NASSAU COUNTY
NINE KEY ELEMENT WATERSHED PLAN
FOR NITROGEN
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By

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Executive Summary

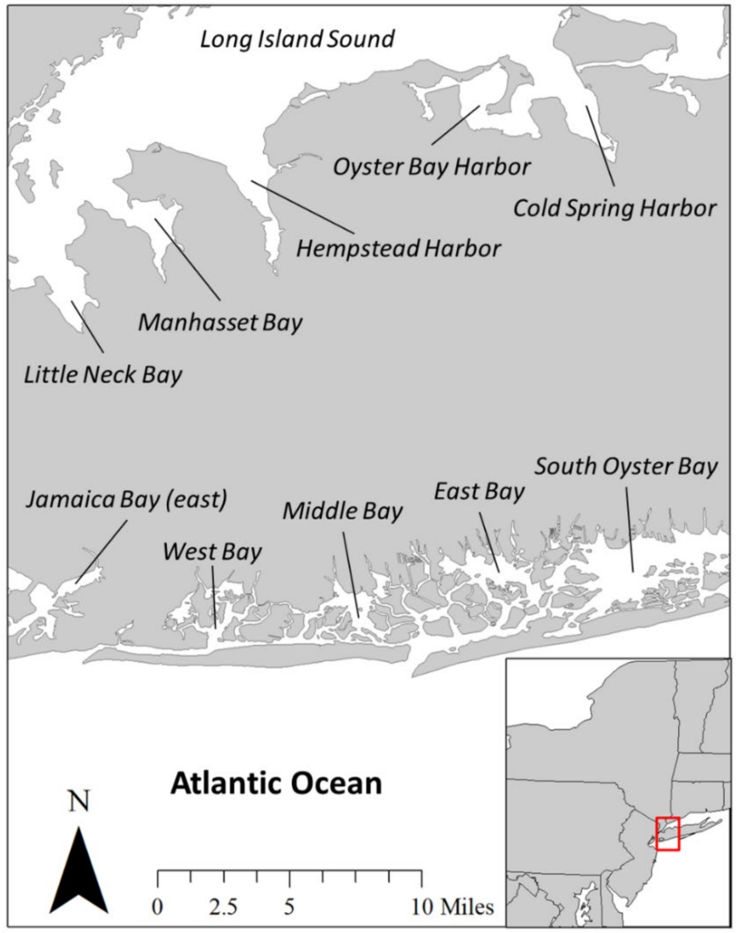
Since the 20th century, delivery of excessive nitrogen (N) into Nassau County coastal waters has led to a host of environmental problems including harmful algal blooms, hypoxic zones, bay water acidification, and habitat degradation and loss. Much of the N enters Nassau County surface waters from precipitation, stormwater (runoff from the land), atmospheric deposition, groundwater seepage - including seepage from septic systems and cesspools, and sewage treatment plant discharge. In 2020, the Nassau County Subwatersheds Study quantified the source of N entering Nassau County surface waters from fertilizer, wastewater, atmospheric deposition and pets. West Bay on the south shore was found to have, by far, the largest N load (2.3×10^6 kg N yr^{-1}) with Cold Spring Harbor, Hempstead Harbor, and Manhasset Bay being an order of magnitude lower than West Bay and the remaining water bodies having lower annual loads. Wastewater from onsite septic systems was the largest N source to all north shore bays, while sewage from the South Shore Wastewater Reclamation facility in Bay Park was the largest source to West Bay (98%). For other south shore sites, wastewater is diverted out of the watershed and fertilizer, primarily from homes, was the largest source of N. Surface run-off was isolated from atmospheric deposition and was found to account for a small fraction of N loads on the north shore (2 – 4%) but a larger fraction of the total on the more urbanized south shore (up to 20%).

For this Nine Element Plan, watershed-based N loading models were updated using newly mapped sub watersheds for Nassau County from the US Geological Survey which were significantly more refined that the original subwatersheds from the 1980s and were, on average, smaller, resulting in smaller N loads for some subwatersheds, such as Cold Spring Harbor, Oyster Bay and Manhasset Bay, but slightly larger loads for Hempstead Harbor and West Bay. The relative contribution of different sources of N were largely unchanged, however. The next Element of this plan was to set N reduction goals which was done by calculating N residence times and using a reference water body approach that was used by Suffolk County, NY< in developing their Nine Element plan. This approach determined that West Bay requires a 99% N load reduction and Oyster Bay, Manhasset Bay, Hempstead Harbor, and Cold Spring Harbor require reductions of 27% – 60%. Next, Best Management Practices for achieving N load reduction were considered and included upgrading septic systems to low N systems, reducing fertilizer use, improving stormwater systems, bioextraction via the aquaculture of oysters and seaweeds, sewering, and rerouting sewage outflow. The Bay Park Conveyance Project which seeks to send sewage from the Bay Park plant to the Cedar Creek plant and out to the Atlantic Ocean would meet virtually all of the N reduction needs for West Bay (98% reduction), while N reduction goals for other subwatersheds can be met by combinations of upgrading septic systems, reducing fertilizer use, implementing aquaculture as a bioextraction approach, and/or sewering some communities. This report goes on to identify programs already in place or programs needed to achieve these reductions, identifies the key individuals and organizations needed to help socialize and implement reductions, lays out a timetable and milestones for the 10-year implementation of reductions, presents criteria for assessing progress, and presents approaches for monitoring progress towards goals as well as monitoring changes in water quality.

Background

Nitrogen (N) found in coastal environments is derived from natural and anthropogenic sources. As the human population within a watershed grows so does the magnitude and proportion of anthropogenic nitrogen to coastal waters (Valiela et al., 1992, Valiela, 2006). Eutrophication of a waterbody is a natural process that occurs over very long periods and can become accelerated when there is an excessive input of anthropogenic nutrients, such as nitrogen. It is one of the most pressing contemporary environmental concerns in coastal areas. High nitrogen loads can degrade salt marshes (Deegan et al., 2012; NYSDEC, 2014) Microscopic marine plants, known as phytoplankton, are normally controlled by periodic nutrient limitation and predation, but in the face of nutrient overloading can become dense and pervasive (Valiela et al., 1992, Valiela, 2006). Such algal blooms can attenuate light penetration through the water column, decreasing the depth at which benthic phototrophs, such as seagrasses, can survive in waters (Valiela, 2006; Waycott et al., 2009; NYSDEC, 2009). Additionally, oxygen concentrations can decrease sharply beneath the surface of the water due to the respiration and decomposition of the excessive organic matter from decaying algal blooms (Gobler and Baumann, 2016). In this way, eutrophication often leads to hypoxia (very low levels of oxygen) or anoxia (zero oxygen), which can be deleterious to fish and benthic communities living in and on the sea floor (Diaz and Rosenberg, 2008).

Figure 1. Nassau County and its priority water bodies



Harmful algal blooms (HABs) are also an environmental problem initiated by nutrient overload, which have increased in their geographic extent, intensity, duration, and diversity in recent decades (Heisler et al., 2008; Anderson et al., 2008). There are clear linkages between increased loading of N in coastal waters and the presence and prevalence of HABs in many ecosystems (Heisler et al., 2008; Anderson et al., 2008). In some coastal areas such as Long Island, HABs promoted by N have become annual occurrences. The phytoplankton that compose these HABs are diverse and can affect ecosystem conditions, commercial and recreational fisheries, and human health.

For example, wastewater-derived nitrogen (i.e. from sewage) has been shown to support the proliferation of saxitoxin-producing blooms of *Alexandrium catenella* that can cause paralytic shellfish poisoning (Hattenrath et al., 2010) and the toxin okadaic acid producing blooms of *Dinophysis acuminata* (Hattenrath et al., 2015, 2018).

Since nitrogen limits primary production (Nixon et al., 1995; Valiela et al., 2006) by plants at the base of the marine food web, it is often the nitrogen delivery rate (weight of nitrogen delivered per land area or water body volume per year) coupled with hydraulic flushing that influences the prevalence of algal blooms, intensity of hypoxia, and the loss of seagrass beds (Bowen and Valiela, 2001, 2004; Valiela et al., 1992; Valiela, 2006). In Suffolk County, NY, the major sources of nitrogen to waterbodies in the north shore, south shore, and east end are, in order, wastewater, fertilizer, and the atmosphere (Kinney and Valiela, 2011; Stinnette, 2014; Lloyd, 2014; Lloyd et al., 2016, SCSWP, 2020). However, the relative importance of a nitrogen source can vary over even small geographic distances (Kinney and Valiela, 2011; Lloyd, 2014; Lloyd et al., 2016, SCSWP, 2020). As a result, nitrogen loading models are required to predict the amount of nitrogen that various sources contribute to estuaries and how those spatial differences in nitrogen load relate to coastal land use.

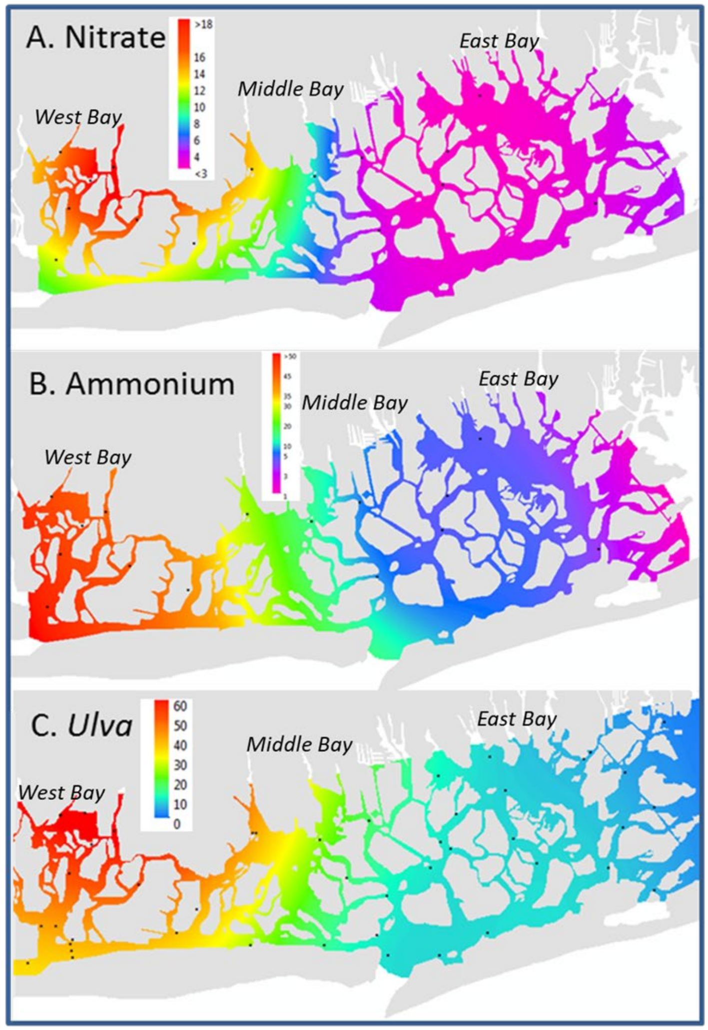


Figure 2. Dissolved nitrate and ammonium concentrations (μM) and percent coverage of *Ulva* across Western Bays during late September 2012.

Nassau County is situated in western Long Island, bordering New York City's borough of Queens to the west, and Suffolk County to the east (Figure 1). It is the most densely populated and second-most populous county in New York state outside of New York City. Nassau County's population was estimated at 1,358,343 in 2018. All of Nassau County's bays have been identified as impaired according to the 2018 *New York State Section 303(d) List of Impaired/TMDL Waters* due to pathogens, although excessive nitrogen may also contribute toward water quality impairment of these systems[i].

Bays and harbors on NYSDEC's Priority Waterbody List (PWL) across Nassau County's north shore include Little Neck Bay, Manhasset Bay, Hempstead Harbor, Oyster Bay, and Cold Spring Harbor, all of which exchange tidally with Long Island Sound (Figure 1) and West Bay, Middle Bay, East Bay, and South Oyster Bay on the south shore.

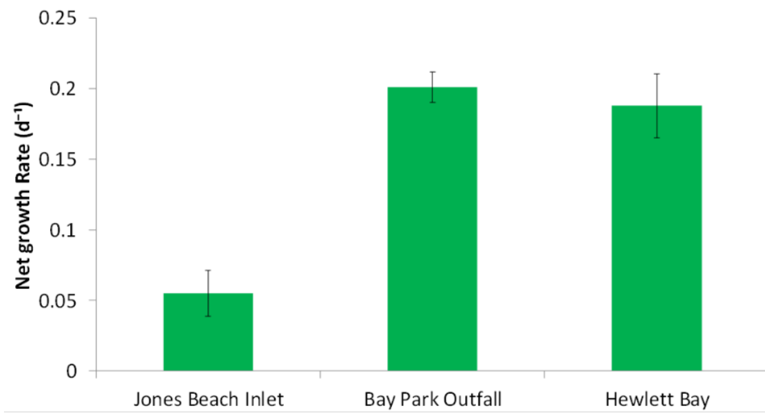


Figure 3. In situ growth of *Ulva* sp. incubated at 1 meter depth at three locations across Western Bays on July 20, 2011

Impairments of Nassau County waterbodies associated with excessive nitrogen have been documented in recent decades and have included hypoxia and harmful algal blooms caused by multiple phytoplankton species. The Stony Brook University study of the Western Bays, which are West Bay, Middle Bay, and East Bay of the South Shore Estuary Reserve, for NYSDEC documented a series of strong links between the overgrowth of *Ulva* and phytoplankton and excessive N loading (SoMAS, 2016). For example, mapping of the Western Bays showed that in regions where levels of nitrogenous compounds are high, *Ulva* covers the bottom of the bays (Figure 2). The *in-situ* growth rates of *Ulva* are high in the regions where N levels are high, and low in regions where N levels are low (Figure 3). Phytoplankton in this region are also strongly limited by N supply, as shown in Figure 4 where the addition of N increased their growth rate in the Western Bays (Figure 4), and together the overgrowth of *Ulva* and phytoplankton promotes anoxia and acidification in this region (SoMAS, 2016). There are number of ecological consequences associated with the overgrowth of *Ulva* including threats to human health associated with sulfide gas, the fouling of beaches, and the smothering benthic fauna or perhaps preventing settlement of fauna on the sea floor (Valiela et al., 1997). Experimental research has also shown that lowering N levels can decrease the intensity of algal blooms and *Ulva* growth in the Western Bays. For example, diluting bay water with ocean water leads to a decrease in the standing concentrations of N and, in turn, slow the growth of *Ulva* and phytoplankton (Figures 5, 6).

On the north shore, the Gobler lab has documented the regular occurrence of HABs and hypoxia in Hempstead Harbor and Cold Spring Harbor. Okadaic acid producing blooms of *Dinophysis acuminata* commonly occur in the water of Nassau County and have been shown to be promoted by N loading (Figure 7; Hattenrath et al., 2015). In addition, decades of research have shown that the growth of phytoplankton communities of Long Island Sound that tidally exchange into the north shore harbors are controlled by N (Figure 8; Gobler et al., 2006). It is the overgrowth of phytoplankton stimulated by N that settle to the benthos and cause hypoxia in this region on an annual basis (LISS, 1994; Gobler et al., 2006).

Despite the prevalence of environmental problems within Nassau County surface waters, the rates and sources of nitrogen loads to these waters have never been comprehensively quantified. This knowledge gap prohibits the formulation and evaluation of management plans to ameliorate nitrogen loads to these bays. Given the large costs associated with many nitrogen mitigation strategies, it is important to quantify the relative contribution of all the major sources of nitrogen to the bays. This information can then be used to determine cost effectiveness of different strategies for reducing nitrogen loads. Quantifying the current nitrogen loads entering Nassau County bays as well as quantifying how those loads would change under different nitrogen mitigation scenarios is a vital tool for proper water quality management.

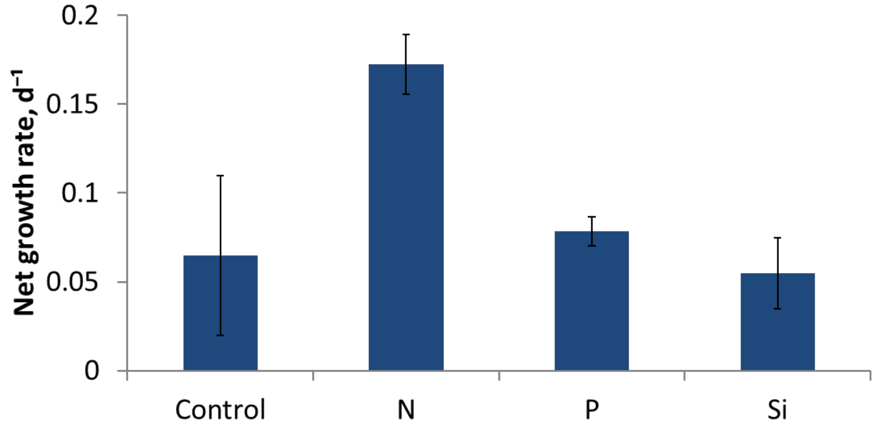


Figure 4. Effects of experimental nitrate, phosphate, and silicate loading on the entire phytoplankton population in Hewlett Bay in late May 2010.

The Nitrogen Loading Modeling for Nassau County Subwatersheds study was published in 2020 (NCSWP, 2020). This study was a first attempt to estimate the amount of N entering Nassau County surface waters from point and non-point sources of nitrogen. Each major bay or harbor watershed on the north and south shore of Nassau County was broken down into subwatersheds using United States Geologic Survey (USGS) Hydrologic Unit Codes (HUC) 12 to narrow the geographic scope and thus obtain accurate estimates of N loading and sources. The study used the Nitrogen Loading Model (NLM), land use, population characteristics, information on fertilizer use, and the most current science regarding N cycling and processes to estimate the relative contribution of wastewater from on-site septic systems, sewage treatment plants, fertilizer, and atmospheric deposition to total N loads in each subwatershed. This study also evaluated some N mitigation scenarios (changing the discharge from the South Shore Wastewater Reclamation Facility, previously known as the Bay Park Sewage Treatment Plant, changing fertilization rates) within each subwatershed.

Longer residence time and less flushing of estuarine waters can lead to greater rates of eutrophication of bay waters which is critical information in management decision making. Therefore, this study also modeled residence time of water within each bay using two different hydrodynamics models, FVCOM and EFDC Water quality data from the Town of Hempstead, Stony Brook University, Friends of the Bay, NYCDEP, CTDEEP, and other regional sources were compiled and compared to each other and to N loading rates.

In addition, residence times of each water body were multiplied by the N loading rates to assess their potential influence on water quality as N loads that are not rapidly flushed from a water body are expected to have a more deleterious effect than the same N load delivered to a well-flushed water body. The waterbodies of Nassau County were ranked based on their mean summer water quality conditions (specifically, chlorophyll *a*, dissolved oxygen, and Secchi disc depths) and then further ranked based on their N residence times (volume-based N loading rates multiplied by residence times). Lastly, the amount of N reductions needed to achieve improved water quality were estimated using a 'reference water body' approach as well as by comparing existing water quality conditions relative to state and federal water quality standards.

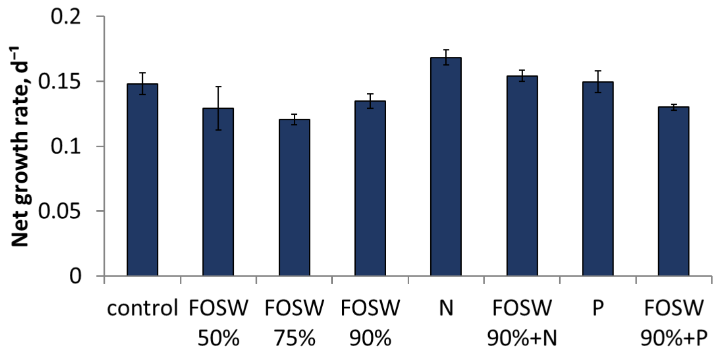


Figure 5. Effects of *Ulva* dilution experiments in Hewlett Bay comparing FOSW (filtered ocean seawater) to the addition of N or P.

Modeling determined that the N loads varied by more than an order of magnitude across Nassau County with West Bay on the south shore having, by far, the largest N load (2.3 x 10^6 kg N yr^{-1}), Cold Spring Harbor, Hempstead Harbor, and Manhasset Bay being an order of magnitude lower than West Bay (1.8 x 10^5 kg N yr^{-1}), and the remaining water bodies having lower annual loads (7 - 9 x 10^4 kg N yr^{-1}). Wastewater from onsite septic systems was the largest N source to all north shore bays, while sewage from the South Shore Wastewater Reclamation facility in Bay Park was the largest source to West Bay (98%). For other south shore sites, wastewater is diverted out of the watershed and fertilizer, primarily from homes, was the largest source of N. Surface run-off was isolated from atmospheric deposition and was found to account for a small fraction of N loads on the north shore (2 – 4%) but a larger fraction of the total on the more urbanized south shore (up to 20%). A proposed change in the recommended fertilizer application rate from 1 to 0.6 lbs per 1,000 square feet would decrease N loads up to 20% depending on the watershed. The diversion of sewage from the Bay Park treatment plant to the ocean outfall at the Cedar Creek wastewater treatment plant would decrease N loads by more than 98% and transform West Bay into a water body with the lowest N load on the south shore with most N emanating from fertilizers.

Residence times were determined and were found to range from 2 – 60 days depending on water body and whether flushing times were on 10% or 37% water retention. Summer water quality conditions were poorest in Hempstead Harbor, Cold Spring Harbor, and West Bay, although most water bodies displayed deviation from state and federal standards. Volume-based N residence times were found to be the largest for West Bay and Cold Spring Harbor, but were also elevated for Manhasset Bay, Oyster Bay, Middle Bay, and Hempstead Harbor.

All six water bodies with elevated residence times required N reductions to achieve volume-based N residence times on par with reference water bodies in Suffolk County with good water quality. These same systems also required N reductions to achieve NYS and federal water quality guidelines and, while there was a significant correlation between the N load reductions required as determined by the two methods, the percent reductions required differed. The N loading rates to West Bay, Cold Spring Harbor, Hempstead Harbor, and Manhasset Bay were higher than the N loads to all but one comparable subwatershed in Suffolk County and West Bay had higher N load per unit volume of water than any water body anywhere for which comparable data was found. Manhasset Bay and Middle Bay also had N load per unit volume that exceeded most known water bodies. These findings further emphasize the need for N reductions to these systems. Future efforts should consider more refined subwatersheds, as well as explore the efficacy of differing N mitigation measures.

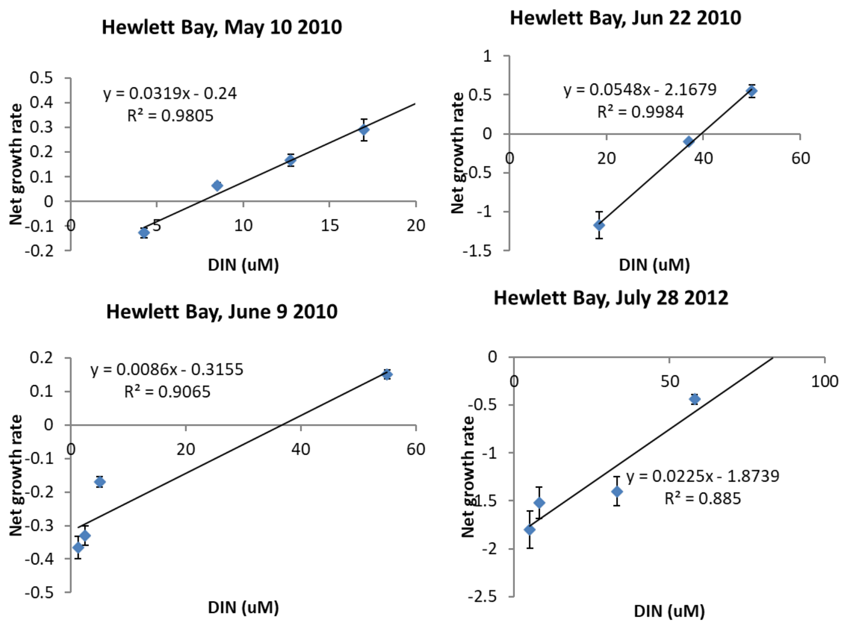


Figure 6. The relationship between dissolved inorganic nitrogen (DIN) and net growth rates of phytoplankton in Hewlett Bay. Differing levels of DIN were achieved by enriching West Bay water with nitrate or mixing Hewlett Bay water with Atlantic Ocean water. Growth rates within dilutions were corrected for reduced zooplankton grazing rates.

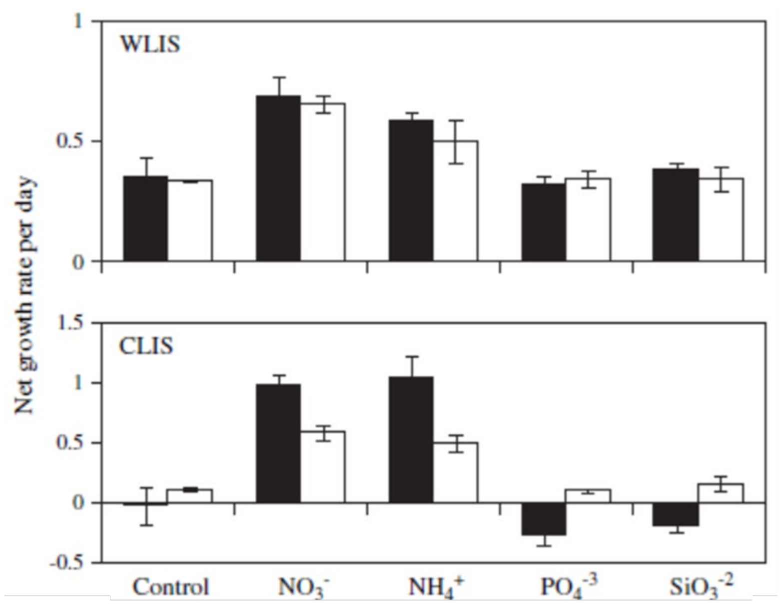


Figure 7. Growth rates of phytoplankton and planktonic carbon (black bars and white bars, respectively) in response to two forms of N, P, and silicon in the waters of western LIS and central LIS that tidally exchange with the north shore of Nassau County (Gobler et al., 2006).

ELEMENT A: CAUSES/SOURCES OF POLLUTION IDENTIFIED

Watershed/Subwatershed Delineation

The surface extents of the 26 watersheds in the study area were obtained from the U.S. Geological Survey regional MODPATH model of 2005-2015. Watersheds that extended beyond the eastern boarder of Nassau County were not clipped. Instead, the study area was expanded to include the full extent of the watersheds along the eastern boarder so that all the N sources to the drainage areas were accounted for. Watersheds that extended westward into Queens were clipped because other model inputs were not available for this area.

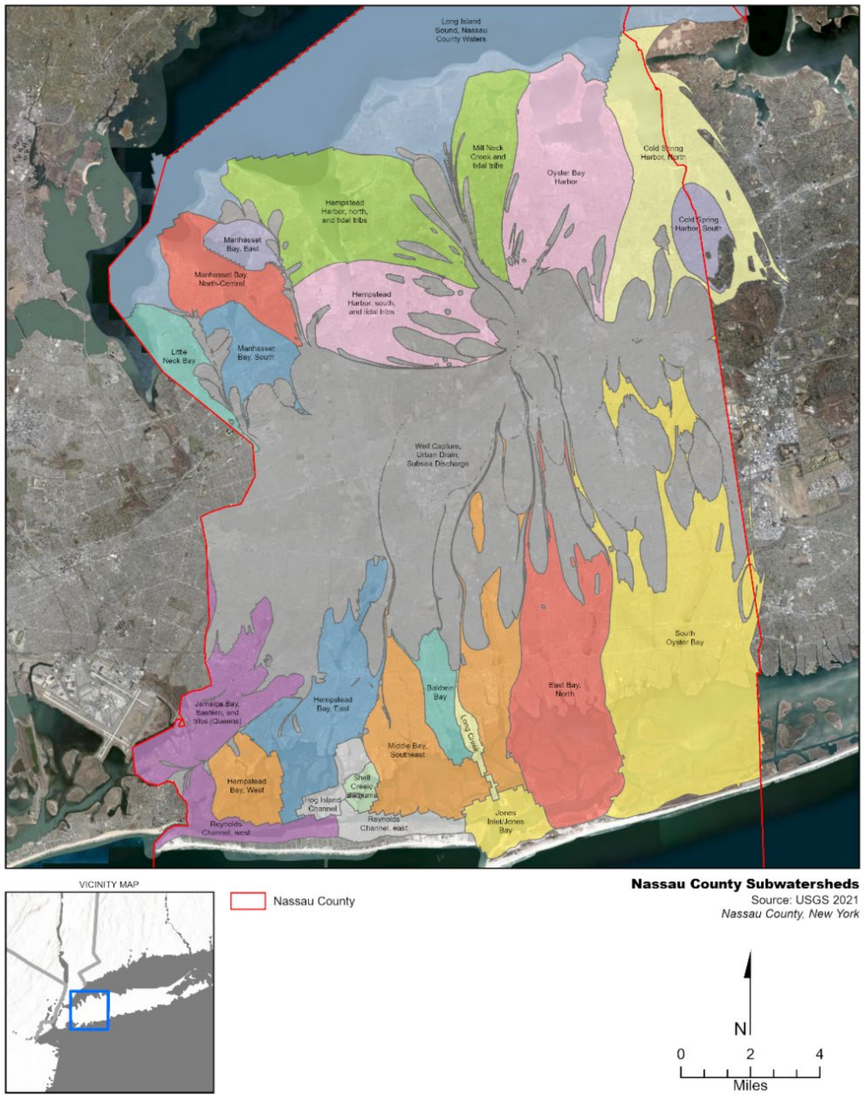


Figure 1. Nassau County watersheds delineated as per the USGS.

Nitrogen Loading Model (NLM)

The model used to predict nitrogen load is the NLM described in Bowen et al. (2007) and recently used in Kinney and Valiela (2011), Lloyd (2014), Lloyd et al. (2016), Stinnette (2014), and Suffolk County (SDSWP, 2019) to quantify N loads to Long Island waterbodies. NLM has been used extensively by the US EPA in the Northeast US (Latimer and Charpentier, 2010) and by NYSDEC Long Island Nitrogen Action Plan's study of nitrogen loading to Suffolk County subwatersheds by the consultants, CDM.

The NLM uses information about land use in a defined watershed to predict both the amount of nitrogen that is released into the watershed from various sources and how much of it ends up in a corresponding bay. This model requires accurate local land-use information, such as area of agriculture, residential areas, and impervious surfaces as well as other environmental data gathered from Long Island-based scientific literature via the Suffolk County subwatersheds study as well as from USGS high resolution orthoimagery, LiDAR, NHD, NYSDEC, NYS GIS portal, and Nassau County.

The NLM assumes that the transport mechanism for nitrogen entering the bay from the watershed is primarily ground water. This is a good assumption for coastal regions of Nassau County, as geologically, Long Island is composed of unconsolidated sands that allow for relatively easy transport of groundwater to coastal zones (Kinney and Valiela, 2011; Stinnette, 2014). The NLM breaks down the nitrogen input into three sources: atmospheric deposition, wastewater and fertilizer. Valiela et al. (2000) validated this model by comparing its nitrogen load prediction to empirically measured nitrogen levels. They found NLM's results to be statistically indistinguishable from measured concentrations and found a linear relationship between the percent contribution from wastewater that NLM predicted and the stable isotope signature for wastewater expected from known values of $\delta^{15}N$ of nitrate in ground water.

The source of all data used within NLM are shown in Table 1. The details of all rates, attenuations, constants, and assumptions used within the NLM model for this project are found in Table 2. In nearly every case, the assumptions, rates, and constants used for this project matched those used for Suffolk County's subwatersheds study (SCSWP, 2020).

Atmospheric Deposition

Atmospheric nitrogen is delivered via precipitation (wet) or via dust (dry). Nitrogen that arrives in the watersheds through wet and dry deposition may have a varied contribution to waterbody nitrogen load depending on where the nitrogen lands. Different land use types (impervious, vegetation, developed) alters the amount of nitrogen that makes it to the waterbody. Nitrogen landing on vegetation has time to be assimilated by plants and organisms in the soils, and/or may be denitrified in the aquifer. Nitrogen that lands on impervious surfaces can runoff directly into a stream, or bay, skipping assimilation. It may also flow through a municipal separate stormwater sewer system (MS4) where it eventually seeps into sandy soils and discharges into coastal zones. In general, when atmospherically deposited nitrogen lands on impervious surfaces, significantly less is removed before entering the waterbodies. For this project, an effort was made to separate N from run-off given that once N enters the water table, there is little N attenuation within the sandy aquifer of Long Island (Kinney and Valiela, 2011; SCSWS, 2019). Hence, to isolate N that is loaded to surface waters as a consequence of surface run-off, the sum of atmospheric N landing on impervious surfaces including roads, driveways, sidewalks, roofs, parking lots, and other impervious surfaces was summed and deemed N load from run-off.

Table 1. Data sources for the Nassau County Nitrogen Loading Model.

Model attribute	Source	Value
Watershed area	USGS	Varied per subwatershed
Area of wetlands (freshwater)	Nassau County	Varied per subwatershed
Area of agriculture	Nassau County parcel dataset	Varied per subwatershed
Area of golf course lawn	Nassau County, Lawn Dataset (see residential lawns)	Varied per subwatershed
Area of parks and athletic fields (fertilized)	Nassau County parcel dataset, Lawn Dataset (see residential lawns)	Varied per subwatershed
Impervious surfaces total	Low NDVI created from USGS High Resolution Orthoimagery, open water areas removed.	Varied per subwatershed
Area of freshwater ponds	USGS National Hydrography Dataset	Varied per subwatershed
Waste Water Treatment Plants N Output	NYSDEC	Varied per subwatershed
Total Occupancy >200m of shore not on sewers	2010 census + Nassau county parcel dataset	Varied per subwatershed
Total Occupancy <200m of shore not on sewers	2010 census + Nassau county parcel dataset	Varied per subwatershed
Percent of unsewered buildings with cesspools	As per Suffolk County subwatershed consensus	50%
Area of residential lawns	High NDVI (USGS HRO), limited to residential parcels, limited to areas where LiDAR height data was	Varied per subwatershed
Percent of parcels with fertilized lawns	The Nature Conservancy, Cold Spring Harbor Office	60%
Area of roof per building	Nassau County	Varied per subwatershed
Area of road	US Census	Varied per subwatershed
Nitrogen inputs from wet and dry deposition	As per Suffolk County subwatershed consensus	0.04lb-N per 1,000sq ft per yr
Forest N leaching	As per Suffolk County subwatershed consensus	25%
Agriculture N leaching	As per Suffolk County subwatershed consensus	40%
Turf N leaching	As per Suffolk County subwatershed consensus	30%
Recharge from impervious surfaces as percent of precipitation	As per Suffolk County subwatershed consensus	50%
N released per person per year	As per Suffolk County subwatershed consensus	10 lbs N
Water use	As per NYSDEC sources	
Percent of N inputs released from septic tanks	As per Suffolk County subwatershed consensus	94%
Leaching ring effluent and plume	As per Suffolk County subwatershed consensus	90%
Fertilizer applied to lawns	As per Suffolk County subwatershed consensus	2.04lb-N per 1,000sq ft per yr
Fertilizer applied to golf courses	As per Suffolk County subwatershed consensus	3.89lb-N per 1,000sq ft per yr
Fertilizer applied to parks and athletic fields	As per Suffolk County subwatershed consensus	0.92b-N per 1,000sq ft per yr
Gaseous loss of fertilizer	As per Suffolk County subwatershed consensus	70% for residental & parks; 80% for Golf
Fertilizer application to agriculture	As per Suffolk County subwatershed consensus	0.46 - 5.742b-N per 1,000sq ft per yr
Denitrification in aquifer	As per Suffolk County subwatershed consensus	0% on south shore, 15% on North shore

Impervious land areas were estimated by finding where the Normalized Difference Vegetation Index (NDVI) was low (NDVI<90). The NDVI was created from the USGS's high resolution orthoimagery. Parcels that were known by land type to not have any impervious surfaces were removed to improve the accuracy. The removal included the classes open water, vacant land, preserved/forested land, and agricultural land. Road area was estimated by expanding road line data into polygons obtained from the US Census Bureau. Lines for primary road, secondary roads, local roads, and ramps were expanded to a width of 12.5m, 10m, 5m, and 5m, respectively.

Areas of the polygons were then calculated and summed for each watershed. Residential impervious areas were estimated by limiting the impervious layer to residential parcels.

Table 2. Constants and rates used in the nitrogen loading model with sources color-coded, light blue for atmospheric deposition, dark blue for wastewater, and green for fertilizer.

Constants and Calculations		
N inputs from wet and dry deposition	5.37	*kg per ha per yr*
Forest N uptake	0.75	*percent of deposition retained*
Forest N release	0.25	*percent od deposition released*
Vadose N uptake	0	*percent of deposition retained*
Vadose N release	1	*percent of deposition released*
Turf N uptake	0.7	*percent of deposition retained*
Turf N release	0.3	*percent of deposition released*
Agriculture N release	0.38	*percent of deposition released*
N throughput from freshwater ponds to aquifer	0.45	*percent of inputs*
N throughput from wetlands to aquifer	0.25	*percent of inputs*
N released per person per year	4.536	*kg per cap per yr*
Percent of N inputs released from septic tanks	0.94	*percent of added N released*
Leaching field effluent	0.9	*percent of added N released*
N released from the plume of the septic system (aquifer loss)	0.94	*percent of added N released*
N released from s4 sewers (advanced individual sewers)	7.87	*kg per sewer per yr*
Percent of buildings with fertilized lawns	1	*percent*
Fertilizer applied to lawns	115	*kg per ha per yr*
Fertilizer applied to golf courses	189.2685186	*kg per ha per yr*
Fertilizer applied to Parks & Athletic Fields	89.65350881	*kg per ha per yr*
Fertilizer applied to agriculture	90.43951916	*kg per ha per yr*
Gaseous loss of fertilizer - residential lawns	0.3	*Percent fertilizer transported*
Gaseous loss of fertilizer - golf courses	0.3	*Percent fertilizer transported*
Gaseous loss of fertilizer - parks & athletic fields	0.3	*Percent fertilizer transported*
Gaseous loss of fertilizer - Agriculture	0.4	*Percent fertilizer transported*
Denitrification in aquifer	0.075	*percent of N entering the aquifer that is lost*
Denitrification in aquifer	0.925	*percent of N entering the aquifer that is released*

All other atmospheric deposition calculations based on land use areas were derivatives of the above processes or taken from source data. Area of turf was calculated from golf course, parks, and residential lawn area. The area of lawns was determined by combining NDVI data with LIDAR data. Any location with an elevated NDVI and that did not contain objects > 10 cm above bare ground was deemed a lawn. Agriculture area was obtained from Nassau County parcel data. Ponds and wetland areas were obtained from the USGS National Hydrography Dataset. Any area that was not included in the above categories was considered natural vegetation. Each one of these categories had appropriate attenuation factors applied.

Wastewater

The contribution of nitrogen load to the bays from wastewater treatment plants was added directly to the model based on measurements of nitrogen output from the plants. Loads were assigned to the various watersheds based on the treatment plant outfall locations. The loads were not attenuated and were directly added to the total nitrogen load for the corresponding watershed.

For parcels that were not connected to the sewer system, nitrogen output was calculated by multiplying the nitrogen released per person by the number of occupants in the watershed. The number of occupants for each parcel was determined from census tracks and parcel land use class. The total count of individuals for each census track was divided up among the residential parcels. The various types of residential parcels (one family, two family, apartment) were weighted accordingly. With each parcel assigned a number of occupants, parcels that were connected to sewer systems were removed. Then the total number of occupants in each watershed outside and within 200m of the water was tallied.

Differing levels of nitrogen were then removed from private sewer loading depending upon the type of on-site sewage disposal system (septic or cesspool) and the system's distance from shore, as there is significantly less nitrogen removed when septic tanks and cesspools are within 200m of coastal waters. Residential parcels have either an individual septic tank system or cesspool, which differ slightly in the fraction of nitrogen released to the underlying aquifer, with the less effective cesspools releasing more. Following the conclusions of the Suffolk County Subwatersheds study, it was assumed that half of the residential users had cesspools.

The NLM breaks down the nitrogen removal in septic tank and cesspool-based systems into three steps: removal in the tank, removal in leach fields, and removal in septic plumes. Cesspools on Long Island are typically composed of cylinders arranged vertically, eliminating any traditional leach field and the associated nitrogen removal therein. Although there is a disposal pit associated with these vertically structured cesspools, only a small amount of nitrogen is removed in this part of the system (<10%).

Fertilizer

The NLM considers fertilizer input from agricultural uses, golf courses, parks and athletic field lawns, and manicured residential lawns. The area of each type was calculated using ArcGIS processes; residential lawn areas were found by limiting high NDVI areas (NDVI>80) to residential parcels and to areas where the LiDAR height layer was near zero (height<0.1m). The height of objects on properties (trees, buildings, decks, etc.) was determined by subtracting a Digital Elevation Model (DEM) from a Digital Surface Model (DSM). These models were created from the same USGS LiDAR point cloud data and represent the bare ground elevation (DEM) and the highest elevation of all objects on the ground (DSM). Golf course boundaries were provided by Nassau County and were combined with the lawn dataset to obtain golf course lawn area. Agricultural land was extracted from the Nassau County parcel data. Parks and athletic field parcels were also extracted from the Nassau County parcel dataset but were then further limited to lawn areas within those parcels with the same process used for residential lawns.

Details of the data sources used for the NLM appear below in Table 1. Many data sources have been generated as part of the NYSDEC Long Island Nitrogen Action Plan's nitrogen loading study of Suffolk County's subwatersheds. Based on that project it is assumed that fertilizer applications rates were 3.89 lbs. per 1,000 square feet for golf courses and 1.84 lbs. per 1,000 square feet for parks and athletic fields. For residential turf fertilization it was assumed that there is a 1.0 lbs. per 1,000 square feet per application with the assumption that 49% of homes have on average 3.5 applications per year, 31% of homes have 1 application per year, 4.5% of homes have 1 application every 3 years and 15.5% of homes do not use fertilizer (Vaudrey, 2015). Therefore, when adjusted to the mean number of applications per year per home, the residential application rate was 2.04 lbs. per 1,000 square feet per year.

Pets

A module was added to NLM to consider the contribution of pets to watershed N loading. The assumptions of the module largely matched those of Suffolk County's subwatersheds studied including that each residence had on average, one dog, and one indoor cat, and 0.74 outdoor cats per home. The 45-year-old data regarding the N contribution of each animal type (Porter, 1978) was updated to reflect more recent findings (Beynen et al., 2001, 2002).

