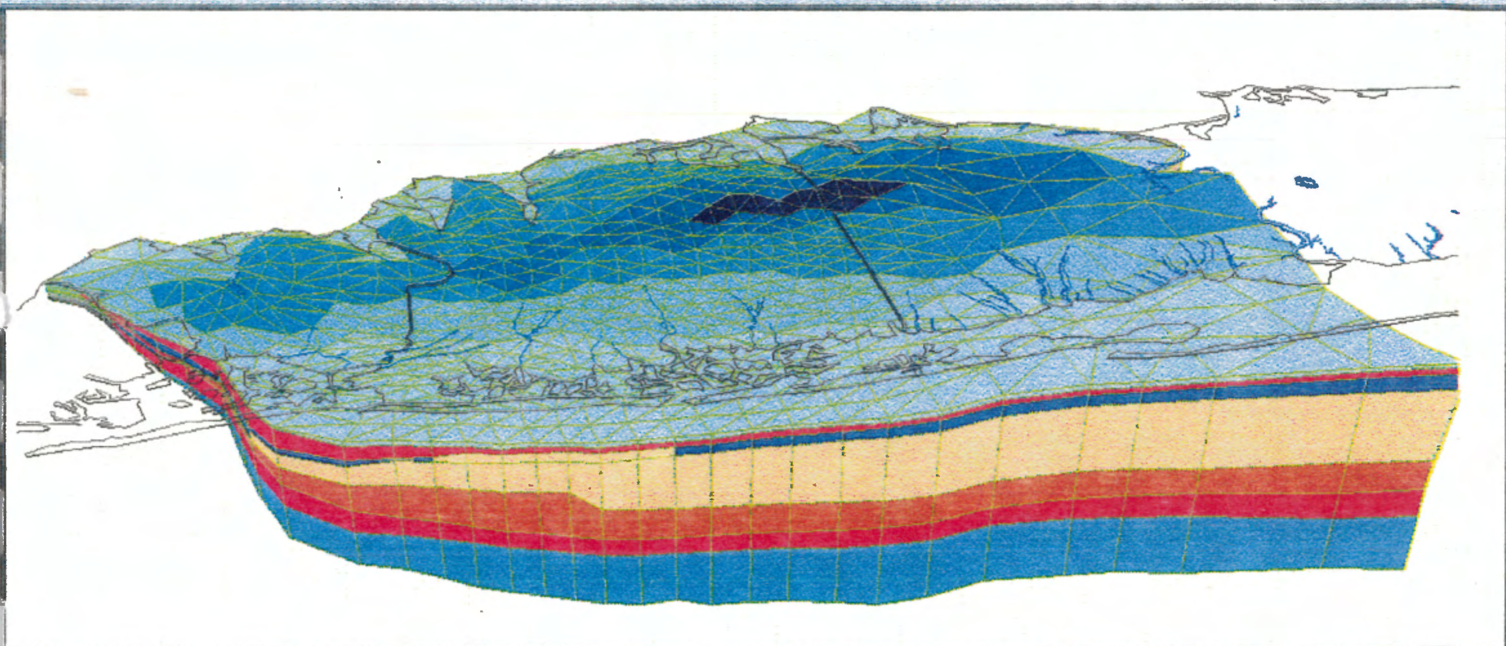
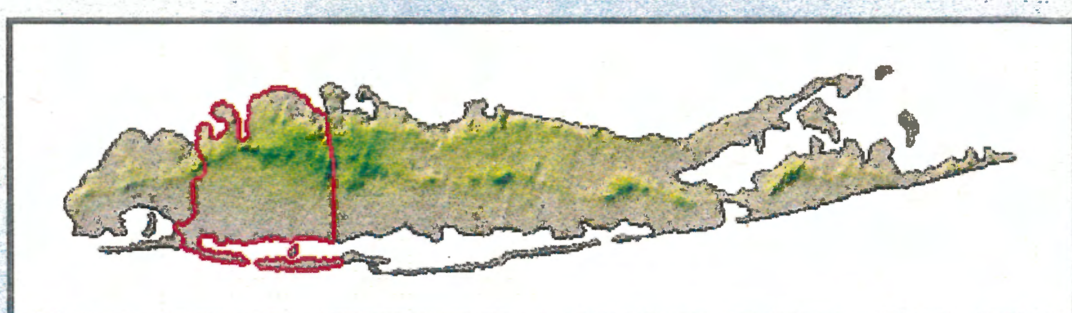
Nassau County 1998 Groundwater Study





Thomas S. Gulotta
County Executive

Nassau County
1998 Groundwater Study

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County Executive

John M. Waltz, P.E.
Commissioner
Department of Public Works

1998
Camp Dresser & McKee

Cover

Top - A three-dimensional representation of Nassau County produced by our computerized groundwater model (see page 2-7 for description). The faint, green triangular-shaped sections correspond to the mathematical grid of the model, while the various colored layers represent the major aquifers and confining units.

Bottom - A topographical map of Long Island with Nassau County outlined in red.

Acknowledgments

This report was developed by the Nassau County Department of Public Works, with the assistance of the staff of Camp Dresser & McKee, Woodbury, New York.

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Executive Summary

Nassau County is totally dependent on groundwater for all its water needs. Because the groundwater supply is critically important to the health and well being of all County residents, it has been studied intensively over several decades.

In early studies, projections of dramatic population growth and of vastly increased demand for water raised serious questions about both the quantity and the quality of the water supply. "Would there be enough water to meet the growing demand?" and "Would the water remain safe to drink?" were common questions. Public concern grew as studies projected that demand would eventually exceed supply, and reported a trend in deteriorating groundwater quality as a result of on-site wastewater disposal systems.

The 1998 Groundwater Study evaluates groundwater conditions through the year 2010 and is the first study to conclude that proper management of the County's groundwater resources will assure a safe and adequate water supply into the future.

This picture has changed markedly in recent years. To reduce groundwater contamination, the County began a comprehensive, multi-year program of installing sanitary sewer systems in the 1950s. By the mid-1980s, more than 90 percent of County residents and most commercial and industrial facilities were connected to these sanitary sewer systems. The sanitary sewers, along with public awareness and a broad range of federal, State and local regulatory programs, have greatly reduced the amount of contaminants entering the groundwater. As a result of the decrease in contaminants discharged to the ground, groundwater quality in the County has shown marked improvement in recent years and is expected to continue to improve.

Over the last several years, the County has utilized computerized groundwater models to study its water resources. These efforts have led to a more accurate assessment of various issues and have enabled the County to determine that the groundwater resource, if properly managed, is more than sufficient to meet future water demand.

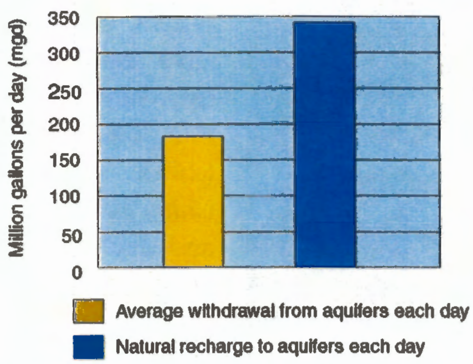
The groundwater system has tremendous ability to adjust to the stresses imposed by population growth and development. Increased rates of groundwater withdrawal and the installation of sanitary sewers have permanently lowered the water table and changed groundwater flow patterns within the groundwater system. These changes have resulted in two environmental impacts. First, the lower water table is causing diminishing flows in streams and declining water levels in lakes, ponds, and freshwater wetlands. Some streambeds are now entirely dry except for stormwater runoff during and after rainfall events. Second, changes in the groundwater system caused by water supply withdrawal and the installation of sanitary sewers are contributing to intrusion of saltwater into portions of freshwater aquifers. This poses a threat to some water supply wells located near the shorelines in several public water supply systems.

The *1998 Groundwater Study* includes an evaluation of groundwater conditions through the year 2010. It is the first County-commissioned study to conclude that proper management of the County's groundwater resource will assure a safe and adequate water supply into the future.

Groundwater Quantity — Supply Exceeds Demand

Over the past two decades, census figures have shown a stabilized County population and planners have revised their estimate of Nassau County's future population for the year 2010. Previous County water studies contained population projections as high as 2 million. Presently, the population is 1.3 million and planners estimate that it will remain almost constant to the year 2010. Based on the stabilization of population and a relatively stable water demand pattern, Nassau County's water demand is expected to average about 180 million gallons per day (mgd) through the year 2010.

The groundwater system that supplies the County's water is continually being recharged at an average rate of 341 mgd. As long as recharge exceeds the amount of groundwater withdrawn for water supply, the quantity of groundwater available for public supply will be more than adequate. The balance of recharged water travels through the groundwater system and is ultimately discharged to the surrounding saltwater bodies as streamflow or underflow.



Natural recharge to the aquifers greatly exceeds the amount withdrawn for public water supply.

Nassau County has pioneered the installation of recharge basins to collect stormwater runoff since the 1930s. The basins have proved invaluable in preventing flooding and in recharging the groundwater system. In fact, the recharge basins are responsible for a slight increase in recharge to the groundwater system when compared to that of pre-development times.

Current groundwater withdrawal, combined with the County's sanitary sewer system, have caused an average drop in the water table of 4 to 5 feet when compared to pre-development levels. This drop corresponds to a loss in storage of less than 1 percent when compared to all water stored in the groundwater system; certainly a negligible decline when considering the availability of groundwater for public water supply.

Nevertheless, groundwater withdrawal and the decline in water levels have caused localized environmental conditions that include diminished streamflow and saltwater intrusion. It is, therefore, important to continue to monitor groundwater withdrawal and implement appropriate actions to address the streamflow and saltwater intrusion problems.

Groundwater Quality — Has Improved and is Expected to Improve Further

The drinking water delivered to County residents by the public water suppliers meets all federal, State, and local standards for drinking water quality.

While all drinking water meets the quality standards, it is important to distinguish between raw groundwater and drinking water. The raw, or untreated, groundwater that is the source of the County's water supply may not always satisfy the quality standards for drinking water. In such instances, treatment is installed on public supply wells to remove any contamination that is present, thereby making the water suitable for public consumption.

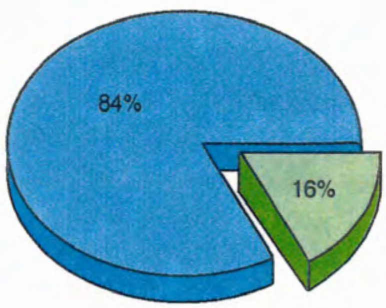
The County, regulatory agencies, and water suppliers continue to take appropriate actions to ensure that safe drinking water is provided. To protect public health, both the raw groundwater and the drinking water delivered to the consumer are continuously monitored. If contamination is found, corrective action is immediately taken by either installing treatment to meet the rigorous drinking water standards or by removing the water source from service. Because the cost to install and operate water treatment systems has only resulted in a very small increase in the cost of water to the consumer, drinking water throughout the County remains very affordable at an average cost of approximately $2.00 per 1000 gallons.

Fortunately, Nassau County's raw groundwater supply is of exceptionally high quality. The sandy materials that comprise the County's aquifers naturally filter out bacteria, viruses, and other undissolved contaminants that trouble other water supplies. As a result of this natural filtering action, water from the majority of the County's public supply wells may be used without treatment for health related substances.

During the 1950s and 1960s, nitrate and detergent contamination were the major water quality problems facing the County. The main sources of these contaminants were on-site wastewater disposal systems and agricultural fertilization. With the decline in agriculture and installation of the County's sanitary sewer systems which serve over 90 percent of the County's population, nitrate and detergents have largely been eliminated as water quality concerns.

Since the 1970s, volatile organic chemicals (VOCs) have become the priority water quality issue in Nassau County. Although many VOCs are known or suspected human carcinogens, the VOCs found in the County's raw groundwater usually occur at low concentrations that are easily treatable. In 1994, water from 84 percent of the County's public supply wells met drinking water standards without treatment for VOCs. There are, however, several highly contaminated aquifer segments in localized areas of the County that are currently being addressed by the regulatory agencies.

The major sources of VOCs in the groundwater are solvents, degreasers, gasoline, and other petroleum products that have been improperly disposed of or accidentally spilled. The sanitary sewers have virtually eliminated on-site wastewater disposal systems as a significant contributor of VOCs to the groundwater, in those areas serviced by sewers. Existing regulatory programs intended to reduce the amount of VOCs entering the groundwater include: underground storage tank testing and replacement, regulation of the use and disposal of hazardous materials, underground injection control, and STOP (Stop Throwing Out Pollutants) programs. These programs are very effective as evidenced by improving groundwater quality trends that have been observed in recent years. Such trends are expected to continue into the future as a further result of these programs.



Nassau County's groundwater is of exceptionally high quality. Most public water supply wells require little or no treatment for VOCs.

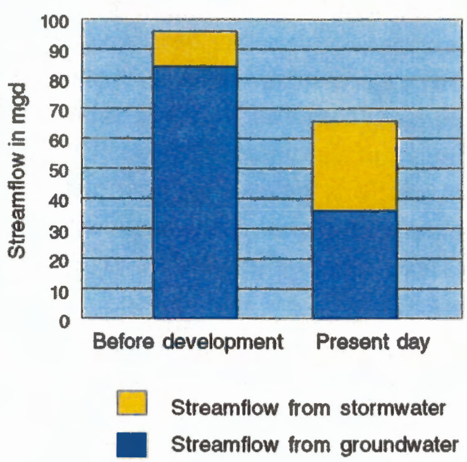
Testing conducted to date indicates that pesticides are not a significant problem in Nassau County groundwater. Pesticides have not been found in the overwhelming majority of monitoring wells tested to date. Although a few pesticides have been detected in the raw groundwater, concentrations have either been well below the drinking water standards or present at low levels that are easily treatable. Based on these findings, the absence of agriculture in Nassau County, and the regulations governing pesticide usage, pesticides are not expected to become a concern in Nassau County groundwater as testing continues.

It is beyond the scope of the *1998 Groundwater Study* to make any connection between environmental factors and how such factors may relate to breast cancer incidence rates in Nassau County. This is a health issue that is being addressed by health officials. However, emphasis is made on the fact that the drinking water supplied to the residents of Nassau County by the various water suppliers meets all federal, State, and County health standards to assure drinking water quality.

Streamflow and Surface Water — A Condition that is Being Addressed

At the turn of the century, before Nassau County was extensively developed, streams were fed predominantly by groundwater seeping continuously through the stream beds and stream banks. About 87 percent of the flow in the County's streams and water courses came from groundwater with the remaining 13 percent from stormwater runoff. Today, most of the groundwater withdrawn for public use is discharged as wastewater into the sanitary sewer systems. It is then treated and discharged directly into the surrounding saltwater bodies. This has permanently lowered the water table, leaving many streams and ponds with little or no flow during dry weather. The problem is most acute on the south shore because of the longer stream lengths and flatter slopes characteristic of south shore streams. While streamflow in the north shore streams has declined over the years, the reduction has not been as dramatic since streambeds are typically shorter and steeper than along the south shore.

Almost half of all streamflow now comes from stormwater runoff during and following rainfalls. Stormwater flow is very different from groundwater flow and has changed the character of south shore streams and surface water features. Stormwater flow is intermittent, not continuous like groundwater flow, and it tends to occur in swift, sporadic bursts, causing erosion and scouring of streambeds, and damaging the ability of the ecosystem to support aquatic plants and animals. Because stormwater is warmer than groundwater, and does not flow continuously, most south shore streams can no longer sustain fish populations of sensitive fish species such as trout.



Replacement of groundwater flow by stormwater flow has completely altered the character of south shore streams.

Land development has drastically altered the composition and volume of streamflow in all County streams. Before development, stormwater represented only 13 percent of total streamflow. Today, stormwater is 46 percent of total flow. The groundwater portion of streamflow has decreased from 84 mgd to 35 mgd and total streamflow — from both sources — has decreased, from 97 mgd under natural conditions to 65 mgd today. Although saltwater wetland areas will nevertheless remain in spite of the reduction in streamflow, a pronounced effect has occurred at the northern reaches of streams and associated freshwater lakes and ponds along the south shore. The County is taking steps to cost effectively improve conditions since to do nothing would result in streamflow impacts within the next few years. These northern inland areas would continue to experience a loss of freshwater wetlands, associated wildlife habitats, and recreational and aesthetic value of parks that are centered around stream and pond features.

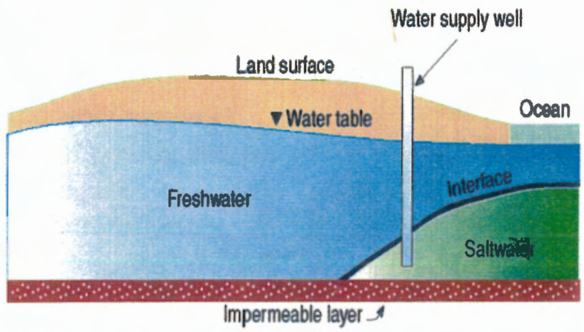
Many opportunities are available to enhance conditions in stream corridors. They range from simple, low-cost approaches, such as improved recharge of stormwater, to more costly and involved solutions, such as construction of instream control structures or relocation of water supply wells.

Saltwater Intrusion — A Localized Condition

The fresh groundwater in Nassau County's aquifers flows naturally towards the Atlantic Ocean on the south shore and the Long Island Sound on the north shore, where it eventually encounters saltwater. The underground boundary where the fresh groundwater meets salty groundwater is called the freshwater/saltwater interface. If the salty groundwater moves too far landward, it can contaminate water supply wells. If this should happen, expensive treatment systems would be needed to make the water drinkable again.

The position of the interface depends on the pressure of the freshwater and the saltwater beneath the ground. If the freshwater pressure diminishes sufficiently, the interface moves landward. If the freshwater pressure increases sufficiently, the interface moves seaward. At present, saltwater is moving landward into the freshwater system in some areas while the interface is stable in other areas. The increase in water supply withdrawal that has occurred due to development has lowered the pressure significantly in certain localized segments of the groundwater system, thereby drawing the saltwater landward.

Landward saltwater intrusion is already occurring in southwest Nassau County and on the Great Neck and Manhasset Neck peninsulas on the north shore. In southwest Nassau County, thirteen public supply wells will be affected in about 50 years. These wells are primarily located within the Long Island Water Corporation service area; some are located in the area serviced by the Village of Rockville Centre. Three public supply wells on the Great Neck peninsula have been closed and several others show rising chloride concentrations indicative of saltwater intrusion. The Water Authority of Great Neck North is addressing the problem by limiting withdrawal from certain wells, by seeking alternate well sites and by imposition of aggressive water conservation measures. On the Manhasset Neck peninsula, which is serviced by the Village of Sands Point and the Port Washington Water District, saltwater is near three well fields, indicating that as many as nine public supply wells could be impacted in the future.



If the freshwater/saltwater interface moves too far landward, saltwater can contaminate water supply wells, making the water undrinkable.

At the present rates of groundwater withdrawal, the aquifers will eventually reach a new equilibrium, and movement of the interfaces will cease. The County is using computer modeling and chloride measurements in monitoring wells to track the movement and positions of the interfaces, and is recommending solutions to saltwater impacts on public supply wells.

Several approaches exist for dealing with saltwater intrusion problems on both the north and south shores. These approaches include reducing withdrawal from public supply wells located near the shorelines, relocation of affected wells with new wells located outside the zone of saltwater intrusion, purchasing water from adjacent water suppliers, and treating brackish water at the well.

Because the water suppliers are responsible for dealing with the effects of saltwater intrusion, they must decide on the appropriate course of action since each situation will be unique for their supply. The New York State Department of Environmental Conservation (NYSDEC) must concur in most, if not all, instances since withdrawal permits will need to be modified. Data from the County's monitoring wells and information from the computer models will greatly assist the suppliers in making the most cost-effective decisions. Regional approaches to the problem are not warranted at this time given the localized nature of the intrusion phenomena.

Recommendations

This Study has found that the County's groundwater system can sustain present and future water demand, although localized streamflow, saltwater intrusion and water quality problems may occur in certain localized areas. Therefore, major actions recommended by previous water management plans to address the predicted water supply deficiencies are not necessary. It is recommended, however, to continue existing programs for protecting the groundwater resource and to use and update the County's groundwater model to continue to manage the problems of streamflow reductions and saltwater intrusion.

Recommendations addressing water quantity include continued water conservation efforts by both the County and water suppliers and ongoing monitoring of groundwater withdrawal to track trends in water demand and changes in groundwater levels. Additionally, the County should, through use of the groundwater model, work in concert with NYSDEC to evaluate existing groundwater withdrawal patterns and any newly proposed public supply well sites. Revised groundwater withdrawal permits for the public water suppliers should consider variable water demand, saltwater intrusion and streamflow in setting allowable withdrawal rates.

Water quality recommendations include continued monitoring of groundwater quality and control of potential contamination sources through education and enforcement of existing regulations. Regulatory programs governing the use and disposal of hazardous chemicals should be strengthened in light of State and County work force reductions that have occurred in recent years.

Under the County's streams and wetlands management programs, as well as federal and State programs, cost-effective measures should be taken in order to continue improving conditions at streams and other surface water bodies that have a high recreational and ecological value. Such measures include improved stormwater management practices, construction of instream control structures, and flow augmentation using shallow wells for critical stream reaches and wetland areas. The County's groundwater model should be used to investigate optimum pumping patterns for public supply wells to help minimize further declines in streamflow and surface water levels. The State, County and water suppliers can then use these results for determining possible changes in pumping patterns to enhance surface water conditions.

Saltwater intrusion recommendations include continued monitoring and study of saltwater movement along both the north and south shores through chloride measurement in monitoring wells, field investigations and use of the County's groundwater model. The County should continue to provide technical assistance to the water suppliers and NYSDEC in the assessment and management of localized saltwater intrusion problems.

Section 1
Setting the Stage

The groundwater contained in the aquifers underlying Nassau County is the sole source of water for the County's 1.3 million residents. In the decades following World War II, as rapid growth spurred a growing need for water, the County began to study the ability of the groundwater system to keep pace with demand. A more refined assessment of the groundwater system evolved with each successive study conducted since that time.

1.1 Evolution in Understanding

Of the many water studies undertaken by the County, the most significant are four comprehensive water supply plans prepared in 1958, 1963, 1971, and 1980. Facing estimates of a County population as high as 2 million people, these four studies all concluded that the aquifers would not be able to satisfy the increased demand for potable water. As study after study predicted demand could exceed supply, and identified such potential threats as chemical contamination and intrusion of salt water into freshwater supplies, the water suppliers, regulatory agencies and the public became increasingly apprehensive. In 1986, the New York State Department of Environmental Conservation (NYSDEC) imposed strict limits on the amount of water most Nassau County water suppliers could withdraw, reinforcing the perception that the County was running out of water.

In the decades following World War II, as rapid growth spurred a growing need for water, Nassau County began to study the ability of its groundwater system to keep pace with demand. When early water studies compared future water needs to available supply, they all concluded the County's aquifers would not be able to meet predicted growth in demand.

The two most recent comprehensive water studies, prepared in 1971 and 1980, illustrate how the County's assessment of its water resources has evolved, and how a better understanding of the groundwater system, combined with a stabilizing population, lowered the projected deficiency.

The 1971 Study

The *1971 Comprehensive Water Supply Plan* was prepared to give Nassau County a plan of immediate and long-range actions to meet water supply needs through the year 2020. The most significant issue identified in the 1971 plan was a projected water supply deficit of nearly 100 mgd by 1990. Although this did not occur, other important water management issues — saltwater intrusion, detergent wastes and nitrates in the groundwater supply, and the high iron content of south shore groundwater — were identified in the plan. Some issues continue to be a source of concern in localized areas.

In response to the 1971 plan, monitoring and study of the County's groundwater continued. Sanitary sewers were extended into the eastern portion of the County to reduce groundwater contamination by nitrates, detergents, and other contaminants. The installation of sanitary sewers was the earliest groundwater protection program undertaken by the County and has proven to be very effective in reducing groundwater contamination.

The 1980 Update

The *1980 Master Water Plan* reassessed water demand and available water resources, and presented an updated plan to provide an adequate supply through the year 2020. Based on a reduced population estimate and an increased estimate of the available groundwater supply, the 1980 study predicted that water demand would exceed available supply by 1995; however, the magnitude of the predicted deficiency was lowered to only 12.5 mgd.

To make up for the predicted shortfall, the 1980 plan recommended a phased water supply program. Phase I of the 1980 plan included the following specific recommendations:

- Enactment of a water conservation program
- Development of plans to construct new supply wells and water transmission systems for intra-County water transfer, if necessary
- Purchase of the existing 72-inch-diameter New York City water main beneath Sunrise Highway
- Construction of interconnections between water districts
- Continued monitoring and evaluation of saltwater interfaces in southern Nassau County
- Test wells at new supply well sites
- Continued study of the Lloyd aquifer and of the hydrogeology of northwest Nassau County
- Groundwater modeling

Phases II and III of the plan called for construction of additional water supply wells and transmission system infrastructure for transfer of water between different locations in the county. Phases II and III were to be initiated if the following conditions occurred:

- Groundwater monitoring showed that groundwater levels declined to specified minimum levels
- Significant movement of saltwater into the freshwater supply was detected
- Deterioration of water quality jeopardized a supplier's ability to provide water

Nassau County responded to and undertook the majority of the plan's Phase I recommendations. Since completion of the 1980 plan, the County has continued to study the groundwater system and its associated environment. Because none of the above three conditions occurred, there was no need to implement Phases II and III of the plan, involving the intra-County transfer of water.

However, by the mid-1980s, the long-term effects of escalating consumptive use had become increasingly evident. A significant decline in the water table, diminishing stream-flow and surface water levels, and saltwater intrusion into some monitoring wells along the south shore were among the most noticeable of these effects. Nevertheless, despite these effects, the County was still confident that the groundwater system was capable of supplying all potable water needs.

> *The* Nassau County 1998 Groundwater Study *is the first to conclude that water quantity and quality are sufficient to meet the County's needs.*

1.2 The Present Study

Responding to the erroneous public perception that the County was running out of water, which was reinforced by NYSDEC's imposition of groundwater withdrawal limits in 1986 and media misrepresentation, the County undertook a major new study of the quantity and quality of its water resources. The *1998 Groundwater Study* represents the conclusion of a long-term effort to more fully understand the dynamic nature of the County's groundwater system. Although it is the first to conclude that water quantity and quality are sufficient to meet the County's needs, this new study also found that many of the localized water concerns identified in the earlier studies remain. Where current or potential problems exist, however, they are localized, not systemwide. Most importantly, there are solutions to these problems. The *1998 Groundwater Study* summarizes the results of recent water supply investigations, defines present and future concerns, and presents a number of recommendations to manage remaining water supply issues.

1.3 Cooperative Action

Regulation and management of Nassau County's water resources is shared among several federal, State, County, and local government agencies as well as individual water suppliers. All have discrete responsibilities, yet they function in a cooperative manner. Making the recommendations of the *1998 Groundwater Study* a reality will require participating agencies and organizations to continue to work in partnership to achieve the common goal of continuing to supply safe water for Nassau County residents, businesses, and industry.

A necessary step toward working in partnership is understanding the division of responsibilities as well as established modes of cooperation and joint action for monitoring, evaluating, and resolving water resource issues. The two Nassau County agencies with significant water management responsibilities are the Nassau County Department of Public Works (NCDPW) and the Nassau County Department of Health (NCDH). The ongoing responsibilities of NCDPW and NCDH are summarized in Tables 1-1 and 1-2.

Other government agencies with regulatory or management responsibilities for water supply include the U.S. Environmental Protection Agency (EPA), NYSDEC, the New York State Department of Health (NYSDOH), the U.S. Geological Survey (USGS), and local towns, cities and villages. The individual water suppliers also have important water management responsibilities at the local level. Table 1-3 summarizes the division of responsibilities and areas of cooperation.

Currently, regulatory efforts focus on:

- Preventing groundwater contamination by regulating overlying land uses, chemical storage requirements, and waste disposal practices
- Identifying, evaluating, and cleaning up existing groundwater contamination
- Monitoring and enforcing existing water quality standards, and developing additional water quality standards.

At present, government at all levels has adapted to the enhanced understanding of the County's water resources, and is structured to accomplish the major goal of assuring an adequate and safe water supply for all Nassau County residents. All concerns identified in the *1998 Groundwater Study,* including streamflow declines and saltwater intrusion, are being addressed. While established avenues for cooperation already exist, all agencies involved in water resources management must continue to work together to assure that water management concerns are fully addressed.

Table 1-1. The Nassau County Department of Public Works is responsible for a wide range of water management activities.

- Maintains a computerized database on groundwater levels, water quality, well construction information, groundwater withdrawals, streamflow, precipitation, temperature, recharge basin characteristics, and wastewater flows
- Development and application of groundwater models to evaluate water management issues
- Monitoring groundwater levels, groundwater quality, precipitation, temperature and streamflow
- Evaluation of the location and rate of movement of saltwater intrusion
- Improvements to major streams and ponds
- Contaminated soil and groundwater remediation at County-owned facilities
- Underground storage tank replacement and testing program at County facilities
- Operation of County-owned sanitary sewer systems and wastewater treatment facilities
- Maintenance of stormwater recharge basins and stormwater collection systems
- Water conservation and public education
- Preparation of County-wide water plans and studies

Table 1-2. The Nassau County Department of Health enforces many of the regulations designed to protect the water supply.

- Enforcement of federal and New York State water quality standards
- Monitoring of water quality at over 400 public supply wells in the County
- Review and approval of plans to construct or modify water supply facilities, including wells, storage tanks, water mains, and water treatment facilities
- Inspection of public water supply facilities
- Evaluation and certification of water treatment plant operators
- Participation in studies of soil and groundwater contamination
- Response to water supply emergencies and imposition of necessary actions to protect human health (such as chlorination and well closure)
- Regulation of facilities using and generating industrial and chemical wastes
- Regulation of the storage, handling, and disposal of hazardous and toxic substances
- Regulation of activities in the Special Groundwater Protection Areas
- Response to spills of toxic chemicals
- Inspection of automotive repair and other facilities to eliminate floor drains that could contribute to groundwater contamination
- Implementation of Integrated Pest Management at County facilities

Table 1-3. Cooperation among many different government agencies and local water suppliers is paramount to assuring a safe and adequate drinking water supply.

Organization	*Responsibilities and Areas of Cooperation*
NCDPW	Responsible for assessing the adequacy of the County's water supply through a program of data collection, analysis, and groundwater modeling. As appropriate, responds to water supply concerns by initiating focused studies. Recently initiated a water conservation program to reduce demand. Participates in a public education and outreach program. Cleans up contaminated soil and groundwater at County facilities. Operates and maintains stormwater collection systems, recharge basins, sanitary sewer systems and wastewater treatment facilities.
NCDH, NYSDOH	Responsible for enforcement of a wide variety of water supply regulations and aquifer protection activities, including enforcement of federal and New York State water quality standards.
NYSDEC	Regulates groundwater withdrawal in the County through the Long Island well permit program. Established and enforces groundwater withdrawal limits and conservation requirements for Nassau County suppliers. Responsible for enforcing cleanups under the State Superfund program. Issues permits to operate and inspects industrial wastewater treatment facilities that discharge to groundwater.
NCDPW, EPA, USGS, NYSDEC	Developed a Stream and Wetlands Area Management Program. EPA, USGS, and NYSDEC all participate in efforts to manage targeted south shore streams, wetlands, and pond areas.
NCDPW, USGS, NYSDEC	NCDPW, in conjunction with USGS, conducts studies of saltwater intrusion on the north and south shores. To support this effort, drilling, geophysical logging, and monitoring activities are conducted under a cooperative agreement between the County and USGS. NYSDEC considers the information and analyses provided by these investigations in the public well permit process.
Local Water Suppliers	Responsible for supplying safe, potable water to consumers, for implementing conservation programs, for local supply infrastructure planning, for addressing identified or potential problems such as saltwater intrusion and contamination, and for public education.

Section 2
Groundwater System Dynamics

A groundwater system is dynamic in that it responds to groundwater withdrawal or any other changes imposed on it by always seeking a new state of equilibrium, or balance, between water flowing into the system and water flowing out of the system. One of the goals of this study was to accurately account for the many different factors that affect the groundwater system, including all freshwater entering and leaving the aquifers. Use of the County's computerized groundwater model resulted in much more accurate and reliable analyses of system behavior when compared to previous studies.

2.1 Basic Concepts

In order to understand how Nassau County's groundwater system functions and how the system

Summary

Groundwater stored within the pore spaces of the gravel, sand, silt and clay sediments beneath Nassau County's land surface is the only source of the County's potable supply. Recharge from precipitation replenishes freshwater contained in these geologic formations or aquifers. Before extensive development took place in the County, about half of the precipitation was returned to the atmosphere via evapotranspiration, with a small portion of precipitation draining directly to surface water features. The remaining half infiltrated down through the ground to recharge the groundwater supply, and then continued to flow through the aquifers, ultimately discharging to surrounding saltwater bodies, either as streamflow, or as underflow from the freshwater system to the saltwater system beneath the bays and ocean bottom. The flow of freshwater into the groundwater system was equal to the natural flow out of the system in the predevelopment hydrologic cycle.

Over the years, development has significantly modified this cycle. About half of the precipitation falling on the County is still returned to the atmosphere by evapotranspiration, and about half still recharges the groundwater system due in large part to the installation of recharge basins. Now, a large amount of groundwater is withdrawn from the aquifers each day for public water supply. Most of the water that is withdrawn is eventually discharged as wastewater to the sanitary sewer systems. It is then treated and discharged offshore. This new loss of water from the groundwater system has resulted in a new balance of flows into and out of the system.

In the past, the complexity of Nassau County's groundwater system made it difficult to assess how the aquifers would respond to changes such as increased groundwater consumption. The County's new three-dimensional computer model of the groundwater system has been successful in representing all of the significant factors affecting groundwater flow, and has provided considerable insight into how the groundwater system has responded to changes over the years.

The model has been used to develop water balances for the County for both predevelopment conditions and for present day/future conditions of development and water consumption. The analyses have been used to demonstrate that recharge greatly exceeds the present and projected water demand of 180 million gallons per day. A comparison between the predevelopment water balance and the present day water balance clearly identifies the two major environmental impacts resulting from increased water consumption - reduced streamflow and localized saltwater intrusion.

responds to changes brought about by development, it is first necessary to discuss some fundamental concepts. This discussion will begin with Nassau County's hydrologic cycle and proceed to hydrogeology and the groundwater flow patterns characteristic of the County's groundwater system.

> *Today, water is lost from the aquifers through large-scale water supply withdrawal and sanitary sewers. This results in a significant new water loss that did not exist at the turn of the century which has lowered the water table, reduced flow in streams, and accelerated saltwater intrusion into portions of the groundwater system.*

2.1.1 The Hydrologic Cycle

The process by which water is transferred from the sea to the land and back again is called the hydrologic cycle. Nassau County's present day hydrologic cycle is illustrated in Figure 2-1. Water evaporates from the sea into the atmosphere, falls on the land as precipitation, then eventually returns to the sea. The water may return to the sea quickly via streams and stormwater runoff, or it may seep deep underground, where its return may be delayed by hundreds or even thousands of years.

Before the County was extensively developed, its hydrologic cycle was characterized by a natural, balanced flow of water into and out of its aquifers. Extensive development over the past few decades has changed these conditions, altering flow pathways both into and out of the aquifers, and resulting in a new, different state of equilibrium.

Predevelopment Conditions

Under natural, or undeveloped conditions, precipitation was the sole source of water recharging the groundwater system. On average, about half of the precipitation falling on the land surface was returned to the atmosphere by

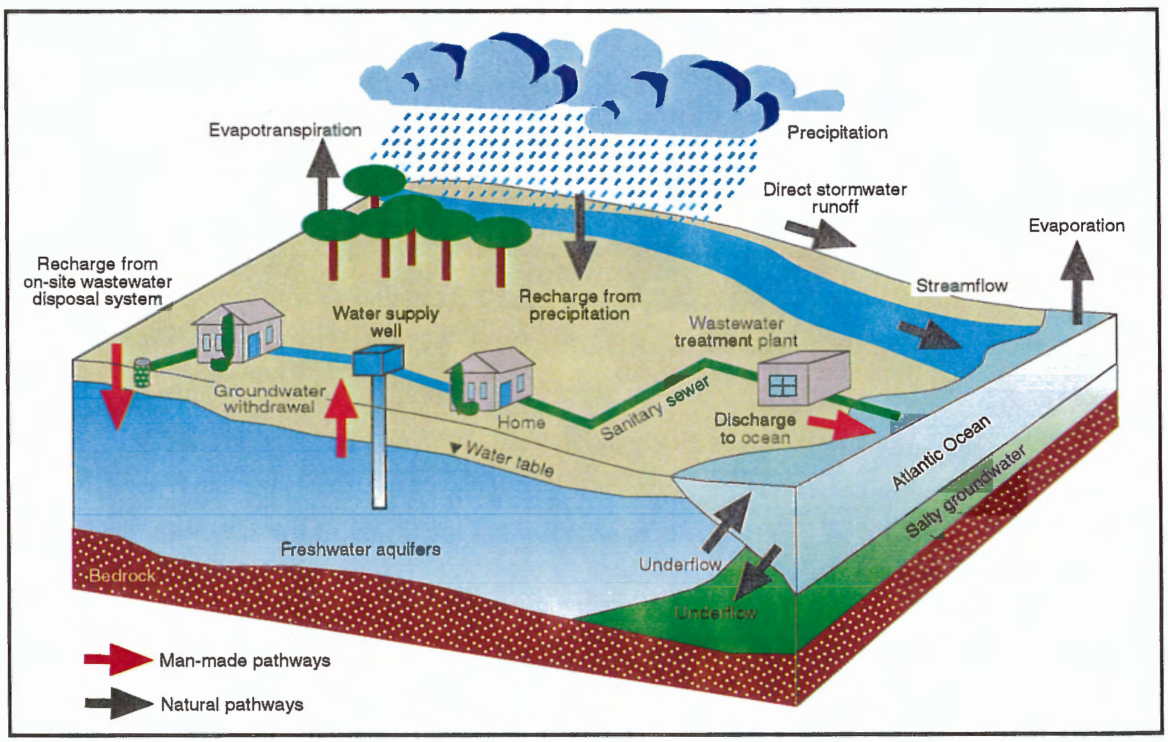


Figure 2-1. Nassau County's hydrologic cycle has been changed by the withdrawal of large amounts of groundwater for water supply and by the installation of sanitary sewers.

evaporation and by transpiration from vegetation (a process called evapotranspiration). A very small amount ran directly into streams that discharged to the saltwater bays on the south shore and to Long Island Sound on the north shore. The other half entered the ground to recharge the groundwater supply, then continued its flow through the aquifers. Eventually this water discharged to surrounding saltwater bodies, either as surface streamflow or as underflow from the freshwater system into the saltwater system beneath the saltwater bays and the ocean bottom. A very minor amount of groundwater was withdrawn from the system by water supply wells, with most of that water being returned to the groundwater system via on-site wastewater disposal systems. Therefore, very little water was lost from the system due to man's activities. Clearly, the vast majority of groundwater flowing out of the system was through natural pathways.

