STATE OF THE AQUIFER

2016

LICAP

Long Island Commission for Aquifer Protection

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December 2, 2016

Dear Reader:

The Long Island Commission for Aquifer Protection's (LICAP) 2016 State of the Aquifer Report was published following a lengthy public comment period in which Long Island residents were invited to offer their comments, questions, concerns and recommendations on an initial draft report. Public comment was submitted to LICAP, both in writing and in person, during one of the commission's three public hearings hosted throughout the region in October of 2016.

While not every recommendation received during this public comment period is reflected in the 2016 State of the Aquifer Report, the voting members of LICAP would like to thank all those who submitted testimony. Having your input is critical to our success and many of the recommendations not included in this year's report will be included in either the 2017 State of the Aquifer Report or the upcoming LICAP Groundwater Resource Management Plan. Future topics to be addressed include, but are not limited to:

1) An analysis of wastewater, sewers and septic systems on Long Island and their effect on surface and drinking water contamination, including recommendations for solutions.

2) Updates on the status of the various contamination plumes throughout both Nassau and Suffolk Counties including the Grumman Naval Plume, and what action is being taken to remediate these plumes.

3) A continuation of LICAP's efforts to create a comprehensive Island-Wide Water Quality database and Monitoring Program.

4) An analysis of surface water pollution on Long Island that encompasses the effects of nitrates, pesticides and other compounds; as well as the impact surface water pollution has on Long Island's drinking water.

5) Continue to fill in significant "data gaps" that historically have made analyzing water quality difficult.

Sincerely,

LICAP voting members:

Frank Koch	Stan Carey	Jeffrey W. Szabo
Walter Dawydiak	Don Irwin	Brian Schneider
Dorian Dale	Chris Ostuni	Michael White

Table of Contents

Welcome

In late 2013, a group consisting of water utility representatives, elected officials and scientists joined to form the Long Island Commission for Aquifer Protection (LICAP) to assess the long-term health of Long Island's aquifer system and to develop a blueprint for its protection. This inaugural State of the Aquifer report is the first step in realizing these goals. We hope that this report, which will be updated every year, will serve as a vital tool in keeping Long Island residents informed about the aquifers that provide all of our drinking water and helping them to make better decisions about how to keep our drinking water safe.

A noteworthy finding during LICAP's first two years is that there are significant data gaps in island-wide water quality information that make it very difficult to draw any definitive conclusions about patterns of contamination. One primary objective of LICAP is to create a water quality database connecting all of Long Island, as well as an island-wide monitoring program. We expect that these steps will help us to better draw conclusions about specific threats to the aquifer system and the potential damage of each threat.

While there can be no doubt that Long Island's groundwater faces threats every day, island residents can be assured that the quality of the drinking water provided by Nassau and Suffolk's public water suppliers is excellent and will continue to be so in the future. Given the extensive water quality testing required of these providers by state and federal law, the millions of dollars spent on treatment systems to remediate contaminants, state-of-the-art technologies including computerized groundwater and distribution system models and the technical expertise of those overseeing Long Island's aquifers, groundwater-related threats can be prevented from becoming drinking water problems impacting Long Island residents. As a result, Long Island's public drinking water supply remains safe .

The purpose and primary focus of this first State of the Aquifer report is to ensure that as many Long Islanders as possible understand that all the water they drink comes from the ground directly beneath us, and thus the actions we take directly above it impact the quality of the water we depend on for daily use. With this in mind, we've included in this report information about the water cycle, how the aquifer system beneath Long Island was formed geologically, the various systems used to collect and treat wastewater, how land use and population growth have influenced water quality and quantity, the threat from saltwater contamination and other contaminants and the overall quantity of water in our aquifer system in relation to the amount we use. Since we are all living and working directly on top of our water supply, issues concerning the quality and quantity of water in Long Island's aquifers directly impact the quality of all of our lives.

Sincerely,

Frank Koch
Current Chairman, LICAP

Jeffrey W. Szabo
Past Chairman, LICAP

Members of the Long Island Commission for Aquifer Protection and the organizations, government entities or agencies they represent.

Seated from left:
Sarah Meyland, *Nassau County Legislature Minority Leader*
Stan Carey, *Nassau-Suffolk Water Commissioners*
Carrie Meek Gallagher, *New York State Department of Environmental Conservation*
Stephen Terracciano, *United States Geological Survey*

Standing, from left:
Frank Koch, *Long Island Water Conference*
Don Irwin, *Nassau County Department of Health*
Brian Schneider, *Nassau County Executive's Office*
Michael White, *Suffolk County Legislature's Presiding Officer*
Walter Dawydiak, *Suffolk County Department of Health*
Chris Ostuni, *Nassau County Legislature*
Jared Hershkowitz, *Suffolk County Legislature's Presiding Officer.*
Absent: Past Chaiman, Jeffrey Szabo

LICAP Facts

FOUNDED: By unanimous votes of the Suffolk County and Nassau County Legislatures in 2013.

MISSION: To advance a coordinated, regional approach to the protection of Long Island's sole source aquifer through the preparation of a State of the Aquifer Report, to be updated annually, and a Groundwater Resources Management Plan.

MEMBERS: LICAP has nine members. The Suffolk County Water Authority, the Long Island Water Conference, the Nassau-Suffolk Water Commissioners Association and the Nassau and Suffolk Departments of Health are permanent members. Additionally, the Nassau and Suffolk County Executive each appoint one member as do the presiding officers of each county's Legislature. There are also 13 ex-officio members with no voting power.

COMMITTEE STRUCTURE: LICAP maintains two standing subcommittees: the 2040 Water Resources and Infrastructure Subcommittee will identify long-term risks to the water supply industry created by global climate change. The Water Resource Opportunities Subcommittee will identify and quantify short-term risks, if any, to groundwater resources.

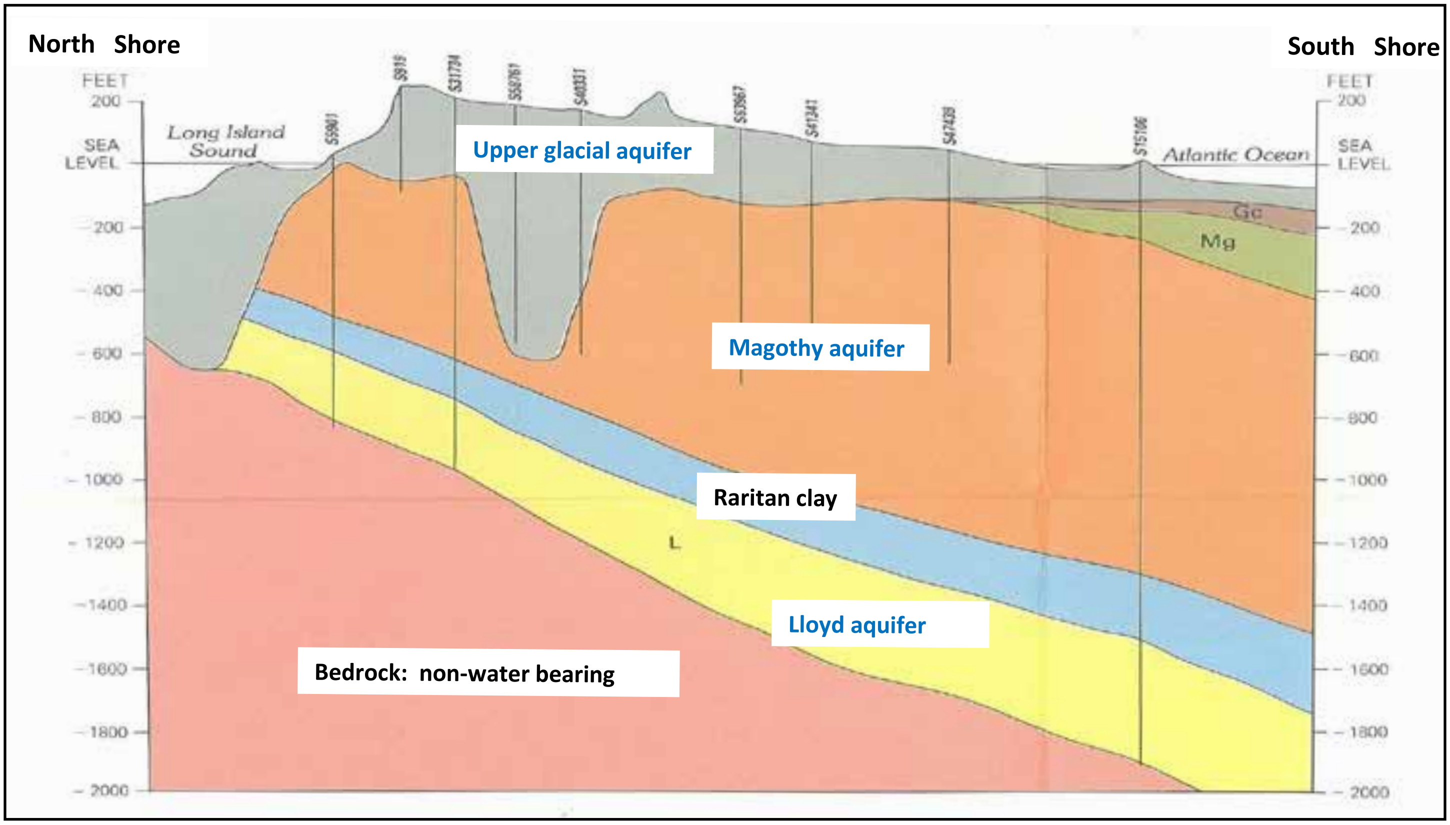
MEETINGS: LICAP is required to meet at least quarterly and hold one public hearing in each county annually.

The State of the Aquifer: Our Most Valuable Natural Resource Faces Challenges

The quality of water supplied to Long Island's residents by their community public water suppliers continues to be excellent, meeting or surpassing all federal and state standards. Local contamination issues are present in various locations in both Nassau County and Suffolk County, and some areas of Long Island face water quantity issues as well. Finding solutions to these issues is an ongoing task for Long Island's water professionals.

This report, and the formation of the Long Island Commission for Aquifer Protection itself, are part of the effort to address these challenges in a coordinated, regional manner. LICAP's goal is to play a vital role in making sure Long Island residents will always continue to enjoy the high quality of life that results from healthy groundwater resources.

Where Does Our Water Come From?



Geologic cross section ("layer cake") showing major aquifers beneath Long Island. Also shown are significant non-water bearing units - The Monmouth Greensand (Mg), the Gordiners Clay (Gc) and Raritan Clay and the Bedrock. (Source: USGS HA-709, 1989).

All water used by Long Islanders for drinking and all other purposes comes from groundwater situated below the land surface. Groundwater is found virtually everywhere beneath Long Island, contained within naturally occurring geologic formations known as aquifers. Long Island's aquifers are underground sand or gravel formations that store and yield significant quantities of water. The water itself is found in the empty spaces, or voids, between the sand and gravel grains. Water within the aquifers behaves in a manner similar to an underground sponge filled with water.

On Long Island, water initially enters these aquifers solely from precipitation (rain, snowmelt, sleet and hail) that falls to the ground and percolates vertically through Long Island's permeable soils until it reaches the aquifers. The "water table" represents the upper most part of groundwater stored in the aquifer system. Below the water table, the voids between the grains of sediment are completely saturated with groundwater. The water table lies just beneath the land surface at coastal locations. Beneath some hilly locations on central Long Island, the water table may be several hundred feet below the land surface.

Most parts of Long Island receive from 42 to 50 inches of precipitation per year (*http://ny.water.usgs.gov/pubs/wri014165/wrir01-4165.pdf - p. 8)* Approximately half of this precipitation is lost to evaporation, the biological processes of plants (known as "transpiration"), or to surface waters ("runoff"). Approximately half of all precipitation enters the aquifer system ("recharge"). Recharge is far greater during the non-growing season (mid-September to mid-May) since evaporation and plant activity (together known as "evapotranspiration") are much less than during the warm months. Conversely, during the summer, very little recharge to the groundwater system occurs. The overall volume of precipitation that is recharged to the aquifer system, averaged all across Long Island and averaged throughout the year, amounts to approximately one million gallons per day of recharge for every square mile of land on Long Island.

The three principal Long Island aquifers are the upper glacial aquifer, the Magothy aquifer, and the Lloyd aquifer. The upper glacial aquifer directly underlies the ground surface. It was formed during the last ice age (approximately 10,000 years ago), as large masses of ice, known as glaciers, covered a large portion of North America, including parts of Long Island. The ice, and the meltwater streams emanating from the ice, deposited the boulders found on the North Shore, and the sandy plains of the south shore. The water bearing sediments of the upper glacial aquifer typically consist of coarse sand and gravel, with some larger pebbles and boulders as well. Wells that tap this aquifer are capable of producing very large quantities of water. However, because it is the shallowest and most permeable of Long Island's aquifers, it is also most prone to contamination from land-derived sources. The vast majority of wells that provide water to farms, golf courses, and industry take water from the upper glacial aquifer. Additionally, most private wells that serve individual homes tap the upper glacial aquifer. The upper glacial aquifer is used for public supply purposes primarily on eastern Long Island, where the population is less dense, and the threat of contamination is also reduced. Many of these public supply wells require some type of treatment for land-derived contaminants. These contaminants and the treatment facilities will be described in greater detail in later sections of this report.

How did the Long Island aquifer system form?

The sediments that comprise Long Island's aquifers were deposited during two distinct time periods in geologic history. The Lloyd and Magothy aquifers were formed approximately 60 to 140 million years ago by the deposition of sediments originating from the erosion of the Appalachian Mountains located to the west of Long Island. The Long Island area at that time resembled the Mississippi River Delta in terms of climate and surface characteristics. The upper glacial aquifer was formed approximately 10,000 years ago when the large continental glaciers that covered large portions of North America (including present-day Long Island) melted. The ice itself, as well as the streams emanating from the ice sheets as they melted, carried sand and gravel southward from them. They also left behind the large boulders observable today on the North Shore of Long Island and the sandy hills of central Long Island. These latter two features, known as "terminal moraines", indicate the actual southernmost advancement of the ice sheets themselves.

The Magothy aquifer is the largest and most extensive of Long Island's aquifers, and was formed approximately 65 million years ago. It contains sediments derived from erosion of the mountains to the west of Long Island. Consisting of fine sand and silt deposits alternating with clay, it attains a maximum thickness of approximately 1,100 feet in southeastern Suffolk County. The Magothy aquifer on Long Island is similar to coastal plain aquifers found up and down the east coast, as far south as the Carolinas. Water in the deepest portions of the Magothy aquifer on Long Island can be as much as 800 hundred years old. Though not as permeable as the upper glacial aquifer, wells that tap the Magothy aquifer are still usually capable of pumping large quantities of water. The vast majority of Long Island's public supply wells take water from the Magothy aquifer. A notable exception is on the North and South Forks of eastern Suffolk. In those areas, most of the Magothy aquifer contains naturally salty groundwater, and so public suppliers must utilize the upper glacial aquifer. There are also areas on Long Island where the Magothy aquifer is not present. Most of these areas are on the North Shore, where the actions of the glaciers gouged out large sections of the Magothy aquifer long after it was initially deposited. In western Nassau County high levels of groundwater pumpage in the Magothy aquifer have caused some degree of saltwater intrusion in portions of the barrier island communities on the South Shore of the County (Atlantic Beach, Lido Beach and Long Beach), and on the peninsulas on the North Shore (Great Neck, Manhasset Neck). This salt water intrusion in the Magothy on the south shore has also reached far enough inland to affect more "mainland" areas as well. Later sections of this report discuss this issue in greater detail.

The Raritan Formation underlies the Magothy, and was formed in a similar manner to the Magothy. Its two primary units are an upper clay member (the "Raritan clay") and a lower sand member named the Lloyd sand. The clay member is very impermeable in most areas, and so helps to minimize the movement of contaminants between the Magothy and Lloyd aquifers. Geologists call formations such as the Raritan clay a "confining" unit. The lower sand unit of the Raritan Formation comprises the Lloyd aquifer.

The Lloyd aquifer is the deepest and oldest of Long Island's aquifers. It consists mostly of fine sand and silt, and ranges from zero to 500 feet thick. At its deepest, it is approximately 1,800 feet below the surface. The water contained in the Lloyd aquifer can be as old as several thousand years. The Lloyd aquifer is not used as extensively as the Magothy, since the Magothy is a highly productive aquifer, and because a moratorium on construction of new Lloyd wells was enacted in 1986 by the New York State Legislature. Due to its depth and degree of "confinement" by the overlying Raritan clay, the Lloyd is generally much less prone to contamination than either the upper glacial or the Magothy aquifers. However, due to its lower permeability and its confined nature, it is not as productive as the other two aquifers. Nevertheless, approximately 40 public supply wells in Nassau County and five public supply wells in Suffolk County draw water from the Lloyd aquifer. Most of these wells were permitted prior to the 1986 moratorium. Some western Nassau water suppliers have seen saltwater intrusion in parts of the Lloyd aquifer as a result of the extensive pumping. The Lloyd is underlain by bedrock, which is not a source of water on Long Island. Several exploratory borings have been drilled through the full extent of the aquifer system and into the bedrock. However, these have been largely for "academic" studies, rather than for the purpose of pumping water from them. There are also several other geologic layers found beneath Long Island that are not water bearing. They include the Gardiners clay and the Monmouth Greensand. They are situated beneath the upper glacial aquifer and above the Magothy, and are considered "confining units" *(https://pubs.er.usgs.gov/publication/ofr95401 - p. 6).* These formations are typically found throughout the south shore of Long Island, and are important on a local scale.

These three major aquifers, together with several minor aquifers that occur in portions of Nassau County, comprise what is known as the Long Island aquifer system. Since this aquifer system is the only source of drinking water for Nassau and Suffolk Counties, in 1978, the United States Environmental Protection Agency (USEPA) designated the Long Island Aquifer System a "sole source aquifer," thereby affording it a high degree of legal protection.

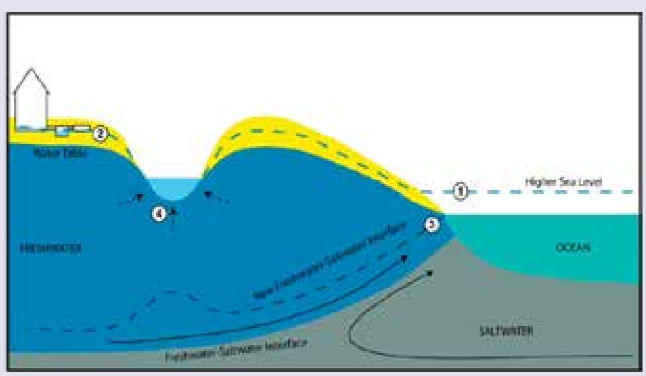
In addition to groundwater's importance as a critical resource for drinking and other purposes, virtually all surface water bodies on Long Island exist because of groundwater that naturally discharges into them. There are over 100 stream channels on Long Island, typically less than five miles long, that flow to the tidewater that surrounds Long Island. The channels were formed by glacial melt water and therefore are more abundant along the southern shore than along the northern shore. Groundwater discharge to streams has a major effect on flow patterns within the groundwater system. Under pre-development conditions, about 21 percent of precipitation was discharged to streams *(http://ny.water.usgs.gov/projects/SOTA/aquifer.html)*.