To view the aforementioned information in an online mapping format (GIS mapping layers for Atmospheric Deposition, Wastewater, Fertilizer and Pets) Please use the link below and visit:

Nassau County 9E Nitrogen Loading Model – Pollution Sources (arcgis.com)

The mapping illustrates how excessive nitrogen (N) into Nassau County coastal waters has led to a host of environmental problems including harmful algal blooms, hypoxic zones, bay water acidification, and habitat degradation and loss. Much of the Nitrogen that enters Nassau County surface waters from precipitation, stormwater (runoff from the land), atmospheric deposition, groundwater seepage - including seepage from septic systems and cesspools, and sewage treatment plant discharge. The layers assist in quantifying the source of Nitrogen entering Nassau County surface waters from fertilizer, wastewater, atmospheric deposition and pets.

RESULTS

Nitrogen Loading Model

Nitrogen loads varied across the subwatersheds on the north and south shores (Figs. 2 – 5; Tables 3 – 9). On the south shore, the largest nitrogen load came from the western section of Reynolds Channel at 2.6 x 10^6 kg N yr^{-1} or ~4,470 kg ha^{-1} yr^{-1}, which was more than an order of magnitude larger than all other watersheds on the south shore (Fig. 2; Tables 3 – 6). Excluding Reynolds Channel, the largest nitrogen load on the south shore comes from South Oyster Bay, with a total nitrogen load of ~63,256 kg yr^{-1}, with the smallest total nitrogen load coming from Shell Creek/Barnums (819 kg yr^{-1}) (Figs. 2 and 3; Tables 3 – 6). For total nitrogen loading based on area, excluding Reynolds Channel, the highest total nitrogen load on the south shore comes from the western section of Hempstead Bay (18.4 kg ha^{-1} yr^{-1}), with the lowest total nitrogen load coming from the Atlantic site (4.9 kg ha^{-1} yr^{-1}) (Figs. 2 and 3; Tables 3 – 6). The nitrogen from Reynolds Channel is derived primarily from sewer treatment plants, which makes up 99.8% of nitrogen from this area and ~92% of all nitrogen to the south shore (Figs. 2 and 3; Tables 3 – 6). However, sewer treatment plants did not contribute nitrogen to any other sites on

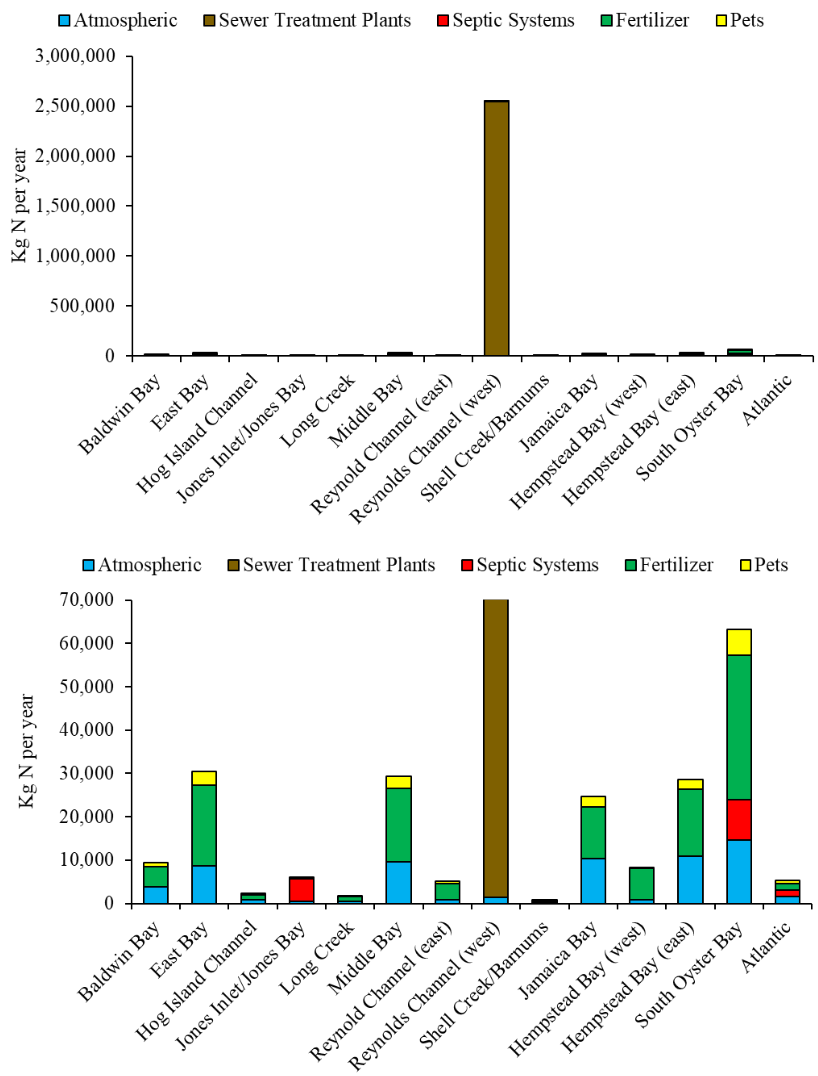


Figure 2. A. Total nitrogen load from south shore subwatersheds in kilograms N per year, and B. Total nitrogen load from south shore subwatersheds in kilograms N per year with the x-axis cut-off to provide resolution of all sites; the Reynolds Channel (west) N load is 2.6 x 10^6 kg N per year.

the south shore (Figs. 2 and 3; Tables 3 – 6). Excluding the contribution of sewer treatment plants to Reynolds Channel, on the south shore, fertilizer contributes most of the nitrogen to the system, ranging from 153 kg N yr^{-1} (Jones Beach/Jones Inlet) to 33,323 kg N yr^{-1} (South Oyster Bay), with an average of 8,576 kg N yr^{-1} (Fig. 2; Tables 3 – 6). On average, fertilizer contributes 49% of nitrogen to south shore sites (Fig. 3; Tables 3 – 6). Atmospheric deposition contributes the second most of nitrogen to the system, ranging from 256 kg N yr^{-1} (Shell Creek/Barnums) to 14,632 kg N yr^{-1} (South Oyster Bay), with an average of 4,625 kg N yr^{-1} (Fig. 2; Tables 3 – 6). On average, atmospheric deposition contributes 26% of nitrogen to south shore sites (Fig. 3; Tables 3 – 6). Septic systems contribute 0 kg N yr^{-1} (Shell Creek/Barnums, western Hempstead Bay, western Reynolds Channel, Middle Bay, Baldwin Bay, and East Bay) to 9,318 kg N yr^{-1} (South Oyster Bay), with an average of 1,141 kg N yr^{-1} (Fig. 2; Tables 3 – 6). On average, septic systems contribute 9% of nitrogen to south shore sites (Fig. 3; Tables 3 – 6). Pets contribute 90 kg N yr^{-1} (Jones Inlet/Jones Bay) to 5,983 kg N yr^{-1} (South Oyster Bay), with an average of 1,474 kg N yr^{-1} (Fig. 2; Tables 3 – 6). On average, pets contribute 9% of nitrogen to south shore sites (Fig. 3; Tables 3 – 6).

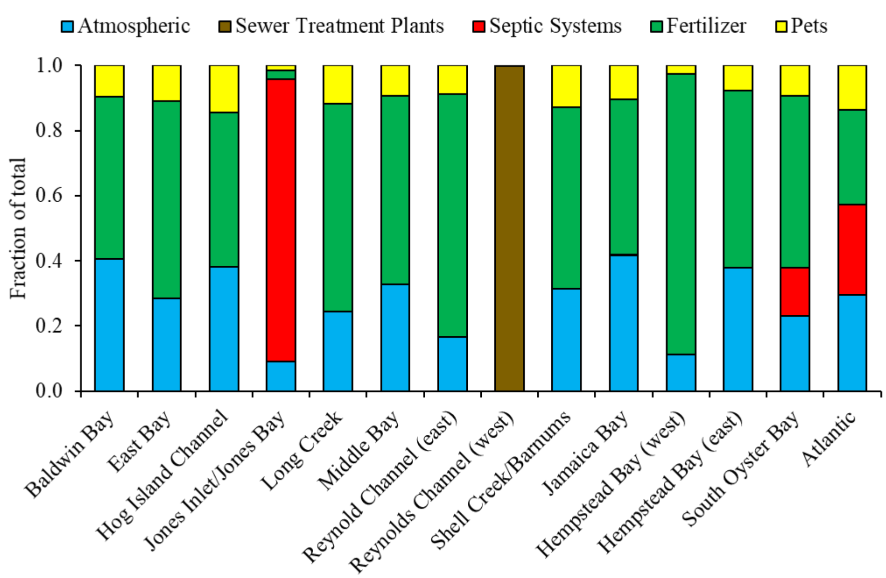


Figure 3. Relative contribution of atmospheric, sewer treatment plants, septic systems, fertilizer, and pets to the total N load of each south shore water body.

On the north shore, the largest nitrogen load came from the north shore well/urban drain/subsea discharge at 3.6 x 10^5 kg N yr^{-1} or 11.4 kg ha^{-1} yr^{-1} (Fig. 4; Tables 6 – 9). Excluding the north shore well/urban drain/subsea discharge, the largest nitrogen load on the north shore comes from the northern section of Hempstead Harbor, with a total nitrogen load of 112,336 kg yr^{-1}, with the smallest total nitrogen load coming from the southern section of Cold Spring Harbor (16,515 kg yr^{-1}) (Figs. 4 and 7; Tables 6 – 9). For total nitrogen loading based on area, excluding the north shore well/urban drain/subsea discharge, the highest total nitrogen load on the north shore comes from Manhasset Bay (133.5 kg ha^{-1} yr^{-1}), with the lowest total nitrogen load coming from Oyster Bay Harbor (18.2 kg ha^{-1} yr^{-1}) (Figs. 4 and 5; Tables 6 – 9). On the north shore, septic systems contribute the highest nitrogen load, ranging from 10,532 kg N yr^{-1} (southern Cold Spring Harbor) to 61,639 kg N yr^{-1} (north shore well/urban drain/subsea discharge), with an average of 34,691 kg N yr^{-1} (Fig. 4; Tables 6 – 9). On average, septic systems contribute 51% of nitrogen to north shore sites (Fig. 5; Tables 6 – 9). Fertilizer is the second highest contributor of nitrogen to the north shore, ranging from 1,458 kg N yr^{-1} (eastern Manhasset Bay) to 210,111 kg N yr^{-1} (north shore well/urban drain/subsea discharge), with an average of 29,094 kg N yr^{-1} (Fig. 4; Tables 6 – 9). On average, fertilizer contributes 24% of nitrogen to north shore sites (Fig. 5; Tables 6 – 9). Sewer treatment plants contribute 0 kg N yr^{-1} (Mill Neck Creek, southern Manhasset Bay, northern and southern Cold Spring Harbor, Long Island Sound, southern Hempstead Harbor, and north shore well/urban drain/subsea discharge) to 43,207 kg N yr^{-1} (Little Neck Bay), with an average of 10,641 kg N yr^{-1} (Fig. 4; Tables 6 – 9). On average, sewage treatment plants contribute 15% of nitrogen to north shore sites (Fig. 5; Tables 6 – 9). Atmospheric deposition contributes 998 kg N yr^{-1} (northern Cold Spring Harbor) to 57,450 kg N yr^{-1} (north shore well/urban drain/subsea discharge), with an average of 9,158 kg N yr^{-1} (Fig. 4; Tables 6 – 9). On average, atmospheric deposition contributes 8% of nitrogen to north shore sites (Fig. 5; Tables 6 – 9). The smallest contributor of nitrogen to north shore sites is pets, which contributes 111 kg N yr^{-1} (southern Cold Spring Harbor) to 27,895 kg N yr^{-1} (north shore well/urban

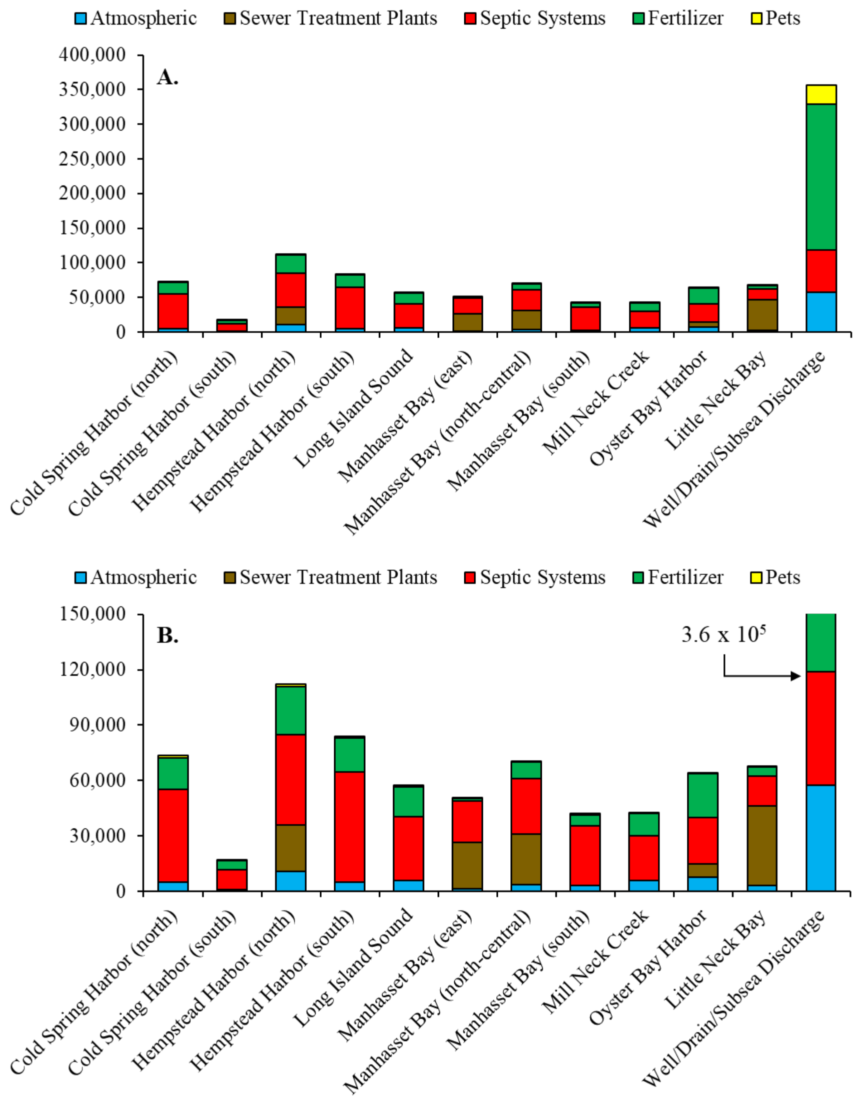


Figure 4. A. Total nitrogen load from north shore subwatersheds in kilograms N per year, and B. Total nitrogen load from north shore subwatersheds in kilograms N per year with the x-axis cut-off to provide resolution of all sites; the Well/Urban Drain/Subsea Discharge N load is 3.6 x 10^5 kg N per year.

drain/subsea discharge), with an average of 2,938 kg N yr^{-1} (Fig. 4; Tables 6 – 9). On average, pets contribute 2% of nitrogen to north shore sites (Fig. 5; Tables 6 – 9).

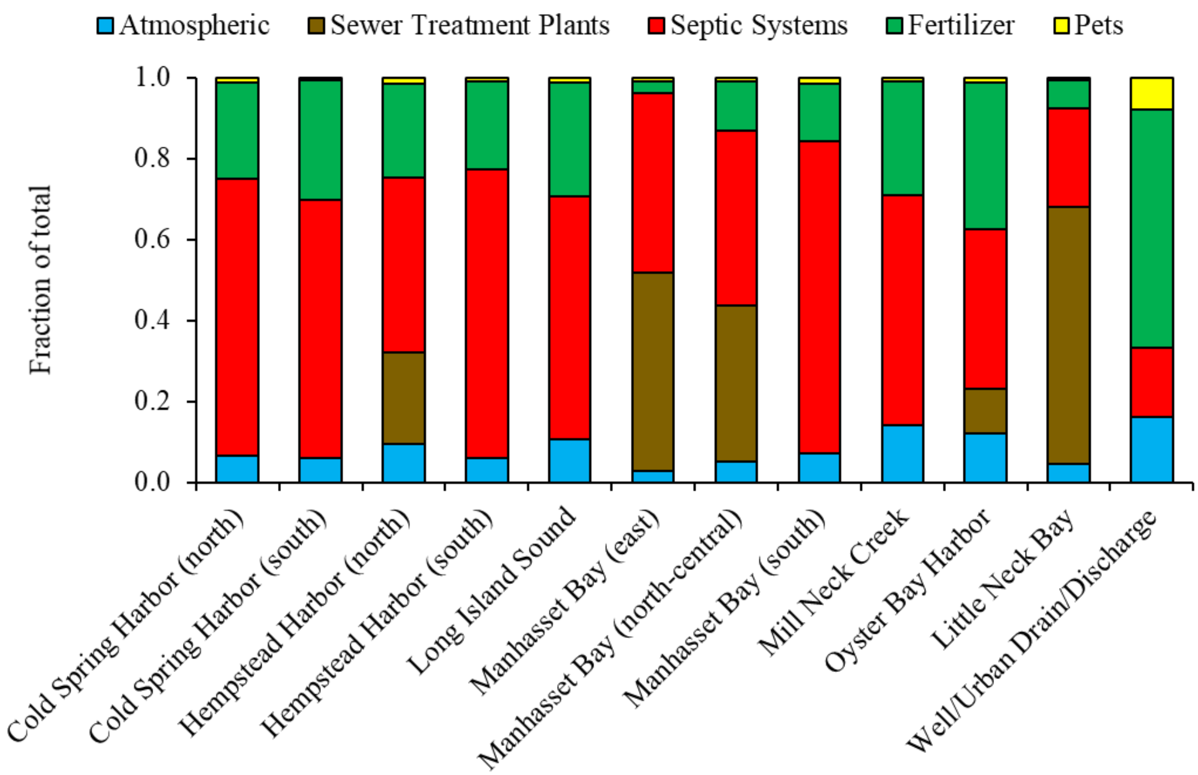


Figure 5. Relative contribution of atmospheric, sewage treatment plants, septic systems/cesspools, fertilizer, and pets to the total N load of each north shore water body.

Table 3. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Unit	Baldwin Bay	East Bay (north)	Hog Island Channel	Jones Inlet/ Bay
Total Occupancy >200m of shore not on sewers	# people	0	0	0	656
Total Occupancy <200m of shore not on sewers	# people	0	0	0	736
Housing Units	# houses	6,471	23,766	2,466	643
Area of Watershed (excluding marine waterbodies)	Ha	751	3,089	311	298
Area of wetlands (freshwater)	Ha	2.6	14.5	0.1	1.8
Area of freshwater ponds	Ha	5.5	31.1	2.4	0.7
Area of agriculture	Ha	0.0	0.0	0.0	0.0
Area of golf course lawns	Ha	0.3	21.1	0.0	0.0
Area of parks and athletic field lawns	Ha	24.3	127.0	1.0	0.0
Area of residential lawns	Ha	126.9	445.5	34.7	4.8
Area of Impervious leading to sump	Ha	11.7	176.3	0.0	0.2
--> Area of Roofs (in sump areas)	Ha	4.3	64.0	0.0	0.0
Area of Impervious leading to outfall	Ha	742.5	1,277.5	155.8	42.2
--> Area of Roofs (in outfall areas)	Ha	276.8	454.4	70.9	0.0
Area of Impervious in Watershed	Ha	308.7	1,169.2	83.5	42.3
Area of Roofs	Ha	122.3	418.1	50.9	10.1
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	215	1,158	186	320
Turf	kg yr^{-1}	244	956	58	8
Agriculture	kg yr^{-1}	0	0	0	0
Ponds	kg yr^{-1}	13	75	6	2
Wetlands	kg yr^{-1}	3	19	0	2
Impervious - to sump sewer	kg yr^{-1}	51	775	0	1
Impervious - to outfall sewer	kg yr^{-1}	3,244	5,640	646	227
Impervious - to turf (portion of roofs)	kg yr^{-1}	99	337	41	8
Subtotal with transport loss	kg yr^{-1}	**579**	**3,071**	**268**	**315**
Subtotal without transport loss	kg yr^{-1}	**3,244**	**5,640**	**646**	**227**
Total	kg yr^{-1}	**3,823**	**8,712**	**915**	**542**
Fertilizer					
Agriculture	kg yr^{-1}	0	0	0	0
Residential Lawns	kg yr^{-1}	4,378	15,370	1,199	166
Golf	kg yr^{-1}	18	1,201	0	0
Parks +Athletic fields	kg yr^{-1}	652	3,417	27	0
Subtotal	kg yr^{-1}	5,048	19,988	1,225	166
Total with transport loss	**kg yr^{-1}**	**4,669**	**18,488**	**1,133**	**153**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	0	0	0	1,216
Septic - outside 200m of shore	kg yr^{-1}	0	0	0	1,094
Cesspools - within 200m of shore	kg yr^{-1}	0	0	0	1,475
Septic - within 200m of shore	kg yr^{-1}	0	0	0	1,327
Sewage Treatment Plants	kg yr^{-1}	0	0	0	0
Total	kg yr^{-1}	**0**	**0**	**0**	**5,113**
Pets					
Cat Nload	kg yr^{-1}	270	990	103	27
Dog Nload	kg yr^{-1}	638	2,342	243	63
Total	**kg yr^{-1}**	**907**	**3,332**	**346**	**90**
Grand Totals					
Total Nload	**kg yr^{-1}**	**9,399.7**	**30,532.0**	**2,393.8**	**5,898.3**
Total Nload	**kg ha^{-1} yr^{-1}**	**12.5**	**9.9**	**7.7**	**19.8**

Table 4. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Units	Long Creek	Middle Bay (southeast)	Reynold Channel (east)	Reynolds Channel (west)
Total Occupancy >200m of shore not on sewers	# people	0	0	0	0
Total Occupancy <200m of shore not on sewers	# people	0	0	2	0
Housing Units	# houses	1,496	19,568	3,246	5,270
Area of Watershed (excluding marine waterbodies)	Ha	182	2,755	380	570
Area of wetlands (freshwater)	Ha	0.0	23.9	0.2	2.1
Area of freshwater ponds	Ha	0.9	22.0	7.0	2.5
Area of agriculture	Ha	0.0	0.1	0.0	0.0
Area of golf course lawns	Ha	0.4	52.6	43.7	36.0
Area of parks and athletic field lawns	Ha	3.7	134.9	14.7	6.2
Area of residential lawns	Ha	32.5	340.9	35.9	57.3
Area of Impervious leading to sump	Ha	9.0	141.7	0.0	0.0
--> Area of Roofs (in sump areas)	Ha	2.3	45.9	0.0	0.0
Area of Impervious leading to outfall	Ha	63.2	1,580.9	89.8	182.9
--> Area of Roofs (in outfall areas)	Ha	34.1	552.3	0.0	43.6
Area of Impervious in Watershed	Ha	57.4	1,117.9	90.2	137.4
Area of Roofs	Ha	28.6	403.7	53.7	91.8
STP Output	kg yr^{-1}	-	-	-	15,549
STP Output	kg yr^{-1}	-	-	-	2,366,654
STP Output	kg yr^{-1}	-	-	-	157,711
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	79	884	181	317
Turf	kg yr^{-1}	59	851	152	160
Agriculture	kg yr^{-1}	0	0	0	0
Ponds	kg yr^{-1}	2	53	17	6
Wetlands	kg yr^{-1}	0	32	0	3
Impervious - to sump sewer	kg yr^{-1}	42	638	0	0
Impervious - to outfall sewer	kg yr^{-1}	248	7,007	482	865
Impervious - to turf (portion of roofs)	kg yr^{-1}	23	325	43	74
Subtotal with transport loss	**kg yr^{-1}**	**190**	**2,575**	**364**	**518**
Subtotal without transport loss	**kg yr^{-1}**	**248**	**7,007**	**482**	**865**
Total	**kg yr^{-1}**	**438**	**9,582**	**846**	**1,383**
Fertilizer					
Agriculture	kg yr^{-1}	0	4	0	0
Residential Lawns	kg yr^{-1}	1,120	11,759	1,238	1,976
Golf	kg yr^{-1}	22	2,985	2,483	2,046
Parks +Athletic fields	kg yr^{-1}	98	3,627	395	167
Subtotal	kg yr^{-1}	1,240	18,375	4,116	4,190
Total with transport loss	**kg yr^{-1}**	**1,147**	**16,997**	**3,807**	**3,875**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	0	0	0	0
Septic - outside 200m of shore	kg yr^{-1}	0	0	0	0
Cesspools - within 200m of shore	kg yr^{-1}	0	0	4	0
Septic - within 200m of shore	kg yr^{-1}	0	0	4	0
Sewage Treatment Plants	kg yr^{-1}	0	0	0	2,539,914
Total	**kg yr^{-1}**	**0**	**0**	**8**	**2,539,914**
Pets					
Cat Nload	kg yr^{-1}	62	815	135	220
Dog Nload	kg yr^{-1}	147	1,928	320	519
Total	**kg yr^{-1}**	**210**	**2,743**	**455**	**739**
Grand Totals					
Total Nload	**kg yr^{-1}**	**1,794.6**	**29,322.2**	**5,115.1**	**2,545,911.9**
Total Nload	**kg ha^{-1} yr^{-1}**	**9.8**	**10.6**	**13.5**	**4,469.6**

Table 5. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Units	Shell Creek/Barnums	Jamaica Bay (east and tribs)	Hempstead Bay (west)	Hempstead Bay (east)
Total Occupancy >200m of shore not on sewers	# people	0	8	0	0
Total Occupancy <200m of shore not on sewers	# people	0	4	0	7
Housing Units	# houses	759	18,252	1,537	15,894
Area of Watershed (excluding marine waterbodies)	Ha	122	2,056	449	2,299
Area of wetlands (freshwater)	Ha	0.0	11.5	0.8	8.9
Area of freshwater ponds	Ha	0.0	5.9	2.1	102.3
Area of agriculture	Ha	0.0	0.0	0.0	0.0
Area of golf course lawns	Ha	0.0	58.7	86.9	81.6
Area of parks and athletic field lawns	Ha	2.2	58.6	3.7	57.5
Area of residential lawns	Ha	12.6	229.1	77.0	307.2
Area of Impervious leading to sump	Ha	0.0	21.4	0.0	14.3
--> Area of Roofs (in sump areas)	Ha	0.0	7.0	0.0	5.4
Area of Impervious leading to outfall	Ha	28.3	2,063.3	120.0	2,008.4
--> Area of Roofs (in outfall areas)	Ha	0.0	824.2	38.4	702.9
Area of Impervious in Watershed	Ha	34.2	898.0	149.3	843.7
Area of Roofs	Ha	16.8	362.0	49.0	320.3
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	75	581	108	775
Turf	kg yr^{-1}	24	558	270	719
Agriculture	kg yr^{-1}	0	0	0	0
Ponds	kg yr^{-1}	0	14	5	247
Wetlands	kg yr^{-1}	0	15	1	12
Impervious - to sump sewer	kg yr^{-1}	0	96	0	62
Impervious - to outfall sewer	kg yr^{-1}	152	8,867	541	8,898
Impervious - to turf (portion of roofs)	kg yr^{-1}	14	292	39	258
Subtotal with transport loss	**kg yr^{-1}**	**104**	**1,439**	**391**	**1,918**
Subtotal without transport loss	**kg yr^{-1}**	**152**	**8,867**	**541**	**8,898**
Total	**kg yr^{-1}**	**256**	**10,306**	**933**	**10,816**
Fertilizer					
Agriculture	kg yr^{-1}	0	0	0	0
Residential Lawns	kg yr^{-1}	435	7,903	2,656	10,598
Golf	kg yr^{-1}	0	3,334	4,931	4,635
Parks +Athletic fields	kg yr^{-1}	58	1,575	99	1,547
Subtotal	kg yr^{-1}	493	12,812	7,686	16,780
Total with transport loss	**kg yr^{-1}**	**456**	**11,851**	**7,110**	**15,522**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	0	15	0	0
Septic - outside 200m of shore	kg yr^{-1}	0	13	0	0
Cesspools - within 200m of shore	kg yr^{-1}	0	8	0	14
Septic - within 200m of shore	kg yr^{-1}	0	7	0	13
Sewage Treatment Plants	kg yr^{-1}	0	0	0	0
Total	kg yr^{-1}	**0**	**43**	**0**	**27**
Pets					
Cat Nload	kg yr^{-1}	32	761	64	662
Dog Nload	kg yr^{-1}	75	1,798	151	1,566
Total	**kg yr^{-1}**	**106**	**2,559**	**215**	**2,228**
Grand Totals					
Total Nload	**kg yr^{-1}**	**819.0**	**24,759.5**	**8,257.8**	**28,592.8**
Total Nload	**kg ha^{-1} yr^{-1}**	**6.7**	**12.0**	**18.4**	**12.4**

Table 6. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Units	South Oyster Bay	Atlantic	Cold Spring Harbor (north)	Cold Spring Harbor (south)
Total Occupancy >200m of shore not on sewers	# people	2,636	262	13,754	2,987
Total Occupancy <200m of shore not on sewers	# people	9	143	454	3
Housing Units	# houses	42,672	5,182	6,875	794
Area of Watershed (excluding marine waterbodies)	Ha	5,787	1,079	3,473	859
Area of wetlands (freshwater)	Ha	107.8	4.0	0.1	5.8
Area of freshwater ponds	Ha	39.2	3.9	14.3	12.2
Area of agriculture	Ha	0.0	0.0	2.5	18.4
Area of golf course lawns	Ha	31.5	4.9	21.0	33.8
Area of parks and athletic field lawns	Ha	186.4	4.6	67.3	0.8
Area of residential lawns	Ha	847.0	36.4	456.3	77.2
Area of Impervious leading to sump	Ha	667.8	0.0	357.5	36.0
--> Area of Roofs (in sump areas)	Ha	213.7	0.0	92.1	7.5
Area of Impervious leading to outfall	Ha	1,681.0	63.8	12.5	0.0
--> Area of Roofs (in outfall areas)	Ha	567.9	0.0	2.0	11.0
Area of Impervious in Watershed	Ha	2,229.6	63.8	928.7	190.6
Area of Roofs	Ha	760.2	92.2	197.4	29.1
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	2,128	1,167	2,398	659
Turf	kg yr^{-1}	1,716	74	877	180
Agriculture	kg yr^{-1}	0	0	5	38
Ponds	kg yr^{-1}	95	10	35	29
Wetlands	kg yr^{-1}	145	5	0	8
Impervious - to sump sewer	kg yr^{-1}	3,013	0	1,672	173
Impervious - to outfall sewer	kg yr^{-1}	7,502	342	62	-30
Impervious - to turf (portion of roofs)	kg yr^{-1}	612	74	159	23
Subtotal with transport loss	**kg yr^{-1}**	**7,130**	**1,230**	**4,760**	**1,028**
Subtotal without transport loss	**kg yr^{-1}**	**7,502**	**342**	**62**	**-30**
Total	**kg yr^{-1}**	**14,632**	**1,573**	**4,822**	**998**
Fertilizer					
Agriculture	kg yr^{-1}	0	0	89	667
Residential Lawns	kg yr^{-1}	29,222	1,257	15,743	2,663
Golf	kg yr^{-1}	1,790	276	1,190	1,918
Parks +Athletic fields	kg yr^{-1}	5,013	124	1,809	20
Subtotal	kg yr^{-1}	36,025	1,657	18,831	5,269
Total with transport loss	**kg yr^{-1}**	**33,323**	**1,533**	**17,418**	**4,874**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	4,886	486	25,496	5,537
Septic - outside 200m of shore	kg yr^{-1}	4,398	437	22,946	4,983
Cesspools - within 200m of shore	kg yr^{-1}	18	287	910	6
Septic - within 200m of shore	kg yr^{-1}	16	258	819	5
Sewage Treatment Plants	kg yr^{-1}	0	0	0	0
Total	kg yr^{-1}	**9,318**	**1,467**	**50,171**	**10,532**
Pets					
Cat Nload	kg yr^{-1}	1,778	216	286	33
Dog Nload	kg yr^{-1}	4,205	511	677	78
Total	**kg yr^{-1}**	**5,983**	**727**	**964**	**111**
Grand Totals					
Total Nload	**kg yr^{-1}**	**63,255.8**	**5,299.8**	**73,374.8**	**16,515.1**
Total Nload	**kg ha^{-1} yr^{-1}**	**10.9**	**4.9**	**21.1**	**19.2**

Table 7. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Units	Hempstead Harbor (north)	Hempstead Harbor (south)	Long Island Sound	Manhasset Bay (east)
Total Occupancy >200m of shore not on sewers	# people	12,854	16,479	6,301	4,142
Total Occupancy <200m of shore not on sewers	# people	870	466	3,206	2,104
Housing Units	# houses	11,192	5,694	5,062	3,362
Area of Watershed (excluding marine waterbodies)	Ha	3,185	2,639	2,796	381
Area of wetlands (freshwater)	Ha	6.3	3.4	55.3	2.0
Area of freshwater ponds	Ha	19.4	21.5	14.4	3.4
Area of agriculture	Ha	45.3	0.0	1.9	0.0
Area of golf course lawns	Ha	209.8	127.6	82.2	0.0
Area of parks and athletic field lawns	Ha	54.2	61.8	45.6	14.0
Area of residential lawns	Ha	383.7	315.6	331.3	34.8
Area of Impervious leading to sump	Ha	51.5	303.8	1.4	0.0
--> Area of Roofs (in sump areas)	Ha	9.6	65.4	0.2	0.0
Area of Impervious leading to outfall	Ha	1,615.9	309.0	680.7	273.0
--> Area of Roofs (in outfall areas)	Ha	328.4	76.9	120.8	89.3
Area of Impervious in Watershed	Ha	1,134.6	933.8	674.1	155.4
Area of Roofs	Ha	261.2	201.8	140.5	67.3
STP Output	kg yr^{-1}	25,402	-	-	24,810
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	1,437	1,307	1,948	140
Turf	kg yr^{-1}	1,043	814	740	79
Agriculture	kg yr^{-1}	92	0	4	0
Ponds	kg yr^{-1}	47	52	35	8
Wetlands	kg yr^{-1}	8	5	74	3
Impervious - to sump sewer	kg yr^{-1}	251	1,456	7	0
Impervious - to outfall sewer	kg yr^{-1}	7,795	1,453	3,331	1,226
Impervious - to turf (portion of roofs)	kg yr^{-1}	210	163	113	54
Subtotal with transport loss	**kg yr^{-1}**	**2,857**	**3,511**	**2,702**	**262**
Subtotal without transport loss	**kg yr^{-1}**	**7,795**	**1,453**	**3,331**	**1,226**
Total	**kg yr^{-1}**	**10,653**	**4,964**	**6,033**	**1,488**
Fertilizer					
Agriculture	kg yr^{-1}	1,638	0	70	0
Residential Lawns	kg yr^{-1}	13,237	10,889	11,430	1,199
Golf	kg yr^{-1}	11,911	7,247	4,666	0
Parks +Athletic fields	kg yr^{-1}	1,458	1,663	1,227	378
Subtotal	kg yr^{-1}	28,245	19,798	17,393	1,577
Total with transport loss	**kg yr^{-1}**	**26,126**	**18,314**	**16,088**	**1,458**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	23,827	30,547	11,679	7,677
Septic - outside 200m of shore	kg yr^{-1}	21,444	27,492	10,511	6,909
Cesspools - within 200m of shore	kg yr^{-1}	1,744	934	6,425	4,216
Septic - within 200m of shore	kg yr^{-1}	1,570	840	5,783	3,794
Sewage Treatment Plants	kg yr^{-1}	25,402	0	0	24,810
Total	kg yr^{-1}	**73,987**	**59,814**	**34,398**	**47,406**
Pets					
Cat Nload	kg yr^{-1}	466	237	211	140
Dog Nload	kg yr^{-1}	1,103	561	499	331
Total	**kg yr^{-1}**	**1,569**	**798**	**710**	**471**
Grand Totals					
Total Nload	**kg yr^{-1}**	**112,335.6**	**83,890.1**	**57,229.4**	**50,824.4**
Total Nload	**kg ha^{-1} yr^{-1}**	**35.3**	**31.8**	**20.5**	**133.5**

Table 8. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs					
Inputs	Units	Manhasset Bay (north-central)	Manhasset Bay (south)	Mill Neck Creek	Oyster Bay Harbor
Total Occupancy >200m of shore not on sewers	# people	7,269	8,183	4,497	6,055
Total Occupancy <200m of shore not on sewers	# people	1,250	937	2,204	1,027
Housing Units	# houses	3,826	4,623	2,345	5,135
Area of Watershed (excluding marine waterbodies)	ha	1,178	1,085	1,895	3,534
Area of wetlands (freshwater)	ha	44.6	1.2	42.9	12.9
Area of freshwater ponds	ha	17.7	6.2	38.8	19.9
Area of agriculture	ha	0.0	0.0	0.0	16.9
Area of golf course lawns	ha	29.4	42.5	22.3	89.5
Area of parks and athletic field lawns	ha	9.6	20.3	31.2	75.9
Area of residential lawns	ha	216.3	100.2	314.1	509.8
Area of Impervious leading to sump	ha	0.7	24.8	0.0	353.3
--> Area of Roofs (in sump areas)	ha	0.4	5.3	0.0	71.2
Area of Impervious leading to outfall	ha	545.6	433.4	819.0	587.8
--> Area of Roofs (in outfall areas)	ha	132.9	80.7	92.3	72.4
Area of Impervious in Watershed	ha	356.5	427.5	514.3	987.0
Area of Roofs	ha	98.3	113.2	65.7	156.5
STP Output	kg yr^{-1}	27,170	-	-	7,105
STP Output	kg yr^{-1}	-	-	-	-
STP Output	kg yr^{-1}	-	-	-	-
Calculations					
Atmospheric Deposition					
Natural Vegetation	kg yr^{-1}	544	502	1,162	2,235
Turf	kg yr^{-1}	411	263	592	1,088
Agriculture	kg yr^{-1}	0	0	0	34
Ponds	kg yr^{-1}	43	15	94	48
Wetlands	kg yr^{-1}	60	2	58	17
Impervious - to sump sewer	kg yr^{-1}	3	119	0	1,706
Impervious - to outfall sewer	kg yr^{-1}	2,573	2,111	4,150	2,962
Impervious - to turf (portion of roofs)	kg yr^{-1}	79	91	53	126
Subtotal with transport loss	**kg yr^{-1}**	**1,055**	**917**	**1,812**	**4,861**
Subtotal without transport loss	**kg yr^{-1}**	**2,573**	**2,111**	**4,150**	**2,962**
Total	**kg yr^{-1}**	**3,628**	**3,028**	**5,962**	**7,823**
Fertilizer					
Agriculture	kg yr^{-1}	0	0	0	611
Residential Lawns	kg yr^{-1}	7,463	3,457	10,836	17,589
Golf	kg yr^{-1}	1,671	2,415	1,268	5,081
Parks +Athletic fields	kg yr^{-1}	257	546	839	2,042
Subtotal	kg yr^{-1}	9,392	6,418	12,943	25,323
Total with transport loss	**kg yr^{-1}**	**8,687**	**5,937**	**11,972**	**23,423**
Wastewater					
Cesspools - outside 200m of shore	kg yr^{-1}	13,475	15,169	8,336	11,224
Septic - outside 200m of shore	kg yr^{-1}	12,127	13,652	7,502	10,102
Cesspools - within 200m of shore	kg yr^{-1}	2,506	1,878	4,417	2,058
Septic - within 200m of shore	kg yr^{-1}	2,255	1,690	3,975	1,852
Sewage Treatment Plants	kg yr^{-1}	27,170	0	0	7,105
Total	kg yr^{-1}	**57,534**	**32,389**	**24,231**	**32,342**
Pets					
Cat Nload	kg yr^{-1}	159	193	98	214
Dog Nload	kg yr^{-1}	377	456	231	506
Total	**kg yr^{-1}**	**536**	**648**	**329**	**720**
Grand Totals					
Total Nload	**kg yr^{-1}**	**70,385.1**	**42,001.0**	**42,493.6**	**64,308.1**
Total Nload	**kg ha^{-1} yr^{-1}**	**59.8**	**38.7**	**22.4**	**18.2**

Table 9. Model inputs, nitrogen loads for each input (atmospheric deposition, fertilizer, wastewater, and pets), and total nitrogen loads (kg yr^{-1} and kg ha^{-1} yr^{-1}) for various waterbodies in Nassau County.

