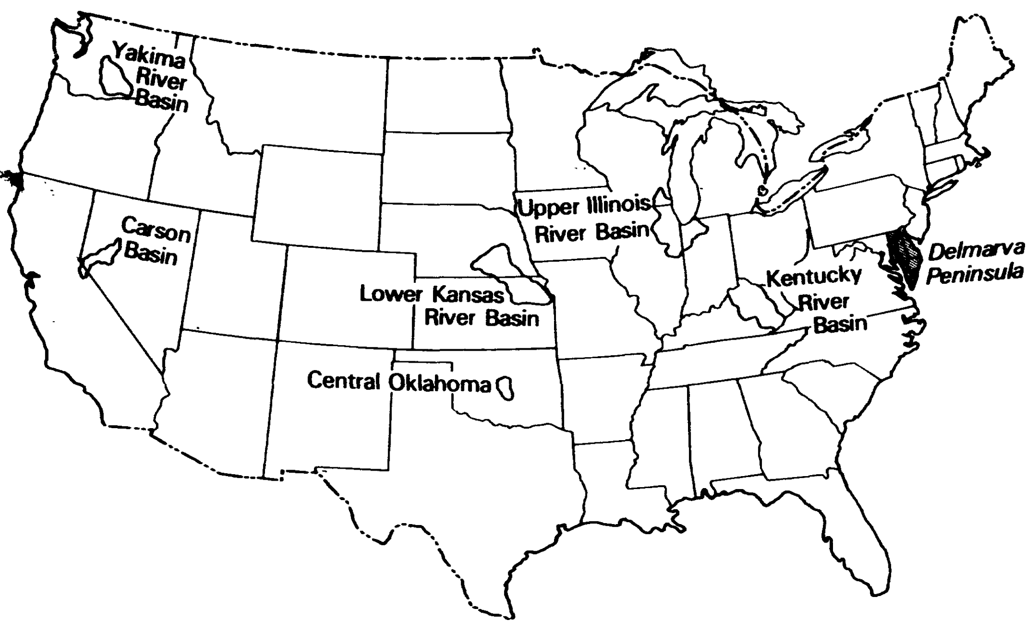
GROUND-WATER-QUALITY ASSESSMENT OF THE DELMARVA PENINSULA, DELAWARE, MARYLAND, AND VIRGINIA: PROJECT DESCRIPTION

by L.J. Bachman, R.J. Shedlock, and P.J. Phillips



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Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 LaSalle Road
Towson, MD 21204

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following conversion factors:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
million gallons per day (Mgal/d)	0.003785	million cubic meters per day (Mm^3/d)

GROUND-WATER-QUALITY ASSESSMENT OF THE DELMARVA PENINSULA,

DELAWARE, MARYLAND, AND VIRGINIA:

PROJECT DESCRIPTION

by L. Joseph Bachman, Robert J. Shedlock, and Patrick J. Phillips

ABSTRACT

In April 1986, the U.S. Geological Survey began a pilot program to assess the quality of the Nation's surface- and ground-water resources. This National Water-Quality Assessment (NAWQA) program is designed to acquire and interpret information about a wide range of water-quality issues. Three ground-water pilot projects have been started, including the project on the Delmarva Peninsula, which covers eastern Maryland and Virginia and most of Delaware. The pilot NAWQA program also includes four surface-water projects.

The Delmarva pilot project will develop and test methods for performing an assessment of ground-water quality. The objectives of the Delmarva project are to (1) investigate regional ground-water quality on the Delmarva Peninsula, emphasizing a description of the occurrence of trace elements and manmade organic compounds; (2) relate ground-water quality to land use and hydrogeologic conditions; and (3) provide a general description of the location, nature, and possible causes of selected water-quality problems prevalent in the study area.

This report contains general descriptions of the ground-water pilot projects and specific information for the pilot project on the ground-water resources of the Delmarva Peninsula. The project will address the shallow aquifer system and the deeper aquifers used for public water supply.

The shallow aquifer system in the Delmarva Peninsula consists of permeable unconsolidated sand and gravel. Flow systems are localized and small-scale. Most recharge to the deeper aquifers passes through the shallow system. Previous studies have characterized the inorganic geochemistry of the ground water and have identified nitrate contamination as an important water-quality problem. Fewer data on trace elements and synthetic organic compounds have been collected; furthermore, most of these data were collected near sites of known contamination problems. However, farming is common on the peninsula and the migration of agricultural chemicals to the ground-water system is a local water-quality concern.

To assess the water quality of the ground-water resources, a regional survey for a wide range of constituents will be conducted in all of the pilot projects to provide a representative sample of ground-water analyses

for a national assessment of ground-water quality. Results of this survey may be used as a baseline to monitor future water-quality trends. Local investigations will be performed in the Delmarva pilot project to relate local factors, such as human activities and hydrogeologic conditions, to the concentration of chemical constituents of particular concern. Such geo-hydrologic and topical studies will include research on flow patterns and water chemistry in different geohydrologic settings and studies of pesticide and nitrate concentrations in ground water. This information will be used with a Geographic Information System to delineate zones of differing responses to water-quality stresses within the ground-water system.

