



# **Sewage Treatment Plants in Suffolk County: Case Studies**

**Prepared by**

**Stony Brook University's Long Island  
Groundwater Research Institute**

**for the**

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## **Stony Brook University's Long Island Groundwater Research Institute**



The State University of New York at Stony Brook established the Long Island Groundwater Research Institute (LIGRI) in 1994 to marshal the resources and expertise of the University for the study of groundwater hydrology and chemistry. One of our goals is to bring the results of scientific research to bear on the region's most pressing groundwater problems. Inquiries on all aspects of groundwater hydrology and chemistry are welcome.

The resolution of hydrogeological and groundwater pollution problems requires basic and applied research from a broad array of disciplines. The Institute coordinates and expands the existing potential for research by faculty, staff and students in groundwater hydrology. The Institute maintains close communication with ground-water professionals in the government and private sector in Long Island. Through the University's Center for Regional Policy Studies, a distinguished Advisory Council has been established with representation of agencies with management responsibilities. In 1997 the Institute was formally established by legislative act.

The Institute is served by faculty in the School of Marine and Atmospheric Sciences, the Department of Earth and Space Science, and the Department of Applied Mathematics and Statistics. The Institute is advised by a Council with representatives of the Suffolk County Water Authority, U.S. Geological Survey, US EPA, NYS DEC, Suffolk County Health Department, Brookhaven National Laboratory, Stony Brook University's Center for Regional Policy Studies, Long Island Water Conference, Nassau County Department of Health, Nassau-Suffolk Water Commissioners Association, Nassau County Department of Public Works.

# **Sewage Treatment Plants in Suffolk County: Case Studies**

**Long Island Groundwater Research Institute  
Stony Brook University  
Stony Brook, NY**

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## **Executive Summary**

Sewering projects benefit groundwater quality by reducing nitrogen contamination in the aquifer. They also alter the hydraulic state of the aquifer and can change groundwater quality in other ways. When reviewing proposed sewerage projects, water suppliers must consider not only the degree of nitrogen reduction but other issues impacting groundwater supplies. Four case studies of sewage treatment plants (STP's) were examined for lessons that would be relevant to the impacts on groundwater resources of new or expanded sewer districts. Any proposal for a new STP would have to be evaluated on a case-by-case basis. However, in the interest of maintaining fresh water supplies, it is important to question impact assessments from the following perspectives.

1. What should we expect from computer models? For ocean discharges, the potential declines in both the water-table elevation and in the potentiometric surface of the Magothy Aquifer need to be evaluated. For discharges into seepage pits, changes in the hydraulic gradients and the distribution of recharge need to be anticipated. Computer models are certainly the best, most consistent, estimates of the above-mentioned impacts, and they should be required for any new or proposed expansions. However, as the history of studies for the Southwest Sewer District (SWSD) demonstrates, even the "best available" models have been inaccurate in the past. Despite substantial improvements in our computational power, modeling results should always be approached with caution (regardless of how well presented). Computer models are limited mostly by available geologic data on a localized scale. This limitation results in uncertainties in the forecast of transient and future conditions.
2. For STPs with ocean discharges, what would be the expected decline in the water table elevation? The water table may also be lowered. The potentiometric surfaces of the deeper aquifers tapped by public supply

wells, also may be expected to decline. Some regional sewer districts in Nassau County have seen water-table declines of ten or fifteen feet as a result of sewerage. Smaller, isolated districts have seen substantially less hydrogeologic impact. Within the SWSD, the changes in water table elevation have been less than the natural variations. These smaller impacts, however, have the potential to become more substantial as local sewerage becomes more regional in nature. Impacted areas may then coalesce and overlap.

