GROUNDWATER RESOURCES MANAGEMENT PLAN

December 11, 2019

 Authored by: 
The Long Island Commission for Aquifer Protection (LICAP)
MESSAGE FROM THE CHAIRMAN

As Chairman of the Long Island Commission for Aquifer Protection (LICAP), I'm delighted to present you with the following document, which completes a six-year initiative undertaken with the voluntary efforts of many groundwater professionals and others with expertise in various environmental fields to produce a working Groundwater Resources Management Plan for Long Island.

When LICAP was created, its primary mission was to establish a framework to manage the sole source aquifer that provides 100% of Long Island’s drinking water in a coordinated, regional manner. To do so, LICAP’s members were charged with two primary deliverables: the creation and annual update of a State of the Aquifer report and development of a comprehensive Groundwater Resources Management Plan to provide a blueprint for municipalities to follow in ensuring Long Islanders will continue to enjoy a plentiful and clean drinking water supply for many generations to come.

The creation of the management plan came in two stages. We created an initial document released in 2017 focusing on the development of management strategies for topics including climate change, geothermal heating and cooling systems, water conservation and the regulation of the Lloyd aquifer. After its release, LICAP members decided it was important to assess, in a more granular fashion, four specific topics including the prevalence of private wells in the counties and options to provide public water to those residents relying on these wells, wastewater management, regulation of contaminants and issues relating to the use of New York City water supplies to provide additional supply to Western Nassau wells.

This month, we present the second component of the plan, and with the completion of the plan, the work of two original LICAP subcommittees—the 2040 Water Resource Infrastructure Subcommittee and the Water Resources Opportunities Subcommittee—is also complete (though two others, the Conservation Subcommittee and Long Island Nitrogen Action Plan Subcommittee, continue their work). Taken together, we feel we’ve provided a realistic management plan that Long Island’s leaders of today and tomorrow can look to for guidance when it comes to the preservation and proper management of our greatest natural resource.

Jeffrey M. Szabo
Chairman
Long Island Commission for Aquifer Protection

[Signature]
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CHAPTER 1
INTRODUCTION AND EXECUTIVE SUMMARY

The aquifer system that underlies Long Island is the sole source of drinking water for Nassau and Suffolk Counties. Numerous reports and studies regarding this aquifer system have been prepared over the years, but due to the proliferation of local governmental entities and decentralized land-use controls on Long Island, the need for addressing groundwater issues on a regional scale continues to be a challenge.

In 2013, Nassau County and Suffolk County established a bi-county entity called the Long Island Commission for Aquifer Protection (LICAP) to address and to advocate a coordinated approach to the groundwater issues facing the region. It was devised to build upon previous groundwater studies and reports, identify areas for further research, suggest programmatic opportunities for stemming further degradation of Long Island’s sole-source aquifer and identify mechanisms, including land use controls, for improving the quality of water within the sole-source aquifer.

LICAP consists of nine voting members. Five entities have permanent membership positions: the Suffolk County Water Authority (SCWA), the Long Island Water Conference, the Nassau-Suffolk Water Commissioner’s Association and the Nassau and Suffolk Health Departments. Four other members, two appointed from Nassau County and two appointed from Suffolk County, complete the voting membership. LICAP also includes 18 ex-officio, non-voting members. These ex-officio members include representatives from Nassau County, Suffolk County, the New York State Department of Environmental Conservation, the United States Geologic Survey and the Long Island Groundwater Research Institute.

LICAP’s legislative mandate includes the creation of a *Groundwater Resources Management Plan* (GRMP). LICAP’s members and ex-officio members have worked cooperatively during the past three years to compile the germane information. The GRMP must include, but is not limited to: (a) qualitative and quantitative groundwater data, (b) anthropogenic threats to groundwater quality and quantity, (c) existing regulatory groundwater management regimes, (d) assessment of adequacy of existing groundwater management regulations, (e) management opportunities, (f) development recommendations, (g) methods for implementing the recommendations and proposed regulatory amendments, and (h) implementation program, including stakeholders, roles and responsibilities, prioritization of actions, schedules and costs.

In order to address these issues, LICAP established a number of working groups to address particular topics. The full unedited reports are contained in a separate document (Appendix A). The GRMP contains ten reports on aspects of Long Island's groundwater, including a series of prioritized recommendations for future management actions. LICAP considered and prioritized the 15 original recommendations, along with five additional recommendations resulting from

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1 LICAP was required to provide notice to the public upon completion of a draft GRMP and to conduct at least one public hearing in both Nassau County and Suffolk County prior to the issuance of the final GRMP.

2 These reports are also available by going to the LICAP website http://www.liaquifercommission.com
several meetings with Suffolk County Health Department and Executive representatives:

1. Investigate ways to further optimize pumping operations for wells located near shoreline areas to help minimize salt water intrusion.

2. Fund the development of a regional groundwater model to be used for planning purposes.

3. Implement conservation pricing at public water suppliers and include a full description of water conservation pricing in annual water quality reports issued by public water suppliers.

4. Establish guidelines for Best Management Practices to reduce peak demand for landscape irrigation.

5. Establish guidelines for use of water by geothermal systems.

6. Make the case against reactivation of public supply wells in Queens County that would impact negatively on Long Island's sole source of water supply.

7. Identify federal, state and local funding sources to conduct groundwater monitoring, plume identification and modeling.

8. Actively remediate or strategically contain groundwater contamination plumes, such as the Grumman/Navy plume, to minimize and prevent potential impacts to public drinking water.

9. Maintain, update and utilize the existing Nassau County Department of Public Works (NCDPW) monitoring well network (599 total wells), including: 366 Upper Glacial Aquifer wells, 167 Magothy Aquifer wells and 66 Lloyd Aquifer wells.

10. Develop and expand WaterTraq for LICAP.

11. Require the notification of a public water supplier before a geothermal system is permitted in its service area.

12. Require the New York State Department of Environmental Conservation and the County Health Departments to review and provide comments on municipal planning board applications that may impact water resources through the State Environmental Quality Review Act process to identify and communicate potential groundwater issues to municipal planning boards.

13. Reauthorize LICAP in the Nassau and Suffolk County Legislatures.

14. Ensure that pumpage caps on public suppliers, if implemented in the future, are based upon sound scientific data.

15. Given the power to regulate and protect drinking water on a regional basis resides with the New York State Department of Health and the New York State Department of Environmental Conservation, creating other oversight entities is unnecessary.

16. Continue expanding programs in both Counties to upgrade wastewater treatment in

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3 The Executive Summary, as approved by LICAP, lists 20 recommendations which are reflected in the attached document entitled “Recommendations and Implementation Planning”. This matrix of recommendations includes suggested responsible stakeholders, milestones for tracking, horizons for implementation, a qualitative assessment of cost and criticality, suggested milestone reporting intervals, and a reference to the appropriate section in the GRMP. Additional short-term and long-term recommendations can also be found in Chapter 8 of the GRMP.
currently unsewered areas, to restore integrity of surface waters while improving quality of drinking water.

17. Identify and promulgate funding sources to enable impacted or threatened private wells in both Counties to connect to public water including water main extensions and service line connections, where applicable, with a long-term goal of making public water available to all residents, to the extent practicable.

18. Identify opportunities to enhance monitoring and regulatory enforcement efforts to prevent VOC releases and mitigate impacts of revealed contamination.

19. Continue to expand monitoring capabilities under the NYSDEC Pesticide Monitoring Program for Long Island groundwaters and support the LI Pesticide Management Strategy and work collaboratively to minimize/eliminate excess pesticide via best management practices. Explore opportunities for intermunicipal agreements to enhance sampling via shared services.

20. Expand assessment/management programs for PCPPs. Enhance monitoring for pharmaceutical and personal care products (PPCP), including 1,4-dioxane, near wastewater effluent discharges from sub-regional wastewater treatment plants and individual onsite wastewater treatment systems and identify wastewater treatment technologies that demonstrate PPCP reduction or removal. Continue to support local STOP programs to reduce improper disposal of PPCPs. Fund local laboratory capacity to analyze potential threats to public and private water supplies from emerging contaminants such as PFAS.
## RECOMMENDATIONS AND IMPLEMENTATION PLANNING

<table>
<thead>
<tr>
<th>RECOMMENDATION</th>
<th>STAKEHOLDERS</th>
<th>INTERESTED PARTIES</th>
<th>SUGGESTED GOALS OR MILESTONES TO BE TRACKED FOR PROGRESS OR COMPLETION</th>
<th>TIME HORIZON</th>
<th>OBJECTIVE COSTS*** CRITICALLY AT A MACRO LEVEL</th>
<th>REPORTING MILESTONE SCHEDULE (e.g., ANNUAL/QUARTERLY-ETC.)</th>
<th>CHALLENGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Investigate ways to further optimize pumping operations for wells located near shoreline areas to help minimize saltwater intrusion</td>
<td>Public Water Suppliers; NYSDEC; County Health Dept.</td>
<td>USGS</td>
<td>Complete GW modeling and assessment of impacts and conditions in affected jurisdictions</td>
<td>Short-term</td>
<td>low/high</td>
<td>Bi-annual Review</td>
<td>Chapters 2, 3</td>
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<td>2 Fund the development of a regional groundwater model to be used for planning purposes</td>
<td>NYSDEC; County Legislatures (funding); USGS (model development underway)</td>
<td>Water Suppliers</td>
<td>Percent Completion of Modeling Project Effort</td>
<td>Immediate</td>
<td>mod/high</td>
<td>Quarterly</td>
<td>Chapters 4, 6</td>
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<td>3 Implement conservation strategies at public water suppliers, and include a full description of water conservation pricing in annual water quality reports issued by public water suppliers</td>
<td>Water Suppliers; PSC (rate structure approval for private utilities); NYSDEC; State Legislature (legal authority)</td>
<td>County Health Dept; County Execs; Public water customers</td>
<td>Percent Water Usage Reduction</td>
<td>medium</td>
<td>NA/moderate</td>
<td>Annual</td>
<td>Chapters 2, 3</td>
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<td>4 Establish guidelines for Best Management Practices to reduce peak demand for landscape irrigation</td>
<td>Water Suppliers; building/plumbing departments</td>
<td>Designers and installers: Water Suppliers; NYSDEC; County Health Dept</td>
<td>Schedule Compliance with Approved Project Plan</td>
<td>Immediate</td>
<td>low/low</td>
<td>Quarterly</td>
<td>Chapter 6</td>
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<td>5 Establish guidelines for use of water by geothermal systems; distinguish open loop geothermal systems using public supply from open and closed loop systems involving well installation.</td>
<td>Public Water Suppliers; Building Dept; NYSDEC; State Legislature</td>
<td>County Health Dept; County Exec; State Legislature</td>
<td>Schedule Compliance with Approved Project Plan</td>
<td>medium</td>
<td>low/low</td>
<td>Quarterly</td>
<td>Chapter 4</td>
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<td>6 Make the case against reactivation of public supply wells in Queens County that would potentially negatively impact Long Island’s sole source of water supply</td>
<td>Water Suppliers: NYSDEC; Nassau County Health Department; NCDPW</td>
<td>County Execs; NYSDEP</td>
<td>Legislative Action Tracking</td>
<td>long</td>
<td>high/moderate</td>
<td>Chapter 4</td>
<td>While this issue has shifted focus for LICAP and the water providers, the continuing challenges remains the development of trust and cooperation between NYC and Long Island. Political detente would appear the biggest impediment to valuable relationships between both parties. The value of regional water sharing and agreements cannot be understated and the risks and benefits carefully weighed, particularly in light of continued challenges with emerging contaminants and adequate supply. Need to work cooperatively with NYC to optimize L.I.’s water supply and minimize impacts from salt water intrusion and to further evaluate supply options for challenged western Nassau suppliers.</td>
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<td>7 Identify federal, state and local funding sources to conduct groundwater monitoring, plume identification and modeling</td>
<td>County Execs; State Leg; NYSDEC; County Health Depts.</td>
<td>Public Water Suppliers; USGS; Federal Legislatures (regarding continued cooperative USGS agreements)</td>
<td>Funding Legislation</td>
<td>medium</td>
<td>low/high</td>
<td>monthly</td>
<td>Chapter 3</td>
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<td>8 Alleviate remediation or strategically contain groundwater contamination plumes, such as the Grumman/Navy plume, to minimize and prevent potential impacts to public drinking water</td>
<td>Fed Leg; State Leg; County Exec; NYSDEC</td>
<td>Public water suppliers; drinking water regulatory agencies</td>
<td>Funding Legislation</td>
<td>medium</td>
<td>high/high</td>
<td>monthly</td>
<td>Chapter 4</td>
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<td>9 Maintain, update, and utilize the existing Nassau County Department of Public Works (NCDPW) monitoring well network.</td>
<td>NCDPW; Nassau Legislature</td>
<td>USGS; County Health</td>
<td>State Leg; County Exec; Federal Leg.; USGS</td>
<td>medium</td>
<td>moderate</td>
<td>Quarterly</td>
<td>Chapter 5</td>
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<td>10 Develop and expand WaterTraq for LICAP</td>
<td>Water Suppliers; Health Departments; Labs</td>
<td>All potential users (ongoing activity)</td>
<td></td>
<td>long</td>
<td>moderate</td>
<td>(dependent on continued funding)</td>
<td>Chapter 7</td>
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<td>Task</td>
<td>Description</td>
<td>Criticality to Supply</td>
<td>Short-term Critical Costs</td>
<td>Long-term Critical Costs</td>
<td>Resources</td>
<td>Timeline</td>
<td>Funding Notes</td>
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<td>11</td>
<td>Require the notification of a public water supplier before a geothermal system is permitted in its service area</td>
<td>Public water suppliers; county or state legislatures regarding creation of authority to regulate</td>
<td>State Leg; NYSDEC; County Health Depts;</td>
<td>Rule making or legislation</td>
<td>Immediate</td>
<td>low/low</td>
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<td>12</td>
<td>Require the New York State Department of Environmental Conservation and the County Health Departments to review and provide comments on municipal planning board applications that may impact water resources through the State Environmental Quality Review Act process to identify and communicate potential groundwater issues to municipal planning boards</td>
<td>County Execs; County Health Depts;</td>
<td>Local Govts; NYSDEC</td>
<td>Rule making or legislation</td>
<td>long</td>
<td>mod/moderate</td>
<td>Legislative Rulemaking Timeline</td>
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<td>13</td>
<td>Reauthorize LCAP in the Nassau and Suffolk County Legislatures</td>
<td>State and County Legislatures</td>
<td>County Execs; State Leg; NYSDEC; County Health Depts; Water Suppliers</td>
<td>Legislative Action Tracking</td>
<td>Immediate</td>
<td>low/high</td>
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<td>14</td>
<td>Ensure that pumpage caps on public suppliers, if implemented in the future, are based upon sound scientific data</td>
<td>NYSDEC; Public Water Suppliers</td>
<td>Public water customers</td>
<td>Annual reporting (currently required for Public Suppliers)</td>
<td>Immediate</td>
<td>low/moderate</td>
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<td>15</td>
<td>Given the power to regulate and protect drinking water on a regional basis resides with the New York State Department of Health and the New York State Department of Environmental Conservation, creating other oversight entities is unnecessary</td>
<td>Public water suppliers; NYSDEC; Health Depts.</td>
<td>County Execs; County Legislatures; State legislature</td>
<td>NA</td>
<td>Immediate</td>
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<td>16</td>
<td>Continue expanding programs in both counties to upgrade wastewater treatment in currently untreated areas to restore the integrity of surface waters while improving quality of drinking water</td>
<td>County Execs; County Health Depts; County Public Works Departments</td>
<td>County Legislatures; State legislature; Public water suppliers</td>
<td>Annual reporting on County Subwatershed Plan outputs/outcomes</td>
<td>Short-term</td>
<td>high</td>
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<td>Identify and promulgate funding sources to enable impacted or threatened private wells in both counties to connect to public water including water main extensions and service line connections, where applicable, with a long-term goal of making public water available to all residents, to the extent practicable</td>
<td>NYS; Public Water Suppliers; Health Departments</td>
<td>County Health Departments; State legislature</td>
<td>Annual SCWA report on PW connections, track WIA grants</td>
<td>Short-term</td>
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<td>18</td>
<td>Identify opportunities to enhance monitoring and regulatory enforcement efforts to prevent VOC releases and mitigate impacts of revealed contamination</td>
<td>NYSDEC; Health Departments</td>
<td>Public water suppliers</td>
<td>Annual report for Suffolk County Comprehensive Water Resources Management Plan</td>
<td>Short-term</td>
<td>low</td>
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<td>19</td>
<td>Continue to expand monitoring and regulatory enforcement capabilities under the NYSDEC Pesticide Monitoring Program for Long Island groundwater, support the LI Pesticide Management Strategy, and work collaboratively to minimize/eliminate excess pesticide usage through best management practices. Explore opportunities for intermunicipal agreements to enhance sampling via shared services.</td>
<td>NYSDEC; Health Departments</td>
<td>Public water suppliers, Cornell Cooperative Extension, USGS, LI Farm Bureau</td>
<td>Continue to update NYSDEC and provide analytical data, meet periodically to review station</td>
<td>Short-term</td>
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<td>Expand assessment/management programs for pharmaceutical and personal care products (PPCPs). Enhance monitoring for PPCPs, 1,4-dioxane, near wastewater effluent discharges from subregional wastewater treatment plants and individual onsite wastewater treatment systems, and identify wastewater treatment technologies that demonstrate PPCP reduction/removal. Continue to support local STOP programs to reduce improper disposal of PPCPs. Expand funding for local laboratory capacity to analyze potential threats to public and private water supplies from emerging contaminants such as PFAS</td>
<td>NYS, NYSDEC, Health Departments, County Legislatures, Police Departments</td>
<td>USGS; County DPWs</td>
<td>Annual reporting on County Subwatershed Plan outputs/outcomes, PPCP STOP program outreach, Suffolk to develop in-house capability for PFAS analysis for 2021</td>
<td>Short-term</td>
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Notes:
- **Low**: Costs that would require marginal budget adjustments <$1 SM
- **Moderate**: Costs that would require consideration and possibly funding or grant assistance <$1 SM - $10M
- **High**: Costs requiring significant investment and consideration; potentially requiring grant funding or grants >$10M
CHAPTER 2
EXISTING CONDITIONS, QUALITATIVE AND QUANTITATIVE GROUNDWATER DATA

Introduction

Long Island is unique. Long Island’s drinking water source is unique. The United States Environmental Protection Agency (USEPA) recognized the importance of the groundwater source of Long Island’s water supply in 1978 by designating it a sole-source aquifer. Every day millions of Long Islanders live, work and play on the watershed which restores water to this aquifer system. This fact has created numerous challenges and opportunities for Long Islanders in managing their water resources. This section is devoted to providing foundational information about Long Islanders’ water resources. Later sections will build on this foundation to discuss how Long Island water resources are managed, how they are challenged and what opportunities exist for protecting or preserving them.

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 between 42-50 inches of precipitation per year (www.ny.water.usgs.gov/pubs/ wri014165/wrir01-4165.pdf, pp.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”) occurs 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 (MGD) of recharge for every 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 1 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 and tidal waters (such as the Great South Bay). Discharge 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.
Using only the two-county land surface area [1,200 square miles (sq. mi.) of land mass] and using a conservative estimate of 1,000 feet (roughly 2/10th 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% for sand and gravel aquifers, it is estimated that Nassau and Suffolk Counties together have between 60-65 trillion gallons of groundwater stored within its aquifer system. However, only 5-10% 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 150-200 billion gallons.

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 more than 100 stream channels on Long Island, typically less than 5 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 natural conditions, approximately 90% of the flow of rivers and creeks is due to the contribution 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.

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.

**Long Island's Aquifers**

The three principal aquifers situated beneath Long Island 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. 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 draw from 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.

The Magothy Aquifer is the most extensive of Long Island's aquifers and was formed approximately 65 million years ago. Consisting of fine sand and silt deposits alternating with clay, it attains a maximum thickness of approximately 1,100 feet in southeastern Suffolk County. Water in the deepest portions of the Magothy Aquifer on Long Island can be as much as 800 years old. Though not as permeable as the Upper Glacial Aquifer, wells that draw from 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 County. 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.

The Raritan Formation underlies the Magothy Aquifer and was formed in a similar manner to the Magothy Aquifer. Its two primary units are an upper clay member (the Raritan Clay) and a lower sand member (the Lloyd Sand). The clay member is very impermeable in most areas and so helps to greatly reduce 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 0-500 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 Aquifer, since the Magothy Aquifer is a highly productive aquifer and because of New York State Law imposing a moratorium on the construction of new Lloyd Aquifer wells in most areas enacted in 1986. Due to its depth and degree of "confinement" by the overlying Raritan Clay, the Lloyd Aquifer 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. The Lloyd Aquifer 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 Aquifer and are considered "confining units." These formations are typically found throughout the south shore of Long Island and are important on a local scale.

The 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 designated the Long Island aquifer system a "sole-source aquifer," thereby affording it a high degree of legal protection.

**Groundwater as Long Island's Drinking Water Supply**

The most significant use of groundwater on Long Island is for public drinking water supply. Between 1985 and 2005, it is estimated that approximately 70-80% 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 MGD. In Suffolk County alone, the number of private wells is estimated at 47,000 (*Suffolk County Comprehensive Plan*, pp. 4-6), and they pump an estimated 15 MGD. Total water use for all purposes (potable, irrigation and commercial/industrial) on Long Island is estimated at 450-500 MGD. More than 75% of all groundwater withdrawals are from the Magothy Aquifer.

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 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 tends 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, and these topics are addressed in greater detail in this publication. While western Suffolk County exhibits water supply infrastructure trends similar to Nassau County, there have been no such water quality issues relating to overuse in that part of Suffolk County.

In stark contrast to Nassau County, 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 County 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. 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 Counties 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.

Records from the Suffolk County Water Authority (SCWA) for the year 2007 show that demand during a typical winter day in ranging from a low of approximately 20,000 gallons per minute (GPM) to a high of approximately 100,000 GPM. In stark contrast to this, water usage during a summer weekend day ranged from a low of approximately 200,000 GPM to a high of almost 500,000 GPM – 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. This trend continues.

These seasonal water use patterns point to the necessity for water suppliers throughout Nassau and Suffolk Counties to manage peak water demand in order to maximize water supply efficiency. Reducing summer peak pumpage "spikes" is an essential ingredient in such a strategy. From the SCWA example, a reduction in peak pumping of as little as little as 5% represents a savings of approximately 25,000 GPM or the equivalent of approximately 20 wells that would not have to be pumping at that time. Both fire protection and operational redundancy would be enhanced by having this extra well capacity in reserve. Additionally, the energy savings of this reduced pumping are significant. Should similar conservation-based demand reductions be realized throughout Nassau and Suffolk Counties, overall stresses on the aquifer system also could be reduced with obvious benefits to the aquifer system. A separate chapter of this publication discusses in detail opportunities to allow for the more efficient use of water.

Non-potable water uses are also significant in different portions of Long Island. Such uses include: golf course irrigation, water used for industrial processes, geothermal heating and air conditioning and, of course, agriculture. The vast majority of wells used for these purposes take water from the Upper Glacial Aquifer. Farms and golf courses pump the largest volumes of non-potable water from the aquifer system. There are more than 200 wells supplying irrigation water to golf courses
throughout Long Island, while 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. A later chapter provides more information on water usage broken down by category.

Farms and golf courses use all of their water between mid-April and mid-October when public water suppliers also are struggling to keep up with consumer demand. This adds 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.

Existing Conditions, Qualitative and Quantitative Groundwater Data

Long Island is entirely dependent on the underlying sole source aquifer system, which currently supplies more than 400 MGD of fresh water from more than 1,200 public-supply wells to more than 2.8 million people in Nassau and Suffolk Counties. As the name implies, Long Island's sole-source aquifer system is the only source of water available to meet the needs of Long Island's population.

In addition to its value for drinking and irrigation, groundwater is also the primary source of fresh water in streams, lakes and wetlands and maintains the saline balance of estuaries. When large volumes of groundwater are withdrawn, the water table is locally depressed; and this, in turn, reduces the quantity of groundwater available to discharge to streams and estuaries. Large-scale sewer ing practices also have reduced groundwater levels and discharge to surface receiving waters. In some areas of Long Island, groundwater pumping has resulted in salt water intrusion into the aquifer system and also has impacted streams, ponds and coastal areas that rely on groundwater discharge to sustain them. In addition to these quantity-related impacts, additional factors such as urban runoff and the widespread use of septic systems also have affected the water quality of the aquifer system. Therefore, development and use of groundwater on Long Island is constrained by ecohydrological (i.e., the interactions between groundwater and surface water ecosystems) and water quality concerns.

Water Suppliers and Drinking Water Consumption

Nassau County Public Water Suppliers

Nassau County's decentralized public water supply system includes numerous suppliers independently managed by either private or municipal entities [Nassau County Master Plan (NCMP), 2010]. According to United States Geological Society (USGS, 2015), "The responsibility of the water supply companies in Nassau and Suffolk Counties is shared between more than 50 supply companies who are members of the Long Island Water Conference (LIWC)." The LIWC companies utilized more than 1,100 large capacity wells to supply potable water to a population of more than 2.6 million and to light industries such as office parks and other commercial business.

Suffolk County Public Water Suppliers

Suffolk County's water supply is managed by 14 different water suppliers (USGS, 2015). An estimated 80% or 1.2 million people in Suffolk County are served by Suffolk County Water Authority. SCWA, for example, delivers 70 billion gallons of potable water each year through nearly 6,000 miles of pipe from 581 active wells and 234 pump stations [Suffolk County
Department of Health Services SCDHS, 2015. Other water suppliers in Suffolk County include: South Huntington, Dix Hills, Riverhead and Hampton Bays Water Districts to name a few (LIWC, 2015).

**Nassau County Public Water Demand**

In Nassau County, encompassing 291 sq. mi. and with a population of 1.34 million people, the average daily withdrawal is 220-340 MGD in the summer months and 130-150 MGD in the winter months (USGS, 2015). Other sources may provide different data. For example, NYSDEC reports water supply pumpage rates for Nassau County. For the period from 2000-2014, the average day rate ranges from 175-205 MGD, with a mean of approximately 189 MGD; non-peak average day range from 139-149 MGD, with a mean of approximately 144 MGD; and a peak average day ranges from 231-288 MGD, with a mean of approximately 251 MGD (NYSDEC, 2016).

With roughly one-third of the land area, Nassau County's dense population consumes approximately the same volume of water as Suffolk County, which has land area that is two-thirds larger and a slightly greater population. The 2014 combined Suffolk and Nassau public water supply pumpage average day was approximately 425 MGD (NYSDEC, 2016).

**Suffolk County Public Water Demand**

In Suffolk County, encompassing 934 sq. mi. and with a population of 1.5 million people, the average daily withdrawal is 187 MGD with summer withdrawals of up to 360 MGD and winter withdrawals of 80-100 MGD (SCDHS, 2015). From 2005-2010, Nassau and Suffolk County’s combined public water supply annual average daily withdrawal was approximately 380 MGD (USGS, 2015). Other sources may provide different data. For example, NYSDEC reports water supply pumpage rates for Suffolk County in 2014. The average day rate is approximately 222 MGD; the non-peak average day is approximately 132 MGD; and the peak average day is approximately 348 MGD on a peak average day (NYSDEC, 2016).

**Defining the Amount of Water in Storage in Long Island’s Aquifer System**

**Historical Studies**

The Long Island aquifer system has been studied in some detail since the 1850s. Attention to the use of groundwater began in Brooklyn (Kings County) and then moved into Queens and Nassau Counties. The first comprehensive report on the Long Island aquifer system was prepared by C.V. Veatch et al in 1906 and published by the United States Geological Survey (USGS).

The groundwater system beneath Long Island is a combination of sand and gravel aquifers with interspersed layers of clay and sandy clay deposits. The Raritan Clay is the largest aquitard formation beneath Long Island. It separates the Magothy and Lloyd Aquifers and averages between 100-200 feet thick. Clay layers can have high porosity, but they do not function as aquifers because clay does not easily transmit or yield water. Groundwater is stored in the miniscule spaces between sand and gravel particles. The USGS publication *Atlas of Long Island’s Water Resources* (1968) provides the following description of groundwater storage and availability (Cohen 1968, pp. 26-27):

> A water-budget area was identified as the land mass from the Nassau-Queens boundary on the west to the eastern limits of Brookhaven Township and a part of Riverhead (excluding the forks). The total volume of material saturated with fresh ground water beneath Long Island ... is nearly 300 cubic miles; the volume of fresh water beneath the
water-budget areas is about 180 cubic miles. Assuming an average porosity of 30%, the amount of groundwater stored beneath the water budget area would be approximately 54 cubic miles or about 60 trillion gallons.

Cohen estimated specific yield of the Long Island aquifer system to be only 5-10%. (Specific yield indicates the total amount of water that can be removed from an aquifer.) More recently, Buxton and Smolensky (1999) analyzed the entire Long Island aquifer system (Kings, Queens, Nassau and Suffolk Counties, excluding the Forks) and estimated the specific yield for each aquifer. The yield ranged from a high average amount in the Upper Glacial Aquifer (25-30%) to a much lower average amount for the Magothy Aquifer (15%) and as little as 10% for the Lloyd Aquifer.

**How an Aquifer Works**

An aquifer system works on the principle of dynamic equilibrium that is described by the equation:

\[
\text{INFLOW} = \text{OUTFLOW} +/- \text{STORAGE}
\]

The process of analyzing a water budget requires that accurate quantitative values be provided for all factors in the equation. A comprehensive analysis of the water budget for the full Long Island aquifer system has never been conducted. The United States Geological Survey has begun to conduct research related to this topic in its *Long Island Sustainability Study* described in a later chapter.

Under natural conditions, over the long term, an aquifer system is in hydrologic equilibrium where the amount of water entering the system (inflow) is in balance with the amount of water leaving the system (outflow). As noted earlier, inflow represents water entering an aquifer system, mainly as precipitation, through the process of recharge. Other sources of inflow can include salt water intrusion or from various surface water features. Outflow represents water leaving the system naturally (prior to human activities). Processes involved in outflow are: groundwater discharge to streams, shallow discharge to coastal waters and deeper subsurface outflow, evapotranspiration and spring flow discharge.

For a groundwater system like Long Island's, the volume of recharge is equal to the volume of discharge, so there would be negligible changes in the amount of water in storage for long-term average pre-development conditions. Human activities such as groundwater pumping add an additional outflow component to the water budget equation. As the amount of groundwater pumpage increases, the additional loss of water can cause the equation to become out of balance and the aquifer system must adjust accordingly. We can observe such an adjustment in the aquifer system beneath Nassau County.

Buxton and Smolensky (1999) developed a water budget for pre-development conditions for the entire Long Island aquifer system. It showed that average recharge was about 1.1 billion/gal/day. The largest loss of water was outflow to the shore (525 MGD or 52%). The second largest loss was groundwater discharging to streams (460 MGD or 41%). The smallest outflow was to subsea coastal areas (81 MGD or 7%). Table 1 provides the details of groundwater flow prior to human impacts.
Table 1
Pre-Development Water Budget for Long Island Aquifer System by County in MGD

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>RECHARGE</th>
<th>DISCHARGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precipitation (MGD)</td>
<td>Stream MGD</td>
</tr>
<tr>
<td>Kings and Queens</td>
<td>160</td>
<td>58</td>
</tr>
<tr>
<td>Nassau</td>
<td>257</td>
<td>125</td>
</tr>
<tr>
<td>Western Suffolk</td>
<td>273</td>
<td>140</td>
</tr>
<tr>
<td>Eastern Suffolk</td>
<td>436</td>
<td>137</td>
</tr>
<tr>
<td>TOTAL (% of total)</td>
<td>1126</td>
<td>460 (41%)</td>
</tr>
</tbody>
</table>

Source: Buxton and Smolensky (1999, pp. 27)

Table 1 illustrates the dominance of groundwater processes in Suffolk County as compared to those in western Long Island (Nassau and Queens Counties and Brooklyn). Pre-development recharge was 709 MGD in Suffolk County compared to only 417 MGD for Brooklyn, Queens and Nassau Counties. Table 1 shows the system in hydrologic equilibrium. It does not quantify water loss from the system due to evaporation, evapotranspiration or runoff.

Table 2 provides additional detail to the recharge process for only Nassau and Suffolk Counties. Not all precipitation reaches the aquifers and precipitation rates are slightly different for the two counties. Nassau County receives, on average, just over 43 inches of rain per year, while Suffolk County receives more than 45 inches per year. When evaluating the fate of precipitation, recharge and evapotranspiration rates far exceed the amount of water lost to runoff.

Table 2
Comparison of Regional Groundwater Budget Components for Nassau and Suffolk Counties: Precipitation, Recharge, Evapotranspiration and Direct Runoff Rates

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>NASSAU COUNTY</th>
<th>SUFFOLK COUNTY</th>
<th>LONG ISLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRECIPITATION (inches)</td>
<td>43.3</td>
<td>45.9</td>
<td>45.2</td>
</tr>
<tr>
<td>RECHARGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (inches)</td>
<td>20.6</td>
<td>23.5</td>
<td>22.7</td>
</tr>
<tr>
<td>Percentage (%) of total precipitation</td>
<td>47.6</td>
<td>51.2</td>
<td>50.2</td>
</tr>
<tr>
<td>EVAPOTRANSPIRATION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (inches)</td>
<td>21.8</td>
<td>22.1</td>
<td>22.1</td>
</tr>
<tr>
<td>Percentage (%) of total precipitation</td>
<td>50.3</td>
<td>48.1</td>
<td>48.8</td>
</tr>
<tr>
<td>DIRECT RUNOFF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (inches)</td>
<td>0.9</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Percentage (%) of total precipitation</td>
<td>2.1</td>
<td>0.7</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Paterson (1987, USGS)
More recently, studies by Nassau County (1998, Table 3) and Suffolk County (2015, Table 4) have described water budgets for each county. Nassau County’s water budget does not identify groundwater flow lost to Queens County or inflow from Suffolk County. Suffolk County’s water budget is in balance. However, changes in storage due to significant groundwater depletion or groundwater flow across county borders are not quantified. This missing piece of information should be included in future efforts to describe subregions of Long Island’s water budget.

Changes in the Aquifer System Due to Pumping

Groundwater lost from the aquifers due to pumping comes from aquifer storage. If the groundwater loss is large enough, it can cause a number of changes in the aquifers as the system re-equilibrates. The observed changes can include:

- Lowering of water table levels.
- Reduction in stream flow.
- Loss of surface water features and ecosystems that depend on them.
- Reduction in coastal discharge.
- Change in bay salinity.
- Shifts in contaminant migration paths.
- A shift in the salt water interface and potential for salt water intrusion.
- Change in recharge zone boundaries and rate of groundwater flow.

All of these responses are considered undesirable changes in the groundwater system. In particular, salt water intrusion represents a system change that limits the supply of potable water in the coastal portions of the aquifers. Groundwater that discharges into coastal waters performs the essential function of holding out the ocean. When fresh groundwater is removed from storage due to excessive pumpage, less fresh water reaches the coastal margins. This result will allow the fresh water-salt water interface to move landward into the fresh water portions of the aquifers beneath the island, making the groundwater too saline for human consumption (Nassau County, 1998).

Competing Uses for Groundwater

Most studies of groundwater resources concentrate on human activities and needs. However, there are many important ecological and hydrologic aspects of the groundwater system beyond human considerations. From the human standpoint, the following sectors that need and use groundwater are:

- Public water supply: existing customers.
- New construction/letters of water availability.
- Irrigation.
- Private water supply.
- Drinking water needs.
- Residential irrigation needs.
- Industrial water uses.
- Commercial water uses.
- Agricultural water needs.
- Recreation/golf course water.
- Housing/built - environment needs (heating, ventilation, air conditioning, HVAC).
- Groundwater-sourced geothermal systems.
- Contaminated site remediation.
- Dewatering activities around infrastructure.
- Waste assimilation.

The environmental and hydrologic need for groundwater includes the following considerations:

- Water table elevation to maintain groundwater discharge to surface water features (wetlands, ponds, lakes and streams) for habitat health and ecosystem balance.
- Groundwater discharge to coastal margins for salinity maintenance.
- Groundwater subsurface discharge to control salt water intrusion.
- Sufficient groundwater storage for drought and other extreme events.
- Sufficient head to support deep recharge processes.

Water Budgets for Each County

Nassau County

Nassau County developed water budgets in several studies between 1980-1998. In 1980, Nassau County set a limit of 180 MGD as the sustainable consumptive level of groundwater withdrawal for the county. However, due to reports that recharge increased due to recharge basins, Nassau County later increased its safe yield value to 185 MGD. In the 1998 Groundwater Study, Nassau County predicted that "average demand in 2010 ... would be 180 MGD, with about 161 MGD attributable to residential use and 19 MGD to commercial/industrial use" (pp. 3-4). The study also noted that, in years with hot, dry summers, annual demand could climb to more than 190 MGD. However, by 2000, Nassau County exceeded this prediction. The Nassau County Department of Public Works (NCDPW) reported that annual demand reached 203 MGD in 2001 and 200 MGD in 2002. During a hot summer, monthly water demand could exceed 300 MGD (Nassau County, 2005, pp. 8). Table 3 identifies the Nassau County Water Budget projected for 2010 conditions by the 1998 study.
Table 3
Present-Day Nassau County Water Budget - Year 2010

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>AMOUNT IN TOTAL MGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFLOW</td>
<td>384</td>
</tr>
<tr>
<td>RECHARGE</td>
<td></td>
</tr>
<tr>
<td>From Precipitation</td>
<td>341</td>
</tr>
<tr>
<td>Recharge to Glacial Aquifer (341 MGD)</td>
<td></td>
</tr>
<tr>
<td>Recharge to Magothy Aquifer (260 MGD)</td>
<td></td>
</tr>
<tr>
<td>Recharge to Lloyd Aquifer (14 MGD)</td>
<td></td>
</tr>
<tr>
<td>OTHER INFLOW</td>
<td></td>
</tr>
<tr>
<td>Saltwater Intrusion/Inflow from Suffolk County</td>
<td>43</td>
</tr>
<tr>
<td>Into Glacial Aquifer (21 MGD)</td>
<td></td>
</tr>
<tr>
<td>Into Magothy Aquifer (16 MGD)</td>
<td></td>
</tr>
<tr>
<td>Into Lloyd Aquifer (6 MGD)</td>
<td></td>
</tr>
<tr>
<td>OUTFLOW</td>
<td>384</td>
</tr>
<tr>
<td>Public Water Supply Pumpage</td>
<td>180</td>
</tr>
<tr>
<td>Pumpage from Glacial Aquifer (2 MGD)</td>
<td></td>
</tr>
<tr>
<td>Pumpage from Magothy Aquifer (166 MGD)</td>
<td></td>
</tr>
<tr>
<td>Pumpage from Lloyd Aquifer (12 MGD)</td>
<td></td>
</tr>
<tr>
<td>Discharge to Streams</td>
<td>35</td>
</tr>
<tr>
<td>Subsurface Flow</td>
<td>169</td>
</tr>
<tr>
<td>Subsurface Flow in Glacial Aquifer (90 MGD)</td>
<td></td>
</tr>
<tr>
<td>Subsurface Flow in Magothy Aquifer (73 MGD)</td>
<td></td>
</tr>
<tr>
<td>Subsurface Flow in Lloyd Aquifer (6 MGD)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Nassau County 1998 Groundwater Study (pp. 2-8)

Table 3 shows a current (2010) water budget for Nassau County that is in balance because the total amount of water coming into the system is balanced by the amount of water going out. But, the "balance" is dependent on extra inflow into all three aquifers totaling 43 MGD. The source of the inflow is not identified which makes the water budget incomplete. It could include the 9.2 MGD reported in the Suffolk County water budget plus salt water intrusion. Masterson et al (2016) has noted that groundwater flow between subregions can be an important component of regional water budgets. Since pre-development conditions, the aquifer system beneath Nassau County has substantially changed. Outflow to streams has declined 58%, from 84 MGD (pre-development) to 35 MGD (current conditions). This change is observed in the dramatic reduction in south shore stream flows and stream lengths.

Subsurface underflow of groundwater into the offshore portions of the aquifers declined from 332 MGD (pre-development) to 169 MGD (current conditions), a net change of 163 MGD or about a 50% reduction in subsurface discharge (Nassau County 1998 Groundwater Study, pp. 2-8). It should be noted that data for this analysis represent conditions from approximately 1995. This change is due to groundwater loss from storage caused by pumping, thus no longer available to hold out the ocean.
In order to compensate for the large loss of groundwater due to pumping, the aquifers adjusted by discharging less water to the oceans. To replace the fresh water lost from the aquifers, salt water intrusion increased significantly over time (Nassau County, 1998, pp. 2-8 to 2-9). Public water supply pumpage now represents between 50-60% of the total recharge, depending on annual demand (and recharge rates).

**Suffolk County**

Suffolk County has developed water budgets for separate areas that cover different parts of the county: the main body, North Fork, South Fork and Shelter Island. Due to the large land area of Suffolk County, the groundwater system receives and discharges roughly three times more water than Nassau County. Suffolk County is surrounded by salt water on three sides, but, from a water budget standpoint, its system is less complicated than that of Nassau County, which has flow boundaries on its eastern and western borders as well as north and south shores. The most recent water budget analysis for Suffolk County (2015) includes all of the budget components needed for it to balance (Table 4).

**Table 4**

<table>
<thead>
<tr>
<th>Suffolk County Water Budget - All of Suffolk County</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PROCESSES</th>
<th>AMOUNT IN MGD</th>
<th>TOTAL MGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFLOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recharge from Precipitation</td>
<td>1367.3</td>
<td></td>
</tr>
<tr>
<td>OUTFLOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Supply Withdrawals</td>
<td>196.7</td>
<td></td>
</tr>
<tr>
<td>Withdrawal from Glacial Aquifer (59.4 MGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal from Magothy Aquifer (134.5 MGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdrawal from Lloyd Aquifer (2.8 MGD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to Streams</td>
<td>506.2</td>
<td></td>
</tr>
<tr>
<td>Discharge to North Shore</td>
<td>304.6</td>
<td></td>
</tr>
<tr>
<td>Discharge to South Shore</td>
<td>233.5</td>
<td></td>
</tr>
<tr>
<td>Discharge to Peconic Bay</td>
<td>117.1</td>
<td></td>
</tr>
<tr>
<td>Discharge to Nassau County</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL WATER LOST FROM THE SYSTEM</strong></td>
<td><strong>1367.3</strong></td>
<td><strong>1367.3</strong></td>
</tr>
</tbody>
</table>

*Source: Suffolk County Comprehensive Water Resources Management Plan (2015, Executive Summary, pp. 40)*

Table 4 reports present the total recharge (inflow) for Suffolk County, which is 1,367.3 MGD, based on:

- Main body: 1,119.6 MGD
- North Fork: 51.7 MGD
- South Fork: 178.4 MGD
- Shelter Island: 17.6 MGD.

This total represents the average amount of water that replenishes the aquifers annually.
Overall, there is a large difference in the amount of water in storage between Nassau and Suffolk Counties. As Suffolk County moves to expand centralized sewer systems, less water will be returned to the aquifer from domestic septic systems. A similar loss of return flow due to sewering has had a substantial impact on the flow system in Nassau County, which is approximately 85% sewered. Currently, Suffolk County reports that water supply withdrawals represent approximately 4% of recharge (2015). In addition, with only 25% of the county sewered, large amounts of the pumped water is being returned to the aquifers through domestic septic systems.

Existing Groundwater Withdrawals

Regional Groundwater Withdrawals: USGS Data

The USGS has reported on Long Island water use in the completed *North Atlantic Coastal Plain Study* (NACP), 2010-present (Masterson *et al*, 2013, 2016). The USGS has reported on total groundwater pumpage per day by use. Pumpage is broken down for the following user groups:

- Agricultural use: 9 MGD.
- Commercial and industrial use: 68 MGD.
- Public and domestic water supply: 376 MGD.

The total annual average pumpage of 165.7 billion gallons of groundwater was reported. The same *NACP Study* found the daily total pumpage from the Long Island aquifers is 441 MGD. By specific aquifer, the totals are:

- Surficial Aquifer (Upper Glacial Aquifer): 82 MGD.
- Magothy Aquifer: 349 MGD.
- Lloyd Aquifer: 10 MGD.

When compared to all the other counties being studied in the NACP, Nassau and Suffolk Counties (2005 data) are the only two counties in the largest pumpage category (176-200 MGD) (Masterson. *et al*, 2013, 2016). Long Island groundwater pumpage is far beyond that of other communities elsewhere along the Atlantic coastal plain. Only Florida rivals New York in groundwater use.

Public Water Supply Pumpage

Public water supply pumpage varies by county and also changes with the seasons. The highest pumpage is in the summer (May-September), usually peaking in July and lowest is in the winter (October-April), especially from December-February.

The New York State Department of Environmental Conservation has summarized pumpage during the period 2000-2014. Table 5 documents pumpage by county for both average pumpage conditions and peak pumpage conditions. It shows a pumpage comparison for 2014 which was a reasonably average year.
Table 5
Public Water Supply Withdrawal Trends by County from 2000-2014

<table>
<thead>
<tr>
<th>PUMPAGE 2000-2014</th>
<th>NASSAU COUNTY MGD</th>
<th>SUFFOLK COUNTY, SCWA 2014 ONLY, MGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 Pumpage Only</td>
<td></td>
<td>222</td>
</tr>
<tr>
<td>Peak Daily Average</td>
<td>261</td>
<td></td>
</tr>
<tr>
<td>Non-Peak Daily Average</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>2000-2014 Non-Peak Average Day</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>143</td>
<td></td>
</tr>
<tr>
<td>2000-2014 Peak Average Day</td>
<td>348</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>231</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>288</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>251</td>
<td></td>
</tr>
</tbody>
</table>

Source: Pilewski (NYSDEC, 2016)

Pumpage by the Suffolk County Water Authority can exceed pumpage in Nassau County (NC) during peak conditions (SCWA-348 MGD vs. NC-288 MGD). However, Nassau County water suppliers may supply more water than SCWA during average conditions in summer (NC-149 MGD vs. SCWA-132 MGD).

**Nassau County Public Water Supplier Pumpage**

The details of recent pumpage in Nassau County are shown in Figure 1.

**Figure 1** Public Water Supply Withdrawal Summary for Nassau County, 2000-2014
**Suffolk County Water Authority Pumpage**

Pumpage for SCWA, shown in Figure 2, shows a typical pattern of pumpage over the course of a year. It is typical of pumpage patterns for water suppliers in both counties. Low demand occurs in the winter and a 200-400% increase in demand occurs during summer months.

**Figure 2  Public Water Supply Withdrawal for SCWA, 2014**

![Water Quantity Graph](image)

Source: NYSDEC (2015)

The *Suffolk County Comprehensive Water Resources Management Plan* (2015) reported that total water supply pumpage for all ten towns would increase from 2008 to the planning year 2030. The total Suffolk County groundwater pumpage for 2013 was reported to be 228.3 MGD. The predicted pumpage for the county by 2030 is estimated to be 314.5 MGD (Suffolk County, 2015 pp. 4-3 and 4-4). An additional 100 public water supply wells, including all public water suppliers, may be needed by 2030.

**Regional Groundwater Use (Brooklyn to Eastern Suffolk County) vs. North Atlantic Coast Plain Aquifers**

When comparing all groundwater use on Long Island to groundwater use along the entire North Atlantic Coastal Plain, the USGS has found that the largest aquifer-specific withdrawals from major regional aquifer systems from North Carolina to Long Island have occurred in Long Island's Magothy Aquifer. Magothy Aquifer groundwater withdrawals represented 28% of all withdrawals in the NACP aquifer system (Matheson *et al.*, pp. 28). Based on 2008 data only for Long Island, 72% of all water use on Long Island is derived from the Magothy Aquifer and 27% comes from the Upper Glacial Aquifer. (pp. 28). The same report found that the net volume of groundwater depletion on Long Island between 1900-2008 was 502,000 million gallons (Table 4).

**How Long Island’s Groundwater is Used**

One important aspect of quantity management is how water is used and disposed of. In areas served by public sewer systems, where the wastewater is treated and discharged to coastal waters, all the wastewater effluent leaving the system is considered a consumptive use. It is permanently lost from the aquifer system. The sewers protect groundwater quality, while impacting groundwater quantity.
Consumptive groundwater use is observed in Nassau County where the majority of all groundwater withdrawal is permanently removed from the aquifer system through evaporation of irrigation water or the coastal discharge of treated wastewater effluent. By comparison, on-site wastewater treatment systems return their waste discharge to groundwater, although the discharge is a pollutant that can impact groundwater quality. Examples of consumptive water use are:

- Central sewering with ocean outfall/discharge.
- Irrigation.
- Some remediation projects where remediated water is not recharged.
- Industrial/manufacturing water use in products, *e.g.*, beverages.
- Some power production that uses groundwater for electricity generation.

**Irrigation: Lawns, Landscape Plants, Farms and Golf Courses**

Virtually all groundwater used for irrigation is a consumptive use. Water applied to the land during the growing season is lost from the aquifer system through evapotranspiration (taken up by plants and then lost) or through simple evaporation from the soil. It is a 100% consumptive use. The high-water demand experienced by water suppliers in the summer is driven by the 200-400% increase in seasonal water use mainly for lawn and landscape irrigation.

There are approximately 134 golf courses on Long Island. Some courses irrigate using water from local public supplies, but most have their own wells. A few courses use recycled water such as the Town of North Hempstead Links Golf Course in Port Washington that uses collected runoff and treated leachate from the nearby closed landfill. A Riverhead public golf course (Indian Island Country Club) is planning to use recycled water from a nearby sewage treatment plant. For nearly all other courses, groundwater is the ultimate source of irrigation water. An example of a large golf course using groundwater is the Bretton Woods course in Coram that used 71 million gallons of water in 2014 (Harrington, 2015). Golf course water use on Long Island has been calculated to be approximately 2 billion gallons of groundwater per year (Monti, 2015). Golf course irrigation is a significant factor affecting groundwater sustainability since it occurs in the high water-stress summer season.

Agricultural activity on Long Island is another category of consumptive use that is hard to track. The amount of acreage in agricultural use changes yearly. Total agricultural acreage in Suffolk County in 2012 was approximately 21,000 acres. In addition, there was 12 million sq. ft. of greenhouse space in use in 2012. Annual agricultural irrigation will change based on summer weather conditions. It has been estimated that, for 2012, agricultural water use was approximately 4.4 MGD, not including greenhouses (Monti, 2015). Other USGS estimates have agricultural water use as high as 9 MGD.

**Per Capita Water Use**

Long Island has some of the highest rates of per capita water use in the United States. The national average for per capita water use is generally reported to be 100 gallons per person per day (g/p/d) or less. The New York City per capita water use is declining (approximately 125 g/p/d) and is now below that of Nassau County.

It is difficult to find specific data on per capita water use for Long Island. According to one estimate, average per capita water use during the winter on Long Island is 100 g/p/d. A yearly average water use per capita is approximately 145 g/p/day. Average summer use is estimated at 200 g/p/d.
and maximum daily use, mainly during peak summer demand, is 300 g/p/d or more (Granger, 2014). The *Cleaner Greener Communities Sustainability Study* (2013) found that, regionally, per capita water use is 135 gallons per day. For Nassau County, the per capita water use was set at 149 g/p/d. For Suffolk County, the per capita rate was 122 g/p/d (2013).

**Large-Scale Water Consumers**

While average water use levels describe how water is used in general on Long Island, there are also examples of sizeable water use by individual categories or individual customers. *Newsday* reported on the relationship between energy production and water use in 2015 (Harrington, 2015). Long Island power plant’s use of groundwater for 2014 was documented. Nearly all the freshwater is used to produce steam to turn turbines for energy production.