Present Day Conditions

Development has modified this cycle. About half the precipitation falling on the County is still returned to the atmosphere through evapotranspiration, and about half still recharges the aquifer system. However, large quantities of groundwater are now withdrawn from the aquifers for public water supply. After the water is used, most is discharged as wastewater to the sanitary sewers. The wastewater is then conveyed to treatment plants, where it is treated, then discharged offshore to the Atlantic Ocean or Long Island Sound. This major new loss of water from the aquifers has dramatically increased the consumptive use. Although the sanitary sewer systems are instrumental in protecting groundwater quality, as explained in detail in Section 4, they have also resulted in a significant new water loss that did not exist before modern development. This water loss has lowered the water table and has produced fundamental changes in the groundwater system.

2.1.2 Recharge

One key component of the hydrologic cycle is recharge, since all groundwater originates with precipitation that infiltrates through the soil to recharge the underlying aquifers. An average of 44 inches of precipitation falls upon the County each year. This amounts to approximately 660 million gallons of precipitation falling upon the land surface of the County each day. About half of this precipitation recharges the groundwater system either by infiltrating through the soil beneath unpaved areas or through the bottoms of recharge basins.

In concert with development, the County, State, and local municipalities have constructed stormwater drainage systems and recharge basins to collect and recharge stormwater runoff from roads, parking lots, and other paved areas. The installation of the recharge basins began in the 1930s and has continued up through the present. There are currently over 800 recharge basins in the County, most of which are located in the central portion of the County. Few are located along the shorelines, particularly the south shore, where the water table is close to the ground surface and it is not possible to achieve recharge. Figure 2-2 portrays a typical Nassau County recharge basin and depicts how stormwater first enters a catch basin or storm drain in the street and is then carried by storm sewers to the recharge basin. Stormwater enters at the inlet and is stored in the basin until it infiltrates into the groundwater.

The main purpose of the basins is to prevent flooding from stormwater runoff; however, the

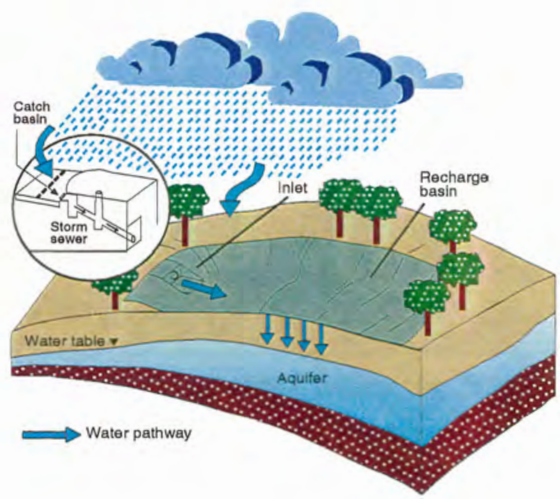


Figure 2-2. Recharge basins throughout the County help to direct stormwater runoff from impervious areas to recharge the groundwater system.

additional benefit is that water that would otherwise be lost is recharged to the groundwater system. By installing recharge basins, the rate of recharge has slightly increased when compared to the rate during predevelopment times.

Unlike precipitation, which is distributed rather evenly through the year, recharge varies with the seasons. Recharge is greatest during the non-growing season when evapotranspiration is low. During the growing season, evapotranspiration increases significantly, and recharge to the groundwater system is reduced.

The network of storm sewers constructed as the County has developed has helped to increase recharge in parts of the County where stormwater is discharged to recharge basins. During the growing season, stormwater runoff that would have been lost to evapotranspiration prior to development is now efficiently conveyed to recharge basins, where it can infiltrate down to the groundwater system. Water from leaking water mains also contributes a small amount of recharge under present day conditions.

2.1.3 Hydrogeology

Nassau County, like the rest of Long Island, is underlain by consolidated bedrock, which does not store or yield any significant amount of groundwater. Groundwater is stored within the pore spaces of the wedge of gravel, sand, silt and clay sediments that overlie the bedrock floor. The thickness of this wedge of unconsolidated sediments increases from zero feet where bedrock outcrops along the north shore in Queens, up to about 2,000 feet along the south shore barrier islands.

Layers of sediments capable of storing, transmitting and yielding large quantities of water are called aquifers. Layers of sediments that do not transmit or yield appreciable amounts of water are called aquitards or aquicludes.

Figure 2-3 shows a simplified view of Nassau County's complex groundwater system. The system consists of three major aquifers — the Upper Glacial, the Magothy, and the Lloyd — and one major, relatively impermeable clay layer — the Raritan Clay. Several minor aquifers and

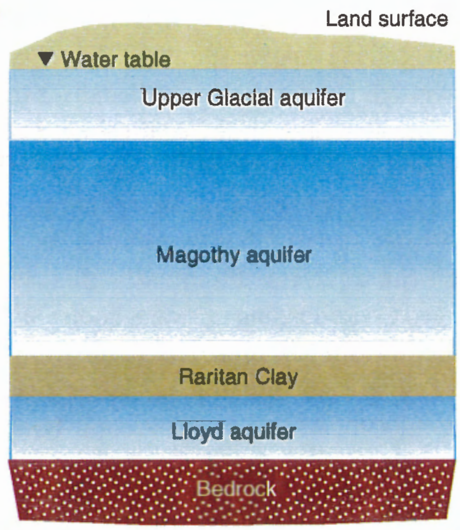


Figure 2-3. Nassau County's groundwater system consists of three major aquifers and one clay layer.

confining clay layers (not shown on the figure) contribute to the complexity of the system and affect aquifer behavior in localized parts of the County. The thickness of each subsurface formation is variable. Beneath the south shore, the Magothy and Lloyd aquifers are thickest. As groundwater is withdrawn for water supply, new water — primarily from precipitation — continuously recharges the aquifers from the surface. Water also flows back and forth between aquifers, and is continuously discharged underground to the Atlantic Ocean and Long Island Sound through a process called "underflow."

The amounts of sand, gravel, silt and clay particles present may vary considerably from place to place within the County, and also vary considerably with depth. The hydraulic conductivity (the relative ease with which water can move through soil) of each aquifer or aquitard unit also vary significantly from place to place. A number of hydraulic conductivity values for each major hydrogeologic unit, estimated from pump test and empirical correlations with specific capacity values and grain size distributions, are reported in the literature. Field and laboratory tests have shown that, in many cases, the hydrogeologic units are anisotropic; that is, their ability to transmit water in the horizontal direction is

Table 2-1. Major Hydrogeologic Units in Nassau County

Hydrogeologic Unit	Approximate Maximum Thickness (feet)	Hydraulic Conductivity (feet/day)	
		Horizontal	Vertical
Upper Glacial aquifer	600	140 - 380	0.1 - 20
Gardiners Clay and 20-foot Clay	300	1.0	0.001-0.01
Jameco aquifer	300	160 - 190	1.75
Magothy aquifer	1,100	25 - 230	0.2 - 1.5
Raritan Clay	300	0.3	0.001 - 0.01
Lloyd aquifer	500	25 - 80	0.35

somewhat greater than their ability to transmit water vertically. The horizontal hydraulic conductivity is often an order of magnitude - or more - greater than the vertical hydraulic conductivity for that unit. The approximate maximum thickness and reported hydraulic conductivities of each hydrogeologic unit are summarized in Table 2-1.

2.1.4 Groundwater Flow and Times of Travel

All groundwater originates with precipitation that infiltrates down through the soil to recharge the underlying aquifers. If the infiltrating water becomes contaminated during its flow over the land surface or through contaminated soil, it carries the contaminants into the groundwater supply. Upon reaching the water table, the infiltrating water becomes part of the groundwater system, subject to the physical laws that govern groundwater flow.

Within the groundwater system, water flows from areas of higher water table elevation toward areas of lower water table elevation in the topmost Upper Glacial aquifer, and from areas of higher pressure to areas of lower pressure in the deeper Magothy and Lloyd aquifers. In Nassau County, the resulting horizontal flow pattern forms a groundwater divide from west to east, located roughly along the Long Island Expressway. South of the divide, as shown in cross section in Figure 2-4, groundwater flows southward toward the Atlantic Ocean; north of the divide, groundwater flows northward toward the Long Island Sound.

Groundwater also flows vertically, working its way down from the water table into the Magothy aquifer, through the Raritan Clay, and finally into the Lloyd aquifer. Just as in horizontal flow, the water moves from areas of higher water pressure to areas of lower water pressure. In most of Nassau County, vertical flow is generally downward from the water table in the Upper Glacial aquifer into the Magothy aquifer. Only near the shorelines and offshore along the south and north shores does the flow reverse itself, moving upward from the Magothy to the Upper Glacial aquifer. Downward flow from the Magothy aquifer through the Raritan Clay into the Lloyd aquifer only takes place in a relatively small area of the County near the groundwater divide.

Water quickly infiltrates through the soil after a precipitation event. Travel time to the water table, or upper surface of the groundwater system, generally takes only hours, or at most, a few days.

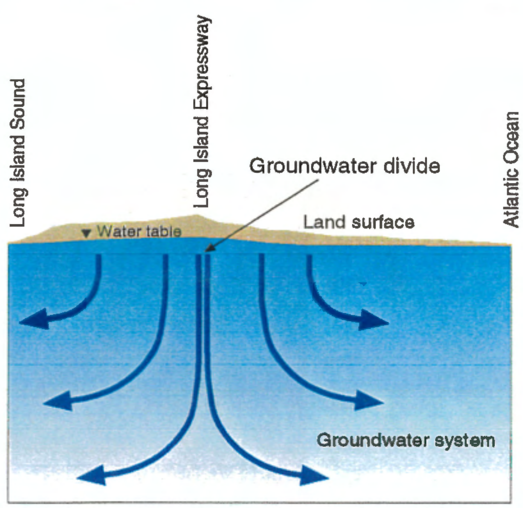


Figure 2-4. South of the groundwater divide, groundwater flows toward the Atlantic Ocean. North of the divide, groundwater flows toward the Long Island Sound.

Once in the groundwater system, water travels quite slowly. As illustrated in Figure 2-5, the age of water that has infiltrated in the eastern portion of the County ranges from several years in the Upper Glacial aquifer to more than several thousand years at the deepest portion of the Lloyd aquifer.

Once public water supply wells are pumped, horizontal and vertical flow patterns as well as the travel times of water are altered greatly. The time it takes water to travel to deeper portions of an aquifer is dramatically reduced once a well is pumped.

In the past, the complexity of Nassau County's groundwater system made it difficult to accurately predict how the aquifers would respond to changes such as increased groundwater withdrawal or severe drought.

It is important to note that as water infiltrates through the soil and recharges the groundwater system, it can easily carry contaminants from the land surface down into the aquifers. Clearly, activities of man, land use, and waste disposal practices have significant impact on what contaminants enter the groundwater and on which aquifers the contaminants ultimately reach. Additionally, time of travel can greatly influence patterns of contamination and the nature of contaminants found in the aquifers. A more detailed discussion of aquifer recharge areas and time of travel as related to contaminants entering the groundwater system is contained in Section 4.

2.2 Groundwater System Behavior

Previous efforts to understand groundwater flow and movement were limited by the complexity of the groundwater system. Without some means of accounting for the many different aspects of aquifer functioning and behavior — such as aquifer recharge areas, flow between aquifers, groundwater withdrawal, underflow, and saltwater intrusion — earlier studies had to rely on simplifying assumptions that necessarily affected their accuracy and reliability. In contrast,

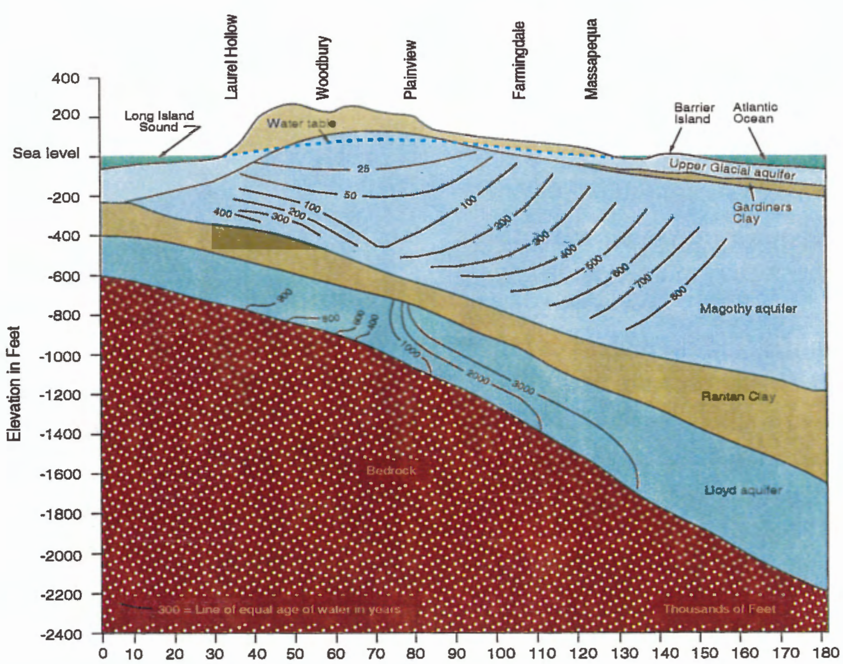


Figure 2-5. Groundwater travel time through the aquifers in the eastern part of the county, under no pumping influences, varies greatly — ranging from less than 25 years in the Upper Glacial aquifer, up to 800 years in the Magothy aquifer, and up to 3,000 years or more in the Lloyd aquifer (Franke and Cohen, 1972).

the *1998 Groundwater Study* used the Nassau County groundwater model to account for the many different factors that affect the aquifers, resulting in much more accurate, and reliable, analyses of system behavior.

2.2.1 Three-Dimensional Groundwater Model

Using recent advances in computer modeling technology, the County developed a three-dimensional computer model of the groundwater system. This model accounts for the many different factors that affect the aquifers, thereby providing more accurate and reliable predictions of system behavior under many different conditions.

The heart of the groundwater model is a group of complex mathematical equations that describes the interrelationship of all factors affecting the quantity and quality of groundwater. Because the equations are very complex, and because many equations are needed to describe groundwater flow throughout the County, manual computation is not practical. However a computer can quickly solve the equations, creating a comprehensive, dynamic simulation of groundwater system behavior.

The Nassau County groundwater model facilitates more informed decision making. It gives the public and government the ability to weigh the effects of water supply withdrawal and to make trade-offs between increasing water demand and resulting environmental impacts.

The groundwater model makes it possible to study how changing conditions, such as increases in water supply withdrawal or reduction in recharge, will affect the aquifers. It is also possible to predict aquifer response to many different stresses, and to predict the environmental effects of different rates of withdrawal. The result is a much more detailed understanding of the aquifers as a dynamic system. The model considers the entire area of the County as a potential recharge zone, and incorporates the spatial variations in recharge over different parts of the County, as well as variations over time, that actually result from changes in precipitation, stormwater management, and wastewater disposal. The model can be used to evaluate the groundwater system's ability to satisfy water supply needs on a County-wide basis. It can also be used to identify and evaluate the localized impacts on the system — such as streamflow reductions and saltwater intrusion — under a variety of recharge and groundwater withdrawal conditions.

Lastly, the model facilitates more informed decision making. It allows the impacts of water management approaches to be quantified directly, giving the public and government the ability to weigh the effects of increased withdrawal and to make trade-offs between increased water demand and resulting environmental impacts. For example, if the model shows increased groundwater withdrawal will cause a stream to completely dry up, decision makers and the public will be able to compare the benefits of additional water supply with the loss of the stream resource.

2.2.2 Water Balance

To understand how an aquifer responds to change, all freshwater flow into and out of the groundwater system must be accounted for. Flow into and out of the system is equal, or in balance, so the process of accounting for all flows, both into and out of the system, is termed a "water balance."

The groundwater model was used to develop generalized water balances for two very different time periods — for predevelopment conditions at the turn of the century, and for the highly developed conditions expected to exist in 2010, which are essentially the same as today. Insights gained from a comparison of these two water balances helps to explain how the system has adapted to changes that have occurred since the turn of the century. Figure 2-6 shows a generalized

Section 3
Water Quantity

Nassau County residents rely on groundwater for all of their water supply needs. Over the past 60 years, numerous studies have evaluated the capacity of the groundwater system to satisfy the increasing water demand of a growing population. These past water studies all projected the County's population would continue to grow into the 21st century, and they all concluded that, eventually, demand would exceed available supply.

Fortunately, recent investigations conducted as part of the *1998 Groundwater Study* have put this concern to rest. This study clearly demonstrates that the County's aquifers can yield enough water to meet the needs of Nassau County residents and businesses into the future.

3.1 Projected Water Demand

Past estimates of water demand were too high, leading to the concern about a possible water shortage. More accurate demand estimates were subsequently developed as described herein.

Summary

Past studies of Nassau County's water resources have focused on the ability of the underground water supply to satisfy the County's need for potable water. Since projections of water demand significantly exceeded estimates of available groundwater, these past studies concluded that additional supplies of water would be needed in the future.

The *1998 Groundwater Study* took a new look at estimates of future population, which are now expected to remain stable. Based on a stabilized population projection, and the fact that the County is virtually fully developed, future water supply needs were reevaluated. It was concluded that available supply can, indeed, meet present and future demands through the year 2010 — but at the cost of some negative environmental impacts. Among the most critical are:

- Reduced streamflow, pond, and lake levels along the south shore, which threaten valuable ecological, recreational, and aesthetic resources
- Intrusion of saltwater into freshwater supplies in southwestern Nassau County and on the Great Neck and Manhasset Neck peninsulas in the northwestern part of the County.

The streamflow impacts occurred as a result of the installation of sanitary sewers throughout the County. Because most of the groundwater withdrawn for public use is now discharged as wastewater to the sanitary sewers, then is treated and discharged offshore, it is permanently lost from the groundwater system. This increase in consumptive use has caused a lowering of the water table which in turn reduced the baseflow component of streamflow.

The increased consumptive use, coupled with an increase in groundwater withdrawal, has accelerated the rate of saltwater intrusion in southwestern Nassau County. Intrusion of saltwater on the Great Neck and Manhasset Neck peninsulas, on the other hand, has occurred mainly as a result of high groundwater withdrawal from near shore public supply wells.

A better understanding of the County's extremely complex groundwater system was key to these new findings. Using a computer model of the groundwater system, the County demonstrated that the amount of water recharging the groundwater system greatly exceeds the amount withdrawn for water supply. Computer models also confirmed the causes of saltwater intrusion and reduced streamflow and are now being used to explore solutions to these problems.

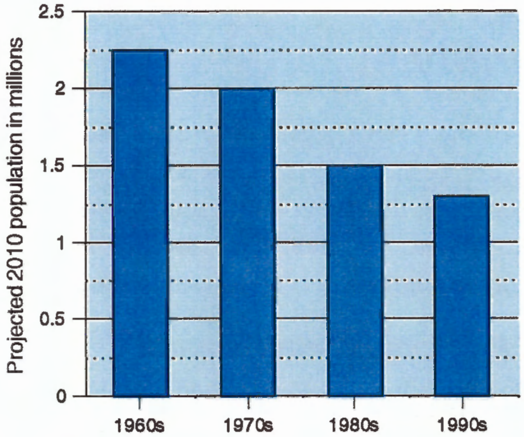


Figure 3-1. Projections of Nassau County's 2010 population have steadily declined.

3.1.1 Historical Perspective

The widespread perception that Nassau County was running out of water was caused chiefly by overly high projections of future population used in previous County water plans. This outlook has changed as population estimates have been adjusted steadily downward based on actual population trends. Figure 3-1 shows how predictions of population growth have declined over several decades. In the 1960s, Nassau County's population was projected to exceed 2 million people by the year 2010. In the 1970s the predicted population was reduced to about 2 million, and by 1980, it was reduced even further, to 1.5 million. The most recent prediction estimates the population will essentially remain at the present day 1.3 million. Because past water demand estimates were based on population and per capita water use, high population projections resulted in estimates of very high water demand. When compared to the ability of the groundwater system to supply this very high demand, these projections indicated the County would need to seek supplementary sources of water.

> *Based on the current population projection through the year 2010, Nassau County's groundwater system can meet the water supply needs of County residents and businesses for the future.*

In 1986, in response to the concern that water demand could exceed groundwater supply, the New York State Department of Environmental Conservation (NYSDEC) imposed strict groundwater withdrawal limits on most of the 51 major water suppliers in the County.

NYSDEC used historical water demand within each water supply area to set the withdrawal limits, and implemented the new limits by modifying the withdrawal permits, which they issue to each supplier. For most water suppliers, two limits on groundwater withdrawal were established:

1. A maximum annual limit on groundwater withdrawal
2. A maximum 5-year average limit on groundwater withdrawal.

Under this permitting system, the sum of all groundwater withdrawal allowed County-wide is 201 million gallons per day (mgd) annually, and 190 mgd averaged over 5 years. Each water supplier was also required to establish and implement a water conservation program to assure compliance with the limits on groundwater withdrawal. Because the County's population has stabilized and water conservation programs have resulted in water savings, it appears that most water suppliers will be able to remain within the NYSDEC limits on groundwater withdrawal.

3.1.2 Updated Water Demand Projection

As part of this study, an updated projection of water demand was developed for the year 2010, using Long Island Regional Planning Board population estimates, which indicate that the County's population will remain approximately the same as the 1990 census of 1.3 million. To project future water demand more accurately, this study examined existing groundwater withdrawal by public water suppliers, which accounts for over 97 percent of the water consumed in the County. Because groundwater consumption by private

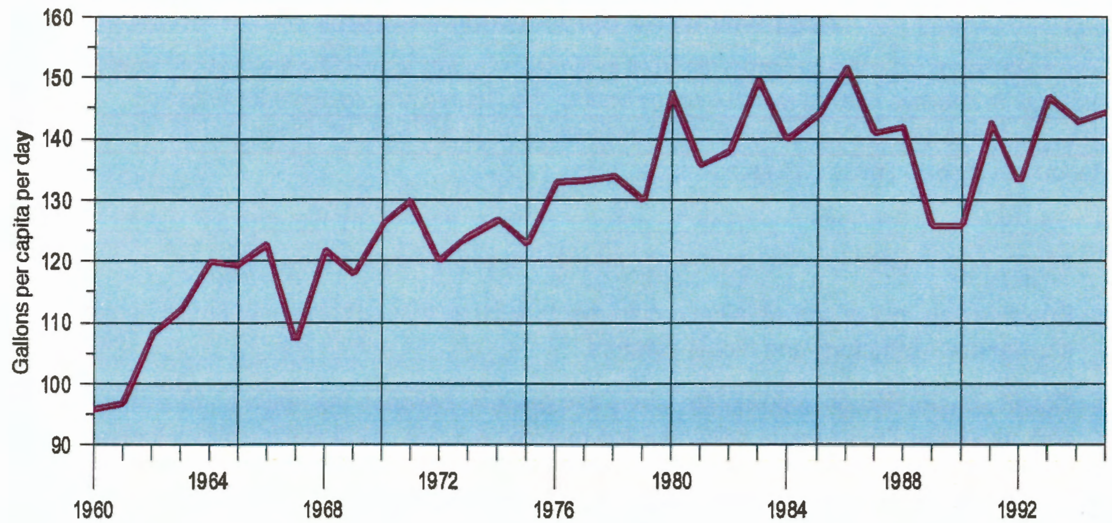


Figure 3-2. Per capita usage has stabilized over the last 9 years.

wells is insignificant, private water use was not included in the demand projection.

Figure 3-2 shows historical per capita water consumption (based on annual water demand from all sources — residential, commercial and industrial) for each year since 1960. Although there are fluctuations from year to year, the figure shows how per capita consumption has stabilized over the last 9 year period at about 139 gallons per capita per day. While useful for analyzing trends in historical demand, per capita usage is inadequate for addressing the various components that comprise overall water demand.

In an effort to refine the forecast of future demand, and recognizing that the growing employment base in the County could be a significant contributing factor in years to come, water demand was separated into two components. These included the residential and commercial/industrial components of water demand.

Residential Water Use Projections

To estimate future residential demand for water, a statistical analysis of water consumption showed that the number of households in the County was a much better predictor of overall water use than population numbers. Using trends in the number of people per household and the projected year 2010 population, the County estimated the number of households in 2010. Development of existing vacant land, according to current zoning, was also considered, although the highly developed character of the County leaves little room for significant impact on future residential water use.

Current rates of water consumption per household were chosen to represent water use in the future. These rates were adjusted to account for water conservation, since recent trends suggest water conservation programs implemented by the County and the water suppliers will achieve a sustainable reduction in annual water use of 4 to 5 percent. Using the estimated number of households in 2010, current rates of water use per household, and reductions due to ongoing conservation, the year 2010 residential water use was projected to be 161 mgd. Therefore, the actual per capita demand, based solely on residential use, is projected to be about 124 gallons per day.

Commercial and Industrial Water Use Projections

Commercial/industrial water use was calculated using the number of people working within Nassau County, the types of employment, and the amount of water each type of employment tends to require. For 1987, the base year of the analysis, commercial/industrial water use was estimated to be 17 mgd. Using Port Authority of New York and New Jersey projections of future

Additional Water Conservation Measures

Water conservation plays an important role in Nassau County's overall water management strategy. To improve current rates of conservation, the County should consider adopting changes to the Water Conservation Ordinance recommended by the Nassau County Water Resources Board. These changes include:

- Initiating requirements for automatic sprinkler systems that would mandate a moisture sensor or rain gage to avoid sprinkling when soil is wet or when it is raining
- Enacting new indoor conservation requirements such as toilet displacement mechanisms, shower flow restrictors, and faucet aerators
- Continuing the ban on sprinkling of lawns and gardens between the hours of 10 a.m. to 4 p.m. as well as the alternate day sprinkling requirement, but granting exemptions for new plantings and for commercial nurseries, farms, garden centers, and golf courses

These changes would strengthen the existing regulations, improve water savings, and provide flexibility to accommodate the needs of a variety of different water users.

employment, the commercial/industrial water use was estimated to increase by about 10 percent by the year 2010, resulting in a water demand of 19 mgd.

Water Use Projections for Year 2010

Based on this analysis, the average water demand in 2010 is projected to be 180 mgd, with about 161 mgd attributable to residential use and 19 mgd to commercial/industrial use, as shown in Figure 3-3. Because of uncertainties associated with such factors as future development and the effectiveness of conservation, the County developed high and low ranges of future water demand, resulting in a projected minimum demand of 178 mgd and a maximum demand of 192 mgd. This demand essentially complies with the NYSDEC withdrawal limits on a County-wide basis. For purposes of comparison, over the period from 1990 to 1995, average annual water demand has ranged from 168 mgd to 189 mgd.

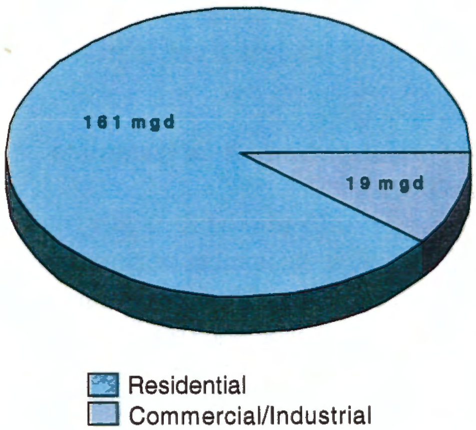


Figure 3-3. Water use in the year 2010 is expected to average 180 mgd.

Variations in Water Demand

Although average annual water demand is expected to remain at about 180 mgd, demand can vary widely from year to year, depending largely on summer weather conditions. In years with unusually hot, dry summers, water use can drive annual demand above 190 mgd. During years with cool, rainy summers, annual demand may dip below 170 mgd. Demand also varies within a given year, with peak monthly demand occurring during summer, when groundwater withdrawal nearly doubles to accommodate water-intensive summertime activities such as lawn and garden watering and recreation. During peak summer months, average monthly water demand can exceed 300 mgd. During the cooler fall and winter months, average monthly demand generally hovers around 140 mgd.

Figure 3-4 shows average monthly water demand in 1988, a year with a hot, dry summer, and 1990, a year with a relatively cool, wet summer. At 291 mgd, the average water use for August 1988 exceeds August 1990 water use by over 40 percent. Such dramatic short-term increases in water supply withdrawal can

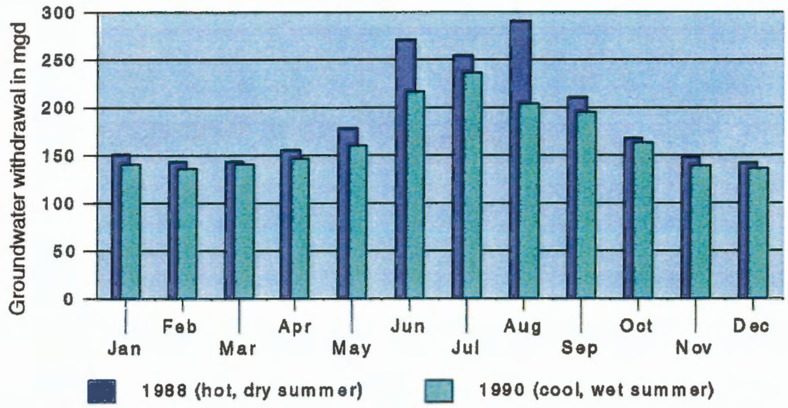


Figure 3-4. Comparison of water use in 1988 and 1990 shows the seasonal and weather related variations in water demand.

temporarily lower the water table, causing dramatic declines in streamflow and pond levels. Weather-related changes in water demand also can exceed water conservation savings, completely masking the effects of water conservation programs for a given year.

Such weather related and seasonal variations in water demand are normal, and their effects are temporary. Any more permanent change in demand, however, particularly a change not related to seasonal or weather-related factors, could indicate need for closer scrutiny or for some kind of corrective action. It is very important that the County have methods available to identify and track any new trends in water demand that might represent a more lasting change in patterns of water use.

As part of the *1998 Groundwater Study,* a new statistical water use formula has been developed that enables the County to do this. This statistical formula relates total water use to the number of households in the County and to weather patterns. The formula's ability to accurately determine water demand is demonstrated in Figure 3-5, which compares actual groundwater withdrawal over a 44-year period to withdrawal calculated using the formula.

This statistical technique is also used to measure the effectiveness of water conservation efforts, which began in earnest in 1987, by accounting for weather-related effects. Because the effects of conservation are not included in the formula, whenever predicted use is greater than actual use, the difference is attributed to water conservation. In Figure 3-6, the shaded area shows the estimated effectiveness of water conservation programs. Nassau County uses this method to track the effectiveness of water conservation measures, and to identify new trends in water consumption that could alter the projection of future demand.

3.2 Streamflow

Nassau County's surface water resources — its ponds, lakes, streams, freshwater wetlands,

Statistical Water Demand Formula

$$D = 22.83(H) + 0.69126(I) - 141{,}260$$

D = predicted monthly public water demand in million gallons per day (mgd)

H = total number of households each month

I = a logarithmic term relating monthly variations in precipitation and temperature

Predicted annual withdrawal is determined by adding each predicted monthly water demand for a given year. The County uses the statistical water use formula to measure the effectiveness of water conservation. The formula relates total water use to the number of households in the County, and takes into account the daily temperature and the frequency of rainfall to provide accurate predictions of average monthly water demand (from all sources) — excluding the effects of conservation programs. Since water conservation began in earnest in 1987, the difference between actual groundwater withdrawal and predicted withdrawal can be attributed to water conservation savings.

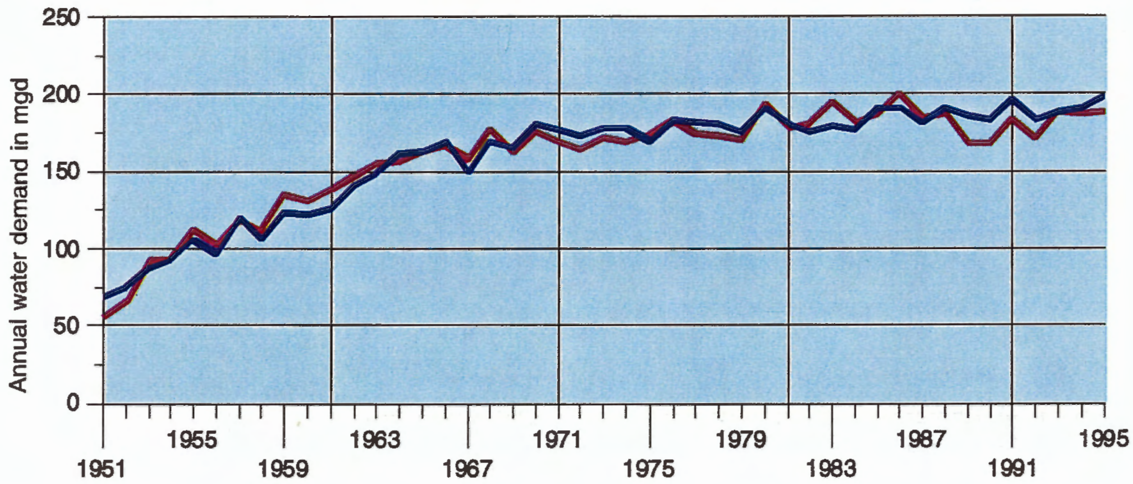


Figure 3-5. Comparison of actual to predicted water demand over 44 years demonstrates the accuracy of the Nassau County statistical water use formula.

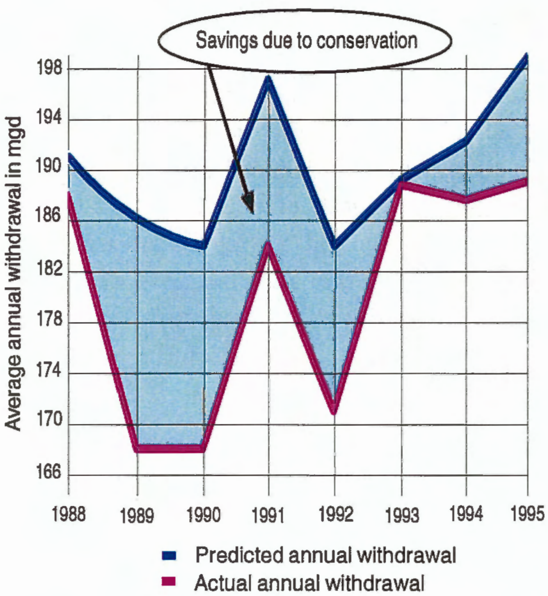


Figure 3-6. Comparing actual rates of groundwater withdrawal to rates predicted by the statistical water use formula measures the effectiveness of water conservation efforts.

estuaries, and their associated environments — are all dependent on groundwater. Ponds and lakes rely on groundwater to maintain water depth and to provide the temperature and chemistry needed to support native aquatic species. Streams require groundwater to maintain a continuous flow between rainfalls and to stabilize temperature and chemistry for sensitive fish such as trout. Bays and estuaries depend on the freshwater contributed by groundwater to maintain salinity at a desired level. Freshwater wetlands are also extremely sensitive to changes in groundwater levels. Such changes alter the type and extent of vegetation and wildlife.

Prior to development, when the water table was higher than it is today, groundwater supplied most of the water in Nassau County's streams, ponds, and wetlands. Constant groundwater flow — called "baseflow" — supplied about 87 percent of all streamflow. Streams were characterized by cool, clear water flowing at a relatively slow, constant rate. Streams flowed continuously during and between rainfalls because the flow was dominated by groundwater seepage. Erosion and scouring of the streambed were rare. Because the streams had a constant source of cold baseflow from groundwater, they were capable of supporting sensitive fish species such as trout.

One of the major consequences of development has been a permanent lowering of the water table, which has reduced baseflow in the County's streams and reduced water levels in its lakes, ponds, and freshwater wetlands. Figure 3-7 depicts the effect of a lowered water table on stream baseflow. Because the water table no longer intersects many streambeds along the entire stream length, baseflow and the length of flowing stream both have decreased. Under developed conditions, streams are warmer and have larger, intermittent flows. Stormwater runoff

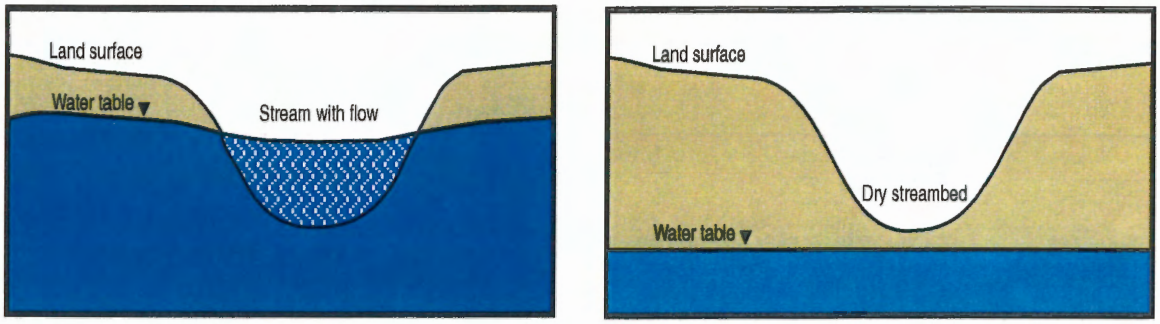


Figure 3-7. The baseflow component of streamflow diminishes as the water table declines. Baseflow disappears when the water table drops below the streambed.

causes erosion, scours the streambed, and can carry litter and pollutants. Without a baseflow component, many streams dry up between rainfalls.