Model Inputs			
Inputs	Units	Little Neck Bay	Well, Urban Drain, Subsea Discharge
Total Occupancy >200m of shore not on sewers	# people	3,863	17,489
Total Occupancy <200m of shore not on sewers	# people	717	11
Housing Units	# houses	3,618	198,960
Area of Watershed (excluding marine waterbodies)	ha	833	31,264.5
Area of wetlands (freshwater)	ha	3.4	28.1
Area of freshwater ponds	ha	16.2	151.3
Area of agriculture	ha	0.0	43.2
Area of golf course lawns	ha	19.3	1,065.0
Area of parks and athletic field lawns	ha	18.9	853.7
Area of residential lawns	ha	101.5	4,120.3
Area of Impervious leading to sump	ha	30.8	8,429.0
--> Area of Roofs (in sump areas)	ha	5.3	2,576.8
Area of Impervious leading to outfall	ha	502.2	12.4
--> Area of Roofs (in outfall areas)	ha	159.2	0.0
Area of Impervious in Watershed	ha	319.1	13,322.0
Area of Roofs	ha	105.9	4,117.1
STP Output	kg yr^{-1}	43,207	-
STP Output	kg yr^{-1}	-	-
STP Output	kg yr^{-1}	-	-
Calculations			
Atmospheric Deposition			
Natural Vegetation	kg yr^{-1}	333	10,154
Turf	kg yr^{-1}	225	9,729
Agriculture	kg yr^{-1}	0	88
Ponds	kg yr^{-1}	39	366
Wetlands	kg yr^{-1}	5	38
Impervious - to sump sewer	kg yr^{-1}	151	38,345
Impervious - to outfall sewer	kg yr^{-1}	2,269	67
Impervious - to turf (portion of roofs)	kg yr^{-1}	85	3,316
Subtotal with transport loss	**kg yr^{-1}**	**776**	**57,383**
Subtotal without transport loss	**kg yr^{-1}**	**2,269**	**67**
Total	**kg yr^{-1}**	**3,045**	**57,450**
Fertilizer			
Agriculture	kg yr^{-1}	0	1,562
Residential Lawns	kg yr^{-1}	3,503	142,151
Golf	kg yr^{-1}	1,094	60,471
Parks +Athletic fields	kg yr^{-1}	509	22,962
Subtotal	kg yr^{-1}	5,106	227,147
Total with transport loss	**kg yr^{-1}**	**4,723**	**210,111**
Wastewater			
Cesspools - outside 200m of shore	kg yr^{-1}	7,161	32,420
Septic - outside 200m of shore	kg yr^{-1}	6,445	29,178
Cesspools - within 200m of shore	kg yr^{-1}	1,437	22
Septic - within 200m of shore	kg yr^{-1}	1,293	20
Sewage Treatment Plants	kg yr^{-1}	43,207	0
Total	kg yr^{-1}	**59,542**	**61,639**
Pets			
Cat Nload	kg yr^{-1}	151	8,290
Dog Nload	kg yr^{-1}	357	19,605
Total	**kg yr^{-1}**	**507**	**27,895**
Grand Totals			
Total Nload	**kg yr^{-1}**	**67,817.7**	**357,094.4**
Total Nload	**kg ha^{-1} yr^{-1}**	**81.5**	**11.4**

ELEMENT B. IDENTIFY WATER QUALITY TARGET OR GOAL AND POLLUTANT REDUCTIONS NEEDED TO ACHIEVE GOAL

Point and nonpoint source load reductions needed to achieve the water quality goals

In the Nassau County subwatersheds plan (2020), volume-based N loads and nitrogen residence times were determined for all Nassau County water bodies. Volume-based N loads account for the total volume of a water body that a given watershed-based nutrient load is discharging into. A large N load in a small volume waterbody will be more impactful than discharge into a larger waterbody and vice versa. Volume-based N loads are, in turn, used to calculate nitrogen residence times. Nitrogen residence times are thought to be highly representative of the extent to which N can manifest into symptoms of eutrophication as a large N load delivered into a large water body or a very small water body will experience differential dilution and thus result in differing standing concentrations of N. Extended residence times allow water bodies to retain N allowing it to be assimilated by phytoplankton to form blooms and create turbidity and upon decay, the organic carbon from those blooms can cause hypoxia and acidification. Hence, the Nassau County subwatershed plans determined N residence times for all water by multiplying the volume-based N load by the water body's 10% flushing residence times, methodology first established by Suffolk County subwatersheds plan (SCSWP, 2020). The role of N residence times in controlling water quality was made very clear during the Nassau and Suffolk County subwatersheds plan as the water bodies with the poorest water quality (lowest dissolved oxygen, poorest water clarity, densest algal blooms, intense harmful algal blooms) were also the water bodies with the largest N residence times. This general finding was the premise for the development of the Reference Waterbody Approach to N reductions. Specifically, for both the Nassau and Suffolk County Subwatersheds Plan, the waterbodies with the best water quality in Suffolk County were deemed 'reference water bodies': no harmful algal blooms in the past 10 years, mean Secchi disc depths > 2 meters, chlorophyll *a* less than 5.5 $\mu g\ L^{-1}$, and dissolved oxygen greater than 4.8 $mg\ L^{-1}$ (SCSWP, 2020). These sites had a mean N residence time of 0.12 $mg\ L^{-1}$ and any site with a value above was deemed to require a reduction in N load commensurate with the amount the rate was over the threshold value (SCSWP, 2020). During the Nassau County Nine-Element Plan process, a consensus was developed among participants that the reference water body approach used to create N reduction goals could be updated to be made more specific to Nassau County. As such, a consensus was reached that the N load reductions for the Nassau County Nine Element Plan would be updated to use the water bodies with good water quality and met the Suffolk County reference water criteria combined with Suffolk County reference water bodies N residence time concentrations to establish a new reference water body N residence time concentration of 0.119 $mg\ L^{-1}$ N load reductions for other water bodies in Nassau County. N reduction goals were subsequently set by assessing the levels of N reduction that would be needed to achieve the mean N residence times of the reference Nassau County water bodies for each individual water body.

Table B1. N loads, N residence times, and N load reductions for Nassau County sub watersheds. Volume-based loads are corrected for waterbody volume whereas residence time-based loads are corrected by watershed area. Nitrogen residence times concentrations are the nitrogen residence times multiplied by the residence times of each water body. The percent load reduction was determined subtracting the Nassau-Suffolk County reference water body nitrogen residence time concentration from the nitrogen residence time concentration of the water body and the dividing that resulting value by the nitrogen residence time concentration of the water body. Water bodies less than the Suffolk County reference water body value for the nitrogen residence time concentration (Middle Bay, South Oyster Bay, East Bay) became part of the Nassau-Suffolk County reference water bodies.

Water body	Shore	N load kg/yr	Volume-based N load kgN/m^3 /yr	Area-based N load kgN/ha /yr	Volume-based N load mgN/L/d	Nitrogen Residence Time concentration mg/L	N load reduction goal %
West Bay	**South**	2,585,156	0.248573	448.2	0.681021	15.1868	**99.2**
Oyster Bay	**North**	106,802	0.001843	17.0	0.005048	0.2974	**59.8**
Manhasset Bay	**North**	163,211	0.006239	47.3	0.017093	0.1949	**38.7**
Hempstead Harbor	**North**	196,226	0.002765	27.4	0.007574	0.1651	**27.7**
Cold Spring Harbor	**North**	89,890	0.001770	22.7	0.004849	0.1629	**26.7**
Middle Bay	**South**	52,349	0.004552	9.8	0.012471	0.1185	**-**
S. Oyster Bay	**South**	63,256	0.001570	8.4	0.0043	0.0753	-
East Bay	**South**	30,532	0.000960	7.9	0.00263	0.0284	-

Among the Nassau County subwatersheds, West Bay had, by far, the largest volume-based N load and the largest N residence time (Table B1) followed by Oyster Bay which had a level that was more than 50-fold lower (Table B1). Cold Spring Harbor, Hempstead Harbor, and Manhasset Bay had similar N residence times of 0.16 – 0.19 mg L^{-1} (Table B1). The remaining three south shore bays (Middle Bay, East Bay, South Oyster Bay) had lower N residence times that ranged from 0.03 – 0.11 mg L^{-1} (Table B1). With the N residence times determined, N reduction goals could be set. Using the new Nassau County specific reference water body approach the three water bodies with the lowest N residence times were combined with the Suffolk County reference water bodies to generate a new reference water body nitrogen residence time concentration of 0.119 mg L^{-1}.

The required N reductions for each water body were as follows. West Bay required a 99% N reduction, Oyster Bay required a 60% reduction, Manhasset Bay required a 39% reduction, while Hempstead Harbor and Cold Spring Harbor required a 28 and 27% reduction (Table B1). In contrast, Middle Bay, East Bay, and South Oyster Bay required no N reduction (Table B1).

Rationale for selecting the best management practices (BMPs)

Best Management Practices (BMPs) considered by this plan were developed via an iterative process. First, Nassau County worked with Stony Brook University and NYSDEC to consider a comprehensive list of potential BMPs that were appropriate given the sources of N to the waterbodies.

Next, Nassau County held public meetings with citizens and citizen-based organizations to discuss the preliminary list and consider additional options. Through this process, a consensus was generated regarding the BMPs to consider based on their ability to mitigate the largest N loads and the feasibility of their implementation in Nassau County.

Replacing existing onsite / household septic systems with innovative and alternative (I/A), N reducing systems, reducing fertilizer use, improving stormwater systems, implementing biextraction, connecting homes to sewage treatment plants, and re-routing sewer outfalls from bays to the Atlantic Ocean. With regard to upgrading septic systems, two scenarios were considered: 60% and 80% upgrade which could be based on the number of homes upgraded, or the precise technology implemented as some approved systems discharge ~20 mg L^{-1} while others achieve closer to 10 mg L^{-1} (SCSWP, 2020). Regarding fertilizer use, options considered were reduced fertilizer use and the elimination of fertilizer use which was primarily a thought experiment. Regarding stormwater, improvement to 50% and 100% of systems was considered. Regarding bioextraction, there were an endless number of options to consider given the dozens of seaweeds and bivalves that are aquacultured globally both individually and in combination. The bioextraction scenario considered was the cultivation of sugar kelp for six months of the year (December – May) and the cultivation of *Gracilaria* for six months of the year (June – November) and the year-round cultivation of oyster. This scenario was selected as oysters are, far and away, the most aquacultured bivalve in NY and kelp and Gracilaria are the most aquacultured seaweeds in NY. Expanding the availability of sewers to unsewered communities around the Point Lookout, Birches, Port Washington, Glen Cove, and Atlantic Beach was considered. Finally, the Bay Park Conveyance Project was considered which is the re-routing of the outfall of Nassau County's largest sewage treatment plant from Reynolds Channel in West Bay to the Cedar Creek sewage treatment plant which discharges three miles south of Long Island in the Atlantic Ocean.

How the selected (BMPs) will reduce the pollutant

Each BMP will reduce N loads differently. Onsite septic systems in Nassau County generally consist of cesspools or septic tanks connected to leaching rings that drain wastewater to groundwater, but do not remove N due to the sequencing of oxygen use and organic matter use in soils. I/A septic systems establish microenvironments that facilitate the microbial processes of coupled nitrification – denitrification which convert fixed N in the wastewater stream to nitrogen gas which is released to the atmosphere, but has no environmental consequence given that 80% of Earth's atmosphere is N gas. There are currently no restrictions nor regulations on fertilizer use in Nassau County and lawn fertilizers are typically at least 3% N, but can vary from 1% - 20%, so reducing fertilizer use would reduce N loads to subwatersheds (Table C1). Stormwater runoff may be enriched in N from the atmosphere and, in some cases, that stormwater may discharge directly to surface waters. Rerouting such stormwater to regions where N can be denitrified or vegetatively assimilated would reduce this N load. Regarding bioextraction, oysters are suspension feeders that remove N-rich plankton from water bodies and assimilate it into their tissues which can be subsequently harvested and thus removed from the ecosystem. Similarly, seaweeds are photosynthetic organisms that assimilate N from seawater as they grow.

If these seaweeds are harvested prior to their decay, the N that had been assimilated will be removed from the water body. Connecting unsewered communities to sewage treatment plants allows the N from wastewater to be denitrified prior to being discharged back to groundwater or surface waters. While wastewater contains ~80 mg L^{-1}, sewage treatment plants typically reduce N and have effluent of 10 mg L^{-1} (SCSWP, 2020). Finally, the Bay Park Conveyance Project will reroute sewage out of West Bay and to the Cedar Creek Plan and out to the Atlantic Ocean, fully eliminating this wastewater source for this Bay.

Provide an estimate of the expected load reductions from the BMPs

The total N load reductions from each process are a function of the efficacy of each BMP as well as the relative contribution of each type of N load the BMP addresses. If a N load is very large, even a moderately efficient BMP will have a substantial impact. Conversely, if a BMP is mitigating a minor source of N, even the most efficient of BMPs will only have a minor impact on the total N load. Regarding I/A septic systems, the generally remove 60-80% of nitrogen and onsite septic systems are the largest source of N on the north shore of Nassau County and thus, they should be maximally effective there (SCSWP, 2020). While wastewater contains ~80 mg L^{-1}, I/A septic systems approved by Suffolk County must reduce N and have effluent of 19 mg L^{-1}. Some of the best systems can achieve 10 mg L^{-1} (SCSWP, 2020). Conversely, most of the south shore of Nassau County is sewered and thus upgrading septic systems in this region would be of minor consequence. Since fertilizer is the largest source of N to the south shore bays but is minor contributor on the north shore, it is expected reductions in fertilizer use will be of maximal benefit on the south shore but will have a smaller effect on the north shore (Table C1). Stormwater N is derived from atmospheric deposition and atmospheric deposition is a minor source of N to all subwatersheds. It is expected, therefore, that mitigating stormwater will be of minor importance for reducing N loads, despite its value for reducing the delivery of pathogens to surface waters. Bioextraction is a relatively new BMP for New York. Its efficacy will be a function of how much of a surface water body is covered with aquacultured organisms. While some communities have set restrictions of no more than 5% of surface waters being used for aquaculture, this percentage presently seems extreme for Nassau County given there is presently no aquaculture and given the large expanse of regions closed to shellfishing. Hence, for this study, a 1% coverage of surface waters was considered a realistic near-term goal that could have a moderate impact on N extractions. The effectiveness of sewering unsewered regions will be a function of the relative importance of unsewered buildings as N sources and the extent of sewering. For this project, only regions within a close proximity (~one mile) to each sewage treatment plant was considered as the cost for extending sewer lines beyond this radius is cost prohibitive (>$100,000 per home) relative to I/A systems (<$30,000). Finally, the Bay Park Conveyance Project is expected to be highly beneficial since it is, by far, the largest source of N in Nassau County and the relocation of sewage to the Atlantic Ocean would fully remove the N source from West Bay and all Nassau County water bodies.

ELEMENT C. IDENTIFY THE BEST MANAGEMENT PRACTICES (BMPS) THAT WILL HELP TO ACHIEVE REDUCTIONS NEEDED TO MEET WATER QUALITY GOAL/TARGET

This Nine Element Plan is considering the BMPs that are most likely to address the sources of N pollution identified in Element A. The next step toward identifying ideal BMPs for each subwatershed was to compare the N reductions required for each subwatershed to the N reductions achieved by each approach. The precise reductions considered were upgrading of septic systems to reduce effluent by 60% or 80% (Table C1), reducing fertilizer following the recommendation of the Long Island Nitrogen Action Plan (Table C1), eliminating all fertilizer which was done primarily as a thought experiment, improving stormwater systems by routing either 50% or 100% of stormwater through natural vegetation, use of moderate bioextraction which is covering 1% of surface waters with oyster aquaculture, kelp aquaculture in winter and spring and *Gracilaria* aquaculture in summer and fall (Table C1). Finally, sewer expansion projects were considered for different communities.

Table C1. Nitrogen mitigation exacted from fertilizer reduction, upgrading septic systems and aquaculture. Fertilizer reductions are based on recommendations via LINAP, while the CCWT and Suffolk County septic reductions were based on systems that achieve removal 80% (10 mg N / L final effluent) or 60% removal (19 mg N / L final effluent; SCSWP, 2020). Bioextraction values are based on literature values (Gorman et al., 2017; Dvarskas et al., 2020; Grebe et al., 202) with oyster removal being based on 12 months of growth, whereas kelp and red seaweed extraction was based on five months of growth each (January – May and June – October, respectively).

Scenario Constants		
Fertilizer applied to lawns - LINAP reduction	58.59	*kg per ha per yr*
Fertilizer applied to golf courses - LINAP reduction	189.2685186	*kg per ha per yr*
Fertilizer applied to Parks & Athletic Fields - LINAP reduction	89.65350881	*kg per ha per yr*
Private septics / cesspool upgrade - CCWT reduction amount	0.8	*percent reduction*
Private septics / cesspool upgrade - Suffolk reduction amount	0.6	*percent reduction*
Bio Extraction N removal		
Eastern oyster (C. virginica)	215.1	*kg per ha per year*
Red seaweed (Gracilaria tikvahiae)	56.0	*kg per ha per year*
Sugar kelp (Saccharina latissima)	112.0	*kg per ha per year*

Nitrogen mitigation scenarios were enacted for all subwatersheds, although it should be noted that N reductions are not needed for East Bay and South Oyster Bay (Table C2). Regarding sewering, this approach removed nearly all of the N load from West Bay (98%) and was nearly identical to the N reduction needed for this subwatershed (99%; Table C2). All other sewering projects were subwatershed specific and would be minimally impactful ($\leq$1%) with the exception of the Point Look-Out sewering project that would mitigate 10% of the N load to Middle Bay where additional N load reduction is not required (Table C2). Mitigating stormwater was of minimal impact with regard to N loading, addressing <2% of the total N load even when 100% of the stormwater load was mitigated (Table C2). As stated in Element B, this is due to the minor contribution of atmospheric deposition to N loads and since only a fraction of that deposition runs directly into coastal water bodies as surface runoff (Table C2). In contrast, this approach is highly effective in mitigating the loading of pathogens into waterbodies due to the large contribution of near-shore fecal matter from pets and other animals. Mitigating fertilizer is a significant BMP across south shore subwatersheds where it is a significant fraction of the total N load as even the reduced N mitigation approach would be enough to reduce loads by ~20% except for West Bay where fertilizer use is dwarfed by the Bay Park sewage treatment plant (Table C2).

On the north shore reducing N loading from fertilizer would be less effective than the south shore but would still reduce total N loads by 3-12% and thus can be considered one of the BMPs considered for these subwatersheds (Table C2). While the elimination of fertilizer is, of course, significantly more effective than simply reducing fertilizer use (Table C2), that is likely not a BMP that would be well tolerated by the populace. Upgrading onsite septic systems is the most impactful BMP for all four of the north shore subwatershed, reducing total N loads by 28-54% depending on the waterbody and the extent of upgrades (60% v 80%; Table C1). Finally, bioextraction appears to be a viable BMP for all water bodies save for West Bay (Table C2). Across other sites, using just 1% of surface waters for aquaculture could extract 2-27% of the N loads, with variance being a function of water body size and the size of the N load.

Table C2. Relative effectiveness of each BMP for each subwatershed compared to the N reductions needed for each waterbody. Actions more likely to be effective are highlighted in Grey.

Scenario Reduction (%)	West Bay	Middle Bay	East Bay	South Oyster	Manhasset Bay	Hempstead Harbor	Oyster Bay	Cold Spring Harbor
Required N reduction (Suffolk ref)	**99.2**	0.0	0.0	0.0	39.0	28.0	60.0	27.0
Upgrade 80% of private septic	0	-7.8	0	-11.8	-41.8	-44.2	-37.1	-54
Upgrade 60% of private septic	0	-5.9	0	-8.8	-31.4	-33.1	-27.8	-40.5
Reduce turf fertilizer	-0.3	-16.6	-22.8	-21	-3.4	-5.6	-12.1	-9.3
Eliminate turf fertilizer	-1.1	-52	-60.6	-52.7	-9.9	-21.9	-32.6	-24
Improve 50% of stormwater sys.	0	-0.8	-0.7	-0.4	-0.1	-0.2	-0.2	0
Improve 100% of stormwater sys.	0	-1.6	-1.4	-0.9	-0.3	-0.4	-0.5	0
Moderate Bioextraction	-0.3	-21.5	-26.7	-19.9	-2.1	-2.5	-4.4	-4.4
Sewer - Point Lookout	0	-9.8	0	0	0	0	0	0
Sewer - Birches	0	0	0	0	0	0	-1.3	0
Sewer - Port Washington	0	0	0	0	-1.3	0	0	0
Sewer - Glen Cove	0	0	0	0	0	-0.2	0	0
Sewer - Bay Park	-97.7	0	0	0	0	0	0	0
Sewer - Atlantic Beach	-0.6	0	0	0	0	0	0	0

With regard to each waterbody, as mentioned above, the Bay Park Conveyance Project creates the N load reductions needed for West Bay (Table C2). For the north shore subwatersheds, achieving the required N load reduction could be achieved by a combination of approaches. For three of the four water bodies, upgrading 80% of onsite septic systems would achieve the N load reduction target with Oyster Bay being the site that would need additional N reductions. However, achieving 80% might not be fully realistic, in which case a combination of reducing fertilizer use, implementing aquaculture, and upgrading large fraction of the septic systems would achieve the total N reduction goal. For Oyster Bay, an aggressive combination of more than 80% septic upgrades, reducing fertilizer use, and aquaculture will be required to meet the total N reduction goal.

How the BMPs will be implemented throughout the watershed.

Regarding implementation, the Bay Park Conveyance Project is underway and will be the process by which the BMP for West Bay and the entire south shore is achieved. Implementing a fertilizer regulation for NYS or Nassau County has been considered by the NYS legislature in the past and legislation would be the likely most effective approach for widespread implementation. Such legislation could seek to reduce the N content of fertilizer applied and/or place a specific restriction on the use of fertilizer, with the later approach being the most difficult to enforce. Regarding the upgrading septic systems, in 2021, Nassau County implemented a process by which residents can upgrade to I/A systems and even began a grant system that offers $20,000 for such installations.

In Suffolk County, the pace of I/A system installations accelerated when $10,000 grants from NYS were matched with $10,000 grants from the County and in the Towns of East Hampton and Southampton, an additional $20,000 in grants were made available. In addition, Suffolk County has passed laws requiring I/A systems for all new construction and for significant home expansions or upgrades. Similar laws and grants programs would help implement I/A septic systems in Nassau County. Regarding aquaculture, several steps would help implement this BMP. First, there would need to be a concerted effort to advance aquaculture within the County. While bivalve aquaculture is permitted across NY, of the three dozen oyster farms across NY, all are located in Suffolk County. This is partly due to well-organized bay-bottom leasing programs in the Peconic Estuary by Suffolk County as well as aquaculture leasing programs in many non-east end Suffolk County townships (e.g. Brookhaven, Islip). Similar programs are needed in Nassau County to advance the aquaculture industry. A second step needed will be state legislation to permit the aquaculture of kelp outside of the Peconic Estuary and to permit the aquaculture of other seaweeds in NY. Finally, it is noted that the Oyster Bay may be difficult to achieve as implementation of aquaculture and fertilizer use changes will require state legislation that could make full implementation challenging within the implementation timeline.

ELEMENT D. TECHNICAL AND FINANCIAL ASSISTANCE

Nine Element plans must identify potential funding sources. This plan relies mainly on multiple sources of funding assistance and sources including but not limited to Nassau County Capital Project Funds, Federal Infrastructure funding opportunities, State Funding including but not limited to Environmental Facilities Corporation (EFC) funds and Environmental Bond Act Funds, Town Programs, other federal/state/local Grant funding opportunities. Components of the plan will require the use of consultants for assistance with all sewer and stormwater nitrogen reduction projects including studies, plans, permitting, design and construction for each project. Public education work and the Septic replacement program will require assistance from the local protection committees and the local Soil and Water Conservation District. The conveyance project requires private construction contractor services and consultants and is funded through various sources of federal, state and local dollars. The plan outlines below the funding (estimate) required to fully implement the various components of said plan. Without appropriate funding opportunities these goals will not be met.

South Shore Conveyance Project:
Bay Park to Cedar Creek connection- The cost to complete the South Shore Conveyance project- is projected to be $500,000,000.00 dollars. The project is ongoing and existing funding assistance include state funds. The project is made possible through existing federal, state and county sources of funding. For more information, please visit https://www.bayparkconveyance.org/.

Nassau County Septic Replacement Program:
The goal of Nassau County's septic replacement program is to install 2,000 innovative and alternative onsite wastewater treatment systems (I/A OSWTS) in ten years. The Nassau S.E.P.T.I.C. program provides $20,000 per installation. With a goal of 2000 systems to be installed over the next 10 years that dollar amount would equal $40,000,000 dollars. Project is ongoing.
The Nassau County Soil and Water Conservation District is currently managing this program and the program is/will be dependent upon a Nassau County funding contribution in addition to existing and future state and federal funding sources such as NYS EFC, American Recovery Act (ARP) funds or additional future grant opportunities not yet released. The funding would be geared toward district administrative costs and unit installation costs. For more information on the program please visit https://www.nassauswcd.org/S-E-P-T-I-C-Replacement-Program.

Nassau County Sewer projects:
Point Lookout Sewer Feasibility Study. The Feasibility Study will cost approximately $400,000 and is to start in 2022. Additional outside state and/or federal financial assistance is required to fund permitting and construction of the sewer connection with the cost to be determined within the feasibility study. The estimated costs provided below are from the "Hempstead Harbor Sewer Feasibility Study of 2016".

The Hempstead Harbor Sewer Feasibility Study considered three projects outlined below. Permitting and design of each project has not commenced and would require state and/or federal funding sources.

Crescent Beach Area Sewer: Total construction with contingency is approximately $37,500,000 which includes force mains, manholes and service connections. The project is dependent upon future state and/or federal grant funding and there is no projected start date presently.

Port Washington Sewer: Total construction with contingency is approximately $18,000,000 and includes force mains, manholes and service connections. The project is dependent upon future state and/or federal grant funding and there is no projected start date presently.

Sea Cliff, Glen Head, Glenwood Landing, Roslyn Harbor, Greenvale Sewer: Total construction with contingency is approximately $613,000,000 and includes force mains, manholes and service connections. The project is dependent upon future state and/or federal grant funding and there is no projected start date at this time.

Plandome Road Commercial Business/Residential Area Sewer Connection to the Great Neck Water Pollution Control District: A Manhasset Sewer Feasibility Study was prepared for the Great Neck Water Pollution Control District in January 2020. The study focused on two areas: the Plandome Road commercial area (Primary Study Area) and a Plandome Road residential area (Secondary Study Area). Two different systems were evaluated: a combination gravity sewer and pump station and a low-pressure sewer. Capital cost estimates were $12.4M -- $16.8M for the Primary Study Area and $20.3M - $23.7M for the Secondary Study Area. The Primary Study Area has 88 parcels, of which 41 are commercial and 40 are mixed use. The Secondary Study Area has 443 parcels, 408 of them are residential.

Target dates for these projects would be 10 to 15 years and would be dependent upon outside federal and state funding sources.

Bioextraction:
A county-wide bioextraction program would primarily rely on Town programs that fund these initiatives. The budget proposal for the next five-year period would include the towns purchasing material such as kelp, shellfish, and aquaculture equipment as well as personnel required for the deployment and maintenance of equipment. In collaborating with the Towns of Oyster Bay and Hempstead stakeholders an estimated budget of $600,000 is required and would cover the aforementioned items over a five-year period. The cost may increase upon program expansion and that may be analyzed later. Projects are ongoing and to expand the program the towns would require outside state and/or federal funding sources. The protection committee's may provide technical assistance with this program as well.

An alternative approach could be to have the Towns and/or County lease bottom lands to aquaculturists who could engaged in shellfish and seaweed aquaculture as a private venture in which case funding would be needed to sustain the lease programs but not to purchase equipment.

Stormwater Nitrogen Reduction
Diverting additional storm water into Nassau County recharge basins and infiltrate into the groundwater system would reduce direct N discharge to surface waters, as well as minimize the flow of pathogens. Basins and the watershed areas would have to be reviewed to determine basin capacity, expansion, and maintenance. The first step would be to evaluate this proposal via a feasibility study. A study (grant dependent) would be proposed within a five to ten-year period, could cost $1,000,000, and could consist of multiple studies examining multiple opportunity areas. The feasibility studies would include focus areas, technical designs, and cost estimates that will evaluate storm water basin rehabilitation and diverting of stormwater into these basins. Rehabilitation projects may include basin scouring, outfall improvements, diversion and would be determined by the study. Cost estimates for construction could be added to the plan once the feasibility study is complete. This study would be explored by Nassau County and would require grant (federal, state) support. Additional state and/or federal financial assistance would be required to implement any permitting/design requirements and construction activity that would be recommended in the feasibility study.

Public Education Campaign Fertilizer Use:
To conduct public education for the fertilizer-use program, the various Nassau County protection committees listed in Element E would require external economic resources through various grants and the continued inter-municipal annual funding from the municipal membership partners. If the following program elements are to be successful, funding for each category would be needed as follows:

Public information campaign via mailers, adding nitrogen reduction information to various protection committee websites, literature handouts at festivals and fairs over two years for $20,000

Legislative policy advocacy to advance programs such as pushing for limits on nitrogen in Long Island fertilizer over 5 to 10 years with no additional costs.

Fertilizer applicator trainings for landscape professionals and homeowners. Nassau County Soil and Water Conservation District could develop a program over five years for $50,000.

Development of new (or updating of current) fertilizer educational materials - This printed and electronic material would be distributed through the already established watershed groups over 2 – 4 years for $50,000.

Other Public Educational Initiatives:
Development of new (or updating of current) stormwater pollution educational materials (print) and distribution through the already established watershed groups. The cost would be $30,000.00 over two-to-four years.

Development of new electronic stormwater pollution educational graphics and distribution through the already established watershed groups The cost would be $30,000.00 over two-to-four years.

The educational components above will be implemented by the groups listed in element E.

ELEMENT E: INFORMATION AND EDUCATION

Nassau County organized numerous stakeholders that contributed to the planning and implementation of the Nine-Element plan. The stakeholder group was originally formed by Nassau County during the development of the Nassau County Nitrogen Loading Model (NLM) in 2017. The group consisted of multiple municipal and various not for profit organizations. In-person meetings with the stakeholders were held during the (NLM) process. The group expanded in membership during the Nassau County 9E Plan development. Virtual meetings which included a kick-off meeting and subsequent meeting updates were conducted. The Nine-Element kick-off meeting was held virtually on July 10th, 2020. The stakeholder group also developed the NLM scenario list via another virtual meeting held on August 9th, 2021 and through follow up email correspondence. In some cases, smaller email correspondence occurred between sub-groups of stakeholders. For example, public education component will rely upon the various protection committees. In this case emails were sent strictly to those committees in order to fine tune their public education methodologies. A final workgroup meeting was held on June 7th, 2022 to review the plan and accept any final comments before submission to DEC. The stakeholder group was involved in all areas of development of the plan.

Table E1. Nassau County Stakeholder Group list:

NAME	AFFILIATION
Estuary Programs	
Mark Tedesco	Long Island Sound Study
Jim Latimer	Long Island Sound Study
Jeremy Campbell	NYSDOS South Shore Estuary Reserve Program
Sally Kellogg	NYSDOS South Shore Estuary Reserve Program
County Soil and Water Districts	
Derek Betts	Nassau County Soil and Water Conservation District
Cornell Cooperative Extension	
Gregory Sandor	Nassau County Cornell Cooperative Extension
Sarah Schaefer-Brown	NY Sea Grant
Town and City Planning	
Anne Fangmann	City of Glen Cove CDA & IDA
Patricia Bourne	City of Long Beach
Tara Schneider-Moran	Hempstead
Michael Levine	North Hempstead
George Baptista, Jr.	Oyster Bay

Protection Committees	
Eric Swenson	Hempstead Harbor Protection Committee
Sarah Deonarine	Manhassett Bay Protection Committee
Rob Crafa	Oyster Bay Cold Spring Harbor Protection Committee
Marshall Brown	Save the Great South Bay
Environmental Organizations	
Adrienne Esposito	Citizens Campaign for the Environment
Maureen Dolan Murphy	Citizens Campaign for the Environment
Carol DiPaolo	Coalition to Save Hempstead Harbor
Heather Johnson	Friends of the Bay
Patricia Wood	Grassroots Environmental Education
Lisa Ott	North Shore Land Alliance
Rob Weltner	Operation Splash
Tracy Brown	Save the Sound
Peter Linderoth	Save the Sound
Katie Friedman	Save the Sound
Roger Reynolds	Save the Sound
Enrico Nardone	Seatuck Environmental Association
Kevin McDonald	The Nature Conservancy
Chris Clapp	The Nature Conservancy
Steve M. Raciti	Hofstra University
Carl Lobue	The Nature Conservancy
SUNY Stony Brook	
Dr. Christopher Gobler	SoMAS
Dr. Thomas Wilson	SoMAS
Dr. Charles Flagg	SoMAS
EPA	
Bob Nyman	USEPA
Jim Latimer	USEPA
Nassau County	
Ken Arnold	Nassau County - NCDPW
Daniel Fucci	Nassau County - NCDPW
Jane Houdek	Nassau County DPW
Vincent Falkowski	Nassau County DPW
LIRPC	
John Cameron	LIRPC
Richard Guardino	LIRPC
Elizabeth Cole	LIRPC
DEC	
Susan VanPatten	DEC Divison of Water
Cathy Haas	DEC Divison of Water
Michele Golden	DEC Divison of Water
Kristin Kraseski	DEC Divison of Water

As stated above Nassau County will be utilizing the existing watershed protection groups below to assist in disseminating information and education pertaining to nitrogen reduction strategies. The groups below, as part of their mission, include nitrogen reduction strategies within the Nassau County Watersheds. Part of what the programs and committees listed below undertake to achieve this goal is the engagement and education of the public. The various committees maintain websites and social media accounts to disseminate information. Additionally, the committees have previously distributed Nassau County-generated print literature through public forums, such as environmental festivals, and the committees are willing and able to distribute new materials that Nassau County generates. The stakeholders listed below usually meet on a monthly basis and report on all progress related to their objectives.

The organizations below have expressed interest in a joint educational program targeted at residential fertilizer use. Nassau County will work with the groups below to explore the following:

- Inventory of exiting fertilizer reduction public education initiatives (as part of the Nassau County 9E Plan) including actions from water resource management plans from around Long Island started including but not limited to (see below):
    - Long Island Sound Study
    - South Shore Estuary Reserve
    - Long Island Nitrogen Action Plan
    - Friends of the Bay Watershed Action Plan
- Analyze the effectiveness of these existing plans and materials.
- Develop, implement, and assess a comprehensive fertilizer reduction campaign, including but not limited to
    - Targeting landscapers, municipalities, institutions, and homeowners
    - Municipal leadership such as:
        - Implementing Best Management Practices, IPM, organic fertilizer, slow-release fertilizer
        - Supporting bioextraction initiatives (i.e., oyster gardening, kelp) as part of education/outreach initiative

Additional information about each group is found below.

Manhasset Bay Protection Committee:

The Manhasset Bay Protection Committee is an inter-municipal organization focused on addressing water quality and coastal issues with a coordinated, watershed-level approach. The Committee has 15 member municipalities who all voluntarily entered into an inter-municipal agreement. The Committee is funded through annual dues from these members. Membership is open to all local governments in the watershed.

The Committee's goals are to protect, restore, and enhance Manhasset Bay to insure a healthy and diverse marine ecosystem while balancing and maintaining recreational and commercial uses. The Committee was founded in the late 1990s and is expected to continue in perpetuity, as their role in achieving the requirements of new regulations has cemented their place in the watershed. Educational materials include references to preferred water uses (i.e., swimming and shellfishing), but don't typically specify that these are also regulatory goals. This is something that can be added going forward. These materials are available at all public outreach events the Committee does. Additionally, these materials will be available at upcoming public outreach meetings during the development of the Water Quality Improvement Plan over the next three (3) years.

The Committee maintains a website that is frequently updated and can serve as a method of distributing educational information. Additionally, the Committee sends out a quarterly newsletter four (4) times per year and places preference on local information and issues. This information is sometimes incorporated into the local municipalities' (villages') own newsletters for distribution to residents. For educational components put together by the County, the Committee can craft articles and send them to the villages for incorporation into their newsletters.

The Committee also has social media accounts and is frequently in search of material to post. Nassau County 9E educational components could be tailored for these platforms and put out at any scheduled frequency.

The Committee currently hosts three (3) volunteer events per year and, unrelated to Nassau County's efforts, is looking to expand these events. The current volunteer events are all beach clean-ups and attract enthusiastic residents of the watershed. At these events, "swag" is distributed (e.g., scout patches, reusable bags, etc.) as well as educational fliers, pamphlets, etc. It's also a great opportunity to have one-on-one conversations with residents.

Related to the volunteer efforts above, the Committee will be developing stand-up educational signs for any "tabling" event the Committee attends. Nassau County's 9E components are also important to the Committee and will, to some extent, be included on these educational signs.

Hempstead Harbor Protection Committee:

The Hempstead Harbor Protection Committee (HHPC) was founded in 1995 as Long Island's first inter-municipal watershed organization. It was created specifically to protect and improve the water quality of Hempstead Harbor.

The Committee accomplishes through planning studies, capital improvement projects, educational outreach, water quality monitoring, information and technology sharing, development of model ordinances, coordination of enforcement, and working with other governmental agencies as well as environmental, educational, community and business groups. This approach saves each municipality expenses and effort by cooperation, provides for a more coordinated approach to solving harbor problems, and provides year-round focus on harbor issues.

The current municipal members of the Hempstead Harbor Protection Committee include the County of Nassau, the Towns of Oyster Bay and North Hempstead, the City of Glen Cove and the Villages of Sea Cliff, Roslyn Harbor, Roslyn, Flower Hill and Sands Point.

Oyster Bay/Cold Spring Harbor Protection Committee:

The Oyster Bay Cold/Spring Harbor Protection Committee's mission is to establish a sustainable, cooperative partnership among the municipalities within the watershed with input from the public and other stakeholders to efficiently protect and improve water quality through a holistic and integrated watershed-wide approach. This will be accomplished by:

- developing long range plans,
- utilizing and implementing the findings of existing studies,
- sharing information, technology and ideas,
- developing and implementing best management practices,
- developing and adopting model ordinances,
- actively pursuing grants, partnerships and other sources of support for the watershed,
- conducting and/or supporting water quality and habitat monitoring,
- enhancing awareness, conducting educational outreach and practicing stewardship,
- developing and undertaking capital improvement projects,
- coordinating enforcement, and;
- consulting with and engaging other governmental agencies, environmental advocates, educational organizations, interest groups, businesses and citizens.

Operation S.P.L.A.S.H.:

Operation S.P.L.A.S.H. (Stop Polluting, Littering and Save Harbors) was founded in 1990, has several thousand concerned members, in 7 chapters dotted all along Long Island's South Shore, primarily in Nassau County. Their 6 SPLASH boats run from March through November and are operated by volunteer captains and crew members, patrolling our local waterways and removing trash, marine debris and navigational hazards from bays, beaches and waterways. This group is also focused on reducing sewage discharged into south shore bays, as well as water runoff. To reduce the flow of pollution into our bays, SPLASH has collaborated on the funding and installation of more than 4,000 street storm drain inserts in Nassau County. SPLASH has education programs teaching thousands of students each year about the importance of our South Shore Bays and the challenges that they face. Students of all ages, from elementary school through college, enjoy the classroom program, the bay tour by boat, the trip down the Nautical Mile, and seeing the saltwater tanks brimming with local marine life.

Citizens Campaign for the Environment and The Nature Conservancy

Citizens Campaign for the Environment and The Nature Conservancy are two large environmental organizations with a strong presence in Nassau County and deep interest in mitigating excessive nitrogen loading into surface waters from Nassau County watersheds. While neither organization represents a specific geography constituency in Nassau County, both organizations have thousands of members and the ability to rapid disseminate information to concerned citizens. Both organizations also have strong ties to local and state politicians to assist advancing issues politically.

Nassau County Soil and Water Conservation District:

Soil and Water Conservation districts are local units of government that develop, manage, and direct natural resource programs at the local level. The Nassau County Soil and Water Conservation District, which has been in existence since 1977, is one of 58 county districts in NY State that provide "on the ground" assistance for soil and water resources, preservation of wildlife, and promote the health, safety, and welfare of residents in their respective communities. Their purpose is to protect, preserve, restore, and enhance natural resources through education and technical assistance. The district provides programs and technical services to all Nassau County residents and municipalities to manage our precious natural resources. They foster coordination among municipalities and other key stakeholders to develop locally driven solutions to natural resource concerns in Nassau County. They work together for clean water and healthy soils with individuals, municipalities, private and public organizations, and schools. Some partners include Soil & Water Conservation Districts in every county in NY State, New York Sea Grant, Cornell Cooperative Extensions of Nassau and Suffolk, Operation SPLASH, Watershed Protection Committees (Manhasset Bay, Hempstead Harbor, and Oyster Bay – Cold Spring Harbor), and the local office of the US Department of Agriculture, Natural Resource Conservation Service (USDA-NRCS).

Long Island Regional Planning Council:

The Long Island Regional Planning Council (LIRPC) is established to build productive linkages between communities, provide focus on issues best handled on a broad geographic scale and foster the development of regional comprehensive planning.

In furtherance of these goals, the LIRPC conducts research, surveys and studies which address regional needs, issues and opportunities. The LIRPC serves as a forum for discourse and debate and focuses on Long Island's economy, equity, tax and governance, infrastructure and, the environment. The LIRPC uses its inherent powers to effectuate positive change and implement the Region's long-range planning goals and strategies through education outreach.

Specific actions the LIRPC is engaged in to educate the public on the Nassau County's Element plan include:

- *Monthly Newsletters and social media*: LIRPC distributes comprehensive newsletters highlighting the activities that support the Long Island Nitrogen Action Plan's (LINAP) goals and objectives including updates on Nassau County's subwatershed planning.
- *Social media platforms*: LIRPC's Facebook and Twitter accounts are maintained and populated with LINAP related content and educational materials.
- *The Long Island Water Quality Annual STEAM Challenge:* Recognizing the need for greater interaction between professionals engaged in Science, Technology, Engineering, Art and Mathematics (STEAM) pursuits and our schools, the LIRPC developed a STEAM program related to LINAP for all public and private Long Island schools. The goal is to connect students, teachers, and their communities with issues being addressed by LINAP including subwatershed planning.
- *Public Meetings*: The LIRPC conducts quarterly public meetings where experts regularly provide updates on the projects that support LINAP's goals and objectives.
- *Collaboration:* The LIRPC staff and Council members actively collaborate with LINAP partners in various capacities. Monthly Project Management Team (PMT) meetings are led by the LIRPC with team members representing Suffolk County, Nassau County, DEC and LIRPC. The PMT is responsible for oversight of committee structure, scope, budget, schedule, contracts, consultant assessment and oversight, annual work plan, interagency agreements and coordination, and timeline compliance. LIRPC staff and DEC staff also meet monthly to provide updates on LINAP activities and plan next steps. In addition, LIRPC staff are active members in several workgroups and committees.
- *Nitrogen Reduction Pledge:* The LIRPC partnered with the South Shore Estuary Reserve, the Peconic Estuary Partnership, and the Long Island Sound Study to promote the Nitrogen Reduction Pledge. The pledge calls for individuals to take steps to reduce their own personal nitrogen inputs and seeks to educate the public about nitrogen loading.
- *The Hempstead Bay Water Quality Monitoring Program*: The program provides a framework for monitoring, analysis, and reporting of water quality within the surface waters of Hempstead Bay and its major tributaries This program also looks at atmospheric nitrogen deposition which is associated with emissions from fossil fuel-related energy production, fertilizer usage, and transportation emissions. The long-term nature of this monitoring work will advance our understanding of the impacts of severe storms, residential and commercial development, and climate change on our water resources. Overall, this water quality monitoring and analysis program will increase our knowledge of nitrogen pollution sources in the region and the associated impacts on environmental quality.

- *Nutrient Bioextraction Initiative*: The LIRPC, the DEC, and the New England Interstate Water Pollution Control Commission (NEIWPCC) partnered to start the Nutrient Bioextraction Initiative. The goal of the Initiative is to improve water quality in marine waters by removing excess nitrogen through the cultivation and harvest of seaweed and shellfish. The Initiative provides information to help decision makers with the guidelines needed to facilitate seaweed and shellfish farming and harvest operations in their coastal waters. In 2021 the LIRPC authorized an agreement with NEIWPCC to transfer LINAP funds to retain a Bioextraction Environmental Analyst to assist in the advancement of the Initiative across Long Island.
- *Nitrogen Smart Communities*: The LIRPC in partnership with the DEC are developing the Nitrogen Smart Communities (NSC) program. The NSC program is a, voluntary program that is part of the LINAP initiative, and promotes local awareness and action. The program encourages municipalities in Nassau and Suffolk counties to take meaningful and effective actions to reduce, prevent or eliminate nitrogen pollution through a coordinated, community specific strategic plan of action.

