Nitrogen Loading to Great South Bay

Management Scenarios

(Report on Phase 2)

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by

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Executive Summary

Nitrogen loading to Great South Bay and its effects on ecosystem health is a concern for a wide range of stakeholders including local, state, and federal agencies and officials. To identify nitrogen loads and sources to Great South Bay, The Nature Conservancy (TNC) of Long Island, New York State Department of State (NYS DOS), and Suffolk County commissioned the first phase of this project in 2006. We found that wastewater is the dominant source of nitrogen to Great South Bay, particularly wastewater from septic systems. Great South Bay's nitrogen load falls in the middle-lower range of estuaries in the US, but it is likely making the bay more susceptible to algae blooms, contributing to the loss of ecologically important eelgrass, and impacting other plants and animals that are susceptible to eutrophication.

In this second phase of work, we explored potential management options to mitigate the nitrogen load to Great South Bay. Specific issues raised by discussion with stakeholders provided the framework for the results described in this report. Modeling results indicated that wastewater continues to be the dominant source of nitrogen to Great South Bay, and more efficient nitrogen removal, either through sewage treatment plants or alternative septic systems, would result in the greatest reduction in nitrogen loading to Great South Bay. With its current level of over 206,000 residences the Great South Bay watershed is very close to build out (based upon current zoning codes), therefore efforts to reduce nitrogen loading require focusing on current nitrogen sources. This was evident both at full and subwatershed scales. All management options must be examined within the context of difficult economic considerations. The most cost effective means of lowering nitrogen loading to Great South Bay may be a combination of actions at different locations throughout the watershed. Although this report presents the nitrogen loading consequences of a variety of management options, it would be useful to explore what suite of nitrogen control options might best suit the various parts of the Great South Bay watershed, adapted to the differences in land cover and existing waste water infrastructure.

Introduction

In response to growing concerns about the nitrogen loading to Great South Bay, in 2006 we were contracted by The Nature Conservancy, New York State Department of State, and Suffolk County to determine the land derived nitrogen load and sources to Great South Bay (GSB). The results of this study on the land-derived nitrogen loads to Great South Bay were completed and were presented in April 2008 and detailed in a final report made to The Nature Conservancy (TNC) and the New York State Department of State (NYS DOS), and Suffolk County. A peer-reviewed version of the report will be published in a future issue of the Journal of Coastal Research (Kinney and Valiela in press).

In the first phase of research we delineated the watershed of Great South Bay and divided it into 33 subwatersheds using the basic principle that groundwater flow is down-gradient and perpendicular to contour lines of ground water elevation (Figure 1). We then utilized land use data from Suffolk County to identify the parameters required to model the nitrogen loads to the subwatersheds and the estuary using the Nitrogen Loading Model (NLM), described in Valiela et al. (1997) and Bowen et al. (2007), and validated in Valiela et al. (2000) and Bowen et al. (2007) (Tables 1 and 2). NLM uses inputs from land use within a delineated watershed, and calculates the fates of nitrogen from wastewater, fertilizers, and atmospheric deposition unto the watershed, and keeps track of the fate of N from these sources as the N traverses soils, vadose zones, and travels in aquifers on its way to receiving estuaries.

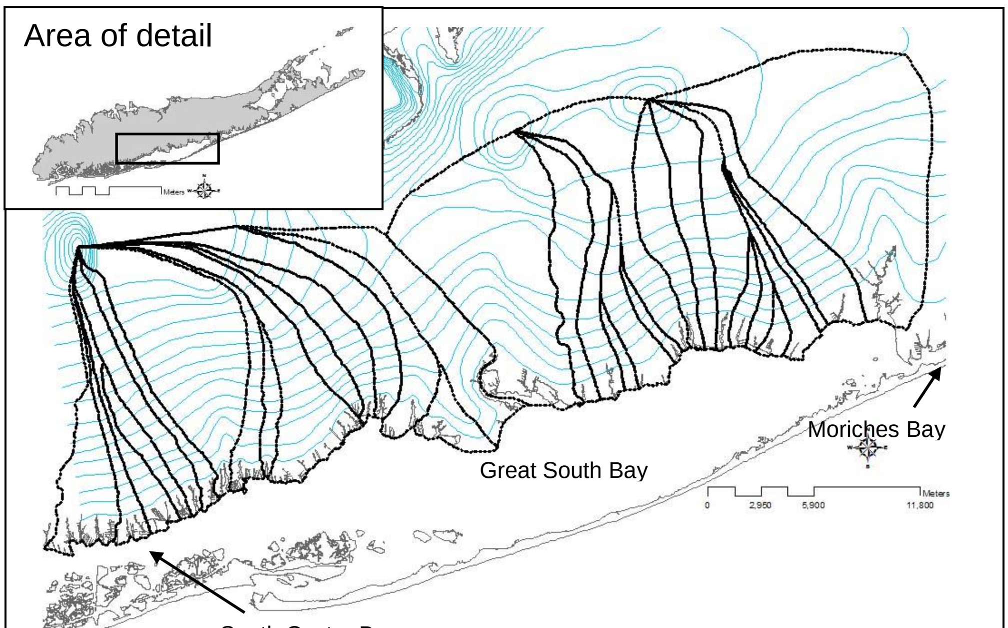

Figure. 1. Watershed and subwatershed delineations drawn by Kinney and Valiela (in press) according to the most recent groundwater contours available from USGS (contours shown in blue).

Table 1. Sources, subsurface nitrogen losses and fate of nitrogen entering the major land covers on the watershed of Great South Bay, and their contribution to the land-derived nitrogen loads to Great South Bay.

Source of nitrogen	Nitrogen loads **to watershed** (kg N yr^{-1})	Percentage of nitrogen load to watershed	% of nitrogen input lost within watershed	Total land-derived nitrogen loads **to Great South Bay** (kg N yr^{-1})	% of land-derived N load to Great South Bay
Atmospheric deposition to:					
Natural vegetation	453,542	13	91	40,241	5
Turf	164,127	5	90	15,810	2
Other agricultural land	3,500	0	90	337	0
Impervious surfaces	451,261	13	75	114,395	14
Wetlands	2,165	0	78	476	0
Total atmospheric deposition	**1,074,595**	**31**	**84**	**171,259**	**22**
Wastewater from:					
Dwellings with septic systems	1,861,791	53	72	530,453	67
Dwellings connected to SWSD	0	0	0	0	0
Dwellings connected to other sewer districts	36,800	1	72	10,354	1
Total wastewater	**1,898,591**	**55**	**72**	**540,807**	**68**
Fertilizer used on:					
Lawns	398,578	11	84	62,139	8
Golf courses	76,878	2	84	11,985	2
Other agricultural land	31,731	1	84	4,947	1
Total fertilizer	**507,187**	**15**	**84**	**79,072**	**10**
Grand total	**3,480,373**	**100**	**77**	**791,138**	**100**
Total N load minus 20% of groundwater flow beneath Great South Bay*				**632,910**	
Atmospheric deposition on to surface of Great South Bay				224,430	
Total N load to Great South Bay				**857,340**	

*Monti and Scorca (2003)

Table 2. Nitrogen loading **to receiving waters of Great South Bay**. These N loads estimate amount of nitrogen from each subwatershed that is delivered to the receiving water for each subestuary. Percent values indicated the relative contribution of each source (atmospheric, wastewater, fertilizer). Yield calculated as N load to receiving water per area of subwatershed.