Figure 3-8 shows that development has altered both the composition and the rate of streamflow in the County. County-wide baseflow from groundwater has decreased from 84 to 35 mgd, and stormwater flow has increased from 13 to 30 mgd, largely because stormwater from impervious surfaces has been routed through storm drainage systems into stream corridors. Before development, stormwater represented only 13 percent of total streamflow. Today, stormwater is 46 percent of total flow. Total streamflow — from *all* sources — has decreased from 97 mgd under natural conditions to 65 mgd today. Because they lack continuous baseflow along most of their lengths, most south shore streams can no longer sustain fish populations.

At the turn of the century, groundwater supplied nearly 90 percent of the water in Nassau County's streams, ponds, and wetlands. Today, many streams receive little or no baseflow.

If no action is taken to enhance streamflow, the south shore will experience loss of inland freshwater wetlands, loss of recreational and aesthetic value of parks since most are centered around stream and pond features, and loss of ecological diversity supported by healthy wetland habitats.

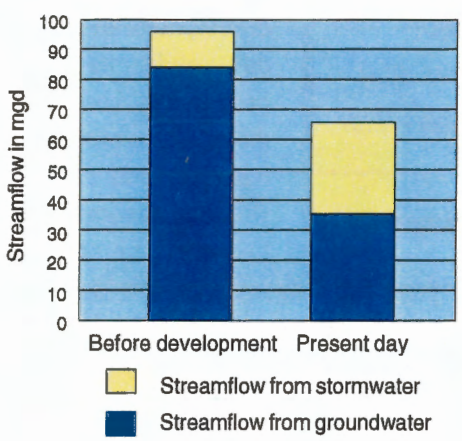


Figure 3-8. The loss of baseflow has completely altered the character of streamflow.

3.2.1 Factors Affecting Streamflow and Water Levels

Sanitary sewers, water supply withdrawal, and stormwater collection systems are the major development-related factors that affect streamflow and surface water levels in Nassau County.

Effects of Sanitary Sewers

Operation of sanitary sewer systems has caused a permanent loss of groundwater from the groundwater system. While sanitary sewers have reduced freshwater volume in the aquifers by less than 1 percent, this relatively small decline has had major impacts on the County's streams, ponds, and freshwater wetlands.

Sanitary sewers have had a much greater impact on south shore streams than on north shore streams. There are two reasons for this:

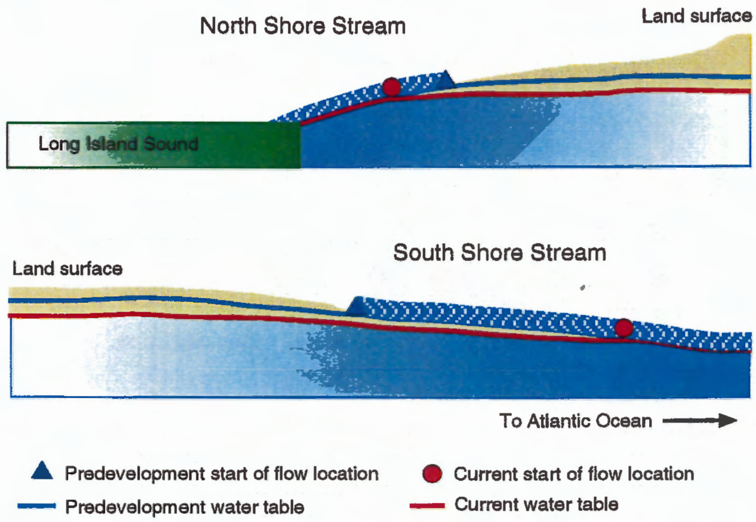


Figure 3-9. Longer stream lengths and flatter slopes make south shore streams more sensitive to small declines in the water table.

- The entire south shore is sewered. Although a large portion of the population on the north shore is served by sewers, specifically in the more densely populated regions such as Glen Cove, Great Neck and Port Washington, in terms of geography these communities only occupy a relatively small area of the north shore.
- South shore streams are longer and have relatively gentle slopes compared with steeper north shore streams, making them more sensitive to small declines in the water table.

Figure 3-9 shows how the longer stream lengths and flatter slopes characteristic of south shore streams make their northern reaches much more susceptible to a lowering of the water table.

> *Sanitary sewers and water supply withdrawal are the major development-related factors that affect streamflow and surface water levels in Nassau County.*

Effects of Water Supply Withdrawal

Since the water table has declined due to the effects of sanitary sewers, streams and other surface water features are even more sensitive to the location of public supply wells. Groundwater model simulations show that water supply withdrawal within 1 mile of a stream corridor can cause a significant local decline in the water table, thereby reducing baseflow. This potential problem is of greatest concern on the south shore. Of the 134 supply wells located within 1 mile of a stream, 110 are located on the south shore.

One notable example of sensitivity to nearby water supply wells is Hempstead Lake on Mill Creek. Water suppliers withdraw approximately 13 mgd from the aquifer along the Hempstead Lake corridor. A localized groundwater model developed for the Hempstead Lake area shows that reducing groundwater withdrawal by several mgd in the area near the northern end of the lake would significantly improve stream baseflow and lake levels.

Water supply withdrawal also intensifies and prolongs the naturally low baseflow conditions that exist during the warm summer months. Such conditions are particularly stressful to the stream ecology during the important summer growing season.

Using East Meadow Brook near the Meadowbrook Parkway as an example, Figures 3-10 and 3-11 illustrate estimates of the seasonal variations in baseflow and length of flowing stream in the brook, under both predevelopment and present day conditions. Under present day conditions, the brook has much lower baseflow and a shorter flowing stream length. During the critical summer growing season, baseflow decreases even further, by 65 percent, and the length of flowing stream decreases by nearly a mile. In contrast, under predevelopment conditions, summer baseflow decreased by only 35 percent and the flowing stream length remained constant throughout the year.

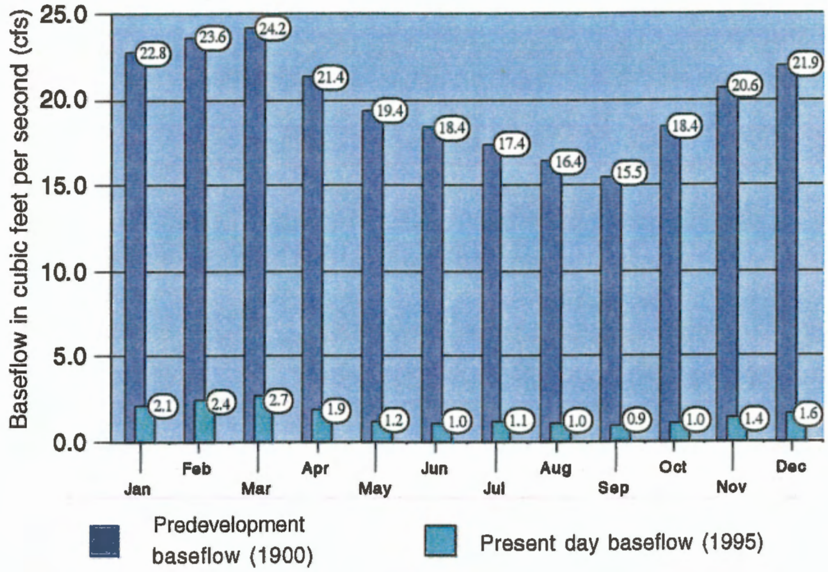


Figure 3-10. Present day baseflow in East Meadow Brook has decreased dramatically as increased consumptive use has lowered the water table.

Depending on what type of modifications are made, positive or negative effects on stream corridors can result. For example, if drainage modifications are implemented to handle additional stormwater runoff, the increased amount of runoff could cause erosion problems in the receiving stream channel. However, by taking the drainage modifications one step further by constructing instream checkdams to control velocity of flow, erosion problems are mitigated, the aquatic habitat benefits and dry weather streamflow is increased. It is therefore extremely important to consider the impacts of any proposed drainage modifications with the environmental requirements of associated surface water features. This will help assure that positive impacts are seen.

Effects of Stormwater Collection Systems

Because flow in many of the south shore streams is now more dependent on stormwater runoff than on groundwater baseflow, the streams are very sensitive to changes in surface drainage. Stormwater collection system modifications, such as elimination or relocation of culverts, could eliminate ponds, wetlands, and large segments of streamflow. In areas where uncontrolled stormwater directly discharges to streams, streambed erosion has eliminated much of the natural aquatic habitat. High flow can wash away aquatic organisms, and in areas of extremely low flow, where eroded sediments settle, streambed organisms can be smothered.

From time to time there are needs to modify existing drainage systems to control both quantity and quality of stormwater runoff.

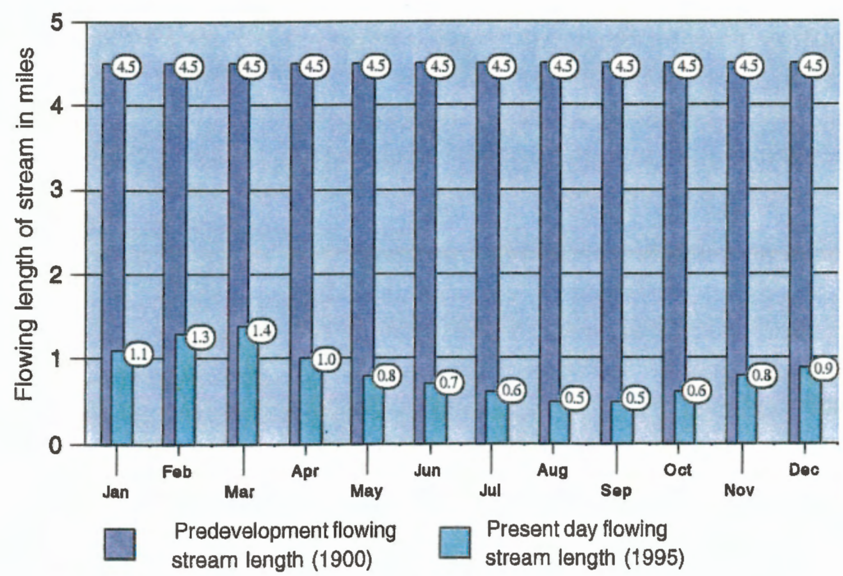


Figure 3-11. In predevelopment times, East Meadow Brook had a constant flowing stream length of 4.5 miles in all seasons. Today, the length of flowing stream is greatly reduced, particularly during the summer growing season.

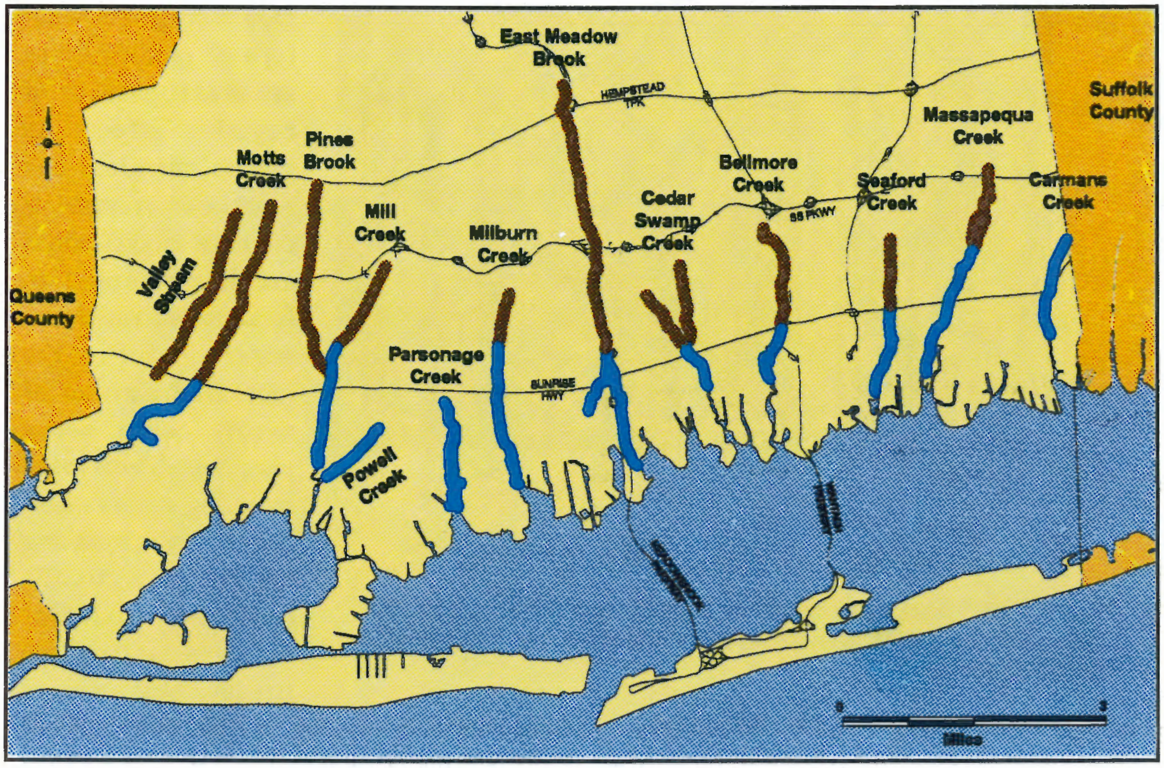


Figure 3-12. Ultimate reductions in flowing stream lengths as a result of development are shown in brown, while blue represents the remaining length of flowing stream.

3.2.2 Trends in Streamflow Conditions

Groundwater model simulations indicate that the groundwater system takes about 10 years to completely respond to any large change such as the reduction in aquifer recharge caused by sanitary sewers. Because of slow aquifer response and phasing of sanitary sewer installation, the full impacts of sewers on County-wide streamflow and groundwater levels have just recently become apparent.

Decreasing Streamflow and Stream Length

The groundwater system requires some time to completely respond to the effects of development and installation of sanitary sewers. Thus, the groundwater model was used to predict the ultimate reductions in stream length and streamflow that can be expected for major south shore streams. Figure 3-12 shows the reductions in stream lengths in south shore streams predicted by the model, which are essentially the same as streamflow conditions today. The total length of each flowing stream prior to development is shown in brown/blue, while blue represents the remaining length of flowing stream expected to result from the effects of development.

Affected Streams

Because sanitary sewers were installed in phases — moving from the western part of the County in the 1950s to the eastern part of the County in the early 1980s — the impacts to the streams have not occurred at the same time.

In western Nassau County, the full impact of the installation of sanitary sewers has been observed for some time in Valley Stream, Motts Creek, Pines Brook, and Mill Creek (including the Hempstead Lake chain) where continuous baseflow has been eliminated. These streambeds are dry most of the time. The stream corridors now serve primarily as stormwater conduits. Most of the water in Hempstead Lake comes from stormwater runoff, not from baseflow.

The central Nassau streams, East Meadow Brook and Cedar Swamp Creek, declined during the 1980s and are not expected to decline further. East Meadow Brook, north of Mullener Pond (at the Southern State Parkway), is dry during much of the year.

To the east, baseflow to Massapequa Creek has continued to decline, even during the years of higher than average precipitation in the late 1980s and early 1990s. Since the higher than average precipitation in the early 1990s masked the sanitary sewer related declines to some degree, present day baseflow is expected to decline further by the year 2010.

3.2.3 Options to Improve Streamflow and Surface Water Levels

A wide range of opportunities are available to protect and enhance key surface waters in Nassau County. They range from simple, low-cost approaches, such as water conservation and stream maintenance programs, to intermediate engineered solutions that target conditions at individual streams and surface water bodies, to very costly and complex engineered solutions that can address regional declines in streamflow and surface water levels.

Simple Low Cost Approaches

Water conservation has long been considered an environmentally sound approach to reducing the amount of groundwater withdrawn and permanently lost from the groundwater system. The State, County and water suppliers have all been instrumental in promoting water conservation since 1987 and the average annual savings since then has been about 4 to 5 percent (10 mgd).

Without any water conservation, future water demand is expected to be about 190 mgd annually. Assuming that conservation continues to save about 10 mgd, future water demand should be 180 mgd. This rate of conservation is consistent with the maximum rate of water conservation — 5 to 10 percent — typically sustained in various communities in the United States where water conservation has been practiced.

Cost-effective options are available to improve streamflow conditions and surface water levels in Nassau County.

The groundwater model was used to estimate stream baseflow resulting from various levels of water conservation. The model determined that groundwater withdrawal for public water supply would have to be reduced to between 100 and 150 mgd to achieve significant increases in stream baseflow as shown in Figure 3-13. This represents a 20 to 45 percent reduction in groundwater withdrawal, clearly an impossible goal under present day conditions. It is clear that water conservation alone cannot effectively enhance baseflow. Nevertheless, conservation efforts of the County and water suppliers have been beneficial in that the water table has risen slightly, enabling more groundwater to supply certain streams and surface water bodies.

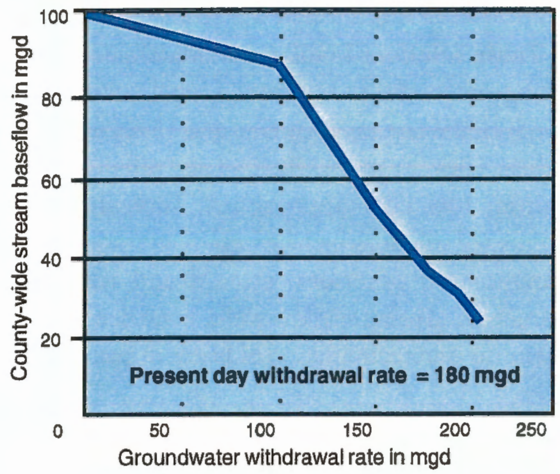


Figure 3-13. To achieve significant increase in stream baseflow, groundwater withdrawal would have to be reduced to between 100 and 150 mgd.

Stream maintenance programs are necessary for controlling nuisance aquatic vegetation and clearing debris from streams and surface water bodies. Although such programs are not effective in mitigating loss in streamflow and declines in surface water levels, they are beneficial in enhancing the aesthetic value to the community and in controlling unwanted rodent populations.

Combined with other solutions to improve surface water conditions, simple approaches are significant components of stream and surface water management programs.

Intermediate Engineered Solutions

These solutions involve a moderate cost and can be successful in improving local conditions at individual stream segments and surface water bodies. They are more effective and reliable than simple, low cost approaches. Intermediate engineered solutions include improved stormwater management practices, stream and wetland augmentation using shallow wells, pond deepening and lining and recirculation of water in ponds and lakes.

The cost of these solutions generally will range from several hundred thousand to several million dollars, depending on the extent of intermediate options selected to address a specific surface water feature. Intermediate solutions are often the most cost-effective approaches to mitigate declines in streamflow and surface water levels.

Improved stormwater management practices involve storing stormwater runoff in detention basins or ponds and slowly releasing runoff into downstream receiving waters. The runoff recharged from detention facilities may also be successful in raising local groundwater levels enough to temporarily increase dry weather flow in streams. Construction of instream control structures such as check dams will slow the velocity of flow and retain water for longer periods between rainfall events. This stormwater management option provides benefits that include reduced peak runoff rates and associated erosion problems downstream, improved downstream water quality, an improved ecosystem, increased dry weather flow and improved aesthetic appeal resulting from open waters.

Shallow wells may be used to pump groundwater into streams, ponds and wetland areas at specific locations along the stream corridors in order to maintain dry weather flow. This option can be used in instances where stormwater management improvements may not be possible and as a means to assure that specific wetland vegetation is continuously inundated with water.

Pond deepening lowers the pond bottom thereby increasing storage volume and increasing depth relative to local groundwater levels. Because groundwater levels have declined, lowering pond bottoms is a possible mitigation alternative for maintaining open waters and capturing more runoff with the increase in storage volume. If groundwater levels are too deep to make pond deepening viable to sustain open waters, ponds can be lined with a clay layer, thereby preventing stored runoff from seeping through the bottom and sides of ponds. Recirculation of water in ponds is an option whereby water is pumped from larger ponds and lakes located in the more southerly portion of the County to smaller ponds and stream corridors located further north.

Complex Engineered Solutions

The most effective solutions are complex engineered projects that can provide large-scale and regional improvements such as restoration of long, continuous segments of flowing streams and/or restoration of predevelopment water levels in lakes and ponds. Examples of complex engineered solutions include the closing of public water supply wells located too near the surface water features and replacement with new wells in other areas, importing water from outside Nassau County to replace water lost from closed wells, or use of advanced wastewater treatment (AWT) technologies to obtain sufficiently treated wastewater that can be used to augment streamflow.

The cost of complex engineered solutions is many times greater than that for intermediate engineered options and can even be an order of magnitude more costly. In addition to the costs, complex solutions are extremely difficult to implement because of the administrative difficulties involved, little available land for new public supply well sites, new infrastructure that would be needed, and lengthy public environmental and regulatory reviews that are required.

It is not cost-effective to relocate public supply wells simply to enhance streamflow conditions. However, an alternate approach can be taken. As water suppliers seek new or replacement wells, the County intends to utilize the groundwater model and work in conjunction with NYSDEC to define potential well locations that would have minimal impacts on surface water features. For the time being, and when possible, water suppliers are encouraged to reduce groundwater withdrawal from wells located near streams and surface water bodies in order to raise local groundwater levels.

Integrated Approach

Enhancement of stream baseflow and surface water levels will be difficult to achieve because the most beneficial solutions are the most costly and often the most difficult to implement. Integrating streamflow restoration efforts with other ongoing projects such as modifications to stormwater collection systems may provide additional opportunities for achieving local streamflow improvements more quickly and at reduced cost.

> *Improvement in streamflow conditions is a challenge because the most beneficial solutions are not the most cost-effective options.*

Other ongoing activities, such as nonpoint source pollution management or habitat restoration programs, may provide similar opportunities to improve streamflow. Nassau County is currently assessing stream restoration opportunities by systematically surveying its stream system and inland watersheds. These surveys are identifying the main causes of stream and pond degradation such as the lowered water table, erosion, or litter from stormwater runoff. As these assessments identify areas where habitat or water quality restoration is feasible, related opportunities for improving streamflow may become evident. Engineering studies to identify the most cost-effective combination of solutions to improve conditions at priority stream segments will be necessary. Such an integrated approach has potential to provide real benefits to the County in terms of resource restoration, economics and ease of implementation.

3.2.4 The County's Approach

As a condition of the U.S. Environmental Protection Agency (EPA) grants that helped defray the cost of design and construction of the sanitary sewer systems, the County was mandated to investigate and mitigate the negative environmental effects of the lowered groundwater table caused by the installation of sanitary sewers. Under the mandate, the County was not required to restore streamflow and surface water levels to predevelopment levels, nor were requirements established to achieve any specific levels of restoration.

In accordance with EPA directives, Nassau County has undertaken two programs to address the decline in surface water features associated with development. In the first, the *Flow Augmentation Needs Study*, or FANS, completed in 1982, the impacts of sanitary sewers on south shore streams were identified, along with options to address predicted declines in streamflow and surface water levels. As a result of FANS and discussions with regulatory agencies, portions of eight south shore streams were selected to be addressed because of their aesthetic, recreational and ecological value to the community. EPA supported an intermediate, cost-effective approach to mitigate conditions at the eight streams:

- East Meadow Brook
- Seaford Creek
- Massapequa Creek
- Mill Creek including Hempstead Lake, and Northeast, Northwest, and South Ponds
- Bellmore Creek including Mill Pond Park, Twin Lakes Preserve, and Forest City Park
- Pines Brook including Tanglewood Preserve and Halls Pond Park
- Cedar Swamp Creek including the Merrick Preserve
- Carmans Creek

Building on FANS, the County initiated a capital project, the "Stream and Wetlands Area Management Program," or SWAMP, to provide funding for design and construction needed to

Table 3-1. Alternatives for streamflow improvement in Nassau County.

- Water conservation
- Stream maintenance
- Stormwater detention facilities and recharge systems
- Instream control structures (check dams)
- Withdrawal of groundwater from shallow wells followed by discharge to the stream, pond or wetland area
- Pond deepening and lining
- Recirculation of water in ponds

improve conditions at these streams. Some of the improvements have been completed at specific streams and surface water bodies and others are currently in the planning and/or design stage. The streamflow improvement alternatives are summarized in Table 3-1.

As a means to supplement and improve many of the intermediate engineered solutions to specific streams, the County also has considered complex engineered solutions. Localized groundwater models were used to evaluate such solutions on a County-wide basis. While complex engineered solutions would be most succesful in restoring surface water conditions to near predevelopment levels, the high cost, difficulty of implementation, limited resources and limited public demand for streamflow restoration preclude such solutions from serious consideration.

3.2.5 Individual Streams

The County has completed one mitigation project, another has been partially completed, two are underway and the remainder are in the conceptual stages. It is anticipated that work on these mitigation projects will continue through the next decade.

East Meadow Brook Project (Uniondale). The first project that was completed was the East Meadow Brook project, which relies primarily on stormwater controls and pond deepening. The project was completed in 1993 at a cost of $2.7 million and consisted of the following components:

- Construction of a detention basin at the stream headwaters with the capacity to capture up to 7 million gallons of stormwater runoff
- Repair or replacement of four downstream check dams which prevent erosion and help to retain water for longer periods between rainfall events
- Deepening Mullener Pond, which was often dry, in order to intersect the permanently lowered groundwater table
- Fish restocking and planting of native aquatic vegetation

The success of the project is evidenced by the increased recreational use of Mullener Pond and aesthetic enhancement for nearby homeowners and travellers on the Meadowbrook Parkway which is adjacent to the pond and stream.

Pines Brook Project (West Hempstead). The first part of this project addressed Halls Pond which was deepened and lined to better control and store stormwater inflows. Due to the large decline of the water table in this area, the pond could not be deepened to intersect the water table. Instead, it is completely stormwater fed. The project, completed in 1994 at a cost of $1.3 million, has restored this pond-oriented park area.

The second part of the Pines Brook Project, which has yet to be undertaken, includes the repair of instream control structures to divert greater amounts of stormwater runoff through the Tanglewood Preserve. Shallow well augmentation and pond recirculation will also be considered.

Seaford Creek Project (Seaford). Planning for the Seaford Creek project has been completed, design is under way, and construction was completed in early 1998. The focus of the Seaford Creek streamflow improvement effort is Tackapausha Preserve. A stormwater detention area has been constructed and wetland plants were introduced to the headwaters area. Several small check dams were constructed to enhance stormwater recharge and to inundate adjacent wetland areas. Stormwater runoff is also diverted to a stand of Atlantic White Cedar trees, which are endangered in New York State, at the southern end of the preserve.

Massapequa Creek Project (Massapequa). Planning for improvements to Massapequa Creek is under way. Preliminary plans include withdrawal of groundwater from a shallow well(s) near the stream to irrigate important wetland areas, and partial deepening of several ponds to improve their detention, recharge, and fisheries functions.

Mill Creek Including Hempstead Lake (Hempstead area). The Mill Creek stream corridor is especially important because it includes Hempstead Lake State Park, with six separate lakes and ponds. The effects of sanitary sewers and groundwater withdrawal have caused the water table to decline nearly 10 feet in this area. As a result, Northeast Pond, Northwest Pond, and Hempstead Lake are dry much of the year. Only deep depressions where stormwater runoff is impounded retain water. Possible solutions to this condition include:

- Dredging portions of ponds and lakes, installation of instream control structures, and use of water withdrawn from shallow wells to augment pond and lake levels. This was determined to be one of the less costly approaches to raise surface water levels, but less effective than the following complex solutions that were evaluated with the groundwater model.
- Relocation of 3 to 10 mgd of water supply withdrawal from within the stream corridor to elsewhere in the County, combined with an effective water conservation program. This approach could increase surface water levels to about two-thirds of predevelopment levels, but will be very difficult to implement.
- Replacement of potable water currently withdrawn from public supply wells near the Lake with water imported from outside Nassau County, or with desalinated water withdrawn from wells located along the freshwater/saltwater interface in southwestern Nassau County. This approach could restore surface water levels to near-predevelopment conditions; however, this approach is very expensive and difficult to implement.

Baseflow to Hempstead Lake and its northern ponds can only be restored by large-scale and very expensive projects. Such efforts would require the cooperation of several agencies, and possibly several water suppliers. However, because of the high potential for restoration, further study of the feasibility of these solutions is recommended.

Streamflow mitigation projects have been completed at East Meadow Brook, Halls Pond Park and Seaford Creek.

Bellmore Creek Project (Wantagh). This project will include pond lining to contain stormwater runoff and augmentation of flow with shallow wells during dry periods. Wetland areas along the creek are also candidates for augmentation using a shallow well(s).

Cedar Swamp Creek Project (Merrick). Aesthetic improvements and control of flooding are the focus of this project. Deepening associated ponds and providing upstream drainage modifications with detention facilities will allow for the storage of additional stormwater runoff and increased upland recharge. Merrick preserve is in good hydrologic condition as adequate local water levels currently exist that keep the preserve inundated with water.

Carmans Creek (Massapequa). Carmans Creek is the last stream to be addressed under SWAMP. It has the lowest priority because water level declines have not yet been detected near the headwater area of this stream. If conditions deteriorate, consideration will be given to pumping a shallow well(s) for flow augmentation or a stormwater management approach using instream control structures to promote stormwater recharge and to inundate wetland areas.

3.3 Saltwater Intrusion

Nassau County's major aquifers are bounded by saltwater along both the north and south shores. At these boundaries, fresh groundwater

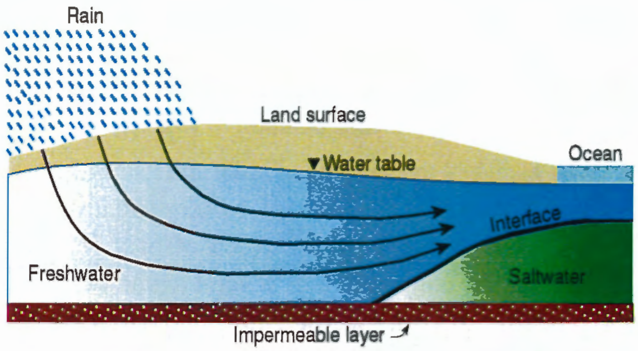


Figure 3-14. Fresh water, continually fed by rainfall, flows up and over the saltwater wedge at the freshwater/ saltwater interface.

meets with the salty groundwater beneath Long Island Sound and the Atlantic Ocean. This boundary is called the freshwater/saltwater interface.

Under natural conditions, fresh groundwater will eventually reach a balance, or equilibrium, with the salty groundwater in the aquifer. Figure 3-14 depicts a typical interface configuration, in which the freshwater that is continually recharged by rainfall flows naturally toward the sea until it meets the saltwater boundary. Instead of mixing with the saltwater, the freshwater flows up over the denser saltwater, and eventually leaves the groundwater system as freshwater released at the bottom of the ocean or Sound. This situation results in a typical configuration of saltwater intruding beneath the freshwater in a wedge shape along coastal areas. Several areas along Nassau County's coastline are currently known to be vulnerable to saltwater intrusion as shown in Figure 3-15.

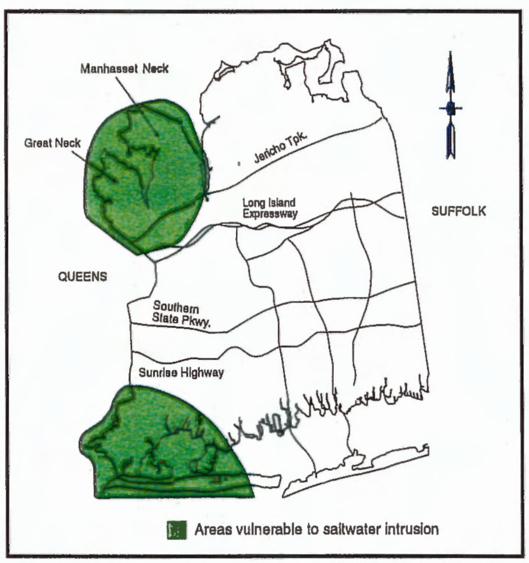


Figure 3-15. Southwest Nassau County, and portions of the Great Neck and Manhasset Neck peninsulas, have proven to be vulnerable to salt water intrusion.

Along the south shore, localized geologic features such as the Jameco aquifer and Gardiners Clay, which are not present in most of Nassau County, create multiple subsurface layers. Figure 3-16 illustrates how several aquifers are interlayered among relatively impermeable clay layers that impede freshwater flow, giving the south shore a multiple wedge pattern of natural saltwater intrusion. The saltwater wedges are characterized by a thin leading edge or "toe" that hugs an impermeable layer. The wedge thickens as one moves seaward, until at some point offshore saltwater fills the entire aquifer.

On Nassau County's north shore, localized geologic features cause saltwater intrusion to occur primarily as a single wedge above bedrock in portions of the Port Washington and Lloyd aquifers largely as a result of high pumping from near shore public supply wells. The Port Washington aquifer is a localized geologic feature specific to the north shore.

3.3.1 Freshwater/Saltwater Interface

In Nassau County's aquifers, the interface between freshwater and saltwater is a relatively sharp one. In areas where the saltwater wedge exists, the water changes from fresh to pure seawater over a change in depth of approximately 100 feet or less. This change is marked by an extremely rapid increase in chloride levels, from less than 50 parts per million (ppm) in the freshwater zone to more than 17,000 ppm in the saltwater zone.

The position of the interface depends on the pressure of the freshwater relative to the pressure exerted by saltwater. If the pressure in the freshwater diminishes sufficiently, the interface moves landward and the wedge thickens. The same effect occurs if the sea level rises over time. If the pressure in the freshwater increases

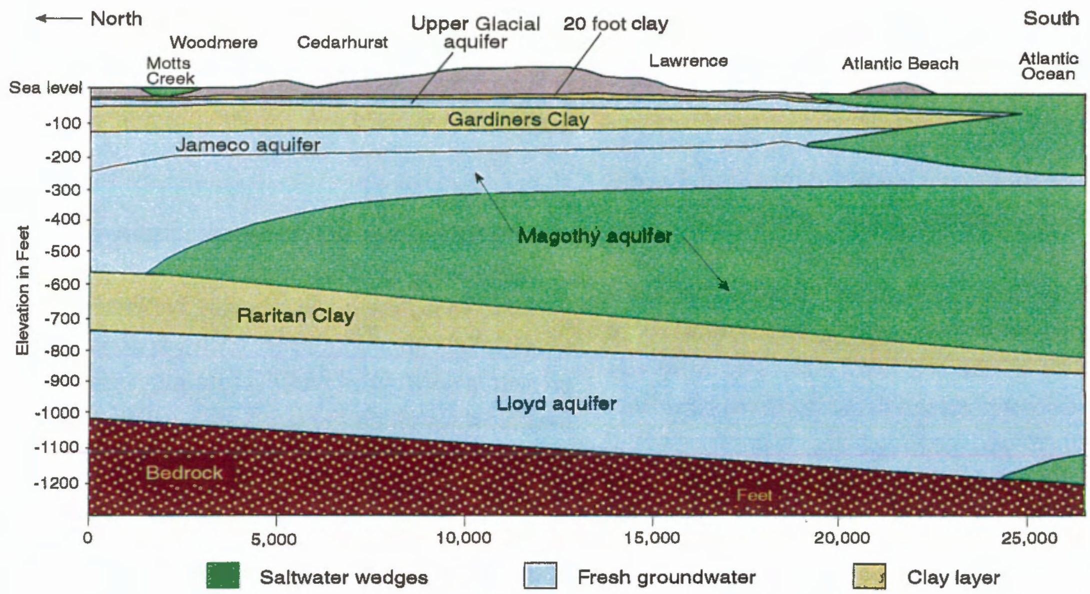


Figure 3-16. The subsurface geology along the south shore has resulted in a multiple wedge pattern of landward saltwater intrusion in southwest Nassau County.

sufficiently, such as by a decrease in public water supply withdrawal, the interface moves seaward and the wedge thins out — but at a much slower rate than landward movement.

3.3.2 Forces Controlling Movement of the Interface

The interface on Nassau County's south shore has been moving landward for centuries. The main reasons for this landward movement, or saltwater intrusion, are a rise in sea level of more than 300 feet since the last ice age which ended about 18,000 years ago, and the increase in groundwater consumption that has accompanied development.

As groundwater withdrawal and consumptive use increased, pressure in the deeper aquifers decreased sufficiently to cause saltwater to move landward in localized areas.

By withdrawing groundwater from the aquifers for public water supply, the freshwater pressure decreases. When the pressure of the freshwater decreases sufficiently, the density difference between the freshwater and denser saltwater forces the interface landward towards a new equilibrium position. This phenomenon has been observed in parts of the aquifers in southwest Nassau County, and in portions of the aquifers in both the Great Neck and Manhasset Neck peninsulas on the north shore.

Since the last ice age, the groundwater system on the south shore has been adjusting to the rise in sea level. The Upper Glacial aquifer has reached its natural equilibrium condition with the salty groundwater. The freshwater/saltwater interface in the Magothy aquifer in southwest Nassau is nearing its final equilibrium position, and along the rest of the south shore, the interface is offshore but is continuing to advance in response to the sea level rise and public water supply pumping.

The Lloyd aquifer along the south shore, however, is very deep and is protected by a relatively impermeable layer, the Raritan Clay, that impedes flow into the aquifer. The saltwater interface in the Lloyd is still moving toward its final position of equilibrium in response to the rise in sea level and water supply pumping and is expected to eventually be north of the coastline. Currently the interface is still at some unknown position south of the barrier islands, and is moving landward at a very slow rate.