3. If the surface water flow in streams, ponds and wetlands need to be augmented (because of declining water-table elevations), how will this be done? In some cases, contingency plans had proposed dedicated, extraction wells solely to pump groundwater from the aquifer systems back into streams and ponds. This practice, of course, would put additional stresses on groundwater resources.
4. For STP discharges into seepage pits, is groundwater mounding an issue? Under areas of concentrated recharge, the water-table may rise locally. This is known as mounding. Based on experience, mounds in the water table might be expected to be several feet high and extend a few thousand feet. The presence or absence of low permeability layers below the seepage pits is critical. While not problematic for public supply wells, these mounds can substantially alter local hydraulic gradients and recharge, and affect the paths of local contaminant plumes.
5. For STP discharge into seepage pits, what untreated contaminants might be a problem given the types of customers served? STPs treat for nitrogen and microbes. However, other untreated contaminants can enter the aquifer with the recharge of treated wastewater. Pharmaceuticals and personal care products (PPCPs), for example, are one class of contaminants that may be of concern. The nature of such untreated contamination will depend on the sources connected to the STP. While the upper glacial aquifer may continue to be recharged by return flow, the areal distribution of the recharge will be altered, and the contaminant loading will be more concentrated. Metals, for example, have proven to be a particular problem at Brookhaven National Laboratory (BNL).
6. What amount of diffuse leakage from sewer mains should be expected? Leakage from sewer mains should be expected regardless of the effluent disposal option. Sewage “indicators” such as pharmaceuticals and personal care products (PPCPs) will still enter the groundwater at about 10% of the discharge.

Other issues encountered during the course of this study included:

- the influence of recharge basins and cluster development on local hydraulic gradients

- the potential impacts of climate change leading to increased precipitation, warmer climate temperatures and a longer growing season
- the feasibility of improved, individual septic systems
- the possible use of nitrogen “credits” gained to increase the discharge of STPs based on the resulting decrease in loading due to the replacement to septic systems.
- the control of plumes by regulation of pumping and recharge

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## Introduction

Sewered areas of Suffolk County can be found at:

[http://www.co.suffolk.ny.us/upload/planning/pdfs2/maps/2011\\_pdf/sewers\\_122010.pdf](http://www.co.suffolk.ny.us/upload/planning/pdfs2/maps/2011_pdf/sewers_122010.pdf).

The benefits of sewer treatment plants (STPs) in reducing nitrate concentrations in the groundwater has been well documented in Nassau County. In addition, the impacts of falling water tables have long been addressed by the Flow Augmentation Needs Study (FANS). For this report, the situations at four sewered systems in Suffolk County were reviewed with the view toward identifying other conditions that could impact water supply. This report is intended to provide guidance for anticipating impacts.

In Nassau County, the development of the sewer system with ocean outfalls beginning in the early 1950's has caused a decline in water-table elevation as well as a reduction of groundwater nitrate concentrations (e.g. Sulam, 1979). For example, in Nassau County Sewage Disposal District 2, the water-table elevation had reached a new equilibrium level by the mid-1970's about nine feet below pre-sewered conditions (Franke, 1968; Garber and Sulam 1976, Sulam 1979, Busciolano, 2004). Countywide, the new equilibrium water-table elevation had been lowered by about thirteen feet in the sewered areas across the county. Some of this decline was due to the spread of depressions in the water table from pumping further west in Queens County. Declines in the water-table elevation would ease flooding risks, however, the need for flow augmentation of surface water due to declines in the water table was an important issue. One plan to augment surface flows called for pumping groundwater from eastern Nassau to mitigate surface water impacts in the west. Recharge basins, on the other hand, were found to recharge more water than equivalent, undisturbed land. As a result, recharge basins may have mitigated some of the declines in the water table due to STPs.

The four cases examined in this report are: (1) the Southwest Sewer District (SWSD), (2) the STP at Brookhaven National Laboratory (BNL), (3) the STP in Northport, and (4) the STP at Stony Brook University (SBU). The SWSD will be used to explore how the abovementioned issues materialize in Suffolk County. There is a long history of modeling and monitoring in the SWSD, which demonstrate (1) the need to consider aggregate, water table impacts from neighboring sewer districts and (2) the difficulty in evaluating water table impacts in light of natural variations in recharge. The STP at BNL is currently eliminating its discharge to surface water and switching to the use of recharge basins. This example is used to illustrate potential issues of groundwater mounding on local hydraulic gradients and untreated sources of contaminants. The Northport STP is dealing with the issues of infiltration and inflow. Leakage and overflow of STP could contribute to water quality issues at supply wells. The case at Stony Brook University was used to explore differences between open-water discharges and seepage recharge. In all cases, the focus will be on the impacts of STPs on the quality and quantity of water supply.

Besides the depression of the water table and the reduction of groundwater nitrate concentrations, other potential issues for water suppliers may include:

- The importance of confining layers in mounding of groundwater
- Potential leakage of sewer mains, resulting in untreated contaminants entering the aquifer
- The presence of untreated contaminants in the effluent. Previous results on STPs and their effluents has focused on nitrogen and microbes which are treated at the plant. However, at BNL, metals became an important issue.