	N load to watershed (kg N yr^{-1}) and percent contribution to total (%) from the three major sources							
Subwatersheds	Atmospheric		Wastewater		Fertilizer		**Total**	Yield
	(kg N yr^{-1})	%	(kg N yr^{-1})	%	(kg N yr^{-1})	%	**(kg N yr^{-1})**	(kg N yr^{-1} ha^{-1})
Amityville Creek	5,469	32	8,798	52	2,759	16	**17,026**	8
Great Neck Creek	2,171	56	386	10	1,289	34	**3,846**	4
Stongs Creek	2,741	55	433	9	1,766	36	**4,939**	5
Neguntatogue Creek	1,968	62	12	0	1,195	38	**3,175**	4
Santapogue Creek	3,771	70	300	6	1,289	24	**5,361**	3
W. Babylon Creek	2,426	33	1,563	21	3,442	46	**7,430**	7
Carlls River	16,036	17	69,090	74	8,285	9	**93,410**	15
Canals and Samparoams	3,848	34	5,824	52	1,602	14	**11,274**	9
Willetts Creek	1,776	30	3,146	53	1,042	17	**5,965**	10
Kleth Canal to Watchogue	8,106	40	8,766	44	3,177	16	**20,049**	7
Pentaquit	3,061	32	5,556	58	983	10	**9,600**	8
Awixia Creek	4,721	22	14,923	70	1,684	8	**21,327**	13
Orowoc Creek	6,365	19	24,481	73	2,586	8	**33,432**	13
Champlin Creek	5,137	21	16,248	65	3,557	14	**24,942**	13
Quintuck Creek	1,618	81	0	0	374	19	**1,992**	2
Connetquot River West	7,934	20	26,569	67	5,244	13	**39,747**	12
Connetquot River East	20,675	16	96,525	76	9,577	8	**126,777**	15
Green Creek	6,691	20	23,900	71	2,972	9	**33,562**	15
Browns River	4,593	14	25,547	79	2,156	7	**32,296**	19
Bayport creeks	822	14	4,611	80	335	6	**5,768**	19
Stillman, Namker, Hormans Creeks	3,419	19	13,892	76	1,022	6	**18,334**	14
Corey Creek	761	27	1,904	67	178	6	**2,843**	10
Tuthills Creek	8,098	17	37,380	77	3,304	7	**48,782**	16
Patchogue River	5,020	15	27,317	79	2,078	6	**34,414**	18
Little Creek	5,132	15	27,908	79	2,092	6	**35,132**	18
Swan River	4,612	21	16,470	74	1,202	5	**22,284**	12
Mud Creek	1,153	27	2,961	68	211	5	**4,326**	9
Abets Creek	1,017	21	3,514	73	284	6	**4,815**	12
Hedges Creek	684	13	4,146	81	309	6	**5,140**	17
Howells Creek	2,123	18	8,691	75	772	7	**11,585**	14
Motts Brook	1,004	23	3,001	68	422	10	**4,427**	13
Beaverdam Creek	5,154	32	9,853	61	1,036	6	**16,043**	7
Carmans River	23,153	28	47,094	58	11,034	14	**81,281**	7
Total	**171,259**	**22**	**540,807**	**68**	**79,072**	**10**	**791,138**	**11**

We also subtracted 20% of the nitrogen load to the estuary to account for groundwater that flows beneath GSB, directly into the sea (Monti and Scorca 2003) and added direct atmospheric deposition on to the surface of GSB as estimated for the northeastern US by Bowen and Valiela (2001) (Table 1). We found that wastewater is the dominant source of nitrogen to Great South Bay, particularly wastewater from septic systems, which account for 67% of the total land derived nitrogen load to Great South Bay. When nitrogen load was calculated per hectare of estuary, Great South Bay's nitrogen load fell in the middle-lower range of estuaries in the US (Table 3), although it is worth noting that this comparison does not account for the volume of water, rate of oceanic exchange, or rate of fresh water input to these estuaries. It has been shown that nutrient pollution promotes the development and persistence of many harmful algae blooms, (Heisler et al. 2008) contributes to the loss of ecologically important eelgrass (Valiela and Cole 2002), and impacts other plants and animals that are susceptible to eutrophication.

Table 3. Total N loads to estuaries per hectare of estuary in the USA and abroad.

Estuary	N load ($kg\ N\ ha^{-1}\ yr^{-1}$)	Reference
Sage Lot Pond, Massachusetts, USA	14	Valiela et al. (2000)
Moreton Bay, Australia	24	O'Donohue et al. (2000)
Barnegat Bay, New Jersey, USA	24.5-30.1	Bowen et al. (2007)
Pleasant Bay, Massachusetts, USA	25	Carmichael et al. (2004)
Tampa Bay, Florida, USA	28	Bianchi et al. (1999)
Chincoteague Bay, Virginia, USA	31	Boynton et al. (1999)
Great South Bay, New York, USA	**38**	**This study**
Sarasota Bay, Florida, USA	56	Bianchi et al. (1999)
West Falmouth Harbor, Massachusetts, USA	76	Carmichael et al. (2004)
Venice Lagoon, Italy	130	Sfriso et al. (1992)
Roskild Fjord, Denmark	204	Nienhuis (1992)
Bass Harbor Marsh, Massachusetts, USA	225	Kinney and Roman (1992)
Great Bay, New Hampshire, USA	252	Short and Mathieson (1992)
Quashnet River, Massachusetts, USA	350	Valiela et al. (2000)
Wadden Sea, Northern Europe	500	Nienhuis (1992)
Childs River, Massachusetts, USA	601	Valiela et al. (2000)

*Shallow coastal lagoons such as GSB (average depth <2 m) have significantly smaller volume of water per ha than some of the other embayment types listed in this table such as Wadden Sea and Roskild Fjord.

In a second phase of work, we were asked to model potential management efforts that were of most interest to the town, county and state managers in order to mitigate the current land-derived nitrogen loads and respond to potential future increases in loads.

To assess the sort of management options that were of most interest to stakeholders, we presented a list of potential nitrogen management options at a meeting of interested parties in Suffolk County, Long Island on November 10, 2010. The list included: expanding sewered areas of the watershed, allowing the use of denitrifying septic systems, reducing fertilizer use, altering zoning regulations and preserving forested tracts. Given that 68% of the land derived nitrogen load to GSB originates from wastewater sources, we emphasized the importance of considering ways of reducing wastewater nitrogen load.

The result of the November 10 meeting was a list of alternative scenarios relating to how different nitrogen management options might impact the nitrogen load to Great South Bay. The issues included diverse tasks which appear below.