Under natural conditions, approximately 90% of the flow of rivers and creeks is due to the contribu-

Sea Level Rise Impact on Coastal Water Resource

Should even the most moderate predictions of sea level rise be accurate, levels will rise two feet between now and 2100, more than tripling the frequency of dangerous coastal flooding throughout most of the Northeast. Subsidence will compound, with the coastal land mass of New York slowly sinking at 1.35 mm/yr *(http://www.ngs.noaa.gov/CORS_Map/).* In addition there has been a 70% rise in extreme precipitation in the Northeast, from 1958 to 2010.

Sea level will impact coastal groundwater systems, raising the fresh water table, thus increasing basement flooding and septic system failure. Groundwater supplies can be contaminated due to landward and upward movement of seawater in coastal aquifers, impacting the freshwater-saltwater interface near public groundwater supply wells. Pumping from public supply wells in coastal aquifers underlain by saltwater can lower the water table with respect to sea level, decreasing the depth to the freshwater-saltwater interface beneath the pumping well. This increases the potential for saltwater intrusion, and potentially limits the amount of potable water available from the well. *(http://wh.er.usgs.gov/slr/coastalgroundwater.html)*



A rise in sea level will affect groundwater flow in coastal aquifers (1). An increase in the elevation of the water table (dashed–blue line) may result in basement flooding and compromise septic systems (2). A rise in sea level may also result in an upward and landward shift in the position of the freshwater-saltwater interface (3). Where streams are present, an increase in the watertable elevation also may increase groundwater discharge to streams and result in local changes in the underlying freshwater-saltwater interface (4).

tion by groundwater discharging into them, while only about 10% of their flow is attributable to surface runoff. Therefore, all of Long Island's surface waters (rivers, lakes, and estuaries such as the Great South Bay) depend on groundwater in order to maintain their viability and health.

In developed portions of western Long Island, the combination of both intense groundwater pumpage and regional sewering has reduced the volume of groundwater to the point where it has seriously affected surface water bodies.

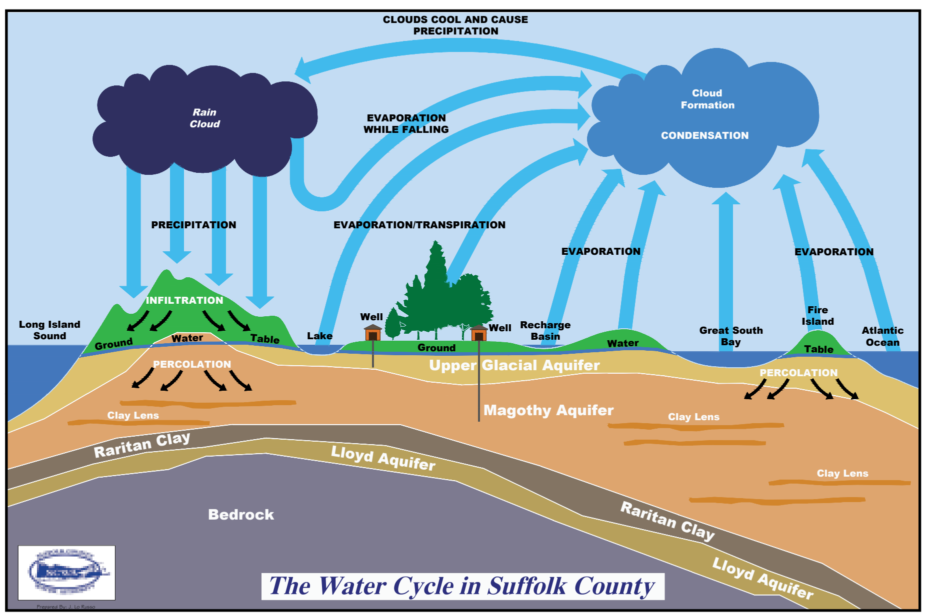
In contrast, in unsewered areas of central and eastern Long Island, the use of cesspools and septic systems has not affected the overall quantity of groundwater. However, the quality of shallow groundwater has become impaired to some degree, and this has negatively affected water quality in rivers, creeks and bays. As the quality and quantity of Long Island's groundwater changes over time, so too will the health of these critical surface water ecosystems.

All of Long Island's surface waters (rivers, lakes, and estuaries such as the Great South Bay) depend on groundwater in order to maintain their viability and health.

The Water Cycle

The overall quantity of water within the Earth and its atmosphere has remained the same throughout the Earth's history. The Earth's water may change its phase—solid, liquid, vapor, or gas—or its location—the ocean, a glacier, river, or below ground,—but the overall quantity of the Earth's water is a constant. On Long Island, we are fortunate to be located in an area of relatively abundant fresh water. Many places on the Earth, such as deserts or small, isolated islands - have much less available fresh water. The water cycle—also known as the "hydrologic cycle"—is the term used to describe everything that happens to water as it moves, or cycles, through the earth and the atmosphere. Since water is in constant motion throughout the earth and its atmosphere, the water cycle has no beginning and no end. In this example, we will begin our entrance into the water cycle in the Earth's oceans.

As heat from the sun warms the water in the oceans, some of that water evaporates and rises into the air. Additional water enters the atmosphere as plants give off water through their biological activity, which is known as transpiration. The combination of these two processes is known as evapotranspiration. Water given off by evapotranspiration rises into the atmosphere to a certain point, at which the atmosphere becomes saturated with water vapor. This



Water Cycle Definitions:

Condensation *– the change in state from a gas or vapor to a liquid.*

Evaporation *– the conversion of a liquid to the vapor state.*

Evapotranspiration *– the overall process whereby water is released to the atmosphere from plants and animals (transpiration), as well as evaporated from soils and surface water bodies.*

Infiltration *– the process by which water enters the subsurface.*

Precipitation *– the falling of water in liquid or solid form that occurs when the atmosphere becomes saturated with water vapor.*

Recharge *– the addition of water into the aquifer system.*

water then condenses to create clouds. As clouds continue to accumulate more water vapor, this vapor falls from them as precipitation. Once precipitation reaches the land surface, it can take several different paths.

Some precipitation falls on impervious surfaces such as pavement, and flows over land into surface water bodies (lakes or streams). This process is known as runoff. Some precipitation may be immediately utilized by plants, and some may also evaporate quickly after reaching the surface ("evapotranspiration" as described above). Approximately 50% of precipitation enters the underground aquifers as recharge. On a yearly basis, the recharge to the aquifer system from precipitation amounts to approximately one million gallons per day per square mile of land on Long Island.

Once water enters the aquifer system, it moves from areas of higher elevation to areas of lower elevation. The average speed of groundwater flow is approximately one foot per day in the horizontal direction, and approximately 1/10 of a foot per day vertically. The speed at which groundwater moves through the aquifers depends upon a number of factors. Some groundwater will flow naturally out of the aquifers (or "discharge") into surface waters, such as rivers, lakes, tidal waters (such as the Great South Bay), or far offshore beneath the Atlantic Ocean or the Long Island Sound. This journey, from where water enters the aquifer as precipitation, to where it discharges from the aquifer, may take up to several thousand years under natural conditions. Some groundwater discharges by being pumped from a well. The pumping of wells can greatly accelerate this horizontal and vertical movement. For this reason, contaminants introduced at the surface can be drawn into the deeper aquifers much faster than if there were no pumping.

Will Long Island Run Out of Water?

Nassau and Suffolk counties together comprise approximately 1,200 square miles of land mass. The aquifer system extends beneath virtually all of this land mass (and beneath many of the bays and inlets, and into Queens and Brooklyn as well), and varies in thickness from a few hun- dred feet beneath the north shore of Nassau, to well over 2,000 feet beneath southeastern Suffolk County. Using only the two-county land surface area, and using a conservative estimate of 1000 feet (roughly 2/10 of a mile) for its average thickness, this amounts to a volume of 240 cubic miles of saturated aquifer material beneath the two counties. Given the typical porosity of 25 percent for sand and gravel aquifers, one can calculate that Nassau and Suffolk counties together have over 65 trillion gallons of groundwater stored within its aquifer system. However, only 5% to 10% of this volume is extractable from the aquifers, which limits the available volume of water to no more than 6.5 trillion gallons. Precipitation adds approximately 300 billion gallons of recharge to the aquifers annually. The total annual pumpage from the aquifers beneath Nassau and Suffolk Counties is approximately 150 to 200 billion gallons. Therefore, total pumpage is less than recharge by precipitation, and much less than the overall volume that is available for extraction.

However, this does not mean that water can be pumped freely from the aquifers without any impacts. Water is always moving through the aquifers from the center of Long Island toward the shorelines. Under natural conditions, the amount of water entering the aquifers is in balance with the water leaving the aquifers. Any use of groundwater, and any change in surface activities will have some effect on the quantity and/or the quality of Long Island's groundwater.

For example, if increased pumping removes a substantial amount of groundwater, the aquifer system adjusts to regain a new balance. The adjustments can include: lowering of the water table, loss of stream flow, saltwater intrusion, reduced outflow to coastal waters, and ultimately a change in the recharge zones to the aquifers. Excessive pumping from deep aquifers may increase the movement of contaminants into deeper aquifers, thus affecting their water quality. Beneath Suffolk County the aquifer system is largely in hydrologic balance and adverse changes have not yet been observed. Beneath Nassau County, conditions in the aquifer system show a notable response to overpumping and the aquifer system has an imbalance. More water is leaving the aquifers than is entering by recharge in Nassau, and saltwater intrusion is actively occurring in small portions of Nassau County. Stream flow hasis been sharply reduced in south shore streams due to a drop in the water table. Further attention to these problems is necessary in Nassau in order to bring them under control.

So, while Long Island is not expected to "run out of water" in the future, improper management of its groundwater resources will affect groundwater quality and quantity, and ultimately our quality of life. Proactive management of Long Island's groundwater is required in order to reverse and/or prevent the previously described problems.

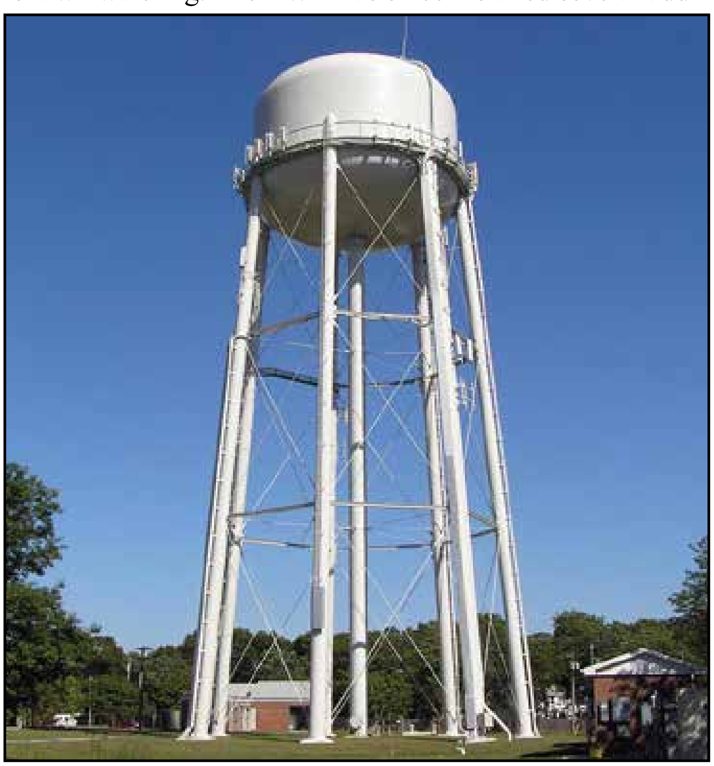
Water Efficiency and Conservation

In many parts of the United States, the main purpose of water conservation is to reduce consumption as much as possible in order to maximize the life of a very limited resource. Strict water use limitations and water conservation measures are a normal part of everyday life in many parts of the United States. Conservation on Long Island is not a matter of preserving a limited quantity of water, but rather one of using our groundwater more efficiently and managing peak usage of water, especially for non-potable purposes such as lawn irrigation.

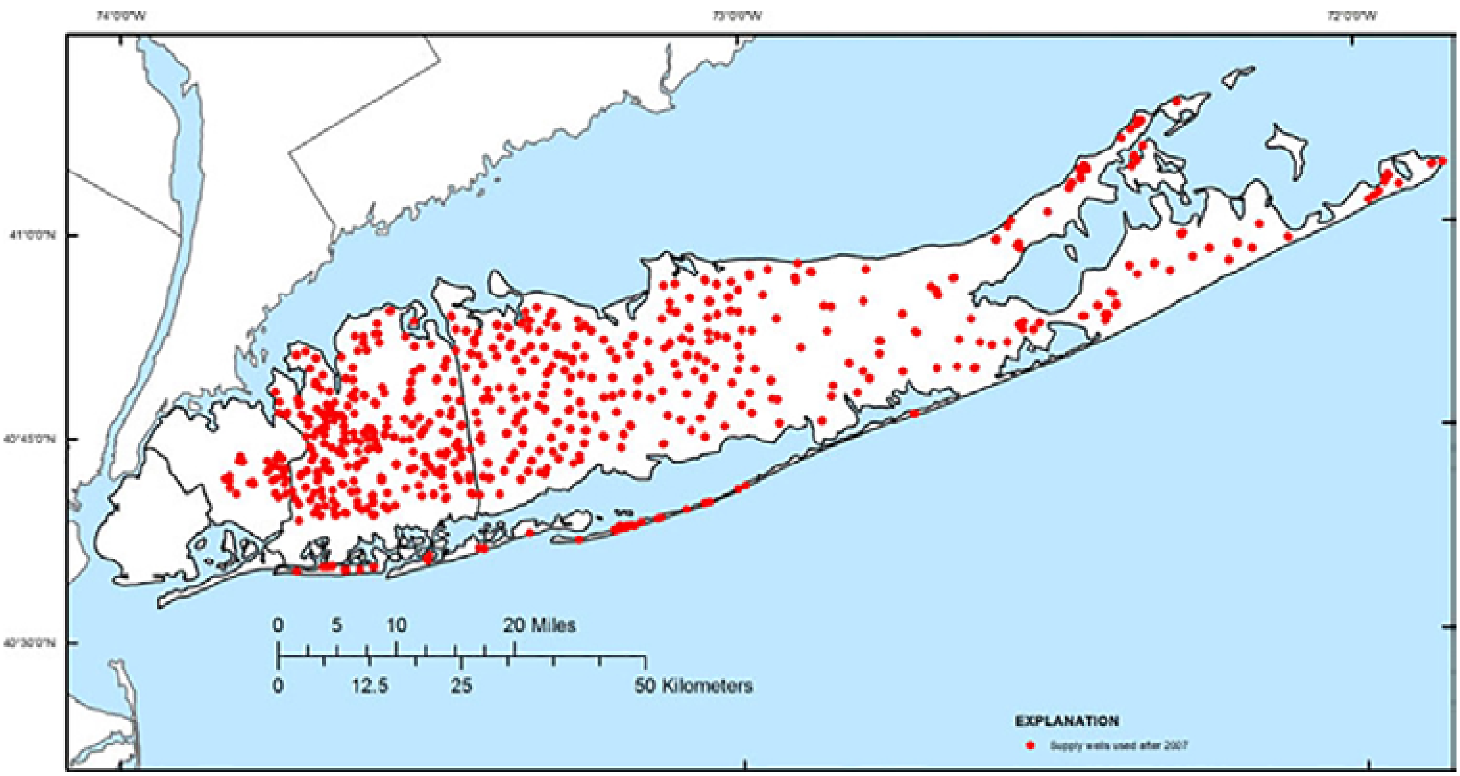
Some savings in indoor water uses have been realized on Long Island through the use of low flow plumbing fixtures (toilets, shower heads), but the most significant potential for conservation and demand management lies in addressing outdoor water use, particularly lawn watering. According the Suffolk County Comprehensive Water Resources Management Plan *("Comp Plan")*, approximately 30 to 60 percent of total pumpage from two of Suffolk's largest water suppliers can be attributed to outdoor use *(p. 4-36).* The Riverhead Water District (RWD) experienced severe increases in demand during the hot, dry summer of 2010, when pumping of all of the District's 13 wells was not sufficient to keep up with demand on several peak days. The Riverhead area experiences a seasonal population increase during the summertime, so some of this water use can be attributed to tourism. However, a large portion of this increase in water demand is attributable to lawn watering. The RWD has since installed several additional wells to meet this summertime demand, but a conservation program to reduce peak pumpage would be beneficial.

One Town in Suffolk County that has imposed strict conservation measures is the town of Shelter Island. Given the limited fresh water resources on the Island, new sprinkler systems have been outlawed for several years, and existing systems were required to be abandoned by late 2013 *(Comp Plan, p. 4-37).* Other, less drastic conservation measures that have been implemented or recommended elsewhere on Long Island have included: mandatory and voluntary "odd-even" lawn watering, altering water rate structures to make high rates of water use more expensive and requiring rain sensors for all lawn irrigation systems. Nassau County enacted a conservation ordinance in 1987 addressing many of these issues.

Although we have enough water to meet present and future demands if managed properly, there are many reasons why conservation is important. Since water from Long Island's wells must be pumped out of the ground using high capacity electrically driven well pumps, conserving water also conserves energy by reducing the amount of electricity needed to meet water demand. Conservation also reduces the need to construct new wells, treatment facilities, and tanks to meet demand, thus saving rate payers money. Conserving water insures that there will be sufficient water pressure – even during peak demand periods – to fight fires. In summary, conserving water not only saves money, it ensures that there will be an adequate supply for future generations.



Water Use on Long Island



Locations of public supply well fields on Long Island

The most significant use of groundwater on Long Island is for public drinking water supply. Between 1985 and 2005, it is estimated that approximately seventy to eighty percent of groundwater withdrawn from Long Island's aquifer system was used for this purpose. In 2014, Long Island's public water suppliers pumped an average of 413 million gallons per day (mgd). There are also an estimated 200,000 people not connected to public water that utilize their own private well for their water supply. The number of private wells is estimated at 47,000 *(Comp Plan, p. 4-6),* and they pump an estimated 15mgd. Total water use for all purposes (potable, irrigation, and commercial/industrial) on Long Island is estimated at 450 to 500 mgd. Over seventy five percent of all groundwater withdrawals are from the Magothy aquifer.

It is important to recognize that not all water pumped is necessarily consumed. For example in unsewered areas, much of the water pumped for public supply returns to the groundwater system as infiltration through onsite septic systems (recharge from wastewater return).Some other uses of groundwater are similar in that some portion of the water pumped is returned to the aquifers. *(http://ny.water.usgs.gov/projects/SOTA/aquifer.html).* However, any water used for landscape or agricultural irrigation is not considered to be returned to the aquifer system.

Residents of Nassau and Suffolk Counties obtain their public drinking water from a decentralized network of water supply wells located throughout both counties. These wells are located within the areas where the water that they pump is consumed. The figure above shows that the development of public water infrastructure on Long Island tends to follow a pattern very similar to population trends. Where population density is greatest, such as in Nassau County, there tend to be more well fields per square mile and therefore more intensive water supply pumping. In total, there are approximately 1,200 community public supply wells throughout Nassau and Suffolk Counties.

The aquifer system underlying some portions of Nassau County has experienced some degree of water quality degradation (particularly salt water intrusion) due to this intensive use in localized areas. While western Suffolk exhibits water supply infrastructure trends similar to Nassau, there have been no such water quality issues relating to overuse in that part of Suffolk County. In stark contrast to Nassau, there are large portions of eastern Suffolk County that have not been developed extensively (or at all) with public water supply infrastructure. As a result, numerous homes in eastern Suffolk are not served by public water, and continue to utilize individual private wells for their water supply. There are an estimated 47,000 private wells supplying drinking water to homes in Suffolk County.

