within a septic system. Additionally, less that 30% of the delineated WHPAs are sewered: densely settled areas that overlie the WHPAs contain many septic systems (and many cesspools). In order for this ban to be effective, the public must be educated about the effects of these cleaners.

Modification of Site Plan Review (SPR)

A Site Plan Review requirement can be an extremely useful tool in the implementation of a WHP Program because it is an "effective mechanism for reviewing and enforcing other requirements" (EPA, 1989). If required as part of a subdivision or zoning ordinance, it ensures compliance with all appropriate ordinances before construction starts. The North Smithfield SPR ordinance can require an impact statement from a developer. This provision could be made mandatory in a WHPA in order to assess impacts on groundwater. Additionally, a site plan review process focuses on ensuring that future development occurs in a desirable manner rather than changing existing conditions.

Because the goal of SPR is to promote appropriate development rather than restricting certain land uses, it has political acceptability.

A complex and detailed Site Plan Review ordinance, such as one used in East Providence RI, requires that a community have sufficient technical expertise and a knowledgeable staff in order to perform the review. The discretion granted by the North Smithfield SPR requires a high level of expertise by the reviewing party. It has been noted that "the less precise the requirements being reviewed, the more difficult it will be to evaluate reviews consistently and the more likely the requirements will be challenged in court." (EPA, 1989).

The addition of a specific listing of detailed requirements (accompanied by an SPR Ordinance checklist) would have three effects: (1) the ordinance be better able to withstand legal challenges, (2) a consistent process for SPR would be provided, and (3) developers would have a better idea of what is expected of them. Detailed requirements would include performance standards (such as zero-net runoff requirements, limits on percentage of impervious surfaces), contaminant source prohibitions, and design and landscaping requirements. In an effort to draw on outside expertise, The Town could request that SPR applications be reviewed by an Environmental Review Team from the RI Resource Conservation & Development agency.

Cluster Ordinance

Cluster zoning is used primarily to control residential development. It allows higher densities on sections of a parcel while preserving open space (under common ownership). This approach would be suitable for undeveloped areas of the WHPAs and aquifer protection areas because it promotes the recharge of clean runoff and is a low-risk land use. Although made mandatory in some critical areas in other communities, it is proposed that the cluster option be made available and encouraged in North Smithfield (refer to Appendix G, Model Ordinances).

Modification of Subdivision Regulations

As with SPR, subdivision requirements are mainly useful for controlling future development and are thus a less objectionable means of control. Ways in which the North Smithfield Subdivisions can be modified to provide wellhead and aquifer protection include the addition of certain requirements for developments that are located within WHPAs and aquifer reservoir or recharge zones. It can be required that development in WHPAs be connected to the sewer system and design standards and source controls (i.e. a prohibition on the placement of hazardous materials storage containers in a wellhead area) that protect groundwater quality can be added. Limits on percentage of impervious area and open space requirements are appropriate conditions

for subdivisions to be built in recharge areas. A modified set of Subdivision Regulations may be of limited use in the Slatersville area WHPAs due to the already developed conditions. However, given the Town's reliance on groundwater as a drinking source, the presence of a GAA aquifer, and the large, undeveloped tracts of land that exist in North Smithfield, these modifications can raise the level of groundwater protection town-wide.

Stormwater Management Provisions

One source of groundwater contamination is stormwater runoff and it is directly related to the use of land. The main contaminants in stormwater runoff are bacteria and viruses, nitrates, pesticides, solvents, chloride, sodium, metals, and sediments (Jaffe and DiNovo, 1987, RIDEM, 1988).

Protection strategies include:

* Adding language to subdivision and site plan review ordinances that encourages the overland flow of runoff and the recharge of uncontaminated runoff into the soil through the use of low-tech best management practices such as grassed swales, riprap channels, and drywells.

* Strengthening of the existing earth removal ordinance by adding specific measures regarding disposal methods, removal of topsoil, and construction mitigation measures.

* Retrofitting of existing drainage systems to reduce contamination from oil/grease and hydrocarbons with management practices such as catch basins and infiltration devices.

* Adopting measures to minimize the use of fertilizers and pesticides. Require the use of slow-release nitrogen fertilizers.

5.7 MANAGEMENT STRATEGIES - Non-Regulatory

Public Education Program

Public knowledge and understanding of groundwater processes and pollution can be expanded through an aggressive public education program. Developed by a committee of local citizens and Town officials, this program can target residents and businesses within the WHPAs initially and then be expanded to include all Town residents. This program provides an opportunity for citizen involvement through volunteer work. Production of an environmental newsletters, brochures, or calendars that provides information about household chemicals, fertilizers and pesticides, car fluid disposal practices, and water conservation for the Town could be handled by volunteer organizations with guidance from the Planning Department and the SWC. Publications can be produced geared to specific users such as local business and industry. Volunteer organizations can act as liaisons to local newspapers and magazines.

Environmental awareness community programs could be organized by citizens groups. Environmental Days could be held at the high school (and other community centers) with slide shows or demonstration projects concerning topics such as air, water (with emphasis on groundwater), conservation, and the Narragansett Bay. The Town could contact agencies such as the URI Cooperative Extension Service and the

EPA/RIDEM Land Management Project to conduct workshops on environmental issues which could be coordinated with local programs.

Source Reduction Program

The many industrial land uses that exist in or near the WHPAs have been in operation for many years. As previously stated, it would not be economically or politically possible to eliminate those uses. Source reduction is possibly the "best long-term strategy for groundwater protection" (National Research Council, 1986).

The RIDEM Office of Environmental Coordination conducts a voluntary State program that encourages commercial businesses and industrial plants to substitute non-hazardous materials for currently used hazardous ones. Grants are available to businesses for feasibility studies of alternative processes. Town officials could encourage local industries to take advantage of this little-publicized program. According to RIDEM's Gene Pepper, this office provides on-site waste reduction assessments by a chemical engineer for industrial plants and conducts seminars regarding the reduction of hazardous materials. The Office has also developed a database that tracks new and less hazardous processes and chemicals. Abstracts of this information will soon be available.

Comprehensive Planning Process

The Rhode Island Comprehensive Planning and Land Use Regulation Act includes as one of its goals the "promotion of growth and development that recognizes the natural characteristics of the land" and the protection of natural resources of the community (RIDEM, 1989). North Smithfield's Comprehensive Planning process provides the Town with an opportunity to review existing and potential land uses over aquifer and wellhead protection areas.

As stated in the North Smithfield Recreation, Conservation, and Open space Plan in 1986, groundwater reservoir areas should be permanently protected. One of the ways in which the Comprehensive Planning process can be used to protect WHPAs is to establish a policy that targets these areas for permanent protection. The community's Zoning Ordinance will have to be amended to be consistent with the land use policies set forth in the Comprehensive Plan.

Household Hazardous Waste Days

The RIDEM Hazardous Waste Collection program consists of a traveling team that periodically collects household hazardous wastes at different publicized locations around the state. This avoids practices such as dumping of used motor oil into storm sewers and flushing solvents and thinners down the drain. Local environmental programs could be coordinated with the RIDEM schedule to provide

information about household wastes prior to the collection days and thus increase participation.

Land Acquisition/Conservation Easements (PDR)

An additional part of a WHP Program could be the determination of all undeveloped parcels within areas to be protected (all parcels affected by the WHPAs are listed in Appendix H). An assessment of the zoning status of these parcels for potential threats to groundwater would be made. Prioritization of parcels targeted for acquisition would be based on groundwater protection values (among other environmental values). This effort could be coordinated with the efforts of other environmental groups such as the Audubon Society and the Blackstone Valley Watershed Association. The Town committed $250,000 for land acquisition projects three years ago and over $200,000 of that fund has not yet been used (K. Sherman, pers. comm. 1991).

An alternative, less costly means of acquiring interest in these properties would be the acquisition of conservation easements which would keep the affected land on the tax rolls. The lower cost of the conservation easement approach would allow the Town to acquire interests in more parcels. The local Conservation Commission could take charge of negotiation efforts to purchase property or conservation easements. The Commission could seek out charitable,

community-minded landowners and attempt to acquire land through donations or "bargain sales." Those landowners who donate land can take advantage of federal and state income and real estate tax benefits.

Protective Industrial Development

The North Smithfield Industrial Development Commission is currently investigating new sites for industrial development. A review of a recent industrial site search document, prepared by C.E. Maguire, showed that characteristics such as proximity to highways and railroads and access to communication systems, were high priorities in this search: environmental factors, such as groundwater protection, receive little mention. The Town should encourage the Commission to take groundwater (and other natural resource) protection into account in seeking new industrial sites.

Road Deicing Practices

A survey conducted by the Salt Institute, of Alexandria, VA, showed that during the winter of 1982-83, over 29,000 tons of salt were applied to Rhode Island's 3,015 lane miles of road (Conservation Foundation, 1987). Most RI communities determine a certain mixture of sand and salt that is sufficient for safe road conditions and apply that mixture to all areas of the community. The Town could

institute a procedure by which WHPAs (Main St. wells #1 and #2 are particularly vulnerable to contamination from road salt) and aquifer protection zones would receive a different sand/salt ratio that would reduce the amount of sodium and chloride that infiltrates into the ground. Only major roads in these areas would receive heavy treatment and trucks could be outfitted with the more accurate delivery systems that are now available. In addition, the use of road runoff BMPs such as retention basins may be feasible in some of the more sensitive areas (for ground and surface water quality protection). Salt storage facilities should utilize BMPs to reduce the risk of groundwater contamination.

Upgrade Slatersville Water Company System

On August 2, 1990, the RI Department of Health conducted a sanitary survey of the Slatersville water system in compliance with provisions of the federal Safe Drinking Water Act. The inspectors identified many shortcomings within the system and made recommendations for corrections. Major recommendations include: the installation of a treatment system for water from the stratified drift wells that are close to the Slatersville Reservoir, security measures to protect the wellheads from vandalism and contamination, equipment and structural repairs, documentation of certain procedures (i.e. chlorination), installation of master meters, the cleaning of wellhead

areas, annual flushing of dead end mains, and the provision of standby power.

The report stated that the system was "woefully inadequate in supply and capacity" and that major fires or power outages could jeopardize the supply. Permanent interconnections with adjacent water systems and the development of additional source supplies were strongly recommended. There exists no workable emergency plan.

If the Town acts on these recommendations, the SWC will continue to serve the Slatersville community. An additional source of water supply (and a good emergency connection) could be obtained through a connection with the Industrial Park well on Tifft Road (this option is being pursued according to Karen Sherman, Town Planner). Work is underway on the development of another well within the Industrial Park. An additional interconnection with the Woonsocket water system would provide adequate emergency protection. Most of the structural repairs have been or will soon be completed.

A major expenditure of funds will be required if a filtration system is to be installed at a cost of $500,000. The Town must assess whether it can develop regulatory and non-regulatory means to adequately protect its groundwater supplies so that system expansion is a worthwhile effort. If groundwater quality cannot be maintained, it may require extensive technical upgrading in the near future.

CHAPTER VI: IMPLEMENTATION

6.1 FRAMEWORK FOR IMPLEMENTATION

The strategies recommended in this report were developed with the Town's staffing and funding capabilities in mind. The best wellhead protection measures will not be effective unless the resources and support for implementation exist. This section provides a framework for prioritization and implementation of the recommended strategies (see Table 6, Implementation Matrix). Criteria considered for this framework are:

* responsibility for action;
* imminent need for a particular strategy;
* the level of involvement required of Town staff and community groups;
* financial considerations;
* coordination opportunities;
* organizational requirements;
* volunteer/citizen resources;
* community support.

Successful implementation of several of these strategies would provide an immediate benefit in terms of groundwater protection and these are identified as high priority strategies. For these approaches, the overriding factors considered are the measure of groundwater protection afforded and the ease of implementation.

IMPLEMENTATION TABLE - MANAGEMENT STRATEGIES				
STRATEGIES	INITIATIVE	ORGANIZATIONAL NEEDS	FUNDING	COMMUNITY ACCEPTANCE
Regulatory Approaches				
Wastewater Management District	Water & Sewer Personnel/Conserv. Commission	Existing Water & Sewer Personnel	Grants/Service Fees, Pumping Fees	Opposition to imposed fees
Hazardous Materials Ordinance	Planner/Dir. Emerg. Mgt. Agency/ Town Council	Existing Staff Town Solicitor	Minimal	Acceptable in Aquifer areas
UST Ordinance/ Program	Planner/Town Council Planning Board	Existing Staff Volunteers	Registration Fees Grants	Community support to protect wells
Groundwater Aquifer Protection District	Planner/Planning Board	Planner/Town Solicitor	Minimal	Restrictive/ Public education
Septic System Cleaner Ban	Planner/Town Council Planning Board	Town Solicitor	Minimal	Difficult to enforce/Public education
Site Plan Review	Planner/Town Council Planning Board	Planner/Town Solicitor	Minimal	Developers may oppose new reg.
Cluster Development	Planner/Conservation Comm./Town Council	Town Planner Town Solicitor	Minimal	Well accepted/ used successfully in RI
Strengthen Subdivis. Regulations	Planner/Town Council Planning Board	Planner/Town Solicitor	Minimal	Public educ./ Developer opposition
Stormwater Mgt. Provisions	Planner/Town Council Planning Board	Planner/Town Solicitor	Minimal	Acceptable/ Public educ.
Non-Regulatory Approaches				
Public Education	WHP Committee/Planner Town Council	Planner/Outside Tech. Assistance	Grants WWMD Fees	Opportunity for Citizen Involv.
Source Reduction	Planner/Industrial Comm/ Town Council	RIDEM Coordination Personnel/Planner	Minimal	Overcome industry image of DEM
Comprehensive Planning Process	Planner/CAC/WHP Committee	CAC/Planner/ Consultant	Minimal	Citizen Involv. Set policy
Hazardous Waste Collection	WHP Committee/Planner Emerg. Mgt. Director	Coordinate with DEM/Planner	Minimal	Popular State Program
Land Aquisition/ Cons. Easements	Conservation Comm/ Env. Groups	Conservation Comm/ Volunteers/State	Existing Open Space Funds	Strong support for conservation
Protective Industrial Development	Planner/Conservation Comm./Industrial Comm	Planner/Industrial Comm/Consultant	Minimal	Sensitive areas education

Table 6. Framework for Implementation

Table 6 (continued)

Limit Road De-icing	Conservation Commission/ Planner/Town Council	Department of Public Works	New equipment New chemicals	Opposition to expenditure
Upgrade SWC System	Water & Sewer Personnel	Contractor/Inhouse	High Cost/ Maintenance	Undecided/ Opposition to cost

Individuals or groups who could be responsible for taking the initiative to start a strategy implementation process are identified. These parties were selected based on position in Town government, level of expertise, and links to other organizations.

Community acceptance of strategies is critical to the success of a local wellhead protection plan. It is intended that public education and involvement programs will help build such support (EPA, 1989). Community support issues to be examined include:

* wellhead protection measures that require intrusion on private property rights;
* measures that impose a heavier burden on one segment of the community over the other, and;
* strategies that have succeeded elsewhere under similar conditions.

These implementation recommendations should be viewed as a starting point for action, not as a definitive how-to-do list. Once a core of interested citizens and Town officials have decided to act on wellhead and aquifer protection (possibly through the formation of a Wellhead Protection

Committee), they will develop a framework for action that will be keyed to local resources and to the Town's political and social environment.

6.2 IMPLEMENTATION OF STRATEGIES: REGULATORY

Wastewater Management District

Initiation of this strategy would be best handled by Water and Sewer Department personnel given their jurisdiction over the sewer system. This State-sponsored program provides funding, technical assistance, and materials for local participation. Additional funding can be obtained through the authorized use of fees, fines for non-compliance, and the issuance of bonds. The community can also establish a revolving low-interest loan program for the upgrading and repair of septic systems. After review by the Town Solicitor, the program can be adopted as an ordinance.

Hazardous Materials Ordinance

A logical choice for an initiator of this strategy would be the local Director of the Emergency Management Agency, although it could also be done by the Planning Department or the Town Council. The Planning Department could research this issue and obtain model ordinances. By working with the Town Solicitor, a suitable bylaw could be developed for the Town. If design standards for transport and loading

facilities are part of this bylaw, inspection training would be required for Town personnel (perhaps the Town Engineer). The Planning Department would be responsible for reviewing spill prevention/clean up plans.

Underground Storage Tank Ordinance/Registry

As stated earlier in this report, many existing USTs are unregulated by State regulations due to their smaller size. Due to the age and condition of USTs that are located over WHPAs and aquifer protection areas, a significant threat to groundwater quality exists.

Recommended control over USTs could take different forms, depending on Town objectives. A UST ordinance could be designed to ban these tanks in WHPAs or to create design standards (i.e. spill detection measures, double-walled tanks, and monitoring wells). This ordinance could be initiated by the Planning Department, Planning Board, or the Town Council. The Town Solicitor and the Planning Department could research the issue and contact other local communities where such ordinances have been instituted (i.e. Jamestown, Tiverton, Glocester) to obtain information and advice on developing the bylaw. The preparation of a UST inventory list and map of all UST locations could be part of this effort. Funding could be obtained through a registration fee and through grants.

A non-regulatory option would be the creation of a UST

registry and mapping program. This voluntary program could be carried out by citizen volunteers and local environmental organizations or the Conservation Commission. Data collection and field surveys could be handled by volunteers. Grant money from federal, state, or private organization sources may be available for community volunteer efforts such as this. Program participants could obtain technical assistance from RIDEM or other technical agencies mentioned in this report.

Modification of the Groundwater Protection Overlay District

Research into other communities' groundwater overlay ordinances by the Planning Department would provide the basis for modification of the Groundwater Protection Overlay District bylaw to make it a more detailed and specific instrument. Recommended modifications, if adopted, would immediately raise the level of groundwater protection within these designated areas. Review by the Town Solicitor would be required. The detailed and more restrictive nature of a modified overlay bylaw would have better community acceptance and compliance after the public has been exposed to a groundwater protection educational program.

Septic System Cleaner Ordinance

Although easy to draft and requiring minimal staff and funding resources, a ban on the use of septic system

cleaners is difficult to enforce. Public cooperation can be improved through the implementation of the recommended public education program.

Modification of Site Plan Review Ordinance and Subdivision Regulations

Members of Town government who are responsible for development review could initiate actions leading to the modification of the existing Site Plan Review (SPR) Ordinance and the Subdivision Regulations. Examination of other communities' development review procedures and ordinances would be helpful in developing these modifications. Consultation with the Town solicitor would be required. Although some developers would oppose the additional restrictions involved in these modifications, most builders would welcome a higher level of consistency in development review processes.

Cluster Ordinance

The Cluster Ordinance strategy would call for Planning Department research into other communities' experiences with this form of development. With this information, the Planning Department and the Town Solicitor could craft a cluster bylaw that is suited to the Town's objectives. The Planning Department, Planning Board, and Town Council would promote and encourage the use of the cluster option wherever deemed appropriate (particularly in WHPAs and aquifer

protection districts). Many RI communities have adopted this type of ordinance and cluster design is generally well-accepted by developers.

Stormwater Management Provisions

The RIDEM Office of Environmental Coordination publishes a manual containing recommended stormwater management practices that can be incorporated into local action. Most of these practices could be administered by the Department of Public Works and would require little additional funding. Stormwater management provisions could be part of the Modification of SPR and Subdivision Regulations strategy; there are many opportunities in these processes in which to inject stormwater management measures. Stormwater management processes would be explained to the community in the public education component of the WHP Program.

