PUBLIC ISSUES IN EARTH SCIENCE

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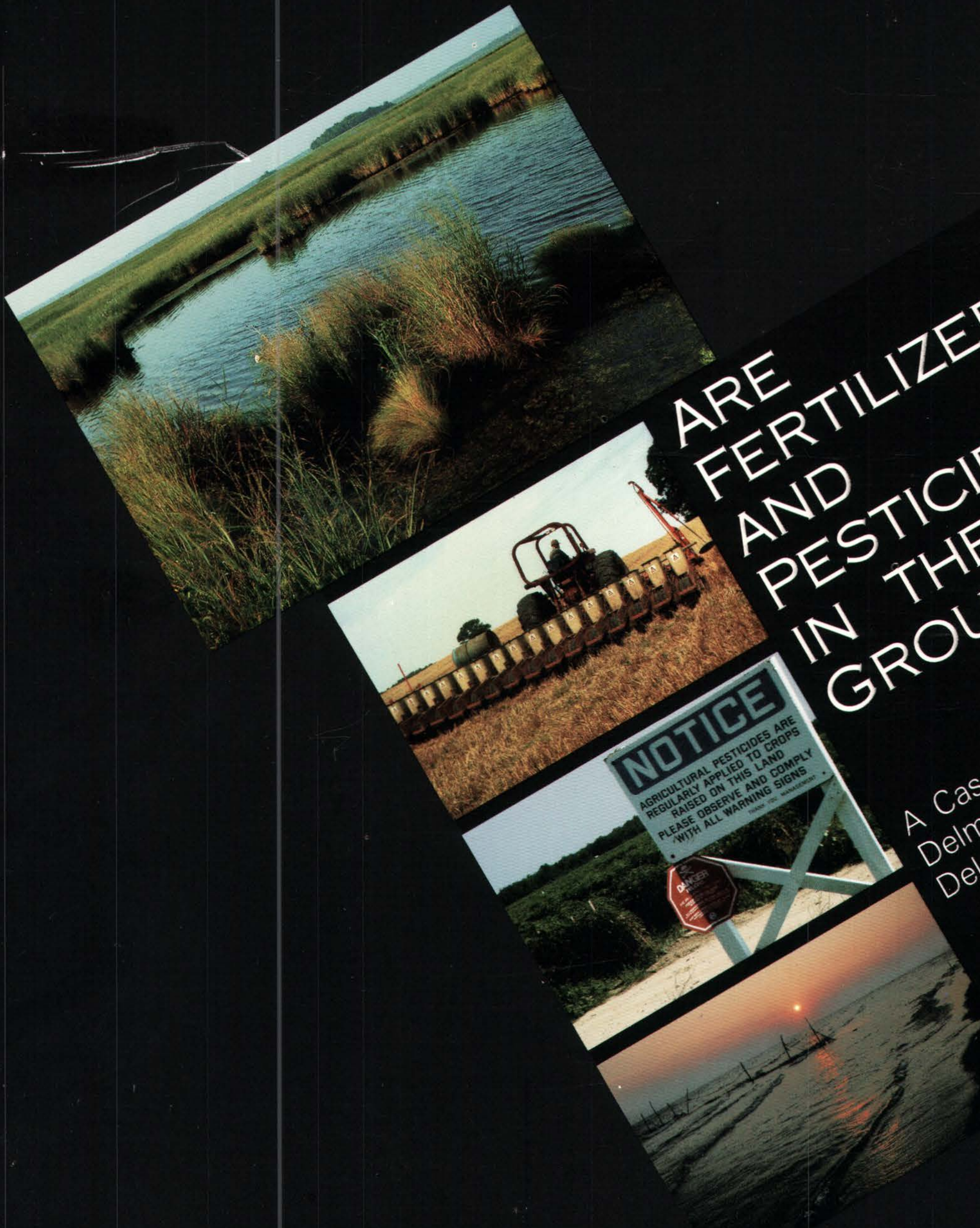
A Case Study of the Delmarva Peninsula, Delaware, Maryland, and Virginia



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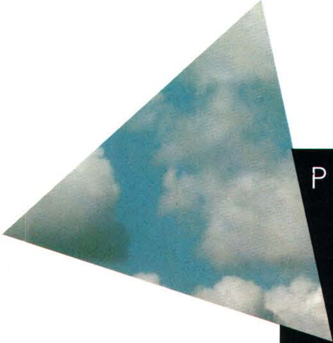

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ARE FERTILIZERS AND PESTICIDES IN THE GROUND WATER ?

A Case Study of the Delmarva Peninsula, Delaware, Maryland, and Virginia

By

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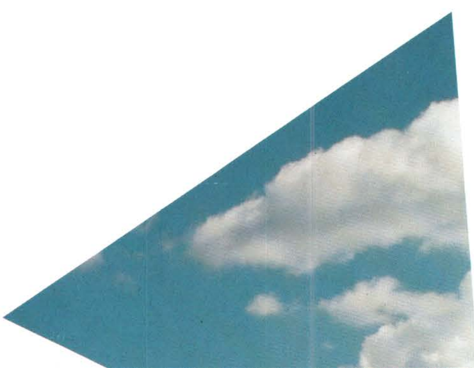


U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1992

Free on application to the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center, Box 25425
Denver, CO 80225

Library of Congress Cataloging in Publication No. 92-10922

FOREWORD

Established in 1879, the U.S. Geological Survey (USGS) has provided scientific information on the Nation's water, energy, and mineral resources, and research on processes related to those resources for the benefit of all Americans. A major part of the mission of the USGS is to assess the quantity and quality of the Nation's water resources and to provide information and data to assist resource managers and policymakers at Federal, State, and local levels in making sound management decisions. To a significant extent, these responsibilities are being carried out by the USGS National Water-Quality Assessment (NAWQA) Program, whose goals include providing a sound understanding of the natural and human factors that affect water quality.

The NAWQA Program consists of investigations in 60 study areas throughout the Nation that represent a variety of geologic, hydrologic, climatic, and cultural conditions. These study areas are the building blocks for understanding regional differences in the chemical and biological quality of the Nation's ground water and streams. Information from the NAWQA Program will address specific water-quality concerns through comparative studies. An important goal of the program is to ensure that key findings are available to the public so that they can be aware of the quality of the Nation's water resources.

This report is the first in a series of non-technical publications on the NAWQA Program. The purpose of these publications is to describe key findings from the individual investigations and to relate those findings to water-quality issues that are of regional and national concern. By disseminating this information, the USGS seeks to increase awareness of water-quality concerns when considering the Nation's environmental issues.

Director

A CONCERN SHA

IN THE NATION AND IN

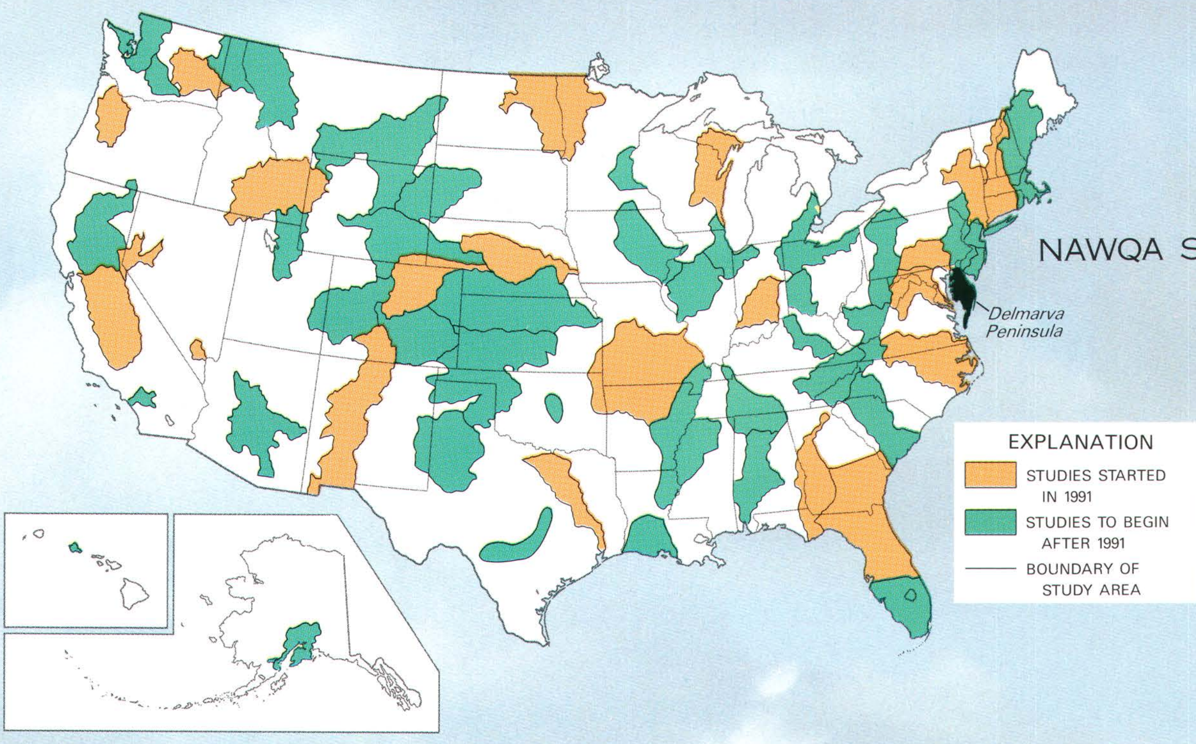
The administration has initiated a concentrated 5-year effort to work with the Nation's farmers to protect our ground water from contamination by fertilizers and pesticides...We must keep your good land in business without unreasonable burdens, but we must also keep it good land.

