Groundwater Quantity and Competing Uses

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Abstract

Groundwater use on Long Island, New York continues to increase in both Nassau and Suffolk Counties, with the largest growth occurring in Suffolk County. The expansion in total groundwater pumping in Suffolk County can be accommodated at the present time because there is ample groundwater in storage to support increased withdrawal. However, the location of pumping is an important issue since withdrawals can affect coastal and stream discharges that, in turn, affect important water-dependent habitats. For Nassau County, the point at which groundwater pumpage is sustainable has been exceeded. As a result, saltwater intrusion, reduced stream flow, and other indicators of aquifer disruption are evident within the aquifer system that serves the County. There are numerous opportunities in Nassau County to bring groundwater withdrawals to more sustainable levels but the problems with over-pumping must first be acknowledged and then reigned in through prudent but effective practices and changes in policy and regulation. The present practice of equating public water supply withdrawals with recharge is a false equivalency that must be replaced with more accurate depictions of pumpage impacts that can be reported to the public and policy makers. Excessive water use by individuals and water-use sectors must be curbed. Public education about water waste and its consequences is essential. Enforcement by the New York State Department of Environmental Conservation (NYSDEC) of pumping limits must be strengthened and implemented in Nassau County and other sensitive areas such as the east end of Long Island.

History of Groundwater Quantity Concerns

Defining the Amount of Water in Storage beneath Long Island

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 to 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 freshwater 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 1986).

Cohen estimated specific yield of the Long Island aquifer system to be only 5 to 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. This explains why the different aquifer formations are more or less productive. Thus, the maximum amount of freshwater that can be withdrawn from the aquifer system is controlled by the aquifer formation being pumped. The Upper Glacial Aquifer is much more generous while the major aquifer, the Magothy Aquifer, is much less so. This also illustrates why it is not possible to remove all 60 trillion gallons stored in the aquifer system. The maximum yield is currently considered to be approximately 20%. If major pumping were to attempt to withdraw most of the groundwater, the result would be the eventual destruction of the aquifer system (Cohen, 1968). Massive saltwater intrusion and other detrimental changes in the system would occur as excessive depletion continued. Localized drawdowns would lead to broad-scale intrusion along the coastal margin that would move significantly landward over time, placing the entire aquifer system at risk.

Saltwater intrusion has been the foremost concern for Long Island's aquifer system for more than 150 years, as supported by numerous studies. The saltwater intrusion caused by excessive pumping in Brooklyn and Queens County ruined the groundwater supply beneath Brooklyn which had to abandon its use of groundwater. Extensive pumping in Queens County eventually caused intrusion along both the north and south shores of Queens County and also contributed to saltwater intrusion beneath the southwest corner of Nassau County as well. With no surface water sources for drinking on Long Island, a heightened awareness of quantity concerns in Nassau and Suffolk Counties is necessary.

Water Budgets and How an Aquifer Works

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

INFLOW = OUTFLOW +/- STORAGE (Equation 1)

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.

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). Inflow represents water entering an aquifer system, mainly as precipitation, through the process of recharge. Other sources of inflow can include saltwater 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 million gallons per day, 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

COUNTY	**RECHARGE**	**DISCHARGE**		
	Precipitation (MGD)	Stream MGD	Shore MGD	Subsea MGD
Kings & Queens	160	58	96	10
Nassau	257	125	94	24
Western Suffolk	273	140	137	28
Eastern Suffolk	436	137	258	19
TOTAL (% of total)	1,126	460 (41%)	585 (52%)	81 (7%)

Source: Buxton and Smolensky (1999, pg. 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 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

COMPONENT	NASSAU COUNTY	SUFFOLK COUNTY	LONG ISLAND
PRECIPITATION (inches)	43.3	45.9	45.2
RECHARGE			
Total (inches)	20.6	23.5	22.7
Percentage (%) of total precipitation	47.6	51.2	50.2
EVAPOTRANSPIRATION			
Total (inches)	21.8	22.1	22.1
Percentage (%) of total precipitation	50.3	48.1	48.8
DIRECT RUNOFF			
Total (inches)	0.9	0.3	0.4
Percentage (%) of total precipitation	2.1	0.7	1.0