**Table 6**

*Groundwater Use for Power Generation on Long Island*

<table>
<thead>
<tr>
<th>NAME OF POWER PLANT</th>
<th>MEGAWATT</th>
<th>GROUNDWATER USE MG/YR</th>
<th>PUBLIC WATER SUPPLY/PRIVATE WELL</th>
<th>SALTWATER FOR COOLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Grid – Northport</td>
<td>1,580</td>
<td>95</td>
<td>SCWA</td>
<td>939 MG</td>
</tr>
<tr>
<td>National Grid – Island Park</td>
<td>391</td>
<td>81</td>
<td>Public Supply</td>
<td>294 MG</td>
</tr>
<tr>
<td>National Grid – Port Jefferson</td>
<td></td>
<td>53</td>
<td>SCWA + private well</td>
<td></td>
</tr>
<tr>
<td>NYPA –Holtsville</td>
<td>230: (49.7 + 180.3)</td>
<td>SCWA + private well</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinelawn Power – Peaking Plant</td>
<td>79.9</td>
<td>32.4</td>
<td>SCWA</td>
<td></td>
</tr>
<tr>
<td>Covanta – Huntington</td>
<td>30.3</td>
<td></td>
<td>SCWA</td>
<td></td>
</tr>
<tr>
<td>Covanta - Babylon</td>
<td>25 + (300*)</td>
<td>SCWA + Treated Landfill Leachate* - not counted</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Covanta - Hempstead</td>
<td>72</td>
<td>450</td>
<td>Public Supply</td>
<td>None</td>
</tr>
<tr>
<td>Caithness Plant I- Yaphank, Brookhaven</td>
<td>350</td>
<td>18.4</td>
<td>SCWA</td>
<td>None – air cooled system</td>
</tr>
<tr>
<td>Caithness Plant II – Proposed, Yaphank</td>
<td>(750) proposed</td>
<td>(52.6) proposed</td>
<td>Not included in total</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL GW/YR</strong></td>
<td></td>
<td>906.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Harrington (2015, Newsday)*

Table 6 shows that nearly 1 billion gallons of groundwater per year is used in power production on Long Island. All of this water use is considered a consumptive use and is not returned to the aquifers. In addition, more than 1 billion gallons of salt water is used for cooling water by some of the power plants. Most of this water may be returned as heated water to coastal marine waters.

Another example of major groundwater use is for open-loop geothermal heating and cooling systems. Some of the larger homes on Long Island use in excess of 20 million gallons of potable
public water per year for geothermal and landscape irrigation. Since both of these uses do not require drinking quality water, some water suppliers are reviewing usage data in order to work with major users and get them to reduce their overall demand. Geothermal use is studied in greater detail in a later chapter.

**New York State Department of Environmental Conservation - Water Conservation Policy**

In January 2017, the NYSDEC notified all public water suppliers on Long Island of a new reporting and water conservation policy. Starting in 2017, the NYSDEC is asking Island water suppliers to prepare and implement a plan to reduce water use in the peak season by 15% over a three-year period or roughly 5% per year. A new reporting form was provided for suppliers to report their progress and document details about water use. The nine-page Water Conservation Reporting Form covers topics such as: water use (daily, annual, peak, etc.); use by sector; unaccounted for water; water bill rates; water meter programs; pipe replacement programs; leak detection; public education; tracking water use reductions; indoor and outdoor water use reductions; drought response and emergency planning; and funding sources to support water conservation.

**Chloride Contamination in Nassau and Suffolk Counties, New York**

Existing chloride contamination of Long Island aquifer system is examined in this section. Chloride concentrations can be a bellweather of salt water intrusion, perhaps related to excessive pumpage or changes in the aquifer system. Chlorides can also relate to land use within a specific well’s zone of capture which is the surface area where groundwater recharge will eventually reach that well. The section presents a summary of chloride concentrations identified in potable supply wells operating within Nassau and Suffolk Counties during 2014, together with an assessment of potential sources of chloride contamination within the vicinity of affected public supply wells. Water quality data was assembled from existing public supply wells in both Nassau and Suffolk Counties for all three principal aquifers. The range of results and their distribution within each county are displayed in Table 7 and Table 8 of this report.

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>0 - 50 ppm</td>
<td>81%</td>
</tr>
<tr>
<td>67</td>
<td>51 - 100 ppm</td>
<td>14%</td>
</tr>
<tr>
<td>19</td>
<td>101 - 250 ppm</td>
<td>4%</td>
</tr>
<tr>
<td>8</td>
<td>Exceeding 250 ppm</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total = 495</strong></td>
<td></td>
<td><strong>Mean Concentration = 41 ppm</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>372</td>
<td>0 - 50 ppm</td>
<td>97%</td>
</tr>
<tr>
<td>9</td>
<td>51 - 100 ppm</td>
<td>2.5%</td>
</tr>
<tr>
<td>1</td>
<td>101 and 250 ppm</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td><strong>Total = 383</strong></td>
<td></td>
<td><strong>Mean Concentration = 12 ppm</strong></td>
</tr>
</tbody>
</table>
### Suffolk County Public Supply Wells - Lloyd Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0 - 50 ppm</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Total = 5</strong></td>
<td></td>
<td><strong>Mean Concentration = 8 ppm</strong></td>
</tr>
</tbody>
</table>

### Suffolk County Public Supply Wells - Raritan Formation

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0 - 50 ppm</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Total = 3</strong></td>
<td></td>
<td><strong>Mean Concentration = 11 ppm</strong></td>
</tr>
</tbody>
</table>

### Suffolk County Private Wells - Glacial Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>210</td>
<td>0 - 50 ppm</td>
<td>82%</td>
</tr>
<tr>
<td>26</td>
<td>51 - 100 ppm</td>
<td>10%</td>
</tr>
<tr>
<td>16</td>
<td>101 - 250 ppm</td>
<td>6%</td>
</tr>
<tr>
<td>5</td>
<td>Exceeding 250 ppm</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total = 257</strong></td>
<td></td>
<td><strong>Mean Concentration = 41 ppm</strong></td>
</tr>
</tbody>
</table>

### Table 8
Summary of Chloride Concentrations:
Supply Wells in Nassau County Operating During 2014

### Nassau County Public Supply Wells - Glacial Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0 - 50 ppm</td>
<td>44%</td>
</tr>
<tr>
<td>5</td>
<td>51-100 ppm</td>
<td>56%</td>
</tr>
<tr>
<td>0</td>
<td>101-250 ppm</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total = 9</strong></td>
<td></td>
<td><strong>Mean Concentration = 46 ppm</strong></td>
</tr>
</tbody>
</table>

### Nassau County Public Supply Wells - Magothy Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>248</td>
<td>0 - 50 ppm</td>
<td>95%</td>
</tr>
<tr>
<td>14</td>
<td>51 - 100 ppm</td>
<td>5%</td>
</tr>
<tr>
<td>0</td>
<td>101 - 250 ppm</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total = 33</strong></td>
<td></td>
<td><strong>Mean Concentration = 21 ppm</strong></td>
</tr>
</tbody>
</table>

### Nassau County Public Supply Wells - Lloyd Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>0 - 50 ppm</td>
<td>94%</td>
</tr>
<tr>
<td>2</td>
<td>51 - 100 ppm</td>
<td>6%</td>
</tr>
<tr>
<td>0</td>
<td>101 - 250 ppm</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Total = 33</strong></td>
<td></td>
<td><strong>Mean Concentration = 12 ppm</strong></td>
</tr>
</tbody>
</table>

### Nassau County Public Supply Wells - Port Washington Magothy Aquifer

<table>
<thead>
<tr>
<th>Number of Wells</th>
<th>Range of Chloride Concentrations</th>
<th>Percentage of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 50 ppm</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Total = 1</strong></td>
<td></td>
<td><strong>Mean Concentration = 50 ppm</strong></td>
</tr>
</tbody>
</table>
The data collected from potable supply wells during this period shows that mean chloride concentrations are significantly below the drinking water and groundwater standard of 250 parts per million (ppm); however, wells located near shoreline areas appear to be susceptible to chlorides via salt water intrusion and upconing. For example, the public supply wells that exceeded the drinking water and groundwater standard in Suffolk County were located within proximity to shoreline areas. In addition, the analytical results indicate that chloride concentrations in wells screened in the Glacial Aquifer are greater than chloride concentrations identified in deeper wells screened within the Magothy and Lloyd Aquifers, suggesting that various land uses and activities may be having a greater impact upon the shallower wells (e.g., road salting; institutional, commercial and residential developments; the operation of salt storage facilities; etc.).

**Introduction**

The potential impact of chlorides upon Long Island aquifers and water resources is an ongoing concern, as the groundwater has been designated by the United States Environmental Protection Agency as a sole-source water supply. Chlorides can impact the Long Island groundwater and drinking water supply primarily through: salt water intrusion via lateral intrusion and upconing when operating supply wells in proximity to surface waters, road salting and runoff from improperly stored road salt and deicing compounds. Other sources of chlorides include: effluent from sewage disposal systems, leachate from municipal landfills and infiltration of stormwater from recharge and drainage basins. Impacts of chlorides from lateral intrusion and upconing are particularly relevant with respect to areas on the North and South Forks of Suffolk County, Shelter Island and various coastal regions along the south shore of Long Island. In addition, several supply wells within areas of the Brookhaven and Islip Towns also have been affected with chlorides. In Nassau County, several public supply wells located in Great Neck, Manhasset Neck and Bayville were shut down due to salt water intrusion and overpumping. It should be noted that removal or treatment of excessive chloride contamination from drinking water supplies is typically not an option because of the difficulty and expense involved. For purposes of this report, drinking water wells that exhibit chloride concentrations exceeding 100 ppm are considered impacted or affected with chlorides.

**Methods**

A query of the Suffolk County Department of Health Services (SCDHS) database was performed to compile the chloride results of samples collected from potable supply wells during 2014 as part of the department's public water supply surveillance monitoring program and private well sampling program. All samples were analyzed by the SCDHS Public and Environmental Health Laboratory in accordance with USEPA's Method 300. Water quality results for wells operating in Nassau County were collected and analyzed by public water suppliers in Nassau County and compiled by the Nassau County Department of Health (NCDOH). Screening values for chlorides were compiled for ranges up to 50 ppm; between 50-100 ppm; from 100-250 ppm, and greater than 250 ppm. In addition, salt storage facilities located within the groundwater contributing areas of public supply wells operating within Suffolk County were identified to help with assessing possible sources of chloride contamination. A compilation of historical water quality results performed by the SCDHS from 1998 and through most of 2015 also was utilized to help identify chloride concentrations at public supply wells exhibiting concentrations that exceeded 100 ppm.
Discussion

Public supply wells serve both community water supply and non-community public water supply systems. Pursuant to the New York State Sanitary Code, public community water supply systems serve at least five service connections used by year round residents or regularly serve at least 25 year round residents. Non-community public water supply systems regularly serve at least 25 people a minimum of 60 days of the year. In general, supply wells serving community public water systems are much deeper than wells serving non-community systems and private wells. In addition, private wells typically serve single-family residences and are not regulated as public water systems.

Chloride Results from Public and Private Wells within Suffolk County

During 2014, the SCDHS collected a total of 1,458 samples for chloride analyses from public and private drinking water supply wells operating within Suffolk County as part of the department's routine surveillance monitoring programs (this total includes 1,099 samples from public wells and 359 samples from private wells). Test results show that 401 public supply wells (81%) screened within the Glacial Aquifer exhibited chloride concentrations below 50 ppm; 67 wells (14%) exhibited concentrations between 51-100 ppm; 19 wells (4%) exhibited chloride concentrations between 101-250 ppm; and eight wells (1%) exceeded the New York State Department of Health's (NYSDOH) drinking water standard and the New York State Department of Environmental Conservation's groundwater standard of 250 ppm (this includes one community supply well and seven non-community supply wells). The mean concentration was 41 ppm. Analysis of public supply wells screened within the Magothy Aquifer show that 372 wells (97%) exhibited chloride concentrations below 50 ppm; nine wells (2.5%) exhibited chloride concentrations between 51-100 ppm; only one well showed chlorides between 101-250 ppm and none exceeded 250 ppm. The mean concentration was 12 ppm. Chloride concentrations identified in all five wells screened in the Lloyd Aquifer were below 50 ppm, with a mean concentration of 8 ppm, while chloride concentrations in all three wells screened in the Raritan Formation also were below 50 ppm, with a mean value of 11 ppm. Samples collected from private wells within Suffolk County during 2014, showed that 210 wells (82%) exhibited chloride concentrations below 50 ppm; 26 wells (10%) exhibited chloride concentrations between 51-100 ppm; 16 wells (6%) exhibited concentrations between 101-250 ppm, and five wells exceeded the drinking water and groundwater standards of 250 ppm. It should be noted that these results represent a small percentage of the estimated 45,000 private wells in Suffolk County.

The eight public supply wells that exceeded the drinking water standard noted above are located within the townships of Shelter Island, Southold and East Hampton and include one community supply well and seven non-community wells. The affected public water systems either: removed the impacted wells from service, provided the appropriate treatment devices or connected to a community water supply system. All of the private well owners were notified accordingly of their results by the SCDHS. Table 7 provides a summary of chloride concentrations identified in public and private supply wells sampled by the SCDHS during 2014. Figures 3, 4 and 5 illustrate the chloride detections identified in public community supply wells, non-community supply wells, and private wells operating within Suffolk County during 2014, respectively.
Suffolk County Department of Health Services
2014 Community Public Water Supply Well Chloride Data

Figure 3

Legend
Chloride Concentrations (ppm)
- 250 to 300
- 100 to 250
- 50 to 100
- 0 to 50

Well Aquifer Segment
- Glacial Well
- Magdathy Well
- Lloyd Well
- Ranitan Well
Suffolk County Department of Health Services
2014 Non-Community Public Water Supply Well Chloride Data

Figure 4
Chloride Results from Public Wells within Nassau County

Water quality results compiled by the NCDOH from 305 public supply wells during 2014 as part of their regulatory programs showed the following results: four wells (44%) screened within Glacial Aquifer exhibited chloride concentrations below 50 ppm, and five wells (56%) exhibited chloride concentrations between 51-100 ppm. The mean chloride concentration was 46 ppm. Public supply wells screened within the Magothy Aquifer showed that 248 wells (95%) had chloride concentrations below 50 ppm, and 14 wells (5%) had concentrations between 51-100 ppm. The mean concentration was 21 ppm. Public supply wells screened within the Lloyd Aquifer showed that 31 wells (94%) had concentrations of below 50 ppm while two wells exhibited chloride concentrations between 51-100 ppm. The mean chloride concentration was 12 ppm. In addition, only one supply well screen within the Port Washington Magothy Aquifer exhibited a mean chloride concentration of 50 ppm. Table 8 includes a summary of the results, and Figure 6 shows the chloride concentrations from public supply wells operating within Nassau County during 2014.
Figure 6 Chloride Concentrations, Nassau County Public Wells, 2014
Evaluation of Source Water Assessment Areas of Public Supply Wells Affected with Chlorides

To help evaluate potential sources of chloride contamination in public drinking supplies, supply wells with chloride concentrations greater than 100 ppm were evaluated in greater detail. Fifteen public supply wells in Suffolk County exhibited chloride concentrations exceeding 100 ppm (Table 9). Of these 15 wells, the groundwater contributing areas of 12 wells have been modeled by Camp, Dresser, and McKee (CDM) as part of the Suffolk County Comprehensive Water Resources Management Plan. A review of this information, as well as identifying potential sources of chlorides in the vicinity of the other three wells that exceeded 100 ppm, indicates that five of the wells are located near roadways that are possibly influenced by road salting; five wells are located in proximity to a salt water body such as the Long Island Sound; three wells are located in proximity to both salt storage facilities and roadways; and two wells are in the vicinity of both a salt water body and roadways (Table 10). This review indicates that there are multiple potential sources of chloride contamination at public supply wells with elevated chlorides.

As noted above, Table 10 provides a summary of potential sources of chloride contamination that exists within the vicinity of public supply wells where concentrations exceeded 100 ppm. Table 5 provides a list of public supply wells where salt storage facilities were identified within the groundwater contributing areas together with the respective trends in chloride concentrations.

In addition, a review of available information shows that approximately 29 road salt storage facilities are located within the groundwater contributing areas serving 33 public supply wells in Suffolk County. A compilation of water quality results obtained from these wells between 1998 through most of 2015 suggests that, overall, chloride concentrations generally increased in 12 of the 33 wells sampled during this period; however, chloride concentrations generally remained the same in 18 wells and decreased in three of the wells. Table 11 provides a list of public supply wells where salt storage facilities were identified within the source water contributing areas together with supporting data.

To help identify and monitor the fresh water-salt water interface near shoreline areas at select locations within Suffolk County, the SCDHS is in the process of installing monitoring wells near shoreline areas of the Southwest Sewer District; within the North and South Forks and at locations within Shelter Island. These monitoring wells will be utilized to measure the concentration and trend in chloride concentrations and to monitor the fresh water-salt water interface through the use of geophysical logging equipment and measuring other chemical parameters. Additional monitoring wells at other locations may be installed and monitored depending upon available resources.
Table 9  
Concentration History: Public Community Supply Wells in Suffolk County Exhibiting Concentrations Exceeding 100 mg/L

<table>
<thead>
<tr>
<th>S-Number</th>
<th>Date of 1st Sample</th>
<th>Date of Last Sample</th>
<th>Number of Samples</th>
<th>Min. Conc.</th>
<th>Max Conc.</th>
<th>Mean Conc.</th>
<th>1st Sample Conc.</th>
<th>Last Sample Conc.</th>
<th>Change in Conc.</th>
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<td>9/9/2015</td>
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<td>147</td>
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<td>100</td>
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<td>6/2/2015</td>
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<td>128</td>
<td>90</td>
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### Table 10
**Potential Sources of Chloride Contamination within Source Water Assessment Areas or Within the Vicinity of Public Supply Wells in Suffolk County Exhibiting Chloride Concentrations Exceeding 100 ppm**

<table>
<thead>
<tr>
<th>S-Number</th>
<th>Location</th>
<th>Groundwater Contributing Area Available</th>
<th>Potential Sources within Source water assessment Area or Within Vicinity of Supply Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-00177</td>
<td>Shelter Island</td>
<td>Yes</td>
<td>Well is located within 800 feet of Dering harbor</td>
</tr>
<tr>
<td>S-103522</td>
<td>Southold</td>
<td>Yes</td>
<td>Well is located within 0.68 miles of the Long Island Sound; adjacent to County Road 48</td>
</tr>
<tr>
<td>S-121811</td>
<td>East Hampton Montauk</td>
<td>Yes</td>
<td>Well is adjacent to Montauk Hwy. and is situated near agricultural areas</td>
</tr>
<tr>
<td>S-124659</td>
<td>East Hampton</td>
<td>No</td>
<td>Well is located within 0.5 miles of the Atlantic Ocean and Lake Montauk</td>
</tr>
<tr>
<td>S-124789</td>
<td>Brookhaven Selden</td>
<td>Yes</td>
<td>Wells are located within the vicinity of a salt storage facility and are adjacent to Nicolls Road. Institutional and residential properties are also within the sources water assessment areas</td>
</tr>
<tr>
<td>S-126076</td>
<td>Southold</td>
<td>Yes</td>
<td>Well is located within 0.40 miles of the Long Island Sound</td>
</tr>
<tr>
<td>S-126912</td>
<td>Shelter Island Heights</td>
<td>No</td>
<td>Well is adjacent to Dering Harbor</td>
</tr>
<tr>
<td>S-129199</td>
<td>Islip Terrace</td>
<td>Yes</td>
<td>Well is located several hundred feet away from Southern State Parkway. A salt storage facility is also located over a mile away and is situated outside of the source water assessment area to the well.</td>
</tr>
<tr>
<td>S-130317</td>
<td>Riverhead</td>
<td>Yes</td>
<td>Well is adjacent to Northville Turnpike and is situated about 1.5 miles from the Long Island Sound.</td>
</tr>
<tr>
<td>S-131612</td>
<td>Southold</td>
<td>No</td>
<td>Well is located about 0.5 miles from the Long Island Sound</td>
</tr>
<tr>
<td>S-29492</td>
<td>Brookhaven Medford</td>
<td>Yes</td>
<td>Well is located in the vicinity of Portion Road and Morris Avenue. Residential and commercial properties exist within the source water assessment area.</td>
</tr>
<tr>
<td>S-33775</td>
<td>Southold</td>
<td>Yes</td>
<td>Well is located within one mile of the Long Island Sound, and is within the vicinity of Old North Road.</td>
</tr>
<tr>
<td>S-66366</td>
<td>Huntington</td>
<td>Yes</td>
<td>Well is adjacent to Oakwood Road. Various residential, commercial, and industrial properties exist within the source water assessment area.</td>
</tr>
</tbody>
</table>
**Table 11**

Chloride Concentration History - Public Community Supply Wells in Suffolk County
with Salt Storage Areas Located Within Source Water Assessment Areas

<table>
<thead>
<tr>
<th>S-Number</th>
<th>Date of 1st Sample</th>
<th>Ending Date</th>
<th>Number of Samples</th>
<th>Min. Conc.</th>
<th>Max. Conc.</th>
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Summary and Conclusions

Based upon the compilation and evaluation of the water quality results and other available information noted above, the following summary and general conclusions can be offered:

• Public supply wells operating within Suffolk County during 2014 revealed that 81% of the wells screened in the Glacial Aquifer exhibited chloride concentrations below 50 ppm; 14% of the wells exhibited chloride levels between 51-100 ppm; 4% exhibited chlorides concentrations between 101-250 ppm; and only 1% of the wells tested exceeded the drinking water and groundwater standard of 250 ppm. The mean concentration was 41 ppm. Public supply wells screened within the Magothy Aquifer revealed that 97% of the wells exhibited chloride concentrations below 50 ppm; 2.5% of wells exhibited chloride levels between 51-100 ppm; less than 1% of the wells tested showed chloride concentrations between 100-250 ppm; and none exceeded 250 ppm. The mean chloride concentration was 12 ppm. All of the wells screened within the Lloyd Aquifer and Raritan Formation were significantly below 250 ppm, with mean values of 8 ppm and 11 ppm, respectively.

• Samples collected and analyzed by the SCDHS from private wells during 2014 revealed that 82% exhibited chloride concentrations below 50 ppm; 10% of the wells had chloride concentrations between 51-100 ppm; 6% of the wells sampled exhibited chloride concentrations between 101-250 ppm; and less than 2% of the wells tested exceeded 250 ppm. Also, a review the data suggests that chloride concentrations exceeding the drinking water standard in the eight public supply wells sampled in 2014 was likely caused by salt water intrusion and storm surges as these wells operated in proximity to surface waters. However, other sources of chlorides, such as road salting also may have contributed to the chloride levels identified in these wells.

• Water quality results compiled by the NCDOH from 305 public supply wells during 2014 showed the following results: four wells (44%) screened within Glacial Aquifer exhibited chloride concentrations below 50 ppm, and five of wells (56%) exhibited chloride concentrations between 51-100 ppm. The mean chloride concentration was 46 ppm. Public supply wells screened within the Magothy Aquifer showed that 248 wells (95%) had chloride concentrations below 50 ppm, and 14 wells (5%) had concentrations between 51-100 ppm. The mean concentration was 21 ppm. Public supply wells screened within the Lloyd Aquifer showed that 31 wells (94%) had concentrations of below 50 ppm, while two wells exhibited chloride concentrations between 51-100 ppm. The mean chloride concentration was 12 ppm. In addition, only one supply well screen within the Port Washington Magothy Aquifer exhibited a mean chloride concentration of 50 ppm.

• The data collected from potable supply wells during 2014 shows that mean chloride concentrations are significantly below the drinking water and groundwater standard of 250 ppm; however, wells located near shoreline areas can be susceptible to chlorides via salt water intrusion and upconing. In addition, the analytical results indicate that chloride concentrations in wells screened in the Glacial Aquifer are greater than chloride concentrations identified in deeper wells screened within the Magothy and Lloyd Aquifers, suggesting that various land uses and activities may be having a greater impact upon the shallower wells (e.g., from road salting, developed properties, salt storage facilities, etc.).

• A review of available information by the SCDHS shows that 29 salt storage facilities are located within the groundwater contributing areas of 33 public supply wells operating within Suffolk County. An evaluation of the water quality results obtained from these wells between
1998 and most of 2015 suggests that overall, chloride concentrations generally increased in 12 of the 33 wells sampled during this period; however, concentrations generally remained the same in 18 wells and decreased in three wells.

- It should be noted that this information includes test results from 2014 and represents only a limited data set. Supply wells that may have had chloride impacts that were taken out of service were not included.

- An evaluation of the source water assessment areas serving 15 public supply wells operating within Suffolk County exhibiting chlorides exceeding 100 ppm indicates that five of the wells are located near roadways; five wells are located in proximity to a salt water body, such as the Long Island Sound; three wells are located in proximity to salt storage facilities and roadways; and two wells are in the vicinity of both a salt water body and roadways (Table 10). This information suggests that a variety of sources and activities could be contributing to the increase in chloride concentrations identified in some of the affected wells.
CHAPTER 3
EXISTING REGULATORY AND MANAGEMENT REGIMES

Existing Regulatory Regimes

The following is a chronological listing of many of the more significant milestones in Long Island water resource management and water supply planning. A brief description of several land preservation programs also is provided in a separate section devoted to Suffolk County’s 2015 Comprehensive Water Resources Management Plan. This listing is not an exhaustive bibliography. Brief descriptions are provided for some grounding as to the progression of our understanding of the Long Island aquifer system, water supply needs, wastewater management, land use and population issues. Individual issue topics, such as contamination occurrence, or water quality investigations relating to a specific contaminant or group of contaminants are not listed; however, they are often listed as information sources in the bibliographies that accompany many of these listed studies. Subregional studies are listed primarily when they were considered a part of a regional plan. Several reports were not readily available for summary.


2. 1957, T.H. Wiggin, Report on a Comprehensive Plan for the Development and Distribution of the Available Water Supply of Suffolk County, Long Island, New York. Report to the Suffolk County Water Authority (SCWA). Includes estimates on recharge adequate for five million people. Wiggin's report said to contain first reference of potentially using recharge basins for aquifer recharge purposes in Suffolk County, in use in Nassau County since 1935. Wiggin report citation in Regional Planning Board's 1968 Existing Land Use Report: water supply is obtained entirely from groundwater; natural replenishment of this supply is derived solely from precipitation, i.e., rain, snow and sleet, which averages 42 inches per year. It estimates that approximately 50% of the precipitation is lost due to evaporation, stream flow and other factors so that only about half of the precipitation reaches the water-bearing strata. On the basis of past experience and engineering projections, the groundwater reservoir appears to be adequate to serve an estimated population of approximately 5 million persons in the two counties.

3. 1963, Greely and Hansen, Nassau County, New York, Report on Water Supply. The primary purpose of this study for Nassau County was to provide a comprehensive plan to avoid a critical water supply problem, which, in 1963, was predicted for 1987. The recommended plan included the following: installation of deep injection wells along the south shore using reclaimed wastewater for creating a fresh water barrier to retard salt water intrusion into the Magothy Aquifer, increasing the aquifer yield; spreading location of future wells throughout Nassau County; and recharging supplemental water into the central part of the county. The third step considered purchase of supplemental water from New York City or Suffolk County, seawater desalinization and (recommended in the final plan) use of reclaimed wastewater. These recommendations prompted the bench and pilot studies of tertiary treatment and barrier-recharge at the Bay Park Sewage Treatment Plant in the 1960s and 1970s, ultimately leading to the feasibility operational testing of recharge at the Cedar Creek plant from late 1979-1982.


6. 1968-1970, Greeley and Hansen, *Nassau County Comprehensive Public Water Supply Study* (CPWS-60). Intended to be a flexible planning guide for 50 years. Population projections, per capita use and estimated consumption were projected to exceed the permissive sustained yield based on the range of estimated sustained yields reported in prior studies. A deficiency supply plan similar to that discussed in CPWS-24 was described and was proposed to be administered by a Water Resources Board. Population projections were, as was the case with the Suffolk County study, substantially higher than what eventually occurred – reaching 2.25 million by year 2020.


9. 1978, Long Island Regional Planning Board, *Long Island Comprehensive Waste Treatment Management Plan* (L.I. 208 Study). Examined many aspects of surface and groundwater pollution on Long Island; established the need for regional management approaches; established eight hydrogeologic zones with differing recharge characteristics; established one-acre development as a level needed to keep groundwater impacts acceptable; and evaluated viral and other pathogenic contamination potential. Provided the basis for the Environmental Protection Agency Sole Source Aquifer designation for Nassau and Suffolk Counties. Management projects continued under the established 208 program structure yielding the *1984 Non-Point Source Management Handbook*, the Suffolk County Drinking Water Protection programs, which acquired critical areas utilizing a dedicated sales tax revenue source, and the Long Island landfill law in 1983.

10. 1980, H2M Corporation, *Nassau County Draft Master Plan*. Reworked population projections and consumption from the prior report, anticipating both numbers would peak in the early 1990s. Permissive sustained yield was estimated at 180 million gallons per day.

11. 1983, ERM-Northeast/Camp, Dresser, & McKee, *North Fork Water Supply Plan*. Prepared for Suffolk County Department of Health Services. Encompassing the Towns of Riverhead and Southold, the study area was divided into five zones with permissive sustained yield assigned to each budget area. Domestic consumptive use and agricultural consumptive use was projected through the year 2000. Several zones were recognized to have critical supply conditions and extensive contamination largely due to agricultural activity was noted and
expected to continue for many years. Five levels of supply alternatives were projected from individual home system treatment through neighborhood systems, through small community, subregional and regional system supply and treatment responses.

12. 1986, New York State Department of Environmental Conservation, *Long Island Groundwater Management Program*. Summarized quality and quantity problems, existing programs, program needs and actions to preserve and protect groundwater; provided a technical basis for withdrawal limitations in Nassau County.


14. 1987, Dvirka & Bartilucci Consulting Engineers and Suffolk County Department of Health Services, *Suffolk County Comprehensive Water Resources Management Plan*. Primary objective was as an update of the Comprehensive Public Water Supply Study CPWS-24 through a planning period of 2020 and beyond. Addressed future land use and growth patterns, population, demands, treatment and water transmission needs, land use impacts on quality, hydrogeologic zone boundaries and critical recharge areas and potential land use impacts on water resource utilization. Structural and non-structural options considered. This resulted in establishment of population-related, nitrogen-based targets for management of non-sewered future developments in the various designated recharge areas. These advanced concepts developed in the 1978 208 Study and provided the necessary technical support for the density based non-sewered allowances formalized in Article 6 of the Suffolk County Sanitary Code. Volume II of the Report developed detailed management options, recommendations and implementation measures to address nine specific groundwater quality, groundwater quantity and water supply problems.

15. 1988, New York State Department of Environmental Conservation, *Long Island Water Resources Management Study*. Following the 1984 passage of the Water Resources Management Strategy Act; first step state-wide to identify deficiencies, both existing and potential for Long Island through year 2030, the rest of New York through year 2000; 49 of 84 systems were surveyed; noted Long Island's well permit system provided more information than elsewhere in the state; Nassau County's current consumptive use near or above most estimates of permissive sustained yield, although exact quantification is not possible, while Suffolk County has adequate supply; noted local pumping along with costs, private wells and streamflow reductions; recognized federal, state and bi-county efforts since the 1970s. Mainly focused on quality. Noted permissive sustained yield as a matter of debate; streamflow reduction coupled with rising per capita use resulted in devising of allocation system or caps in Nassau County; noted need to continue and expand monitoring to adjust allocated pumpage as necessary. Noted need for $0.5 billion in infrastructure needs by year 2000, about one third of which in storage to provide one-day demand.


20. 1993, Long Island Pine Barrens Protection Act and Amendments (LIPBA). The LIPBA established the Central Pine Barrens Joint Planning and Policy Commission (CPBJPPC) and empowered the Commission to regulate development activities within 105,492 acre within the Suffolk County towns of Brookhaven, Riverhead and Southampton. The LIPBA, among other things, describes the duties of the Commission, defines development and "non-development" activities in the Central Pine Barrens (CPB) and defines the boundaries of both the Core Preservation Area (Core) and Compatible Growth Areas (CGA) of the CPB. The Core contains 56,836 acres of area, and the CGA contains 48,656 acres. The main goals and objectives of the LIPBA Act are to: (a) protect the quality of surface water and groundwater in the CPB, and (b) protect, preserve and enhance the functional integrity of the Pine Barrens ecosystem and the significant natural resources, including plant and animal populations within it. In 1995, the CPBJPPC adopted the *CPB Comprehensive Land Use Plan* (CLUP). The CLUP outlines review procedures for development in the CPB, standards and guidelines for development in the CGA, and Pine Barrens Credit Program criteria for the transfer of development rights, as well as other duties of the Commission. The CLUP has been periodically amended, and the CPNJPPC is currently considering another set of amendments.

21. 2003, Camp, Dresser, & McKee, New York State Department of Health, *Long Island Source Water Assessment Summary Report*. The Nassau-Suffolk County assessments for 938 community and 418 non-community wells built on earlier resource/land use initiatives at state and county levels and incorporated groundwater modeling and geographic information system tools. Five existing CDM groundwater models (the Nassau County Regional Model, the Suffolk County Main body flow model and three salt water intrusion models developed for the North and South Forks and for Shelter Island in Suffolk County) were refined and recalibrated for the purpose of the Source Water Assessment Plan (SWAP), with simulations of aquifer conditions resulting from long-term average precipitation, recharge and stormwater management for the SWAP delineations. As described in the New York State SWAP for wells on Long Island, the source water assessment for each well has three components: delineating the source water recharge area for the well, determining the prevalence of contaminants within the source water area and analyzing the susceptibility of the well to potential contamination. The major deliverable products for the Nassau-Suffolk County SWAP were assessment reports and geographic information system-based maps indicating sources of supply, the respective delineated source water areas, the land use coverages within the assessment area and discrete sources of contamination.
Land Preservation Programs

Special mention is made of existing land protection programs in the following section. Land preservation programs provide important opportunities to protect watershed areas from development. The following sections briefly describe some of the existing programs. When combined with the information developed under *The Long Island Comprehensive Special Groundwater Protection Area Plan*, land preservation purchases can protect lands with important recharge value attributes.

In Nassau County, more than 80% of the land area is suburbanized. However, over the last 10-15 years, a number of land preservation programs have been established in Nassau County in order to attempt to preserve a significant portion of the remaining undeveloped land. Land preservation studies, entities and programs in Nassau County include, but are not limited to, the Nassau County Open Space Plan, Nassau County Open Space and Parks Advisory Committee, Open Space Acquisition Fund, 2004 and 2006 Environmental Bond Acts, Special Groundwater Protection Areas and site-specific preservation efforts (NCMP, 2010).

In 2004 and 2006, Nassau County Environmental Bond Acts acquired approximately 300 acres at an estimated cost of $100 million. The majority of properties acquired through Bond Act funds are located in the Oyster Bay Special Groundwater Protection Area (NCMP, 2010). The acquisitions were aimed at preserving open space, but indirectly served to protect groundwater resources by eliminating the possibility of development on land above the sole-source aquifer (Schneider, 2015). Another preservation effort targeted the Underhill Property, a 96-acre parcel in Jericho, which was a priority acquisition for government officials and organizations for many years. Maintaining this property as open space also was found to provide valuable area for recharge of the local groundwater supply (NCMPU, 2008).

The North Shore Land Alliance (NSLA), founded in 2003, has facilitated $225 million in municipal funding measures and more than $10 million in private funding to date to protect 560 acres of farmland and open space. As of 2014, the North Shore Land Alliance owns and/or manages 11 nature preserves totaling 210 acres. The NSLA also holds 16 conservation easements on 195 acres of privately held land. The NSLA has protected nearly 1,000 acres of land in Nassau County (NSLA, 2016). See Figure 1.
According to the *Suffolk County Comp Plan*, Suffolk County has purchased more than 53,000 acres of land over the past six decades at a cost of more than $1 billion to preserve important environmental resources and significant ecological areas (SCDHS, 2015). See Figure 2. In addition, more than 10,745 acres of agricultural land has been protected for continued agricultural use. Suffolk County's purchase of development rights program to protect farmland was started in 1974 and is the oldest in the nation. In 2013, Suffolk County was the number one producer of agricultural products in New York State in terms of market value, with a market value generated of approximately $240 million ($273,693,592 in inflation-adjusted 2013 dollars) (SCDEDP, 2013). As of 2013, more than 162,500 acres or more than 25% of Suffolk County has been preserved, which includes 38,000 acres of the 55,000 acres of Core Preservation Area in the Central Pine Barrens (SCDHS, 2015).

**Figure 2  Open Space in Suffolk County**

Land preservation occurs in Suffolk County through a variety of programs, including transfer of development rights (TDR), the Suffolk County Drinking Water Protection Program (quarter percent sales tax program), other county-sponsored programs, municipal Community Preservation Fund (CPF), New York State programs, miscellaneous municipal programs and private preservation programs. An inventory of existing TDR programs in Suffolk County was prepared in a report by the Suffolk County Department of Economic Development and Planning in 2014 (Suffolk County, 2014). Some of the programs identified in the report include, but are not limited to, the Suffolk County Sanitary Credits program to protect the integrity of the groundwater in locations where wastewater is discharged through on-site disposal systems; the Purchase of Development Rights (PDR) program for farmland preservation, which is the oldest of its kind in the United States; and the Pine Barrens Credit Program, established as a result of the New York State Legislature's adoption of the Long Island Pine Barrens Protection Act of 1993 (the Act) and the subsequent adoption of the *Central Pine Barrens Comprehensive Land Use Plan* in 1995. The Pine Barrens Credit Program, managed by the Central Pine Barrens Joint Planning and Policy Commission, supports the preservation of groundwater and ecological resources that occur when a property owner of land in the Core Preservation Area records a conservation easement on their property and in return obtains Pine Barrens Credits to transfer development outside of the Core and/or outside of the Central Pine Barrens region.

In 1987, Suffolk County approved, by voter referendum, the Drinking Water Protection Program. It approved the use of one quarter of 1% of the sales tax to purchase and preserve land in critical watershed areas. As part of this program, the county acquires lands in mapped and designated...
Special Groundwater Protection Areas (SGPA’s) most likely to have an impact on existing or future drinking water supplies (Jones and Conrin, 2010). Article XII of the Suffolk County Code (SC Code 2015) describes the program in which it states, “Suffolk County Drinking Water Protection Program designed to provide funding for sewer district tax rate stabilization, environmental protection and property tax mitigation is hereby extended in a modified form beginning on December 1, 2007 and ending on November 30, 2030” (SC Code, 2015).

According to the Suffolk County Comprehensive Water Resources Management Plan (2015), the Suffolk County Planning Division has identified the New Drinking Water Protection Program, the Multifaceted Land Preservation Program, the Save Open Space Program and the Environmental Legacy Program as the most significant county open space acquisition programs moving forward. The county’s 2012 Comprehensive Master List Update identified 86 proposed open space sites and assemblages, totaling 4,650 acres that are recommended for future open space acquisitions (SCDHS, 2015).

The Community Preservation Fund is derived from a 2% mortgage transfer tax and was established in 1998 by local voter referendum in the five East End Towns of Riverhead, Southampton, East Hampton, Shelter Island and Southold. The CPF also required authorization by the New York State Legislature. The CPF is administered by each of the five east end towns and has resulted in hundreds of millions of dollars in funding for open space preservation in these municipalities. In 2006, voters in all five towns approved a referendum to extend the collection of the tax through 2030 (PLT, 2015). In 2015, the CPF program was extended through 2050 and amended to allow 20% of funds to be used toward water quality improvement projects (NYS Legislature, 2015). It is important to note that CPF properties are not currently available to public water suppliers for wellfield development.

Other municipal programs can be found in central and western Suffolk County towns, which do not have a CPF. These towns have established alternative funding sources for acquisition and preservation of open space. Towns that have created significant programs include Brookhaven, whose program includes major preservation efforts in the Carmans River Watershed and Huntington.

New York State also acquires and preserves open space primarily in Suffolk County. In the last 10-15 years, significant new state parks and open space areas have been acquired either wholly by the state or through joint funding with Suffolk County and its towns. These acquired and preserved properties are managed by the New York State Office of Parks, Recreation and Historic Preservation and the New York State Department of Environmental Conservation. Acquisitions have included areas of the Central Pine Barrens Core Preservation Area.

Finally, there are a number of private non-profit entities involved in land preservation and management on Long Island, which include, but are not limited to, Peconic Land Trust, the Nature Conservancy, North Shore Land Alliance, Friends of the New York State Environment, Land Trust Alliance and the Trust for Public Land. The Peconic Land Trust, for instance, a private, non-profit organization, has protected nearly 11,000 acres of land in eastern Suffolk County including farmland (PLT, 2015). The Nature Conservancy has acquired and manages more than 4,500 acres in Suffolk County (TNC, 2015).

**Current Water Conservation and Efficiency Initiatives**

Special mention also is given to efforts under way to curtail groundwater usage though the means identified in this section.
New York State Department of Environmental Conservation Pumpage Caps

During 1987, the New York State Department of Environmental Conservation (NYSDEC) imposed pumpage constrains, or "caps" on all Nassau County public water suppliers. The long-term preservation of Long Island's underground water supply by maintaining existing water levels was the basis for these caps. The caps were predicated on a then-current 5-year running average and a maximum volume in any 1 year, while still maintaining the 5-year average when developed in 1987. According to the NYSDEC, the caps have been maintained at their 1987 levels.

The caps program was designed to slowly bring down the average groundwater pumpage through gradual improvements in water use efficiency and water conservation. When begun, the 5-year average cap for the entire county was 188.5 MGD. This represented total pumpage between the years 1981-1985, divided by five. This approach allowed the highest pumpage to be offset by the lowest annual pumpage over a 5-year period. The annual cap was originally based on the highest yearly pumpage in 5-year blocks from 1976-1985 (e.g., 1976-1980, 1977-1981, 1978-1982, etc.) The highest amount for any 5-year block would represent the single highest pumpage of each supplier and would in effect simulate a "worst-case" peak demand. Over time, the 5-year cap and the annual cap would be adjusted as the program produced lower pumpage, thereby slowly bring down permitted withdrawals.

During the late 1980s, several water suppliers challenged the pumpage caps due to perceived inadequacies with the methodology utilized by the NYSDEC in developing the caps. These perceived shortcomings included: no allowance for water conservation programs that may have been implemented before the caps and no consideration of safe permissible yield and mathematical deficiency in the NYSDEC rules for calculating the current 5-year cap that existing regulatory and management regimes produces a "roller coaster" effect. Despite these perceived shortcomings, the regulatory initiative had one of its intended effects, namely of promoting water conservation awareness and the virtues of reducing waterwaste.

Based on prior legal challenges and the aforementioned inadequacies, the NYSDEC has authority to take enforcement action on the caps with the exception of the Village of Bayville. The agency recognizes the inadequacy of the current practice and cap calculation and will be looking in the future to formulate the caps in a way that can balance sustainable yield with the needs of the individual water suppliers. The NYSDEC plans to have a conservation plan template completed during 2016 (LO1). Discussions will ensue with each water supplier regarding overall conservation in general and its pumpage cap specifically.

After the NYSDEC lost litigation in the challenges to the caps, it stopped re-calculating new 5-year caps on a rolling 5-year average as the program was originally envisioned. It also stopped enforcing situations where a water supplier exceeded their caps. By the early 2000s, Nassau County saw annual pumpage reach 203 MGD (Nassau County, 2005).
Table 1
Public Water Supply Pumpage in Nassau County, 2000-2003

<table>
<thead>
<tr>
<th>YEAR</th>
<th>WINTER LOW MGD</th>
<th>SUMMER HIGH MGD</th>
<th>ANNUAL MGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>141 MGD - January</td>
<td>287 MGD - July</td>
<td>187</td>
</tr>
<tr>
<td>2001</td>
<td>134 - February</td>
<td>296 - August</td>
<td>203</td>
</tr>
<tr>
<td>2002</td>
<td>128 - February</td>
<td>340 - July</td>
<td>200</td>
</tr>
<tr>
<td>2003</td>
<td>135 – December</td>
<td>293 - July</td>
<td>184</td>
</tr>
<tr>
<td>Four Year Average</td>
<td></td>
<td></td>
<td>193.5</td>
</tr>
</tbody>
</table>

Source: Nassau County (2005, Tables 4-12 to 4-15)

Between 1990-2003, the Nassau County Department of Public Works (NCDPW) reported that water supply pumpage had equaled or exceeded the county’s updated safe withdrawal level of 185 MGD, in 12 of 14 years or 85% of the time (Nassau County, 2005). For all of the years analyzed, pumpage exceeded the 180 MGD goal originally used in the caps program. The recent analysis by the NYSDEC shows peak pumpage in Nassau County during 2000-2014 reached 251 MGD (see Figure 1, Chapter 2, page 14).

Well Permit Program on Long Island

The Long Island well permit program regulates any well or wells on any one property with a total pumping capacity of 45 gallons per minute (GPM) or more. The NYSDEC issues well permits that are valid for 10 years. The permit covers such issues as the rated capacity of the well (meaning how much water the well can produce) as well as the depth of the well. All permit holders must report their monthly pumpage to the NYSDEC.

In addition to public water suppliers, well permits are issued by the NYSDEC for a wide variety of operations. These include residential wells for irrigation, hospitals, private businesses, industry, golf courses, municipal parks and schools (for irrigation of recreation fields) as well as operations for remediation, dewatering and geothermal systems. To date, the program has not been a reliable source of information on water use and consumption for Nassau and Suffolk Counties. Personnel shortages and funding cutbacks have only exacerbated the problem.

Nassau County Water Conservation Ordinance (Ordinance 248-A-1987)

In 1987, a progressive water conservation ordinance was adopted by Nassau County (Ordinance 248-A-1987). The centerpiece of the ordinance involved strategies to reduce outdoor water use. In particular, lawn sprinkling is prohibited from the hours of 10:00 a.m.-4:00 p.m. and is limited during other hours to odd and even days corresponding to a resident's street address number. In addition, the ordinance also regulated outdoor water hose usage by requiring the use of a hand operated automatic-off nozzle valve. Furthermore, the hosing of driveways, sidewalks and streets is prohibited. Habitual violators of the county ordinance can be subject to a $50 fine from the local police department. Since the promulgation and enforcement of the lawn sprinkling regulation more than 27 years ago, many Nassau water purveyors have found the ordinance to be a valuable water resource management tool. It has been determined that outdoor water use is more uniformly distributed with the odd/even irrigation ordinance. This subsequently reduces peak
water demand significantly, which results in far reaching environmental, financial and operational benefits for water suppliers and the community.

Presently Suffolk County has not adopted such an ordinance. In October 2015, the Town of Brookhaven adopted an ordinance requiring new in-ground irrigation systems to be equipped with a rain sensor. Rain sensors prevent an irrigation system from activating while it is raining or the lawn is still moist and watering is not needed.

**NYSDEC Water Conservation Plans**

In July 1988, the Governor of New York State signed legislation requiring a water conservation program as a condition of a water supply permit. To assist local governments in complying with this new requirement, the law directed the NYSDEC to develop a model water conservation plan, which includes beneficial short- and long-range water conservation procedures reflecting local water resource needs and conditions. This manual serves as a model to help advise local officials regarding water conservation techniques that individual suppliers may use to conserve water.

Current plans (submitted with water withdrawal permit applications) include an evaluation of existing information consisting of source water inventory, water usage, metering and rate structure, water supply auditing, leak detection and repair, and the review of current water conservation initiatives. Recommended water conservation polices evaluated reducing distribution system losses, leak detection, water efficient landscaping, water audits, and public awareness.

Recently, the NYSDEC has stressed that all water conservation plans must have measurable short-term objectives that will require an annual update. This includes a commitment to finance water conservation measures. The plan must provide time frames/schedules, discuss funding allocated or to be allocated for implementing water conservation measures and state a commitment to implement measurable objectives. Applicants must use the term "will implement" rather than "should implement."

A conservation plan must cover the following elements:

- Water rate structure – how often reviewed.
- Water meters – number of replaced, tested, calibrated and/or repaired per year.
- Top ten water users – have provisions to provide audits.
- Leak detection – miles of main surveyed.
- Water main replacement – 100-year replacement schedule.
- Measures to reduce unaccounted for water. (*i.e.*, leak detection, main replacement and/or water meter replacement/calibration).
- Public outreach efforts – bill stuffers, newsletters, social media, news releases, etc. Must go beyond Annual Water Quality Report (ADWQR).
- Flagging of high bills/potential leaks.
- Automatic irrigation – customer education and outreach.
- Reduce summer peaks associated with irrigation demand.
- Leak repairs – number of leaks, time to repair.
Most water suppliers have many of the above elements implemented, so the requested changes should not have a significant impact. The NYSDEC will be preparing a template in the near future.

**2015 Suffolk County Comprehensive Water Resources Management Plan**

The *Suffolk County Comprehensive Water Resources Management Plan (Comp Plan)* released in 2015 evaluated groundwater and surface water quality issues in Suffolk County. While the *Comp Plan* was broad in scope, specific contaminants were evaluated, including: nitrates, chlorinated solvents, methyl tertiary butyl ether (MTBE), pesticides and possible emerging contaminants. Due to its scope, it deserves special recognition.

The *Comp Plan* considered regional groundwater quantity needs and sea-level rise with an eye to the year 2030 for planning purposes. Surface water degradation and its correlation to coastal resiliency against storm damage, such as what was experienced during Superstorm Sandy in October 2012, also were discussed. The *Comp Plan*’s first two sections covered the value of clean water globally and also outlined several possible policy and management initiatives for the county and others’ consideration to finance, remedy and protect these vital water resources. Sections 3-8 of the *Comp Plan* provided the then-current state of affairs and historical trends, where applicable, related to Suffolk County’s groundwater quality/quantity, surface water, estuaries, coastal resiliency and wastewater management. Section 9 provided a road map for plan implementation listing numerous recommendations and assigning responsible agencies in a framework for implementing prioritized goals guiding future resource management. The following is a discussion of some of the key takeaways and goals of Suffolk County’s *2015 Comprehensive Water Resources Management Plan*.

**Groundwater and Drinking Water**

Public water supply in Suffolk County is extremely undervalued. The Suffolk County Water Authority, the largest water supply system in Suffolk County serving more than 80% of the county’s population, charged $1.67 for 1,000 gallons of water at around the time the *Comp Plan* was written. At this price point, there is little incentive for consumers to conserve public water. Although Chapter 3 of the *Comp Plan* has estimates that indicate there is sufficient water in our groundwater aquifers to meet existing and projected demands, there are certain areas that are more sensitive to contamination, including chlorides due to over-pumping and salt water intrusion. As consumption increases, additional and expensive potable water supply infrastructure must be constructed, which can include:

- Property to be acquired at approximately $100,000-$400,000 per acre.
- New wells drilled at an estimated cost of $300,000-$500,000 each.
- New water treatment facilities with costs varying widely depending on the source water quality, costing $500,000-$3 million each.
- New bulk water storage tanks with an estimated cost of $500,000-$3 million each.
- New and/or larger water mains at about $150-$250 per foot including restoration.

One of the reasons drinking water in Suffolk County is so inexpensive is due to its high yield groundwater aquifers with generally very good groundwater quality. Suffolk County does contend with industrial, petroleum, defense industry and agricultural water quality issues, but fortunately to a lesser extent than they could be, due in large part to source water protection efforts, regulatory
permitting/inspections/enforcement and effective planning. In 2015, approximately 24% of Suffolk's public water supply wells had treatment for volatile organic compounds or pesticides. Monitoring, enforcement and voluntary restriction of select products have helped to reduce contamination of Suffolk County's sole-source aquifer. The county's bane remains a lack of sewering as there is an estimated 74% of the population that continues to discharge sanitary waste and chemicals into on-site cesspools and conventional wastewater systems with little to no reduction of the contaminants poured down the drain or being flushed. The *Comp Plan* evaluated a select group of contaminants of concern for trends from 1987-2013 in the county's monitoring program. Nitrate levels in the county's shallowest Upper Glacial Aquifer increased by an average of 1 milligram per Liter (mg/L) in the same set of wells over the 26-year period; and there was a similar increase of 0.76 mg/L in the same set of Magothy Aquifer wells, the next deepest aquifer. While the nitrate concentration in nearly all public supply wells was below the drinking water standard of 10 mg/L, this is a disturbing trend. Increased nitrate concentrations in groundwater also can have an indirect impact on our surface water quality as groundwaters migrate through our aquifers and upflow into streams, rivers and estuaries. Elevated nitrogen levels in surface waters can cause algal blooms, which may be harmful themselves but also can reduce oxygen levels and result in fish kills.