## **I. The Southwest Sewer District**

### **Principal issue: Modeling and Monitoring of long term water-table decline**

The SWSD opened in 1981. It now serves 84,000 properties, maintains over 1250 miles of pipe. The SWSD operates 21 STPs in Islip and Babylon primarily south of the Southern State Parkway. STPs range in size from 0.035 MGD to 30.5 MGD. In December 2010, a \$65 million resolution was passed to increase capacity at the West Babylon STP by thirty-three percent. This would raise the discharge to 41 MGD from its current limit of 30 MGD. New development both at the Pilgrim Psychiatric Center (a 9,000-unit Heartland Town Square), and in downtown Wyandanch (Wyandanch Rising) may require 2.5 MGD and 0.4 MGD respectively. There are twenty-four public supply wells within the SWSD.

Calculations to forecast the lowering of the water table were done in 1975, when construction was in progress (Franke and Gertzen, 1976). This was a “one-line” model, limited by the computing power at the time. (A “one-line” model is essentially a calculation in two dimensions only). At the time, it was the best estimate available. Actual depressions were expected to be different, but it was not known whether they would be higher or lower or by how much. Three-dimensional modeling subsequently was added to the forecast (Kimmel and Harbaugh 1975). The maximum decline in water table level was anticipated to be between 3 and 8 feet in the western part of the SWSD and near its northern border. Declines were expected to be about 2 feet at the south shoreline and at the water table divide. Hydraulic heads in the Magothy also were expected to decline (Reilly et al. 1983; Buxton and Reilly 1985; Reilly and Buxton, 1985). Most of the adjustment was expected to occur within 5 years, which would be by 1986. A new equilibrium would be established, so that no measurable changes would occur after 10 years, that is, by 1991. This was consistent with actual observations of the water table in Nassau County. In anticipation of a need for flow augmentation, pumping of groundwater was considered solely for this purpose. It was recognized, however, that pumping groundwater for mitigation would not necessarily be benign.

Regional water levels were examined in 1988 (post-sewering) and compared to the pre-sewered (1977) condition (Camp Dresser and McKee, 1991). The results of this analysis



did not conform to predictions made by the U.S. Geological Survey (USGS; Camp Dresser and McKee, 1991). Although the magnitudes of the water-table declines were comparable to USGS predictions, the distribution of these declines had not been anticipated. Declines were “greatest in the middle of the sewered areas and to the east in unsewered areas” (Camp Dresser and McKee, 1991). The level of the water table actually rose in the western part of the SWSD. The results were believed to have been affected by a period of low precipitation in 1988. In addition, during the period, development north of the SWSD, added recharge basins upgradient. Because recharge basins are known to increase recharge, the new recharge basins may have augmented groundwater flow into the SWSD. The addition of recharge from the basins could have negated, in part, declines in the water table due to the ocean discharges.

Since the declines predicted by the initial calculations were not observed, new modeling was done. A modern, three-dimensional model was used in 1996. This work confirmed that the water-table elevations had declined as a result of sewerings. The model predicted a decline of the water table by about one foot both in the center of the District (around Willets Creek) and in a east, specifically on the west shore of the Connetquot River. Calculated declines in the water table elevation of up to seven feet in the western part of the District were clearly due to impacts from Nassau County. (Recall that earlier, similar impacts from pumping in Queens had been documented in Nassau County). The calculated changes however, could not be verified from direct measurements for two reasons. First, the measurements had not been made consistently at the same wells or in the same seasons. Second, the trends were obscured by natural changes in precipitation and recharge. A long-term analysis of hydrologic records in 2004 (Busciolano, 2004) concluded that “water levels in the western part of Suffolk have fallen and risen markedly (more than 15 feet) in response to fluctuations in pumpage, and have declined from the increase use of sanitary and storm-sewer systems”.