On the north shore, the rise in sea level has not caused significant landward intrusion. Except for landward encroachment of saltwater along the northern tips of the Great Neck and Manhasset neck peninsulas, natural landward intrusion is no longer occurring on the north shore as a result of the sea level rise. The Magothy aquifer does not extend to the northern coastline, and the landward movement that is now occurring in portions of the Port Washington and Lloyd aquifers on the north shore is a result of groundwater withdrawal for public water supply.

3.3.3 How Interface Movement is Studied

Nassau County, in cooperation with the U.S. Geological Survey (USGS), has been conducting studies of saltwater intrusion for more than 35 years. Monitoring wells, geophysical surveys, and computer modeling have been used to perform these studies. Used together, these methods have have helped to develop a more comprehensive understanding of saltwater movement. This makes the prediction of future saltwater intrusion impacts on public supply wells possible. The great importance in studying interface movement is that actions can be planned and implemented by the water suppliers sufficiently in advance of anticipated impacts, thereby saving public supply wells.

Monitoring Wells

The traditional, and most expensive, method of measuring interface movement is through periodic sampling of monitoring wells to record water levels and to measure chloride content. At present, a network of wells is routinely monitored for chlorides along the south shore. These wells, shown in Figure 3-17, are sampled twice a year, and the chloride concentrations are evaluated. This semiannual monitoring provides a snapshot of the position of the interface, and allows long-term tracking of its movement.

The interface moves very slowly, often less than 100 feet per year, making field measurement a difficult way to track the advance. A closely spaced set of wells, located exactly above the interface, and at the right depth, would be needed to measure the yearly advance. This would be prohibitively expensive.

Since the late 1980s, several new, less costly techniques for saltwater intrusion analysis have been used in Nassau County. Three of the techniques are types of geophysical surveys; the

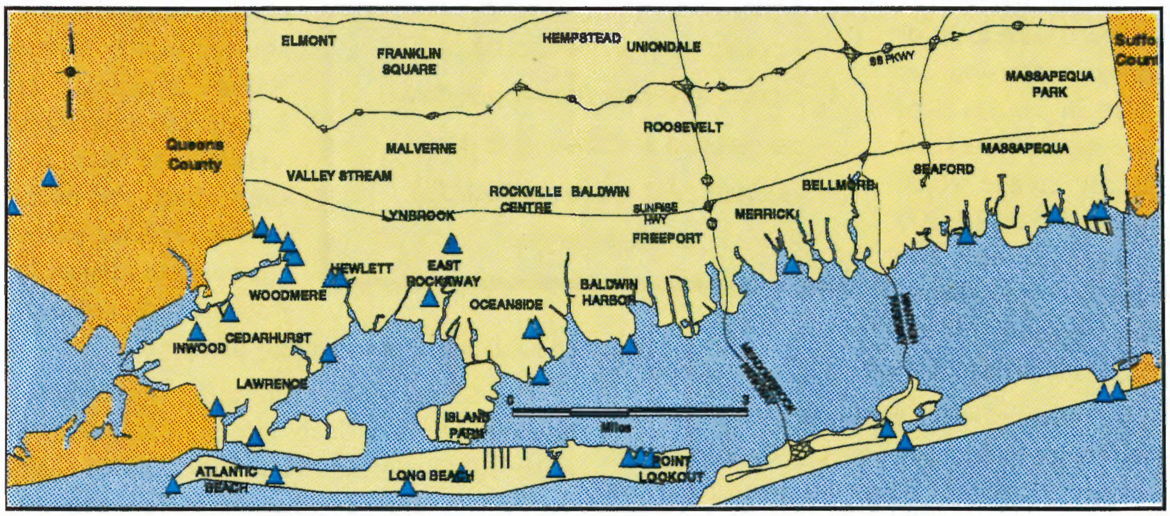


Figure 3-17. Routine monitoring for chlorides at selected wells along the south shore provides a snapshot of the position of the freshwater/saltwater interface, allowing long-term tracking of its movement.

fourth involves computer modeling of saltwater intrusion.

Geophysical Surveys

The three types of geophysical surveys used by Nassau County and USGS to study movement of the saltwater interface are time domain electromagnetic (TDEM) surveys, focused downhole induction logging, and offshore seismic reflection surveys.

The TDEM survey uses electric currents at the ground surface to estimate the electrical resistivity (the resistance of a material to conducting electricity) of groundwater to depths of 400 feet. The electrical resistivity is highly influenced by the salinity of the groundwater, enabling the measurements to distinguish between freshwater and saltwater. Nassau County has conducted two separate TDEM surveys, one in southwest Nassau to map a portion of the Magothy aquifer interface, and one on the Great Neck Peninsula to map the position of the interface in the Lloyd aquifer. In both cases, the results helped to refine the original estimates of the location of the freshwater/saltwater interface based on the more widely spaced monitoring well network.

A second geophysical technique, focused downhole induction logging, is used by USGS to measure the exact thickness of the saltwater wedge at a monitoring well. By measuring the electrical conductivity of the groundwater outside the well casing along the entire length of the well, continuous, indirect measurements of the chloride content are made from the water table to the bottom of the well. This technique can only be applied to wells cased with plastic pipe, which excludes use of this technique on the older, steel-cased wells. Downhole induction logging is a powerful field technique that has shown that the mixing zone between saltwater and freshwater is very narrow, especially along the north shore.

Seismic reflection surveys, a third geophysical technique being used by USGS, uses reflected sound waves to determine the location and depth of underground geological features. Seismic reflection is helping to gain a better understanding of offshore deposits along the north shore, and is expected to improve future saltwater intrusion modeling efforts.

Saltwater Intrusion Modeling

The fourth analytical technique being used by the County is computer modeling. The Nassau County groundwater model has been applied to study those areas most susceptible to saltwater intrusion. To date, saltwater intrusion models have been developed for both the south and north shores of Nassau County. An even more detailed model for the Great Neck peninsula was also developed.

The models have enabled the County to estimate the rate of movement of the interface, to predict the expected position of the interface in each aquifer under a variety of future scenarios, and to explore solutions to saltwater impacts on public supply wells.

3.3.4 Locations and Effects of Saltwater Intrusion

Saltwater intrusion is occurring in southwest Nassau County, on the Great Neck peninsula, and on the Manhasset Neck peninsula. Saltwater has intruded into portions of the Magothy, Lloyd and Port Washington aquifers and is a concern because these aquifers are a public water supply source. Saltwater intrusion into the Upper Glacial aquifer is not a major concern in Nassau County because this aquifer is not used as a significant water supply source near the shorelines.

Once salt water intrudes inland and chloride concentrations in the freshwater aquifer exceed the drinking water standard of 250 ppm, that portion of the aquifer is no longer available for water supply purposes unless expensive treatment systems are installed. The models show that, once the saltwater has advanced inland, it is very slow to recede, even if water supply withdrawal in the area is reduced or eliminated. Thus, saltwater intrusion represents a long-term loss of a portion of the aquifer for drinking water use.

South Shore

Based on field surveys, saltwater intrusion has been found to occur in the southwest part of the County. Figure 3-18 shows the present position

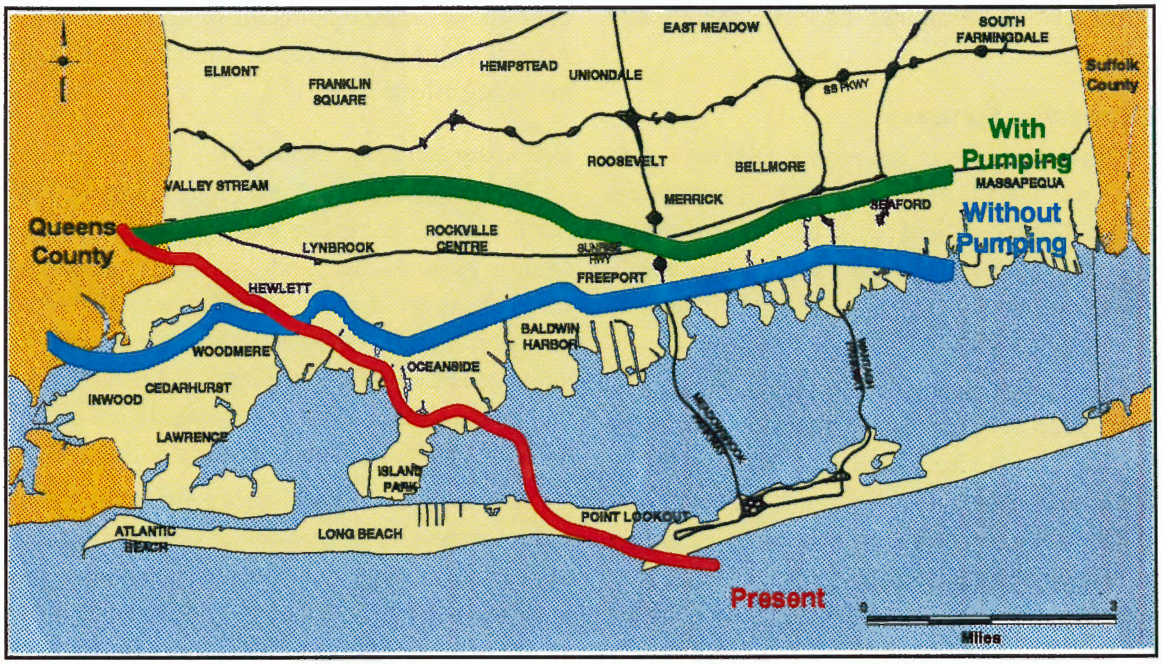


Figure 3-18. Final freshwater/saltwater interface positions in the deep Magothy aquifer under present levels of groundwater withdrawal and under no pumping conditions.

of the freshwater/saltwater interface in the deep Magothy aquifer. Computer modeling was used to determine the estimated final, or equilibrium, position of the interface if present rates of groundwater withdrawal are maintained and if no withdrawal occurred. Comparison of these scenarios on the figure illustrates how public water supply pumping influences saltwater intrusion beyond that which would naturally occur due to the rise in sea level over the last 18,000 years.

It is important to note that the final position of the interface in the deep Magothy aquifer under the influences of pumping would not be reached for several hundred years. Additionally, the modeling results showed that the Magothy interface is moving at a rate of over 150 feet per year in southwestern Nassau County. Along the rest of the south shore where the interface is still offshore, the rate of landward movement is about 50 to 75 feet per year.

Saltwater intrusion has occurred in parts of the aquifers in southwest Nassau County, the Great Neck peninsula and Manhasset Neck peninsula. The County is using field surveys and computer modeling to estimate the movement and position of the interfaces, and to explore solutions to saltwater impacts on public supply wells.

The present configuration of the interface has been strongly influenced by past groundwater withdrawal in Queens, Brooklyn, and southwest Nassau County, and by a discontinuity in the Gardiners Clay, which exposes the Magothy aquifer to shallow seawater intrusion beneath Jamaica Bay. Saltwater intrusion is expected to affect up to 13 public supply wells in southwest Nassau in about 50 years from the present.

The present position of the freshwater/saltwater interface in the Lloyd aquifer is not known. Computer modeling suggests that it is more than a mile south of the barrier islands. It is still far from reaching its

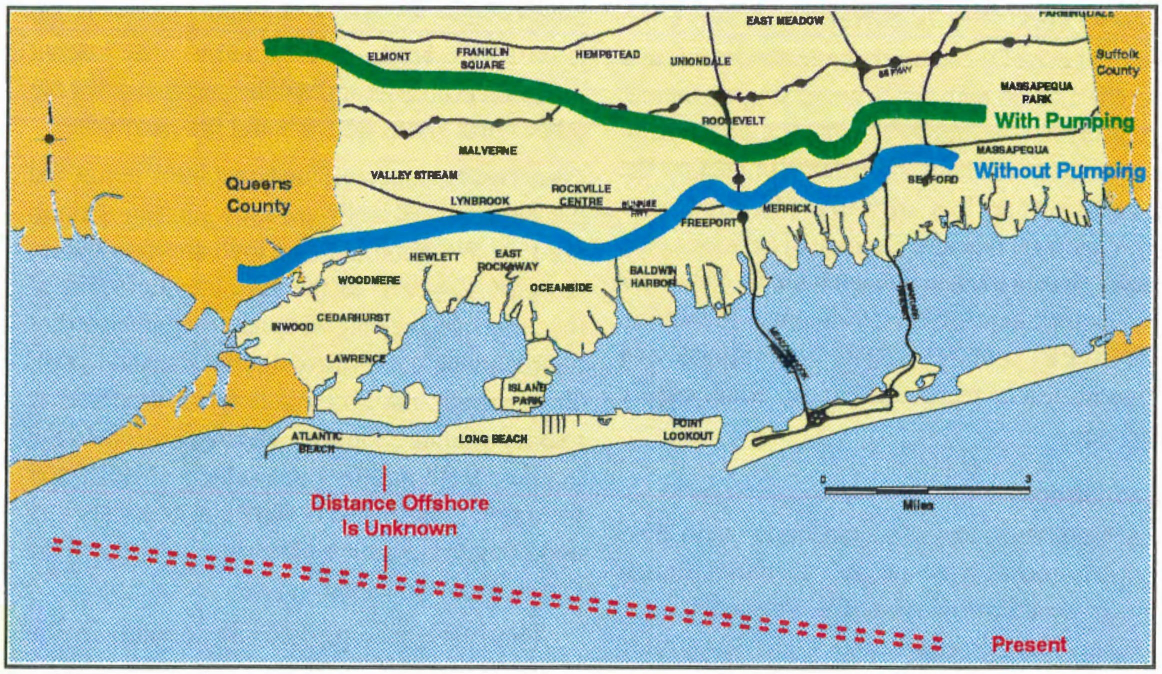


Figure 3-19. Final freshwater/saltwater interface positions in the Lloyd aquifer under present levels of groundwater withdrawal and under no pumping conditions.

eventual equilibrium position near the Southern State Parkway, and is still reacting to the centuries old rise in sea level. Lloyd aquifer withdrawal in this century has accelerated the landward movement of the offshore interface to an estimated 30 feet per year; however, it is probably more than 100 years away from causing significant problems to Lloyd wells on the barrier islands.

The natural equilibrium position of the freshwater/saltwater interface in the Lloyd aquifer is estimated to be onshore, near Sunrise Highway. Under current levels of groundwater withdrawal, the interface will reach its final equilibrium position near the Southern State Parkway. These positions are shown in Figure 3-19. Computer modeling predicts that the final equilibrium position would not be reached for over 1,000 years, even if pumping continues.

Once saltwater intrudes inland that portion of the aquifer is no longer available for water supply. Because saltwater intrusion can be costly to water suppliers, it is important to anticipate problems before they develop.

Although the present withdrawal from Lloyd wells on the barrier islands is accelerating the landward movement of the interface in this aquifer, the freshwater would ultimately be replaced by natural intrusion of saltwater even without public supply well withdrawal. Because freshwater eventually would be lost to the sea anyway, there is a strong rationale for allowing continued use of this freshwater resource on the barrier islands, where it will eventually be lost, regardless of any present day restrictions on withdrawal.

Obtaining fresh water from the Magothy aquifer beneath the barrier islands is not possible because of the saltwater that has already intruded into this portion of the Magothy aquifer. Withdrawal from the Lloyd aquifer beneath inland areas, where fresh Magothy water is available, should continue to be restricted because additional withdrawal from the Lloyd aquifer at such areas would accelerate the rate of intrusion.

New York City is currently studying the potential use of the aquifers beneath Queens and Brooklyn as an additional water supply source. Groundwater withdrawn from the aquifers in these areas could have significant impact on the saltwater that has already intruded into southwestern Nassau County. Therefore, the County should work in concert with the New York City Department of Environmental Protection (NYCDEP) and NYSDEC to evaluate any proposed use of these aquifers for water supply purposes.

North Shore

Several years ago, Nassau County and USGS began a cooperative project to better define geologic conditions and potential saltwater intrusion problems along the entire north shore. The project, which progressed from west to east along the north shore areas, included the installation of monitoring wells and the use of geophysical surveys to gather this information.

Saltwater intrusion was found to be occurring on the Great Neck peninsula and Manhasset Neck peninsula which led to more extensive study in these areas. Although the north shore investigation is not yet completed, no other areas with significant saltwater intrusion have been found to date. Computer modeling has been and is currently being used to address the known intrusion problems and will be performed for the other north shore areas should the need arise.

Great Neck Peninsula. The Great Neck peninsula has experienced landward saltwater intrusion in the Port Washington and Lloyd aquifers within the past 30 years. In the northern most part of the peninsula, the Port Washington aquifer overlies bedrock where the Lloyd aquifer does not exist. To the south, the Port Washington aquifer is in hydraulic connection with, and overlies, the Lloyd aquifer. Both aquifers are subject to saltwater intrusion. Figure 3-20 shows a cross section depicting the complex subsurface geology of the Great Neck Peninsula.

Three water supply wells located in the northern part of the peninsula experienced sharp increases in chloride concentration during the mid-1960s, and subsequently were closed. Several other wells (public, private and monitoring) show rising chloride concentrations indicating continued landward movement of the freshwater/saltwater interface in these aquifers.

In 1992, Nassau County conducted an investigation of saltwater intrusion on the Great Neck peninsula that included a TDEM

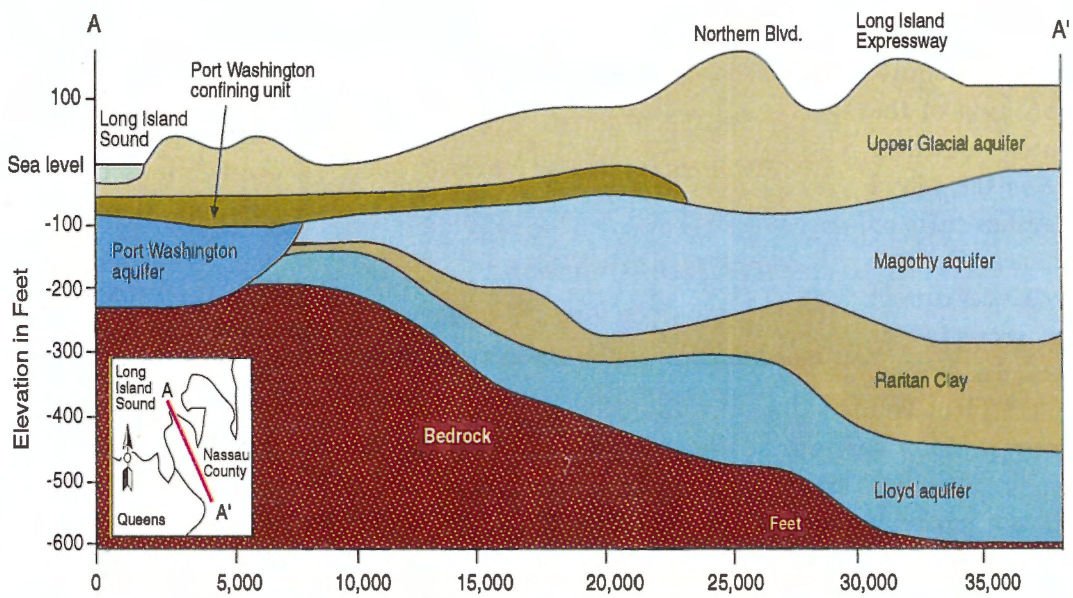


Figure 3-20. The subsurface geology of the Great Neck peninsula includes the Port Washington aquifer and Port Washington confining unit.

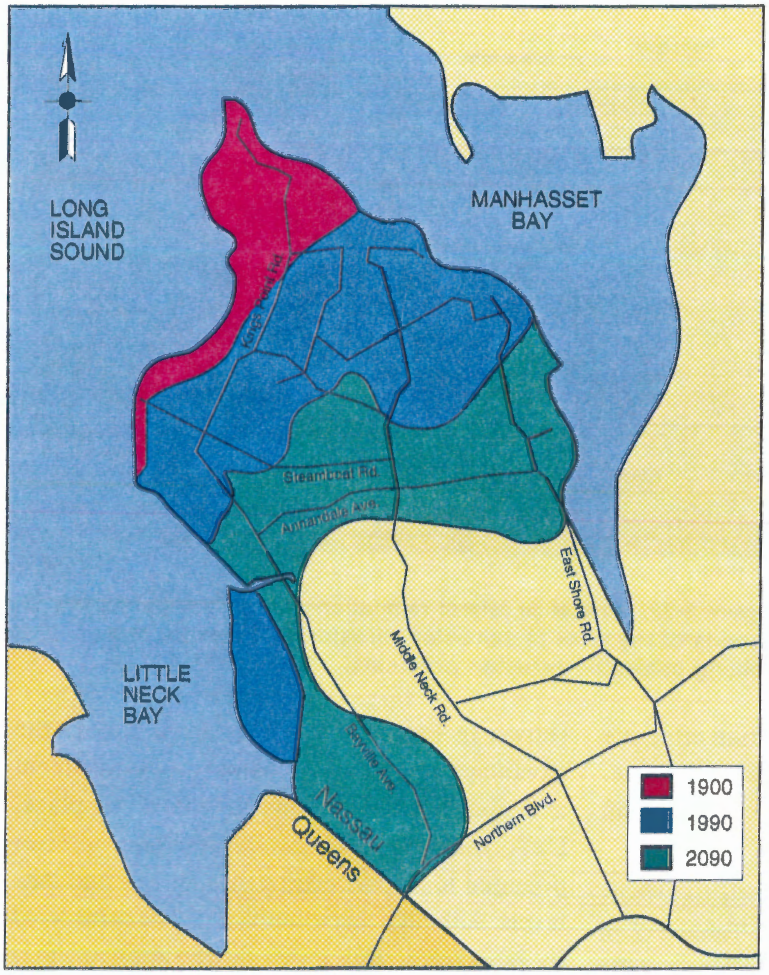


Figure 3-21. Computer modeling shows the estimated positions of the interface in 1900, 1990, and 2090 (if 1995 pumping patterns were to continue) on the Great Neck peninsula.

geophysical survey, the drilling of 12 monitoring wells to bedrock at the bottom of the Lloyd and Port Washington aquifers in cooperation with USGS, and development of a computerized saltwater intrusion model. All wells were cased with plastic pipe to allow downhole induction logging. The information obtained from the field investigation was instrumental in the model development. The investigation indicated widespread and active intrusion fronts as a result of water supply pumping along the north, west, and northeastern shores of the peninsula, with intrusion extending farther inland than was previously suspected. Figure 3-21 shows the landward position of the freshwater/saltwater interface in 1900, 1990, and 2090 (if 1995 pumping patterns and rates were to continue) as determined by the model.

Modeling indicates that groundwater withdrawal from the Lloyd aquifer beneath the Great Neck peninsula should not exceed 0.6 mgd if saltwater intrusion is to be completely prevented. At present, average annual water supply withdrawal from the Lloyd aquifer exceeds 2.5 mgd. Additional impacts to supply wells are expected in the next 25 years if present withdrawal patterns are continued. In response to this situation, the Water Authority of Great Neck North (WAGNN) has recently taken action to deal with this problem as described in Section 3.3.5.

Manhasset Neck Peninsula. On the Manhasset Neck peninsula, several public supply wells were closed years ago due to the effects of saltwater intrusion and as many as nine more supply wells may be impacted in the future. Preliminary data from field studies indicate that intrusion is occurring in the northwestern and western shores of the peninsula, within the Village of Sands Point and the Port Washington Water District service areas. Computer modeling is currently being performed to address the intrusion problem on the Manhasset Neck peninsula and assist the water suppliers in selecting the most beneficial alternatives in dealing with these problems.

Table 3-2. Solutions to saltwater intrusion are listed in order of increasing complexity and cost.

- Reduce withdrawal from nearshore wells
- Replace deep wells with shallower wells on same site
- Replace affected wells with new wells located outside the zone of saltwater intrusion
- Intra-County transfer of water
- Treat brackish water
- Create hydraulic barriers

3.3.5 Solutions to Saltwater Intrusion

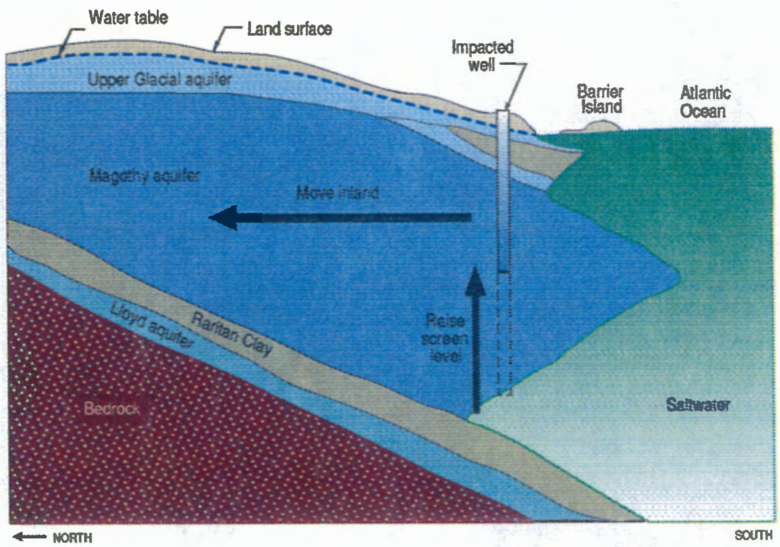


Figure 3-22. Vertical or lateral relocation of public supply wells outside of the zone of saltwater intrusion may be effective in solving saltwater intrusion problems.

Solving problems associated with saltwater intrusion can be costly to water suppliers. Because saltwater intrusion results in long-term loss of affected groundwater as a drinking water source, it is important to plan in advance of expected intrusion.

Computer modeling has shown that water conservation of up to 10 to 15 percent, in itself, does not have an appreciable effect in alleviating saltwater intrusion concerns, nor is conservation effective in slowing the rate of interface advance. However, numerous other solutions to this problem are possible.

Several approaches to dealing with the effects of saltwater intrusion are listed in Table 3-2 in order of increasing complexity and cost. The feasibility of these solutions in addressing individual intrusion problems needs to be evaluated in detail before any are recommended for actual implementation.

Reduction in Withdrawal from Nearshore Wells. An effective response is to reduce groundwater withdrawal nearshore in favor of increased withdrawal elsewhere within the water supply area, at existing well fields located farther from the saltwater interface. Although capacity limitations often make it difficult for water suppliers to significantly reduce withdrawal at a particular wellfield, this approach should be examined by all water suppliers that utilize coastal public supply wells.

Replace Deep Wells with Shallower Wells on Same Site. Another potential solution to the intrusion of salt water in the deep Magothy aquifer and in the Lloyd aquifer is to withdraw groundwater at the same location as existing deep wells, but at a shallower depth that is sufficiently distant vertically from the saltwater wedge as shown in Figure 3-22. This solution has the advantage of allowing existing water treatment and distribution systems to remain in place. Unfortunately, shallow wells have greater potential to impact nearby streamflow and lake levels. Although this solution could be considered by both north and south shore suppliers, it is believed to have greater potential on the south shore, where the shallower deposits generally have a higher yield than those to the north.

Replacing existing deep Magothy aquifer wells with wells withdrawing from shallower depths and possibly in the Upper Glacial aquifer should be studied further, with particular attention given to the permanence of the solution, as well as to the possible additional loss of streamflow and lowered surface water levels.

Relocation of Supply Wells. Wells projected to be subject to intrusion in the near future could be targeted for abandonment. Replacement wells would then be drilled in areas located outside of the final zone of saltwater intrusion as shown in Figure 3-22. This is an effective response that will ensure fresh drinking water indefinitely if the new wells are sited properly.

Intra-County Transfer of Water. Nassau County water suppliers could purchase water from adjacent suppliers within the County to replace the capacity of public supply wells impacted by saltwater intrusion. A feasibility study for this solution would have to consider the questions of availability of water, adequacy of interconnections, environmental impacts of increased withdrawal by adjacent suppliers, cost of water purchases, as well as the implications of loss of local control of the water supply by a supplier.

Treatment of Brackish Water. Another possible solution would be to leave affected public supply wells on line, and simply treat the brackish water to meet drinking water standards. New advances in reverse osmosis and membrane filtration have reduced the cost of treating brackish water. Treatment could occur at a centrally located plant, or by individual treatment units at each affected well. This is a relatively expensive solution compared to other options, and would require a careful cost/benefit analysis by the affected water supplier(s) in addition to consideration of such technical issues as brine disposal. Nevertheless, as the cost of desalination technologies continues to decline, this approach could become increasingly viable.

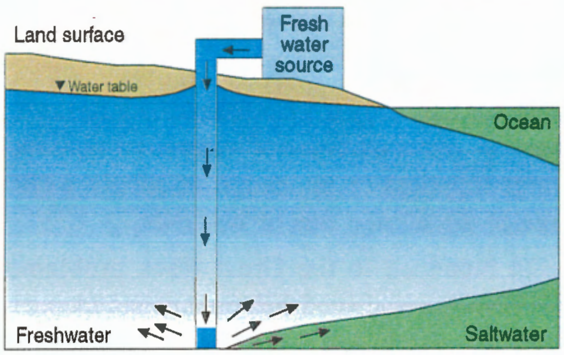


Figure 3-23. Injecting freshwater at the interface raises the pressure in the freshwater, thereby driving the saltwater seaward.

At the current time, desalination treatment on Long Island is estimated to be approximately $4.00 per 1,000 gallons. This estimate assumes brackish water as the water supply source, reverse osmosis technology at a cost of $1.5 million per mgd amortized over 20 years, and typical operation/maintenance and administration costs.

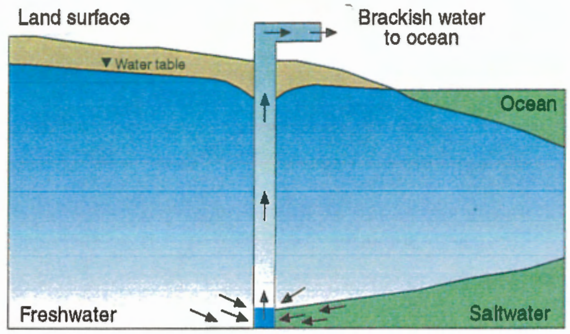


Figure 3-24. Extracting brackish water from the interface creates a hydraulic trough, stopping the landward advance of the saltwater.

Hydraulic Barriers. A regional solution to saltwater intrusion along the south shore is the use of a hydraulic barrier to stop the advance of the saltwater. Figure 3-23 shows how this could be accomplished. Approximately 15 mgd of freshwater would need to be injected into a series of injection wells along the interface to create a local rise in the freshwater level, parallel to the coast. By artificially raising the pressure in the freshwater to 15 feet above mean sea level, saltwater would be driven seaward. This solution requires a permanent, reliable source of freshwater, some of which would be lost as it flows to the sea.

This alternative is attractive because it protects existing wells and raises local water levels, positively affecting both low-flow streams and surface water bodies. However, the need for a permanent source of freshwater (which in itself could be used for water supply purposes), the prohibitive costs of constructing and operating such a system, and the localized nature of the saltwater intrusion phenomenon, makes this alternative impractical.

A second hydraulic barrier concept, shown in Figure 3-24, would use a series of extraction wells, withdrawing approximately 15 mgd, placed along the interface. Water would be pumped out to create a ridge of low pressure (literally a hydraulic trough) of about 10 feet below mean sea level along the entire length of the interface. Brackish water would be continuously pumped out and wasted to an ocean outfall, holding the advance of salt water to the line of extraction wells. The advantage to this system is that no permanent source of freshwater is required. The disadvantages are that the local water levels are

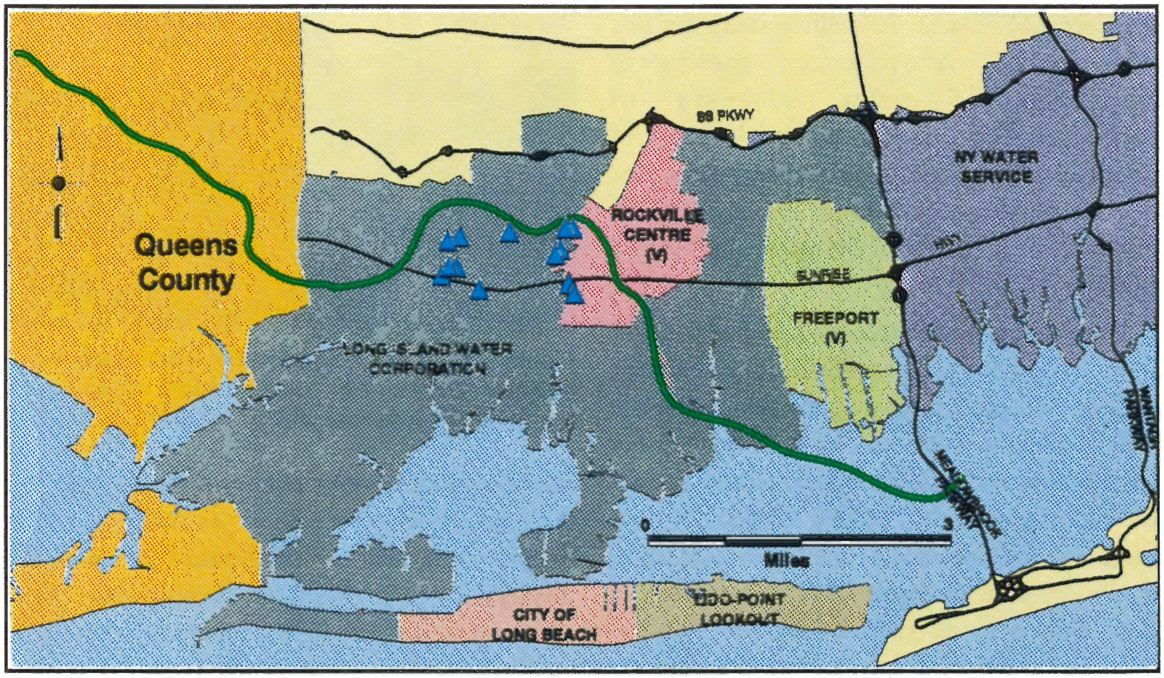


Figure 3-25. Relocation of these south shore wells expected to be impacted by saltwater intrusion in approximately 50 years will ensure high quality drinking water. The green line represents the estimated position of the interface in the Magothy aquifer at that time.

lowered even further, with potential impacts to streamflow and lake levels, and the cost to construct and operate such a system is high with no beneficial use of the water withdrawn. In light of these considerations, the hydraulic trough concept is also considered impractical.

South Shore

Thirteen south shore supply wells, shown in Figure 3-25, are projected to be impacted by saltwater in approximately 50 years. The 13 wells, all of which are in the Magothy aquifer, are located in the Long Island Water Corporation and Village of Rockville Centre service areas. A preliminary evaluation of this situation indicates that relocation of these wells, both vertically or laterally farther north, could be an effective solution. Because 50 years are expected to pass before the first effects are seen, sufficient time exists to continue evaluation of potential alternatives.

North Shore

Although saltwater intrusion is now occurring on both the Great Neck and Manhasset Neck peninsulas, studies have only been completed for Great Neck. These studies indicate that only two solutions are likely to be effective over the long term — either purchase of water from adjacent water suppliers or relocation of supply wells outside the service area of WAGNN.

In response to the Great Neck problem, WAGNN has evaluated their options and adopted a plan of action to deal with the saltwater intrusion on the peninsula. The water authority has developed a well management plan designed to reduce pumpage from certain existing wells, is seeking new well locations to replace capacity of impacted wells, and has implemented an aggressive water conservation program.

Computer modeling has indicated that new wells should be placed south of the water authority boundary to avoid drawing salt into either the Lloyd or Port Washington aquifers. Accordingly, new well locations are being sought by the WAGNN within the Manhasset-Lakeville Water District service area. Included with the new well construction will be the installation of 2.5 miles of 20 inch diameter transmission main necessary to convey water from the new well locations to the Great Neck peninsula. This transmission main will be connected to the existing distribution system of WAGNN. Further modifications to the existing system will not be necessary. The new wells and larger diameter transmission main will also benefit the water authority by increasing distribution system pressure, thereby improving fire protection capabilities in the Great Neck area.

3.4 Safe Yield

The amount of water that can be withdrawn from a groundwater system without causing unacceptable environmental impacts has traditionally been expressed as a single number, called the "permissive sustained yield" or "safe yield". Because "acceptable" environmental effects were rarely defined, it was generally assumed that the safe yield was not being exceeded as long as public water demand was satisfied and the total flow into the groundwater system was greater than the total flow leaving the system.

In reality, because the groundwater system is a dynamic system that adjusts to varying rates of groundwater withdrawal, drought, or other stresses, defining the safe yield by a single number can be misleading. Although the County's groundwater system as a whole is presently able to supply more than enough water to meet water demand, localized impacts — including reduced water table levels, reduced streamflow, and accelerated rates of saltwater intrusion along certain south and north shore areas — have been observed. These impacts have occurred as a result of withdrawing water at an average rate of 180 mgd from over 400 public supply wells distributed throughout the County, and the increase in consumptive use due to the installation of sanitary sewers.

As part of the *1998 Groundwater Study*, the County's computerized groundwater model was used to evaluate the behavior of the groundwater system in response to changes in factors such as precipitation, recharge, and the magnitude and location of water supply withdrawal. While the 341 mgd recharged annually to the groundwater system is much greater than the 180 mgd withdrawn now and projected through the planning period, the model was nevertheless used to identify parts of the groundwater system that are at, or close to, their respective "safe yield". For example, the current 12 mgd Countywide withdrawal from the Lloyd aquifer is very close to that aquifer's recharge rate of 14 mgd. Because most of the water recharging the Lloyd aquifer is withdrawn for water supply, underflow from the Lloyd aquifer to surrounding saltwater bodies has been significantly reduced, thereby accelerating the rate of saltwater intrusion in that aquifer.