Volatile organic compounds (VOCs) include industrial and commercial cleaners, but they also include consumer products, such as paint, household cleaning agents, deodorants, adhesives and gasoline. The *Comp Plan* focused on three of the most commonly detected VOCs: the chlorinated solvents being tetrachloroethene (PCE), trichloroethene (TCE) and 1,1,1-trichloroethane (1,1,1-TCA) as well as a long-since banned but persistent gasoline additive, methyl tertiary butyl ether (MTBE). Water quality status and trends were evaluated for these contaminants between 1987-2013. Unfortunately, the total number of wells impacted by PCE doubled during this time frame (29 to 59), and the average concentrations in the Upper Glacial and Magothy Aquifers about doubled in a comparison of the same set of public supply wells. An evaluation of TCE showed similar results where the total number of impacted wells more than doubled (34 to 84). The average concentration of TCE in the same set of Upper Glacial and Magothy Aquifers nearly tripled in a same well comparison. On a positive note, chemical bans previously put in place for 1,1,1-TCA and MTBE appear to have been effective. Concentrations of 1,1,1-TCA have decreased in a same well comparison between 1987-2013 in the Upper Glacial Aquifer from 3.16 to 0.47 micrograms per Liter ug/L and the Magothy Aquifer from 0.57 to 0.47 ug/L. Similarly, MTBE saw a decrease in the number of public water supply wells with detections from 16% in 2005 to approximately 5% in 2013.

As one of the leading agricultural counties in New York State based on sales, Suffolk County has rich agricultural roots. In the *United States Department of Agriculture's 2012 Census*, Suffolk County was listed as having 604 farms over a total of 35,975 acres (www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1_Chapter_2_County_Level/New_York). An unfortunate byproduct of farming is the need to kill or control pests and nuisance vegetation using pesticides such as insecticides, herbicides and fungicides. Many similar, or the same products, are used by homeowners and commercial businesses either to maintain lush, green, weed-free lawns or to control insects such as termites, ants, grubs and ticks. Suffolk County Department of Health Services has implemented a widespread pesticide monitoring program to test for about 150 pesticides and their breakdown products to help inform the public, regulators, researchers and farmers of detections and potential health impacts.
Sampling efforts over the years from public and private drinking water wells and monitoring wells have identified more than 100 pesticide-related compounds. At least one pesticide compound was detected in about 20-25% of public community, non-community or private water supply wells sampled between 1997-2012. Of the 10 most frequently detected pesticides in private well samples, only simazine, metalaxyl, imidacloprid and atrazine were still registered for use on Long Island. Suffolk County continues to work with the New York State Department of Environmental Conservation, Cornell Cooperative Extension, the United States Geological Survey and others to monitor groundwater and surface water and advise policy makers on potential changes to be considered for pesticide regulations.

Several emerging contaminants were also discussed in *Suffolk County’s Comp Plan* including a number of pharmaceutical and personal care products (PPCPs), 1,4-dioxane, chlorate and hexavalent chromium. While the majority of these are not specifically regulated by the federal or state government, it is essential to develop occurrence data to support the development of regulation by one or both of these agencies. Suffolk County continues to monitor and identify suspected sources of many of these contaminants through groundwater investigation work. This places Suffolk County ahead on the learning curve prior to anticipated regulation of these compounds and benefits the Suffolk County residents, visitors and environment by addressing contamination early on.

Section 3 and 4 of the *Suffolk County Comp Plan* discussed groundwater quantity in our aquifers. There is recognition of sanitary flow as a considerable source of water to the aquifers, albeit with the potential to contaminate said aquifers. This concept of indirect reuse of sanitary flows, although not highly publicized or savory, is a reality in the county’s water cycle. The general public must be educated and understand that waste down the drain is likely to impact either a drinking water source (public or private supply well) or a surface water body on our island. In evaluating the alternative, Suffolk County also recognizes that discharging treated sanitary waste to surface waters will result in a net loss of groundwater to our aquifer. This may cause the elevation of groundwater to drop and can even result in streams drying up or the fresh water-salt water interface to move inland closer to existing groundwater wells, potentially contaminating them with high chloride levels. The good news is that water balances confirmed that the Suffolk County aquifer system, on a county-wide basis, is sustainable for projected groundwater pumping and that average pumping was only about 15% of the recharge rate.

**Surface Water, Estuaries and Coastal Resiliency**

Sections 5, 6 and 7 of the *Comp Plan* evaluate surface water quality, estuary programs and the county’s coastal resiliency. The NYSDEC has identified more than 200 fresh water streams and ponds and regulate more than 1,050 fresh water wetlands covering nearly 24,000 acres in Suffolk County. Several of these water bodies are on New York State’s list of impaired waters caused by impairments such as pathogens, metals, phosphorous, ammonia, pesticides, silt/sediment and a lack of dissolved oxygen. Stormwater runoff has been identified as the primary source of these contaminants; however, contaminated groundwater also plays a role.

Since the majority of the county’s stream baseflow is from groundwater, fresh and coastal resources may become impacted by contaminated groundwater. Sampling streams can help determine if there are contamination sources in a watershed. This also can be a great tool in evaluating the impact of different land use types in resource management and planning around sensitive watersheds. The increased nutrient loads from groundwater discharge, especially
nitrogen, to surface waters have caused algal blooms, resulting in a drop in the dissolved oxygen concentrations. These conditions can impair various ecosystems by reducing eelgrass beds, which are significant to the propagation of finfish and shellfish. These contaminants and conditions degrade the quality of Suffolk County’s three major estuaries: the Long Island Sound, the South Shore Estuary and the Peconic Estuary. It is estimated that 80% of all fish and shellfish used estuaries as a primary habitat or as a spawning or nursery ground making them ecologically significant as well as a mainstay in Suffolk County’s east end economy.

Modest sea-level rise predictions between 2015-2100 are on average between about 2-3 feet. This projected rise in sea level coupled with a major storm event such as Superstorm Sandy would devastate places such as Fire Island and Suffolk County’s south shore. The National Resource Council identified a strategy to reduce the impact of flooding or waves for coastal resiliency. In addition to hard structures, nature-based risk reduction strategies to absorb floodwaters and wave energy included restoration or expansion of natural areas such as oyster reefs and salt marshes. Improved water quality is key to wetland enhancement and establishing oyster reefs and expanding clam beds. While these nature-based risk reduction strategies are not the only measures that should be evaluated to enhance resiliency against sea-level rise and large coastal storms, there are other indirect benefits to supporting these strategies.

Some of the recommendations identified to protect surface waters from degradation included: additional open space preservation, improved sanitary wastewater management practices – including a recommendation to require 1 acre density in hydrogeologic zones IV and VIII to protect surface water quality –, expansion of existing sewer districts, evaluation of alternative on-site sewage systems as part of a county-wide wastewater planning study and reducing the impacts of fertilizer on groundwater and surface water.

**Wastewater Management**

Section 8 of the *Comp Plan* provides a history of wastewater management efforts in Suffolk County, a review of feasibility studies for major county sewering projects, wastewater treatment technologies and a look at several innovative on-site wastewater treatment systems. This chapter also covers wastewater as a source of contaminants that can impact groundwater and surface waters, as previously mentioned. Pharmaceutical and personal care products; pathogens such as bacteria, viruses and protozoans; and other contaminants of emerging concern that can originate from wastewater are discussed. Suffolk County has implemented a monitoring program to evaluate and understand the potential impact from some of these compounds while discussing and evaluating research and efficacy of various treatment technologies. Understanding these potential impacts is paramount in the decision-making process of wastewater treatment technology selection and final treated discharge endpoint.

**Plan Implementation**

Section 9 is the culmination of the *Comp Plan* and provides the prioritized list of implementation strategies to meet *Plan* objectives. These are separated into seven separate, but often interrelated and overlapping categories, including: 1) nitrogen, 2) VOCs, 3) pesticides, 4) PPCPs, 5) potable supply, 6) project management and data collection and 7) coastal resiliency and surface water quality. The crux of this management framework is to collaboratively tackle big-picture planning and management initiatives with federal, state, county, town and non-governmental organizations.
Groundwater Quality Initiatives

During and since publication of the 2015 Comp Plan, Suffolk County and numerous stakeholders have embarked on several initiatives to address groundwater quality. Suffolk County has been extremely active in addressing high priority VOCs, pesticides, nitrates and emerging contaminants. A brief overview of some these contaminants and initiatives is provided below.

Volatile Organic Chemicals

The Comp Plan highlighted several areas where additional resources could be allocated to reverse the trend of VOCs increasing in groundwater, namely, chlorinated solvents and gasoline-related contaminants. Due to higher risk for environmental damage, gas stations and dry cleaners have the highest inspection priority and have been inspected annually under the VOC Action Plan. Compliance at gasoline stations has increased significantly since the Plan was adopted. The annual inspections of dry cleaners ensure that the sites are operated properly and that chlorinated solvent spills are kept in check. Another benefit of the VOC Action Plan is that it has allowed the office to increase the number of samples collected to more than 1,000/year vs. approximately 200/year before the program began. Below is a summary of the outputs and outcomes from implementing Suffolk County’s VOC Action Plan and other enhanced Office of Pollution Control (OPC) activities in 2016.

2016 Outputs

**Tank Compliance Inspections**
7,139 tanks inspected.
488 gasoline station facilities inspected.
61 gasoline station sites sampled.
0 gasoline station sites required remediation in 2016.

**Dry Cleaner Inspections**
283 facilities inspected.
42 facilities sampled.
3 chlorinated solvent remediations.
9 other chemical remediations (e.g., toluene).

**Industrial State Pollutant Discharge Elimination System (SPDES) Inspections**
62 facilities inspected.
1,118 industrial samples collected.

**Environmental Assessment Report Reviews** 390 reports reviewed.
99% resulted in remediations.

**Sanitary Abandonment Reviews** 120 facility reports.
30% resulted in remediations.

**OPC Random Industrial Facility Sampling**
100 facilities sampled.
30% resulted in remediations.
**Environmental Enforcements**
541 enforcement actions resulting in $400,000 in penalties

**Gasoline Station Compliance**
52% compliance for gasoline site inspections in 2015.
32% compliance for gasoline site inspections in 2016.
28% compliance for gasoline site inspections in 2017 (to date).

**Environmental Remediations**
222 remediations performed.
4,934 tons of contaminated soil removed from the environment.
871,650 gallons of contaminated liquid removed from the environment.
80 remediations to date are a direct result of the VOC Action Plan.

**Reducing Toxics Study**
The next phase of the VOC Action Plan, the Reducing Toxics Study, also is critically important. This study is intended to develop a method to control hazardous materials at industrial and commercial sites in Suffolk County that are not inspected on a regular basis. Random sampling performed at these sites shows that they are a threat to the environment. This study will look at data collected from such sites and suggest methods and practices to ensure that hazardous materials at the sites are properly controlled.

**Nitrates**
Suffolk County is pursuing proactive measures to reduce nitrogen pollution to its waters. The Comp Plan characterized negative trends in groundwater quality in the Upper Glacial and Magothy Aquifers in recent decades. The Comp Plan linked increasing nitrogen levels in groundwater to drinking water as well as surface waters, including significant impacts of nitrogen on dissolved oxygen (DO), harmful algal blooms (HABs), eelgrass and other submerged aquatic vegetation, wetlands, shellfish and, ultimately, coastal resiliency. For the first time, the Comp Plan established an integrated framework to address the legacy problem of on-site wastewater disposal systems, acknowledging that patchwork sewer is insufficient to solve the problem.

**Subwatersheds Wastewater Plan**
The Suffolk County Subwatersheds Wastewater Plan (SC SWP), an early action/initial step of the overall long-term Long Island Nitrogen Action Plan (LINAP) program, will provide a recommended wastewater management strategy to reduce nitrogen pollution from wastewater sources. The primary objective of the SC SWP will be to provide information regarding data gaps, areas requiring further study and, ultimately, to present data to support long-term LINAP scope refinement and focus on related initiatives throughout Suffolk (e.g., Long Island Sound Study, Peconic Estuary Program, South Shore Estuary Reserve and related town/village initiatives). Recommended wastewater upgrades will focus on the use of innovative alternative on-site wastewater treatment systems (I/A OWTS), sewer where existing feasibility studies indicate it is cost effective and the use of decentralized/clustered systems (e.g., small pre- packaged treatment plants or I/A OWTS that connect multiple tax lots or buildings). The SC SWP cost-
benefit analysis will identify the criteria and locations where the use of decentralized/clustered systems represents the most cost-beneficial approach. In addition, the SC SWP will evaluate and provide preliminary recommendations on overcoming some of the challenges associated with implementing these systems (e.g., existing setback constraints, long-term O&M responsibility, approval process, etc.). Finally, an increase of the minimum lot size may be considered in select subwatersheds where sufficient undeveloped land exists to provide a meaningful environmental benefit.

**Pesticides**

Suffolk County has been a leader in water quality monitoring and assessment of pesticides working in close cooperation with the USGS, NYSDEC, New York State Department of Health (NYSDOH), Cornell Cooperative Extension and others. Pesticide monitoring and management is complicated as many pesticide compounds break down into other chemicals that leach through our sandy soils, are mobile in groundwater and may persist for decades. Over the 20 years since Suffolk initiated its pesticide program in 1997, the SCDHS has installed monitoring wells at nearly 70 different locations such as golf courses, greenhouses, nurseries, farms and vineyards. The results from this testing are used to advise the NYSDEC in its pesticide registration decisions, to support the Long Island Pesticide Pollution Prevention Strategy and to assess the status and trends of pesticide contamination in groundwater, surface waters and drinking water wells. More than 100 pesticide-related compounds have been detected in groundwater since the program's inception. Data collected between 1997-2012 from drinking water sources revealed the following results:

- At least one pesticide compound was detected in about 22% of the 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 (2,300 of 9,900 wells sampled).

The SCDHS plans to continue to address pesticides and their potential impacts to groundwater, surface waters and drinking water supplies. Suffolk expects to continue to sample and monitor for a variety of pesticides and degradation products, to sample for pesticides as part of surveillance and self-monitoring programs, to expand the capabilities of the Suffolk County Public and Environmental Health Laboratory (PEHL) to detect pesticide compounds and degradation products and to identify commercial products that can impact water resources. Finally, as part of the NYSDEC’s Pesticide Pollution Prevention Strategy, stakeholders, regulators and agricultural communities will continue to work together to implement Best Management Practices (BMP) to help mitigate the impact of pesticide use on Long Island.

**Emerging Contaminants such as 1,4-Dioxane and Perfluorinated Compounds (PFOS and PFOA)**

Suffolk County has implemented a three-point approach to addressing emerging contaminants such as 1,4-dioxane and perfluorinated compounds. This includes: 1) facilitating and supporting maximum contaminant level (MCL) development by providing data from monitoring efforts to the NYSDOH and the NYSDEC, 2) encouraging public water supply management to reduce exposure
where possible and 3) providing public education and outreach. Following is an overview of Suffolk County’s efforts under this approach for 1,4-dioxane and the perfluorinated compounds perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS).

(1) Support MCL Development

(a) 1,4-Dioxane

- The SCDHS PEHL has obtained the Environmental Laboratory Approval Program (ELAP) approval for analysis of 1,4-dioxane in drinking water (March 2015) and high-level soils, low-level soils and non-potable liquids (November 2016).
- 1,678 drinking water samples were analyzed by the PEHL from SCDHS. Office of Water Resources samples collected April 2015-December 2016:
  - ~29% detection rate in community water supply wells tested.
  - ~16% detection rate in non-community water supply wells tested.
  - ~7% detection rate in private wells tested.

1,4-dioxane appears to be much more prevalent in deeper wells, which would strongly suggest that its presence in groundwater may be associated with historic releases, not recent discharges. The Office of Water Resources has a goal to test all non-community and community public supply wells by the end of 2017.

- Based upon 2015 and 2016 monitoring efforts by the SCDHS Office of Ecology, 1,4-dioxane was detected in six water bodies at levels as high as 9.65 parts per billion (ppb) (at Little Neck Run in Brookhaven). The goal is to sample all routinely monitored fresh water streams and tributaries again in 2017.

- The SCDHS Office of Pollution Control has sampled for 1,4-dioxane at various industries, including laundromats, dry cleaners, car washes, salons, etc. From January 2017-June 2017, 370 samples were collected at 89 facilities. Five detections from 5-12 ppb were observed in sludge and liquid samples. Sites found to exhibit 1,4-dioxane detections include a multi-tenant commercial center with a dry cleaner, a car wash and two laundromats. SCDHS OCP’s goal is to collect approximately 500 samples in 2017 at high-risk facilities and at random sites. High-risk facilities to be considered include: laundromats, wet cleaners, dry cleaners, car washes, wineries/breweries, power plants, airports, auto repair shops and junkyards (1,4-dioxane may be present in auto coolants and deicing fluids). The SCDHS and NYSDEC are conducting a collaborative sampling effort evaluating laundromat SPDES discharges and existing treatment effectiveness in 2017.

- The SCDHS Office of Wastewater Management is collecting samples from several sewage treatment plant effluents in 2017.

- SCDHS Office of Water Resources is collecting samples from upgradient and downgradient monitoring wells near sewage treatment plant outfalls and also targeting groundwater investigations near five or more laundromats in 2017.

(a) Perfluorinated Compounds

- The SCDHS has leveraged resources with the SCWA’s Laboratory and the NYSDOH’s Wadsworth Laboratory to enable sampling and analysis of perfluorinated compound samples from public, private and groundwater samples near areas of known or suspected contamination.
The SCDHS Office of Water Resources has collected samples from more than 150 public and private drinking water wells between July 2016-September 2016. Of these, about 29 samples were above the United States Environmental Protection Agency health advisory level of 70 parts per trillion. An additional 44 samples had detections below the USEPA’s health advisory level. Approximately 45 monitoring wells have also been installed and sampled by the SCDHS at locations near known or suspected sources of perfluorinated compounds in Suffolk. Of these, 22 had detections above the health advisory level, and 14 had detections below the health advisory level. The goal is to continue sampling at locations suspected to have stored or released perfluorinated compound containing products in consultation with local, state and federal agencies.

(2) Encourage Public Water Supply Management to Reduce Exposure where Possible

(a) 1,4-Dioxane

- Public Health Significance of Drinking Water Results to Date
  1. The EPA lifetime health advisory level (HAL) is 200 ppb in drinking water.
  2. There is no current federal or New York State drinking water standard specifically for 1,4-dioxane. It is currently regulated under a general 50 ppb standard for unspecified organic contaminants (UOC) in New York State.
  3. The EPA 1 in 1 million cancer risk, assuming consumption of 2 liters of water per day for 70 years, is 0.35 ppb.
  4. New Hampshire has created a drinking water standard around one in 100,000 cancer risk at 3 ppb.
  5. While the majority of Suffolk County’s detections are below 3 ppb, there have been at least four pump stations that have pumped water into the distribution system above 3.5 ppb (the highest was 12.5 ppb). The SCDHS has encouraged affected water suppliers to blend wells to reduce concentrations where possible, and Suffolk County is supporting the full-scale Advanced Oxidation Process (AOP) pilot program of the SCWA. This consists of hydrogen peroxide injection, ultraviolet reactor and granular activated carbon quenching of residual hydrogen peroxide at a site in Brentwood. This application was approved after review by the NYSDOH and the SCDHS. Construction of the pilot project was completed in July 2017 and is undergoing rigorous analytical testing during startup.

(b) Perfluorinated Compounds

- Public Health Significance of Drinking Water Results to Date
  1. EPA lifetime HAL for PFOS and/or PFOA is 70 parts per trillion.
  2. There is no current federal or New York State drinking water standard specifically for PFOS and/or PFOA. They are currently regulated individually under a general 50 ppb standard for unspecified organic contaminants (UOC) in New York State.
  3. As of September 2017, the SCDHS was aware of PFOS and/or PFOA detections in at least 24 community public water supply wells. All community public water supply wells with detections have either been voluntarily removed from service, provided with treatment or are blending to reduce concentrations below the HAL.
(c) Public Education and Outreach

1. The SCDHS has required large community public water suppliers to continue sampling for select emerging contaminants from the Unregulated Contaminant Monitoring Rule 3 (UCMR3) such as 1,4-dioxane, PFOS and PFOA in 2016 and 2017 where they have observed detections. These results must be reported in the public water suppliers’ annual water quality reports that are provided to the public.

2. The SCDHS, in collaboration with the NYSDOH and NYSDEC, has developed a 1,4-dioxane fact sheet and frequently asked questions for perfluorinated compounds tailored specifically to Suffolk County. This information on emerging contaminants is posted on the County’s website:
https://suffolkcountyny.gov/Departments/Health-Services/Environmental-Quality/Emerging-Contaminants

Regulatory Framework for Groundwater Management on Long Island

The sole-source aquifer system serving businesses and homes where the 2.9 million residents of Nassau and Suffolk live, and work requires a complex and interrelated regulatory structure in order to assure that it is properly protected and sustainably utilized to meet public needs. Various existing federal, state and county regulations address the many aspects of the management, protection and utilization of the aquifer system for Long Island. Such regulations and programs focus broadly on water resource management and protection and some are specifically directed toward the Long Island aquifer system.

Federal Regulations

Sole-Source Aquifer Designation

The United States Environmental Protection Agency defines such a sole-source aquifer as one supplying at least 50% of the drinking water for its service area and where no reasonably available drinking water source would be available should the aquifer become contaminated. Nassau and Suffolk Counties were so designated in 1978, Kings and Queens Counties followed in 1984. While the designation is significant regarding community planning and awareness, the power designated to the EPA regarding SSAs is limited. The Safe Drinking Water Act (SDWA) requires that the EPA administrator determine that a project incorporating federal financial assistance (through a grant, contract, loan guarantee or otherwise) will not result in a significant public health hazard through recharge zone contamination of a SSA. Measures to mitigate contamination can be incorporated into project planning.

Water Pollution Control Act and Clean Water Act (CWA) – National Pollution Discharge Elimination System (NPDES) Permit System

The regulation of pollutant discharges began with the Federal Water Pollution Control Act in 1948. This Act was significantly reworked in 1972 as the Clean Water Act. CWA authority is statutorily limited to navigable waters. The CWA regulates discharges through a permitting process known as the National Pollution Discharge Elimination System. NPDES authority is substantially delegated to New York State Department of Environmental Conservation, which, under the State Environmental Conservation Law (ECL), greatly broadened its scope to include groundwater discharges.
**Resource Conservation and Recovery Act (RCRA)**

The Resource Conservation and Recovery Act established a system for the environmentally responsible management of hazardous and non-hazardous wastes from point of origin to final disposal point – most commonly referred to as "cradle to grave." Aspects of RCRA regarding waste tracking (manifesting and labeling) and solid waste disposal do facilitate groundwater protection measures and activities. Four federal agencies, the EPA and the Departments of Commerce, Interior and Energy, have specific responsibilities under RCRA, including the promotion of research, regulations for waste management and disposal and financial aid to states to manage their programs.

RCRA delegates states to develop and enforce their own hazardous waste programs in place of the implementation elements assigned to EPA. The delegated program in New York State includes a requirement that all large and small quantity generators over sole-source aquifers that store greater than 185 gallons of liquid hazardous wastes at one time have secondary containment for this storage. In addition, large quantity generators of liquid hazardous wastes must have a closure plan and close the storage areas in compliance with this plan. Federal regulations for underground storage tanks (discussed subsequently) are authorized by RCRA.

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

The Comprehensive Environmental Response, Compensation, and Liability Act established broad EPA response authority over releases of hazardous substances that may endanger public health or the environment. CERCLA accomplished several objectives: 1) it established requirements concerning closed and abandoned hazardous waste sites; 2) it placed liability on those responsible for releases of hazardous waste at these sites; and 3) it provided a cleanup mechanism (through a trust fund) when a responsible party could not be identified. CERCLA response authority includes short-term actions requiring immediate response as well as remedial actions to reduce dangers that are more significant in the long term. This latter authority is limited to sites placed on the National Priorities List (NPL), commonly referred to as the Superfund List. The NPL was amended in 1986 [Superfund Amendments and Reauthorization Act (SARA)] to work out some of the complexities of the original Act and to broaden public participation in the cleanup decision-making process.


Nationally, problems involving leaking underground storage tanks (LUSTs), primarily those holding petrochemicals, became groundwater contamination issues in the mid-1980s. Initially, federal efforts were directed at cleanups, through existing Superfund authority. Initial regulations were published in 1988. In 2005, Congress directed the EPA to establish a spectrum of operational, training and facility requirements. Nassau and Suffolk County and New York State UST requirements predate these federal requirements and, in some respects, are more restrictive. The state has not sought federal delegation authority; however, DEC implements all aspects of the program. Nassau and Suffolk Counties are two of five New York counties for which DEC delegated authority for petroleum bulk storage (PBS) management. LUSTs were long recognized as significant groundwater contamination issues well before national regulations came forward; state and local (county) UST management is discussed later.
Underground Injection Wells – SDWA Authority

As defined by the EPA, an injection well is generally any hole that is deeper than it is wide and is used to emplace fluids underground. The Underground Injection Control (UIC) Program was created pursuant to the SDWA in 1974 to establish control over five classes of injection wells. Under the SDWA regulations, the EPA added a sixth class, geological sequestration wells, in 2010 to address emerging issues relating to the potential subsurface disposal of carbon dioxide to reduce industrial air emissions. On Long Island, Class V injection wells are most common – generally shallow waste disposal wells, septic systems, storm water and agricultural drainage systems or other devices used to release fluids either directly into underground sources of drinking water or into the shallow subsurface that overlies such sources. In order to qualify as a Class V injection well, the fluids released cannot be a hazardous waste as defined under RCRA.

Under the UIC program regulations, Class V injection wells are “authorized by rule,” meaning that Class V injection wells do not (under federal rules) require a permit if they do not endanger underground sources of drinking water and comply with other UIC program requirements – the foremost of which is the submission of basic inventory information. The EPA authorized a Class V Underground Injection Control Study (EPA/816-R-99-014, September 1999) that summarizes the occurrence and numbers of Class V injection wells of each type and also covers what is being injected into these wells and how states regulate them. The Class V Report contains sections on six other subcategories of wells: storm water drainage wells, special drainage wells (examples include swimming pool drainage and construction dewatering injection wells), aquifer remediation wells, non-contact cooling water wells, geothermal direct heat wells, heat pump/air-conditioning-return flow wells and agricultural drainage and food processing wells.

Two specific types of Class V injection wells – motor vehicle waste disposal wells and large capacity cesspools – were banned under the Class V Rule promulgated in December of 1999 because these wells posed the highest risk to underground sources of drinking water (USDW). On June 7, 2002, the EPA published its Final Determination that existing federal UIC regulations were adequate to prevent Class V injection wells from endangering USDW and additional federal requirements were not needed. In addition, the Suffolk County Department of Health Services considers the groundwater-contributing areas to public supply wells in review of new discharges for two injection well subcategories: sewage treatment effluent wells and large-capacity septic systems.

Source Water Assessment Program – SDWA Authority

The NYSDOH worked with the Nassau and Suffolk County Health Departments and other interested parties to develop a specific approach appropriate for Long Island. The Long Island Source Water Assessment Program (SWAP) noted that the regional aquifer systems on Long Island had been extensively investigated and assessed and that extensive groundwater resource management and protection efforts have evolved related to Long Island’s unique regional setting and hydrogeological characteristics. Camp, Dresser, and McKee (CDM) completed the initial source water assessments for public water systems in Nassau and Suffolk Counties, which included: review of aspects of historical and ongoing ground water management programs; evaluation of emerging contaminant issues, relevant well data, inventory of specific contaminant sources and land use within a well’s recharge area; delineation of source water assessment and well recharge areas utilizing a refined Nassau-Suffolk groundwater model determining each well’s susceptibility to contamination; and source water assessments for each well, digital GIS
contaminant source and land use information. Past updates to the SWAP had not been done as no further federal funding had been provided. In Suffolk County, the assessments were subsequently updated as part of the recent *Suffolk County Comprehensive Water Resource Management Plan*, adding newly constructed wells and updating contaminant inventory information. Full digital format groundwater contributing area information is forthcoming.

**Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)**

FIFRA requires the EPA to register a pesticide if it meets certain specific conditions: labelling and application material must be complete and conform to FIFRA requirements and it will work as intended without unreasonable human health or environmental effects. In the United States, no pesticide can be sold or distributed that is not registered under FIFRA. FIFRA allows the EPA to delegate limited powers to the states. For example, states may issue permits to sell and use or control pesticide labelling to the extent that it does not conflict with FIFRA. This provision does not bar ordinances that restrict application or which require pesticide applicators to post notices informing the public of a pesticide application. FIFRA permits State laws such as California Proposition 65, which requires manufacturers and distributors to inform the public that a given product contains a chemical that the State of California has determined causes cancer or birth defects. Under delegated authority, FIFRA encourages and historically has provided limited funding for groundwater state management plans. The NYSDEC requests additional information on chemical properties of proposed pesticides and has limited use permits with objectives of protecting the state's water resources.

**State Regulations**

**State Pollution Discharge Elimination System (SPDES)**

SPDES regulations are more extensive than the NPDES requirements in that they control point-source discharges to groundwater as well as the surface water pollution sources authorized by the federal CWA. Like the CWA, the permit system is directed at maintaining water quality to permit its best use. Under that system, groundwater and surface waters are classified. All fresh groundwater in New York State is classified as GA. The NYSDEC document, *Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations* (Division of Water Technical and Operational Guidance Series (1.1.1, October 22, 1993, Reissued Date: June 1998)) helps regulators respond to a number of emerging contaminant issues. For many of these contaminants, values were developed utilizing the NYSDOH's drinking water standards for two broad organic contaminant groups, known as principal organic contaminants and unspecified organic contaminants.

**State Superfund Program**

New York State cooperates with both Nassau and Suffolk Counties in their efforts to obtain voluntary remediation at sites with contamination issues that may not rise to the level of qualifying under State Superfund.

**State Brownfield Program**

The State Brownfield Cleanup Program, as administered by the NYSDEC, provides a process for voluntary cleanup of sites contaminated with hazardous waste or petroleum. In exchange for the
cleanups, the law provides the applicant with a liability release and tax incentives. Three types of costs can qualify for tax incentives: site preparation costs, tangible property costs and ongoing on-site water treatment costs for five years.

**Watershed Rules and Regulations**

Article 11 of the Public Health Law authorizes the NYSDOH to adopt rules and regulations for watersheds within the state. This authorization dates back to 1885, predating the NYSDOH (which was not created until 1900). Watershed rules and regulations are considered largely outdated and effectively replaced by other regulations with two notable exceptions: New York City and the City of Syracuse. Both were substantially updated as part of filtration avoidance determinations pursuant to the EPA's surface water treatment rule.

**State Pesticide Program**

Under FIFRA, the NYSDEC has been assigned limited authority in the regulation of pesticides. Every pesticide product used, distributed, sold or offered for sale in New York State must be registered with the NYSDEC Bureau of Pest Management. The New York State pesticide product registration procedures informs potential registrants with the guidelines for product registration submission. The registration period is two years. Prior to registration, products must provide "an overview of the potential for the pesticide product to contaminate groundwater from normal labelled use in New York State (including Nassau and Suffolk Counties) conditions." Given prevailing subsurface conditions, Long Island is usually considered a worst-case scenario for potential groundwater contamination. The procedures explain a labelling provision known as a Long Island restriction (prohibition), which reflects the NYSDEC's evaluation that use of the pesticide, as labelled, would pose an unacceptable risk to Long Island's sole-source aquifer.

In the NYSDEC's New York State pesticide administration database (NYSPAD), 527 product names are listed indicating product labelling not for use, sale and/or distribution on Long Island (including statewide limitations). The current NYSDEC groundwater management approach to address low detections of pesticide-related compounds is the Long Island pesticide pollution prevention strategy (LIPPPS), which lists 61 pesticide related chemicals detected in Long Island groundwater at least once between 1996-2010 and associated with 47 active ingredients currently registered for use in Nassau and Suffolk Counties. LIPPPS outlines a process to prioritize and evaluate the 47 active ingredients detected in groundwater during this period by the Suffolk County Department of Health Services. An additional 56 pesticide related compounds associated with 35 active ingredients are restricted from further use and continue to be monitored. LIPPPS is one of the ways in which pesticides are evaluated as potential emerging contaminants in the NYSDOH/NYSDEC collaborative efforts in the New York Ocean Action Plan. It also incorporates ongoing workplan activities conducted under the NYSDEC contract with SCDHS, which cover sampling activities in both Nassau and Suffolk Counties, water analyses completed by the Suffolk County Public and Environmental Health Laboratory (SCPEHL) and monitoring well installations by the SCDHS Bureau of Groundwater Investigation.

**Long Island Landfill Law**

The Long Island landfill law codified in the environmental conservation law, effectively closed all solid waste disposal by 1990 with six current operating landfills left on Long Island, two of which are ash monofills. Landfills or expansions are permitted if located outside the deep-flow recharge
area. These facilities can accept material that is the product of resource recovery, incineration, composting and downtime waste and untreatable waste. These landfills require a double-composite liner system with a primary and secondary leachate collection and removal system. Any new landfill or expansion, located within the deep-flow recharge area, can accept only clean fill and must have, at a minimum, a double liner system consisting of an upper geomembrane and a lower composite liner system with a primary and secondary leachate collection and removal system. Clean fill landfills outside the deep-flow recharge area must have a single composite liner system with a provision for leachate collection and removal.

**Spill Response Program**

Under this program, DEC responds to and manages real time emergency spills of petroleum, hazardous materials and non-hazardous materials that range from several gallons to several thousand gallons and oversees all petroleum subsurface investigation and remediation projects by responsible parties or contractors hired with spill fund monies.

**Major Oil Storage Facility (MOSF)**

In 1978, the state established regulations under the navigation law for the safe transfer and storage of petroleum at MOSFs. The MOSF program applies to facilities that store a total of 400,000 gallons or more of petroleum in aboveground and underground storage tanks. Facilities must be licensed by the DEC and managed in compliance with applicable regulations for the storage and handling of petroleum. On Long Island, this includes groundwater monitoring at all facilities.

**Petroleum Bulk Storage (PBS)**

The state PBS program applies to facilities that store more than 1,100 gallons of petroleum in aboveground and larger than 110 gallons in underground tanks. All tanks (except in delegated counties) for the storage of petroleum at facilities must be registered with the DEC and managed in compliance with applicable regulations for the storage and handling of petroleum. In October 2015, DEC modified the regulations to consolidate and increase consistency with updated federal regulations. With the modification, the counties must implement changes to their codes to continue with delegation.

**Chemical Bulk Storage (CBS)**

In 1994, the state established regulations under the ECL listing hazardous substances subject to handling, storage, and release reporting requirements. The CBS program applies to facilities that store a listed "hazardous substance" in an aboveground storage tank larger than 185 gallons, any size underground storage tank and some non-stationary tanks. All regulated tanks at facilities must be registered with the DEC and managed in compliance with applicable regulations for the storage and handling of hazardous substances. Unlike the PBS program, CBS authority is not delegated to any local entity and many of the county regulations have been superseded.

**Nassau and Suffolk Counties Regulations**

The most significant and innovative county regulations date to the *Long Island 208 Plan* in 1978.
These new regulatory measures primarily built on the 208 Study’s development of hydrogeological zones that opened up regulatory approaches which would cross municipal boundaries and could better accommodate and respond to innovative land use approaches such as clustering and transfer of development rights. In addition to the Long Island 208 Plan, the Long Island Regional Planning Board completed a Special Groundwater Protection Area (SGPA) Study in 1992. The nine SGPs consisted of large fairly continuous undeveloped tracts – two in Nassau County and seven in Suffolk County – and received additional planning recommendations.

**Chemical Storage Tank Approaches**

Suffolk County regulations specifying storage and handling requirements for defined toxic and hazardous materials under the authority of the Suffolk County Sanitary Code (SCSC) Article 12 (initially adopted in 1979). These regulations cover both new and existing aboveground, inground and indoor storage installations; permitting; inspectional right of access; standards for tanks; associated piping and spill containment; tank testing and tester qualifications; spill reporting; and seizure authority. Compliance timetables were established based on the age of the existing tanks and addressed upgrading spill containment, and monitoring systems were similarly phased in as standards were revised. Tank removal required inspection; if evidence of failure or spills was observed NYSDEC would be notified and would require remediation.

Article XI of the Nassau County Public Health Ordinance is structurally identical to SCSC Article 12. The Nassau County Fire Marshall regulates flammable material storage. With the establishment of New York State chemical bulk CBS (non-petroleum) requirements, many of the county regulations have been superseded, except for certain chemicals that fell outside the state regulation.

SCSC Article 7 (initially adopted in 1985) provides additional protection to designated deep groundwater recharge and water supply sensitive areas by restricting the quantities of defined toxic and hazardous materials that can be stored in these areas. The intent is to minimize the impact of spills and discharges in these areas.

**Wastewater Management Approaches**

SCSC Article 6 (1980) ties communal sewering requirements to SCDHS standards which limit nitrogen contribution for non-sewered developments to the equivalent of two single-family units per 40,000 sq. ft. in groundwater management zones (GMZs) III, V or VI, and one single-family unit per 40,000 sq. ft. in all other GMZs. For other than single-family homes, the SCDHS has provided Article 6 density design loading rates for a range of common commercial facilities and other residential applications. A 1995 Article 6 amendment included provisions to permit the transfer of the appropriate density equivalent from existing undeveloped open space controlled by the applicant to land proposed for development. Article 6 empowers SCDHS to adopt standards for on-site sewage disposal systems (OSSDS).

Nassau County Article X (1985) focuses on new subdivisions and a limited range of property redevelopments in un-sewered areas countywide and in the two SGPs designated in Nassau. The approach is similar to that in Suffolk County – aimed at limiting OSSDS to 40,000 sq. ft. lot developments with an additional sewage design flow equivalency approach to non-residential developments.
**Groundwater Resource Monitoring Activities**

Article 4 of the SCSC authorizes the commissioner to collect and analyze appropriate water, soil and geological information to determine if water quality is being maintained. It also authorizes the commissioner to prepare and review comprehensive water supply plans and prepare necessary water resources management as well as numerous other resource management tasks. The Commissioner additionally is authorized to take appropriate legal action, which may include fines for failure to comply with the intent of this Article. It allowed investigation of groundwater impacts from activities within the county and monitoring of private wells. Private well survey work initially uncovered groundwater contamination from chlorinated solvents in the mid-1970s, water soluble pesticides beginning with aldicarb in 1979, methyl tert-butyl ether (MTBE) in 1990s and pharmaceuticals in the first decade of this century. Suffolk maintains drilling equipment for wells up to 300 feet deep. The county's ready access to public rights of way allows the department to investigate suspected contamination sources for code implementation or formal Superfund applications to state or federal agencies, augmenting on-site inspections as needed. Nassau County Department of Health maintains a private well program and enforces well construction standards authorized by Article IV of the County Public Health Ordinance.

**Open Space, Farmland Acquisition and Transfer of Development Rights Programs**

The *208 Study* prioritized actions in the designated deep recharge groundwater management zones. In the late 1970s and early 1980s, nearly every town with large tracts in the designated deep recharge zones selected residential areas for less-intensive uses, redesignated industrial areas for low-density residential uses and made undeveloped industrially zoned lands subject to additional requirements involving storage of toxic and hazardous materials. Water recharge overlay districts were incorporated into zoning categories in Southampton, East Hampton, North Hempstead and Oyster Bay. A program for outright purchases of areas of critical environmental significance set water supply facilities as a designated use and several Suffolk County Water Authority wells have been sited in lands acquired under this program. New York State's Long Island Pine Barrens Protection Act, which affected nearly 100,000 acres, added 20,000 acres to 30,000 public domain acres to form a Pine Barrens Core in which no development would be allowed. The remainder acres, designated a compatible growth area, received the cooperation of individual towns in the development of compatible land use.

**Source Water Withdrawal Regulations**

Permits for public water withdrawal are currently issued by the NYSDEC and are required for any potable and non-potable water withdrawal system having the capacity to withdraw 100,000 gallons per day (gpd) or more of surface water, groundwater or combination thereof. The Long Island Well Permit Program, addressing water withdrawals exceeding 45 gallons per minute, was established to regulate most non-public water withdrawals in the four designated counties composing Long Island and includes relatively short-term withdrawals exceeding that rate such as dewatering activities. A state well driller certification program for Long Island requires filing of preliminary and well completion reports and certain operational reporting requirements for permittees. Permits for public water withdrawal on Long Island are now issued for a maximum period of ten years, allowing for their modification.

Permits often contain site-specific special conditions, general conditions relevant to water withdrawals and general conditions applicable to all ECL-authorized permits. ECL Section 15-
1527 amendments directed that the department undertake, as part of the permit renewal process, categorization of areas of all Long Island groundwater that are exhibiting stress with respect to quality or quantity. The amendments directed the NYSDEC to re-open, review, modify or delete permit conditions as necessary to reduce consumption in overstressed areas. Resulting permit modifications imposed annual pumpage caps on 41 public water suppliers in Nassau County.

By amendment of the ECL, a moratorium was established on the "granting of new permits to drill public water supply, private water supply or industrial wells into the Lloyd Sands or to permit new withdrawals of water from the Lloyd Sands." The moratorium applies "to all areas that are not coastal communities" and requires the NYSDEC to identify which areas of Long Island are to be considered coastal communities. ECL Section 1502 defines coastal communities as "those areas of Long Island where the Magothy Aquifer is either absent or contaminated with chlorides." Exemptions to non-coastal communities can be granted "upon finding of just cause and extreme hardship." A later amendment bans without exemption "the storage or pumping of water into the Lloyd Sands," which applies to both coastal and non-coastal communities. Nassau County controls private well water systems under Article IV of the Public Health Ordinance, while Suffolk's control is under Article 6 of its Sanitary Code; both codes serve to limit proliferation of private potable residential and non-residential wells.

Public Water Supply Regulations

Prior to the SDWA (1974), federal jurisdiction over public water suppliers was limited to only water supply systems involved in water transmission across state lines or via modes of interstate transportation through standards developed by the United States Public Health Service (USPHS). The USPHS standards for drinking water originally regulated 28 contaminants, many which are still used today. Beginning in 1969, USPHS and the EPA raised awareness of volatile organics and trihalomethane (THM) disinfectant by-products as emerging contaminants and surveys were done of local suppliers, initially for six halogenated volatile organic compounds. In 1987, the EPA proposed its first "Phase I" VOC maximum contaminant levels (MCLs) for seven organic contaminants ranging from 2 ppb for vinyl chloride to 200 ppb for trichloroethane.

In 1989, the NYSDOH exercised its right under the SDWA to set MCLs that were more restrictive than those promulgated by the EPA and created two broad regulated contaminant groups of organic compounds known as principal organic compounds and unspecified organic compounds (POCs and UOCS, with individual MCLs of 5 and 50 ppb, respectively, and 100 ppb for the total of all POCs and UOCs). The POC definition has an enforceable standard for trichloroethane of 5 ppb (as an MCL), substantially lower than the 300 ppb federal limit. By early 1989, 36 Long Island public wells out of nearly 900 wells tested were restricted voluntarily. The POC and UOC contaminant definitions and MCLs brought to light occurrence of other contaminants (e.g. MTBE and freons) that would remain unregulated nationally after their initial detection on Long Island or not regulated or receive EPA health advisories for some time (e.g., tetrachloroethylene, dichloropropane and dacthal).

Later SDWA amendments addressed specific issues, such as: provisions banning lead solder and revising "lead-free" definitions for plumbing fittings; requirements for public water supplier vulnerability assessments and emergency response plans; transparency and public accountability; revision of the public notification process associated with regulated contaminants, and consumer confidence reports beginning in 2000.
**Primacy under the SDWA**

The EPA delegates primary enforcement responsibility (primacy) for public water systems to states and Indian tribes if they meet certain requirements:

- Have regulations for contaminants no less stringent than the EPA’s.
- Have adopted and be implementing procedures for enforcement.
- Maintain an inventory of public water systems.
- Have a program to conduct sanitary surveys.
- Have a program to certify laboratories for regulated water sample analyses.
- Have a laboratory that will serve as the state’s "principal" lab that is certified by the EPA.
- Have a program for new/modified systems to have capacity for regulatory compliance.
- Have adequate enforcement authority to compel water systems to comply, to sue in court, to enter and inspect water system facilities, to require systems to keep records and release them to the state, to require systems to notify the public of any system violation of the state requirements and to assess civil or criminal penalties for violations.
- Have adequate recordkeeping and reporting requirements.
- Have adequate variance and exemption requirements as stringent as the EPA’s.
- Have a plan to provide for safe drinking water in emergencies like a natural disaster.
- Have adopted authority to assess administrative penalties for violations.

A state can take up to two years to adopt a new rule while, concurrently, the EPA can choose to directly enforce its requirements. The NYSDOH historically has selected a process of formally adopting new EPA regulations into its code; other states have adopted some or all EPA SDWA regulations "by reference."

**SDWA Drinking Water Standard Setting**

The three criteria for a contaminant to become regulated are: it must have an adverse health effect; it must be known to occur in distributed public water as a health concern; and its regulation would present a health risk reduction nationally. The SDWA requires that EPA simultaneously propose an MCL (the enforceable maximum contaminant level) and an MCLG (maximum contaminant level goal) and that the MCLs are set as close to the MCLGs as possible based on use of best available technology (BAT) and cost. The process is addressed by three operations occurring in overlapping five-year cycles: contaminant candidate lists (CCL), unregulated contaminant monitoring rules (UCMR) and regulatory determinations (RD).

The CCL process has been to add contaminant nominees to the prior list, removing only those that have had formal prior RDs. The current CCL4 includes 100 chemicals or chemical groups and 12 microbial contaminants that are known or expected to possibly occur in public water systems. The UCMR requires public water systems serving more than 10,000 people to sample entry points (after treatment) for no more than 30 suspected contaminants in each UCMR cycle (three years). However, UCMR data, gathered post-treatment, inadequately reflects water supply source waters contaminant occurrence and concentrations. UCMRs do provide opportunities for
new analytical methods to be evaluated.

The EPA must make RDs every five years for a minimum of five contaminants. In three successive actions since 2003, EPA determined not to regulate a total of 24 contaminants and to regulate one contaminant (strontium). Many emerging contaminants have significant exposure routes besides drinking water. Assigning a "relative source contribution" for such a drinking water contaminant is challenging, particularly for one with cancer risks demonstrated through limited animal studies. The slow evaluation process for perchlorate has been a recent challenge illustrating this issue.

The 1996 Amendments required the EPA to review all existing contaminant regulations every six years and to determine if there is a need to revise existing regulations. One contaminant, coliform, has received a revised regulation (revised Rule effective April 1, 2016). The EPA is in the process of developing revised regulations for two of the most commonly found chlorinated solvents: trichloroethylene and tetrachloroethylene. Contaminant studies have reinforced previous conclusions on health effects, detection limits have been lowered and BAT systems are attaining excellent reliability.

**EPA’s New Regulation Strategy and Possible VOC Group Regulation**

In 2010, the EPA began a public process of a new strategy for contaminant regulation, focusing on contaminants as a group based on: similar health effects or endpoints, removal by common control or treatment processes, common analytical methods and known or likely co-occurrence. Approximately 16 volatile organics (eight currently with EPA individual MCLs) were the most viable group to meet these criteria.

**Emerging Contaminants and Risk Communication**

There is a growing list of "emerging contaminants" and an increasing number of contaminant detections due to improved analytical methods with lower detection limits. The challenges facing state agencies and public water suppliers are risk communication and public perception, including the required public disclosure of detections of "new" contaminants in the most recent UCMR3 monitoring program. States have promulgated their own regulations, based on the current state of knowledge, leading to many differing approaches and MCLs for contaminants and differing targets for contaminants of concern at Superfund remediation sites. Conflicts in New York and several other states arise from dramatic changes in EPA advisory approaches to findings of two unregulated perfluorinated organic compounds PFOS and PFOA.

On Long Island, the contaminant in question is 1,4-dioxane. Although detected nationally in 22% of public suppliers in the UCMR sampling, only 7% of suppliers (336 suppliers) detected levels within an EPA range of levels of concern in at least one sample. Twenty-seven of these 336 suppliers are on Long Island.

**State and County Sanitary Codes**

NYSDOH has adopted the new EPA/SDWA-derived rules into the NYS Sanitary Code as they are developed and has delegated to Nassau and Suffolk County health departments a broad range of public water supply regulatory responsibilities. State requirements for publication and public comment are slow and can miss EPA’s rule implementation deadlines. On occasion, this has resulted in compliance issues often relating to water suppliers’ lack of awareness of the
effective date of a federal rule. Most recently, the NYSDOH has shouldered compliance issues associated with the April 1, 2016 revised total coliform rule (RTCR) implementation date, although part 5 incorporation of RTCR has not yet run its course.

The NYSDOH has formally adopted some MCLs for contaminants that are not regulated by EPA and also has the POC/UOC definition for state regulation of organic chemical groups. Part 5 establishes discretionary authority allowing monitoring of contaminants and at set frequencies which can differ from that adopted in federal rules. Part 5 also addresses issues of plan approval, completed works approval and design standards that are not for the most part addressed in federal rules. Part 5 incorporates recommended standards for water works as the basis for approval of public water systems. The Sanitary Code also incorporates standards for water well construction. Although cross-connections have been documented as sources of waterborne disease outbreaks, there are no implicit federal requirements for cross connection control.

NYSDOH codified operator certification requirements in 2001, and subpart 5-4 of the NYSSC was amended to formalize certain operator certification baseline standards established by EPA pursuant to the 1996 SDWA amendments. Suffolk County Sanitary Code Article 4 addresses both public and private water supply systems. Nassau County Public Health Ordinance Article VI was last revised in 1987 and contains a number of specific operational requirements for public suppliers. Proliferation of private potable wells in areas served by public water is discouraged by these regulations. Both counties require monitoring programs exceeding the minimum requirements of the NYSSC, but enforceable through the part 5 discretionary authority in monitoring and regulatory reporting requirements.

**Conclusion and Recommendations**

Existing federal, state and county requirements constitute an effective watershed rule and regulation matrix equivalent to and often exceeding the regulatory controls exercised over water resources elsewhere in the country. Strong levels of communication, regulatory compliance and cooperation between regulatory agencies and among water suppliers are necessary in achieving common goals. There has been an ongoing commitment to expanding knowledge of the water resource, emerging contaminant research and advancement of water supply and treatment technology. However, funding limitations have slowly eroded the overall level of commitment in these areas, most notably seen in overall staff reduction and a loss of institutional knowledge and capacity due to ageing-out and retirements of specialized staff.

Many of the contaminant occurrence problems experienced by public suppliers reflect legacy contamination by industries that are no longer active or involve chemical storage and use practices that have been curtailed or changed. New problems will be found due to newer developed chemicals that escaped notice of the regulatory agencies or as the result of lower limits of analytical detection.

The following actions are recommended for future consideration. It should be noted that much of this framework has already been initiated in Suffolk County as many of the same or similar recommendations were identified in their 2015 Comprehensive Water Resources Management Plan:

1. Restore and expand existing analytical capabilities at local health department laboratories such as aquifer evaluation, emerging contaminant studies, development of new analytical procedures and support of groundwater investigation and increased monitoring.
2. Expand and enhance public water suppliers’ self-monitoring activities, recognizing the need for additional monitoring commitments.

3. Support local laboratory and trained staff response capabilities to meet the objectives of the New York State Water Quality Rapid Response Task Force currently under development.

4. Restore and expand existing county level test well drilling capabilities.

5. Expand and assess a cooperative relationship with the USGS to optimize the strength of local capabilities.

6. Restore health department industrial waste inspections to previous levels.

7. Develop and expand the new GIS-based water quality database developed by Suffolk County Water Authority for the Long Island Commission for Aquifer Protection (LICAP).

8. Commit to continued bi-county updates of water resource management plans and update existing SWAPs to also include GIS output.

9. The NYSDEC and the county health departments must review and provide comments on village and town planning board applications that may impact water resources. Through the State Environmental Quality Review Act (SEQRA) process, these agencies shall identify and communicate any potential issues to the planning boards regarding conservation measures and possible aquifer contamination. Likewise, planning boards must work closely with water suppliers to mandate conditions for the sustainability and protection of water resources prior to approving site plans.
CHAPTER 4
GROUNDWATER QUALITY AND QUANTITY THREATS

Groundwater threats can be generalized as to being a regional threat or a local threat. Regional threats are pervasive issues that may impact, to different degrees, all geographic areas of the Long Island aquifer system. For example, nonpoint source contamination impact is a regional threat. Conversely, discrete impacts resulting from a site-specific land use practice is considered for the purpose of this publication a localized threat. These definitions are broad, and some local threats may become so large as to be a regional threat. This chapter analyzes several types of threats in each category.

Regional Threats

Threats to Groundwater Quality

Emerging Contaminants

Several emerging contaminants were discussed in the Suffolk County Comp Plan, including a number of pharmaceutical and personal care products (PPCPs), 1,4-dioxane, chlorate and hexavalent chromium. While the majority of these are not regulated by the federal or state government, it is essential to develop occurrence data to support the development of regulation by one or both of these agencies. Suffolk County continues to monitor and identify suspected sources of these contaminants through groundwater investigations. This places Suffolk County in a good position prior to regulation of these compounds and benefits the county’s residents, visitors and environment by addressing contamination early.