The USGS has twenty-two monitoring wells in the SWSD (Appendix). Twelve of these have water quality data. Many of the records are sparse or contain gaps but, where the records are fairly continuous (e.g. well 1805.4, Figure 1), three features are apparent. First, the drought of 1960s, as well as the periods of low precipitation in the late 1980’s and in 1995 have all resulted in a decline in water-table elevation approximately five to six feet\*. Second, long-term declines are not immediately obvious in the data. During the period from the end of sewer construction (1981) and the predicted time to a new equilibrium (1991), the water-table elevation declined about four feet at well 1805.4. However, this was also a period of lower than normal precipitation. In some locations, the average water level actually rose after sewerling. Third, after 1991, the average water

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\* It may be helpful to consider how a few inches of rainfall can change in several feet in the water-table elevation by several feet. The greatest factor is in the degree of saturation of the vadose zone. The aquifer is, of course, composed of about 50% solid particles and 50% pore space that can or cannot be filled with water. (So, right off the bat, one inch of recharge corresponds to a 2 inch rise in the water-table). Below the water-table, all the empty space in the aquifer is filled with water so that hydrostatic pressure pervades the fluid). Above the water-table, however, the aquifer is not completely dry. Some of the pore space is filled with isolated pockets of water held in place by surface tension rather than hydrostatic equilibrium. As a result, to raise the water table, the recharge doesn’t have to fill all the pore space but merely add enough new water to connect the water that is already present in the vadose zone. If the pore space in the vadose zone already 90% water, then the new recharge only has to add 25% more to raise the water table. One inch of recharge could raise the water-table almost a foot. There is also an issue concerning the irregular distribution of the recharge (mounding and focusing).

levels rebounded, but the maximum levels tended to be lower (below +45' msl) than the historical high (+47' msl). In addition, the minima were lower than those observed during the drought of the 1960s by nearly six feet. To put any impact due to the sewerage into perspective, some additional quantification may be helpful.

The SWSD pumps about 30 MGD (Camp, Dresser and McKee 2000). This is about half of the annual average recharge to the SWSD. If groundwater did not enter the district from the north, such a loss would represent drought conditions and the water-table would be expected to fall to drought levels of the past. It does not, however, because the SWSD receives groundwater from upgradient recharge from the north. Development in the upgradient area since the time of sewer construction has added recharge basins and supplemented recharge helping to mitigate “drought” conditions in the SWSD itself.

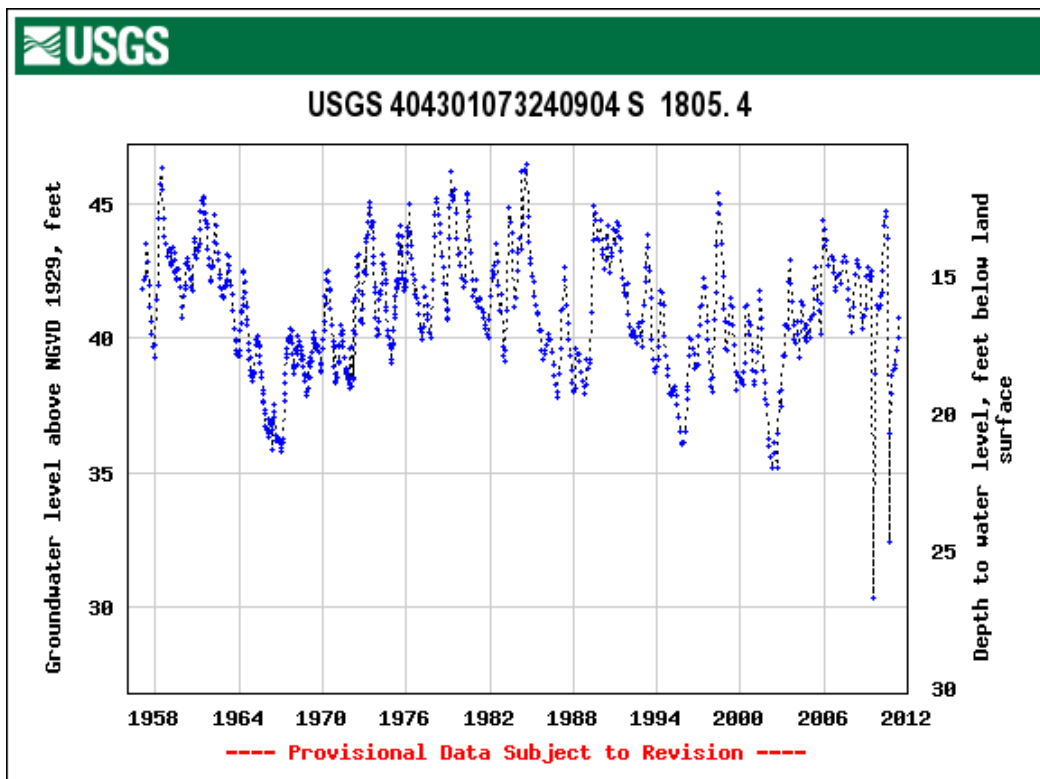


Figure 1. Groundwater levels at well 1805.4 from the Upper Glacial Aquifer in North Lindenhurst (40°43'02.1"N; 73°24'07.2"W).