Model simulations showed that, in addition to rates of withdrawal, the location of water supply wells with respect to the coastlines and important surface water features is a critical factor in determining the magnitude of impacts resulting from water supply pumping. If supply wells were located sufficiently distant from the coastlines and important stream corridors, not only would the current 180 mgd rate of water supply withdrawal be sustainable, but a higher rate of withdrawal could be sustained with less environmental impact. Alternatively, the withdrawal of 180 mgd from wells located near the coastline and streams would result in a more immediate saltwater intrusion concern and further reduction in stream baseflow. Other model simulations demonstrated that the vertical location of supply wells in the aquifers is also an important factor in determining the extent to which saltwater intrusion and reduction in stream baseflow would occur.

Since there are an unlimited number of pumping scenarios for given well locations, each having its own degree of environmental impacts, and because no criteria or standards exist either at the federal, State, or local level of government regulation to define what impacts are acceptable, a "safe yield" value is impracticable to establish for the groundwater system as a whole. Lacking such criteria or standards, the only realistic approach to managing the groundwater system is to scientifically evaluate the environmental effects of water withdrawal and determine through a review process whether the calculated environmental effects are reasonable. The technical evaluation is best accomplished through the utilization of groundwater models which can accurately predict the environmental impacts. While the groundwater system can safely support the County's water supply need, it is clear that localized impacts have and will continue to result. The goal is to minimize the effects of water supply withdrawal on stream baseflow and saltwater intrusion by enlisting the cooperation of the water suppliers in modifying pumping patterns and well locations over time where possible.

As a practical matter, since the County is already highly developed and very few new public supply wells will be installed in the future, there is little opportunity to site public water wells in idealized locations. However, as the opportunities arise, the County will advise the water purveyors and the NYSDEC regarding siting of future wells using the groundwater model. By doing so, we would effectively be increasing the "safe yield" of the groundwater system.

Section 4
Water Quality

Nassau County's aquifers can provide a sufficient *quantity* of water to meet the needs of all County residents. But if the water is not of drinking water *quality*, it must either be excluded from public use or treated to meet drinking water standards. An assessment of the quality of the groundwater is essential to a full understanding of water supply issues facing the County.

4.1 Water Quality and the Groundwater System

All groundwater is continuously in motion, moving downward from the water table, then flowing, both vertically and horizontally, through the aquifers. Because groundwater flow is responsible for the transport of dissolved contaminants, a knowledge of groundwater movement within the groundwater system is critical to understanding water quality. For this discussion, the reader is referred to Section 2.

4.1.1 Contaminants in the Groundwater

Typical parameters found in groundwater are listed in the box on the following page. These parameters may be found in groundwater supplies throughout the United States, although they are not all present in Nassau County groundwater.

Summary

Nassau County's groundwater, for the most part, is of high quality due to the protective nature of the sandy soils above the water table as well as the many programs instituted to safeguard the groundwater system. The unsaturated sand layer above the water table provides a high degree of filtering action that removes many contaminants passing through the ground before ever getting into the groundwater. Some health related contaminants, such as nitrates and volatile organic chemicals which dissolve in water, do reach the groundwater in spite of the natural filtration process and, therefore, are of great concern in the County. However, the majority of public supply wells in the County provide water that meets drinking water standards with little or no treatment for health related substances.

Sanitary sewers, which service over 90 percent of the County's population, have virtually eliminated the concern over nitrate contamination in all but a select few areas in the County. These sanitary sewer systems have also reduced the levels of volatile organic chemicals and other household and commercially generated contaminants that enter the groundwater. A broad range of federal, State, and local regulations exist today such that far fewer contaminants are entering the groundwater than was the case years ago. For these reasons the groundwater quality in the County has improved in recent years and is expected to continue to improve.

Continued enforcement of the regulatory programs by the United States Environmental Protection Agency, New York State Department of Environmental Conservation, New York State Department of Health and Nassau County Health Department are critical to ensuring groundwater protection. Continued maintenance and upgrading of sanitary sewer systems and wastewater treatment facilities by the County and other municipalities is likewise critical in groundwater protection. Superfund sites and other contaminated sites need to be addressed diligently especially as they relate to the removal of continued sources of contamination. Water suppliers, in providing cost-effective treatment at the wellhead, should be encouraged to continue such treatment in favor of abandonment of affected public wells. The federal and State superfund programs should continue to recognize and financially support the cost of treatment at these wells. By such efforts, the cost of water to the consumer should remain at its very affordable level both now and for the future.

Some are naturally occurring and are an aesthetic concern, while others result from contamination introduced by the activities of man and are health concerns. Due to the occasional presence of various parameters in the raw (or untreated) groundwater, treatment is sometimes necessary to remove some of these objectionable substances before delivery of water to the consumer.

Water that originates as recharge at the land surface varies greatly in quality. Water recharging the aquifers from natural, undeveloped areas is generally free of contaminants, although it is naturally acidic (low pH). Additionally, iron, manganese, and hydrogen sulfide that may be present in the subsurface deposits can dissolve into the groundwater in objectionable amounts.

As illustrated in Figure 4-1, residential, commercial, industrial, and agricultural land uses may be responsible for introducing contaminants to the groundwater. Water from lawns and golf courses may carry contaminants from the over application of fertilizers and pest control chemicals into the groundwater. Homes in unsewered areas discharge wastewater to on-site wastewater disposal systems, which release nitrate and other pollutants to the ground. Unlined municipal landfills may leak household chemical wastes and other contaminants into the groundwater. Water from paved areas or other developed areas is often turbid, and may be contaminated with heavy metals and petroleum products from automobiles, or may contain viruses and bacteria, either from animal waste, or from leaking sanitary sewers and on-site wastewater systems. Water from industrial areas is sometimes contaminated by solvents and heavy metals from improper waste disposal or accidental spillage.

In Nassau County, many of the contaminants commonly found in other water systems are not present. Just as a water treatment plant uses filtration to remove many contaminants, water moving through Nassau County's aquifers undergoes a natural filtration process. Turbidity, bacteria, viruses, most metals, and other organic matter often found in surface water, stormwater runoff, or shallow groundwater systems are

Typical Groundwater Quality Parameters

	Aesthetic Concerns
Acidity	A measure of the corrosion capacity of water; acidity can cause pipes and plumbing fixtures to release iron, lead and copper
Iron and manganese	Undesirable aesthetic effects including colored water and staining of plumbing fixtures
Hydrogen sulfide	"Rotten egg" odor resulting from decay of naturally occurring organic matter that imparts taste and odor problems
Turbidity	Fine, suspended particles, which cause cloudy water
	Health Concerns
Bacteria and viruses	Disease-causing organisms sometimes found in shallow groundwater systems if influenced by surface waters
Nitrate	Originates from waste products or decay of organic matter and in high concentrations, may cause "blue baby" syndrome, which can be fatal to infants
Heavy metals	Especially lead and chromium, which can be toxic at high levels
Solvents, degreasers, and petroleum products	Sources of volatile organic chemicals (VOCs), many of which are known or suspected human carcinogens
Pesticides and Herbicides	Potentially serious human health effects; many are known or suspected to be human carcinogens.

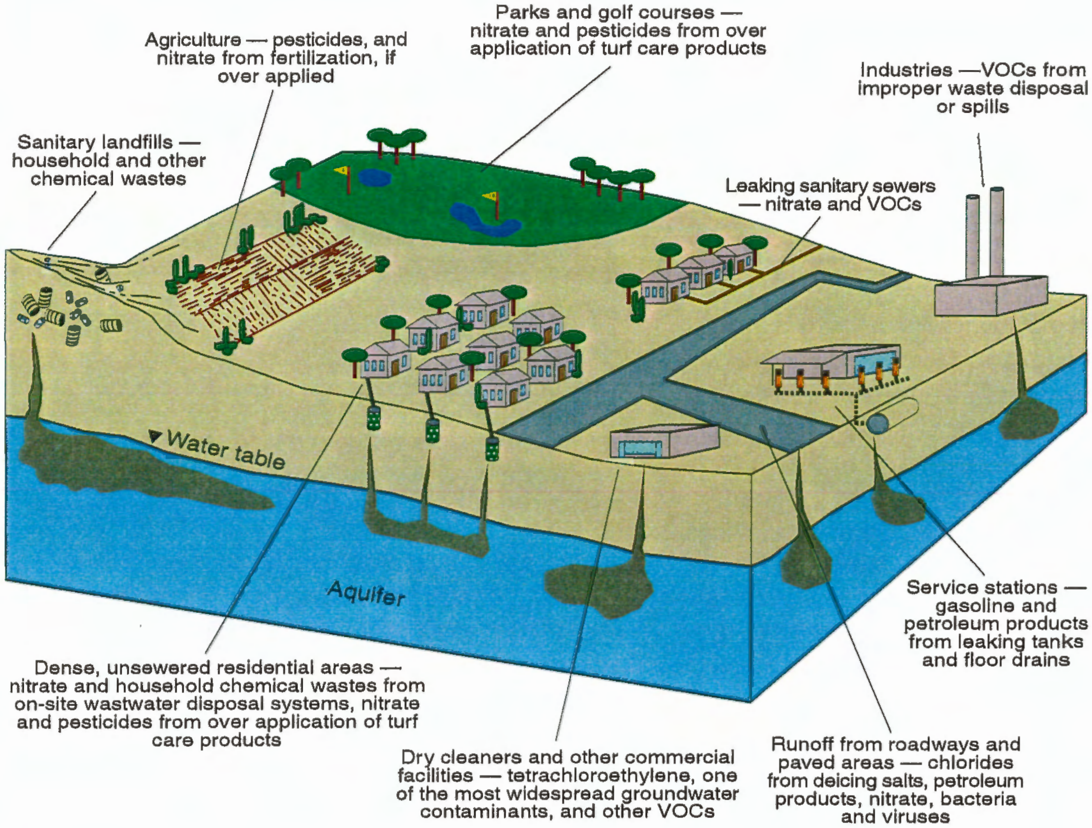


Figure 4-1. Contaminants can enter the groundwater supply from many different sources.

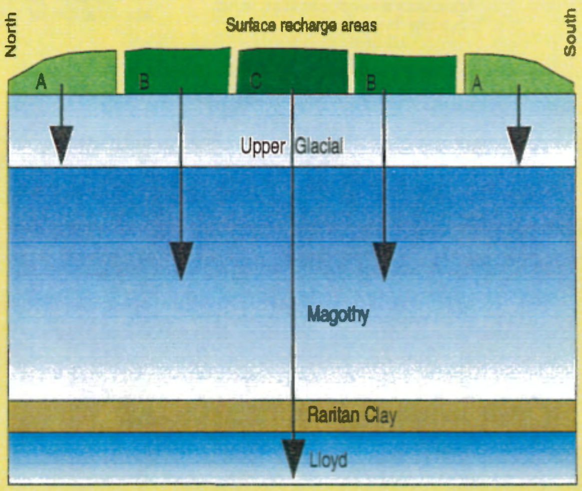
quickly filtered out. Only the contaminants that dissolve in the water are of concern in Nassau County. These include nitrate, solvents, degreasers, gasoline and petroleum products, certain pesticides and certain heavy metals. Acidity, iron, and manganese also occur naturally in the County's groundwater, and often at concentrations that require treatment.

Some dissolved contaminants interact with the aquifer material. Others do not. Nitrate, for example, does not interact, although it may be diluted as it mixes with cleaner groundwater. Other contaminants, such as solvents and degreasers, also are subject to dilution but, more significantly, they also interact with aquifer material in ways that change their behavior. They tend to sorb, or stick, to soil particles. The net effect of this interaction with the soil is to retard the movement of these contaminants relative to groundwater flow, until eventually these contaminants are released from the soil. This effect is referred to as "retardation." Such contaminants may remain in the aquifers for many years, until they are released and discharged from the groundwater system, enter public supply wells, or eventually break down.

Gasoline and petroleum products such as benzene, xylene, and toluene also dissolve in the groundwater and are subject to retardation. They are also subject to another process, called "biodegradation." Naturally occurring microbes in the soil and groundwater feed on the petroleum products, converting them to harmless carbon dioxide and water. The effect of this process is to reduce contamination to such a degree that these compounds are rarely encountered far from the source of the contamination. For this reason, these contaminants are not often encountered in deep public supply wells.

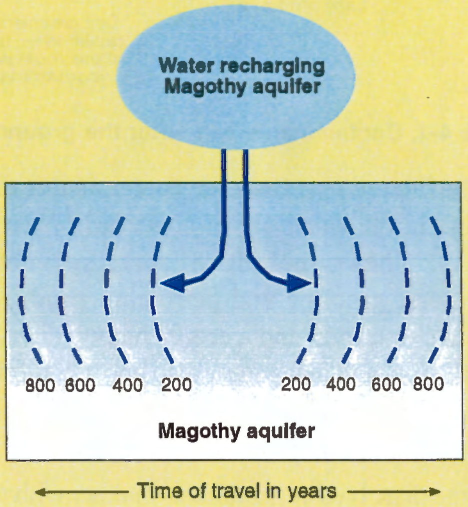
While most pesticides are designed to strongly bind to soil particles near the surface, and to biodegrade in the shallow soils over time, some do not bind to soil. Such pesticides may move as dissolved contaminants through the groundwater system, occasionally reaching shallow supply wells. Although they may be subject to

Aquifer Recharge Areas



Precipitation falling on the land surface recharges Nassau County's aquifers. But all areas of the County do not recharge all aquifers. As the highly simplified figure at right illustrates, precipitation falling on area A recharges only the Upper Glacial aquifer. Precipitation falling on area B moves through the Upper Glacial to recharge the Magothy aquifer. And precipitation falling on area C moves first through the Upper Glacial, then through the Magothy, and finally into the Lloyd aquifer. As water recharges from the land surface, it can easily carry contaminants from the surface deep into the aquifers. Clearly, activities of man, land use, groundwater withdrawal patterns, and waste disposal practices in recharge areas have significant impact on what contaminants enter the groundwater and on which aquifers the contaminants ultimately reach. Knowledge of aquifer recharge areas is important in developing programs to protect the groundwater supply from contamination.

Time of Travel



Once water enters an aquifer, it may remain only a brief time or it may remain for hundreds or even thousands of years. When water recharges the Magothy aquifer, for example, if it is not withdrawn by a water supply well, it remains in the aquifer, moving horizontally until it reaches a point of discharge. As the figure at right shows, this movement can be very slow. In some cases, several hundred years may elapse before the water discharges from the aquifer. Travel time is accelerated once a well is pumped, greatly affecting patterns of contamination and the nature of contaminants found in the aquifers.

biodegradation and retardation, the processes are very complex. Analyses performed on public supply wells and monitoring wells in the County for many pesticides indicate that in the rare instances when pesticides have been detected in the raw groundwater, they occur at levels below drinking water standards, or at low concentrations that are easily treatable.

4.1.2 Aquifer Recharge Areas and Time of Travel

The areas of the County contributing recharge to each aquifer and the time it takes for water to travel through the aquifer system are important in studying contamination patterns (see box). The greater the travel time, the greater the cleansing effects of dilution, retardation, and biodegradation. However, the greater the travel time, the longer it takes for contaminants that do not interact with aquifer materials to flush out of the system.

Time of travel through the system under natural, or undeveloped, conditions has been documented by the U.S. Geological Survey (USGS). Nassau County's groundwater model was used to confirm these results and to evaluate the time it takes for water to travel through the groundwater system on a County-wide basis, both prior to existing development, and under today's conditions of heavy water supply withdrawal (180 mgd).

Figure 4-2 is a cross-section of eastern Nassau County showing the approximate travel time of groundwater under present day conditions. (Figure 2-5 in Section 2 depicts travel time under predevelopment conditions.) The figure shows that groundwater in the Upper Glacial aquifer remains in that aquifer for less than 20 years, either moving downward into the Magothy aquifer, or discharging to surface water bodies near the shoreline. Prior to development, travel time to the bottom of the Magothy aquifer was 100 to 300 years at the center of the County, and travel time to the bottom of the Magothy, beneath the south shore barrier islands, was about 800 years. Today, because withdrawal from water supply wells in the Magothy tend to pull water down from shallower parts of the groundwater system, travel time has been reduced to about 100 years on average, at both the center of the County and at the south shore. Travel time to the Lloyd aquifer remains greater than 1,000 years in spite of the withdrawal from public supply wells, primarily because of the thickness and relative impermeability of the Raritan Clay. The aforementioned times of travel are averages for the eastern part of the County. Travel times to water supply wells screened at the bottom of the Magothy aquifer in the western part of the County are shorter because the aquifer thicknesses are considerably less and groundwater withdrawal rates are generally higher.

The areas contributing recharge to each aquifer have also changed. Figure 4-3 shows aquifer recharge areas as they were before development. Precipitation falling on the areas in dark blue recharged the Lloyd aquifer. Areas where water recharged the deeper portion of the Magothy aquifer are shown in light blue, and areas where the water recharged and remained in the shallow Upper Glacial aquifer are shown in green.

In contrast, Figure 4-4 shows the present day recharge areas. Withdrawal of water from over 400 public supply wells at a total average rate of 180 mgd has greatly altered these areas. Today, the reduction in area recharging the Upper Glacial aquifer (in green) is reflected in the declining streamflow observed in the County. The surface area recharging the Magothy (in light blue) has increased considerably, as public supply wells

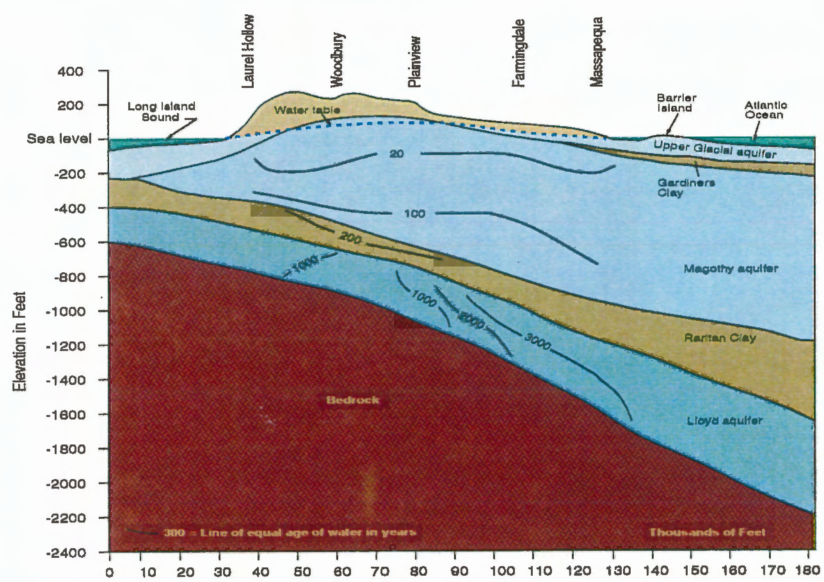


Figure 4-2. Under present day conditions, groundwater travel times through the aquifers in the eastern part of the County vary greatly — ranging from 20 years or less in the Upper Glacial aquifer, to over 100 years in the Magothy aquifer, and up to 3,000 years or beyond in the Lloyd aquifer.

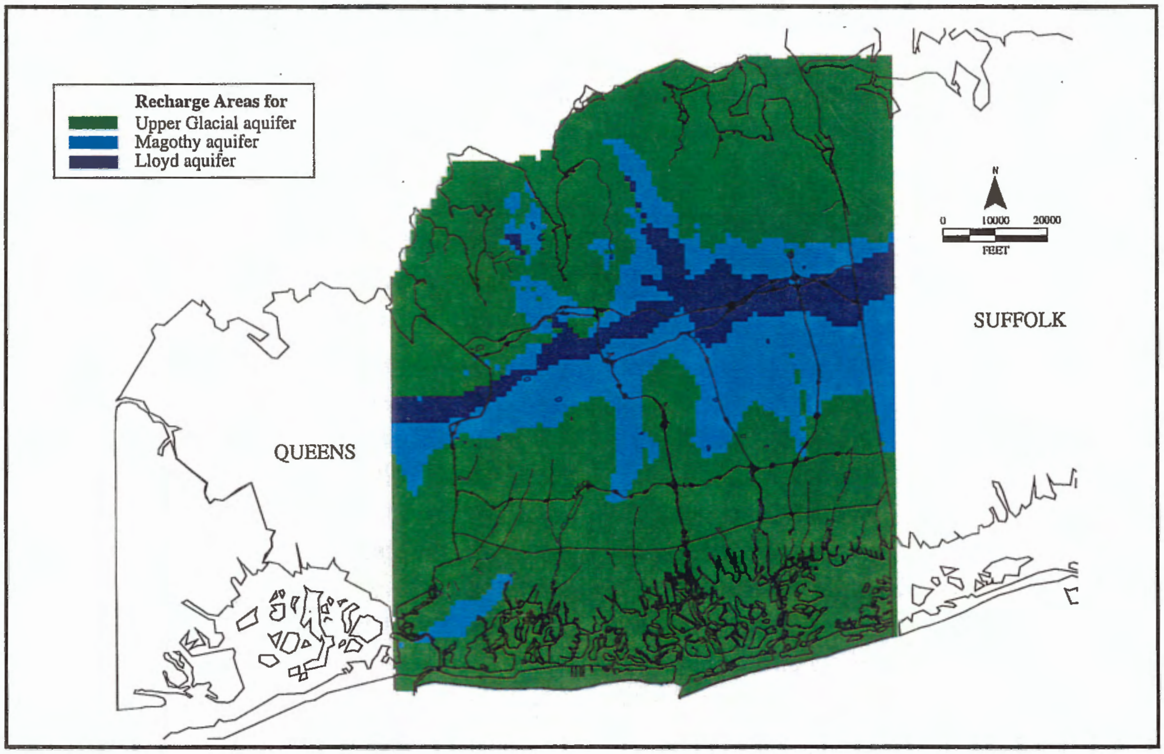


Figure 4-3. Before development, recharge areas for the Magothy aquifer and the Lloyd aquifer were concentrated in the center of the County, with the majority of land surface recharging only the Upper Glacial aquifer.

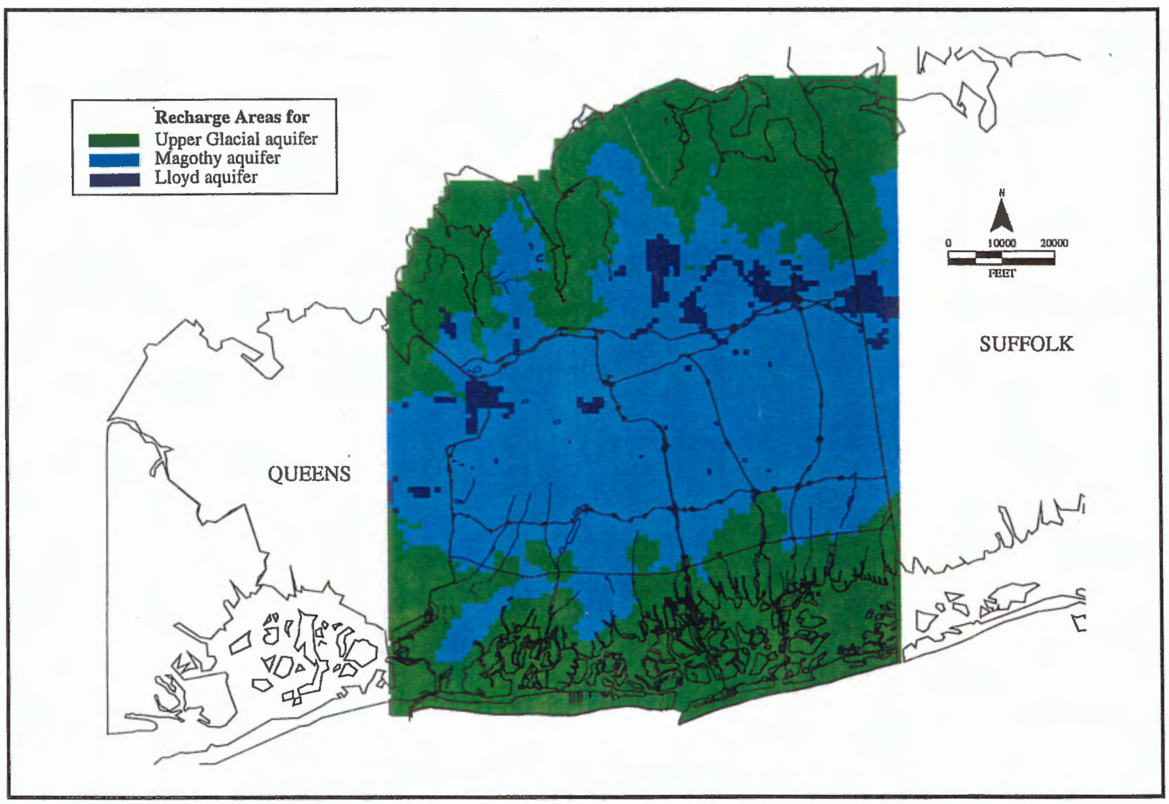


Figure 4-4. Under present day conditions, recharge areas have changed. The majority of the land surface now recharges the Magothy aquifer and only smaller areas near the center of the County recharge the Lloyd aquifer.

screened deep within the aquifer pull water down from the overlying Upper Glacial aquifer. The recharge area for the Lloyd aquifer, which previously stretched from west to east throughout the County, roughly coinciding with the path of the Long Island Expressway, has been reduced to smaller patches (in dark blue) as water supply withdrawal in the Magothy aquifer disrupts the natural flow field by capturing water before it reaches the Lloyd aquifer.

These changes are very significant regarding water quality. Under today's conditions, most of the surface area of the County can now be considered a "deep recharge zone" supplying water to the Magothy aquifer, which provides over 90 percent of Nassau County's drinking water. Wellhead protection programs used in other areas of the country to protect supply wells are of limited use in Nassau County because of the depth and great number of supply wells spread throughout the County and the extent to which Nassau County is developed. Today, recharge to the Magothy aquifer occurs over a much larger area and groundwater protection programs must therefore address the entire County to be effective.

The groundwater model was used to estimate the time it takes for water recharging at the surface to reach the major water supply wells in Nassau County. The results are shown in Figure 4-5. In many areas of the County, water from the surface takes less than 50 years, and in some cases less than 10 years, to reach public supply wells.

In Figure 4-5, it is evident that groundwater flow in western and eastern Nassau County is markedly different. Water and associated contaminants in western Nassau have a much shorter travel time through the aquifer than in the central and eastern part of the County. This helps explain the presence of solvents and nitrate in the deep Magothy aquifer in the western part of the County where travel times are shortest.

4.2 Water Quality Parameters and Trends

Compared to other areas of similar population and density, Nassau County's groundwater supply is of high quality. Water from the majority of the County's public supply wells can be used with little or no treatment for health related substances.

Many of the contaminants found in other water supplies are not present in Nassau County groundwater, and therefore only the following

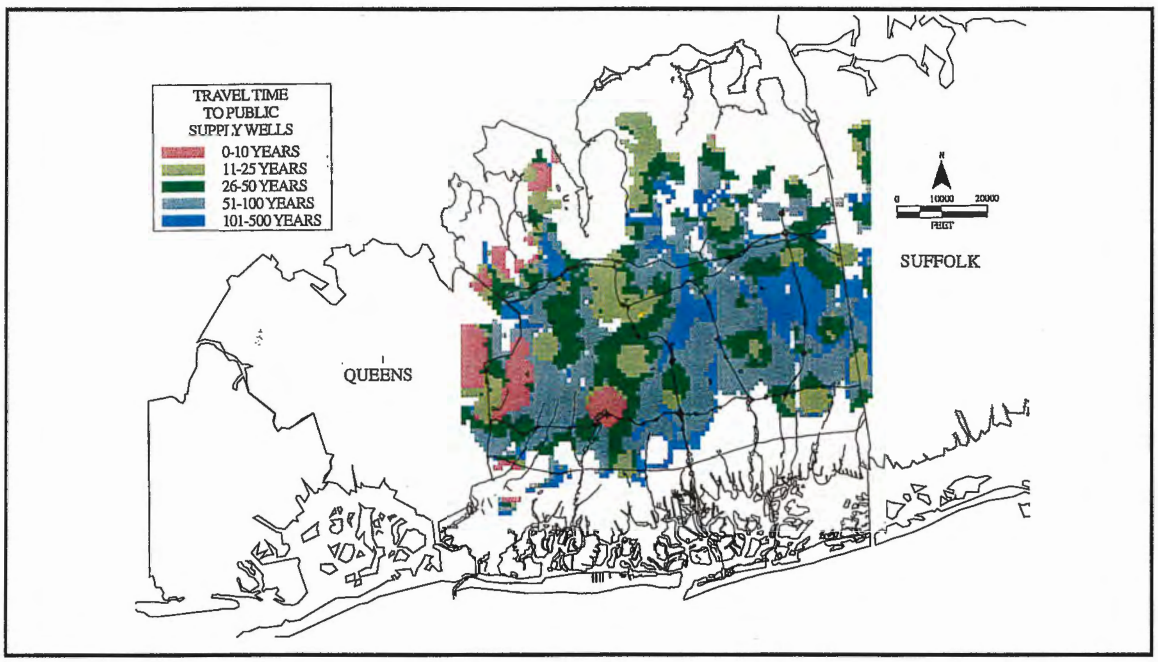


Figure 4-5. In western Nassau County, groundwater in many areas reaches public supply wells in less than 10 years after recharge. Travel times in the western part of the County are generally shorter than in central and eastern Nassau.

parameters are of primary concern in the delivery of potable water to County residents:

- Acidity
- Iron and Manganese
- Hydrogen Sulfide
- Nitrate
- Volatile Organic Chemicals (VOCs)
- Pesticides and Herbicides

While acidity, iron and manganese, hydrogen sulfide and small amounts of nitrate are naturally occurring, the other parameters — most nitrate, all VOCs, and all pesticides found in the County's groundwater — come from man-made sources.

As Nassau County changed from a relatively rural setting to highly suburbanized in nature, the presence of nitrate, primarily from on-site wastewater disposal systems and agriculture, became the priority groundwater quality problem during the 1950s and 1960s. During that time, the presence of phosphate containing detergents, or MBAS (methylene blue active substance), in the groundwater was also a major concern.

Compared to other areas in the United States, Nassau County's groundwater is of high quality. Water from the majority of the County's public water supply wells can be used with little or no treatment.

Sanitary sewer systems and wastewater treatment facilities have dramatically reduced the discharge of man-made nitrate into the groundwater system. These systems, combined with the banning of phosphate containing detergents in the 1970s, have also helped eliminate MBAS from being a present day problem. More recently, data analyzed from monitoring wells has shown that contamination by VOCs — including solvents, degreasers, gasoline and petroleum products — is the most significant groundwater quality issue facing Nassau County today.

4.2.1 Naturally Occurring Parameters

Some water supply wells require treatment for naturally occurring groundwater characteristics — acidity, iron and manganese, and hydrogen sulfide — that can have undesirable aesthetic effects on water quality.

Acidity

Natural groundwater is relatively acidic, typically having a pH of 4.7 to 6.5 (7.0 is neutral). The corrosive properties of water generally increase with decreasing pH. While the relatively low acidity of most groundwater is not known to have any direct health effects, acidic conditions can lead to corrosion in water distribution systems. Corrosion can leach metals such as copper, iron, and lead from water systems, leading to aesthetic problems, such as unattractively colored water or staining of laundry and plumbing fixtures. It can also result in exceedances of health-related criteria for copper and lead, both of which can be toxic at elevated levels. Fortunately, pH can be easily controlled at low cost by introducing lime or caustic soda into the water at the public wells. These chemicals neutralize the natural acidity of the water, and help to minimize the leaching of metals from pipes and plumbing fixtures. Although there is no standard for pH, the Nassau County Department of Health (NCDH) guideline calls for a pH in the range of 7.5 to 8.5. As a result, pH adjustment is typically required in water supplies throughout the County.

Iron and Manganese

When air mixes with groundwater, iron and manganese oxidizes to form a reddish-brown to black sediment. Even though Long Island aquifers have relatively low levels of dissolved minerals compared to other areas of the United States, iron and manganese are present in objectionable concentrations in several areas and especially along the south shore. For aesthetic reasons, the State drinking water standards specify a maximum contaminant level (MCL) of 0.3 parts per million (ppm) for either iron or manganese and an MCL of 0.5 ppm for a combined concentration of iron and manganese. Naturally occurring iron and manganese in Nassau County groundwater can exceed these concentrations, and some water supply systems provide treatment to remove them from the water, or add a chemical to inhibit formation of iron and manganese sediments.

South shore water systems (primarily south of the Southern State Parkway) that use the lower Magothy aquifer have the greatest problem with iron, and much of the water from these wells requires treatment. The elevated concentrations of dissolved iron in the groundwater is the result of low pH, low levels of dissolved oxygen, and the tendency of this portion of the lower Magothy aquifer to be rich in iron-bearing minerals such as pyrite and hematite. In other areas, where iron concentrations are not quite as high, water suppliers can treat the water with chemicals that sequester the iron (keeps the iron dissolved in solution to prevent the formation of objectionable color and turbidity).

Hydrogen Sulfide

The decomposition of naturally occurring organic matter under anaerobic conditions can cause hydrogen sulfide to be present in the water which produces the classic "rotten egg" odor. There are no adverse health effects from consuming water containing hydrogen sulfide, however, even concentrations less than 1 ppm can impart strong odors. Although there is no drinking water standard for this gas, it is recommended that no odor should be detected by the consumer. Along the south shore, where groundwater containing hydrogen sulfide exists in Nassau County, it is easily controlled at low cost by chlorination or aeration of the water.

4.2.2 Nitrate

The natural sources of nitrate — precipitation and decaying biological matter — contribute only small amounts to the groundwater. Man-made sources are far more significant in elevating nitrate levels. Such sources include: homes in unsewered areas that discharge wastewater to on-site wastewater disposal systems, the over application of turf care products to lawns and golf courses, and the over application of fertilizers in agricultural areas.

In undeveloped areas, nitrate concentrations in groundwater are usually very low, generally less than 1 ppm. In densely populated unsewered areas served by on-site wastewater disposal systems, nitrate can exceed 10 ppm, the drinking water standard. Nitrate levels above 10 ppm are a health concern. Concentrations of nitrate in excess of the drinking water standard can cause a type of methemoglobinemia in infants ("blue baby syndrome"), in which nitrate interferes with the transfer of oxygen into the blood. The condition can be fatal to infants, although no cases of methemoglobinemia have been confirmed in Nassau County. In surface water supplies, nitrate also encourages growth of algae and other organisms that produce undesirable tastes and odors. In densely populated areas served by sanitary sewers, nitrate is generally not a problem because high nitrate loadings to the groundwater are prevented by the sanitary sewers.

Nitrates exceeding the drinking water standards can be addressed in a variety of ways. The raw groundwater can be blended with cleaner water to dilute nitrate concentrations, the supply well may be deepened to reach cleaner groundwater, ion exchange treatment can be employed, or the well can simply not be used.

Nitrate Contamination

An extensive analysis of nitrate data was performed to assess existing water quality. Analysis of samples from 269 Upper Glacial monitoring wells in 1993 and 1994, shown in Figure 4-6, clearly indicates that groundwater has been impacted by nitrate; however, only 12 wells exceeded the nitrate standard of 10 ppm. Monitoring wells were used to assess groundwater quality in the Upper Glacial aquifer because there are too few public supply wells in this aquifer to form a representative data base.

Portions of the shallow groundwater system in unsewered, densely populated areas of the north shore exceed the 10 ppm nitrate drinking water standard. However, because of the shallow groundwater discharge near the shoreline and the great depth of the water supply wells, nitrate has

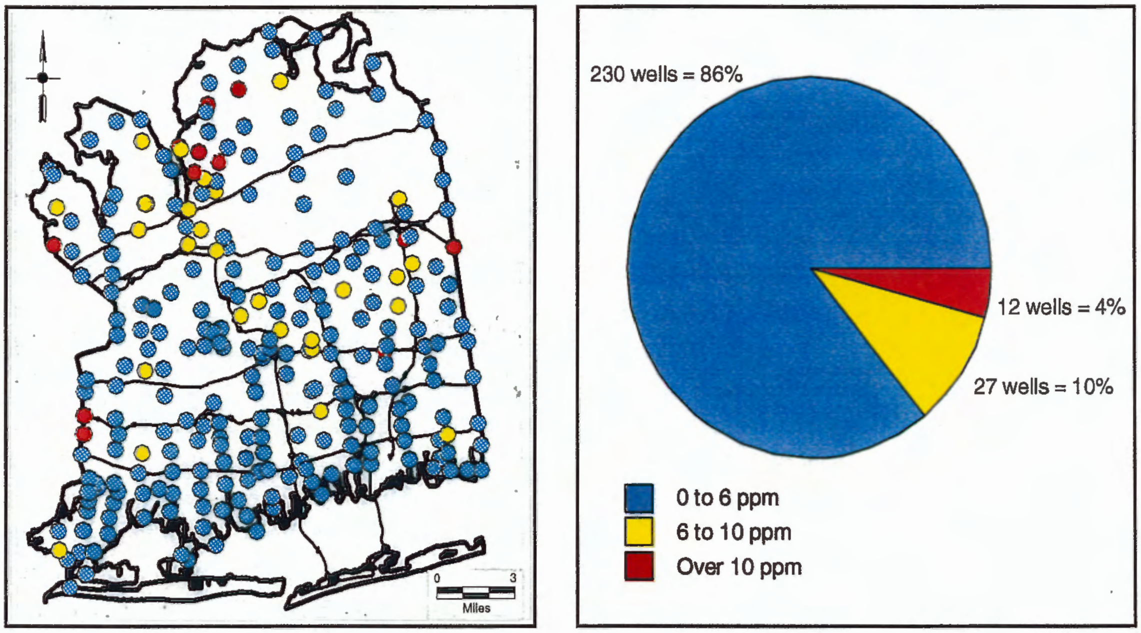


Figure 4-6. Sampling for nitrate in 269 Upper Glacial monitoring wells shows only 4% of the wells exceeded the drinking water standard of 10 ppm in 1993-1994.

not significantly impacted water supplies in those areas. Other more localized nitrate contamination in the more recently sewered part of eastern Nassau appears to be caused by nitrate released before the sanitary sewers were constructed.