Nitrate

Monitoring, enforcement and voluntary restriction of select products have helped to reduce contamination of Suffolk County's sole-source aquifer. An estimated 74% of the population continues to discharge sanitary waste and chemicals into on-site cesspools and conventional wastewater systems with little to no reduction of the contaminants. The Comp Plan evaluated a select group of contaminants for trends from 1987-2013 in the county’s monitoring program. Nitrate levels in the county’s Upper Glacial Aquifer increased by an average of 1 milligram per Liter (mg/L) in the same set of wells over the 26-year period. There was a similar increase of 0.76 mg/L in the same set of Magothy Aquifer wells. Increased nitrate concentrations in groundwater also can have an indirect impact on our surface water quality as groundwater migrates through our aquifers and into streams, rivers and estuaries. Elevated nitrogen levels in surface waters can cause algal blooms, which may be harmful themselves, but also can reduce oxygen levels and result in fish kills.

Volatile Organic Compounds

Volatile organic compounds (VOCs) include industrial and commercial cleaners as well as consumer products such as paint, household cleaning agents, deodorants, adhesives and gasoline. The Comp Plan focused on three of the most commonly detected VOCs: tetrachloroethene (PCE), trichloroethene (TCE) and 1,1,1- trichloroethane (1,1,1-TCA) as well as methyl tertiary butyl ether (MTBE). Water quality status and trends were evaluated for these contaminants between 1987-2013. Unfortunately, the total number of wells impacted by PCE
doubled (29 to 59), and the average concentrations in the Upper Glacial and Magothy Aquifers were similar in comparison of the same set of public supply wells. An evaluation of TCE showed similar results. The total number of impacted wells more than doubled (34 to 84). The average concentration of TCE in the same set of Glacial and Magothy Aquifer wells nearly tripled in the same well comparison. Chemical bans previously put in place for 1,1,1-TCA and MTBE appear to have been effective. Concentrations of 1,1,1-TCA have decreased in a same well comparison between 1987-2013 in the Upper Glacial Aquifer from 3.16 to 0.47 micrograms per liter (ug/L) and the Magothy Aquifer from 0.57 to 0.47 ug/L. Similarly, MTBE saw a decrease in the number of public water supply wells with detections from 16% in 2005 to approximately 5% in 2013.

**Pesticides**

As one of the leading agricultural counties in New York State based on sales, Suffolk County has rich agricultural roots. In the United States Department of Agriculture’s 2012 Census, Suffolk County was listed as having 604 farms over a total of 35,975 acres (www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1_Chapter_2_County_Level/New_York/). An unfortunate byproduct of farming is the need to kill or control pests and nuisance vegetation using pesticides, herbicides and fungicides. Many similar products are used by homeowners and commercial businesses to maintain lush, green, weed-free lawns or to control insects. The Suffolk County Department of Health Services (SCDHS) has implemented a pesticide monitoring program to test for about 150 pesticides and breakdown products to help inform the public, regulators, researchers and farmers of detections and potential health impacts. Sampling efforts over the years from drinking water and monitoring wells have identified more than 100 pesticide-related compounds. At least one pesticide compound was detected in about 20-25% of public community, non-community or private water supply wells sampled between 1997-2012. Of the 10 most frequently detected pesticides in private well samples, only simazine, metalaxyl, imidicloprid and atrazine were still registered for use on Long Island. Suffolk County continues to work with the New York State Department of Environmental Conservation (NYSDEC), Cornell Cooperative Extension, the United States Geological Survey (USGS) and others to monitor ground and surface water and advise policy makers on potential changes to be considered for pesticide regulations.

**Climate Change Impacts**

Climate change will present numerous challenges to water suppliers in the next decades. In addition to infrastructure-related issues, aquifer conditions will change in response to future weather variables, including sea-level rise, increased temperature and precipitation and increased occurrence of weather extremes. The United States Environmental Protection Agency (USEPA) defines climate change as any significant change in the measures of climate such as temperature, precipitation and other effects that last for an extended period of time (USEPA, http://www3.epa.gov/climatechange/basics/). It can be identified from changes in, "the average state or the variability of weather and can refer to the effects of 1) persistent human caused changes in the composition of the atmosphere and/or land use, or 2) natural processes, such as volcanic eruptions and Earth's orbital variations" (IPCC, 2007a, pp. 8).

The anticipated aquifer conditions resulting from climate change include: elevated water table, increased streamflow and both vertical and lateral migration of the salt water interface. Impacts to both the quantity and quality of surface water features such as lakes, streams and estuaries
are predicted as well, and elevated water tables also are anticipated to affect wastewater disposal practices in coastal areas. The Suffolk County groundwater model has been utilized to help analyze and quantify these anticipated conditions on the aquifer system in Suffolk County. Responses by water suppliers and regulatory bodies to these new conditions should include such actions as: development of a user-friendly, Island-wide groundwater flow model as is currently underway as part of the Long Island Groundwater Sustainability Project, regional water quality and quantity monitoring, longer distance transmission of water from central Long Island toward the coastal communities, changes to water withdrawal permit conditions to adapt to changing aquifer characteristics (both quality and quantity) and reduced reliance on on-site sewage disposal systems in coastal areas. These potential challenges will be addressed through the prism of what may best be described as "new normal" conditions. As climate change conditions increasingly deviate from current conditions, water suppliers will be required to reevaluate both water resource and facilities management responses and also contend with potential policy and regulatory changes.

**Climate Change Characteristics, Impacts and Projections**

Temperature rise, extreme temperature and heat waves, hot and cold weather events, precipitation patterns, extreme storm events and sea-level rise are measurable parameters of climate change; and the impacts of these attributes will, individually and collectively, negatively impact Long Island water resources and water supply.

**Temperature Rise**

The mean annual temperature in Nassau and Suffolk has increased 5 degrees Fahrenheit (F) between 1900 and 2010. The likely future warming is predicted to be approximately 5.4 degrees F additional by 2050 (Zhang, *et al*, 2014). In addition to general rise in temperature, the frequency, intensity and length of heat waves are expected to increase as well. The impacts of warming trends will cause changes in seasonal water demand from public water suppliers as well as agricultural and recreational (particularly golf course) water users. According to the EPA, the northeast region of the United States, between 1895 and 2011, temperatures rose by approximately 2 degrees F. EPA projections show that the warming trend will continue through the foreseeable future with temperatures rising on average of 4.5-10 degrees F by the 2080s (Source: USEPA, http://www3.epa.gov/climatechange/impacts/northeast.html).

![Figure 1](image-url)

**Observed Annual Temperature in New York City** *(NPCC Climate Risk Information 2013: Observations, Climate Change Projections and Maps pp. 12)*
Extreme Temperature and Heat Waves

The *NPCC CLIMATE RISK INFORMATION 2013 Report* defines extreme temperature events using daily data from Central Park since 1900 using the following metrics:

- Individual days with maximum temperatures at or above 90 degrees F.
- Individual days with maximum temperatures at or above 100 degrees F.
- Heat waves, defined as three consecutive days with maximum temperatures at or above 90 degrees F.
- Individual days with minimum temperatures at or below 32 degrees F.


According to the National Panel Climate Change, "[t]he total number of hot days, defined as days with a maximum temperature at or above 90 and 100 degrees F, is expected to increase as the 21st century progresses. By the 2020s, the frequency of days at or above 90 degrees F may increase by more than 50 percent relative to the 1971-2000 base period; by the 2050s, the frequency may more than double. While 100 degrees F days are expected to remain relatively rare, the percentage increase in their frequency of occurrence may exceed the percent change in days at or above 90 degrees F. The frequency and duration of heat waves, defined as three or more consecutive days with maximum temperatures at or above 90 degrees F, are very likely to increase. In contrast, extreme cold events, defined as the number of days per year with minimum temperature at or below 32 degrees F, are expected to become more infrequent, with a 25% decrease projected by the 2020s and more than a 33% decrease by the 2050s." (*NPCC CLIMATE RISK INFORMATION 2013: Observations, Climate Change Projections, and Maps* pp. 20).

Precipitation Patterns

Climate change has the potential to affect the precipitation patterns. Both the total amount of precipitation and the frequency of heavy precipitation events have been rising. Between 1958 and 2012, the northeast saw more than a 70% increase in the amount of rainfall measured during heavy precipitation events, more than in any other region in the United States ([http://www3.epa.gov/climatechange/impacts/northeast.html](http://www3.epa.gov/climatechange/impacts/northeast.html)). Total annual precipitation is predicted to be anywhere from 10-25% higher by the end of the 21st century (Zhang, 2014). Excessive precipitation could influence the groundwater system by elevating the water table due to increased recharge. Increased water quality and quantity monitoring would likely be necessary in order to accurately track these changing hydrogeologic conditions. The development of and increased reliance on regional groundwater models to help interpret changing conditions in the groundwater system is recommended.
The effects of excessive flooding can negatively impact water quality and can damage water supply infrastructure such as distribution mains and well fields (www3.epa.gov/climatechange/impacts/water.html). These impacts will likely require changes in regional sewerage vs. on-site sewage disposal due to rising groundwater levels. Impacts on aquatic habitat also will occur due to changes in streamflow, which also will affect salinity of bays and estuaries and possibly inundate marginal areas. Projections indicate continuing increases in precipitation, especially in winter and spring, and changes in the timing of winter and spring precipitation could lead to drought conditions in summer as warmer temperatures increase evaporation and accelerate snow melt (http://www3.epa.gov/climatechange/impacts/northeast.html). The impact of precipitation timing would directly influence seasonal water demand needs with regard to public supply, agricultural and recreational (i.e. golf course irrigation).

**Sea-Level Rise**

In addition to climate change, sea-level rise is a threat to Long Island. According to the *Climate Risk Report for Nassau and Suffolk County*, TR-014-01, the sea level is projected to rise 34.0 inches by the end of the 21st century. Aquifers face risks from sea-level rise because as the sea rises, salt water moves into fresh water areas, laterally constricting the transition zones and pushing the water table up. According to the USEPA, in the northeast, sea level has risen by approximately 1 foot since 1900, which has caused more frequent flooding of coastal areas (http://www3.epa.gov/climatechange/impacts/northeast.html).
**Extreme Storm Events**

"Hurricane Sandy has focused attention on the significant effects that extreme climate events have on New York City. Other recent events in the United States, such as the widespread drought of 2012, also have raised awareness of the impacts of weather and climate extremes. While it is not possible to attribute any single extreme event such as Superstorm Sandy to climate change, sea-level rise already occurring in the New York City area, in part related to climate change, increased the extent and magnitude of coastal flooding during the storm." (NPCC CLIMATE RISK INFORMATION 2013: Observations, Climate Change Projections, and Maps pp. 7).

**Figure 4**  Sea, Lake and Overland Surges from Hurricanes (SLOSH) – NYSEMO GIS

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**The “New Normal”**

The northeast is experiencing warming temperatures and a large increase in the amount of rainfall measured during heavy precipitation events. Sea-level rise and more frequent heavy rains are expected to increase flooding and storm surge, threatening infrastructure. The Climate Risk Report for Nassau and Suffolk County, TR-014-01 examined two different scenarios for climate change based upon different predictions for future global greenhouse gas emissions: a scenario wherein future emissions are mitigated aggressively, and a "business as usual" scenario, with minimal mitigation of future greenhouse gas emissions. Values from this latter scenario will be utilized for purposes of this report. Issues that Long Island's public water suppliers will have to contend with under this new normal scenario include, but are not limited to, the following:

- Changes in "safe yield" of aquifer.
- Increased recharge from precipitation.
- Changes in seasonal water demand-public supply, agricultural, recreational (golf course)
from longer growing season.

- Increased upconing (east end) and lateral salt water intrusion (Nassau).
- Increase in water table elevation and resulting changes to aquatic habitat.

In addition to the above issues, which will result in changes to Long Island's water resources as a whole, the increased frequency of extreme weather events such as heavy downpours, hurricanes or nor'easters could impact operations and infrastructure in low-lying or coastal areas of Long Island. Due to threats of intensity, duration and frequency of these events, and the associated impacts such as inundation, wind damage and storm surge damage may cause water suppliers to abandon or relocate assets. In addition, if inundations become permanent, the relocation of populations out of at-risk areas will be necessary. Populations moving in-land will require water suppliers to create additional infrastructure (out of at-risk areas) to supply newly settled regions.

When the draft 2010 Suffolk County Comprehensive Water Resources Management Plan was developed, global climate models at that time projected the following increases in sea-level elevation in the New York City area:

**Decade Increase**

- 2020s, 2-5 inches
- 2050s, 7-12 inches
- 2080s, 12-23 inches

Newer data suggests that higher sea levels are extremely likely by mid-century. Projections for sea-level rise in New York City are as follows:

- By the 2020s, the middle range of projections is 4-8 inches, and the high estimate is 11 inches.
- By the 2050s, the middle range of projections is 11-24 inches, and the high estimate is 31 inches.

The USEPA states that in the northeast, even higher sea-level rise is possible due to the combined effects of warming waters and local land subsidence. The rate of sea-level rise has been increasing, with average sea-level rise since 1900 now at 1.2 inches/decade. Global warming is predicted to further accelerate the rate of rising sea level, both as a result of the expansion of the warming oceans and as a result of ice melt. (Suffolk County Comprehensive Groundwater Resources Management Plan, pp. 3-118).

**Suffolk County Groundwater Model Projections**

The effects of sea-level rise on groundwater resources have been studied extensively as part of the Suffolk County Comprehensive Groundwater Resources Management Plan (SCCGRMP). A portion of this Plan was devoted to utilizing the Suffolk County groundwater model to investigate the effects of various sea-level rise scenarios on the groundwater resources of the main body of Suffolk as well as the north and south forks. As a conservative approach, the mean sea-level rise projection under the "business as usual" case as presented in Zhang et al (2014) was utilized, projecting an increase in sea level of 34 inches. For consistency purposes, a baseline value of 0.5 feet was used as the beginning mean sea level in all model simulations.
These simulation results were used to assess the potential impact to on-site sewage disposal systems, as discussed in Chapter 8. Model simulations were run through 2099 assuming an increase in sea level of 34 inches.

Assuming a 34-inch rise in sea level, the change in water level varies from 2.8 feet to less than 0.25 feet, with most of the model area showing an increase of 1 foot or less. Similar to the original sea-level rise scenarios (Task 4.4 SCCGRMP), the predicted change in water level is much lower along the south shore, compared to the north shore, because increases in stream baseflow limit the water level rise in the vicinity of the non-tidal portion of the south shore streams (simulated to increase by approximately 48% in response to a 34-inch rise in sea level).

Over most of the north fork, the change in water level varies from 1-2 feet. Short, non-tidal segments of streams along the southern shore of the north fork locally limit the water level increase because of increases in stream baseflow. The simulated fresh water-salt water interface position following a 34-inch rise in sea level is shown in cross section on Figure 3-39 SCCGRMP in black. The simulation suggests that the interface moves inland by approximately 800 feet.

Over most of the south fork, the simulated change in water level varies from 1-2 feet. The simulated interface migrates approximately 1,000 feet inland in the shallow aquifer along portions of the south shore.

Flow models used in the Comp Plan confirm that Suffolk County's aquifer system can continue to meet current and projected rates of water supply pumping on a county-wide basis. Nevertheless, as water supply pumping increases in the future and becomes a larger percentage of the overall water budget on Long Island, fresh groundwater supplies and surface water bodies will most likely become more limited in many areas, particularly the north and south forks. The water balances also identify the net loss of baseflow to area streams and to coastal areas in those parts of the county where water supply pumping is not returned to the aquifer, i.e., sewer district areas with tidal water discharge (Southwest Sewer District and others).

This report recommends the utilization of a similar type of model to investigate the effects of various sea-level rise scenarios on the groundwater resource in Nassau County.

**Impacts on Wastewater Treatment Practices in Suffolk County**

Pre-1972 Suffolk County standards identified a minimum distance of 1 foot from the bottom of a cesspool to groundwater (providing 9 feet from ground surface to the water table).

Current standards identify a minimum distance of 3 feet (providing 11 feet from ground surface to the water table). There are many areas along the coast that currently are developed where the existing depth to groundwater is less than 10 feet below grade. These areas also generally correspond with areas that are projected to be further impacted by rising sea level. It is possible that many of the systems within these areas are currently just above the seasonal high water table and may become flooded as sea-level rises in the future. This would not only reduce treatment capability of existing on-site treatment systems, but could completely eliminate the functionality of the system(s). At greatest risk to elevated sea level are the communities along the south shore barrier island. Not only does the water table rise significantly, but much of the land area becomes flooded, similar to a wetland as the groundwater system adjusts to the rising sea level.
As part of the *Suffolk County Comp Study*, the number of unsewered parcels in Suffolk County where the depth to groundwater is less than 10 feet were estimated based on the 2013 simulated water table. On a county-wide basis, it is estimated that more than 80,000 of the existing 360,000 unsewered parcels, or more than 20%, are currently located in areas where groundwater is less than 10 feet below grade. These areas should be prioritized for evaluation of appropriate wastewater management alternatives. Shallow depth to groundwater that potentially compromises septic system effectiveness will be exacerbated with increasing sea-level rise. Based on recent mid-range projections of sea-level rise, it is projected that more than 10,000 additional unsewered parcels (total of more than 90,000 parcels) may be located in areas where the depth to groundwater will be less than 10 feet by the turn of the century.

**Regional Groundwater Threats**

In addition to the generalized threats posed by holistic challenges such as climate change, regional threats also impact groundwater quality. This section discusses three such threats: the potential that NYSDEC public water supply permits originally issued to the Jamaica Water Supply Company will be renewed and issued to the City of New York; localized legacy contamination sites and the impacts associated with geothermal heating, ventilation and cooling systems, in depth.

**Reactivation of Public Water Supply Wells in Queens County, New York**

A system of groundwater pumping wells located in southeastern Queens and southwestern Nassau Counties was owned and operated by the Jamaica Water Supply Company (JWSC) between the years of 1887 and 1996. In 1996, New York City (NYC) purchased and operated the Queens County groundwater well system, supplying drinking water to a roughly 5.5 square mile (sq. mi.) area of NYC until 2007. Although the system has not operated since 2007 and an earlier NYC plan to reactivate the wells has been abandoned, NYC is seeking to reapply for groundwater use permits (which expire in 2017) through the New York State Department of Environmental Conservation for the 68 wells that make up the groundwater supply system in the Queens County area. According to NYC, the reissuance of the permits are necessary in case an emergency condition in some other area of NYC’s distribution system occurs, requiring NYC to pump groundwater to make up for the deficiency. Although NYC has no plans to activate any of the wells within the system in the immediate future, the reissuance of the permits alone is cause for concern to all in Nassau County as any withdrawals from southeastern Queens County could have far-reaching impacts on water quantity and water quality in Nassau County.

NYC supplies more than 1 billion gallons of fresh water each day from large upstate reservoirs – some located more than 125 miles from City Hall – to the taps of 9 million customers. Figure 5 depicts the NYC Water Supply System.
A small area of southeastern Queens and Nassau Counties was serviced by a system of 68 groundwater wells at 44 well stations and several water storage tanks between the years of 1887 and 1996 by the Jamaica Water Supply Company.
Figure 6  NYC Queens Groundwater System

Figure 7  NYC Groundwater System Annual Production 1998-2005
Since the 1990s, NYC has been monitoring leaks in the Delaware Aqueduct reservoir and tunnel system where as much as 35 million gallons per day (MGD) has been leaking from the system. A series of repairs was proposed to be conducted by NYC between the years of 2013-2020 that would result in the construction of a bypass tunnel combined with other system components and initiatives to account for the 500 MGD necessary to make up the difference while the portion of the Delaware Aqueduct system was shut down and repaired. One of the proposed components was the reactivation of the Queens County groundwater well system. The proposal included reactivating 23 wells at 20 well stations in order to provide 33 MGD with a total capacity of 40 MGD to include redundancy. The wells would pump from the Glacial (two stations), Magothy (16 stations), Jameco (one station) and Lloyd (four stations) Aquifers. NYC has indicated that, from an economic and volumetric perspective, it would have to invest more than $200 million in order to restore enough wells and well stations to provide 40 MGD.

As discussions of the plans for the reactivation of the Queens County groundwater well system and the potential for negative impacts to Nassau County’s water resources became more publicized, NYC was made aware of Nassau County’s opposition and significant concerns. In June 2015, NYC decided to abandon the concept of utilizing the Queens County groundwater well system to supplement the reservoir system during the Delaware Aqueduct repair and will utilize other means to make up the water shortage. Although NYC has abandoned the groundwater withdrawal proposal from the overall plan to repair the Delaware Aqueduct system, NYC is still seeking to have the NYSDEC reissue the well permits in case future emergency conditions warrant the reactivation of the groundwater well system in any fashion.

There have been a number of studies conducted over the last 50 plus years examining the use, impacts and potential reuse of the groundwater aquifer system beneath Queens County. The theme of these studies have concluded that, without stringent management, the resource could become useless due to salt water encroachment or other type of contamination. There is particular sensitivity toward the use of the Lloyd Aquifer, the deepest confined aquifer and only source of fresh water for the barrier beach communities around Long Beach in southwest Nassau County. Similarly, concerns raised from the northwestern Nassau County water suppliers on Manhasset Neck and the Port Washington peninsulas have publicized the importance of further study and evaluation of the impacts of re-energizing the Queens County groundwater well system. Historically, measured groundwater elevations have shown that significant cones of depression develop during periods of groundwater pumping from eastern Queens County wells. These cones of depression, as much as 40 feet below sea level, can cause changes in groundwater flow direction, rate of movement and salt-water intrusion potential as well as changing known groundwater contamination plume migration. Although the wells have not pumped since 2007, and the consideration to reactivate the wells during a perceived emergency has been removed for now, NYC is moving forward with a plan to have all the well permits reissued. NYC currently is developing a scope for a Draft Environmental Impact Statement (DEIS) for the reissuance of the well permits. There is serious concern that, without updated hydrogeological framework information, the same assumptions will be made when utilizing and running a groundwater flow model to determine impacts of groundwater withdrawals. Without even a basic acknowledgment of where the current position of the fresh water-salt water interface is in the various aquifers, it would be highly unlikely that a groundwater flow model can accurately predict how and where it will move.
The United States Geological Survey has proposed a project to evaluate the hydrogeologic framework, groundwater availability and water supply sustainability in western Long Island. The need for further study, including the installation of additional monitoring wells drilled to bedrock, before allowing the well permits in Queens County to be reissued, is paramount and needs to be conducted as soon as possible. Recent developments regarding funding this study to be conducted by the USGS have been made public through a February 21, 2016 announcement by the New York State Governor’s Office. The announcement detailed the allocation of $6 million toward the study of Long Island’s aquifer system. Specific details on how the funds will be distributed between several projects have not been made available yet, but funding the additional study of water availability and impact of groundwater withdrawals from the Queens County groundwater wells is of the utmost importance.

The reissuance of these permits requires the preparation of a DEIS, which is currently in the scoping phase. Given the uncertainty of a number of key parameters needed in order to make the proper decisions regarding the operation and use of the Queens County groundwater well system, further study of the hydrogeologic framework and position of the fresh water-salt water interface, including the development of a groundwater model that will predict its movements in response to groundwater withdrawals, must be conducted immediately. Regardless of the outcome of the study, the protection of the Lloyd Aquifer must be further enhanced by eliminating the potential for any additional withdrawals of water from the Queens County groundwater well system going forward.

The reactivation of NYC Lloyd Aquifer supply wells, which have not been used for extended periods in areas where other cost-effective sources of water supply are available, will promote increased salt water intrusion. This will be the case in Queens County if the NYCDEP reactivates four Lloyd Aquifer public supply wells that pumped an average of 4.1 MGD of water from 1920-1995 (for a total withdrawal of 112 billion gallons) and where a 20 foot depression in the potentiometric surface of the aquifer resulted (Cartwright, 2002). This depression extended into western Nassau and eastern Kings Counties. This over-pumping occurred in Queens County where there are combined sewers that discharge stormwater and sewage to treatment plants with outfalls to the surrounding water bodies. In these areas, groundwater recharge by precipitation is vastly reduced and the major source of recharge water to the aquifer is leakage from water supply and sewer lines (Buxton and Smolensky, 1998).

**Regional Contamination Threats**

These types of challenges are largely influenced by historic land use, development and industrialization. More than 250 hazardous waste sites have been identified on Long Island. The United States Environmental Protection Agency and the New York State Department of Environmental Conservation have identified approximately 145 inactive hazardous waste sites in Nassau County and 109 sites in Suffolk County.

Many of the sites can be considered legacy sites where soil and groundwater contamination related to former industrial activities have been affecting the environment for more than 75 years. Many of the older sites and their associated contaminants have become well known to local governments, water suppliers and regulatory agencies. These sites have been listed and studied to varying degrees over the years.

The historic and current formation of groundwater contamination plumes associated with these sites and their movement within Long Island’s aquifer system have impacted both public and
private drinking water wells and continue to present a significant threat to many of Long Island's public water supplies. The contamination of drinking water supply wells results in greater risk to public health, increased cost to produce potable water and lower consumer confidence that the tap water is safe to use. Proper assessment and remediation of this threat requires increased monitoring of groundwater quality and pumpage from all sources. This information, in turn, can be used to expand the effective use of state-of-the-art modeling techniques currently under development by the United States Geological Survey and others.

**Nassau County**

Regional groundwater contamination in Nassau County has been well documented in recent years. More than 145 inactive hazardous waste sites are known to exist on both the federal National Priorities List (NPL) and New York State Superfund lists. Although there are many smaller sites that have been documented and, in some cases remediated, a significant regional threat to local groundwater and public supply comes from long-lived legacy sites. These sites contaminated soil and groundwater as part of industrial activities related to war time production and post-war expansion and commercialization within Nassau County. Historic contamination began at many of these sites due in large part to the lack of public sanitary sewer systems in place at the time of operational discharges associated with production and manufacturing. In most cases, the utilization of on-site sanitary and drainage systems, coupled with prolonged, unregulated discharges of significant quantities of volatile organic and inorganic contaminants, resulted in the discharge of these contaminants into on-site sanitary systems and the ultimate migration of these contaminants once they reached the groundwater table. The resulting contamination caused the formation of groundwater plumes, which developed first in the Upper Glacial Aquifer and then migrated horizontally and vertically (dependent on chemical properties of specific contaminants) to deeper portions of the Magothy Aquifer. Groundwater plumes on Long Island have been documented at depths of greater than 500 feet and have achieved lengths greater than a mile in the direction of groundwater flow.

In many cases these historical or legacy sites and their associated source areas and contaminants are known. However, the full extent of the problem often is not. These sources have manifested for decades, even after discharges have ceased. Plumes that have been mapped during early stages of most remedial investigations (RI) are continuously modified by the effects of natural groundwater flow and, more significantly, groundwater pumpage, primarily driven by summer water demand for irrigation. The depth and area impacted can change significantly even through the preparation of site feasibility studies (FS), the issuance of records of decision (RODs) and, finally, the construction and implementation of remedial actions.

The location and extent of these contaminants are routinely influenced or altered by pumping of nearby industrial, cooling and public water supply (PWS) wells. The ever-increasing density of these wells in Nassau County, a function of population density, makes this problem particularly acute when compared to Suffolk County, a county of equivalent population having a land area that is three times the size of Nassau County. Currently, there are six large legacy sites in Nassau County, which are undergoing further study and ongoing remediation of soil, soil vapor and groundwater. They include the following sites and the agencies responsible for their remediation:

- Old Roosevelt Field (USEPA).
- Grumman Corporation/United States Navy at Bethpage (NYSDEC).
Fulton Avenue Industrial Area at Garden City Park (USEPA).
New Cassel Industrial Area (USEPA).
Lockheed Martin at Lake Success (NYSDEC).
Old Bethpage Industrial Area (USEPA and NYSDEC).

Suffolk County

Regional groundwater contamination in Suffolk County also has been influenced by land use and development but, to a much lesser degree, by industrial activity. An agrarian-based economy lasted much longer in Suffolk County well into the late 1960s and 1970s. Contamination related to farming, specifically the presence of pesticides and herbicides in soil and groundwater, was common on the east end of the county in the early to mid-1980s (when the first pesticide detected, aldicarb, was documented to cause contamination of groundwater and private wells). Contamination related to the construction of new homes and associated cesspool effluent has led to regional issues involving nitrogen pollution and the spread of nitrates in shallow groundwater and estuarine environments in Suffolk County (and, to a lesser extent, in some of the shorefront communities that remain unsewered along the north shore of Nassau County).

Discussion and Status of Nassau County Legacy Sites

The first major effort at identifying contaminated aquifer segments in Nassau County was undertaken as a collaborative effort between the Nassau County Department of Health (NCDOH) and the Nassau County Department of Public Works (NCDPW) under a contract with Dvirka and Bartilucci Consulting Engineers. This effort ultimately produced a June 1986 report titled, Investigation of Contaminated Aquifer Segments – Nassau County, New York. In this report, five separate and distinct areas of volatile organic compound contamination were identified conclusively in the aquifers beneath New Hyde Park, Garden City Park, New Cassel (Westbury) and the west and north Hicksville areas. This was in addition to the Old Roosevelt Field site, the Grumman Corporation/United States Navy and Ruco site and the former Sperry/Unisys/Lockheed Martin sites that were already known to have significant VOC contamination in groundwater beneath those sites. Based on this report, the NYSDEC conducted multiple preliminary site investigations in each of the areas identified and listed many sites that were subsequently included in their “Registry of Inactive Hazardous Waste Disposal Sites in New York State”:

Old Roosevelt Field (USEPA) – Site No. NYSFN0204234

The USGS, the NCDOH and the NCDPW collaborated on the investigation of this site during the early 1980s subsequent to the identification of VOC contamination in several private wells located in this area. The USEPA initiated the most recent investigation of subsurface conditions in 2010. This investigation resulted in the mapping of new portions of a deeper Magothy Aquifer plume and the installation of a small treatment plant to address additional source area contamination along the western edge of the current Roosevelt Field Mall complex. This location is considered to be the area of that site with the highest remaining levels of groundwater contamination by VOCs, primarily trichloroethene (TCE). Additional contamination was discovered further down-gradient and is suspected to be the source of TCE contamination impacting the Village of Hempstead PWS wells. Portions of the aquifer located east of this primary source area are still under investigation. The NCDPW and the NCDOH have supported this additional investigation.
and strongly agree with the need for additional wells to further define the vertical and horizontal extent of contamination emanating from other unknown sources located on the Old Roosevelt Field property.

The long travel time (60-70 years) associated with any potential releases from the Old Roosevelt Field site, coupled with the intensive and varied groundwater pumpage (public supply, heating and cooling, industrial and remedial) in the area, has the potential to move and distribute VOC contaminants throughout large portions of the Magothy Aquifer. Water suppliers impacted by this groundwater contaminant plume include the Village of Garden City Water Department, the Village of Hempstead Water Department and the Town of Hempstead Water Department (Uniondale). A repository of information relative to this investigation can be found at www.cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0204234.

**Grumman Corporation/United States Navy at Bethpage (NYSDEC) – Inactive Hazardous Waste Site No. 130003**

Nassau County was one of the first areas in the United States to study the presence of VOCs in groundwater. In the early 1970s, employees at the Grumman Aerospace and Naval Weapons Industrial Reserve Plant (NWIRP) in Bethpage, New York noticed an unusual taste and odor emanating from water faucets located on the site. At this time, Grumman operated its own water supply system and was not connected to the Bethpage Water District. The taste and odor condition was reported to the New York State and Nassau County Health Departments. Testing by Grumman and these health agencies confirmed that the Grumman water well system was contaminated by trichloroethene (TCE). In 1976, Grumman then asked the Bethpage Water District to permit connection to the public water supply. After 1976, the Grumman on-site water supply wells were no longer used for potable supply, but continued to be used for industrial and cooling purposes. All potable water use at the Grumman facility was then connected to the Bethpage Water District.

Following the initial discovery of the problem in the 1970s, the site was subsequently listed in the Registry of Inactive Hazardous Waste Sites in New York State in 1983. The original Site No. 130003, as defined, did not include Bethpage Community Park (a donated section of the Grumman Corporation property). Subsequently, on March 10, 1993, the Grumman Aerospace Bethpage Facility Site (#130003) was acquired by and divided into the Northrop Grumman-Bethpage Facility Site (#130003A) and the Naval Weapons Industrial Reserve Plant Site (#130003B). During the early 1990s, many portions of the Northrop Grumman-Bethpage Facility Site (#130003A) were delisted as the investigation of area was completed. However, soil vapor issues were not studied at these formerly delisted areas until the NYSDEC addressed these issues under a legacy site policy directive in 2006. This directive required the NYSDEC to investigate previously delisted sites that did not address the soil vapor intrusion pathway of possible human health exposure.

Since the mid-1970s, the original groundwater contamination plume emanating from the site has plagued and threatened the sole-source aquifer system that provides water for nearly a quarter of a million people in southeastern Nassau County. Two separate plumes of VOC contamination and at least one groundwater hotspot release from the source area have resulted in the formation of a significant larger off-site groundwater plume that has impacted both the Upper Glacial and Magothy Aquifers. These two contamination plumes have become co-mingled south of the Grumman Corporation site. Some of the contamination extends to a depth of 550 feet below grade
and appears to be approaching the Bethpage Water District No. 4 well field.

One of the largest and most complicated and concentrated groundwater contamination plumes in the country, the NWIRP plume has grown to 4 miles long, 2 miles wide and 800 feet deep over the past 30 plus years. Additional groundwater investigations currently are underway to help determine both the lateral and vertical extent of contamination, but years of exhaustive studies have done little to mitigate and remediate this massive plume. Clearly, the current regulatory framework is insufficient in marshalling the resources necessary to compel the responsible parties to resolve this environmental disaster. The consequence has been an admittance that treating the contaminated water at the drinking water wellhead was the preferred approach to protecting public health. Preventing the contamination from getting to the wellhead has been routinely dismissed in the regulatory process. This regulatory approach to responding to groundwater contamination must end. Wellhead treatment must be an action of last resort. If not, the protection of public health will always be at risk as the contamination was permitted through the regulatory process to reach the wellhead and only a water treatment barrier exists as the measure between public health protection and public health crisis.

The NWIRP groundwater contamination plume, as well as all other contamination plumes that impact the sole-source aquifer on Long Island, must be remediated to lessen the impact to already impacted public supply wells and protect against the impact to currently unimpacted supply wells. Regulations must be put in place to make wellhead treatment an option of last resort and strengthen the regulatory enforcement capability to make the responsible parties fully responsible, and if improper action is taken, allow the state to take action and the costs fully borne by the responsible parties. Therefore, LICAP fully supports the strategic containment of this massive groundwater plume to minimize future impacts to public supply wells.

Water suppliers impacted by this groundwater contaminant plume include the Bethpage Water District, the South Farmingdale Water District, the Town of Hempstead Water Department (Levittown) and New York American Water (Seamans Neck well field). Additionally, this plume of contamination is threatening, but has not yet impacted the Massapequa Water District, based on its southerly migration pathway and data that confirms the plume is approaching Massapequa. A repository of information relative to this investigation can be found at www.epa.gov/region02/waste/fsgrumm.htm, www.dec.ny.gov/press/101689.html, and www.dec.ny.gov/chemical/8431.html.

Fulton Avenue Industrial Area at Garden City Park (USEPA) – Site No. NY0000110247

The Fulton Avenue site (150 Fulton Avenue, Garden City Park) is a former fabric cutting mill that operated from 1965-1974. Discharges from this operation resulted in both soil and groundwater contamination. Soil contamination at the site has been addressed through excavation, removal and treatment of contaminated soils in the vicinity of an on-site drywell. Following excavation, any remaining soil contamination was addressed using an interim remedial measure (IRM). This measure involved the use of an air sparging/soil vapor extraction (AS/SVE) system that operated from October 1998-November 2001. In early 2004, a sub-slab ventilation system was installed beneath the building as a protective measure to remove any remaining VOC-enriched soil gas.

The primary groundwater contaminant in this plume contaminant was tetrachloroethylene or perchloroethylene. This contamination is subject to additional source control that will be provided by in-situ chemical oxidation and a groundwater extraction and treatment system. A second plume of VOCs, primarily composed of trichloroethene and not associated with activities at this site, was
subsequently discovered. The control of on-site groundwater contamination and the investigation of the second plume of trichloroethene is the focus of additional investigation and remediation. The Village of Garden City Water Department, the Franklin Square Water District, the Water Authority of Western Nassau and the Village of Mineola Water Department all are affected by this groundwater contaminant plume. A repository of information relative to this investigation can be found at www.cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0203853&msspp=med.

**New Cassel Industrial Area (USEPA) – Site No. NY0001095363**

The New Cassel Industrial Area was first identified as a source of VOC contamination of soil and groundwater as part of the 1986 joint *Contaminated Aquifer Segment (CAS) Study*. The results of the 1986 study determined that the New Cassel Industrial Area had "extensive and substantial" contamination of groundwater. Total volatile organic compound (TVOC) contamination in groundwater collected from the 35 wells installed during the investigation ranged from 1,000-10,000 parts per billion. Sampling results obtained from up-gradient monitoring wells appeared to isolate the industrial area located south of the Long Island Rail Road (LIRR) and north of Old Country Road as a potential source area for the detected organic compounds. The VOCs associated with this industrial source were detected within the Magothy Aquifer at depths greater than 250 feet. A potential threat to the Bowling Green Estates public supply wells (part of the Town of Hempstead Water Department) was recognized at the completion of the study, and the wells were subsequently found to be contaminated and require treatment to meet drinking water standards.

In 2010, the NYSDEC requested that the USEPA list the site on the federal Superfund NPL and it was listed subsequently in September 2011. After the listing, site investigations to determine the nature and extent of contamination and to identify and evaluate possible remedial alternatives resumed. The New Cassel/Hicksville groundwater contamination site continues to be an area of widespread groundwater contamination in the Towns of North Hempstead, Hempstead and Oyster Bay. Sampling of public supply wells identified contaminants in four Town of Hempstead PSW, six Hicksville Water District PSW and one Village of Westbury Water Department PSW. The primary contaminants observed in groundwater at the site include PCE, TCE and other VOCs. Consistent with the federal Safe Drinking Water Act that protects public water supplies throughout the nation, public water suppliers in the area of the New Cassel site monitor water quality regularly and have installed treatment systems to remove VOCs from the groundwater. A repository of information relative to this investigation can be found at www.epa.gov/Region2/superfund/npl/newcassel/index.html.

**Lockheed Martin (former Unisys site) at Lake Success (NYSDEC) – Inactive Hazardous Waste Site No. 130045**

The former Unisys site is located in the Village of Lake Success. The 94-acre site is bounded by Marcus Avenue to the north, Union Turnpike to the south, Lakeville Road to the west and The Triad Office Park to the east. This facility was an active aerospace and defense systems manufacturing facility from its start-up in 1941 until approximately 1995, when most manufacturing activities ceased. However, some limited production activities continued at the facility until 1999. Groundwater had been used for non-contact cooling purposes since the facility was constructed. The non-contact cooling water system consisted of three extraction wells and four diffusion wells that were located to the north and south of the main manufacturing building, respectively.
Past manufacturing processes include casting, etching, degreasing, plating, machining and assembly. Chemicals used during manufacturing at the facility included halogenated solvents, cutting oils, paints, fuel oils, plating compounds and associated metals. The facility had five drywells located near the southeast corner of the main building. These drywells were used to dispose of water containing solvents and oils from approximately 1941-1978. Additionally, on-site recharge basins also were contaminated with plating solutions that contained metals but which were mostly filtered out by soils in those basins.

A ROD was issued for the site in March 1997 and groundwater treatment was initiated in 2002. The treatment plant consists of three groundwater extraction wells operating at a combined flow rate of approximately 725 gallons per minute (GPM). Additional investigation and treatment of the off-site area beyond the property boundary where contaminants and groundwater have migrated was required. Eleven active PSWs are located off-site, nine which draw water from the Magothy Aquifer and two which draw from the Lloyd Aquifer. Four inactive PSWs also are located off-site in the plume vicinity as are six active irrigation wells. Generally, groundwater flow in this area is north-northwest; however, public supply and irrigation wells operating in the area have altered local groundwater flow direction.

The primary site-related groundwater contaminants of concern are numerous VOCs including Freon 113. Another groundwater plume originating from the nearby 400 Lakeville Road site (Site No. 130176) is known to contain Freon 22 and co-mingles with the Unisys groundwater plume. During the remedial investigation of the off-site plume, it became apparent that VOCs in the groundwater north of the former Unisys site were present at a location and depth where a large portion of the contaminants could be removed by an additional IRM. An IRM groundwater treatment plant was designed and constructed and began operation in 2006.

Groundwater migration from this site has resulted in a significant off-site groundwater plume that has impacted both the Upper Glacial and Magothy Aquifers and has affected nearby public supply and golf course irrigation wells. The Lloyd Aquifer has not been impacted. Several of these public supply wells have treatment systems in place to assure that the supplied water meets all drinking water standards.

Recent activities at the site during July 2014 call for an amendment to the original site remedy prepared in 1997 and the development of a proposed remedial action plan (PRAP). The final remedy proposed for the off-site groundwater contamination that has migrated from the site included:

- The continued operation of the existing 500 GPM IRM groundwater extraction and treatment system.
- Upgrading the current 730 GPM groundwater remediation system by the installation of a new 120 GPM extraction well to collect and treat an additional volume of groundwater to bring the total system up to 850 GPM.
- Implementation of a Public Water Supply Protection and Mitigation Program that includes:
  - An installation, operation and maintenance plan for PWS wellhead treatment systems on wells affected by site-related contamination, now or in the future, to assure that drinking water standards are achieved.
  - A response plan that will be implemented if site-related contaminant concentration(s) in the sentinel well(s) approach or exceed site-specific action levels.
Development of a site management plan approved by the NYSDEC and operation of a treatment system on the Lake Success irrigation well should it be used again.

Water suppliers impacted by this groundwater contaminant plume include the Manhasset/Lakeville Water District and the Water Authority of Great Neck North. A repository of information relative to this investigation can be found at www.lockheedmartin.com/content/dam/lockheed/data/corporate/documents/remediation/great-neck/fact-sheet-june2014.pdf.

Old Bethpage Industrial Area (USEPA and NYSDEC) – Inactive Hazardous Waste Site No. 1-30-171

The site is located in both the Town of Oyster Bay in Nassau County and the Town of Huntington in Suffolk County. The Nassau-Suffolk County boundary bisects the site in a north-south direction. Of the 33 commercial properties that comprise the site, 17 are in Nassau County and the remaining 16 are in Suffolk County. Most of the properties are located along Bethpage-Sweet Hollow Road, Spagnoli Road, Winding Road and Hub Drive. The site is located in a mixed commercial and industrial area and is approximately 230 acres. Most of the buildings on the Nassau County side were built between 1963-1973, while the structures on the Suffolk County side were constructed between 1969-1979.

In January 2006, at the seventh year of operating the groundwater treatment system (more than 1,362,111,408 gallons of contaminated groundwater treated) for the remediation of the VOC related to operations at the Nassau County Fire Service Academy (Nassau County Fireman's Training Center, FTC), NCDPW concluded that four of the seven operating FTC off-site recovery wells had been impacted by sources other than the FTC. These wells were located in the eastern portion of the recovery well network and exhibited the following characteristics: they were not hydraulically downgradient of the FTC, and influent from these recovery wells regularly contained VOCs that were not common to the FTC plume.

As a result, the commercial/industrial properties located in the Old Bethpage Industrial Area were investigated as potential up-gradient sources. Following a cooperative review of existing NCDOH records, it was determined that six properties on the Nassau County side of the site had stored and used halogenated solvents. A record search and site reconnaissance, conducted by Malcom Pirnie, Inc. on behalf of the NYSDEC in 2008, revealed that 11 companies had used similar compounds on the Suffolk County side of the site.

Malcolm Pirnie, Inc. conducted a full investigation of environmental conditions in the industrial area, including analysis of soil, soil vapor and groundwater and completed a Site Characterization Report – Old Bethpage Industrial Area Plume Trackdown, Oyster Bay and Huntington NY, Site #1-30-171, September 2009. Volatile organic compounds were detected in soil gas and groundwater samples at multiple locations. These compounds included, but were not limited to, PCE, TCE and chlorofluorocarbon (CFC-113). However, many of the detected compounds were found at levels below applicable standards in groundwater.

The investigation resulted in the listing of one site – American Louvre, Inc., 301 Winding Road, Old Bethpage. The site was found to have elevated levels of halogenated compounds, including TCE and PCE in both soil and groundwater. A ROD was issued for onsite contamination in March 2013. The selected treatment technologies include: soil removal, in-situ thermal treatment, air sparging and soil vapor extraction. Subsequent investigation of groundwater conditions in the
area indicates that the groundwater plume of organic compounds emanating from the American Louvre site is not the source of volatile organic compounds previously observed in both Town of Oyster Bay and NCDPW recovery wells. These organics are from an unknown source(s) located to the east and north of the former Claremont Polychemical site, Old Bethpage Solid Waste Disposal Complex (Town of Oyster Bay landfill) and the Nassau County Fire Service Academy, and form a plume that extends more than 5,000 feet in length. This plume is still being investigated as it presents a potential threat to the Village of Farmingdale public supply wells. A repository of information relative to this investigation can be found at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1000YCG.txt.I

Localized Groundwater Threats

Geothermal Heating, Ventilation and Air Conditioning Systems

Geothermal heating, ventilation and air conditioning systems utilize geothermal heat pumps (GHPs) that tap into its cool naturally occurring ground temperatures for energy-efficient space heating and cooling. GHP systems represent less than 1% of all the heating, ventilation and air conditioning (HVAC) systems in use on Long Island, although they are expected to grow in the future. They presently make up a high percentage of the HVAC systems installed in new homes in some communities (Southampton and Laurel Hollow, for example). These systems pose localized groundwater quantity and quality threats, and this section provides a general description of the technology, presents the major questions and concerns and provides recommendations to addresses the risks, raise awareness and improve understanding by the stakeholder community.

Background Information

Geothermal is a technology that taps into the cool naturally occurring ground temperatures that exist in Long Island’s aquifers for energy-efficient heating and cooling and, in some instances, domestic hot water heating. Utilizing this technology for HVAC systems provides an alternative to conventional fossil-fuel based furnaces used for heating as well as chillers, cooling towers and window air conditioning units used for conventional cooling systems. The primary difference between a GHP system and a conventional HVAC system is the use of two distinct components: 1) one or more GHPs are installed inside the building, and 2) a ground coupling, or ground heat exchanger (GHE) is installed in the ground next to the building. Mechanical piping and ductwork inside the building are like a conventional HVAC system. A GHP system essentially couples the building's HVAC system to the ground.

Groundwater temperatures on Long Island range between 50-55 degrees F and provide a consistent and moderate temperature source of energy for heating and an energy sink for cooling. The two main types of GHEs in use on Long Island utilize either standard water wells (open loop system) or high-density polyethylene (HDPE) plastic loops (closed loop system). Both are routinely installed to depths of up to hundreds of feet deep in vertical drilled boreholes. Another type of GHE known as a direct exchange (DX) system is used but is uncommon on Long Island.
There is a general lack of understanding about how GHP systems work and are installed and operated. There also have been instances in which GHP systems have failed or locally impacted the aquifers on Long Island, which has resulted in a general concern of local municipal and regulatory agency staff, members of the public and some members of the Long Island Commission for Aquifer Protection over their use. This report addresses the major questions and concerns, which include:

- Gaps in regulatory and inspection responsibility for certain aspects and types of systems. For example, closed loop systems are largely unregulated in New York State, including Long Island.
- Lack of documentation of locations of some type/size systems.
- Potential impacts on other groundwater users, ecological resources, surface water bodies and wetlands and on the groundwater resource, in general.
- Aggregate hydraulic and thermal effects on the aquifers from high concentration of many small GHP systems installed near each other, *e.g.*, suburban environments.
- Increases in regional groundwater temperatures from extended operation of large air conditioning-only facilities (*e.g.*, Roosevelt Field Mall/Mitchell Field complex).
- Potential cross contamination of aquifers by pesticides, herbicides and any other contaminant spilled on or in the general vicinity of the property during drilling through confining clay units.
- Potential contamination of the aquifer from return water in open loop systems containing refrigerants (*e.g.*, Freon contamination in northern Nassau County).
- Potential contamination of groundwater by the working fluid in closed loop boreholes from leaks in the plastic piping.
State of the Geothermal Industry on Long Island

On Long Island, open loop GHP systems have been used for over a century for air conditioning and industrial and municipal process water cooling uses. The advent of the reversible heat pump in the 1960s allowed for the combined heating and cooling of buildings employing open loop wells and, more recently, closed loop GHEs.

There are roughly 4,000-5,000 operating GHP systems in use in Nassau and Suffolk Counties, with roughly 70% open loop and 30% closed loop. Figure 9 shows the locations of systems that have received Public Service Enterprise Group (PSEG) rebates (both open and closed loops) and open loop systems permitted by New York State Department of Environmental Conservation under the Long Island Well Permit (LIWP) program in Suffolk County GHP systems represent less than 1% of all the HVAC systems in use on Long Island. However, in certain communities (Southampton and Laurel Hollow, for example) GHP systems may represent 50-70% of the HVAC systems installed in new home construction.

GHP systems offer numerous benefits to Long Island residents and business owners. Despite their higher first cost compared to conventional HVAC systems, the GHP market on Long Island is expected to grow in the future. Various levels of state government, including the New York State Energy Research and Development Authority (NYSERDA), the New York State (NYS) Governor’s Office and the Public Service Commission (PSC), PSEG, the NYS Legislature and Suffolk County have recognized that GHPs can play an important role in the state’s goal to increase building efficiency and reduce energy consumption and greenhouse gas (GHG) emissions. On a local level, GHPs are the preferred alternative to oil and electric resistance heating in the Cleaner Greener Long Island Regional Sustainability Plan.

More widespread adoption of GHP systems benefits Long Island’s electric provider, PSEG, in numerous ways, which translate to lower electric costs to ratepayers, including:

- Reduced summer peak load demand on the power plants and electric grid.
- Reduced or eliminated need to construct new generation capacity.
- Reduced utilization of inefficient peaking power plants and the purchase of more expensive off-grid power from outside vendors.
- Improved load factor of power plants in the winter when their current usage is otherwise low.

However, as noted above, there are numerous potential risks to the groundwater system that can result from widespread and unregulated use of geothermal systems. These potential risks are discussed in this report.
Geothermal Heat Pump System Components

Geothermal heat pumps are mechanical devices that transfer heat between the GHE and the building spaces to be conditioned. A GHP is essentially a reversible chiller that can both cool and heat a building. Being all electric systems, GHPs eliminate the use of fossil fuel-based boilers and the particulates and GHGs they emit. The two main types of GHPs are water-to-air and water-to-water heat pumps. A water-to-air heat pump heats or cools air that is ducted to and from the interior spaces. Water-to-water heat pumps produce chilled or hot water that is circulated to fan coil units for cooling or to radiant floor systems or fan coils for heating. A device called a de-superheater or dedicated GHPs can be utilized to heat domestic hot water.

Ground heat exchangers (GHE) are the in-ground, buried part of a GHP system where heat is transferred between a circulating heat transfer fluid (HTF) and the ground by the difference in temperature between the fluid and the ground. Depending on system type, the HTF is groundwater, fresh water, a fresh water/antifreeze mixture or refrigerant.

GHP Types

The predominant types of GHEs in use on Long Island are vertical closed loop boreholes and open loop systems, as described in the following.

Open Loop Systems

Open loop systems withdraw ambient temperature groundwater from a standard supply well(s), passes the groundwater directly through the GHPs and returns the temperature-altered water back into the aquifer via a return, or diffusion, well(s). Some system designers add an intermediate plate-frame heat exchanger (HX) to separate the building piping system and components from the groundwater (Figure 10). The open loop system is one of the more common systems found on Long Island due to the highly productive aquifers. Well depths depend on the local
hydrogeology. Wells must be sized to supply and return to the ground a consistent 1.5-3 GPM per ton of cooling or heating load (Note: a ton equals 12,000 British thermal units or BTUs per hour of heating and cooling demand).

**Figure 10 Open Loop System**

Despite misperceptions to the contrary, the daily and seasonal temperature range of the circulating HTF used in GHP systems is not constant, but varies by system type. An open loop system operates by pumping groundwater at its stable natural temperature. However, the return water temperature is typically 10-15 degrees F colder during winter heating and 15-30 degrees F warmer during summer cooling than the ambient groundwater temperature (see Table 1). The groundwater passes once through the system.