New York Sea Grant:

New York Sea Grant (NYSG), a cooperative program of Cornell University and the State University of New York (SUNY), is one of 34 university-based programs under the National Oceanic and Atmospheric Administration's National Sea Grant College Program. Since 1971, NYSG has supported a statewide network of integrated research, education and extension services promoting coastal community economic vitality, environmental sustainability and citizen awareness and understanding about the State's marine and Great Lakes resources. The program maintains offices from Long Island to Buffalo, including an office at Nassau County Cornell Cooperative Extension.

Through NYSG's efforts, the combined talents of university scientists and extension specialists help develop and transfer science-based information to many coastal user groups—businesses and industries, federal, state and local government decision-makers and agency managers, educators, the media and the interested public. In order to create an engaged community acting as stewards of the Long Island Sound watershed, a collaborative regional framework of better trained and informed community decision makers, and to support the planning and implementation of infrastructure improvements and best management practices NYSG plans to regularly coordinate and engage with Nassau County communities in the Long Island Sound watershed to disseminate the information and strategies included in the Nassau Nine-Element Plan. NYSG plans to establish forums that can support knowledge-sharing related to the Nassau Nine-Element Plan - an annual Long Island Sound regional workshop and an online user-friendly clearinghouse of Long Island Sound-related resources focused on provide additional support to implement practices, policies and tools related to land use, climate adaptation planning and implementation, water quality management and habitat protection.

Element F. Implementation Schedule:

Implementation progress is varied based upon the specific nitrogen reduction best management practice involved. Implementation progress will ultimately depend upon funding made available for said implementation practices and other required resources such as staffing required to complete such tasks. Significant Delays are possible in areas where funding is insufficient to implement and complete these tasks. For example-the sewer studies currently do not have timeframes available due to insufficient funding. The plan will be reviewed and updated as significant implementation occurs towards short/medium/long term goals to evaluate effectiveness in implementing actions and identify additional steps, if necessary. At a minimum, the plan will be reviewed and updated after 2 years to assess progress on the milestones noted in Element G. Given the considerations stated above the schedule below is broken down into specific Best Management Practice Tasks as identified by the Nassau County Nine Element Stakeholder group.

South Shore Conveyance Project:
The Bay Park to Cedar Creek connection is to be completed within five years of the plan date. Please refer to https://www.bayparkconveyance.org/ for the information on the project. The website provides monthly updates on project progress and upcoming construction tasks.

Nassau County Septic Replacement Program:
Goals of this program are as follows:

- Install 200 innovative and alternative septic systems Countywide in 2 years
- Install 1000 innovative and alternative septic systems Countywide in 5 years
- Install 2000 innovative and alternative septic systems Countywide in 10 years

For additional information on the Nassau County Septic Program or S.E.P.T.I.C please visit the following websites:

http://www.nassaucountyny.gov/septicreplace

https://www.nassauswcd.org/S-E-P-T-I-C-Replacement-Program

Nassau County Sewers:
Projects under consideration include

- Point Lookout Sewer:
- Crescent Beach Area Sewer:
- Port Washington Sewer:
- Sea Cliff, Glen Head, Glenwood Landing, Roslyn Harbor, Greenvale Sewer:
- Attaching homes and businesses along Plandome Road in Manhasset to the Great Neck Water Pollution Control District

The timeframe for these projects is likely 10 to 15 years and dependent upon outside federal and state funding sources.

Bioextraction:
Townships and other local municipalities will be running the bioextraction projects over the next five-to-ten years. Currently the towns of Oyster Bay and Hempstead are working on this initiative. Bioextraction programs may include kelp farming, shellfish seeding, and oyster gardening.

Stormwater Nitrogen Reduction:
This task is dependent upon future funding opportunities but may include studying the feasibility of retaining storm water runoff where opportunities exist. One example may be the use of diverting additional storm water into Nassau County recharge basins and infiltrate into the groundwater system. Basins and the watershed areas would have to be reviewed in order to determine basin capacity/expansion/maintenance, etc. This program first will require a Feasibility Study. This may include multiple studies looking at multiple opportunity areas. The feasibility studies would include focus areas, technical designs and cost estimates that will evaluate storm water basin rehabilitation, diverting of stormwater into these basins, etc. When the studies are complete then budgeting of proposed improvements delineated will be accessed. The feasibility study is projected to occur in 5 to 10 years and is dependent upon federal and state funding.

Public Education Campaign Fertilizer Use:
Nassau County will work with all protection committee groups listed in Element E in evaluating the type of effective public education programs that will be most effective in meeting this specific task. Based upon funding opportunities and municipal input, the plan would explore the following possibilities:

- Public information campaign via mailers, adding nitrogen reduction information to various protection committee websites, literature handouts at festivals and fairs over two years
- Explore legislative advocacy possibilities – such as pushing for limits on nitrogen in Long Island fertilizer over five to ten years
- Fertilizer applicator trainings for landscape professionals and homeowners. A possibility may be to have the Nassau County Soil and Water Conservation District develop a program over five years
- Development of new (or updating of current) fertilizer educational materials (print) and distribution through the already established watershed groups over two-to-four years
- Development of new electronic fertilizer educational graphics and distribution through the already established watershed groups over two-to-four years

Other Public Educational Initiatives:
Other public educational initiatives might include the development of new (or updating of current) stormwater pollution educational materials (print) and distribution through the already established watershed groups, an initiative that could take two-to-four years. In addition, the development of new electronic stormwater pollution educational graphics and distribution through the already established watershed groups, an initiative that could take two-to-four years.

ELEMENT G. MILESTONES

The progress of the Nitrogen Reduction Initiatives may be measured based upon the specific Nitrogen Reduction Strategy being evaluated. It is anticipated that each initiative to be implemented will be evaluated at the two, four, five then ten-year mark from the plan date, depending upon the initiative timeframe listed within Element F of the Nine Element Plan. The plan will be reviewed after two years to assess progress as well as to evaluate and make corrections on the milestones discussed herein in the event milestones are delayed or incomplete. The milestones that will be accessed within this report are the following:

Two years from the plan date:

- Work with the soil and water conservation district in the goal of installing 200 innovative alternative septic systems.
- Inventory of public education initiatives relative to fertilizer reduction. This may be measured by the following metrics below:
  - Collaborate with the three north shore protection committees in commencing in the development of one fertilizer educational brochure.
  - Begin Collaboration with three protection committees and the Soil and Water Conservation District on how to best implement and develop a public presentation educational program specific to residential fertilizer and lawn-care practices
  - Work with four watershed groups relative to generating newsletter articles specific to fertilizer education
  - Collaborate with four protection groups in generating social media postings on their existing sites that feature a fertilizer education message.
  - Work with three protection groups on developing a new electronic stormwater pollution educational graphic.
  - Work with three protection committee groups on the development of two new storm water pollution brochures.

Five years from the plan date:

- 1000 I/A systems installed
- South Shore Conveyance Project to be fully operational by 2024.
- Distribute one new fertilizer educational brochure throughout three targeted watersheds served by three protection committees.
- Role out one new public presentation educational program specific to residential fertilizer and lawn-care practices in three targeted watersheds.
- Collaborate with two additional protection groups or organizations relative to generating newsletter articles specific to fertilizer education.
- Collaborate with two additional protection groups in generating social media postings on their existing sites that feature a fertilizer education message.
- Work with three protection committees/organizations to distribute two new storm water brochures within three targeted watersheds.

- Commence collaboration with at least one major environmental organization on drafting legislation for limits on nitrogen in fertilizer, if possible.
- Collaborate with the Towns of Oyster Bay and Hempstead on creating four bioextraction sites-two per township. Work with the two townships to develop a written metrics statement setting specific goals relative to how many feet of Kelp lines to be installed, how many pounds of Kelp produced, how many bio extraction farming locations in place, and how many acres of surface waters are used for aquaculture in a set amount of years.

Ten years from the plan date:

- 2000 I/A systems have been installed
- Point Lookout Sewer connection project to commence construction by year ten.
- Crescent Beach Area Sewer to commence construction by year ten.
- Port Washington Sewer to commence construction by year ten.
- Sea Cliff, Glen Head, Glenwood Landing, Roslyn Harbor, Greenvale Sewer projects to commence construction by year ten.
- Plandome Road commercial business/residential connection to Great Neck Water Pollution Control District.
- If possible, pass one piece of legislation for limits on nitrogen in fertilizer.
- Evaluate the Nassau County MS4 progress (annual report) relative to status of storm water nitrogen reduction initiatives and the ongoing feasibility study.

- Complete one feasibility study for storm water nitrogen reduction in Nassau County.
- Retain a consultant based upon the completed feasibility study to implement three nitrogen reduction projects in three targeted watersheds that will include planning, engineering designs, permitting, construction.

ELEMENT H. CRITERIA TO EVALUATE LOAD REDUCTIONS

The criteria set forth in this Nine Element Plan can be evaluated. The most specific quantitative criteria to be considered are the N reduction goals set in Element C. The goals that have been set forth can be compared to BMPs implemented to evaluate the extent to which goals are met.

To create this Nine Element Plan, comprehensive Nitrogen Loading Models (NLM) were constructed for dozens of subwatersheds that were subsequently aggregated for the eight major subwatersheds in Nassau County. In addition, the model was modified to consider the quantitative impact of each individual BMP for each individual subwatershed in a Nitrogen Mitigation Model (NMM). These models will be the basis by which the achievement of N loading goals are evaluated over time. As stated in Element C, the major BMPs to be implemented are the Bay Park Conveyance Project, reduction in fertilizer use, upgrading of septic systems, and the implementation of aquaculture. The completion of the Bay Park Conveyance Project will be an 'all at once' occurrence, as once the sewage is rerouted out of West Bay and into the Cedar Creek plant and out to the Atlantic Ocean, that BMP will be fully implemented. The implementation of other BMPs can be accounted for in the NLM as actions are taken, year-by-year. This will require a collaboration between Nassau County and Stony Brook University whereby Stony Brook can update models as new information is available or Stony Brook could transfer the models to Nassau County and future evaluation of load reductions could be performed by the County. This would require careful tracking of multiple factors over time. Firstly, Nassau County will need a comprehensive data set indicating, with GIS, the precise location of each septic system upgrade made in the County as well as an indication of the type of system installed. A program for monitoring I/A system performance would allow for the most precise evaluation of each system. Regarding fertilizer use, any official change in fertilizer laws in the County (time restrictions, lower N content) could be accounted for in models. Similarly, each aquaculture facility implemented in any waterbody could be accounted for in the NLM.

Evaluation of load reductions will, therefore, be dependent on careful monitoring and tracking. Nassau County will need programs to monitor progress on the installation of septic systems and the implementation of aquaculture and other bioextraction efforts. Other approaches (Bay Park Conveyance Project, changes in fertilizer laws) are 'all at once' strategies that will require a less comprehensive effort. Collectively, these efforts will assure N load reductions are quantitatively accounted for and up-to-date assessments of progress towards goals are in place.

The current tracking mechanism for the various nitrogen reduction strategies is as follows:

The Nassau County SEPTIC program will be tracked by the Nassau County Soil and Water Conservation District who administers the program as they utilize a comprehensive online database/portal system to track the number of total installations and as well as tracking at what step each individual installation application is within the application/permitting/installation process. The Bio extraction program will be tracked by the townships that administer the program. Currently the Towns of Hempstead and Oyster Bay have programs and are discussed within the plan. The County will rely on and collaborate with said towns to provide updated tracking during the two, five, and ten-year marks. Storm water nitrogen reduction strategies will be tracked and documented by Nassau County via future updates within the Nassau County Storm Water Management Program Plan and through required MS4 annual reporting.

All components related to fertilizer and public education, social media, educational brochures and trainings will be a collaborative effort with the County relying on the various environmental protection committees to track progress. This will be accomplished through the committees annual reporting process, database tracking and their respective libraries of information that they document and store either physically or electronically. The Bay Park to Cedar Creek South Shore Conveyance project is tracked online at https://www.bayparkconveyance.org/. This site provides monthly real time progress reports and provides monthly future forecasts as to what next steps and tasks will be accomplished with a scheduled timeline. All other previously discussed sewering projects will require a collaborative tracking effort between Nassau County, the local municipalities within the sewer district area and the sewer district that proposes the improvements. This tracking effort is still a work in progress and updates will be provided during the two-year plan review process.

Every two years review the progress in reducing nitrogen loads that may be made by Stony Brook University and/or Nassau County in collaboration with the NYSDEC.

ELEMENT I. MONITORING

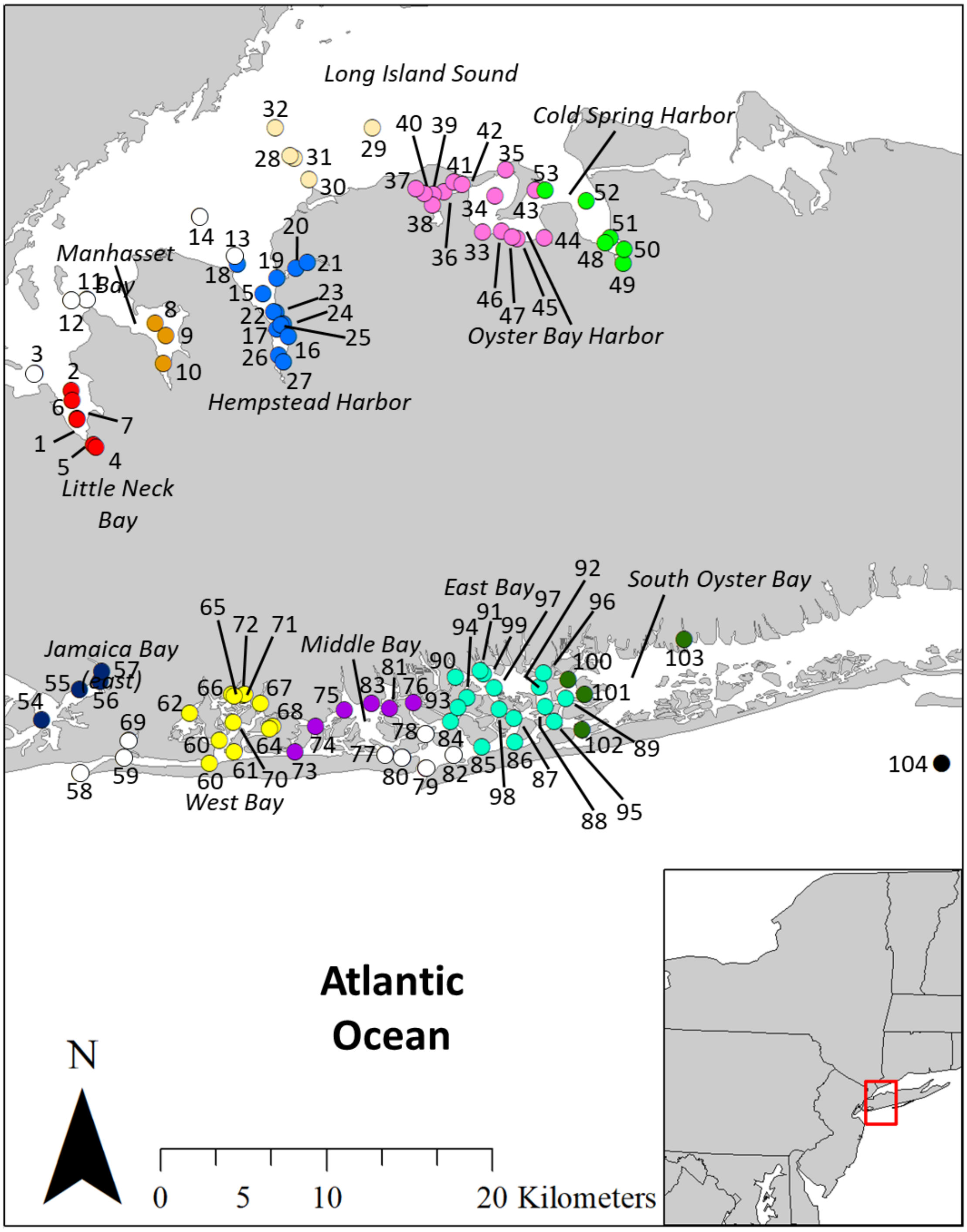
This Element describes monitoring approaches that can be used to evaluate the effectiveness of the implementation efforts in this Nine Element Plan over time, measured against the criteria established under Element H. There are multiple levels of monitoring that will be required to assess the progress and effectiveness of this Nine Element Plan. Monitoring could be performed by Nassau County or perhaps another hire to keep tabs of BMPs implemented to mitigate N loads across the County. Monitoring of progress is a critical aspect of a Nine Element Plan, as it is the only way to quantitatively assess the extent to which goals set for by the Plan have been met by specific actions taken. As was revealed in Element C, there are many BMPs that would have minimal effect on achieving N mitigation goals, whereas some BMPs will allow Nassau County to fully achieve N mitigation goals with a single action (e.g. the Bay Park Conveyance Project; new fertilizer use laws). Hence, a quantitative assessment of BMPs is needed and this is achieved via monitoring. Monitoring is also extremely important for adaptive management. While this Nine Element Plan has set forth a plan of action based on the best available data, science, and information, it is possible that future lessons learned may require re-evaluation of this plan or reconsideration of some BMPs. Such adaptive management must be based on quantitative data and can only be effectively executed with a careful monitoring program that continually evaluates and re-evaluates progress made towards goals, ideally on an annual basis.

To track progress on the installation of I/A septic systems, Nassau County will need a to create a comprehensive monitoring program. Such a program would be GIS-based and would note the precise location of each septic system upgrade made in the County and an indication of the type of system installed. An operation and maintenance program for I/A systems that included monitoring I/A system performance in terms of the total nitrogen concentration in the effluent of systems installed would allow for the most precise evaluation of each system. The estimated amount of N mitigated by the installation of each I/A septic systems could them be accounted for within the Nitrogen Mitigation Model (NMM) to assess progress toward total N mitigation goals.

A similar tracking of aquaculture would be of value for the evaluation of bioextraction as a BMP. In monitoring aquaculture organizations or bioextraction projects, multiple data streams will be of value. This would include GIS-based tracking of the location of the farms and projects and a precise evaluation of the crop / organisms extracted by each facility. Presently, bivalve farms are required by NYSDEC to report the harvest and sale of bivalves. Such information that would ideally include the species, size, and number of organisms extracted as this would allow for precise estimates of N removal by such practices. Similarly, with regard to seaweeds, tracking the total weight of seaweeds and the species of seaweeds harvested by each farm / facility / project would allow the N extracted to be estimated. The estimated amount of N bioextracted by bivalves and seaweeds could then be accounted for within the NMM to assess progress toward total N mitigation goals.

For all tracking of progress regarding the ability of implemented BMPs to achieve N reduction goals, an annual evaluation and reporting would be appropriate. Such reporting would include quantitative measures of kilograms of N mitigated and the percent reduction in N load that has been achieved for each subwatershed each year. An online tracking system for progress would be of maximal benefit and transparency for the public.

Figure I.1 Water quality monitoring sites across Nassau County. Additional sampling sites by Suffolk County and the Unified Water Study supported by Save the Sound are not represented in this map.



A second tier of monitoring to evaluate the effectiveness of BMPs as mitigation strategies would be monitoring of surface waters across Nassau County. Surface water monitoring would examine metrics responsive to N enrichment and N-limitation and could include water clarity (such as Secchi depth), total nitrogen, chlorophyll *a*, and dissolved oxygen. These parameters tend to co-vary and thus may be considered as a suite of variables and are most dynamic and responsive during summer months when waters can be high in nitrogen and chlorophyll *a,* but low in oxygen and water clarity, all of which contributes to impairment of water bodies and ecosystem services.

Surface water quality monitoring is performed by seven organizations which cover more than 100 sampling stations across Nassau County (Figure I1 above; Table I1, I2, and I3 below). The Connecticut Department of Energy and the Environment (CTDEEP) which focuses specifically on the main stem of Long Island Sound, the Gobler Laboratory of Stony Brook University's School of Marine and Atmospheric Sciences (SoMAS) which has long term monitoring stations in Cold Spring Harbor, Oyster Bay, Hempstead Harbor, West Bay, Middle Bay, and South Oyster Bay, the Town of Hempstead which has long term monitoring across West, Middle, and East Bay, the Interstate Environmental Commission run by NEIWPCC which monitors western Long Island Sound as well as Manhasset Bay and Hempstead Harbor, Suffolk County's Department of Health Services which monitors Cold Spring Harbor, Friends of the Bay which monitors Oyster Bay and Cold Spring Harbor and the Coalition to Save Hempstead Harbor which monitors Hempstead Harbor. Each of these agencies have their own quality assurance programs (QAPP). The water quality monitoring stations are shown in Figure I1. In addition, the Unified Water Study supported by Save the Sound samples stations in each of Nassau County's north shore water bodies, measuring dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature at least monthly from May through October. In the Nassau County Subwatersheds Plan, chlorophyll *a*, Secchi disc depth, and dissolved oxygen identified as parameters for which there are good long-term data from which trends and spatial differences could be resolved. In contrast, total nitrogen data was scarce and suspect.

There are several changes to monitoring that could be implemented to ensure proper monitoring of the changes in water quality over time and to ensure proper evaluation of the effects of BMPs on surface water and water body changes. Firstly, it would be ideal to unify the methods and metrics used by the seven monitoring agencies to ensure all data is comparable. This might be achieved with a unified QAPP potentially organized by Nassau County. Next beyond monitoring chlorophyll *a*, dissolved oxygen and water clarity, additional parameters to add to monitoring might include the nitrogen series (total nitrogen, total dissolved nitrogen, nitrate/nitrite, ammonium) and phytoplankton identification to assess for the presence and intensity of harmful algal blooms. Beyond water quality, benthic assessments of seagrasses and seaweeds would also have value in understanding how changes in water quality may translate into changes in benthic habitats overtime. Finally, while some bays have many monitoring sites, South Oyster Bay and Manhasset Bay have disproportionately fewer sampling sites than other water bodies. Monitoring in these locations could be expanded. Finally, real-time monitoring could also be expanded to more locations. Presently, USGS has a real-time monitoring site on Hog Island near Reynolds Channel and the Gobler Lab uses real-time monitoring of dissolved oxygen and temperature at all six of its monitoring stations in Nassau County during summer months. Expanding the network of real-time monitoring sensors would provide a more robust evaluation of water quality changes than discrete sampling alone.

Monitoring recommendations

Given the disparate entities involved in monitoring Nassau County surface waters, it is recommended that an entity is identified to organize the sampling and data sets and perhaps seek to coordinate the monitoring entities. Nassau County or Stony Brook University may be ideal organizations for this task. The review and reporting of the data will be included in the biennial review of the plan. In addition, it is recommended that total nitrogen concentrations of surface waters become a routinely monitored parameter for all monitoring programs.

Table I1. Organizations responsible for each sampling site in Figure I1.

Source	**Site**
IEC (WLIS)	8-403
IEC (WLIS)	8-405
IEC (WLIS)	A2M
NYC DEP	AC1
NYC DEP	AC2
NYC DEP	E11
NYC DEP	LN1
IEC (WLIS)	9-409
IEC (WLIS)	9-412

IEC (WLIS)	9-413
IEC (WLIS)	A3
NYCDEP	E10
IEC (WLIS)	H-C
IEC (WLIS)	H-C1
IEC (WLIS)	H-D
LIMMN	HEMP
Coalition to Save Hempstead Harbor	CSHH #1
Coalition to Save Hempstead Harbor	CSHH #2
Coalition to Save Hempstead Harbor	CSHH #3
Coalition to Save Hempstead Harbor	CSHH #8
Coalition to Save Hempstead Harbor	CSHH #13
Coalition to Save Hempstead Harbor	CSHH #14
Coalition to Save Hempstead Harbor	CSHH #15
Coalition to Save Hempstead Harbor	CSHH #4
Coalition to Save Hempstead Harbor	CSHH #5
Coalition to Save Hempstead Harbor	CSHH #6
Coalition to Save Hempstead Harbor	CSHH #7
CT DEP	B3
CT DEP	02
IEC (WLIS)	B2
IEC (WLIS)	B3M
IEC (WLIS)	B4
Friend of the Bay	FOB-10
Friend of the Bay	FOB-11
Friend of the Bay	FOB-12
Friend of the Bay	FOB-13
Friend of the Bay	FOB-14
Friend of the Bay	FOB-15
Friend of the Bay	FOB-16
Friend of the Bay	FOB-17
Friend of the Bay	FOB-18
Friend of the Bay	FOB-19
Friend of the Bay	FOB-6
Friend of the Bay	FOB-7
Friend of the Bay	FOB-8
Friend of the Bay	FOB-9
LIMMN	OBH
LIMMN	CSH
Friend of the Bay	FOB-1
Friend of the Bay	FOB-2
Friend of the Bay	FOB-3
Friend of the Bay	FOB-4
Friend of the Bay	FOB-5

NYCDEP	GHC
NYCDEP	HOB
NYCDEP	TB1
NYCDEP	TB2
Town of Hempstead	1
Town of Hempstead	2
Town of Hempstead	3
Town of Hempstead	4
Town of Hempstead	5
Town of Hempstead	6
Town of Hempstead	7
Town of Hempstead	8
Town of Hempstead	9
Town of Hempstead	10
USGS	01311143
Town of Hempstead	2A
Town of Hempstead	6A
LIMMN	HB
State Project	HB
Town of Hempstead	11
Town of Hempstead	12
Town of Hempstead	13
Town of Hempstead	14
Town of Hempstead	15
Town of Hempstead	16
Town of Hempstead	18
USGS	01310740
Town of Hempstead	13A
Town of Hempstead	18A
LIMMN	MB
Town of Hempstead	17
Town of Hempstead	19
Town of Hempstead	20
Town of Hempstead	21
Town of Hempstead	22
Town of Hempstead	23
Town of Hempstead	24
Town of Hempstead	25
Town of Hempstead	30
Town of Hempstead	31
Town of Hempstead	32
Town of Hempstead	33
Town of Hempstead	34
Town of Hempstead	146

Town of Hempstead	147
State Project	EB
Town of Hempstead	26
Town of Hempstead	27
Town of Hempstead	28
LIMMN	SOB
Suffolk County Department of Health Services	090220

Table I2. Additional testing stations by the Coalition to Save Hempstead Harbor

CSHH #9 (outfall in Glen Cove Creek, immediately west of GC STP outfall, bacteria sample only)

- CSHH #10 (outfall in Glen Cove Creek, immediately west of CSHH #9, bacteria sample only)
- CSHH #11 (in Glen Cove Creek, east of STP outfall, bacteria sample only)
- CSHH #12 (further east in Glen Cove Creek, tested for bacteria and total nitrogen)
- CSHH #14A (outfall at the end of Glenwood Rd, tested year-round for bacteria and total nitrogen)
- CSHH #15A (outfall draining Littleworth Ln in Sea Cliff and Scudder's Pond, tested year-round for bacteria and total nitrogen)
- CSHH #15B (Scudder's Pond, bacteria sample only)
- CSHH #16 (outer harbor station, vertical profile testing plus bacteria and total nitrogen)
- CSHH #17 (outer harbor station just outside the uncertified shellfishing area near Crescent Beach, vertical profile plus bacteria sample)
- CSHH #17A (close to Crescent Beach shoreline where stream enters the harbor, bacteria sample only)

Table I3. Nassau County sites sampled at least monthly, May - October by the Unified Water Study.

Station ID	Embayment	Longitude	Latitude	Parameters
LNE-I-01	Little Neck Bay, NY	-73.75791	40.77224	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature, total nitrogen, total dissolved nitrogen, total phosphorus,
LNE-I-02	Little Neck Bay, NY	-73.7608	40.7778	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
LNE-I-03	Little Neck Bay, NY	-73.75823	40.78314	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
LNE-I-04	Little Neck Bay, NY	-73.75061	40.78377	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature, total nitrogen, total dissolved nitrogen, total phosphorus,
LNE-I-05	Little Neck Bay, NY	-73.76862	40.78606	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature, total nitrogen, total dissolved nitrogen, total phosphorus,
LNE-O-06	Little Neck Bay, NY	-73.7582	40.7888	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature, total nitrogen, total dissolved nitrogen, total phosphorus,
LNE-O-07	Little Neck Bay, NY	-73.77112	40.794	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
LNE-O-08	Little Neck Bay, NY	-73.76179	40.79561	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
LNE-O-09	Little Neck Bay, NY	-73.75442	40.79884	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
LNE-O-10	Little Neck Bay, NY	-73.76992	40.80202	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature, total nitrogen, total dissolved nitrogen, total phosphorus,
LNE-I-1B-L	Little Neck Bay, NY	-73.75578	40.77757	Continuous data logging: dissolved oxygen, salinity, pressure
LNE-O-1B-l	Little Neck Bay, NY	-73.76199	40.80482	Continuous data logging: dissolved oxygen, salinity
MAN-I-01	Manhasset Bay, NY	-73.71316	40.80772	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-I-02	Manhasset Bay, NY	-73.71461	40.81244	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-I-03	Manhasset Bay, NY	-73.70714	40.81586	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-M-04	Manhasset Bay, NY	-73.71242	40.82271	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-M-05	Manhasset Bay, NY	-73.70551	40.83064	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-M-06	Manhasset Bay, NY	-73.71454	40.83228	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-M-07	Manhasset Bay, NY	-73.72375	40.82616	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-M-08	Manhasset Bay, NY	-73.72564	40.83644	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-O-09	Manhasset Bay, NY	-73.73613	40.83179	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-O-10	Manhasset Bay, NY	-73.73672	40.84517	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MAN-O-11	Manhasset Bay, NY	-73.74556	40.84097	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-I-01	Cold Spring Harbor, N	-73.46501	40.8625	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-I-02	Cold Spring Harbor, N	-73.46333	40.86667	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-I-03	Cold Spring Harbor, N	-73.46605	40.86898	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-O-04	Cold Spring Harbor, N	-73.47908	40.8796	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-O-05	Cold Spring Harbor, N	-73.48873	40.89025	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-O-06	Cold Spring Harbor, N	-73.48468	40.90344	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
COL-O-07	Cold Spring Harbor, N	-73.50969	40.91512	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MNC-01	Mill Neck Creek, NY	-73.5675	40.89888	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MNC-02	Mill Neck Creek, NY	-73.55809	40.90138	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
MNC-03	Mill Neck Creek, NY	-73.55167	40.90333	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
OYB-01	Oyster Bay, NY	-73.53963	40.89789	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
OYB-02	Oyster Bay, NY	-73.52878	40.91181	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
OYB-03	Oyster Bay, NY	-73.53113	40.88073	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
OYB-04	Oyster Bay, NY	-73.51553	40.89036	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-M-01	Hempstead Harbor, N	-73.65353	40.83189	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-M-02	Hempstead Harbor, N	-73.65854	40.84172	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-M-03	Hempstead Harbor, N	-73.65216	40.85365	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-O-04	Hempstead Harbor, N	-73.67396	40.86077	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-O-05	Hempstead Harbor, N	-73.67493	40.87349	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature
HEM-O-06	Hempstead Harbor, N	-73.65016	40.88365	Dissolved oxygen, chlorophyll-a, turbidity, salinity, temperature

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QUALITY ASSURANCE PROJECT PLAN
for

NASSAU COUNTY NITROGEN LOADING MODEL (NLM)

Nassau County, NY

Prepared for:
New York State
Department of Environmental Conservation
Albany, NY 12231

Prepared by:
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MOU#: AM11838

May 2021

PROJECT MANAGEMENT

Approval Sheet

Chris Gobler – Lead Investigator **Stony Brook University**	**Date**
	25 May 2021
Ryan Anderson – Project Manager **Woods Hole Oceanographic Institution**	**Date**
Craig S Young	26 May 2021
Craig S. Young – Project Quality Assurance Officer **Stony Brook University**	**Date**
Michele Golden	May 24, 2021
Michele Golden – DEC Project Officer **NYSDEC**	**Date**
	24 May 2021
Lewis McCaffrey – DEC Assistant QA Officer **NYSDEC**	**Date**

Project QAPP Update Log

Prepared/Revised By:	**Date:**	**Revision No:**	**Summary of Changes:**
Ryan Anderson	03/28/2021	4.1	New subwatershed boundaries, added MS4 runoff to modeling.
Anderson, Gobler	4/17/2021	4.2	Expanded organization responsibility section, addressed comments
Gobler	5/21/2021	4.3	Added abstract, budget, time table

'No substantive changes' may be listed to reflect updating of references, correcting typographical errors, and clarifying certain language to make the document more useful and effective.

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ABSTRACT:

Excessive nitrogen loading from land to sea has been shown to cause a multitude of water quality impairments in Nassau County, NY's, surface waters including the stimulation of harmful algal blooms, low dissolved oxygen concentrations, and poor water clarity as well as the loss of critical marine habitats such as seagrasses and salt marshes. The Long Island Nitrogen Action Plan was implemented by NYSDEC to address excessive nitrogen loading into Long Island's coastal waters. In 2020, the Nassau County Subwatersheds study was completed by the Gobler Laboratory of Stony Brook University on behalf of NYSDEC. That study used the Nitrogen Loading Model (NLM) to identify the rates and sources of nitrogen loading from 11 subwatersheds across Nassau County into surface waters. The study specifically identified nitrogen loading from onsite septic systems as the largest nitrogen source on the north shore of Nassau County and the Bay Park sewage treatment plant as the largest source on the south shore and identified the reductions in nitrogen loading required to improve water quality across the County. For this study, the Gobler Laboratory will update the Nitrogen Loading Model for surface waters across Nassau County, NY, using updated watersheds from the USGS and the most up-to-date watershed information available. Thereafter, a GIS-based parcel scale analysis will be conducted to determine best wastewater management for each parcel across Nassau County, NY. This information will be used in parallel with the consideration of larger scale management actions to identify the management actions needed to reduce nitrogen loading from each of the newly aggregated USGS subwatershed to improve water quality. All scenarios will be run through NLM to access the efficacy of each approach. These models run will be shared with Nassau County to support the development of their Nine Element Plan.

1. PROJECT DESCRIPTION

1.1. Background

Many efforts are underway to improve understanding of water quality impacts to the ecology of surface water across New York State. To advance water quality management measures, including possible preparation of total maximum daily load plans that would set maximum pollutant levels a water body can receive and still meet water quality standards, adequate information must be generated regarding nitrogen (N) loads to these systems. Since nitrogen limits primary production in many coastal marine environments (Nixon, 1995; Borum, 1996), it is often the delivery rate of N that influences the prevalence of algal blooms, hypoxia and the loss of seagrass beds (Bricker et al., 2008). Nitrogen overload causes eutrophication, in which phytoplankton populations that are normally kept in check by periodic nutrient limitation and grazing become dense and pervasive (Nixon, 1995). Such algal blooms can attenuate light penetration through the water column, decreasing the depth at which benthic phototrophs, such as seagrasses, can survive (Waycott et al., 2009). Additionally, oxygen concentrations sharply decrease beneath the surface of the water due to the respiration and decomposition of the sinking organic matter. In this way eutrophication often leads to hypoxia (very low levels of oxygen) or anoxia (zero oxygen), which can be deleterious to fish and benthic communities (Diaz and Rosenberg, 2008). Harmful algal blooms (HABs) are an additional environmental problem initiated by nutrient overload. HABs have increased in their geographic extent, duration and species variety over the past several decades (Hallegraeff, 1993; Heisler et al., 2008; Anderson et al., 2021). There is a strong correlation between increased nitrogen in coastal waters and the presence and prevalence of HABs (Heisler et al., 2008). HABs have become a yearly occurrence in Nassau County waterbodies. In New York's marine waters, links have been made between excessive nitrogen loading and harmful algal blooms (Hattenrath et al., 2010; Gobler et al., 2011, 2012; Hattenrath-Lehmann et al., 2015), the loss of eelgrass (Wall et al., 2008), hypoxia (Swanson et al., 2010), and inhibition of shellfish performance (Weiss et al., 2007; Wall et al., 2013).

In light of the prevalence of hypoxia and harmful algal blooms in Nassau County surface waters, and the perceived role of nitrogen loading in exacerbating these conditions, the rates and sources of nitrogen loads to Nassau County's surface waters should be quantified to better understand nitrogen's role and its sources. This knowledge gap prohibits formulation and evaluation of management plans to effectively ameliorate nitrogen loads to these systems. Given the very large costs associated with such efforts, it is important to precisely quantify the relative contribution of all major sources of nitrogen to Nassau County's surface waters to ensure that expenditures made for these efforts are cost-effective. Quantifying current nitrogen loads entering Nassau County's surface waters, as well as quantifying how those loads will change under differing nitrogen mitigation and land development scenarios, will be a vital tool for proper management of these systems. For this project, data regarding nitrogen loads to the Nassau

County's surface waters will be generated and interpreted to provide an informed description of the locations and causes of water quality impairments.

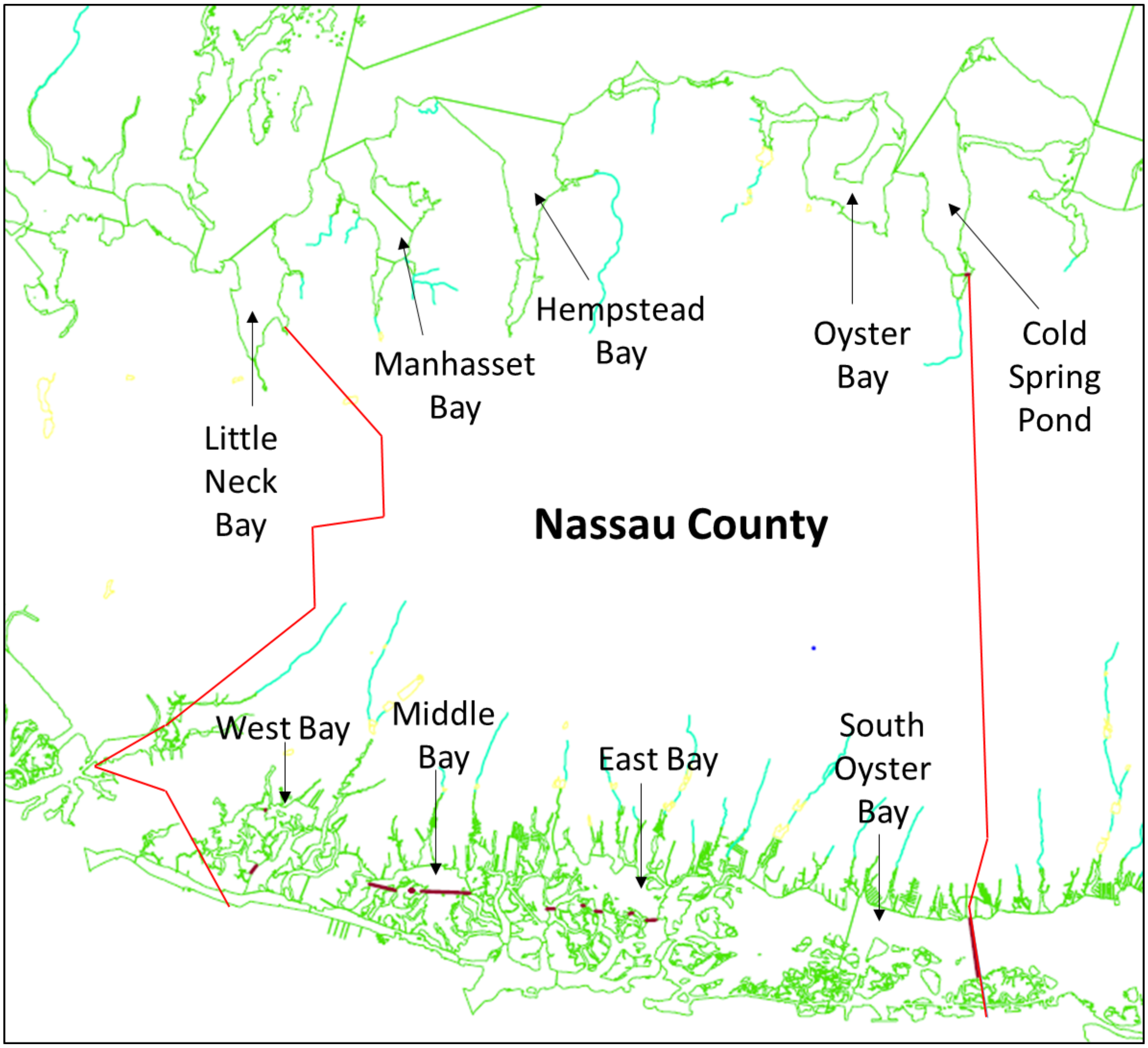


Figure 1. Priority Water List estuaries in Nassau County, New York.

1.2. Project Objectives

1. Update the Nitrogen Loading Model for surface waters across Nassau County, NY
2. GIS parcel scale analysis to determine best wastewater management per parcel for Nassau County, NY
3. Identify the appropriate management scenarios for the reduction of nitrogen from each of the newly aggregated subwatersheds.
4. Run the selected management scenarios through NLM.

2. ORGANIZATION AND RESPONSIBILITIES

Project planning will be coordinated between the participates listed below (2.1) and the data users, Nassau County and NYSDEC.