INTRODUCTION

Public awareness of the importance of water quality has increased greatly over the last 20 years, and both the Congress and state legislatures have responded by enacting wide-ranging pollution control legislation. This commitment to pollution abatement has been augmented by administrative regulations and the efforts of industry. As a result, the quality of many of the Nation's rivers and streams has improved greatly during the last 15 years despite increases in industrial activity and population (Association of State and Interstate Water-Pollution Control Administrators, 1984). Most of this improvement, however, has been the result of control of point-source discharges. Evaluating the effectiveness of the reduction of ground- and surface-water contamination from nonpoint pollution, acid precipitation, and the disposal of hazardous waste is a more difficult problem. The existing body of information on toxic substances is largely site-specific, and is derived mainly from mandated monitoring of water near waste-disposal sites, industrial and municipal discharges, and landfills. A better understanding of the regional distribution of contaminants is needed to provide a more representative assessment of the quality of the Nation's water resources.

The National Water-Quality Assessment Program

In response to this need, the U.S. Geological Survey began a pilot National Water-Quality Assessment (NAWQA) program in April 1986. The long-range objectives of the NAWQA program are to (1) provide a nationally consistent description of the current status of water quality for a major part of the Nation's water resources; (2) identify and describe water quality in relation to natural factors and human activity; and (3) define changes in water quality that have occurred in recent decades, if possible, and to provide a baseline for evaluating future trends in water quality.

A key element of the NAWQA design is the organization of the program into projects to assess the water quality of study units based on known hydrologic systems. For ground water, the study units are large portions of aquifers or aquifer systems with areas of thousands of square miles. Study units for the assesssment of surface water will include large watersheds or portions of watersheds representing river reaches with lengths of hundreds of miles.

Because the NAWQA program is national in scope, the assessments of individual study units will have common approaches, methods, and report formats so that comparable information can be integrated and analyzed in a national context. However, each project will include investigations of the water-quality problems specific to the study unit, thus considering its unique hydrogeologic and geochemical conditions.

At present (1987), the pilot program consists of seven projects that will develop and test approaches for water-quality assessments in preparation for a proposed full-scale national program. The pilot program also provides an opportunity to evaluate the potential benefits and costs of a fully implemented program. Four pilot projects in river basins have been started: the Yakima River basin, Washington; the lower Kansas River basin, Kansas and Nebraska; the upper Illinois River basin, Illinois, Indiana, and Wisconsin; and the Kentucky River basin, Kentucky. Three pilot studies of ground-water systems have also been started: the Carson basin, western Nevada and eastern California; the central Oklahoma aquifer in the vicinity of Oklahoma City; and the Delmarva Peninsula, Delaware, Maryland, and Virginia.

The specific objectives of the ground-water pilot projects are to (1) investigate regional ground-water quality in the study unit, particularly with respect to trace elements and manmade organic compounds; (2) relate water quality to local factors such as human activities and hydrogeologic conditions; and (3) describe the responses of different parts of the study unit to water-quality stresses. Some of the wells sampled in the pilot projects will also be used to provide data for possible future evaluations of the change of ground-water quality over time.

Purpose and Scope

This report is the first publication of the Delmarva project. It states the goals, concepts, and general approach of the national NAWQA program, describes the study unit, and presents a proposed study approach for the Delmarva project, relating it to the national NAWQA program.

The Delmarva Pilot Project

The Delmarva Peninsula covers nearly all of Delaware, as well as the parts of Maryland and Virginia east of Chesapeake Bay (fig. 1). This area was chosen for a pilot project for several reasons. First, it is representative of the northern part of the Atlantic and Gulf Coastal Plain ground-water region defined by Heath (1984). Second, nearly all of the study area is underlain by an unconsolidated surficial aquifer which is generally under water-table conditions. The surficial aquifer overlies a thick sequence of unconsolidated sediments which contains nine confined aquifers. Flow patterns in the surficial aquifer are more localized than those in the confined aquifers, so variations in ground-water chemistry and migration patterns of contaminants in such local flow systems are likely to differ appreciably from those in ground-water systems where flow patterns are more regional in scale.