6.3 IMPLEMENTATION OF STRATEGIES: NON-REGULATORY

Public Education Program

This necessary component of any WHP Program brings groundwater protection issues in the public arena in a way that all in the community will learn of environmental issues that affect them daily. Many people do not realize that some of their everyday practices are harming natural systems. This recommended course of action will provide many opportunities for citizens involvement at all levels,

from delivery of newsletters to shaping Town environmental policy. Interested community members could take part in the formation of a Groundwater Protection Committee which, in concert with the Planning Department and the Planning Board, could develop an educational program that would be effective in North Smithfield. Funds derived from the Waste Water Management District program could be used to purchase materials, to publish newsletters, and to cover administrative costs for the Committee activities. Federal and State environmental agencies can be drawn upon for technical assistance and guidance.

Source Reduction Program

The Planning Department, the North Smithfield Industrial Commission, and the Town Council could encourage local industries to participate in the RIDEM Source Reduction Program and make them aware that grant money is available to them to develop new, safer industrial processes. Personnel from the RIDEM Office of Environmental Coordination are committed to increasing their involvement in this program which is considered one of the most effective ways that industrial areas can be made more environmentally safe. The Town can act as a liaison between the businesses and the RIDEM.

Comprehensive Planning Process

As in the Public Education program, this approach allows citizens involvement in setting future policy for the Town. This is an excellent time to take advantage of the ongoing Comprehensive Planning process to create policies designed to protect the area's groundwater resources and wellheads. Members of the Citizens Advisory Committee and the Groundwater Protection Committee could research groundwater issues to provide needed information or the Plan consultant could be required to provide such information.

Household Hazardous Waste Collection Days

The Groundwater Protection Committee could coordinate its public information program with the RIDEM's Hazardous Waste Collection Program in order to increase community participation. The Director of the local Emergency Management Agency could also have a part in initiating this effort because of his experience with hazardous substances. This popular State program could be even more effective if communities act in coordination with the RIDEM.

Land Acquisition/Conservation Easements

Many state and local groups are involved in land acquisition programs for various purposes ranging from river corridor recreational areas to wildlife habitat protection. The Conservation Committee and other local environmental

action groups are good candidates for initiating a system to coordinate land acquisition efforts in the North Smithfield area and to seek out new sources of funding (grants from public and private agencies and foundations) for land acquisition and the purchase of conservation easements. Many members of these groups have valuable negotiating experience. The Town has over $200,000 earmarked for land acquisition and the above groups could aid in identifying the most valuable parcels from an environmental standpoint.

Protective Industrial Development

The Planning Department and the Conservation Commission should provide the Industrial Commission with land suitability information to aid in the search for new industrial sites. If the Industrial Commission sees that there is institutional and public support for siting industrial development outside of critical protection areas then those factors will have greater weight in any decisions made.

Road Deicing Practices

The Planning Department and the Conservation Commission could work with the Public Works Department and its contractors to develop safer salting practices, especially in groundwater protection areas. It may be difficult to find funding for new salt measuring devices for trucks, but

other less expensive measures can be taken (apply less salt, lightly salt sensitive areas, utilize protective salt storage methods).

Upgrade Slatersville Water Company System

The Water and Sewer Department has corrected many of the structural deficiencies noted in the RIDOH Sanitary Survey of August, 1990 (K. Sherman, pers. comm. 1991). It is difficult to find wide support for providing a new filtration system (as recommended by the DOH) at the cost of one-half million dollars in the current fiscal environment. The question facing the Town is whether the investment is worthwhile (and who would bear the cost) for a system that serves only 445 households. If the community commits to expanding and upgrading the system, it will be the responsibility of the Water and Sewer Department to hire consultants and contractors. No decision has been reached on this issue.

CONCLUSIONS

In the course of conducting research for this report, materials regarding the protection of groundwater in other states were reviewed. The political and legislative environment of many states allows local communities to institute groundwater protection measures that are more stringent and detailed than Rhode Island communities have initiated.

Rhode Islands antiquated zoning and subdivision acts retain a traditional zoning perspective that grants little authority to local government. Constrained by this lack of authority, local environmental officials act conservatively, ever wary of litigation. Although the trend is slowly being reversed, there remains many areas in which inadequate protection measures threaten the integrity of the State's natural resources, including groundwater. Because people can not see groundwater contamination, it does not receive the same attention as visible surface water pollution. However, many other areas of the country have been made aware of the extreme vulnerability of groundwater resources and legislators there have acted to protect this resource.

If the Rhode Island legislator passes the proposed Zoning Enabling Act, local communities will have greater authority to provide environmental protection and will possess a wider array of regulatory tools to use in resource protection.

The people of North Smithfield, like most Rhode Islanders, have become increasingly aware of environmental protection issues and how their lives can be affected by pollution. Research done for this report has revealed that there exists further opportunities for the town to adopt environmental protection measures and regulations that will not overburden existing town staff or require excessive funding. Coordination with Federal and State technical assistance programs can be explored further and there are possibilities for successful volunteer action.

Successful Wellhead Protection Programs depend on community support and involvement. This support can best be developed through public education programs that target all segments of the community; school children to senior citizens, suburbanites to farmers. Through these programs, citizens learn of their responsibilities to protect the environment and how small changes in their everyday life can have a large impact on groundwater quality.

REFERENCES

Arthur D. Little Inc., Beta Engineering Inc., CH2M, H2O Engineering, Consulting Associates Inc., Wallace Floyd Associates Inc. 1990. *Water Supply Analysis for the State of Rhode Island.*

Cape Cod Aquifer Management Project. 1988. *Guide to Contamination Sources for Wellhead Protection.* (Cape Cod, MA: CCAMP).

Connecticut, State of, Department of Environmental Protection. 1990. *Protecting Connecticut's Groundwater: A Guide to Groundwater Protection for Local Officials.*

Conservation Foundation, The. 1987. *Groundwater Protection.* Washington D.C.

Dunne, Thomas and Leopold, Luna B. 1978. *Water in Environmental Planning.* W.H. Freeman and Co. New York.

Horsley Witten Hegemann, Inc. 1990. *An Evaluation of Critical Area Protection in RI.* Prepared for the Narragansett Bay Project, Providence RI.

Jaffe, Martin S. and DiNovo, Frank. 1987. *Local Groundwater Protection.* (Washington, D.C.: American Planning Association)

Lowry, Jerry D. 1987. *Radon at Home.* Civil Engineering.

Maguire Group Inc. 1991. *North Smithfield Industrial Site Survey.* Prepared for the Town of North Smithfield Industrial Development Commission.

Myers, Jennie C. 1988. *Governance of Non-Point Source Inputs to Narragansett Bay: A Plan for Coordinated Action.* Prepared for the RIDEM/EPA Narragansett Bay Project, Providence, RI.

National Research Council. Committee on Groundwater Quality Protection. 1986. *Groundwater Quality Protection: State and Local Strategies.* National Academy Press, Washington D.C.

North Smithfield, Town of, *Zoning Ordinance and Subdivision Regulations.*

Page, William G. 1987. *Planning for Groundwater Protection.* Academic Press, Orlando FL.

Patrick, Ruth, Ford, Emily and Quarles, John. 1987. *Groundwater Contamination in the United States.* University of Pennsylvania Press, Philadelphia PA.

Rhode Island, State of, Department of Administration. 1987. *Wastewater Management Districts...A Starting Point.*

_____, Office of Environmental Coordination. 1988. *Recommendations Of The Stormwater Management And Erosion Control Committee Regarding The Development And Implementation Of Technical Guidelines For Stormwater Management.*

_____, Office of Environmental Coordination. 1989. *Rhode Island's Nonpoint Source Management Plan.*

_____, Office of Environmental Coordination. 1990. *State of the State's Waters 305 (b) Report.*

_____, Division of Groundwater and Freshwater Wetlands, Groundwater Section. 1990. *Rhode Island Wellhead Protection Program.*

_____, Division of Groundwater and Freshwater Wetlands, Groundwater Section. 1989. *Groundwater Protection Strategy.*

_____, Statewide Planning Program. 1984. *State Guide Plan Overview.* State Guide Plan Element 010, Report #48. Revised 1988, Providence, RI.

Travis, Curtis C. and Etnier, Elizabeth L. 1984. *Groundwater Pollution: Environmental and Legal Problems.* Westview Press for the American Association for the Advancement of Science, Boulder CO.

_____, Office of Ground-Water Protection. 1988. *Developing A State Wellhead Protection Program: A User's Guide to Assist State Agencies Under the Safe Drinking Water Act.* (Washington D.C.: OGWP).

_____, Office of Water. 1989. *Wellhead Protection Programs: Tools For Local Governments.* (Washington D.C. : OGWP).

_____, Office of Water and Hazardous Materials. 1991. *National Primary Drinking Water Regulations: Final Rule.* Washington, DC.

_____, Office of Water and Hazardous Materials. 1986. *Quality Criteria for Water.* (Washington D.C.).

U.S. Department of the Interior, U.S. Geological Survey. 1988. *Groundwater Studies in RI.* Water Fact Sheet.

_____, U.S. Geological Survey. 1986. *Rhode Island Groundwater Resources.* Water Supply Paper 2275.

University of Maine. 1986. *Radon in Water and Air: Health Risk and Control Measures.* Coorperative Extension/Land and Water Resource Center. Orono, ME.

Weston and Sampson Engineers Inc. 1990. *Water System Master Plan (Draft Report)*: North Smithfield RI. Peabody MA.

PERSONAL COMMUNICATIONS

Bobiak, Sofia. Groundwater Section, RI Department of Environmental Management.

DiCicco, Tony. Assistant Administrator, RI Department of Labor.

Swallow, June. RI Department of Health, Division of Water Supply.

RADIO BROADCAST

National Public Radio. All Things Considered News Show. Groundwater Problems in the U.S. West.

APPENDIX A

WHPA DELINEATION

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

INTER-OFFICE MEMO

Karen Sherman
Town Planner
North Smithfield Planning Department

DATE: April 26, 1991

T:

OM: Sofia Bobiak SB
Hydrogeologist
T: Groundwater Section

JECT: Wellhead Protection Area (WHPA) Delineations for Community Wells in North Smithfield

I am writing this memorandum to describe the general methodology used to delineate the draft initial WHPAs for community wells in North Smithfield used by Richard Ribb and Mark Gardella to develop a Wellhead Protection plan as part of their internship with the Town of North Smithfield.

A total of eight community wells are present in the town of North Smithfield. Three are screened or dug in stratified drift, and five are finished in bedrock. A combination of analytical modeling with hydrogeologic mapping was used for these delineations.

For the bedrock wells, the downgradient area is a circle with a radius calculated from the Theis equation (see Rhode Island Wellhead Protection Program, pp. 18-19). The upgradient area was delineated using hydrogeologic boundaries.

Bedrock Well	Discharge (gpm)	Theis Radius (ft)
Slater Village Condominium	40	2,600
No. Smith. (Slatersville) Park Well 3	40	2,600
Coast Guard Housing	30	2,400
No. Smith (Slatersville) Halliwell School 5	10	1,750
Woodland Convalescent Center Well	3	1,750

In the case of the stratified drift wells, the downgradient portion was delineated using the MWCAP Module of the WHPA Code, an EPA approved software package. The MWCAP Module is an analytical model which utilizes the uniform flow equation in conjunction with particle tracking. The model requires information such as pumping rate, hydraulic gradient, transmissivity and saturated thickness. These data were obtained from a variety of sources, including a US Geological Survey report (Water-Resources Investigations 18-74). Hydrogeologic mapping completed the upgradient portions of these WHPAs.

Should you have any further questions, please contact me at 277-2234.

cc: Richard Ribb
Mark Gardella

EQUATIONS PERTINENT TO WELLHEAD PROTECTION DELINEATION

THEIS EQUATION: $s = \frac{114.6\ Q}{T}\ W(u)$ $\qquad u = \frac{1.87 r^2 S}{Tt}$

where:
- s = drawdown (ft)
- Q = well pumping rate (gpm)
- T = transmissivity (gpd/ft)
- S = storage coefficient (dimensionless)
- r = distance from pumped well to observation well
- t = time (days)
- $W(u)$ = well function (dimensionless)

UNIFORM FLOW EQUATION: $-\frac{Y}{X} = \tan\left(\frac{2\pi Kbi}{Q}\right) Y$

$$X_L = -\frac{Q}{2\pi Kbi} \qquad Y_L = \pm\frac{Q}{2Kbi}$$

where:
- Q = well pumping rate (ft^3/day)
- K = hydraulic conductivity (ft/day)
- b = saturated thickness (ft)
- i = hydraulic gradient (dimensionless)
- X_L = distance to downgradient null point (ft)
- Y_L = lateral boundary limit (ft)
- X & Y = cartesian coordinates of points along the groundwater divide

THIEM EQUATION for unconfined aquifer: $h_2^2 - h_1^2 = \frac{1055\ Q\ (\log r_2/r_1)}{K}$

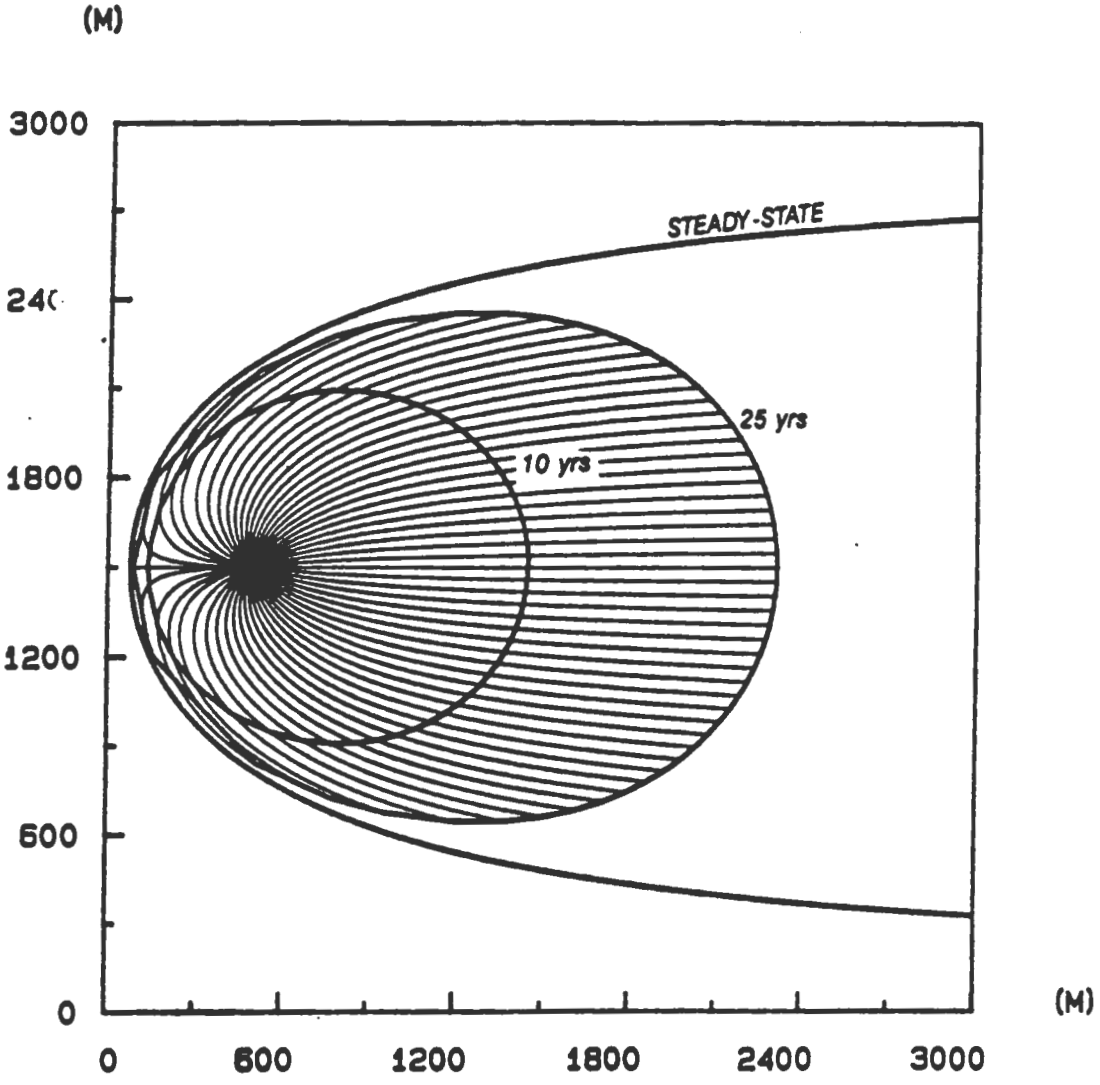
where:
- h_1 = hydaulic head at point nearest well (ft)
- h_2 = hydraulic head at point farther from well (ft)
- Q = well pumping rate (gpm)
- K = hydraulic conductivity (gpd/ft^2)
- r_1 = distance from well to point at h_1 (ft)
- r_2 = distance from well to point at h_2 (ft)

VOLUMETRIC FLOW EQUATIONS:

for cylinder: $r = \sqrt{\frac{Qt}{\pi nH}}$ $\qquad$ for cone: $r = \sqrt{\frac{Qt}{.333\pi nH}}$

where:
- r = radius of cylinder or base of cone (ft)
- Q = well pumping rate (ft^3/day)
- t = time (days)
- n = porosity (dimensionless)
- H = height of cylinder or cone (ft)

Steady-State, and 10- and 25-Year Time-Related Capture Zones Delineated Using MWCAP. For The Time-Related Capture Zones the Number of Pathlines is 50.



APPENDIX B

RHODE ISLAND GROUNDWATER CONTAMINANTS

Table 4B-8 Contaminants Detected in Groundwater

Synthetic Organic Chemicals/
Volatile and Semi-Volatile

Acetone
Benzene
Benzo (a) anthracene
Benzo (a) pyrene
Benzo (b) fluoranthene
Bromodichloromethane
Bromoform
Carbon Tetrachloride
Chlorobenzene
Chloroethane
Chloroethene
Chloroform
Chrysene
Dibenzo (a,h) anthracene
Dibromochloromethane
1,4 - Dichlorobenzene
Dichlorodifluoromethane
1,1 - Dichloroethane
1,2 - Dichloroethane
1,1 - Dichloroethene
1,2 - Dichloroethene
Dichloromethane
1,2 - Dichloropropane
1,3 - Dichloropropene
Di-n-butylphthalate
Dioxane
Ethylbenzene
Ethylene glycol monoethylether
Fluoranthene
Fuel Oil #2
Fuel Oil #4
Fuel Oil #6
Gasoline
Indeno (1,2,3 -cd) pyrene
Methyl Ethyl Ketone
Methyl Isobutyl Ketone
Methyl t-Butyl Ether
2 - Methylphenol
Napthalene
Phenanthrene
Phenol
Polychlorinated biphenyls
Pyrene
1,1,2,2 - Tetrachloroethane
Tetrachloroethylene
Tetrahydrofuran
Toluene
1,1,1 - Trichloroethane
1,1,2 - Trichloroethane
Trichloroethylene
Trichlorofluoromethane
1,1,2,-Tricloro-1,2,2-trifluoroethane
Vinyl Chloride
Xylenes

Synthetic Organic Chemicals/
Pesticides

Aldicarb	Atrazine
Butylate	Carbofuran
Carbaryl	Oxamyl
Dicamba	Dinoseb

Inorganic Chemicals/
Heavy Metals

Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver

Other Inorganic
Chemicals

Boron	Calcium
Chloride	Cyanide
Fluoride	Iron
Magnesium	Manganese
Nitrate	Potassium
Sodium	Sulfate
Zinc	

Radionuclides

Radon
Strontium - 90
Technetium - 99

Microbiological

Coliform Bacteria

APPENDIX C

RHODE ISLAND DEPARTMENT OF HEALTH

WATER QUALITY REPORT: SLATERSVILLE WATER COMPANY

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

D E P A R T M E N T O F H E A L T H

1615614
Jim Decelles, Water Supt.
Slatersville Public Supply
Memorial Town Building
Slatersville, RI 02876

March 29, 1990

Dear Jim Decelles, Water Supt.:

Under the Safe Drinking Water Act Amendments of 1986, the Environmental Protection Agency (EPA) promulgated monitoring requirements for 8 regulated solvents VOC'S (volatile organic chemicals) and 51 unregulated organic chemicals. These became effective in Rhode Island on October 30, 1989. As stipulated by these regulations public water systems serving 3,300 to 9,999 people were to begin analyzing their source water by January 1, 1989. Systems serving <3,300 people were to begin by January 1,1991.