Figure 4-7 shows nitrate concentrations in 372 Magothy aquifer monitoring and public supply wells in 1994. This data base is comprised of both monitoring wells and raw groundwater quality from public supply wells in order to establish the most representative data base. Only 10 wells exceed the standard; however, there is a clear pattern of increased nitrate concentration in the lower Magothy in the center of the County, at the groundwater divide, where the natural flow of

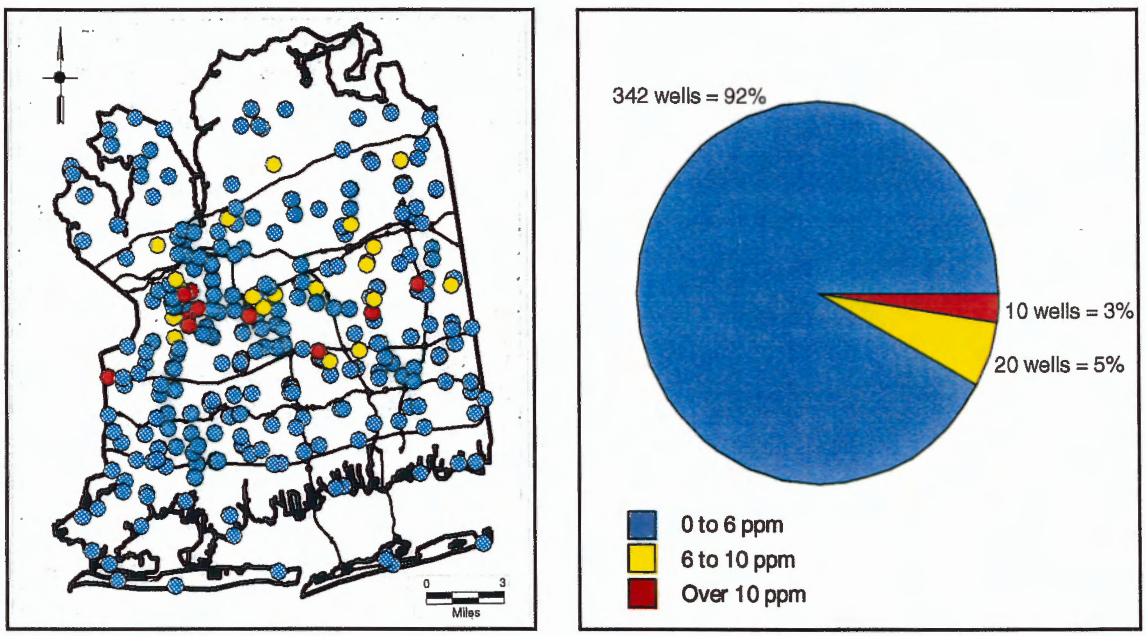


Figure 4-7. Sampling for nitrate in raw groundwater from 372 Magothy aquifer monitoring and water supply wells shows that only 3% exceeded the drinking water standard of 10 ppm in 1994.

groundwater is downward. Most of this nitrate came from past sources that have been eliminated by sanitary sewer systems and the cessation of agriculture.

Raw groundwater from areas in Garden City Park, Mineola, Hicksville and several other localized areas at the center of Nassau County exceeds drinking water standards for nitrate. While this is naturally a deep recharge area, high levels of groundwater withdrawal have accelerated vertical movement of nitrate from historical sources into deeper portions of the Magothy aquifer in these areas, impacting a number of public supply wells. It is important to understand that water exceeding the drinking water standard is not delivered to the consumer. Water from a public supply well that exceeds the drinking water standard for nitrate can either be treated, blended with cleaner water in order to meet the standard, or not used.

Trends in Nitrate Sources

The reduction of nitrate loading to the groundwater from on-site wastewater disposal systems and agricultural land use is expected to result in a continuing reduction in the number of supply wells restricted by nitrate contamination. Sanitary sewers have reduced the most significant source of nitrate, on-site wastewater disposal systems. The second most significant source, agricultural land use, has greatly decreased as a result of the decline in agriculture in Nassau County. Although the remaining sources are relatively minor, they appear to only contribute about 3 ppm of nitrate to the Upper Glacial aquifer as shown by the leveling off of nitrate concentrations in Figure 4-8 which portrays average concentrations from a representative set of wells. Remaining sources include unsewered residential areas, leaking sanitary sewers, over application of fertilizers on golf courses and over applications to lawns in high density residential areas.

Unsewered Residential Areas. Unsewered residential areas with home densities greater than 2 to 4 dwelling units per acre that rely on on-site wastewater disposal systems have a significant effect on local groundwater quality. Groundwater in portions of unsewered communities on the north shore currently exceeds drinking water standards for nitrate in the Upper Glacial aquifer and upper portions of the Magothy aquifer. The groundwater from these portions of the aquifers discharges to the bays and does not reach the deeper aquifers used for public water supply purposes. However, since substandard water could potentially be pulled down deep enough to pose a threat to public supply wells, further study in this area is needed.

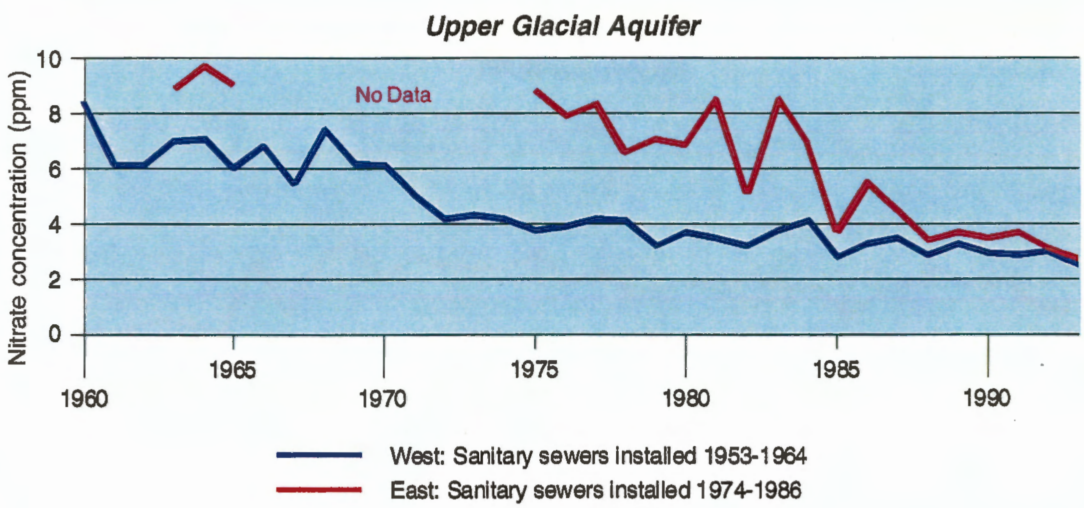


Figure 4-8. Average nitrate concentrations in the Upper Glacial aquifer declined first in the western part of the County, where sanitary sewers were first installed. Nitrate in the east began to decline after sanitary sewer installation began in 1974.

A stable population trend along with little available land for further development suggest that this situation will not affect water supply in the future.

Sewered, High-Density Residential Areas. Installation of sanitary sewers in residential areas has significantly reduced the amount of nitrate entering the groundwater. However, turf fertilization and minor sanitary sewer leakage contributes to nitrate loading on the groundwater system. Over-fertilization of turf areas most probably accounts for the majority of this loading. Once again, this is a stable situation, and current nitrate concentrations in the shallow groundwater are expected to continue to decline.

Parks and Golf Courses. Some monitoring wells in the Upper Glacial aquifer near and downgradient of parks and golf courses have shown exceedances of the nitrate standard. However, the amount of nitrate leaching from golf courses and parks has not been found to have major impacts on the deeper aquifers that supply the County's drinking water. As fertilization practices continue to improve and be more efficient, the amount of nitrate leaching from these areas should diminish.

Trends in Nitrate Contamination

Nitrate concentrations in groundwater have declined as agriculture diminished and sanitary sewers were constructed in Nassau County. Overall concentrations in the Upper Glacial aquifer declined, as shown in Figure 4-8, as the major source of nitrate, on-site wastewater disposal systems, was virtually eliminated. As the Upper Glacial water continued to travel down through the groundwater system, dilution occurred to a large degree. As illustrated in Figure 4-9, average nitrate concentrations from a representative set of wells in the Magothy aquifer have been, and are presently, below the drinking water standard. Nitrate concentrations in the western part of the County, which was sewered from 1953 through 1964, are lower than those in the eastern part of the County, where sanitary sewers were constructed from 1974 through 1986.

Historically, nitrate contamination has significantly affected water supply wells in certain areas. Since 1962, a total of 25 wells have been deepened or abandoned (7 deepened, 18 abandoned) and 24 wells have been restricted because of nitrate contamination, as shown in Figure 4-10. In 1994, of the 24 restricted wells, 21 wells were not used, one well was treated using ion exchange and water from two wells was blended with cleaner water in order to meet standards.

It has taken years for the full impact of nitrate to be seen in the Magothy aquifer. As a result of the decreased nitrate loading on the groundwater

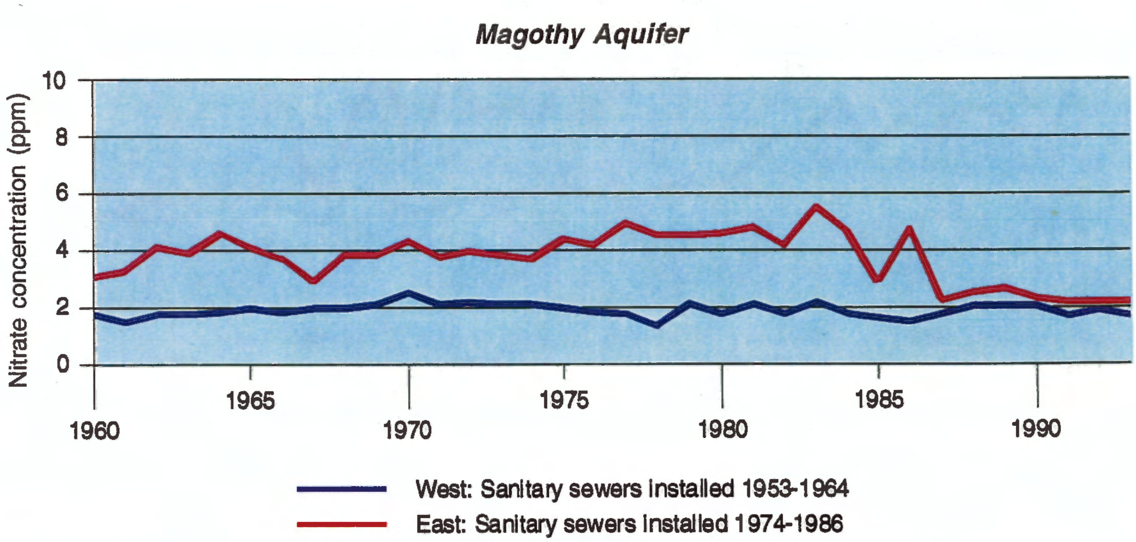


Figure 4-9. Average nitrate concentrations in the Magothy aquifer were and continue to be well below the drinking water standard of 10 ppm.

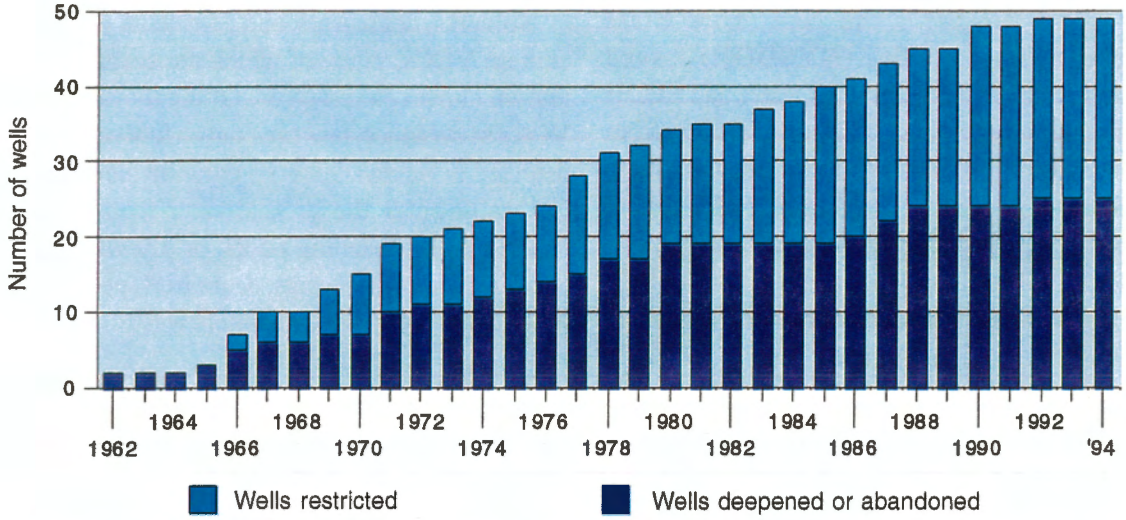


Figure 4-10. A total of 49 public supply wells have been impacted by nitrate contamination since 1962. Water from restricted wells can be treated to meet standards, blended with cleaner water to dilute the nitrate to meet standards, or simply not used.

system, it is expected that nitrate concentrations in some of the affected wells will decrease to levels below the drinking water standard. It is entirely possible, therefore, that some of the public supply wells not used in the past may be used again in the future.

Nitrate concentrations in portions of the Magothy aquifer have yet to completely respond to the effects of sanitary sewers, and therefore nitrate can be expected to continue to impact a small number of Magothy supply wells into the near future. Fortunately, the rate at which supply wells have been impacted has essentially stabilized. Eventually, nitrate will not be of any concern in most of the County, especially where sanitary sewers service the area.

Nitrate contamination, primarily from on-site wastewater disposal systems and agriculture, was the County's major groundwater quality problem during the 1950s and 1960s. Today, sanitary sewers have dramatically reduced the amount of nitrate entering the groundwater. Nitrate is no longer a high priority water quality concern.

4.2.3 Volatile Organic Chemicals (VOCs)

In the years following World War II, synthetic volatile organic chemicals were widely manufactured and their use as solvents and degreasers became widespread. VOCs were commonly used by industry, commercial establishments and even homeowners through the mid-1970s with no restrictions on their use or disposal.

Beginning in the mid-1970s, many groundwater supplies across the United States that were once pristine were found to contain measurable amounts of VOCs. The VOCs are significant because they pose a possible health risk since a number of these compounds are known or probable carcinogens. The compounds are named VOCs because of their distinctive high volatility (tendency to be released to the air as a vapor at relatively low temperatures) relative to other synthetic organic substances such as pesticides.

Nassau County was one of the first areas in the country to study the presence of VOCs in groundwater. As early as 1974, while responding to taste and odor complaints, NCDH found a number of VOCs in an industrial water supply well of the Grumman Aerospace facility in Bethpage. In 1977, the New York State Department of Health (NYSDOH) issued guidelines for VOCs in drinking water, and NCDH began routine sampling of raw groundwater from public water supply and monitoring wells for these compounds. More stringent federal drinking water standards, termed Maximum Contaminant Levels (MCLs), were later promulgated by the U.S. Environmental Protection Agency (EPA) in 1989, in recognition of the health implications of VOCs and their widespread occurrence in drinking water supplies throughout the country.

The New York State Sanitary Code has established MCLs of 5 parts per billion (ppb) for all principal organic contaminants, which are the majority of individual VOCs that are routinely tested for in public supply wells. A few compounds have less stringent MCLs, while vinyl chloride, for example, has a more restrictive MCL of 2 ppb. The MCL for unspecified organic contaminants (any compound not specifically referenced in the State sanitary code) is 50 ppb, and the MCL for total principal and unspecified organic contaminants is 100 ppb. In addition to the MCLs, federal, State and local regulations governing VOC usage and disposal were established. Much of the VOC contamination now observed in groundwater supplies is the result of past disposal practices that occurred prior to the establishment of regulations governing VOC usage and disposal.

Contamination by VOCs is the most significant groundwater quality issue facing Nassau County today and is being dealt with successfully at relatively low cost.

Raw groundwater from public supply wells that does not meet drinking water standards for VOCs is always treated to remove these compounds before the water is delivered to the consumer. VOCs may be removed from water supplies by aeration treatment or granular activated carbon (GAC) filtration at a cost of less than ten cents per 1,000 gallons. Abandoning or not using a public supply well is also an option in dealing with VOC contamination.

VOC Contamination

Solvents, degreasers, and petroleum products contain VOCs, many of which are suspected or known human carcinogens. Of the thousands of VOCs in existence, however, only a few have been detected in Nassau County's groundwater. VOCs generally enter the groundwater from spills, leaking tanks, leaching pools, or dry wells that contain industrial solvents, degreasers, petroleum products, or household chemical waste.

In 1994, groundwater from 84 percent of the County's public water supply wells met drinking water standards for VOCs without treatment. Water from the other 16 percent of the public supply wells received treatment for VOC removal. While this is a sign of aquifer degradation, the most commonly detected VOCs in raw groundwater from public supply wells during 1994 included only five compounds. These compounds, and the percentage of public supply wells in which they were detected, are listed in Table 4-1. Several other VOCs were detected in the raw groundwater from some supply wells at much lower frequencies. All of these compounds are associated with solvent and degreaser products and, if present at low concentrations, can be reliably treated at relatively low cost.

The VOCs commonly observed in water supply wells are the most frequently observed in

Table 4-1. Most commonly detected VOCs in raw groundwater from public supply wells during 1994 (NCDH).

VOCs detected	*% of wells in which detected*
Tetrachloroethylene	16
Trichloroethylene	15
1,1,1-Trichloroethane	11
1,1-Dichloroethane	8
1,1-Dichloroethylene	7

the shallower monitoring wells. Benzene, and other VOCs found in petroleum products including gasoline, have been observed in a few shallow monitoring wells but rarely in deeper water supply wells because these compounds float, do not readily dissolve and are quickly biodegraded in the aquifer.

The County routinely samples monitoring wells screened in all aquifers to determine groundwater quality and provide early warning of possible contamination of the public supply wells. These monitoring wells are also used to identify contaminant plumes and to determine trends in the quality of water recharging the deeper aquifers. By evaluating this data, it is possible to anticipate future water quality problems and evaluate the effectiveness of groundwater protection measures.

Although 16% of the public water supply wells have treatment to remove VOCs, treatment has only resulted in a very small increase in the cost of water in certain areas.

Studies by the County and USGS have concluded that "hot spots" of VOC contamination are frequently associated with commercial and industrial land uses. These studies show that industry has not been the only source of VOC contamination. Hot spots are also occasionally associated with residential areas, particularly those with 5 to 10 dwelling units per acre. An important source of low levels of VOC contamination is the multitude of household and commercial uses of products containing these compounds. USGS has also concluded that sanitary sewer systems have not entirely eliminated all sources of VOC contamination.

Figure 4-11 shows results of testing for total volatile organic chemical (TVOC) concentrations in raw groundwater from 265 Upper Glacial water supply and monitoring wells in 1993 and 1994 (TVOC concentrations are the summation of all individual VOC concentrations in a given well). Typically, TVOC concentrations greater than 100 ppb require more costly and more extensive treatment processes to meet drinking water standards. Such systems would involve larger aeration towers and/or GAC filter units than would normally be required with lower

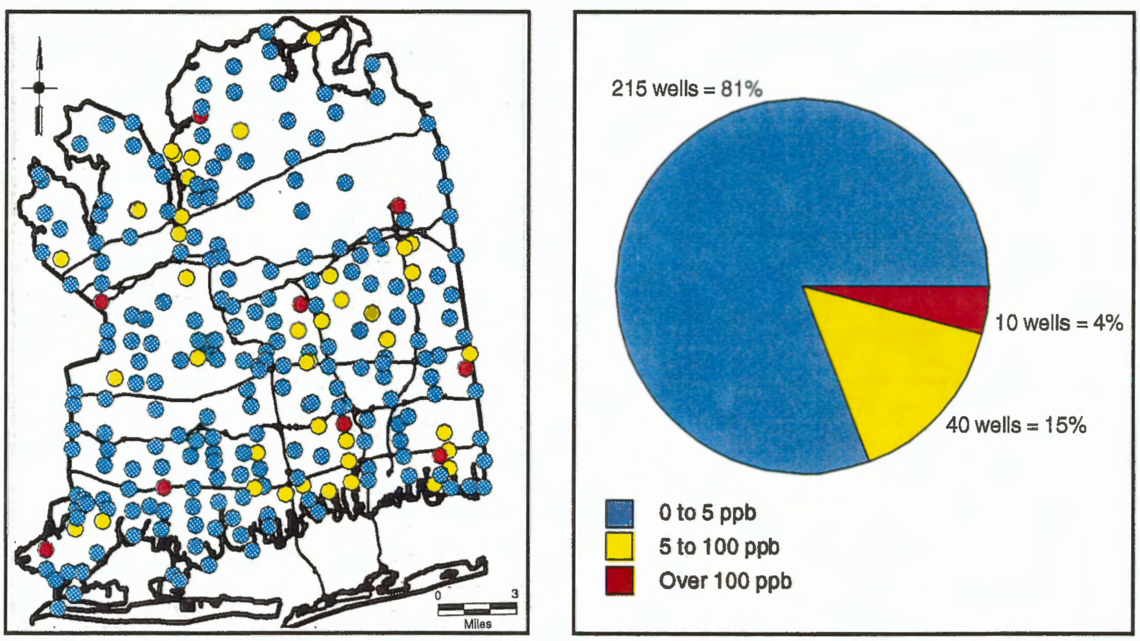


Figure 4-11. Sampling for TVOCs in raw groundwater from 265 Upper Glacial aquifer water supply and monitoring wells in 1993-1994 shows 96 percent of the wells can meet drinking water standards with either no treatment or inexpensive, readily available treatment technology.

concentrations of VOCs. The operation costs for these larger treatment systems are also higher.

Assuming that the 265 wells represent raw groundwater quality in the Upper Glacial aquifer, approximately 81 percent of the Upper Glacial aquifer meets drinking water standards for VOCs without treatment, and approximately 15 percent of the aquifer requires inexpensive, traditional treatment for VOCs. It is estimated that about 4 percent of the aquifer would require large scale, more costly treatment systems to meet standards. This percent represents VOCs from highly contaminated groundwater plumes that have emanated from some inactive hazardous waste sites in the County.

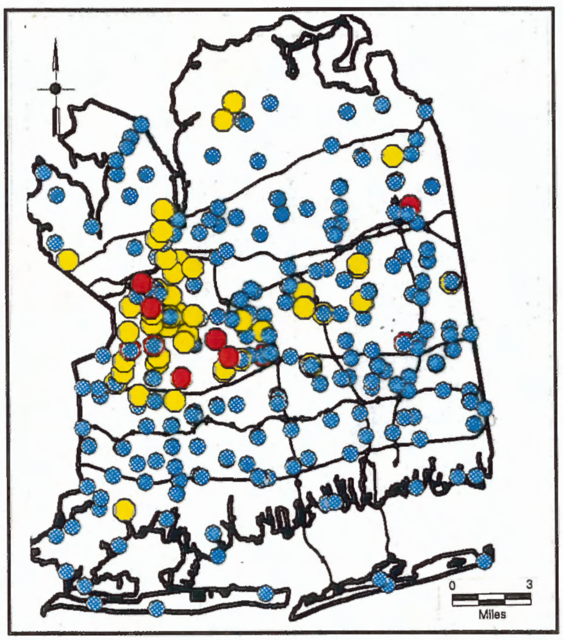
Figure 4-12 shows TVOC concentrations detected in raw groundwater from 244 Magothy water supply and monitoring wells during 1993 and 1994. Assuming the 344 wells represent raw groundwater quality in the Magothy aquifer, about 82 percent of the Magothy aquifer meets drinking water standards for VOCs without treatment, and approximately 15 percent of the aquifer requires inexpensive, traditional treatment for VOCs. It is estimated that about 3 percent of the aquifer would require more extensive treatment systems to meet standards.

While much of the Magothy aquifer shows nondetectable to low concentrations of TVOCs, contaminated aquifer segments are evident. The location of contamination in the aquifer is influenced by the effects of water supply withdrawal on the flow pattern of groundwater throughout the aquifer. Most of the public supply wells are located deep in the Magothy aquifer and tend to draw contaminants downward from the shallower depths more rapidly than would naturally occur.

Table 4-2 summarizes existing water quality in terms of the total number of supply wells

Table 4-2. Treatment at public supply wells for VOC removal during 1994 (NCDH, 1996).

Aquifer	*No. of supply wells*	*No. wells treating*	*% wells treating*
Upper Glacial	23	6	26
Magothy	343	56	16
Lloyd	41	3	7
All aquifers	407	65	16



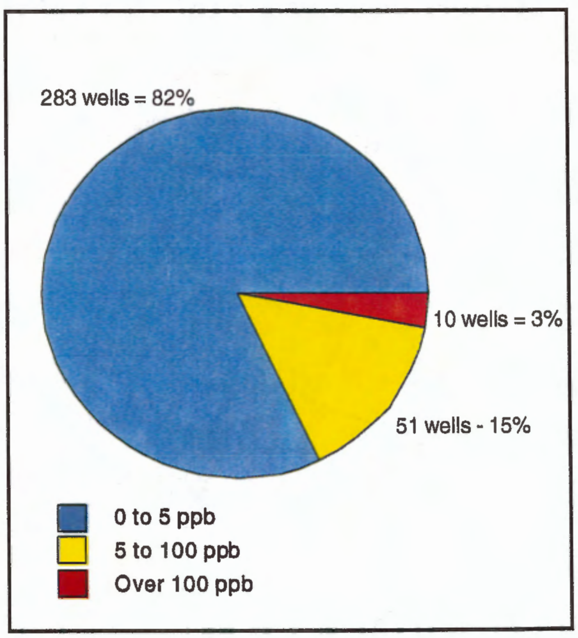


Figure 4-12. Sampling for TVOCs in raw groundwater from 344 Magothy aquifer water supply and monitoring wells in 1993-1994 shows 97 percent of the wells can meet drinking water standards with either no treatment or inexpensive, readily available treatment technology.

withdrawing water from each aquifer, and the number and percentage of supply wells in each aquifer equipped with treatment to remove VOCs.

The presence of VOCs in the Lloyd aquifer has been confirmed in raw groundwater from three public supply wells. One Lloyd water supply well is treated for VOCs to meet drinking water standards while the two others meet standards without treatment although they receive treatment anyway. The presence of VOCs in two of the Lloyd wells resulted from leakage that travelled along the well casing and entered the Lloyd aquifer. This problem has been corrected in one of the wells and is currently being addressed in the other.

Relatively low levels of VOCs are widely distributed in the Upper Glacial aquifer. However, the supply wells that rely primarily on the deeper Magothy aquifer are able to benefit from the natural processes of dilution, retardation, and biodegradation to attenuate VOC contamination as groundwater travels through the aquifers. This is evidenced by the fact that only 56 of the 343 Magothy supply wells are treated for VOC removal. It is noted that some of the public supply wells that are equipped with treatment do so as a contingency and could actually provide water meeting the drinking water standards with no treatment for VOCs whatsoever.

VOCs in the raw groundwater of impacted public supply wells have been effectively managed by the water suppliers with readily available, low cost treatment technologies. It is certainly encouraging that only 16 percent of the 407 supply wells in all aquifers are treated for VOC removal.

Trends in VOC Sources

Potential sources of VOCs entering Nassau County's aquifers include small to large industrial/commercial facilities, household chemical wastes, inactive waste sites, unlined municipal landfills, leaking underground storage tanks, and leaking sanitary sewers. These sources, which are being addressed by federal, State, and County pollution prevention programs and by sanitary sewers, are summarized in Table 4-3 and discussed in the pages that follow.

Large Industrial/Commercial Facilities. Large industrial/commercial facilities, often users of large quantities of solvents, are no longer an important source of groundwater contamination in Nassau County. According to the *New York State 1991 Toxic Release Inventory (TRI) Review*, a total of approximately 4.5 million pounds of listed toxic chemicals are released to the environment or disposed of annually by reporting facilities in Nassau County. Almost all of these chemicals are either disposed of outside the County or released to the air. About 3 percent of these compounds are released to wastewater treatment plants. Only a fraction of a percent are discharged each year to water (9 pounds) and to land (6 pounds) each year. These discharges are significantly lower than the amounts reported by other New York State counties of similar size, which release about 1,000 to 2,300 pounds of the listed toxic chemicals to water and land each year.

Nassau County's extremely low discharge rates to water and land are a direct result of groundwater protection regulations. Very low discharges from large industrial/commercial facilities to groundwater are expected to continue.

Small-to-Medium Industrial/Commercial Establishments. Small-to-medium industrial and commercial establishments, like larger facilities, are required to comply with a number of groundwater protection regulations. Although the majority of these facilities are believed to be in compliance with applicable regulations, the large numbers of these establishments in Nassau County (several thousand) makes it difficult to routinely inspect each for determining compliance.

The most common problems at noncomplying facilities have been illegal connections to on-site wastewater disposal systems, leaching pools and dry wells, and leaking underground storage tanks. NCDH continues to inspect these facilities. Recent emphasis has been on promoting industrial/commercial connection to existing sanitary sewers, inspecting all dry cleaning operations, and inspecting auto repair facilities to eliminate chemical discharges to the ground.

Releases of solvents are being systematically reduced; however, the number of facilities in

Table 4-3. A wide range of VOC sources have caused groundwater contamination in Nassau County.

VOC Source	*Relative Significance in Causing Groundwater Contamination*		*Trend*
	Past	*Present*	
Large industrial/ commercial facilities	High	Very Low	Decreasing as a result of groundwater protection and waste management regulations.
Small-to-medium industrial/ commercial establishments	High	Uncertain	Difficult to determine level of compliance because of large number of facilities.
Household chemical waste	High	Moderate	Minor decrease due to increased public awareness and STOP programs.
Inactive hazardous waste sites	High	Low	Decreasing as sites are investigated and remediated.
Unlined landfills	Moderate	Low	Decreasing, all landfills are closed.
Leaking underground storage tanks	Low	Very Low	Number of reported leaking tanks is increasing because of State and local inspections, but overall number of leaks is decreasing as tanks are replaced.
Leaking sanitary sewers	Very Low	Very Low	No change.

noncompliance is unknown because thorough inspection of the very large number of facilities is difficult. In the face of this uncertainty, no estimates of releases of VOCs from small-to-medium industrial/commercial facilities can be made, and the trend in this category of contaminant sources is not apparent. Inspections, compliance evaluations, and regulation should be a priority by the regulatory agencies.

Household Chemical Wastes. It is becoming increasingly clear that the average household is a significant source of groundwater contamination by solvents and petroleum products. Although each individual source is small, the aggregate quantity of chemical waste emitted from households is substantial. In Nassau County, about 7 million pounds of chemical waste are generated by residences each year, compared to 4.5 million pounds generated by large industries.

Household chemical waste remains a significant source of the relatively low-level of VOC contamination observed in Nassau County's raw groundwater.

The vast majority of waste household products containing VOCs find their way into the solid waste stream or the sanitary sewer system. However, if VOCs enter on-site wastewater disposal systems or are spilled onto the ground or into a storm drain, these chemicals can cause groundwater contamination. Studies of household chemical waste by the NCDH and others indicate that, in sewered suburban areas, 10 to 20 pounds are generated each year by each residence, and about 6 to 23 percent of this amount is disposed of indiscriminately. Applying this information to the number of households in Nassau County, it is then estimated that a total of between 700 to 5,500 pounds of household chemical waste is disposed of indiscriminately each day. Thus, significant amounts of household chemical wastes could enter the groundwater.

Despite the difficulty in estimating disposal rates, household chemical waste in all probability

Sources of Household Chemical Wastes

Common VOC-containing products used around the household include:

- Household products — nail polish remover, insect sprays, floor-care products, furniture polish, and window cleaner
- Automotive products — antifreeze, automatic transmission fluid, brake fluid, car wax with solvent, gasoline and oils
- Workshop products — paint brush cleaner with solvent, cutting oil, solvent-based glue, oil-based paint, paint thinner, paint stripper, rust remover, turpentine, varnish, and wood preservative
- Other miscellaneous products — artist's paints, dry-cleaning fluid, fiberglass epoxy, and photographic chemicals

remains a major source of the relatively low-level groundwater contamination frequently observed in a number of Nassau County wells. A decrease in the magnitude of this source would be expected as a result of heightened public education about the use and disposal of household chemicals. A brief review of STOP (Stop Throwing Out Pollutants) programs in the County indicates that they can be significantly improved.

Inactive Hazardous Waste Sites. To date, 60 hazardous waste sites in Nassau County have been the sources of uncontrolled releases of VOCs. Typically, these sites have released large quantities of VOCs to the groundwater, although actual quantities released are unknown. The number of new sites identified each year has been consistently decreasing, and it is now believed that the majority of these sites has been identified. Many of the releases from identified sites have ceased or are being controlled, and others are being remediated. As a result, releases of VOCs from hazardous waste sites have begun to decrease countywide.

Unlined Municipal Landfills. Unlined municipal landfills also have contributed to VOC contamination. Such groundwater contamination at these landfills appears to have come primarily from household chemical wastes. These contributions by the landfills are essentially localized, largely limited to the groundwater in the immediate areas of the landfills, not widespread throughout the County's groundwater as erroneously portrayed by the media in the past.

In any event, the groundwater contamination associated with landfills provided much of the justification for closing all landfills on Long Island. Existing landfills can no longer be utilized nor expanded and new landfills cannot be constructed under the Long Island landfill ban. The trend of closing landfills and controlling leachate by capping these landfills has and will continue to help decrease VOC concentrations in the groundwater into the future.

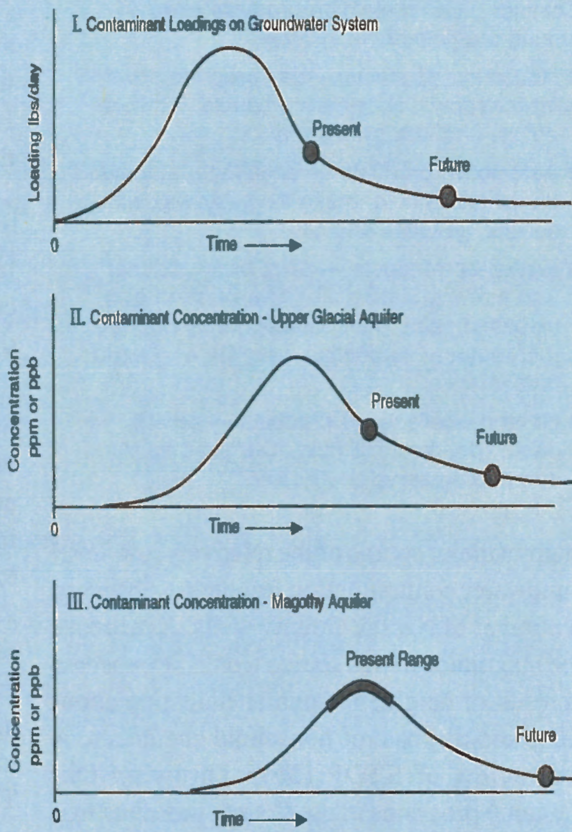
Leaking Underground Storage Tanks. The vast majority of reported leaks and spills from underground storage tanks are petroleum related and the number of reported spills has steadily increased since 1985. In 1994, for example, the total number of reported spills and leaks was 2,259. Of these, 95 percent were petroleum related. This increase is indicative of more stringent spill reporting requirements and aggressive activities associated with ongoing maintenance, testing and removal of leaking tanks. These activities are presumed to have resulted in a significant decrease in the volume of leakage entering the groundwater system. However, the number of tanks in noncompliance is unknown because thorough inspection of the very large number of storage facilities is difficult.

A recent Nassau County study on the impact of residential underground fuel oil storage tanks showed that residential fuel oil releases, although unknown in frequency and location, and probably variable in volume, are small enough and attenuated enough in the soil to have only a very limited impact on groundwater quality. Fuel oil from these smaller leaks undergoes both a high degree of retardation and biodegradation in the soil, and rarely causes dissolved contamination problems in groundwater any appreciable distance from the source of the spill. This supports the exemption for residential fuel oil storage from County and State underground storage tank regulations.

Leaking Sanitary Sewers. Sanitary sewers have greatly reduced the quantity of VOCs reaching

Contaminant Loading and Groundwater Quality

The simplified curves to the right illustrate conceptually how contaminants that are introduced at the land surface can eventually affect groundwater quality. Although this discussion is specifically geared to conditions that evolved in Nassau County, the concepts are applicable to any area that relies on groundwater sources for public water supply.



Prior to development, contaminant loading on the groundwater system was essentially non-existent (Curve I at time zero). As development proceeded and the population grew, the activities of man caused contaminant loading to increase over the years, eventually reaching some maximum level. With the advent of regulatory programs to control such loadings and minimize the associated detrimental effects on the environment, contaminant loading began to decrease. In Nassau County, these controls included the installation of sanitary sewers, source cleanups, and various regulations governing the storage, use, and disposal of hazardous materials.

Contaminant loading in Nassau County has decreased significantly as depicted by Curve I. As regulatory programs continue and the full effects of sanitary sewers are realized, present day contaminant loading will decrease further. At some point in the near future, loading will reach some minimum level, although this level will never again be zero. Nassau County's 1.3 million population living above the groundwater resource will always be a source of low level contaminant loading.