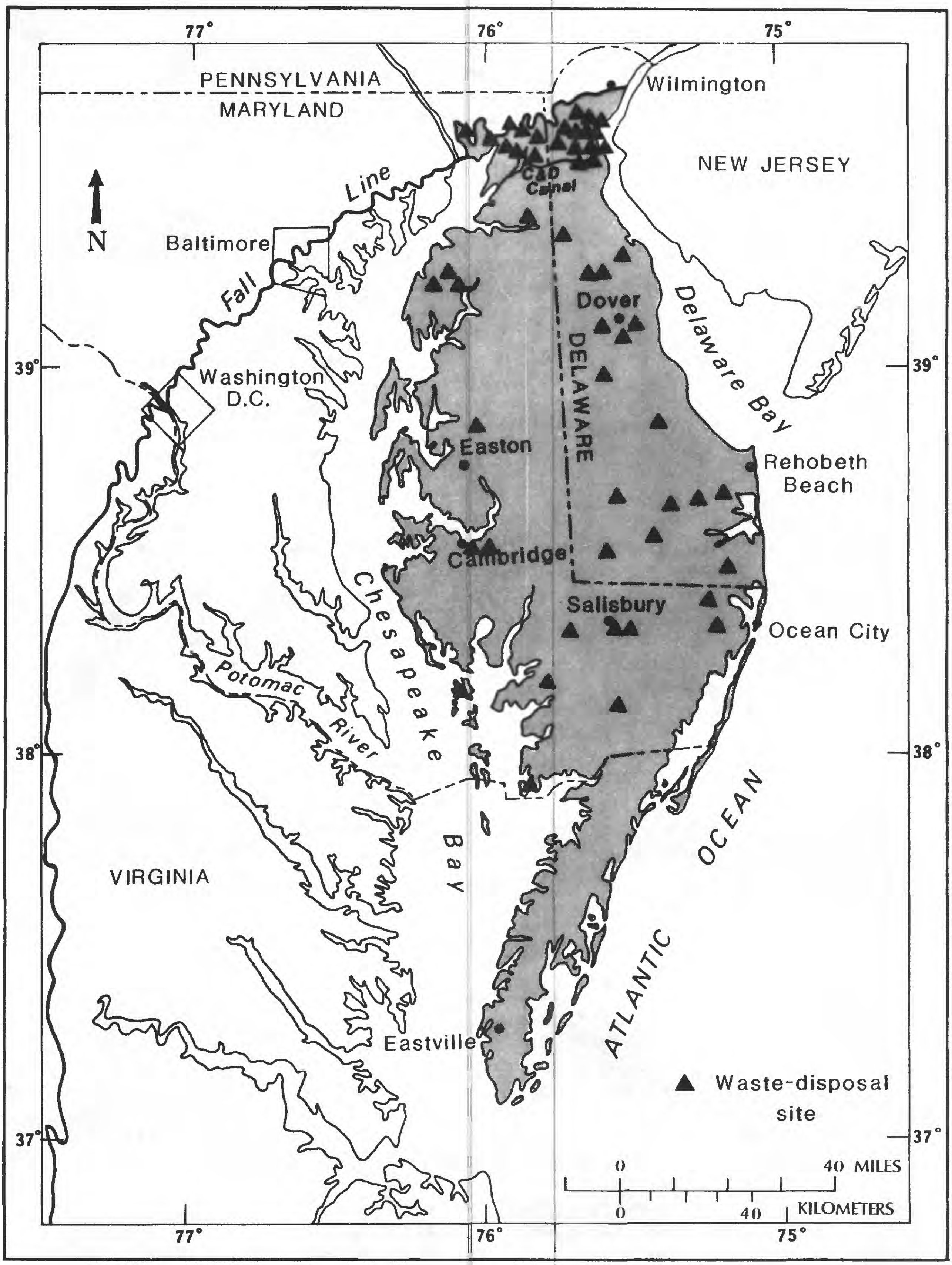

Figure 1. Location of Study Unit.

Although the confined aquifers will be sampled in this study, much of the effort will be on the water quality of the shallow aquifer system for two main reasons. First, all water entering the deeper confined aquifer system is derived as recharge through the shallow system (Cushing and others, 1973, p. 37-47). Most of the likely sources of contaminants in the Delmarva Peninsula, such as pesticides, fertilizers, septic tank effluents, and metals along the highways, probably enter the aquifer system at or near the water table. Thus, since the shallow aquifer system is the part of the larger ground-water system most susceptible to contamination, assessment of the water quality in the shallow system should be a good general indicator of water-quality trends throughout the Delmarva Peninsula. The potential for water-quality degradation in the deeper aquifer systems, especially those used for public water supplies, will also be evaluated in areas where there is direct ground-water flow between the shallow aquifer system and the deeper systems.

Although the Delmarva Peninsula has its own unique hydrogeologic characteristics, this pilot project should produce results applicable to many areas of the Atlantic Coastal Plain from North Carolina to Long Island, New York. Some of the results may also be applicable to other hydrogeologic settings with permeable sediments and low relief, such as outwash plains and valleys in glaciated areas of the Northeast and upper Midwest. In addition, because the Delmarva Peninsula contains many small freshwater wetlands as well as tidal wetlands along its coastlines, results concerning water-quality patterns around wetlands may be applicable to other areas with similar extensive distribution of wetlands.

DESCRIPTION OF STUDY UNIT

The Delmarva Peninsula lies east of Chesapeake Bay and west of the Atlantic Ocean and Delaware Bay. It extends southward from the Pennsylvania State line to the mouth of Chesapeake Bay (fig. 1). The peninsula extends about 150 miles (mi) north to south, and about 70 mi east to west at its widest point. Total land area is about 6,050 square miles (mi^2).

The population of the area is about 966,000 (U.S. Department of Commerce, 1986). The northern part is highly urbanized; the population of New Castle County, Del., containing the greater Wilmington area, is 407,643 (U.S. Department of Commerce, 1986), making it the largest urban center in the study area. However, a significant percentage of the population of New Castle County is located northwest of the Fall Line (fig. 1) outside of the study unit. Other large urban centers include Dover, Del., and Salisbury, Cambridge, and Easton, Md. The population of the coastal resorts, including Rehobeth Beach, Del., and Ocean City, Md., fluctuates during the year, ranging from a few thousand during the winter to several hundred thousand during the height of the summer tourist season.