Corrected nitrogen loads from watershed to GSB

After we had completed the nitrogen loads to GSB under phase 1 of this work, (for a full description of the modeled nitrogen load and sources to GSB, see the final report from Phase I of this work and Kinney and Valiela in press) we learned from Ben Write of Suffolk County Department of Public Works that there were approximately 10,900 dwellings within the Southwest Sewer District (SWSD) that were not actually connected to sewers, but had conventional septic systems. To adjust for this correction, we re-ran the model for nitrogen loading to GSB for dwellings that were not connected to sewer pipes, but had conventional septic systems (Table 4). Unfortunately, we were not able to identify the exact location of these dwellings so we were unable to identify the specific subwatersheds where these dwellings not served by the sewage treatment plants were located, except that they were in Suffolk County, within the Southwest Sewer District, and within the western-most 16 subwatersheds. We therefore re-ran the calculation of nitrogen load for the entire GSB watershed rather than recalculating the nitrogen load to each of the subwatersheds of GSB. All other variables in the NLM model (available on the NLOAD website: http://nload.mbl.edu) remained the same.

Table 4. Land-derived N loads to GSB calculated with updated SWSD information.

Source	N load to watershed (kg N y^{-1})	% land-derived N load	% retention within watershed	N load to estuary (kg N y^{-1})	% land-derived N load to estuary
Atmospheric deposition	1,074,595	30	84	171,259	21
Wastewater	2,053,996	56	72	584,533	70
Fertilizer	507,187	14	84	79,072	9
Total	3,635,778	–	77	834,863	
-20% of groundwater flow beneath GSB	–	–		667,890	
Direct atm. Deposition to GSB	–	–	–	224,430	
Total N load	–	–	–	892,320	–

In comparison to the earlier calculation (Table 1), the addition of the 10,900 unsewered dwellings led to the increase of 5% of total land-derived nitrogen load delivered to the estuary, from 791,138 to 834,863 kg N yr^{-1} (Table 4). The total nitrogen load to GSB, including atmospheric deposition directly on the Bay, increased by 4% from previous estimate (Table 4).

The relative contribution by wastewater nitrogen sources increased by 2%, while atmospheric deposition and fertilizer contributions to total nitrogen load did not change. Most importantly, the percent of nitrogen retained within the watershed for each nitrogen source did not change. While 10,900 dwellings may sound like a lot of units, the number of total units in the watershed (206,302) is so large that the correction for the unsewered units did not change overall results very much. Likewise, the relative retention of nitrogen furnished by wastewater still was the lowest compared to retention of atmospheric nitrogen and fertilizer nitrogen with the watershed (Table 4). The large magnitude of the input and the lower retention of nitrogen within the watershed suggest that management of wastewater nitrogen should be the major target of management options.

The total nitrogen load to GSB per hectare of the Bay did not change from 38 kg N ha^{-1} yr^{-1} as a result of the updated SWSD dwellings, so that our assessment of the relative status of GSB among other US and international estuaries did not change (Table 3). GSB still falls within the middle-lower range of nitrogen loads (per unit area) to global estuaries.

Nitrogen removal efficiency of submerged septic systems

Prediction of faster sea level rise in this century created concern among some stakeholders about the consequences if septic systems near shore were to be submerged in rising water tables. We were asked to address the possibility of some conventional septic systems being partially submerged by groundwater. The United States Geological Survey (USGS) has collected data on water table depths less than 5 feet below the surface, which may be within the zone of where septic systems are present (Monti and Busciolano 2009). These shallow groundwater areas fall along the shoreline of GSB, including some highly populated areas, and the concern was that such septic systems might be flooded with groundwater.

Stakeholders were interested in the question of whether partially or fully submerged systems might not process nitrogen as effectively as systems situated above the groundwater table. Research on denitrification in groundwater suggests that the effects of submergence on nitrogen processing would be complex (Bowen et al. 2007, Hiscock et al. 1991, among others). Coupled nitrification/denitrification requires anoxic conditions, but also requires available nitrate, which is only found in oxic environments. The highest rates of denitrification, therefore, occur at the boundary between oxic and anoxic environments. In submerged septic systems, this process may or may not necessarily be disrupted. Denitrification could occur on the boundary of anoxic microzones.

We consulted John Colman of USGS (pers. comm.), who suggested that while there has not been as much study on such "submerged" septic systems, there might not be much decrease in the nitrogen processing capacity as a result of the submergence in groundwater. Submergence might decrease or increase the ability of the bacterial activity to denitrify nitrate. In any case, one might expect that the difference might not be a large one. The same might not be the case for pathogenic organisms. Submergence would most likely increase down-gradient movement of bacteria, and more to the point, viruses. There are studies that report substantial travel of viruses, thousands of feet from a source. Bacteria, being much larger, do not travel as readily, but still, one supposes that submergence would make for easier pathways for water to transport these organisms. Pathogens, which are also delivered through storm water runoff, are a human health concern and much of the waters along the mainland shore of GSB are listed by EPA as use impaired due to the presence of pathogens. Given the number of septic systems currently in shallow depth to groundwater areas, and the potential for additional groundwater or salt water intrusion through sea level rise, more attention and more research on the impacts of submerged septic systems is warranted.

<u>Nitrogen removal efficiency of package treatment plants</u>

At the stakeholder meeting in November, we were asked to update the nitrogen removal efficiencies of the package sewage treatment plants that were used to calculate nitrogen loads (Tables 1 and 4). We used the newest Suffolk County performance evaluation (Doroski and Olsen 2010) to recalculate the performance of the plants in regard to nitrogen removal efficiency. There are 172 sewage treatment plants located in Suffolk County (Doroski and Olsen 2010), only residential plants that discharge within the GSB watershed are included here.

We used estimated nitrogen influent concentrations of 50-70 mg N l^{-1} and the published average effluent concentrations for each of the residential sewage treatment plants within the Great South Bay watershed, to calculate the nitrogen retention for each sewage treatment plant serving dwellings within the Great South Bay watershed. Only residential plants are considered in our analyses to avoid double counting (Kinney and Valiela in press). We then used the arithmetic mean of the nitrogen retention values to calculate how much wastewater-derived nitrogen would be entering the watershed from these residential package sewage treatment plants (Table 5, Doroski and Olsen 2010).

Table 5. Package sewage treatment plants (STPs) serving dwellings within the GSB watershed (Doroski and Olsen 2010).

STP Name	TN (mg/l) Average for all samples analyzed in 2008	% N removal efficiency
Patchogue**	(not available)	
Strathmore Huntington	3.2	95
Twelve Pines*	3.3	95
Woodside*	6.6	89
College Park*	1.5	98
Selden*	3.4	94
Holbrook/Birchwood*	4	93
Parkland*	2.7	96
Nob Hill*	4.6	92
Coventry Manor*	5.1	92

* additional N removal treatment
** The Patchogue Village STP discharges into the surface waters of Patchogue River, We were unable to obtain the information necessary to estimate this plants retention efficiency or to estimate the potential impacts of adding tertiary treatment to this plant.