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 show it balanced and 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 causes the water budgets to be incomplete. 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 saltwater interface and potential for saltwater 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, saltwater intrusion represents a system change that limits the supply of potable water in the coastal portions of the aquifers. A common misconception is that groundwater discharge into coastal marine waters is "wasted water." To the contrary, groundwater that discharges into coastal waters is performing 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 freshwater-saltwater interface to move landward into the freshwater 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, plus
    - 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 saltwater intrusion
- Sufficient groundwater storage for drought and other extreme events
- Sufficient head to support deep recharge processes

Reports Relevant to the Water Quantity Management

Numerous studies of the Long Island groundwater system have touched on various aspects of groundwater quantity issues. Some of the more well-known studies are listed in the References section of this report.

Discussion and Analysis

Water Budgets for Each County

Nassau County

Nassau County developed water budgets in several studies between 1980 and 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, pg. 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

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

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

Table 3 shows a current (2010) water budget for Nassau County that is technically 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 saltwater 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 due to over-pumping. 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, pg. 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 freshwater lost from the aquifers, saltwater intrusion increased significantly over time (Nassau County, 1998, pp. 2-8 to 2-9). Public water supply pumpage now represents between 50 and 60% of the total recharge, depending on annual demand (and recharge rates). However, the comparison of pumpage to recharge is a false equivalency. Given the large increase in summer groundwater pumping and continuing saltwater intrusion, the present level of water pumping in Nassau County is not sustainable.

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 saltwater 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
Suffolk County Water Budget - All of Suffolk County

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

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

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

- Main body: 1119.6 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. However, it should not be assumed that Suffolk County can continue to increase its withdrawals without any significant impacts. 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 90% sewered. Extensive sewering with direct discharge at the coast has meant that most of the public water supply use in Nassau County is not being returned to the aquifers. Currently, Suffolk County reports that water supply withdrawals represent approximately 14% 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.

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, and
- 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, and
- 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 and, like Long Island, groundwater consumption is becoming a serious issue for sustainable resource management.

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 through September), usually peaking in July and lowest is in the winter (October through April), especially from December to February.

The New York State Department of Environmental Conservation (NYS DEC) has summarized pumpage during the period 2000 through 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

PUMPAGE 2000-2014	NASSAU COUNTY MGD	SUFFOLK COUNTY, SCWA 2014 ONLY, MGD
2014 Pumpage Only		222
Peak Daily Average	261	
Non-Peak Daily Average	139	
2000-2014 Non-Peak Average Day		132
Low	139	
High	149	
Mean	143	
2000-2014 Peak Average Day		348

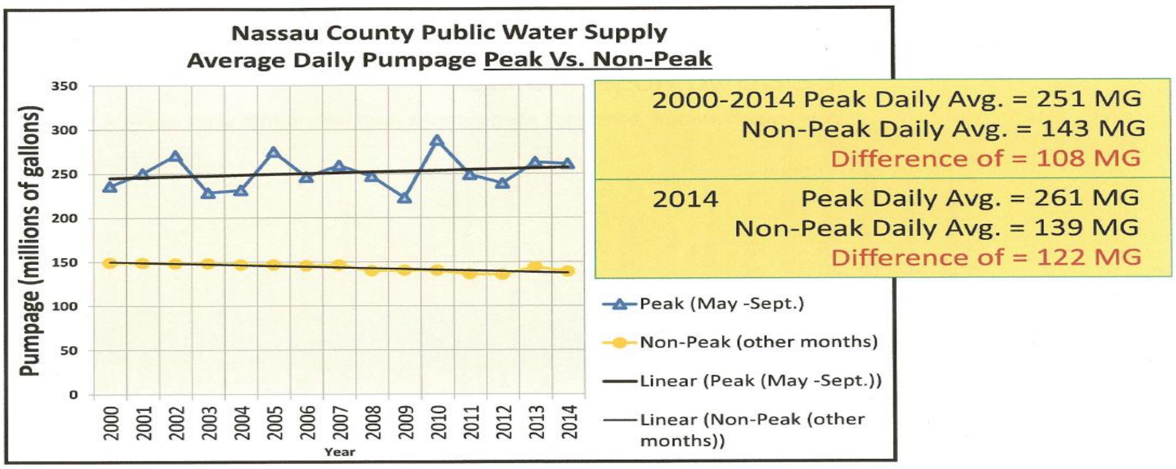
Low	231	
High	288	
Mean	251	

Source: Pilewski (2016, NYSDEC)

Pumpage by the Suffolk County Water Authority (SCWA) 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).