Agriculture is the largest single land use in the study unit (table 1). The areas of other land uses are also shown in table 1. The figures in table 1 are based on the computerized data base used to produce recently published land-use maps (U.S. Geological Survey, 1979a, 1979b, 1980a, 1980b) and were determined from remote sensing observations made between 1972 and 1976. Recent field observations indicate that during the past 10 years,

Table 1.--Land use and percentage of total land area for each, Delmarva Peninsula

Land use	Area (square miles)	Percentage of total land area
Urban	403	7
Agricultural	2,917	48
Woodland	1,877	31
Wetland	787	13
Barren land	74	1
Total	6,058	100

considerable woodland has been converted to agricultural land, and woodland and agricultural lands have been converted to urban use. More recent computer-readable land-use data will be used, if available, for the data analysis.

With some exceptions, major land uses are fairly evenly distributed around the study area. The area around Wilmington, a major national center of the chemical industry, contains the most extensive urban and industrial areas, although industry can be found in all of the larger towns of the peninsula. Food processing and other miscellaneous light industries predominate in the rest of the study unit. Agriculture is common across the peninsula. Most of the acreage is in a soybean-corn rotation, and the crops are mostly sold locally for feed. The area is one of the Nation's leading producers of broiler chickens. Truck farming of vegetables is also common. Large areas of the peninsula are wooded, and most of the areas bordering the bays and the ocean are fringed with tidal marsh.

The study unit is located within the Coastal Plain physiographic province. The boundary between the Coastal Plain and the Piedmont province to the northwest is known as the Fall Line (fig. 1). The Coastal Plain is underlain by unconsolidated deposits of sand, silt, clay, gravel, and shell, whereas the Piedmont is underlain by metamorphic and igneous rocks.

The Coastal Plain is relatively flat with a maximum altitude of 80 feet (ft) above the levels of Chesapeake and Delaware Bays and the Atlantic Ocean. The area is drained by small, short streams, many of which become wide tidal rivers. Many of the tidal rivers extend a considerable distance inland. Local relief on the Coastal Plain is greatest in the northern area, near the Fall Line; bluffs rise 50 to 60 ft above the larger rivers and along the Chesapeake and Delaware (C&D) Canal (fig. 1). Lowlands of very low relief border the Atlantic Ocean and Chesapeake Bay and are separated from the upland surface by a dissected scarp (Weigle, 1974, p. 7; Owens and Denny, 1979, p. A24; and Mixon, 1985, p. G5). The upland surface is pocked with hundreds of small oval depressions ranging in size from a few hundred yards to a few miles. The interiors of these depressions are commonly freshwater wetlands, and the depressions may have a significant impact on the recharge and discharge of shallow ground water (Rasmussen and Slaughter, 1957, p. 23). The origin of these depressions has been discussed in some detail by Rasmussen and Andreasen (1959, p. 18-24).

The buried surface of Piedmont rocks on which the Coastal Plain sediments lie dips to the southeast. The sediments range in thickness from zero ft at the Fall Line to over 8,000 ft at the Atlantic coast (Cushing and others, 1973, p. 3).

In the Coastal Plain, subsurface water flows through pores between the individual sediment grains. Sand and gravel generally tend to have larger and more interconnected pores than clay and silt, and thus form the water-bearing units called aquifers. Ten aquifers have been identified in the Coastal Plain sediments (Cushing and others, 1973, p. 37). As one or another of these aquifers covers the entire Coastal Plain, drilling at any location will usually yield enough water for domestic use. Cushing and others (1973) have compiled detailed maps of the thickness and areal extent of these aquifers as well as a summary of the areal distribution of the base of freshwater and the number of freshwater aquifers at a given location.

The uppermost aquifer in the Coastal Plain is a blanket of mostly sand and gravel of irregular thickness called the Columbia aquifer. This aquifer has been called other names in previous studies, and a short description of the various terms of nomenclature can be found in the report by Bachman (1984a, p. 3, 8-10). The Columbia aquifer covers over 90 percent of the study unit (Cushing and others, 1973, p. 55) and is the unit through which recharge to the deeper aquifer systems passes. Where the Columbia aquifer is thin or absent, outcropping or subcropping parts of deeper units may be part of the shallow aquifer system.

Flow in the shallow aquifer system is local; recharge areas tend to be only a few miles from discharge areas. The distance from recharge areas is slightly larger and the slope of the water-table surface is slightly less in the areas along the Atlantic coast than to the north (Bachman, 1984a, p. 17). Surficial clay and silt layers are also more common near the coast, providing some protection from potential contaminants applied on the land surface.