President George Bush in his remarks to members of the American Farm Bureau Federation, January 8, 1990

We must recognize that productive agriculture and a sound environment can be compatible, especially in terms of water quality.

A systematic assessment of the status, changes, and causes of water-quality conditions across the country is a key element of President Bush's water-quality initiative. I am confident that, by working together, we can begin to develop practical solutions to some of the Nation's critical water-quality problems. NAWQA will provide the first systematic assessment of water-quality conditions across the United States. Its goals are to provide nationally consistent water-quality information, to define long-term water-quality trends, and to describe the factors that affect water quality.

Manuel Lujan, Jr., Secretary
U.S. Department of the Interior



NAWQA STUDY AREAS

RED BY MANY . . . .

HE DELMARVA PENINSULA

The 60 study-area design of the NAWQA Program is based on the observation that the Nation's water resources are an aggregation of many surface- and ground-water systems, each of which has its own set of hydrologic and chemical characteristics and each of which responds to natural and human-induced stress in its own way. Investigations in these individual areas are the foundation for understanding regional differences in the quality of the Nation's streams and ground water, as well as for addressing issues that are of both regional and national concern. One primary national issue is the degradation of water quality from nonpoint sources of pollution, including the prevalent use of fertilizers and pesticides on agricultural land. This concern is shared by the residents, water-resource managers, and policymakers associated with one of the first NAWQA study areas, the agricultural community of the Delmarva Peninsula.

The Delmarva Peninsula, which includes most of Delaware and the entire Eastern Shore of Maryland and Virginia, remains primarily a rural area where the lives of many residents depend one way or another on farming. As in many agricultural areas, crop yields are linked to the amounts and kinds of fertilizers and pesticides that are applied to the soil. The potential movement of these chemicals into ground water is a concern among water-resource managers and residents of the Delmarva Peninsula because ground water is the sole source for both drinking and irrigation purposes and because it is a major source of surface water. The relatively flat topography and porous soils provide favorable conditions for chemicals applied on the land to move downward to the water table.

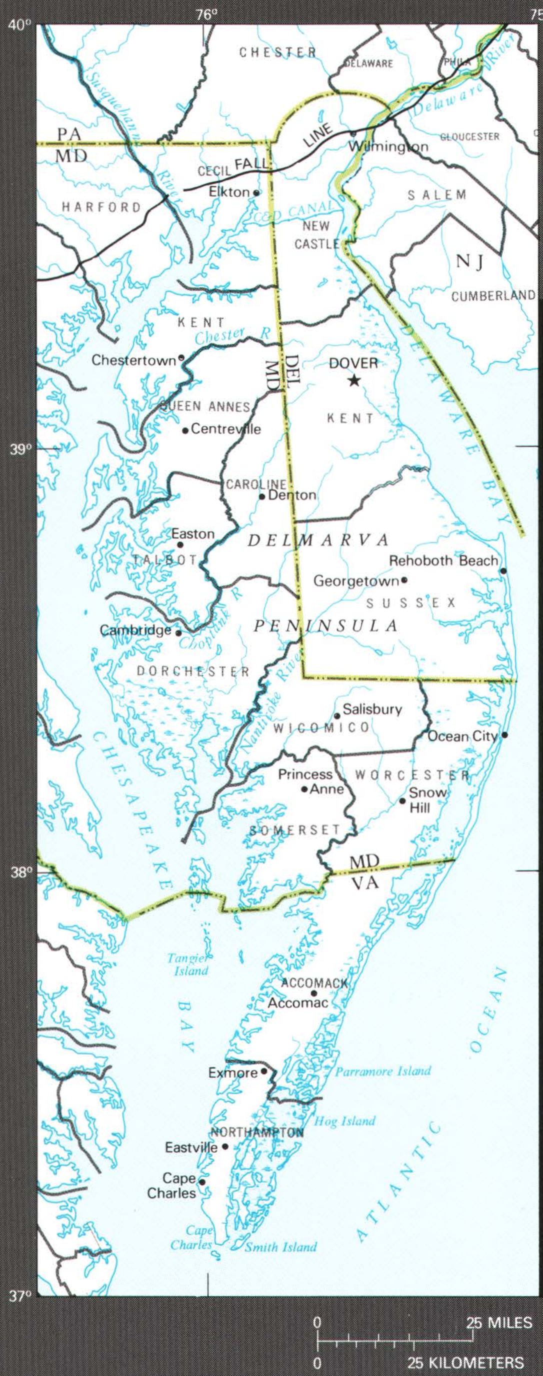
GENTLY ROLLING FARMLAND IN THE DELMARVA PENINSULA. THE RELATIVELY FLAT TOPOGRAPHY AND POROUS SOILS IN THE PENINSULA PROVIDE FAVORABLE CONDITIONS FOR CHEMICALS APPLIED ON THE LAND TO MOVE DOWNWARD TO THE GROUND WATER.

Are fertilizers and pesticides affecting the ground water?

What are the risks to human health and the environment?

How do soils, land use, and hydrology affect the movement of fertilizers and pesticides to ground water?

AGRICULTURE IN THE
A BILLION



DELMARVA PENINSULA

AREA: 6,050 SQUARE MILES

POPULATION: 600,000

MAJOR INDUSTRIES: AGRICULTURE, FISHING, TOURISM

GROUND-WATER USE: ABOUT 170 MILLION GALLONS PER DAY; ABOUT 35 PERCENT FOR AGRICULTURE

Agriculture is an important part of the economic vitality of the Delmarva Peninsula. Nearly half of the land is used for farming. Most of the farmland is used to produce soybeans and corn for animal feed. Truck farming is also widespread; major crops include tomatoes, potatoes, cucumbers, and beans. The area is also one of the Nation's leaders in poultry production. Small towns scattered throughout the peninsula (Dover, Del., population 32,500, and Salisbury, Md., population 25,000, are the largest) support some food processing and other miscellaneous light industries.

The Delmarva Peninsula is relatively simple in its physical features, with a gently rolling central upland flanked by low plains that slope toward Chesapeake Bay, Delaware Bay, and the Atlantic Ocean. Large areas of the peninsula are wooded, and most of the land bordering the bays and ocean is fringed with tidal wetlands.

DELMARVA PENINSULA:
DOLLAR INDUSTRY

The soft beauty of Delmarva's subtle blend of sea and bays, marsh and shore, is in sharp contrast to the abrupt headlands and pebbly beaches of New England. Yet what Delmarva lacks in dramatic landscape is more than compensated by the fact that people here have never had to war with nature to make their livings from the rich loamy soils and the surrounding sheltered waters. From the moment the first colonist stepped ashore this was, indeed, a promised land of pleasant living.

Yet not even Paradise can sustain a recklessly expanding human population. Demand for all resources, but particularly fresh water, is the barometer by which any quality of life must be measured. Without an ample supply of uncontaminated water, there is no hope or future for people living anywhere. This is especially true for those of us on the Delmarva Peninsula where water sources are limited, and where most income stems from water-intensive activities, such as farming, fishing, and tourism. Few of us who live here, especially those who have come from elsewhere, want Delmarva to change. Yet change it will.