Water quality data is available in the FANS reports from 1980 for comparison to any recent data bases (Table 1). Recent USGS water quality data is not sufficient for meaningful comparisons. For example, the most recent data was one sample from each of three wells in 2006. Almost all of the other data was taken in various periods between 1970 and 1987.

Well No.	Water-table data	Water Quality data
1803.0	Few data	none
1803.4	Few data	none
1803.5	Starts in '95. Gap after 2007	1 sample in 2006
1805.4	Best record. From 1959	none
1807.6	Starts in 1992	1 sample in 2001
1808.5	Starts IN 1990, then good 'til 2011	2 samples in 2001
1809.4	Good from 1981	none
10314.1	Good from '58 to '86; sparse thereafter	none
10370.1	Good from '58 to '86; sparse thereafter	none
17987.4	OK. Starts in 2000.	1 sample in 2006
37681.1	Sparse 1977 to 2011	29 samples 1970-85
42762.1	Sparse record from 1978	17 samples 1972-85
43809.1	Starts in '74. Sparse from '86 to 2005 then OK	71 samples 1970-85
43815.1	'74 to '86. Gap 'til 2005 then good.	62 samples 1970-85
50546.1	Very sparse but starting in '78	14 samples 1975-92
63618.1	Very sparse but starting in '84	8 samples 1979-87
63830.1	Sparse '79 to 2007. Good after 2007	none
63835.1	Sparse with gaps from '78 to 2005, then good	1 sample in 2006
64192.1	From 1978, but sparse and several gaps.	none
66145.1	Some data '80 to '83. Gap 'til '05, then good.	none
66156.1	Some data from '80 to '83 and from 2009.	none
67537.1	Few data	9 samples 1986-85
123414.1	Sparse. Only from 2005	none

Table 1. USGS monitoring wells in the SWSD. From:  
[http://groundwaterwatch.usgs.gov/googlemaps/NY\\_103\\_gm.html](http://groundwaterwatch.usgs.gov/googlemaps/NY_103_gm.html)

## II. Northport Sewage Treatment Plant

### **Principal issue: Leakage and the input of contaminants from both sewered and unsewered areas**

The Northport STP serves both residential and commercial properties in Northport Village. Its historical average monthly flow has been 0.3 MGD with a maximum average monthly flow of 0.4 MGD. The SPDES-permitted flow is 0.45 MGD. Inflow can raise the discharge by 50% during storms and possibly at times of high tides. One particular event in March, 2010 lead to a maximum flow of 0.6 MGD. The plant is pursuing numerous improvements and repairs intended to reduce infiltration and inflow. Illegal discharges are also being investigated such as unauthorized connections from down spouts, foundation drains. Northport officials hope to eliminate storm sewer cross-connections from the sanitary sewer system.

The USGS and Stony Brook University has studied nitrogen fluxes as well as an investigation of the occurrence of nuisance algal blooms. Nitrogen, and other mobile contaminants, from unsewered areas enter the groundwater. These are eventually discharged into ponds, streams, or open, coastal waters. The flux of nitrate *via* subsurface groundwater discharge under the shoreline is higher for unsewered areas. However, the detection of pharmaceuticals in the shallow groundwater at the shoreline is an indicator of sewage input. At the Northport Village shore, concentrations of carbamazepine, an anticonvulsant drug, ranged up to 3 mg/l adjacent to the sewer area (Zhao et al. 2011). This was lower than detections in unsewered areas of Northport but higher than the sewerage shoreline in Manhasset Harbor (Zhao et al. 2011). It would appear to indicate leakage from sewer mains within the Northport sewer district.