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

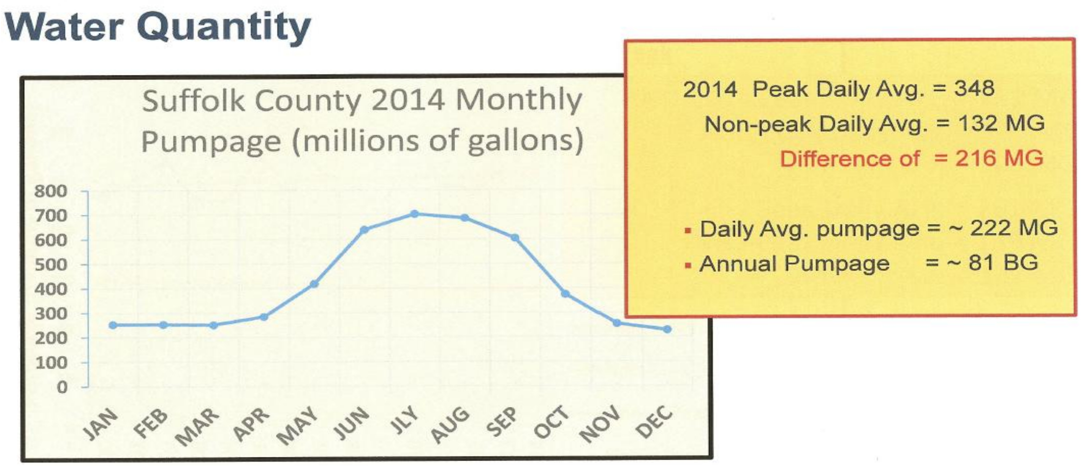


Source: NYSDEC (2015)

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.

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.

Figure 2
Public Water Supply Withdrawal for SCWA, 2014



Source: NYSDEC (2015)

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 (NACP), 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., pg. 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. (pg. 28) The same report found that the net volume of groundwater depletion on Long Island between 1900 and 2008 was 502,000 million gallons (Table 4, pg. 39).

Consumptive Water Use

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 to 400% increase in seasonal water use, mainly for lawn and landscape irrigation.

During the summer, the recharge to the aquifer system approaches zero (June-August) while, simultaneously, pumping demand reaches its peak level. As a result, water table elevations will substantially decline when compared to winter elevations. Thus, there is a regular cycle of rise and fall in water table elevations across much of Long Island. The extremely low recharge rates in summer were first reported in the *Long Island 208 Study* (Koppelman, 1978, Table 2-4).

An example of aquifer response to summer stress is described by the 2005 Nassau County Department of Public Works Report. It reported as follows:

> "The low amount of precipitation that occurred during the latter half of 2001 and early in 2002, coupled with the effect of high public water demand during the unusually hot, dry summer of 2002 manifested itself in water table elevations and potentiometric heads at numerous monitoring wells that were at historic lows" (pg. 73).

Golf Courses

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.

Agriculture

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 square feet 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

Residential 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.

Per Capita Water Use

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 Groundwater Users: Examples of Extreme Water Use on Long Island

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

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

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, over 1 billion gallons of saltwater 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.

Groundwater Use by Sector

Groundwater use should be able to be analyzed by category of user. User categories should include:

- Public Water Supply
- Private Water Supply
- Industrial/Commercial
- Recreation/Golf Courses
- Agriculture
- Habitat/HVAC/Geothermal