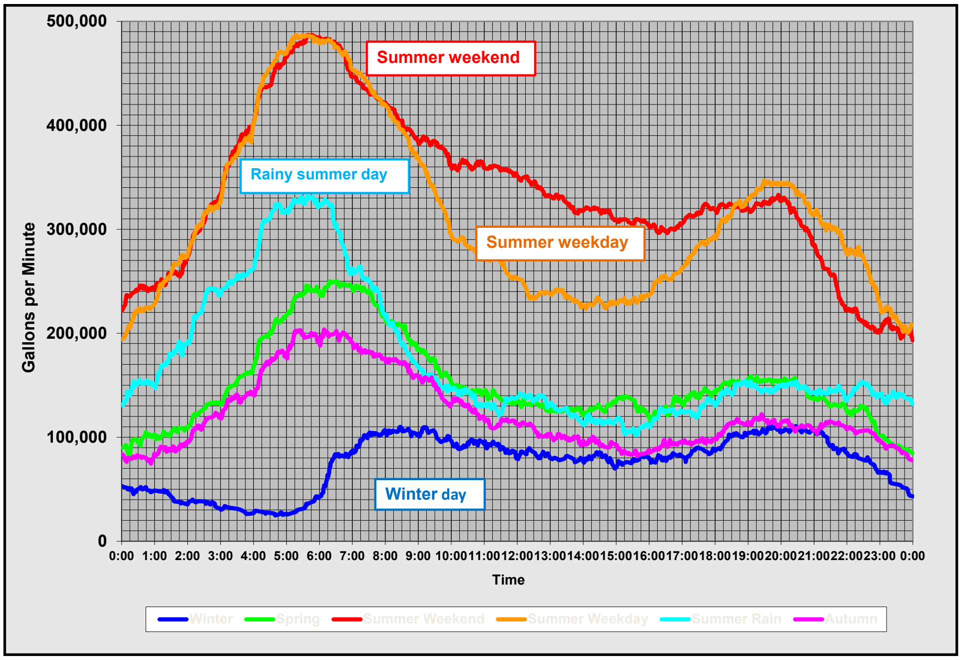
Seasonal use is a major factor in how much water is pumped and used on Long Island. During the past 30 years, there has been a marked increase in summertime water usage across Long Island. In Nassau County during the period from 1988 to 2009, summer pumping averaged 220-340 mgd while the winter averaged 130-150 mgd. For Suffolk County, the summer average was 160-360 mgd and for winter the average was 80-100 mgd. This is largely attributed to the increased use of underground sprinkler systems for lawn irrigation. Outdoor recreational activities and increased summertime population in some areas, also contribute to increased water use. However, even in Nassau and western Suffolk County with minimal population increase in the past decades, per capita water usage has increased significantly, due almost entirely to lawn watering with automatic sprinkler systems.

The graph on this page shows overall system wide pumpage at SCWA on several specific days in 2007. The dark blue line shows demand during a typical winter day ranging from a low of approximately 20,000 gallons per minute (gpm) to a high of approximately 100,000 gpm. This level of usage can be considered the baseline, or "essential" volume of water necessary for typical residential indoor purposes. In stark contrast to this, the red line on the graph shows water usage during a summer weekend day. Usage ranged from a low of approximately 200,000 gallons per minute to a high of almost 500,000 gallons per minute—almost 10 times the water use at the same time of day in the winter. This means that public water suppliers must provide sufficient well capacity and infrastructure to handle this additional water demand on peak summer days above and beyond what is necessary for "normal" usage, largely for the purpose of accommodating lawn watering, although seasonal population increase is also a factor is some places. Also shown on this graph is water usage during a rainy summer day (light blue line). Even during this rainy day, water use peaked at approximately 350,000 gpm in the early morning.The remaining lines on the graph (green and magenta) show water use on spring and fall days, respectively. Demand on those days lies somewhere between winter and summer usage, as expected.

These seasonal water use patterns point to the necessity for water suppliers throughout Nassau and Suffolk to manage peak water demand, in order to maximize water supply efficiency. Reducing summertime peak pumpage "spikes" is an essential ingredient in such a strategy. If the summertime peaks could be reduced by as little as five percent, instantaneous demand for the SCWA system would be reduced by approximately 25,000 gallons per minute. This represents approximately 20 wells that would not have to be pumping at that time. The energy savings of this reduced pumping are significant. Additionally, both fire protection and operational redundancy would be enhanced by having this extra well capacity in reserve. Should similar conservation-based demand reductions be realized throughout Nassau and Suffolk, overall stresses on the aquifer system could also be reduced, with obvious benefits to the aquifer system.

Non-potable water uses are also significant in different portions of the Long Island area. The vast majority of wells used for these purposes take water from the upper glacial aquifer. Farms and golf courses pump large volumes of water from the aquifer system. There are over 200 wells supplying irrigation water to golf courses on Long Island. Additionally, agricultural water use is quite extensive in eastern Suffolk County.

Suffolk County has for many years been among the top three agricultural counties in New York State, based on the dollar value of crops produced. These agricultural products all depend on the availability of groundwater for irrigation. The number of active agricultural wells is difficult to de-

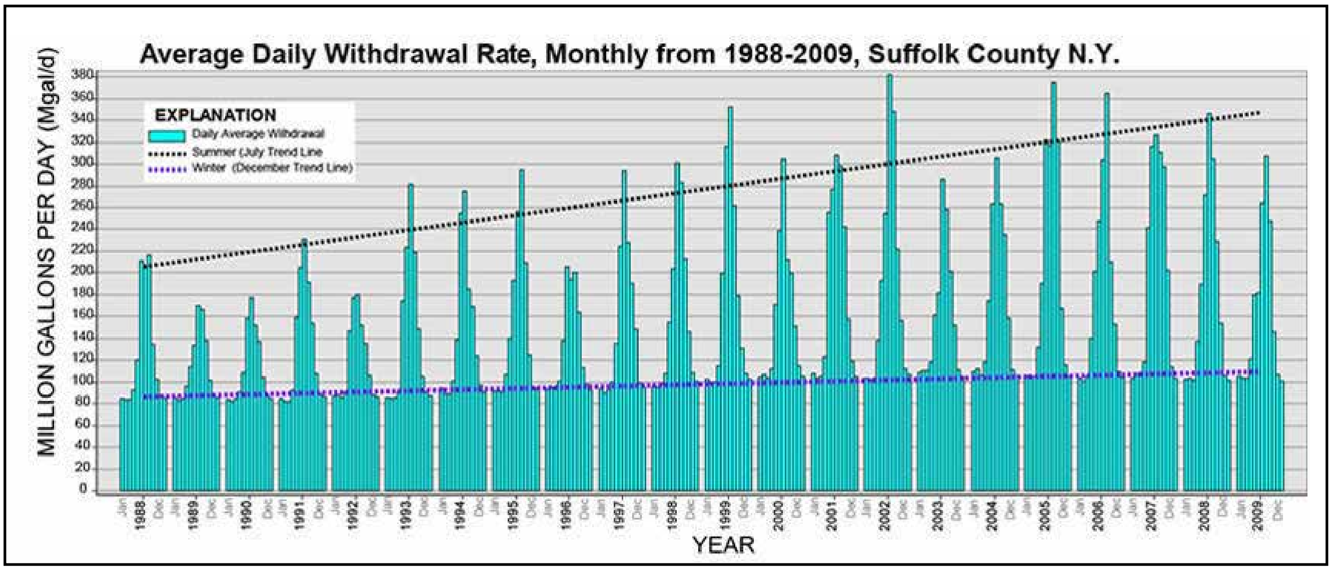


This graph illustrates the demand, in gallons per minute, on the entire SCWA supply system, throughout the day on several specific days during one calendar year. Note the difference in demand in the early morning in winter (blue line) vs. summer (red line) due mostly to lawn watering.

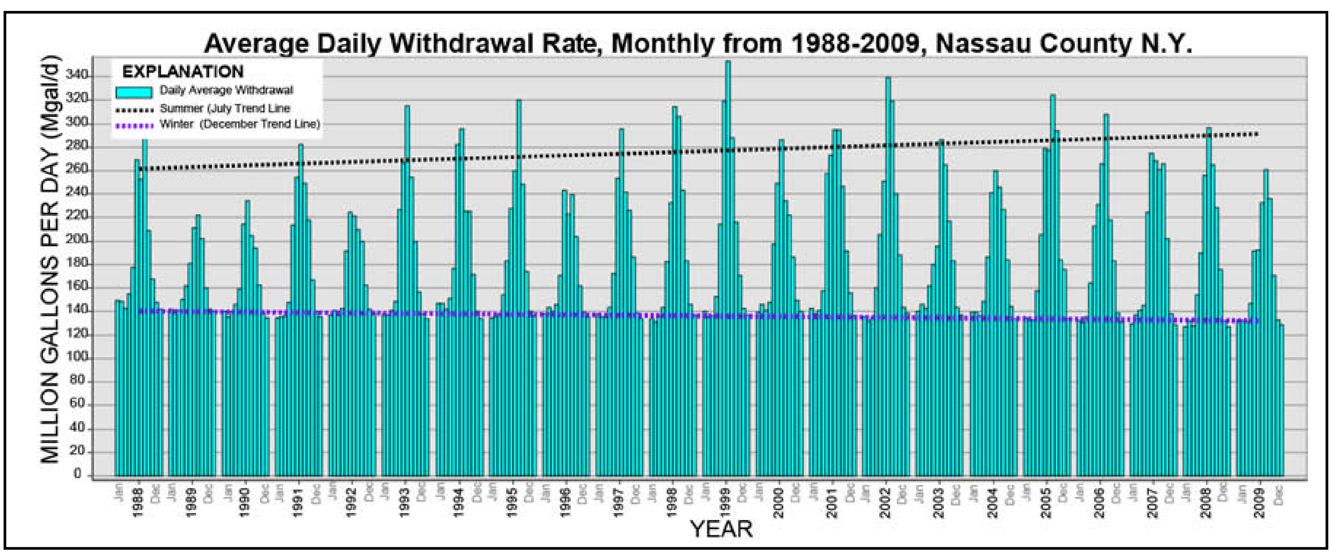
termine. Many of these wells are not documented, because they may have been in service for decades, and pre-date any permitting programs.

Farms and golf courses use all of their water between mid-April and mid-October, adding to the increased seasonal stress on the aquifer system during that time. If these seasonal stresses are significant enough, long-term impacts to both the quality and quantity of Long Island's groundwater can result. The United States Geological Survey estimates that the total groundwater pumpage for agricultural and golf course irrigation is approximately 10 mgd when averaged throughout the year.

There are also hundreds of wells throughout Nassau and Suffolk that supply water for laundry facilities, lake and pond augmentation, cooling and heating operations, and other industrial processes. Numerous wells also pump water for construction dewatering operations, and as part of groundwater contamination clean-ups. All of these wells use water from the Long Island aquifer system, and contribute to the overall water use throughout Long Island. In 2005, an estimated 67 mgd was used for industrial purposes across Long Island *(http://ny.water.usgs.gov/projects/SOTA/aquifer.html)*



The graph above shows the overall trend in public supply water use in Suffolk County. While winter pumpage has increased slightly over time, summer pumpage has increased much more dramatically.



The graph above shows data from the same time period for Nassau County. Winter pumpage has actually decreased in Nassau over time. Summer pumpage has shown a slight increase, but nothing of the magnitude seen in Suffolk.

LICAP
Long Island Commission for Aquifer Protection

Land Use and Water Quality

Land use and land management practices can have a significant impact on the quality and quantity of water within the aquifer system. With approximately three million residents living and conducting business and industrial activities above the water supply, contaminants released at the land surface can seep through the ground and reach the aquifers. Despite these population and land use pressures, the quality of drinking water provided by Long Island's community water supply systems continues to meet all state and federal drinking water standards. However, there are areas throughout Long Island where groundwater quality has degraded over time due to land use activities. This fact highlights the lifestyle choices desired by Long Islanders and the potential groundwater impacts resulting from them.

Whether or not any degraded groundwater quality impacts drinking water depends on a number of factors, including the depth, locations, and pumping rates of any nearby drinking water wells, the natural direction of groundwater flow in the area and the subsurface geology. Groundwater quality is affected by both human activities and natural processes that occur as groundwater flows through the aquifer system. The arrangement of the geologic layers beneath the subsurface also plays an important role in the susceptibility of the aquifer to changes in water quality.

An unconfined aquifer is one that has no impermeable layers (usually consisting of clay) above it. The upper glacial aquifer is an example of an unconfined aquifer. Because groundwater can flow easily into an unconfined aquifer from the land surface above it, unconfined aquifers like the upper glacial are more vulnerable to contamination from land surface based sources. A confined aquifer has a low permeability layer lying above it, between the aquifer and the land surface. These types of aquifers are less vulnerable to land based contamination, due to the low permeability effects of the overlying confining units. The Magothy aquifer is unconfined in some areas, particularly on the north shore, and confined in other locations on Long Island (*https://pubs.er.usgs.gov/publication/ofr95401 - p. 6).* The Lloyd aquifer is confined over virtually its entire extent, which is one reason why it is much less prone to surface-derived contamination than the other two aquifers. As a general guideline, the deeper beneath the ground that an aquifer is situated, and the greater its degree of confinement by overlying clay layers, the less prone it is to contamination. However, there are numerous localized exceptions to this.

It is a well known fact that human activity can have a major impact on groundwater quality. Urban and suburban development above the aquifers can reduce aquifer recharge by increasing the area of impervious surface. Additionally, the manner in which domestic wastewater is managed – whether by regional sewering or via individual septic systems – has important implications for shallow water quality (and water quantity), especially when the density of suburban development is considered. High density residential development in unsewered areas has a high potential to introduce contamination (especially nitrate) to underlying groundwater. Larger residential lot sizes, and reduced population density usually result in a lower nitrogen impact to the aquifers in unsewered areas. This may be somewhat offset by nitrogen impacts from residential lawn fertilization, which may be greater in areas with larger lot sizes. Human activity can pollute the water that recharges the aquifer, as well as runoff that flows into surface waters. Regional sewering with ocean discharge of the effluent, as is practiced in almost all of Nassau and parts of Suffolk Counties, has helped reduce the pollutant load to the upper glacial aquifer from domestic and industrial wastewater. However, this type of sewering has also reduced the overall volume of water in the upper glacial aquifer by conveying domestic wastewater out to tidal waters, thereby removing it completely from the aquifer system. While there have been some negative consequences to this (such as declining water levels), the overall contamination loading to shallow groundwater has been reduced in such sewered areas.

Although residential development can have an adverse impact on groundwater quality, particularly with regard to nitrate, land use impacts to groundwater are certainly not limited to residential development. Agricultural practices may also adversely impact groundwater by introducing nitrate, pesticides, and other chemicals associated with farming. In addition, commercial and industrial land uses may be a source of volatile organic compounds *(Camp, Dresser, and Mckee, 2009).* There have been numerous large VOC plumes that have affected communities across Nassau and Suffolk, and have necessitated extensive and costly clean-ups. Industrial sites such as Grumman in Bethpage, Northville Industries in both Setauket and Holtsville, Lawrence Aviation in Port Jefferson, Lockheed Martin in Lake Success, and Brookhaven National Laboratory in Upton (to name only a few) have had a long history of extensive VOC contamination and resulting remediation efforts. Once pollutants are discharged at the surface or into the shallow portions of the aquifer system, pumpage of wells screened in the deeper aquifers can accelerate the vertical movement of contaminants from shallow depths into these deeper aquifers.

Excessive pumpage can also induce the flow of salty groundwater from offshore toward a well, resulting in lateral salt water intrusion. This was first observed locally in the early 1900s in Brooklyn, as wells were over pumped and the water table dropped to elevations below sea level. When pumping was stopped from these wells in the 1940s, the water table slowly recovered to close to its original elevation in the ensuing decades.

Groundwater quality can also be altered by natural processes that affect groundwater as it flows through the aquifer system. For example, iron and manganese levels are usually higher in Magothy and Lloyd wells that pump deeper, older water. The drinking water standards for these compounds are known as "secondary" standards. This means that they do not represent health concerns at levels typically found in Long Island's public supply wells, but are aesthetically undesirable (largely due to taste and odor issues associated with them). Many water suppliers utilize filter systems to remove iron and/or manganese from the water before it reaches the distribution system.

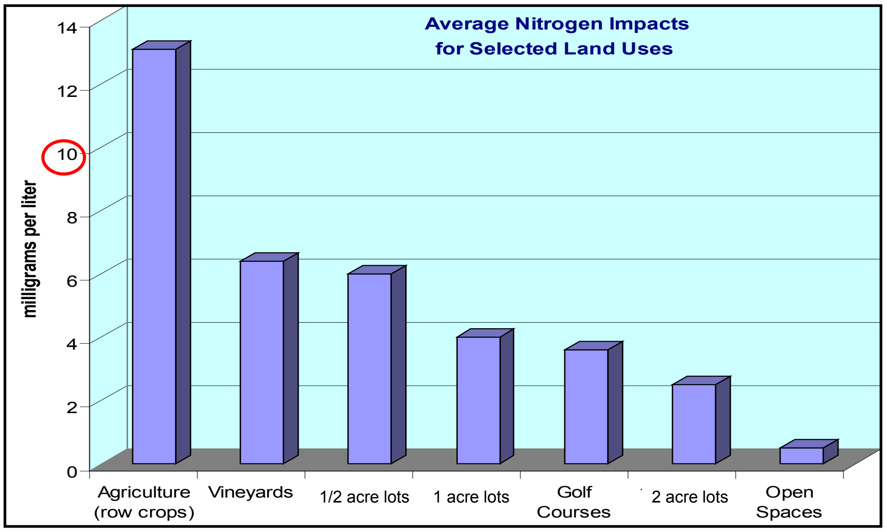
Source Water Protection

There are over 1,200 community public supply wells located throughout Nassau and Suffolk Counties. Most of these wells are located within the neighborhoods that they serve. Water used by Long Islanders most likely was pumped out of the ground from a well located no more than a few miles from where it was consumed. Since public supply wells are located throughout Long Island, any activity on the land's surface has the potential to affect the quality and/or quantity of the water we drink. While the quality of water that is consumed by the public is generally excellent, threats to the overall quality of the groundwater resources exist throughout Nassau and Suffolk Counties. For this reason, water suppliers and public health officials have become more interested in better determining the specific locations ("capture zones") from where a well ultimately draws its water.

As defined by the USEPA, source water is the "raw", untreated water from our underground aquifers that is utilized as the source for drinking water. For all public water supplies regardless of their initial water quality, some degree of basic water treatment is usually necessary, prior to delivery to the customer. Municipal public water suppliers on Long Island are required to chlorinate the water for disinfection, and to adjust the pH of the water (in order to minimize corrosion of distribution pipes and household plumbing fixtures) before it is consumed by the public. It is important to note that unlike New York City, no public water suppliers on Long Island add fluoride to their water.

As previously mentioned, human activities within the source area for a well (its "capture zone") can impact quality of the source water, possibly necessitating more enhanced treatment on the part of the utility in order to meet drinking water standards.

The costs of constructing, installing, and operating any enhanced treatment facilities, such as those needed to remove nitrate or organic contamination, can be reduced or even avoided altogether by protecting source water from contamination. Protecting groundwater quality also has benefits to the surface waters to which it discharges. Pollution prevention is always preferable to remediation. The USEPA and other federal agencies, as well as New York State, Nassau and Suffolk Counties, local communities, businesses and citizens all play a role in ensuring that drinking water is protected.