The Division Of Drinking Water Quality has completed these monitoring requirements for your system and the analytical results have been forwarded to you. The following water sources were monitored: DUG WELL, DRIVEN WELL, PACHECO PARK WELL, HALLIWELL SCHOOL WELL, WELL#6. If you are unable to locate any or all of the analytical results, or wish to receive a complete set, please call our office at 277-6867.

The test results for the 8 volatile organic compounds revealed the following: **TRICHLOROETHENE 1 to 2 PPB HALLIWELL SCHOOL WELL.** This office will continue quarterly surveillance of the well(s) for the presence of these 8 volatile organic chemicals. Should the running average concentration of these chemicals remain below their respective maximum contaminant levels over a three year period the monitoring will then be reduced to annually. However should the running average of a volatile organic chemical exceed its respective MCL value, then treatment must be adopted for the source and a public notice issued by the water system.

Samples from the same water sources were also analyzed for the 51 unregulated organic chemicals. The results

are as follows: all were non-detectable at current MDL's. Further testing will be suspended until 1992 (3 year cycle).

This Division will inform EPA that monitoring of the water system sources for both the 8 volatile organic chemicals and the 51 unregulated organic chemicals have been completed. Under State and EPA regulations cited above, you are required to notify your customers by way of a public notice in the first set of water bills following receipt of this letter or by written notice within three(3) months of this date that: monitoring for the 51 unregulated organic chemicals has been completed and the results are available for public review. A draft of this notice with all necessary verbiage must be submitted to our office for approval prior to mailing. The notice must include a contact person and a telephone number for information regarding the monitoring results. If you need any assistance, please call this office at 277-6867.

Should any questions arise regarding the health effects of any organic chemicals found as a result of the 1989 monitoring, Dr. Bela Matyas, M.D., Chief, Environmental Health Risk Assessment may be consulted at 277-3424.

The results of this 1989 survey are public information and may be released. Your cooperation in this endeavor is essential.

Sincerely,

June Swallow

June Swallow, P.E.
Acting Chief
Drinking Water Quality

JS/eg

cc: Walter S. Combs Jr.
Edgar Girard

State of Rhode Island and Providence Plantations

Department of Health
CANNON BUILDING
Davis Street
Providence, R.I. 02908

(4)

Jim Decelles
Slatersville Public Supply
Memorial Town Building
Slatersville, RI 02876

April 5, 1990

Dear Mr. DECELLES:

In response to your inquiry as to the necessary verbiage required for the VOC notification for the 8 regulated and 51 unregulated organic chemicals, the following is an example.

****

Public Notice
Slatersville Water System

As required by the Safe Drinking Water Act Amendments of 1986 testing has been completed during 1989 for the 8 regulated and 51 unregulated organic chemicals. The data indicates that none of these chemicals are present in amounts that would pose a threat to the health of the consumer.

Please be advised that the results are available for public review at the Town Hall in Slatersville. Anyone requiring more detailed information may contact ~~Jim~~ James Decelles at 767-2202 between the hours of 8am and 4pm. ← check hours

Jim Decelles
Water Superintendent
Slatersville Water Department

****

If this example notice is acceptable to you, please advise this department. The water system may notify its consumers by inserting this notice with the next water bill within three months or by notification in a newspaper that is received by a majority of its consumers. If you would kindly provide this office with a copy of the printed notice, we will regard it as sufficient evidence that Slatersville has satisfied the requirement of the Safe Drinking Water Act Amendment of 1986.

If you have any additional questions, please contact me at 277-6867.

Sincerely,

Edgar Girard

Edgar Girard
Principal Sanitarian
Drinking Water Quality

eg/
cc: June Swallow

Rhode Island Departme[illegible]f Health
Cannon Building, Providence, Rhode Island 02908-5097

Date Received	Date Completed	Lab Number
03/06[illegible]1	03/14/91	85943

VOLATILE ORGANIC ANALYSIS-EPA 524(in ppb)

	RESULT	STANDARD
Bromodichloromethane	<1	100.00m
Chloroform	<1	100.00m
Carbon Tetrachloride	<0.5	5.0000m
1,4-Dichlorobenzene	<0.5	75.000m
Vinyl Chloride	<0.5	2.0000m
Chlorobenzene	<1	
2-Chlorotoluene	<1	
1,3-Dichlorobenzene	<1	
cis-1,2-Dichloroethene	<1	
1,1-Dichloropropene	<1	
1,3-Dichloropropene	<1	
Styrene	<1	
1,1,2,2-Tetrachloroethane	<1	
Toluene	<1	40.000s
Bromochloromethane	<1	
Trichlorofluoromethane	<1	
p-Isopropyltoluene	<1	
sec-Butylbenzene	<1	
1,2,4-Trichlorobenzene	<1	
Methyl Tertiary Butyl Ether	<1	
Bromoform	<1	100.00m
1,2-Dibromoethane	<5	
1,2-Dichloroethane	<0.5	5.0000m
1,1-Dichloroethene	<0.5	7.0000m
Bromobenzene	<1	
Chloroethane	<1	
4-Chlorotoluene	<1	
1,2-Dichlorobenzene	<1	
Methylene Chloride	<1	
1,2-Dichloropropane	<1	
2,2-Dichloropropane	<1	
1,1,2-Trichloroethane	<1	
Tetrachloroethene	<1	
Xylene	<1	20.000s
n-Butylbenzene	<1	
Hexachlorobutadiene	<1	
Naphthalene	<1	
tert-Butylbenzene	<1	
1,2,4-Trimethylbenzene	<1	
Hexane	<1	
Dibromochloromethane	<1	100.00m
Benzene	<0.5	5.0000m
Trichloroethene	1	5.0000m
1,1,1-Trichloroethane	<0.5	200.00m
Bromomethane	<1	
Chloromethane	<1	
Dibromomethane	<1	
trans-1,2-Dichloroethene	<1	
1,1-Dichloroethane	<1	
1,3-Dichloropropane	<1	
Ethylbenzene	<1	
1,1,1,2-Tetrachloroethane	<1	
1,2,3-Trichloropropane	<1	
1,2-Dibromo-3-Chloropropane	<10	
Dichlorodifluoromethane	<1	
Isopropylbenzene	<1	
n-Propylbenzene	<1	
1,2,3-Trichlorobenzene	<1	
1,3,5-Trimethylbenzene	<1	

COMMENT(s):Refer to the enclosed summary sheet for the following codes -> 5

The Continued Presence Of A Volatile Organic Compound Was Detected In The Sample, Continued Quarterly Testing Will Be Done To Satisfy Regulations.

m=Maximum Contaminant Level, s=Secondary Maximum Contaminant Level

UNITS:ppm=Parts Per Million, ppb=Parts Per Billion, pCi/l=Picocurie Per Liter, ntu=Nephelometric Turbidity Units

JIM DECELLES, WATER SUPT.
SLATERSVILLE PUBLIC SUPPLY
MEMORIAL TOWN BUILDING
SLATERSVILLE, RI 02876

Date Collected	Lab Number
03/06/91	85943

Cty/Twn:North Smithfield
Owner:JIM DECELLES, WATER SUPT.
Src:Raw Halliwell Well

PWSID:1615614

June A. Swallow, Chief, Drinking Water Quality
Mar 19, 1991

Rhode Island Department of Health
Cannon Building, Providence, Rhode Island 02908-5097

Page 1 of 2 | Date Received 04/17/9 | Date Completed 05/17/90 | Lab Number 72369

	RESULT	STANDARD		RESULT	STANDARD		RESULT	STANDARD
INSECTICIDES(in ppb)								
Aldrin	<0.2		Chlordane	<2		DDT-Para,Para	<1	
Dieldrin	<0.06		Endrin	<0.2	.2000m	Heptachlor	<0.1	
Heptachlor Epoxide	<0.1		Lindane(GBHC)	<1	4.0000m	Methoxychlor	<3	100.00m
Toxaphene	<5	5.0000m						
HERBICIDES(in ppm)								
2,4-D	<0.05	.1000m	2,4,5-TP Silvex	<0.005	.0100m			
MICROBIOLOGICAL(units as indicated)								
Coliform(MF-per 100ml)	<1							
PHYSICAL CHARACTERISTICS(units as indicated)								
Turbidity(ntu)	0.1		Sediment	0	1.0000s	Odor	0	3.0000s
Color(color units)	0	15.000s						
BASIC CHEMISTRY(in ppm)								
Total Dissolved Solids-TDS	178	500.00s	Solids-Loss on Ignition	18		pH(Field Test)	5.70	
Free Ammonia as N	<0.05		Nitrite as N	<0.02		Nitrate as N	0.2	10.000m
Alkalinity, Total	11		Chloride	82.9	250.00s	Fluoride	<0.2	4.0000m
Hardness, Total	13.9		Iron	0.02	.3000s	Manganese	0.02	.0500s

JIM DECELLES WATER SUPT.
SLATERSVILLE PUBLIC SUPPLY
MEMORIAL TOWN BUILDING
SLATERSVILLE, RI 02876

PWSID:1615614

Date Collected 04/17/90 | Lab Number 72369
Cty/Twn:North Smithfield
Owner:JIM DECELLES WATER SUPT.
Src:Raw-Dug Well

June A. Swallow, Acting Chief, Drinking Water Quality
May 22, 1990

Rhode Island Department of Health
Cannon Building, Providence, Rhode Island 02908-5097

Date Received 04/17/9
Date Completed 05/17/90
Lab Number 72369

	RESULT	STANDARD		RESULT	STANDARD		RESULT	STANDARD
Sodium	46.6		Potassium	1.70		Calcium	9.3	
Magnesium	1.5		Sulfate	9.2	250.00s			
HEAVY METALS(in ppm)								
Arsenic	<0.005	.0500m	Barium	<0.02	1.0000m	Cadmium	<0.001	.0100m
Chromium	<0.005	.0500m	Copper	<0.02	1.0000s	Lead	<0.005	.0500m
Mercury	<0.001	.0020m	Nickel	<0.02		Selenium	<0.005	.0100m
Silver NOREPORT	<0.001	.0500m	Zinc	<0.02	5.0000s			
ADDITIONAL CHEMICALS(units as indicated)								
MBAS(ppm)	<0.05							

COMMENT(s):Refer to the enclosed summary sheet for the following codes -> 1,5
Elevated Sodium Level Refer To Fact Sheet

m=Maximum Contaminant Level, s=Secondary Maximum Contaminant Level
UNITS:ppm=Parts Per Million, ppb=Parts Per Billion, pCi/l=Picocurie Per Liter, ntu=Nephelometric Turbidity Units

JIM DECELLES WATER SUPT.
SLATERSVILLE PUBLIC SUPPLY
MEMORIAL TOWN BUILDING
SLATERSVILLE, RI 02876

PWSID:1615614

Date Collected 04/17/90
Lab Number 72369
Cty/Twn:North Smithfield
Owner:JIM DECELLES WATER SUPT.
Src:Raw-Dug Well

June A. Swallow, Acting Chief, Drinking Water Quality
May 22, 1990

Rhode Island Department of Health
Cannon Building, Providence, Rhode Island 02908-5097

Page 1 of 1 | Date Received 03/06/9[illegible] | Date Completed 03/28/91 | Lab Number 85942

	RESULT	STANDARD		RESULT	STANDARD		RESULT	STANDARD
RADIOLOGICAL								
Gross Alpha(pCi/l) 3.2 MDL: 1.2 14		5.0000m	Gross Beta(pCi/l) 1.2 MDL: 1.1_ 6.4		15.000m			
BASIC CHEMISTRY(in ppm)								
pH(Field Test)_____	6.90							

COMMENT(s):Refer to the enclosed summary sheet for the following codes ->
Alpha Radiological Results Are High And The Four Quarterly Test Will Be Evaluated To Determine It's Status.

m=Maximum Contaminant Level
UNITS:ppm=Parts Per Million, ppb=Parts Per Billion, pCi/l=Picocurie Per Liter, ntu=Nephelometric Turbidity Units

JIM DECELLES, WATER SUPT.
SLATERSVILLE PUBLIC SUPPLY
MEMORIAL TOWN BUILDING
SLATERSVILLE, RI 02876

PWSID:1615614

Date Collected 03/06/91 | Lab Number 85942
Cty/Twn:North Smithfield
Owner:JIM DECELLES, WATER SUPT.
Src:Raw Pacheco Park Well

June A. Swallow, Chief, Drinking Water Quality
Apr 1, 1991

Rhode Island Department o[illegible]alth
Cannon Building, Providence, Rhode Island 02908-5097

Page 1 of 1

Date Received	Date Completed	Lab Number
06/13/90	07/16/90	74912

	RESULT	STANDARD		RESULT	STANDARD		RESULT	STANDARD
RADIOLOGICAL								
Radium 226(pCi/l)	.57	.79	3.0000m					
Radium 228(pCi/l)	.88	.17	5.0000m					

COMMENT(s):Refer to the enclosed summary sheet for the following codes -> 5

The Results Of The Radium 226 And 228 Are Within Acceptible Range

m=Maximum Contaminant Level

UNITS:ppm=Parts Per Million, ppb=Parts Per Billion, pCi/l=Picocurie Per Liter, ntu=Nephelometric Turbidity Units

JIM DECELLES, WATER SUPT.
SLATERSVILLE PUBLIC SUPPLY
MEMORIAL TOWN BUILDING
SLATERSVILLE, RI 02876

PWSID:1615614

Date Collected	Lab Number
06/13/90	74912

Cty/Twn:North Smithfield
Owner:JIM DECELLES, WATER SUPT.
Src:Raw Well Pacheco Park

June A. Swallow, Acting Chief, Drinking Water Quality
Jul 19, 1990

APPENDIX D

LAND USE IMPACTS

This matrix identifies what contaminants may be associated with certain land uses. Not all land uses have necessarily resulted in demonstrated contamination problems from all pollutants listed. Sources of information are listed below.

Key: ▩ = threat to surface water ■ = threat to groundwater ■ = threat to surface and groundwate

	Acids	Bases	Chlorides	Iron/Manganese	Metals	Nitrogen	Oxygen demand	Pathogens	Pesticides	Petroleum products	Phenols	Phosphorus	Sediment	Sodium	Solvents	Surfactants/det.	Thermal pollu.	Key Pollutants
Agriculture - cropland						■			■			■	■					Nitr, phos, pest, sed
Ag.- pasture/hay land						■	■	■				■	■					Nitr, phos, pest
Ag.- feedlots, manure pits						■	■	■				■	■	■				Nitr, phos, ox, path
Airports			■		■	■		▩	■	■		■	■	■			■	Petr, solv
Aquaculture						■	■					■						Nitr, phos
Asphalt plants, storage										■								Petr
Auto: car washes			■		■					■			■	■	■			Surfac, petr
Auto salvage	■			■	■					■				■	■			Metals
Auto service shops					■					■				■	■			Solv, petr
Beauty parlors		■			■									■	■			Surfac
Boat use & maintenance					■	■	■	▩		■		■					■	Path, petr
Boat yards/builders					■					■	■			■				Petr, solv
Cemeteries						■			■			■						Nitr, phos
Chemical mfrs.	■	■	■	■	■	■			■	■	■			■	■	■		Various
Combined sewer lines			■	■	■	■	■	■		■		■	■	■	■	■	■	Nitr,phos,path,&other
Construction										■			▩				■	Sed
Dry cleaners															■			Solv
Furniture stripping	■	■			■										■			Solv
Golf courses						■			■			■	▩				■	Nitr, phos
Hazardous mat. stor/trans.	■	■	■	■	■	■		■	■	■	■	■		■	■	■		Any haz. material
Household haz. wastes					■				■	■					■			Solv, surf, petr
Household lawn/garden						■			■			■						Nitr, phos, pest
Hydrologic modifications						■	▩					■	■				■	Sed, therm
Infiltration wells/basins			■			■				■		■		■				Petr, sod, chlor
Jewelry, metal plating	■	■		■	■					■				■	■	■		Metals, acids, bases
Landfills, dumping grounds	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	Any
Laundromats								■							■	■		Surf, path, solv
Machine & metal shops	■	■			■					■					■	■		Metals,acid,base,solv
Manufacturing: misc.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Various
Printing, photography	■	■			■										■	■		Metals,acid,base,solv
Research labs, hospitals	■	■		■	■	■		■	■	■	■	■			■	■		Various
Road de-icing			■										■	■				Sodium, chlor, sed
Road maint. depots			■						■	■				■	■			Sodium, chlor, petr
Road runoff			■		■	■	■	■		■		■	■	■	■		■	Sod,chl,petr,met,ther
Road/bridge construction			■		■				■	■			■	■			■	Sed, petr
Sand & gravel operations										■			■		■		■	Sed
Septic systems (ISDS)			■	■	■	■		■	■			■		■	■	■		Nitr, phos, path
Sewer lines & plants			■	■	■	■	■	■				■		■	■	■		Nitr,phos,path,&other
Silviculuture							■		■				■				■	Sed
Sludge disposal sites	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■		Various
Stormwater drains/lines			■		■	■	■	■	■	■		■	▩	■	■			Sod,chl,petr,met,ther
Underground storage tanks					■				■	■					■			Petr
Urban runoff			■		■	■	■	▩	■	■		■	■	■			■	Petr, metals, others
Waste lagoons, pits	■	■	■	■	■	■	▩	■	■	■	■		■	■	■	■	▩	Various
Wood preserving					■					■	■				■	■		Phenols, metals

* Primary sources of information were:

Horsley, R. 1988. Ready Reference Guide to Non Point Source Pollution (Draft). U.S. EPA, Boston MA.

Hoskins, K.D. 1988. Guide to Contamination Sources for Wellhead Protection. Cape Cod Aquifer Management Project, Mass. DEQE, U.S. EPA Region I, Cape Cod Planning and Dev. Commission, and USGS. 207 pp. + appendices.

List of Categories of Potential Sources of Groundwater Contamination (See explanatory notes on following page.)

Higher Risk

- Airports-Commercial (maintenance & repair, fuel storage)
- Automotive Repair Shops
- Automotive Body Shop
- 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

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 (leaching systems)
- Transmission Line Rights of Way
- Transportation Corridors (road deicing, materials transport)
- Utility Substations/Transformers
- Waste Transfer Stations

APPENDIX E

SUN OIL/DB MART DOCUMENTATION

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Department of Environmental Management
DIVISION OF GROUNDWATER AND
FRESHWATER WETLANDS
291 Promenade Street
Providence, R.I. 02908 - 5767

February 22, 1991

Mr. William Hawkins, President
Town Council, Town of North Smithfield
Town Hall Main Street
Slatersvills, Rhode Island 02876

Dear Mr. ~~Hawkins~~ Mr. Faricy,

Enclosed please find a copy of the Consent Agreeement entered into between the Department of Environmental Management and the Sun Refining and Marketing Company concerning the remediation of groundwater contamination at the North Smithfield Sunoco and in the Woodland Road neighborhood. A copy has been sent to the town clerk for filing in the land evidence records.