George Reiger, Locustville, Virginia
Conservation Editor, Field and Stream Magazine

OTAL MARKET VALUE OF ALL AGRICULTURAL PRODUCTS ON HE PENINSULA EXCEEDS $1 BILLION. MAJOR CROPS ARE OYBEANS AND CORN. THE PENINSULA IS ALSO ONE OF THE ATION'S LEADERS IN POULTRY PRODUCTION.

NEARLY HALF OF THE LAND IN THE DELMARVA PENINSULA IS USED FOR AGRICULTURE.

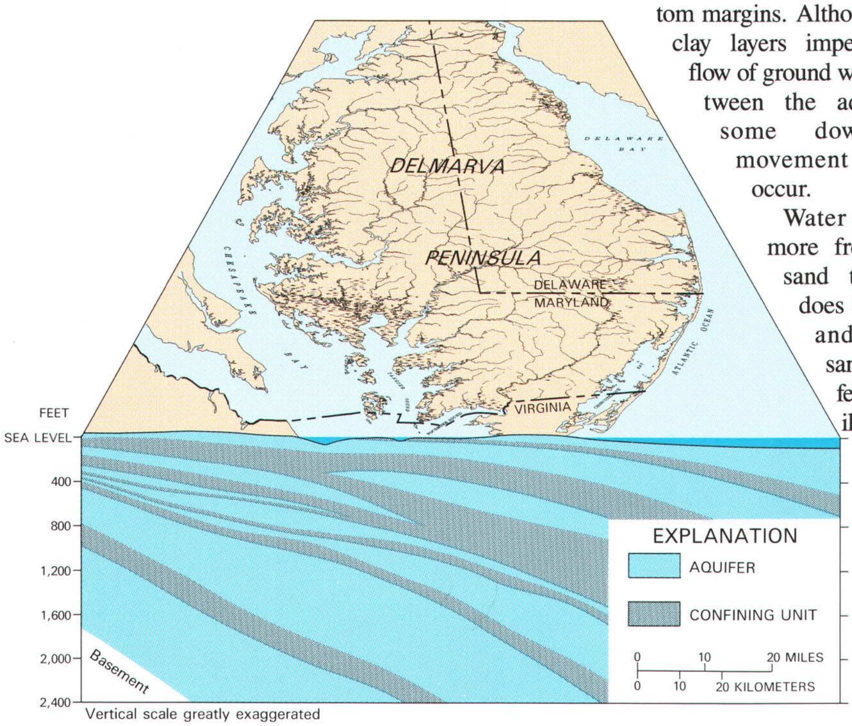
GROUND WATER–

LOOKING BENEATH THE SURFACE

Contrary to popular belief, ground water does not form underground "rivers." Instead it fills the tiny spaces between individual sediment grains. Ground water moves very slowly, at a typical rate of one-quarter to 2 feet per day in the water-table aquifer. As a result, water could remain in this aquifer for several decades, and as long as centuries or longer in the underlying confined aquifers.

SURFACE WATER, SUCH AS STREAMS, AND GROUND WATER ARE INTERCONNECTED. GROUND WATER CAN SIGNIFICANTLY AFFECT THE QUALITY AND QUANTITY OF SURFACE WATER, PARTICULARLY ON THE PENINSULA WHERE IT IS THE MAJOR SOURCE OF STREAMFLOW.

Ground water originates as rainfall that percolates through the soil. Annual rainfall on the Delmarva Peninsula is about 44 inches. Most of this is used by plants or flows over the land to surface water, such as streams, ponds, and bays. The remaining water moves through the soil to ground water. Contrary to popular belief, ground water does not form underground "rivers." Instead, it fills and flows very slowly through tiny spaces between sediment grains.



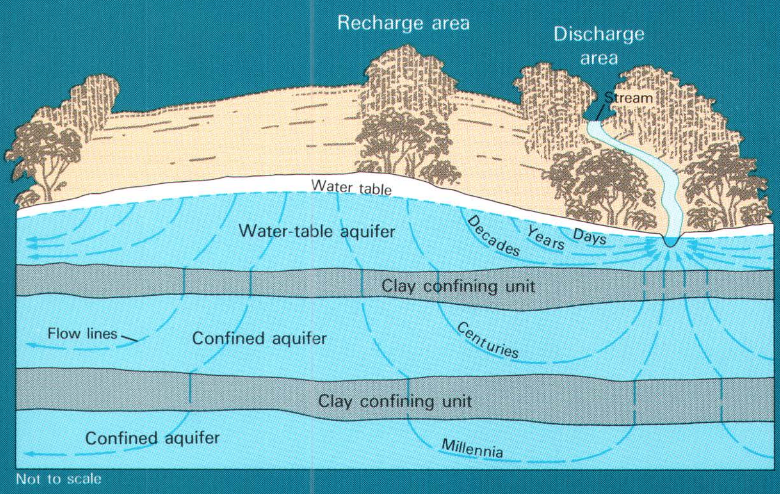
Underground sediments are not uniform. In the Delmarva Peninsula they are arranged in a layered sequence of sandy water-bearing formations, known as aquifers, separated from one another by layers of clay, known as confining units. The uppermost sandy layer, extending to a depth of 40 to 100 feet, is known as the water-table aquifer. The deeper sandy layers, extending to about 8,000 feet, are known as confined aquifers because they are confined by clay at both their top and bottom margins. Although the clay layers impede the flow of ground water between the aquifers, some downward movement does occur.

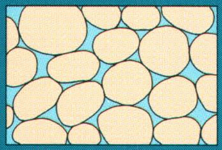
Water flows more freely in sand than it does in clay, and the sand aquifers readily transmit useful amounts of water to wells. The confined aquifers are the primary source of public-drinking water, except in the southern counties of Maryland and in Sussex County, Delaware, where the water-table aquifer is the primary source. The water-table aquifer also supplies large quantities of water for irrigation, and is tapped by domestic wells in rural areas. About half of the 170 million gallons per day pumped from wells on the peninsula is from the water-table aquifer. The water-table aquifer is the focus of the Delmarva NAWQA study because of its extensive use and because it supplies water to the underlying confined aquifers.

Rainfall percolates through the soil and recharges the water-table aquifer. Ground water moves by gravity from these recharge areas through the aquifer to low-elevation discharge areas, such as streams, agricultural ditches and ponds, bays, and the Atlantic Ocean. It is common to think of surface water and ground water as separate resources; however, they are highly interconnected. Ground water can significantly affect the quality and quantity of surface water. This is particularly important on the Delmarva Peninsula where ground water is the major source of streamflow.

HYDROLOGISTS COLLECTING WATER SAMPLES FROM WELLS FOR ANALYSES OF NITRATE, PESTICIDES, AND OTHER CONSTITUENTS.

Ground-water movement is very slow. Typically, water in the water-table aquifer moves one-quarter to 2 feet per day. Total distance that this water travels under ground varies from hundreds of feet to several miles. Depth of flow varies from near the surface to about 100 feet. The depth of flow usually increases with increasing distance between recharge and discharge areas. As a result of the slow movement, water can remain in the water-table aquifer for several decades. Because of the even slower movement of water in the intervening clay layers, as well as deep (thousands of feet) and long (hundreds of miles) travel paths, water could remain in the confined aquifers for centuries or longer.





GENERAL DIAGRAM OF GROUND WATER IN THE DELMARVA PENINSULA. GROUND WATER FLOWS MOSTLY FROM RECHARGE TO DISCHARGE AREAS THROUGH SPACES BETWEEN SAND GRAINS IN THE AQUIFERS. WATER FLOWS LESS FREELY IN THE CLAY CONFINING LAYERS, ALTHOUGH MOVEMENT BETWEEN AQUIFERS OCCURS. THE TIME FOR WATER TO MOVE THROUGH THE AQUIFER, FROM A POINT OF RECHARGE TO A POINT OF DISCHARGE, IS SHOWN ON THE GROUND-WATER FLOW LINES.