2.1. Participants

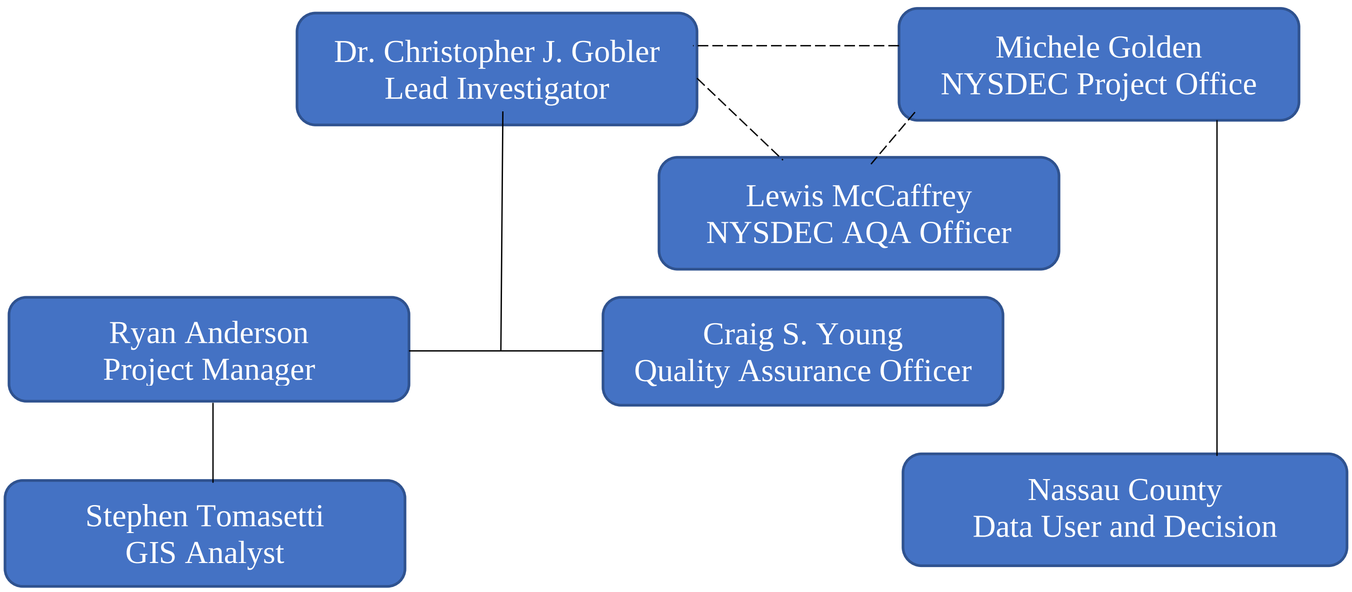
Name	Organization	Task
Dr. Christopher J. Gobler	Stony Brook University	Lead Investigator: Oversee all aspects of this project including secondary data collection and model results, scheduling and co-authoring reports
Ryan Anderson, M.S.	Woods Hole Oceanographic Institution	Project Manager: Research secondary data, run models, create maps figures and co-authoring reports.
Craig S. Young, M.S.	Stony Brook University	Quality Assurance Officer: Meets regularly with Lead Investigator and Project Manager to determine if project is following QAPP.
Stephen Tomasetti, M.S.	Stony Brook University	GIS Analyst: Providing GIS data for watershed determination, land use information and analysis for this project
Dr. Lewis McCaffrey PG,	NYSDEC	Assistant Quality Assurance Officer: Provides the quality assurance approval for NYSDEC.
Michele Golden	NYSDEC	NYSDEC Project Office: Oversees the project to ensure it meets the required objectives.

2.2 Data Users

Organization	Use
Nassau County	Will use model results to inform nitrogen reduction planning and implementation
NYSDEC	Will receive final data reports and model.

2.3 Hierarchy of Organization

Performance and system audits will be conducted by the Lead Investigator and Project Manager to ensure the modeling efforts and analysis are being performed properly. Work will be suspended if an issue is detected. The issue will be addressed before work continues within one month of its detection. Issues detected by other participates will immediately report the issues to the Lead Investigator and Project Manager.



2.4 Special Training Requirements

Specific training on model use and geographical analysis techniques will not be conducted for this study. Analysts, which includes the Project Manager and GIS Analyst have already been trained in previous nitrogen loading model studies for other study regions. Both are professionals in the data science industry and specialize in marine modeling. Their training originates in both academic graduate setting and through their experience from other studies. Health and safety guidelines for office work provided by Stony Brook University will be followed.

3. DOCUMENTS AND RECORDS

The study's analysis will not begin until the QAPP has been completed and approved.

3.1. Document Control

Version control of this QAPP will be maintained by indicating the version, date, and distribution list on the cover page, and for the QAPP, in the table of contents header. The Final QAPP will be identified as "Final", dated and distributed to all on the distribution list. If the Final QAPP is subsequently revised, the header will identify the document revision number. Changes in project scope, approach or data usage will be identified to the NYSDEC. Major changes prompting

QAPP revision and distribution would include changes such as use of a different model and documentation regarding the model. Changes prompting an addendum to the QAPP might include replacement of a key team member such as the NYSDEC or Nassau County. Changes that could be documented in the task-specific deliverable could include addition of data from a yet unidentified source of data or modification of sensitivity criteria. All signatories of this QAPP will be notified by e-mail if modifications of this QAPP are required due to unforeseen circumstances. Modifications to the QAPP will be noted in any updated versions of the QAPP which will be maintained by the Lead Investigator. Upon completion of each task, the results will be documented in quarterly progress report. Both paper and electronic copies of data, model outputs, calculations, GIS mappings and task documentation will be stored.

3.1.1. Software and Hardware Requirements

Data manipulation software to be used for this portion of the project includes commercially and publicly available packages, such as Microsoft Office 365 (specifically Word, Excel, Access, and PowerPoint), ArcGIS Pro 2.6.3, SigmaPlot 14.5 and SigmaStat 4.0. Hardware will consist of personal computers.

3.1.2. Products of Research

Upon analysis, all data will be entered into a master spreadsheet as well as individual files for each parameter measured (described below).

3.1.3. Data Storage and Preservation

New data discovery will be noted in dated logbooks, and model inputs will be organized in tables and saved as dated Microsoft Office documents. References will be kept current throughout research and analysis. Model results will be saved in dated Microsoft Excel documents. All electronic documents should be electronically accessible at all times and will be kept in a clearly labeled computer folder. All project data will be transferred to electronic format daily. Project data sets will be saved daily to cloud-based servers as well as on redundant, physical hard drives in the labs of the Lead Investigator, minimizing the possibility to data loss. As we have done in past, all data will be maintained in standard formats (Excel, Access) and will be made publicly available to inquiring individuals for modeling or compiling metadata. In addition, we will have physical printouts and laboratory notebooks as backups that will be maintained throughout the study and will be stored for at least 10 years. Upon completion of the project all electronic data will be saved on CDs. Long-term storage of hard copy material, final reports, and lab notebooks will be kept for future access by Christopher Gobler for at least 10 years.

3.1.4. Data Formats and Metadata

We will document our metadata by taking careful notes in a Microsoft Word Document regarding the specifics of data collection, data processing, and abbreviations used for modeling. This word document will be converted to PDF and included in the final project deliverables.

3.1.5. Data Dissemination and Policies for Data Sharing and Public Access

The data will be made available to other investigators after its approved use by the authors and NYSDEC.

3.1.6. Roles and Responsibilities

The Quality Assurance Officer will head the implementation and monitoring of the data management plan procedures.

3.1.7. QAPP Maintenance

The Lead Investigator will keep the official copy of the QAPP at Stony Brook University and will perform distribution and maintenance of the QAPP. Drafts and updates will be written in conjunction with the Project Manager and QA Officer. Updating the QAPP necessitates a change in version number of the QAPP and redistribution will occur upon noteworthy changes.

4. SCIENTIFIC APPROACH

4.1 Watershed/Subwatershed Delineation

The surface extents of the 26 watersheds in the study area were obtained from the U.S. Geological Survey regional MODFLOW-NWT model and MODPATH model of 2021. Watersheds that extended beyond the boarder of Nassau county were clipped to the county boundary excluding Cold Spring Harbor which was split into Nassau and Suffolk county contributions.

Nassau County Subwatersheds
Figure 2
Nitrogen Loading Project
Source: USGS 2021
Nassau County, New York

4.2. Nitrogen Loading Model (NLM)

The model that will be used to predict nitrogen load is the NLM (Valiela et al., 1997) available through the N load web-based modeling tool (nload.mbl.edu), described in Bowen et al. (2007) and used in Kinney and Valiela (2011), among others. NLM has been used extensively by the US EPA in the Northeast US (Latimer and Charpentier, 2010) and altered significantly for use by NYSDEC Long Island Nitrogen Action plans study of nitrogen loading to Suffolk County subwaterheds by the consultants, CDM. The NLM uses information about land use in a defined watershed to predict both the amount of nitrogen that is released into the watershed from various sources and how much of it ends up in a corresponding bay. This model requires accurate local land-use information, such as delineations of agriculture, residential, and impervious surfaces as well as other environmental data gathered from Long Island-based scientific literature via the Suffolk County subwatersheds study as well as from NYSDEC, NYS GIS portal, and Nassau County.

NLM assumes that the transport mechanism for nitrogen entering the bay from the watershed is primarily ground water. This is a good assumption for coastal regions of Nassau County as geologically, Long Island is composed of unconsolidated sands that allow for relatively easy transport of groundwater to coastal zones (Kinney and Valiela, 2011; Gobler and Stinnette, 2016). The NLM breaks down the nitrogen input into three sources: atmospheric deposition, waste water and fertilizer. Valiela et al. (2000) validated this model by comparing its nitrogen load prediction to empirically measured nitrogen levels. They found NLM's results to be statistically indistinguishable from measured concentrations and found a linear relationship between the percent contribution from wastewater that NLM predicted and the stable isotope signature for waste water expected from known values of $\delta^{15}N$ of nitrate in ground water. Additionally, the Gobler lab has measured $\delta^{15}N$ values from *Ulva lactuca* (Sea lettuce) and stream water found in the bays or watershed that we can compare to the NLM's percent contributions from wastewater and fertilizer, affirming the ability of NLM to identify N sources (Stinnette, 2014).

4.3. Atmospheric Deposition

Atmospheric nitrogen is delivered via precipitation (wet) or via dust (dry). Nitrogen that arrives in the watersheds through wet and dry deposition may have a varied contribution to waterbody nitrogen load depending on where the nitrogen lands. Different land use types (impervious, vegetation, developed) alter the amount of nitrogen that makes it to the waterbody. Nitrogen landing on vegetation has time to be assimilated by plants and organisms in the soils, and/or may be denitrified in the aquifer. Nitrogen that lands on impervious surfaces can runoff directly into a stream, or bay, skipping assimilation. It may also flow through a municipal separate stormwater sewer system (MS4) where it eventually seeps into sandy soils and discharges into coastal zones or it discharges directly to waterbodies. Runoff from impervious areas draining to MS4 systems that directly discharge to streams and waterbodies do not have any attenuation. In general, when atmospherically deposited nitrogen lands on impervious surfaces, significantly less is removed before entering the waterbodies. MS4 sewersheds were obtained from Nassau County to model N load runoff separately for atmospheric deposition. This includes outfall locations, the collection boundaries, and areas that collect to sumps.

Runoff from roofs drain to turf and sewer systems. The portion of roof runoff draining to turf is attenuated because it first passes through the turf and then into the sandy soils. The remaining portion of roof runoff and all other runoff from impervious surfaces will not have this turf attenuation factor since it drains directly to sewer systems. All atmospheric deposition also goes through denitrification in the aquifer. The atmospheric deposition of nitrogen is decreasing on Long Island and the Northeast in general, a trend expected to continue due to changes in industrial atmospheric discharge in the Midwest (Stinnette, 2014).

Impervious land areas will be estimated by finding where the Normalized Difference Vegetation Index (NDVI) is low (NDVI<90). The NDVI was created from the USGS's high resolution orthoimagery. Parcels that are known by land type to not have any impervious surfaces will be removed to improve the accuracy. The removal will include the classes open water, vacant land, preserved/forested land, and agricultural land. Road area will be estimated by expanding road line data into polygons obtained from the US Census Bureau. Lines for primary road, secondary roads, local roads, and ramps will be expanded to a width of 12.5m, 10m, 5m, and 5m, respectively. Areas of the polygons will then be calculated and summed for each watershed. Residential impervious areas will then be estimated by limiting the impervious layer to residential parcels.

All other atmospheric deposition calculations based on land use areas will be derivatives of the above processes or taken from source data. Agriculture area will be obtained from Nassau county parcel data. Ponds and Wetland areas will be obtained from the USGS National Hydrography Dataset. Any area that is not included in the above categories will be considered natural vegetation. Each one of these categories will have appropriate attenuation factors applied (Table 1) (Kinney and Valiela 2011).

4.4. Wastewater

The contribution of nitrogen load to the bays from wastewater treatment plants was added directly to the model based on measurements of nitrogen output from the plants. Loads were assigned to the various watersheds based on the treatment plant outfall locations. The loads were not attenuated and were directly added to the total nitrogen load for the corresponding watershed.

For parcels that were not connected to the sewer system nitrogen output was calculated by multiplying the nitrogen released per person by the number of occupants in the watershed. The number of occupants for each parcel was determined from census tracts and parcel land use class. The total count of individuals for each census tract was divided up among the residential parcels. The various types of residential parcels (one family, two family, apartment) were weighted accordingly. With each parcel assigned a number of occupants, parcels that were connected to sewer systems were removed. Then the total number of occupants in each watershed outside and within 200m of the water was tallied.

Differing levels of nitrogen were then removed from private sewer loading depending upon the type of on-site sewage disposal system (septic or cesspool) and the system's distance from shore as there is significantly less nitrogen removed when septic tanks and cesspools are within 200m of coastal waters. Residential parcels have either an individual septic tank system or cesspool, which differ slightly in the fraction of nitrogen released to the underlying aquifer, with the less effective cesspools releasing more. For this study, half of the residential users were assumed to have cesspools.

The NLM breaks down the nitrogen removal in septic tank and cesspool-based systems into four steps: removal in the tank, removal in leach fields, and removal in septic plumes. Cesspools on Long Island are typically composed of cylinders arranged vertically, eliminating any traditional leach field and the associated nitrogen removal therein. Although there is a disposal pit associated with these vertically structured cesspools systems, only a small amount of nitrogen is removed in this part of the system (<10%).

4.5. Fertilizer

The NLM considers fertilizer input from agricultural uses, golf course turfs, parks and athletic field turfs, and manicured residential turfs. Turf areas were determined using high resolution orthoimagery and LiDAR data. Using ArcGIS processes, turf areas are found by limiting high NDVI areas (NDVI>80) to areas where the LiDAR height layer is near zero (height<0.1m). The height of objects on properties (trees, buildings, decks, etc.) will be determined by subtracting a Digital Elevation Model from a Digital Surface Model. These turf areas will then be further subdivided to residential, golf courses, and parks using Nassau county parcel data. Nitrogen contribution from fertilized agricultural land will be calculated based on agricultural land area extracted from the Nassau County parcel data.

Details of the data sources used for the NLM appear below in Table 1 and include low level layers like parcel data, aerial imagery, and census data. Equivalent data sources that were used for NYSDEC Nitrogen Action Plan's nitrogen loading study of Suffolk County's subwatersheds will be used for this study.

Table 1. Data Sources for the Nassau County NLM

Model attribute	Source	Value
Watershed area	USGS	Varied per subwatershed
Area of wetlands (freshwater)	Nassau County	Varied per subwatershed
Area of agriculture	Nassau County parcel dataset	Varied per subwatershed
Area of golf course lawn	Nassau County, Lawn Dataset (see residential lawns)	Varied per subwatershed
Area of parks and athletic fields (fertilized)	Nassau County parcel dataset, Lawn Dataset (see residential lawns)	Varied per subwatershed
Impervious surfaces total	Low NDVI created from USGS High Resolution Orthoimagery, open water areas removed.	Varied per subwatershed
Area of freshwater ponds	USGS National Hydrography Dataset	Varied per subwatershed
Waste Water Treatment Plants N Output	NYSDEC	Varied per subwatershed
Total Occupancy >200m of shore not on sewers	2010 census + Nassau county parcel dataset	Varied per subwatershed
Total Occupancy <200m of shore not on sewers	2010 census + Nassau county parcel dataset	Varied per subwatershed
Percent of buildings with cesspools	As per Suffolk County subwatershed consensus	50%
Area of residential lawns	High NDVI (USGS HRO), limited to residential parcels, limited to areas where LiDAR height data was near zero. (USGS LiDAR)	Varied per subwatershed
Percent of parcels with fertilized lawns	The Nature Conservancy, Cold Spring Harbor Office	60%
Area of roof per building	NYS GIS portal	Varied per subwatershed

Model attribute	Source	Value
Area of driveway per building	NYS GIS portal	Varied per subwatershed
Area of road	NYSDEC	Varied per subwatershed
Nitrogen inputs from wet and dry deposition	As per Suffolk County subwatershed consensus	0.04lb-N per 1,000sq ft per yr
Forest N leaching	As per Suffolk County subwatershed consensus	25%
Agriculture N leaching	As per Suffolk County subwatershed consensus	40%
Turf N leaching	As per Suffolk County subwatershed consensus	30%
Recharge from impervious surfaces as percent of precipitation	As per Suffolk County subwatershed consensus	50%
N released per person per year	As per Suffolk County subwatershed consensus	10 lbs N
Water use	As per NYSDEC sources	
Percent of N inputs released from septic tanks	As per Suffolk County subwatershed consensus	94%
Leaching ring effluent and plume	As per Suffolk County subwatershed consensus	90%
Fertilizer applied to lawns	As per Suffolk County subwatershed consensus	2.04lb-N per 1,000sq ft per yr
Fertilizer applied to golf courses	As per Suffolk County subwatershed consensus	3.89lb-N per 1,000sq ft per yr
Fertilizer applied to parks and athletic fields	As per Suffolk County subwatershed consensus	0.92b-N per 1,000sq ft per yr
Gaseous loss of fertilizer	As per Suffolk County subwatershed consensus	70% for residential & parks; 80% for Golf

Model attribute	Source	Value
Fertilizer application to agriculture	As per Suffolk County subwatershed consensus	0.46 - 5.742b-N per 1,000sq ft per yr
Denitrification in aquifer	As per Suffolk County subwatershed consensus	0% on south shore, 15% on North shore

5. DATA GENERATION AND ACQUISITION

5.1. Quality Requirements of Secondary Data

The quality of secondary data will determine its suitability for use in this study. All secondary data will come from government organizations or peer review publications that have already gone through a rigorous quality assessment. Data will not be re-analyzed if it is already from a peer review publication data source. Data sources like parcel data are performed by the US Census and we cannot perform an accuracy assessment to the level the US Census does or any of these other data sources have provided. The most important quality criterion is the quality and relevance of the data. The requisite level of quality is typically expressed in terms of accuracy, precision, representativeness, comparability, and completeness. The basic acceptance criteria below are proposed for data to be of sufficient quality for this project. The criteria will be based on its use in that some uses (e.g., modeling) may require more accuracy than others (e.g., water quality trends). Certain regulatory uses of data may require absolute compliance with quality standards; for instance, the New York State Department of Health (NYSDOH) oversees an Environmental Laboratory Accreditation Program (ELAP) that ensures that results for specific parameters are produced in accordance with acceptable methods. ELAP-compliant data will be noted so that they can be segregated for exclusive use if required by regulatory agencies. Overall, the project’s objectives are to maximize accuracy, precision, sensitivity, representativeness, completeness, and comparability.

5.1.1. Accuracy and Precision

The accuracy and precision of secondary data published with references to its accuracy or precision (e.g., available through publicly accessible databases or peer-reviewed literature) will be assumed to be acceptable if they meet the data quality standards of this study and will not be further verified. If data are unpublished, we will then seek information from the source regarding the quality assurance and control procedures applied to data collection and review (e.g., were data collected under an appropriate QAPP or Quality Management Program (QMP)? If so, were the objectives of that study applicable? Were instruments calibrated and QC sample results acceptable? Were data validated? Data must be traceable, validated, and clearly documented to be used for this project. Statistical outliers will be q-tested and pruned from data sets if their accuracy and precision are not documented. Data not meeting standards will not be used. Data that meets standards, but are less than ideal in other ways will be documented and footnoted within data files.

The sources of data will be evaluated for both spatial and temporal accuracy. Given the project relies entirely on secondary data, every effort is made to utilize data from the region of study. When that is not available, data will be sourced from other regions that are comparable based on the input parameter. For example, for “percent recharge to the aquifer” we would use data from a region that has comparable topography; for “water use” we would use data from a region with comparable population and density. The more recent data will always be used for data that is changing over time. For example, atmospheric deposition of nitrogen is decreasing on Long Island and nitrogen concentrations are increasing in some groundwater wells with time. While data regarding these parameters dates to decades ago, only data from the last several years will be used for these two items in order to model current, not prior, conditions. Where possible, data can be corroborated using a secondary source. For example, the models requires an input for the percentage of precipitation that recharges the aquifer. The NLM gives a value for this field based on the metadata analysis conducted by Valiela et al. (1997). Steenhuis et al. (1985) concluded that the best way to get the recharge value was to take 75-90% of precipitation from October to May. That the value provided by NLM falls within the 75-90% indicated by Steenhuis et al. (1985) supports the precision of the data (Gobler and Stinette, 2016). Several other model inputs are supported by more than one source or an average of values found in multiple sources. Similarly, consensus values will be evaluated regarding atmospheric deposition (Paerl, 1993; Hu et al., 1998; Bowen and Valiela, 2001; Kinney and Valiela, 2011) and percentage of imperviousness for a given land use (Arnold and Gibbons, 1996; Center for Watershed Protection, 2002; Hoffman and Canace, 2002; Kellogg et al., 1997; Mass. GIS, 2003).

Criteria: Data were collected in accordance with an acceptable QA/QC documentation process, such as a QAPP or QMP. If “yes” then data will be used with caution; if “no” or “unable to be determined”, then data will undergo a Data Usability Assessment.

5.1.2. Bias/representativeness

Data must have documented spatial and temporal use characteristics. Spatial metadata must define northing and easting with sufficient accuracy to place the data into specific segments of the bays. Spatial metadata should also document the vertical position of samples in the water column or sediment. Temporal metadata must describe the year and month of samples. Day and time of day will be helpful but not required. Where necessary, we will use multiple data sets independently to assess if single data sets are biased.

Criteria: Data were collected with documented spatial and temporal information. If “yes,” data are usable; if “no” or “unknown,” data are not usable.

5.1.3. Completeness

The study seeks to use data that represent the preponderance of information available. A sufficient, representative amount of data is needed to estimate nutrient loadings. Completeness constraints include availability of critical parameters and geographical and temporal coverage. To ensure that no major data sets are overlooked, a literature search for other relevant data sets will be performed using relevant search words as time and budget allow. Data sets that are entirely missing key information, such as units, will be considered unusable. The data set will be considered complete if all model inputs have been supplied using the most locally relevant information from scientific literature, governmental data, or empirical measurements. The goal for this study is 100% completeness.

5.1.4. Comparability

For data to be comparable, they need to have been produced by sampling and analytical methods that have similar sensitivity, bias, and scale. The NYSDOH ELAP certifications are an example of adherence to standards and methods, which, if followed, produce comparable data. Other federal sampling programs offer methods that have been recognized as achieving a common standard, for example, the USEPA methods. Wherever possible we will identify whether secondary data were produced by any of these recognized methods. However, we will not make any attempt to validate or verify the extent of method compliance achieved. Reported data will be used at face values (e.g., we will make no assumptions that non-reported data imply undetected values). Detection limits should be reported if a parameter is reported as not detected. Sample handling or analytical performance metrics will not be investigated. Where available, we will use qualifier flags. Reporting limits will be compared to regulatory thresholds and among the data sources. Data will be deemed not usable if the reporting limits are too high, resulting in non-detects at environmentally significant concentrations or if they are much higher than other datasets making them unusable for creating an overall portrait of estuarine and nitrogen loading conditions. Data may be reported in various conventions, depending on the source of the data. Wherever possible, data will be converted to the same units. If units are unavailable from the source entirely, then data will be rejected from use. Data sources with inconsistent documentation of units will not be used. When dealing with data from multiple sources to populate a common field parameter, the units and methods used to obtain that data will be determined and data will be combined and used in unison only if the data is standardized and comparable.

This study is comparable to other studies that use the same modeling techniques and represent similar geographical landscapes. Our project has comparability built-in, as we will utilize two different approaches to assess nitrogen loads to the water bodies of interest. For example, the NLM is best suited to watersheds that are a mix of residential, forested and agricultural lands, where groundwater flow is the primary freshwater input to the estuary (Valiela et al., 2000).

Comparability will also be maintained by being cognizant of methods used and results obtained by earlier studies and following documented standard methods foranalysis. Of greatest relevance will be studies that have examined nitrogen loading rates to the South Shore Estuary Reserve (Kinney and Valiela, 2011, Monti and Scorca, 2003; Gobler and Stinette, 2016), Long Island Sound (Georgas et al., 2009).

Criteria: Data comparability will be based on whether they were produced with similar methods, documented units and compatible reporting limits. Similar methods are the most important criteria to ensure the range of values reported are comparable. If analytical methods are known and similar, then all data will be treated as comparable. If methods are not known, then this increase in uncertainty will be noted and data distributions will be examined qualitatively to determine comparability. If a data set has an anomalous distribution relative to others, and if no further metadata information is readily available, then it will not be employed in the study. Data comparability will be optimal if reporting and detection limits are known and similar. Unknown reporting and detection limits will be documented as another source of potential uncertainty. Reporting limits known to be dissimilar will be noted and may, or may not, be used depending on the data sets' contribution to spatial and temporal coverage.

5.2. Quality Procedure

Bi-weekly meetings will be held with the Quality Assurance Manager. He will assess data and, if necessary, determine a need for re-sampling or a corroborative source. Scientists familiar with nutrient loading and coastal biochemistry will also read all proposals and reports. The Quality Assurance Manager and readers should follow this QAPP for guidance and should ask for further justification for using a particular secondary source as needed.

5.2.1. Validation and Verification Methods

Data validation and verification will occur at multiple stages of this study in order to ensure that the existing data are relevant and suitable for use. Individuals responsible for leading data collection efforts within each topic will review candidate data according to the criteria defined above. For example, data sets that describe ambient water quality levels over time, or long-term hydrographic records will be screened for statistical outliers based on the range of values reported within the data sets (e.g., Q-test or other methods depending on data set characteristics). Assessments will be performed as early as possible to avoid loading data into the database if it is not of adequate quality. Any data deemed unfit for inclusion will be deleted and the reason for exclusion will be documented. All reports will be reviewed for technical content and accuracy. During this review any results included in the final report will be assessed vs. the data to ensure that statistics and summaries are accurately described and depicted. This review will also validate the report contents against the work assignment to ensure that the scope and content of the report achieve the project goals.

5.3 Data Management

Data workflow will be monitored using the following checklist to track each essential step has been accomplished for each secondary data source.

Model attribute	Data Quality Assessed	Data Delivered	Data Long Term Stored
Watersheds			
wetlands (freshwater)			
agriculture			
golf course lawn			
parks and athletic fields (fertilized)			
Impervious surfaces			
freshwater ponds			
Waste Water Treatment Plants N Output			
Total Occupancy >200m of shore not on sewers			
Total Occupancy <200m of shore not on sewers			
residential lawns			
roofs			
driveways			
roads			

6. DATA ANALYSIS AND EVALUATION

6.1. Sensitivity Analyses

Model runs will be performed using mean values for model input. In cases where a range of realistic values are available, this range will also be utilized, and the output of the model will be determined to assess how variability in each input parameter impacts the output of the model. As such, a ratio of the relative standard deviations of data inputs and model outputs can be generated and the most sensitive of the input parameters will be identified. Parameters showing the largest sensitivities will be noted and these data sets will be provided an additional level of scrutiny as detailed above and below to assure model accuracy. Nitrogen loads from the NLM cannot be verified with actual groundwater data as the NLM model is based on data from 2021 and groundwater travel times are decadal. In 2016, the Gobler Laboratory completed a report for NYSDOS "Long Island South Shore Estuary Reserve Eastern Bays Project: Nitrogen Loading, Sources, and Management Options" (Gobler and Stinette, 2016) which used NLM and a second nitrogen loading model called the 'Volumetric flux model' which ascribed nitrogen loads based on volumes of water (rain, groundwater, streams) and measured levels of nitrogen in the various source waters. Overall, the two models produced similar nitrogen loading results for each subwatershed with differences between the models varying by 3 – 38%. There was a highly significant correlation between the amount of nitrogen predicted across the subwatersheds via the two models ($p<0.001$) and neither model was consistently lower or higher than the other.

6.2. Model Output Evaluation

Once the nitrogen load is calculated for each subwatershed the values can be compared, providing an initial sense of the models' accuracy. The nitrogen yield from a subwatershed can be calculated by dividing the nitrogen load by the area of the subwatershed yielding a load per hectare, for example. Such yields can be used to assess which areas of total watershed contribute the most nitrogen. Loads can also be divided by water volume of receiving water bodies. The resultant sources of nitrogen from the NLM will be compared on a subwatershed level. Finally, the nitrogen load to each water body can be divided by the area of the waterbody and compared to other studies that have quantified the nitrogen for different water bodies: Moriches, Shinnecock, and Quantuck Bay (Gobler and Stinette, 2016; Great South Bay, NY (Kinney and Valiela, 2011); Barnegat Bay, NJ (Bowen et al. 2007); Chincoteague Bay, VA (Boynton et al., 1996); West Falmouth Harbor and Pleasant Bay, MA (Carmichael et al., 2004) among others (Bowen and Valiela, 2001, 2004; Bowen et al., 2007). Comparisons to the subwatershed results in this study will also be compared to the prior subwatersheds study performed for Nassau County in 2020.

7. REPORTING

Christopher Gobler and staff will produce reports at the completion of each individual task which will be submitted to the NYSDEC for review and comment. The final report, model, and data will be delivered to the NYSDEC who will share it will Nassau County and its towns for the purpose of environmental planning and peer reviewed publication. All data including, model inputs, raw data, final models, lab logs, and QAPP revisions, will be sent to NYSDEC at the completion of the project in proper form (maps as PDF and ArcGIS compatible files including all associated data necessary to read map in ArcGIS, data as excel spreadsheets, and reports as word documents; other formats as necessary).

Figure, tables, and text will include nitrogen load to the bays from all subwatersheds from the models, nitrogen load divided by the area of the subwatersheds, sources of nitrogen loading, nitrogen loads to the bays compared to other bays, salinity of the bay compared to measured nitrogen concentration, and percent of nitrogen load decreased with each mitigation scenario. Maps in ArcGIS and PDF form will be provided showing ground water nitrogen concentrations and salinity and nitrogen loading from each subwatershed.

8. TIMELINE AND BUDGET

Objectives:	**Dates of completion**
1. Update the Nitrogen Loading Model for surface waters across Nassau County, NY	February - May
2. GIS parcel scale analysis to determine best wastewater management per parcel for Nassau County, NY	June - July
3. Identify the appropriate management scenarios for the reduction of nitrogen from each of the newly aggregated subwatersheds.	August - September
4. Run the selected management scenarios through NLM.	October - November

Budget: This project is being supported by NYSDEC. The total cost is $189,831

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Quality Assurance Project Plan (QAPP)

EFDC and FVCOM Modeling for Nassau County Long Island Embayments

Prepared for:

NYS Office of General Services

NYS Department of Environmental Conservation

Prepared by:

School of Marine and Atmospheric Sciences

Stony Brook University
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Concurrences and Approvals:

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Claudia Henrichs SoMAS FVCOM QA Officer	Date

Quality Assurance Project Plan (QAPP) for:

EFDC and FVCOM Modeling for Nassau County Long Island Embayments

DISTRIBUTION LIST

This original QAPP, and any subsequent revisions or modifications, shall be distributed to the below listed individuals who are identified by organizational affiliations and project specific roles. If for any reason during the conduct of the project additional individuals become involved, the QAPP shall be distributed to those individuals as well.

QAPP RECIPIENT	ORGANIZATION	PROJECT ROLE
Carolyn Dunderdale	NYSOGS	Project Officer
Lorraine Holdridge	NYSDEC	Project Officer
Rose Ann Garry	NYSDEC	QA Officer
Robert Wilson	SoMAS	Project Manager
Charles Flagg	SoMAS	Project Manager
Han Sun	SoMAS	QA Officer (EFDC)
Claudia Henrichs	SoMAS	QA Officer (FVCOM)

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Attachments

Appendix A....EFDC Hydrodynamic Modeling Areas
Appendix B....FVCOM Hydrodynamic Modeling Areas

This quality assurance project plan (QAPP) has been prepared according to guidance provided in EPA QAPP Requirements for Secondary Data Research Projects to ensure that environmental and related data compiled for this project are complete, accurate, and of the type, quantity, and quality required for their intended use. SoMAS will conduct work in conformance with the QAPP.

1 Project Organization

The purpose of this document is to present the quality assurance project plan (QAPP) for hydrodynamic modeling for groups of embayments on Long Island in Nassau County for the New York State Office of General Services (NYSOGS), New York State Department of Environmental Conservation (NYSDEC). Specifically it is a QAPP for: (1) Environmental Fluid Dynamics Code (EFDC) hydrodynamic modeling for embayments on the North Shore of Long Island in Nassau County and (2) Finite Volume Community Ocean Model (FVCOM) hydrodynamic modeling for embayments on the South Shore of Long Island in Nassau County. The NYSDEC is funding this project through the NYSOGS. The modeling effort will be performed by School of Marine and Atmospheric Sciences (SoMAS), Stony Brook University, Stony Brook, NY.

The QAPP provides general descriptions of: (1) the work to be performed to develop each of the separate EFDC models for North Shore embayments; (2)) the work to be performed to apply the existing SoMAS FVCOM model to the South Shore embayments; (3) the efforts involved in calculating flushing times for the tidal priority receiving water bodies contained in each of the modeled areas; (4) the procedure used to calculated flushing times for freshwater priority receiving water bodies; and (5) the procedures that will be used to ensure that the modeling results are technically valid and defensible. The secondary data that will be used in this modeling effort were all collected by agencies submitting either a QAPP to EPA, a QAQC plan to the State or local government entity, or following well established existing guidelines and policy (e.g., USGS, NOAA). This project does not require the collection of additional primary data. Data quality guidelines and accreditation for the USGS and NOAA data sources are available at the following locations.

USGS – https://www2.usgs.gov/info_qual/

NOAA – http://www.cio.noaa.gov/services_programs/info_quality.html

The organizational aspects of the project provide the framework for conducting the specified tasks. They can also facilitate project performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key project roles are filled by those persons responsible for ensuring the use of valid data and the person(s) responsible for approving and accepting final products and deliverables. The program organization includes relationships and lines of communication among all participants and data users. The responsibilities of these persons are described below.

Carolyn Dunderdale (NYSOGS Project Officer) and Lorraine Holdridge (NYSDEC Project Officer) will provide overall project oversight for this work and will work with the Long Island Nitrogen Action Plan (LINAP) Subwatersheds Wastewater Plan (SWP) Surface Water Modeling Workgroup to ensure the coordination of this project with other projects being undertaken for LINAP. This will include specific emphasis on coordination with the Nassau County SWP and Generic Environmental Impact Statement (GEIS) project, and with Robert Wilson and Charles Flagg (SoMAS Project Managers) and the SoMAS graduate student modeling staff to ensure that project objectives are attained. They will also have the following responsibilities.

- Reviewing and approving the project work plan, QAPP, technical approach, and other materials developed by HDR to support the project.
- Coordinating with reviewers, and others to ensure technical quality and contract adherence.

The SWP workgroup, is made up of representatives from Nassau and Suffolk Counties, NYSDEC, United Stated Environmental Protection Agency (EPA), State University of New York Stony Brook University (SBU), The Nature Conservancy (TNC), CDM-Smith and HDR. Lorraine Holdridge, Ken Zegel, Andrew Thuman, Mary Anne Taylor (CDM Smith SWP Project Manager), and Dan O'Rourke (CDM smith) will be responsible for ensuring there is coordination between this hydrodynamic project and other work being done under the LINAP. They will also have the following responsibilities.

- Coordination with other LINAP Focus Area Work Groups, the Wastewater Plan Advisory Committee and Other Agencies and Programs.
- Reviewing and approving the project work plan, QAPP, technical approach, and other materials developed by SoMAS to support the project.

Carolyn Dunderdale is responsible for coordinating with reviewers and others to ensure technical quality and contract adherence.

Robert Wilson (SoMAS) and Charles Flagg (SoMAS) are the Project Managers for this project. They are accountable for the overall performance and technical content of the project deliverables and the quality of the associated services provided to NYSOGS, NYSDEC during the performance of the project. They are responsible for communicating with the Project Officers regarding the progress of the project, and for ensuring that appropriate and sufficient resources are available to meet the project goals. They will be responsible for planning, directing, and controlling the project tasks and ensuring the progress is commensurate with the project budget and schedule. He will also be responsible for communication with NYSOGS and NYSDEC for reviewing all interim and final products, preparing written correspondence to NYSOGS and NYSDEC and for addressing any deviations from schedule, budget or work quality. Specific responsibilities of the Project Managers include the following.

- Coordinating project assignments, establishing priorities, and scheduling.
- Ensuring completion of a high-quality project within established budgets and time schedules.

- Acting as primary points of contact.
- Providing guidance, technical advice, and performance evaluations to those assigned to the project.
- Implementing corrective actions and providing professional advice to staff.
- Preparing or reviewing preparation of project deliverables, including the QAPP and other materials developed to support the project.
- Providing guidance on the application of existing models and on revising (if necessary) the existing models.
- Providing support in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements of the study design objectives are met.

The QA Officers are Claudia Henrichs (SoMAS) for the FVCOM modeling assignment and Han Sun (SoMAS) for the EFDC modeling assignment. They are responsible for coordinating all QA activities and for ensuring that project procedures are conducted in accordance with the SoMAS QAPP. They will also monitor QC activities with regard to model code, model inputs, model execution, and interpretation of results. Overall, these QA Officers will function in a position of oversight and review.

SoMAS will be responsible for the development of three-dimensional EFDC hydrodynamic models for North Shore embayments that will include the tidal priority receiving water bodies where flushing time calculations are needed, as well as all necessary model inputs. SoMAS will also be responsible for the application of existing three-dimensional FVCOM hydrodynamic model to Sorth Shore embayments that will again include the tidal priority receiving water bodies where flushing time calculations are needed, as well as all necessary model inputs. In addition, SoMAS will also calculate flushing times for freshwater priority receiving water bodies using the EFDC and FVCOM hydrodynamic modeling results. SoMAS modeling staff will use the EFDC Explorer software (DSI, 2015), which is a Windows-based graphical user interface (GUI) as well as MATLAB for pre- and post-processing of EFDC model inputs and outputs. SoMAS modeling staff also uses the SMS AQUAVEO software (Aquaveo, 2017) which is again a Windows-based graphical user interface (GUI) as well as MATLAB for pre- and post-processing of FVCOM model inputs and outputs. Digital coastline and bathymetric data used to develop the model inputs and will be of have been obtained from readily available sources such as NOAA.

The Project will use the EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (EPA/100/k-09/003, March 2009) as a guideline during model development. Model review components will include the following project elements.

1. Appropriateness of model input data (water depths, freshwater inflow and meteorological conditions).
2. Appropriateness of model boundary condition specifications (tidal elevations, salinity/temperature).
3. Documentation of model inputs and assumptions.

4. Applicability and appropriateness of selected model parameter values (e.g., bottom friction).
5. Documentation and justification for adjusting model inputs to improve model performance.
6. Model application with respect to the range of its validity.
7. Supporting empirical data that strengthen or contradict the conclusions that are based on model results.

2 Problem Background/Objective

The NYSDEC and the Long Island Regional Planning Council are working with stakeholders to develop a Long Island Nitrogen Action Plan (LINAP) to reduce the level of nitrogen in the waters around Long Island. The purpose of the Nassua County SWP will be to provide a wastewater management plan specific to all parcels within the priority subwatersheds of Nassau County to meet the County's first order nitrogen load reduction goals for surface water restoration and the protection of groundwater and drinking water. The SWP is expected to guide County wastewater policy by providing policy makers with a road map depicting the location, number, and location-specific methodology for recommended sanitary upgrades using a phased approach linked to current and predicted ecological and public health risks. The SWP will also identify areas requiring further study through long-term LINAP or other related water quality restoration programs.

2.1 Problem Objective

Nassau County and NYSDEC are in the process of developing a Subwatersheds Wastewater Plan (SWP) and Generic Environmental Impact Statement for Nassau County. An impact assessment will be completed using nitrogen loading rates, receiving water residence times and baseline ecological conditions, as metrics for the establishment of tiered priority areas for wastewater management upgrades. This effort will include: nitrogen load calculations for priority subwatersheds; calculation of residence times or flushing times; and prioritization of the subwatersheds for wastewater management upgrades.

Establishing the tiered priority areas will include: developing baseline water quality for the priority receiving water bodies using existing data; establishing a final list of primary water quality indicators along with the ranking methodology; developing a matrix approach to rank subwatersheds for wastewater management upgrades using nitrogen loads, receiving water flushing times and water quality indicators.

Flushing times for the receiving water bodies in the Suffolk County priority subwatersheds are not available. In order to provide the flushing times for this ranking process, the following project objective is presented.

- Hydrodynamic modeling will be completed to calculate flushing times associated with tidal priority receiving water bodies defined by NYSDEC and USGS in order to support preparation of the Nassau County SWP. Environmental Fluid Dynamics

Code (EFDC) models will be developed for North Shore embayments in Nassau County and the existing FVCOM model will be applied to South Shore embayments in Nassau County. The calculation of flushing times for all priority receiving water bodies will provide a consistent county wide approach.

SoMAS will complete surface water modeling using the EFDC and FVCOM hydrodynamic models for the determination of flushing times for tidal priority receiving water bodies in order to meet Objective 2 defined in MOU AM10141.

Figures 1 and 2 show the North Shore and the **extremely complex** South Shore priority receiving water bodies where flushing times will be calculated. SoMAS will develop four separate EFDC hydrodynamic models in which each of the North Shore tidal priority receiving water bodies will be included. Attachments A and B present the EFDC and FVCOM modeling areas and the model grids. The single existing FVCOM model, which incorporates all Nassau County South Shore tidal priority receiving water bodies, is described in detail in Hinrichs (2018a, 2018b) and http://po.msrc.sunysb.edu/GSB/gridding.htm.

The method for calculating residence or flushing times for Nassau County tidal priority receiving water bodies is through the application of the hydrodynamic models EFDC and FVCOM. These models allow three-dimensional analysis of the tidal priority receiving water bodies based on freshwater inflow (surface water and groundwater), tidal and density driven circulation and also provides the foundation for future water quality modeling efforts. The calculation of priority receiving water body flushing times will allow the Nassau County and NYSDEC to make informed decisions in their tiered ranking process on which priority receiving water bodies are the most at risk from nitrogen loading and require nitrogen management efforts.

2.2 Data Availability and Quality Assurance

The following data will be used to develop the EFDC hydrodynamic model inputs in Nassau County:

- Digital coastline and bathymetric data: Digital coastline data is available from both NOAA at https://www.ngdc.noaa.gov/mgg/shorelines/ and from the US Fish & Wildlife Service Wetlands Inventory at https://www.fws.gov/wetlands/data/State-Downloads.html. Specific NOAA bathymetry files used to develop the EFDC models are inventoried in Appendix A. Bathymetry data used to develop the FVCOM model is described at http://po.msrc.sunysb.edu/GSB/gridding.htm and in Hinrichs (2018).

- Annual average groundwater inflow: The USGS sub-groundwatershed delineations used to define groundwater input in the EFDC models are currently available at http://dx.doi.org/10.3133/sir20165138 and are described in USGS Scientific Investigations Report 2016–5138 (Masuit and Monti, 2016). Groundwater input to the South Shore FVCOM model is described at http://po.msrc.sunysb.edu/GSB/forcing.htm and in Hinrichs (2018).