The agreement requires Sun Refining and Marketing (Sun) to submit plans for further investigation, monitoring and remediation of the contamination. The remedial plan must be designed with the goal of restoring the drinking water supply to all affected areas. While the agreement was being finalized, Sun prepared and submitted a remediation plan. The plan, which is under DEM review, is being supplemented by additional information to be submitted by Sun. In accordance with the plan and with DEM approval, Sun has gone forward and installed the components of a groundwater treatment system and obtained the necessary discharge permits. The groundwater treatment system became operational this week. It will be periodically monitored to an evaluation of its effectiveness over time.

Pursuant to the agreement, Sun was required to provide an interim drinking water supply to all private homes in the area whose water was contaminated by gasoline constituents above drinking water standards. Sun has complied by installing carbon filters to all those residences indicating any presence of contamination- both above or below drinking water standards. The filter systems will be monitored monthly and the results will be made available to the individual homeowners.

The DEM Groundwater Section will continue its oversight role with respect all remediation and monitoring activities. If you should have any questions concerning this matter, please do not hesitate to contact me at 277-2234.

Sincerely,

Susan Kiernan
Deputy Chief

cc: Elizabeth Faricy
Stephen Morin, DEM

re: Well Contamination

Handex®

HANDEX OF NEW ENGLAND, INC., 620 Boston Turnpike Rd., P.O. Box 310, Shrewsbury, MA 01545 • (508) 842-0504 • FAX (508) 842-1512

January 24, 1991

Mr. Phil Kaczorowski
Director of Public Works
P.O. Box 248
Slattersville, Rhode Island 02876

Mtg 7@ 7:30 pm
Town Hall

Re: Groundwater Treatment System Connection
to Storm Sewer System
Sunoco Service Station
1047 Eddie Dowling Highway
North Smithfield, Rhode Island

Dear Mr. Kaczorowski

The following information is submitted to inform you of the status of the above referenced project. The project is scheduled to begin February 1, 1991.

SITE LOCATION Sunoco Service Station
1047 Eddie Dowling Highway
North Smithfield, Rhode Island

SUNOCO CONTACT Mr. Carl Borkland, hydrogeologist - Regional Engineer for RI
Sun Refining & Marketing
35 Terminal Road
Providence, RI 02908
(401) 461-9105

Attached you will find an area map and site plan detailing the proposed connection to the catch basin.

REASON FOR DISCHARGE The Rhode Island Department of Environmental Management (RIDEM) is requiring the installation of a ground water treatment system at the site location referenced above. The ground water treatment system will result in a discharge of treated ground water into the Rhode Island Department of Transportation (RIDOT) storm sewer system. Discharge to the storm sewer system will be to a catch basin located at the intersection of Eddie Dowling Highway and Iron Mine Road.

TREATMENT SYSTEM The treatment system will consist of a single 6 inch diameter pumping well. The pumping well will pump ground water to a packer tower air stripper treatment system. Effluent from the air stripping tower will be treated or "polished" prior to discharge using two 500 pound capacity granular activated carbon adsorption (GACA) units piped in series.

ESTIMATED FLOW RATE Treatment system effluent flow rate is expected to be approximately 7 gallons per minute.

DISCHARGE POINT Effluent from the treatment system will be piped to the RIDOT storm sewer system. Rhode Island Department of Transportation permits and local authorization will be secured prior to discharging into the storm sewer system. A site map has been provided detailing where the proposed connection will be made. The connection to the catch basin will be made in accordance with all RIDOT Blue Book specifications.

EFFLUENT SAMPLING Effluent sampling and monitoring will be conducted in accordance with the RIDEM Order of Approval issued. A copy of the Order of Approval has been provided.

If you require additional information, please do not hesitate to contact our office.

Sincerely,

James Wagner

James Wagner
Environmental Scientist
Permits Manager

Enclosures

cc w/attachments:

Carl Borkland, Sun Refining & Marketing
Phil Fielding, RIDOT

RECEIVING WATER CLASSIFICATION: B

The facility which is the source of the wastewater discharge is engaged in the storage and sale of gasoline. The permit authorizes the discharge of groundwater from a treatment system which consists of two (2) granular activated carbon adsorption filters arranged in series. Discharge limitations were established to ensure that minimum Database Guidelines for Benzene, Ethyl-benzene, Toluene and Total Xylene are met at the end of the discharge pipe. This discharge is subject to State antidegradation provisions. The RIDEM has made the determination that the impact to the receiving water is insignificant and does not warrant further review at this time.

PERMIT NUMBER: RI0021945

NAME AND MAILING ADDRESS OF APPLICANT:

SUN REFINING AND MARKETING COMPANY
TEN PENN CENTER
1801 MARKET STREET
PHILADELPHIA, PA 19103-1699

NAME AND ADDRESS OF THE FACILITY WHERE DISCHARGE OCCURS:

SUNOCO SERVICE STATION
1047 EDDIE DOWLING HIGHWAY
NORTH SMITHFIELD, RI

RECEIVING WATER: Wetland Tributary to Crookfall Brook

RECEIVING WATER CLASSIFICATION: A

The facility which is the source of the wastewater discharge is engaged in the storage and sale of gasoline. The permit authorizes the discharge of groundwater from a treatment system consisting of a packed-tower air stripping column followed by two (2) activated carbon filters arranged in series. The discharge concentrations must be below the analytical detection limit of one (1) part per billion for Benzene, Ethyl-benzene, Toluene and three (3) parts per billion for Total Xylenes. This discharge is subject to State antidegradation provisions. The RIDEM has made the determination that the impact to the receiving water is insignificant and does not warrant further review at this time.

PERMIT NUMBER: RI0021971

NAME AND MAILING ADDRESS OF APPLICANT:

DeBLOIS OIL COMPANY
P.O. BOX 6027
PROVIDENCE, RI 02940

NAME AND ADDRESS OF THE FACILITY WHERE DISCHARGE OCCURS:

DB MART
80 EDDIE DOWLING HIGHWAY
NORTH SMITHFIELD, RI

RECEIVING WATER: Unnamed Stream Tributary to Spring Brook

RECEIVING WATER CLASSIFICATION: A

The facility which is the source of the wastewater discharge is engaged in the storage and sale of gasoline and other services. The permit authorizes the discharge of groundwater from a treatment system consisting of a packed-tower air stripping column followed by two (2) activated carbon filters arranged in series. The discharge concentrations must be below the analytical detection limit of one (1) part per billion for Benzene, Ethyl-benzene, Toluene and three (3) parts per billion for Total Xylenes. This discharge is subject to State antidegradation provisions. The RIDEM has made the determination that the impact to the receiving water is insignificant and does not warrant further review at this time.

PERMIT NUMBER: RI0000191

NAME AND MAILING ADDRESS OF APPLICANT:

KENYON INDUSTRIES, INC.
10 EAST 39th STREET
NEW YORK, NY 10016

NAME AND ADDRESS OF THE FACILITY WHERE DISCHARGE OCCURS:

THE KENYON PIECE DYEWORKS, INC.
MAIN STREET
KENYON, RI 02836

RECEIVING WATER: Pawcatuck River

RECEIVING WATER CLASSIFICATION: C

APPENDIX F

FEDERAL AND STATE REGULATIONS AFFECTING GROUNDWATER

APPENDIX F: FEDERAL AND STATE STATUTES

FEDERAL STATUTES

The Clean Water Act (CWA) as amended by the Water Quality Act of 1987 (Public Law 92-500)

The Clean Water Act has two goals: (a) the achievement of a level of water quality that provides for the propagation and protection of fish and wildlife and for recreation in and on the water and (b) the elimination of the discharge of pollutants in United States waters. This act regulates all discharges from all point sources into the navigable waters of the United States. Outfalls from land-based facilities such as sewage treatment plants and industrial plants are subject to regulation under the CWA through the National Pollution Discharge Elimination System (NPDES). A permitting program, co-administered with the Army Corps of Engineers, regulates discharge of dredged or fill material into U.S. waters. Water quality standards are set for all significant surface waterbodies. Also included are provisions for water quality management plans (under Section 208) which some states have used to develop their own groundwater protection plans.

Although there is an emphasis on control of point sources, Section 319 (1987) of the Act also provides for the development and implementation of non-point source pollution management plans (subject to EPA review). These plans can include BMPs and other regulatory and non-regulatory programs. State plans deemed inadequate can cause ineligibility for Section 319 grant funds. The non-point source management plans are required to be developed, whenever possible, on a watershed-by-watershed basis. One other aspect of the 1987 amendments is the requirement that states take into account the impact of management practices on groundwater quality in order to prevent protection of surface water quality at the expense of groundwater quality.

Water Quality Act of 1987 (amends Clean Water Act) 35 USC 1257-1287

While this act does not specifically address public drinking water supplies, it does require that states adopt an "Anti-degradation Policy" that prohibits the introduction of any new pollution source that would degrade waters designated by the State as "high quality." This would included surface water reservoirs and groundwater aquifers.

The Safe Drinking Water Act (SWDA)

This act was passed 1974, authorizing the EPA to adopt regulations for a system of national standards and treatment

technologies for public drinking water. Maximum contaminant levels (MCLs) were also required to be set. States may adopt more stringent standards and may regulate more substances than provided for in the federal act. Monitoring and testing of community and non-community wells is required to ensure that drinking water quality meets SWDA standards. It was amended on 1986 in part to more adequately address implementation efforts. The amendments included a requirement for groundwater protection.

RIDEM regulates point sources of pollution and has been authorized to establish regulations to protect groundwater quality. The 1986 amendments to the Act established a federal Wellhead Protection Program (WHPP). EPA guidelines for WHPPs are adopted by the states in the development of state WHPPs which are subject to EPA approval. Elements of the WHPP include the delineation of wellhead protection areas (states are given great flexibility in defining these areas), the inventory of contamination sources, the development of management strategies, public education, and contingency planning.

The amendments include provisions for underground injection control. This method of underground waste disposal poses great risks to groundwater resources due to the possibility that these wastes will not remain isolated in one area and could migrate into potable water supplies. Some states, such as Minnesota and Wisconsin, discourage the use of underground injection devices.

The 1986 amendments to the SWDA also contain provisions for the designation of Sole Source Aquifers (SSA). The EPA reviews projects which receive federal financial assistance in their development and implementation. Projects which may result in adverse impacts on groundwater resources may be prohibited from construction by preventing a commitment of federal funds. The Act is used to negotiate modifications to projects that will reduce negative impacts. It is important to note that this provision affects only federally-funded projects, leaving sole source aquifers vulnerable to threats from private or state projects.

Resource Conservation and Recovery Act (RCRA)

This federal statute provides standards for treatment, storage, and disposal facilities for hazardous wastes all aimed at preventing contamination of surface and groundwater and at public safety. Hazardous wastes are tracked from "cradle-to-grave" (point of generation to point of ultimate disposal). The importance of this type of regulation is underscored by the fact that approximately one ton of hazardous wastes is generated each year for every person in the United States (US Congress, Office of Technology Assessment, 1983). The Act was amended in 1984 to address groundwater contamination from leaking underground storage

tanks. An underground storage tank is subject to RCRA regulation if 10 percent of a tank's volume is beneath the ground surface and if the tank contains a material regulated under RCRA or CERCLA.

The US EPA has not added to the list of RCRA-regulated materials since 1980 although several states have requested that the list be expanded (Jaffe and DiNovo, 1987). Four factors are used to classify hazardous wastes under RCRA: ignitability, corrosivity, reactivity, and toxicity. Substances not regulated under RCRA are those that are carcinogenic, infectious, and able to cause birth defects (teratogenic) although there are provisions in the 1986 amendments to add such substances.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

This act established the Superfund - a funding source used to clean up existing or closed toxic waste sites. There are three such sites in the Town of North Smithfield. Toxins disposed of or stored at waste sites have been found to leach into groundwater. This act created a funding mechanism for clean-up actions. The broad powers this act grants of assigning liability for cleanup of such sites to hazardous waste transporters, generators, and landfill owners acts as a deterrent to continued toxic dumping practices. CERCLA sets forth a cost-sharing formula in which the states must contribute 10 to 50 percent of the cost of clean-up, depending on whether the site in question was publicly or privately owned. The high costs associated with toxic waste removal or remediation has hampered the effectiveness of this act as many states currently do not have the financial resources to allocate funds for CERCLA actions.

The Superfund Amendments and Reauthorization Act (SARA) Title III requires businesses to notify governments (Right-to-Know) of potentially hazardous substances stored or used on-site. SARA records for the State of Rhode Island are managed by the RI Department of Labor.

Toxic Substances Control Act

Passed in 1976, this act authorizes the EPA to regulate toxic pollutants from generation to disposal. The EPA can require the testing of chemical substances manufactured or processed by a company and any adverse effects must be reported to the EPA. Authorization is granted to the EPA to regulate or to ban any chemical on the basis of unreasonable risk to human health or the environment.

Federal Insecticide, Fungicide, and Rodenticide Act

This legislation provides for the establishment of procedures for the registration, classification, sale, use, research, monitoring, and disposal of pesticides. Pesticide use has been the source of much groundwater contamination in the U.S., particularly in agricultural regions. Through this act, the EPA can require extensive study of pesticide effects on humans, animals, and the environment to determine if there are any adverse effects.

National Environmental Policy Act (NEPA)

NEPA requires that any project involving federal legislation, funds, or activities that could significantly alter the quality of the human environment must be the subject of an environmental impact statement (EIS). The purpose of the act is to raise environmental protection to the same level as other considerations in the decision-making process of federal agencies.

STATE GROUNDWATER PROTECTION

In 1983, the State of Rhode Island's Water Pollution Control Act was amended to include groundwaters under the definition of the State's waters. In doing so, the RIDEM was given authority to regulate the prevention of groundwater contamination and to restore groundwater quality to acceptable levels. The State enacted the Groundwater Protection Act in 1985 which was designed to provide for the development of a comprehensive groundwater protection program. Policies established by the Act provided measures to restore, protect, and maintain the quality of the State's groundwaters. These measures included aquifer, recharge area, and watershed protection. Degradation of groundwater was prohibited unless the state chose to allow "lower quality as a result of essential, desirable, and justifiable economic, commercial, industrial, or social development" (RI Groundwater Protection Strategy, RIDEM 1989). This act also directed the RIDEM to identify and classify groundwater aquifers and to establish standards for the four classes of groundwater.

STATE STATUTES

Water Pollution RIGL 46-12

This statute provides for the control of pollution of the waters of the State, including groundwater and established the Underground Storage Tank Replacement Revolving Loan Fund. The statute prohibits the location of drinking water wells within 1000 feet of any solid waste disposal facility unless the water samples meet quality standards set by the Department of Health. It also includes

the Underground Injection Control Program which regulates this subsurface method of waste disposal.

Groundwater Protection Act RIGL 46-13.1

This statute establishes state policies for groundwater protection and requires the RIDEM to classify and develop standards for the State's groundwater resources.

Underground Storage Tanks (UST) RIGL 46-12.1

State regulations for the control of design, siting, and location of USTs are based on the federal program which does not regulate tanks under 1100 gallon capacity. Though small, many of these tanks are located in the vicinity of public drinking wells and present a significant threat due to tank failure of aging systems. The petroleum products usually stored in USTs are very mobile in groundwater.

Department of Health Regulations RIGL 46-14

The RI Department of Health (DOH) monitors the quality of drinking water wells to insure compliance with federal standards. The Department has the power (authorized by Section 46-14 "Contamination of Drinking Water Act") to inspect public water supply systems,to enter onto private property, and to order the removal of any substances that endangers a public drinking water supply. In practice, the DOH does not go beyond the testing of drinking water quality.

ISDS Permit Regulations RIGL 42-17.1, 17.2

The purpose of the ISDS regulations is to ensure that the siting, design, and operation of septic systems occur in such a manner as to protect public health and environmental quality. Regulation involves a series of setback regulations.

<u>General Setbacks:</u>

Surface drinking water supplies or tributaries	200 feet
Watercourses	50 feet
Public drinking water supply well	400 feet
Private well	100 feet

On-site septic systems are prohibited in areas where the groundwater table is less than three feet from the original ground surface or where an impervious layer is less than five feet from the original ground surface. The regulations do provide a variance procedure. A Wetlands permit is required if the ISDS is to be within 50 feet of a wetland, 100 feet of a river less than 10 feet wide, 200 feet of a river more than 10 feet wide, or if it is to be

located in a floodplain.

For ISDS in proximity to the ocean on a site that is subject to erosion, the minimum setback from the solstice tide elevation to the edge of the system shall not be less than 150 feet.

ISDS regulations identify three areas as critical resource areas and provide more stringent requirements for systems located in these areas. The critical areas are the South Shore Coastal Ponds, the Scituate Reservoir and its watershed, and the Narrow River and its watershed. For large systems (over 2,000 gallons per day) in these areas, the separation distances to water table and impervious layer are increased to five feet and seven feet, respectively. Large ISDS are not allowed in areas of highly permeable soils (faster than three inches per minute) unless proven otherwise for a site. Horizontal distances to waterbodies and wells are increased to three times the minimum required. For subdivisions designed to produce over 2,700 gpd of sewage, an assessment of impacts to groundwater, freshwater wetlands, and coastal wetlands in critical resource areas, can be required.

Critical Area Setbacks:

Coastal Ponds and Narrow River shoreline features and tributaries	150 feet
Indirectly connected watercourses	100 feet
Private wells	150 feet
All watersheds to surface water reservoirs including contributing perennial streams	200 feet

Requests for variances are heard by a review committee composed of representatives from the Dept. of Health, the Division of Groundwater and Freshwater Wetlands ISDS Section, and the Board of Engineering and Land Surveyors. Variances are allowed if they are deemed not contrary to the public health or interest.

Wastewater Management Districts

The RI General Assembly passed legislation in 1987 that enables cities and towns to establish Wastewater Management Districts (WWMD). Adopted in the same manner as an ordinance, a WWMD is designed to eliminate and prevent the contamination of the state's waters caused by malfunctioning individual septic disposal systems. This goal is achieved through the use of inspection and maintenance programs. Provisions of the WWMD legislation include:

* authority for the passage of local officials onto private property to periodically inspect septic systems;

* the ability to raise funds for the administration of a WWMD through taxes, annual fees, borrowing or issuing of bonds, and septic system pumping fees.

* authority to establish administrative, financial, technical, enforcement, maintenance, and legal structures to implement and conduct WWMD programs;

* the establishment of a public education program;

* the establishment of revolving funds for low-interest loans to be used to correct failed septic systems;

* authority to levy fines not to exceed $500 for each day of non-compliance.

RI Wellhead Protection Program - mandated by the 1986 amendments to the federal Safe Drinking Water Act (SDWA) Section 1428. Administered by the Groundwater Section of RIDEM.

This program is designed to delineate wellhead areas in need of protection, identify contamination sources, develop locally administered management strategies and ordinances, to guide siting of new wells, and to provide contingency plans in the event of public well contamination. Land use control measures are the responsibility of local governments. RIDEM will provide technical assistance and administrative tools to be used by local authorities in groundwater protection initiatives.

Underground Storage Tank (UST) Regulation RIGL 46-12, 42-35, and 23-19.1.

The purpose of these regulations is to implement a registration system, establishing facility design requirements, tank testing schedules and procedures, and measures for siting of new USTs that will protect the groundwater and the surface water of the State from pollution that can result from the use of USTs.

Hazardous Waste Regulation RIGL 23-19.1, and the 1984 Hazardous and Solid Wastes Amendments.