The figure above shows the overall nitrogen impacts to groundwater from different land uses. The drinking water standard of 10 ppm is indicated by the red circle

SWAP – Source Water Assessment Program on Long Island

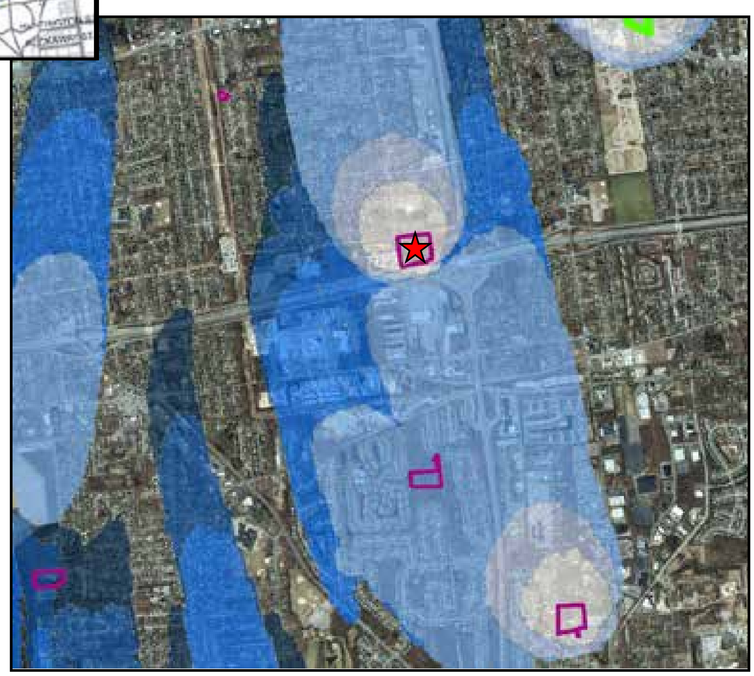
Even routine land uses impart some type of "contaminant signature" to the underlying groundwater. The bar graph illustrates the nitrogen impacts of several different land uses found throughout various portions of Long Island. It is important to note that the mere presence of some type of contamination of the groundwater in an area does not automatically mean that the quality of your drinking water is impacted. The federal Safe Drinking Water Act (SDWA) Amendments of 1996 created a Source Water Assessment Program (SWAP) to evaluate existing and potential threats to the quality of the public drinking water supplies throughout the U.S. The figure below shows the overall nitrogen impacts to groundwater from different land uses.

The foundation of SWAP is to ensure safe drinking water by being able to track the fate of groundwater as it flows through the subsurface. By knowing the general area from which a well draws its water, the potential for contamination from both routine land uses as well as specific point sources of contamination of a given public supply well can be accurately assessed.

New York State Department of Health (NYSDOH) developed Source Water Assessment Program (SWAP) in the early 2000's to better determine the vulnerability of public supply wells to contamination from both general land uses and specific contamination events occurring within a well's source area. A computerized groundwater model was developed in order to simulate the pumping of all public supply wells throughout Nassau and Suffolk at their average annual pumping rates. Using this model, the source areas were determined for each well. Existing data bases were then utilized to determine land uses and contamination sites within those source areas, and ultimately the overall susceptibility to different types of contamination for all public supply wells in Nassau and Suffolk Counties was evaluated.

A major finding that came from the SWAP was the realization that, while many land uses and specific instances of groundwater contamination do have a negative impact on drinking water, there are also a great many such instances that are not a threat. If a point source of contamination lies outside of any public supply well capture zone, it may still pose an environmental threat, but is not a threat public drinking water. The SWAP analyses allowed water suppliers and public health officials to determine which groundwater contamination problems in a specific area were a threat to the drinking water supply to a community and which were not.

Above is an example of the source area to one particular public supply well in Suffolk County. (Land uses within the capture zone are shaded).



The figure to the right shows the capture zones of all wells within the vicinity of a given area. Note that in densely populated areas, the capture zones abut each other. (The well field shown in the previous figure is indicated with a red star).

Testing and Regulation

Historically, drinking water regulations were enacted to prevent waterborne diseases such as typhoid and cholera that had plagued mankind for centuries. Over the past century, as these regulations have been adhered to, and as drinking water infrastructure has been upgraded, waterborne diseases in the United States have become uncommon. In more recent decades, as new contaminants are discovered and analyzed, and laboratory equipment becomes capable of detecting smaller and smaller concentrations of these compounds, the primary public health concern with drinking water is the prevention of non-pathogenic diseases.

In addition to drinking water regulations to protect public health, federal, New York State, and local governments have enacted strict groundwater regulations to protect the environment from pollution. Such groundwater regu- lations include chemical and hazardous materials storage requirements, zoning laws that prohibit a variety of industries from locating within the "deep recharge" areas that contribute recharge to the Magothy and Lloyd aquifers, and strengthened sewage treatment requirements. Additionally, Long Island's public water suppliers have had a long-standing commitment to working alongside the state and county health departments in the best interests of public health and safety, and take many steps (such as redundant, or "back-up" sampling of public water supplies by both the county laboratory and the water suppliers laboratory) to protect against the possibility of contamination of drinking water.

As required by law, public water suppliers conduct hundreds of thousands of water quality tests each year, testing for more than 140 different substances including volatile organic chemicals, inorganics (such as iron, manganese, and chlorides), pesticides and herbicides at a cost of over $3 million per year to insure that the water is safe to drink. Some suppliers actually test for more substances and at higher frequencies than the law requires.

Results of these tests are published each year in an an-

Community public Water suppliers are required by law to test for more than 140 different substances annually.

nual drinking water quality report, many of which are now available online. The test results are reported to the respective Health Departments, which conduct their own duplicate samples to verify the results. Any supply well with any sample exceeding drinking water quality standards is required by law to be shut down until corrective measures are implemented.

The standard unit of measurement for many compounds is parts per million (ppm). This means that the concentration of a particular substance is extremely low, even though the regulatory agency may consider it to be significant. To illustrate how minute this concentration is, the following comparisons are the equivalent of **one part per million** *(source: sgufo-rums.com)*:

1 inch to 16 miles
1 minute to 2 years

There will always be traces, no matter how minute, of inorganic and organic constituents in water. The world in general, and the aquifer system specifically, are not "sterile" environments. Within the last thirty years, allowable levels of certain contaminants in drinking water have been reduced to the part per billion or even part per trillion level. The following comparisons further illustrate how miniscule **one part per billion** is:

1 inch to 16,000 miles
1 second to 32 years

Drinking water standards are set based on two primary factors: the maximum level of any constituent determined to be safe for humans and the lower limit that can be detected reliably by current laboratory technology. As both laboratory technology and treatment technology evolve over the years, drinking water standards for some contaminants often become stricter. An example of this pertains to many volatile organic chemicals (VOCs). From the time they were first regulated in drinking water in the mid 1970s until 1988, the allowable concentration was 50 parts per billion (ppb). This allowable level was reduced to 5 ppb in 1988. Safe levels are established by the EPA based on a rigorous protocol of tests. The levels established, called MCL's (maximum contaminant levels), are enforceable standards based on current testing and treatment technology. The exhaustive testing protocols used by the United States EPA result in standards that represent those levels at which a contaminant presents a very minimal risk to humans.

Every five years, the EPA requires major public drinking water providers to test additional unregulated contaminants. This is known as the Unregulated Contaminant Monitoring Rule (UCMR). The UCMR lists 20 to 30 unregulated contaminants that must be monitored for by large public water systems. Used as a tool to find unregulated contaminants of concern in drinking water, the EPA can then determine whether to set drinking water standards or to require providers to use certain treatment systems to reduce or eliminate these contaminants. Consumers should rest assured that the public water they drink is one of the most extensively tested product that they consume.

There are still approximately 47,000 households on Long Island (located mostly in eastern Suffolk) that rely on individual private wells for their water supply. Most private wells are very shallow (typically 40 feet below the top of the water table), and are therefore susceptible to contamination from virtually any household chemicals used on the property or within the neighborhood. According to the Comp Plan, nitrate exceeded the drinking water standard in 7% and VOCs exceeded the drinking water standard in 19% of private wells sampled by the SCDHS between 1997 and 2013. Homeowner wells are not constructed to public supply standards, and are not tested with any degree of frequency, if at all. The SCDHS provides water quality testing services for private well owners for a nominal fee. However, very few homeowners with private wells (approximately 1%) have utilized this program *(Comp Plan, p. 4-6).* Additionally, in Nassau County, the Department of Health will provide an initial test for drinking water quality of a private well at no cost to the homeowner. The New York State Dept. of Health recommends that homeowners with a private well should test the well at least annually at a qualified laboratory to make sure their water is safe to drink.

Water Quality Issues on Long Island

Saltwater Contamination

Since Long Island is surrounded on all sides by salt water, contamination of the aquifers by salt water is always a concern. In the central portion of Nassau and Suffolk, fresh water exists throughout the entire aquifer system, all the way down into the bedrock (over 2,000 feet below ground in many places), and no real threat of saltwater contamination exists in those central areas. However, for more coastal locations, particularly the peninsulas on the North Shore and the barrier islands on the South Shore of Nassau County, and portions of the North and South Forks of eastern Suffolk County, salt water contamination of the aquifers has been, and continues to be, an ongoing issue.

The principal indicator of salt water contamination for most water suppliers is the level of dissolved chlorides in the water being pumped by a well. Chlorides at very low concentrations are naturally occurring in Long Island's aquifers, principally because precipitation (and therefore recharge) is largely derived from evaporation of seawater (see the Water Cycle section of this report). Natural (or "background") chloride levels are approximately 20 to 40 mg/L in the upper glacial aquifer and approximately 5 to 10 mg/L in the Magothy and Lloyd aquifers *(https://pubs.er.usgs.gov/publication/ofr95401 - p. 7)*. The drinking water standard for chlorides is 250 mg/L, and is a secondary standard based on the levels at which consumers will begin to notice a salty taste in their water. However, many Long Island water suppliers will take action at far below this level. This is because elevated chloride levels in wells are an indicator of an environmental problem—salt water contamination—that may result in the degradation of water quality in an aquifer, even at levels below the drinking water standard.

There are three principal ways that Long Island's groundwater can become contaminated by salt water: (1) lateral salt water intrusion, (2) upconing, and (3) road salting.

Lateral Salt Water Intrusion

The most familiar way that groundwater can become contaminated with salt water is what is known as "lateral salt water intrusion." This has occurred recently in western Nassau County, and in the past in parts of Brooklyn and Queens. It has also been an ongoing problem throughout the United States, affecting portions of Texas, Florida, and California, among other places. Lateral salt water intrusion occurs due to continued overpumping of the aquifers in an area in close proximity to the coast. Excessive withdrawal of fresh water from the aquifers over a long period of time results in lowering of the water table, often times below sea level. This lowering of the water table allows salty groundwater beneath tidal water bodies to advance landward.

When this happens, the levels of dissolved chlorides in water pumped by wells in these coastal locations will begin to increase. This initial increase in chlorides is an early warning to the water suppliers that a problem may be starting. Reducing or eliminating pumpage from affected wells usually eases the problem temporarily. However, if the over pumping continues, this salty groundwater may migrate all the way into a well's production zone, rendering the well and the surrounding aquifer segment unusable for potable water supply. Once native fresh groundwater becomes "replaced" by salty groundwater, the entire water resource is compromised, and the results are very difficult to reverse.

The Great Neck and Manhasset Neck peninsulas in northwestern Nassau County, as well as the Long Beach-Lido Beach areas on the barrier islands of southern Nassau, are currently experiencing this type of saltwater contamination in both the Magothy and Lloyd aquifers. Due to the very dense population in those areas, and the highly localized nature of public water supply to those communities, there has been over pumping of the public supply wells located within those communities. Remedial measures have been enacted, resulting in some short term resolution to the problem. Such remedial measures have included limiting or eliminating water supply well construction on the peninsulas and the construction of wells outside of areas prone to salt water intrusion. A long-term solution must be enacted however, in order to completely solve the saltwater contamination problems in these areas.

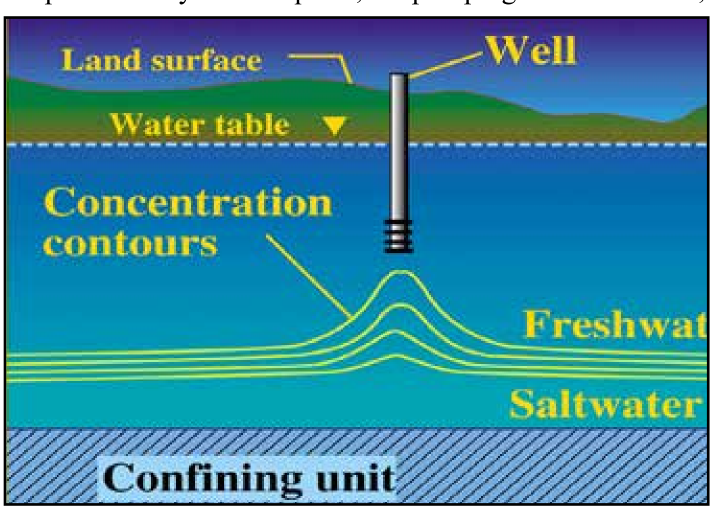
Suffolk County is fortunate in that development on its barrier islands is minimal, and so pumpage from wells situated on them is negligible. Additionally, because of the way that water distribution infrastructure has been built, water can be more easily transmitted in Suffolk County from inland areas to coastal areas, which minimizes pumping stresses near the coast. As a result, there have been no large scale regional problems with lateral salt water intrusion in Suffolk County, although isolated areas on the north fork and Shelter Island have seen problems.

Salt Water Upconing

A second, highly localized and less severe way that groundwater can become contaminated with salt water is known as "upconing". Upconing typically occurs beneath individual pumping wells that are located in areas where fresh groundwater exists as an isolated "bubble". Such areas include the north and south forks of eastern Suffolk County. Since fresh water is less dense that salt water, fresh groundwater in those areas occurs as a lens or "bubble" floating on the salty ground water beneath it. The depth at which the salty ground water is encountered is known as the "salt water interface."

The density of salt water is 1.025 vs. 1.000 for fresh water. Therefore, since salt water is 1/40th more dense than fresh water, for every foot above sea level that the water table occurs, the salt water interface will be located 40 feet below that. The relationship is known as the "Ghyben-Herzberg relationship," named after the Dutch hydrogeologists who first defined it in the early 1900s. Since the elevation of the water table over most of the north and south fork is approximately five feet above sea level, the depth to the interface is generally no greater than 200 feet below sea level (although there are numerous local exceptions where the interface is deeper). The maximum thickness of the fresh groundwater lense is therefore generally no greater than 205 feet. It is important to note that this "40 to 1 relationship" is strictly based on the density differences between fresh and salt water. Since Long Island's aquifers are less permeable in the vertical direction than in the horizontal direction, these differences in subsurface geology usually increase the depth of the interface below what would be expected simply from this density relationship. However, for purposes of being as conservative as possible, the Ghyben-Herzberg relationship is usually used.

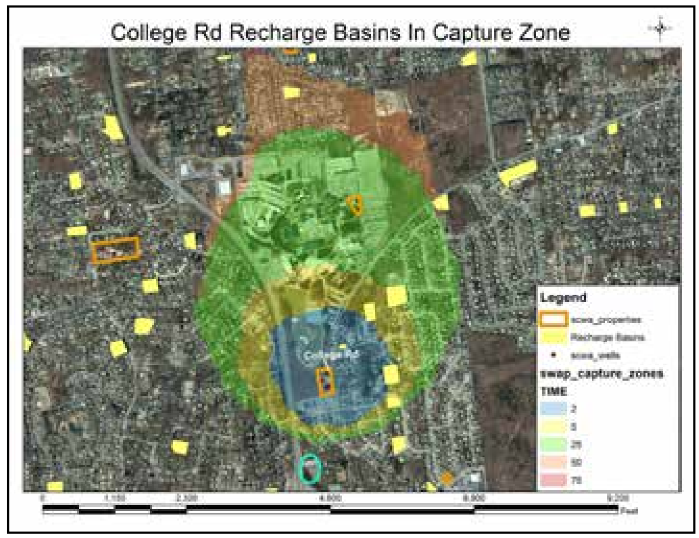
The potential for upconing beneath a pumping well situated in this "floating lense" setting can be calculated utilizing mathematical equations first proposed by hydrogeologists over forty years ago *(Schmorak and Mercado, 1969)*. These equations have been utilized by hydrogeologists at the SCWA to minimize the impacts of pumping of shallow wells located on the North and South Forks of eastern Long Island. When shallow East End wells are pumped, the saltwater interface will rise to some extent in response to this pumping stress. The degree to which the interface will rise in response to pumping depends upon the following factors: the permeability of the aquifer, the pumping rate of the well,



An illustration of salt water upconing beneath a pumping well. As the pumping rate increases, the interface is drawn upward, closer to the well screen. This results in increasing chlorides in the pumped water.

and the original distance from the bottom of the well screen to the top of the saltwater interface.

Once these three factors are known, a "critical rise" can be calculated. SCWA scientists have calculated a "critical rise" of the salt water interface, which is the amount of rise in the interface beneath a pumping well that will potentially result in long term water quality degradation. Even though experience has shown that maintaining a rise in the interface of 50% of the original distance is acceptable, SCWA scientists use a figure of 30% for an extra factor of safety. As long as pumpage remains relatively low, this rise will should result in any long term water quality degradation, although the levels of dissolved chlorides will usually increase somewhat during the summer. However, if a well's pumping



The location of an SCWA well field affected by road salting. Capture zone is shaded according to time of travel to the well. (Yellow squares indicate roadside recharge basins).

rate is too high, the interface will rise to a point very close to the bottom of the well. When this happens, chloride levels increase more drastically, and the pumping rate must be cut back immediately and properly managed throughout the summer peak pumping season.

Road Salting

Contamination of shallow groundwater due to road salting is a recently discovered issue. Given the frequent and heavy snowstorms that have occurred in recent winters, and the public safety related issues of maintaining safe, passable roads at all times, the increased use of road salts for de-icing and snow removal has caused some unexpected groundwater quality problems. Some shallow wells on the North and South forks, and some deeper wells in central portions of Long Island, have seen marked increases in chloride levels during winter and early spring that do not subside when pumpage is reduced. This stands in contrast to the previously mentioned scenarios, when the increases in chlorides occurred in response to summer peak pumpage.

Despite the fact that there are strict guidelines pertaining to proper storage and usage of road salt at municipal maintenance yards, road salt contamination remains a problem due to its routine and widespread use throughout the area. As the snow covering a road begins to melt, any salt applied will dissolve along with it, and the water/salt solution will flow into the nearest drain or recharge basin. The salt residue builds up in the recharge basin, so that any succeeding precipitation will dissolve it as it recharges the aquifer, and carry it downward into the aquifer system. It was discovered that the water in some recharge basins located along major highways had a salt content greater than that of the Atlantic Ocean for brief periods immediately after a snowmelt. Any well that captures some of this water as it recharges the aquifer will reflect this water quality trend. SCWA scientists discovered that by analyzing the water chemistry from specific wells, they could determine whether a chloride increase was due to road salting or saltwater intrusion/upconing. By determining the specific source of the chloride increases, a management strategy was devised by SCWA to minimize chloride impacts from road salting, and increase the useful life of supply wells.