Given the abundance of aquifers in the Coastal Plain, ground water is the most significant source of water supply in the study unit. Cushing and others (1973, p. 50) estimated total water use from Coastal Plain sources of about 137 million gallons per day (Mgal/d), of which about 90 percent was from ground-water sources (Cushing and others, 1973, p. 51). Total ground-water withdrawals for 1985 were estimated by the U.S. Geological Survey to be about 120 Mgal/d (Judy Wheeler, Arthur Hodges, and Thomas Kull, U.S. Geological Survey, written commun., 1986); about 47 percent of this withdrawal came from the shallow aquifer system. The shallow aquifer system is a major agricultural, municipal, and industrial water-supply source in southern Delaware, in parts of Maryland east of Cambridge (especially the Salisbury area), and in Virginia, and is also extensively used for domestic supplies in other inland areas. The deeper confined aquifers are more extensively used for municipal and industrial supplies in the northern part of the study unit and in towns near the shorelines of the Atlantic Ocean and the Chesapeake and Delaware Bays.

GROUND-WATER QUALITY

The chemical composition of water in the shallow aquifer system is related to the quality of precipitation, the interaction of the water with soil and aquifer material, and the addition of various compounds by human activities. The results of previous studies indicate that compounds added by human activities have a significant effect on water chemistry (Denver, 1986, p. 25). Such activities include agriculture, on-site domestic sewage disposal, industrial and municipal waste disposal, and pumpage from the aquifer near coastal areas.

Precipitation in the study unit is a dilute solution primarily composed of hydrogen, sulfate, and nitrate ions, with lower concentrations of sodium and chloride ions. The pH is about 4.5 and the dissolved solids concentration is about 5 milligrams per liter (mg/L) (Bachman and Katz, 1986, p. 11). Evaporation concentrates this by a factor of about three (Cushing and others, 1973, p. 7), so recharge enters the aquifer with a dissolved solids concentration of about 15 mg/L. Soil and aquifer reactions described by Denver (1986, p. 18-25) and Bachman and Katz (1986, p. 20-26) raise the pH to about 5 to 5.5, and the dissolved solids concentration to about 50 to 60 mg/L. Despite these changes, water in the shallow aquifer system is still more acidic and lower in dissolved solids than water from the deeper aquifer systems.

The relative proportions of dissolved material in water with such low dissolved solids concentration can be radically changed by the addition of substances from human activities. Agriculture results in the addition of fertilizer nitrogen and pesticides. Nitrogen and pesticides applied in excess of the needs of the crop may be available to percolate into the aquifer. This is especially true where the soils are well drained and permeable, a common condition in the study unit. Domestic, municipal and industrial wastes commonly have high concentrations of nitrate and chloride. Furthermore, they may also contain elevated concentrations of various trace metals and synthetic organic compounds. The exact types of compounds in the waste will vary greatly depending on the source of the waste. This means that water samples must be analyzed for a wide variety of organic compounds in order to characterize the effects of waste disposal on water quality.

Excessive pumpage from shallow aquifers near saltwater bodies may result in the reversal of ground-water flow and the infiltration of saline water into the aquifer. Such saltwater intrusion has been reported in the Maryland coastal resorts (Weigle, 1974), in the shallow aquifer system in northern Delaware (S. Phillips, U.S. Geological Survey, written commun., 1986), and in southern Delaware (Rasmussen and others, 1960, p. 103).

The chemical quality of the water in the shallow aquifer system has been extensively studied over the last 30 years. Reconnaissance studies at county and multicounty scales have been made over the entire study unit (Rasmussen and Slaughter, 1955 and 1957; Overbeck and Slaughter, 1957; Rasmussen and others, 1960; Marine and Rassmusen, 1955; Cushing and others, 1973; Bachman, 1984a; Boggess and Heidel, 1968, Sinnott and Tibbetts, 1954, 1968, and Weigle, 1974). Analyses reported in these studies provide a range of the inorganic chemical composition of water in the shallow system, but wells were not selected to provide a statistically representative sample. The long time period over which these studies were done limits the comparability of some aspects of regional water quality due to possible changes in water quality through time. More recent studies, including those by Denver (1986), Bachman and Katz (1986), Bachman (1984b), and Robertson (1979), have attempted to obtain a representative sample of water from the Columbia aquifer, describe areal trends, and evaluate the processes controlling the inorganic water chemistry. Studies of the contamination of ground water by synthetic organic compounds are less common and have typically been confined to areas of known or suspected contamination problems (CABE Associates, 1980, p. 2).

The most thoroughly documented water-quality problem of the shallow aquifer system is that of nitrate contamination. The water-quality standard for nitrate set by the U.S. Environmental Protection Agency (EPA) is 10 mg/L as nitrogen (U.S. Environmental Protection Agency, 1977, p. 107-110). Excessive amounts may cause methemoglobinemia in infants. Denver (1986, p. 25-25, 35-36) described some of the chemical processes controlling nitrate occurrence in ground water in west-central and southwestern Delaware. Miller (1972) described nitrate occurrence in two areas of Delaware and prepared generalized maps showing potential problem areas. Bachman (1984b) studied nitrate variation in the Columbia aquifer in neighboring parts of Maryland and included some of Denver's data in his analysis. Bachman found statistically significant areal variation of nitrate concentrations as well as nitrate concentrations significantly higher at sites with urban or agricultural land use than at woodland or wetland sites and sites with well-drained soils (Bachman, 1984b, p. 26-29). The overall median nitrate concentration was 3.5 mg/L as nitrogen, considerably more than would be expected from natural sources (Bachman, 1984b, p. 10, 18-21). About 15 percent of the water samples had nitrate concentrations in excess of the water-quality standard of 10 mg/L as nitrogen (Bachman, 1984b, p. 18). These results are in agreement with earlier observations by Robertson (1979, p. 331), who reported an overall median concentration of 5.5 mg/L as nitrogen, and 20 percent of the samples exceeding the water-quality standard of 10 mg/L as nitrogen.