These regulations are designed to protect the environment and the public health and safety from the effects of improper, inadequate, or unsound management of hazardous waste. This is accomplished through regulations governing the storage, transport, treatment, and disposal of

such wastes. Permits from the RIDEM Division of Air and Hazardous Materials are required for hazardous waste activities. Section 10.1 (the Hagan Amendment) authorizes cities and towns to adopt ordinances which prohibit the disposal of hazardous wastes in the recharge zones of public drinking water supply wells.

Solid Waste Regulation RIGL 23-18.9

An amendment to the Refuse Disposal Act 1982 authorized the DEM and local governments to prohibit the disposal of solid waste in groundwater aquifer areas which are existing or potential public drinking water supplies.

Underground Injection Control Program RIGL 42-17.1 and 46-12.

These regulations are intended to preserve the quality of the groundwaters of the State by assuring the proper location, design, construction, maintenance, and operation of injection wells and other subsurface waste disposal systems. Permitting is the responsibility of the RIDEM Division of Groundwater and Freshwater Wetlands, Groundwater Section.

Public Drinking Water Protection Act of 1987 RIGL 46-15.3

In order to protect the quality and safety of the public drinking water supply, this act grants authority to public water supply agencies to impose a charge (currently $0.01 per 100 gallons) on water use. This charge will provide funding for the acquisition of watershed land in order to protect water supplies (both surface and groundwater) and for certain other water quality protection measures, such as the development of Water Quality Protection Plans and monitoring programs. Educational programs regarding watershed and aquifer protection that target planning boards, zoning boards, and other officials can be funded through this act. Also funded are pollution prevention activities and remedial actions.

46-13.2 Drilling of Drinking Water Wells

This act establishes the RI Well Drilling Board and authorizes the DEM to promulgate regulations for the design, construction, installation, and maintenance of wells. Drillers and installers are required to submit well data to the State.

46-13 Public Drinking Water Supply

Under this act, the Department of Health is authorized to establish requirements for public water supply systems

that will ensure that the public is provided with a safe and potable drinking water supply.

42-44.1 Sewage and Water Supply Failure Fund

This act establishes a fund to be used for the mitigation of problems caused by failed septic systems and the contamination of private drinking water wells.

45-22.1 Comprehensive Planning and Land Use Act

In requiring communities to update their Comprehensive Plans, this act adds provisions for groundwater resource inventories and for policies regarding the management and protection of these resources.

23-19.4 Septage, Industrial Wastes and Waste Oil Pumping, Cleaning and Transportation

Any business that is engaged in the business of pumping, cleaning, or transporting septage, industrial wastes, or waste oil is required by this regulation to obtain a permit from RIDEM.

23-19.5 Percolation Tests and Water Table Elevation Determination

Percolation tests and water table elevation determinations are required by RIDEM prior to the conveyance of real property where a sewer system is not available and ISDS will be required.

23-19.6 Used Oil Recycling

This act prohibits the improper disposal of used oil and requires a public education program on the benefits of collecting and recycling used oil.

23-19.7 Hazardous Waste Management Facilities

This act establishes a process for the siting of hazardous waste management facilities that provides protection to groundwater resources.

APPENDIX G

MODEL ORDINANCES

Appendix C-1

Well Field Protection Ordinance

Broward County, Florida, May 1984, Draft

Section 1. Short Title; Applicability; Construction

(1.01) This Ordinance shall be known as the "Potable Water Supply Well Field Protection Ordinance." The provisions of this ordinance shall be effective countywide within Broward County, Florida, and shall be considered an ordinance setting minimum standards to prevent potable water-supply contamination by toxic substances, and an ordinance protecting against the destruction of the resources of the county belonging to the general public, pursuant to Section 8.04 of the Broward County Charter. This ordinance shall be liberally construed to effect the purposes set forth herein.

Section 2. Legislative Intent

(2.01) The intent and purpose of this ordinance is to safeguard the public health, safety, and welfare of the residents of Broward County, Florida, by providing scientifically established criteria for regulation of the storage, handling, use, and/or production of toxic substances within identified zones of influence surrounding well fields, thereby protecting potable water supply wells from contamination.

(2.02) The substances to be controlled include but are not limited to certain known toxic substances that are prone to be persistent in the environment, to pass downward through surface soils in the event of spillage, to enter into groundwater strata, to mix with groundwater, and to be transported by the movement of groundwater to water supply wells.

Section 3. Definitions

(3.01) The following definitions apply within this ordinance:

(a) **Aquifer.** A rock formation, group of rock formations, or part of a rock formation that contains enough saturated permeable material to yield significant quantities of water.

(b) **Biscayne Aquifer.** The aquifer underlying Dade, Broward, and Palm Beach Counties, which supplies these counties with potable water.

(c) **Broward County Water Resource Management Division.** Division of county government charged with responsibility for management, control, regulation, and planning in relation to water resources.

(d) **Contamination.** The presence of any harmful or deleterious substances in the water supply.

(e) **Groundwater.** Subsurface water in the saturated zone from which wells, springs, and groundwater runoff are supplied.

(f) **Lithology.** The general characteristics of any rock formation.

(g) **One-Foot Drawdown Contour.** The locus of point around a well or well field where the free water elevation is lowered by one (1) foot due to the pumping of the well or well field.

(h) **Permitted Pumping Capacity.** The amount of water authorized to be pumped from a well during a one (1) year period.

(i) **Person.** Any natural person, individual, public or private corporation, firm, association, joint venture, partnership, municipality, governmental agency, political subdivision, public officer, or any other entity whatsoever or any combination of such, jointly or severally.

(j) **Pollutant Travel Time.** The time required by pollutants to travel from one point to another.

(k) **Pollution.** The presence of any substance (organic, inorganic, radiological, or biological) or condition (temperature, PH, turbidity) in water that tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

(l) **Potable Water.** Water that is satisfactory for drinking, culinary, and domestic purposes, meeting current drinking water standards.

(m) **Public Utility.** Any privately, municipally, or

county-owned system providing water or wastewater service to the public that has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals daily for at least sixty (60) days of the year.

(n) **Toxic Substance.** Any substance that has the capacity to produce personal injury or illness to humans through ingestion, inhalation, or absorption into the body.

(o) **Transmissivity.** The rate at which water is transmitted through a unit width of any aquifer under a unit of hydraulic gradient.

(p) **Travel-Time Contour.** A locus of points from which water takes an equal amount of time to reach a given designation such as a well or well field.

(q) **Travel Time Zones.** The area bounded by travel time contours.

(r) **Water Pollution.** The introduction in any surface or underground water, or tidal saltwater, or any organic or inorganic deleterious substance in such quantities, proportions, and accumulations that are injurious to human, plant, animal, fish and other aquatic life, or property, or that unreasonably interferes with the comfortable enjoyment of life or property or the conduct of business.

(s) **Well.** A pit or hole sunk into the earth to reach a resource supply such as water.

(t) **Well Field.** A tract of land that contains a number of wells for supplying water.

(u) **Zones of Influence.** Zones delineated by iso-travel time contours around wellfields, within which toxic substances will be regulated to protect the quality of the groundwater resource. These zones are calculated, based on the rate of movement of groundwaters in the vicinity of wells with an allowance for the dispersion of a pollutant entering into and moving with the groundwater.

Section 4. Maps of Zones of Influence

(4.01) Zone of influence maps and any amendments thereto are incorporated and made a part of this ordinance. These maps shall be on file at the Water Resources Management Division. Any changes, additions, or deletions to said maps shall be approved by the Board of County Commissioners of Broward County. The Broward County Water Resources Management Division, or its successor agency, shall maintain these maps of the zones of influence of public utility potable water-supply well fields. Said maps shall be provided to the Office of Planning, the Building and Zoning Enforcement Division, the Broward County Health Department, the Broward County Planning Council, the Environmental Quality Control Board, and any other agency requesting said maps.

(4.02) The Zone of Influence maps may be updated on an annual basis. The basis for such an update may include, but is not limited to, the following:

(a) Changes in the technical knowledge concerning the Biscayne Aquifer relating to:

1. Transmissivity;
2. Lithology;
3. Extent

(b) Changes in permitted pumping capacity of municipal well fields.

(c) Addition of wells to existing well fields.

(d) Designation of new well fields.

(4.03) The zones of influence indicated on the Zone of Influence maps are as follows:

(a) **Zone 1:** The land area situated between the well(s) and the ten (10) day travel time contour.

(b) **Zone 2:** The land area situated between the ten (10) day and the thirty (30) day travel time contours.

(c) **Zone 3:** The land area situated between the thirty (30) day and the two hundred ten (210) day travel time contours, or the thirty (30) day and the one-foot drawdown contours, whichever is greater.

Section 5. Prohibitions and Restrictions Within Zones of Influence

(5.01) No person who engages in nonresidential activities within Zone 1 as indicated on the Zone of Influence Maps shall store, handle, use, and/or produce any toxic substances set forth in Table 1, attached hereto and made a part of hereof.

(5.02) All persons who engage in nonresidential activities within Zone Two (2) and Zone Three (3) of the Zones of Influence as indicated on the Zone of Influence Maps, who store, handle, use, and/or produce any toxic substances set forth in Table 1 shall obtain a Well Field Protection Permit from the Water Resources Management Division and shall comply with the provisions of this ordinance and the rules and regulations promulgated hereunder.

(5.03) A Well Field Protection Permit shall be renewed annually and shall not be transferable.

(5.04) Prior to the issuance of a new or renewal permit, the applicant shall pay to the county a permit fee that shall be established by resolution of the Board of County Commissioners. Such fee shall be used to defray the cost of monitoring the compliance to the rules and regulations.

(5.05) Any person who engages in nonresidential activities relating to the storage, handling, use, and/or production of any toxic substances set forth in Table 1 who is exempted from this ordinance by law shall not be subject to the restriction contained herein.

Section 6. Protection of Future Well Fields

(6.01) The prohibitions and restrictions set forth in this ordinance and in the regulations shall apply to any new well field sites developed as new well fields or designated for development as new well fields within Broward County.

Section 7. Determination of Location Within Zones

(7.01) In determining the location of properties within the zones depicted on the Zone of Influence Maps, the following rules shall apply:

(a) Properties located wholly within one (1) zone reflected on the applicable Zone of Influence Map shall be governed by the restrictions applicable to that zone.

(b) For properties having parts lying within more than one (1) zone as reflected on the applicable Zone of Influence Map, each part shall be governed by the restriction applicable to the zone in which the part of the property is located.

Section 8. Well Field Protection Enforcement

(8.01) A Well Field Protection Officer shall be designated by the County Administrator to supervise the implementation and enforcement of this ordinance. The duties and responsibilities shall be as set forth in the regulations.

(8.02) The Water Resources Management Division through the Well Field Protection Officer designated by the County Administrator shall, by the issuance of a Notice of Violation as provided herein, have the power and authority to enforce the provisions of this ordinance and any rules and regulations promulgated hereunder.

(8.03) The Well Field Protection Officer shall

Table 1

Toxic substances are prohibited in Zone 1 and regulated in Zone 2 and Zone 3 of the zones of influence as indicated on the Zones of Influence Maps. Toxic substances include but are not limited to the following:

Acephate
Aldicarb
Aldrin/Dieldrin
Arsenic
Benzene
Bromodichloromethane
Bromoform
Cadmium
Carbaryl
Carbon Tetrachloride
Chlordane
Chlordecone
Chlorobenzene
Chloroform
Chlorotoluene(s)
Chromium (total)
Chromium (hexavalent)
Copper (excluding elemental metal)
Cyanide
2-4 D
DDT
Demeton
Diazinon
Dibromochloromethane
1,2-Dibromo-3-Chloropropane
Dichlorobenzene(s)
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
cis and/or trans 1,2-Dichloroethene
Dichloroidomethane
1,2-Dichloropropane
cis and/or trans 1,3-Dichloropropene
Disulfoton
Endosulfan(s)
Endothall
Endrin(s)
Ethylbenzene
Ethylene Dibromide
Guthion
Heptachlor
Isopropylbenzene
Lead
Lindane
Malathion
Mancozeb
Mercury
Methomyl
Methylene Chloride
Methoxychlor
Mirex
Nickel (excluding elemental metal)
Nitrates
Oxamyl
Paraquat
Parathion
Phenolic Compounds
Polychlorinated Biphenyls
n-Propylbenzene
Selenium
Silver (excluding elemental metal)
Silvex
Styrene
1,1,1,2-Tetrachloroethane
Tetrachloroethene
Toluene
Toxaphene
Trichlorobenzene(s)
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Vinyl Chloride
Xylene(s)
Zinc (excluding elemental metal)

Gasoline
Kerosene
Pathogens
Petroleum Products
Radionuclides

designate such inspectors as are necessary to enforce this ordinance and the rules and regulations promulgated hereunder.

Section 9. Inspections

(9.01) The Broward County Well Field Protection Officer or Inspector is hereby authorized and empowered to make inspections of all buildings, structures, and land within well field zones of influence in Broward County, Florida, in order to determine if the provisions of the Broward County Code of Ordinances and regulations relating to well field protection are being followed.

(9.02) Inspections may be made without notice, and it shall be a violation of this ordinance to refuse an inspection. A refusal of an inspection shall be sufficient grounds to revoke a permit.

(9.03) The Well Field Protection Officer or Inspector shall have the power and authority to enter and inspect all buildings and structures within well field zones of influence for the purpose of making an inspection.

(a) In the event a person who has common authority over a building structure shall not permit an inspection, such person shall reschedule an inspection for a time-certain within forty-eight (48) hours of the inspector's initial contact. Failure of such person to thereafter permit an inspection shall be sufficient grounds and probable cause for a court of competent jurisdiction to issue a search warrant to the Water Resources Management Division to inspect such premises.

(b) In the event a building or structure appears to be vacant or abandoned, and the owner cannot be readily contacted in order to obtain consent for an inspection, the officer or inspector may enter into or upon any open or unsecured portion of the premises in order to conduct an inspection thereof.

(9.04) The Well Field Protection Officer or Inspector shall have the power and authority to enter upon and inspect all vacant, fenced, or enclosed land with or without the consent of the owner or occupant thereof in order to conduct an inspection.

(9.05) The Well Field Protection Officer or Inspector shall be provided with official identification and shall exhibit such identification when making any inspection.

(9.06) It shall be the duty of all law enforcement officers to assist in making inspections when such assistance is requested by the officer or an inspector.

Section 10. Notice of Violation and Hearing

(10.01) Whenever the officer or an inspector determines that there is a violation of this ordinance, he shall give notice thereof in the manner hereinafter provided.

(a) A notice of violation shall:

(1) Be in writing;

(2) Be dated and signed by the officer or inspector;

(3) Specify the violation or violations;

(4) State that said violation(s) shall be corrected within a specified period of time as issued in writing by the inspector;

(5) State that if the violation is not corrected within said specified period of time the Well Field Protection Officer may request a hearing before the Board of County Commissioners within thirty (30) days from the expiration of the period of time stated in the violation recommending that the permit be revoked.

(10.02) If the Well Field Protection Officer finds that revocation of a permit is warranted, he shall notify the permit holder and the board of such finding in writing, by certified mail within twenty (20) days prior to the hearing. Thereafter, upon notice to the concerned permit holder, a hearing shall be held by the Board of County Commissioners for the purpose of consideration of the revocation of the permit.

Section 11. Injunctive Relief

(11.01) If any person who engages in non-residential activities stores, handles, uses, and/or produces toxic substances listed in Table 1 within the well field zones of influence, as indicated on the Zone of Influence Maps, without having obtained a permit as provided for herein or continues to operate in violation of the provisions of this ordinance, then Broward County may file an action for injunctive relief in the circuit court of the Seventeenth Judicial Circuit in and for Broward County, Florida.

Section 12. Penalties

(12.01) Any person who violates any provision of this ordinance shall, upon conviction, be punished by a fine not to exceed five hundred dollars ($500) or by imprisonment in the county jail not to exceed sixty (60) days or by both such fine and imprisonment.

Section 13. Severability

(13.01) If any section, sentence, clause, or phrase of this ordinance is held to be invalid or unconstitutional by any court of competent jurisdiction, then said holding shall in no way affect the validity of the remaining portions of this ordinance.

Section 14. Inclusion in Code

(14.01) It is the intention of the Board of County Commissioners that the provisions of this ordinance shall become and be made a part of the Broward County Code; and that the sections of this ordinance may be renumbered or relettered and the word "ordinance" may be changed to "section," "article," or such other appropriate word or phrase in order to accomplish such intentions.

Section 15. Effective Date

(15.01) This ordinance shall become effective (*date*).

Appendix B-3

Model General Bylaw: Hazardous Materials

Conservation Law Foundation of New England, Inc., 1981

Section 1: Authority
This bylaw is adopted by the town under its home rule powers, its police powers to protect the public health and welfare, and its authorization under Mass. Gen. Laws, ch. 40, §21.

Section 2: Purpose
The purpose of this bylaw is to protect, preserve, and maintain the existing and potential groundwater supply, groundwater recharge areas, and surface water within the town from contamination with hazardous materials.

Section 3: Definitions
The following definitions shall apply in the interpretation and implementation of this Bylaw.

Section 3.1
"Hazardous material" means a product or waste, or combination of substances that, because of quantity, concentration, or physical, or chemical, or infectious characteristics, poses in the board of health's judgment a substantial present or potential hazard to the human health, safety, or welfare, or the environment when improperly treated, stored, transported, used or disposed of, or otherwise managed. Any substance deemed a hazardous waste in Mass. Gen. Laws, ch. 21C, shall also be deemed a hazardous material for the purpose of this bylaw.

Section 3.2
"Discharge" means the disposal, deposit, injection, dumping, spilling, leaking, incineration, or placing of any hazardous material into or on any land or water so that such hazardous material or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters.

Section 4: Registration
Section 4.1
Every owner or operator of a commercial or industrial establishment (including home occupations) storing hazardous materials in quantities totaling more than 50 gallons liquid volume or 25 pounds dry weight shall register with the board of health the types, quantities, location, and method of storage of said hazardous materials. Registration required by this provision shall be initially submitted by [initial date] and annually thereafter within 30 days of [month, day] each year.

Section 4.2
Owners or operators of commercial or industrial establishments who have not previously registered in accordance with Subsection 4.1 shall, if they meet registration requirements, register initially within 30 days of meeting such requirements and thereafter within 30 days of [month, day] each year.

Section 4.3
In addition to registration, owners or operators of commercial or industrial establishments registered in accordance with Subsections 4.1 and 4.2 shall maintain on the premises an inventory, reconciled on a monthly basis, of purchase, use, sale, and disposal of hazardous materials. The purpose of this account is to detect any product loss and to provide an ongoing record of all quantities of hazardous materials within the town over the registration threshold.

Section 4.4
Upon the request of the board of health, owners or operators shall produce within 24 hours the latest reconciled inventory.

Section 4.5: Hazardous Wastes Generally
Wastes containing hazardous materials shall be held

on the premises in product-tight containers for removal by a licensed carrier and for disposal in accordance with the Massachusetts Hazardous Waste Management Act, Mass. Gen. Laws, ch. 21C

Section 4.6: Aboveground Storage of Hazardous Wastes
Aboveground containers of wastes containing hazardous materials shall be stored on a surface impervious to the material being stored. The storage area shall be enclosed by a permanent dike of impermeable construction. The volume of the area enclosed by the dike shall be equal to or greater than the capacity of the containers within the dike.

Section 5: Underground Storage
The following provisions shall apply to all underground liquid hazardous material storage systems with capacities of 55 gallons or greater.

Section 5.1
Owners shall file with the Board of Health the size, type, age, and location of each tank, and the type of hazardous material stored in each, on or before [initial date]. Evidence of date of purchase and installation, including Fire Department permit, if any, shall be included along with a sketch map showing the location of such tanks on the property.