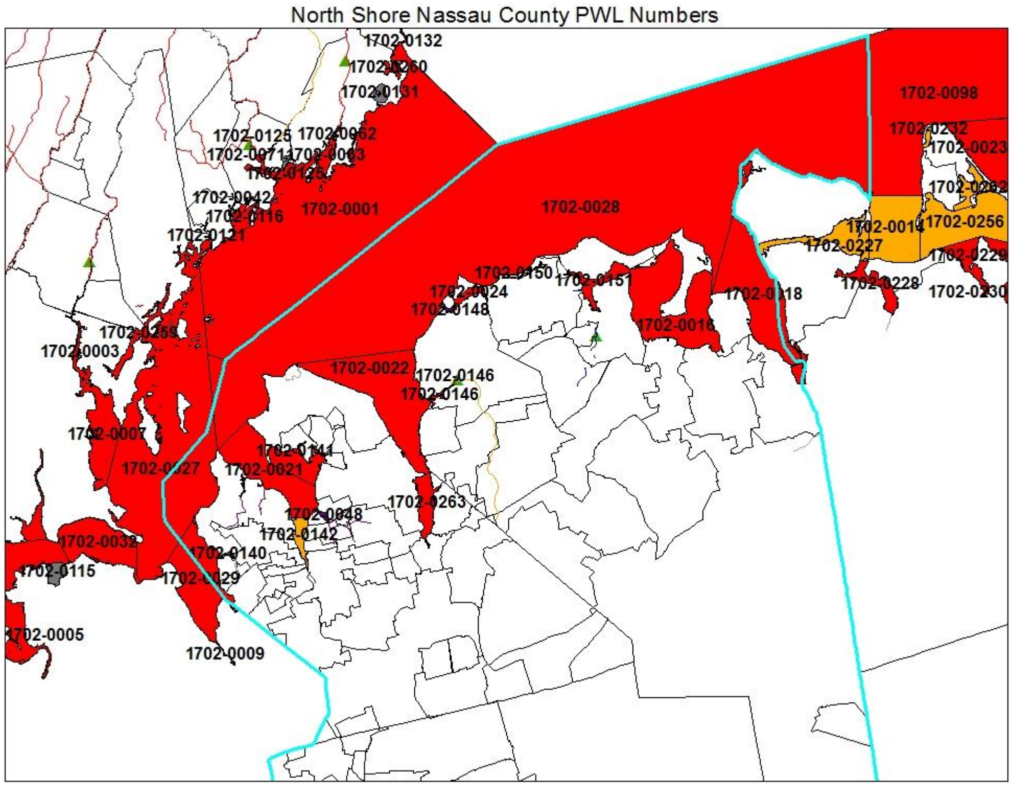

Figure 1. North Shore priority receiving water bodies

- Annual average surface water runoff: The USGS maintains a very limited number of daily streamflow gauges within the North Shore EFDC model domains. https://nwis.waterdata.usgs.gov/nwis/dv/?referred_module=sw. Annual average surface water runoff will therefore be estimated from annual rainfall and drainage areas plus additional point sources associated with WWTPs. The North Shore embayments have spring tide ranges > 3.2 m, and so may be characterized as high-mesotidal to low macro-tidal (Hayes, 1979). It is, therefore, it is anticipated that flushing times in most of the tidal priority water bodies are dominated by tidal flushing as opposed to freshwater flushing or wind driven flushing. Surface water input to the South Shore FVCOM model is described at http://po.msrc.sunysb.edu/GSB/forcing.htm and in Hinrichs (2018). It also relies primarily on estimates from annual rainfall and drainage areas to obtain distributed surface water input along the north shore of GSB.

- Tidal boundary condition water elevation, salinity and temperature model inputs: For the North Shore EFDC models in Nassau County, water elevation, salinity and temperature are obtained from the HDR Long Island Sound model (see Appendix A). The HDR Long Island Sound model also provided boundary conditions for the north shore EFDC models in Suffolk County. For the South Shore FVCOM model, open boundary conditions for water elevation, salinity and temperature are described at http://po.msrc.sunysb.edu/GSB/forcing.htm and in Hinrichs (2018).

- Meteorological conditions (wind speed and direction): The NOAA National Climatic Data Center (NCDC) has long established guidelines for measuring meteorological conditions and has supervision for quality assurance. Meteorological data used for model inputs will be obtained from the nearest NOAA NCDC data source to the EFDC and FVCOM modeled area.

The secondary data used in this modeling effort were all collected with each collection agency submitting either a QAPP to EPA, a QAQC plan to the State or local government entity (e.g., SCDHS), or following well established existing guidelines and policy (e.g., USGS, NOAA). No new primary data are anticipated to be needed nor collected for this project.

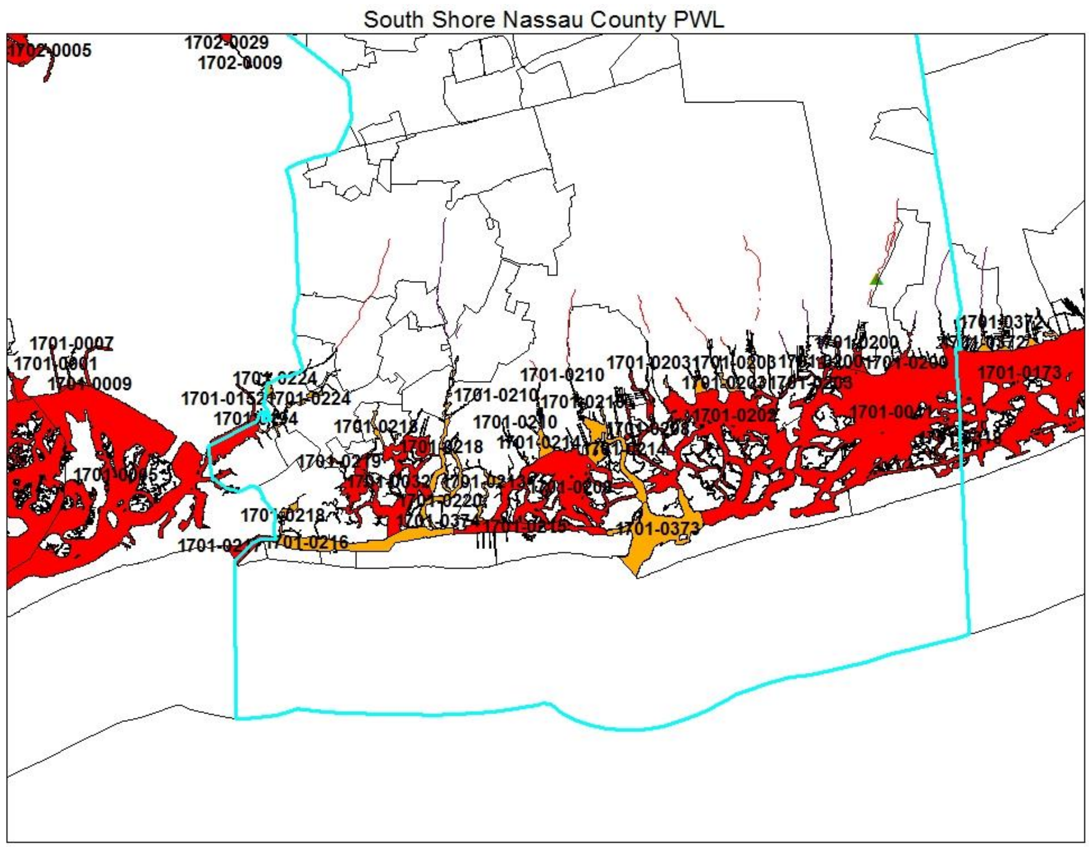

Figure 2. South Shore priority receiving water bodies

3 Project/Task Description

In the conduct of this project the Project Team will perform the following tasks.

3.1 Task 1 – Nassau County Embayment Area Groupings

SoMAS will develop 4 EFDC hydrodynamic models in Nassau County to cover all of the North Shore tidal priority receiving water bodies (Figure 3). The final list of North Shore (and South Shore) priority receiving water bodies was provided by NYDEC (email from Lorraine Holdridge dated 05/11/2017). The modeled areas include: Oyster Bay, Hempstead Bay, Manhasset Bay, and all of Little Neck Bay. The open boundaries of these model domains extend beyond the tidal priority receiving water bodies under consideration. As discussed in Appendix A, there are, however, a total of 4 extremely small PWLs which are not included in the gridded domains. Flushing times within these PWLs will be estimated independently using either simple tidal prism or hydraulic residence time methods. SoMAS will develop these North shore EFDC models in three dimensions (horizontal and vertical model grid segmentation) to provide sufficient vertical model segment resolution.

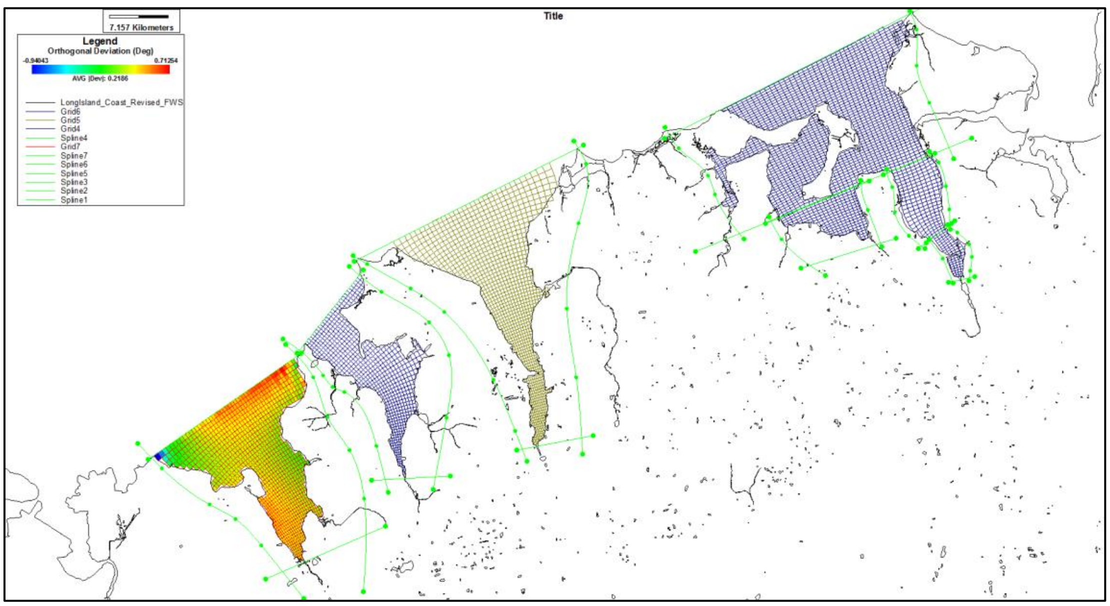

Figure 3. North Shore EFDC modeling areas.

The domain of the existing high resolution three dimensional FVCOM model (Figure 4) includes all of Nassau County South Shore PWLs shown in Figure 2. It is important to note, that **because of the complexity of the PWL definitions, and the highly coupled and channelized nature of these PWLs**, it was decided to define nine large sub-domains (Appendix B), and to determine both the average flushing rate and the spatial patterns of flushing within that domain. From this detailed spatial information, the flushing rate of any small PWL is easily defined

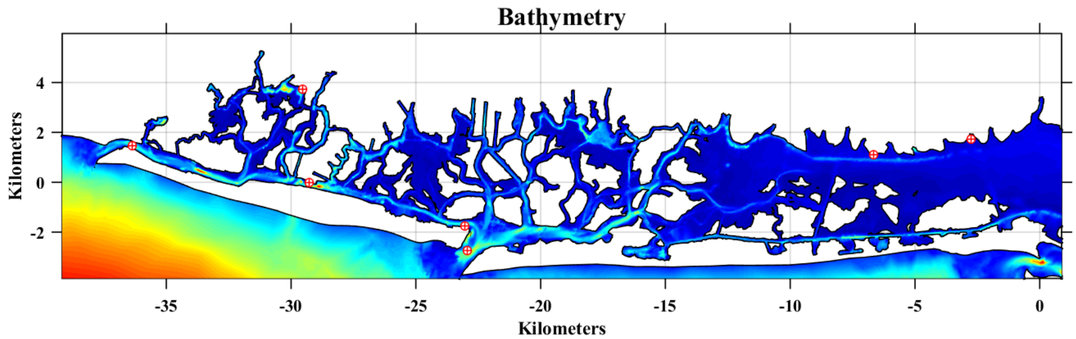

Figure 4. South Shore FVCOM model domain.

3.2 Task 2 – EFDC and FVCOM Model Segmentation & Input Development

SoMAS will develop three-dimensional model grids for the 4 North Shore areas discussed above that will include the individual tidal priority receiving water bodies where flushing time calculations are needed. The model grids (Appendix A) are developed to represent important coastline and bathymetric features using the EFDC Explorer software, which is a Windows-based graphical user interface (GUI) for pre- and post-processing of model inputs and outputs. NOAA digital coastline data and bathymetric data files (Appendix A) are used in the development of model grids.

The EFDC model inputs will be developed for a 60-day time period as follows.

- Freshwater model inputs: annual average groundwater estimates will be based on USGS Scientific Investigations Report 2016–5138 (Masuit and Monti, 2016). The groundwater input will be uniformly distributed over the model domain. The annual average surface water will be estimated using available USGS streamflow gauges and from annual rainfall and drainage area estimates plus additional point sources associated with WWTPs.

- Tidal boundary conditions for water elevation, salinity and temperature**: For the north shore EFDC models in Nassau County, these inputs are obtained from the HDR Long Island Sound model (Appendix A) for a 60-day time period beginning at midnight GMT of July 1, 2014. This time period was chosen to be consistent with HDR EFDC modeling in Suffolk County which relied on output from the SoMAS GSB model for that period.** Note that the HDR Long Island Sound model also provided boundary conditions for the North Shore EFDC models in Suffolk County.

- Meteorological model inputs: The meteorological inputs including wind speed and wind direction are obtained from the regional NOAA stations for the time period beginning July 1, 2014.

The North Shore embayments in Nassau County in Table 1 have spring tide ranges > 3.2 m, and so may be characterized as high-mesotidal to low macro-tidal (Hayes, 1979). It is, therefore, it is anticipated that flushing times in most of the tidal priority water bodies are dominated by tidal flushing as opposed to freshwater flushing or wind driven flushing. The use of open boundary water elevation, salinity, temperature and meteorological inputs based on the availability of model output for a specific period beginning July 1, 2014 should, therefore, not be considered overly restrictive.

Preliminary model validation will be completed for water elevations where data is available inside an EFDC modeling area. Available data will be collected from available active and inactive NOAA water level stations (Appendix A). An acceptable level of preliminary model water elevation calibration is defined as a root mean square error (RMSE) of 15 cm. The RMSE = $\left[\frac{1}{n}\sum_{i=1}^{n}(Model_i - Data_i)^2\right]^{1/2}$. For active stations, for which time series for the actual simulation period are available, a direct model/data comparison can be made. For inactive stations, data for the simulation period predicted from harmonic constituents can be compared with high pass filtered model results. This step is not to be considered a full model calibration but rather a preliminary step to ensure that realistic model results are produced. Rigorous model calibration will not be completed at this time in this project.

Model segmentation and model inputs for the South Shore FVCOM model are described in detail in Hinrichs (2018a, 2018b). These same references provide a detailed description of model skill In connection with both water level and salinity. Hinrichs (2018a) has reported RMSE values ranging from 8 to 16 cm for water level stations around the perimeter of the model domain.

3.3 Task 3 – Flushing Time Calculations

After the EFDC models are developed, SoMAS will complete flushing time calculations for the tidal priority receiving water bodies included within the EFDC models and listed in Appendix A. Flushing time calculations will be completed as follows for each individual tidal priority receiving water body.

- The model segments in each tidal priority receiving water body will be assigned an initial constituent concentration of 1 mg/L. The concentration will be treated as a conservative substance in the EFDC model.

- The EFDC model will be run for the 60-day modeling time period; the calculated concentrations in all model segments and the volume averaged concentration versus time will be presented graphically.

- The time series of volume averaged concentration for the tidal priority receiving water body will be used to calculate a flushing time based on one e-folding time (times when 36.8% of the initial mass exists in the tidal priority receiving water body).

- The resulting flushing time calculations will be tabulated in EXCEL for each priority receiving water body along with PWL ID.

As discussed **Section 3.2**, because of the complexity and dendritic nature of the South Shore Nassau County PWLs (Figure 2), FVCOM is used to evaluate the mean flushing time within sub-domains to the west of PWL 1701-0173 (Appendix B). Within those sub-domains flushing times are also defined at individual model nodes which can then be associated with an adjacent PWL.

3.4 Project Schedule

An approximate project schedule for completing Tasks 1-3 and preparing the report is proposed in Figure 4. It will need to be restructured following approval of this QAPP.

Project Schedule	1 st Quarter	2 nd Quarter	3 rd Quarter	4 th Quarter	5th Quarter	6 th Quarter	7 th Quarter	8 th Quarter
Task								
Task 1 – Nassau County Embayment Area Groupings								
Task 2 – EFDC Model Segmentation & Input								
Task 3 – Embayment Flushing Time								
Calculations Review								
Draft Modeling Report								
Draft Comments								
Final Modeling Report								

Figure 4. Project Schedule

4 Quality Objectives and Criteria

SoMAS is committed to the implementation of internal policies and operating procedures that are designed to assure the quality and completeness of its work:

1. Engineering analysis, non-EFDC codes (e.g. MATLAB) and model results and the final work product will undergo technical review to assure that products are accurate and complete, fall within guidelines for accepted engineering practices and meet the project objectives.

2. Prior and continuing review by technical and policy committees, such as the NYSOGS, NYSDEC and SCDHS, will ensure that the objectives of the study are achieved.

This project involves the use of the hydrodynamic model EFDC and the EFDC Explorer software. This modeling product is developed and supported by Dynamic Solutions International, LLC and the EFDC model is also supported by EPA. The QA Officer (Han Sun) will ensure that the latest version of the EFDC model and EFDC Explorer Software is used. This project also involves the use of the community hydrodynamic model FVCOM and the SMS software. The community model FVCOM is maintained by UMASS Dartmouth; the SMS modeling product is developed and maintained by AQUAVEO, LLC [US]. The QA Officer (Claudia Hinrichs) will ensure that the latest version of the FVCOM model is used.

4.1 Model Testing

Preliminary model calibration will be completed for water elevations where data is available inside an EFDC modeling area. Available data will be collected from available active and inactive NOAA water level stations (Figure A4). An acceptable level of preliminary model water elevation calibration is defined as a root mean square error (RMSE) of 15 cm. The RMSE = $\left[\frac{1}{n}\sum_{i=1}^{n}(Model_i - Data_i)^2\right]^{1/2}$. For active stations, for which time series for the actual simulation period are available, a direct model/data comparison can be made. For inactive stations, data for the simulation period predicted from harmonic constituents can be compared with high pass filtered model results. This step is not to be considered a full model calibration but rather a preliminary step to ensure that realistic model results are produced. Once this preliminary model calibration is complete, the EFDC models will be considered suitable for calculation of tidal receiving water body flushing times.

The South Shore FVCOM model has already been subject to extensive water level calibration as described by Hinrichs (2018). Hinrichs has reported RMSE values ranging from 8 to 16 cm for water level stations distributed around the perimeter of the model domain. It should be considered suitable for calculation of tidal receiving water body flushing times.

5 Special Training Requirements/Certifications

SoMAS staff involved in the development of EFDC and FVCOM model input datasets and EFDC and FVCOM model application have experience in hydrodynamic modeling gained through their work on numerous similar projects.

No additional training or certifications are required for this project.

6 Documentation and Records

The approved QAPP will be provided in electronic form to all members of the distribution list. The QA officer will ensure that all personnel involved in the research are informed of updates to the QAPP.

After completing Tasks 1 through 3, we will prepare a draft Embayment Flushing Time report that documents the embayment area groupings, EFDC model development, FVCOM model application and flushing time results. The draft report will include a description of the data used, model theory and inputs, and various tabular and graphical summaries of the model results. The final EXCEL file summarizing the flushing time results will be included as a table in the draft report. After submitting the draft report, we will incorporate agreed upon comments into a final report for submittal as the final deliverable on the project.

7 Quality Control

Quality control is defined as the process by which quality assurance is implemented in this project. Project modelers will conform to the following guidelines:

- All outputs will be documented, and tracked with regard to the software version used to generate the outputs. The EFDC Explorer software and code is maintained by Dynamic Solutions International, LLC along with the associated quality control. The community FVCOM software and code is maintained by UMASS Dartmouth.

- All new and modified computer non-EFDC and non-FVCOM (e.g. MATLAB) codes will be documented. This relates to code used to assist in the development of model inputs and post-processing of model outputs.

- Modelers are instructed to maintain written or electronic records related to modeling activities including data interpretation, flushing time calculations, or other related computational activities.

8 Reporting Process

SoMAS will prepare a draft report, a final report and other deliverables, which will be distributed to project participants. The final report will include the following sections:

1. Data used as model inputs
2. Model application
3. Sensitivity analyses
4. Flushing time results

9 References

Dynamic Solutions International, LLC, 2015. EFDC Software website & information. http://www.efdc-explorer.com/.

Aquaveo, 2017. SMS Software website & information. https://www.aquaveo.com/software/sms-surface-water-modeling-system-introduction.

USEPA, 2000. Guidance for the Data Quality Objectives Process (G-4). EPA 600-R-96-055. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

USEPA, 2001. EPA Requirements for Quality Assurance Project Plans, QA/R-5. EPA 240-B- Ol003. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Misut, P.E., and Monti, Jack, Jr., 2016, Delineation of areas contributing groundwater to selected receiving surface water bodies for long-term average hydrologic conditions from 1968 to 1983 for Long Island, New York, :U.S. Geological Survey Scientific Investigations Report 2016–5138, 22p.,http://dx.doi.org/10.3133/sir20165138.

Hayes, M. O., 1979. Barrier island morphology as a function of wave and tide regime, in Leatherman, S. P. ed., Barrier islands from the Gulf of St. Lawrence to the Gulf of Mexico: Academic Press, New York, NY, pp 1-29.

Hinrichs C., 2018a. Assessment of hydrodynamic changes in the Great South Bay after breaching during Hurricane Sandy. PhD dissertation, School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, 107 pp.

Hinrichs C., C.N. Flagg and R.E. Wilson, 2018b. Assessment of hydrodynamic changes in the Great South Bay after breaching during Hurricane Sandy. Estuaries and Coasts, 41:2172–2190, https://doi.org/10.1007/s12237-018-0423-6.

Appendix A
EFDC Hydrodynamic Modeling Areas

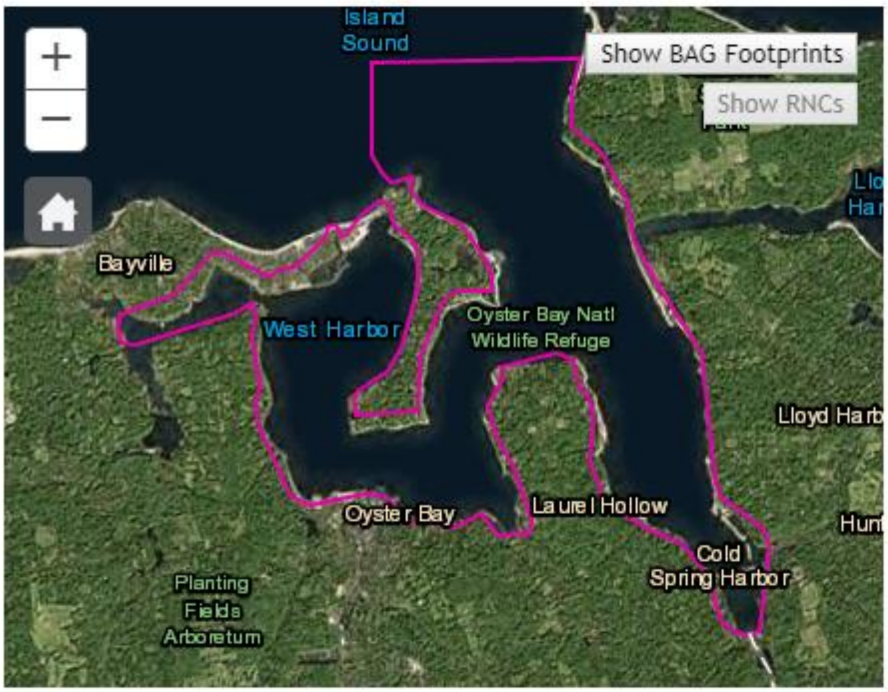

Figure A1a. Oyster Bay bathymetry survey H10349 (1990).

Figure A1b. Manhasset Bay bathymetry survey H10346 (1990).

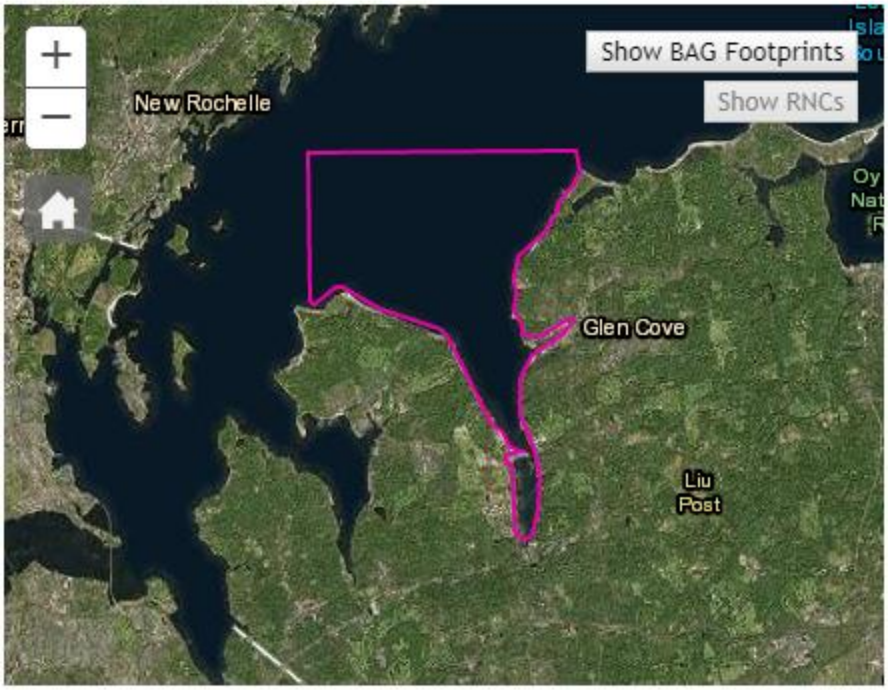

Figure A1c. Hempstead Bay bathymetry survey H10347 (1990).

Figure A1d. Little Neck Bay bathymetry survey H10541 (1994).

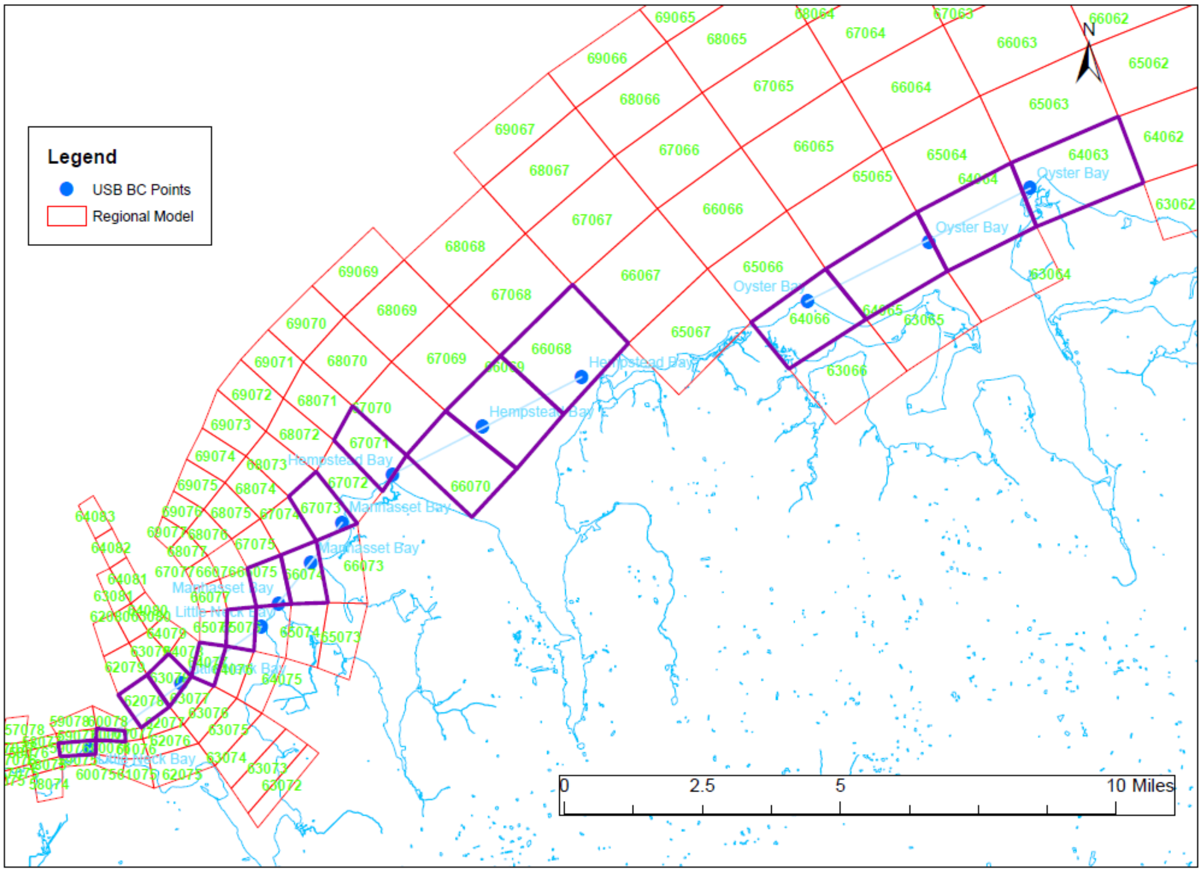

Figure A2. HDR regional model grid and EFDC open boundary nodes.

Table A1. EFDC grid statistics

	Oyster Bay	Hempstead Bay	Manhasset Bay	Little Neck Bay
Valid Cell Records	1844	1056	578	1031
Valid Cell Area-ha (m^2)	3213.75	1901.47	880.04	1659.63
Valid Cell Min DX (m)	65.4	83.82	80.27	95.28
Valid Cell Avg DX (m)	100.25	133.33	130.92	144.98
Valid Cell Max DX (m)	158.27	251.04	206.46	255.02
Valid Cell Min DY (m)	98.98	56.66	68.04	70.23
Valid Cell Avg DY (m)	173.65	124.82	113.62	107.76
Valid Cell Max DY (m)	224.82	292.66	176.73	184.49

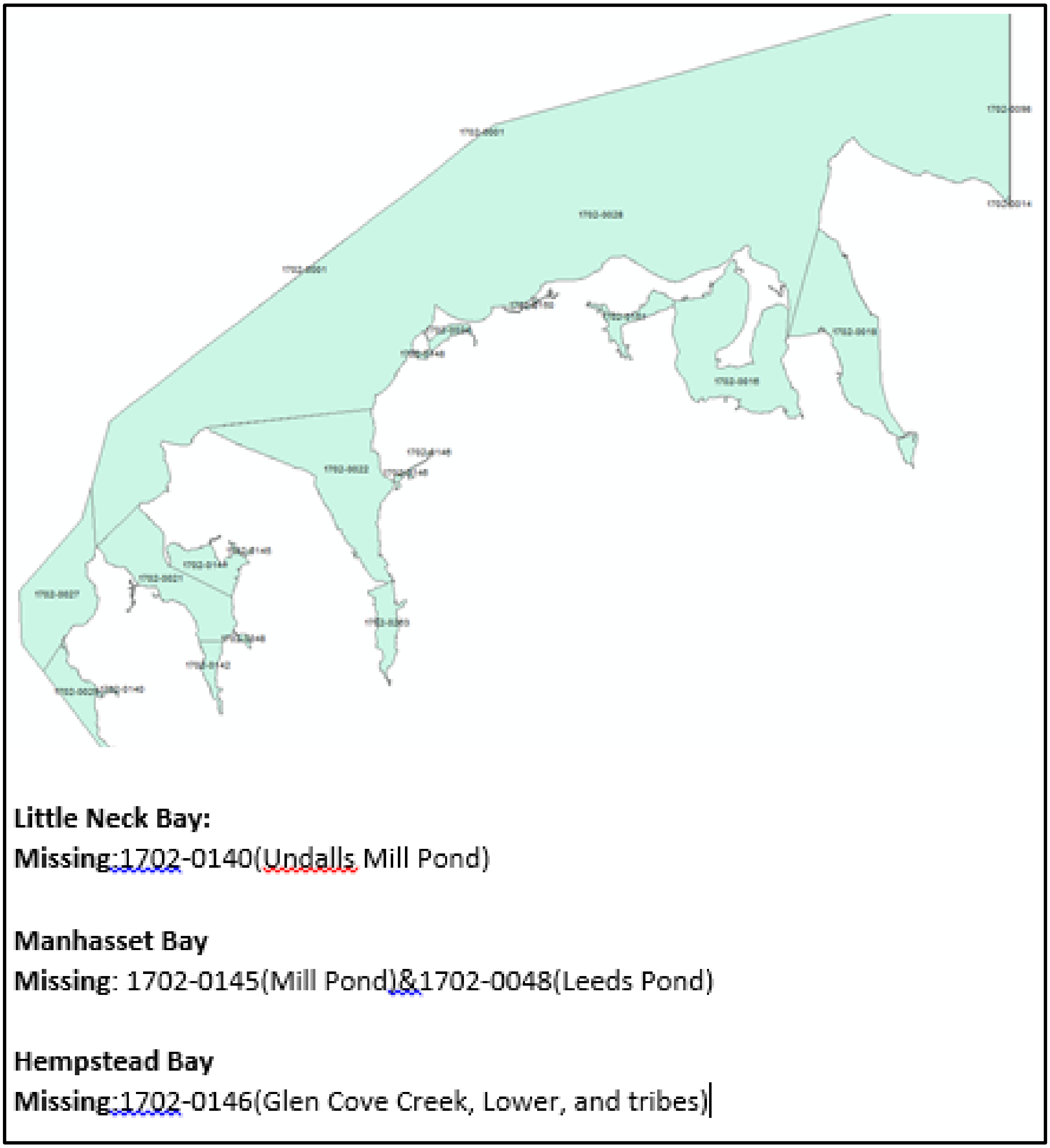

Figure A3. North Shore PWLs and PWLs missing from EFDC grids.

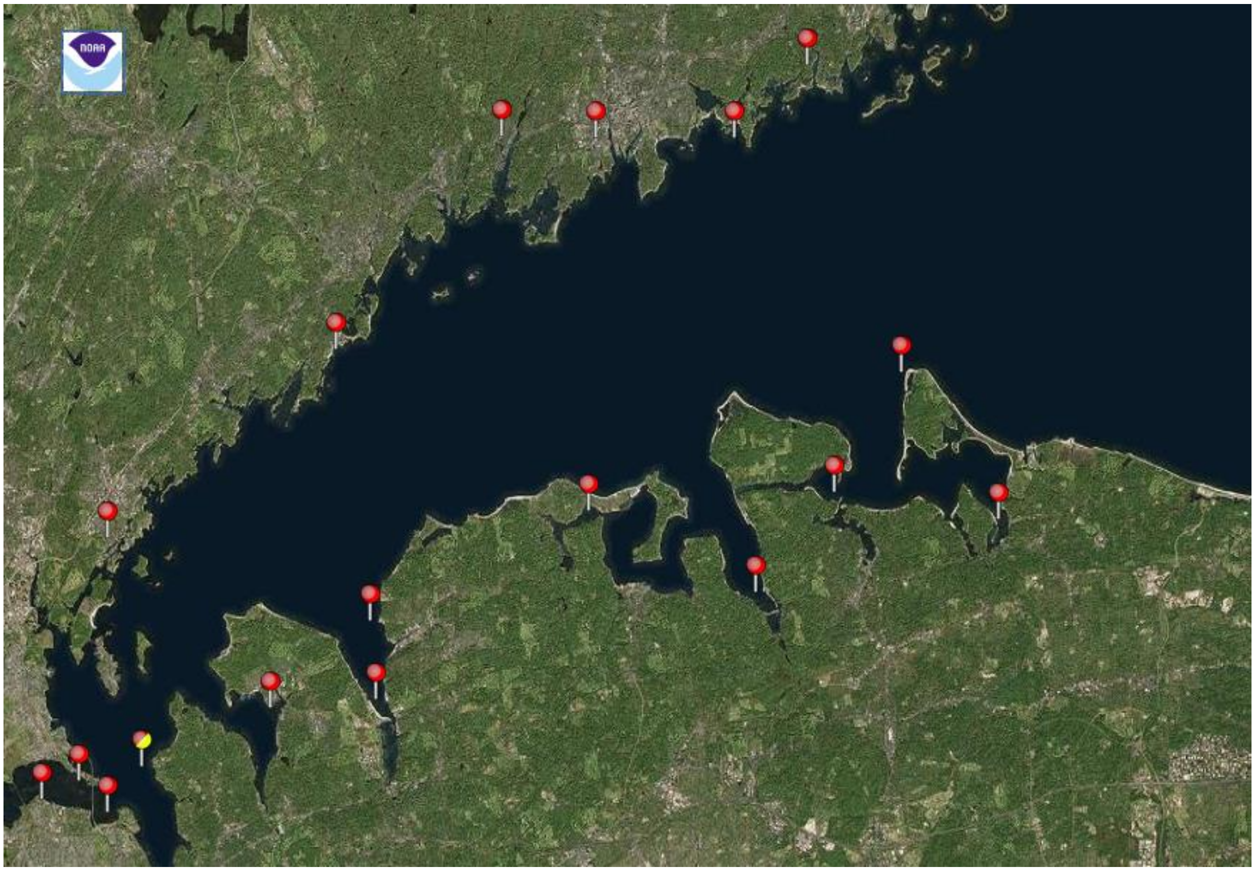

Figure A4. NOAA tide gauge stations available for EFDC model skill assessment.

Appendix B
FVCOM Hydrodynamic Modeling Areas

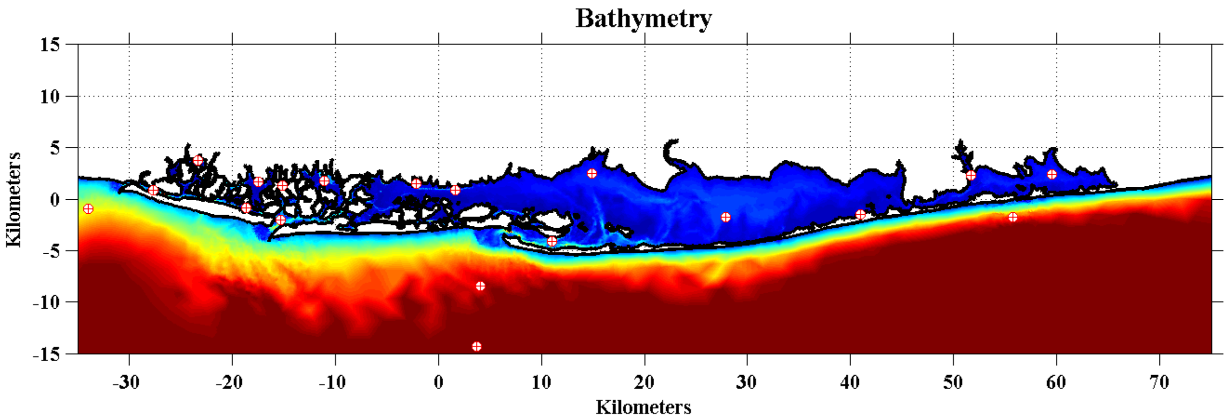

Figure B1. FVCOM hydrodynamic model domain LI south shore.

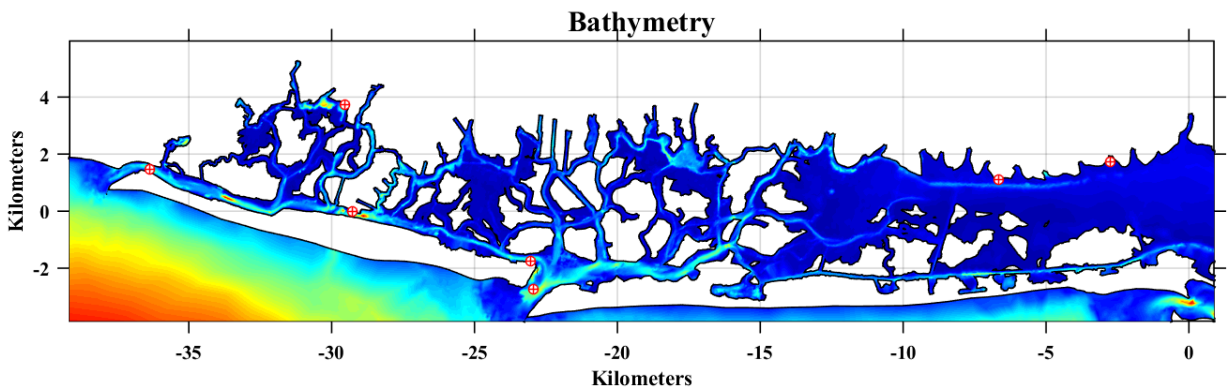

Figure B2a. FVCOM hydrodynamic model domain for Nassau County simulations including water level stations for model skill assessment.

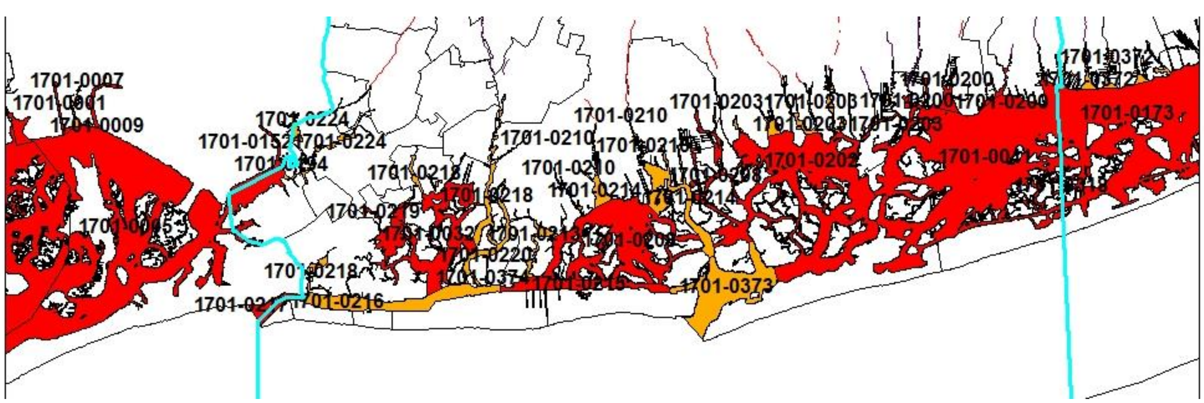

Figure B2b. Nassau County south shore PWLs.