A systematic appraisal of the occurrence of trace metals and synthetic organic compounds in the ground water of the study unit has not been done. Biggs and others (1973) examined concentrations of cadmium, lead, copper, and mercury in selected watersheds in Delaware. They felt that these samples represented ground-water discharge because a large part of total streamflow is ground-water discharge (estimated for the whole peninsula at about 37 to 64 percent according to Cushing and others, 1973, p. 35; and for parts of southern Delaware at 75 to 90 percent according to Johnston, 1971,

p. D212). Trace metal concentrations were higher in southern Delaware than in the north (Biggs and others, 1973, p. 46). Bachman and Katz (1986, p. 12) reported elevated concentrations of dissolved aluminum (up to 1.9 mg/L) in the base flow of streams in eastern Maryland, whereas aluminum in deeper parts of the shallow aquifer system was barely detectable. Dissolved aluminum concentrations greater than 0.2 mg/L may be toxic to fish (Cronan and Schofield, 1979). Elevated aluminum concentrations in other streams in eastern Maryland were reported by Ecological Analysts, Inc. (1983) and by Janicki and Cummins (1983).

Manmade organic compounds are a potential water-quality problem; the study unit has 50 sites (fig. 1) from which ground-water contamination has been reported or is likely to be contaminated (J.C. Wheeler and J.M. Denver, U.S. Geological Survey, written commun., 1986). A study of drinking-water supplies in Delaware by CABE Associates (1980) found that occurrences of manmade organic chemicals were common in the sampled water supplies. However, the sampling sites were selected because of their high susceptibility to contamination.

Although much is known about selected individual occurrences of trace elements and manmade organic compounds in ground water, more needs to be understood about the nature and scope of occurrence in the shallow aquifer system of the Delmarva Peninsula; this includes a better description of the areal variation of trace elements and manmade organic compounds as well as the relationship between the occurrence of these substances and hydrogeologic and land-use factors. Also, a better understanding is needed of the nature of the chemical and physical processes that affect the mobility and distribution of the trace elements and organic compounds.

PROPOSED STUDY APPROACH

The study approach described here has been designed to deal with the large area and complex local ground-water flow patterns in the study unit. The emphasis will be on widespread water-quality problems caused by nonpoint sources or extensively distributed point sources rather than on locating and identifying individual contaminant plumes in the aquifer. Existing water-quality data will be used to provide a preliminary assessment of ground-water quality, illustrate gaps in understanding the quality of the aquifer, and reveal potential problems that may occur when undertaking a regional water-quality assessment. Data collected to meet the major objectives of the ground-water pilot projects will require two distinct but complementary components.

To investigate the regional ground-water quality of the study unit, a regional sampling of a wide range of inorganic and organic constituents, including trace elements and manmade organic compounds, will be performed. This component will be known as the regional survey and will use samples from a network of existing wells. Additional investigations will be conducted to relate ground-water quality, hydrogeologic conditions and human activity. These geohydrologic and topical studies will help in the interpretation of the results of the regional survey and provide more specific information about important water-quality problems in the study unit.

Characterization of Existing Data

Although the objectives of the study require the collection of new data, existing ground-water-quality data from a variety of sources will be reviewed to assess their suitability in meeting NAWQA objectives. If possible, these data will be used to make a preliminary assessment of regional water quality. More importantly, a review of these data should help to identify deficiencies in the existing data for use in a regional ground-water-quality assessment.

Review of the existing data will focus on the following four characteristics which may effect their suitability for use in a regional ground-water quality assessment: (1) comprehensiveness in terms of the types and numbers of chemical constituents analyzed, (2) comparability of different data sources that have analyses from different laboratories with some difference in analytical procedures, (3) location and purpose of the sampling sites, and (4) retrieving and summarizing the data. For example, few individual studies or monitoring programs are designed to collect water-quality samples for a complete list of constituents. In addition, much of the data for manmade organic compounds and trace metals seem to be collected near known waste-disposal areas. Much less is known about the distribution of such compounds in parts of the aquifer system that may be affected by nonpoint sources. Finally, existing data may be filed under a number of systems, not all of which are designed for easy retrieval and analysis in a manner necessary to achieve the objectives of the NAWQA pilot project.