- Contaminated Site Remediation
- Power Production

Presently, only public water supply pumpage on Long Island is routinely tracked and reported. All non-public water supply withdrawals are regulated under the Long Island (LI) Well Permit program rather than the water withdrawal program. Wells permitted through the LI Well Permit program are exempt from the water withdrawal permitting program. The Long Island water well permit program in the NYSDEC has been in use since 1933. In the current program, monthly pumpage reporting is not required for every permit. Pumpage reporting requirements vary from monthly to annually and non- consumptive users typically are not required to report pumpage. Agricultural water use for regulated wells is reported, though not all agricultural wells required reporting. Any agricultural wells which had not been reporting their pumpage prior to the water withdrawal regulation changes are now required to obtain a LI well permit. As part of the permit, pumpage reporting is required. In 2011, the water withdrawal permitting and reporting program was expanded statewide to any water withdrawal of more than 100,000 gallons per day from any water source. The NYSDEC was directed to summarize and regularly report on the permits and water use state-wide. The mandated reporting has lagged, but some withdrawal locations are posted on the NYSDEC website. Long Island was excluded from the statewide reporting mandate. The NYSDEC is in the process of digitizing water use information and, once the monthly reports are available electronically, the NYSDEC should be able to provide reports on the amount of water pumped on Long Island.

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 9-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.

Safe Yield in Theory and Practice

The term “safe yield” is commonly used to describe the maximum amount of water that can be withdrawn from a water resource without causing unacceptable consequences. It was originally derived from surface water reservoir studies. 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. As the term is used on Long Island, it gives a false sense of “safety” and incorrectly compares pumpage to recharge.

There is an important relationship between the aquifer equilibrium and groundwater-fed surface water features. “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). In spite of the evolving understanding of groundwater dynamics on Long Island, safe yield has been misconstrued as the long-term balance between “the amount of ground water withdrawn annually and the annual amount of recharge to the aquifers (Nassau County, 1998; Suffolk County, 2015).

For an island aquifer system like that on Long Island, the claim that safe yield is the relationship between recharge and pumping is not only incorrect but it represents a fundamental misunderstanding of groundwater hydrologic functions. A more precise view of system balance should be used in its place. As already noted, public water supply withdrawal in Nassau County has reached nearly 60% of all water lost from the aquifers and the groundwater system is changing in unacceptable ways as a result, especially with increased saltwater intrusion. A new term that is well-matched to Long Island conditions is “*managed yield*” which adds a margin of safety to traditionally developed levels of sustainable pumpage. As with other efforts to understand safe yield, this determination should be a community-wide assessment, not strictly a “scientifically defined” level of water withdrawal. Defining the unacceptable consequences from human water withdrawals from an aquifer system requires input from all interested stakeholders.

Water Caps in Nassau County

In September 1986, the NYSDEC announced a new program to bring water withdrawals in Nassau County back to a level that, in its view, was more sustainable. The NYSDEC found that pumping had reached 200 MGD which was well above the generally accepted safe level of 180 MGD (*New York Times,* September 21, 1986). All 41 public water supply systems were given pumpage limits that would “cap” pumpage to their highest previous level. Two caps were established for each affected water supplier: an annual pumpage cap and a five-year average cap. Many water suppliers objected to the program and the development industry protested, claiming that these limits would stop economic growth. Some water districts sued the NYSDEC to lift the caps.

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 Five Year Average cap for the entire county was 188.5 MGD. This represented total pumpage between the years 1981 to 1985, divided by five. This approach allowed the highest pumpage to be off-set by the lowest annual pumpage over a five year period. The Annual Cap was originally based on the highest yearly pumpage in 5-year blocks from 1976 to 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 Five-Year cap and the Annual Cap would be adjusted as the program produced lower pumpage, thereby slowly bring down permitted withdrawals.

After the NYSDEC lost litigation in the challenges to the caps, it stopped re-calculating new Five-Year Caps on a rolling five-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 7
Public Water Supply Pumpage in Nassau County, 2000–2003

YEAR	WINTER LOW MGD	SUMMER HIGH MGD	ANNUAL MGD
2000	141 MGD - January	287 MGD - July	187
2001	134- February	296 - August	203
2002	128 - February	340 - July	200
2003	135 – December	293 - July	184
Four Year Average			193.5

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

Between 1990 and 2003, the 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 through 2014 reached 251 MGD (See Figure 1).

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 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.