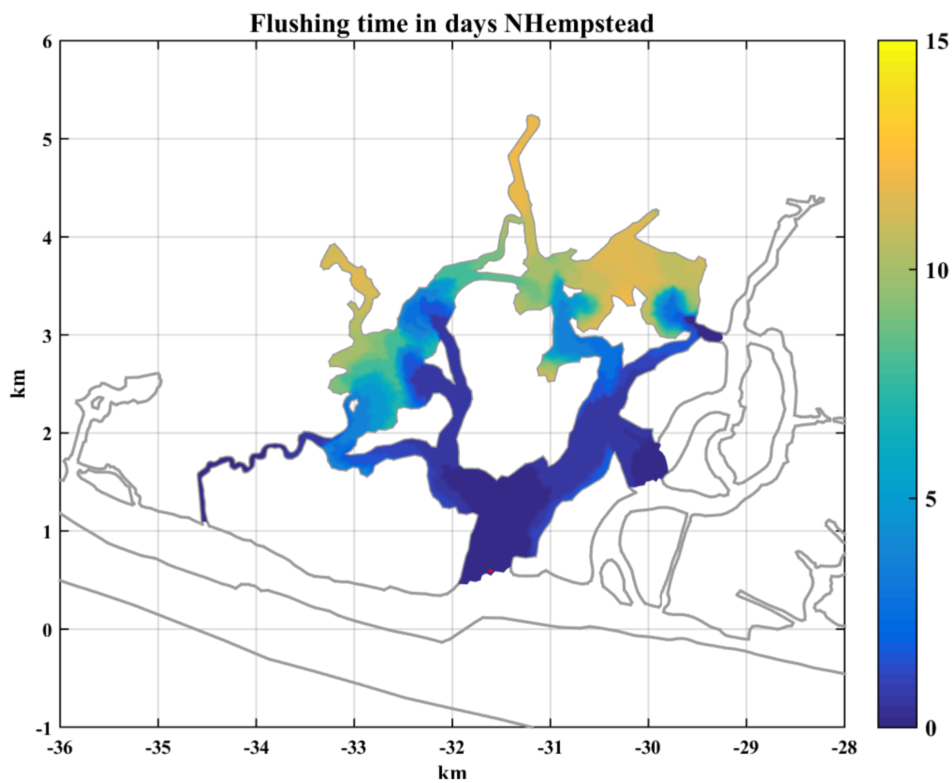

Figure B3a. Hempstead Bay sub-domain and flushing time pattern (days).

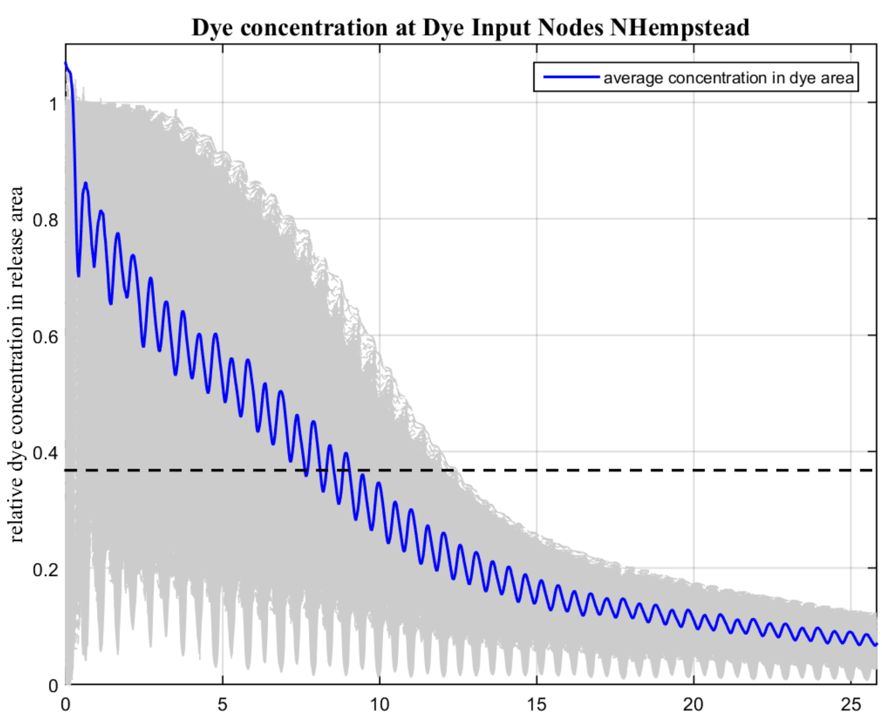

Figure B3b. Hempstead Bay mean flushing time (days).

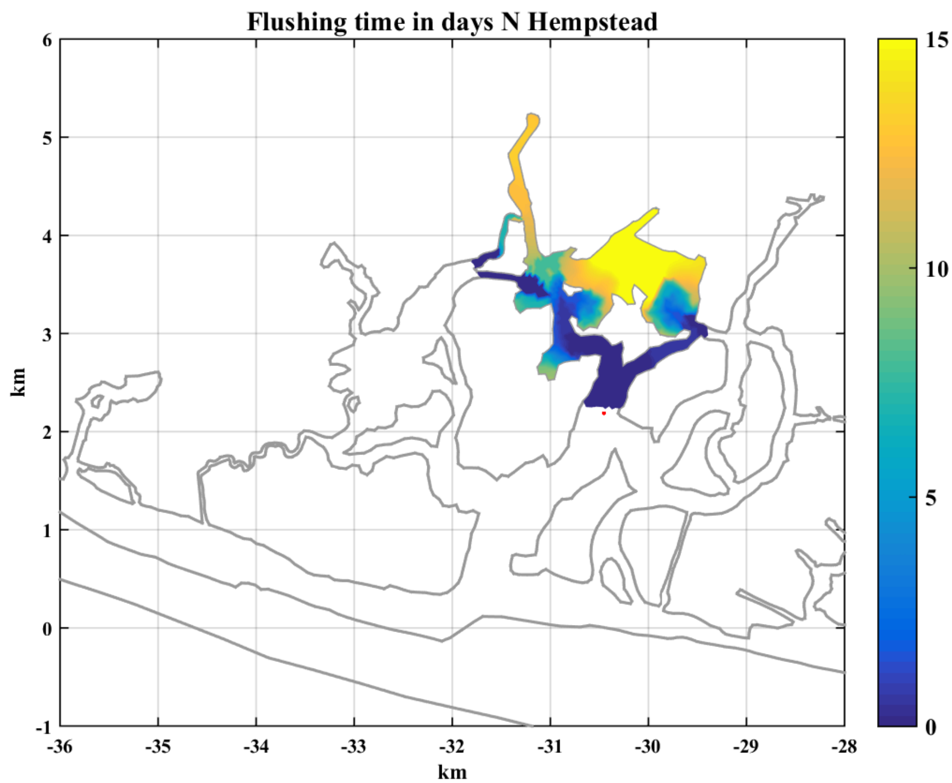

Figure B4a. N Hempstead Bay sub-domain and flushing time pattern (days).

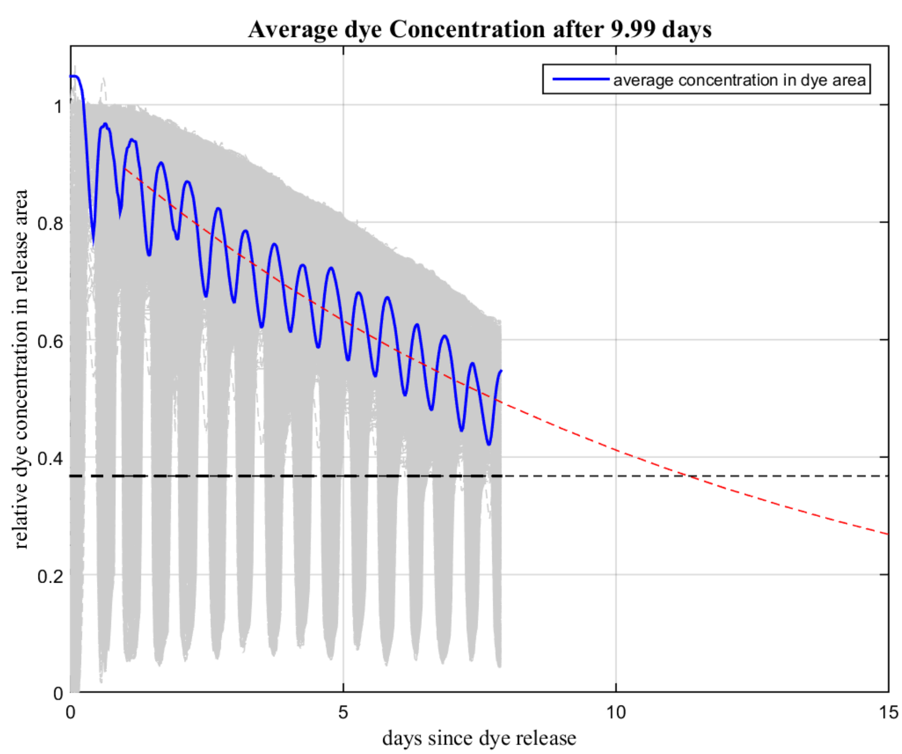

Figure B4b. N Hempstead Bay sub-domain mean flushing time (days).

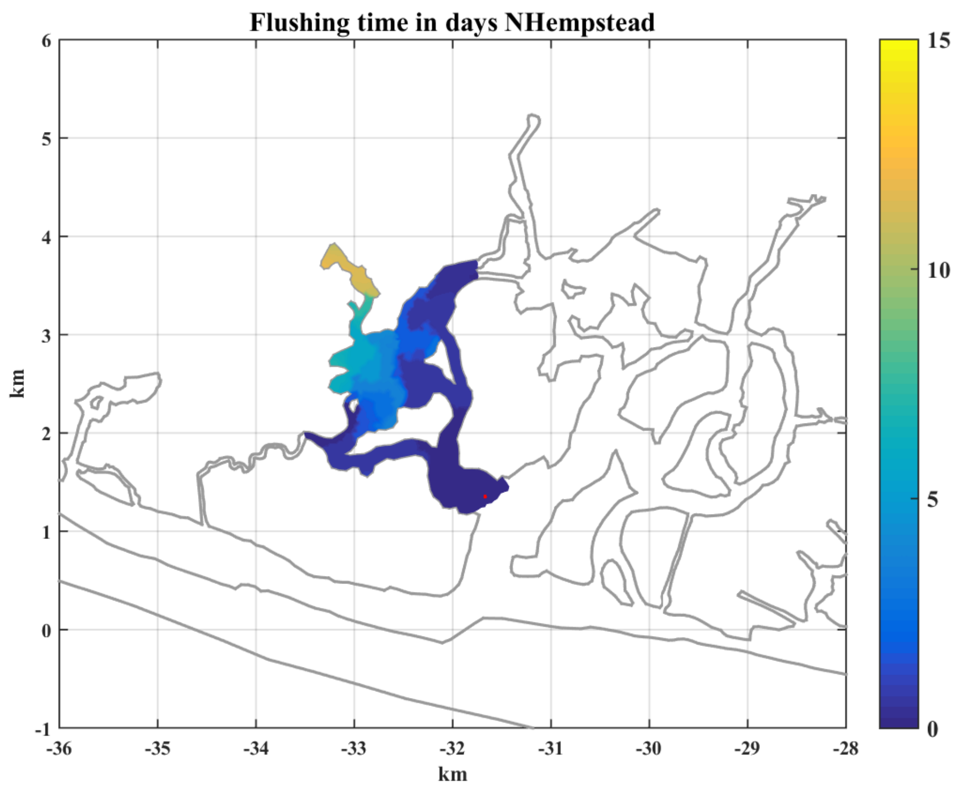

Figure B5a. NW Hempstead Bay sub-domain and flushing time pattern (days).

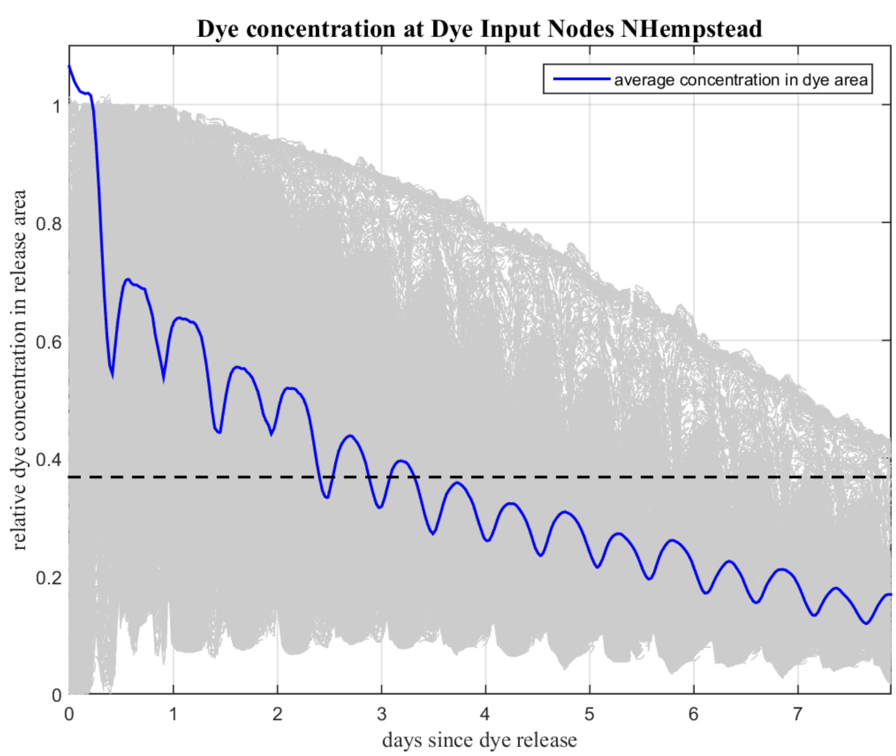

Figure B5b. NW Hempstead Bay sub-domain mean flushing time (days).

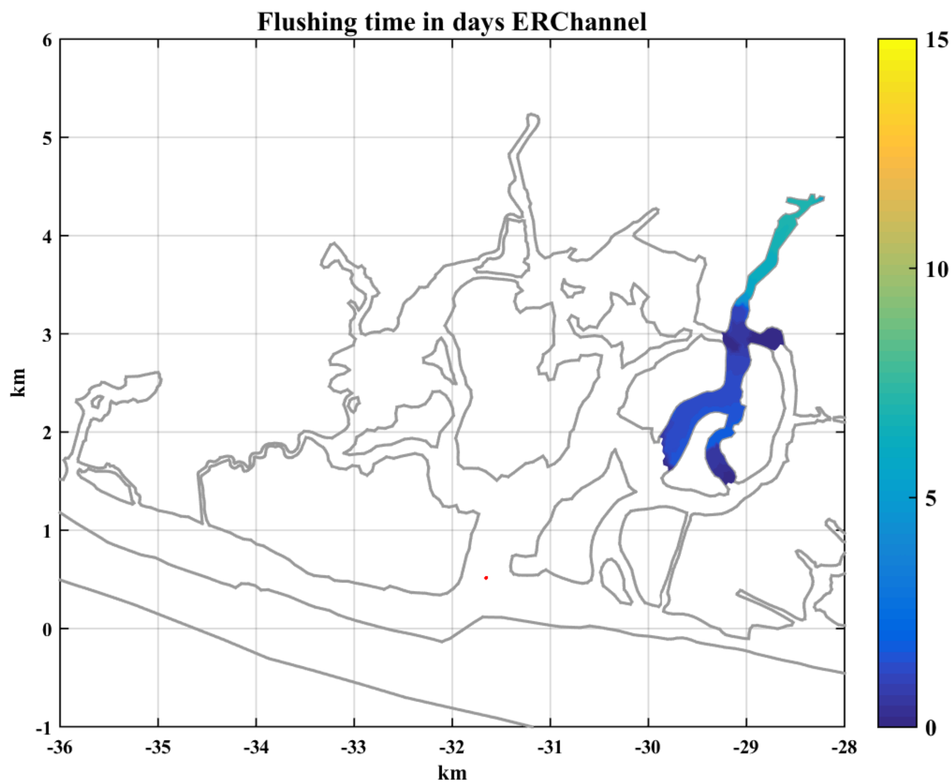

Figure B6a. East Rockaway Channel sub-domain and flushing time pattern (days).

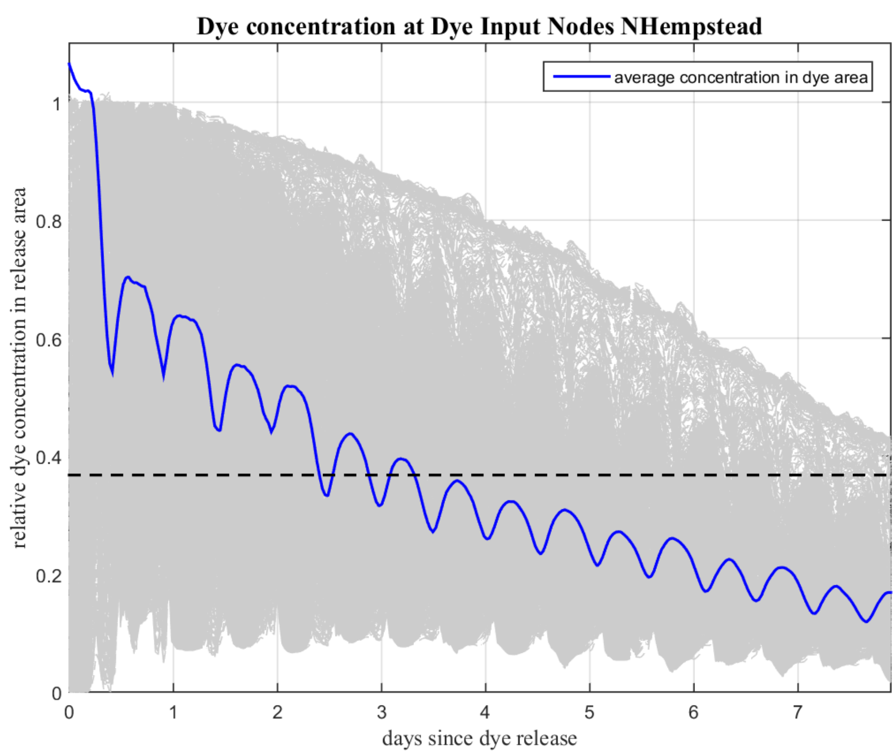

Figure B6b. East Rockaway Channel sub-domain mean flushing time (days).

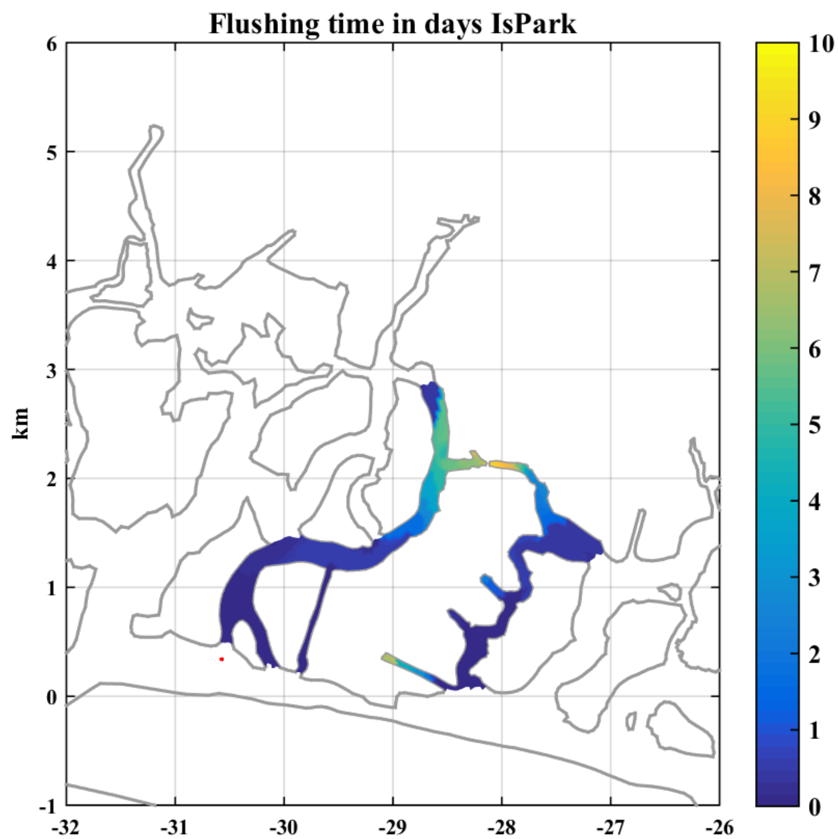

Figure B7a. Island Park sub-domain and flushing time pattern (days).

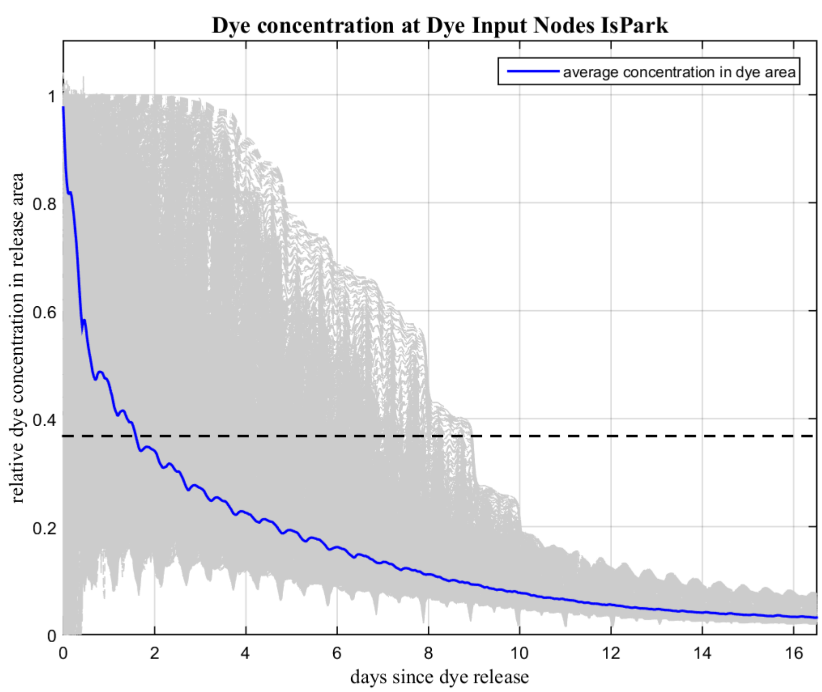

Figure B7b. Island Park sub-domain mean flushing time (days).

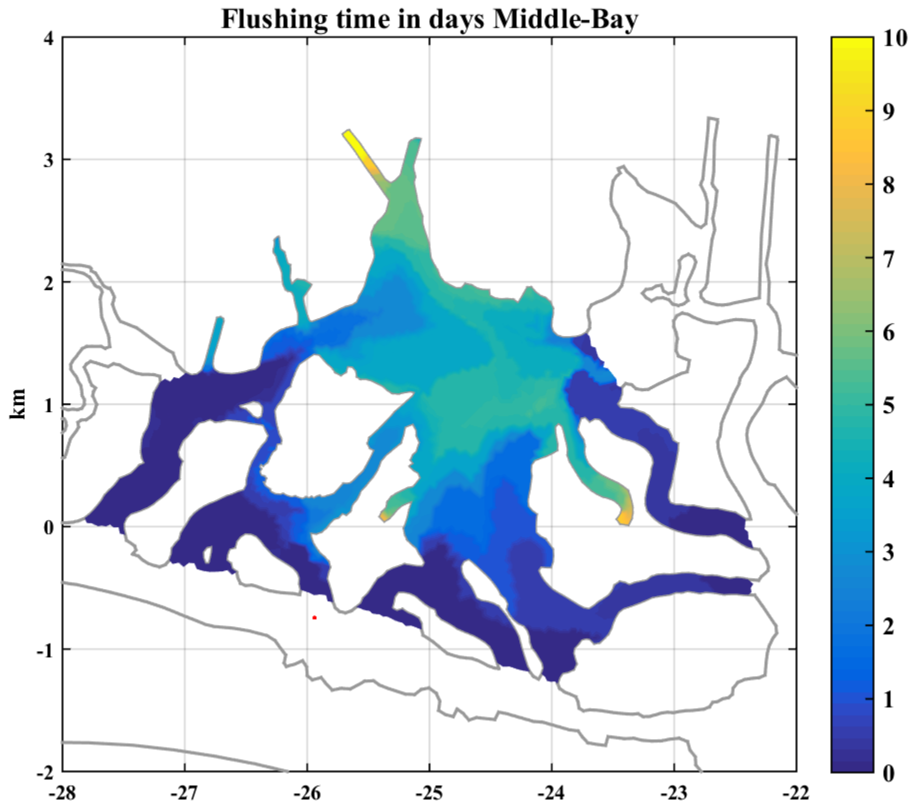

Figure B8a. Middle Bay sub-domain and flushing time pattern (days).

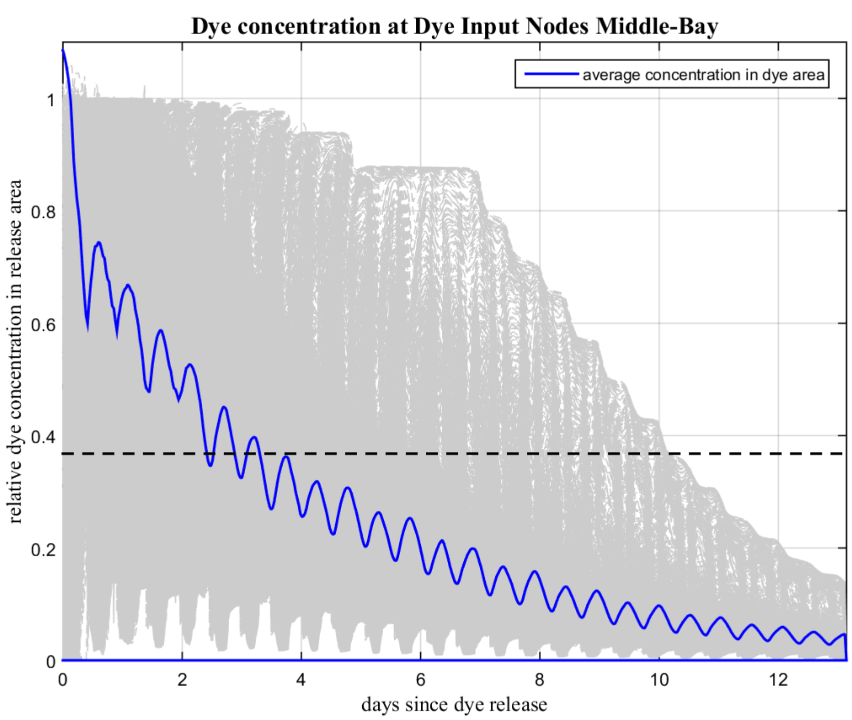

Figure B8b. Middle Bay sub-domain mean flushing time (days).

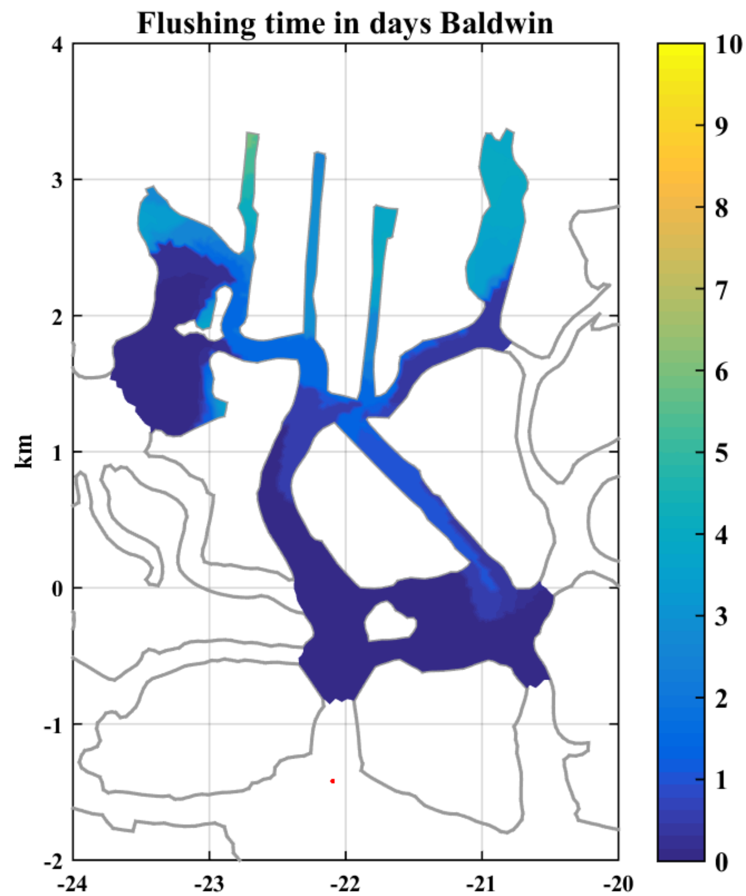

Figure B9a. Baldwin Bay sub-domain and flushing time pattern (days).

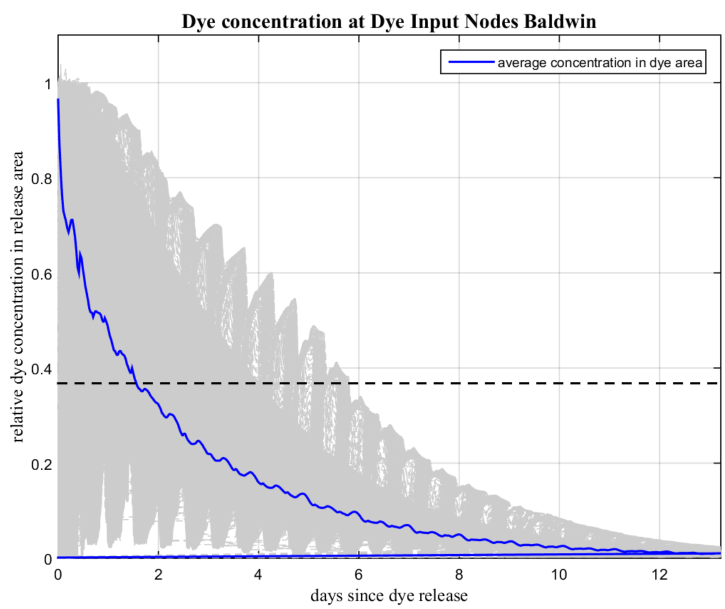

Figure B9b. Baldwin Bay sub-domain mean flushing time (days).

QUALITY ASSURANCE PROJECT PLAN
for

WATER QUALITY MONITORING FOR LONG ISLAND SURFACE WATERS

Suffolk and Nassau County, NY

Prepared for:
New York State
Department of Environmental Conservation
Albany, NY

Prepared by:
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NYSDEC MOU #: AM11838

Version 2.0

Effective: 2022-04-08
Expires: 2024-04-08

Abstract: Upon approval of this document, the project detailed within will develop a procedure for the sampling of surface waters across the north and south shores of Nassau and Suffolk County, NY as a means to evaluate water quality in these waterbodies. This project will discuss methods of field sampling and laboratory analyses, including discrete monitoring and quantification of total chlorophyll *a*, brown tide (*Aureococcus anophagefferens*), and fecal coliforms. The two major components of this project are to: (1) Develop a standard of gauging water quality parameters, such as water clarity, phytoplankton biomass, *A. anophagefferens*, and fecal coliforms, and (2) Evaluate the water quality of waterbodies across the north and south shores. The results of this project will not only provide water quality data for much of the major waterbodies in Nassau and Suffolk County, NY, but will provide a standard by which water quality monitoring can be carried out by state and local agencies, other laboratories, and citizen scientists. Data collected by this project will provide quality-controlled data on various water quality parameters to gauge ecosystem health concerns, such as harmful algal blooms.

QUALITY ASSURANCE PROJECT PLAN

WATER QUALITY MONITORING FOR LONG ISLAND SURFACE WATERS

Suffolk and Nassau County, NY

Prepared by:
Stony Brook University
School of Marine and Atmospheric Sciences
Stony Brook, NY 11794-5000

April 2022

REVIEW AND APPROVALS (signature, date)
This quality assurance project plan (QAPP) will be approved prior to the start of work.

Stony Brook University Principal Investigator Dr. Christopher J. Gobler		2022-04-11
Stony Brook University Project Manager Jennifer Goleski, M.S.		2022-04-11
Stony Brook University Project QA Officer Craig S. Young, M.S.		2022-04-08
NYSDEC Quality Assurance Officer Zachary M. Smith		2022-04-08

DOCUMENT VERSION

Author	Version #	Date	Notes
Christopher Gobler	1.0	January 2022	First submission
Christopher Gobler	2.0	April 2022	First revision

DISTRIBUTION LIST

This document will be distributed to the following project participants once approval has been received:

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1. PROJECT DESCRIPTION

1.1. Background

Many efforts are underway to improve understanding of water quality impacts to the ecology of these systems. To advance water quality management measures, including possible preparation of total maximum daily load plans that would set maximum pollutant levels a water body can receive and still meet water quality standards, adequate information must be generated regarding water quality standards found in 6 NYCRR Part 703 and current nitrogen loads to these systems. Since nitrogen limits primary production in many coastal marine environments (Nixon, 1995; Borum, 1996), it is often the delivery rate of nitrogen that influences the prevalence of algal blooms, hypoxia and the loss of seagrass beds (Bricker et al., 2008). Nitrogen overload causes eutrophication when phytoplankton populations that are normally kept in check by periodic nutrient limitation and grazing become dense and pervasive (Nixon, 1995). Such algal blooms can attenuate light penetration through the water column, decreasing the depth at which benthic phototrophs, such as seagrasses, can survive (Waycott et al., 2009). Additionally, oxygen concentrations sharply decrease beneath the surface of the water due to the respiration and decomposition of the sinking organic matter. In this way, eutrophication often leads to hypoxia (very low levels of oxygen) or anoxia (zero oxygen), which can be deleterious to fish and benthic communities (Diaz & Rosenberg, 2008). Harmful algal blooms (HABs) are an additional environmental problem initiated by nutrient overload, which have increased in their geographic extent, duration, and species variety over the past decade (Hallegraeff, 1993; Heisler et al., 2008). There is a strong correlation between increased nitrogen in coastal waters and the presence and prevalence of HABs (Heisler et al., 2008). HABs have become a yearly occurrence in the waterbodies we are investigating. Within the waterbodies we are investigating, links have been made between excessive nitrogen loading and harmful algal blooms (Hattenrath et al., 2010; Gobler et al., 2011; Gobler & Sunda, 2012), the loss of eelgrass (Wall et al., 2008), hypoxia (Swanson et al., 2010), and inhibition of shellfish performance (Weiss et al., 2007; Wall et al., 2013).

Another group of microbes of concern in coastal ecosystems are pathogenic bacteria, which present a hazard to humans recreating in affected waters by infecting the alimentary canal, ears, eyes, nasal cavity, skin or upper respiratory tract by exposure through immersion or the splashing of water (Thompson et al., 2005). Consumption of contaminated shellfish is one of the most common exposure routes for marine pathogens. Fecal coliform bacteria are the recommended indicator for human pathogens in marine waters and gastrointestinal symptoms are a frequent health outcome associated with exposure (Thompson et al., 2005)

In light of the prevalence of algal blooms, harmful or otherwise, the copious volume of wastewater that enters the coastal waters around Long Island, the listing of many Western and Eastern Bays under New York State Section 303(d) impaired waters, and the perceived role of nitrogen loading in exacerbating these conditions, it is important to establish metrics by which to monitor water quality in surface waters along the north and south shores of Long Island. This knowledge gap prohibits formulation and evaluation of management plans by municipalities or DEC to effectively ameliorate the sources of decreased water quality. Given the very large costs associated with such efforts, it is important to establish efficient means by which water quality can be quantified within the numerous coastal systems that surround Long Island to ensure that expenditures made for these efforts are cost-effective. Quantifying water quality metrics, as well identifying potential causes for poor water quality, will be a vital tool for proper management of these systems. For this project, data regarding water quality, such as water clarity, algal biomass, the presence of harmful algal blooms, and fecal coliforms will be generated and interpreted to provide an informed description of the locations and water quality impairments the systems may experience.

1.2. Project Objectives

Objective 1. Evaluate metrics of water quality parameters including water clarity, phytoplankton community composition and biomass, "brown tide" harmful algal blooms, dissolved oxygen, and fecal coliform bacteria. These metrics will serve as indicator thresholds and will be compared to existing NYS and federal water quality standards, previously collected data from the collection sites, and existing scientific literature.

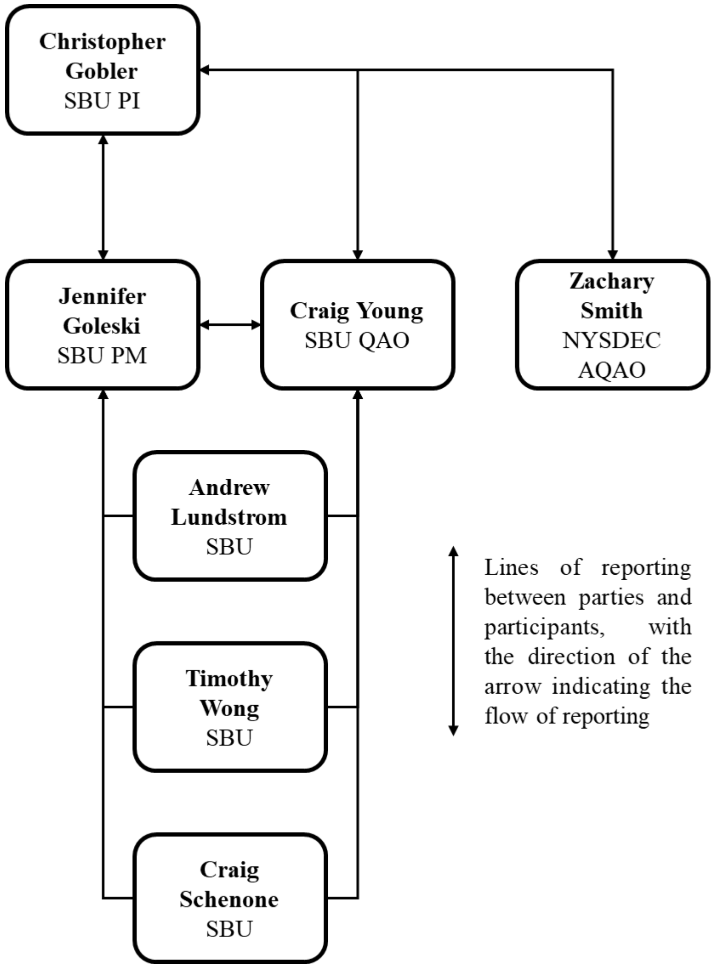
Objective 2. Use these metrics to evaluate water quality of various waterbodies across the north and south shores in Nassau and Suffolk County, NY. The results of water quality evaluations will be reported to local and state agencies (SCDHS, NYSDEC).

2. ORGANIZATION AND RESPONSIBILITIES

2.1. Participants

Name	Organization	Task
Dr. Christopher J. Gobler	Stony Brook University	Principal Investigator: Oversee all aspects of the project including secondary data collection, scheduling, and co-authoring reports
Jennifer Goleski, M.S.	Stony Brook University	Project Manager: Executing field projects, laboratory manager
Craig S. Young, M.S.	Stony Brook University	Project Quality Assurance Officer: Co-investigator, meets regularly with PI and PM to determine if project is following QAPP
Zachary M. Smith	NYSDEC	Quality Assurance Officer for the NYSDEC
Andrew Lundstrom	Stony Brook University	Personnel for field projects (setting up and deploying field instruments, discrete sampling)

Timothy Wong	Stony Brook University	Personnel for field projects (analysis and evaluation of fecal coliforms and *A. anophagefferens*, discrete sampling)
Craig Schenone	Stony Brook University	Personnel for field projects (evaluation of phytoplankton community; analysis of chlorophyll *a*, discrete sampling)



2.2. Special Training and Certifications

All members from Stony Brook University have a least a Master of Science degree or higher with necessary laboratory and field experience to carry out their specific task(s). For this project, no other special training or certifications are required from individuals of Stony Brook University. All field team members have completed a New York State Boating Safety training course. All individuals performing laboratory analyses are familiar with best laboratory practices regarding health and safety, including use of protective equipment and proper disposal and storage of reagents used in laboratory analyses. The PM will ensure that all individuals involved with the field and laboratory aspects of the project receive and are familiar with this document to ensure proper adherence to the procedures outlined within.

2.3. Roles and Responsibilities

The PI will head the implementation and monitoring of the document control procedures (*see below, section 3.1*). Drafts and updates will be written in conjunction with the PM Jennifer Goleski and Project QA Officer (PQAO) Craig Young. Updating the QAPP necessitates a change in version number of the QAPP and redistribution will occur upon noteworthy changes. The PI will be responsible for overseeing, organizing, coordinating, and executing all aspects of this project except for field work and obtaining permits. The PI will work closely with PM, who will organize and execute field and laboratory work. Craig Young, M.S., is a research technician in the Gobler Laboratory with seven years of making water quality measurements in the field who will apply his expertise toward this project. The PM of this project regularly works with NY regulatory agencies (NYSDEC) and will renew and obtain all necessary permits for this project as they have done for decades (see letter of support from NYSDEC). Andrew Lundstrom, Timothy Wong, and Craig Schenone are lab technicians in the Gobler Laboratory with experience with water quality monitoring and will be responsible for carrying out all field work- and laboratory-related aspects of the project.