Regional Survey

The regional survey component of the Delmarva NAWQA project will be designed to characterize regional ground-water quality in a manner consistent with the other NAWQA ground-water pilot projects. Because the same chemical constituents will be investigated using procedures consistent with the Central Oklahoma and Nevada NAWQA projects, it will be possible to compare the results of this regional survey with those of the other two pilot projects, as well as with continuing projects under a possible full-scale program. The regional survey component will involve sampling for both common inorganic constituents and trace elements and manmade organic compounds. Besides serving as a basis for comparison between the study units, the regional survey will help to identify the variability present in the ground-water quality of both the surficial aquifer and parts of the deeper aquifers.

The principal aquifers in the study unit will provide the water samples for the regional surveys. The aquifers will be divided between the surficial system, which includes the Columbia aquifer and any underlying units in direct hydraulic connection with the Columbia, and the deeper flow systems. Wells will be chosen from randomly selected areas to reduce systematic bias. All types of wells which can yield a suitable ground-water sample will be considered: community water-supply wells, non-community public supply wells, rural domestic supply wells, irrigation wells, and observation wells. Most wells will be sampled from the surficial system, but enough wells will be sampled from updip parts of the deeper system to evaluate whether contaminants are entering the deeper aquifers. Samples drawn from all wells will consist of untreated ground water. In addition, only those sites with detailed well-construction information will be sampled. Most of the regional survey wells will be sampled only once during the pilot project. However, some of these sites will be sampled in the future to study changes in ground-water quality under a possible full-scale NAWQA program.

As part of the general NAWQA objective of developing new methods to analyze and display ground-water-quality data, the Delmarva project will use a Geographic Information System, which is a computer program that draws maps and relates data to geographical location. Water-quality data can be easily mapped and displayed using this system, and can also be matched to the variety of geographic factors present in the data files in the system. A Geographic Information System permits the exploration of spatial relations between ground-water quality and mappable features, such as surficial geology, soil, and land use that are not readily evident from an examination of summary statistics.

Geohydrologic and Topical Studies

More specific geohydrologic and topical studies will be done to develop a better understanding of the relations among geohydrologic features, human activities, and ground-water quality. These studies will vary among the pilot projects. However, the studies will be chosen to help interpret the data from the regional survey or deal with important water-quality problems in the study units. The studies may address the distribution of important chemical constituents or classes of constituents, or important geohydrologic or geochemical processes that significantly affect water quality. These studies will also lead to a better understanding of how the scale and extent of water-quality degradation may vary in different parts of the ground-water system.

Variation in the surficial geology of the study unit has resulted in a number of surficial geohydrologic settings which may each have a different type of shallow flow system, geochemical environment, and response to water-quality stresses. Bachman (1984a; 1984b, p.26-29) has pointed out differences in water-table configurations and chemical compositon of ground water between the northern and southern parts of the study unit. More recent field examination of the study unit has revealed that upland areas near the headwaters of major streams are flat-lying with numerous small depression wetlands. In areas closer to the major tidal rivers and bays, the upland areas are flat and well drained, and stream channels are incised more deeply. Examination of soil and surficial geology maps indicates that other geohydrologic settings may also be present in the study unit. One geohydrologic-topical study will be to delineate these units and investigate the chemical composition of the underlying ground water in each unit.

The geohydrologic settings will be studied by sampling the water in the upper part of the surficial system within 5 to 10 ft of the water table. This part of the aquifer would be most likely to be affected by surficial conditions and water-quality stresses due to human activities. Specially installed wells probably will be used to collect the samples. These sites will also be the focus of other hydrogeologic and topical studies.

A geohydrologic study now planned is to investigate the relations between the geohydrologic setting and ground-water flow patterns, which may have important implications for describing the effects of water-quality stresses on aquifer systems in the various parts of the study unit. Previous research in areas of hummocky terrain similiar to that of the depression wetlands (Meyboom, 1966; Lissey, 1971; and Winter, 1983) indicates that recharge tends to be focused around the depressions. Furthermore, flow patterns may be transient and take considerable time to dissipate, which indicates flow patterns in the depression wetlands may be quite different from those in other settings.

These flow patterns will be investigated by studying water-table profiles in representative sites in each geohydrological setting. Water levels will be monitored along lines of shallow observation wells roughly parallel to the direction of ground-water flow. In addition, the geochemical environment of the aquifer at the sites will be investigated. Water sampled will be collected periodically from the wells and analyzed for major inorganic constituents, selected trace elements, and organic compounds. In addition, some water samples will be analyzed for the stable isotopes of hydrogen, oxygen, and carbon to help delineate patterns of flow and recharge suggested by the water-table profiles. Multiple sampling of wells will be most important in those areas found to have transient flow patterns.

An important potential source of water-quality degradation in the study unit may be agricultural chemicals. A topical study will address the distribution of nitrate and selected pesticides commonly used in the Delmarva Peninsula. Nitrate occurrence has already been documented in previous studies, but little is known about the existence or concentration of pesticides in shallow ground water. Samples will be collected from shallow wells installed in areas most likely to have agricultural chemicals in the ground water. Sites will be selected based on agricultural practices, previous nitrate analyses, and available results of the investigations of ground-water flow patterns in each geohydrologic setting.