The USGS began the NAWQA study of ground water in the Delmarva Peninsula in 1986. Hydrologists collected water samples from more than 200 wells in the water-table aquifer and more than 35 wells in the underlying confined aquifers. The samples were analyzed for nitrate, pesticides, and other dissolved constituents that can affect water quality. Locations of the wells were selected without bias toward any known or suspected problem areas. Areas around the wells differ in land use and soils, as well as in geologic characteristics and landscape. This site diversity ensures that the NAWQA analysis include a peninsula-wide characterization of ground-water quality and problems, and a detailed assessment of cause-and-effect relations between water quality and ground-water flow, land use, soils, and geology.

"Natural" ground-water quality (not affected by human activities) is controlled primarily by the chemical properties of rainwater in combination with minerals and biological activity in the soil and aquifers. Like rainwater, natural water in the water-table aquifer is moderately acidic with a pH of about 5.5 (a pH of 7.0 is neutral). It contains a lower concentration of dissolved constituents (generally less than 100 milligrams per liter)[1] compared to ground water in other parts of the country because aquifer materials on the Delmarva Peninsula consist mostly of quartz sand, which does not readily dissolve. Because of the relatively dilute concentrations of dissolved constituents, additional inputs, such as fertilizers applied to the land, could significantly change the chemical properties of the water. The quality of natural water in the water-table aquifer is generally good and suitable for most purposes. In some areas, the water has concentrations of iron and manganese in excess of 300 and 50 micrograms per liter, respectively, which can cause brownish discolorations to plumbing fixtures and laundry and a bitter taste. Chloride concentrations in excess of 250 milligrams per liter, which can make the water taste salty, can result from intrusion of saltwater into aquifers along coasts and tidal streams.

As water moves from the water-table aquifer to the confined aquifers, it dissolves various minerals and its chemistry changes. Confined ground water is less acidic and has a greater amount of dissolved constituents then does water in the water-table aquifer. Natural water in the confined aquifers also has concentrations of iron that reach a maximum of 27,000 micrograms per liter.

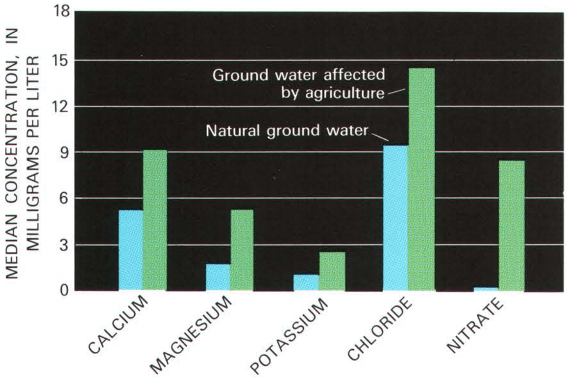
[1]The terms milligrams and micrograms per liter are used in this report. A milligram is equal to one-thousandth of a gram, and is approximately equal to the weight of 6 crystals of common table salt. A microgram is a smaller quantity, and is equal to one-millionth of a gram.

IS NITRATE IN THE

As water seeps through the soil to the water table, it can be affected by substances applied to the land, such as lime and inorganic and organic fertilizers. More than 40 millions tons of inorganic fertilizers are used annually in the Nation. Not all of it is used by plants, and the excess might enter ground water. On the Delmarva Peninsula, chicken manure is an important additional source of nutrients. In Delaware alone, about 140 million chickens are raised annually. Even though the birds generally are raised indoors, the litter (about 5 tons per 1,000 chickens per year) is stored in piles outdoors or spread on fields.

Applications of lime, inorganic fertilizers, and manure have changed the natural chemical properties of water in the water-table aquifer in the Delmarva Peninsula. Nitrate, derived from nitrogen in the inorganic fertilizers and manure, is a major constituent in the water-table aquifer in agricultural areas, partly because nitrate readily dissolves and moves freely to the water table with rainwater or irrigation water that is applied to the land. Concentrations of potassium and chloride from inorganic potash fertilizers, and calcium and magnesium from liming, also are significantly elevated. These constituents together impart a distinctive agricultural-chemical trademark to the ground water, different from the natural water. Except for nitrate, these constituents do not pose a health risk; however, their presence does provide an efficient means for distinguishing ground water affected by agricultural practices and can be used to identify areas that might be vulnerable to contamination from other agricultural chemicals, such as pesticides.

NITROGEN FERTILIZER GENERALLY IS APPLIED TO FIELDS IN THE FORM OF AMMONIA, LIQUID NITROGEN, AND POULTRY MANURE, ALL OF WHICH READILY CONVERT TO NITRATE.



MAJOR CONSTITUENTS IN WATER IN THE WATER-TABLE AQUIFER IN AGRICULTURAL AREAS ARE NITRATE FROM INORGANIC FERTILIZERS AND MANURE, CALCIUM AND MAGNESIUM FROM LIMING, AND POTASSIUM AND CHLORIDE FROM POTASH.

The peninsula-wide survey showed that water from more than 70 percent of all wells in the water-table aquifer has detectable concentrations of nitrate and that about 15 percent contain concentrations that exceed 10 milligrams per liter, the maximum contaminant level for drinking water established by the U.S. Environmental Protection Agency.

SOME NITRATE FACTS

NATURAL SOURCES: Insignificant on the Delmarva Peninsula (generally less than 1 milligram per liter); some nitrogen in soil and atmospheric deposition

HUMAN-RELATED SOURCES: Inorganic fertilizers, manure, and septic effluent

HOW MUCH IS TOO MUCH? 10 milligrams per liter (maximum contaminant level for drinking water, established by the U.S. Environmental Protection Agency, 1986)

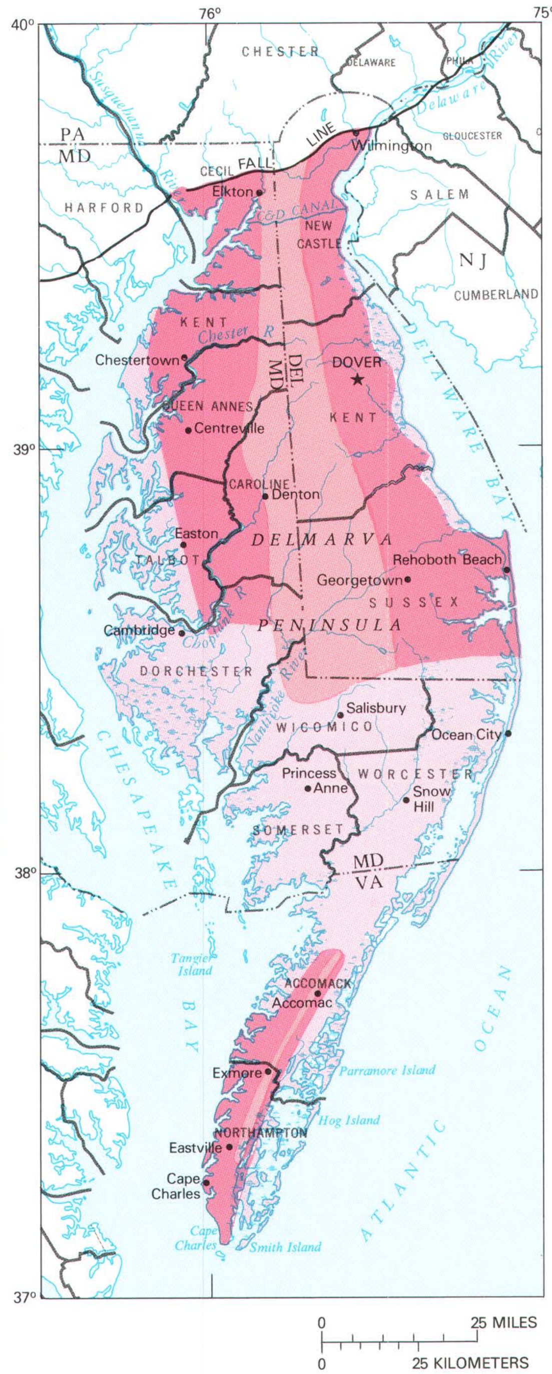
POSSIBLE HEALTH IMPACTS: Methemoglobinemia or ''blue-baby syndrome'' in infants; stomach disorders in some animals

TERMINOLOGY: Nitrate concentrations in this report are expressed as nitrogen content.