Curve II shows how raw groundwater quality in the Upper Glacial aquifer responded to contaminant loadings. When loadings first occurred, groundwater quality degradation was not seen until sufficient time passed for contaminants introduced at the land surface to travel through the unsaturated soils and enter the shallow groundwater of the Upper Glacial aquifer. This lag time

Continued on next page...

the groundwater and will continue to result in discernible improvements in groundwater quality into the future. Some sewer leakage routinely occurs, however, because design and construction standards allow for a negligible amount of leakage (no more than 0.1578 gallons per 100 feet of sewer pipe per inch diameter of sewer pipe per day) from sanitary sewers. Leakage tends to increase as sewers age and is localized, rather than uniformly distributed. It is difficult to estimate VOC loading on the groundwater system as a result of such leakage. However, in any community serviced by sanitary sewers, leakage has the potential of being a widely distributed, although relatively dilute, source of VOCs. In Nassau County over 98 percent of the sewage flow is sanitary wastewater from domestic sources and therefore any VOCs discharged to the sanitary sewers will be subject

Contaminant Loading and Groundwater Quality (continued)

can be seen when comparing Curves I and II, and noting how Curve II has shifted to the right. As time continued to pass, contamination in the shallow groundwater reached some maximum level and then began to decrease, again lagging behind the contaminant loading curve. This lag was caused by the time it took for cleaner water (resulting from the decrease in loading) to recharge and flush out the Upper Glacial aquifer.

Monitoring data indicates that groundwater contamination in the Upper Glacial aquifer has decreased significantly. This decrease is depicted on Curve II. The curve shows that contamination levels will continue to move to the right and reach some minimum level in the future as cleaner water continues to recharge shallow groundwater. Continued groundwater quality monitoring is needed to establish when this minimum level of contamination in the Upper Glacial aquifer is attained.

In the Magothy aquifer, the first appearance of groundwater contamination lagged behind that of the Upper Glacial aquifer as shown by Curve III. In this case, the lag was due to the time it took for contaminated water in the Upper Glacial to travel deeper into the groundwater system and enter the Magothy aquifer. As contaminated water from the Upper Glacial aquifer continued to recharge the Magothy aquifer, contamination levels in the deeper groundwater increased. The maximum concentration that will be attained in the Magothy aquifer will be less than that which occured in the Upper Glacial aquifer due to the effects of dilution, retardation and biodegradation as contaminants travel through the groundwater system.

Recent groundwater monitoring data indicates that contamination in the Magothy aquifer is close to its maximum concentration. The range depicted on Curve III shows the approximate contaminant concentration level in the deeper groundwater at the present time. The continued collection of groundwater quality data will confirm the exact position on the curve. As cleaner water continues to recharge and flush out the Magothy aquifer, steady decreases in contamination levels will be observed. At some point in the future, groundwater contamination in the Magothy aquifer is expected to stabilize at very low levels.

Contaminants introduced at the ground surface can take years to appear in the groundwater. Even though the contaminant loading has decreased significantly as a result of sanitary sewers and regulatory controls, much of the contamination that continues to be observed in the raw groundwater was introduced years ago. It will take many more years for current contamination levels to be flushed out of the groundwater system, especially in the deeper groundwater. With the continuation of the regulatory programs, and as the full County-wide effects of sanitary sewers are realized, further reductions in groundwater contamination can surely be expected to be seen in the future.

to a very high degree of dilution before ever entering groundwater. In addition, the County has a highly aggressive industrial wastewater pretreatment program in place which requires industrial/commercial establishments to treat their chemical wastes prior to discharge to the sanitary sewer system. This program has been in place for years. Lastly, under the County's sanitary sewer evaluation program, unacceptable sections of sewer pipe are repaired or replaced. The combination of these factors causes leaking sanitary sewers to only be a minimal source of groundwater contamination in Nassau County.

Trends in VOC Contamination

Since the mid 1970s, VOC contamination and stringent drinking water standards have impacted the use of some public supply wells in the county. The numbers of public supply wells exceeding VOC drinking water standards or guidelines in each year since 1982 are shown in Figure 4-13. These wells have either been treated to meet

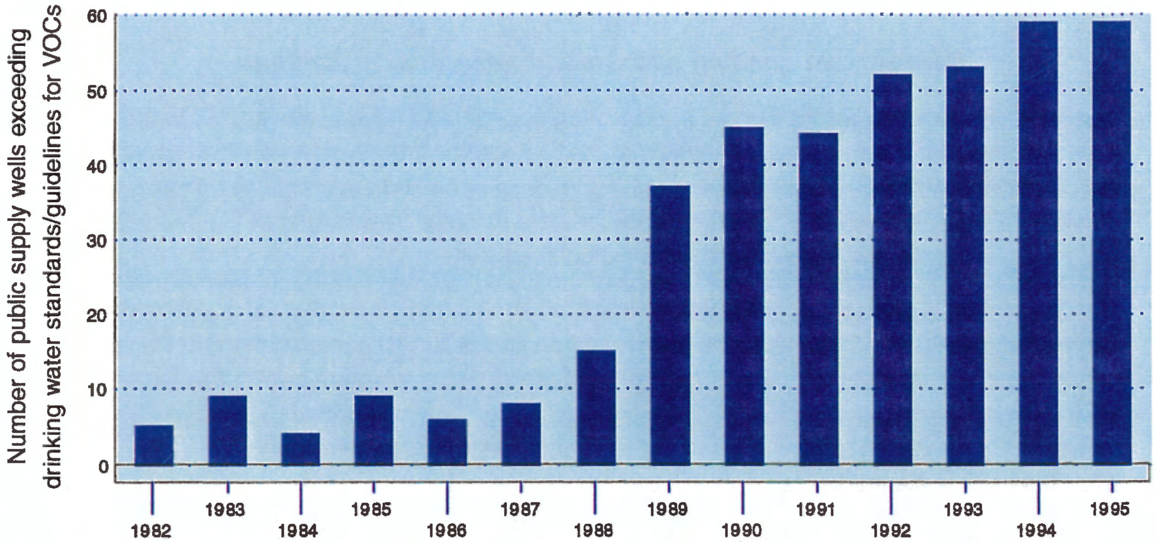


Figure 4-13. VOC contamination has impacted the raw water from a number of public supply wells. The significant increase in 1989 reflects promulgation of more restrictive drinking water standards, not a degradation of groundwater quality.

standards, closed (meaning the well can only be used again if treated to meet drinking water standards), deepened to reach cleaner water (equivalent to drilling a new well), or abandoned (permanently removed from service). The largest increase of affected public supply wells occurred in 1989. This coincides with the implementation of increasingly more restrictive drinking water standards.

Although the number of affected wells has grown in recent years, much of the VOC contamination now being seen at the public wells was introduced into the groundwater system in the past. With the advent of regulations and programs governing usage and disposal of VOCs, beginning in the late 1970s and continuing today, the loading of VOCs on the groundwater system is much, much less. Recent data indicates that TVOC concentrations at the water table have declined, which substantiates the assertion that VOC loadings have been reduced. Figure 4-14 compares TVOC concentrations from shallow monitoring wells from 1988 through 1993/1994.

Although the number of public supply wells impacted by VOCs has grown in recent years, the trend of declining VOCs in shallow monitoring wells suggests the number of impacted supply wells will decrease in the future.

The decreasing concentrations of VOCs in the shallower groundwater represents the cumulative effect of VOC source controls (regulations on usage and disposal and sanitary sewers). This declining trend in shallow VOC concentrations will become evident in the Magothy aquifer in the future as the cleaner water from shallower depths travels down through the aquifers and flushes out the groundwater system.

As illustrated in Figure 4-13, the number of public supply wells exceeding the drinking water standards for VOCs appears to have begun to stabilize. It is expected that the decreased loading of VOCs will eventually translate into a smaller number of public supply wells requiring treatment in years to come. More data is needed to be collected in future years in order to establish such a trend. In light of the recent manpower reductions in various regulatory agencies, it is especially important that the regulatory programs governing VOC users be continued. This will ensure that a decreasing trend in affected public supply wells will eventually be realized.

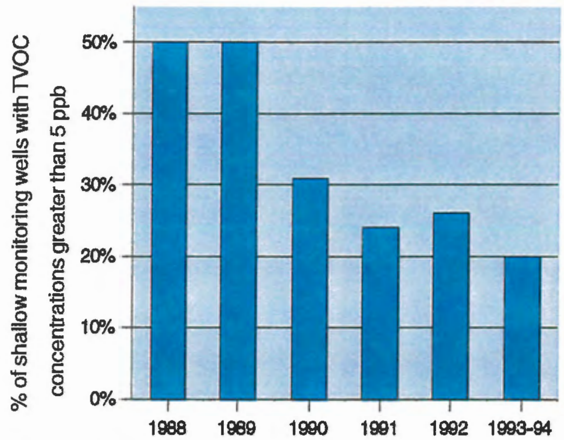


Figure 4-14. Since 1988, TVOC concentrations in shallow monitoring wells have declined significantly.

The levels of VOCs that affect some public supply wells have and will continue to be manageable problems with effective, low cost treatment. The number of affected wells, coupled with the relative ease of treatment, has resulted in an increasing preference for treatment, rather than abandonment, thereby keeping the wells in service.

4.2.4 Pesticides and Herbicides

Pesticides and herbicides include a group of synthetic organic chemicals that are used to kill or control insect pests, nuisance vegetation and diseases that affect crops, turf and other vegetation. These chemicals are widely used throughout the United States in agricultural, recreational, and residential settings.

During the early to mid-1980s, pesticides and herbicides have emerged as an important national concern as contamination resulting from the use of these substances has been detected in the water supplies of many states. Numerous chemicals have been found in the nation's groundwaters including aldicarb, chlordane, dibromochloropropane (DBCP) and ethylene dibromide (EDB) — all of which are detrimental to human health.

Due to human health risks, EPA has banned certain pesticides and herbicides from use including chlordane (1988), EDB (1984), dieldrin (1974) and heptachlor (1988), and has established MCLs for some compounds at much lower levels than for the VOCs. As the majority of these compounds are not responsive to aeration treatment as are VOCs, GAC filtration may be used to effectively remove pesticides and herbicides from raw groundwater.

Pesticides and Herbicides in Groundwater

Application of pesticides and herbicides in agricultural settings has been identified as a major activity that has affected the quality of the nation's groundwater. Other activities that have introduced these compounds to groundwater include applications to golf courses, parks, and to a lesser extent, residential areas. Although these substances are designed to break down and adhere to the soil as they perform their intended function, accidental spills, improper use, over application and certain soil conditions can cause residuals to leach through the soil and eventually appear in groundwater.

In Nassau County, the majority of agricultural areas had virtually disappeared by the 1960s as the County developed into a suburban community. As a result, the County's groundwater has not been subject to pesticides and herbicides emanating from agricultural activities for the last thirty-plus year period. However, applications to golf courses, parks and residential settings have continued to occur in Nassau County.

Testing for Pesticides and Herbicides

Current regulations call for water suppliers to test for over forty pesticide and herbicide compounds in the raw groundwater from their public wells. Testing conducted by both the water suppliers and Nassau County has found only a few compounds in the raw groundwater of a very small percentage of public supply and monitoring wells. In the rare instances when these compounds were detected, they were present at relatively low levels. Table 4-4 summarizes the compounds that were found during 1995, along with the number of positive detections in the raw groundwater from both public supply and monitoring wells.

It is noted that chlordane and EDB both were found in the raw groundwater of the same Upper Glacial supply well. Although these constituents were below their respective MCLs, this well is nevertheless equipped with GAC treatment. A low

Table 4-4. Recent testing shows pesticides and herbicides are rarely detected in raw groundwater in Nassau County (PS* = public supply; M = monitoring).

Compound Name	No. of Wells Tested	Well Type	No. of Wells Detected	Maximum Level Detected, ppb	Drinking Water Standard, ppb
Chlordane	202	PS	1	0.34	2.0
Dieldrin	202	PS	1	0.10	5.0
Heptachlor-epoxide	202	PS	2	0.06	0.2
"	93	M	1	0.30	"
Ethylene-dibromide (EDB)	99	PS	4	0.61	0.05

* Based on 1995 data reported in NCDH report "Groundwater and Water Supply Facts - 1996."

level of dieldrin was found in a second Upper Glacial supply well and a low level of heptachlor epoxide was found in a third Upper Glacial supply well. Both concentrations were well below their respective drinking water standards.

EDB was found in the raw groundwater of three Magothy supply wells, two of which exceeded the drinking water standard. GAC treatment is currently being installed on one of these wells, while usage of the other well has been discontinued. The third Magothy supply well in which EDB was found, at a concentration below the MCL, is equipped with GAC treatment. The presence of EDB in the wells at these low levels may have resulted from its use as a pesticide, or from its historical use as an additive in leaded gasoline. A fourth Magothy supply well contained a low level of heptachlor epoxide, which was below the drinking water standard. No pesticides or herbicides were detected in the Lloyd aquifer. In all of the monitoring wells that were tested, heptachlor epoxide was found in only one Upper Glacial monitoring well.

Pesticides and herbicides have not been found to be a significant problem in Nassau County groundwater.

Pesticide and Herbicide Trends

The preceding testing results demonstrate that pesticides and herbicides are not a significant concern in Nassau County groundwater. Further, they show that applications to recreational and residential areas have not had a significant detrimental effect on groundwater quality.

The combination of regulatory and other efforts makes it unlikely that pesticides and herbicides will become a concern in the future. These efforts include the New York State Department of Environmental Conservation (NYSDEC) certification program for applicators; the education being made available by various organizations stressing proper storage, handling and application techniques; and the increasing trend over the last several years towards Integrated Pest Management (IPM) techniques whereby environmentally safe products and natural management processes are incorporated instead of sole reliance on chemical controls.

However, since pesticides and herbicides have been and will continue to be used, to some extent, in recreational and residential settings, testing of raw groundwater should continue and be expanded in the monitoring well network. This will serve as early warning in the unlikely event that significant amounts of these compounds enter the groundwater system. Drinking water regulations assure that testing of raw groundwater from public supply wells will continue.

4.3 Water Quality Protection

Measures to protect and improve water quality are already in place. They include:

- Sanitary sewers and wastewater treatment facilities
- Continued aquifer protection through regulations and programs governing the use and disposal of chemical contaminants
- Continued use of treatment to produce high quality drinking water when water supplies have been affected by contamination

Although groundwater protection regulations and programs have been successful, some programs need to be improved and expanded to prevent contaminants from entering the groundwater supply. Nevertheless, when contaminants are found, they usually can be removed relatively inexpensively using readily available technologies, thereby providing a product that satisfies all drinking water criteria.

The solutions to the groundwater quality problems facing the County are twofold: continued aquifer protection, and continued use of treatment to produce high quality drinking water in tainted wells. Aquifer protection programs need to be maintained and strengthened to safeguard the groundwater supply from contamination.

4.3.1 Wastewater Collection and Treatment

Planning for the installation of sanitary sewers as a groundwater protection measure for Nassau County groundwater began as far back as the 1930s. Sanitary sewer and wastewater treatment plant construction began in the early 1950s and continued for close to forty years. In the mid-1980s, the collection and treatment systems were completed at a cost of over one billion dollars in federal, County, and local funds.

Sanitary sewers serve over 90 percent of the County's population and are the single most effective protection measure implemented in the County for protecting groundwater quality. Figure 4-15 depicts the areas of Nassau County served by sanitary sewers. Improving raw groundwater quality that has been recently documented by groundwater monitoring data is due, in large part, to the sanitary sewers.

4.3.2 Water Quality Regulations and Programs

During the late 1970s and the 1980s, awareness of the sensitivity of the groundwater resources to contaminants associated with overlying land uses grew rapidly throughout the United States. In an effort to protect groundwater quality, numerous federal, State, and local regulations and management programs were put in place to control these substances and the ways in which they are used. Regulations addressed such concerns as on-site wastewater discharge to the ground, underground fuel and chemical storage tanks, collection and disposal of household chemical wastes, road salt storage, bulk chemical storage, and landfills. Standards were also established that set maximum permissible levels of various chemicals in drinking water, in addition to regulations governing water supply facilities. Table 4-5 summarizes these regulations and their compliance requirements.

Successful implementation of these regulations was expected to minimize, if not eliminate, the release of contaminants to the groundwater. Trends showing reductions in both nitrate and VOC concentrations and numbers of sources indicate the success of these programs in Nassau County. Nevertheless, VOCs and nitrate continue to be detected in the County's groundwater today. Their persistence is due in large part to slow travel times in parts of the groundwater system and to the chemical properties of the individual contaminants. Current data also suggest that VOCs and nitrate continue to be released to the

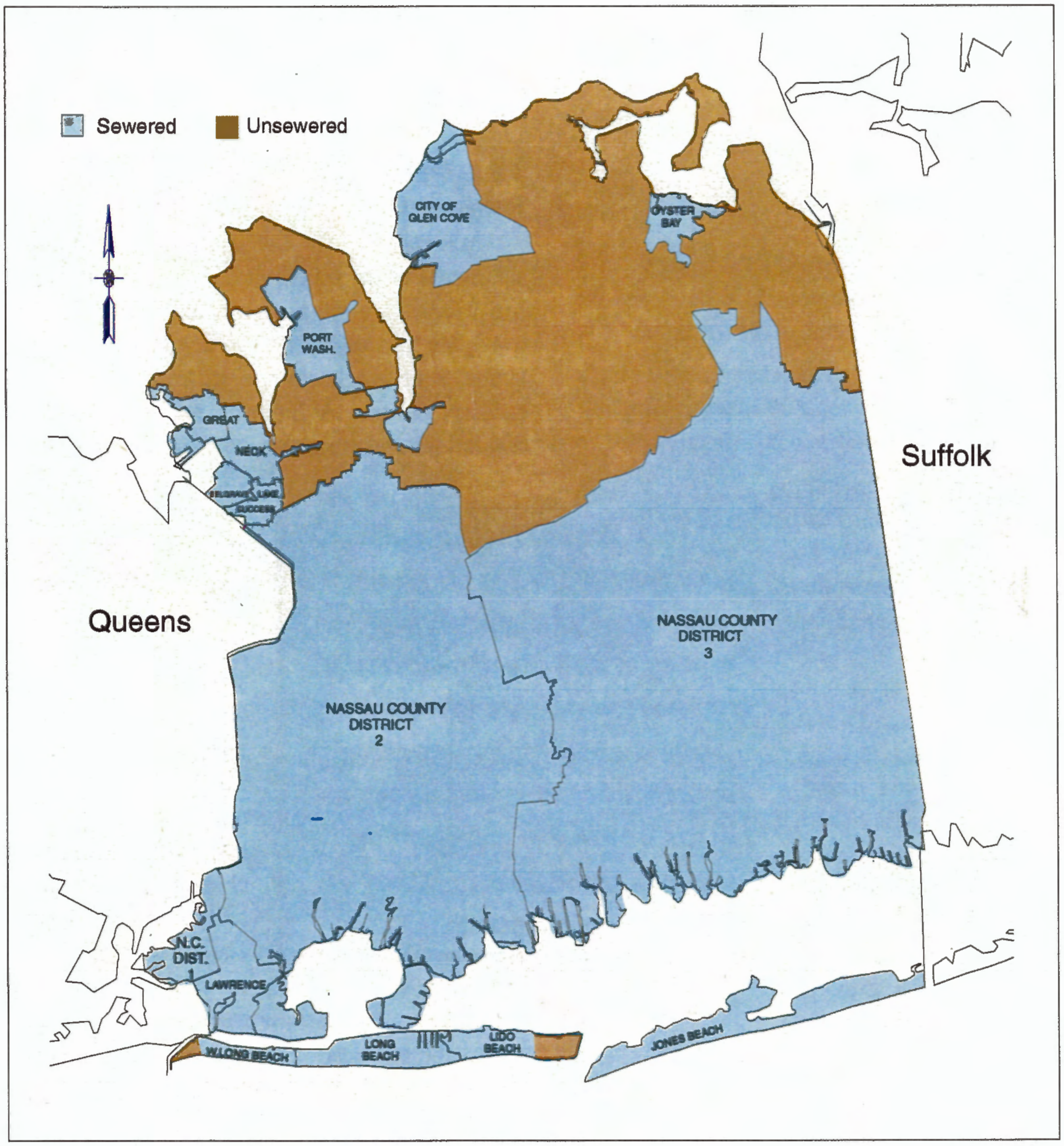


Figure 4-15. Sanitary sewers in Nassau County serve over 90% of the County's population.

groundwater, although in greatly reduced amounts.

Drinking Water Quality Standards

Enacted in 1974 and amended in 1986, the Safe Drinking Water Act directed EPA to establish national drinking water standards to limit the amount of various chemical concentrations in drinking water. These standards, defined as maximum contaminant levels, or MCLs, are technologically achievable levels of drinking water quality that are protective of human health. Primary standards have been developed for many chemicals by determining the concentration of each chemical in drinking water that is unlikely to cause an adverse health impact. Once this level was established, many factors of safety were incorporated by setting the MCL much lower than the level at which health impacts were unlikely to occur. Secondary drinking water standards also have been developed. These standards set limits for inorganic chemicals that are not detrimental to human health but can cause aesthetically unpleasing taste, odor, and color.

Table 4-5. Numerous federal, State, and local regulations and management programs protect groundwater and drinking water quality.

Regulation	***Compliance Requirements***
	Federal
National Environmental Policy Act (1969)	Requires federal agencies to determine whether proposed actions will have a significant effect on the environment, and if so, that an Environmental Impact Statement be prepared.
Water Pollution Control Act (1972), amended by the Clean Water Act (1977) and the Municipal Wastewater Treatment Construction Grant Amendments (1981)	Provided funds to states for areawide waste treatment management planning and construction of wastewater treatment plants; grants were used to fund the Long Island Comprehensive Waste Treatment Management Plan (Long Island Regional Planning Board), wastewater collection and treatment systems within the County, and the Long Island Groundwater Program (NYSDEC).
Safe Drinking Water Act (SDWA) (1974) and amendments (1986),(1996)	Directed EPA to establish national drinking water regulations. Set maximum permissible levels for certain contaminants in drinking water and established monitoring requirements for public water supply systems.
Hazardous Materials Transportation Act (1974)	Authorizes the regulation of interstate commerce and transport of hazardous materials.
Federal Insecticide, Fungicide and Rodenticide Act (1975)	Requires pesticide manufacturers to register products with EPA, and directs EPA to evaluate product risk to human health and the environment.
Toxic Substances Control Act (1976)	Regulates toxic chemical manufacturing, use, storage, labeling and disposal.
Resource Conservation and Recovery Act (1976)	Provides for a hazardous wastes control program, a land disposal regulatory program in each state, and initiation and support of state and local resource conservation programs. Also provides for identification and listing of hazardous wastes, provides standards for storage, treatment and disposal of wastes, establishes federal requirements for upgrade or closing of open dumps, mandates establishment of criteria for sanitary landfills (for nonhazardous wastes).
Comprehensive Environmental Response, Compensation and Liability Act (1980) (Superfund)	Provides EPA with financial resources needed for response to spills and environmental accidents that threaten the environment. Directed EPA to establish a national priority list of hazardous waste (Superfund) sites.
Additional regulations contained in the Code of Federal Regulations (CFR), including the Underground Injection Control Program (UIC), and a series of regulations governing the treatment, storage, disposal, identification and listing of hazardous wastes.	Provides for protection of groundwater resources, pollution control, and hazardous materials control.
	State
New York State Environmental Conservation Law (ECL)	NYSDEC administers the laws and programs of ECL. Articles of ECL particularly germane to water quality management are summarized below.
ECL Article 8 - State Environmental Quality Review Act (1974)	Similar to National Environmental Policy Act (see above).

Table 4-5 (continued). Numerous federal, State, and local regulations and management programs protect groundwater and drinking water quality.

Regulation	Compliance Requirements
	State
ECL Article 15 - Water Resources (1983)	Directs NYSDEC to approve all applications for water supply development and extension. Requires all wells on Long Island with capacities greater than 45 gallons per minute to be approved by NYSDEC.
ECL Article 17 - Water Pollution Control (1973)	Includes the State Pollutant Discharge Elimination System (SPDES) permit program, requiring permits for all liquid discharges greater than 1,000 gallons per day to the ground and other special requirements for chemical waste discharges.
ECL Article 27 - Collection, Treatment, and Disposal of Refuse and Other Solid Waste (1978)	Contains an amendment banning new landfills or expansions of existing landfills in deep recharge zones.
ECL Article 33 - Pesticides (1983)	Authorizes NYSDEC jurisdiction over distribution, sale, use, and transport of pesticides.
ECL Article 55 - Sole Source Aquifer Protection (1987)	Establishes procedures for the designation of Special Groundwater Protection Areas (SGPA) in local areas.
Navigation Law (1977 - Article 12 enacted)	Authorizes NYSDEC to control the transfer and storage of petroleum, and requires prompt cleanup of petroleum discharges within the state.
Transportation Law	Authorizes the New York State Department of Transportation to control transport of hazardous materials.
General Municipal, County, Town, and Village Laws	Empowers local authorities to develop water supplies, wastewater systems, drainage facilities, and to regulate land use and zoning.
New York State Code of Rules and Regulations, Title 6 "Conservation"	Includes regulations pertaining to pesticides, solid waste management facilities, hazardous and industrial wastes, as well as groundwater classifications, quality standards, effluent standards, and SPDES permits.
NYCRR, Title 10, "Health" (Sanitary Code - Part 5-1)	Establishes drinking water standards and sets monitoring requirements for drinking water suppliers.
	Nassau County
Nassau County Sewer Ordinance (1977)	Provides for the regulation of contributors to the sanitary sewer systems and wastewater treatment facilities.
Nassau County Public Health Ordinance, Article II, General Sanitation (1983)	Requires all establishments to be connected to sanitary sewers if located in an area served by sanitary sewers.
Nassau County Public Health Ordinance, Article X, Groundwater Protection - Regulation of Sewage and Industrial Wastewater (1985)	Established two Special Groundwater Protection Areas — in the North Hills area and northeastern areas of the Town of Oyster Bay — and controls the types and amounts of wastewater being discharged to the ground in these SGPAs.
Nassau County Public Health Ordinance, Article XI, Toxic and Hazardous Materials Storage, Handling and Control (1986)	Includes requirements for hazardous material and medical waste storage and transportation, for testing, monitoring, and protection of underground and aboveground storage tanks, and for road deicing bulk storage facilities.

Table 4-5 (continued). Numerous federal, State, and local regulations and management programs protect groundwater and drinking water quality.

Regulation	Compliance Requirements
Nassau County Public Health Ordinance, Article IV, Private Drinking Systems (1987)	Requires that all residences and establishments be connected to a public water system for drinking water purposes as long as a public water system is available.
Nassau County Public Health Ordinance, Article VI, Public Drinking Water Supply, (1990)	Regulates the public drinking water supply in order to assure the protection of sources and quality of drinking water in addition to safety at water supply facilities.
	Local Legislation and Programs
Zoning	The Town of North Hempstead upgraded zoning within the boundaries of the North Hills SGPA from 2.5 to 5 acres, and the Village of Lake Success upgraded zoning from 1.0 to 5 acres within these boundaries.
Hazardous Waste Collection	The Town of Oyster Bay, the Town of Hempstead, and the Town of North Hempstead have all established STOP (Stop Throwing Out Pollutants) programs to collect and dispose of household hazardous wastes.

Drinking water standards and monitoring requirements, based on those established in EPA's Safe Drinking Water Act, have also been adopted by both New York State (State Sanitary Code 10 NYCRR Part 5-1) and Nassau County (Nassau County Public Health Ordinance, Article VI). These standards are at least as stringent as the federal standards. The current primary and secondary drinking water standards, and New York State drinking water standards are summarized in the Appendix.

Water Supply and Groundwater Monitoring

In 1994, County residents were served by 55 public water systems, including 51 community public water systems and four non-community public water systems. Non-community systems are small and generally serve a transient population and/or very few County residents. To protect human health these systems are required by NYSDOH and/or NCDH to monitor water quality. Specifically, requirements include:

- Monitoring of raw groundwater quality (prior to treatment) obtained from each public supply well for the constituents listed in the Appendix
- Monitoring of the effectiveness of each supplier's water treatment facilities
- Monitoring of finished water quality (after treatment) within each supplier's distribution system

In addition to the monitoring conducted by each water supplier, NCDH also samples public supply wells and tap water for organic and inorganic chemicals and bacteria. Any violation of drinking water standards and any monitoring violations are promptly reported to the regulatory agencies. Customers are also notified of violations through public and private notification procedures. Corrective action is then immediately taken by the water supplier and regulatory agencies.

The Nassau County Department of Public Works (NCDPW) routinely samples a network of groundwater monitoring wells screened in the Upper Glacial, Magothy, and Lloyd aquifers. These wells are used to identify contaminant plumes and trends in groundwater quality, thus warning of potential contamination of public water supply wells.

Control of Pollution Discharges

Pollution control and groundwater protection regulations focus on preventing contaminants and waste products from entering and contaminating groundwater by regulating the use, storage, and disposal of a variety of products used in homes, industry, and commercial establishments.

Regulations and programs targeted at controlling discharges from small, medium, and large industrial/commercial facilities are included in Table 4-5. These regulations have been successful in reducing discharges from large industrial/commercial facilities. Because of the large number of smaller facilities, however, enforcement has been more difficult for the small-to-medium industrial/commercial facilities. Although the majority of the small-to-medium facilities are believed to be in compliance with applicable regulations, the large numbers of such facilities make it difficult to determine their degree of compliance. Inspection of these facilities, especially in sensitive water supply areas, should be a priority for the regulatory agencies. Accordingly, the regulatory programs governing the use and disposal of hazardous materials should be strengthened in light of the State and County work force reductions that have occurred in recent years.

It is important to distinguish between groundwater quality and drinking water quality. While some groundwater may contain objectionable levels of various contaminants, current regulations assure the water is either not used as a drinking water source, or is treated to meet drinking water standards, before it is delivered to the consumer.

At the residential level, household chemical wastes have been found to be a source of groundwater contamination. The three towns in Nassau County have instituted educational programs and established programs for the collection of household hazardous wastes. These STOP (Stop Throwing Out Pollutants) programs do not appear to be very effective, mainly because of a lack of participation. However, it is important for such programs to be strengthened, and implemented County-wide.

Land Use Planning

Overlying land uses have a significant effect on the quality of water recharging Nassau County's groundwater system. Understanding how land use can affect groundwater quality establishes the basis for all County groundwater protection efforts.

The foundation for groundwater protection through land use planning was established in the *208 Areawide Waste Treatment Management Plan*, which identified two deep recharge zones. Since the water recharging the aquifer in these zones was expected to remain in the system for hundreds of years, protection of the quality of that recharge was identified as a significant concern. Identification of large undeveloped or lightly developed areas of land in these zones then prompted the establishment of Special Groundwater Protection Areas (SGPAs), where development would be minimized or carefully managed to protect the quality of resulting recharge in these unsewered areas.

Nassau County has designated two (2) SGPAs — one in the Oyster Bay area and the other in the North Hills area. Specific conditions governing any new development in the SGPAs include:

- no more than one (1) residential dwelling per 40,000 square feet of land area
- the average design rate of wastewater discharges from on-site wastewater disposal systems serving new non-residential establishments must not exceed 0.00375 gallons per day per square foot of building area.
- discharges of industrial wastewater to the ground, whether treated or untreated, are prohibited

The SGPAs are depicted in Figure 4-16.

However, since it has been determined that most of the surface area of the County functions as a deep recharge zone supplying water to the Magothy aquifer, and since much of the County is already heavily developed, land use restrictions are no longer applicable to the majority of the County and therefore have only limited effectiveness. The importance of land use planning today lies in improved public education for

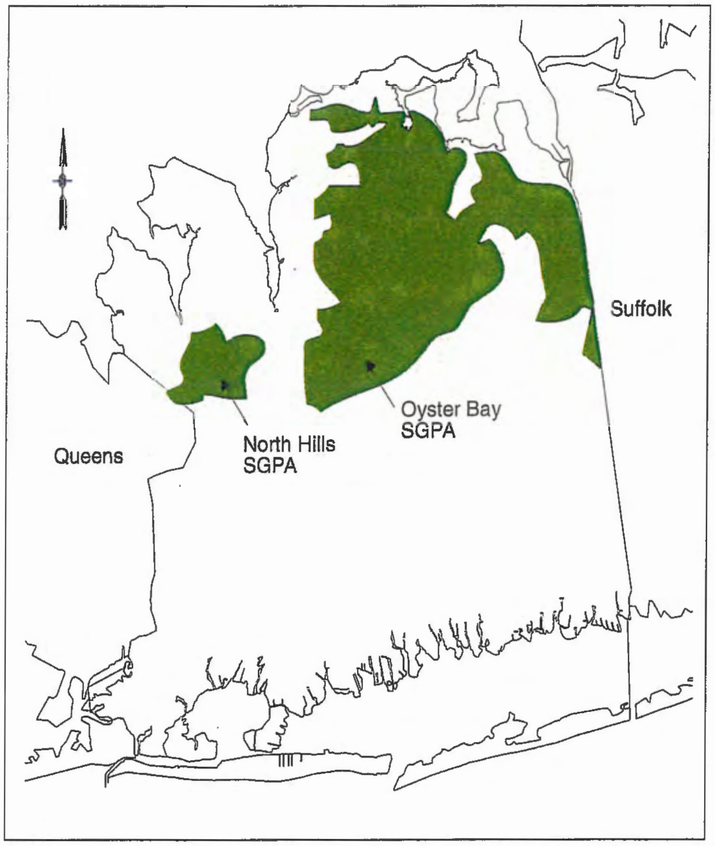


Figure 4-16. Special Groundwater Protection Areas (SGPAs) in Nassau County.

homeowner disposal of chemical wastes and regulation of the small-to-medium sized industrial/ commercial establishments using hazardous materials. Such facilities should be considered a priority for inspection and enforcement by the regulatory agencies. In addition, SPDES permits issued to any facility should be especially scrutinized to ensure that discharges will not affect public supply wells.

4.3.3 Treatment

It is important to distinguish between raw groundwater quality and drinking water quality. While some groundwater may contain objectionable levels of various contaminants, regulations assure the groundwater is either not used as a drinking water source, or is treated to meet drinking water standards, before it is delivered to the consumer.

Future treatment approaches, as well as treatment methods now being used to control various parameters in Nassau County groundwater, are summarized in Table 4-6. Groundwater containing VOCs and/or nitrate exceeding drinking water standards can be treated using traditional, readily available treatment technologies. Air stripping and GAC filtration can be used for VOC removal. Nitrate in groundwater above the drinking water standards may be removed with ion exchange treatment or blended with cleaner water to dilute concentrations to below the standard. Conventional treatment processes are also available to control corrosion and to sequester various metals. Pesticides may be effectively removed with GAC filtration. Based on groundwater monitoring results, however, pesticides have not been found to be present in any significant amounts in Nassau County groundwater.

4.4 Water Quality in the Future

Nassau County has long recognized the value of water quality protection and has implemented measures - most notably sanitary sewers - to prevent contaminants such as nitrates and VOCs from entering the groundwater. While the 1.3 million people who live in Nassau County will inevitably affect the quality of the water recharging the groundwater system, sanitary sewers and the implementation of a comprehensive set of waste management and groundwater protection regulations have greatly reduced the potential for contaminants contained in our waste products to reach the County's groundwater supply. In general, groundwater quality can be expected to continue to improve over time, as the major sources of contaminants have been greatly reduced.

Nevertheless, as a result of groundwater flow patterns, groundwater quality will continue to reflect the historical loadings of contaminants such as nitrates and VOCs for some time into the future.

Table 4-6. Current and future conditions of Nassau County's groundwater can be successfully treated using cost-effective, readily available technologies.

Parameter	*Current Treatment Status*	*Future Conditions Expected*
Iron and Manganese	As of 1994, 16 water systems, generally along the south shore, provided for sequestering, iron removal, or both at one or more of their wells.	These metals may be removed by a series of treatment processes including aeration, coagulation, sedimentation, and filtration. Alternatively, water containing low levels of iron may be treated by chemical sequestering agents that keep the metals in dissolved form thereby preventing discoloration of the water. The number of wells receiving treatment is not expected to increase or decrease because of the natural presence of these metals in the aquifer.
Acidity	Most water suppliers practice corrosion control because Nassau County groundwater is naturally acidic.	Will not change due to natural acidity of precipitation.
Hydrogen Sulfide	Water suppliers experiencing odors caused by this gas remove hydrogen sulfide from the water by aeration or control the odors with chlorination.	Will not change due to decay of naturally occurring organic matter in the aquifers.
Bacteria	Although groundwater pumped from Nassau County's aquifers is bacteria free, many water suppliers chlorinate to protect against any accidental bacterial contamination that may occur during the distribution process.	Chlorination, as a protection measure, will continue.
Nitrate	Over the last several decades, numerous public supply wells were not used because nitrate exceeded drinking water standards. As of 1994, of the 24 wells restricted from normal use because of nitrates, 21 were not used, one received ion exchange treatment, and two blended groundwater with cleaner water from other wells to dilute the nitrate to meet the standard.	Levels can be reduced by blending water that does not meet drinking water standards with cleaner water. Due to the non-existence of agriculture and because source control measures are in place, concentrations have peaked in shallow groundwater, and are declining. However, historical loadings may continue to impact a small number of Magothy supply wells. Eventually, some of the public supply wells not used in the past may be used again in the future as cleaner water flushes through the groundwater system.
VOCs	As of 1994, 17 of the County's 55 public water supply systems treated one or more water supply wells for VOC contamination using air stripping or GAC filtration.	Traditional treatment processes for VOC removal — air stripping and GAC filtration — can cost-effectively reduce contamination to meet drinking water standards, and use of these techniques is expected to continue in areas with low levels of contamination. Over a long period of time, the number of public supply wells needing treatment should decrease due to the regulatory programs, site cleanups, restricted use of certain chemicals, and other measures in place to safeguard the groundwater system. As more VOC-contaminated

Table 4-6 (continued). Current and future conditions of Nassau County's groundwater can be successfully treated using cost-effective, readily available technologies.

Parameter	Current Treatment Status	Future Conditions Expected
VOCs (continued)		groundwater travels deeper into the Magothy aquifer, the number of wells receiving VOC treatment may actually increase over the short term, then level off, and eventually decrease over decades as the groundwater system is flushed out with cleaner water that results from the decreased VOC loading on the groundwater system.
Pesticides and Herbicides	Currently GAC treatment is provided to remove the low levels of pesticides observed in the raw groundwater from a few public supply wells.	Pesticides detected above drinking water standards would be addressed by GAC or well closure in the few instances where this may become necessary. Based on testing conducted to date, pesticides are not expected to become a major concern in the future.