Recent discussions centering on the Northport STP have raised the possibility of increasing the discharge of STPs currently limited by TMDLs (Total Maximum Daily Loads) by giving credit for the reduction of the nitrogen load to the groundwater gained by replacing individual septic systems in a sewer district. As a rule-of-thumb, sewerage is expected to give a 60% reduction of the nitrogen load. Alternatively, about a 40% load reduction might be gained with alternative septic systems.

### **III. Brookhaven National Laboratory**

#### **Principal issue: groundwater mounding and untreated contaminants**

Brookhaven National Laboratories (BNL) intends to end the discharge from its STP to the Peconic River and, instead, build new, leaching pits to recharge treated water to the aquifer. Most STP's in Suffolk County use similar methods. The BNL STP began operation in 1917. Discharges in the past were reported to have exceeded one MGD. It has now been discharging between 0.3 MGD (winter) and 0.5 MGD (summer) to the Peconic River. Biological removal of nitrogen is accomplished by regulating the oxygen levels during the treatment process, thereby forcing the bacteria to use nitrate-bound oxygen for respiration. Wastewater from the STP secondary clarifier has been released to sand filter beds. Here the water percolated through three feet of sand and gravel before being recovered by an underlying clay-tile pipe drain system. Approximately 20% of the water released to the filter beds is lost either to evaporation or to direct groundwater recharge. Surface water discharge to the Peconic River requires a SPDES permit. The existing permit is being updated to lower the limits on metals. Mercury poses a particular problem. Not only were input concentrations of mercury, and other metals elevated but they were not removed in the treatment process at the STP. Additionally, the sand in the filter beds has accumulated metals and was now acting as an additional source of metals to the discharge. A SPDES permit modification will be required when the new system is installed. Clean filter sand in the new seepage pits can be expected to be more efficient in removing metals.

The existence of shallow, clay layers under the seepage pits has resulted in a perched water table and groundwater mounding. Under these conditions, the recharge of between 0.06 MGD and 0.1 MGD (approximately 20% of the discharge) has produced a groundwater mound about four feet high, 2100 feet long and 1150 feet wide. There was concern that the groundwater mound might “breakthrough” the land surface. If the mound grew to reach the land surface overland runoff and flooding might occur. This did not happen however. Similar mounding conditions have been found under a recharge basin on the Stony Brook University campus (Pizzulli and Hanson, 1999; Kilb, 2006). The mound under the BNL seepage pits contains about 0.6 MG of water. This is equivalent to seven or eight years’ worth of discharge. Since this is produced by a recharge of, at most, 0.4 MDG, similar mounds might be expected to contain 1.5 times the excess daily recharge. A recent review of quantitative methods for estimating groundwater mounding has been done by Poeter et al. (2005). The dimensions of such groundwater mounds depend upon the infiltration rate and the hydraulic conductivities of the sediments receiving the recharge.

Mounding, as described at the BNL STP, could also become an important issue under recharge basins or in clustered developments with individual septic systems. Significant mounding typically is perched above shallow clay layers. Long Island’s glacial geologic history makes such layers prevalent but often undetected. Localized, lateral groundwater movement away from such mounds conceivably could impact nearby supply wells. Calculations can be performed fairly quickly and easily to determine what might be a problem in a particular area as long as the extent of subsurface clay layers is known.

Conditions at BNL also highlight the importance of “transient analysis” that includes changes in pumpage and recharge. At one location in BNL, a contaminant plume was being monitored by a series of wells but a decrease in recharge through nearby seepage pits altered the hydraulic gradients and shifted the plume far off its original course. While not necessarily a surprising development, the event does draw attention to changes in the migration of known, contaminant plumes caused by modulating pumpage and recharge, or alternatively, of unknowingly drawing in plumes in the normal course of operation. A similar situation was encountered at the Grumman plant, emphasizing the need for transient analysis under variable conditions.

## **IV. Stony Brook University**

### **Principal Issue: ocean outfall *versus* seepage pits**

Stony Brook University’s (SBU) STP achieves a 95% reduction in total nitrogen. Further reductions are not possible with the available technology. Currently, its effluent is combined with the tertiary-treated effluent from the Port Jefferson plant before both are discharged to the Harbor. The SCWA has two distribution zones that include Port Jefferson. Groundwater from these two distribution zones ultimately discharges into Port Jefferson Harbor carrying its associated load of nitrogen. According to SCWA reports,

potable water supplied from Magothy aquifer wells located within Distribution Zone 14 has an average nitrate value of 0.16 mgN/L. Potable water supplied from Magothy aquifer wells located within Distribution Zone 15 has an average of 3.13 mgN/L. While the latter figure is well below the NYS drinking water standard for nitrate of 10 mg/L, it is above the nitrate concentration of SBU-STP (2.4 mgN/L). However, since many of these supply wells draw their water from outside of the area that is sewered, correlation of sewerage to public supply well water quality is unreliable.