**Table 1**  
Typical Temperatures of Heat Transfer Fluid

<table>
<thead>
<tr>
<th>GHE</th>
<th>Heat Transfer Fluid</th>
<th>Summer Operation Temperature Range</th>
<th>Winter Operation Temperature Range</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| Closed Loop | Water or water and antifreeze mixture | 60-90 deg. F | 30-45 deg. F | Typical ΔT between supply and return water is 5-10 deg.  
F. Antifreeze is required if winter operating temperatures will drop below 32 deg. F |
| Open Loop | Groundwater | 50-55 deg. F from supply well (ambient), 65-80 deg. F to diffusion wells | 50-55 deg. F from supply well, 40-45 deg. F to diffusion wells | Constant supply well groundwater temperature; return temperature to diffusion wells depends on ΔT preference of designer |

Notes: ΔT = delta T or difference in
For large open loop systems, research of local hydrogeology and groundwater testing are advisable to select well depths and gather data for proper well design. For systems requiring a LIWP (pumping rate >45 GPM; see Open Loop Systems under Chemical Effects), the NYSDEC reviews the site relative to the presence of and potential impacts to wells on adjoining properties, nearby ecological resources, groundwater contaminant plumes or the fresh water-salt water interface (coastal sites). In certain cases, the NYSDEC may require site testing, which could include a test well, pumping test and appropriate hydrogeologic analysis and/or groundwater modeling as part of the permitting process to demonstrate that there will be no impacts to these resources.

Other unconventional open loop systems, described in the following, are in use on Long Island. Although believed to be limited in number, it is recommended that these types of systems are disallowed except under the conditions noted. One option to prevent their use would be for the NYSDEC to require that dedicated supply and return wells are in use for all open loop GHP systems when renewing an existing permit or permitting new well installations. This is currently the case for systems governed under the LIWP program. However, smaller systems not regulated under the LIWP program (flow rate <45 GPM) only require filing of a preliminary report on proposed well form (PRPW). Technically, PRPWs must be filed only for new wells for consumptive use. Based on discussions with the NYSDEC, there may be instances where a permit to drill a new diffusion well(s) is issued without an associated supply well(s) and vice versa.

**Closed Loop Systems**

Closed loop systems circulate either water (or a water and antifreeze mix) as the HTF through a series of HDPE plastic loops installed horizontally in trenches or, more routinely, vertically in drilled boreholes. Unlike an open loop system, a closed loop GHE does not involve pumping and re-injection of groundwater and the plastic piping isolates the HTF from the aquifer. Heat exchange occurs by conduction between the circulating fluid and the ground across the plastic piping.

Each loop consists of two pipes, ¾-1.25 inches in diameter and connected at the bottom with a 180-degree "U" fitting as shown in Figure 11. The loop assembly is lowered to the bottom of the borehole and the space between the borehole wall and the closed loop piping (the annulus) is filled with a thermally-enhanced grout, which is a low-permeability clay, water and sand mixture. The main purpose of the grout is to prevent migration of contamination from the surface into the aquifer or between multiple aquifers. The grout also provides a thermal bridge between the loop and the ground.

![Figure 11](image.png)

**Figure 11**

**U-Bend Fitting**
The loops are connected using horizontal HDPE piping. For larger systems, the loops are grouped into "circuits" of typically four to ten loops, as illustrated in Figure 12. The individual circuits are connected to supply and return mains that lead to a manifold in the mechanical room. The HDPE is joined together using a heat-fuse welding method. The HTF is circulated through the borefield and the GHPs using circulator pumps located in the mechanical room. The HDPE piping is comparable to piping used in the natural gas industry and is warranted for 50 years by the manufacturers.

![Figure 12
Closed Loop System](image)

The operating temperature of the HTF in a closed loop system varies daily and seasonally. At the start of a season, the temperature of the HTF may start at about the ground's natural temperature. However, its temperature will generally increase over the summer and decrease over the winter as more and more heat energy builds up or is depleted from the ground around the borefield, respectively (see Table 1).

For larger closed loop systems, a test closed loop is typically installed and a thermal conductivity test performed to confirm the geologic conditions and develop the data needed for borefield sizing and design. The piping also can be laid out horizontally in an open excavation in coils or in straight runs of piping in trenches and backfilled.

HDPE coils also can be emplaced in an open water body (for example, a lake, marine bay or river) and used for heat exchange if the water body meets certain minimum volume, depth and quality criteria depending on the building's thermal load profile. Approval also may be necessary from the appropriate agencies as environmental impacts could occur from altering the temperature of the water body.

The closed loop piping undergoes multiple stages of pressure testing during construction to make sure there are no breaks and the joints are tight. Individual loops and circuits are pressure tested prior to backfilling. Finally, the entire system gets pressure tested after the circuits are connected to the main supply and return lines. The NYS Mechanical Code, under which most municipal agencies on Long Island operate, requires pressure testing of the piping system for closed loop GHP systems.

If the piping were to leak, and the HTF contained an antifreeze, this would result in a release of antifreeze into the groundwater (see Closed Loop Systems under Chemical Effects). Fortunately, leaks in the HDPE piping network are rare, and when they occur it is usually by an excavator breaking a line. A leak can be detected by a loss of pressure in the working fluid across a loop or circuit. A loop or circuit with a leak can be repaired or isolated from the rest of the system and
decommissioned. It is important to plot the locations of the individual loops and horizontal connector piping on a plot plan for future reference to prevent excavation and damage to the piping during future building maintenance or expansion. When ownership of the home or facility changes, transferal of this information to the new owner is critical.

Direct exchange systems are a type of closed loop system with the following major differences: 1) the GHE is copper tubing, not HDPE pipe, and 2) the HTF is refrigerant (R-410A). Some configurations of a "DX-to-Ground Contact" DX system are shown in Figure 13. The copper tubing is installed in a vertical drilled borehole and grouted like an HDPE closed loop or buried in trenches in a horizontal configuration.

The copper tubing assembly is pressure tested prior to introducing refrigerant. DX systems must be protected against corrosion of the copper by using sacrificial anodes or other means of cathodic protection.

A version of a DX system, the GeoColumn(c) (Figure 14), submerges the copper tubing in an enclosed HDPE plastic cylinder filled with water that isolates the tubing from contact with the soil and aquifer. The GeoColumn(c) is typically installed to a depth of 25 feet or less. Because of their shallow installation depth and the physical containment provided by the HDPE cylinder, these GHEs are not grouted.

Pressure testing, potential for leaks and the need for adequate documentation of the buried piping are the same as the closed loop system.
Standards, Guidelines and Regulations

Federal and State Regulations

Presently, comprehensive regulations covering all types of GHP systems do not exist and standards and guidelines that do exist are not consistently applied on Long Island. Therefore, impacts to the aquifers beneath Long Island from widespread unregulated use of GHP systems are possible. There are ongoing efforts by the GHP industry throughout the state to put into effect uniform design, installation and maintenance standards and code to address concerns over potential environmental impacts of GHP systems. Depending on the outcome of these efforts, formal regulations may need to be enacted to safeguard Long Island’s aquifers from such impacts.

National design and installation standards and guidelines exist for GHP systems and have been published by the following organizations: American Society for Testing and Materials (ASTM), American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), Air-Conditioning and Refrigeration Institute (ARI), Air Conditioning Contractors Association (ACCA) and the refrigeration section of the International Building Code. The following additional standards and guidelines apply for specific GHP system types:

- Open loop systems: National Ground Water Association (NGWA) and American Water Works Association (AWWA) water well construction guidelines.
- DX systems: Canadian Standards Association (CSA) and National Association of Corrosion Engineers (NACE).

IGSHPA certifies geothermal drilling contractors for closed loop borehole drilling and installation; and IGSHPA and the HDPE manufacturers certify the piping installation contractors for heat-fuse welding. The equipment and materials manufacturers also recommend that their guidelines, methods and specifications are followed. Recently, IGSHPA and NGWA also have developed GHP system inspector training programs that are being offered to the public.

Most recently, the CSA, in conjunction with ANSI, published C448 Series-16, a comprehensive set of standards for the installation, testing, operation and maintenance of all types of GHP systems. These standards were developed by a bi-national (United States and Canada) working group of industry representatives and trade groups including IGSHPA and NGWA.

Most Long Island municipalities have adopted or otherwise defer to the NYS Mechanical Code (NYSMC) for building HVAC design and construction requirements, which, in turn, has adopted the International Mechanical Code (IMC). Section 1210 of the IMC covers certain aspects of closed loop GHP systems, including pressure testing and flushing requirements for the piping and the HTF. Local GHP industry representatives are in discussion with NYSMC officials and representatives of the IMC, as well as the Uniform Solar Energy and Hydronics Code (USEHC) – the competing code to the IMC – about adopting the C448 Series-16 standards into their respective codes. To that end, the USEHC committee has proposed to add a reference to the CSA standards into its next code revision in 2018.

Another means to address concerns over GHP systems that the local GHP industry is undertaking is to tie utility rebates to adherence to strict quality control measures. The NYS Governor has
released an "emergency" rebate program for GHP installations to offset loss of the federal tax credits that expired at the end of 2016. As part of that program, NYSERDA will issue rigorous quality control measures that must be followed to earn the rebates. Local GHP representatives are in discussion with PSEG to consider issuing similar measures as part of PSEG's rebate program.

As discussed previously, the NYSDEC requires that a PRPW is filed before drilling for any planned new water well (including open loop GHP wells) with its Region 1 Division of Water in Stony Brook, New York. Further, any proposed well(s) with a rated pumping capacity greater than 45 GPM or 64,800 gallons per day (or if there are existing wells on the property, then the combined pumping rate for the existing and proposed wells if exceeding 45 GPM) is regulated under the NYSDEC LIWP program. This 45 GPM threshold equates to up to approximately 25 tons of peak heating or cooling capacity (2 GPM/ton). All open loop wells must be installed by a NYSDEC-registered well driller and the submersible pump must be installed and the system started up by a NYSDEC-registered water well driller. Hydrogeologic calculations and details on the well design, use and construction must be provided with the LIWP application. As noted earlier, the NYSDEC reviews the site relative to potential impacts to other nearby groundwater users, public drinking water wells, surface waters, wetlands and ecological resources, contaminated groundwater remedial systems and the fresh water-salt water interface at coastal sites. In some instances, the NYSDEC will require that a more detailed engineering report be prepared and submitted with the LIWP application. Among other items, the engineering report involves more in-depth hydrogeological analysis, potentially along with groundwater testing and modeling to demonstrate no impact to these resources.

The NYSDEC regulations do not specify either upper or lower limits on the temperature of the return water, although regulations do state that the discharge must not prevent others from being able to use the groundwater for its best intended usage. As with any water supply well, an open loop well system may be designated a Class I Action under the State Environmental Quality Review Act by the NYSDEC if its rated pumping capacity exceeds 2 million gpd (or 1,388 GPM), thus triggering a SEQRA review.

The United States Environmental Protection Agency must be notified of all return wells of an open loop system, as these wells are designated Beneficial Re-Use Class V wells in the federal Underground Injection Control (UIC) regulations under the Safe Drinking Water Act. USEPA can authorize operation of such wells "by rule" pursuant to the regulations.

NYSDEC presently does not regulate closed loop or DX systems with the exception that a permit is required from the NYSDEC Division of Mineral Resources (DMN) if drilling will be deeper than 500 feet, which is an uncommon practice in the industry on Long Island.

Because the fluid within a closed loop/DX GHE does not directly contact the environment, it is not considered a Class V well under the federal UIC regulations. Therefore, the USEPA has no jurisdiction over these GHEs.

Any size or type of GHE intended to be installed in or within a regulated distance from a wetland, floodplain, pond, lake, river or coastal erosion hazard area requires state and/or federal environmental agency approval. Additionally, if the return water from an open loop system is intended to be discharged into a regulated wetland or surface water body, state and/or federal permits are required.
County and Local Codes and Guidelines

Nassau County claims no jurisdiction and defers regulatory authority for GHP systems to the NYSDEC and the local towns and villages.

Suffolk County through its Department of Health Services regulates GHP systems that are proposed to be installed in conjunction with a proposed wastewater and/or water supply system. The SCDHS requirements are contained within its General Guidance Memorandum #25. The major requirements relate to setbacks for open loop wells and closed loop boreholes from public and private water supply wells, sanitary and stormwater system structures and piping, property lines and other utilities. The SCDHS guidelines also stipulate that there shall be no cross-connection between the GHP system and domestic water supply system. Memo #25 was recently revised to incorporate in its entirety the Model Geothermal Code developed by the Suffolk County Planning Commission (see next section). SCDHS requires that the proposed geothermal wells or borehole locations and piping routes are shown on the site plan with the proposed sanitary and storm drainage structures and submitted to SCDHS for approval prior to construction.

In 2014, Suffolk County adopted the Suffolk County Uniform Model Geothermal Code (Model Code), developed by the SCPC in association with the local GHP trade organization the Long Island Geothermal Energy Organization (LI-GEO). Input to the Code was provided by key stakeholders including the NYSDEC, SCDHS, SCWA, the Suffolk County Legislature and the NYS Department of State’s Division of Building Standards and Codes. The main objectives of the Model Code were to address concerns that local municipalities have about GHP systems, provide a uniform filing process for the typical GHP systems that are being installed on Long Island and in the process facilitate more widespread acceptance and deployment of systems. The Model Code identifies standards, best practices and environmental protections specifically for systems proposed to be installed in "non-sensitive areas," which comprise most GHP systems. The Model Code also requires well drilling contractors to notify the SCWA of the location of open loop wells installed within SCWA’s service area. The Model Code provides a basic working framework for local jurisdictions to incorporate into their existing code or simply be issued as guidelines to its building inspectors.

Some local municipalities disallow certain types or any GHP system installations for various reasons. Specifically, the villages that are serviced by the Water Authority of Great Neck North (WAGNN) and the Village of Sands Point Water Department and the Town of Shelter Island disallow GHP systems over concerns on impacts on the stressed aquifers upon which these locales rely for drinking water. The Town of Oyster Bay has issued a referendum on new GHP systems until a suitable process is established. Otherwise, the filing and permitting process within jurisdictions that allow GHP systems varies widely. The Towns of North Hempstead and Hempstead allow closed loop systems but not open loop systems. The Town of North Hempstead is required by its own statute to review and discuss with the WAGNN any application for any new well within the WAGNN’s service area.

The towns, cities and villages on Long Island have not readily adopted Suffolk’s Model Code, partly due to confusion over professional sign-off responsibility of the in-ground portion of the system. Two exceptions are the Towns of Smithtown and Brookhaven that have adopted the Model Code into their administrative framework, requiring sign-off by a professional engineer for the design, installation and as-built drawings. Other municipalities not mentioned above allow and permit new GHP systems within their jurisdictions under their existing building department code.
Potential Groundwater Impacts

It is a practice for some homeowners, primarily on the north and south forks, to use their domestic potable water connection as the source water to the system in place of the standard approach to use on-site water supply wells. This practice should be disallowed, since it places an undue burden on public water suppliers and is an inappropriate use of potable water. The NYSDEC should close the gap that allows permitting a new diffusion well(s) without an associated supply well(s).

Groundwater Return through Infiltration Devices other than Wells

It is possible to return groundwater to the aquifer through means other than return wells, such as a drywell, horizontal buried perforated pipe or other means. This practice should be disallowed except where the supply well(s) taps the upper/first aquifer, such that return through the infiltration device is back to that same aquifer. The NYSDEC should close the gap that allows permitting a new supply well(s) without an associated diffusion well(s).

Groundwater Return through Infiltration through the Ground Surface

This practice is not presently regulated by NYSDEC, but there have been reported instances of discharge water overflowing the property line and entering adjoining regulated water bodies and wetlands in violation of NYSDEC wetlands regulations. Further, this practice has created nuisance conditions such as soil erosion, sedimentation, freezing and migration onto adjacent private properties and public roadways. As such, this practice should be disallowed and the NYSDEC should close the gap that allows permitting a new supply well(s) without an associated diffusion well(s).

Groundwater Return to a Surface Water Body or Wetlands

The NYSDEC regulates all discharges to regulated surface water bodies and wetlands on Long Island. A State Pollutant Discharge Elimination System (SPDES) permit would be required and temperature limits apply to the discharge water. The NYSDEC should disallow this practice to avoid unintended impacts to these resources.

Dual Use Wells

Open loop system supply wells conceivably can be used for other purposes besides heating and cooling, for example, irrigation and drinking water. Where public water is not available, this practice should be allowed with approval of the local authorities. The Suffolk County Department of Health Services General Guidance Memorandum #25 prohibits cross connections between a potable water supply system and geothermal wells where a GHP system is proposed for a project with a new wastewater and/or water supply system (see County Codes and Guidelines, Suffolk County section). Otherwise, standards for acceptable design and installation of dual use (geothermal, potable water) wells are provided in the NYS Mechanical Code.

Typical GHE Depths

Table 2 presents the typical install depths for GHEs. DX boreholes/loops are installed to the shallowest depths of all the GHEs. In virtually all cases, GeoColumns(c) would terminate above
or slightly into the Upper Glacial Aquifer where the depth to the water table lies less than about 25 feet deep. With a typical depth of up to 100 feet, DX-to-Ground Contact DX systems would terminate in the Upper Glacial Aquifer or potentially into the top of the Magothy Aquifer where it may be shallower than 100 feet (most of Nassau County and the extreme west end of Suffolk County).

Most open loop wells terminate at relatively shallow depths in the Upper Glacial Aquifer to keep drilling costs down. Approximately 89% of Nassau County's public drinking water supply wells are screened in the Magothy Aquifer (Long Island Regional Planning Board, 1993), and, therefore, would not be impacted by open loop GHP systems. This percentage is significantly higher in Suffolk County – per the Suffolk County Water Authority's website (SCWA, 2015), approximately 45% of its wells are installed in the Upper Glacial aquifer. If a proposed GHP system must be permitted under the NYSDEC LIWP program (flow rate >45 GPM) and is located within the capture zone of an existing public supply well field, the NYSDEC should require the owner of the system to perform the appropriate aquifer testing and modeling to assess the potential impact to the well field to the satisfaction of the water supplier. Smaller proposed GHP systems that are not regulated under the NYSDEC LIWP program can be addressed as discussed in future report sections.

Closed loop borehole depths vary depending on subsurface conditions, driller preference and size of the property. Their depths are not usually dependent on hydrogeology. Although clay has a low thermal conductivity, more loops drilled to a shallower depth and terminated above a major clay unit might be a preferred option for a GHP system designer.

Table 2
Typical Installed Depths of GHEs

<table>
<thead>
<tr>
<th>GHP System Type/GHE</th>
<th>Typical Depth (feet below ground surface)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Loop Supply and Diffusion Wells</td>
<td>Variable; dependent on depth to water table and suitable aquifer conditions</td>
<td>Generally constructed in Upper Glacial Aquifer to minimize cost, with suitable thickness and water quality</td>
</tr>
<tr>
<td>Closed Loop Vertical Boreholes</td>
<td>200-500 feet deep</td>
<td>Depth depends on available land to drill and driller capabilities, not aquifer conditions; avoid thick clay, if possible</td>
</tr>
<tr>
<td>Closed Loop Horizontal</td>
<td>4-10 feet deep</td>
<td>Where sufficient land area exists; typically not installed below the water table</td>
</tr>
<tr>
<td>“DX to Ground” Vertical</td>
<td>100 feet deep</td>
<td>Depth depends on available land to drill and driller capabilities, not aquifer conditions</td>
</tr>
<tr>
<td>“DX to Ground” Horizontal</td>
<td>4-10 feet deep</td>
<td>Where sufficient land area exists; typically not installed below the water table</td>
</tr>
<tr>
<td>“DX to Water” (“GeoColumn©”)</td>
<td>&lt;25 feet deep</td>
<td>Water containment device is standard 20 feet long</td>
</tr>
</tbody>
</table>


**Comparison to other Groundwater Uses**

Heating and cooling with a GHP system is just one of the many uses of Long Island's groundwater resources. Factors that distinguish a GHP system from other uses are:

- It is a non-consumptive use of groundwater.
- The temperature of the groundwater is altered, either increased or decreased on a seasonal basis.
- For an open loop GHP system, the groundwater is injected back into the aquifer after it is used.

These processes have the potential to cause certain thermal, chemical and hydraulic effects that need to be understood and controlled to protect the aquifers. Each of these potential effects are discussed in this section along with other significant issues and conditions relevant to aquifer protection.

**Thermal Effects**

GHP systems seasonally increase the local groundwater temperature during the summer and decrease the temperature during the winter (one exception is a cooling-only open loop system where only the groundwater temperature is increased during the cooling months). The thermal effect on the aquifer dissipates some distance from an operating system depending upon groundwater flow velocities and soil characteristics and varies between the different types of systems as discussed in the following.

For an open loop system, the thermal effect occurs around the diffusion wells where the thermally-altered water is injected into the aquifer. The effect is generally localized at the depth of the diffusion well screens. The affected distance around the wells will depend on the thermal load imposed on the aquifer, which is determined by the injection flow rate, injection water temperature and duration. Since all groundwater flows, albeit slowly, open loop GHP systems cause seasonal thermal "pulses" of cool or warm water flowing away from the diffusion wells along the natural groundwater flow path. Each pulse dissipates as it moves away from the diffusion wells through the processes of conduction, advection and mixing of the thermally altered water with ambient temperature groundwater. The distance where the natural groundwater temperatures are re-established depends on the thermal load, aquifer properties and the groundwater flow velocity.

The long-term effect of these thermal pulses varies between a cooling-only system and one used for both heating and cooling. The overall length of the thermal plume for a heating and cooling system will be shorter because the alternating seasonal warm and cool pulses mix and cancel each other out. An example of such a system is shown in Figure 15, illustrating the effect after operating a large open loop geothermal system for heating and cooling for 20 years. The system heats for seven months each year with a return water flow rate of 275 GPM at a temperature of 41 degrees F. The system cools for the other five months with a return water flow rate of 430 GPM at a temperature of 71 degrees F. There are numerous public water supply well fields located within 1-2 miles from the diffusion wells. Public supply well fields located downgradient of the diffusion wells were modeled to pump continuously over the 20-year period at a flow rate of 900 GPM each. Based on numerical model simulation, the thermal effect on the aquifer dissipates within a significantly shorter distance than the groundwater flows over the same duration, because of the mixing of the seasonal warm and cool pulses (1,200 feet vs. 2,550 feet). Therefore, there will be no effect from this system on the temperature of the groundwater drawn from the public supply wells.
Figure 16 is an example showing the results from a numerical model simulation of an extreme case of a large cooling only open loop system after operating for 30 years. A public water supply well field is located approximately 3,500 feet directly downgradient of the diffusion wells. The GHP system is simulated to pump and recharge continuously at the peak design flow rate of 3,600 GPM. The public supply well field has three wells that are simulated to pump continuously over the 30-year period at a combined flow rate of 1,200 GPM. The return water temperature to the aquifer is 10 degrees F warmer than ambient conditions or approximately 65 degrees F. The return water cools via advection, conduction and blending with cooler surrounding groundwater as it moves along the natural groundwater flow path. After 30 years, the temperature of the water reaching the wellfield from the diffusion wells is approximately 2-3 degrees F warmer than the natural groundwater temperature. However, because the public supply wells draw in water radially from all sides, besides groundwater originating at the diffusion wells, there will be no measurable effect on the public supply wells water temperature.
For a closed loop or DX system, the thermal effect occurs within the volume of the aquifer material directly surrounding each closed loop or DX borehole. The heat is injected into or extracted from the interval lying between the surface and the completed depth of each borehole. The radial thermal effect around a closed loop or DX borehole is on the order of 10-15 feet, thus much smaller than an equivalent capacity open loop system since the thermal energy is spread out over a significantly thicker vertical depth interval.

The temperature is greatest within the center of a closed loop or DX borefield and decreases outward where the heat can dissipate by conduction to the surrounding ambient temperature aquifer materials. In the winter, the pattern is reversed. Temperatures within the "core" of the borefield are coolest as heat is extracted from the ground and heat energy flows into the borefield from the surrounding aquifer that is at higher ambient temperatures.

Closed loop and DX borefields exhibit the same seasonal thermal "pulses" of cool or warm water flowing away from the borefield as an open loop system and are controlled by the same factors as described above. The long-term effect of thermal pulses from closed loop and DX borefields used for both heating and cooling will be like an open loop system as described above. The borefield temperatures are at their highest in late summer and lowest in late winter. As presented in Table 1, the typical temperature of the HTF circulating in a closed loop borefield is as low as 30 degrees F during heating (if antifreeze is used in the HTF) and as high as 90 degrees F during cooling. The resulting temperatures in the surrounding aquifer between the boreholes do not reach these extremes due to the heat loss across the HDPE piping and grout.

During the spring and fall, the residual heat or cold in the ground continues to flow through and beyond the boundaries of the borefield with the natural groundwater flow. Due to the slow flow
rate of groundwater, when winter arrives, there is normally still some stored heat within the borefield left over from the previous summer season that can be extracted for heating. Similarly, when summer arrives, there is normally still some stored cold from the previous heating season that can be used for cooling.

The thermal effect of large GHP systems, either open or closed loop type, may extend beyond the property boundaries. Therefore, large systems could potentially alter the temperature of groundwater being extracted from nearby wells and interfere thermally with other GHP systems on adjoining and/or downgradient properties. Thermally impacted groundwater also could discharge into downgradient surface water bodies or wetlands and result in ecological impacts and violations of NYSDEC limits.

A better understanding of thermal transport from large GHP systems in Long Island’s aquifers and potential impacts on ecological resources is necessary. Regulations should be enacted to prevent such impacts, including requiring modeling or other means to determine “safe” setbacks from these resources. Areas served by small private drinking water wells would be particularly susceptible to impacts from large GHP system thermal plumes. As noted previously, under the LIWP program, the NYSDEC requires demonstration that there will be no thermal impact by large open loop systems on nearby drinking water supply wells, thus offers protection of public drinking water systems.

A high concentration of small open loop geothermal systems serving individual homes on small lots (particularly dense suburban areas of Nassau, western Suffolk and much of the south shore) would result in some thermal interference between neighboring systems. The current state policy of first-come-first-served for underground water rights may need to be reassessed to address cumulative effects. In the meantime, a system of better tracking the installation of small open loop systems (not regulated under the LIWP) is warranted; for example, modifying the SCPC code to require drilling contractors and the NYSDEC to notify not only the SCWA but all public drinking water suppliers.

In addition, the cumulative thermal effect of large numbers of these type systems could be to change the average groundwater temperature in the aquifer (most likely increase since some percentage of such open loop systems are used for cooling only purposes). This may be of concern in areas within the capture zone of a drinking water supply well where the Upper Glacial Aquifer is used for drinking water supply (most small open loop system wells are shallow and tap this aquifer). Regional modeling (building on the USGS groundwater model) could be performed to define the “safe” concentration of such systems that would prevent this from occurring with appropriate limits enacted by either NYSDEC or the local municipalities.

Because the thermal effect around a residential closed loop system dissipates within 10-15 feet away, there would be no or only insignificant thermal interference between neighboring systems in dense suburban areas. For the same reason, there would be no significant cumulative thermal effect on downstream ecological resources, drinking water supply wells or other groundwater users. Unlike open loop systems, closed loop systems must be used for heating and cooling, which balances out the thermal effect on the ground. Nevertheless, it would be prudent to track the installation of small closed loop systems as recommended above for small open loop systems.

Historically, the aquifer below the Roosevelt Field Mall/Mitchell Field complex has become thermally impacted (overheated) from extended operation of numerous large, commercial open loop type air conditioning systems. It is presumed that the systems’ wells were permitted before NYSDEC established the LIWP or became aware of the potential for overheating of the aquifers.
by air conditioning systems. The increased groundwater temperatures have resulted in lowered system efficiencies and abandonment of some of these systems.

**Chemical Effects**

The return water of an open loop system that does not employ an intermediate HX could become contaminated by refrigerants (e.g., Freon) and other chemicals used in the mechanical equipment should a breach occur in the heat pump or chiller coils. This has contaminated the aquifer at several locations in northern Nassau County. In addition, there are existing, older operating open loop systems that do not employ HXs and may presently be leaking refrigerants to the groundwater or could in the future. Modern HX technology provides an additional physical barrier that protects the aquifer from contamination by refrigerants.

If an antifreeze is used in the HTF of a closed loop borefield and a leak or break occurs in the buried HDPE piping, antifreeze would be released to the aquifer. A concern would be what impact this could have on the drinking water source and if remediation of such a situation is warranted. The three main antifreezes used in the industry are methanol, propylene glycol and ethanol (ethyl alcohol). Neither the NYSDEC nor the USEPA have established groundwater quality or discharge standards or guidelines for any of these three chemicals. Methanol is the most common antifreeze and is the same product also used in windshield washer fluid. Besides being used as an antifreeze, propylene glycol is also a common additive to food products. Methanol and ethanol are highly volatile and flammable liquids in their raw form and are toxic to humans if ingested at high concentrations. However, antifreeze is not used at a full concentration in closed loop GHP systems but mixed with water typically at a 20-25% mix or less. All three compounds biodegrade quickly in groundwater and none are presently designated as carcinogens or mutagens. Nevertheless, all precautions should be taken to prevent a release of these compounds from a GHP system, including enforcing strict pressure testing as discussed earlier and other best practices described throughout this report.

If a leak occurred in the buried copper piping of a DX-to-ground contact loop, refrigerant could be released to the surrounding aquifer. Refrigerants are regulated by both the NYSDEC and the USEPA. Concerns related to these types of DX systems are that there are no regulations for monitoring, reporting or mitigating a release of refrigerants nor for checking and replacing the sacrificial anodes and cathodes when depleted. If a leak occurred in the copper piping submerged in the water containment of a DX-to-water contact loop [GeoColumn(c)], the leak would be contained within the containment device and not be released to the surrounding soil or aquifer. Refrigerant could leak to the ground through the horizontal piping, thus double-wall piping should be required.

**Hydrogeologic Effects**

Of the three GHP system types discussed in this report, only open loop systems affect the natural groundwater flow. The water table around a pumping supply well is drawn down in the shape of a cone and mounds up around the return wells as shown in Figure 10. The extent of these areas is a function of the pumping and diffusion rates and the hydraulic conductivity of the surrounding geologic materials. However, there is no net effect on groundwater in storage since 100% of the extracted water is returned to the aquifer. The effect on groundwater levels is localized around the wells and, when pumping stops, groundwater flow patterns return quickly to the natural non-pumping conditions.
Like the thermal effects discussed previously, the hydrogeologic effect of a large operating open loop GHP system may extend beneath an adjoining property or into a nearby surface water body or wetland. The water levels could be lowered or raised depending on the location of these resources relative to, respectively, the supply or return wells. It is also possible that a large GHP system could interfere hydrogeologically with another GHP system or other water supply well on an adjoining property. The effect would be greatest during the peak heating and cooling seasons. In any case, any such interference and potential impact of a large open loop GHP system would be identified and addressed by the NYSDEC as part of the LIWP process as is the case for all new water supply well applications.

The hydrogeologic effect around a small open loop system is much more localized and less likely to extend beyond the property boundary or potentially impact a nearby natural resource. Given Long Island’s prolific aquifers, the maximum amount of drawdown and mounding of the water table around the wells serving a typical residence (2-3 ton cooling or heating demand or approximately 4-6 GPM peak flow) would not exceed 1-2 feet and is temporary during system operation only. The same would be true for a high density of small GHP systems as the drawdown and mounding effects offset one another.

**Other Issues and Sensitive Environments**

An ungrouted borehole that penetrates a major confining clay unit represents a conduit for vertical migration of contamination in the shallow Upper Glacial Aquifer into the deeper aquifers and contamination of a shallow fresh water aquifer by salt water present below the clay unit. The locations of major confining clay units on Long Island are shown on Figure 17 (below).

**Figure 17**

Generalized cross section of Long Island showing the main aquifers and confining units (Cohen and others, 1968) (Public domain.)
The thermally impacted aquifer beneath the Roosevelt Field Mall/Mitchell Field complex discussed earlier also was impacted by the release of volatile organic compounds from the prior industrial usage of some of the properties. The extensive and sustained pumping and re-injection of contaminated groundwater by commercial open loop air conditioning systems has distributed VOCs throughout the aquifer. As noted previously, this practice may have preceded close regulation of water supply wells under the NYSDEC LIWP program. The NYSDEC now checks under the LIWP program that proposed new water wells (including open loop GHP system wells) will not alter the pathway of pre-existing legacy contamination plumes or impact groundwater remediation efforts at regulated contaminated sites.

Sensitive aquifers exist beneath the Great Neck peninsula and portions of the Port Washington peninsula, Shelter Island and portions of the north and south forks. These aquifers are limited in size as they are surrounded by salty groundwater, thus they are particularly susceptible to the potential impacts from GHP systems discussed previously. GHP systems may need to be curtailed or restricted in these areas due to their sensitive nature.

The NYSDEC disallows the installation of open loop geothermal wells in the Lloyd Aquifer. Because closed loops are not pumping wells, neither the current NYSDEC regulations nor Lloyd Aquifer moratorium exclude closed loops from being drilled and installed into the Lloyd Aquifer, although the authors are not aware of any such systems installed in this manner.

**Mitigation of Potential Impacts**

While there are gaps in the existing regulations, the following programs exist that protect Long Island's aquifers and regulated ecological resources:

- The NYSDEC and the SCDHS have construction guidelines in place for open loop wells, such as grouting/sealing of the annular space, including through clay units that are penetrated.

- For open loop systems regulated under the LIWP program, the NYSDEC performs a rigorous review of potential impacts of a system on the groundwater, surface water and wetlands resources. This includes a search for sites of environmental concern within the area of influence of the system and an evaluation of the potential thermal and hydraulic effects on neighboring systems and other groundwater users.

- Activities within sensitive areas (e.g., flood zones, wetlands and surface water bodies) are regulated by several other state and federal agencies.

In addition, the following local GHP industry practices and programs are in place or in the planning stages with the goal to ensure quality of installations and thus prevent impacts to groundwater and the environment:

- The current industry practice for commercial and large residential open loop GHP systems is to separate/isolate the well loop from the building's HVAC equipment and distribution system with an intermediate HX to prevent contamination of the return water by refrigerants and other chemicals present in the mechanical equipment. The HXs are made of appropriate material, e.g., stainless steel or titanium, for the site groundwater quality.
• Standard industry practices and guidelines for closed loop GHP systems that use antifreeze in the HTF include pressure testing of the loops and piping at multiple stages of installation to prevent leaks of antifreeze to the aquifers.

• Additional best practices designed to protect Long Island's aquifers from potential impacts from GHP systems have been implemented by Suffolk County through Memo #25 and by municipalities that have adopted the Model Code.

• GHP system inspector training programs have been developed by IGSHPA and NGWA, and LI-GEO is developing a training program specifically for Long Island municipal building inspectors.

• The local GHP industry is in discussion with NYS, IMC and USEHC code officials about adopting the comprehensive ANSI/CSA standards into their respective code.

• Quality control and contractor certification requirements are being developed that must be met for owners to receive rebates from PSEG for GHP systems.
CHAPTER 5
ASSESSMENT OF ADEQUACY OF EXISTING PROGRAMS

In this chapter, three issues highlighting two significant mechanisms for affecting groundwater and surface are addressed. The first concerns how Long Island treats its wastewater. Broadly, there are two ways of disposing wastewater, on-site or in an off-site treatment facility. Long Islanders have tried both, Nassau treats the majority of its wastewater in off-site facilities, while in Suffolk, the majority of wastewater is treated on-site. Each method has its advantages and disadvantages.

The second topic addresses how much water can be withdrawn from Long Island’s aquifer system without causing undesirable impacts to the system.

The third topic presents a discussion on the Lloyd Aquifer, including the amount of water recharged to it, the amount of water withdrawn from it, the quality of the water withdrawn and the legal protections afforded to it.

Wastewater Management in Nassau and Suffolk Counties, New York

Wastewater treatment on Long Island is essentially "A Tale of Two Counties." Nassau County is approximately 85% sewered (though large stretches of the north shore of Nassau County, approximately 50,000 houses, utilize cesspools or septic tanks), while only 26% of Suffolk County is connected to sewers. Nassau County’s largest sewage treatment plant, in Bay Park, handling 40% of the County wastewater, has been discharging effluent that has only gone through secondary treatment prior to discharge into Nassau County’s south shore embayment. About 74% of Suffolk County’s wastewater is released essentially untreated and ultimately finds its way into ground and surface waters. About 360,000 houses in Suffolk County currently utilize non-performing cesspools or septic systems. As a result of these contrasting sewage treatment practices, each county has its own set of water quality and quantity issues.

Potential climate change effects are also a compounding consideration regarding sewage treatment practices in each county. While the Bay Park treatment plant was significantly damaged in Superstorm Sandy, Suffolk County’s principle wastewater treatment plant at Bergen Point barely escaped unscathed. Options are being examined to pipe Bay Park’s discharge out into the ocean, while the portion of Bergen Point’s ocean outflow pipe running through the Great South Bay is being replaced to avoid catastrophic failure. Diverting wastewater into the ocean rather than recharging to ground raises concerns about the water budget in Long Island’s sole-source aquifer and poses the tradeoff between water quality and water quantity. Other issues associated with ocean discharge include coping with future sea level rise and the resulting impacts on coastal infrastructure, declining groundwater levels and the potential for salt water intrusion.

History

The Long Island Sanitary Commission (which included Robert Moses) was appointed by New York Governor Franklin D. Roosevelt on March 10, 1930 to "investigate the problem of developing a scientific administration and control over the disposal of sewage and garbage in Nassau and western Suffolk Counties. ... The commission recommends that, pending the adoption of its plan by the county supervisors, no municipal sewage project shall proceed without approval ... and that the commission provide and operate trunks or outlet sewers and sewage treatment plants wherever such facilities are required." The cost would be financed by county bonds to be paid by the county as a whole or paid by assessments on the benefitted properties.
Reportedly, there were 13 systems at this point, covering about 25% of the residents. Earlier in the century, the principle sewage treatment plants were opened in Garden City (1908), Hempstead (1911), Freeport (1920), Glen Cove (1920s), Mineola (1928), Rockville Centre (1928) and Mitchel Field (1920s). With a population of 300,000, Nassau County was the fastest growing county in the country. The first priority was "to maintain the purity of the water of the Long Island Sound, the Atlantic Ocean and the numerous bays and inland streams. ... The greatest asset of Nassau County, and one of the greatest assets to the metropolitan community, is the shore front. Pollution of these waters is inevitable unless the problem of waste disposal is properly solved." (The New York Times, May 15, 1931, page 20).

By 1957, Nassau County's census population was 1,178,075. In reporting to the Commissioner of Public Works (May 1958) relative to trunk sewers and sewage treatment plants for proposed Sewage Disposal District (SDD) No. 3, the engineering firm of Lockwood, Kessler, & Bartlett (LKB) estimated the cost at $227 million. LKB recommended "complete biological treatment by the 'activated sludge' process, chlorination and disposal of clear, disinfected, inoffensive effluent into one of the major boat channels of the bay waters." Such treatment removes 90-95% of biochemical oxygen demand and suspended solids with the bacteria count kept below 50 coliforms per 100 cubic centimeter. There was no mention of nitrogen loading. The report further noted that, "Our hydrographic studies indicate that all the major boat channels provide sufficient dilution of waters and dispersion currents for disposal of the treated effluent." These conclusions were subject to completed improvements to Jones Inlet, Long Creek and Fire Island Inlet.

The Bay Park Sewage Treatment Plant was placed into operation in 1950 with a design capacity of 27 million gallons per day (MGD) with only primary treatment. The plant expanded in the 1960s to 60 MGD with secondary treatment. A major upgrade in the 1980s brought capacity to 70 MGD, servicing an area of approximately 70 square miles (sq. mi.) with a population of 550,000. The Cedar Creek Water Pollution Control Plant was placed into operation in 1974 with a design capacity of 45 MGD. It was expanded in the 1980s to 72 MGD, servicing approximately 105 sq. mi. with a population of 600,000.

A 1972 report from the United States Environmental Protection Agency (USEPA) on the Environmental Impact Statement on Wastewater Facilities Construction Grants for Nassau and Suffolk Counties, New York offered a "general description of 'secondary' treatment plants. ... Nitrogen removal data is not given because the references cited did not give it. We know, however, that none of the processes described removes more than 30-50% of the effluent nitrogen (Eliasen and Tchobanoglous, 1969). ... While the physical-chemical scheme described removes more phosphorous than conventional secondary treatment, it removes less nitrogen since biological growth which assimilates soluble is not promoted." As for recharging, "The Bay Park experiments so far have shown it is possible to recharge to the Magothy Aquifer with reclaimed sewage through the use of injection wells. However, the assessment of economic practicality must await better definition of (1) the rates and causes of injection-well clogging and (2) the geochemical stability and long-term character of the injected water."

Among other concerns raised by the 1972 EPA report were algal blooms, which would create an anoxic environment detrimental to all oxygen dependent organisms. Loss of coastal wetland had adversely impacted the biota and increased the impact of severe coastal storms. The concept of oceans as an infinite sink was rejected, since there had been no impact assessment of large inputs of trace materials in sewage effluent into coastal waters. Concern was expressed over the decline of groundwater levels resulting from discharge of treated sewage effluent into Long Island Sound and the Atlantic Ocean, especially regarding the "sacrificing" of water quantity to water
quality. A cautionary note was sounded over the installation of community sewering capable of supporting higher density, the counter being control of zoning practices.

In 1961, a feasibility study was conducted to explore the construction of public sewers within Suffolk County. In 1965, Suffolk County established the County Sewer Agency, which was responsible for sewage collection, conveyance, treatment and disposal. By 1970, the county acquired its first sewage treatment plant in the already constructed 1.5 MGD plant, located in Port Jefferson and known as Suffolk County Sewer District #1.

In an article titled "U.S. Warns Suffolk It May Act on Sewers," Alan Eysen reported in Newsday on April 24, 1969: "Murray Stein, assistant commissioner for enforcement for the U.S. Water Pollution Control Administration, told a water pollution conference here that the federal government would join with the state in seeking development of a regional sewage collection and treatment system if the County of Suffolk fails to take action." More specifically, there was a call for duck farmers to install pollution treatment facilities.

In a Newsday article dated September 26, 1969, "Sewers Needed Now, Suffolk Warned," Earl Lane wrote, "Mention Long Island to some people in Bangalore, India or Tashkent, USSR, and they might wrinkle their noses and ask, 'Isn't that where they have cesspools'? Recounting his travels through India, Russia and other countries, Dwight Metzler, New York State's deputy health commissioner for environmental services, said, "Long Island is the outstanding example in the world where a major population discharges sewage in groundwaters. Even people in underdeveloped countries tell me they can't understand it."

In 1969, according to "Utilities Inventory & Analysis" by the Nassau-Suffolk Regional Planning Board, "More than 50% of Nassau's homes and 98% of Suffolk's homes are still served by cesspools and septic tanks. ... The critical need for sewage collection and treatment is a direct outgrowth of the inadequacies and failures of disposal by septic tanks and cesspools. In the past ten years these failures have become more obvious. Some of the resultant effects are as follows:

- Pollution of the shallow fresh groundwater supply.
- The possibility of the rapid spread of intestinal disease caused by overflowing cesspools has increased.
- A slow but steady pollution of recreational waters has been produced.

The Report of the Suffolk County Sewer Agency to the Suffolk County Board of Supervisors (March 21, 1969) provided background on the Southwest Sewer District (SWSD) plans and cost estimates in preparation for the general election referendum authorizing the funding and construction of the SWSD on November 4, 1969. Total construction costs and interest over 40 years were projected at about $522 million. The project included the Bergen Point Sewage Treatment Plant (STP) (30.5 MGD capacity) with 71 miles of interceptor lines, 817 miles of lateral, main and trunk lines, 14 pump stations and a four-mile ocean outfall. Construction was slated to occur in stages over ten years. The Long Island Comprehensive Waste Treatment Management Plan (LICWTMP) prepared by the Board of Supervisors in 1978 indicated that, by 1976, 101 public and private sewage treatment plants were operating in Suffolk County with a total average discharge of 14.26 MGD.

In the late 1970s and 1980s, the SWSD, also known as Sewer District #3 (SD3), was created and the Bergen Point STP was built utilizing funding from the federal government and New York State. Bergen Point went online in October 1981. The SD3 is the largest sewer district in Suffolk County.
consisting of an area of 57 sq. mi. with 950 miles of sewer lines, 14 remote pumping stations and serving an estimated population of 340,000. Evidence has shown that sewering can help reduce nitrogen loads to both ground and surface waters. For example, the average nitrogen level in the Carlls River in the 1970s was 3.2 milligrams per Liter (mg/L). By the 2000s, this level was reduced to 1.8 mg/L.

There is, however, a "flip side" to this scenario relating to stream flow and water quantity. Base flow in the Carlls River dropped from a 27.3 cubic feet per second (cfs) flow during predevelopment times, to 20.5 cfs during the 1968-1983 period. Furthermore, the United States Geological Survey (USGS) predicts that flow will decline to 11.9 cfs by 2020, a 50% loss of more than 50% of its pre-development base flow. Similarly, East Meadow Brook in Nassau County is predicted to go to 0 cfs stream flow in 2020 (Buxton and Smolensky, 1999). Other surface water features in Nassau and western Suffolk Counties have seen similar declines in base flow accompanying an improvement in nitrate levels. A larger discussion of this topic is detailed in the 2016 State of the Aquifer Report (SOTA).

An outgrowth of the SD3 undertaking was the SWSD corruption case. It involved substantial delays and cost overruns. When started in 1969, the budget for construction was $315 million. By the time the first homes were hooked up in 1981, the cost of the project had ballooned to more than $900 million. Additionally, a project director and lawyers for the company that built the system had been convicted of conspiracy and racketeering. No public officials were convicted of criminal charges but several were assessed damages in civil suits filed by the county. As a result, no other major sewer projects were pursued in the ensuing 40 years.

Wastewater Treatment in Nassau County

The Nassau County Department of Public Works is responsible for the operation and maintenance of the county’s three sewage facilities, which include the Bay Park Sewage Treatment Plant, the Cedar Creek Water Pollution Control Plant and the Glen Cove Wastewater Treatment Plant. The Glen Cove plant has been recently upgraded to meet the requirements associated with protecting the Long Island Sound from hypoxia or low dissolved oxygen. This plant currently treats approximately three MGD, leaving a surplus capacity of more than 2.5 MGD, which could be used to sewer some of the communities in the north shore that are currently served by cesspools. In addition to the sewage collection systems operated by the county, there are six village-owned and operated collection systems in the county that discharge to the county’s sewage collection system. The villages are: Freeport, Garden City, Hempstead, Mineola, Rockville Centre and Roslyn.

The county recently completed a joint project with the Villages of Cedarhurst and Lawrence to construct the infrastructure necessary to divert wastewater flows from the antiquated village sewage treatment plants to the county’s Bay Park STP. The county assumed ownership of the villages’ sanitary sewer collection systems and is currently undertaking the decommissioning and demolition of the former villages’ sewage treatment plants. Excess treatment plant property will be returned to the villages for their use.

Eight other independent treatment facilities operate within the county, including the City of Long Beach, Jones Beach, the Village of Great Neck, the Port Washington Water Pollution Control District, the Belgrave Water Pollution Control District, the Great Neck Water Pollution Control District, the Greater Atlantic Beach Water Reclamation District and the Oyster Bay Sewer District. Together, these ten facilities process 15% of the county’s effluent.
Nassau County also operates 57 sewage pump stations and approximately 3,000 miles of sewer main. The Bay Park STP collects wastewater from an area of approximately 70 sq. mi. in the western portion of Nassau County. It serves an estimated population of 524,000. The majority of the sanitary flow is from residential with the remainder from commercial establishments. Only about 1.5% of the flow to Bay Park is from industrial facilities.

The Bay Park STP was originally constructed in the late 1940s and was placed into operation in 1950. It was initially permitted for the treatment of 27 MGD of municipal sanitary waste. The plant was first expanded in 1960 to provide secondary treatment and increase its capacity to 60 MGD. Beginning in the mid-1980s, the plant was expanded again to increase its capacity to achieve secondary treatment of an average daily flow of 70 MGD. The plant currently treats on average 50 MGD of wastewater. The plant discharges its treated effluent into Reynolds Channel through an 84-inch diameter outfall pipe, which is approximately 2.3 miles long.

The Cedar Creek Water Pollution Control Plant (WPCP) collects wastewater from an area of approximately 105 sq. mi. in the eastern portion of Nassau County and serves an estimated population of 600,000. Similar to Bay Park, the majority of the sanitary flow is from residential and commercial areas with minimal industrial flows (1.5%). The Cedar Creek WPCP was originally constructed in the early 1970s and was placed into operation in 1974. It was initially permitted for the treatment of 45 MGD of municipal sanitary waste and complied with secondary treatment standards through the utilization of the activated sludge process. The plant was expanded as part of a capital improvements program in the mid-1980s through the early 1990s to achieve secondary treatment of an average daily flow of 72 MGD. The plant currently treats on average 55 MGD of wastewater. The plant discharges its treated effluent into the Atlantic Ocean through an 84-inch diameter outfall pipe approximately 2.5 miles off the shore of Jones Beach.

The Glen Cove Wastewater Treatment Plant (WWTP) serves an area of approximately 19 sq. mi. in the northern portion of the county with an estimated population of approximately 27,000. All of the sanitary flow is from residential and commercial areas. The Glen Cove WWTP was originally constructed in the 1920s with only primary treatment and chlorine disinfection. Beginning in 1950, the plant was upgraded to secondary treatment with the addition of trickling filters and secondary clarifiers. In 1980, a new plant was constructed that utilized the activated sludge process for secondary treatment. The old trickling filter plant was decommissioned and demolished. In 2002, the plant was upgraded to include processes for nitrogen removal from the wastewater. The plant is currently permitted for an average daily flow of 5.5 MGD. The plant actually treats approximately 3 MGD of wastewater. The plant discharges its treated effluent into Glen Cove Creek.

The county is responsible for the operation and maintenance of 57 sewage pump stations, which transport sanitary wastes where gravity is not a viable transport option. There are 25 pump stations that serve the collection system delivering sanitary wastes to the Bay Park STP, 15 pump stations that help deliver sanitary wastes to the Cedar Creek WPCP and 17 pump stations that are tributary to the Glen Cove WWTP. The wastewater collection system operated by the county is comprised of approximately 3,000 miles of sanitary sewers (ranging in size from 8-108 inches in diameter), 64,000 manholes and 300,000 individual service connections. The sewer maintenance program is designed to annually inspect and clean a portion of the sewers and manholes within the system. This program includes visual inspection, remote video inspection, power flushing, biological treatments (grease control) and herbicide treatments (root control).

The wastewater treatment plants' operations are regulated by the Clean Water Act under the direction of the United States Environmental Protection Agency (EPA). The EPA has delegated
permitting authority to the New York State Department of Environmental Conservation (NYSDEC), which administers the State Pollution Discharge Elimination System (SPDES).

**Wastewater Treatment in Suffolk County**

In contrast to Nassau County, only 26% of Suffolk County is connected to a community sewage collection and treatment system capable of reducing nitrogen. The remaining 74% of the county utilizes on-site sewage disposal systems to meet their sewage disposal needs.

These on-site sewage disposal systems are either systems consisting of cesspools (also known as leaching pools) or a combination of a septic tank and leaching pool (conventional on-site sewage disposal system). These systems typically have little nitrogen reduction capabilities. The wastewater effluent from these on-site sewage disposal systems discharges into the ground eventually impacting ground and surface water resources. Suffolk County contains the highest density of on-site septic systems within the Tri-State area with approximately 360,000 homes currently utilizing on-site sewage disposal systems. Of particular concern are the on-site septic systems located in the groundwater-contributing areas of potable supply wells and estuarine surface waters.

Suffolk County witnessed a population explosion between the 1950s and 1960s. According to United States Census data, the population of Suffolk County increased from approximately 276,000 in 1950 to more than 1,127,000 by 1970 -- an increase of more than 300%. Since that time, Suffolk County’s population has grown at a much more modest pace (i.e., a population growth of 5.2% between 2000 and 2010). From 2010 through 2015, Suffolk County gained a mere 8,296 people bringing the total to 1,501,587. The population of Suffolk County is projected to grow modestly through 2035 ultimately reaching a population of approximately 1.77 million.