Nitrate concentrations in some water samples are as high as 48 milligrams per liter. How vulnerable ground water is to nitrate contamination depends on a combination of factors such as geology, soils, land use, and hydrology. For example, nitrate concentrations are not commonly elevated in the central part or the western fringes of the peninsula. This is in part because the water-table aquifer in these areas contains a substantial amount of clay and silt instead of sand. The abundant clay and silt impedes downward movement of water. Clay and silt also enhance nitrogen uptake by plants; thus, less nitrogen is available to move through the soil to the ground water. In general, agricultural plots are small and there is a higher percentage of woodlands in these parts of the peninsula than elsewhere.

In contrast, nitrate concentrations are elevated in the water-table aquifer in the northern part and southern tip of the peninsula, particularly in the areas that flank the central upland. This is mostly because the sandy soils and aquifer sediments are more permeable, allowing nitrate to move readily to the water table. Agricultural plots are large and well drained in these areas, with woodlands primarily confined to borders along streams.

Nitrate is not commonly detected in the underlying confined aquifers. None of the water samples had nitrate concentrations that exceeded the maximum contaminant level for drinking water. This is mostly attributable to the slow movement of water in the clay confining layers that separate the confined aquifers from the overlying water-table aquifer.

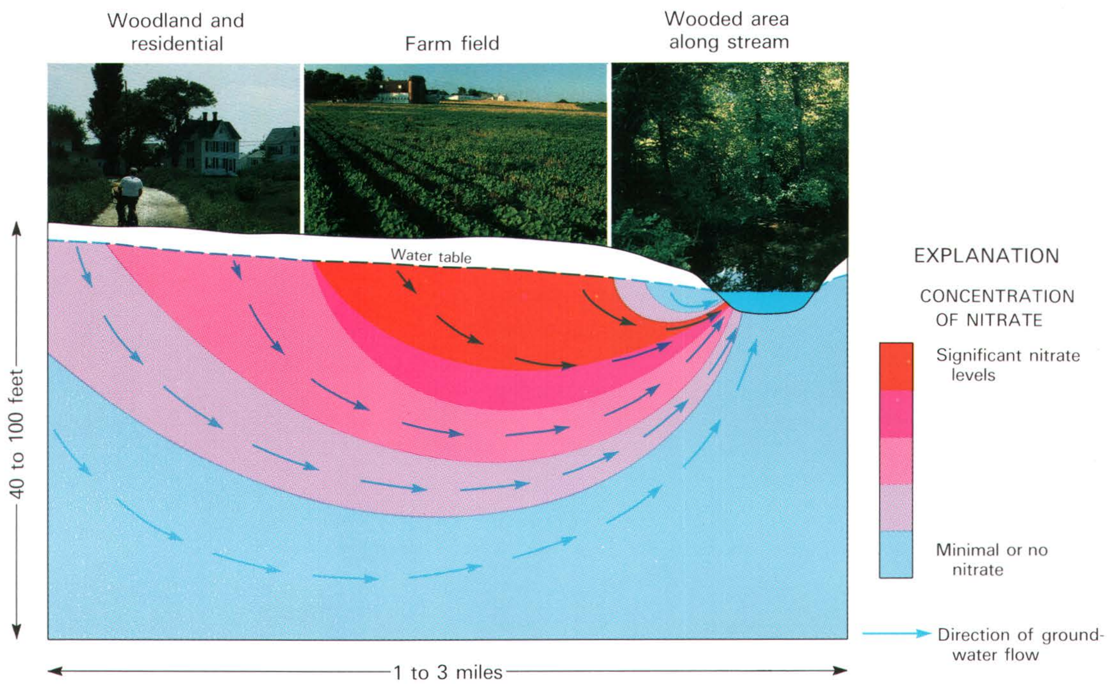


EXPLANATION

Nitrate concentrations vary regionally, depending on factors such as geology, soils, land use, and hydrology

- Area with little nitrate
- Area with detectable concentrations of nitrate, generally less than 10 milligrams per liter
- Area with detectable concentrations of nitrate, commonly near or exceeding 10 milligrams per liter

Elevated nitrate concentrations are not limited to near-surface ground water, but occur in the deepest part of the water-table aquifer, 80 to 100 feet below the land surface.



NITRATE CONCENTRATIONS ARE VARIABLE OVER SMALL DISTANCES, BOTH HORIZONTALLY AND VERTICALLY, DEPENDING ON LAND USE AND THE MOVEMENT OF WATER. NITRATE CONCENTRATIONS ARE HIGHEST IN NEAR-SURFACE GROUND WATER BENEATH FARMLAND AND LOWEST BENEATH WOODLANDS AND MARSHES. NITRATE CONCENTRATIONS ARE ELEVATED IN DEEP GROUND WATER WHERE DISTANT RECHARGE AREAS ARE AGRICULTURAL OR RESIDENTIAL.

USGS hydrologists studied the local distribution of nitrate in the water-table aquifer in a network of wells in several small watersheds (1 to 3 square miles). Concentrations of nitrate vary over small distances, both horizontally and vertically, depending on ground-water flow and land use. The typical land-use pattern includes woodlands and residential areas in the upland regions of the watersheds, woodlands and marshes along streams and coasts, and agricultural areas in between. In ground water near the land surface (less than 20 feet deep), nitrate concentrations generally reflect overlying land use within 100 to 200 feet of the well. Nitrate concentrations are highest beneath farmland and lowest beneath woodlands and marshes. Nitrate concentrations also are elevated in near-surface ground water beneath residential areas, which is attributable to septic effluent and lawn fertilizers. These nitrate concentrations, however, are not as elevated as they are in water beneath farmland.

Elevated nitrate concentrations are not limited to near-surface ground water but occur in the deepest parts of the water-table aquifer, 80 to 100 feet below the land surface. The deep ground water flows along longer paths in the water-table aquifer than does the near-surface ground water and can remain in the aquifer for several decades. As a result, water from a deep well reflects land use at a distant recharge area rather than land use directly around the well.

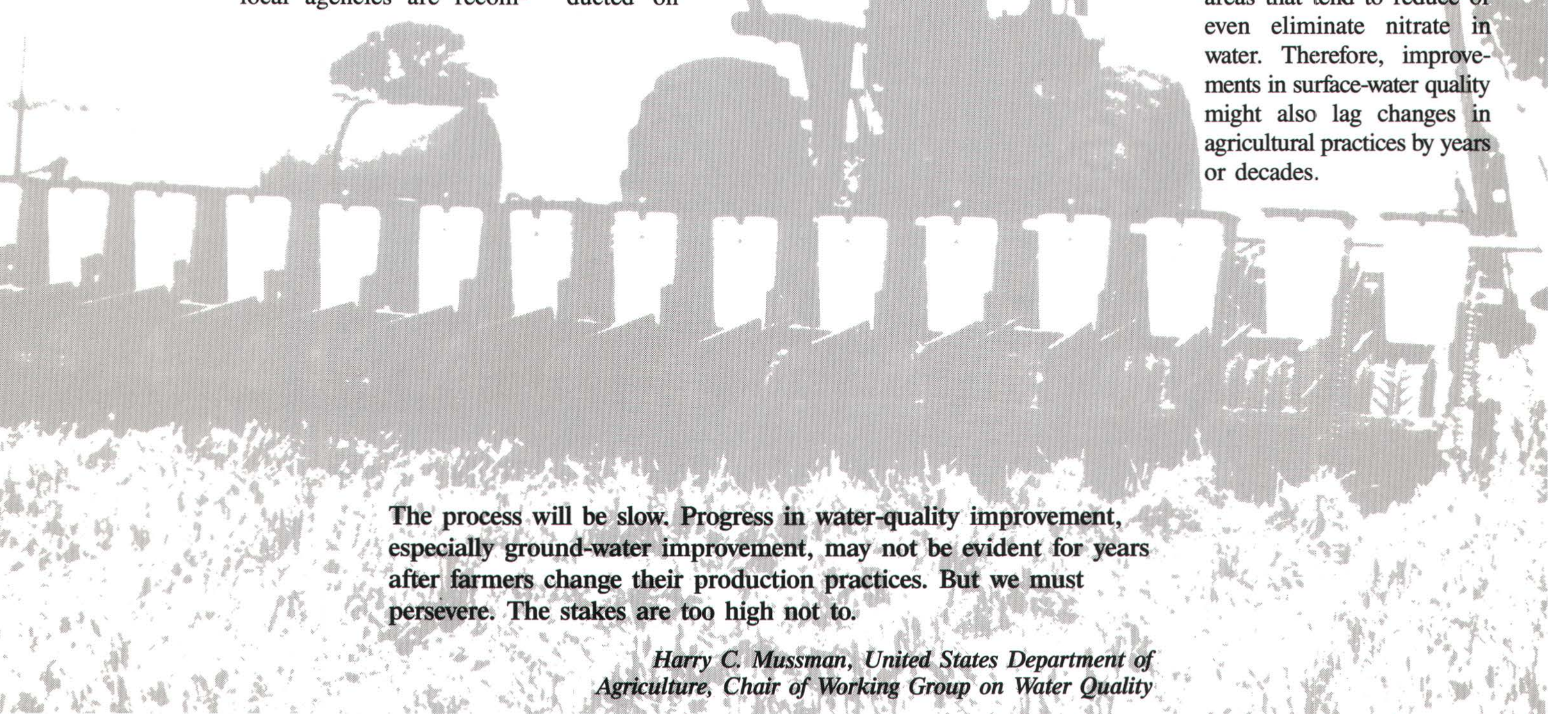
ROTATION OF WHEAT WITH SOYBEANS IS A CROP-MANAGEMENT STRATEGY THAT CAN REDUCE THE AMOUNT OF NITRATE LEAVING THE ROOT ZONE, THUS REDUCING THE AMOUNT AVAILABLE TO GROUND WATER.