Specific Case Studies in Saltwater Contamination:

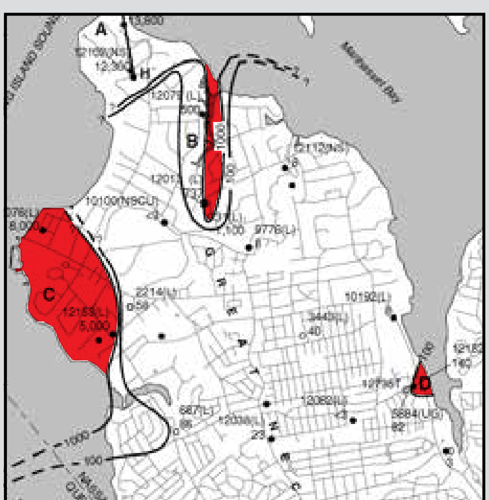
Great Neck and Manhasset Neck Peninsulas Saltwater Intrusion

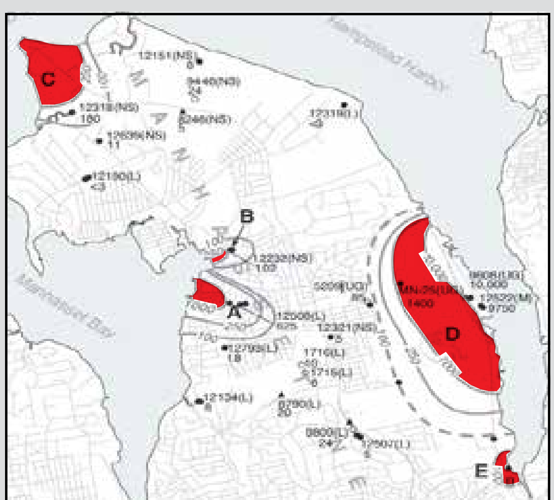
Since the 1980s, public supply wells on both the Great Neck and Manhasset Neck peninsulas of northwestern Nassau County have been impacted by lateral salt water intrusion. In response to this threat, an extensive research project was undertaken to define the extent of the intrusion beneath each peninsula, and to minimize or reverse its advance. Over 30 boreholes were drilled between 1991 and 1996 to collect geologic and water quality data, and to monitor changes in the magnitude of the intrusion. Additionally, offshore geophysical surveys were done to better define the subsurface geology beneath the surrounding bays.

Four distinct areas of salt water intrusion were discovered and delineated beneath the Great Neck Peninsula, and five such areas were discovered on Manhasset Neck. All aquifers were affected to differing extents, and chloride levels within them ranged from just over 100 mg/L (below drinking water standards but far above normal "background" levels) to over 13,000 mg/L (a little less than half as salty as ocean water). Two of the areas on Manhasset Neck showed active salt water intrusion, and numerous public supply wells on both necks have been either shut down or significantly affected by elevated chlorides in the areas. *(USGS WRI 00-4193 and WRI 99-4280).*

Southwest Nassau Saltwater Intrusion

The United States Geological Survey (USGS) and Nassau County Department of Public Works (NCDPW) have been studying saltwater intrusion in southwestern Nassau since the early 1950's. As Nassau County developed, and pumpage from all aquifers was increasing dramatically at that time, the need arose for an enhanced delineation of the extent of the aquifers, and the extent of any salt water intrusion that may have been occurring in response to the increased pumpage. Numerous monitoring wells were constructed during several investigations, and geologic and water quality information was obtained from them. The





The figures to the left illustrate the extent of saltwater intrusion on Great Neck (left) and Manhasset neck (right). Individual salty water "wedges" are labeled A through E, and chloride concentration contours are illustrated by the black contour lines. (USGS WRI 00-4193 and WRI 99-4280).

monitoring wells were also utilized to track the movement of groundwater in response to stresses such as well pumping and tidal influences.

In a 1966 USGS report *(Lusczyenski and Swanzenski, 1966),* several distinct wedges of salty water were discovered within the upper glacial and Magothy aquifers, and in some of the clay confining units from these early investigations. Groundwater in some of these wedges had chloride concentrations as high as 16,500 mg/L. Some of these deeper wedges extended up to seven miles inland at that time and were advancing landward at measureable rates. The report also mentioned that salty water was also beginning to migrate vertically from the base of the Raritan clay downward into the Lloyd aquifer. Elevated chloride levels in Lloyd aquifer public supply wells in Atlantic Beach, Lido Beach and Rockaway Park were noted at that time.

For several decades, the NCDPW maintained an extensive network of monitoring wells throughout the county and was actively monitoring water quality data, part of which included chlorides within the deeper aquifers. In recent years, much of the groundwater monitoring program has become inactive. In order to effectively monitor and trend elevated levels of chlorides on Nassau County's south shore, upgraded groundwater monitoring program should be enacted, and a long term funding source needs to be secured.

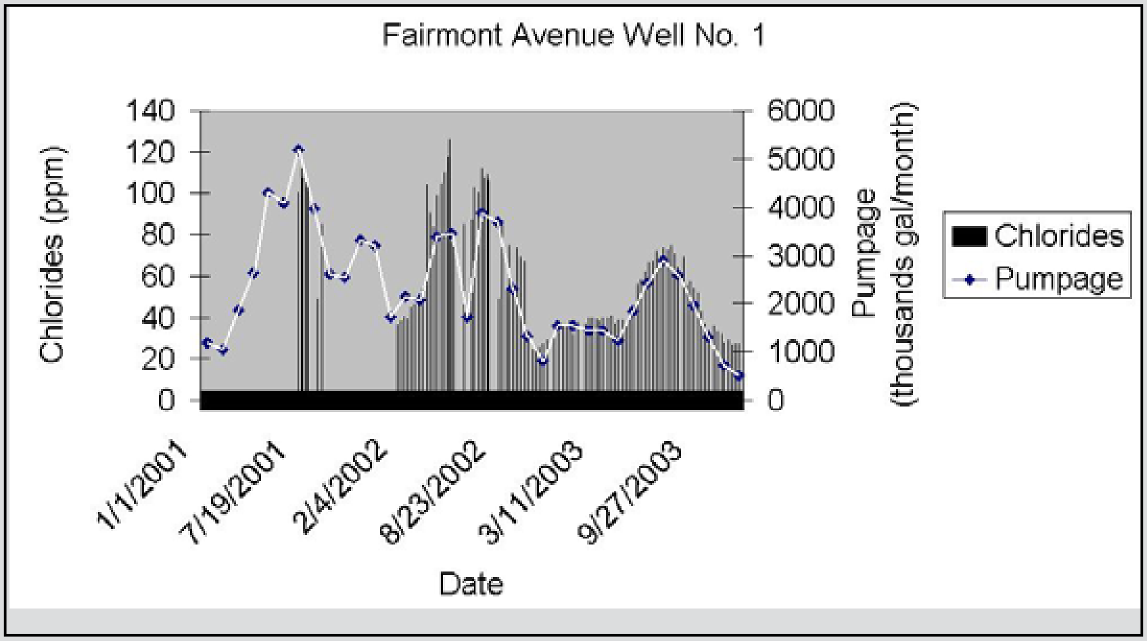
Saltwater intrusion along the south shore will become more pronounced and may affect public supply wells in the coming decades, based on current pumping patterns and the anticipated rise in sea level. For this reason, efforts to restart the monitoring program are underway.

Montauk Upconing

In the 1980s, SCWA began experiencing saltwater upconing in its Montauk wells. SCWA had taken over the Montauk Water Company in the 1970s and added numerous wells to increase overall system capacity. By the mid 1980s, many of the wells serving the village began showing increased chlorides during the summer peak pumping season. SCWA embarked on a 10-year study to determine the exact cause of the problem and to find and enact a solution.

Many of the Montauk area supply wells produce water with elevated concentrations of chloride when pumped at their permitted capacities (for the purposes of this report, elevated chloride concentrations are considered to be those in excess of 60 mg/l (milligrams per liter), which is the concentration at which experience has shown may cause permanent degradation of water quality in a particular Montauk well. Chlorides occur in production wells because the wells tap a thin freshwater zone within the principal aquifer which is underlain by a salt water zone *(Prince, 1986).* As stated in the above sections, when the pumpage from the wells exceeds a certain critical threshold, the interface between the freshwater and saltwater zones is drawn upward until it is intercepted by the well. This process, known as "upconing," typically occurs within a limited radius around the well.

Previous analyses of the Montauk area, as well as the experience of the SCWA, have indicated that chloride concentrations are typically correlated to the pumpage of individual wells. However, the magnitude and timing of the response of the chloride concentrations to increases and decreases in the pumpage varies among the individual wells in the system. This is typically explained by differences in the thickness of the freshwater zone at various well locations, as well as the presence of a semi-confining silt and clay stratum (the "marine clay unit") within the principal aquifer. In some locations in Montauk, the freshwater/



Graph of pumpage (white line) vs. chlorides (black bars) at a well in Montauk affected by salt water upconing. Note the close relationship between pumpage and chloride levels. Chloride levels remain far below the 250 mg/L drinking water standard.

salt-water interface occurs within the marine clay. At other locations, the interface occurs within the transmissive zone above the marine clay unit. The graph on the previous page illustrates the close correlation between pumpage and chlorides for one particular well in Montauk. It is important to note that even though the drinking water standard for chlorides is 250 mg/L, chloride levels from this well were kept at approximately half this level in order to avoid further water quality degradation.

It was discovered that some of the wells were screened very close to the salt water interface, and/or were being pumped at too high a rate to maintain chlorides at proper concentrations.

Previous analyses indicated that chloride concentrations in the Montauk area wells can be controlled by ensuring that the pumpage of each well does not exceed corresponding critical threshold values. The pumping protocols that were developed for each Montauk area well included limits on the amount of water pumped in a single day, the amount of water pumped in a single month, and on the total amount pumped during the high demand season and the recovery season. Where it was possible to implement these recommendations, the SCWA was generally successful in controlling chloride concentrations. However, on many occasions during the summer season, the demand on the Montauk area system resulted in pumping of the wells in excess of their respective assigned limits. In some cases, this over pumping led to long-term degradation in local groundwater quality.

Chloride levels remained manageable through the 1990s. Eventually, however, demand in Montauk continued to grow, and a transmission main was installed to supplement the water supply to Montauk. The transmission main allowed the SCWA to pump water from the main body of East Hampton and transmit it to Montauk, thus reducing the demand on the individual Montauk wells, pumping them at lower rates. Since the transmission main was installed and put into service in 2000, no chloride problems have occurred in any of the Montauk wells. The lessons learned from Montauk have been applied to the SCWA territory on the north fork. Upconing behavior of wells situated there has been both studied and managed to a great extent, with minimal problems.

North Fork Road Salting

Concerns as to both the quality and quantity of drinking water are particularly acute on the North Fork, where freshwater is only available at shallow depths, and there are many large volume groundwater users (farms, golf courses) within a fairly small geographic area. Contamination by agricultural chemicals (fertilizers and pesticides) has always been a concern to water suppliers. A contaminant of particular interest more recently is road-deicing salt (sodium chloride, or NaCl), and the role it plays in elevating chloride levels within the upper glacial aquifer. This process is of concern at present because high concentrations of chloride have been detected in storm water and in shallow groundwater. In the recent past, several SCWA public supply wells on the North Fork became impacted by elevated chloride concentrations, potentially due to road salt contamination, or saltwater intrusion. In 2000, the Suffolk County Water Authority studied the effects of storm water runoff on the water quality at the Mill Lane and Ackerly Pond Road well fields in Peconic. Because these well fields consist of shallow wells that are in close proximity to water bodies and a major road (County Route 48), SCWA was concerned with the vulnerability of these wells to chloride contamination. The locations of these sites are approximately midway between Peconic Bay and the Long Island Sound. SCWA scientists developed an interesting method for determining the source of the elevated chlorides by looking at the Bromide-Chloride Ratio (Br/Cl) ratio in the water pumped by affected wells.

The majority of precipitation on Long Island originates from evaporation of seawater and so has an average molar Br/Cl ratio of 1.54 nM/uM (nanomole/micromole). Therefore, the Br/Cl ratio in groundwater will be similar to that of both precipitation and ocean water *(Schoonen, 1995)*. As a result, analyzing the deviations in the Br/Cl ratio can be used to determine source of chloride contamination, because certain contaminants will result in a Br/Cl ratio above or below that of normal precipitation and normal groundwater. Road salt, which in Suffolk County consists of NaCl (halite), is an ever-increasing problem affecting shallow aquifers and the elevated chloride levels that result its presence in shallow groundwater are often mistaken for saltwater upconing. Analyzing molar Br/Cl ratios allow for differentiation between the two chloride sources. Since seawater, precipitation, and groundwater have an average molar Br/Cl ratio that is relatively constant, a well field impacted by saltwater encroachment or upconing will still show the Br/Cl ratio similar to that for seawater *(Schoonen, 1995)*. A well field impacted by road salt would display a much lower Br/Cl ratio.

Vertical profiles were collected at the Mill Lane well field in Peconic during January and July of 2000, allowing for both spatial and temporal analysis of Na+, Br, and Br/Cl ratios. The temporary boreholes were drilled using hollow stem augers. The cutter head of the lead auger was sealed with a plastic plug to prevent leakage into the augers. Subsequent auger sections were sealed at the joints by O-rings to prevent groundwater infiltration. The same methodology was used to collect samples at Ackerly Pond well field in March of 2002. The molar Br/Cl data analyzed from Mill Lane is summarized in Tables 1 and 2, on the next page.

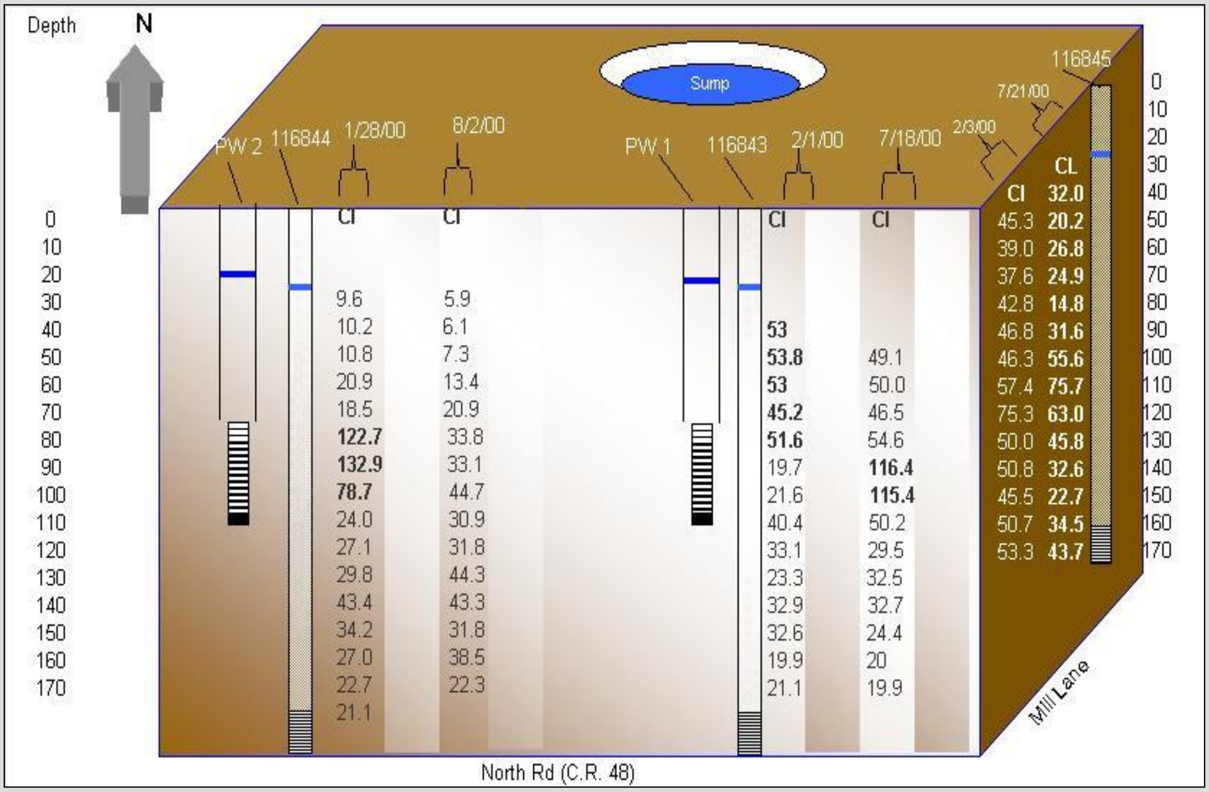


Table 1 Mill Lane Vertical Profile Results (chlorides in mg/l)

The vertical profiles above indicate that, at depths ranging from 80 to120 feet, the chloride levels are elevated (exceeding 100 mg/L), while Table 1 indicates that, at those same depths, the Br/Cl ratio is consistent with road salt. This depth corresponds to the screen setting of the production well. Pumping of the production well would be expected to draw in contaminants (such as road salt) from the surrounding area and the data collected supports the idea of surface contaminants affecting the well field. The results of this study show that Br/Cl ratios are an effective means of identifying road salt contamination within well fields and differentiating between road salt and naturally salty groundwater or seawater. A side benefit of this study was that, since chloride levels never exceeded approximately 150 mg/L (and therefore never came close to the drinking water standard despite increased pumping rates during the summer), the SCWA was able to pump the Mill Lane wells at their full capacity.

Table 2 Br/Cl Molar Ratio of Vertical Profiles at Mill Lane

The vertical profiles show a distinct difference in Br/Cl ratios at depths where the unusually high chloride concentrations were detected (yellow shading). The sample results from profile S-116843 indicated at a depth of 90 feet, the Br/Cl ratio is .3 nM/uM (table 1). This unusually low ratio was also present at a depth of 100 feet (.35 nM/uM), but improved at a depth of 120 feet (1.8 nM/uM). Comparison of these results with the chloride concentrations shown in Table 1 show that at depths where the chloride concentrations are higher, the Br/Cl molar ratio is much lower than that found in either precipitation, groundwater, or seawater. Additionally, unlike in the upconing examples mentioned previously, chloride levels returned to their low background levels below the screen area. These data therefore indicate an alternative "external" source for the high chlorides, namely road salt.

MW-116843	PW- 1	Depth	S-116843 July 2000 Cl Mg/l	S-116843 July 2000 Br/Cl (nM/uM)
		30		
		40		
		50	49.10	0.54
		60	50.00	0.62
		70	46.50	0.57
		80	54.60	0.41
		90	116.40	0.30
		100	115.40	0.35
		110	50.20	0.80
		120	29.50	1.80
		130	32.50	1.77
		140	32.70	1.90
		150	24.40	1.82
		160	20.00	1.55
		170	19.90	1.56
		180		

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are carbon-containing compounds that evaporate easily from water into air at normal air temperatures (this is why the distinctive odor of gasoline and many solvents can easily be detected). The most common VOCs include (1) chlorinated solvents and (2) fuel components.

Chlorinated solvents are widely used in industry and in common household products. These are chemicals used as degreasing fluids for many different purposes such as dry cleaning clothes, removing the caffeine from coffee, cleaning metal machinery, and dissolving grease build up in septic tanks. Some chlorinated solvents are found in such household products as spot removers, typing correction fluids, adhesives, automotive cleaners, inks, and wood furniture cleaners. One VOC, vinyl chloride, is used to make plastic materials, such as vinyl and plastic wrap and pipe. People are most commonly exposed to VOCs through the air, in food, or through skin contact. When VOCs are found in groundwater, the potential exists for the drinking water supply to become an exposure pathway for VOCs.