Fueled by national housing and transportation policies that favored suburban tract development, the landscape of the county began to be transformed as the population of Suffolk County increased. By 1970, the number of housing units within Suffolk County was just above 325,000. From 1970 to 2013, the number of housing units grew to more than 568,000. Currently, approximately 360,000 housing units use on-site sewage disposal systems that have limited nitrogen-reducing capabilities. The remaining units are connected to a community wastewater treatment system.

With population growth came an increased need for potable water and wastewater infrastructure to serve the needs of the people. A study was performed by the Suffolk County Department of Health Services (SCDHS) beginning in the early 1970s (known as the 208 Study) to determine the effects of building density on groundwater quality. The LICWTMP was based on the results of the 208 Study. Eight Groundwater Management Zones (GMZs), each with differing recharge characteristics, were identified. The 208 Study showed that one-acre zoning was needed to keep nitrate in groundwater impacts acceptable while allowing development utilizing on-site wastewater disposal systems to proceed. As a result, Article 6 was added to the Suffolk County Sanitary Code in 1981, which defined the means and methods for wastewater treatment in Suffolk County. Based on differences in regional hydrogeological and groundwater quality conditions, Article 6 delineated boundaries of the 8 GWMZs for protection of groundwater quality. The goal of creating the GWMZs was to limit groundwater nitrogen to 4 mg/L in GWMZs III, V and VI and to 6 mg/L in the remaining zones.

In order to facilitate reaching these nitrogen goals, residential properties located within GWMZs III, V and VI were required to have a minimum lot size of 40,000 square feet (sq. ft.) if using a
conventional on-site sewage disposal system and either public water or private wells. Residential properties located in the remaining zones are required to have a minimum 20,000 sq. ft. of land when utilizing conventional on-site sewage disposal systems and public water or 40,000 sq. ft. with private wells. Commercial/industrial properties located in GWMZs III, V and VI were limited to a total discharge of 300 gallons per day (GPD) per acre when using a conventional on-site sewage disposal system and a public water or private well. The remaining zones were allowed 600 GPD per acre with public water or 300 GPD per acre with a private well. Exemptions from these guidelines were permitted for lots that existed prior to 1981, which allowed for higher densities in certain areas.

Projects that exceed the density requirements as stated in Article 6 of the Suffolk County Sanitary Code and do not meet one of the exemptions are required to provide advanced treatment capable of reducing effluent nitrogen to 10 mg/L. This is accomplished by connecting the site to an existing or proposed community sewage treatment plant. However, many areas of Suffolk County were built before the Article 6 density restrictions or prior to conventional treatment system requirements. The Suffolk County Department of Economic Development and Planning estimated that more than 60% of the residential parcels in Suffolk County (more than 372,000) are less than or equal to one half acre. Of these, more than 257,000 (52.9%) are not sewered.

Additionally, there are more than 214,000 residential parcels less than one quarter acre, of which 26.7% are not sewered. As of 2017, changes were being considered to Article 6 that would require innovative/advanced on-site wastewater treatment systems (I/A OWTS) for new construction, modification of “grandfathering” provisions for commercial properties and establishing requirements for the replacement of conventional cesspools and septic systems.

**Recent Developments in Suffolk County**

Suffolk County has recently started to evaluate the feasibility of sewering various areas throughout the county. In 2008, the Suffolk County Sewer District/Wastewater Treatment Task Force was established by the Suffolk County Legislature. The goals of the Task Force were, among others, to evaluate Suffolk County’s existing wastewater treatment infrastructure and to seek out public and private funding sources in order to expand its wastewater treatment facilities to additional areas within the county.

![Suffolk County: Proposed Sewer Areas with the Great South Bay](image)
In 2014, Suffolk County was awarded $383 million of Superstorm Sandy Recovery funds from New York State to install sewers and connect approximately 10,000 properties to sewage collection and treatment systems. This will be the first major sewer-based project within Suffolk County in more than 30 years. The goal of the project is to reduce nitrogen pollution to ground and surface waters and to improve coastal resiliency against future storm events. The areas to be sewered are listed below:

- Mastic: Parcels in the Forge River area will be connected to a new wastewater treatment plant located near the Brookhaven Town Airport.
- North Babylon, West Babylon and Wyandanch: Parcels in the Carlls River area will be connected to the SWSD.
- Great River: Parcels in the Connetquot River and Nicolls Bay area will be connected to the SWSD.
- Patchogue: Parcels in the Patchogue River area will be connected to the Patchogue Sewer District.

Without extensive federal support, sewerization has become prohibitively expensive. As an example, the 465 sewer connections proposed for Great River (number three above), which would be financed with a low 2% interest loan from the Environmental Facilities Corporation and involves simply connecting to an existing Bergen Point STP interceptor beneath nearby Heckscher Parkway, would cost an estimated $3,000 per year per parcel. A recent estimate from D&B Engineering and Architects, P.C. for connecting 5,600 Nassau County north shore properties to sewers came in at $120,000 per parcel.

**Figure 2  May 2014 Feasibility Study**

<table>
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<th>Property Type</th>
<th>“Typical Assessed Value ($)</th>
<th>Annual Debt Service (Sewer Assessment)</th>
<th>Annual Depression Cost &amp; Service Contract</th>
<th>Annual O&amp;M</th>
<th>Village of Patchogue Sewer User Fee</th>
<th>Total Annual Amount</th>
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**Existing Sewage Treatment Plants and Sewering in Suffolk County**

As of 2013, Suffolk County has 197 operational STPs, 171 of which are designed to remove nitrogen from the wastewater with typical effluent total nitrogen of 10 mg/L or less. These types of plants are considered tertiary plants. The remaining 26 STPs are considered secondary plants, capable of reducing biochemical oxygen demand (BOD5) and suspended solids (SS). Of the 197 STPs, 15 discharge directly to surface waters. The 2013 average effluent total nitrogen for the tertiary plants in Suffolk County was 8.7 mg/L, which is less than the maximum allowed of 10 mg/L per SPDES permits.
The STPs in Suffolk County can be categorized as either centralized or decentralized. Centralized systems involve advanced processes that collect, convey, treat and discharge large quantities of wastewater. Municipalities usually own the centralized STPs. There are approximately 23 centralized STPs located in Suffolk County. Some of the major centralized sewer districts in the county include Bergen Point (Sewer District #3) and Selden (Sewer District #11), owned and operated by Suffolk County and the Town of Riverhead and Village of Patchogue STPs, which are operated by those municipalities. Bergen Point STP is the largest treatment plant in Suffolk County with an operating capacity of 30 MGD and is currently under construction to expand the plant to 40 MGD. Bergen Point STP is a secondary plant that discharges treated effluent two miles offshore into the Atlantic Ocean.

Sewer collection systems in Suffolk County consist mainly of gravity sewer lines with remote pump stations. In certain cases, low-pressure force mains have been utilized. The Village of Patchogue Sewer District has been expanding in recent years through the use of low-pressure force mains with pumping systems. The advantage of installing low-pressure force mains is the cost. They reduce the number of remote pump stations required, reduce the need for costly deep excavations to install gravity sewers and lower dewatering costs. Conversely, gravity sewers may be more expensive for developers or municipalities to install in certain cases but are less expensive for homeowners since the homeowner does not have to maintain and operate their own low-pressure pump station located on their property.

Unsewered Areas in Suffolk County

Most of the STPs located within Suffolk County are considered decentralized. Decentralized STPs are designed to operate on a smaller scale than centralized STPs and do not require multiple remote pump stations to convey sewage to the plant. The historical use of decentralized STPs in the county has been to serve single lots containing condominium complexes, apartment complexes, hotels or industrial or commercial buildings. The SCDHS has been actively requiring older plants that are under-performing and/or lack nitrogen removal capability to be renovated or replaced. During the past 15 years, 100 new STPs were constructed, 20 of which replaced existing facilities whose physical conditions and/or treatment capability had deteriorated. For example, the Kings Park STP, located on the grounds of the former Kings Park Psychiatric Center, was built in 1935, rehabilitated in 1960 and upgraded again in 2004.

Types of decentralized STPs in use throughout Suffolk County include rotating biological contactors (RBCs), sequence batch reactors (SBRs), extended aeration systems with a denitrification filter, membrane bioreactors (MBRs) and biologically engineered single sludge treatment (BESST) processes. All of these tertiary treatment plants are designed specifically to remove nitrogen. With the recent concerns regarding emerging contaminants [such as pharmaceuticals and personal care products (PPCPs)], some modifications may be required to some of the plants in order to remove these types of contaminants in the future.

As stated previously, 74% of Suffolk County residences use on-site sewage disposal systems. The effluent from on-site sewage disposal systems is discharged into the ground. The sands, silts, gravels and clays that make up the unsaturated zone and the aquifer function as a large sand filter and help to limit the impact of contaminants contained in effluents to groundwater as long as the density of development is not excessive.

Most commercial buildings within Suffolk County are also served by on-site sewage disposal systems. It has been estimated that there are more than 39,000 active commercial properties
within Suffolk County using on-site sewage disposal systems. Some of these sites have multiple on-site sewage disposal systems serving the building(s) located on the parcel. Similar to residential sewage disposal systems, commercial on-site sewage disposal systems that comply with current standards consist of a precast septic tank for primary treatment and precast leaching pool(s). In 1984, standards were developed to address both the construction of such systems as well as the allowable sanitary flow permitted to be discharged from a commercial/industrial parcel. Therefore, there are many sites constructed prior to 1984 that may exceed the current density requirements of Article 6 and may have cesspools as a means of sewage disposal.

Subsequent to a 2014 tour of the septic replacement programs in Maryland, New Jersey, Rhode Island and Massachusetts, Suffolk County launched the first of two pilot programs to test I/A OWTS. Thirty-nine systems were donated by 14 vendors and installed at homes around the county. As of early 2017, three of the systems have been provisionally approved by Suffolk County. These systems have reduced average nitrogen concentrations in the effluent from an average of 70 mg/L to less than 19 mg/L. An upcoming pilot will look to install several hundred systems in critical areas in close proximity to surface waters as was done in the Maryland and Rhode Island programs. This preliminary success will prepare the county for the up to $22 million in water quality funding starting in 2018 for the five East End towns pursuant to the referendum that approved allocation of 20% of the Community Preservation Fund for that purpose.

Since the cost of sewering has become prohibitively expensive, it is expected that the vast majority of the 360,000 residents and businesses using systems that do not reduce nitrogen or other contaminants will opt for the relatively reasonable cost of I/A OWTS. The typical price for such a system at a site with no complicating factors currently is $17,500. An amendment in 2016 of Article 19 of the Suffolk County Sanitary Code authorizes the SCDHS to act as “Responsible Management Entity” in the evaluation, approval, registration and oversight of I/A OWTS installations. Given that the north shore of Nassau County has at least 50,000 homes on cesspool/septic systems and given the prohibitive expense of connecting to sewers, these developments address their circumstances.

**Environmental Impacts due to Wastewater Effluent**

Nitrogen in various forms can present a public health hazard in drinking water and can impact surface waters. The SCDHS samples for total nitrogen in wastewater effluent. Tertiary wastewater treatment plants discharging into the ground in Suffolk County are required to have an effluent total nitrogen concentration of 10 mg/L or less. Total nitrogen consists of organic nitrogen, ammonia (NH4+), nitrate (NO3-) and nitrite (NO2-). It has been estimated that wastewater nitrogen contributes approximately 69% of the total nitrogen to ground and surface water resources. The main source of wastewater nitrogen in Suffolk County is from the approximately 360,000 on-site sewage disposal systems utilized by county residents to meet their wastewater needs. Other sources of nitrogen to Suffolk County’s water resources are storm water, fertilizers and atmospheric deposition.

In 2014, the SCDHS prepared an evaluation report of nitrate trends in Suffolk County supply wells. This report was an expansion of work previously completed by Camp, Dresser, and McKee (CDM) in the *Draft Comprehensive Water Resources Report*, which compared the 1987 and 2005 nitrate water quality data. The SCDHS expanded CDM’s work by including 2013 nitrate data. Suffolk County has approximately 1,000 public water supply wells and an estimated 45,000 private wells. Several public water supply wells in Suffolk County are approaching or exceeding the nitrate drinking water standard and must blend or treat to reduce nitrate concentrations in drinking water.
delivered to the public. Public water suppliers on Long Island can spend an estimated $3.5 million in capital expenses for a nitrate removal system at a typical pump station and can spend an additional $125,000 per year in operating costs for electricity and disposal of waste products.

Nitrate data was compared at public supply wells screened in the Glacial and Magothy Aquifers. The Lloyd Aquifer was not evaluated since there are currently only a total of five public supply wells installed in the Lloyd Aquifer. The nitrate results for the Glacial Aquifer wells were based on samples collected from the same 173 wells sampled in 1987, 2005 and 2013. Nitrate concentrations in the Glacial Aquifer wells rose more than 41% from an average concentration of 2.54 mg/L in 1987 to 3.58 mg/L in 2013. As with the Glacial Aquifer, the nitrate levels in the Magothy Aquifer were based on samples collected from the same 190 public supply wells sampled in 1987, 2005 and 2013. Nitrate concentrations in the Magothy Aquifer wells rose more than 93.2% from an average concentration of 0.91 mg/L in 1987 to 1.76 mg/L in 2013. While these average concentrations are still below the drinking water standard of 10 mg/L, the increases are still a cause for major concern.

While nitrogen has historically been the most discussed and studied pollutant associated with wastewater management, it constitutes only one portion of our wastewater problem. Wastewater effluent contains other contaminants of concern such as pharmaceuticals, microfibers, 1,4-dioxane, volatile organic compounds, gasoline, herbicides, heavy metals and pathogens. Some of these substances are legacy pollutants while others are newly emerging.

In addition to impacts on groundwater, wastewater effluent also impacts surface waters. Many of Suffolk County’s 360,000 homes with cesspools and septic systems are situated in low-lying areas that have less than 10 feet separating their systems from the water table. When flooded or submerged in groundwater, septic systems do not function as designed and fail to adequately treat pathogens. In addition, the excess nutrient load from this wastewater is impacting coastal ecosystems through groundwater flow to our estuaries. Recent studies by researchers Kinney and Valiela demonstrate that 69% of the total nitrogen load for the Great South Bay is from septic systems and cesspools.

**Impact of Wastewater Treatment on Water Balance**

In the mid-1980s, the United States Geological Survey (USGS) did an extensive evaluation on the impact of sewering and reported that increasing eastward urbanization on Long Island during the past century has placed an increasing stress on the Island's groundwater resources. The introduction of sanitary sewers to reduce groundwater contamination from underground waste-disposal systems has deprived the groundwater reservoir of a large amount of water that would otherwise provide substantial recharge. This investigation was undertaken to predict the declines in groundwater levels and base flow that would result from an estimated loss of 140 cfs of recharge through the implementation of sewering in Nassau County SDD 2 and SDD 3 and, in Suffolk County, the SWSD. Results indicate that the stress will cause drawdowns as great as 8 feet along the Nassau-Suffolk County border, but the effects will decrease eastward across the subregional area. The predicted effect of sewering in southwest Suffolk County is less severe than that in Nassau County (Reilly, T. E., and Buxton, H. T., 1985, "Effects of sanitary sewering on groundwater levels and streams, Long Island, New York. Part 3 Model development for southern Nassau County"; U.S. Geological Survey Water-Resources Investigations 83-4210, pp. 41).
Hydrologic conditions on Long Island since the 1950s have shown a direct response to increasing urbanization. Extensive impervious land-surfacing also contributed to a decrease in infiltration and resulted in further reduced recharge. From the late 1960s through the mid-1970s, the stress of lost recharge abated and the hydrologic system approached a temporary equilibrium condition. In addition, the steady increase in consumptive pumpage in neighboring Queens County had stopped. This had been a large stress with considerable effect on the area studied, but, during the 1970s, it remained relatively constant (Buxton and others, 1981).

By 1990, sanitary sewers in the Nassau County SDDs 2 and 3 and the Suffolk County SWSD were projected to divert to ocean outfall 140 cubic feet of water per second that would otherwise be returned to the groundwater system through septic tanks and similar waste disposal systems. Sanitary sewers have long been used in western Long Island to limit the amount of contamination entering the groundwater system through septic tanks and similar waste disposal systems. The disposal of the treated wastewater to the surrounding salt water, however, instead of to the ground, removes a large volume of water that provided substantial recharge to the groundwater system. This reduction in recharge lowered the water table and potentiometric head throughout the groundwater system. The greatest water table decline (approximately 8 feet) occurs along the Nassau-Suffolk County border and decreases eastward. This is because most of the sewer stress is in Nassau County SDD 2 and 3.

The Comprehensive Water Resources Management Plan (the Comp Plan) concluded sanitary sewer systems that discharge to surface waters result in a net loss of groundwater from the aquifer system and a potential reduction in the local water table elevation. Because groundwater provides the baseflow for the county’s fresh surface water features, sanitary sewer with surface water discharge can also result in a loss of stream baseflow. Consideration of these impacts requires site-specific evaluation. The impacts of sanitary sewer in Suffolk County’s largest sewer district, Sewer District No. 3 (SWSD) on groundwater elevations and stream baseflow have been previously documented (CDM, 1995, 2002). Suffolk County considers the potential impacts of sanitary sewer on groundwater levels (an increase in the water table due to recharge of treated effluent or a decline in the water table due to discharge of treated effluent to a surface water body – as part of its evaluation of sewer feasibility. (www.suffolkcountyny.gov/Departments/HealthServices/EnvironmentalQuality/WaterResources/ComprehensiveWaterResourcesManagementPlan.aspx, pp. 3-102)

The present day water balance reflects the impacts of development, most notably groundwater withdrawals of 187 MGD, which account for 17% of total recharge. Although the installation of sanitary sewers in portions of the county has reduced the amount of water returned directly to the groundwater system, total recharge to the system (estimated to be 1,120 MGD) is calculated to be greater than total predevelopment recharge. This is due to the construction of a network of storm sewers and recharge basins (Comp Plan, pp. 3-107). Only minor differences in inflows and outflows exist in the predevelopment and present day water balances. The construction of stormwater recharge basins has resulted in an increase in total recharge from 1,203 MGD prior to development to a present day total of 1,367 MGD.

The water balances confirm earlier assessments that, on a county-wide basis, the aquifer system can sustain current and projected rates of water supply pumping. While development of a “safe” or sustainable aquifer yield was not within the scope of this report, the water balances show that average water supply pumping is only approximately 15% of the average recharge rate. In fact, much of the water withdrawn in the county is returned to the aquifer system through on-site
wastewater disposal systems. Consequently, throughout much of the county, significant declines of stream baseflow have not been observed (Comp Plan, pp. 3-118).

Conclusions

One of Suffolk County’s primary groundwater resource management goals is the reduction of nitrogen loading in order to protect current and future drinking water supplies and to restore/maintain ecological functions of streams, lakes, estuaries and marine waters. Also, the goal is to arrest and reverse the trend of increasing nitrogen concentrations in ground and surface waters to the greatest extent feasible and practical by decreasing the nitrogen loading from septic systems and fertilizers. Sanitary wastewater management is the most important factor affecting nitrate levels in groundwater throughout most of the county. Due to the significant contribution of groundwater baseflow to the county’s surface waters, improved sanitary wastewater management practices can also affect nitrate levels in surface waters.

The impacts of rising sea level could be very significant in coastal areas and along the forks with significant implications for water supply, stormwater and sanitary waste management as well as more widespread flooding. The impacts of sea level rise on the location of the salt water interfaces must also be monitored and addressed from a water supply perspective. The impacts of both sea-level rise and more frequent extreme precipitation events should also be monitored so that wastewater and stormwater runoff management strategies can be developed and implemented.

Recommendations

Given the disparate construct of wastewater treatment between the Nassau and Suffolk Counties, the preponderance of recommendations must necessarily be tailored to their respective circumstances. There are, however, some shared principles. Their large-scale STPs are located in close proximity to the ocean and are thus subject to the vicissitudes of sea-level rise. It is one thing to draw notice to the jeopardy coastal infrastructure may face moving forward and another matter entirely to face as practical proposition, both in terms of logistics and costs. In the near term, the challenges faced by existing STPs will necessarily be addressed in place. It is essential to coordinate with federal, state and local partners to continue to assess the vulnerabilities to sea-level rise.

As harmful algal blooms are an Island-wide issue, it is imperative to engage a coordinated strategy to reduce sources of nitrogen and other contaminants of concern and to address wetland stewardship and shellfish restoration as well as continuing to support and fund the use, where appropriate, of marine plants and shellfish as biofiltration to reduce pollutants in surface waters.

Nassau County Priorities

Nassau County priorities include nitrogen reduction, storm hardening and contaminants of emerging concern (CECs). Nitrogen reduction differs for Nassau County’s north shore and south shore. The north shore must find cost-effective means to improve residential on-site septic systems and to leverage the available wastewater treatment capacity of the Glen Cove WWTP. The south shore must remove the Bay Park STP effluent discharge from local waterway (Reynolds Channel/western bays) through either a new ocean outfall or diversion of treated effluent to the Cedar Creek WPCP to share existing ocean outfall. Funding for this project has not yet been identified. As learned from Superstorm Sandy, climate change is a concern as treatment facilities are located near shorelines for ease of discharge. Storm mitigation/hardening must be considered along with usual technical aspects of a project. Contaminants of emerging concern,
including pharmaceuticals and personal care products, are increasingly being detected at low levels in surface water and there is concern that these compounds may have an impact on aquatic life. Given the vast number, types and complexities of these contaminants, it is vital that federal and state agencies develop guidance information so that owners of wastewater treatment plants can include best practices in projects for mitigating impacts.

**Suffolk County Objectives**

**STPs**

- Siting of new or expanded STPs within the 0-25 year contributing area to sensitive surface waters should be minimized to the extent feasible; if an STP is located within this zone, an advanced treatment process shall be provided (SCDHS, 2014).

- Widespread adaption of discharge regulation that utilize mass loading of nitrogen rather than effluent concentration (parts per million). Currently, STPs discharging to the Long Island Sound have this type of restriction.

- Promotion of STP treatment technologies that addresses CECs.

- Accelerate wastewater reuse, mining for resources, energy production and source separation as ways to better value wastewater.

- Identify and prioritize parcels and determine the sewage treatment plant capacity to permit the connection of identified parcels.

- Identify and implement treatment technologies to improve wastewater effluent quality to reduce impacts and for permitting water reuse akin to Riverhead STP’s initiative to re-use wastewater effluent for golf course irrigation for consideration countywide.

- **I/A OWTS & Appendix A Systems.**

- Prioritize parcels in critical areas that shall be required to install nitrogen-reducing I/A OWTS.

- Amend the Suffolk County Sanitary Code Article 6 to revise GWMZ 4 density requirements to conform to GWMZs 3, 5 and 6 to improve groundwater protection in the zone and improve surface water quality in the Peconic Estuary.

- Moving forward, separation distances between a water supply well and the leaching field of OWTS should be sufficient to ensure both pathogen removal and contaminants of emerging concern removal. Horizontal setback distances between OTWS and surface waters should be increased in order to increase treatment of CECs and PPCPs.

- Create a Wastewater Management District with a responsible management entity (RME) to oversee the financing, operation, maintenance and enforcement of I/A OWTS and cluster systems. Consider municipal partners to help advance installations.

- Create and/or identify funding sources and costs to meet on-site system objectives. Continue to advance a range and combination of on-site solutions that can treat to higher levels of treatment. Allow the vetting of systems to occur regionally to speed the acceptance of a larger range of options.

- Evaluate ways to reduce costs for the installation, oversight and maintenance of on-site systems. (e.g., guaranteeing X number of sales to manufacturers, alternative reporting methods, reduced permit fees for I/A OWTS upgrades, etc.)

- Allow installations of nonproprietary, natural and source separation systems.
- Modify the Sanitary Code to minimize the "grandfathering" of SPDES and/or SCDHS-permitted sanitary flows that exceed and predate Sanitary Code density requirements on other than single-family residential lots, without the installation of an I/A OWTS or connection to sewers; Review options to effect upgrades under the Environmental Conservation Law; New York State Codes, Rules, and Regulations and SPDES. Assess feasibility of updating the Sanitary Code to prohibit the replacement of failed on-site wastewater technology (e.g., "replacement in-kind") without SCDHS approval.

- Implement a comprehensive integrated data collection, analysis and evaluation program to monitor groundwater, drinking water and surface water, and guide informed protection and management strategies.

- Reinstate comprehensive groundwater and stream monitoring program and report annually.

- Implement and upgrade the Bureau of Public Health Protection and Division of Environmental Quality databases and enhance their capabilities to provide a comprehensive integrated geo-coded data management program for all regulated facilities, public, and non-residential private wells (location, pumpage and quality); private well quality; groundwater and surface water quality data; salt water intrusion monitoring data; facility data; inspection records; STP Discharge Monitoring Reports (DMRs) and monitoring data; and on-site wastewater management systems' installation, maintenance, inspection and performance.

- Work closely with federal, state and local partners to share readily accessible, actionable information, identify synergies and share resources.

- Evaluate feasibility of inter-governmental water resource cradle-to-grave data management plan. (USEPA, USGS, NYSDEC, New York State Department of Health, SCDHS, Suffolk County Water Authority, towns and villages, other suppliers, stakeholders, etc.).

- Continue to support and to coordinate with the Peconic Estuary Program, the Long Island Sound Study and the South Shore Estuary Reserve Program to implement projects.

**Safe Yield**

The Long Island aquifer system consists of a sequence of unconsolidated deposits of Late Cretaceous and Pleistocene Age that rest on bedrock beneath Kings (Brooklyn) and Queens Counties in New York City and Nassau and Suffolk Counties to the east. This groundwater system contains four major aquifers – the Upper Glacial, Jameco, Magothy and the Lloyd Aquifers (the Lloyd Aquifer being the deepest of the major aquifers). These aquifers provide the water supply that is used for drinking, domestic, commercial, industrial, agricultural, institutional and fire-fighting uses by residents of Nassau and Suffolk Counties.

The Long Island groundwater system has been designated by the United States Environmental Protection Agency to consist of the sole-source aquifers (SSA) of Brooklyn-Queens and Nassau-Suffolk, as authorized under Section 1424(e) of the Safe Drinking Water Act of 1974. The USEPA defines a sole or principal source aquifer as an aquifer which supplies at least 50% of the drinking water consumed in the area overlying the aquifer with no reasonably available alternative drinking water sources should the aquifer become contaminated. The SSA program enables the USEPA to designate an aquifer as a sole source of drinking water and establish a review area that includes the area overlying the SSA to ensure that proposed projects that receive federal funding do not contaminate the SSA.

The aquifers beneath Long Island have been used for water supply purposes for hundreds of
years. According to the USGS (Nemickas, Mallard & Reilly, 1989), in the mid-17th century, virtually every house had its own shallow well that tapped the uppermost unconsolidated geologic deposits and also had its own cesspool that returned wastewater to the same deposits. By the end of the 19th century, as population increased, individual wells in some areas had been abandoned in favor of shallow public supply wells. During the first half of the 20th century, the contamination resulting from increased wastewater discharges led to the eventual abandonment of many domestic and shallow public supply wells for deeper high capacity wells. By the 1930s, over-pumping in Kings County had induced salt water intrusion; and, in 1947, all pumping for public supply in Kings County was stopped to prevent further salt water intrusion and replaced with water from upstate reservoirs (Buxton and Smolensky, 1998). The introduction of large-scale sewer systems in more heavily populated areas during the 1950s, which protected the aquifers from further contamination, diverted sewage to treatment plants, the bays and the Atlantic Ocean, thereby lowering the water table and reducing or eliminating stream flow.

Safe yield is defined as the maximum quantity of water that can be extracted from an underground reservoir, yet still maintain the supply unimpaired (Todd, 1959). Pumping in excess of safe yield leads to overdraft, which is a serious problem in certain groundwater basins in the United States and elsewhere. Until overdrafts are reduced to safe yields, permanent damage or depletion of the groundwater supplies can be expected.

The safe yield of a (surface water) reservoir of known size and capacity, defines the "maximum quantity of water that can be supplied from the reservoir during a critical period" such as a drought (Alley, et al, 2004). The term safe yield was first used in 1915 (Meyland, 2011). Its meaning has evolved over time, including its more recent use in groundwater studies.

Alley et al (1999) and Maimone (2004) have described the case of Nassau County, New York, as a tradeoff between groundwater quality and surface water quantity. In the 1970s and 1980s, with nitrate concentrations in groundwater increasing due to on-lot septic systems, a decision was made to install sewer lines and treatment facilities in approximately 85% of the Nassau County land area. The treated effluent then was discharged through ocean outfalls. In the ensuing years, groundwater levels dropped by as much as 14 feet in some parts of Nassau County. Thus, a decision had been made to allow for significant surface water and groundwater quantity impacts in exchange for improved groundwater quality.

In contrast to Nassau County, approximately 74% of Suffolk County is unsewered. As a result, most streams in Suffolk County still have relatively undiminished baseflow. Suffolk County officials chose to maintain groundwater and surface water quantity through the widespread use of on-site sewage disposal systems. This decision resulted in some degree of water quality impairment as a result of the use of such sewage disposal systems. Although Suffolk County has not adopted a formal definition of sustainable yield, the acceptable impact to streams has been defined. Permissible sustainable yields have been tentatively defined in water budget areas as percentages of the average recharge rates in order to control saltwater intrusion (Maimone, 2004).

The 1986 Long Island Groundwater Management Plan estimated the safe yield for Nassau County to be 180 MGD. The plan also provided an estimate for Suffolk County of 466 MGD. It should be noted that those were just initial estimates. In addition, different approaches were used to formulate the initial estimates. Detailed scientific study and review is needed to determine actual safe yield. Such a detailed study is underway and is part of the $6 million Long Island Groundwater Sustainability Project that United States Geological Survey is performing for the New York State Department of Environmental Conservation.
It is estimated that Nassau and Suffolk counties together have approximately 60 trillion gallons of groundwater stored within its aquifer system. Additionally, precipitation adds approximately 438 billion gallons of recharge to the aquifers annually (Masterson, 2016). According to the NYSDEC public water supply well pumpage data from 2000 through 2013, total annual pumpage from the aquifer system beneath Nassau and Suffolk Counties is approximately 137 billion gallons (this estimate is for public water supply only). Therefore, total pumping throughout Long Island is less than recharge by precipitation and only a fraction of the overall volume of water already stored in the aquifer system. However, only about 5-10%, or 3-6 trillion gallons, is “drainable” from the aquifers. So, while there is an abundance of groundwater beneath Long Island, judicious and efficient use of it is key to its sustainability. It should also be noted that there are natural discharges or outflows from the aquifer system that need to be maintained with the "excess" water in storage. This includes discharge to streams, and flow to deeper aquifers. Therefore, safe pumpage must be maintained at quantities far below recharge in order to preserve these outflows and keep the entire hydrogeologic system intact.

The 15-year daily pumpage average in Nassau County (from 2000 through 2014) has been 189 MGD, which is in excess of the initial estimated sustained yield of 180 MGD. Average daily water withdrawal in Suffolk County over the same period has been documented to be 187 MGD, which is less than the estimated safe yield of 466 MGD. The following summarizes recharge, withdrawal and underflow to surface water bodies for each county:

**Nassau County**
- On average, 330 MGD of recharge enters the groundwater system.
- Withdrawal, on average, is 189 MGD from the system.
- Therefore, there is 152 MGD of underflow to subsurface sediments and surface water bodies.
- Salt water intrusion is a concern in Great Neck, Port Washington, Glen Cove, Locust Valley, Bayville and the southwestern section of the county.

**Suffolk County**
- On average, 1,120 MGD of recharge enters the groundwater system.
- Withdrawal, on average, 213 MGD from the system.
- 933 MGD as underflow to subsurface sediments and surface water bodies.
- Salt water upconing concerns on North and South Forks.
- Since the 1950s, consolidation of water supply systems in Nassau County has been discussed. Comprehensive studies in 1971 and 1980 formulated recommendations for various degrees of consolidation to address forecasted water supply deficits during the 1990s. Both studies projected that countywide pumpage would exceed permissible sustained yield during the respective planning periods. All water suppliers undertook responsible action during the mid to late 1980s to address potential water deficit concerns by embracing the Nassau County Water Conservation Ordinance (see Section 6.2). The ordinance was promulgated in 1986. Water utilities used this ordinance to promote customer awareness and to educate the public on conserving water.
This data clearly shows that a uniform (applied in a consistent manner to both counties) and more refined method for calculating safe yield must be developed. "The sustainable yield of an aquifer must be considerably less than recharge if adequate amounts of water are to be available to sustain both the quantity and quality of streams, springs, wetlands and groundwater-dependent ecosystems." (Sophocleous, 1998). Some have suggested that a term well-matched to Long Island conditions is "managed yield," which adds a margin of safety to traditionally developed levels of sustainable pumpage. (Meyland 2011). Meyland posits that this determination should be a community-wide assessment, not strictly a "scientifically defined" level of water withdrawal to determine a community assessment of what impacts are acceptable to the interconnected aquifer and surface water system.

The current data shows that Nassau County needs to evaluate water use and implement progressive water efficiency measures based on current pumpage patterns and preliminary safe yield estimates. Although Suffolk County pumpage is below the estimated safe yield, water efficiency strategies and measures should also be implemented to address regional salt water intrusion concerns, reduce the likelihood of wetland loss and reduce the rate at which contamination moves downward into the groundwater system.

**Water Use and Regulation of the Lloyd Aquifer on Long Island, New York**

The Lloyd Aquifer is the deepest of the four major aquifers on Long Island and contains groundwater that is up to thousands of years old and in many places of pristine quality. This aquifer is used extensively in Nassau County and minimally in Suffolk County as a source of public water supply. The aquifer is threatened by increasing salt water intrusion and migration of chemical contamination from aquifer segments in the overlying Upper Glacial and Magothy Aquifers. This report examines the hydrogeological condition of the aquifer, water quality, pumpage, the 1986 Moratorium on new Lloyd Aquifer wells, recharge and monitoring programs. The report also identifies investigations that are needed to further evaluate the condition of the Lloyd Aquifer, including the determination of "managed yield" and "water budget" and to further evaluate salt water intrusion. Lastly, this report provides recommendations for amendment of New York State Environmental Conservation Law (ECL) or the issuance of regulatory decisions by the commissioner of the NYSDEC to improve protection of the Lloyd Aquifer and the North Shore aquifer, which is interconnected with the Lloyd Aquifer, for future beneficial and sustainable use.

This report examines the quality of groundwater in the Lloyd Aquifer, the quantity of supply well pumping, the estimated aquifer recharge, salt water intrusion investigations, monitoring programs and aquifer management and protection needs in accordance with the Nassau County and Suffolk County 2014 legislation that established the Long Island Commission for Aquifer Protection (LICAP).

**United States Geological Survey Investigations and Reports**

The USGS has completed extensive investigations of the Lloyd Aquifer on Long Island that were identified and summarized by Chu (2006). This report states that the earliest comprehensive study of Long Island's groundwater resources was done by Veatch et al (1906) who were the first to name a stratigraphic deposit from Lloyd Neck as the Lloyd Aquifer. Chu (2006) identified subsequent USGS reports that estimated hydraulic properties, potential groundwater yield, regional rates of groundwater movement and the age of groundwater in the four aquifers, including the Lloyd Aquifer. The USGS has mapped Long Island's geologic units, thickness, water table and potentiometric-surface altitudes of the Upper Glacial, Magothy and Lloyd Aquifers and
has reported pumping of the Lloyd Aquifer in western Long Island. The USGS has also studied the geology and groundwater conditions in southern Nassau and southeastern Queens Counties and has demonstrated that the Lloyd Aquifer is hydraulically separated from the overlying units and contains fresh water.

**Lloyd Aquifer Hydrogeology**

The USGS (Chu, 2006) reports that the Lloyd Aquifer (Lloyd Sand Member of the Cretaceous Age Formation) on Long Island extends from central Kings, northwestern Queens and Nassau Counties and northeastern Suffolk County to the east and south. The aquifer deposits may be clear, white, yellow or grey and consist of a fine to coarse sand and gravel with layers of clay, fine sandy clay and clayey sand that give it moderate to low permeability. The Lloyd Aquifer rests upon a bedrock surface, is completely bounded above by the Raritan confining unit (or Raritan Clay), which has very low permeability and is considered by the USGS to be the only fully confined aquifer on Long Island (Chu, 2006). The Lloyd Aquifer’s thickness varies from zero in northern Kings County to more than 500 feet in south central Suffolk County. The depth to the top of the aquifer ranges from about 200 to about 1,500 feet below sea level (FBSL) (Olcott, 1995).

**Groundwater Withdrawal from the Lloyd Aquifer**

Table 1 identifies 46 Lloyd Aquifer public water supply (PWS) wells located in 18 public water systems in Queens, Nassau and Suffolk Counties (Leung and Pilewski, 2016; Young, 2016). The list provides the local and NYSDEC well number, depth and capacity in gallons per minute (GPM) and includes four Lloyd Aquifer wells in Queens County, 37 in Nassau County and five in Suffolk County. Figures 1 and 2 show the location of these wells and select observation wells in Kings, Queens, Nassau and Suffolk Counties, which are referred to later in this report.

### Table 1

**Long Island Lloyd Sands Aquifer Public Water Supply Wells**

<table>
<thead>
<tr>
<th>PWS GPM</th>
<th>WELL</th>
<th>DEC #</th>
<th>DEPTH</th>
<th>PWS GPM</th>
<th>WELL</th>
<th>DEC #</th>
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Note: SCWA: Suffolk County Water Authority; VA Medical Center: Veterans Administration Medical Center; NYAW: New York American Water; WAGNN: Water Authority of Great Neck North.
Table 2 summarizes the quantity of Lloyd Aquifer public supply well pumpage in millions of gallons per day during 19 years of NYSDEC records from 1996 to 2014 (Pilewski, 2016) and compares it to the USGS (Chu, 2006) historical annual average and maximum (peak year) pumping from the Lloyd Aquifer in Kings, Queens Nassau and Suffolk Counties up to 1995.

This Table reveals a decrease in the Long Island average annual Lloyd Aquifer well pumping from 13.84 to 11.3 MGD and a decrease from 28.7 to 14.1 MGD in the total peak year pumping, resulting from the discontinuation of pumping in King and Queens Counties and a significant reduction in peak year pumping in Nassau County.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Kings</td>
<td>0.74 (1929-46)</td>
<td>0</td>
<td>3.0 (1931)</td>
<td>0</td>
</tr>
<tr>
<td>Queens</td>
<td>4.1 (1920-95)</td>
<td>0</td>
<td>8.2 (1944)</td>
<td>0</td>
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<tr>
<td>Nassau</td>
<td>9.0 (1920-95)</td>
<td>10.9</td>
<td>17.5 (1971)</td>
<td>13.3 (2012)</td>
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<tr>
<td>Suffolk</td>
<td>NR²</td>
<td>0.4</td>
<td>NR</td>
<td>0.6 (2007)</td>
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<tr>
<td>Long Island³</td>
<td>13.84</td>
<td>11.3</td>
<td>28.7</td>
<td>14.1</td>
</tr>
</tbody>
</table>

Note: 1. Excludes 0 MGD in 1993; 2. NR: Not Reported; 3. Sum of the Average Annual MGD or Maximum Annual MGD pumping in each county during pumping periods.

Also, the NYSDEC (Leung and Pilewski, 2015) reported that Lloyd Aquifer public supply well pumping in Nassau County, for the 15-year period of 2000-2014, averaged 10.6 MGD, approximately 6% of the 189 MGD average annual public supply well pumping in Nassau County during those years.

**Lloyd Aquifer Recharge**

The USGS (Chu, 2006) reports that the Lloyd Aquifer contains about 9% of Long Island's fresh water, but receives only 3.1% of the recharge through a narrow corridor that is only 0.5 mile wide along the groundwater divide in Kings, Queens, Nassau and Suffolk Counties. The USGS has also estimated that the annual recharge to the Long Island aquifer system is approximately 50% of total precipitation (Petersen, 1986); and has defined the "water-budget area" for Long Island (Cohen et al, 1968) as including about 760 sq. mi. in Nassau and Suffolk Counties excluding the north and south forks in Suffolk County. (Kings and Queens Counties are excluded from the water-budget area because of intensive urbanization and other related factors).

Since the average annual precipitation on Long Island is 45 inches per year (Petersen, 1986), it may be estimated that the total recharge to all aquifers in the "water-budget area" is approximately 814 MGD with approximately 25.25 MGD (3.1%) recharging the Lloyd Aquifer. This estimate of recharge, however, may not consider all of the water lost due to outflow from the Lloyd Aquifer, which for Nassau County has been reported to be as high as 6 MGD (Nassau County, 1998). It is also important to note that as the total volume of fresh water in the Magothy and Upper Glacial Aquifer declines, the amount of water that recharges the Lloyd Aquifer also declines. A distribution
of the total estimated Lloyd Aquifer recharge in proportion to the effective recharge areas indicates that Lloyd Aquifer recharge is approximately 7.25 MGD (29%) in Nassau County and 18.0 MGD (71%) in Suffolk County.

The average annual Lloyd Aquifer pumping in Nassau County (10.9 MGD) substantially exceeds the estimated Lloyd Aquifer recharge (7.25 MGD) indicating a significant deficit (3.65 MGD) condition that is reducing Lloyd Aquifer storage and, hence, inducing salt water intrusion. This deficit and reduction in storage may be even greater than 3.65 MGD depending upon the actual amount of aquifer outflow. It should be noted that these estimates do not include any inflow or outflow across county borders. The threat of a reduction in Lloyd Aquifer storage and eventual depletion has been recognized by NYCDEP when it warned in 2007 that "Currently, the Lloyd Aquifer's resources are depleting, mainly due to the rate of consumption by Long Island communities that is greater than the rate of natural recharge." In Suffolk County, the average annual Lloyd Aquifer pumping (0.4 MGD) is well below the estimated Lloyd Aquifer recharge (17.75 MGD), also not considering outflow losses.

**Lloyd Aquifer Public Supply Well Quality**

Table 3 lists the highest concentration of select chemical constituents detected in the most recently available testing of Lloyd Aquifer public supply wells in Queens County (Cartwright, 2002), Nassau County (Young, 2016) and Suffolk County (Hime, 2016). The NYCDEP (2015) has reported the following range of contaminants in the Queens County groundwater supply system but has not reported the range of contaminants in Lloyd Aquifer supply wells that are part of the system: Iron: ND to 18.9 parts per million (ppm); Manganese: ND to 3.3 ppm; Nitrate: ND to 12.0 ppm; and Volatile Organic Compounds (VOCs): ND to 3,170 parts per billion (ppb).

<table>
<thead>
<tr>
<th>County</th>
<th>Chloride (mg/L)</th>
<th>Iron (mg/L)</th>
<th>Nitrate (mg/L)</th>
<th>Perchlorate (mg/L)</th>
<th>VOCs (ug/L)</th>
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<tr>
<td>MCL/PAL</td>
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<td>10.0</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>Queens (1992/96)</td>
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<td>NR</td>
<td>1.30</td>
<td>NR</td>
<td>23.9 (TTHMs)</td>
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<td>Nassau (2013-2015)</td>
<td>141</td>
<td>13</td>
<td>4.33</td>
<td>1.1</td>
<td>29.8 (Freon 22)</td>
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<td>11</td>
<td>0.12</td>
<td>4.5</td>
<td>1.9</td>
<td>4.4 (TCE)</td>
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</table>

Note: mg/L: milligrams per Liter; ug/L: micrograms per Liter; N/A: Not applicable (there are no public supply wells in Kings County); NR: Not Reported; MCL/PAL: Maximum Contaminant Level (Primary Action Level for Perchlorate); TTHMs: Total Trihalomethanes; Freon 22: Chlorodifluoromethane; TCE: Trichloroethylene.
Chloride, which is found in high concentrations in sea water and road salt, has been detected in Lloyd Aquifer public supply wells in Great Neck (42.1-141 mg/L) and indicates that salt water intrusion is occurring. These levels are, however, below the 250 mg/L MCL, and the supply wells continue to be used. The level of chloride in Locust Valley Water District Well No. 5 (39.5 mg/L), Queens County Well No. 17 (22 mg/L) and Port Washington Water District Well N-2 (19.1 mg/L) indicate potential salt water intrusion. The chloride level in five Lloyd Aquifer public supply wells in Suffolk County (6-11 mg/L) and 22 Nassau County Lloyd Aquifer wells in the communities of Atlantic Beach (1), Bayville (3), Jericho (1), Lido-Point Lookout (3), Long Beach (8), Manhasset (4), New Hyde Park (1) and Westbury (1) that have less than 10 mg/L of chloride reflect pre-development conditions when chloride probably ranged from 3-12 mg/L (Cartwright, 2012). (See Tables 4 & 5 for chloride levels in monitoring wells).

Iron is a naturally occurring mineral that dissolves from aquifer deposits under reducing/oxygen depletion conditions. The highest levels of iron in Lloyd Aquifer public supply wells are found in the barrier beach communities of Atlantic Beach (7.1 mg/L), Long Beach (3.5-13 mg/L) and Lido-Point Lookout (3.16-4.81 mg/L) and require iron removal treatment. Lloyd Aquifer public supply wells inland and on the north shore of Nassau County have iron levels below 1.0 mg/L (< 0.02 to 0.84 mg/L) as do Suffolk County Lloyd Aquifer public supply wells (<0.1 to 0.12 mg/L).

Nassau and Suffolk County Lloyd Aquifer public supply wells have been impacted by nitrate contamination that originates from fertilizer and sanitary sewage discharges. These wells, which contain nitrate below the MCL of 10 mg/L, are located in Locust Valley (3.83-4.33 mg/L), Huntington and Northport (2.1-4.5 mg/L), Great Neck (1.74-3.7 mg/L), Mill Neck (1.42-1.46 mg/L) and Queens County (1.3 mg/L). Lloyd Aquifer wells in the Nassau County barrier beach communities of Atlantic Beach, Long Beach and Lido-Point Lookout have the lowest nitrate levels (<0.05-<1.0 mg/L) and reflect pre-development nitrate levels of less than 0.2 mg/L, measured as nitrogen (Cartwright, 2002).

Volatile organic compounds (VOCs) are found in industrial chemical solvents, paints, refrigerants, cleaning products, adhesives and numerous other products that may be toxic or carcinogenic. Trihalomethanes (THMs), which are typically produced by the reaction of chlorine or other disinfectant chemicals with organic material found in sewage, surface water, drainage or public water supply distribution systems, were the principal VOCs found in Queens County public supply wells where Total THM (TTHM) levels were found at a maximum level of 23.9 ug/L in USGS 1992/1996 testing (Cartwright, 2002). VOCs have also been detected in eight of 37 Lloyd Aquifer public supply wells in Nassau County. This includes: Manhasset-Lakeville Water District Valley Road Well (Freon 22: 29.8 ug/L), which has a VOC removal air stripping tower (AST) treatment; 3 Locust Valley Water District wells (0.6-5.8 ug/L) including Well 5, which has granular activated carbon (GAC) treatment; and four wells in Great Neck (0.5-17 ug/L) including Well 6 and Well 8 that also have ASTs. In Suffolk County, four of five Lloyd Aquifer public supply wells also contain VOCs (0.5-4.4 ug/L) but at levels below the MCL of 5 ug/L for an individual VOC.

Perchlorate, which is a component of rocket fuel, pyrotechnics and Chilean caliche fertilizer, has been detected in one Lloyd Aquifer public supply well in Nassau County (Locust Valley Water District Well No. 4) at a level of 1.1 ug/L and in one Lloyd Aquifer public supply well in Suffolk County (Northport Veterans Administration Hospital Well) at maximum levels of 1.8 and 1.9 ug/L. Perchlorate has not been detected in any of the three SCWA Lloyd Aquifer public supply wells in Huntington.
**Salt Water Intrusion**

The USGS (Luscynski and Swarzenski, 1966) has reported that salty groundwater occurs in southern Nassau and southeastern Queens Counties as three wedge-like extensions that project landward in unconsolidated deposits from a main body of salty water that lies seaward of the barrier beaches in Nassau County and Jamaica Bay in Queens County. The highest chloride content of the wedges is reported to be approximately 16,000 ppm, which is approaching the typical chloride content of sea water (19,400 ppm). A leading edge of the deep wedge of salt water intrusion is located at the base of the Magothy Aquifer and at the shoreline east of Lido Beach extending inland about four miles to Woodmere and seven miles to South Ozone Park. The extent of salt water intrusion in the Lloyd Aquifer, which lies below the Raritan Clay, however, is not known. The USGS report also indicates that along and near the barrier beaches, salty water from the underside of the deep wedge is moving downward very slowly toward the freshwater in the Lloyd Aquifer. The report concludes that the very small increases in chloride detected in Long Beach, Atlantic Beach and Rockaway Park supply wells suggest downward salt water intrusion into the Lloyd Aquifer and possible lateral intrusion from offshore areas to supply wells in the upper beds of the Lloyd Aquifer.

Nassau County reopened a study of salt water intrusion in 1987 (Fitzgerald and Maimone, Camp Dresser & McKe, 1991) and reported that, although the location of the interface of a salt water wedge in the Lloyd Aquifer is not known, the use of a salt water intrusion computer model (DYNSWIM) -- using an arbitrary assumption that the wedge is located three miles offshore projected very slow rates of advance of less than 30 feet per year and only a one-half mile advance of the wedge over a 100-year period. The USGS updated previous studies of salt water intrusion and used a three-dimensional model to simulate salt water intrusion in the four major aquifers in Kings, Queens and western Nassau Counties (Terracciano, 1997; Misut, et al, 2002).

Table 4 presents the results of the testing of two Lloyd Aquifer observation wells in Kings County and four of eight observation wells in Queens County in 1992 and/or 1996 (Figure 1) that were found to have the highest chloride testing results as reported by the USGS (Cartwright, 2002).

<table>
<thead>
<tr>
<th>Observation Well</th>
<th>Location</th>
<th>Chloride (mg/L)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2859</td>
<td>Coney Island</td>
<td>54</td>
<td>1992</td>
</tr>
<tr>
<td>K-3426</td>
<td>Southern Brooklyn near Queens</td>
<td>8,500</td>
<td>1996</td>
</tr>
<tr>
<td>Q-1071</td>
<td>Queens Barrier Beach</td>
<td>56</td>
<td>1992</td>
</tr>
<tr>
<td>Q-0287</td>
<td>Jamaica Bay Island (Howard Beach)</td>
<td>120</td>
<td>1992</td>
</tr>
<tr>
<td>Q-3657</td>
<td>Southern Queens</td>
<td>10,500</td>
<td>1992</td>
</tr>
<tr>
<td>Q-1373</td>
<td>Northern Queens near Flushing Bay</td>
<td>1,300</td>
<td>1996</td>
</tr>
</tbody>
</table>
The chloride levels detected in K-3426, Q-3657 and Q-1373 are far higher than the chloride concentrations detected in coastal Lloyd Aquifer observation wells such as K-2859 in Coney Island, Q-287 in Jamaica Bay and Q-1071 on the Queens County Barrier Beach. The USGS (Cartwright, 2002) suggests that the cone of depression in southern Queens County generated by public supply withdrawal from the Lloyd Aquifer (Buxton and Shernoff, 1995) has caused inland migration of salt water and that the fresh water-salt water interface may be about seven miles farther inland than previously estimated by Buxton and Shernoff. The USGS has also investigated the extent of salt water intrusion in the Lloyd Aquifer in northern areas of Nassau County and published three reports (Stumm, 2001; Stumm, et al, 2002; 2004) that provide information regarding the hydrogeological conditions of the aquifer, including the water table, potentiometric surface and salt water intrusion. A USGS paper (Stumm, 2006) states that the Lloyd Aquifer has been extensively or completely eroded in places and is hydraulically interconnected to a confined Pleistocene Age Aquifer (North Shore Aquifer). This report also states that public supply pumping reduced water levels to as much as 40 feet below sea level and over-pumping has induced eight wedges of salt water intrusion into the aquifer.

Stumm (2006) states that chloride concentrations in Lloyd Aquifer supply wells ranged from 5-10 mg/L and those in the North Shore aquifer were similar. However, six public supply wells (five in the Lloyd Aquifer and one in the North Shore Aquifer) have been shut down due to elevated chloride concentrations. A total of eight salt water wedges have been identified in Great Neck, Manhasset Neck and Oyster Bay, having peak chloride concentrations ranging from 180-13,750 mg/L.