CLOSER LOOK....

In some areas of the Delmarva Peninsula, deep ground water with elevated nitrate concentrations is overlain by near-surface ground water with low nitrate concentrations. This seemingly unexpected pattern of nitrate concentrations is most commonly found in marshes and wooded areas next to streams. In these areas, the near-surface ground water is recharged through soils covered with natural vegetation and the deeper ground water is recharged in distant agricultural or residential areas.

Many Federal, State, and local agencies are recommending changes in crop-management strategies to reduce inputs of nitrate in farm fields in ground-water-recharge areas. These strategies are designed to reduce the amount of nitrate leaving the root zone, and therefore the amount of nitrate available to move to the water table. Typical strategies include the rotation of crops that require high fertilization rates (such as wheat) with those that require little fertilization (such as soybeans). As more research is conducted on nitrogen needs and uptake by individual crops, farmers have learned to optimize the amount and timing of fertilizer applications, which also minimizes the amount of nitrate available to ground water. These strategies are critical; however, in order to properly evaluate their effectiveness, one must understand how ground-water flow and land use affect water quality over both time and space. Shallow ground-water quality below farmland will improve first, in several years or less. Decades may pass, however, before water improves in the deep parts of the aquifer.

The time lag between the adoption of crop-management strategies and water-quality improvement also affects surface-water quality. Deep ground water containing elevated nitrate concentrations can discharge directly to streams and bays. These deep waters commonly bypass the rich organic matter and low dissolved oxygen conditions in the marshes and wooded areas that tend to reduce or even eliminate nitrate in water. Therefore, improvements in surface-water quality might also lag changes in agricultural practices by years or decades.



The process will be slow. Progress in water-quality improvement, especially ground-water improvement, may not be evident for years after farmers change their production practices. But we must persevere. The stakes are too high not to.

Harry C. Mussman, United States Department of Agriculture, Chair of Working Group on Water Quality

ARE PESTICIDES IN

NEARLY 3 MILLION POUNDS OF AGRICULTURAL HERBICIDES, INSECTICIDES, AND FUNGICIDES ARE USED ANNUALLY IN THE DELMARVA PENINSULA TO ENHANCE PRODUCTION BY CONTROLLING WEEDS, INSECTS, AND FUNGI.

A large quantity (about 570 million pounds) of herbicides, insecticides, and fungicides is used annually throughout the Nation to enhance agricultural production by controlling weeds, insects, and fungi. In the Delmarva Peninsula, nearly 3 million pounds of these chemicals are used annually for agricultural purposes. Most by far are herbicides, with metolachlor (such as Dual), alachlor (such as Lasso), and atrazine (such as AAtrex) accounting for about 70 percent. These herbicides are used primarily on corn and soybeans, the two most widespread crops in the Delmarva Peninsula.

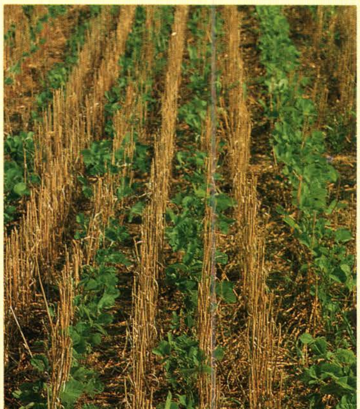
Water samples from more than 100 wells in the water-table aquifer were analyzed for about 40 different pesticides. These include metolachlor, alachlor, and atrazine, and most of the other commonly used agricultural pesticides in the peninsula. One of the findings of the peninsula-wide sampling is that two of the most commonly used herbicides, alachor and atrazine, were also the most likely to be detected in ground water. Atrazine and (or) alachlor were detected in more than 20 water samples. The only insecticide detected was carbofuran, in only two water samples. The frequency at which pesticides were detected is roughly related to the amount of the pesticide applied and the total number of acres treated with it. Some variability is probably attributable to the varying solubility and mobility of individual pesticides in soil.

Concentrations of pesticides were generally low: 94 percent of the water samples with detectable concentrations of pesticides were less than the U.S. Environmental Protection Agency maximum contaminant and health advisory levels for drinking water.[2] Concentrations above these levels are thought to contribute to long-term health problems. Atrazine exceeded the maximum contaminant level in one sample. Alachlor exceeded the level in two samples. Pesticides were not found in ground water used for public or private water supply except for trace concentrations in water samples collected from a few domestic wells.

[2]Maximum contaminant levels and health advisory levels are established by the U.S. Environmental Protection Agency. Maximum contaminant levels are enforceable, and represent the maximum permissable level of a contaminant in water that is delivered to any user of a public-water system. Health advisory levels are not enforceable, and represent the maximum concentration of a contaminant in water that may be safely consumed over a specific length of time.

PLANE DUSTING CROPS WITH PESTICIDES, PRIOR TO EMERGENCE OF CROPS.

The distribution of detected pesticides depends on land use, crop type, and ground-water flow. In most water samples in which herbicides were detected, the well was near farmland (generally within 100 feet) used to grow corn and soybeans, the two crops associated with the highest herbicide use and most extensive acreage. These water samples commonly contained calcium, magnesium, and nitrate as major constituents, indicating that the water also had been affected by agricultural lime and fertilizers. Water samples in which pesticides were detected were generally collected from no more than 20 feet below the water table, and generally reflected pesticide use in the immediate vicinity (within 100 to 200 feet of the well). Only a few pesticides were detected in samples from wells greater than 50 feet below the water table. The apparent absence of the pesticides in deep ground water may relate to chemical changes or breakdown of the pesticides to other products. Desethylatrazine, a breakdown product of atrazine, was detected in water samples from a few wells at depths as great as 70 feet below the water table. Atrazine was not detected in several water samples in which the breakdown product desethylatrazine was detected. These breakdown products probably were derived from applications of atrazine in distant farmland in the past, perhaps during its early use in the late-1950's and 1960's in the peninsula.



HOW DOES ATRAZINE IN THE DELMARVA PENINSULA AND IOWA COMPARE?

[Atrazine, commonly used on corn, was the most frequently detected pesticide in rural ground water in both the cornbelt State of Iowa and in the Delmarva Peninsula. Atrazine was detected at a similar frequency in wells tapping the aquifer less than 50 feet below land surface, and most of the concentrations were below the national maximum contaminant level for drinking water established by the U.S. Environmental Protection Agency.]

	Delmarva Peninsula	Iowa[1]
Number of wells tapping the aquifer less than 50 feet below the surface:	89	192
Percentage of wells with atrazine detections greater than 0.13 micrograms per liter[2]:	4.5	5.2
Percentage of wells with atrazine concentrations greater than the national maximum contaminant level for drinking water, 3.0 micrograms per liter:	1.1	1.6
Maximum atrazine concentration, in micrograms per liter:	11.0	6.6

[1]The Iowa State-Wide Rural Well-Water Survey, Iowa Department of Natural Resources, November 1990

[2]A higher detection level was used in the Iowa study (0.13 micrograms per liter) than in the Delmarva Peninsula NAWQA study (0.05 micrograms per liter) because of differences in laboratory techniques; therefore, only detections in ground water in the Delmarva Peninsula above 0.13 micrograms per liter are cited in this table. Differences in sampling times, climate, soil type, hydrology, and land use may affect the comparison between the two studies.