Because sanitary sewers were first installed in the western part of the County, and because public water supply pumping has greatly accelerated the time it takes for recharging water to move through the system in the western part of the County, continued improvements in raw groundwater quality are expected over the planning period. Further to the east, where the aquifers are thicker, and public supply wells are not as densely clustered, the time it takes for water to move through the system is considerably longer. As a result, low levels of contamination resulting from historical loadings can be expected to remain for some time until they are eventually flushed out of the groundwater system.

The effectiveness of existing groundwater protection efforts focusing on proper use, storage and disposal of products that can contaminate groundwater can be strengthened by continued enforcement of applicable regulations, and by increasing public awareness. For example, VOCs contained in household products are one remaining source of the low level contamination observed in groundwater today. Increased educational efforts and more effective STOP programs would help reduce contaminant loading and the impacts of development on groundwater quality.

Routine testing of both monitoring wells and public supply wells provides timely identification of trends in groundwater quality or the presence of contamination. Any public supply source found to contain contaminants in excess of drinking water standards is either removed from service or treated using readily available technologies to meet drinking water standards. Because the cost to install and operate water treatment systems has only resulted in a very small increase in the cost of water to the consumer, drinking water throughout the County remains very affordable at an average cost of $2.00 per 1,000 gallons.

Although localized instances of groundwater contamination may be identified in the future, existing regulations ensure that high quality drinking water will continue to be provided in Nassau County.

Section 5
Conclusions and Recommendations

The *1998 Groundwater Study* represents the conclusion of a long-term effort to more fully understand the dynamic nature of the County's complex groundwater system. The study entailed field investigations, data collection and database development, extensive computer modeling, and data analyses. Herein are presented the most significant conclusions and recommendations organized according to the four major concerns — water quantity, streamflow, saltwater intrusion, and water quality.

5.1 Conclusions

The study produced significant findings and new insights into the present condition and future of Nassau County's groundwater resources as compared to the last comprehensive County water study of 1980. These findings can be used to shape future policy affecting the County's groundwater resources, whether carried out by County agencies, federal and/or State agencies, or individual water suppliers.

Water Quantity

- Average annual water demand is projected to remain at or slightly below its present average of 180 mgd through the year 2010.
- Available groundwater resources are sufficient to meet future water demand, and no alternative source of water is required for water supply purposes.
- The Magothy aquifer can sustain the present rate of groundwater withdrawal. Withdrawal from the Lloyd aquifer, however, at approximately 12 mgd, is approaching the total recharge of the aquifer (14 mgd). This may already represent a rate of withdrawal that cannot be maintained indefinitely, especially near the shoreline areas and on the barrier islands.
- The locations of groundwater withdrawal can cause localized adverse environmental impacts such as saltwater intrusion and loss of streamflow. Therefore it is more appropriate to consider the locations of pumping centers in relation to such impacts when establishing allowable withdrawal rates instead of assigning a single "safe yield" value for the groundwater system.
- Water conservation measures have been successful in achieving long-term annual savings of about 5 percent.

Streamflow

- Loss of streamflow is an environmental consequence of the lower water table caused by increased consumptive use in Nassau County. The full impact of the installation of sanitary sewers is, for all practical purposes, complete.
- The lower water table has significantly lowered pond and lake levels and dried up many freshwater wetland areas along the entire south shore.
- The characteristics of streamflow along the south shore have been changed by development and increased groundwater withdrawal. In the past, streams were characterized by continuous, consistent flows of clean, cold water fed from the groundwater system. Streams are now characterized by intermittent, high flows of warmer, potentially more polluted water from stormwater runoff. These conditions cause scouring of streambeds and increased erosion, as well as long periods during which the streams are completely dry along most of their northern reaches.

Streamflow (continued)

- There are instances where public supply wells are located in close proximity to streams which causes a significant reduction in streamflow and/or surface water levels.
- Only an unrealistically large decrease in water consumption of over 80 mgd would restore continuous stream baseflow at levels approaching predevelopment conditions in most south shore streams.
- An integrated approach to stream and wetland management — combining drainage improvements, shifts in public water supply pumping, and possible public water supply well relocation — offers the most promising approach to maintaining surface waters.

Saltwater Intrusion

- Landward movement of saltwater into Nassau County's fresh groundwater is caused by both the slow rise in sea level since the last ice age and by increased groundwater withdrawal from the Magothy and Lloyd aquifers.
- Saltwater is moving landward along the south shore in the Magothy aquifer at rates estimated at 50 to 75 feet per year. In southwestern Nassau County, saltwater intrusion is occurring at rates of about 150 feet per year. The increase in the rate of interface movement is the result of pumping effects from the southernmost public supply wells. Saltwater intrusion into coastal aquifers has been accelerated and made more extensive by public water supply withdrawal.
- In approximately 50 years, saltwater intrusion in the Magothy aquifer will impact thirteen south shore supply wells.
- Landward saltwater movement is occurring in the Lloyd aquifer along the entire south shore, with the rate of movement estimated to be about 30 feet per year. The present position of the Lloyd aquifer interface is offshore, but its exact position is not known. Computer modeling estimates that impacts to public supply wells in the Lloyd aquifer are not expected within the next 100 years. Once the interface reaches the barrier islands, however, public supply wells will be impacted within 3 to 10 years, leaving little lead time for advance planning for alternative water supply sources.
- Saltwater intrusion into the Lloyd aquifer has already affected several public supply wells on the Great Neck peninsula. At present rates of groundwater withdrawal from the peninsula, further impacts are expected within the coming 25 years. Total withdrawal from the Lloyd aquifer on the Great Neck peninsula would have to be reduced to below 1 mgd to halt the advance of salt water.
- Based on preliminary field studies, saltwater intrusion on the Manhasset Neck peninsula is occurring. Additional study is needed to fully characterize the extent of the problem.
- Although preliminary model simulations indicate that the rest of the north shore is not susceptible to large-scale intrusion, there are too few monitoring wells to adequately define hydrologic conditions and to assess the threat of small, more localized intrusion problems at nearshore well fields. Additional monitoring wells and studies are needed to fully assess this potetnial problem.
- Water conservation measures will not be effective in slowing the rate of saltwater intrusion. Cessation of nearshore groundwater withdrawal at the depth in the aquifer where the intrusion is occurring is a more effective approach.

Water Quality

- The most significant groundwater quality concerns in the County are organic chemicals and nitrates, largely resulting from past practices.
- Organic chemicals from solvents and degreasers are the most pervasive contaminants in the groundwater system. Currently, 65 of 407 public supply wells in the County (16 percent) have had treatment installed to remove these organic chemicals.
- Petroleum products are not a major water quality problem, primarily because they are adsorbed to soils, evaporated, or biologically broken down. However, petroleum product contamination can be a local water quality problem in shallow parts of the aquifer.
- Based on testing conducted to date, indications are that pesticides are not a significant problem in Nassau County groundwater. Due to the absence of agriculture in the County and the regulatory programs governing pesticide usage, pesticides are not expected to be a cause for concern as testing of the groundwater continues.
- Nitrate in groundwater is widespread, but is generally found at relatively low concentrations below drinking water standards. The installation of sanitary sewers has virtually eliminated the major source of nitrate contamination — on-site wastewater disposal systems. As a result, trends in nitrate concentrations in the Upper Glacial aquifer are significantly downward, and nitrate is no longer considered a major concern in sewered areas which serve over 90 percent of the County's population. Nitrate levels in portions of the shallow groundwater system in a few unsewered and densely populated areas of the north shore exceed drinking water standards. Since this portion of the groundwater system is not used as a drinking water supply source and does not recharge the deeper groundwater, nitrates are not a problem in these areas. However, since nitrate contaminated water could conceivably be pulled down deep enough to impact public supply wells, continued monitoring of this situation is essential.
- The movement of contaminants has been significantly changed by large scale water supply withdrawal. Previous groundwater management strategies focused on protection of land areas identified as the deep recharge zone. It has been determined that groundwater withdrawal from the deeper part of the Magothy aquifer has actually increased the areas of deep recharge to encompass most of Nassau County's land surface.
- Groundwater travel times from the land surface to the bottom of the Magothy aquifer have been reduced due to increased groundwater withdrawal. In some areas of the County, the travel time to the deep portions of the Magothy aquifer has been reduced to less than 10 years, whereas under natural conditions (no groundwater withdrawal) the travel time was hundreds of years.
- Regulations and groundwater protection measures have had a positive effect on water quality. The installation of sanitary sewers and the various regulatory programs have decreased the contaminant loading on the groundwater system. As a result, vastly improved quality in the Upper Glacial aquifer has been observed. Recent data suggests that organic chemical contamination in the Magothy aquifer will decline in the coming years. The data also shows that trends in nitrate concentrations are generally downward although nitrate loadings from historical sources may continue to impact a small number of supply wells into the future.

5.2 Recommendations

Recommendations to address existing water quantity, streamflow, saltwater intrusion, and water quality concerns were developed in response to the findings of this study. Taken together, the recommendations form a practical, cost-effective management program that addresses all issues of the groundwater system.

The recommendations addressing water quantity are aimed at continued water conservation and flexibility in the management of the groundwater system in order to minimize detrimental environmental impacts. Because it is not feasible to achieve significant increases in stream baseflow barring major aquifer recharge or large scale reduction in groundwater withdrawal, streamflow recommendations target improving conditions at high priority stream corridors through cost-effective measures. Although the expected lead time prior to saltwater contamination of public supply wells is fairly long, saltwater intrusion recommendations are geared to the continuation of monitoring saltwater movement and providing technical assistance to water suppliers confronted with saltwater intrusion problems. Recommendations for water quality focus on continued groundwater monitoring and controlling contaminant loading from various sources.

Water Quantity

- Although the groundwater supply is adequate to meet water needs for many years to come, the County should work with New York State Department of Environmental Conservation (NYS-DEC) and the water suppliers to develop a more flexible County-wide withdrawal permitting system — one that considers saltwater intrusion, streamflow, and variable water demand in setting maximum withdrawal rates. Additionally, the County should assess any Water Supply Application (WSA) submitted by the water suppliers for new or modified wells prior to approval by NYSDEC. The County's groundwater model should be used to assess the impacts of WSA proposals on the groundwater system, and updated accordingly.
- In accordance with existing NYSDEC policy, water supply withdrawal in the Lloyd aquifer should be limited to existing wells, primarily on the barrier islands, where other sources of fresh water are not available. The Water Authority of Great Neck North should continue their efforts in reducing groundwater withdrawal in the Lloyd aquifer in light of the saltwater intrusion that is occurring on the Great Neck peninsula.
- The County and water suppliers should continue to actively encourage water conservation measures to control nonessential water use, and to track the effectiveness of conservation measures. The Water Resources Board's recommended revisions to the County's Water Conservation Ordinance should be adopted, and the County should continue to support educational efforts by working with the Cornell Cooperative Extension Association and the water suppliers. Educational efforts and promotion of the County's Water Conservation Ordinance should target the summer months, when water supply withdrawal is at its highest.
- Monitoring of water levels, weather patterns, and public water supply withdrawal should continue.

Streamflow

- The County should continue to work with the U.S. Environmental Protection Agency, NYSDEC, and local community groups on the streams and wetlands management programs in order to develop appropriate restoration goals and plans. Efforts should be directed at streams and surface waters that have a high recreational and aesthetic value.
- New public supply wells should not be sited in areas where they would significantly reduce stream baseflow and/or pond and lake levels. Existing wells could be relocated over time where possible.
- Because stormwater runoff is a major component of streamflow management strategies, County and other municipal drainage improvements should be coordinated with stream and wetland improvement measures to the greatest extent feasible.

Streamflow (continued)

- Monitoring of streamflow should continue.

Saltwater Intrusion

- Chloride monitoring should continue on both the north and south shores, in all aquifers, to provide the necessary data to monitor the advance of the saltwater interfaces. New monitoring wells should be added to the chloride monitoring network where deemed necessary.
- Communities on the south shore barrier islands depend solely on groundwater from the Lloyd aquifer for water supply. The position of the freshwater/saltwater interface in the Lloyd aquifer is not known and to effectively plan for future water supply sources to these communities, federal and/or State agencies should consider offshore drilling south of the barrier islands to determine the exact position of the interface in the Lloyd aquifer. The results of these efforts should be incorporated into the southwest Nassau saltwater intrusion model to update the estimates of saltwater impacts on public supply wells. To that end, the saltwater models should be updated periodically to incorporate new information from the chloride monitoring network.
- The County should continue to provide technical assistance to water suppliers confronted with saltwater intrusion problems. Alternative solutions to saltwater intrusion problems that should be explored with the aid of saltwater models include relocation of public supply wells (either vertically or laterally) outside of the zone of saltwater intrusion, purchasing water from adjacent water suppliers, treatment of brackish water, and minimizing groundwater withdrawal from impacted supply wells.
- Use of the Magothy and Lloyd aquifers for water supply in Brooklyn and Queens could have a significant impact on the position of the freshwater/saltwater interface. Accordingly, the County should continue to participate in the Southeast New York Inter-Governmental Water Supply Advisory Council. This will allow the County to evaluate and comment on water supply options being considered by the New York City Department of Environmental Protection for augmentation of water supply in the Brooklyn and Queens areas.

Water Quality

- Monitoring of the groundwater should be continued to track water quality trends and to serve as an early warning system to protect public supply wells. The pesticide monitoring program should be expanded to include any additional chemicals that may have a likelihood of occurring in Nassau County's groundwater.
- Almost the entire land surface of Nassau County should now be considered a deep recharge zone and protected accordingly.
- The County should continue inspecting industrial/commercial facilities for compliance with hazardous chemical usage and discharge regulations. Enforcement should be strengthened especially in light of manpower reductions that have occurred in recent years, focusing attention on the collection of information from the large number (several thousand) of small-to-medium size facilities in order to characterize associated contaminant contributions.
- The County's groundwater model should be revised on a regular basis in order to more effectively characterize groundwater quality and movement.

Water Quality (continued)

- Because household hazardous wastes have been shown to be a major contributor of contaminants to the groundwater, STOP (Stop Throwing Out Pollutants) programs and the use of environmentally safe products should be encouraged, publicized, and improved to help control the disposal of household chemical wastes.
- Since shallow groundwater quality has improved significantly, water suppliers should explore using the Upper Glacial aquifer as a water supply source for new or replacement supply wells. Shallower wells are less costly to install and operate and are not likely to accelerate saltwater intrusion into deeper portions of the groundwater system. Because the installation of shallower wells can negatively affect streamflow and water levels in surface water bodies, and be subject to saltwater impacts if located near the shoreline, locations should be selected accordingly.
- Federal and/or State agencies should continue to provide financial assistance to water suppliers for costs involved with installing treatment on supply wells and/or source cleanups in instances where the responsible polluters cannot be targeted.

5.3 The County's Role

For many decades all levels of government have played significant roles in the water industry in Nassau County. The most significant role, by far, in protecting the groundwater system during this time has been at the County level.

It is County government that has taken a leadership position in scientific studies necessary to understand how the groundwater system functions, the groundwater quantity and quality issues and, most importantly, has undertaken actions that deal with these issues on a County-wide scale. The County's role is not duplicated at the federal, State nor local level of government nor is it expected to be in the future. One must understand the past actions by County government in order to appreciate the need for its continued involvement in the future.

As the County began its rapid development in the 1930s and 1940s, the County Department of Public Works along with the County Department of Health realized that the groundwater resources to support the ever increasing population were being taxed more and more both in terms of water demand and groundwater quality degradation. Two major programs were initiated to address these concerns after comprehensive studies were completed by County engineers and supported by elected officials in federal, State, County and local governments. The first major program consisted of protecting the quantity of groundwater by means of the construction of recharge basins which serve to collect stormwater in order to both prevent local flooding and recharge the aquifers. Today there are over 800 such basins in the County which recharge billions of gallons of water annually into the groundwater system. This has helped ensure a plentiful supply of water for all consumers.

The second major program undertaken by the County consisted of protecting the quality of the groundwater. Billions of dollars were spent over several decades to install sanitary sewers and construct three wastewater treatment plants in order to prevent contamination of the water supply. The cost of designing and constructing these facilities was covered primarily by federal dollars with assistance from State and County governments. Also, special sewer districts were formed in several local municipal areas, providing additional sewering and treatment. Thus, today, over 90 percent of the population in the County is serviced by sanitary sewers thereby providing the best singular protection possible to the drinking water supply. Water quality data confirms the effectiveness of the program. This translates into a direct benefit in providing high quality drinking water to the County's residents without the need, in most instances, for treatment of the raw groundwater for health related substances.

The role of the County goes far beyond the construction and operation of recharge basins, sanitary sewers, and wastewater treatment facilities in managing the groundwater system. Constant surveillance of groundwater levels and quality is achieved by routinely taking measurements and groundwater samples from over 500 monitoring wells installed throughout the County. No other agency collects this magnitude of data, which is then computerized and made available to the public for a multitude of uses. Having developed a computerized groundwater model that simulates the movement of water in the aquifers, the County has been able to identify where contamination is moving once it enters the groundwater system. The model has been utilized to determine when and where saltwater intrusion may impact public wells near the shoreline. Likewise, it is being used to determine where new supply wells should be drilled so that saltwater intrusion would not occur nor would the well adversely affect streamflow and surface water bodies. Water conservation has been promoted and legislated in the past ten years in order to ensure the quantity of water available for the future. By working closely with the State and local water suppliers, the County has achieved conservation amounting to an average of 10 million gallons of water daily. As a result of this effort, the water table has risen by as much as 2 feet, thus enabling more groundwater to supply the valuable lakes and streams enjoyed by all.

While federal and State agencies are assigned the primary role of regulating the withdrawal of water and the discharge of waste products to the groundwater, they do not "manage" the groundwater system in the manner heretofore ascribed to the County. Although regulation and protection of the groundwater resource is essential, the reality is that groundwater problems do exist and will continue to occur as a result of 1.3 million people living above their water supply and utilizing it to meet their needs. Continued involvement by County government in seeking and developing detailed solutions to these problems is essential as has been proven over and over again.

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Glossary

Aeration - The introduction of air into a liquid usually accomplished by bubbling air through the liquid; commonly referred to as air stripping.

Anaerobic - A condition whereby no free oxygen is available.

Anisotropy - A condition in which the hydraulic conductivity varies with the direction of groundwater flow in an aquifer.

Aquifer - A water bearing formation capable of yielding significant quantities of water to wells and springs.

Baseflow - The portion of streamflow that is sustained by groundwater seepage into the stream channel.

Biodegradation - The destruction of organic matter as a result of the action of microorganisms in the soil and water.

Brackish - A term applied to waters whose mineral content is intermediate between that of freshwater and seawater. Dissolved solids range from 1,000 to 10,000 ppm.

Brine - Concentrated saline waters containing more than 36,000 ppm of dissolved solids.

Catch basin - A chamber, usually built at the curbline of a street, which collects stormwater runoff for discharge to a storm sewer.

cfs - Cubic feet per second; a unit of measure of the rate of liquid flow equal to the number of cubic feet passing a specific point in one second (see mgd).

Community water system - A public water system which serves at least five service connections used by year round residents or regularly serves at least 25 year round residents (NYS Sanitary Code).

Confining layer - A geologic formation in an aquifer, which, because of its position and its impermeability or low permeability relative to that of the aquifer, inhibits groundwater flow.

Consumptive use - That portion of water withdrawn from the groundwater system but not returned due to sanitary sewer discharges, industrial/commercial processes, transpiration from vegetative growth, evaporation to the atmosphere, etc.

Contamination - The introduction of microorganisms, chemicals, wastes, or wastewater into water at a concentration that makes the water unfit for potable use.

Downhole induction logging - A scientific method used to obtain information on the composition of a geologic formation or chemical characteristics of groundwater by measuring resistivity (or conductivity) resulting from induced electromagnetic currents in a borehole or through non-conductive casing in a borehole.

Drawdown - The magnitude of the lowering of the water surface in a well, and of the water table or piezometric surface adjacent to the well, resulting from the withdrawal of water from the well by pumping.

EPA - United States Environmental Protection Agency

Equilibrium - A state of balance such that inputs equal outputs.

Estuary - An area where freshwater meets saltwater (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as nurseries, spawning and feeding grounds for marine life and provide shelter and food for birds and wildlife.

Evapotranspiration - The combination of water lost from the land surface and surface water bodies due to evaporation plus the water lost from plants due to transpiration.

Freshwater - Water with a low mineral content that is generally considered fit for potable water use. Dissolved solids are less than 1,000 ppm.

Freshwater/saltwater interface - The boundary where fresh groundwater meets salty groundwater in an aquifer.

Filtration - The process by which a liquid is passed through a filter media to remove suspended or colloidal particles.

GAC - Granular activated carbon; adsorptive carbon granules possessing the capacity to remove soluble substances from a solution.

Groundwater - Subsurface water occupying the zone of saturation.

Groundwater model (computerized) - A representation of the groundwater system whereby data and theories concerning the behavior of the system are organized into mathematical equations that are solved by a computer.

Headwaters - The uppermost reach of a stream near its source.

Heavy metals - Toxic metals of high specific gravity, such as lead and chromium, which can be present in stormwater runoff and industrial waste.

Hydraulic conductivity - A measure of the relative ability of a fluid to be transmitted through a permeable media and a function of both the fluid and the media's physical characteristics.

Hydrologic cycle - The circulation of water movement from the atmosphere to the earth and back to the atmosphere through various processes that include precipitation, evaporation, and transpiration.

Impermeable layer - A geologic formation which, for practical purposes, does not allow the movement of water.

Infiltration - The downward flow of water through the pores of a soil or other porous medium.

Leachate - Water that has percolated through solid waste, such as in a landfill, and has extracted soluble substances.

MCL - Maximum contaminant level; a standard for drinking water quality that is protective of public health.

mgd - Million gallons per day; a measure of flow equivalent to 1.547 cfs.

NCDH - Nassau County Department of Health

NCDPW - Nassau County Department of Public Works

Nitrate - A form of nitrogen characteristic of sewage effluent, fertilizer, precipitation and decaying biological matter. A concern for infants when found in drinking water in concentrations of 10 ppm or more.

NYCDEP - New York City Department of Environmental Protection

NYSDEC - New York State Department of Environmental Conservation

NYSDOH - New York State Department of Health

Non-community water system - A public water system that is not a community water system (NYS Sanitary Code).

Oxidize - The addition of oxygen to a dissolved compound which can cause the compound to precipitate out of a solution (e.g., when dissolved iron or manganese oxidizes, a reddish brown sediment is formed).

ppb - Parts per billion; the number of units of a constituent present in a solution per one billion units of that solution (also referred to as micrograms per liter).

ppm - Parts per million; the number of units of a constituent present in a solution per one million units of that solution (also referred to as milligrams per liter).

pH - A measure of the concentration of hydrogen ions in a solution, which ranges from very acid (pH = 1) to alkaline (pH = 14). pH 7 is neutral and most groundwaters range between 5 and 7. pH values less than 6 are considered acidic, and most life forms cannot survive at pH of 4 or lower.

Per capita water demand - The water consumption, in gallons per day, attributed to each person in a community. Per capita demand is commonly based on the total water consumption from all sources in the community. It is actually more representative to base per capita demand solely on the residential component of water demand.

Permeability - The property of a material that permits appreciable movement of water to flow through it when the material is saturated.

Permissive sustained yield - See safe yield.

Plume - An elongated area of clearly defined groundwater contamination attributed to a specific source and moving in the direction of groundwater flow.

Potable - Water that is satisfactory for human consumption.

Public water system - A community or non-community water system which provides potable water to the public for human consumption, if such system has at least five service connections or regularly serves an average of at least 25 individuals daily at least 60 days of the year (NYS Sanitary Code).

Reach - A specific stretch along the length of a stream.

Recharge - The addition of water to the groundwater system from the infiltration of precipitation and stormwater runoff.

Recharge area - The land area for which there are downward components of hydraulic head in the aquifer. Water introduced at the land surface infiltrates downward into the deeper parts of an aquifer in these areas.

Retardation - A process which reduces the rate of travel of dissolved contaminants through an aquifer relative to the movement of groundwater flow. This reduction is caused by the dissolved contaminants interacting with the aquifer materials encountered along the groundwater flow path. These interactions include adsorption, advection, and ion exchange.

Safe yield - The amount of water than can be safely withdrawn from an aquifer for water supply without causing undesirable environmental impacts. Also referred to as permissive sustained yield.

Saltwater - Water in the seas that has a high mineral content. Dissolved solids range from 10,000 to 36,000 ppm.

Sanitary sewer - A conduit that carries liquid and waterborne wastes from residences, industrial/ commercial establishments, institutions, etc. to wastewater treatment facilities.

Seismic reflection - A scientific method used to obtain information on the character of geologic formations and groundwater chemistry by sending sound (seismic) waves from the land surface into the groundwater system. The information is obtained by measuring the time it takes for the seismic waves to pass through the subsurface material.

Specific capacity - The rate of yield of a well per unit drawdown, usually expressed as gallons per minute per foot of drawdown.

Sequester - The use of chemicals (sequestering agents) to prevent dissolved metals, such as iron and manganese, from precipitating out of solution. Sodium hexametaphosphate is a sequestering agent.

Storm sewer - A conduit that carries stormwater runoff, but excludes domestic wastewater and industrial/commercial wastes.

Stream - A course of running water flowing in a particular direction in a definite channel and discharging into some other body of water.

Stream corridor - The landscape features on both sides of a stream, including soils, slope, and vegetation. Any alterations can directly impact the stream's physical characteristics and biological properties.

Streamflow - The flow of water that occurs in a natural channel or surface stream course. This flow results from baseflow, stormwater runoff and diversions from other surface water features.

TDEM - Time domain electromagnetic survey; a scientific method used to obtain information on the chemical characteristics of groundwater. This method sends electromagnetic (low frequency) waves from the land surface into the groundwater system. By measuring the magnetic field associated with these currents, different geologic units and saltwater intrusion along coastal areas can be ascertained.

Time of travel - The time required for water to flow between two points, such as the time it takes groundwater to flow from the water table to a supply well.

Transpiration - The process by which plants give off water vapor through their leaves.

Turbidity - A condition in water caused by the presence of suspended particles imparting a visible haze or cloudiness to the water.

Underflow - In Nassau County, the component of groundwater flow that discharges to the surrounding saltwater bodies, and the net component of groundwater flow that is either discharged to or received from Suffolk and Queens counties.

VOCs - Volatile organic chemicals; synthetic organic chemicals containing carbon that are characterized as being highly mobile in groundwater and which are readily evaporated at relatively low temperatures into the atmosphere. Common sources of VOCs include solvents, degreasers, and petroleum products.

WAGNN - Water Authority of Great Neck North.

Water balance - An accounting of all components of flow of a groundwater system whereby inflows must equal outflows.

Watershed - A drainage area or basin in which all land areas and surface waters drain or flow toward a central catchment area at a lower elevation.

Water table - The upper surface of groundwater in an unconfined aquifer where water pressure is atmospheric.

Drinking Water Standards
for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards MCL
		Primary		Secondary	
		MCL	MCLG		
Asbestos (mf/L)	Asbestos	7	7	NA	7
Physical	Turbidity	0.5 - 1.0 NTU	NA	NA	5
	Color	**	**	15.0	15
	Odor	**	**	3.0	3
Inorganic (mg/L)	Arsenic	0.05	**	NA	0.05
	Barium	2.0	2.0	NA	2.0
	Cadmium	0.005	0.005	NA	0.005
	Chromium	0.1	0.1	NA	0.10
	Fluoride	4.0	4.0	NA	2.2 [1]
	Lead	[2]	Zero	NA	0.015 [2]
	Mercury	0.002	0.002	NA	0.002
	Selenium	0.05	0.05	NA	0.01
	Silver	**	**	0.10	0.05
	Chloride	**	**	250.0	250.0
	Copper	1.3	1.3	NA	1.3 [2]
	Iron	**	**	0.3	0.3 [3]
	Manganese	**	**	0.05	0.3 [3]
	Nitrate as N	10.0	10.0	NA	10.0 [4]
	Nitrite as N	1.0	1.0	NA	1.0 [4]

SOURCE: Nassau County Department of Health.

Drinking Water Standards
for Water Quality Parameters

Category of Analysis	*Constituents*	*USEPA Drinking Water Standards*			*New York State Drinking Water Standards MCL*
		Primary		*Secondary*	
		MCL	*MCLG*		
Inorganic (mg/L)	Sodium	**	**	**	[5]
(Continued)	Sulfate	Proposed	Proposed	250.0	250.0
	Zinc	**	**	5.0	5.0
	Antimony	0.006	0.006	NA	0.006
	Beryllium	0.004	0.004	NA	0.004
	Nickel	0.1	0.1	NA	0.1
	Thallium	0.002	0.0005	NA	0.002
	Cyanide, Free	0.2	0.2	NA	0.2
Corrosivity	pH	**	**	6.5-8.5	7.5 - 8.5 [6]
	Total Dissolved Solids	**	**	500.0	**
	Langelier Index	**	**	**	** [7]
Pesticides And SOCs (μg/L)	Alachlor	2.0	Zero	NA	2.0
	Aldicarb	3.0	1.0	NA	3.0
USEPA Phase II	Aldicarb Sulfoxide	4.0	1.0	NA	4.0
Or	Aldicarb Sulfone	2.0	1.0	NA	2.0
NYSDOH Group 1	Atrazine	3.0	3.0	NA	3.0
	Carbofuran	40.0	40.0	NA	40.0
	Chlordane, Total	2.0	Zero	NA	2.0
	1,2-Dibromo-3-Chloropropane (DBCP)	0.2	Zero	NA	0.2

SOURCE: Nassau County Department of Health.

Drinking Water Standards
for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards MCL
		Primary		Secondary	
		MCL	MCLG		
Pesticides And SOCs (µg/L)	2,4-D	70.0	70.0	NA	50.0
(Continued)	Endrin	2.0	2.0	NA	0.2
USEPA Phase II	1,2-Dibromoethane (EDB)	0.05	Zero	NA	0.05
Or	Heptachlor	0.4	Zero	NA	0.4
NYSDOH Group 1	Heptachlor Epoxide	0.2	Zero	NA	0.2
	Lindane	0.2	0.2	NA	0.2
	Methoxychlor	40.0	40.0	NA	40.0
	Polychlorinated Biphenyl (PCB)	0.5	Zero	NA	0.5
	Pentachlorophenol	1.0	Zero	NA	1.0
	Toxaphene	3.0	Zero	NA	3.0
	2,4,5-TP (Silvex)	50.0	50.0	NA	10.0
Pesticides And SOCs (µg/L)	Aldrin	**	**	NA	5.0
	Benzo (a) Pyrene (PAHs)	0.2	Zero	NA	0.2
USEPA Phase V	Butachlor	**	**	NA	50.0
Or	Carbaryl	**	**	NA	50.0
NYSDOH Group 2	Dalapon	200.0	200.0	NA	200.0
	Di (2-Ethylhexyl) Adipate	400.0	400.0	NA	400.0
	Di (2-Ethylhexyl) Phthalates	6.0	Zero	NA	6.0
	Dicamba	**	**	NA	50.0
	Dieldrin	**	**	NA	5.0
	Dinoseb	7.0	7.0	NA	7.0
	Glyphosate	700.0	700.0	NA	700.0
	Hexachlorobenzene	1.0	Zero	NA	1.0
	Hexachlorocyclopentadiene	50.0	50.0	NA	50.0
	3-Hydroxycarbofuran	**	**	NA	50.0
	Methomyl	**	**	NA	50.0

SOURCE: Nassau County Department of Health.

Drinking Water Standards
for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards MCL
		Primary		Secondary	
		MCL	MCLG		
Pesticides And SOCs (µg/L)	Metolachlor	**	**	NA	50.0
(Continued)	Metribuzin	**	**	NA	50.0
USEPA Phase V	Oxamyl (Vydate)	200.0	200.0	NA	200.0
Or	Picloram	500.0	500.0	NA	500.0
NYSDOH Group 2	Propachlor	**	**	NA	50.0
	Simazine	4.0	4.0	NA	4.0
Pesticides And SOCs (µg/L)	Diquat	20.0	20.0	NA	20.0
	Endothall	100.0	100.0	NA	100.0
[Areawide Waiver For Monitoring]	2,3,7,8-TCDD (Dioxin)	3×10^{-5}	Zero	NA	0.03
Principal Organic Contaminants I	Bromochloromethane	**	**	NA	5.0
Volatile Halocarbons	Bromomethane	**	**	NA	5.0
(µg/L)	Carbon Tetrachloride	5.0	Zero	NA	5.0
	Chloroethane	**	**	NA	5.0
	Chloromethane	**	**	NA	5.0
	Dibromomethane	**	**	NA	5.0
	Dichlorodifluoromethane	**	**	NA	5.0
	1,1-Dichloroethane	**	**	NA	5.0
	1,2-Dichloroethane	5.0	Zero	NA	5.0
	1,1-Dichloroethylene	7.0	7.0	NA	5.0
	cis-1,2-Dichloroethylene	70.0	70.0	NA	5.0
	trans-1,2-Dichloroethylene	100.0	100.0	NA	5.0
	1,2-Dichloropropane	5.0	Zero	NA	5.0
	1,3-Dichloropropane	**	**	NA	5.0
	2,2-Dichloropropane	**	**	NA	5.0

SOURCE: Nassau County Department of Health.

Drinking Water Standards for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards MCL
		Primary		Secondary	
		MCL	MCLG		
Principal Organic Contaminants I Volatile Halocarbons (µg/L) *(Continued)*	1,1-Dichloropropene	**	**	NA	5.0
	cis-1,3-Dichloropropene	**	**	NA	5.0
	trans-1,3-Dichloropropene	**	**	NA	5.0
	Dichloromethane	5.0	Zero	NA	5.0
	1,1,1,2-Tetrachloroethane	**	**	NA	5.0
	1,1,2,2-Tetrachloroethane	**	**	NA	5.0
	Tetrachloroethylene	5.0	Zero	NA	5.0
	1,1,1-Trichloroethane	200.0	200.0	NA	5.0
	1,1,2-Trichloroethane	5.0	3.0	NA	5.0
	Trichloroethylene	5.0	Zero	NA	5.0
	Trichlorofluoromethane	**	**	NA	5.0
	1,2,3-Trichloropropane	**	**	NA	5.0
	Vinyl Chloride	2.0	Zero	NA	2.0
	Bromoform	**	**	NA	50.0
	Bromodichloromethane	**	**	NA	50.0
	Chloroform	**	**	NA	50.0
	Chlorodibromomethane	**	**	NA	50.0
Principal Organic Contaminants II Volatile Aromatics (µg/L)	Benzene	5.0	Zero	NA	5.0
	Bromobenzene	**	**	NA	5.0
	n-Butylbenzene	**	**	NA	5.0
	sec-Butylbenzene	**	**	NA	5.0
	tert-Butylbenzene	**	**	NA	5.0
	Chlorobenzene	100.0	100.0	NA	5.0
	o-Chlorotoluene	**	**	NA	5.0
	p-Chlorotoluene	**	**	NA	5.0
	m-Dichlorobenzene	**	**	NA	5.0

SOURCE: Nassau County Department of Health.

Drinking Water Standards for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards
		Primary		Secondary	
		MCL	MCLG		MCL
Principal Organic Contaminants II Volatile Aromatics (µg/L) *(Continued)*	o-Dichlorobenzene	600.0	600.0	NA	5.0
	p-Dichlorobenzene	75.0	75.0	NA	5.0
	Ethylbenzene	700.0	700.0	NA	5.0
	Hexachlorobutadiene	**	**	NA	5.0
	Isopropylbenzene	**	**	NA	5.0
	p-Isopropyltoluene (Cymene)	**	**	NA	5.0
	n-Propylbenzene	**	**	NA	5.0
	Styrene	100.0	100.0	NA	5.0
	Toluene	1,000.0	1,000.0	NA	5.0
	1,2,3-Trichlorobenzene	**	**	NA	5.0
	1,2,4-Trichlorobenzene	70.0	70.0	NA	5.0
	1,2,4-Trimethylbenzene	**	**	NA	5.0
	1,3,5-Trimethylbenzene	**	**	NA	5.0
	m-Xylene	10,000.0 [8]	10,000.0 [8]	NA	5.0
	o-Xylene	[8]	[8]	NA	5.0
	p-Xylene	[8]	[8]	NA	5.0
Trihalomethanes (µg/L)	Total Trihalomethanes	100.0	NA	NA	100.0

SOURCE: Nassau County Department of Health.

Drinking Water Standards
for Water Quality Parameters

Category of Analysis	Constituents	USEPA Drinking Water Standards			New York State Drinking Water Standards MCL
		Primary		Secondary	
		MCL	MCLG		
Microbiological	Total Coliform	Not Detected	Zero	NA	None Detected
	Escherichia Coliform	[9]	[9]	NA	None Detected
Radiological (pc/L)	Gross Alpha Activity	15	Zero	NA	15

KEY:
mg/L - Milligrams per liter (Parts per million)
µg/L - Micrograms per liter (Parts per billion)

[1] - In supplies that fluoridate, the fluoride level must be maintained in the range of 0.8 to 1.2 mg/L
[2] - Action level set at 0.015 mg/L for lead, action level set at 1.3 mg/L for copper
[3] - Combined concentration of iron and manganese should not exceed 0.5 mg/L
[4] - Total nitrate and nitrite should not exceed 10.0 mg/l.
[5] - The NYDOH recommends that the sodium level not exceed 20 mg/L for severely restricted sodium diets and 270 mg/L for moderately restricted sodium diets.
[6] - NCDH guideline
[7] - The NCDH recommends that the Langelier Saturation Index should be as close to zero as possible.
[8] - Total Xylenes - 10,000 µg/L
[9] - The E. coliform test is only required in a sample where the total coliform is positive.
** - Monitoring requirements only - no MCL or MCLG specified

SOURCE: Nassau County Department of Health.