Table 5 presents the results of the Nassau County Department of Public Works (NCDPW, 2005) testing of two Lloyd Aquifer south shore, eight Lloyd Aquifer north shore and one North Shore (Lloyd Aquifer-interconnected) Aquifer observation wells (Figure 3) that had chloride levels which reflect varying degrees of salt water intrusion.

Table 5
Select 2003 Chloride Testing Results Lloyd and North Shore Aquifer Observation Wells (NCDPW, 2005)

<table>
<thead>
<tr>
<th>Observation Well</th>
<th>Location</th>
<th>Chloride (mg/L)</th>
<th>Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-00287</td>
<td>Howard Beach</td>
<td>145</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-10620</td>
<td>Atlantic Beach</td>
<td>45</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12076</td>
<td>Kings Point</td>
<td>780</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12153</td>
<td>Kings Point</td>
<td>5,900</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12793</td>
<td>Port Washington</td>
<td>112</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12508</td>
<td>Port Washington</td>
<td>800</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12318</td>
<td>Sands Point</td>
<td>155</td>
<td>North Shore</td>
</tr>
<tr>
<td>N-12618</td>
<td>Bayville</td>
<td>45</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12790</td>
<td>Bayville</td>
<td>2,850</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12870</td>
<td>Bayville</td>
<td>108</td>
<td>Lloyd</td>
</tr>
<tr>
<td>N-12646</td>
<td>Lattingtown</td>
<td>28</td>
<td>Lloyd</td>
</tr>
</tbody>
</table>
The NCDPW (2005) report also contains a map that shows a 5-foot potentiometric surface depression in the Lloyd and North Shore Aquifers that extends from the southeast corner of Great Neck to the southwest corner of the Manhasset Neck peninsula into the lower area of Hempstead Harbor. This cone of depression suggests that public supply well withdrawals from the Lloyd and North Shore Aquifers has resulted in the inland migration of salt water or salt water wedges as reported by the USGS (Stumm, 2001; and Stumm, et al, 2002; 2004). Chu (2006) reports that nearly all pumping from the Lloyd Aquifer has been in the western part of Long Island and states that the excessive pumpage has led to salt water intrusion in the Lloyd Aquifer in coastal areas.

NCDPW tested a line of progressively deeper Lloyd Aquifer monitoring wells from Long Beach Island to Jones Beach and Tobay Beach (Busciolano and Terracciano, 2013) that show a trend of low to high to lower chloride levels. The westernmost well in Atlantic Beach (N-13682, 1,237 feet deep) has 42 mg/L of chlorides while the next deeper and easterly well in Long Beach (N-13879, 1,400 ft. deep) has 110 mg/L, showing clear evidence of salt water intrusion. The remaining deeper and more easterly wells from Long Beach (1,500 feet deep and 1,600 feet deep) to Tobay Beach (1,800 feet deep) have lower chloride levels (15, 18 and 6 mg/L, respectively).

There is currently very limited USGS monitoring of groundwater levels and no network of deep outpost wells to monitor salt water intrusion in Kings and Queens Counties, and it has been more than 12 years since the position of the fresh water-salt water interface in the Magothy and Lloyd Aquifers was last assessed (done in 2004) (Misut and Voss, 2007). Nassau County has recently provided funding to reinstate the USGS annual well monitoring program; however, that contract expired on September 30, 2017 (Mangano, 2017). The county requested that the state provide a permanent annual funding source for the work which totaled $220,000 for the 2016-2017 federal fiscal year.

The Water Authority of Great Neck North (2013) has developed a Water Conservation plan of action to protect its resources. The plan consists of an aggressive conservation program coupled with a comprehensive well management plan. Under this plan, the Authority has constructed three operating wells off the peninsula to provide some relief for any salt water intrusion on the peninsula.

**Lloyd Aquifer Moratorium**

The New York Environmental Conservation Law (New York ECL) titled "Moratorium on the drilling of new wells in the Lloyd" (ECL, §15-1528) established a moratorium on the granting of new permits to drill public water supply, private water supply or industrial wells into the Lloyd Aquifer or to permit new withdrawals of water from the Lloyd Aquifer. The moratorium applies to all areas that are not "coastal communities" but shall apply to all areas including "coastal communities" for the storage or pumping of water into the Lloyd Aquifer. The moratorium requires that the waters of the Lloyd Aquifer be reserved for the use of "coastal communities," but does not affect the permits of wells that were screened in the Lloyd Aquifer and withdrawing water at the time that the moratorium was enacted (1986). The NYSDEC commissioner, however, may grant exemptions to the moratorium upon a finding of "just cause and extreme hardship." ECL§15-1528 was amended (September 25, 2008) to also apply to the storage or pumping (recovery) of water into the Lloyd Aquifer.

Per ECL §15-1528, the moratorium may only be lifted upon a finding by the commissioner that sufficient research has been conducted providing a sound working knowledge of the details, dynamics, water volume and levels of safe withdrawal appropriate to maintain a safe quantity of
Lloyd Aquifer water. The commissioner must also find that a "workable program is in place that can properly administer a well permit program for the Lloyd Sands water. Such program shall take into account both the localized and regional aspects and implications of Lloyd Sands water withdrawals, with special attention given to the prevention of water contamination and salt water intrusion. The program must ensure that a safe level of withdrawal from the Lloyd Sands is not exceeded" (ECL§15-1528 Moratorium).

The NYSDEC has been directed under ECL §15-1528 to identify those areas of Long Island within the counties of Kings, Queens, Nassau and Suffolk, which for the purpose of that section, shall be considered "coastal communities." ECL §15-1502 defines "coastal communities" as meaning those areas on Long Island where the Magothy Aquifer is either absent or contaminated with chlorides. The NYSDEC, however, has not yet undertaken a comprehensive assessment of what constitutes a "coastal community" as required by the statute, thus the delineation at present has to be determined on a case-by-case basis (Grannis, 2007).

On April 27, 2004, the NYSDEC determined that a permit application (SCWA, DEC Project No. 1-4700-00010/00583) to install a production well into the Lloyd Aquifer was complete, and the application was referred for a hearing by the Department's Region 1 Office (Sanza, 2004). The application requested approval for the proposed construction of a 300 GPM well (No. 3) at the SCWA's Middleville Road well field that would pump Lloyd Aquifer water to blend with water from a Magothy Aquifer well that was contaminated with nitrates. The SCWA application was denied by the NYSDEC in the "Decision of the Commissioner" (Grannis, 2007), which stated that SCWA did not establish that its existing Middleville Road well field was "contaminated with chlorides" and cannot, therefore, be considered an exempt "coastal community" and that SCWA failed to meet the statutory standard of "just cause and extreme hardship."

During 2014, two new applications for the installation of new Lloyd Aquifer wells were submitted to the NYSDEC by public water suppliers in Nassau County, including the Bethpage Water District, which is pending, and the New York American Water-Sea Cliff (NYAW-SC) water system, which was withdrawn on November 3, 2015. NYAW-SC has also submitted a Water Withdrawal Application (WWA) to the NYSDEC to replace the Lloyd Aquifer Well 1 at the Sea Cliff station, which had a screen failure in November 2016, with a replacement Well 1A at the same site. NYAW-SC inserted a new well screen in the existing well as a temporary repair for the 2017 pumping season.

The North Shore Aquifer

The North Shore Aquifer is defined as a sequence of poorly to moderately sorted, dark, olive-brown and olive-gray gravel sand and silt layers (Stumm, 2001). The aquifer was penetrated during drilling in the northernmost part of Great Neck in 1991-1996 where it was determined that the Lloyd Aquifer, the Raritan confining unit and the Magothy Aquifer had been completely removed from the northern part of the peninsula by extensive glacial erosion. The North Shore Aquifer name was introduced as a distinct hydrogeologic unit to represent a sequence of Pleistocene-Age sediments that are confined by a Pleistocene-Age clay (North Shore confining unit), that are in contact with bedrock and hydraulically interconnected with the Lloyd Aquifer. The North Shore Aquifer was also investigated in the northernmost and central part of Manhasset Neck (Stumm, Lange, and Candela, 2002) and in the northwestern, central and northeastern parts of the Town of Oyster Bay (Stumm, Lange, and Candela, 2004).
Stumm (2001) states that the North Shore Aquifer deposits were called the Jameco Gravel and the Port Washington Aquifer by Kilburn and Krulikas (1987). The top of the aquifer ranges from 70-90 feet below sea level (FBSL) in the Great Neck peninsula, 70-300 FBSL in Manhasset and 150-500 FBSL in the Town of Oyster Bay. The aquifer thickness ranges from as little as 5-10 feet to more than 150 feet thick in Great Neck; 50-150 feet thick in Manhasset; and 100-230 feet thick in Oyster Bay. The rapid response of water levels to tides and/or pumping indicates the North Shore Aquifer is moderately permeable and confined (except for one area in Manhasset, where it appears to be semi-confined) (Stumm, Lange and Candela, 2002). Both the North Shore and the Lloyd Aquifers are impacted by pumping and tidal effects and vulnerable to salt water intrusion.

**Long Island Groundwater Study**

On February 25, 2016, Governor Andrew Cuomo announced a series of water quality initiatives, which will include a $6 million Long Island study conducted by the USGS for the management of groundwater across Long Island (Nikic, 2016). An NYSDEC (April 2016) statement indicated that the purpose of the USGS study is to create an updated and enhanced Long Island Regional Groundwater Flow modelling tool for use by the USGS, NYSDEC, Nassau County, Suffolk County and other key water resources management partners in the region. This will enable better management of the region’s groundwater resources, including, but not limited to, managing for over-pumping, salt water intrusion, salt water upconing, plume migration, surface water impacts of groundwater outflow and determining safe-yield. The study will also update the hydrogeologic framework of Long Island to obtain a better understanding of groundwater flow and include the installation of a network of deep Lloyd and Magothy Aquifer observation wells to augment the current monitoring well network and determine the current and predicted future extents of salt water intrusion and salt water upconing.

**Conclusions**

The NYSDEC is the agency that has the responsibility of managing the water resources of New York State and enforcing the requirements of the ECL so as to protect the Lloyd Aquifer from the adverse impacts described in this report. The NYSDEC implements water supply protection programs on Long Island and the Water Withdrawal Application (WWA) permitting program to assure that groundwater resources are properly managed and allocated. The NYSDEC role is critical in assuring that the Lloyd Aquifer is protected and withdrawals allocated in a manner that will preserve this resource. The 1986 Lloyd Aquifer moratorium has been in place for more than 30 years to prevent the installation of new Lloyd Aquifer wells in non-coastal communities. This has helped preserve the aquifer for those communities that have no other cost-effective source of public water supply. The moratorium must be continued in the absence of a finding by the NYSDEC commissioner that a workable program is in place to properly administer a well permit program for the Lloyd Aquifer water with special attention to the prevention of water contamination and salt water intrusion. The program must ensure that a safe level of withdrawal from the Lloyd Aquifer is not exceeded. The absence of such a finding by the NYSDEC commissioner and evidence of continued over-pumping of the Lloyd Aquifer that promotes water contamination and increasing salt water intrusion requires that additional measures be taken to protect and preserve the aquifer and ensure that a safe level of withdrawal does not continue to be exceeded.
CHAPTER 6
MANAGEMENT OPPORTUNITIES

This section addresses several methods for protecting groundwater quality or quantity – by protecting the ground through which precipitation passes, using water more efficiently, reusing water or transmitting from an area with a groundwater surplus to another area with a groundwater deficit.

Land Preservation Opportunities

Land preservation is usually directed with the intent to preserve land for open space purposes. Avoiding future development and the potential adverse environmental impacts thereof also provides a significant direct benefit of water quality protection. Agencies in New York State, Nassau County, Suffolk County and New York City have historically employed land preservation efforts as a goal to protect water supplies. This section discusses measures and efforts affecting water quality preservation, including drinking water consumption rates, public water supply, land preservation, water quality and recharge rates, growth and demand for drinking water resources, water supply needs, indirect and economic benefits of land preservation and water quality protection initiatives and recommendations for further study.

Land and Preservation Needs for Water Quality Preservation

A number of state and regional studies, master plans and other adopted plans emphasize land preservation goals for the purpose of water quality protection. For example, New York State's 2014 Open Space Conservation Plan states, "Preventing development of land in Special Groundwater Protection Areas and Deep Flow Recharge Zones will help ensure the long-term integrity of Long Island's water supply and preclude the need for costly water filtration systems and groundwater remediation efforts." Nassau County's 1998 Comprehensive Plan states, "The first major environmental goal is to protect and preserve the county's critical natural resources, including the wetlands, aquifers, shorelines, water bodies, open space, significant vegetation and nature preserves." The Suffolk County Comprehensive Water Resources Management Plan states, "Preservation of open space is the most effective way to protect ground and surface water quality from a water resources management perspective" (SCDHS, 2015).

Although New York City's public water supply is surface-water dependent, unlike the sole source aquifer system supplying Nassau and Suffolk Counties, New York City protects the quality of its water supply through the acquisition of undeveloped land in the Catskill and Delaware River watersheds. By investing $1.5 billion, primarily in land acquisition, to protect its 2,000 square mile (sq. mi.) watershed, NYC has avoided spending $6 billion to develop a water filtration plant (The City of New York, 2015; NYCDEP, 2014).

The Long Island Comprehensive Special Groundwater Protection Area Plan referred to the "hierarchy of preservation techniques that can be employed to maximize the quantity and quality of future recharge. These techniques range from outright fee acquisition through acquisition of development rights or transfer of development rights to large lot zoning with clustering on one acre parcels." It also stated, "Often the most effective, most complete and often most costly strategy for maintenance of aquifer quality in the Special Groundwater Protection Areas (SGPAs) is to protect the overlying watershed land surfaces by placing undeveloped lands in the public domain, fencing them in and proving adequate policing to ensure against pollution."
In Nassau and Suffolk Counties, approximately 168,000 acres (22% of all land on Long Island) have been protected from development by federal, state, county and municipal governments. Approximately 20%, or 33,600 acres of this protected land, is located in Nassau County while the remaining 80% of the protected open space is located in Suffolk County. In both counties, an estimated 113,000 acres of unprotected, undeveloped parcels consisting of farms, wetlands, forests, meadows and beaches still remain (NCMP, 2010). More than one third of the 113,000 acres is unlikely to ever be developed due to site constraints such as topography or other physical characteristics, but approximately 67,000 acres in Nassau and Suffolk Counties could still be developed (NCMP, 2010). More than 90% of the 67,000 acres, 60,300 acres, is in Suffolk County, and approximately 10% or 6,700 acres of private, vacant, developable land is in Nassau County.

According to the Nassau County Master Plan (2010), the number of undeveloped acres in Nassau County is expected to dramatically decrease from approximately 1,200 acres in 2010 to 250 acres by 2050. The report indicates that development pressure is significant due to competing needs and interests; however, efforts will be made to redevelop property, focus development in existing and emerging downtowns and protect open space.

**Indirect and Economic Benefits**

Land development is typically accompanied by increases in demand on water resources. Community and recreational facilities such as public schools, hospitals, emergency, services and recreational facilities such as parks and athletic fields also can place additional stress on existing water resources. When land is preserved for water supply protection, the increased demands for these resources and facilities are minimized. Preservation results in secondary or indirect benefits that add value to properties and communities. These secondary benefits include: habitat protection, soil conservation and natural groundcover for aquifer recharge protection of scenic resources, preservation of historic and archaeological resources and natural open space. All of these secondary benefits also potentially offer significant quantitative economic benefits such as increased property values and resulting real estate tax revenue, and, in Suffolk County, increased agricultural food production and sales.

A 2012 report titled *The Economic Benefits of New York’s Environmental Protection Fund* prepared by the Trust for Public Land (TPL) states that lands conserved through the Environmental Protection Fund (EPF), New York’s funding source for critical environmental programs, provide valuable natural goods and services such as air pollution removal, water quality protection and stormwater management. The TPL estimated that $23.9 million is saved annually on Long Island in stormwater management and treatment costs due to the natural filtration of stormwater in parks and open spaces. The TPL analyzed EPF-conserved lands and found that every $1 invested by the State of New York returns $7 in economic value in natural resource goods and services alone.

The Nassau County Master Plan (2010) discussed transfer of development rights (TDR), tax revenue and cost saving relative to TDR programs. It states: “The key fiscal advantage of land preservation via TDR is that the assessed value of the preservation parcel is transferred to a receiving site along with the purchased development credit. This prevents the reduction of the local property tax base when property is preserved through other measures (i.e., government/not-for-profit acquisition). This regional planning approach may lead to future municipal cost savings due to the incremental increase in service and infrastructure demand resulting from new development in areas that are already provided with adequate infrastructure.”
Recent proposed amendments to the Community Preservation Fund program in Suffolk’s five eastern towns were approved by local residents to allow funds collected on the program to be used on water quality improvement projects and to extend the self-imposed transfer tax until 2050. Now, a maximum of 20% of each town’s fund may be utilized for implementation of water quality improvement projects, such as: wastewater treatment improvement, non-point source abatement and control program projects, aquatic habitat restoration, pollution prevention, and operation of the Peconic Bay National Estuary program. The funds may not be used to permit or accommodate new growth.

**Water Transmission**

Unlike many parts of the country that have relied on distant water sources (consisting of either large well fields or surface impoundments) and long distance transmission to the points of consumption, Long Island water suppliers have relied on localized supply and distribution of water. It was recognized early on that an abundant fresh water supply exists below the ground virtually everywhere on Long Island; and the most economical and efficient method of providing water to an expanding Long Island population was to acquire land, construct wells as needed in response to population trends and to interconnect these multiple local sources of supply with appropriately-sized pipes for local distribution. The existing water supply infrastructure reflects this practice. Even in areas where regional-scale groundwater contamination has been a problem, such contamination has, for the most part, been handled using a similar localized approach. Beginning in the 1970s, volatile organic compound (VOC) contamination affected numerous wells throughout Nassau and Suffolk Counties. Such contamination has been addressed through the installation of granular activated carbon (GAC) adsorption units or air strippers installed at individual well fields.

Mains supplying water on Long Island are typically 12” to 16” in diameter and are designed to accommodate flows up to several thousand gallons per minute. Well fields are located within one to 2 miles of each other in populated areas. This practice has allowed for local control and local resolution to distribution-related problems. The manifestation of this local approach has been the formation of numerous water purveyors supplying water to a relatively small geographic area.

Nassau County exemplifies this localized approach, with 46 community public water systems serving a 287 sq. mi. area. In Suffolk County, this practice has been modified somewhat, with the formation of the Suffolk County Water Authority (SCWA), which today serves approximately 85% of Suffolk residents. Even so, Suffolk County historically has had a multitude of small- to medium-sized water purveyors serving many parts of the county. Over time, the SCWA has acquired the majority of them. Despite these acquisitions, there still currently are more than 30 other community public water systems and more than 200 non-community systems located throughout Suffolk County. This preponderance of small municipal and private suppliers has suppressed the implementation of a more regional approach to water supply, such as large centralized pumping centers and/or large diameter, high-capacity transmission mains.

The purpose of this report is to discuss the benefits and concerns of transferring bulk water across county lines or between public water supplier boundaries within a county.

**Historical Studies of Water Transmission Opportunities**

Since the 1960s, numerous studies of the groundwater and drinking water resources of Long Island have been prepared. Virtually every one of them has included discussions and
recommendations relating to the transfer of water from a source other than the groundwater underlying a supplier's specific service area. In general, these reports identified issues with salt water intrusion in coastal communities as well as the potential for over-pumping the aquifers beneath Nassau County. The following is a partial listing of some of these studies and the recommendations of each with regard to long-distance transmission of water.

**Comprehensive Public Water Supply Study CPWS-24 (Holzmacher, McLendon and Murrell, 1970)**

This report predicted a water deficiency in Nassau County of 40 million gallons per day (MGD) by 1980 and 200 MGD by 2020 (pp. 179). Two possible plans for transmitting water from central and eastern Suffolk County to Nassau County were analyzed. Plan A would export 120 MGD to Nassau County until 2015 and 80 MGD thereafter, until the year 2020. Implementation would require 80 well fields, approximately 7,000 ft. apart, each with two wells with capacities of 2 MGD each, 55 miles of new transmission main (16” to 60” diameter) along the Long Island Expressway corridor, and two booster stations to maintain water pressure in the mains (pp. 180). Plan B would provide for the export of 80 MGD to Nassau County until the year 2020 using 70 well fields, 48 miles of new transmission main and two booster stations (pp. 181). The cost of these scenarios in 1970 was estimated at $1.9 billion for Plan A and $1.8 billion for Plan B (pp. 237). Adjusted to 2016 with inflation, this equates to $12 billion and $11 billion, respectively. Given the additional costs involved in well and pump station construction today that were not a factor in 1970 (such as additional contaminant sampling and environmental review), these inflation-adjusted costs could easily double or triple.

**City of Long Beach, Nassau County, New York Master Water Plan (Holzmacher, McLendon and Murrell, 1971-1985)**

This report recognized resource limitations and the distribution capacity problems of the Long Beach water supply system at that time and suggested the city "seek and support a county program of providing supplemental water...from new supplies in Suffolk County and from New York City..." (pp. 2). The report also recommended upgraded interconnections to adjacent suppliers to facilitate the wholesale purchase of water from them and also mentioned the possibility of other interconnections to the main body of Nassau County (pp. 120).

**Comprehensive Public Water Supply, County of Nassau, State of New York (Greeley and Hanson, 1971)**

This report summarized numerous other studies, all of which mention predicted deficiencies within Nassau County and possible supplemental supplies, including both Suffolk County and New York City (pp. 50). One particular report that was referenced mentioned the potential for a 50 mile-long aqueduct from upstate reservoirs within the Hudson River watershed to Nassau County, to provide 60-106 MGD by the year 2000 (pp. 52). Another report referenced in this study suggested linking New York City and Long Island water supplies together as well as importing water from Suffolk County into Nassau County (pp. 53-54).

**Long Island Groundwater Management Program [New York State Department of Environmental Conservation (NYSDEC, 1986)]**

Portions of this report mention that the transfer of water from areas of abundance to areas with inadequate supply is an important alternative to consider in supplying these deficient areas (pp.
III-62). The report later suggests interconnection of systems for greater flexibility and better emergency preparedness (pp. IV-75). It also suggests that Nassau County purchase the 72" diameter aqueduct that runs along Sunrise Highway and incorporate it into a county-wide transmission system (pp. IV-78).

**Commonalities Among Studies**

While the overall scope of each of the referenced studies was not exactly the same, similar conclusions and recommendations were made throughout the decades. The following is a brief summary of the most relevant conclusions and recommendations:

- Importation of water from Suffolk County or New York City to Nassau County to reduce pumping in Nassau County and/or to supplement its water supply.
- Interconnections and agreements between Nassau County water suppliers to assist smaller water suppliers most susceptible to salt water intrusion or other sustainability issues.
- Formation of a Nassau County Water Authority to manage the locations of aquifer withdrawals county-wide.
- Shutdown of the Jamaica Water Supply system and connect it to the New York City surface water supply system.
- Installation of centralized drinking water wells and transmission mains to provide water to smaller water suppliers most susceptible to saltwater intrusion or other sustainability issues.
- Purchase of and rehabilitation of the 72-inch aqueduct along Sunrise Highway.

Some of the above conclusions and recommendations have been realized while others have not. A recent attempt to import water from the SCWA into the Village of Farmingdale was unsuccessful due to political objections. Interconnections now exist between all neighboring water suppliers. However, formal agreements may not exist in all cases. The formation of a Nassau County Water Authority has been met with political resistance. The former Jamaica Water Supply wells have been removed from service; however, NYC is currently pursuing the idea of returning these wells to service for possible drought protection. The concept of centralized wells and transmission mains has not been implemented.

**Feasibility of Long Distance Water Transmission**

Since construction of a long-distance water transmission main has never been attempted before on Long Island, developing an accurate cost estimate for such a specific project is difficult. Fortunately, the SCWA has investigated the concept of long-distance water transmission through relatively large-diameter water mains in two areas affected by elevated nitrate levels.

One such estimate consisted of more than 88,000 feet (16.8 miles) of water main ranging in size from 12" to 30" diameter. This main would originate in the Dix Hills area and connect to the Northport, East Northport and Huntington areas, all of which have wells with elevated nitrate levels. This main is designed to transmit approximately 12,000 gallons per minute (GPM), at an estimated cost of $20.5 million or $1.22 million per mile (about $231 per linear foot). The second transmission main project investigated by the SCWA involves construction of a water main connecting Greenport to Orient in the Town of Southold. It would consist of more than 17,000 ft. (3.36 miles) of 12" diameter pipe. With a design flow of approximately 500 GPM, its estimated cost is approximately $3.84 million or approximately $1.14 million per mile (about $216 per linear
foot). There is remarkable similarity in price between the two project estimates, despite the fact that they are quite different in terms of quantity of water, size, and length.

Other area water suppliers have investigated the concept of long-distance water transmission as well. In a recent project under design, the Westchester Joint Water Works (WJWW) has investigated the use of the New York City Department of Environmental Protection Delaware Aqueduct (Shafts 20 and 22) as replacement water for its Rye Lake water source. The cost estimate for the transmission mains, which include mains from 12” to 60” in diameter, ranges from $200 per linear foot for 12” mains up to $3,000 per linear foot for 60” mains.

The WJWW also is investigating the feasibility of a 16” diameter transmission main project. The project design is done by modeling and involves 9,800 feet of 16” inch main. The cost estimate is approximately $5 million or $510 per linear foot. The cost includes a bridge crossing and approximately eight utility crossings.

**Factors Affecting the Current Status of Water Transmission on Long Island**

Many, if not all, Nassau and Suffolk County suppliers have emergency interconnections in place currently. However, formal agreements for the exchange of water do not exist at all interconnections. Further, many of these interconnections are not metered.

Many coastal water suppliers are vulnerable to the impacts of salt water intrusion and would most likely be among the first public water suppliers to consider importing water from neighboring water suppliers. These agreements should be incentivized and implemented.

Water suppliers which are impacted by large contamination sources may benefit from importing water from neighboring water suppliers. A cost analysis will be required to determine whether this is beneficial. Further, the potential impact to the movement of the contamination plume must be understood. Groundwater modeling is required prior to implementing this policy.

Prior to moving large volumes of water from county to county or from supplier to supplier, research must be conducted in several areas:

(Impacts to the aquifer from the supplier providing the water by over-pumping a well or well field that could potentially change aquifer flow patterns and draw in contamination that may affect other supplier’s sources.)

- Jurisdictional boundaries set by state law (franchise territory) when districts and/or authorities were created that prohibit that district or authority from operating or managing systems outside of their coverage area.
- Studies, reports and hydraulic models should be referenced or conducted when investigating the effects of moving large volumes of water from one geographic area to another.
- Development of a regional groundwater model is required to fully understand the sustainability of the aquifer(s). A full understanding of pumpage versus recharge is required in order to make sound policy decisions. Data must be collected on a continuous basis in order to maintain the model into the future.
- A thorough cost analysis must be done. Such an analysis must include the actual cost of installing water mains of appropriate diameter as well as any land acquisition and booster stations that may be needed. The cost of any additional wells to supply water into the transmission mains must also be calculated. Ancillary costs, such as environmental studies, engineering and laboratory sampling, must also be included.
Additional Considerations

Routing

Numerous factors go into the decision on the exact route of a transmission main. Construction-related factors include the road opening permits that may be required from different municipalities (and the resulting necessary restoration), the proximity to wetlands and the mitigation that will be required, the depth to groundwater and any dewatering that may be necessary during construction (including the discharge and/or disposal of the pumped water) and the requirements for jacking or horizontal directional drilling for long underground crossings of creeks or highways. Overall planning-related factors influencing the route include: elevation changes and the number and severity of any bends in the pipeline, both of which dictate head losses along the route of the pipeline and the possible requirement for booster pumps. In order to recover the head loss due to friction and provide water at the proper pressure and at the proper elevation, several booster pumps undoubtedly will be required. Acquiring land for booster pumps as well as the electricity to operate the pumps will add substantially to the overall costs of any transmission project. All of these factors add to the expense of the overall project to a degree indeterminate at this time.

Hydrogeologic Impacts

In addition to the recommendations regarding the infrastructure and facilities required for long distance transmission, more recent studies have attempted to evaluate the potential hydrogeologic impacts of this practice. Since all the water in any scenario involving long distance transmission will be used and recharged a substantial distance from its source, it will be permanently lost from the groundwater system in the area from which it is pumped. This could result in the long-term lowering of the water table in coastal plain ponds and wetlands within sensitive areas (such as the Pine Barrens). The impacts of this hydrologic imbalance will need to be investigated to see if they meet permit criteria. Groundwater models are excellent tools for investigating and quantifying such impacts. In consideration of its transmission proposal as described above, the SCWA utilized the Suffolk County Groundwater Model in order to obtain a rough "order of magnitude" estimate of the hydrologic impacts of a hypothetical scenario involving consumptive pumping from the Pine Barrens area. In this simulation, five pumping centers were chosen each with a pumping rate of 2 MGD, for a total of 10 MGD of total additional pumpage. Each well was simulated to be screened in the middle Magothy Aquifer, in order to minimize impacts to the water table. The simulations resulted in water table drawdowns of up to three feet in some portions of the Pine Barrens at the simulated rate of 10 MGD. Some mitigating measures undoubtedly would be necessary to prevent long-term impacts to surface waters and wetlands. The NYSDEC would be best to comment on the feasibility of and mitigations required for a project of this size and scope.

Permitting

A cross county water transmission proposal would require a coordinated review by local health departments, water suppliers affected, the New York State Department of Health, the NYSDEC and possibly the United States Environmental Protection Agency. A process for evaluation and approval would need to be developed by those involved regulatory entities. As a minimum, it would include the preparation of an engineering report, engineering plans, obtaining public comment and potentially an Environmental Impact Statement. There would be a host of issues that would have to be addressed in the engineering report, including: the source and quality of the treated water, the protection of the water supply, storage and pumping, source and distribution system controls, pressure, flow and water quality monitoring, etc.
Conclusions and Recommendations

The following conclusions and recommendations are offered:

- Incentivize the implementation of intermunicipal agreements for water transfer to water suppliers that are threatened by salt water intrusion or other major sources of contamination.
- This includes the purchase and transmission of water from both New York City and Suffolk County into Nassau County.
- Fund the development of a regional groundwater model to be used for planning purposes.
- Evaluate the potential costs involved.

Efficiency Programs

Efficiency programs tailored to reduce the amount of water consumed offer significant benefits as described in this section. At present, there is no shortage of drinking water on Long Island. However, due to the combination of groundwater pumpage from the aquifers and ocean discharge of treated sanitary waste, the overall volume of water in the aquifers has decreased over the past several decades causing water table elevations to drop and the salt water interface to move landward. This has resulted in a loss or reduction of surface water wetlands such as streams, ponds and lakes. This loss of wetlands has required the implementation of expensive habitat and flow restoration programs in some areas such as Massapequa Creek. Because of changing climate conditions, proactive planning and implementation of efficiency measures to reduce water use will be vital to ensure that future Long Islanders will have both a safe and adequate supply of drinking water and healthy and abundant surface waters.

Proactive water efficiency measures have far reaching financial, emergency preparedness and operational benefits for water suppliers and the communities they serve. These water efficiency measures also can provide significant environmental benefits that result from reduced pumping rates. These benefits include: maintenance of surface water features by minimizing the lowering of the water table, minimizing salt water intrusion incidents and slowing the potential downward movement of contaminants entrained in the groundwater.

Efficient and sustainable use of potable water also will reduce energy demand, since pumping water from wells requires electric power. High-capacity electric pump motors, ranging in capacity from 60-200 horsepower, provide the primary power required to draw water from the aquifer and ultimately deliver it to homes. More efficient use of water will reduce electric demand on the water supplier and ultimately on the entire power system maintained by the electrical utility. In addition, less pumpage, particularly under peak conditions, allows water suppliers to reduce local stresses on the aquifer. This also ensures that an ample supply of water will be available during an emergency (such as a fire).

Water Demand and Usage

Water demand within both counties has been increasing in recent years due to increased usage, primarily from lawn irrigation, as depicted in Figures 1 and 2. This trend is even more significant in Suffolk County (Figure 2).
Figure 1  Water Use in Nassau County from 2000-2014

Nassau County Public Water Supply
Average Daily Pumpage Peak Vs. Non-Peak

Figure 2  Water Use in Suffolk County from 1988-2009

Average Daily Withdrawal Rate, Monthly from 1988-2009, Suffolk County N.Y.
Non-peak or cold weather water demand has been in slight decline in Nassau County and relatively flat in Suffolk County. This can be attributed to specifications in the state plumbing code requiring the use of water-conserving plumbing fixtures in both new construction and building retrofits. Figure 3 illustrates the clear difference between warm (May through September) and cold (October through April) weather pumpage. Peak summer pumpage is more than triple the average winter usage for a typical Long Island water system. Therefore, lawn irrigation is a practice that should be targeted in an attempt to prevent annual water demand from continuing to increase in the future.

**Figure 3**  
**Average Pumpage per Month for a Typical Large Water System**

![Graph showing average pumpage per month for a typical large water system.]

This increased warm weather water demand is largely due to automatic underground lawn irrigation systems. Such systems are more prevalent as real estate values increase and residents and business owners place a higher emphasis on property beautification through landscaping. In order to meet this increased demand, water purveyors need to accelerate their efforts at public education and conservation enforcement.

**Benefits of Efficiency Improvements**

Since best practices take time and planning to effectively implement, water efficiency measures must be proactively implemented prior to the onset of drought and emergency conditions. Effective water efficiency measures will provide numerous environmental, infrastructure and economic benefits while helping to ensure the long-term availability of a high quality drinking water supply. Environmental and infrastructure benefits include: protection of wetlands, prevention of salt water intrusion, better water quality, less energy use, reduced strain on the electric grid and improved drought and emergency response/preparedness.
**Water Quality Benefits**

- Efficient pumpage management assists with addressing water quality concerns.
- The less stress that is placed on the local aquifer segment reduces the potential for drawing contaminants deeper into the groundwater system. This leads to better management of contamination plumes.

**Environmental Benefits**

- Protection of wetlands.
- Prevention of salt water intrusion.

**Energy Use Benefits**

- Water transmission and distribution requires a significant amount of electric power.
- High capacity electric pump motors, ranging in capacity from 60-200 horsepower, provide the primary power required to draw water from the aquifer and ultimately to the home.
- Lower water demand results in lower energy use. Reduces potential for local brownouts and blackouts.
- Less energy that is used the less fossil fuel is used resulting in reduction of greenhouse gas emissions.

**Economic Benefits**

- Since water systems are designed to meet peak day and hour demand, less water demand results in less water supply infrastructure required in order to meet peak demand.
- Less use of treatment chemicals, since less overall water is pumped.
- Lower energy costs. As shown below (what is this referring to) energy costs can range from 20-30% of the budget of a mid-sized Long Island water supplier.
- For consumers, lower water and energy use could lead to lower monthly bills.
- Effective sustainable practices will decrease energy, chemical, maintenance and capital costs.

**Efficiency Implementation Challenges**

Challenges to the successful implementation of sustainable practices include lack of public engagement, the proliferation and widespread improper use of automatic irrigation systems, aging infrastructure, the low cost of water (under valuation) and loss of revenue through metered water sales. To engage the public in order to change water use habits requires proactive public outreach. In order to be effective, outreach and education initiatives must be implemented through various platforms such as schools (engage the younger population to develop good water use habits), civic associations, newsletters, press releases and social media.

Changing habits through public engagement is an obvious and important element for promoting sustainable water efficiency. However, an evaluation and implementation of programs and measures that will achieve large-scale water savings must be undertaken. Such programs should focus on outdoor water use, water rate structure, aging and homeowner leak repair.
Efficiency Opportunities

Irrigation Efficiency Opportunity

Studies disseminated by Cornell Cooperative Extension of Nassau County have concluded that lawns on Long Island tend to be over-irrigated. Irrigation of lawns every other day at a rate of 1 inch per week is sufficient for most areas of Long Island. Because of this overwatering by automated irrigation systems, focusing efficiency efforts in this area yields the greatest potential results. Water suppliers should work with local planning boards to promote water-friendly landscaping and efficient irrigation system design.

The proper design and operation of automatic irrigation systems are vital to efficient use of the resource. Understanding and properly using various water applications, such as spray versus drip irrigation, can have a profound impact on water use. For example, the type of spray head and pattern are critical for optimizing water use. The strategic and proper use of weather sensors (such as solar radiation, temperature, rain and/or freeze sensors), soil moisture sensors and flow control devices can also achieve water savings. Use of smart controllers and weather sensors on lawn irrigation systems will automatically adjust water usage based on weather and soil moisture conditions. Finally, having a good understanding of the watering needs for particular landscape is essential to system design. Proper training and knowledge in the area of outdoor irrigation is necessary to achieve sustainable watering goals.

Irrigation industry professionals can be an invaluable asset in helping use water more efficiently. The Irrigation Association of New York (IANY), established in 1985, is a professional organization of contractors representing all specialties and disciplines of New York State's irrigation industry. It aims to foster development and economic advancement for its members and to promote water conservation through efficient irrigation practices and products. One of the organization's objectives is to support legislation to require irrigation contractors be certified and adhere to "Best Management Practices." The association has introduced the "Landscape Irrigation Contractor Certification Act" in the New York State legislature as a consumer protection measure that will foster adherence to the highest professional standards by irrigation contractors. Certifying irrigation professionals promotes the protection of public health and safety; supports the environmental, economic and social benefits of cultivated landscapes and helps to ensure the efficient use of water resources.

Louisiana, New Jersey, North Carolina and Texas are the only states that require irrigation contractors to obtain a license in order to practice landscape irrigation. The following states have provisions as an irrigation sub-category under plumbing or landscape contracting: California, Connecticut, Oregon, Illinois and Rhode Island. Florida offers a voluntary license that exempts the licensed individual from local irrigation contracting licenses.

In summary, outdoor water efficiency can be optimized through restrictions, efficient landscape design, properly scheduled irrigation (reducing peak demand impacts to water systems), efficiently designed and constructed irrigation systems and the use of technology (rain sensors, tensiometers, etc.). In addition, certification of irrigation contractors can provide Long Island water supply systems with a central database of contractors. This database could prove valuable to water suppliers who can use it to contact irrigation installers for assistance in cases where irrigation systems need to be adjusted or the use of them needs to be controlled or restricted.
Xeriscaping is a systematic method of promoting water conservation in landscaped areas. Although xeriscaping is mostly used in arid regions, its principles can be used in any region to help conserve water. Basic xeriscaping principles consist of the following:

- Planning and design. Provides direction and guidance, mapping water and energy conservation strategies, both of which will be dependent upon regional climate and microclimate.
- Selecting and zoning plants appropriately. Selecting and locating plants that will thrive in the regional climate and microclimate; grouping plants with similar water needs together.
- Limiting turf areas. Reducing the use of bluegrass turf, which usually requires a lot of supplemental watering, and substituting with a turf grass that uses less water.
- Improving the soil. Enabling the soil to better absorb water and to encourage deeper roots.
- Irrigating efficiently. Using the irrigation method that waters plants in each area most efficiently.
- Use of mulches. This keeps plant roots cool, minimizes evaporation, prevents soil from crusting and reduces weed growth.
- Maintaining the landscape. Keeps plants healthy through weeding, pruning, fertilizing and controlling pests.

Maximizing Water System Efficiencies

"Unaccounted-for water" is water that is pumped by suppliers, but is not consumed by their customers. It is calculated by subtracting the water that is billed from the total water pumped. Unaccounted-for water consists of water used for flushing of water mains; water lost to leaks, main breaks and firefighting and numerous other purposes. This water is important to track and understand. As water main infrastructure ages, the potential for water leaks increases. This is critical to determine the effectiveness of conveying water to the consumer with minimal losses in the transmission and distribution system.

In 1996, the American Water Works Association (AWWA) Leak Detection and Accountability Committee recommended 10% as a benchmark for unaccounted-for water. Water systems that are approaching the 10% threshold, or have exceeded it, should strongly consider the implementation of a proactive leak detection program. At a general cost of $120 per mile of water main surveyed, the payback can be considerable when leaks that have not surfaced are detected and repaired. Not only can significant water savings be achieved, leaks can be repaired in a planned manner rather than under emergency conditions that could involve overtime and damage to roads and other utilities.

A leak detection program also should be used in conjunction with a water main replacement program. At a minimum, water mains should be replaced on a 100-year cycle. It should be noted that many factors contribute to main breaks and failure that can drive the need for water main replacement. These factors can include pipe age, pipe material, soil conditions, pipe laying/bedding conditions, temperature (internal water and ambient soil), frost load (related to soil temperature), traffic loading conditions, surges and higher than normal operating pressures.

Accurate metering of source water (pumped from wells) and consumption (water service lines) are vital to obtaining an accurate understanding of water use and loss. Proper meter management will control apparent water losses and provide a better understanding of water use patterns.
Metering strategies include the following:

- **Meter management**: This includes meter selection based on flow requirements, meter type and selection critical to accurate metering as well as the development and implementation of testing and replacement schedules.

- **Calibrate production/plant-site metering** that includes venturi tubes, orifice plates and other metering devices. AWWA recommends testing and calibration every year.

- **Customer meter testing/replacement program**.

Challenges to the successful implementation of sustainable measures include the potential loss of revenue. Reduced water use can result in lower revenue, but that can be offset by decreased operating, maintenance and capital expenses associated with lower water production. In addition, effectively crafted water rate structures can also assist with maximizing revenues in the face of decreased water demand. Since water system customer bases vary, careful consideration of rates must be provided to determine the best application of uniform, inclining and seasonal rates. Water tends to be undervalued and underpriced with rates that generally do not reflect the true cost of the resource and the need for infrastructure investment and/or replacement. The figure below from the American Water Works Association provides an overview of the price of water across the United States depicting the monthly combined water and sewer prices trends from 1998-2014.

**Typical Water and Wastewater Bills***

*Residential monthly water or wastewater bills at a usage level of 7,460 gallons/month CPI, starting with the average of the water and wastewater bills in 1988, this level increase based on changes in the Consumer Price Index (CPI) provided by the Bureau of Labor Statistics*

For more information, see the Water and Wastewater Rates webpage at awwa.org
Indirect Potable Water Use

Indirect potable reuse is currently in place in many municipal water systems outside of Long Island in which wastewater is treated to remove pollutants and released into local bodies of water. Once the effluent is released and mixed with the local water bodies, the water is pumped out to a municipal water supply and redistributed to its customers. However, there are instances where the middle step that releases treated effluent into local bodies of water is skipped. This is called direct potable reuse, and, although it is less common, it has been part of a solution in response to the recent droughts that have riddled arid regions of the country such as California.

Water reuse for non-potable situations is commonplace in the United States. According to the USEPA, approximately 2.2 billion gallons of water are reused daily in the United States. Florida, California, the arid Southwest and Virginia lead the way. The primary outlet for the reused or reclaimed wastewater is for irrigation purposes on golf courses, other green spaces and on a variety of agricultural crops, including both non-food and food products.

Industrial Reuse

Industrial reuse is one of the more prevalent forms of wastewater reuse in large-sale operations, typically used for cooling purposes. Because industry can account for significant water demand, many large operations outside of Long Island have implemented their own private treatment plants. This avoids tapping into the municipal water supply to meet non-potable operational needs such as cooling and washing.

Residential Reuse of Potable Water

On a residential scale, there are various options based on local circumstances. For instance, if an area typically requires septic tanks, people in that area could incorporate their own wastewater treatment system. There is also the option to avoid reusing wastewater as whole and instead use the water from daily tasks like laundry, showering and washing dishes. In this form, the reused water is called grey water and can be used for non-potable purposes such as laundry, toilets and irrigation.

Reclaimed Wastewater for Irrigation Water Reuse

Perhaps the most environmentally sound strategy for supplying water for the irrigation of landscaped properties, agricultural crops and golf courses is through water reuse. This involves irrigation utilizing wastewater from either a regional sewage treatment plant or a homeowner’s on-site sanitary system (with appropriate treatment) rather than using water pumped from Long Island’s underground aquifers. An important benefit of using reclaimed wastewater for irrigation purposes is that it can improve water quality in the receiving waters into which the wastewater was formerly discharged. Perhaps, as importantly, reusing wastewater for irrigation purposes can supplant the consumptive use of groundwater from the Upper Glacial Aquifer, thereby reducing stress on the groundwater system due to reduced pumping.

Reclaimed wastewater from sewage treatment plants has been reliably and safely used for irrigation purposes for many decades throughout the United States, most notably in California, Florida and the arid Southwest. The main recipients of the treated effluent have typically been golf courses, landscaped green spaces and non-food crop agricultural areas. Other uses have included industrial cooling and wetland creation and supplementation. As of 2008, the United States used approximately 2.2 billion gallons of reclaimed wastewater per day for these purposes.
Additionally, reclaimed wastewater has been used in a number of other countries, such as Israel, where 70% of the wastewater is reused for irrigation and other purposes. During this time a very extensive and comprehensive performance record has developed and no known human health problems have emerged from the use of and exposure to reclaimed water in these applications.

The general Long Island-wide benefits of water reclamation are significant. First, widespread reuse of highly treated wastewater, from the many publicly- and privately-owned sewage treatment plants, can achieve meaningful reductions in the total amount of nitrogen discharged directly to the Island's groundwater and coastal waters. This is accomplished by redirecting nitrogen-laden wastewater from these resources to beneficial reuse applications as mentioned above, some of which take up the nitrogen as a plant nutrient. Second, using reclaimed wastewater can reduce stresses on the Island's groundwater supplies since the reclaimed wastewater supplants the use of groundwater, thereby reducing pumping by an equivalent amount.

NYSDEC data on reported pumpage for golf course irrigation wells for the years 2010 and 2014 show that a total of approximately 2 billion gallons per year of water is pumped by golf course irrigation wells each year (it should be noted that the estimates provided did not include every golf course as there are some with no available data). Additionally, there are some golf courses that also utilize potable water for at least a portion of their irrigation requirements. Golf course irrigation is considered to be purely consumptive use of water, since virtually all water utilized for this purpose is lost to the aquifer system via either plant uptake or evaporation. Little, if any, irrigation water is recharged back to the aquifer system.

In this regard, there are several obvious benefits resulting from the reduction in the amount of water pumped from the Long Island aquifer system. From a water quality perspective, the less water pumped generally means a slower downward movement of contaminants through the aquifer system. Another key benefit has to do with water quantity: reducing pumpage minimizes water table drawdown, thus preserving surface water features such as lakes and streams and possibly preventing the landward movement of the fresh water-salt water interface in certain areas. There are also potential energy savings and a reduction in quantity of fertilizer required.

As an example of the reuse of potable water for irrigation purposes is the recently completed water recycling project between Suffolk County and the Town of Riverhead. This project (initiated in the summer of 2016) will redirect approximately 350,000 gallons per day of tertiary-treated wastewater from the Riverhead Sewage Treatment Plant (STP) away from the Peconic River to the adjacent Indian Island County Golf Course for irrigation of the turf grass.

Engineers involved with the project have determined that this single project will eliminate 2,000 pounds of nitrogen annually from entering the Peconic Bay/River system, and will eliminate the need to pump approximately 66 million gallons of water annually from the Upper Glacial Aquifer. An added benefit of the project will be financial savings to the golf course from reduced energy costs as a result of less pumping and lower fertilizer costs due to the elevated nitrogen concentration of the reused water which encourages plant growth. While this example involves two adjacent properties (which represents the ideal situation, economically and operationally), many water reuse projects may involve transmitting water over greater (but still feasible) distances. The Suffolk County Department of Planning has documented 26 golf courses within the county situated within one-half mile of a sewage treatment plant. Other potential recipients of treated effluent for irrigation include sod farms and other non-food agricultural crops such as nurseries, Christmas tree farms, floriculture and hay fields.
Emerging sewage treatment technologies for on-site sanitary systems can potentially assist homeowners in irrigating their landscaping and lawns. In these systems, the treated wastewater is dispersed through narrow tubes situated about 6-12 inches below the ground, collectively known as the drain field. The shallow depth of the tubes allows for the water to be taken up by the roots of the turf grass. A significant advantage to this approach is that there is little to no opportunity for the wastewater to come into direct human contact. While these systems do not entirely replace the need for irrigating turf grass (since the drain field covers only a portion of the lawn area), they can reduce the amount of groundwater used for residential landscape irrigation.

**Additional Strategies**

On Long Island, two additional strategies need to be undertaken in order for the potential of water reuse to be fully realized. The first is for the NYSDEC to promulgate the enabling rules and regulations required to implement Title 6 of Article 15 – Water Efficiency and Reuse. The second is to undertake an Island-wide water reuse feasibility study which assesses the technical, logistical, financial and social dimensions of water reuse so as to provide a roadmap and blueprint for its implementation Island-wide.

Industrial reuse of treated sewage effluent also has some conservation potential. For example, the Port Jefferson Village STP is adjacent to the Public Service Enterprise Group (PSEG) power plant. Using treated wastewater to cool the plant rather than utilizing water from the Port Jefferson Harbor (as is the current practice), could have positive impacts on the ecosystem of the Harbor.

Other strategies that can be employed to achieve practical and sustainable water savings include:

- Water use audits for top users.
- Homeowner assistance programs to repair leaks and install water efficient devices.
- Plumbing code enforcement.
- Plumbing retrofit.

**Conservation Pricing**

Americans are not accustomed to paying and have been largely unaware of the true cost of treating and delivering clean, safe water to their taps. Americans pay less for water – about a penny per gallon on average – than do residents of most other developed nations. The historic underpricing of water is largely due to a perception that water is “free” – a fundamental human need supplied by the earth itself. The vast infrastructure required to treat and deliver that water where it is needed, however, is far from free.

Water rate structures should be designed to promote water efficiency and investment in water infrastructure replacement. In most instances on Long Island, water is the smallest part of any utility bill. For many, if not all water districts, the monthly cost of water for the average residential homeowner (based on water rates and property taxes) is less than broadband Internet service, despite the fact that water is vital to public health. Full-cost pricing will not only help water utilities continue to provide customers with safe and clean water, but will have the added benefit of encouraging more conservative use, ensuring a sustainable supply for future generations.
Alternative Water Sources and Technologies

The utilization of alternative water sources and technologies could supplement or even replace a portion of traditional fresh groundwater sources and help to alleviate aquifer stresses resulting from overpumping and reduction in recharge. The most common examples of alternative water supplies are desalination and aquifer storage and recovery. These technologies are in widespread use throughout the United States and internationally, though they are not developed on Long Island. Alternative technologies are generally higher in cost and require more technical expertise than simply pumping a new source of fresh groundwater. However, as more complications arise that may inhibit conventional groundwater extraction, Aquifer Storage and Recovery (ASR) and desalination may merit additional consideration locally. Additional water resource alternatives include non-potable reuse or supplemental use from such sources as: rainwater from roofs; stormwater collected from at- or below-grade surfaces, gray water and blackwater taken from the wastewater stream, water discharged from industrial processes and even condensate water from air handling units. Some municipalities, particularly in drought prone areas in the western United States, have extensive reclaimed non-potable water programs. These are discussed in the following sections.

Desalination

Desalination is the removal of salts or other dissolved substances from seawater and/or brackish groundwater to produce water that is suitable for potable water needs. In areas of the United States, the "drought resistant" nature of desalination makes it an attractive alternative to those water sources that rely on rainfall [Florida Department of Environmental Protection (FDEP), April 2010, pp. i] or plentiful surface water supplies.

Desalination technologies include reverse osmosis (RO), electrodialysis reversal (EDR) and thermal distillation (TD). The type of source water (surface or ground, salt or brackish), the desalination technology employed and the concentrate management method used are significant factors affecting the environmental evaluation and regulation of these facilities. In addition, desalination technologies have greater energy consumption and associated greenhouse emissions compared to other traditional water supplies (FDEP, April 2010, pp. ii). According to the FDEP, "as the salt content of the source water increases from brackish water to seawater, there is a proportional increase in the energy usage and greenhouse gas emissions" (April 2010, pp. ii).

Reverse Osmosis (RO)

Reverse osmosis uses pressure to force a solution through a membrane that will hold solute (waste concentrate) on one side while allowing solvent (potable water) to pass to the other side. Membranes used in this process are "semi-permeable," meaning the membrane will allow solvent (water) to pass, but not solutes such as salt ions. RO removes the broadest range of substances of the three technologies, but in general, it has been energy intensive and involves costly operation and maintenance. Recent membrane improvements have lowered the costs and improved efficiency (FDEP, April 2010, pp. 18).