The use of VOCs on Long Island started to become widespread in the mid 1940s. The aircraft industry, as well as other manufacturing and heavy industries, many of which are gone from Long Island, were the biggest users of these chemicals. VOCs began being detected in groundwater in 1976 (Ponturo, 2015, personal communication) and regulations on allowable VOC concentrations were enacted beginning in the late 1970s. By 1979, a total of 13 public supply wells in Suffolk County and 23 public supply wells in Nassau County (out of a total of 872 wells tested) were closed due to VOC contamination.

VOCs have become a very common class of contaminants affecting groundwater and surface water supplies nationwide. Most VOCs found in the environment result from human activity. Exposure to VOCs poses a threat to human health because many of them may be carcinogenic. Since they are so commonly used, they are commonly detected in Long Island's groundwater. When VOCs are spilled or improperly disposed of, a portion will evaporate, but some of it will percolate vertically into the ground. Once they are in or below the soil, VOCs may eventually reach the groundwater table. VOCs travel through the subsurface at the same speed and in the same manner as groundwater, and so can show up in drinking water wells. Water suppliers are required to test for organic compounds on at least a quarterly basis, and the finished water that they supply must meet very stringent standards, as defined by the USEPA. Initially, most VOCs in drinking water were regulated at a level of 50 parts per billion (ppb). As detection and treatment technology improved, and the carcinogenic effects of VOCs were better understood, the drinking water standard for most VOCs was lowered to five ppb in 1989.

Close up of actual granular activated carbon media used in VOC removal

In order to prevent or reduce the chances of health effects from occurring due to drinking water contamination, MCLs have been established by the United States Environmental Protection Agency (USEPA) for many VOCs. MCLs are limits that public water systems are required to meet by law, and are set at levels well below those known to cause health effects in lab animals and humans. In Nassau and Suffolk counties, MCLs for many VOCs are more strict than the USEPA levels. Additionally, some drinking water providers in Nassau and Suffolk Counties have voluntarily set MCLs for many VOCs at far more stringent levels that required by the EPA while other providers take facilities out of service when trace levels of VOCs (well below the MCL) are detected.

Several factors increase the likelihood that a water supply will be contaminated. One factor is the distance between the well and a source of contamination. Many wells contaminated with VOCs are located near industrial or commercial areas, gas stations, landfills or railroad tracks. A second factor is the amount of VOCs dumped or spilled. Some spills are small and localized. Others occur over a long period of time, or involve large quantities of contaminants. When a large quantity of chemicals has leaked or spilled, as may occur with leaking underground tanks or industrial spills, a large geographical area may be affected. Third, the depth of a well can be a factor. Shallow wells are often affected sooner and more severely than deep wells when contaminants have been spilled on the land surface.

A fourth factor is local geology. Unconfined aquifers, especially those where the depth to groundwater is shallow, are most vulnerable to contamination from surface activities. Low permeability confining units (clay and silt layers) may slow down the movement of contaminants and may help to absorb them somewhat. The fifth factor affecting contamination of water is time. Groundwater typically moves very slowly. A spill may take years to reach nearby wells. So wells may not be contaminated until years after the spill is discovered. Additionally, some contaminants naturally degrade over time.

The highest levels of VOC contamination are found in industrial, commercial, transportation and institutional areas. However, low levels of VOC contamination are detected in shallow groundwater throughout both Nassau and Suffolk Counties. This suggests that VOC use is very widespread, albeit mostly at very low levels, *(Comp Plan, p. 3-65, 3-67).* In the unsewered areas of Suffolk County, cesspools and septic systems can serve as point sources for low levels of VOCs to shallow groundwater. As a result, homeowners in Suffolk utilizing private wells may be especially vulnerable to VOC contamination. In Nassau County, most of which is served by municipal sewers with discharges to tidal waters, and with almost no areas using private wells, the problem is less widespread. However, with more industry than Suffolk, where VOC contamination problems exist in Nassau, they tend to be quite severe. Numerous widespread VOC plumes are documented throughout Nassau. Remediation of them is ongoing.

Treatment for Volatile Organic Compounds (VOCs)

When public supply wells become contaminated by VOCs at levels close to or above the drinking water standard, Long Island water suppliers choose one of two treatment options in order to supply their customers with water that meets the standard. The two technologies used most often on Long Island are: (1) Granular Activated Carbon (GAC) adsorption, and (2) Packed tower aeration (PTA), also known as air stripping. A brief description of each follows. It is important to note that there are numerous other technologies for remediating VOC contamination which are constantly being tested by public water suppliers. In the future, these other technologies may also be used in place of, or in addition to GAC and air stripping.

Granular Activated Carbon (GAC)

GAC is basically carbon in a granular form, which is made from raw carbon materials such as coconut shells or coal. This material is "activated" using heat to burn off some of the raw materials and produce microscopic pores within the carbon grains which are capable of trapping the molecules of contaminants in water in a process known as "adsorption." The activated carbon is then pulverized and sieved into appropriate and uniform particle sizes before it is used for water treatment. The carbon material is placed in large vessels (often as large as twelve feet in diameter). These vessels are installed at the well field, and piped in such a way that contaminated water from the well enters the vessels from the top of the carbon bed and is allowed to move through the porous carbon medium before exiting out the bottom of the vessel and into the distribution system. As the water moves through the carbon bed, the contaminants are removed by adsorption. Eventually, the carbon bed is no longer capable of adsorbing any more of the contaminant, and becomes "spent." At this point, the carbon material will be replaced so that the well can be put on line once again. Most organic contaminants found in public water supplies on Long Island can be treated by GAC; however, there are some organic compounds that cannot be effectively treated by this method. GAC vessels are quite large, and require a large piece of land for the vessels, a building to contain them, and all of the piping required. For this reason, they are more common in Suffolk County, where space limitations are fewer.

Packed Tower Aeration

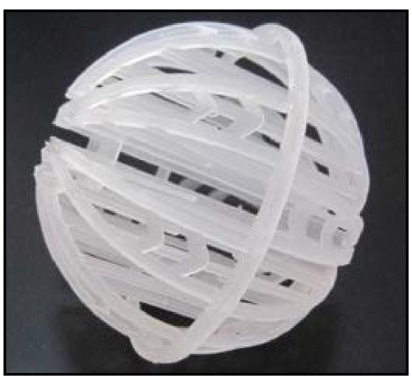
Packed Tower Aeration, or "air stripping" is the process of moving air through contaminated water in an above-ground treatment system. An air stripper provides contact between air and water that encourages VOCs to be released from the water. Air stripping removes VOCs since these are chemicals that easily evaporate. This means that they can change from a liquid to a vapor (gas). The air passing through contaminated water helps evaporate VOCs faster. After treating the water, the air and chemical vapors are collected, and the vapors are either removed or vented outside if VOC levels are low enough.

A typical Granular Activated Carbon (GAC) adsorption vessel in use at a public supply well field in Suffolk County. Each vessel is 12 ft. in diameter and 15 ft. high and contains 20,000 lb. of carbon media

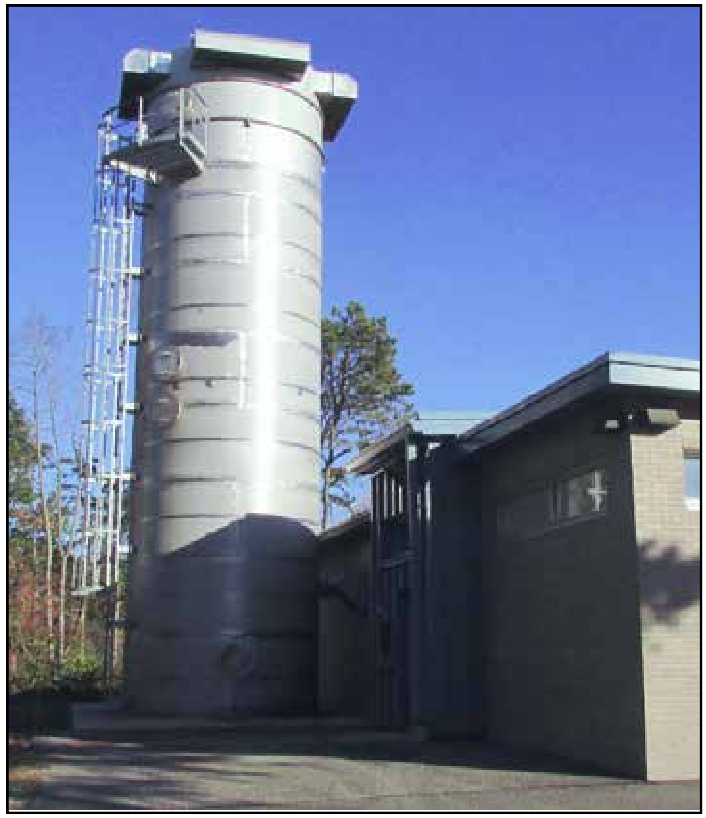
The most common type of air stripper is a packed-column air stripper, which is a tall tank filled with pieces of plastic, steel, or ceramic packing material. Contaminated water is pumped above ground and into the top of the tank and sprayed over the top of the packing material. The water trickles downward through the spaces between the packing material, forming a thin film of water that increases its exposure to air blown in at the bottom of the tank. Rising air and vapors accumulate at the top of the air stripper where they are either released to the atmosphere, or collected for treatment. Treated water flows to the bottom, where it is collected in an underground tank known as a "clear well". Uncontaminated water is then pumped from the clear well into the distribution system.

VOC Treatment of Drinking Water on Long Island

According to the Health Departments of both Nassau and Suffolk Counties there are approximately 89 air strippers in use by Long Island's public water suppliers, treating 120 wells. They are more common in Nassau County than in Suffolk (83 units vs. six), principally because space limitations at many Nassau well fields may preclude the use of large GAC systems. A total of 146 GAC vessels are in use by Long Island's public water suppliers, treating 161 wells. The Suffolk County Water Authority, Suffolk's largest public supplier, uses 132 GAC vessels to treat 143 of its wells for VOC contamination. In Nassau County, a total of 140 public supply wells are treated for VOC contamination, including eight wells that have both an air stripper and a GAC adsorption unit, *(Alarcon, 2015)*.



Close up of typical packing material used in an air stripper



An air stripper in use at a well field in East Farmingdale.

Pharmaceuticals and Personal Care Products (PPCPs)

Pharmaceuticals and personal care products include virtually anything that people apply to their skin and hair, or injest into their bodies. This diverse array of thousands of chemical substances, includes:

- **prescription and over the counter therapeutic drugs**
- **fragrances and cosmetics**
- **lotions such as sunscreen and insect repellants**
- **food and drink additives, including: caffeine and nicotine**
- **vitamins**

PPCPs are continually released into the environment from bodily excretion, bathing, and disposal of unwanted medications to septic systems, sewers or trash. They have the potential to enter our groundwater system via septic discharge or sewage treatment plants that discharge their effluent inland. In 2002, the U.S. Geological Survey (USGS), in cooperation with the Suffolk County Water Authority (SCWA), began a four-year study to document the occurrence of pharmaceutically active compounds in groundwater monitoring wells throughout Suffolk County. Seventy (70) water samples were collected from 61 monitor wells in the upper glacial and Magothy aquifers (nine wells were sampled twice) during 2002–2005 and analyzed for 24 pharmaceuticals. Wells were selected for their proximity to known wastewater-treatment facilities that discharge to the shallow upper glacial aquifer. Of the 70 samples taken, over half of them had no pharmaceutical compounds detected. Pharmaceuticals were detected in 28 of the samples taken, of which 19 contained one compound, and nine contained two or more compounds *(http://ny.water.usgs.gov/projects/SOTA/aquifer.html)*. There are thousands of PPCPs, their metabolites, and their breakdown products that can potentially be released into the environment. For example, in shallow monitoring wells located near laundromats in unsewered areas, the insect repellant compound DEET has been routinely detected. DEET has also been detected in monitoring wells near golf courses, reflecting use by golfers and course staff *(Comp Plan, p. 3-93)*.

The two studies cited underscore the point that in most cases, detections of PPCPs in groundwater occur in shallow monitoring wells constructed for the purpose of targeting these compounds.

The mere presence of these compounds in groundwater (or even in a public water supply well) is not necessarily cause for alarm, since these compounds are routinely used and encountered in our daily lives through medicines, food, beverages and other sources. However, since they usually enter groundwater from the waste stream, they are an indication that some element of wastewater discharge is present in groundwaters where they are detected. Fortunately, while detections of these compounds in groundwater (especially shallow groundwater in unsewered areas) has become fairly commonplace, detection of them in public drinking water is less common.

There are no compound-specific drinking water standards for individual PPCPs. Instead, they are regulated in New York State as part of the "unspecified organic contaminant" standard of 50 parts per billion. Where PPCPs have been detected in public supply wells, levels have been far less than 50 ppb. In many cases in Suffolk County, granular activated carbon (GAC) treatment is already present at well fields where PPCPs have been detected. GAC is usually, but not always, effective in remediating PPCP contamination.

The detection and quantification of these chemicals has only recently been possible due to advances in laboratory testing technology. We have the technology today to detect more substances and at lower levels (i.e. parts per trillion) than ever before. As described in previous sections of this report, the following analogies can be used to illustrate how small **one part per trillion** is:

1 inch to 16 million miles
1 second in 320 centuries

Concentration of PCPPs at these minute levels have no documented effect on human health, since they are thousands of times below the levels necessary to cause a "therapeutic effect." As an example of this, studies have shown that a person would need to consume almost 1,300 eight- ounce glasses of water per day in order achieve the lowest therapeutic dose of a cholesterol lowering drug known as gemfibrozil (brand name "Loprid"), if the water had the highest known concentration of this drug ever detected to date in groundwater in Suffolk County *(Comp Plan, p. 3-89)*.

The SCDHS has begun monitoring PPCPs in groundwater. Since 1997, the SCDHS has analyzed over 21,000 samples from both public supply and private wells for the presence of 30 PPCPs. Each year, an average of 2.5% of community supply wells, and 5.5 to 10% of private wells, have had detections of PPCPs, mostly in the part per trillion to low part per billion range *(Comp Plan, 2015, p. 3-92)*.

PPCPs are also being found at these low levels in many of our nation's lakes, rivers and streams. Even at these low concentrations, these compounds may have significant effects on aquatic wildlife. Some of the known potential impacts on organisms include delayed development in fish, delayed metamorphosis in frogs, and a variety of reactions including altered behavior and reproduction. Researchers at several universities have recently discovered that a group of antidepressants, including drugs like Prozac, Zoloft, Paxil, and Celexa may be found in frogs and fish and significantly slow their development. Synthetic estrogen hormones are taken by many women for birth control and hormonal replacement therapies and are sometimes taken by men for treatment of prostate cancer. Increased feminization of fish populations (e.g., inter-sex, hermaphroditic fish—males with eggs, high proportion of females to males) has been observed in several fish populations exposed to waste water containing estrogens *(www.campusecology.wsu.edu/page_055.htm)*. Therefore, the environmental and ecological effects of PPCPs are being increasingly investigated by scientists.

PPCPs are not removed from the waste stream at sewage treatment plants, so they can enter the groundwater system in their discharge stream even if all "conventional" water quality criteria are being met.

There are currently no EPA health standards for pharmaceuticals in drinking water and public water providers are not required to test for them. However, in order to be proactive with regard to public health, many suppliers test for PPCPs, as does the SCDHS. When PPCPs are found in public supply wells, water suppliers have utilized existing GAC systems in an effort to minimize their presence in finished drinking water.

As new drugs are developed, the number of PCPPs detected in Long Island's groundwater is likely to increase. By properly disposing of unwanted or expired medications at approved drop-off locations , citizens can help to help prevent release of these compounds into ground and surface waters. In Suffolk County, Operation Medicine Cabinet allows residents to drop off unwanted medications at drop boxes in any Suffolk County Police Precinct, 24 hours a day, seven days a week. East End residents can drop off unwanted medications at participating local police departments. In Nassau County, all police precincts are now accepting unwanted medications. New federal rules allow pharmacies to collect unwanted and unused medications. Ask your local pharmacy if they plan to implement a drug take back program.

Nitrogen in the Aquifer: Nitrate

Nitrate is a common contaminant found in groundwater. Nitrate is a naturally occurring chemical made of nitrogen and oxygen. Nitrate is found in air, soil, water, and plants. Much of the nitrate in our environment comes from decomposition of plants and animal wastes. Some additional nitrate is derived from precipitation containing airborne nitrous oxides. The impacts from man-made sources of nitrate are far greater than those of these naturally derived sources. The primary sources of nitrate contamination to Long Island's groundwater are on-site cesspools and septic systems, sewage treatment plants that discharge their effluent on the land surface, and fertilizers used in agriculture and on suburban lawns. Fortunately, nitrate concentrations at the levels that are harmful to human health are rare in our environment on Long Island. Nitrate delivered to coastal waterbodies via groundwater, however, is having detrimental effects.

Historically, as Long Island developed into a suburban area, nitrate levels in the upper glacial aquifer increased. The construction and use of municipal sanitary sewers has greatly reduced the levels of nitrate (as well as other contaminants such as detergents) in the upper glacial aquifer in sewered areas. Unsewered areas that continue to rely on cesspools and septic tanks to handle household sewage have not seen such a reduction in nitrate. In fact, in many unsewered areas, nitrate levels in the upper glacial aquifer have continued to increase. This phenomenon is more pronounced in Suffolk County, where approximately 70% of the population utilizes cesspools and septic tanks rather than regional municipal sewers. In some of the more densely populated unsewered areas, nitrate levels within the upper glacial aquifer exceed the drinking water standard of 10 mg/L. *(Comp Plan, p. 3-4)*. This water quality trend has also been observed in surface waters, such as lakes, rivers, and bays. Elevated nitrate in surface waters can cause harmful algal blooms and reduced oxygen levels, resulting in fish kills and other negative effects.

Nitrate in drinking water starts affecting the health of the general populace at levels in the range of 100 to 200 mg/l but the effect on any given person depends on many factors, including other sources of nitrate and nitrite in their diet. Infants and nursing mothers may experience nitrate related health problems at concentrations as low as 40 mg/L. Excessive concentrations of nitrate in drinking water can cause serious health problems for young infants, such as methemoglobanemia, or "blue baby syndrome". Fortunately, cases of methemoglobanemia, are exceptionally rare. According to local public health officials, there has never been a documented case of it due to tainted drinking water anywhere on Long Island. The drinking water standard of 10 mg/L, many times lower than the level at which health is impacted, greatly minimizes the likelihood that public drinking water supplies will cause nitrate-related adverse health effects to humans.

Wells that are most vulnerable to nitrate contamination are typically shallow and screened in the upper glacial aquifer, and are most often situated in agricultural areas (such as Eastern Long Island), or in fairly high density residential areas where homes are served by individual on-site septic systems for waste disposal. Wells that provide irrigation water to golf courses and farms often have elevated nitrate levels. Private homeowner wells in areas not served by public water (typically eastern Suffolk County), especially in agricultural areas, often show elevated nitrate levels. Efforts have been made by public water suppliers to extend public water to these residents. Some public supply wells in more densely populated, unsewered portions of western Suffolk County have seen marked increases in nitrate levels over the past 20 to 30 years. These wells are typically screened in shallow sections of the Magothy aquifer, in areas where no overlying confining units are present. In many instances, these are areas that were agricultural prior to post World War II suburbanization, and the legacy nitrate contamination has been exacerbated by more recent residential nitrate contamination.