Section 5.2
Owners of tanks for which evidence of installation date is not available shall, at the order of the board of health, have such tank systems tested. If either the board of health or the head of the fire department determines that the tank is not product-tight, it shall be disposed of under the direction of the board of health or the head of the fire department.

Section 5.3
All steel tanks shall be subject to one of the following tests 15 years after installation and annually after 20 years or if evidence of installation date is not available: a five-pounds-per-square-inch air pressure test performed on an empty tank, or a Kent-Moore Pressure test, or any other testing system approved in advance by the board of health or the head of the fire department. Certification of testing shall be submitted to the board of health and the head of the fire department. Any tanks failing the test shall be disposed of under the direction of the board of health or the head of the fire department.

Section 5.4
Newly installed tanks shall be protected from internal and external corrosion and shall be of a design approved by the board of health and the head of the fire department. The following tank construction systems are considered to provide adequate corrosion protection: all fiberglass construction steel with bonded fiberglass and internal lining; the Steel Tank Institute 3-Way Protection System; and such other tank construction systems as the board of health and the head of the fire department shall approve.

Section 6
The following provisions apply to all underground hazardous material storage systems of any capacity.

Section 6.1
All leaking tanks must be emptied by the owner or operator within 12 hours of leak detection and removed by the owner or operator in a time period to be determined by the board of health.

Section 6.2
Tank installations on lots not having a permit prior to adoption of this bylaw are not permitted within four feet of maximum high water table or within 100 feet of a surface-water body.

Section 7: Variances
The Board of Health may vary the application of any provision of this bylaw, unless otherwise required by law, in any case when, in its opinion, the applicant has demonstrated that an equivalent degree of environmental protection required under this bylaw will still be achieved. The applicant at his own expense must notify all abutters by certified mail at least 10 days before the board of health meeting at which the variance request will be considered. The notification shall state the variance sought and the reasons therefore. Any variance granted by the board of health shall be in writing. Any denial of a variance shall also be in writing and shall contain a brief statement of the reasons for the denial.

Section 8: Enforcement
Section 8.1: Protection
All discharges of hazardous material within the town are prohibited.

Section 8.2: Reporting of Discharge
Any person having knowledge of a discharge of hazardous material shall immediately report the discharge to the board of health, and if involving flammable or explosive materials, to the head of the fire department.

Section 8.3: Right of Entry
The board of health and its agents may enter upon privately owned property for the purpose of performing their duties under this bylaw.

Section 8.4: Penalty
Any person who violates any provision of this bylaw shall be punished by a fine of not more than $_____. Each day or portion thereof during which a violation continues shall constitute a separate offense; if more than one, each condition violated

MODEL GENERAL BYLAW/HEALTH REGULATION TO CONTROL TOXIC AND HAZARDOUS MATERIALS IN THE TOWN OF _____ (December 1981)

Section 1. Findings

The Town of _____ finds that—

(1) The groundwater underlying this town is the sole source of its existing and future water supply, including drinking water;

(2) The groundwater aquifer is integrally connected with, and flows into, the surface waters, lakes, streams, and coastal estuaries which constitute significant recreational and economic resources of the town used for bathing and other water-related recreation, shellfishing, and fishing;

(3) Accidental spills and discharges of petroleum products and other toxic and hazardous materials have repeatedly threatened the quality of such groundwater supplies and related water resources on Cape Cod and in other Massachusetts towns, posing potential public health and safety hazards and threatening economic losses to the affected communities;

(4) Unless preventive measures are adopted to prohibit discharge of toxic and hazardous materials and to control their storage within the town, further spills and discharges of such materials will predictably occur, and with greater frequency and degree of hazard by reason of increasing construction, commercial and industrial development, population, and vehicular traffic in the Town of _____ and on Cape Cod;

(5) The foregoing conclusions are confirmed by findings set forth in the Environmental Impact Statement and *Water Quality Management Plan for Cape Cod* (September 1978), prepared by the Cape Cod Planning and Economic Development Commission pursuant to Section 208 of the Federal Clean Waters Act; by the report entitled *Chemical Contamination* (September 1979), Commonwealth of Massachusetts; and by the report, *Chemical Quality of Ground Water, Cape Cod, Massachusetts* (1979), prepared by the U.S. Geological Survey.

Section 2. Authority

The Town of _____ adopts the following measures under its home rule powers, its police powers to protect the public health and welfare, and its authorization under Chapter 40, M.G.L.A., Sec. 21. (FOR HEALTH REGULATION: under its authorization under Chapter 111, Sec. 31.)

Section 3. Definitions

(a) The term, "discharge" means the accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying or dumping of toxic or hazardous material upon or into any land or waters of the Town of _____. Discharge includes, without limitation, leakage of such materials from failed or discarded containers or storage systems, and disposal of such materials into any on-site sewage disposal system, drywell, catch basin, or unapproved landfill.

The term, "discharge" as used and applied in this bylaw, does not include the following:

(1) proper disposal of any material in a sanitary or industrial landfill that has received and maintained all necessary legal approvals for that purpose;

(2) application of fertilizers and pesticides in accordance with label recommendations and with regulations of the Massachusetts Pesticide Control Board;

(3) application of road salts in conformance with the Snow and Ice Control Program of the Massachusetts Department of Public Works; and

(4) disposal of "sanitary sewage" to subsurface sewage disposal systems as defined and permitted by Title 5 of the Massachusetts Environmental Code.

(b) The term, "toxic or hazardous material," means any substance or mixture of such physical, chemical, or infectious characteristics as to pose a significant actual or potential hazard to water supplies, or other hazard to human health, if such substance or mixture were discharged in this town. "Toxic or hazardous materials" include, without limitation, organic chemicals, petroleum products, heavy metals, radioactive or infectious wastes, acids, and alkalies, and include products such as pesticides, herbicides, solvents, and thinners. The following activities, without limitation, are presumed to involve the use of toxic or hazardous materials, unless and except to the extent that anyone engaging in such an activity can demonstrate the contrary to the satisfaction of the board of health:

- Airplane, boat, and motor vehicle service and repair
- Chemical and bacteriological laboratory operation
- Cabinet making
- Dry cleaning
- Electronic circuit assembly
- Metal plating, finishing, and polishing
- Motor and machinery service and assembly
- Painting, wood preserving, and furniture stripping
- Pesticide and herbicide application
- Photographic processing
- Printing

The Board of Health may, consistent with this definition, and by author-

ity of Chapter 111, Section 31, issue regulations further identifying specific materials and activities involving the use of materials which are toxic or hazardous.

Section 4. Prohibitions

(a) The discharge of toxic or hazardous materials within the Town of _____ is prohibited.

(b) Outdoor storage of toxic or hazardous materials is prohibited, except in product-tight containers which are protected from the elements, leakage, accidental damage, and vandalism, and which are stored in accordance with all applicable requirements of Section 5 of this bylaw. For purposes of this subsection, road salts and fertilizers shall be considered as hazardous materials.

Section 5. Storage Controls, Registration, and Inventory

(a) Except as exempted below, every owner, and every operator other than an owner, of a site at which toxic or hazardous materials are stored in quantities totalling at any time more than _____ gallons liquid volume or _____ pounds dry weight, shall register with the board of health the types and quantities of materials stored, location, and method of storage. The board of health may require that an inventory of such materials be maintained on the premises and be reconciled with purchase, use, sales, and disposal records on a monthly basis, in order to detect any product loss. Registration required by this subsection shall be submitted within 60 days of the effective date of this bylaw, and annually thereafter. Maintenance and reconciliation of inventories shall begin within the same 60-day period. Exemptions: Registration and inventory requirements shall not apply to the following:

(1) Fuel oil stored in conformance with Massachusetts Fire Prevention Regulations and regulations of the _____ Board of Health for the purpose of heating buildings located on the site; or

(2) The storage of toxic and hazardous materials at a single-family or two-family dwelling, except where such materials are stored for use associated with a professional or home occupation use as defined by Section _____ of the Zoning Bylaws of the Town of _____.

(b) Toxic or hazardous wastes shall be held on the premises in product-tight containers and shall be removed and disposed of in accordance with the Massachusetts Hazardous Waste Management Act, Ch. 21C, MGLA.

(c) The board of health may require that containers of toxic or hazardous materials be stored on an impervious, chemical-resistant surface compatible with the material being stored, and that provisions be made to contain the product.

Section 6. Report of Spills and Leaks

Every person having knowledge of a spill, leak, or other loss of toxic or hazardous materials believed to be in excess of _____ gallons shall immediately report the spill or loss of same to the board of health or other public safety official.

Section 7. Enforcement

(a) The provisions of this bylaw shall be enforced by the board of health. The agent of the board of health may, according to law, enter upon any premises at any reasonable time to inspect for compliance.

(b) Upon request of an agent of the board of health, the owner or operator of any premises at which toxic or hazardous materials are used or stored shall furnish all information required to enforce and monitor compliance with this bylaw, including a complete list of all chemicals, pesticides, fuels, and other toxic or hazardous materials used or stored on the premises, a description of measures taken to protect storage containers from vandalism, corrosion, and spillage, and the means of disposal of all toxic or hazardous wastes produced on the site. A sample of wastewater disposed to on-site septic systems, drywells, or sewage treatment systems may be required by the agent of the board of health.

(c) All records pertaining to storage, removal, and disposal of toxic or hazardous materials shall be retained by the owner or operator for no less than three years, and shall be made available for review upon request of the agent of the board of health.

(d) Certification of conformance with the requirements of this bylaw by the board of health shall be required prior to issuance of construction and occupancy permits for any nonresidential uses.

Section 8. Violation

Written notice of any violation of this bylaw shall be given to the owner and operator by the agent of the board of health, specifying the nature of the violation; and corrective measures that must be undertaken, including containment and cleanup of discharged materials; and preventive measures required for avoiding future violations; and a schedule of compliance. Requirements specified in such a notice shall be reasonable in relation to the public health hazard involved and the difficulty of compliance. The cost of containment and cleanup shall be borne by the owner and operator of the premises.

Appendix B-4

Model Health Regulations To Prevent Leaking of Underground Fuel and Chemical Storage Systems

Cape Cod Planning and Economic Development Commission, 1982

Under Chapter 111, Section 31 of the Massachusetts General Laws, the _____ Board of Health hereby adopts the following regulations to protect the ground and surface waters from contamination with liquid fuel or toxic materials from leaking storage tanks. The following regulations apply to all underground fuel and chemical storage systems of 1,000 gallons or greater.

Section 1. Definitions

"Abnormal loss or gain" shall mean a loss or apparent gain in product exceeding 0.5 percent of the volume of product used or sold.

"Operator" shall mean the lessee or person(s) in control of and having responsibility for the daily operation of the facility for the storage and dispensing of flammable and combustible liquids.

"Owner" shall mean the person(s) who owns, as real property, the tank storage system used for the storage and dispensing of flammable and combustible liquids.

Section 2. Tank Registration

(2.1) Every owner of an underground gasoline, fuel, or chemical storage system shall file with the board of health the size, type, age, and location of each tank, and the type of material stored, on or before _____. Evidence of date of purchase and installation, including fire department permit shall be included.

(2.2) Owners of tanks for which evidence of installation date is not available shall at the order of the board of health have such tanks tested or uncovered for inspection. If in the opinion of the agent of the board of health or head of the fire department, the tank is not product-tight, it shall be removed.

Section 3. Inventory Control

(3.1) Every underground storage system shall have a method of accurately gauging the volume contained in the tank and a method of accurately metering the quantity of product removed during service. The metering device shall be maintained in accurate calibration. Storage systems in service at the time of passage of this regulation shall be in compliance within 90 days of the effective date of this regulation.

(3.2) Accurate daily inventory records, as required by Mass. Fire Prevention Regulations-527 CMR 5.05 (3), shall be based on actual daily measurement and recording of tank product and water levels and the daily recording of actual sales, use, and receipts. The inventory records shall include a daily computation of gain or loss. The mere recording of pump meter readings and product delivery receipts shall not constitute adequate inventory records.

(3.3) The owner and operator shall participate in a program of regularly scheduled inventory verification. Frequency of inventory verification shall be as follows: annually, for systems from which less than 25,000 gallons/month of product is sold or used; semiannually for systems from which 25,000-100,000 gallons/month of product is used or sold; quarterly for systems from which more than 100,000 gallons/month is used or sold. Owners shall submit annually to the board of health a certified statement that inventory records have been maintained and reconciled as required by Massachusetts fire prevention regulations. Such records shall be made available to the board of health upon their request.

Where the storage tanks are owned by the operator, inventory verification shall be performed by a certified auditor or other independent qualified person approved by the board of health.

(3.4) All steel tanks shall be subject to a Petro-Tite

(Kent-Moore) Pressure Test or any other pressure test providing equivalent safety and effectiveness 15 years after installation and annually thereafter. The 5 PSI air pressure test is a recognized method of leak detection but is not recommended since it can cause explosions.

(3.5) Nonconforming steel tanks installed prior to January 1, 1960, shall be removed and properly disposed of by _____. All other nonconforming steel tanks installed prior to the effective date of this regulation shall be removed when 20 years old. At such time, the exhumed tank shall be examined for leaks. If a leak exists, an investigation of amount and location of spilled substance shall be undertaken at the expense of the owner. If, in the opinion of the agent of the board of health, the spilled substance poses a significant threat to health and safety, it shall be removed by the owner.

Section 4. Report of Leaks or Spills

(4.1) Any persons who is aware of a spill or abnormal loss of product shall report such spill or loss immediately to the head of the fire department and, within two hours, to the board of health.

(4.2) All leaking tanks *must be emptied within 24 hours of leak detection* and either removed or repaired within a time specified by the board of health, under the direction of the head of the fire department.

(4.3) Service companies shall report to tank owners and the board of health any unaccounted for significant increase in heating fuel consumption that may indicate a leak.

(4.4) All tank installations within four feet of high water table or within 100 feet of a surface water body shall be of fiberglass construction.

Section 5. Tank Selection and Installation

(5.1) All tanks shall be properly installed as per Massachusetts Fire Prevention Regulations and manufacturers specification, under the direction of the head of the fire department. Tanks shall be of approved design and protected from internal and external corrosion. The following tank construction systems are considered to provide adequate corrosion protection: all-fiberglass construction; steel with bonded fiberglass or enamel coating and noncorrosive internal lining, and the Steel Tank Institute 3-Way Protection System. All underground storage of chemicals other than gasoline and fuel shall be contained in tanks approved by the agent of the board of health. Any other system must be shown to provide equivalent protection.

(5.2) Tanks shall be installed by a manufacturer's approved installation contractor.

(5.3) If it is necessary to replace or interior-coat an underground steel tank that developed a corrosion-induced leak, all other steel tanks at the facility that are the same age or older whether or not they are leaking shall be interior-coated or replaced with tanks that meet the requirements of 5.1.

(5.4) If a cathodic protection system is installed, an ongoing monitoring and maintenance program shall be conducted. If sacrificial anodes have been installed, their proper operation shall be confirmed by a qualified person at least once a year.

(5.5) The operator shall notify the head of the fire department prior to the commencement of tank installation. The head of the fire department or the board of health may require repair of protective coatings prior to installation or final cover.

Section 6. Product Storage at Residential Sites

(6.1) Following the effective date of this regulation, the installation of underground fuel, gasoline, or other chemical storage tanks on single-family or two-family residential sites is prohibited.

(6.2) All fuel, gasoline, or other chemical tanks in service at single-family or two-family residential sites on the effective date of this regulation shall be removed from service 30 years after the date of installation. If the date of installation is unknown, it shall be assumed to be January 1, 1960.

Section 7. Proximity to Water Supplies

(7.1) The installation of subsurface fuel, gasoline, or other chemical storage systems within 2,000 feet of a public water supply well is prohibited.

(7.2) The board of health may require the installation of one or more groundwater observation wells at any site where fuel, gasoline, or other chemical is stored underground within 2,000 feet of a public or private water supply well. Water samples from such observation wells may be required by the board of health at any reasonable time and shall be analyzed at the expense of the owner at the order of the board of health.

Section 8. Costs

In every case, the operator shall assume responsibility for costs incurred necessary to comply with this regulation.

Section 9. Variances

(9.1) Variances from this regulation may be granted by the board of health after a hearing at which the applicant establishes that the installation or use of an underground storage tank will not adversely affect public or private water resources.

(9.2) In granting a variance, the board will take into consideration the direction of the groundwater flow, soil conditions, depth to groundwater, size, shape, and slope of the lot, existing and known future water supplies.

APPENDIX H

WHPA PARCEL LIST

Plat No. 1			Plat No. 1		
Lot	Sq. Ft.	Acreage	Lot	Sq. Ft.	Acreage
4	598950	13.75	92	79715	1.83
5	927392	21.29	93	10760	0.25
6	412949	9.48	105	10904	0.25
9	701316	16.10	106	19720	0.45
10	537966	12.35	108	75794	1.74
12	107593	2.47	111	338026	7.76
13	1077239	24.73	112	87991	2.02
33	243936	5.60	113	52272	1.20
34	217800	5.00	114	56192	1.29
35	1715393	39.38	125	113692	2.61
36	520542	11.95	127	149411	3.43
37	1553567	35.67	129	80586	1.85
39	507474	11.65	130	81022	1.86
41	26136	0.60	131	87991	2.02
42	67082	1.54	132	68825	1.58
43	175111	4.02	134	131987	3.03
44	639025	14.67	138	32234	0.74
45	445619	10.23	139	83200	1.91
46	148104	3.40	140	74488	1.71
47	756202	17.36	141	120661	2.77
48	24255	0.56	142	71874	1.65
52	64033	1.47	143	169448	3.89
53	21150	0.49	146	98881	2.27
54	20115	0.46	148	58806	1.35
55	22185	0.51	150	72745	1.67
56	341075	7.83	151	72963	1.68
57	1080288	24.80	152	14812	0.34
58	21735	0.50	153	173804	3.99
59	42248	0.97	155	90169	2.07
60	22680	0.52	156	20677	0.47
61	18532	0.43	158	43996	1.01
62	24850	0.57	160	34920	0.80
63	27443	0.63	161	67082	1.54
64	15410	0.35	162	15000	0.34
65	74305	1.71	163	14300	0.33
66	17792	0.41	164	10890	0.25
72	14705	0.34	165	228690	5.25
73	6717	0.15	166	91040	2.09
74	114127	2.62	167	9731	0.22
75	17500	0.40	169	8580	0.20
77	31000	0.71	170	8375	0.19
78	16250	0.37	171	27443	0.63
79	85378	1.96	173	20200	0.46
80	15139	0.35	174	10390	0.24
81	140699	3.23	175	14959	0.34
82	3120	0.07	176	213880	4.91
83	23245	0.53	177	13400	0.31
84	12342	0.28	178	13553	0.31
85	12725	0.29	179	6114	0.14
90	14000	0.32	180	5988	0.14
91	12455	0.29	181	6377	0.15