IMPLICATIONS OF FIN[DINGS] OF WATER QUALITY ON [THE BAY]

NITRATE: IS THERE A CONCERN?

What do these results mean to residents who drink the water?

- Potential concern to residents who drink water from wells in the water-table aquifer.
- Little to no concern to residents who drink water from wells in the underlying confined aquifers.

What are the other concerns?

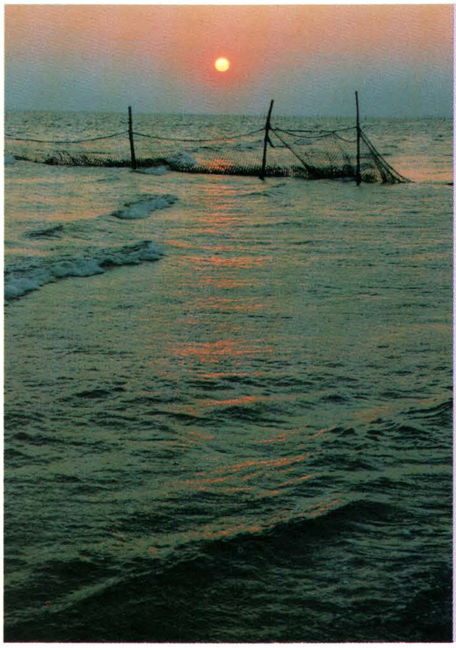
- Long-term concern that contaminated ground water might move from the water-table aquifer to the underlying confined aquifers.
- Potential effects of elevated nitrate concentrations in ground water on the Chesapeake Bay and its ecosystem.

Agricultural applications of lime, inorganic fertilizers, and manure have changed the natural composition of water in the water-table aquifer in large areas of the peninsula, and nitrate has become one of the major constituents in the water. Nitrate concentrations exceed the maximum contaminant level for drinking water of 10 milligrams per liter in about 15 percent of the wells that tap the water-table aquifer, and pose a health risk for residents who drink this water. Nitrate does not pose a health risk for residents who drink water from the deeper and relatively uncontaminated confined aquifers. However, there is a long-term concern that contaminated water might move from the water-table aquifer down to the underlying confined aquifers, which are the chief source of public-water supply in the peninsula. Nitrate contamination in the deep aquifers is a major problem for water-resource managers on Long Island, New York–an area that is similar to the Delmarva Peninsula in hydrology and topography.

A more immediate concern is the effect of elevated nitrate concentrations in ground water on the Chesapeake Bay and its ecosystem. Recent studies have shown that the contribution of ground water to this immense estuary might be similar in quantity to that of a major tributary, such as the James River in Virginia. Increased concentrations of nitrate can contribute to excessive growth of algae whose subsequent decay results in a decline in dissolved-oxygen in the water. Low dissolved oxygen concentrations can harm fish and shellfish that are ecologically and economically important to the Bay.

Many local, State, and Federal programs have been implemented to monitor and protect surface water (including the entire Chesapeake Bay) and ground water from potential nitrate contamination. These programs include the protection of marshes and wetlands, crop-management strategies, and wellhead protection strategies. Patterns of ground-water flow and land use are important considerations in the implementation, management, and evaluation of these programs (see inset). Rates and paths of ground-water flow, as well as character of the land in which the ground water originates, can substantially affect improvement efforts.

Patterns of ground-water flow and land use also are important factors in the distribution of pesticide contamination in the peninsula. For example, in most cases in which pesticides were detected, the sampled water was within 20 feet of the water table. These samples generally reflect overlying farmland, used to grow corn and soybeans, that is within 100 to 200 feet of the well. Breakdown products of selected pesticides were detected in some water samples at depths as great as 70 feet

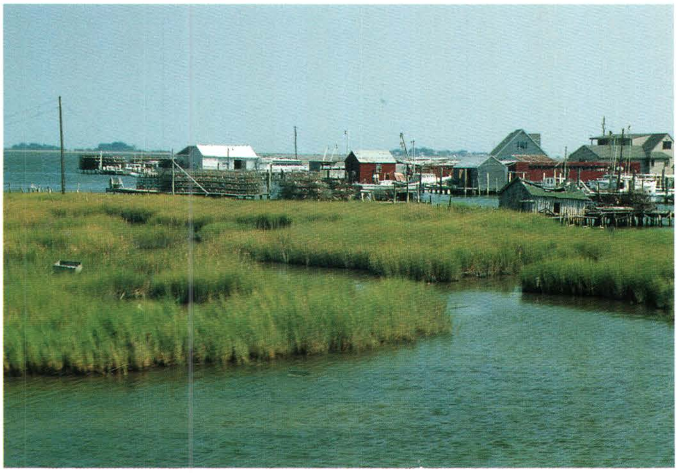


THE CHESAPEAKE BAY AT SUNSET.

Ground-water contribution to the Chesapeake Bay is seemingly invisible but may be the equivalent to that of a major tributary, such as the James River in Virginia. Ground water, like surface water, can carry excessive nutrients from farmers' fields, urban areas, and residential developments which routinely deprive the Bay of the oxygen needed to support more than 2,700 species of plants and animals. It is now time to consider the role of ground water in the decline of this fragile and immense national treasure.

Charles Spooner, U. S. Environmental Protection Agency, Deputy Director of the Chesapeake Bay Program

NGS ON MANAGEMENT
E DELMARVA PENINSULA



LITTLE IS KNOWN ABOUT THE EFFECTS OF LONG-TERM EXPOSURE OF AQUATIC PLANTS AND ANIMALS TO GROUND WATER THAT CONTAINS LOW CONCENTRATIONS OF PESTICIDES.

PESTICIDES: IS THERE A CONCERN?

What do these results mean to residents who drink the water?

Minimal health risk from agricultural pesticides for residents who drink ground water in the Delmarva Peninsula. Pesticides were detected at very low levels; 94 percent of those detected were less than U.S. Environmental Protection Agency maximum contaminant and health advisory levels for drinking water.

What are the other concerns?

Unknown health risks of pesticide breakdown products and of pesticides in combination with each other.

Undefined presence of homeowner and agricultural pesticides for which water samples were not tested.

Unknown environmental effects of low concentrations of pesticides in ground water on the Chesapeake Bay and other surface water.

Inadequate information on historic and current use of pesticides.

below the water table. An understanding of the ground-water-flow and land-use patterns can help water-resource managers to identify areas most likely to be affected and, thus, be useful for optimizing resources required for monitoring pesticides (see inset).

Most of the pesticides were detected at very low concentrations, and concentrations of 94 percent of those detected were less than U.S. Environmental Protection Agency maximum contaminant and health advisory levels for drinking water. On the basis of these levels for the compounds tested and analyzed, the findings suggest that there is no immediate peninsula-wide health risk to the residents of the Delmarva Peninsula who drink ground water. There are some further considerations, however. The first relates to the breakdown products of the pesticides, which were only monitored in a limited number of wells because of the relatively new laboratory techniques used to measure them. Little is known about the chemical properties and possible health effects of these breakdown products. Additional sampling is needed to assess their distribution across the region, particularly in deep ground water. A second consideration involves the effects of pesticides in combination with each other. Concentrations of individual pesticides were generally less than U.S. Environmental Protection Agency maximum contaminant and health advisory levels for drinking water; however, possible health effects of combinations of these pesticides are unknown. A third consideration relates to the scope of the pesticides that were analyzed. Water samples were tested for about 40 pesticides for which laboratory techniques were available. Some commonly used agricultural pesticides, such as linuron, were not tested; the concentrations of these pesticides in ground water and the potential effects on the potability of ground water are unknown. In addition, most of the pesticides tested were designed to control weeds, insects, and fungi on agricultural land. Many of the pesticides commonly used by homeowners were not tested. The fourth consideration is the lack of information on the environmental effects of these chemicals when they ultimately discharge into surface water. Little is known about the long-term exposure of aquatic plants and animals to low concentrations of pesticides. A final consideration is the inadequacy of information on historic agricultural and residential use of pesticides, including the kinds used and the rates of application. Because of the typically slow movement of ground water, pesticides applied in the past can affect deep ground water for many decades.