Water Quality Mapping:

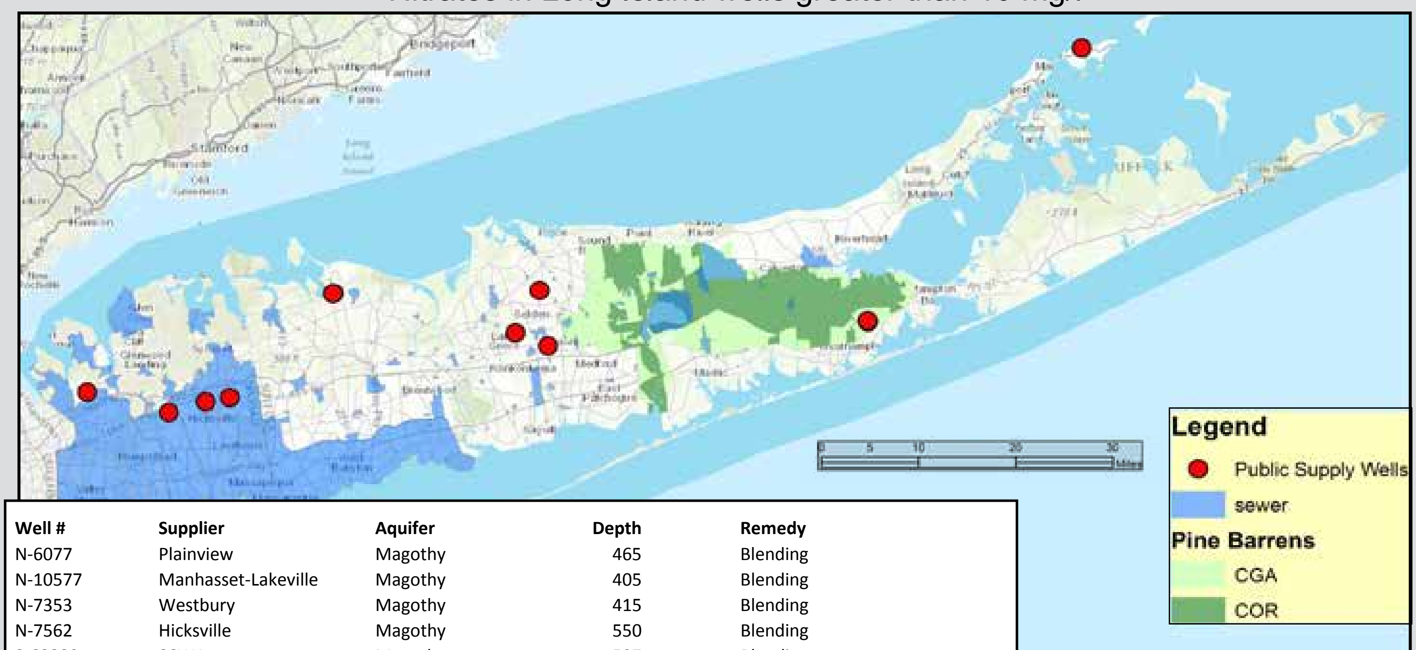
The Next Step in Coordinated Water Resources Management

For decades, researchers, scientists and officials from public agencies and water utilities have collected and analyzed water quality data from wells located all across Long Island. This data has been used to produce reports vital to the understanding of Long Island's aquifers. Water quality data from thousands of wells—as well as information about well location, the aquifer from which water was drawn, water table elevation and pumping history—is managed in dozens of independent databases by various entities. But until now, no one has attempted to unify all available information into a single database available to everyone, including the general public.

As stated in the mission at the beginning of this report, Suffolk and Nassau county officials created LICAP to advance a coordinated regional approach to groundwater resources management. To that end, water suppliers from across Long Island shared water quality data from calendar year 2015 to develop a single, unified database called WaterTraq. The creation of this database allows water utilities and public agencies to search for any chemical constituent and have results visually displayed by concentration, location, depth and sample date, among other criteria.

This tool offers an unprecedented view into the Long Island aquifer system. The next step will be to add all monitoring wells within Nassau and Suffolk and create a web-based version of the system. The program may also be expanded to include geologic and source water data.

Nitrates in Long Island wells greater than 10 mg/l



Well #	Supplier	Aquifer	Depth	Remedy
N-6077	Plainview	Magothy	465	Blending
N-10577	Manhasset-Lakeville	Magothy	405	Blending
N-7353	Westbury	Magothy	415	Blending
N-7562	Hicksville	Magothy	550	Blending
S-68880	SCWA	Magothy	597	Blending
S-103815	SCWA	Glacial	50	In home filtration units
S-23371	SCWA	Glacial	475	Blending
S-46400	SCWA	Glacial	265	Blending
S-39347	SCWA	Glacial	176	Abandoned - no longer in service
S-23184	SCWA	Glacial	118	Abandoned - no longer in service
S-353593	SCWA	Glacial	162	Blending

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, MI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

The above map shows the approximate locations of public supply wells on Long island that had nitrate levels above the NYS drinking water standard of 10 mg/L in 2015. These wells cannot be pumped directly nto their distribution system, but must be either (1) outfitted with a nitrate removal system, similar to that shown at the top of page 30, or (2) pumped simultaneously ("blended") with a lower nitrate well. The data table in this section also shows how each water supplier mitigated their nitrate problem. Water delivered to customers is required by state and federal law to have a nitrate level below 10 mg/L.

Nitrate and Human Health

Nitrate can interfere with the ability of the blood to carry oxygen to vital tissues of the body in infants of six months old or younger. The resulting illness is called methemoglobinemia, or "blue baby syndrome". In the presence of nitrate, hemoglobin in the blood can be converted to methemoglobinemia, which cannot carry oxygen. Consuming drinking water with nitrate levels near the drinking water standard does not normally increase the methemoglobinemia level of humans beyond infancy. Some individuals, however, may have increased susceptibility to methemoglobinemia due to a number of different factors (such as pregnancy or certain rare diseases). Once diagnosed, methemoglobinemia can be readily reversed, although permanent damage may have occurred. Eighty to 90 percent of the nitrate most people consume comes from vegetables, but this is unlikely to cause health problems because very little of the nitrate in vegetables is converted to nitrite. Meat products account for less than 10 percent of nitrate in the diet, but 60 to 90 percent of the nitrite consumed. This is primarily because of sodium nitrite added to foods such as hot dogs, bacon, or ham. Fruits, grains, and dairy products contribute almost no nitrate or nitrite to people's diets.

A picture of a nitrate removal plant in use at a public supply well in E. Northport. Photo shows one component of the system known as the "ion exchange media carousel"

This phenomenon was investigated extensively as part of the Comp Plan. A set of 390 public supply wells in all three major aquifers were sampled in 1987 and again in 2013. Data showed that nitrate levels in public supply wells increased in all three aquifers between 1987 and 2013. Nitrate levels increased by an average of 1 mg/L in the upper glacial aquifer (from an average of 2.63 mg/L to an average of 3.69 mg/L) and by 0.76 mg/L in the Magothy aquifer (0.95 mg/L to 1.71 mg/L). Only one Lloyd aquifer well was sampled in both years, and nitrate levels in that Lloyd public supply well increased by 0.5 mg/L.

Some of the above-mentioned increase in nitrate levels as described above may be attributable to increased public supply pumpage over the past four decades. While the population of Suffolk County has increased by 14 percent between 1980 and 2013, public supply pumpage has increased by 56 percent during that same time period (146 mgd in 1980 vs. 228 mgd in 2013). Much of this increase can be attributable to increases in lawn watering. Winter pumpage during this time period is up by approximately 15 mgd, while summer pumpage is up by over 100 mgd *(Comp Plan, p. 4-34)*. As mentioned in a previous section of this report, increased pumping can have the effect of accelerating the movement of water (and any contaminants dissolved in it) through the aquifer system. The good news from all of this is that, despite these nitrate increases, the average nitrate concentration in the sampled public supply wells remained at less than half the 10 mg/L drinking water standard.

Surface Water Impacts

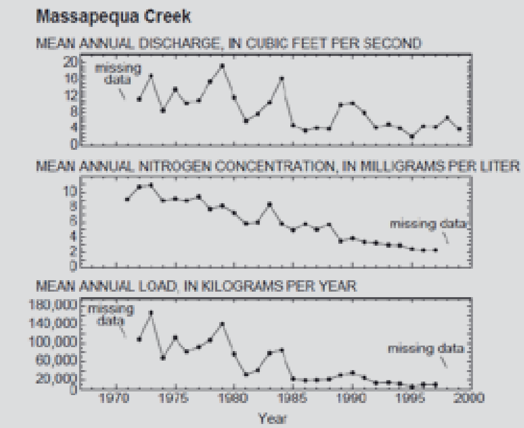
In recent years, Long Islanders have come to recognize that the potential for groundwater pollution to impact surface waters is just as important as drinking water impacts. Groundwater is a primary conduit for contaminants entering coastal water bodies. Pesticides, organic contaminants and metals can all impact coastal ecosystems, but nitrogen loading via groundwater is the primary threat to water quality in all of Long Island's estuaries. More than forty years of research has revealed areas where nitrate concentrations in shallow groundwater are elevated to at or near drinking water standards – typically in agricultural areas in eastern Suffolk County, and in high density residential areas without sanitary sewering, most of which are in western Suffolk County (with some notable exceptions).

Since all surface water bodies on Long Island are groundwater dependant, contamination of the groundwater resources, particularly by elevated nitrate levels, impacts the water quality of a receiving surface water body. Negative ecological effects in coastal systems can result from groundwater nitrate concentrations far below the drinking water standard. Surface water bodies can begin showing negative ecological effects at nitrate concentrations much lower than 2 mg/L.

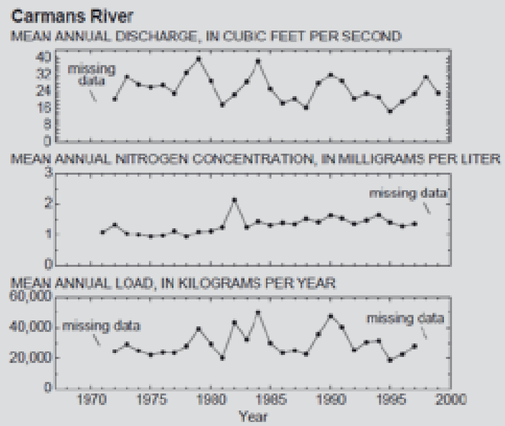
Excess nitrogen loading contributes to many impacts to Long Island's bays, including harmful algal blooms, fish kills, loss of aquatic plants such as eelgrass, and wetland degradation. This leaves parts of Long Island more vulnerable to flooding and storm and hurricane damage.

These species are important for erosion control and serve as habitat for fish and shell fish in the bays. For improved estuary health, nitrogen delivered to estuaries via groundwater must be reduced. Possible solutions to reducing nitrogen levels in shallow groundwater include reduction of fertilizer use, expansion of regional sanitary sewers and the use of "high performance" septic systems for individual homes in place of conventional septic sys- tems. These high performance systems can reduce the nitrogen content of domestic sewage by over half, resulting in lower nitrate levels in shallow groundwater.

Regional sanitary sewering has the dual effect of reducing nitrogen loading in streams and ultimately the receiving tidal water body, while also reducing the baseflow of the stream itself. The overall nitrogen load to both the upper glacial aquifer and to receiving surface water body is reduced by regional sewering , but the reduction in streamflow may have negative effects on the health of the receiving water. The two graphs below represent historic nitrogen loading and stream flows in creeks flowing through sewered (Massapequa Creek) and unsewered (Carman's River) areas *(http://ny.water.usgs.gov/pubs/wri/wri024255/).*



These two diagrams of streamflow and nitrogen vs. time indicate the difference in shallow groundwater quality in a sewered vs. unsewered area. Left – Massapequa Creek, showing reduced flow and reduced nitrogen as sewering has taken effect. Right – Carmans River, located in an unsewered area, showing no decrease in flow and a slight increase in nitrogen over time



Pesticides

Pesticides include any substances (or mixture of substances) intended to destroy, repel, or otherwise mitigate problems associated with organisms determined by the NYSDEC to be pests, including insects, rodents, fungi, weeds, viruses (or other forms of plant or animal life) present in the environment or living on humans or animals.The term also applies to the degradation products of these substances. Pesticide monitoring and management is a complex issue, because many of these compounds and their breakdown products easily dissolve in and move through groundwater. They can exist within the aquifer system for decades. This is a concern not only for drinking water, but also for Long Island surface water features, such as lakes, streams and estuaries.

In accordance with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), New York State has developed a pesticide product registration program and reporting law that includes requirements for the registration and use of pesticides. This law mandates that a water quality monitoring program be conducted in order to provide an adequate understanding of the health and environmental impacts of pesticide use within New York State. SCDHS first began a pesticide monitoring program in 1997. Since then, this program has expanded to include numerous monitoring wells installed at nearly 70 different locations to help assess any impacts to water resources from pesticide use. As part of this effort, the SCDHS works with a variety of stakeholders, including the NYSDEC, the New York State Department of Health (NYSDOH), USEPA, Cornell Cooperative Extension (CCE), the Nassau County Department of Public Works, public water suppliers and the USGS.

The program has been tailored to testing groundwater quality associated with specific land uses, including golf courses, vineyards, greenhouses, nurseries, farms, residential areas and public utility right of ways. The information obtained from this program is also to be used to support the NYSDEC's Long Island Pesticide Pollution Prevention Strategy and the long-term monitoring of pesticides as recommended in Suffolk County's Comprehensive Water Resources Management Plan.

Pursuant to the NYS Sanitary Code, all organic compounds without a specific drinking water standard are classified as either unspecified organic contaminants (UOCs) with an assigned drinking water standard of 50 parts per billion (ppb) or principal organic contaminants (POC) with an assigned value of 5 ppb. Most pesticides and their degradation products do not have specific drinking water standards and, as such, have an assigned value of 50 ppb. The SCDHS Public and Environmental Health Laboratory (PEHL) tests for approximately 150 different pesticides including degradation products. However, this may only represent about 15% of the active pesticide ingredients registered in the state for use on Long Island.

Pesticide Monitoring Results / Detections

According to the SCDHS, more than 100 pesticide-related compounds have been detected in Long Island groundwater since the pesticide monitoring program began in 1997. Public water suppliers operating in Nassau and Suffolk Counties also routinely test for a variety of pesticides as part of their self-monitoring requirements conducted under the NYS Sanitary Code. For example, SCWA tests for approximately 70 different pesticide compounds as part of their public water supply monitoring efforts. Through Suffolk County's ongoing monitoring programs, the SCDHS has observed the following:

- Pesticide breakdown products have been detected more frequently and in higher concentrations than parent compounds. However, the majority of pesticide detections have been low.
- Sampling performed by the SCDHS in cooperation with other agencies and stakeholders has helped to facilitate the voluntary withdrawal of several pesticides registered for use on Long Island. Notable examples include aldicarb, carbofuran, oxamyl, dacthal, and dichloropropane in the 1980s and metolachlor and alachlor in the 2000s.
- SCDHS records indicate that there have been fewer detections of the oldest pesticides, most of which are no longer used. Also, the maximum concentrations detected by the SCDHS of several of these compounds have decreased. However, these compounds are persistent and in some cases still exceed the drinking water standards.
- According to SCDHS records, between 1997 and 2012, the most prevalent compounds detected in drinking water wells have all been withdrawn for use on Long Island, except for one (atrazine), which has been restricted for use by the NYSDEC.
- There has been an increase in the frequency of detections of other pesticides, although the measured concentrations remain lower than their respective drinking water standards.
- Samples collected by the SCDHS between 1997 and 2012 show that treated samples collected from public drinking water wells meet NYS drinking water standards .
- Sampling data compiled by the SCDHS between 1997 and 2012 from drinking water sources revealed that pesticide compounds were detected with the following results:
  - At least one pesticide compound was detected in about 22% of Public Community Supply Wells tested during this period (196 of 865 wells sampled);
  - At least one compound was detected in about 25% of the Public Non-Community Supply Wells sampled during this period (150 of 589 wells sampled);
  - At least one compound was detected in about 23% of the private wells sampled during this period (2300 of 9900 wells sampled).

Recommendations / Actions Moving Forward

In order to address the ongoing potential impacts of pesticides to groundwater and surface waters, the SCDHS and involved stakeholders will continue its robust monitoring and sampling programs and continue to identify compounds that are frequently used on Long Island and can potentially impact our water resources.

Recently, staff at Cornell Cooperative Extension have identified at least twelve pesticides that could potentially impact our water resources. Involved agencies and stakeholders are in the process of exploring the ability to test for these compounds. Finally, as part of the NYSDEC's Pesticide Pollution Prevention Strategy, stakeholders, regulatory agencies and agricultural communities will continue to work together to implement Best Management Practices (BMP) at various agricultural settings to help mitigate the impact of pesticide use on Long Island.

Emerging Contaminants

Recently, other significant water quality challenges have emerged, including 1,4 dioxane ("dioxane") and perfluorinated compounds ("PFCs"). Dioxane is a synthetic organic chemical that has been used as a solvent and as a stabilizer for industrial chemicals, especially trichloroethane. It is not uncommon to detect 1,4 dioxane in public water supplies on Long Island since it is highly soluble, mobile, persistent, and difficult to treat. PFCs are fluorinated organic chemicals that have been used to make carpets, clothing, fabrics for furniture, paper packaging for food, and coatings for cookware that are resistant to water, grease or stains. PFCs were also used for decades in certain firefighting foams.

Neither dioxane nor PFCs have exceeded drinking water standards for unspecified organic compounds in public water supplies. However, both have exceeded EPA health advisory levels in some areas of Long Island. Water suppliers, NYSDEC, NYSDOH, and local health departments have been extremely proactive in the monitoring and management of these emerging contaminants. Actions have included enhanced monitoring, treatment (carbon and blending for PFCs, advanced oxidation processes and blending for dioxane), public outreach, and mitigation (connection of affected residents to public water supply is being planned downgradient of the Air National Guard Gabreski Airport PFC Superfund site). These contaminants underscore the need for continuing vigilance, in terms of monitoring for emerging contaminants and managing historic and ongoing potential sources of pollution. Future State of the Aquifer Reports will focus on a comprehensive update on these, and other, emerging contaminants.

Grumman - Navy Groundwater Plume

Background

The Northrop Grumman Corporation was established in 1929 in Bethpage on a 635-acre parcel, 105 acres of which were occupied by the Naval Weapons Industrial Reserve Plant (NWIRP), a Government Owned Contractor Operated (GOCO) facility. Activities conducted at the facility included engineering, administrative, research and development, and testing operations, as well as manufacturing operations for the Navy and NASA. The facility also had an active airfield. Both Northrop Grumman and the NWIRP sites had maintained numerous industrial groundwater supply wells, drinking water supply wells, and recharge basins. Former manufacturing and other operations have been phased out, and Northrop Grumman has sold significant portions of the property. Northrop Grumman does, however, maintain a permanent presence with minimal staff at the site.

Groundwater beneath the site has been contaminated by both volatile organic compounds (VOCs) (primarily trichloroethylene, tetrachlorethylene, dichloroethylene and vinyl chloride) and chromium which entered the groundwater through various source areas. These include recharge basins, sumps, dry wells, spill areas and former hazardous waste storage areas at both the Grumman facility and the adjacent Hooker/RUCO EPA Superfund site. In 1976, water pumped from some of the on-site Grumman public supply on wells was found to contain VOCs. Subsequently, Grumman discontinued use of its wells for drinking water purposes and connected to the Bethpage Water District (BWD) public water system.