The result of the updated estimate was that package sewage treatment plants serving dwellings within the GSB watershed averaged 93% nitrogen removal efficiency (Table 5). This is a rather high estimate, but 9 of the 10 package sewage treatment plants with available effluent concentrations include some additional nitrogen removal treatment. This tertiary treatment removes much more nitrogen than secondary sewage treatment plants (Bowen and Valiela 2004). These 9 residential plants within the GSB watershed have lower nitrogen concentrations in their effluent than does the average plant in Suffolk County as reported in Doroski and Olsen 2006, 2010). We were unable to obtain the information necessary to estimate the retention efficiency or to estimate the potential impacts of adding tertiary treatment to the Patchogue Village plant which discharges directly to the surface waters of Patchogue River.

<u>Reducing current nitrogen from wastewater and fertilizer</u>

The next questions raised by the stakeholders related to reducing nitrogen loads by management of wastewater and fertilizer inputs. For wastewater, we were asked to explore 1) expanding the number of dwellings connected to sewage treatment plants, and 2) requiring homeowners to install alternative septic systems like those used by State of New Jersey Pinelands Commission (2010). Fertilizer might be reduced by regulating doses that are allowed on lawns and golf courses.

Wastewater

- *Effect of expanding current sewer districts*

As mentioned above, there are 10,900 dwellings within the SWSD that are not currently connected to the sewage treatment plant. If those were to be connected, the total land-derived nitrogen load to GSB would lowered by 5% (Table 6). Next, we modeled the potential impact of the expansion of current sewer districts, obtained from Suffolk County (Figure 2). Expansion of sewer pipes into these areas is currently being explored by Suffolk County.

To calculate the potential impact of these proposed sewer districts, we assumed that the expansion of the Southwest Sewer District (Figure 2, largest blue and green areas on left) would divert effluent away from discharge within the watershed altogether. For the package sewer districts, we assumed a nitrogen removal efficiency of 93%, the current average for existing package sewage treatment plants on the Great South Bay watershed. The effect of these additional sewered areas was an 8% reduction in total N load to GSB (Table 6).

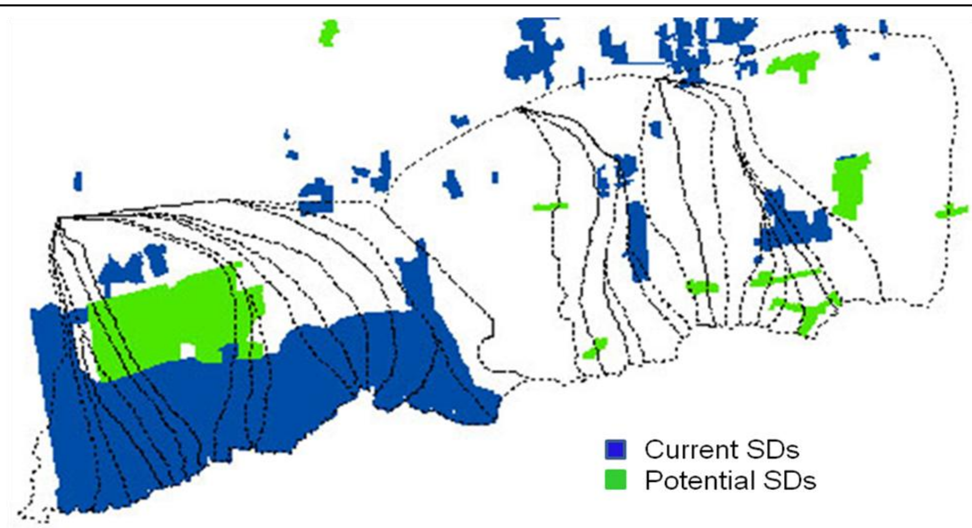

Figure 2. Great South Bay subwatersheds (black lines) with current sewer districts (blue) and proposed new and expanded sewer districts (green). Image courtesy of Suffolk County.

- *Effect of targeted sewering of dwellings nearer GSB*

Another method to address wastewater management that could reduce costs might be to only target areas near shore. This alternative is based on previous modeling results elsewhere that anticipate that dwellings within 200 m of shore would make relatively larger contributions to nitrogen loading to water bodies such as GSB than dwellings with septic systems farther away. In addition the shorter ground water travel times in areas close to shore would result have a more immediate impact to surface waters. We modeled the N load in response to sewering areas within 200 m of the shoreline, assuming that nitrogen removal efficiency would continue to average 93%, and found that nitrogen loading to GSB would be lowered by 2% if all dwellings within 200 m of the shoreline were sewered (Table 6). If sewering of dwellings within 200 m were to be combined with the proposed sewer districts, the total nitrogen load to GSB would be lowered by 12% (Table 6).

An additional alternative proposed by stakeholders was to target areas within 1000 m of the shoreline, which would include most of the septic systems that might be affected by the shallow water table depths (Monti and Busciolano 2009). Modeling of this alternative suggested that nitrogen loading to GSB would be lowered by 14% if all dwellings within 1000 m of the shoreline were connected to sewage treatment plants (Table 6). If sewering of dwellings within 1000 m were to be combined with the sewer districts already proposed by Suffolk County, the total nitrogen load to GSB would be lowered by 22% (Table 6).

- *Effect of sewering different percentages of dwellings*

As an alternative to targeted sewering of areas within the GSB watershed, such as the examples discussed above, we replaced the way wastewater is disposed by connecting dwellings currently served by conventional septic systems to a sewage treatment plant. To define the nitrogen load reduction resulting from different percentages of dwellings sewered, we simulated nitrogen calculations for 0, 10, 20, etc. percent of dwellings if they were connected to sewers. We found that the total nitrogen load to GSB could be reduced by 25% if 40% of dwellings were sewered, and up to 58% if 90% of dwellings were connected to sewers (Figure 3).

Table 6. Lowering of N load due to changes in wastewater treatment and fertilizer dose

Option	**% Lower N load**
Sewering of 10,900 dwellings in SWSD	5
Potential new sewer districts	8
Dwellings within 200 m sewered	2
Dwellings within 200 m sewered + new sewer districts	12
Dwellings within 1000 m sewered	14
Dwellings within 1000 m sewered + new sewer districts	22
40% dwellings sewered	25
60% dwellings on alternative septic systems	25
80% dwellings sewered	50
50% reduction in fertilizer dose on lawns + golf courses	4

- *Effect of converting existing conventional septic systems to newer designs*

There is much literature on novel in situ septic treatment designs with greater potential to intercept nitrogen (Table 7, State of New Jersey Pinelands Commission 2010, Bowen and Valiela 2004). Conventional septic systems retain about 40% of nitrogen (Valiela et al. 1997), while the novel designs may retain 65 – 90% (State of New Jersey Pinelands Commission 2010, Bowen and Valiela 2004).