Goals: Recommendations and Conclusion for Groundwater Quantity Management

1. A comprehensive regional water budget should be developed for all of Long Island. It should note changes to water in storage when water withdrawals increase and identify anticipated impacts. The water budget should analyze aquifer conditions on a sub-regional basis as well to distinguish conditions by county. Goals should be set for achieving certain sustainability levels for the aquifer system.

2. Groundwater over-pumping in Nassau County must be curtailed, with specific goals recommended within a realistic timeline. The public should be informed regarding the negative impact that lawn irrigation has on water resources. The Water Caps, or a similar program, should be re-established for Nassau County with appropriate enforcement. Water caps and pumpage should be reported annually along with performance and enforcement information.

3. A Managed Yield level should be developed for each county, and should also be recalculated on a regular basis such as 10-year cycles to compare the goals with actual conditions. The public should be involved in the discussion to establish managed yield goals and have input into the final level adopted. Managed Yield can be refined to include sub-regional water withdrawal goals/limitations. .

4. For areas with water conservation mandates, effective enforcement is essential. All of Long Island should be practicing water conservation because it promotes both water quantity and water quality improvements. Conservation pricing for large volume water users should be implemented. All Annual Water Quality Reports should include a full description of water rates in effect for each reporting year.

5. Water use for each county, with details on large water-user categories, should be annually reported, possibly coinciding with the Annual Water Quality Reports. Water use data should be computerized and available via the internet so that it can be tracked more easily. In the absence of a regional aquifer management entity, the NYSDEC should provide this service. Per capita water use levels for Long Island and a comparison to other major suburban areas, is needed. Water bills should highlight the number of gallons used in each bill to help the public be more informed about water consumption.

6. The NYSDEC should comply with the state law requiring it to identify quantity- and quality-stressed areas of the aquifers/groundwater system.

7. Public education is essential in the area of excessive summer water demand. New guidelines should be developed that provide the public with better Best Management Practices for lawn irrigation. The current guideline of one inch of water per week for a typical lawn is not easily converted into effective irrigation strategies. A better way of gauging adequate watering should be developed. Even better, practices that avoid landscape irrigation would be preferred.

8. Strategies for reducing water demand in summer are needed, especially where landscape irrigation is concerned. Wider use of rain barrels, rain gardens, and use of gray-water could help ease the summer demand. A change in landscape practices to promote low water demand plantings is needed, as is a sweeping public education program emphasizing conservation and the value of water.

9. Reporting on water use by geothermal systems is needed. Closed-loop vs. open-loop systems should be tracked and a regulatory program developed.

10. 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, public water supply, etc.

11. The practice of comparing annual pumpage to recharge as a way to denote aquifer health or sustainability should be ended because the comparison is a false equivalency. Overall, water lost from the aquifers compared to recharge is a more appropriate comparison for an aquifer system like that on Long Island.

12. Overpumping portions of the Glacial and Magothy Aquifers puts the viability and sustainability of the Lloyd Aquifer in jeopardy because it reduces recharge to the Lloyd Aquifer. The protection of the Lloyd Aquifer should be strengthened.

13. Improvements in recharge basin management should be implemented to increase aquifer recharge and water in storage.

14. Where contaminated plume remediation projects are operating, the recommended practice should be that, wherever possible, the extracted and treated groundwater is recharged to the aquifer system and not discharged as waste or to the coastal waters.

15. 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.

16. A drought monitoring and response plan needs to be developed and implemented. This means that a monitoring well network for this purpose is needed as recommended by the USGS in SIR report 2004-5152 (Busciolano, 2005).

17. The well permit program should be revised to make it a valuable tool for managing the groundwater resource. This is an essential requirement for effective groundwater management. The NYSDEC should expand the tools it uses groundwater management. A key change in the program should include the posting of well permit renewals as notices in the Environmental Notice Bulletin (ENB). Violations of water withdrawal limits should be enforced. Permitting should be guided by strong scientific knowledge of aquifer conditions and processes as well as managed yield goals and limits.

18. Long Island needs regional, comprehensive groundwater management, either through a properly funded and staffed NYSDEC or a stand-alone professional management entity with independent funding similar to surface water management agencies in NYS.

19. As more information is provided on the location of the freshwater-saltwater interface and risk from saltwater 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 saltwater intrusion and its mitigation.

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