In the two years before the TMDL's were established (1988-1990), Stony Brook was delivering about 208 pounds total nitrogen per day and the Port Jefferson Plant was putting in 202 pounds per day. By comparison with other STPs in Suffolk County Zone 11, Huntington was delivering 448 pounds daily; Northport, 52 pounds; Kings Park 134 pounds; and Greenport, 76 pounds. Over the past two years, the SBU-STP has had an average monthly discharge of 1.76 (MGD). This discharge is 70% of its designed capacity of 2.5 MGD. It is currently (2010) limited to 82 pounds of nitrogen per day. Its monthly average load has been 81 pounds/day total nitrogen. In 2014, the limit will be reduced to be 40 pounds N/day.

Like the SBU-STP, the Port Jefferson STP is a nitrogen removal plant. In early 2008, the plant completed its denitrification upgrade to meet 2014 TMDL (total maximum daily load) applicable to Long Island Sound. On average, the Port Jefferson STP discharges 0.67 MGD per month or 58% of its design capacity of 1.15 MGD. It is currently limited to discharge 80 pounds total nitrogen per day and actually discharges 27 pounds total nitrogen per day on average over the year. In 2014, its TMDL will be reduced to 39 pounds total nitrogen per day. By comparison, the input of nitrogen to the Harbor *via* groundwater underflow had been estimated to be 847 lbsN/day (Gross et al. 1972). The 1972-estimate is that 14 million cubic meters per year (10 MGD) freshwater enters the harbor as groundwater.

Seepage pits were considered as a way to accommodate an increased discharge. Five locations have been considered. Each covered approximately four acres. The conventional guideline is to assume a 50% loss of nitrate in the vadose zone. However, the actual fate of nitrogen in the shallow subsurface is speculative. Some denitrification may occur in the open seepage field, but the amount, if any, is uncertain. Below the ground, vadose zone denitrification does not appear to be significant. Kenny and Valiela (2010) estimate a 61% loss in the vadose zone and 35% loss in groundwater based on studies done on from Cape Cod. However, Bleifuss *et al.* (2000), using N and O isotopes in a similar setting on the north shore of Long Island came to a different conclusion. Subsequently, Young *et al.* (2009) found an average of only 7% denitrification in groundwater in Northport. Cation exchange in the vadose would not be a significant source of loss if pits were used to remediate SBU-STP effluent because the N is already in NO<sub>3</sub> form when it reaches this point, not NH<sub>4</sub>.

Nitrogen from the proposed seepage fields would eventually reach the open water in either West Meadow Creek, Stony Brook Harbor or Port Jefferson Harbor. Further loss in N would be expected below the water table as the effluent travels toward the shore, but

with a delay of many years before reaching coastal waters. From seepage-pit sites around Stony Brook, travel times ranged from 9 to 45 years. The uncertainties in these forecasts are large. Detailed studies of the situation at Lawrence Aviation Industries (e.g. Camp, Dresser & McKee, 2000) showed a complex stratigraphy including discontinuous clay layers that would alter the groundwater flow patterns. A similar, but currently unknown, complication should be expected between the Stony Brook campus and the shore. In particular, clay layers may hinder leaching rates as well as cause water-table mounding. Studies at the existing recharge basin on campus (Pizzulli and Hanson, 1999; Kilb, 2006) for example, show mounding of the groundwater beneath the basin resulting from slow flow both vertically and laterally. On the other hand, if conditions allow greater than expected lateral flow, a groundwater plume could emerge at inappropriate places.

Denitrification may occur as the groundwater seeps through the marsh and marine sediments just before discharging into the surface water but site-specific studies would be needed to evaluate the effectiveness of this process. On Cape Cod, measurements in a coastal pond did document denitrification as N-rich groundwater mixed with DOC-rich, saline pore water.