We modeled the N load in response to converting 0 – 90% of current dwellings from conventional septic systems to alternative septic systems, using an estimated 65% nitrogen removal by alternative septic systems (State of New Jersey Pinelands Commission 2010). We found that by converting 60% of dwellings with conventional septic systems to alternative septic systems functioning like those used by the New Jersey Pinelands Commission, the nitrogen load to GSB could be reduced by 25%, and converting 90% of dwellings to alternative septic systems could reduce the load by 40% (Figure 3).

Table 7. N loads to estuaries per hectare of estuary in the USA and abroad (from Bowen and Valiela 2004, State of New Jersey Pinelands Commission 2010).

Alternative Wastewater Treatment	% N retention		Source	Reference
	Mean	Range		
Conventional system	39	10 - 90	Various published estimates	Valiela et al. (1997)
Peat filters[1]	43	30 - 65	6 in situ systems in Massachusetts	Heufelder and Rask (2001)
Trickling filters[2]	54	22 - 86	Various systems	Stokes (2000)
Recirculating sand[3]	64	59 - 70	Mean from 4 systems in Maryland	Piluk and Peters (unpublished data)
RUCK[4]	88	66 - 99	Mean from 6 systems in Massachusetts	Rask (1998)
Amphidrome, Bioclere, FAST	65		Observed efficiency	NJ Pinelands Commission (2010)

1 In peat filters effluent is passed through roughly a meter thick layer of peat before entering the leaching field, providing a carbon rich source for bacterially-mediated N removal.
2 In trickling filters effluent leaves the septic tank and enters a filtration unit that contains some form of synthetic medium to promote nitrification. Many trickling filters are available that use different media with varying results.
3 Recirculating sand filters send effluent through a sand filter, after which a portion of the effluent is sent to the leaching field, and the remainder of the effluent is sent back through the sand filter.
4 RUCK systems separate black water from septic system waste from the gray water that is the waste from sinks, showers, and other nonseptic wastewater. The black water flows through the RUCK filtration system and is then added to the gray water and pumped to the leaching field.

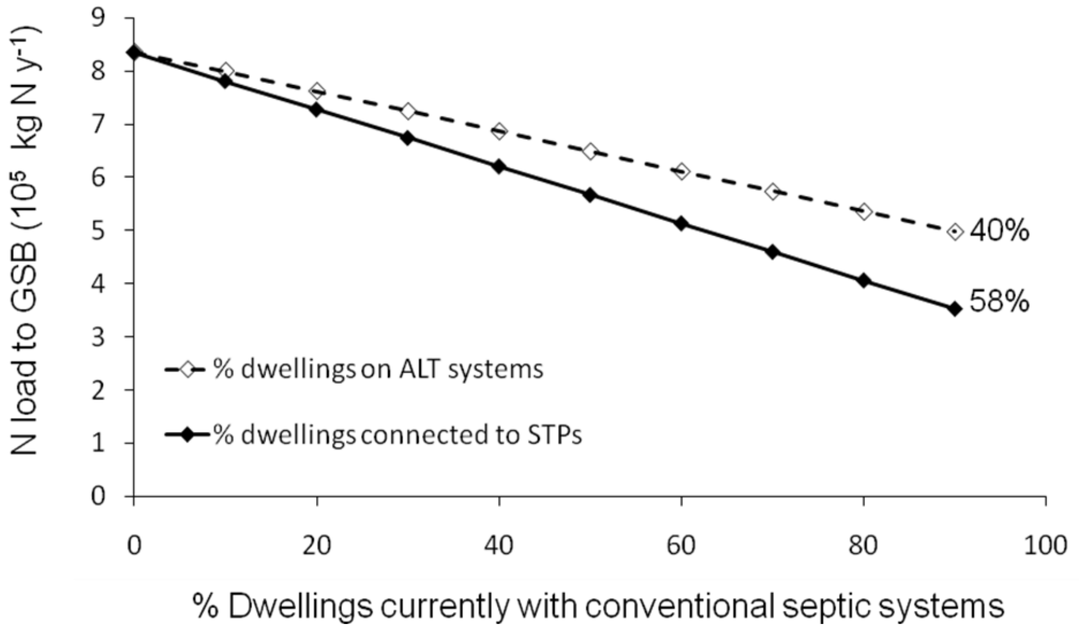

Figure 3. N loads to GSB when percentage of currently unsewered dwellings are connected to sewage treatment plants (closed symbols) compared to N loads when percentage of currently unsewered dwellings are connected to alternative septic systems with 65% nitrogen removal efficiency (open symbols). Percentages on figure represent lowering of nitrogen load as a result of 90% of dwellings being converted.

Not surprisingly, nitrogen loading was reduced more by sewering than by use of alternative septic systems (Figure 3, Table 6). The maximum potential reduction in N load resulted from connecting dwellings to package sewage treatment plants. Wastewater was by far the largest contributor to total nitrogen load, and reductions in wastewater nitrogen had the largest effect on lowering total nitrogen load.

Fertilizer

- *Effect of reducing fertilizer dose to lawns and golf courses*

The nitrogen load contributed by fertilizer use in the GSB watershed added only 9% (Table 6) of the total estuarine nitrogen load, so management of fertilizer use has a limited potential. Nevertheless, because any amount of nitrogen reduction could be worthwhile, control of fertilizer use should be explored. To define the effect lowering the fertilizer dose on lawns and golf courses might have on GSB nitrogen load, we modeled the nitrogen load in response to reducing fertilizer dose to lawns and golf courses by 0 – 90% (Figure 4). A 50 % reduction in dose resulted in a 4% lowering in GSB nitrogen load, while a 90% reduction in dose resulted in a 7% lowering of GSB nitrogen load (Figure 4, Table 6).