The topical studies conducted in the Delmarva NAWQA project present a unique opportunity to develop methods to extrapolate water-quality patterns from small-scale areas to larger areas. Relationships identified in this phase can be used to map areas of potential ground-water-quality degradation with a Geographic Information System. For example, areas with similar topography and surficial geology could be delineated by the Geographic Information System, and the recharge characteristics of the areas could be related to possible water-quality patterns.

Quality Assurance

A quality assurance plan is being developed under the auspices of the national program to maintain and document the reliability of the results of the pilot projects. The plan will cover all aspects of sample collection, data analysis, and reporting needed to produce reliable data in a nationally consistent manner. The plan will be based on the extensive quality-assurance policies and procedures now used by the U.S. Geological Survey, including material described in the manuals by the Survey's Office of Water Data Coordination (U.S. Geological Survey, 1977) and Friedman and Erdman (1982).

Agency Coordination

Each pilot project will be advised by a liaison committee made up of representatives from state, local, and other Federal agencies that deal with appraisal and regulation of the water resources, geology, and environment in the study unit. These committees will be the primary vehicle of communication between the pilot project teams and the agencies. This communication will ensure that the scientific information produced by the NAWQA program is relevant to local and regional water-information needs and interests. The committee will provide information to the project team about local water-quality issues and concerns and sources of existing data. The project teams will communicate scientific findings and provide drafts of reports to the committee for review and comments.

A National Coordinating Work Group has also been established by the Director of the U.S. Geological Survey to provide communication between the Survey and other national users of water-quality information. The work group operates under the auspices of the Interagency Advisory Committee on Water Data and the Advisory Committee on Water Data for Public Use. Its membership consists of the Chief Hydrologist of the U.S. Geological Survey, representatives of Federal and state agencies and organizations having an interest in water-resources and environmental issues, and representatives from the pilot project liaison committees. The work group will (1) advise the U.S. Geological Survey on the water-information needs of water users both within and outside the Federal Government, and (2) help develop procedures for making data and interpretations from the NAWQA projects available in a timely and appropriate manner.

SUMMARY

In April 1986, the U.S. Geological Survey began a program of studies known as the National Water-Quality Assessment (NAWQA) program designed to (1) provide a description of the current status of water quality for a major part of the Nation's water resources, (2) establish a base of information and set up the apparatus for evaluating future trends in water quality, and (3) develop a better understanding of relations among water quality, land use, and hydrogeologic conditions.

The emphasis in NAWQA will be on the occurrence and distribution of trace elements and manmade organic compounds in both surface- and ground-water systems, although the general chemistry of the water will also be studied. In the first phase of NAWQA, a series of pilot projects are being done, four of surface-water systems and three of ground-water systems. The pilot projects are to develop and modify study approaches and test the feasibility of a fully implemented program.

The preliminary plans for the pilot projects in ground water, including the project on the Delmarva Peninsula described in this report, include two distinct but parallel efforts. The first is to conduct a regional assessment of a wide range of inorganic and organic constituents in a manner consistent with that of the other pilot projects. These assessments, called the regional surveys, will be the first step toward a national assessment of ground-water quality and will set up the apparatus for monitoring future changes in ground-water quality.

The second major effort is to identify and interpret relations among water quality, land use, geohydrologic conditions, or any other features of the landscape through a series of more local geohydrologic or topical studies. These studies will help interpret the results of the regional survey and investigate important water-quality problems within the study unit. The studies are expected to provide a better understanding of the varying degrees of vulnerability of different parts of the ground-water system to water-quality degradation.

In the pilot project of the Delmarva Peninsula, which includes the Eastern Shore of Maryland and Virginia and most of Delaware, the focus of effort will be on the surficial aquifer, although the confined Coastal Plain aquifers will also be sampled. The project area is entirely within the Atlantic Coastal Plain and the surficial aquifer consists mainly of sand and gravel. Although the relief in the study unit is low, the surface topography is hummocky and many of the lowlands are wetlands. The shallow ground-water system is characterized by local flow cells that have flow paths usually less than a few miles from recharge to discharge. Agriculture is the largest single land use in the project area. Consequently, the most commonly perceived threats to ground-water quality are nitrates and pesticides, although trace metals are also a concern owing to the relatively low pH of the shallow ground water (average pH of about 5.0 to 5.5).

The regional survey for the Delmarva Peninsula project will be accomplished by sampling and analyzing water from a network of wells located at sites chosen from randomly selected areas. Most of the wells will tap the surficial system, although sampling of the deeper system will also be done to evaluate the potential for deeper flow of contaminants.

Topical and geohydrologic studies will provide an understanding of the relations between ground-water quality, geohydrologic features, and human activity. Such studies will include an investigation of the differences in ground-water flow patterns in different hydrologic settings as well as an investigation of agricultural chemicals in shallow ground water. The knowledge gained from these studies and the data from the regional surveys will be used to identify zones of the ground-water system which may have different responses to water-quality stresses. Where relations between water quality and mappable features or data are discovered, the relations will be mapped and interpreted using a Geographic Information System. Through such geographic information analysis, information from the regional survey can be enhanced by relations developed from the process-oriented topical studies. Such analysis should also be helpful in the design of an appropriate network for the determination of future trends in water quality.

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