Plat No. 1			Plat No. 1		
Lot	Sq. Ft.	Acreage	Lot	Sq. Ft.	Acreage
182	15480	0.36	260	8000	0.18
183	12165	0.28	261	23600	0.54
184	13500	0.31	262	22950	0.53
185	17947	0.41	265	11488	0.26
186	34800	0.80	266	7484	0.17
187	103237	2.37	267	7440	0.17
188	17795	0.41	268	6209	0.14
189	435600	10.00	269	5858	0.13
190	84942	1.95	270	8437	0.19
192	14979	0.34	271	6860	0.16
194	33925	0.78	272	7210	0.17
196	20660	0.47	273	6090	0.14
201	22355	0.51	274	6923	0.16
203	46174	1.06	275	9480	0.22
205	16272	0.37	276	6475	0.15
207	32234	0.74	277	7000	0.16
208	77537	1.78	278	7521	0.17
209	116305	2.67	279	23350	0.54
210	27653	0.63	288	20000	0.46
211	20473	0.47	289	74485	1.71
212	9583	0.22	291	23958	0.55
213	28314	0.65	293	41758	0.96
214	28314	0.65	294	34000	0.78
215	29000	0.67	299	100624	2.31
216	33568	0.77	300	6955	0.16
217	33568	0.77	302	36914	0.85
218	22216	0.51	305	114998	2.64
219	27600	0.63	306	7800	0.18
220	42689	0.98	307	5511	0.13
221	60000	1.38	310	771883	17.72
222	20038	0.46	311	14720	0.34
225	46599	1.07	312	10250	0.24
228	14235	0.33	313	22091	0.51
229	54014	1.24	314	24902	0.57
230	29185	0.67	315	14810	0.34
233	19943	0.46	316	14810	0.34
237	40075	0.92	325	49223	1.13
238	20038	0.46	327	10000	0.23
239	41900	0.96	329	87991	2.02
240	20470	0.47	330	40946	0.94
241	22216	0.51	339	22900	0.53
243	39640	0.91	340	30000	0.69
244	20038	0.46	341	20038	0.46
245	20825	0.48	342	10000	0.23
246	52708	1.21	343	24525	0.56
247	20000	0.46	344	27780	0.64
248	20473	0.47	345	4144	0.10
252	20875	0.48	346	37462	0.86
254	13600	0.31	347	37636	0.86
258	10000	0.23	348	17249	0.40
259	20000	0.46	349	32890	0.76

Plat No. 1

Lot	Sq. Ft.	Acreage
350	10019	0.23
353	62291	1.43
354	8000	0.18
355	34710	0.80
359	141134	3.24
360	32323	0.74
361	25000	0.57
362	72310	1.66
363	23300	0.53
365	47045	1.08
371	30482	0.70
372	197327	4.53
374	78000	1.79
375	24630	0.57
377	56535	1.30
378	21335	0.49
380	21924	0.50
381	24000	0.55
382	21780	0.50
391	18900	0.43
396	24000	0.55
397	30000	0.69
398	20000	0.46
399	60984	1.40
400	30484	0.70
401	21780	0.50
402	21120	0.48
403	23237	0.53

Plat No. 1

Lot	Sq. Ft.	Acreage
404	21780	0.50
405	24000	0.55
406	40800	0.94
407	33326	0.77
408	58370	1.34
409	35120	0.81
410	21780	0.50
419	22430	0.51
422	82764	1.90
424	47480	1.09
425	70567	1.62
426	43770	1.00
427	36170	0.83
428	21344	0.49
429	60418	1.39
430	76622	1.76
431	44997	1.03
432	44997	1.03
433	43212	0.99
434	40206	0.92
435	43255	0.99
436	40922	0.94
437	20000	0.46
438	24000	0.55
440	428630	9.84
447	65035	1.49
448	65035	1.49
449	54886	1.26

Plat No. 2

Lot	Sq. Ft.	Acreage
7A	130244	2.99
8	57064	1.31
9	163350	3.75
9A	140263	3.22
10	116305	2.67
11	205603	4.72
18	1403068	32.21
19	549727	12.62
23	9000	0.21
24	30928	0.71
29	22525	0.52
30	15050	0.35
30	27800	0.64
32	75794	1.74
33	264409	6.07
34	6513	0.15
35	38768	0.89
35	22651	0.52
36	114127	2.62
37	15000	0.34
38	190793	4.38
40	60984	1.40
41	1637420	37.59
42	11202	0.26
43	21396	0.49
46	20038	0.46
48	146362	3.36
49	23736	0.54
50	40946	0.94
51	13068	0.30
52	89298	2.05
53	26800	0.62
58	91476	2.10
61	8956	0.21
62	17868	0.41
63	77101	1.77
65	18386	0.42
66	32580	0.75
68	7755	0.18
69	67082	1.54
70	32250	0.74
73	113256	2.60
73A	74052	1.70
74	136343	3.13
75	13610	0.31
76	121968	2.80
77	41818	0.96
78	121968	2.80
79	19360	0.44
82	23240	0.53
84	27300	0.63

Plat No. 2

Lot	Sq. Ft.	Acreage
86	15407	0.35
89	17730	0.41
90	8800	0.20
91	23717	0.54
92	56628	1.30
93	13185	0.30
94	34338	0.79
102	22477	0.52
104	22216	0.51
113	11683	0.27
114	14878	0.34
121	10000	0.23
124	35284	0.81
125	27007	0.62
130	66211	1.52
131	318859	7.32
132	204732	4.70
133	155074	3.56
134	72310	1.66
140	28750	0.66
147	188179	4.32
157	39691	0.91
166	20000	0.46
167	37331	0.86
177	33600	0.77
178	20000	0.46
181	19100	0.44
184	21038	0.48
186	30380	0.70
192	16455	0.38
193	13430	0.31
194	22484	0.52
195	23916	0.55
196	12059	0.28
197	18600	0.43
198	14386	0.33
199	12265	0.28
201	22481	0.52
202	23020	0.53
203	24810	0.57
204	23766	0.55
204	23711	0.54
206	23634	0.54
207	21976	0.50
210	30810	0.71
211	30810	0.71
212	33159	0.76
217	35884	0.82
223	31430	0.72
229	20640	0.47
231	64430	1.48

Plat No. 2

Lot	Sq. Ft.	Acreage
233	20640	0.47
235	20477	0.47
246	32114	0.74
247	32040	0.74
248	125017	2.87
250	101059	2.32
253	64904	1.49
256	70567	1.62
257	86249	1.98
258	78844	1.81
259	76666	1.76
260	74052	1.70
266	75359	1.73
267	65340	1.50
268	78844	1.81
269	76666	1.76
270	71438	1.64
271	65776	1.51
272	179903	4.13
273	208217	4.78
274	193842	4.45
275	304920	7.00
276	82764	1.90
278	100188	2.30
279	228254	5.24
280	130680	3.00
281	67082	1.54
282	52272	1.20
284	55757	1.28
285	47480	1.09

Plat No. 2

Lot	Sq. Ft.	Acreage
286	73181	1.68
287	64904	1.49
288	66647	1.53
289	132422	3.04
290	88862	2.04
291	66647	1.53
292	119790	2.75
293	104980	2.41
294	65340	1.50
295	72310	1.66
296	71438	1.64
297	85378	1.96
298	775368	17.80
299	73616	1.69
300	122839	2.82
301	121532	2.79
303	61855	1.42
304	67082	1.54
305	66211	1.52
306	80150	1.84
307	65776	1.51
308	64904	1.49
309	65776	1.51
310	132858	3.05
311	64904	1.49
312	65776	1.51
313	68389	1.57
314	68389	1.57
315	81457	1.87
316	64904	1.49
317	67518	1.55

Plat No. 4			Plat No. 4		
Lot	Sq. Ft.	Acreage	Lot	Sq. Ft.	Acreage
1	96703	2.22	80	36590	0.84
2	57064	1.31	81	40946	0.94
3	44431	1.02	84	43560	1.00
4	53143	1.22	85	6668	0.15
5	32295	0.74	86	213444	4.90
6	112820	2.59	87	21780	0.50
7	126324	2.90	88	11996	0.28
8	108029	2.48	90	21780	0.50
9	756202	17.36	91	23832	0.55
10	1080288	24.80	93	9700	0.22
11	74488	1.71	95	129373	2.97
12	22045	0.51	96	10454	0.24
13	28425	0.65	97	5000	0.11
14	68580	1.57	98	23250	0.53
15	31800	0.73	102	15000	0.34
16	9600	0.22	105	16263	0.37
17	51836	1.19	107	16000	0.37
18	19594	0.45	110	23958	0.55
19	11340	0.26	111	8200	0.19
20	11500	0.26	118	10093	0.23
21	12457	0.29	119	14428	0.33
22	15835	0.36	120	11151	0.26
23	37800	0.87	121	5600	0.13
24	16910	0.39	122	17112	0.39
25	47430	1.09	123	20461	0.47
26	43530	1.00	124	6842	0.16
29	50094	1.15	125	11477	0.26
30	20909	0.48	126	8548	0.20
34a	152460	3.50	127	20029	0.46
36	8683	0.20	128	12850	0.29
38	12188	0.28	129	12355	0.28
39	40465	0.93	130	44135	1.01
40	198198	4.55	131	9070	0.21
41	1687950	38.75	132	8670	0.20
42	653400	15.00	134	16252	0.37
45	2613164	59.99	135	19176	0.44
51	41655	0.96	136	18884	0.43
57	3470425	79.67	137	19699	0.45
58	520978	11.96	138	24530	0.56
59	38768	0.89	139	15385	0.35
65	40290	0.92	140	14500	0.33
66	20148	0.46	141	31435	0.72
67	98170	2.25	142	12532	0.29
68	36155	0.83	143	12310	0.28
69	166399	3.82	144	196000	4.50
71	21912	0.50	145	12497	0.29
72	47916	1.10	147	40000	0.92
74	19410	0.45	148	20000	0.46
75	246114	5.65	149	80000	1.84
76	87120	2.00	150	20000	0.46
79	17424	0.40	151	15085	0.35

Plat No. 4

Lot	Sq. Ft.	Acreage
152	9072	0.21
153	20475	0.47
154	28000	0.64
155	15873	0.36
156	46746	1.07
157	33433	0.77
159	30000	0.69
161	40573	0.93
162	39193	0.90
163	65776	1.51
165	27699	0.64
166	18789	0.43
168	67954	1.56
169	5775	0.13
171	22549	0.52
173	23439	0.54
174	13400	0.31
175	10000	0.23
176	15900	0.37
177	17500	0.40
178	20000	0.46
179	18883	0.43
181	25315	0.58
182	18121	0.42
184	217800	5.00
185	14464	0.33
186	10000	0.23
187	14567	0.33
188	10000	0.23
191	14991	0.34
192	25976	0.60
193	24116	0.55
194	25171	0.58
196	20883	0.48
197	10000	0.23
199	36550	0.84
203	296208	6.80
205	13189	0.30
206	13860	0.32
207	22800	0.52
208	13766	0.32
209	15600	0.36
210	15560	0.36
211	20500	0.47
212	18500	0.42
213	15930	0.37
214	19540	0.45
215	22300	0.51
216	58034	1.33
217	263102	6.04
219	11930	0.27

Plat No. 4

Lot	Sq. Ft.	Acreage
220	28160	0.65
221	27144	0.62
223	177289	4.07
224	327571	7.52
225	33019	0.76
227	15000	0.34
228	40800	0.94
229	158994	3.65
230	18932	0.43
236	30964	0.71
237	327571	7.52
239	20667	0.47
240	25630	0.59
242	16210	0.37
247	20906	0.48
248	69958	1.61
249	23866	0.55
250	22616	0.52
252	22800	0.52
255	40230	0.92
267	15121	0.35
268	13809	0.32
269	22730	0.52
272	21000	0.48
273	13000	0.30
275	36155	0.83
276	13068	0.30
278	23907	0.55
279	21363	0.49
280	55813	1.28
286	21707	0.50
287	20230	0.46
288	21591	0.50
289	20000	0.46
290	452153	10.38
292	48532	1.11
294	27549	0.63
296	68825	1.58
297	24557	0.56
299	24311	0.56
303	24750	0.57
305	21900	0.50
307	22315	0.51
309	41700	0.96
310	30722	0.71
312	76666	1.76
313	40786	0.94
314	51980	1.19
315	27853	0.64
316	27670	0.64
317	57499	1.32

Plat No. 4

Lot	Sq. Ft.	Acreage
321	22519	0.52
322	20000	0.46
323	9148	0.21
324	24000	0.55
325	28700	0.66
327	35557	0.82
328	27851	0.64
329	31709	0.73
330	20000	0.46
331	24500	0.56
334	41430	0.95
336	33450	0.77
337	20965	0.48
338	22140	0.51
339	22545	0.52
340	24335	0.56
341	20000	0.46
343	28047	0.64
344	41561	0.95
345	20825	0.48
346	69696	1.60
347	35512	0.82
349	65007	1.49
351	25669	0.59
352	76053	1.75
353	20115	0.46
355	13225	0.30
355	99317	2.28
356	26230	0.60
357	30722	0.71
358	27200	0.62
359	48117	1.10
360	24098	0.55
361	24240	0.56
363	53730	1.23
367	29259	0.67
368	27233	0.63
369	27085	0.62
370	31843	0.73
371	20497	0.47
372	31847	0.73
373	21573	0.50
374	23942	0.55
375	10242	0.24
377	23077	0.53
378	27751	0.64
379	21294	0.49
380	21605	0.50
381	58370	1.34

Plat No. 4

Lot	Sq. Ft.	Acreage
383	39117	0.90
384	23100	0.53
385	24000	0.55
386	25738	0.59
387	27443	0.63
388	20150	0.46
390	23844	0.55
392	22173	0.51
393	20012	0.46
394	26189	0.60
395	21536	0.49
396	27200	0.62
401	21146	0.49
402	16378	0.38
403	30608	0.70
404	20997	0.48
405	24636	0.57
406	23152	0.53
407	65776	1.51
408	24000	0.55
409	10700	0.25
410	27549	0.63
411	25317	0.58
412	21682	0.50
413	24000	0.55
414	334541	7.68
415	24426	0.56
416	24868	0.57
417	23940	0.55
420	40370	0.93
421	43430	1.00
422	48512	1.11
423	61918	1.42
424	108029	2.48
425	43664	1.00
426	46619	1.07
427	48307	1.11
428	49574	1.14
429	46153	1.06
430	41015	0.94
432	78014	1.79
433	117612	2.70
434	36144	0.83
435	87991	2.02
436	723532	16.61
438	65001	1.49
439	65001	1.49
440	65001	1.49
441	65002	1.49

Plat No. 5

Lot	Sq. Ft.	Acreage
1	22985	0.53
2	190793	4.38
4	364162	8.36
5	34160	0.78
6	16400	0.38
7	25800	0.59
8	19020	0.44
9	15575	0.36
10	20000	0.46
11	25000	0.57
12	18860	0.43
13	18284	0.42
14	12300	0.28
15	15760	0.36
16	31000	0.71
17	17701	0.41
19	1641776	37.69
20	57064	1.31
22	39345	0.90
32	1523729	34.98
33	212137	4.87
38	117612	2.70
40	14375	0.33
41	286189	6.57
105	26572	0.61
131	4400	0.10
132	35100	0.81
133	26122	0.60
134	26540	0.61
135	28113	0.65
136	30195	0.69
137	7085	0.16
138	11722	0.27
139	12906	0.30
140	18777	0.43
141	19228	0.44
142	19529	0.45
143	18022	0.41
144	24477	0.56
145	27459	0.63
146	31317	0.72
147	21385	0.49
148	21150	0.49
149	21150	0.49
150	23500	0.54
151	25850	0.59
170	10000	0.23
171	27822	0.64
173	114127	2.62
174	12180	0.28
175	24829	0.57

Plat No. 5

Lot	Sq. Ft.	Acreage
176	96268	2.21
177	77972	1.79
178	23692	0.54
181	7050	0.16
183	7900	0.18
185	8089	0.19
186	12300	0.28
187	28500	0.65
188	7305	0.17
189	11175	0.26
190	15330	0.35
191	10000	0.23
192	15670	0.36
199	20437	0.47
201	20179	0.46
204	10100	0.23
206	26569	0.61
208	30000	0.69
209	21236	0.49
230	20878	0.48
231	34124	0.78
233	15030	0.35
234	12285	0.28
235	16075	0.37
237	12900	0.30
238	17690	0.41
240	12639	0.29
243	30169	0.69
245	11170	0.26
248	18000	0.41
252	26398	0.61
264	7500	0.17
265	12123	0.28
269	7600	0.17
277	174240	4.00
281	9370	0.22
282	27571	0.63
283	16959	0.39
284	45092	1.04
285	45094	1.04
286	19242	0.44
295	10190	0.23
296	9896	0.23
298	12207	0.28
299	10332	0.24
300	10020	0.23
301	9702	0.22
303	9660	0.22
304	15000	0.34
305	21485	0.49
309	9952	0.23

Plat No. 5

Lot	Sq. Ft.	Acreage
310	15000	0.34
313	14666	0.34
314	15600	0.36
315	17550	0.40
316	13500	0.31
317	21000	0.48
318	20259	0.47
319	27434	0.63
320	29595	0.68
321	22423	0.51
322	20378	0.47
323	22344	0.51
324	11839	0.27
325	42767	0.98
326	20390	0.47
327	21181	0.49
331	6211	0.14
332	6306	0.14
333	6402	0.15
334	6325	0.15
335	5823	0.13
336	6016	0.14
338	12996	0.30
339	6482	0.15
340	5081	0.12
341	5101	0.12
342	5101	0.12
344	6313	0.14
353	11670	0.27
354	692168	15.89
356	11500	0.26
358	7640	0.18
359	7380	0.17
365	4911	0.11
366	39204	0.90
367	13920	0.32
370	19690	0.45
372	15200	0.35
373	18020	0.41
374	7515	0.17
379	18546	0.43
380	13344	0.31

Plat No. 5

Lot	Sq. Ft.	Acreage
381	12952	0.30
383	11740	0.27
384	15196	0.35
386	29555	0.68
387	38692	0.89
388	22497	0.52
389	155074	3.56
390	10000	0.23
391	10000	0.23
393	29432	0.68
395	11300	0.26
396	10260	0.24
397	23500	0.54
398	21620	0.50
399	25500	0.59
400	11500	0.26
401	40288	0.92
402	10900	0.25
403	18657	0.43
404	19076	0.44
405	12037	0.28
406	24799	0.57
408	22018	0.51
409	45724	1.05
412	60910	1.40
413	38336	0.88
414	237838	5.46
415	147233	3.38
417	349351	8.02
418	167706	3.85
419	18526	0.43
420	18656	0.43
423	138956	3.19
424	18368	0.42
429	42562	0.98
437	45738	1.05
444	20854	0.48
446	22930	0.53
448	55555	1.28
449	32245	0.74
456	12415	0.29
468	23087	0.53

Plat No. 7

Lot	Sq. Ft.	Acreage
12	1492801	34.27
14	68389	1.57
15	1314641	30.18
16	3739190	85.84
21	42689	0.98
22	176418	4.05
23	1319868	30.30
24	179467	4.12
25	215622	4.95
27	69260	1.59
27a	56628	1.30
28	413820	9.50
29	426888	9.80
39	121968	2.80
44	54886	1.26
44	54886	1.26
45	378972	8.70
47	32550	0.75
49	131551	3.02
52	260053	5.97
53	53579	1.23
55	126324	2.90
57	87120	2.00
58	130680	3.00
59	265716	6.10
60	113256	2.60
61	95832	2.20
62	13504	0.31
63	4356	0.10

Plat No. 7

Lot	Sq. Ft.	Acreage
65	84942	1.95
66	80586	1.85
69	41382	0.95
75	43560	1.00
76	39989	0.92
91	33035	0.76
92	33535	0.77
92	13068	0.30
93	33675	0.77
94	67980	1.56
95	236966	5.44
96	25154	0.58
97	27147	0.62
98	20446	0.47
99	20190	0.46
116	198634	4.56
117	175111	4.02
118	179903	4.13
119	196891	4.52
124	69260	1.59
139	64904	1.49
140	116741	2.68
141	66211	1.52
142	228254	5.24
143	120226	2.76
144	69696	1.60
145	64904	1.49
148	83200	1.91
149	53579	1.23