## **Summary and Recommendations**

The computer models of groundwater impacts are indeed the state-of-the-art. They are sophisticated and represent the best predictions possible, but they are not infallible. The experience with the results of model calculations in the SWSD is instructive. In the current situation, the calculational power and resolution is vastly superior than it had been in earlier decades. However, site-specific realities, such as the occurrence of localized clay layers, variations in hydraulic conductivities in three dimensions, and the process of dispersion, are more poorly resolved. In the SWSD, declines in the water table were over-predicted. Actual changes in the water table elevation due to sewerage were obscured by natural variations due to precipitation and, perhaps, elevated recharge from the construction of recharge basins.

Declines in the water table due to pumpage and open-water discharge in the neighboring Nassau County sewer districts impinged on the SWSD substantially depressing the water table there. A similar impact had been seen in Nassau County due to sewerage in Queens. In other areas of Suffolk County, small, isolated sewer districts are unlikely to be impacted by sewerage neighbors, but as new sewer districts are added, or existing STPs expanded, at some point the influences will overlap. (In principle, a rule-of-thumb has it that this will happen when about one-eighth, of the total area is sewerage). Efforts to enhance infiltration and increase recharge should be considered as partial remediation.

The issue encountered with metals at the BNL STP might be of concern at other STPs. STPs are designed to remove suspended solids, reduce organic matter, eliminate pathogens, and reduce total nitrogen. With biological nitrate removal nitrogen levels can be reduced as low as 3 to 6 mg/L. As the experience at BNL shows, however, other

contaminants, mercury in this case, were not treated at the STP and became a serious problem. In this case, mercury contamination was not just unique to laboratory operations but included sanitary sources and wash water from painting. Copper, iron, lead and nickel had similar sources not unique to research laboratory operations. Removal of metals by treatment at the STP may actually cause other impacts depending on the process used. Specialized contaminants in the source water of any STP may be an environmental or ecological issue in the future as they enter the shallow aquifer. Pharmaceutical and personal care products are examples of such untreated contaminants. New or expanded sewer districts should be examined for especially strong sources of untreated contamination.

Mounding under seepage pits can be anticipated by a variety of quantitative means (Poeter et al. 2005). One important element controlling the size of groundwater mounds is the presence of shallow confining layers. Such layers are prevalent throughout Long Island because of its glacial history but they are often discontinuous and poorly mapped if they are known at all. While mounding, because it is generally a local phenomenon, should not be expected to impact the hydraulic potential at supply wells, it would influence both the dispersion and course of contaminant plumes leaving the discharge area. Flooding could also be aggravated if breakthrough occurs. Recharge basins, on the other hand, can increase the amount of recharge and, in principle, partially offset declines in water tables due to STP open-water discharge. This may have been a mitigating factor in the and around the SWSD.

Other relevant issues were encountered during the course of this study that would warrant further investigation. For example, some of the problems encountered at Northport were due to an aging infrastructure. Clearly, new STPs will have sufficient longevity to insure proper operation during exposure to extremes in the weather (droughts and flooding) and potentially, long-term climatic changes. The design factors for much of our infrastructure were determined from climatic measurements made half a century ago. Since then, Long Island has been experiencing unprecedented episodes of drought and flooding. Future predictions indicate a strong possibility of wetter conditions, a longer growing season, greater fluctuations in both temperature and precipitation, and a rising sea level.

Recommendation: If engineering plans for new or expanded STP are available, they should be reviewed in the light of the historical impacts to the water supply considered here.

Recommendation: Localized recharge occurs at STP seepage pits, recharge basins and in clustered housing using septic systems. The impact due to mounding should be systematically considered.

Recommendation: Updating design criteria for future infrastructure based on current precipitation records and predicted trends would be prudent.

Finally, improved alternatives to individual, private septic systems exist. If properly installed and maintained such systems can be expected to function as designed. Potential



obstacles are the cost of these systems (estimated to be \$30,000 per household), as well as the degree to which private homeowners can properly install and maintain them. In many cases, physical space will limit the feasibility of alternative systems. Sixty percent of residential lots in Suffolk County are less than one-half acre (Camp, Dresser & McKee, 2010). In western Suffolk, about 30% are smaller than one-quarter acre. Alternatively, hamlet-based systems are less costly than full STPs and might be used in developments to serve multiple households. They are currently limited by Suffolk County to discharges of less than 15,000 gallons per day.

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## Appendix