2.4. Schedule

Tasks / Activities / Milestones	Beginning Month and Year: **February 1, 2022**																							
Task	Funding Year 1												Funding Year 2											
	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24
Prepare, submit, and finalize QAPP	X	X	X	X																				
Monitor water quality					X	X	X	X									X	X	X	X				
Analyze Samples and data					X	X	X	X									X	X	X	X				
Write reports					X			X			X			X			X			X				X

3. DOCUMENTS AND RECORDS

3.1. Document Control

Version control of this QAPP will be maintained by indicating the version, date, and distribution list on the cover page, and for the QAPP, in the table of contents header. The Final QAPP will be identified as “Final”, dated, and distributed to all on the distribution list. If the Final QAPP is subsequently revised, the header will identify the document revision number. Changes in project scope, approach or data usage will be identified to the NYSDEC. Changes prompting an addendum to the QAPP might include replacement of a key team member such as the NYSDEC. Changes that could be documented in the task-specific deliverable could include addition of data from a yet unidentified source of data or modification of sensitivity criteria or the inclusion of new field/laboratory experiments/analyses not previously defined in the QAPP. All signatories of this QAPP will be notified by e-mail if modifications of this QAPP are required due to unforeseen circumstances. Modifications to the QAPP will be noted in any updated versions of the QAPP which will be maintained by the Principal Investigator. Upon completion of each task, the results will be documented in a progress report. Both paper and electronic copies of data, results, calculations, and task documentation will be stored.

3.1.1. Hardware and Software Requirements

Hardware will consist of personal computers, water quality sensors (YSI EXO3 multi-parameter sondes, Trilogy fluorometer (Turner Designs) to quantify chlorophyll *a*, and Beckman Coulter CytoFLEX flow cytometer to quantify *A. anophagefferens*. Data manipulation software to be used for this project includes publicly available packages such as Microsoft Office (specifically Word, Excel, and PowerPoint), ESRI ArcGIS®, SigmaPlot, SigmaStat, R and RStudio, KorEXO, and CytExpert. Specific software version numbers will be uniform to ensure consistency.

3.1.2. Products of Research

Upon analysis, all data will be entered into a master spreadsheet as well as individual spreadsheets and files for each parameter measured (*described below*).

3.1.3. Data Storage and Preservation

Both paper and electronic copies of data, calculations, GIS mappings and task documentation will be stored. All collected data will be noted in dated data collection forms (*see Appendix*), and will be digitized, organized in tables, and saved as dated Microsoft Office documents. References will be kept current throughout research and analysis. All electronic documents should be electronically accessible at all times and will be kept in a clearly labeled computer folders. All project data will be transferred to electronic format daily. Project data sets will be saved daily to cloud-based servers as well as on redundant, physical hard drives in the lab of the PI, minimizing the possibility of data loss. All computers used in the project will be provided with regular updates and anti-malware software to ensure the security of the computer and all data contained within. All data will be maintained in standard formats (Excel) and will be made publicly available to inquiring individuals for modeling or compiling metadata. Upon completion of the project, all electronic data will be saved on CDs, which can be kept for future access by the PI for at least ten years. Long-term storage of hard copy materials (printed final reports and lab notebook) should not be necessary.

3.1.4. Data Formats and Metadata

Data will be collected using standardized and robust data collection forms (*see Appendix*). Additionally, we will document our metadata by taking careful notes in laboratory notebooks regarding the specifics of data collection, abbreviations used for experiments and for treatments. Data collection forms and laboratory notebooks will be dated, contextualized, and notarized by the individual that collected the data. We will then construct a .txt file summarizing the metadata (date and time of collection, person collecting data, laboratory receival time, time to each laboratory analysis, weather conditions, notes on state of sensors, if any, results of calibration prior to data collection) and attach it to the data file. A pre-determined format for the .txt files will be used for consistency.

3.1.5. Data Dissemination and Policies for Data Sharing and Public Access

The data will be made available to other investigators after its approved use by the authors, NYSDEC, and the Suffolk County Department of Health Services (SCDHS). Beyond NYSDEC and SCDHS, the authors will retain the right to the data until the resulting publication is produced within two years of data production. After publication or two years (whichever comes first), the authors will open the data to public use. Publication of the final report will be sought only after the report has been approved for release to the peer-review process.

3.1.6. QAPP Maintenance

The PI will keep the official copy of the QAPP at Stony Brook University and he will perform distribution and maintenance of the QAPP. Drafts and updates will be written in conjunction with the PI and PQAO. Updating the QAPP necessitates a change in version number of the QAPP and redistribution will occur upon noteworthy changes.

4. SCIENTIFIC APPROACH

4.1. Field Sampling

4.1.1. Water Quality Monitoring

Discrete sampling will be performed using YSI Professional Pro Plus handheld sensors in order to collect data for temperature, dissolved oxygen (DO), salinity, and pH (NBS scale) at the surface and bottom at all sites shown in Fig. 1 and Table 1. Surface measurements will be collected by lowering the sensor to ~0.5 m below the surface, while bottom measurements will be collected by lowering the sensor to just above the sediments. YSI EXO3 multi-parameter sondes will continuously monitor levels of temperature, DO, pH (NBS scale), conductivity (i.e., salinity), and total chlorophyll *a* at all sites shown in Fig. 1 and Table 1. Discrete measurements will be taken from each site weekly. Continuous data will be internally logged within sondes every 10 min and will be downloaded from the sondes and stored in cloud storage (Stony Brook University Google

Drive) every week. YSI EXO3 sondes will be deployed at the beginning of each sampling year and will retrieved at the end of the sampling year. The daily arithmetic mean of data will be calculated upon retrieval of data and stored to cloud storage as well. To compliment continuous and discrete measurements, discrete surface water samples (depth = 0.5 m) will be collected weekly at each site and region for the evaluation of the phytoplankton community, quantification of chlorophyll *a*, *A. anophagefferens*, and fecal coliforms.

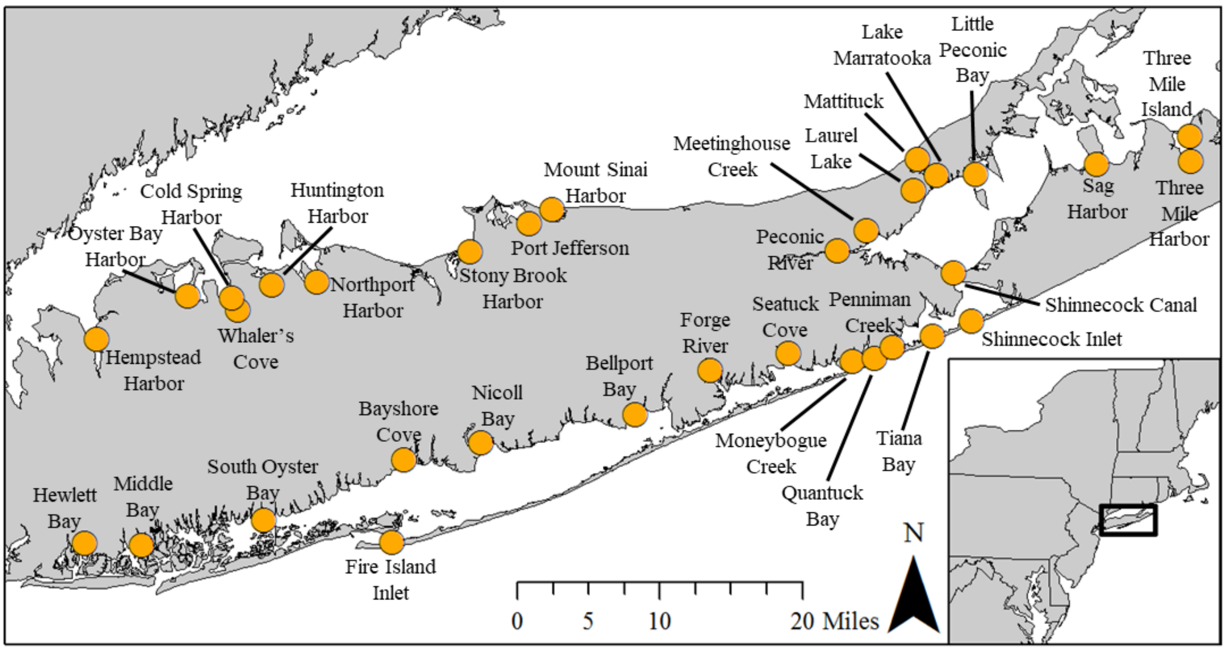


Fig. 1. Location of all stations across Long Island.

Table 1. List of site names and coordinates for sampling sites.

Site	Latitude	Longitude	Site	Latitude	Longitude
Bayshore Cove	40.7100	-73.2428	Northport Harbor	40.8917	-73.3572
Bellport Bay	40.7532	-72.9320	Oyster Bay Harbor	40.8779	-73.5302
Cold Spring Harbor	40.8755	-73.4716	Peconic River	40.9168	-72.6574
Fire Island Inlet	40.6262	-73.2592	Penniman Creek	40.8185	-72.5865
Forge River	40.7975	-72.8309	Port Jefferson	40.9483	-73.0713
Hempstead Harbor	40.8345	-73.6528	Quantuck Bay	40.8074	-72.6103
Hewlett Bay	40.6275	-73.6694	Sag Harbor	41.0002	-72.3073
Huntington	40.8884	-73.4169	Seatuck Cove	40.8140	-72.7259
Lake Maratooka	40.9918	-72.5236	Shinnecock Canal	40.8929	-72.5018
Laurel Lake	40.9766	-72.5548	Shinnecock Inlet	40.8432	-72.4798
Little Peconic Bay	40.9919	-72.4705	South Oyster Bay	40.6504	-73.4301
Mattituck	41.0087	-72.5484	Stony Brook Harbor	40.9200	-73.1512

Meetinghouse Creek	40.9371	-72.6183	Three Mile Harbor	41.0007	-72.1815
Middle Bay	40.6252	-73.5940	Three Mile Island	41.0270	-72.1810
Moneybogue Creek	40.8048	-72.6404	Tiana Beach	40.8285	-72.5318
Mount Sinai Harbor	40.9629	-73.0398	Whaler's Cove	40.8633	-73.4633
Nicoll Bay	40.7271	-73.1392			

4.1.1. Water Clarity

The use of a secchi disk can serve to quantify water clarity, which decreases with increased turbidity and/or phytoplankton biomass. Once on-station, the secchi disk should be lowered into the water on the shadiest side / region of the sampling site (dock or boat) until it visually disappears, and the depth at which this occurs should be recorded. Total depth should also be obtained, which can be accomplished by simply lowering the secchi disk until it touches the bottom and record the depth. If the secchi disk touches the bottom before it visually disappears, that depth should be recorded and annotated to indicate this occurrence. The secchi disc depth can be affirmed by raising the disk and noting the depth it reappears upon surfacing, with the ultimate secchi disk depth being the mean of the two observations if they are not in perfect agreement. All secchi disk depth readings should be recorded in a logbook until the readings can be transferred to the relevant Excel spreadsheets.

4.1.2. Water Collection for Laboratory Analyses

Prior to the day of sampling, 1 L bottles (one for each site) should be prepared by liberally rinsing each with deionized water before being acid-washed with 10% HCl, and left for at least 24 h, or until the bottles are ready to be used for water collection. Prior to water collection, the acid-washed bottles should again be liberally rinsed with deionized water. On site, a bucket or Van Dorn bottle is lowered to the desired depth, and water is brought to the surface of a dock or vessel. The collected water is used to fill the 1-L bottle with 10 – 20% of its total capacity, and that water is used to rinse the sample bottle. In case of use of a Van Dorn bottle, the effluent nozzle will be placed at the bottom of the sampling bottle to ensure minimal bubbling. The rinse step is repeated and then the sample bottle is filled to the top with minimal bubbling. Once water is collected on-site, the sampling bottle should be transferred to and kept in a dark, cool container (~5°C) until laboratory analyses can be performed within < 6 hours of collection.

4.2. Laboratory Processing

Once seawater from all sites has been collected and transported to Stony Brook Southampton, samples will be processed for phytoplankton community composition, total chlorophyll *a*, *A. anophagefferens*, and fecal coliforms. Phytoplankton community composition will be evaluated by use of a light microscope (*see below, section 5.2*; Hasle, 1978; Gobler et al., 2019). Extracted chlorophyll *a* will be measured from samples collected on glass fiber filters (pore size = 0.7 µm) and analyzed fluorometrically (*see below, section 5.3*; Parsons & Strickland, 1963;

Parsons,). *A. anophagefferens* samples will be preserved with 10% glutaraldehyde and analyzed via an immunological-based flow cytometry (*see below, section 5.4*; Stauffer et al., 2008; Koch et al., 2014). Lastly, fecal coliforms will be quantified and analyzed by use of the direct membrane (MF) method (*see below*, *section 5.5*; USEPA, 1978; Eaton et al., 1998). Stony Brook Southampton (NY Lab ID #12076) is NYSDOH ELAP certified for the analysis of fecal coliforms. A tabular form of water quality samples with their relevant replication, volume, container, preservation technique, and allowable holding times is depicted in Table 2.

Table 2. The number of replicate samples, volumes, containers for transportation and storage, preservation techniques, and allowable holding times for water quality samples collected.

Parameter	Sample replicates	Sample Volume	Transportation container	Storage container	Preservation technique	Holding times prior to analysis
Phytoplankton community	2	50 mL	10 L carboy	50 mL falcon tube	Lugol's iodine solution	<1 week
Total chlorophyll *a*	3	200 mL	10 L carboy	7 mL scintillation vials	Frozen; acetone before analysis	<1 week
A. anophagefferens	3	4.5 mL	10 L carboy	7 mL scintillation vials	10% glutaraldehyde	<1 week
Fecal coliforms	2	100 mL	10 L carboy	125 mL containers	N/A	<1 day

5. DATA ANALYSIS AND EVALUATION

A list of methods for each measured parameter, along with the precision, accuracy, calibration frequency, holding time requirements, and detections limits can be found below in Table 3.

Table 3. Analytical specifications and QA/QC requirements for all measured parameters of the project. Standard methods for all field measurements and fecal coliforms can be found in Standard Methods for the Examination of Water and Wastewater (Lipps et al., 2018). For fecal coliforms, the precision is 45% at 20 CFU per volume filtered or 22% at 80 CFU per volume filtered. Calibration of field measurements will be conducted weekly for the YSI Professional Plus or monthly for the YSI EXO3 multiparameter sondes.

Parameter	Lab	Standard method	Precision	Accuracy	Calibration	Holding times	Detection limit
Field measurements							
Temperature	*In situ*	2550 B	±0.5%	±0.01°C	Weekly to monthly	---	0.001°C
Dissolved oxygen		4500-O G	±1%	±0.1 mg L^{-1}		---	0.01 mg L^{-1}
Conductivity		2510 B	±0.5%	±0.001 mS cm^{-1}		---	0.0001 mS cm^{-1}
pH		4500-H^+ B	±0.1 SU	±0.1 SU		---	0.01 SU
Laboratory analyses							
Chlorophyll *a*	SBU	USEPA 445.0	±0.7%	0.01 µg L^{-1}	Daily	<1 week	0.025 µg L^{-1}
Aureococcus anophagefferens (Brown tide)		N/A	<5% rCV	±150 cells mL^{-1}	Daily	<1 week	150 cells mL^{-1}
Fecal coliforms		SM 9222D-2006	45% or 22%	N/A	N/A	<1 day	20 CFU 100 mL^{-1}

5.1. Retrieval of continuous data collected by field instruments

Data collected by the YSI EXO3 multi-parameter sondes are stored onboard the devices and will be transferred to a data collection platform or directly to a computer via cable, USB connection, or Bluetooth connection using the KorEXO software and stored as raw data on the computer. Raw data from the YSI EXO3 will be saved as .csv files on a computer and will be processed, analyzed, and evaluated in Microsoft Excel.

5.2. Phytoplankton Community Composition

Prior to sampling, 50 mL falcon tubes will be labeled, in duplicate, with the site, date of collection, and space left for indication of the volume that was added. On the day of collection, the seawater should be shaken gently to homogenize the contents and 50 mL will be added to the falcon tubes. Following this, ~1 mL of Lugol's iodine solution will be added to preserve the samples. Gloves should be worn, and basic aseptic techniques should be followed to avoid contamination of the sample. For analysis, the samples should be inverted several times, and a suitable volume (1 mL) should be removed via pipette and transferred to a Sedgewick-Rafter counting chamber. An inverted light microscope (Nikon ECLIPSE TS100) will be used to evaluate the phytoplankton community, during which the most prevalent of plankton will be recorded to the highest taxonomic level possible.

5.3. Total Chlorophyll *a*

Prior to the day of sampling, 7 mL scintillation vials will be labeled, in triplicate, with the site, date of collection, and space left for indication of the volume of water filtered. The bottles containing the water collected from each site will be kept (<5°C), but not frozen, and should be processed within 0 – 6 h after the water samples are collected. Gloves should be worn, and basic aseptic techniques should be followed to avoid contamination of the sample. Using sterilized forceps, a glass fiber filter (size GF/F = pore size = 0.7 µm) should be placed on the base of a filtration tower. Once the filter is in place, the filter tower should be attached. The samples should be inverted several times, and a suitable volume (100 – 300 mL) should be measured in a graduated cylinder and transferred into the filter tower. Using a vacuum pump (pressure <5 psi), the water should be drained until the filter is nearly dry, upon which the filter tower should be thoroughly rinsed with 0.2 µm filtered seawater from the collection site or a site with equal salinity. Again, the water should be drained until the filter is nearly dry. The filter tower should be removed, and the filter removed from the base using sterilized forceps. The filter should then be folded in half, placed in its respective scintillation vial, and stored at -20°C until it is ready to be processed (USEPA, 1997).

When the filters containing the samples are ready to be processed (within 7 days), 4 mL of 90% acetone should be added to each scintillation vial, which should then be placed in a freezer and allowed to sit for 24 h. After 24 h, 1.5 mL of sample should be extracted via pipette and placed into a 1.8 mL glass scintillation vial. Each vial should be wiped carefully with a Kimwipe before being placed into a Trilogy fluorometer, calibrated with liquid certified standard twice annually and with a solid standard and blank daily (*see below*). The parameters on the fluorometer should be set to account for the volume of the acetone (4 mL) as well as the volume of the water sample that was filtered (100 – 300 mL). All data readouts (expressed as µg L^{-1}) from the fluorometer will be recorded in an Excel spreadsheet or a logbook and entered in the relevant Excel spreadsheets.

As the sample are in triplicate, the average and standard deviation of the three samples will reflect the concentration of total chlorophyll *a* for the given site on the given date. Triplicate filtered seawater blanks will be run with each analytical run and the detection limit will be defined as three-times the standard deviation of blank measurements. Procedures for quantifying chlorophyll *a* and QA/QC standards for the procedure are based on Parsons and Strickland (1963), USEPA (1997), and Parsons (2013). Upon completion of analyses, samples and reagents used during analyses will be carefully disposed in marked containers and safely stored until containers can be properly disposed.

5.4. Quantification of *Aureococcus anophagefferens*

The quantification of *A. anophagefferens* will be performed by use of an immunological-based flow cytometry technique that utilizes a fluorescently-labeled purified monoclonal mouse immunoglobulin G MAb antibody that specifically targets *A. anophagefferens* (Stauffer et al., 2008; Koch et al., 2014). The antibody is conjugated with fluorescein isothiocyanate (FITC), which can be quantified via flow cytometry. Furthermore, the antibody will be kept in a -80°C freezer until ready to be used. It is also important to note that throughout the preparation of samples, the antibody should have minimal exposure to light and thus it is disrupted into multiple, small volume aliquots. After the required volume of antibody has been used, the remaining volume should either be stored in the dark at room temperature for short durations (~1 – 2 h) or returned to the -80°C freezer for longer-term storage.

Prior to sampling, a phosphate buffered saline (PBS) solution will be made to serve as a buffer to the antibody. The buffer is created by dissolving an entire packet of PBS (TWEEN®) powder in 1 L of ultrapure deionized water. This buffer solution can be used throughout the duration of the sampling season. Also prior to sampling, an internal standard will be created by adding 0.5 mL of the 10% glutaraldehyde solution and 4.5 mL of a culture of *A. anophagefferens* that is quantified in quadruplicate via light microscopy. The glutaraldehyde solution is created by a 1:9 dilution of 100% glutaraldehyde and 0.2 µm filtered seawater. Triplicate glass 7 mL scintillation vials be labeled in advance of sampling with the site and date of collection, and 0.5 mL of a 10% glutaraldehyde solution should be added to each vial. Upon the return of water samples to the laboratory, 4.5 mL of each sample will be removed after gently mixing the sample container thoroughly, creating a 1:4 dilution. The preserved samples will be kept in refrigeration until analyses. After one hour, 2 µL of the antibody, 800 µL of PBS, and 200 µL of thoroughly mixed sample will be added to individual 5 mL polypropylene test tubes, and vortexed thoroughly. The test tubes should be kept in the dark at room temperature for 30 minutes. After the 30 minutes, test tubes will be thoroughly vortexed, and 200 µL should be removed from each and placed into a 96-well plate, which will be loaded into the flow cytometer and run. The acquisition settings of the flow cytometer should be set to acquire the target populations with a consistent gain and threshold throughout the run. These settings may be subject to change if the target population is not completely visible in a series of plot windows (Fig. 2). The samples will be set to run for 30 seconds on a fast sample flow rate (60 µL min^{-1}).

Upon the completion of a sample run, densities of FITC-containing cells will be quantified in CytExpert using the FITC and side-scatter (SSC) channels (Fig. 2) for plot windows. As not all FITC-containing cells are the target organism, the error can be accounted for by creating another plot window using the appropriate channels. (Fig. 2). Finally, concentrations of *Aureococcus anophagefferens* can be quantified by subtracting the background signal (filtered seawater) from the total amount of FITC-detected cells (Fig. 2). All data readouts (expressed as Events µL^{-1}) from the flow cytometer will be saved in an Excel spreadsheet. The concentrations should be entered in the relevant master spreadsheet, which calculates the final concentration of *A. anophagefferens* by first multiplying the concentration (in Events µL^{-1}) by the sample dilution (200 µL sample in 800 µL PBS; 1:4 dilution, or by 5) and converting to cells mL^{-1} (concentration * 5 * 1000 µL), and then accounting for the dilution factor by the glutaraldehyde preservative (cells mL^{-1} * 0.11). The final concentration should be the sum of the concentration (in cells mL^{-1}) and the dilution factor. As the sample are in triplicate, the average and standard deviation of the three samples will reflect the concentration of *A. anophagefferens* for the given site on the given date. Triplicate filtered seawater blanks will be run with each analytical run and the detection limit will be defined as three-times the standard deviation of blank measurements.

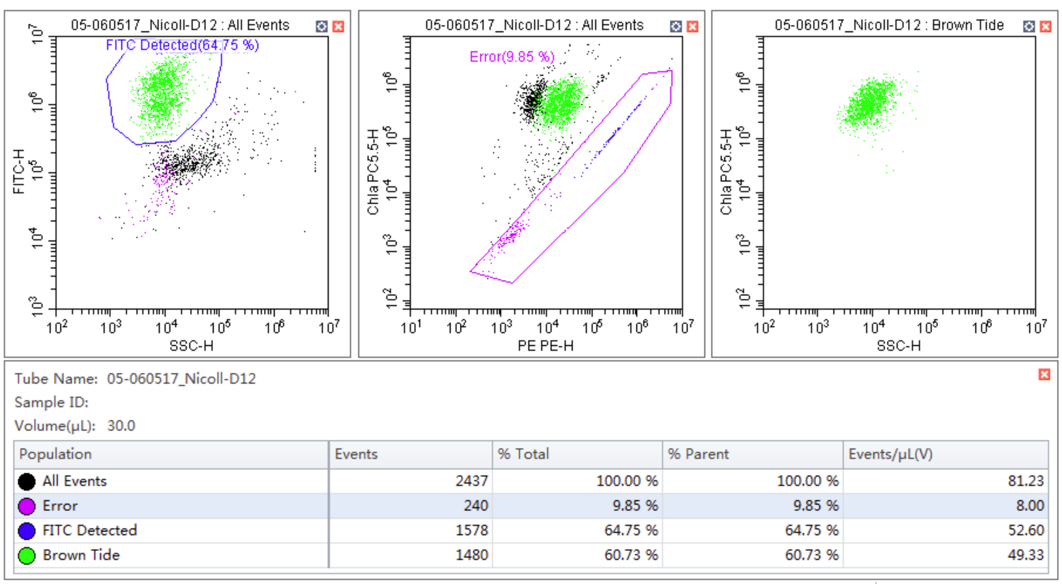


Fig. 2. An example of procedure used for the quantification of *Aureococcus anophagefferens* in CytExpert.

5.5. Fecal coliform

Fecal coliforms are gram-negative, non-spore forming rod bacteria that ferment lactose in 24 hr and are an indicator of the presence of fecal contamination in various types of water. The quantification of fecal coliforms in waters can be performed using the direct membrane (MF) method. Each water sample is filtered onto a membrane filter to retain bacteria. The filter is then placed in a Petri dish with m-FC agar, which is then incubated at an elevated temperature (44.5°C) for 24 h. Fecal coliforms ferment lactose in agar plates. Aniline blue and rosolic acid are used to differentiate fecal coliforms. Following analysis, the blue colonies are counted and reported as per 100 mL of sample. This method is based on standard protocols (USEPA, 1978; Eaton et al., 1998; Lipps et al., 2018).

Samples from each site are collected in sterile 125 mL containers. The samples are to be labeled with the site, date, and time of collection. The samples will be kept cold (<5°C), but not frozen, and will be processed the day that the water sample was collected. Gloves will be worn, and basic aseptic techniques will be followed to avoid contamination of the sample container. The sample should be filled to the 100 mL mark, and immediately capped to avoid contamination. For quality control, a blank sample should be created using ultrapure deionized water to check for contamination, and samples should be processed in duplicate to assess method precision.

The filtration units should be sterilized with 70% ethanol and rinsed three times with sterile, ultrapure deionized water. Using the EZ Pak filter membrane and sterilized forceps, a sterile filter membrane should be placed on the filter base with the grid side up, and the autoclaved and ethanol sterilized filter tower should be attached. The sample should be inverted 10x, and an appropriate volume should be extracted (Table 2) to achieve a recommended count of 20 – 60 colonies on a filter membrane. If bacterial density is unknown, several volumes should be filtered; the estimated volume to achieve the recommended count (Table 2), one-tenth of the estimated volume, and ten times the estimated volume. The sample should then be filtered by use of an attached vacuum pump, taking care not to exceed 5 psi. Once the sample is filtered, the filter tower should be rinsed twice with autoclaved filtered seawater (0.2 µm) of the same salinity of the sample. Upon turning off the pump, and removal of the filtration tower from its base, the filter membrane should be removed with sterilized forceps and placed, grid side up, on m-FC agar in a Petri dish, taking care to avoid air bubbles, and the dish cover should be placed. Within 30 minutes of filtering, the Petri dishes should be placed in an incubation chamber set for 44.5°C for 24 h.

After 24 h, the typical blue colonies on plates should be counted using the following procedure:

- Counting plates with 20 – 60 typical blue colonies:

$$\text{Fecal coliforms per 100 mL} = \frac{\text{Number of fecal coliforms counted}}{\text{Volume of sample filtered in mL}} * 100$$

- If there are less than 20 typical blue colonies for duplicate plates for a given site, record the total fecal coliforms and volumes filtered between the duplicate plates, which is calculated and reported as:

[Estimated count] fecal coliforms per 100 mL

$$\text{Estimated count} = \frac{\text{Total fecal coliforms counted}}{\text{Total volume filtered in mL}} * 100$$

- If there are no countable typical blue colonies, the count should be reported as:

<[Calculated value] fecal coliforms per 100 mL

$$\text{Calculated value} = \frac{1}{\text{Largest volume filtered}} * 100$$

- If there are greater than 60 typical blue colonies, and the plate has a readable count, record the count and volume from the replicate with the highest dilution, and report as:

>[Calculated value] fecal coliforms per 100 mL

$$\text{Calculated value} = \frac{\text{Number of fecal coliforms counted}}{\text{Volume of sample filtered in mL}} * 100$$

- If there are greater than 60 typical blue colonies, and the plate does not have a readable count, the count should be reported as:

>[Calculated value] fecal coliforms per 100 mL

$$\text{Calculated value} = \frac{60}{\text{Smallest volume filtered}} * 100$$

Table 2. Recommended volumes filtered for fecal coliform analysis.

Chlorinated sewage effluent	Raw sewage
10 mL	100 µL
1 mL	10 µL
100 µL	1 µL

6. DATA GENERATION AND ACQUISITION

The objective of this project will be to generate and collect data of the parameters listed above to evaluate the water quality of various waterbodies across the north and south shores of Nassau and Suffolk County, NY. As this work proceeds, there will be a need to maintain consistency in terms of field sampling and laboratory analyses to avoid the generation of gaps in the data. This project will not be using any existing data.

6.1. Quality Requirements

The most important quality criteria are the quality of data reported by the various instruments involved, the existence of standards and blank samples, and proper calibration of the instruments. The requisite level of quality is typically expressed in terms of accuracy, precision, representativeness, and comparability. The basic acceptance criteria below are proposed for data to be of sufficient quality for this project.

6.1.1. Accuracy and Precision

Project field and laboratory team members (Andrew Lundstrom, Timothy Wong, and Craig Schenone) will immediately report any issues regarding sampling, analytical, or other unanticipated issues to the PI and PM immediately for review. Corrective actions or significant changes in the experiment design will be reported to the PI and PM. Significant changes in sampling or analytical design will require technical and management review and approval from NYSDEC. The PQAO will document deviations and corrections in the next quarterly report and if significant, will be written into the QAPP as an amendment. Project field members will document observations, comments, and actions taken and report them directly to the PI, PM, and PQAO.

The YSI Professional Pro Plus handheld units require regular weekly calibration to ensure the accuracy of readings from the device, while YSI EXO3 multi-parameter sondes require periodic calibration. Each sensor on the device follows the same calibration procedures but with slight variations for particular parameters. Calibration of the YSI Professional Pro Plus can be performed using functions available on the handheld portion of the device and does not require being interfaced with a computer or software. YSI EXO3 multi-parameter sondes are interfaced to a computer using the KorEXO software. Calibration for both instruments begin by thoroughly rinsing the calibration cup of the sonde with deionized water (DI) before being rinsed with small amounts of the calibration standard for the specific sensor being calibrated. In the calibration menu of the KorEXO software, the parameter is selected, which initiates the sensor's calibration against the standard. At the end of the calibration cycle, a quality control score is given within the summary of the calibration. The quality control of sondes is performed by the use of the SmartQC mechanism built into the KorEXO software, which is used to normalize the different sensors and to assess the current state of each sensor's performance relative to factory-defined performance parameters. Conductivity and temperature readings are performed with the same sensor. Temperature is measured with a highly stable and aged thermistor that requires no prior calibration, while conductivity (used to measure salinity) is calibrated using a conductivity standard with a recommended standard of 1 mS cm^{-1} (1000 µS cm^{-1}) for the highest stability. Calibration for conductivity is performed with the conductivity solution in a 25°C water bath. DO (as ODO % saturation) is calibrated by placing the sonde into a container with 100% air saturation (in mg L^{-1}) or that is within ±10% of complete air saturation as determined by winkler titration. Calibration of chlorophyll *a* is performed by use of 0.625 mg L^{-1} solution of the standard Rhodamine WT and by 0 µg L^{-1} calibration. Lastly, pH will be calibrated by use of three NIST pH buffers with known pH levels of 4, 7, and 10. Data generated the sonde are considered acceptable if the parameters return a result of “Green” in the KorEXO software when calibrating. The full calibration protocol of both instruments is detailed in Xylem (2010) and Xylem (2020).

The accuracy of all laboratory analyses will be maintained through use of controls, quality control metrics, and proper calibration of all instruments involved. To ensure the accuracy of the Trilogy fluorometer when measuring total chlorophyll *a* concentrations, the instrument will be calibrated twice annually with a single use liquid standard, along with the use of a blank and solid standard to update the calibration daily. Data generated by the instrument is considered acceptable if replicated measurements of the fluorescence of the solid standard is not significantly different than the provided values of the standard. Fluorescence of the solid standard is considered significantly different than the provided values of the standard if the mean ± standard deviation (SD) of the replicated readings do not overlap with the range of certified value of the liquid certified reference material.

For the CytoFLEX, the two most important factors to consider in terms of accuracy are the maintenance of the flow cytometer and a proper control sample. A quality control test will be performed regularly, which can be accomplished with the use of CytoFLEX Daily QC Fluorospheres to determine the strength and consistency of the lasers within the cytometer. The CytExpert software is used to perform all quality control and maintenance functions, including daily and deep cleans. Quality control tests should be performed prior to analyzing samples. Prior to sampling, a control sample will be created from a culture of *A. anophagefferens*. The concentration of the control will be initially determined via light microscopy and analyzed alongside collected samples to assess accuracy. A full review of calibration methods for the instrument can be found in Beckman-Coulter (2015).

For phytoplankton community composition and fecal coliforms, which are analyses which do not require specific instruments to record data, accuracy and precision are based on best-laboratory practices and/or referral to the appropriate literature. When evaluating phytoplankton community composition, identification of plankton to the highest taxonomic levels possible requires the use of reliable identification guides (e.g., Tomas, 1997). For fecal coliforms, blank sample will be created using sterile, deionized water during each run to ensure the accuracy of the samples, ensuring that the agar plates and materials associated with sample preparation are not contaminated.

The precision of all laboratory analyses, apart from phytoplankton identification, will be quantified through use of sample replication, be they in triplicates or duplicates. Prior to the extraction of volumes of water for each respective analysis, the water collection container should be well-mixed. For samples collected and analyzed in replicate, the relative standard deviation (RSD) between the samples should be less than or equal to 0.25. If the RSD between the samples exceeds 0.25, the relevant samples should be reanalyzed, or the instrument should be checked to ensure that it meets the criteria for accuracy. This will ensure precision of the methods in preparation of the samples.

Apart from the YSI EXO3 and Professional Pro Plus, which have calibration events stored internally, the calibration events of the Trilogy fluorometer and CytoFLEX flow cytometer will be performed according to the criteria listed above and stored in laboratory notebooks as part of the metadata. When calibration events are performed, the date, results, and name of individual that performed the calibration will be recorded in the notebooks.

6.1.2. Bias / Representativeness

Sampling stations will be chosen based on how well they represent a given body of water, and the same location on the station will be used throughout the project to maintain consistency of water samples taken from each station. If water is not collected from a site for a given day, this will be noted. If water is sampled from a different location within the same waterbody, the sampling date and coordinates of the location will be annotated. Any suggestion to change sampling locations within a given waterbody will be conveyed to the PI and PM immediately.

6.1.3. Comparability

For generated data to be comparable to other sources, they need to have been produced by sampling and analytical methods that have similar sensitivity, bias, and scale. The NYSDOH ELAP certifications are an example of adherence to standards and methods, which, if followed, produce comparable data. Other federal sampling programs offer methods that have been recognized as achieving a common standard, for example, the USEPA methods. Detection limits should be reported if a parameter is reported as not detected with detection limit, which is defined as three-times the standard deviation of blank measurements. Where available, we will use qualifier flags. Reporting limits will be compared to regulatory threshold and among the data sources. Data will be deemed not comparable if the reporting limits result in non-detects at environmentally significant concentrations or if they are much higher than other datasets, making them unusable for creating an overall portrait of estuarine conditions.

6.1.4. Completeness

The data generated during this project will be considered complete if all water quality parameters, continuous or discrete, have been accounted for and scrutinized for potential errors or gaps. Completeness includes the full record of replicates of samples collected on sampling dates for the duration of the project. A full record of sample replicates is needed to ensure that statistical analyses are performed to the highest level of accuracy and without bias. If not all replicates of a given sample set will be accounted for when analyzing data, this will be noted.

6.2. Inspection of Supplies and Instrument Maintenance

6.2.1. Inspection of Supplies

All supplies used for laboratory analyses will be washed, disinfected, and visually inspected by field team members prior to distribution and use. Sterile sample bags and coolers will be stored and maintained in a manner ensuring their integrity prior to use. All sample bags or collection containers will be single-use. All containers for samples and associated supplies will be visually inspected for cleanliness and possible contamination prior to use. All sampling supplies and containers will be kept closed until time of sample collection. All laboratory supplies and reagents used in laboratory analyses at Stony Brook University will be inspected for cleanliness and possible contamination by team members performing the analyses prior to use. Reagents are to be stored as advised in proper containers and locations. Laboratory instruments will be stored and maintained in a manner ensuring their integrity prior to use (*see below for details*).

6.2.2. Instrument Maintenance

All instruments used by members of Stony Brook University in this study will undergo routine maintenance and preventative and corrective action. Short-term storage of the YSI Professional Pro Plus handheld unit and YSI EXO3 involves keeping 1 cm of distilled water in the bottom of the calibration cup and tightly securing the instrument to the cup and keeping the instrument upright during storage. All replacement parts (O-rings, bails, sensors, etc.) are to be stored in labeled containers or bags along with the instrument when not in use. A full description of the maintenance and cleaning of the instrument and the individual sensors used on the instrument can be found in Xylem (2010) and Xylem (2020).

The Trilogy Laboratory Fluorometer requires little to no maintenance beyond the cleaning of the cuvette, cuvette holder, and lens with a Q-tip or soft cloth, as well as routine calibration. All spare parts (cuvettes and cables) will be kept in a separate, dedicated drawer located near the instrument in the laboratory.

The CytoFLEX flow cytometer requires daily to yearly maintenance in order to ensure the performance of the instrument. Daily maintenance consists of performing daily cleans following quality control tests and after samples have been run, while monthly maintenance requires deep cleans to be performed. The peristaltic pump should be replaced once every 6 months to 1 year, depending on usage, and should also be labeled with the date that it was changed. The tubing of the peristaltic pump should be changed the same interval or sooner, depending on usage and signs of excessive wear, such as irregular sample flow or inconsistences between replicate samples. Thin wires that are provided with the instrument can be used to clear any clogs that may form in the peristaltic pump tubing. A full description of the maintenance and cleaning of the instrument can be found in Beckman-Coulter (2015).

To ensure proper maintenance and cleaning is being performed, all maintenance-related events (replacement of parts, cleaning, battery replacement, calibrations, etc.) will be recorded in the laboratory notebook for metadata, which will have a section dedicated to the maintenance of all instruments used in the present study. Each entry in the notebook will include the individual performing the maintenance, the instrument being serviced, what maintenance was performed, the date of the event, and any additional notes related to the event.

6.3. Quality Procedure

Weekly meetings will be held with the PQAO and PI. The PQAOwill assess data and, if necessary, determine a need for re-sampling or re-analysis. Scientists familiar with any of the laboratory analyses will also read all data reports.

6.3.1. Review, Verification, and Validation

All data generated from field sampling and laboratory analyses will be subject to review, verification, and validation to ensure that data quality meets an appropriate standard. The data verification process includes the initial review of the master Excel spreadsheet with new additions to ensure that it is accurate and complete as described in the Quality Requirements section (*see above*, *section 6.1.1*). Data validation is the process of reviewing data utility by accepting, qualifying, or rejecting data based on its compliance with the screening criteria defined above. Data values will be assessed individually and in sets to determine if the data are acceptable for use or if some type of qualification is needed, such as repeating the analysis to ensure replicability of the data.

The PQAOwill verify the accuracy of data handling and processing as part of a database audit. Audits will be performed by the PQAO, which will consist of scanning all data for values that appear inconsistent with other datapoints, for example measurements out of the realm of expected results (e.g., salinity > 32; temperature > 35°C) as well as values that are greater than three standard deviations from the mean. As data generated in this project on each day of sampling is not vast in terms of individual data points, all data can be thoroughly audited. If possible, laboratory samples resulting in unusually high or low outputs will be re-analyzed or sampled. High/low results will be determined using standard methods like the 1.5 IQR rule, where a data point is considered an outlier if it is 1.5 IQR above the third quartile or below the first quartile. However, re-analysis may be limited based on holding times and/or amounts of biomass submitted to laboratories for analysis. During the audit, data will be traced to the source files and documentation of data management procedures will be reviewed for completeness. All errors will be tracked within the individual and master Excel spreadsheets that data are placed in by highlighting the error and placing a note and/or comment next to it and any errors that may appear. QA audits will be documented in an audit report to the Principal Investigator. Audit reports will be generated and reported to the PI weekly to bi-weekly, or sooner if the matter is urgent, such as water quality sensors consistently providing measurements out of the realm of expected results and thus requiring immediate calibration and/or maintenance. All errors will be deleted by the PQAO in the final data and a review of the data for similar error types will be conducted to ensure that systematic errors are identified and deleted. Audits of the field and laboratory data will be performed quarterly by the PQAO, including in the beginning of the project to ensure that issues with data are addressed early. Field and laboratory notebooks and data collection forms will be retrieved, and the most recent versions of spreadsheets will be inspected using the criteria described above. Audit assessment reports which include any necessary corrective action taken will be generated.

6.3.2. Validation and Verification Methods

Data validation and verification will occur at multiple stages of this study to ensure that the existing data are relevant and suitable for use. Individuals responsible for leading data collection efforts within each topic will review candidate data according to the criteria defined above (*see above, section 6.1.1*). Assessments will be performed as early as possible to avoid loading data in the database if it is not of adequate quality. Any data deemed unfit for inclusion will be deleted and the reason for exclusion will be documented. All reports will be reviewed for technical content and accuracy. During this review, any results included in the final report will be assessed by comparison to the data to ensure that statistics and summaries are accurately described and depicted. This review will also validate the report contents against the work assignment to ensure that the scope and content of the report achieve the project goals.

7. REPORTING

The PI and PM will produce reports during and at the completion of the project. Progress reports will be generated quarterly and distributed to all participants on the distribution list to verify the accuracy of the deliverables within. Quarterly reports will contain the following:

- Projective goal and objectives up to that point
- Methodology
- Any revisions made to the QAPP during that quarter
- Sample collection and calibration records
- Overall status of the project (current findings made during the quarter, if any)
- QC data

- QA audits
- Next steps in the project

Upon completion of the project, a final report will be generated and will contain the following information:

- Project goal and objectives
- Methodology
- Any and all revisions made to the QAPP
- Sample collection records
- Calibration records
- Raw data (sent to NYSDEC in Excel spreadsheets)
- Laboratory analyses
- QC data
- QA audits
- Problems and corrective actions and resolutions
- Conclusions
- Recommendations and next steps

At the conclusion of the project and final report, all data will be sent to NYSDEC in Excel spreadsheets.

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9. APPENDIX

9.1. Discrete water quality data collection form

LONG ISLAND MARINE MONITORING NETWORK – WATER QUALITY MONITORING FIELD DATA FORM

Sampler	Date	Region	Sampling start time	Sampling end time

Station name	Time	Depth (m)	Secchi (m)	Depth	Temp. (°C)	D.O. (mg/L)	Salinity (ppt)	Biofouling Index 0 None	1 <25%	2 ~50% exchange?	3 >75% Bring In	Notes
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
	Out:			Bottom								
	In:			Surface								
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