In 1986, the Nassau County Health Department, in conjunction with the United States Geological Survey (USGS), began an investigation of the groundwater resources in the vicinity of the Grumman plant. During this study, a groundwater plume estimated to be more than 2,000 acres in area and more than 700 feet deep in places has been identified beneath, and south of, these facilities. This plume is emanating from this facility, and is comingled with a plume from the upgradient and adjacent Hooker/RUCO site.

Northrop Grumman has implemented an on-site groundwater remediation and monitoring system which is known as OU-1. OU-1 includes three extraction wells which remove contaminated groundwater from the site and pump it through an air stripping treatment system for VOC removal. Following treatment, the groundwater is discharged into recharge basins located along the southern boundary of the site. This process has not only treated on-site contaminated groundwater but has also created a partial hydraulic barrier which has supposedly minimized off-site migration of the contamination. However, recent vertical profile boring data upgradient from Bethpage Water District Plant 6 indicates that the on-site system may not be capturing deep contamination.

A second operable unit, OU-2, includes a network of wells which are used to monitor the off-site contamination plume. Data from these monitoring wells indicate there is a significant contaminant plume flowing in a southeasterly direction that is not being treated by the OU-1 Groundwater Remediation System. Therefore, the groundwater plume is poorly delineated, and part of the plume has "broken away" from the Grumman-Navy site and impacted public supply wells to the south. In 2014 the Navy commenced with additional delineation work.

Since 1986 off-site groundwater contamination has adversely impacted or threatened several public drinking water supply wells including facilities operated by the Bethpage Water District (BWD), Levittown Water District (LWD) and New York American Water (NYAW). Public supply wells operated by South Farmingdale Water District (SFWD) and Massapequa Water District (MWD) are threatened by the contamination. To address this threat, the NYSDEC implemented a sentinel well installation program siting early warning monitoring wells upgradient of public supply wells operated by SFWD, MWD and NYAW. Based on contaminants detected in some sentinel wells, wellhead treatment systems were constructed at SFWD Plants nos. 1 and 3 and NYAW Seamans Neck Road Plant in 2014.

Operable Unit 3 (OU-3), an area immediately off-site which was used for sludge drying and fire control training, is an 18-acre area that now is the Bethpage Community Park. Prior to being developed as a park, this property was reportedly used by Grumman as a wastewater discharge recharge area, sludge drying bed area, and fire training facility, where waste oil and jet fuel were ignited and extinguished. Preliminary data indicates that the OU-3 area could have been a historic source of six chlorinated volatile organic compounds. As part of the off-site investigation into the contamination plume emanating from the park, vertical profile borings (VPBs) were installed and extensive off site contamination of the deep magothy aquifer was documented. The NYSDEC issued a Record of Decision in April of 2013.

Plume Location

The dissolved VOC plume is currently approximately 15,000 feet long (north to south), 9,000 feet wide (east to west) and approximately 700 feet deep. The aerial photograph on page 34 depicts the extent of the commingled OU-2 and OU-3 plumes which encroach into the NYAW, SFWD, and LWD service areas. The plume of contamination, the largest impacting a federally designated sole source aquifer in the country, travels both horizontally and vertically in the Magothy aquifer and moves in a range of 0.3 to two feet per day, based on information from reports prepared by Grumman or the Navy. An average estimated rate of one foot per day has been typically used to define groundwater movement in the area.

Drinking Water Wells Impacted and Threatened

In addition to the wells referenced above, this extensive plume is expected to impact additional public supply wells operated by the SFWD and NYAW. The Massapequa Water District (MWD) is further south and will likely be impacted by the plume in the future if proper action is not taken to perform full delineation and remediation of the plume.

A total of 34 public drinking water supply wells operated by five regional purveyors with an aggregate capacity of over 70 mgd are threatened or already impacted by the plume. These five regional suppliers provide potable water to a population of over 250,000. A total of nine wells are already equipped with wellhead treatment in response to the plume, with two more planned to be constructed in the near future. 23 remaining public drinking water supply wells are in the path of the commingled OU-2 and OU-3 plume.

Contaminants of Concern

TCE is the primary contaminant that has impacted or is threatening public drinking water supply wells in the path of the plume. TCE is heavier than water and therefore sinks in the aquifer as it migrates down gradient. TCE has been classified as carcinogenic to humans. Concentrations of TCE in deep aquifer sections far exceed applicable drinking water standard of 5 parts per billion (ppb). For example, TCE was detected in a vertical profile boring upgradient from BWD Plant 6 during 2014 at a concentration of 4,600 ppb. Additionally, a Total Volatile Organic Compound (TVOC) concentration of 14,700 ppb was most recently discovered upgradient of BWD wells as part of an OU-3 pre-design investigation by Grumman. This represents the highest TVOC concentration found off site to date and is almost 3,000 times greater than the MCL.

Future Drinking Water Regulatory Action

The EPA is considering lowering the MCL for tetrachloroethylene (PCE) and trichloroethylene (TCE). to a level that is closer to the detection limit of 0.5 ppb, based onthe context of the Safe Drinking Water Act (SDWA) requirement that the MCL must be as close to the MCLG "as feasible." The lowering of the MCLs will result in far higher wellhead treatment costs. 1,4-dioxane is another contaminant of concern. EPA risk assessments indicate that the drinking water concentration representing a one in a million cancer risk level for 1,4-dioxane is 0.35 ppb (EPA IRIS 2013). For purposes of comparison, the State of Massachusetts has established a drinking water guideline level of 0.3 ppb (Mass DEP 2012).

During Grumman's December 2015 sampling program for the OU-3 pre-design, 1, 4-dioxane was detected in an upgradient monitoring well at a peak level of 114 ppb. According to the EPA, 1,4-dioxane is a compound likely to be present at sites contaminated with certain chlorinated solvents because of its widespread use as a stabilizer for those solvents. Since the Navy and Grumman started to incorporate testing for 1,4-dioxane, it has been consistently detected in the plume. Air stripping and GAC Adsorption do not remove this contaminant. A more costly advanced oxidation process (AOP) using hydrogen peroxide with ultraviolet light or ozone has been shown to be potentially successful to remove 1,4-dioxane. The probably MCL for 1,4-dioxane is 50 ppb. Therefore this contaminant must be considered as plume delineation and remediation moves forward.

Perchlorate has been detected in BWD supply wells. To date no sampling has been conducted by Grumman and Navy to determine the source of the contamination. Such testing needs to be performed immediately, especially since fire training operations were a part of Grumman past practices on the property and perchlorate is a component of jet fuel and munitions.

The New York State Department of Health (NYSDOH) provisional standard for perchlorate requires public notification when perchlorate is found at 18 ppb, and requires large water suppliers to report findings in their Annual Water Quality Reports. Several states have initiated regulatory reviews to prepare a drinking water standard for perchlorate. California and Massachusetts have set "public health goals" for the contaminant levels of 6ppb and 1ppb respectively. Accordingly this contaminant must be considered as plume delineation and remediation efforts at this time.

Remediation Efforts

Until very recently, the NYSDEC has not required off-site cleanup of the groundwater contamination, but decided to allow the funding of treatment systems at impacted public supply wells. In reaching this determination, the NYSDEC has decided that the groundwater contamination can remain and will not be subject to cleanup. NYSDEC regulations list four remediation measures: (1) removal and/or treatment; (2) containment; (3) elimination of exposure; and (4) treatment of source at the point of exposure. The plume containment and remediation approach was reviewed by the NYSDEC during 2001.

Another option for remediation, would be the construction of extraction wells north and south of Hempstead Turnpike in order to contain and remediate the plume. Such an

Aerial photograph showing the location of the Grumman-Navy plume relative to nearby public supply wells

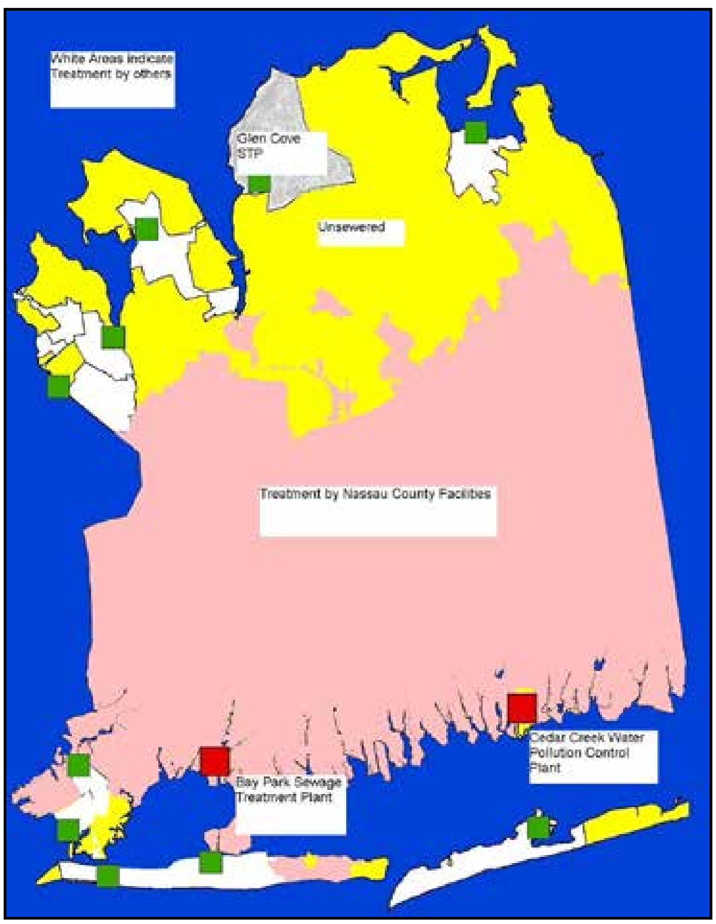
approach could prevent additional public drinking water supply wells from being adversely impacted or threatened and protect public health. Potential areas for installation of recovery wells and treatment facilities have been tentatively identified, and impacted and threatened water suppliers continue to meet with regulatory agencies and the responsible parties to encourage the installation of recovery facilities to intercept the plume to prevent further impacts. Since locating a plume containment/remediation extraction treatment system in residential areas can be potentially difficult, conveying the extraction water back to the Grumman property for treatment may be necessary if this approach is adopted. Treated water effluent will be re-injected into the aquifer and also should be considered for stream flow augmentation and golf course irrigation. The Bethpage State Park Golf Course is located in very close proximity to the Grumman-Navy site. This would be most beneficial to the water balance as the treated plume water would re-enter the aquifer system.

Benefits of proactive plume containment and remediation may include a potentially significant cost savings given the cost for wellhead treatment, as compared to cleanup of the groundwater; fewer upgrades to existing wellhead treatment systems to treat for 1,4 dioxane; optimum public health protection via the prevention of contamination from impacting supply well source water and maintaining a multi-barrier approach for drinking water quality protection; cleanup of the environment; and elimination of any negative impact to Great South Bay.

Sewering vs. Septic Systems

The method by which domestic wastewater is treated in an area is an important influence on both the water quality and the water quantity in that area. Municipal sanitary sewers, especially those with effluent discharge to tidal waters, completely remove wastewater from the groundwater system. This has a positive effect on shallow groundwater quality by eliminating pollutants such as nitrate and industrial waste. However, since this water is not recirculated back into the groundwater system, sewering also has the effect of reducing the overall volume of water within the aquifer system, which has a negative effect on water quantity.

Approximately 90% of the population in Nassau County is served by municipal sanitary sewers. Construction of these large public works began in the 1950s, and was essentially finished by the early 1980s, except for a few small areas within the county. The Nassau County Sewer and Stormwater Authority (NCSAA) operates two large wastewater collection and treatment systems which primarily serve the south shore of the County. These two plants are the Bay Park and the Cedar Creek sewage treatment plants, which together treat an average of 58 million gallons per day (mgd) of wastewater. After treatment, the effluent from these plants is discharged to the south shore estuaries or to the Atlantic Ocean. The NCSAA also operates the City of Glen Cove sewage treatment facility, and receives effluent from an additional six municipal sewer districts in Nassau. Nine additional independent municipal sewage treatment systems serve Nassau County. Collectively, these nine system process approximately 15% of Nassau's wastewater.



Map showing sewered areas in Nassau County and locations of municipal wastewater treatment facilities. County facilities are shown in red. Unsewered areas utilize on site disposal systems for domestic sewage.

Construction and use of regional sewers in Nassau has resulted in significant changes to the groundwater system in the county. Since these sewer systems remove wastewater from the groundwater system along with all contaminants associated with it, shallow groundwater and surface water quality in Nassau have improved dramatically, especially with regard to nitrate levels. However, since regional sewering reduces the overall volume of water within the upper glacial aquifer, water levels in portions of central Nassau have declined as much as 10 to 15 feet since the onset of sewering. Some of this water table decline has even been observed in portions of western Suffolk County (as much as 5 to 8 feet). This decline has negatively affected water levels in surface water bodies (lakes and streams) located within the sewered areas. Some creeks have shortened in length or completely dried up, and the water level of many lakes have declined significantly since the onset of sewering.

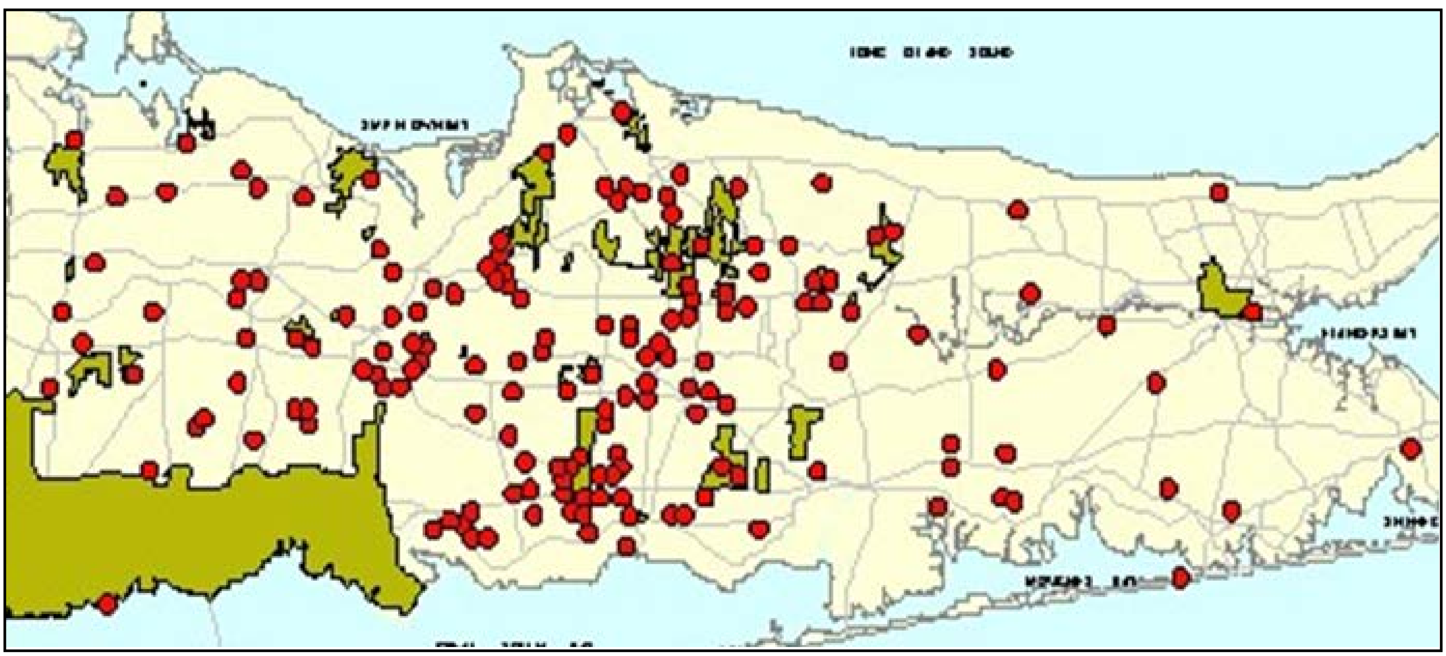
In contrast to Nassau County, approximately 70% of Suffolk County's residents utilize individual cesspools and septic tanks for domestic waste disposal. Rather than having wastewater conveyed to a distant treatment facility, the septic/cesspool system is located on the homeowners property. However, since untreated domestic waste typically has a nitrate concentration of over 40 mg/L, the quality of water within the upper glacial aquifer in areas served by on-site cesspools and septic systems is usually somewhat degraded.

Suffolk also has numerous larger municipal, and smaller privately owned wastewater treatment plants that discharge treated effluent to a large basin located near the plant. While these two above-mentioned practices tend to maintain groundwater levels in the upper glacial aquifer by keeping water within the groundwater system, they often result in water quality degradation within the upper glacial aquifer (especially in the case of individual homeowner septic systems).

Suffolk County does have several large municipal wastewater treatment facilities that discharge to tidal waters (similar to those in Nassau County), the largest of which is the Bergen Point treatment plant in West Babylon. Some water level declines within the upper glacial aquifer have been observed since the construction of the Bergen Point plant. However, the vast majority of Suffolk's residents rely on individual cesspools and septic tanks.

Utilizing cesspools for individual homes also affects the quality and quantity of groundwater, in the opposite manner of regional sewers. Since water is re-circulated back into the ground via the cesspool, minimal impact to overall volume of water within the upper glacial aquifer results. However, since untreated domestic waste is quite high in nitrate concentration, the quality of water within the upper glacial aquifer in areas served by cesspools is usually degraded. The degree to which nitrate levels are elevated depends upon the density of the housing units.

Previous studies conducted on Long Island by scientists and planners have shown that in unsewered areas with lot sizes of ¼ acre or smaller, groundwater in the upper glacial aquifer typically has nitrate levels above the drinking water standard of 10 parts per million (ppm). In unsewered areas with lot sizes averaging ½ acre, nitrate levels are typically 5 to 6 ppm, lot sizes averaging 1 acre in unsewered areas typically result in nitrate levels of 3 to 4 ppm and lot sizes of 2 acres or larger have minimal nitrate impact on groundwater quality. Many residential neighborhoods on Long Island are situated on lands that were farmland at one time. On such lands, there is often "legacy" groundwater contamination from past agricultural activity even before residential development began. Succeeding residential development using septic systems often exacerbates such contamination. In conclusion, larger lot sizes in unsewered residential areas results in lower nitrate concentrations in the local shallow groundwater. However, utilization of regional sewering, with offshore wastewater disposal virtually removes sewage-related contaminants from the groundwater system altogether.



Map showing sewered areas in Suffolk County. Regional sewer districts are shown in green, and sewage treatment plants are shown by the red circles.
Note that most of Suffolk County is not sewered, and therefore utilizes on-site cesspoolseptic systems for wastewater disposal.

Concluding Thoughts...

In just a short period of time, the Long Island Commission for Aquifer Protection has taken great strides toward creating a blueprint for a coordinated approach to groundwater resources management on Long Island, such as through the creation of this State of the Aquifer Report. But these are just initial steps. The protection of our water supply depends on the continued active involvement of researchers, scientists, officials from public agencies and water utilities, elected officials and the general public.

To that end, LICAP will continue work on its Groundwater Resource Management Plan, which will include detailed information about groundwater data management, threats to water quality and quantity and recommendations for potential regulatory changes, among other related topics.

The State of the Aquifer Report and the Groundwater Resources Management Plan will provide the impetus for a new era of groundwater management on Long Island. It is our sincere hope and expectation that others will build on the work we've started to protect forever this incredible natural resource.

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