Plat No. 8

Lot	Sq. Ft.	Acreage
4	52272	1.20
5	60984	1.40
6	10890	0.25
7	118048	2.71
8	1829956	42.01
12	658192	15.11
13	74488	1.71
16	1039342	23.86
17	2724678	62.55
20	143748	3.30
26	497401	11.42
27	428195	9.83
39	517057	11.87
40	1461002	33.54
46	21780	0.50
53	7300	0.17
54	86249	1.98
59	90169	2.07
60	304920	7.00
61	43560	1.00
62	254826	5.85
64	3746160	86.00
70	148104	3.40
75	32639	0.75
77	160301	3.68
78	56628	1.30
79	60000	1.38
80	40000	0.92
82	41382	0.95
83	42484	0.98
89	49658	1.14
90	39204	0.90
93	27000	0.62
94	41520	0.95
107	30000	0.69
108	29670	0.68
109	44000	1.01
110	43000	0.99
111	40166	0.92
112	40000	0.92
113	159865	3.67
116	38585	0.89
117	29536	0.68
118	2088702	47.95
119	21097	0.48
120	40000	0.92
121	21899	0.50
122	20000	0.46
123	40277	0.92
124	40625	0.93
125	24610	0.56

Plat No. 8

Lot	Sq. Ft.	Acreage
126	20969	0.48
129	26662	0.61
131	21593	0.50
132	19995	0.46
134	21240	0.49
138	339768	7.80
139	24197	0.56
141	72171	1.66
147	148975	3.42
150	21450	0.49
152	21900	0.50
154	28820	0.66
155	25611	0.59
156	20801	0.48
158	55757	1.28
168	55757	1.28
169	25172	0.58
170	40511	0.93
171	23952	0.55
172	48787	1.12
173	65340	1.50
175	27577	0.63
177	43693	1.00
178	28841	0.66
180	67082	1.54
181	37474	0.86
183	40299	0.93
190	40014	0.92
193	25204	0.58
198	55004	1.26
199	100188	2.30
200	54886	1.26
201	43560	1.00
202	43560	1.00
203	245243	5.63
210	376358	8.64
213	51836	1.19
227	307098	7.05
232	67954	1.56
233	68389	1.57
234	46174	1.06
238	65340	1.50
239	40005	0.92
240	145926	3.35
243	60548	1.39
244	115870	2.66
262	161608	3.71
263	138956	3.19
265	67518	1.55
266	81457	1.87

Plat No. 17

Lot	Sq. Ft.	Acreag
7	430808	9.89
8	802375	18.42
9	260053	5.97
10	39640	0.91
14	467834	10.74
15	21344	0.49
16	47480	1.09
17	21780	0.50
18	13068	0.30
22	2360516	54.19
25	54450	1.25
26	49223	1.13
27	104544	2.40
29	20516	0.47
30	150282	3.45
31	3140676	72.10
32	151589	3.48
34	87120	2.00
35	115870	2.66
36	47045	1.08
37	117176	2.69
38	240016	5.51
39	141570	3.25
40	58127	1.33
42	43560	1.00
43	44867	1.03
44	196020	4.50
45	31363	0.72
46	14810	0.34
47	3404650	78.16
58	66800	1.53
59	23395	0.54
66	31363	0.72
67	426888	9.80
70	182516	4.19
73	435600	10.00
74	61420	1.41
75	89298	2.05
76	7492	0.17
78	3242	0.07
79	49223	1.13
80	64469	1.48
81	53143	1.22
83	14251	0.33
84	57064	1.31
87	123275	2.83
88	13520	0.31
89	137650	3.16
90	14882	0.34
91	12050	0.28
94	16217	0.37

Plat No. 17

Lot	Sq. Ft.	Acreag
95	9727	0.22
98	11250	0.26
99	28860	0.66
102	9320	0.21
103	10202	0.23
104	53579	1.23
105	8020	0.18
106	435600	10.00
107	19166	0.44
108	9728	0.22
109	10874	0.25
110	22798	0.52
113	52000	1.19
114	27821	0.64
115	25670	0.59
118	10910	0.25
120	24100	0.55
122	13670	0.31
124	12900	0.30
129	36540	0.84
131	5580	0.13
132	18352	0.42
133	15159	0.35
134	19200	0.44
138	24394	0.56
140	60984	1.40
141	18000	0.41
142	90492	2.08
143	19200	0.44
145	12970	0.30
146	20000	0.46
147	66211	1.52
149	12070	0.28
150	15165	0.35
151	23522	0.54
153	13000	0.30
155	6680	0.15
156	16000	0.37
158	26000	0.60
160	19200	0.44
161	19200	0.44
164	15000	0.34
166	19200	0.44
167	66313	1.52
169	429502	9.86
171	15171	0.35
172	47916	1.10
177	12341	0.28
192	65776	1.51
193	73616	1.69
196	8563	0.20

Plat No. 17

Lot	Sq. Ft.	Acreag
197	18731	0.43
198	49151	1.13
199	110642	2.54
200	37480	0.86
201	95832	2.20
207	10743	0.25
209	64033	1.47
210	26000	0.60
212	76230	1.75
213	13000	0.30
214	6628	0.15
231	94090	2.16
232	64578	1.48
235	23958	0.55
237	331056	7.60
240	121532	2.79
242	39345	0.90
243	81022	1.86
244	199069	4.57
250	73616	1.69
256	78408	1.80
257	40000	0.92
258	19200	0.44
259	42800	0.98
261	43684	1.00
263	15750	0.36
264	96703	2.22
266	52571	1.21
271	89734	2.06
279	40075	0.92
280	128938	2.96
281	119790	2.75
282	191664	4.40

BIBLIOGRAPHY

American Water Works Association. 1984. Emergency Planning for Potable Water Suppliers. Denver, CO.

Arthur D. Little Inc., Beta Engineering Inc., CH2M, H2O Engineering, Consulting Associates Inc., Wallace Floyd Associates Inc. 1990. *Water Supply Analysis for the State of Rhode Island.*

Ash, Ronald M. and Associates Inc. 1983. *Engineering Report on Water System Improvements at the North Smithfield Industrial Park.* Prepared for the North Smithfield Industrial Development Corporation.

Barcelona, Michael [et al.]. 1988. *Handbook of Groundwater Protection.* Science Information Center, NY. Hemisphere Publishing Corp.

Bobrowski, Mark and Jackson, Nancy, Rural New England, Inc. 1985. *Negotiated Groundwater Protection Strategies.* Waldoboro ME.

Bricknell, Mark. 1982. *Assessment of Groundwater Contamination from a Municipal Landfill and Evaluation of Remedial Measures.* Thesis (M.S.), University of Rhode Island. Kingston, RI.

Calhoun, Yael. 1988. *Underground Storage Tanks: A Guide for Local Officials.* Town of South Kingstown Planning Department, South Kingstown RI.

Camp Dresser and McKee Inc. 1990. *Water Quality Protection Plan for The City Of Woonsocket.* Providence, RI.

Canter, Larry and Knox, R.C. 1985. *Groundwater Pollution Control.* Lewis Publishers, Chelsea MI.

Cape Cod Aquifer Management Project. 1988. *Guide to Contamination Sources for Wellhead Protection.* (Cape Cod, MA: CCAMP).

Citizen's Clearinghouse for Hazardous Wastes. 1985. *Deep Well Injection: An Explosive Issue.* The Clearinghouse, Arlington VA.

Connecticut, State of, Department of Environmental Protection. 1990. *Protecting Connecticut's Groundwater: A Guide to Groundwater Protection for Local Officials.*

_____, Department of Environmental Protection. 1991. *Connecticut Water Supply Plan Emergency Provisions.*

Conservation Foundation, The. 1987. *Groundwater Protection.* Washington D.C.

Doenges, James M., et. al. 1990. Land-Tech Consultants, Inc. *Carrying Capacity of Public Water Supply of Watersheds: A Literature Review of Impacts on Water Quality From Residential Development.* Prepared for The Litchfield Hills Council of Elected Officials, Litchfield CT.

Dunne, Thomas and Leopold, Luna B. 1978. *Water in Environmental Planning.* W.H. Freeman and Co. New York.

Hayden, Harding and Buchanan, Inc. 1969. *Water Pollution Abatement Program for North Smithfield.* Boston MA.

_____. 1969. *Water System Improvements for North Smithfield.* Boston MA.

Henderson, Timothy R., Traubermann, Jeffrey and Gallagher, Tara. 1984. *Groundwater: Strategies for State Action.* Environmental Law Institute. Washington D.C.

Horsley, Scott W. 1990. *Water Resource Protection Strategies: A Summary of Options for Local Government Officials to Protect Ground and Surface Water Resources.* Presented at the Save The Bay Growth Management for Rhode Island Conference.

Horsley, Scott W. and Jon D. Witten, IEP Inc. 1987. *The Town of Duxbury MA Aquifer Protection Plan: A Case Study In Innovative Water Quality Protection Strategies.* Barnstable MA.

Horsley Witten Hegemann, Inc. 1990. *An Evaluation of Critical Area Protection in RI.* Prepared for the Narragansett Bay Project, Providence RI.

IEP, Inc. 1989. *Regulatory Recommendations: Groundwater Protection.*

Jaffe, Martin S. and DiNovo, Frank. 1987. *Local Groundwater Protection.* (Washington, D.C.: American Planning Association)

Johnston, H. E. and Baer, M. J. In Press. 1987. *Rhode Island Water Supply and Use.* In U.S. Geological Survey. National Water Summary. U.S. Geological Survey Water-Supply Paper 2325.

Kiely Associates. 1974. *Environmental Assessment Statement: Sanitary Sewer Program Town of North Smithfield, RI.*

Ku, H. F. and Simmons, D. L. 1986. *Effect of Urban Stormwater Runoff of Groundwater Beneath Recharge Basins on Long Island, New York.* U.S. Geological Survey Water-Resources Investigations Report 85-4088.

Lang, S.L. 1961. *Appraisal of Ground-Water Reservoir Areas in Rhode Island*: Rhode Island Water Resource Coordinating Board, Geological Bulletin 11.

Lowry, Jerry D. 1987. *Radon at Home.* Civil Engineering.

Maguire Group Inc. 1991. *North Smithfield Industrial Site Survey.* Prepared for the Town of North Smithfield Industrial Development Commission.

Mason, C. O., Aldinger, P. B., Wright, T. E., and Forkey, B. 1986. *Evaluating Private Well Contamination in Rhode Island.* In Proceedings of the Third Annual Eastern Regional Conference, Springfield, Mass., July 28-30, NWWA.

Maxwell, Mary K. 1988. *The Regulation of Underground Storage Tanks.* Graduate Curriculum in Community Planning and Area Development, University of Rhode Island, Kingston RI.

McGregor, Gregor I. 1986. *Laws and Regulations Protecting Massachusetts Groundwater.* Mcgregor, Shea and Doliner, Boston, MA.

Metropolitan Area Planning Council. 1982. *Groundwater Protection: A Guide for Communities.* Boston, MA.

Murphy, James. 1985. Connecticut Department of Environmental Protection Water Compliance Unit. *Groundwater Protection: A Planning Process for Local Government.* Hartford CT.

Myers, Jennie C. 1988. *Governance of Non-Point Source Inputs to Narragansett Bay: A Plan for Coordinated Action.* Prepared for the RIDEM/EPA Narragansett Bay Project, Providence, RI.

National Research Council. Committee on Groundwater Quality Protection. 1986. *Groundwater Quality Protection: State and Local Strategies.* National Academy Press, Washington D.C.

North Smithfield Planning Board. *1990 North Smithfield Comprehensive Plan.* Prepared by Burk Ketcham and Associates.

North Smithfield, Town of, *Zoning Ordinance and Subdivision Regulations.*

Page, William G. 1987. *Planning for Groundwater Protection.* Academic Press, Orlando FL.

Patrick, Ruth, Ford, Emily and Quarles, John. 1987. *Groundwater Contamination in the United States.* University of Pennsylvania Press, Philadelphia PA.

Pettyjohn, Wayne A., author/ed. 1985. *Protection of Public Water Supplies from Groundwater Contamination.* Center for Environmental Research Information, Cincinnati OH.

Princeton University Water Resources Program. 1984. *Groundwater Contamination from Hazardous Wastes.* Prentice-Hall, Englewood Cliffs NJ.

Quinn, A.W. 1971. *Bedrock Geology of Rhode Island*: U.S. Geological Survey Bulletin 1295.

Rhode Island, State of, Department of Administration. 1987. *Wastewater Management Districts...A Starting Point.*

_____, Division of Planning. 1990. *Scituate Reservoir Watershed Management Plan.* Report Number 70.

_____, Division of Planning. 1988. *Water Supply Policies for Rhode Island.* Report Number 61.

Rhode Island, State of, Department of Environmental Management, Division of Water Resources. 1988. *Water Quality Regulations for Water Pollution Control.*

_____, Department of Environmental Management in Cooperation with the U.S. Geological Survey. 1985. *Classification And Delineation Of Recharge Areas To The Blackstone And Lower Blackstone-Moshassuck Ground-Water Reservoirs In Northeastern Rhode Island.* Recharge Area Report 1.

_____, Office of Environmental Coordination. 1988. *Recommendations Of The Stormwater Management And Erosion Control Committee Regarding The Development And Implementation Of Technical Guidelines For Stormwater Management.*

_____, Office of Environmental Coordination. 1989. *Rhode Island's Nonpoint Source Management Plan.*

_____, Office of Environmental Coordination. 1990. *State of the State's Waters 305 (b) Report.*

_____, Division of Groundwater and Freshwater Wetlands, Groundwater Section. 1990. *Rhode Island Wellhead Protection Program.*

_____, Division of Groundwater and Freshwater Wetlands, Groundwater Section. 1989. *Groundwater Protection Strategy.*

Rhode Island, State of, Emergency Response Commission. 1989. The Scituate Reservoir Hazardous Material Spill Contingency Plan.

Rhode Island, Statewide Planning Program. 1981. *Land Uses and Groundwater Quality.* Technical Paper #98, State of Rhode Island Division of Statewide Planning. Providence RI.

_____, Statewide Planning Program. 1978. *Detailed Analysis of Landfill Impacts on Water Quality,* prepared by Roy F. Weston, Inc. Providence RI.

_____, Statewide Planning Program. 1984. *State Guide Plan Overview.* State Guide Plan Element 010, Report #48. Revised 1988, Providence, RI.

_____, Statewide Planning Program. 1982. *Summary And Analysis Of State Law Relating To Water Supply And Drinking Water Quality.* Technical Paper Number 104.

Rhode Island, State of, Department of Health, Division of Water Supply. 1989. *Chemical Results Slatersville Public Supply.*

_____, Department of Health, Division of Water Supply. 1988. Emergency Drinking Water Plan.

Schueler, Thomas R. 1987. *Controlling Urban Runoff; A Practical Manual for Planning and Designing Urban BMPs.* Washington Metropolitan Water Resources Planning Board.

Solley, W.B., Merk, F.M. and Pierce, R.R. 1988. *Estimated Use of Water in the United States in 1985.* U.S. Geological Survey Circular 1004.

Special Legislative Commission On Water Supply. 1986. *Contamination In Municipal Water Supplies.* Commonwealth of Mass.

Todd, David Keith and McNulty, Daniel E.O. 1976. *Polluted Groundwater: A Review of the Significant Literature.* Water Information Center, Port Washington NY.

Travis, Curtis C. and Etnier, Elizabeth L. 1984. *Groundwater Pollution: Environmental and Legal Problems.* Westview Press for the American Association for the Advancement of Science, Boulder CO.

U.S. Department of Agriculture, Soil Conservation Service. 1981. *Soil Survey of Rhode Island.*

United States Environmental Protection Agency, Office of Emergency and Remedial Response. 1987. *Determining Soil Response Action Levels Based on Potential Contamination Migration to Groundwater: A Compendium of Examples.* (Washington D.C.: OGWP).

_____, Office of Ground-Water Protection. 1987. *An Annotated Bibliography on Wellhead Protection Programs.* (Washington D.C.: OGWP).

_____, Office of Ground-Water Protection. 1988. *Developing A State Wellhead Protection Program: A User's Guide to Assist State Agencies Under the Safe Drinking Water Act.* (Washington D.C.: OGWP).

_____, Office of Ground-Water Protection. 1988. *Septic Systems and Ground-Water Protection, A Program Manager's Guide and Reference Book.* (Washington D.C.: OGWP).

_____, Office of Ground-Water Protection. *Priority Groundwater Resource Based Mapping Project Branch River Basin Rhode Island.*

_____, Office of Water. 1990. *Guide To Ground-Water Supply Contingency Planning For Local And State Governments: Technical Assistance Documents.* (Washington D.C.: OGWP).

_____, Office Of Water. 1988. *Local Financing for Wellhead Protection.* (Washington D.C. OGWP).

_____, Office of Water. 1989. *Wellhead Protection Programs: Tools For Local Governments.* (Washington D.C. : OGWP).

_____, Office of Water and Ground-Water Protection. 1990. *A Review of Sources of Groundwater Contamination from Light Industry.* (Washington D.C.: OGWP).

_____, Office of Water and Hazardous Materials. 1991. National Primary Drinking Water Regulations: Final Rule. Washington, DC.

_____, Office of Water and Hazardous Materials. 1986. *Quality Criteria for Water.* (Washington D.C.).

_____, Office of Emergency and Remedial Response. 1988. *Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites.* (Washington D.C.).

_____, Office of Underground Storage Tanks. 1988. *Musts for USTs: A Summary of the New Regulations for Underground Storage Tank Systems.* (Washington D.C.).

_____, 1987. *Radon, Radium, and Other Radioactivity in Groundwater: Hydrogeological Impact and Application to Indoor Airborne Contamination.* Jointly with the Association of Groundwater Scientists and Engineers, NWWA, Chelsea MI.

U.S. Department of the Interior, U.S. Geological Survey. 1988. *Groundwater Studies in RI.* Water Fact Sheet.

_____, U.S. Geological Survey. 1986. *Rhode Island Groundwater Resources.* Water Supply Paper 2275.

University of Maine. 1986. *Radon in Water and Air: Health Risk and Control Measures.* Coorperative Extension/Land and Water Resource Center. Orono, ME.

Wang, Xinhao. 1986. *The Relationship of Land Use and Groundwater Quality.* Graduate Curriculum in Community Planning and Area Development, University of Rhode Island, Kingston RI.

Weston and Sampson Engineers Inc. 1990. *Water System Master Plan (Draft Report)*: North Smithfield RI. Peabody MA.

Wilson, Rande J. 1989. *Bristol County Water Authority - Emergency Operations Procedure Manual.* Prepared for the Bristol County Water Authority.

Yates, M. V. 1987. *Septic Tank Siting to Minimize the Contamination of Groundwater by Microorganisms.* USEPA Report.

PERSONAL COMMUNICATIONS

Bobiak, Sofia. Groundwater Section, RI Department of Environmental Management.

Branconnier, Peter. Emergency Management Agency, Town of North Smithfield.

Cambio, William. State of Rhode Island, Emergency Management Agency.

Cathcart, Alan H. Town of Littleton, Mass. Water Department.

DeCelles, James. North Smithfield Water and Sewer Director

DiCicco, Tony. Assistant Administrator, RI Department of Labor.

Kiernan, Susan. Groundwater Section, RI Department of Environmental Management.

Sherman, Karen. North Smithfield Town Planner.

Swallow, June. RI Department of Health, Division of Water Supply.

Therrien, Paula. Groundwater Section, RI Department of Environmental Management.

RADIO BROADCAST

National Public Radio. All Things Considered News Show. Groundwater Problems in the U.S. West.