IMPLICATIONS OF FINDINGS ON MANAGEMENT OF WATER QUALITY ON THE DELMARVA PENINSULA

IMPLICATIONS OF FINDINGS ON THE MANAGEMENT OF PROGRAMS THAT MONITOR AND PROTECT GROUND-WATER QUALITY

CROP-MANAGEMENT PRACTICES:

Changes in crop management are designed to reduce inputs of nitrate in farm fields. Reduction in nitrate will be slow, however, because of the slow rates at which ground water flows. The quality of water will improve first in near-surface parts of the water-table aquifer beneath farmland; decades might pass before quality improves in deep parts of the aquifer.

WELLHEAD PROTECTION STRATEGIES:

The appropriate recharge area needed to be protected depends on land use, the depth of the well, and ground-water flow. The quality of water in near-surface parts of water-table aquifer reflects land use in a recharge area usually within 100 to 200 feet of the well; the quality of water in deep parts of the aquifer reflects land use at a distant recharge area.

PROTECTION OF WETLANDS, MARSHES, AND WOODED AREAS ALONG STREAMS:

Wetlands, marshes, and wooded areas along streams are protected to help maintain the quality of nearby surface waters and associated ecosystems. Deep ground water, however, frequently bypasses these areas and discharges directly to adjacent streams and bays. This deep ground water can, therefore, potentially degrade the quality of the surface water associated with the wetlands, marshes, and wooded areas.

IMPLICATIONS OF FINDINGS ON PESTICIDE SAMPLING STRATEGIES:

How to identify areas most likely to be affected in order to optimize limited resources for monitoring pesticides...

Commonly used pesticides are present in ground water near farmland used to grow corn and soybeans—two crops that account for the highest pesticide use and most extensive acreage. Areas where ground water is most likely to contain pesticides could, therefore, be identified from available information on land and pesticide use and crop type.

Nitrate, calcium, and magnesium are major constituents in water affected by agriculture. Relatively inexpensive analyses for these constituents could be used to help identify areas that might be vulnerable to other agricultural chemicals, such as pesticides.

Pesticides are most common in water within 20 feet of the water table. Breakdown products of pesticides are in water in both shallow and deep parts of the water-table aquifer. An understanding of ground-water-flow patterns is useful for identification of the distribution of pesticides and their breakdown products in ground water.

Extensive agricultural land use on the Delmarva Peninsula has introduced nitrate and pesticides to ground water. This study has helped identify where the contamination is most likely to occur. The pattern of contamination depends on a number of factors, including crop type, geology, soils, land use, and ground-water flow. An understanding of these factors is critical to those individuals who make decisions about crop-management practices, land-use planning, and water management. Facilitating data exchange among water-resource managers in agencies at the Federal, State, and local levels, as well as university researchers and extension personnel, is a major mission of the NAWQA Program, and will remain so for its duration.

Communication and coordination among the USGS and other interested scientists and water-management personnel are important components of the NAWQA Program. To make best use of the resources available, we are committed to foster information exchange and cooperation among all relevant agencies through the duration of this long-term program. Every level of government and the private sector has a role to play.

Philip Cohen, U.S. Geological Survey, Chief Hydrologist, Water Resources Division

A COORDINATED EFFORT

Coordination among agencies and organizations at all levels is essential to understanding effects of agricultural chemicals in ground water on the Delmarva Peninsula. This publication was coordinated with the following organizations:

FEDERAL AGENCIES:

U.S. Department of Agriculture
Agricultural Research Service
Economic Research Service
Soil Conservation Service

U.S. Army Corps of Engineers

U.S. Department of the Interior
Fish and Wildlife Service

U.S. Environmental Protection Agency

DELAWARE STATE AGENCIES:

Delaware Geological Survey
Delaware Water Resources Center
Department of Natural Resources
and Enviromental Control

MARYLAND STATE AGENCIES:

Maryland Department of Agriculture
Maryland Department of the Environment
Maryland Geological Survey
Maryland Institute for Agriculture
and Natural Resources

VIRGINIA STATE AND LOCAL AGENCIES:

Accomack-Northampton Planning
District Commission
Department of Agricultural and
Consumer Services
Department of Mines, Minerals, and Energy
Virginia Eastern Shore Soil and
Water Conservation District
Virginia Water Control Board
Virginia Water Resources Research Center

UNIVERSITY AND NONPROFIT ORGANIZATIONS:

The Nature Conservancy
University of Maryland, Department
of Agricultural Engineering
Virginia Polytechnic Institute
and State University

Much appreciation is extended to U.S. Geological Survey employees for their expertise in the production of illustrations by Leslie J. Robinson and James O. Whitmer; type composition by Shirlie A. McManus; and photography by David F. Usher.

Appreciation is also extended to those individuals and agencies that contributed photographs:

Delaware Department of Natural Resources
and Environmental Control
Dwight Dyke, Richmond, Virginia
Maryland Institute for Agriculture
and Natural Resources
Maryland Department of Agriculture
Soil Conservation Service, U.S. Department
of Agriculture
Virginia Eastern Shore Soil and Water
Conservation District

FOR ADDITIONAL INFORMATION:

Many Federal, State, and local agencies and non-profit organizations involved with general ground-water research and regulatory functions have published numerous reports on ground water in the Delmarva Peninsula. The reports provide results of studies on movement of ground water, chemical quality of the water, and general ground-water resources. General information on water resources can be obtained by writing to:

FEDERAL ORGANIZATIONS:

U.S. Department of Agriculture, Soil Conservation Service	339 Revell Highway Annapolis, Md. 21401	301-757-2872
U.S. Environmental Protection Agency Region 3, Ground Water Protection	841 Chestnut Bldg. Philadelphia, Pa, 19107	215-597-8826
U.S. Geological Survey, Water Resources Division	208 Carroll Building Towson, Maryland 21204	301-828-1535

DELAWARE ORGANIZATIONS:

Delaware Department of Natural Resources and Environmental Control	P.O. Box 1401 89 Kings Highway Dover, Delaware 19903	302-739-4556
Delaware Geological Survey	University of Delaware Newark, Delaware 19716	302-831-2834
Delaware Water Resources Center	101 Hullihen Hall, U. of Del. Newark, Delaware 19903	302-831-2191

MARYLAND ORGANIZATIONS:

Maryland Department of Agriculture	50 Harry S Truman Parkway Annapolis, Maryland 21401	301-841-5770
Maryland Department of the Environment, Water-Quality Program	2500 Broening Highway Baltimore, Maryland 21224	301-631-3572
Maryland Geological Survey	2300 St. Paul Street Baltimore, Maryland 21218	301-554-5503
Maryland State Soil Conservation Committee	50 Harry S Truman Parkway Annapolis, Maryland 21401	301-841-5871
University of Maryland, Department of Agricultural Engineering	1126 Shriver Laboratory College Park, Maryland 20742	301-454-3901

VIRGINIA ORGANIZATIONS:

Accomack-Northampton Planning District Commission	P.O. Box 417 Accomac, Virginia 23301	804-787-2936
Department of Mines, Minerals, and Energy	Box 3667 Charlottesville, Virginia 22903	804-293-5121
Virginia Department of Agricultural and Consumer Services, Pesticides	P.O. Box 1163 Richmond, Virginia 23209	804-371-0152
Virginia Eastern Shore Soil and Water Conservation District	P.O. Box 127 Accomack, Va. 23301	804-787-1251
Virginia Water Control Board, Ground Water Program	P.O. Box 11143 Richmond, Virginia 23230-1143	804-527-5203
Virginia Water Resources Research Center	617 N. Main Street Blacksburg, Virginia 24060	703-231-5624

Additional information on the National Water-Quality Assessment Program can be obtained by writing to:

Deputy Assistant Chief Hydrologist NAWQA Program
U.S. Geological Survey
National Center, 12201 Sunrise Valley Drive, MS 413
Reston, Virginia 22092

Suggested Readings:

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Hamilton and Shedlock—ARE FERTILIZERS AND PESTICIDES IN THE GROUND WATER?—U.S. Geological Survey Circular 1080