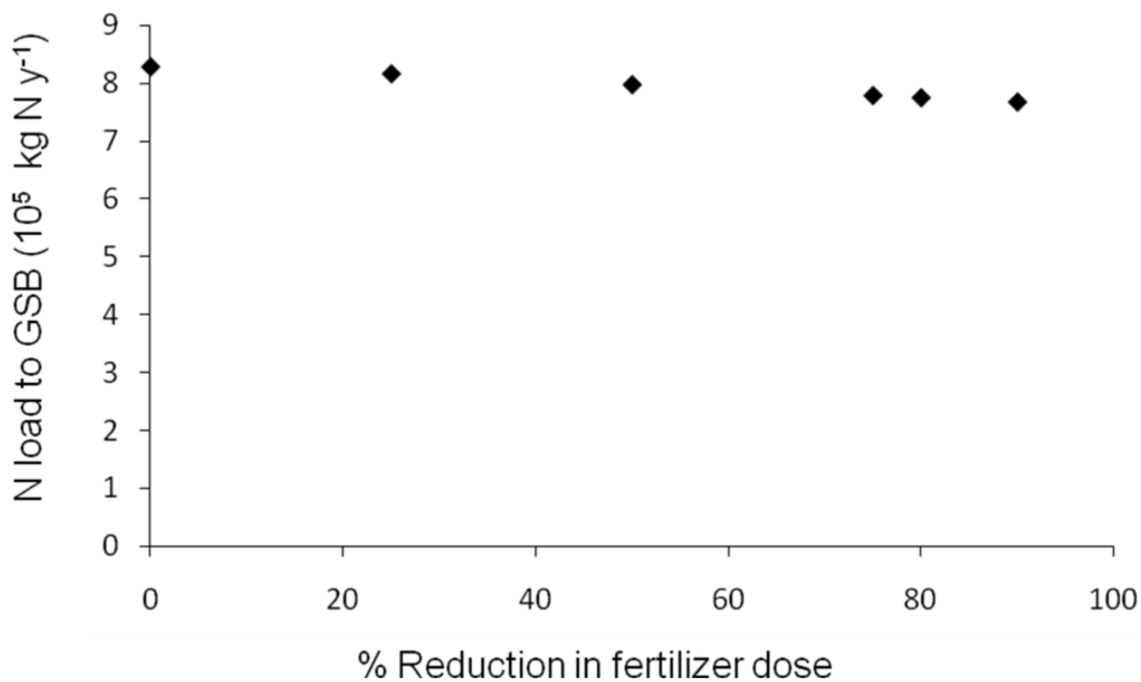

Figure 4. N loads to GSB when fertilizer dose to lawns and golf courses is reduced.

Effects of build out within the watershed of GSB on nitrogen load

In any coastal watershed, there is some potential for addition of wastewater by further construction of building units. It is useful to anticipate what contribution to nitrogen load might result from build out to the current legal limit of construction. Modeling the nitrogen load at such a build out level might tell stakeholders what conditions in the receiving water body might result. By knowing the mechanisms of build out that contribute to increased nitrogen loading, we can assess the options available for mitigating the effects of increased nitrogen loads.

Defining build out potential

To obtain a build out nitrogen load for GSB, we used the GIS files generated with the 2009 report on Land Available for Development and Population Analysis (Suffolk County Department of Planning 2009) to identify the residentially zoned parcels that were available for development in the GSB watershed. To provide a baseline of potential residential development we contacted the Suffolk County Department of Planning to discuss reasonable parameters for likely maximum build out. As a result of our discussion, we considered only residential lots larger than 6,000 ft^2 for development, as that size is the minimum allowed in Suffolk County without a variance. To determine whether a lot could be divided for development, we assumed that any lot larger than 1 acre could be subdivided. Lots larger than 1 acre were considered sub-dividable according to the “yield factors” listed in Table 9-2 of the 208 report (Koppelman 1978). Yield factors take into account roads and infrastructure required for subdivision of a lot. For the town of Brookhaven, where the lots are typically larger, we used 1/2 acre zoning or a yield factor of 0.8 lots per acre. For lots in the towns of Babylon, Huntington, Islip and Smithtown, where lots are typically smaller than those in Brookhaven, we used a yield factor for 6,000 ft^2 lots, which is 4.5 lots per acre. Building dwellings on available residential lots as described above would result in an additional 6,995 dwellings in the GSB watershed.

Effect of build out for entire watershed of GSB

Future regulations of new dwellings could potentially be written to reduce additional nitrogen loading to GSB. To examine the effect of the new dwellings on nitrogen loading to GSB, as well as how different management options might be applied to new dwellings, we modeled the nitrogen load to Great South Bay with three different assumptions: 1) that all new dwellings would have conventional in situ septic systems, 2) that all new dwellings would be connected to package sewage treatment plants like those currently operating in the GSB watershed, 3) that all new dwellings would be required to have newer alternative septic systems (Table 8).

Building 6,995 new dwellings would result in a total land-derived nitrogen load to GSB of 881,969 kg N yr^{-1}, a 5% increase from the current land-derived load of 834,863 kg N yr^{-1}. The total nitrogen load to GSB (including atmospheric deposition) would increase 4% to 930,005 kg N yr^{-1} from 892,320 kg N yr^{-1}. These small increases in nitrogen load, speak to the fact that the watershed of GSB is very near build out, as there are currently 206,302 dwellings on the GSB watershed, a number much larger than the potential for new construction. Even if all new dwellings were to be connected to sewers or alternative septic systems, those changes would result in only a 3% reduction in build out nitrogen load (Table 8).

Modeling build out scenarios with fertilizer changes

We also examined how changing fertilizer dose regulations for lawns and golf courses, might mitigate the increases in nitrogen loading from build out. A 25% reduction in fertilizer dose to the entire watershed could reduce the total nitrogen load to GSB after build out by 3%. This is a relatively small reduction in total nitrogen load, but it would be equivalent to the effect of sewering of all new dwellings (Table 8).

Table 8. Percent lowering of build out nitrogen load to GSB as a result of changes to wastewater and fertilizer use.

Option	**% Lower N load**
All new dwellings are sewered	3%
All new dwellings on alternative septic systems	3%
25% reduction in fertilizer dose (total watershed)	3%

The results of modeling the nitrogen load at build out indicate that the only way to substantially reduce to the nitrogen load to GSB is to focus on the current sources of nitrogen, the largest contributing source being wastewater.

Effects of build out within the subwatersheds of GSB on nitrogen load

In addition to the effect of build out on the entire watershed of GSB, we were asked to model the effects of build out on the N load from specific subwatersheds. To provide a view of the magnitude of the potential addition of dwellings that could be present at build out, we plotted for each subwatershed, the current number of dwellings that the predicted number at build out (Figure 5). In all cases, more development could appear (the points lie above the 1:1 line in at

Figure 5), but the additions are small compared to the current dwelling number. This again points to how near build out the watershed of GSB is. We identified the subwatersheds with the largest potential for added dwellings from Figure 5 and to tease apart the differences before and after build out, we calculated the percent increase in dwellings at build out, and identified those subwatersheds with a greater than 5% increase (Figure 6). These were, not surprisingly, the eight eastern-most subwatersheds within the GSB watershed. The increase in nitrogen load from the subwatersheds to GSB was highest for the Carman's River watershed (Figure 6), which was four times higher than the next highest watershed, Swan River. In all of the subwatersheds, wastewater was the largest source of land derived nitrogen.