Electrodialysis Reversal (EDR)

EDR desalination is also a type of membrane process. An electric current draws dissolved salt ions through an electrodialysis stack consisting of alternating layers of cationic and anionic exchange membranes. The result is ion-charged salts and other chemicals are electrically pulled
from the source water to produce the finished water. (FDEP, April 2010, pp. 19). EDR has the lowest energy requirement of the three primary desalination technologies but it has inherent limitations. It works best at removing low molecular weight ionic components from a feed stream. Non-charged, higher molecular weight and less mobile ionic species often will not be removed. Also, in contrast to RO, EDR becomes less economical when extremely low salt concentrations in the finished water are required (FDEP, April 2010, pp. 19).

**Thermal Distillation (TD)**

The basic concept of thermal distillation is to heat a saline solution to generate water vapor and direct the vapor toward a cool surface where it will condense to liquid water. The condensate is mostly free of the salt. Thermal distillation is the oldest desalination method used and, until recently, provided the most worldwide production of water. According the 19th International Desalination Association plant inventory [Global Water Intelligence (GWI), 2006b], in 2006, thermal distillation technologies represented 43% of the total worldwide desalination capacity. Membrane technologies accounted for 56% of the capacity. However, it is very energy intensive and is less efficient at removing volatile substances such as VOCs or ammonia. It is most efficient when treating higher salinity source waters. With the cost of RO-produced water decreasing, the use of distillation technology is declining (FDEP, April 2010, pp. 19).

**Desalination Issues and Considerations**

Disposal of waste brine can present environmental challenges. Desalination produces a salt concentrate. The concentration of the waste brine depends largely on the initial salinity of the raw water. Brackish ground and surface waters are preferred over seawater for this reason. If located near a seawater body, the concentration of the waste brine from brackish water desalination could closely match that of seawater, thereby minimizing the environmental impact of brine disposal.

Among the disposal methods in use are surface water discharge, discharge to sewers, deep well injection, land application, evaporation ponds/salt processing and brine concentration. The brine disposal option used depends mostly on the plant location and desired efficiency. For inland brackish groundwater desalination plants, surface water discharge, sewer discharge and land application can increase the salt load in the receiving waters and soils, which may contaminate water resources and reduce soil fertility. Evaporation ponds often require large land areas and are appropriate only in arid climates and, like other brine concentration techniques, they typically require impervious disposal areas to prevent contamination of fresh water supplies and soils.

Deep well injection is not permitted in many states. However if deep wells were to be allowed, it is likely that it would require permits, monitoring wells and possibly completion of the wells in deep confined aquifers to protect freshwater supplies. The Safe Drinking Water Act of 1974 gave the United States Environmental Protection Agency authority to manage disposal and reuse of concentrates and brines resulting from the desalination of brackish groundwater through the Underground Injection Control (UIC) Program.

**Other Considerations**

Desalination processes require significant amounts of energy. Generally speaking, the higher the salinity and total dissolved solids (TDS) levels of the raw water, the higher the energy cost of the desalination process. The base cost of energy (along with the previously mentioned costs associated with brine disposal) is a key factor in the relatively high total cost of desalination. In 2010, the United States average cost for treating 1,000 gallons of water was $2.00. Even though
desalinated brackish groundwater is becoming increasingly cost-competitive, particularly in areas of the country such as the southwestern United States where water scarcity is a problem, desalination remains a more expensive process for producing potable water [National Ground Water Association (NGWA) Information Brief, Brackish Groundwater, 2010, pp. 2-3].

According to the NGWA, desalination systems have recovery efficiencies of 60-85% for brackish groundwater, which means 15-40% of the available water is not used but is instead disposed of as a concentrate stream. Improving recovery efficiencies to 90 or 95 percent would significantly reduce concentrate disposal volumes, extend the supply of brackish resources and potentially reduce overall desalination costs (NGWA Information Brief, Brackish Groundwater, 2010, pp. 2-3).

Aquifer Storage and Recovery (ASR) and Artificial Recharge (AR)

Aquifer Storage and Recovery and Artificial Recharge are processes that convey water underground. These processes replenish ground water stored in aquifers for beneficial purposes. Although the terms are often used interchangeably, they are separate processes with distinct objectives.

Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is a water resources management technique for actively storing water underground during wet or "off peak" periods and subsequently recovering it when needed, usually during dry or "peak" periods. The timeframe between water injection (or "storage") and pumping (or "recovery") cycles can range from months to decades. Intentional aquifer storage, with the intent of using the water later, has been used for hundreds of years, but is being further developed and refined as demand for fresh water threatens to exceed supply in California and many other parts of the world. Many states (including, but not limited to, Arizona, California, Florida, Nevada and Texas) have ASR sites ranging from pilot projects to full operations.

As population centers grow, some of the water resources historically used for irrigated agriculture shifts to urban uses, suggesting that additional storage in and near urban areas may be needed. With limited space in urban settings, underground water storage through artificial recharge is an increasingly attractive option. Long-term pumping rates in excess of recharge can have adverse hydrogeologic effects, such as reducing aquifer potentiometric pressures, lowering water tables, causing land subsidence and infrastructure damage, impairment of water quality and significantly increasing pumping costs. Pumping this water is similar to mining a non-renewable resource, a practice called "overdrafting." To control or even reverse the adverse effects of overdrafting, artificial recharge can be employed. Many coastal aquifers have been overdrafted for decades. One of the results has been a reversal of groundwater flow, causing seawater to be drawn inland through the aquifer, making water in affected aquifers unsuitable for most uses.

Although ASR has been used for a long time, the development of ASR facilities in an area with complex water management demands and practices (such as California) requires comprehensive information on the physical and chemical characteristics of the recharged geologic formations and the quality of recharge water. In addition, ASR facilities must be integrated with local and regional water distribution systems to allow optimal use of available water resources, legal control of stored and recovered water needs to be established and potential off-site effects should be identified and evaluated to avoid unintended consequences.
Historically and currently, spreading basins are the primary technique used for artificial recharge. Ideally, basins are located in or adjacent to natural streams, have sand or gravel beds and good hydrologic connection to a well-defined, high storage capacity aquifer. However, such ideal conditions are rare. Techniques continue to develop and evolve, enabling water managers to recharge water at higher rates in areas with geologic materials that do inhibit relatively rapid recharge. At the opposite end of the AR spectrum from spreading basins, are aquifer injection wells that are designed to place recharge water directly into an aquifer. The same wells may be used for recovery. In general, water quality requirements are much more stringent for aquifer injection vs. surface disposal.

The quality of water used for ASR purposes should be consistent with existing and anticipated groundwater uses. This can mean that stored water must meet drinking water standards prior to storage. The USEPA sets maximum contaminant levels for trace elements, different types of organic carbon, microbial (biological) contaminants, trihalomethanes (THMs) and many other potential contaminants to ensure that the water is safe for human consumption. THMs are disinfection by-products formed by the reaction of dissolved organic carbon in water that has been chlorinated to meet microbial drinking water standards. Water may also be chlorinated prior to injection to control "biofouling" or plugging of wells by bacterial growth. The injection of treated surface water has resulted in the recovery of water with concentrations of THMs that exceed drinking water standards. One of the most common water quality problems associated with ASR projects is elevated concentrations of dissolved solids or salts. The major soluble cations (calcium, magnesium and sodium) and anions (sulfate, chloride and bicarbonate) are often higher in recharge water than in native groundwater. This is usually not a health issue, but changes in taste, scaling in household appliances and "hardness" may cause complaints from water users.

Chemical reactions between groundwater and recharge water can create other problems such as mineral precipitation and mobilization of trace elements. Mineral precipitation can be sometimes avoided by adjusting pH or other properties of the recharge water. Study of the aquifer system matrix materials and water can identify trace elements or other contaminants that might be mobilized by ASR processes. Knowledge of the presence and distribution of anthropogenic and natural contaminants in an AR project area is needed to avoid mobilization of contaminants. In Yucca Valley, California, a potential source of nitrate contamination of an aquifer was shown to occur from septic tank seepage. Seepage can cause high nitrate levels in the unsaturated soils between the septic systems and the water table. When ASR was used in the Yucca Valley groundwater basin, rising water intercepted the nitrates in some cases causing nitrate levels to exceed the USEPA's maximum contaminant level.

Physical, biological and chemical clogging of infiltrating surfaces and injection wells with the resulting reduction in infiltration rates is perhaps the most obvious problem in ASR systems. Although spreading basins are less prone to serious plugging than injection wells, recharge water should be of an adequate quality to avoid clogging the infiltrating surface. Clogging can be caused by precipitation of minerals on and in the soil, entrapment of gases in the soil, formation of biofilms and biomass on and in the soil and by deposition and accumulation of suspended algae and sediment. Pretreatment of the water can greatly reduce suspended solids and nutrients, but the infiltrating surfaces usually require periodic cleaning to maintain infiltration rates.

Surface infiltration systems require permeable soils and relatively thick unsaturated zones to get water into the aquifer. Aquifers recharged from infiltration basins must be unconfined and have sufficient transmissivity to allow lateral flow of the water away from the infiltration sites to prevent excessive groundwater mounding. Soils, unsaturated zones and aquifers should be free of
significant contamination. Locations that do not have sufficiently permeable soils and/or available land area may be able to recharge groundwater through vertical infiltration systems (trenches, ditches, wells) in the unsaturated zone. For direct injection through wells, water is pumped or gravity-fed into confined and unconfined aquifers. Clay lenses, faults and other features that can significantly retard the movement of recharged groundwater can render a seemingly straightforward ASR project only marginally effective or worse.

A potential hazard that can occur from ASR/AR is liquefaction, caused by creating a very shallow water table in poorly consolidated geologic materials that is subsequently shaken by an earthquake of sufficient magnitude. San Francisco’s Marina District was a well-publicized example of liquefaction immediately following the 1989 Loma Prieta Earthquake, where structures were shaken off their foundations. Such areas are often popular building sites because they tend to be fairly level and may have readily available groundwater supplies.

A primary issue of importance for water managers is water supply reliability. One aspect of reliability is the physical proximity of stored water to users of that water. In southern California and many other urbanized areas, there is a heavy dependence on aqueducts hundreds of miles long to maintain water supplies. Aqueducts and their support facilities are subject to damage and potentially extended periods of service interruptions by natural hazards such as earthquakes, landslides and even floods. They are also potential terrorist targets. The extensive use of ASR in urban areas can mitigate the effects of interrupted water import capacity by increasing the volume of water stored near users.

**Artificial Recharge**

Artificial recharge (AR) is used solely to replenish water in aquifers. Water used for artificial recharge can come from a variety of sources, including: perennial and intermittent streams; water imported through aqueducts and pipelines; storm runoff from urban, suburban and agricultural areas, irrigation districts and drinking water and wastewater treatment plants. On Long Island, a form of AR has been practiced for many years by conveying precipitation and resulting runoff into recharge basins or "sumps" for recharge. These basins are located within existing development and the recharge they provide has offset some of the water table declines resulting from regional sewering.

Elsewhere, reclaimed water is becoming an important resource that can be treated and processed to meet or exceed standards and, in some instances, is the highest quality water available for artificial recharge. If AR is used for recharge without sufficient understanding of the hydrogeologic conditions and near surface saturation occurs, an earthquake of sufficient magnitude can destabilize foundations and destroy buildings with loss of many lives. In California, earthquakes are an everyday occurrence and this is a significant risk.

In addition to intensively managed artificial recharge programs, there are a number of land use practices that can increase water recharge:

**Other Methods to Increase Recharge**

Enhanced recharge through vegetation management involves replacing deep-rooted vegetation, like trees, with plants with shallow root systems can increase recharge rates. However, there may be unintended consequences such as habitat destruction, increased surface water temperatures and sedimentation of streams and reservoirs.
Induced recharge alters groundwater flow patterns (or "gradients") to induce water movement from streams to adjacent groundwater systems. This may be a deliberate management technique or an unintended consequence of pumping. The natural filtration provided by the sediments in the vicinity of the surface water body can be used to "pretreat" water as it moves through stream bank and channel bottom sediments before recovery and treatment to use in public water supplies.

Incidental recharge created by enhanced surface water management may result in additional recharged water even though recharge was not an original objective. Urbanization, with land covered with impermeable surfaces, produces more runoff and has less evapotranspiration than comparable un-urbanized areas. Urban runoff can be collected and stored in holding ponds for flood control or, increasingly, to help meet total maximum daily load (TMDL) requirements in streams. There are inherent conflicts in the management of storm runoff water. For some managers, there is a need to retain "first flush" waters with relatively high contaminant levels to meet water quality standards in receiving streams. Others want to have the first flush discharged to allow the capture of subsequent cleaner water for artificial recharge operations.

Resolution of these kinds of competing objectives is an ongoing process. Other activities contributing to incidental recharge include deep percolation of irrigation water (to prevent salt accumulation in the root zone) and wastewater discharge from septic tanks (Aquifer Storage and Recovery, United States Department of the Interior, United States Geological Survey, URL: http://ca.water.usgs.gov/misc/asr/index.html.).

**Alternative Water Sources**

Buildings often may have water uses that can be met with non-potable water from alternative water sources. Alternative water sources are those not supplied from fresh surface water or potable groundwater and that offset the demand for fresh water. Examples of alternative water sources include: harvested rainwater from roofs, on-site storm water, gray water, discharged water from water purification processes, on-site reclaimed wastewater and captured condensate from air handling units. Though there may be some water quality requirements for non-potable supplemental water, such alternative water is usually not treated to potable standards and is therefore not safe for human consumption. Common uses of alternative water include: landscape irrigation, ornamental pond and fountain filling, cooling tower make-up and toilet and urinal flushing.

**Rainwater Harvesting**

Rainwater harvesting is the collection of rainwater from rooftops that is then diverted and stored for later use. Captured rainwater is often used to irrigate landscaping because the water is free of salts and other harmful minerals and typically requires only minimal treatment. Rainwater harvesting can help to manage stormwater by reducing the amount of runoff, which eases flooding and erosion, and by allowing it to soak into the ground, turning stormwater problems into water supply assets. Less runoff also means less contamination of surface water from sediment, fertilizers, pesticides and other pollutants that might be transported in rainfall runoff.

The major components of a rainwater harvesting system include:

- Roof surface.
- Gutters and downspouts to carry the water to storage.
- Leaf screens to remove debris.
• First-flush diverter that prevents the system from collecting the initial flow of rainwater.
• Cisterns/storage tanks to store the harvested rainwater.
• Conveyances to deliver the stored water either by gravity or pump.
• Water treatment system to settle, filter and disinfect the water, if required.

The level of treatment required for harvested rainwater depends on how the water will be used. Minimal treatment is required for irrigation uses. However, at a minimum, a rainwater harvesting system should have a leaf screen and a method to settle out suspended solids.

Rainwater collection and distribution systems can be incorporated into almost any site, although it is easier to incorporate them into new construction. Rainwater harvesting systems may require a permit from local or state government. According to *The Texas Manual on Rainwater Harvesting*, 620 gallons of water can be collected per inch of rain per 1,000 square feet of catchment area. All rainwater systems require some degree of maintenance, which should include monitoring collection tank levels, periodic cleaning of system parts (including gutters and first-flush diverters), monitoring for leaks, maintaining treatment systems (including filter replacement) and disinfection equipment and testing for water quality.

**Stormwater Harvesting**

Stormwater is precipitation runoff over at- or below-grade surfaces that does not soak into the ground but has not entered a waterway such as a stream or lake. Much like rainwater described in the previous section, stormwater can be harvested and reused for irrigation, wash applications, cooling tower make-up or process water, dust suppression, backup fire protection, vehicle washing and other non-potable uses. Stormwater harvesting differs from rainwater harvesting in that runoff is collected from ground-level hard surfaces such as sidewalks, streets and parking lots rather than from roofs. The characteristics of stormwater harvesting and reuse systems vary considerably by project, but most include collection and storage (temporarily in dams or tanks awaiting use in non-potable applications), treatment and distribution. The benefits of stormwater harvesting include reduction of pollutants and potential flooding from large water events that flow to surface water. Other benefits include reduction of stream bank erosion, sewer overflows and infrastructure damage.

Captured stormwater normally requires more treatment than captured rainwater because it is exposed to additional pollutants from drainage systems and surfaces that may have hydrocarbons or other miscellaneous debris. Treatment options to reduce pathogens and pollution levels include: the use of constructed wetlands, sand filters and membrane filters and disinfection techniques including chlorination and ultraviolet radiation. The degree of treatment required depends on the proposed use and the level of public exposure.

Successful stormwater harvesting and reuse plans need specialist input from a number of areas, including stormwater management, water supply management, environmental management and public health. There may also be local limitations on the storage and reuse of stormwater and/or there may be permit requirements from local or state governments. Stormwater systems require monitoring and maintenance similar to rainwater collection systems as mentioned previously. Potential limitations and disadvantages of stormwater harvesting include: variable and unreliable rainfall patterns, environmental/land use impacts of storage facilities and potential health risks.
Reuse of Reclaimed Wastewater

Reclaimed wastewater (gray water) is water that is discharged from buildings and processes and then reused in non-potable applications such as irrigation and industrial processes. It is becoming more common for local municipalities to reclaim wastewater to help lower the community's demand for fresh water. This water is often available at a significantly lower cost than potable water.

Gray water likely needs secondary treatment such as additional filtration and disinfection to further remove contaminants and particulates to ensure the water is safe for non-potable applications. An efficient and successful reclaimed water project requires a reliable source of wastewater of adequate quantity and quality to meet non-potable water needs. These projects may be more economically viable when the cost of fresh water is high and there is a lack of high-quality fresh water or there are future supply risks due to conditions such as drought. Methodology for Use of Reclaimed Water at Federal Locations provides a step-by-step process on developing on-site reclaimed wastewater projects.

State and local governments regulate the use of gray water and the associated water quality requirements. To minimize cross-connection problems, reclaimed water pipes must be color coded with purple tags or tape according to standards set by the American Water Works Association. Signs should be used to indicate that reclaimed water is non-potable. Place these signs in public places such as in front of a fountain and on valves, meters and fixtures. To avoid accidental cross-connection, keep the pressure of reclaimed water 10 psi lower than potable water mains to prevent backflow and siphonage. Run reclaimed water mains at least 12 inches lower in elevation than potable water mains and horizontally at least 5 feet away. Review the quality of reclaimed water to minimize the potential for harmful effects from long-term use such as salt buildup.

- The use of on-site gray water recycling systems should be considered when constructing new buildings. Even though many of these systems are costly to purchase, the payback period in savings from discharging less wastewater can be 10 years or less.

- The pathogenic organisms in sanitary gray water must not come into contact with either humans or animals. This can be done by treating the water to eliminate pathogens or avoiding their introduction into water by not mixing sanitary gray water with any potable water source. Human exposure can be prevented by not collecting or storing the gray water in an open container.

- Sanitary gray water used for irrigation should not be applied through a spraying device, but rather injected directly into the soil through drip irrigation. Drip irrigation provides the benefits of gray water use without contaminating animals, humans or edible plants.

- If a gray water recycling system is utilized, consideration must be given to the types of cleaning products used. Products that contain sodium, chlorine or boron should not be used. Cleaning products that contain high chemical levels may enter the gray water recycling system and could poison plants or damage soil through the buildup of inorganic salts.

- When gray water is used for irrigation, rain or excessive irrigating could cause ground saturation and result in pools of gray water on the surface. To help eliminate this situation, turn the gray water system off and divert the gray water to the sanitary sewer line during rainy periods.
• For buildings with slab foundations, recoverable gray water may be limited to washing machine discharge because most drain pipes, such as for sinks, are buried beneath the slab and thus are not easily accessible without a significant expense.

• For buildings with perimeter foundations, gray water may be recoverable from most sources by accessing piping from crawl spaces.

• The most appropriate gray water treatment method (e.g., media filtration, collection and settling, biological treatment units, reverse osmosis, sedimentation/filtration, physical/chemical treatment) will depend on the gray water source, application, recycling scheme and economics.

Maintenance programs for a gray water system must include the following steps, all of which must be performed regularly:

• Inspecting the system for leaks and blockages. Cleaning and replacing the filter.

• Replacing the disinfectant.

• Ensuring that controls operate properly.

• Periodically flushing the entire system.

**Captured Air Handling Condensate**

Water condenses on air handling units (AHUs) and cooling coils when humid air contacts these cool surfaces. A large amount of condensate can form on cooling equipment in areas with hot, humid summers such as the southeastern United States. Water that collects on the AHUs and cooling coils must be drained to prevent damage to the equipment or building from water build-up. Typically, the condensate is collected in a central location and discharged to a sewer drain. In a condensate capturing system, the condensate is directed to a central storage tank or basin and then distributed for reuse.

Make-up water for cooling towers can be an ideal use of captured air handler condensate. Cooling tower make-up water is needed the most during the hot summer months when the largest amount of air handler condensate can be collected. By nature this water is very pure with very low dissolved mineral content, which is ideal for cooling towers. However, condensate can potentially grow bacteria during the storage phase, requiring disinfection to avoid introducing bacteria-contaminated water to the cooling tower system. Condensate can also contain heavy metals because of contact with cooling coils. Treatment to remove these heavy metals may be required.

CHAPTER 7
IMPLEMENTATION OPPORTUNITIES

This chapter reviews the current initiatives with the potential to provide significant quantities of data that will inform the implementation of the recommendations discussed in the following sections.

WaterTraq

In September 2016, the Long Island Commission for Aquifer Protection (LICAP) officially launched the historic mapping and database website known as WaterTraq. The program, the first of its kind in New York State, revolutionized the way public water providers tracked potential threats to the water supply and provided web accessible information to both the general public and to regulatory officials. With WaterTraq, this information about groundwater and drinking water quality became readily available to the public via the LICAP website:

www.liaquifercommission.com

The idea for WaterTraq was proposed through the LICAP Water Quality Management Group subcommittee. One of the most frequently cited concerns during the early meetings of this subcommittee was the lack of a coordinated regional water quality monitoring and reporting program. The primary objectives of the Water Quality Management working group were to determine the water quality parameters most critical to monitor and report, to develop a universal data reporting format and to identify the most appropriate platform to store, analyze and share the water quality data. Earlier attempts by New York State to implement standardized electronic data deliverable formats utilized environmental information management systems, such as the database software application EQuisTM, and the United States Environmental Protection Agency (USEPA) storage and retrieval data warehouse (STORET). Some of the advantages of these programs were their capability in handling multiple sample types and their usability by other agencies to visualize data in specific geographical areas. While these programs had success with requiring certain types of data to be submitted electronically, the data had to be formatted to meet the guidelines specified by the reporting agency. In addition to the added complexity of formatting datasets, multiple versions of the same program existed and were incompatible with each other. The substantial costs associated with training laboratory staff and hiring consultants to process the data also proved to be a disadvantage.

The ESRI ArcGIS (geographic information system) platform was deemed by the working group to be a more user friendly platform due to the availability of the program across the various utilities and agencies. Because most organizations leverage GIS, or have GIS staff available, cost savings would result from greater efficiency in the logistics of transferring data. Since GIS maps provide an ideal platform to visualize and interpret datasets, using this platform in conjunction with water quality data would allow for increased decision-making and improved communication. While the ESRI ArcGIS could provide a mechanism to store and visualize the data, the greater concern was how to make the information easily accessible to the public.

ArcGIS requires users to have a license with ESRI, the maker of ArcGIS, which would be costly. In addition, users would have to learn how to use the desktop version of the program in order to search through the water quality data.

The challenge of sharing the data from various agencies with the public was ultimately solved through the introduction of the ArcGIS online platform. ArcGIS online is a cloud-based
collaborative mapping platform that provides the ability to use, create and share maps, analytics and data. Because this online program required minimal implementation steps and no programming ability, the costs of implementation would be substantially reduced. In addition, the program could be made available to anyone with a web browser or mobile device and does not require a download.

With the GIS platform established as the tool to visualize the data, the next challenge focused on the data type that would be shared and exported to GIS. The initial concerns centered on the coordination efforts in having more than 50 water districts agree to share well data and have the respective laboratories in Nassau and Suffolk Counties export water quality data. Water suppliers were requested to provide both the latitude/longitude coordinates for all of their public supply wells as well as the well attributes (such as well depths, aquifer type and district served). The laboratories were requested to supply raw water quality information for the calendar year 2015. Suffolk County Department of Health Services also provided groundwater quality data from their monitoring well network.

The Excel program was then utilized as the tool to export the data because it is a universally accessible program used by both the water utility agencies and laboratories. The ease of Excel’s use and the program’s functionality allowed the data to be shared by all parties with minimal formatting. Since Excel allows for the analysis of large amounts of data, the data provided by the individual suppliers could be combined and analyzed efficiently with the existing filtering, sorting and search tools. The common identifier used to link the water quality sample data provided by the laboratory with the corresponding well location data was the New York State Department of Environmental Conservation-issued (NYSDEC) "S" or "N" (Suffolk or Nassau County) identification number uniquely assigned to each well. Combining the water quality data for each well with the well attribute data provided a mechanism to search for a compound and have the results visually displayed by concentration range and location. In addition, compounds could be searched based on well depth, aquifer type, water district and sample data. This allowed the water quality data to be displayed both in spatial dimensions and time. The framework of ArcGIS, linking the water quality data with public supply wells, provided an unprecedented view of water quality data on Long Island.

Both Nassau and Suffolk County water suppliers sample for more than 200 compounds, more than required by federal health regulation. Through this platform, water quality parameters can be immediately searched for and made visually accessible. WaterTraq was also able to attach existing aquifer-related datasets created by the United States Geological Survey (USGS), including depth to water and hydrogeologic units. These additional overlays allow for water quality samples to be contrasted with regional geology and water level variations. Borehole geophysical logs maintained by the USGS Water Science Center in Coram, New York were also attached to WaterTraq to create an interactive map that links the borehole database points to the corresponding hydrogeologic data.

WaterTraq blends interactive maps with data from spreadsheets in an effort to paint a clear picture of what exactly is in Long Island’s drinking water for health officials, industry professionals and the general public. Users can set search parameters that will allow them to look up specific contaminant levels for any New York State drinking water parameter. These parameters include inorganic compounds (such as iron or chlorides), volatile organic chemicals (typically industrial solvents or gasoline constituents), emerging contaminants (such as pharmaceuticals) and a myriad of other compounds and chemicals for which drinking water purveyors are required by law to sample. WaterTraq users can then see if a given untreated water sample is at or below safe...
drinking water standards for a particular well or set of wells.

WaterTraq also allows the user to overlay aerial photography, geological boundaries and contours that illustrate the depth to groundwater. The data provided through WaterTraq includes both untreated (raw) water test results and treated water that is sent to customers. The success of WaterTraq is the ability for the tool to share information with regulators and the general public at the click of a button. Unlike previous datasets that focused on a specific location or compound, WaterTraq gives users the chance to visualize all sampled data from an Island-wide perspective. WaterTraq allows for water professionals to draw conclusions based on the patterns of the dataset they see.

A WaterTraq user can now easily click on interactive maps to see data about water in a particular area or search for information by entering an address. In addition, a user can search among chemicals or compounds tested by water suppliers to determine their presence in groundwater. The WaterTraq site also contains links on how to read drinking water reports, water quality standards set by state and federal officials and listings of top compounds detected on Long Island. Instructional videos were also made available to show the public how to navigate WaterTraq; conduct address searches; search for untreated aquifer samples and search for compounds by aquifer, range, well depths and sample dates. The public was also educated about the state of the aquifer and the differences between groundwater and drinking water. The outreach campaign also discussed drinking water standards in New York State that are considered some of the most conservative in the nation.

WaterTraq has been cited by public officials as being an outstanding accomplishment and a valuable tool that allows water suppliers to share information with regulators and the general public. The increased knowledge gained through WaterTraq has empowered residents to be proactive in advocating to regulators for additional groundwater supply protection. The initiative has also been able to help advance a critical regional approach to Long Island water resources. WaterTraq has also been used to help the New York State’s water quality rapid response team identify and respond quickly to drinking water issues. At colleges across Long Island, WaterTraq has been used to gather, map and display water quality data to help identify risks to drinking water sources. WaterTraq has also served as a mechanism for state officials to better coordinate and analyze water quality samples.

During the 2017 State of the State Address, Governor Andrew Cuomo offered a proposal to further develop WaterTraq, noting the considerable resources invested in cleaning up spills and remediating Superfund and Brownfield sites, all of which require considerable testing. Acknowledging the lack of integration with existing data statewide, he recognized the need to better combine the datasets to predict threats to public health and the environment and better facilitate interagency cooperation. Similar to WaterTraq's methodology, the state hopes to use the data it collects to pioneer a leading technology platform to manage sustainability, risks and potential contamination to drinking water supplies across New York.

**United States Geological Survey Long Island Sustainability Study**

Long Island is entirely dependent on the underlying sole-source aquifer system that currently supplies more than 400 million gallons a day (MGD) of fresh water from more than 1,200 public supply wells to more than 2.8 million people in Nassau and Suffolk Counties. As the name implies, Long Island's sole-source aquifer system is the only source of water available to meet the needs of Long Island's population.
In addition to its value for drinking and irrigation, groundwater is also the primary source of fresh water in streams, lakes and wetlands, and maintains the saline balance of estuaries. When large volumes of groundwater are withdrawn, the water table is locally depressed and this, in turn, reduces the quantity of groundwater available to discharge to streams and estuaries.

Large-scale sewering practices have also reduced groundwater levels and discharge to surface receiving waters. In some areas of Long Island, groundwater pumping has resulted in salt water intrusion into the aquifer system and has also impacted streams, ponds and coastal areas that rely on groundwater discharge to sustain them. In addition to these quantity-related impacts, additional factors such as urban runoff and the widespread use of septic systems have also affected the water quality of the aquifer system. Therefore, development and use of groundwater on Long Island is constrained by ecohydrological (i.e., the interactions between groundwater and surface water ecosystems) and water quality concerns.

Long Island’s aquifer system is comprised of several aquifers, generally ranging in increasing depth from the Upper Glacial, North Shore, Jameco, Magothy and the Lloyd Aquifer. Several major clay layers are also present including the Gardiners and Raritan, which overlie most but not all of the Magothy and Lloyd Aquifers, respectively. These clay units influence the aquifer system in several ways: they act to confine and isolate the underlying fresh water zones; limit the rate of recharge to units below; protect underlying fresh water from surface contaminants; and in coastal marine environments, also influence formation of seaward-extended fresh water aquifer wedges under natural discharge conditions and, conversely, formation of inland salt water intrusion wedges under pumping conditions.

In 2016, Governor Andrew Cuomo announced a partnership between New York State, USGS, Nassau County and Suffolk County to study the effective management of Long Island’s groundwater resources. Nassau and Suffolk Counties get their water solely from groundwater that is pumped from its aquifers (subsurface sands and gravels that store and transmit water). The quantity and quality of groundwater can be affected by natural processes such as drought or human activities such as groundwater pumping and urbanization. For that reason, decreases in groundwater levels, salt water intrusion and groundwater contamination have led to concerns about the future availability of groundwater on Long Island.

Groundwater sustainability can be defined as the development and use of groundwater in a manner that can be maintained for indefinite time without causing unacceptable environmental or socioeconomic consequences. Informed management of the Long Island aquifer system can help ensure a regionally sustainable groundwater resource. This study will evaluate the sustainability of Long Island’s groundwater resource, now and for the future, by geologic mapping, water quality, and water level monitoring, and groundwater flow modeling this critical aquifer system.

**Groundwater Flow Modeling**

Groundwater models represent the understanding of how groundwater flow systems work and they provide tools that water resources managers can use to effectively plan for sustainable aquifer development. However, existing models lack the necessary geologic information to fully assess the sustainability concerns of the Long Island aquifer system. To improve the existing model, the USGS will map new geologic information by drilling groundwater wells throughout the Island. The extent of salt water intrusion will be identified by monitoring these new wells. Mapping and monitoring results will be used to improve existing models.
A groundwater flow model will be developed using the USGS MODFLOW computer program (Harbaugh, 2005). Additional computer programs will be used to track groundwater flow paths from recharge to discharge and model the salt water-fresh water interface (Pollock, 1994; Bakker and others, 2013). The model will utilize updated geology and information about the observed location of the fresh water-salt water interface in the Magothy and Lloyd Aquifers. The groundwater flow model will be calibrated to match observed field data including chloride and water-level information. The model will be used to simulate various scenarios, including changes in groundwater withdrawals, aquifer recharge management and climate change. These scenarios will be developed in collaboration with the NYSDEC and the Steering Committee.

**Hydrogeologic Mapping**

A network of Lloyd and Magothy Aquifer groundwater wells will be installed at about 30 locations throughout the Island to fill in substantial data gaps. The existing groundwater well network consists mostly of shallow and deep wells in Nassau County, some wells in Suffolk County and some shallow wells in Kings and Queens Counties. The locations of the proposed groundwater wells will be selected by reviewing geologic, hydrologic and water quality information from the existing network. Geologic information obtained from newly installed groundwater wells will be used to improve existing maps (Smolensky and others, 1990) of Long Island's geology and included in newly developed groundwater models. During and after completion of the newly drilled wells, rock and sand core samples will be collected and analyzed to improve the understanding of Long Island's geology. Core samples will be analyzed at specific depths in wells to determine the presence of saline groundwater. Continuous geologic and water quality information will also be collected using geophysical methods along each well's depth.

**Water Quality Monitoring**

Land-based and waterborne geophysical surveys will be used to map geologic features, including aquifers and confining units. Results from these surveys will help guide site selection for new groundwater wells and fill data gaps where drilling new wells may not be feasible. Geophysical logging and chloride well sampling will also be used to monitor salt water intrusion in the Magothy and Lloyd Aquifers. Periodic and continuous water level measurements will be collected to define aquifer water levels (such as the elevation of the water table) that will be used to calibrate groundwater flow models.

**Anticipated Outcomes**

Hydrogeologic data on Long Island, pertaining to both water quality and water quantity (or availability), has been collected and archived for more than 70 years by a variety of public agencies and private firms. These data collection efforts have evolved over time in a rather piecemeal fashion and have been executed for specific purposes or projects. Until recently, there has been little coordination among agencies to share the data or to make it more publicly accessible. The two initiatives described in this chapter represent a change in this paradigm. The WaterTraq database allows anyone to obtain water quality data from wells across Nassau and Suffolk Counties for all aquifers. The USGS Long Island Sustainability Project will fill in some of the data gaps that have developed over time and will provide fresh insight into data analysis and predictive modeling moving forward. It is hoped that both of these initiatives will foster a new era of data sharing and cooperative problem-solving among public officials and private citizens.
CHAPTER 8
RECOMMENDATIONS AND IMPLEMENTATION SCHEDULE

The reports that comprise the main body of the Long Island Commission for Aquifer Protection (LICAP) Groundwater Resources Management Plan contain a total of 143 specific recommendations pertaining to some aspect of Long Island’s groundwater environment and/or community. All of these recommendations were compiled into a spreadsheet, and prioritized by the LICAP board members into three categories: immediate, short-term or long-term. Additionally, some recommendations were eliminated from consideration completely. Occasionally, recommendations were combined and edited for brevity. The following pages summarize each category of recommendations.

Recommendations

Recommendations for Immediate Implementation

The following recommendations taken from the reports that comprise the Groundwater Management Plan have been deemed by LICAP to be considered for immediate implementation:

1. Investigate ways to further optimize pumping operations for wells located near shoreline areas to help minimize salt water intrusion.

2. Fund the development of a regional groundwater model to be used for planning purposes.

3. Implement conservation pricing at public water suppliers and include a full description of water conservation pricing in annual water quality reports issued by public water suppliers.

4. Establish guidelines for Best Management Practices to reduce peak demand for landscape irrigation.

5. Establish guidelines for use of water by geothermal systems.

6. Prevent public supply wells in Queens County from being reactivated because of their negative impacts to Long Island’s sole source of water supply.

7. Fund federal, state and local agencies so they can conduct groundwater monitoring, plume identification and modeling.

8. Actively remediate or strategically contain groundwater contamination plumes, such as the Grumman/Navy plume, to minimize and prevent potential impacts to public drinking water.

9. Maintain, update and utilize the existing Nassau County Department of Public Works (NCDPW) monitoring well network (599 total wells) including: 366 Upper Glacial Aquifer wells, 167 Maggoty Aquifer wells and 66 Lloyd Aquifer wells.

10. Develop and expand WaterTraq for LICAP.

11. Require the notification of a public water supplier before a geothermal system is permitted in its service area.

12. Require the New York State Department of Environmental Conservation and the County Health Departments to review and provide comments on municipal planning board applications that may impact water resources through the State Environmental Quality Review Act process to identify and communicate potential groundwater issues to municipal planning boards.
13. Reauthorize LICAP with legislation in the Nassau and Suffolk County Legislatures.

14. Ensure that pumpage caps on public suppliers, if implemented in the future, are based upon sound scientific data.

15. Do not create any new state or regional entity to provide oversight of drinking water because the power to regulate and protect drinking water on a regional basis is already vested in the New York State Department of Health and the New York State Department of Environmental Conservation.

Recommendations for Short-Term Implementation

The following recommendations should be implemented in the near term:

1. Efforts to monitor the fresh water-salt water interface near shoreline areas should be continued or enhanced. Water suppliers with affected wells should initiate monitor well construction and water quality monitoring programs irrespective of governmental entities.

2. Facilities stockpiling and utilizing road salt and deicers should ensure that the requirements in the NYSDOT Highway Maintenance Guidelines, as well as the items noted the NYSDOT's Environmental Handbook for Transportation Operations, are being met. In addition, facilities should meet the requirements of Article 12 of the Suffolk County Sanitary Code and Article XI of Nassau County Public Health Ordinance.

3. Municipalities should consider coordinating their efforts with water suppliers and the appropriate regulatory agencies when planning new salt storage facilities and/or recharge and drainage structures as these relate to the location of drinking water wells. Source water assessments could be utilized for these purposes to help with optimizing the locations of these facilities with respect to drinking water supplies.

4. Water use efficiency programs should be mandated during the summer in order to reduce pumpage during peak hours of the day.

5. Consideration should be given to connections to New York City’s water supply for western Nassau County barrier island and peninsula locations with salt water intrusion issues.

6. A computerized regional groundwater model should be developed with active participation among water suppliers, regulators and consultants to assess potential problems and evaluate solutions.

7. The NYSDEC should develop a method of coding water well permits to easily identify different water using sectors such as: irrigation, agricultural, geothermal, remediation, dewatering, industrial and public water supply.

8. Where contaminated plume remediation projects are operating, the recommended practice should be that, wherever possible, the extracted and treated groundwater be recharged to the aquifer system.

9. The well permit program should be revised to enhance its value in managing the groundwater resource, including the posting of well permit renewals as notices in the Environmental Notice Bulletin (ENB). Permitting should be guided by scientific knowledge of aquifer conditions and processes and managed yield goals and limits. Water withdrawal limits should be enforced.

10. Comprehensive groundwater management should be accomplished through a properly funded and staffed NYSDEC.
11. Water suppliers and land use regulators should coordinate to identify areas where population growth and development potential are expected to occur based on current zoning and land use regulations. Some funds may also need to be set aside to allow water suppliers to continue operating and to defray the costs of development to continue to provide clean drinking water to the public.

12. Coordination should occur among municipal authorities, water suppliers and developers to ensure that easement agreements are established on parcels to be developed or preserved. A portion of the land, if preserved for water quality preservation, should be set aside with an easement to the local water supplier to fulfill future public water supply needs.

13. Technologies, maps and other data and information used by municipal authorities and water suppliers should be shared to provide the most current and relevant information for efficient water supply planning purposes.

14. Explore water conservation preservation opportunities to avoid potential impacts on the aquifer and natural resources that may be affected by hydrologic changes.

15. Maintain and update the NCDPW monitoring well database to provide historic water quantity and water quality data.

16. Provide access to the NCDPW monitoring well network by other government agencies such as the NYSDEC, USEPA, USGS and NYSDOH and designate groundwater professionals and environmental firms for: collection of water level measurements and water quality sampling.

17. Restore and expand existing analytical capabilities at local health department laboratories such as aquifer evaluation, emerging contaminant studies, development of new analytical procedures and support of groundwater investigation.

18. Expand and enhance public water suppliers' self-monitoring activities, recognizing the need for additional monitoring commitments.

19. Support local laboratory and trained staff response capabilities to meet the objectives of the New York State Water Quality Rapid Response Task Force currently under development.

20. Restore and expand existing county-level test well drilling capabilities.

21. Expand the cooperative relationship with the USGS.

22. Restore health department industrial waste inspections to previous levels.

23. Commit to continued bi-county updates of water resource management plans and update existing Source Water Assessment Programs to also include GIS output.

24. Further development of a local uniform code and consistent permitting and approvals process should be explored. Suffolk County's Model Code could serve as the starting point and be modified as necessary.

25. Municipalities that have not adopted the Model Code should be encouraged to do so. Municipalities at their discretion can impose stricter requirements given local concerns.

26. A centralized database and map of existing geothermal heat pump (GHP) systems and a process to add future installations to the database should be created.

27. For a proposed open-loop GHP system located within the capture zone of an existing public
supply well field, the NYSDEC should require the owner of the system to perform the appropriate aquifer testing and modeling to the satisfaction of the water supplier.

29. For all open-loop systems, the NYSDEC should confirm that dedicated supply and return wells are in use when a permit is filed or being renewed in order to prevent the use of public water for supply water or the discharge of the return water to the ground.

30. The NYSDEC should disallow discharge of the return water from an open-loop system to a regulated surface water body or wetlands.

31. GHP systems may need to be curtailed or restricted in sensitive aquifer areas as per the concerns of local municipalities. Local municipalities can also opt to limit the drilling depth of GHP boreholes within their jurisdiction (to minimize breaching of clay layers).

32. Regulations should be enacted for reporting and addressing a release of refrigerants from a direct exchange (DX)-to-ground contact system and for replacing the sacrificial anodes and cathodes.

33. Regulations should be enacted to require double-wall piping of the horizontal return pipes for a direct exchange (DX)-to-water contact system [geocolumn(c)] to prevent a release of refrigerant to the ground from a break or leak in the piping.

34. Require an inspection signoff by an International Ground Source Heat Pump Association (IGSHPA) accredited GHP system installer, GHP system inspector or certified geothermal designer (CGD) for grouting of closed loop boreholes if major confining clay layers are penetrated.

35. The NYSDEC and the county health departments should delineate areas over or near known contamination plumes where GHP systems may not be recommended and promulgate the appropriate restrictions.

36. North shore areas in Nassau must improve residential on-site septic systems and the available capacity of the Glen Cove Wastewater Treatment Plant. South shore areas must reroute the Bay Park effluent discharge through a new ocean outfall to the Cedar Creek Plant to share its existing ocean outfall. Storm mitigation/hardening must be considered as part of the technical aspects of a project.

37. Siting of STPs inside of the 25-year contributing area to sensitive surface waters should be minimized; if this is not possible, an advanced treatment process shall be provided.

38. Efforts should be made to improve wastewater effluent quality to reduce impacts and for permitting water reuse for golf course irrigation.

39. Upgrade the Bureau of Public Health Protection and Division of Environmental Quality databases to provide a more comprehensive data management program for all regulated facilities; groundwater and surface water quality data; facility data; inspection records; STP monitoring data; and on-site wastewater management system installation, maintenance and inspection.

40. Develop science-based permissive yield pumpage values for each county and regions subject to salt water intrusion.

41. Target lawn irrigation as a water use practice in an attempt to prevent annual water demand from continuing to increase in the future.
42. Expand Nassau County water conservation ordinance to Suffolk County standards (with appropriate modifications).

43. Require irrigation contractors to be certified/licensed in New York State and require that these certification requirements adhere to the guidelines of a national professional organization, such as the National Irrigation Association. Additionally, require that these regulations follow standards established by the United States Environmental Protection Agency's "Water Sense" program.

44. Request water suppliers to work with local planning boards to promote water-friendly landscaping and efficient irrigation system design.

45. Promote conservation by requiring rain sensors, at a minimum, to prevent automatic sprinkler systems from switching on while it is already raining. This must include retrofitting existing systems. Require that rain sensors be tested annually and replaced every five years.

46. The 1986 Lloyd Aquifer Environmental Conservation Law (ECL) §15-1528 Moratorium must be continued in the absence of a finding by NYSDEC that a workable program is in place to properly administer a Lloyd Aquifer well permit program. Additional measures should be taken to protect the aquifer and ensure that a safe level of withdrawal is not exceeded.

47. Incentives should be considered to encourage water suppliers to drill Lloyd replacement wells in overlying aquifers. These incentives could take the form of financial grants to offset potential treatment costs or other means to discourage the continued use of Lloyd Aquifer wells in areas where other aquifers are available.

48. The North Shore Aquifer should be protected from overpumping, salt water intrusion and migration of contamination in a similar manner to the Lloyd Aquifer.

49. The state should provide permanent funding of groundwater quality and water level monitoring programs, including updated studies of the location of the salt water interface in the Magothy and Lloyd Aquifers. Water budget and managed yield analyses should be performed along with appropriate computer modeling. This information should be evaluated by the NYSDEC to improve the management and protection of Long Island groundwater resources.

Recommendations for Long-Term Implementation

1. The information in the Chloride contamination report should be shared with municipalities and other entities that maintain roadways so that alternative deicing compounds and practices may be considered. In addition to compliance with permit conditions, public water systems may want to investigate and identify sources of elevated chlorides in supply wells as part of their own due diligence. This work has already been performed by the SCWA and at several public supply wells.

2. The cost, benefits and environmental impacts of water supply alternative technologies such as ASR and brackish water desalination should be studied for possible use in marginal areas.

3. Incentivize intermunicipal agreements for water transfer to water suppliers that are threatened by salt water intrusion or other major sources of contamination. This should include the purchase and transmission of water from both New York City and Suffolk County into Nassau County with consideration to the potential costs involved.

4. Water use for each county, with details on large water-user categories, should be reported
annually, and this data should be available on the Internet so that it can be tracked more easily. NYSDEC should provide this service. Per capita water use data for Long Island is needed.

5. The NYSDEC should comply with the state law requiring it to identify quantity and quality-stressed areas of the aquifers/groundwater system.

6. Improvements in recharge basin management should be implemented to increase aquifer recharge.

7. An educational program for all well permit holders should be developed and implemented so that accurate information on water pumped can be reported and the information used.

8. Implement a drought monitoring plan with an associated monitoring well network.

9. As more information is provided on the location of the fresh water-salt water interface and risk from salt water intrusion becomes available, a change in water withdrawals programs should be developed and implemented. More attention should be given to all the issues related to salt water intrusion and its mitigation.

10. Consider the preparation of a groundwater study that analyzes the feasibility, sustainability and potential environmental impacts that may occur as a result of transporting water across multi-jurisdictional boundaries.

11. Quantify drawdown impact thresholds for future water supply projects.

12. Identify contamination sources or locations and need to supply public water in developed communities where water quality is degraded and water resources are limited.

13. Assessing the sustainability of long-distance transmission should become a routine practice in the future. This may include changes to zoning codes to modify the developed landscape where it is sustainable based on the availability of resources.

14. Identify areas where growth should be encouraged or discouraged relative to available clean drinking water supplies. Coordinate with current land use development initiatives (e.g., around transit hubs, in downtown areas, etc.) to ensure adequate water supplies exist.

15. Examine existing policies, provisions and regulations that apply to the transmission of public water, including permit requirements and prohibited activities (i.e. across jurisdictional boundaries).

16. Coordinate with the Central Pine Barrens (CPB) Joint Planning and Policy Commission on a determination of jurisdiction for the transmission of water from the CPB to communities outside of Suffolk County.

17. Identify the locations of water supply wells that have groundwater contributing areas inside the CPB area to better understand exactly which wells draw groundwater from the CPB.

18. Evaluate cumulative impacts of expanded sewerine in Suffolk County along with potential impacts from long-distance public water transmission on groundwater resources.

19. The NYSDEC should clarify whether closed loops can be drilled and installed into the Lloyd Aquifer even though they are not pumping wells.

20. Prior to designing and installing a large closed-loop GHP system, conduct due diligence focused on determining the presence, depth and thickness of major clay confining units;
presence of contaminated soil or groundwater; and presence and distance to sensitive ecological receptors, water supply wells and other GHP systems.

21. Better define as-builts drawing requirements to include showing other buried infrastructure that could conflict with a GHP bore field or wells, such as drywells, on-site sanitary, underground storage tanks, etc., and transfer to the new owner when the property changes hands.

22. Demonstrate that the ground heat exchanger (GHE) is properly sized for the heating and cooling load profile for large GHP systems as determined through a suitable building energy model. Address any serious imbalance in the load profile and implement measures to reduce the loads and/or supplement the design with conventional mechanical equipment (i.e., a hybrid design).

23. Engage in a study with the NYSDEC, the SCWA and the USGS on the feasibility of using a quifer thermal energy storage (ATES) systems on Long Island, whereby the usual thermal effects on the aquifer are contained rather than allowed to migrate beyond the site's boundaries.

24. Promote further research into the potential thermal effects of individual operating GHP systems on groundwater, surface water and ecological resources with a goal to establish procedures to determine safe setbacks from these resources and to enact appropriate regulations if needed. Potential research partners could include local colleges and universities, the NYSDEC, the SCWA, the counties, private industry and the USGS.

25. The current state policy of first-come-first-served for underground water rights should be reassessed to address cumulative thermal and hydrogeologic effects of high concentrations of small GHP systems. Regional modeling (building on the USGS groundwater model) could be performed to define the safe concentration of such systems with appropriate limits enacted by either the NYSDEC or the local municipalities.

26. The NYSDEC should require intermediate heat exchange (HX) for open-loop systems permitted under the Long Island Well Permit program. The NYSDEC should also require installation of an intermediate HX on existing systems that do not employ HXs before permits are renewed. The NYSDEC could reach out to owners of such existing systems in advance of the permit date for voluntary retrofit.

27. The NYSDEC should require due diligence for LIWP applications for large GHP systems similar to that required by Region 2.

28. Better education and training is needed on the proper implementation of GHP systems, possibly facilitated by local professional organizations in association with the NYSDEC or other agencies. A GHP system inspector training program should be developed specifically for Long Island municipal building inspectors.

29. Siting of STPs inside of the 25-year contributing area to sensitive surface waters should be minimized; if this is not possible, an advanced treatment process shall be provided.

30. Enact discharge regulations that utilize mass loading of nitrogen rather than effluent concentration.

31. Accelerate wastewater reuse, mining for resources, energy production and source separation as ways to better value wastewater.
32. Identify and prioritize parcels and determine the sewage treatment plant capacity to permit the connection of identified parcels.

33. Prioritize parcels in critical areas that shall be required to install nitrogen reducing in-site wastewater treatment systems (I/A OWTS).

34. Revise Article 6 Groundwater Management Zone 4 density requirements to conform to Zones 3, 5 and 6 to improve groundwater and surface water quality in the Peconic Estuary.

35. Increase horizontal setback distances between OWTS and surface waters.

36. Create a Wastewater Management District with a responsible management entity (RME) to oversee the financing, operation, maintenance and enforcement of I/A OWTS and cluster systems. Consider municipal partners to help advance installations.

37. Create and/or identify funding sources and costs to meet on-site system objectives. Continue to advance a combination of on-site solutions that can treat to higher levels. Allow the vetting of systems to occur regionally to speed the acceptance of a larger range of options.

38. Evaluate ways to reduce costs for the installation, oversight and maintenance of on-site systems.

39. Modify the Sanitary Code to minimize the "grandfathering" of State Pollutant Discharge Elimination System (SPDES) and/or Suffolk County Department of Health Services Approvals. The following issues should be reviewed:
   a. SCDHS permitted sanitary flows that exceed and pre-date Sanitary Code density requirements, on other than single-family residential lots, without the installation of an I/A OWTS or connection to sewers; review options to effect upgrades under the Environmental Conservation Law, New York Codes,
   b. Rules and Regulations and SPDES.

40. Assess the feasibility of updating the Sanitary Code to prohibit the replacement in kind of failed on-site wastewater technology without SCDHS approval.

41. Implement a comprehensive integrated data collection, analysis and evaluation program to monitor groundwater, drinking water and surface water, including reinstatement of the comprehensive groundwater and stream monitoring program.

42. Require that certified contractors obtain continuing education credits by attending technical and business related classes. Use the certification process to establish and maintain a database for use in cooperation with public water supply systems.

43. Require water purveyors to adopt a rate structure that promotes water conservation and to implement a homeowner conservation assistance program. Have the NYSDEC develop an Island-wide water reuse feasibility study, looking at the logistical, financial, technical and social issues related to water reuse, and develop the necessary rules and regulations so the legal framework is in place to fully implement water reuse as required by the ECL Article 15, Title 6.
CHAPTER 9
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