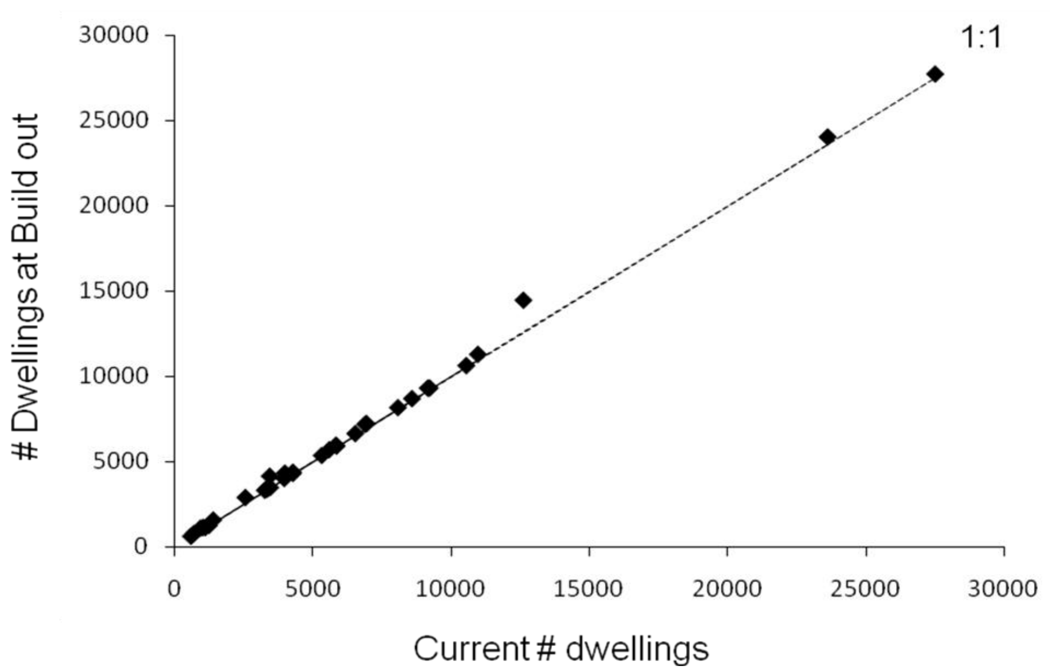

Figure 5. Number of dwellings before and after build out in the subwatersheds of GSB compared to a 1:1 line.

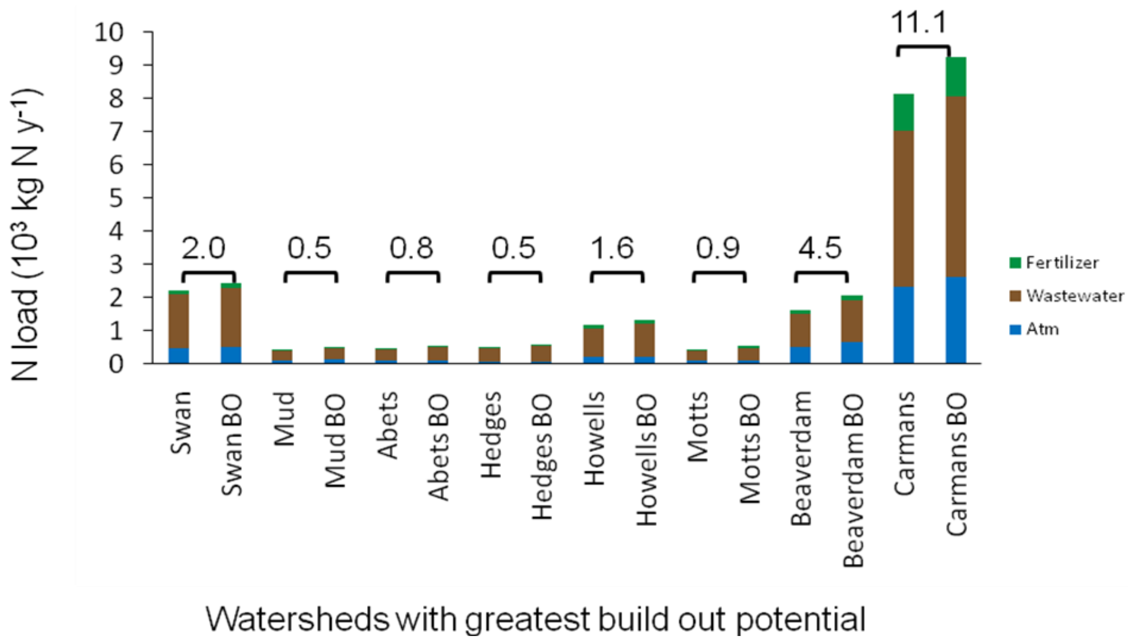

Figure 6. Nitrogen loads to GSB from subwatersheds with the highest percent build out potential before and after build out (BO). The magnitude (10^3 kg N yr^{-1}) of the resulting increase in nitrogen load is the number above each pair of bars. Relative contribution of nitrogen sources are indicated by color: blue = atmospheric, brown = wastewater, green = fertilizer.

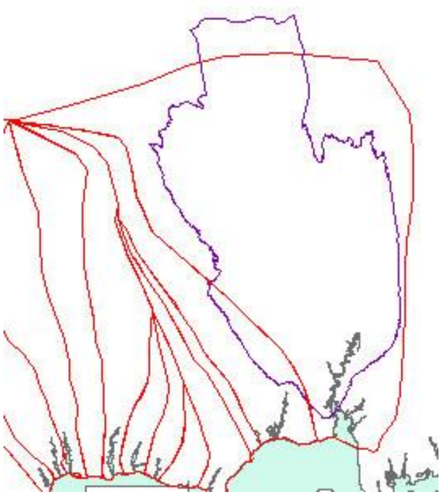

Figure 7. Our Carman's River watershed delineation (red) and CDM's Carman's River delineation (purple) (CDM).

Effects of build out on the Carman's River watershed

For further investigation of build out on the Carman's River watershed, ran the same build out scenarios relating to wastewater treatment options and conversion of agricultural lands to natural vegetation, but for the watershed area delimited by the consultants at CDM, as this area is currently being used as part of the Comprehensive Water Resources Management Plan developed for Suffolk County (Figure 7). The area is different in shape from the watershed boundary we defined using hydrogeologic principles. The watershed delineated by CDM is implausible on hydrologic principles, but nevertheless, we used that delineation to capture land uses. The nitrogen loads from the different boundaries are similar and increase with build out (Table 9). Using CDM's boundary, we calculated the effect of different wastewater and fertilizer nitrogen management options (Table 10). The results show that changes to wastewater treatment of new build out dwellings would have little impact on the total nitrogen load to GSB.

Table 9. Nitrogen loads to GSB from the Carman's River watershed before and after build out, using our watershed delineation and that developed by CDM.

Delineation	Current N load kg N yr^{-1}	Build out N load kg N yr^{-1}	% increase
Kinney and Valiela	81,281	92,408	14%
CDM	67,419	77,730	15%

Table 10. Percent lowering of build out nitrogen load to GSB as a result of changes to wastewater and fertilizer use on the Carman's River subwatershed (CDM boundary). Magnitude changes are from the current nitrogen load and are expressed as the percent of the total nitrogen load to GSB.

Option	**% Higher N load**	**Magnitude (kg N y^{-1})**	**% Total GSB N load**
Build out with conventional septic systems	15	+10,310	1.2
Build out with sewers	7	+4,867	0.6
Build out with alternative septic systems	10	+6,506	0.8
Build out with all agricultural land converted to natural vegetation	8	+5,337	0.6

<u>Effects of different development strategies on nitrogen loading from a hypothetical 200 acre parcel</u>

In any development of land parcels, zoning restrictions, or allotment of land by planners, can result in different nitrogen loads, depending on number of septic systems, fertilized lawns, impervious surfaces, and clustering of dwellings. To assess, in a preliminary way, the magnitude of the resulting difference in development plan on nitrogen loads to a receiving water body, there was interest in knowing what the nitrogen load from a 200 acre parcel would be if it was developed in 2 different ways:

1. 100 dwellings, 65% of the parcel would be fertilized lawn, 35% of the parcel would be impervious surfaces
2. 100 dwellings, 75% of the parcel would be left as natural vegetation, 12.5% of the parcel would be fertilized lawn, 12.5% of the parcel would be impervious surfaces

These scenarios were conducted to provide some indication of the relative role of cluster development, impervious surfaces or lawns on nitrogen load. We modeled the nitrogen loads from these two scenarios, and also considered the additional possibilities that all dwellings were within 200 m of the shoreline, and that the fertilizer doses were reduced by 50%, to show the relative effect of those added differences in design on the nitrogen load. For comparison, we also plotted the nitrogen load from the 200 acres if the entire area was left forested and no dwellings were built.

There were significant differences in the nitrogen loads that resulted from these different scenarios. The nitrogen load from the deforested parcel (1) had a 54% higher nitrogen load than the mostly forested parcel (2) (Figure 8). If all dwellings were within 200 m of the shoreline, the nitrogen load from the 200 acre parcel increased by 193 kg N yr^{-1} in both scenarios. A 50% reduction in fertilizer dose reduced the nitrogen load from the 200 acres by 32% in scenario 1, and by 13% in scenario 2.

Overall, clustering dwellings, and leaving 75% of the area forested reduced the nitrogen load more than reducing the fertilizer dose or moving the dwellings away from the shoreline.

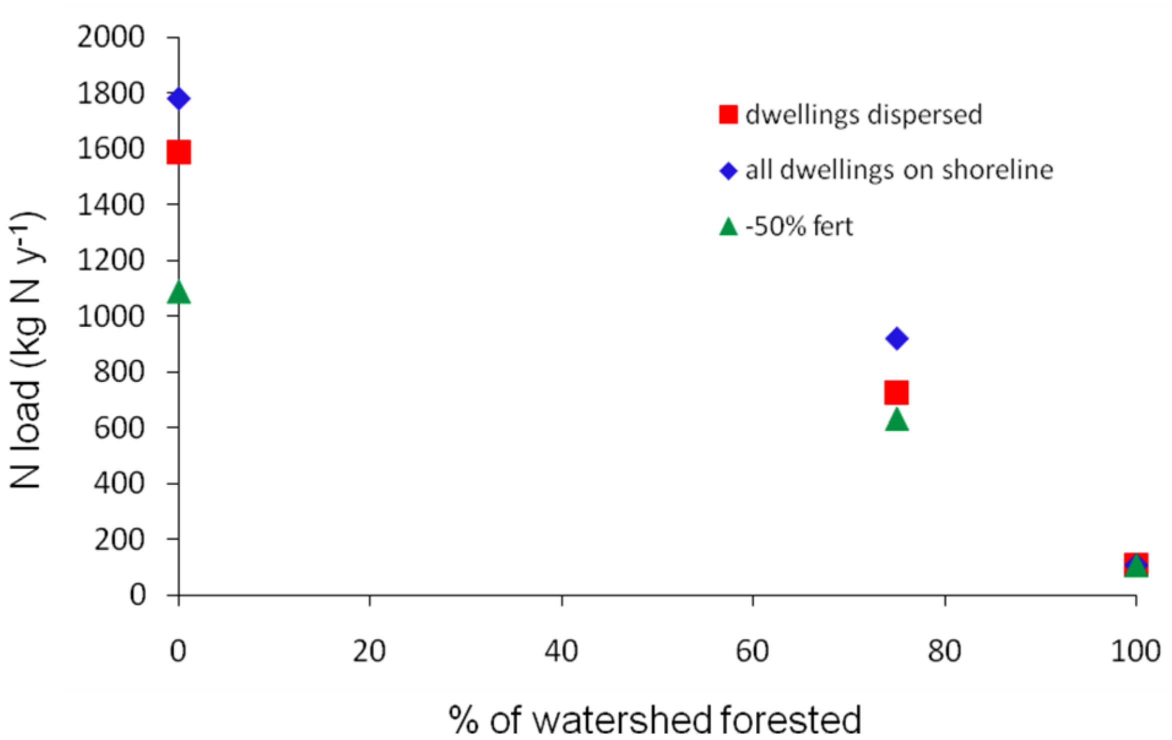

Figure 8. Nitrogen loads from hypothetical 200 acres developed according to 2 different scenarios and with all dwellings within 200 m of shoreline (“on shoreline”) or with a 50% reduction in fertilizer dose to lawns (-50% fert). A third scenario, far right, is the nitrogen load from the 200 acres if the area was left forested and no dwellings were built.

Conclusions

In phase 1 of our assessment of nitrogen loading to Great South Bay, GSB was found to have a nitrogen load of 38 kg N ha^{-1} yr^{-1}, a value which did not change with a correction to the number of dwellings connected to the Southwest Sewer District (Tables 1 and 4). The impact of that nitrogen load confirmed that GSB falls within the middle-lower range of global estuaries (Table 3), elevating its susceptibility to harmful algae blooms (Heisler et al. 2008) and placing it at risk for losing more of its valuable seagrass beds if nitrogen loads continue to increase (Valiela and Cole 2002).

GSB’s watershed is currently very close to build out, as are most of the 33 subwatersheds, therefore focusing on reducing current nitrogen loads would do more to lower the nitrogen loading to GSB than focusing on potential future dwellings at build out. In all cases, current and build out, wastewater is by far the dominant nitrogen source to GSB and should be the focus of efforts to reduce nitrogen loading. Expansion of the current package treatment plants, which removed 93% of nitrogen from influent, could have a large impact on the nitrogen loading to GSB. Alternative septic systems, have been successfully implemented by the New Jersey Pinelands Commission, and could be effective in reducing the nitrogen loading to groundwater and to GSB.

From our examination of the land cover in each subwatershed, we know that the distribution of different land uses (forest, agriculture, impervious surfaces, residential area, etc.) vary for one subwatershed or general area of the watershed of GSB. The sharp contrast in land cover suggests that somewhat different suites of nitrogen control options might be best suited for different areas of the watershed of GSB.

Acknowledgment that land cover, and use of coastal resources are spatially heterogeneous underscores the value of utilizing spatially explicit planning as a tool for environmental management of land- and sea-scapes. Rather than adopting one fits-all solution (for example, sewering the whole area), it would be useful to explore what suite of nitrogen control options might best suit the various parts of the GSB watershed, adapted to the differences in land cover. Such explorations might end up with more economical and ecologically acceptable means of addressing eutrophication issues.

It is obvious that all the options need scrutiny in the context of difficult economic considerations. The mix of spatially explicit solutions might provide less costly measures. Additionally, a number of other methods have been proposed deal with waste nitrogen, which we have not mentioned in this report (e.g. composting toilets, Clivas Multrum systems, shellfish mariculture, and others). It would be useful for the stakeholder community of GSB to consider these options which might be less costly.

Acknowledgments

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