Assessment of Nitrogen Loading and Nitrogen Management Alternatives for the Little Bay Watershed (Fairhaven & Acushnet, MA)

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by

Joseph E. Costa, Ph.D. Executive Director
Mark P. Rasmussen[1], Regional Planner

Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, East Wareham, MA 02538

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[1] Current Address: Coalition for Buzzards Bay, 17 Hamilton St., New Bedford, MA 02740

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Executive Summary

Little Bay is a 208-acre shallow embayment located on the eastern side of Sconticut Neck in the Town of Fairhaven, and represents the innermost portion of Nasketucket Bay. The Nasketucket River provides the primary source of freshwater inputs to Little Bay. While shellfish habitats are abundant in Little Bay, the area is under Conditional Closure to shellfish harvest due to elevated bacteria levels following rain events. Single family residential and commercial properties, farms, and open forest lands comprise the majority of land uses within Little Bay's 3,006 acre watershed. There are no point source discharges of pollution to the bay. The Fairhaven Wastewater Treatment Facility is located in the Little Bay watershed, but it discharges to the Acushnet River.

In Buzzards Bay, as in most coastal waters, nitrogen is the nutrient that usually limits the growth of algae. Increased supplies of nitrogen from an embayment's watershed threaten water quality in many areas by stimulating rapid growth, or blooms, of algae which often lead to decreases in water column oxygen levels. Other effects of excessive nitrogen inputs include alteration of coastal ecosystems such as the replacement of eelgrass beds with macroalgae, reduction in water clarity, and loss of shellfish habitat. Poorly flushed, shallow, semi-enclosed embayments such as Little Bay are most susceptible to excessive nitrogen loading.

Six water quality stations have been monitored in Little Bay at various times by the Buzzards Bay Project-Coalition for Buzzards Bay Citizens Water Quality Monitoring Program between 1992 and 1997. In comparison to other Buzzards Bay embayments, nutrient concentrations are higher in Little Bay than most Buzzards Bay harbors and coves monitored.

In order to estimate the natural ability of Little Bay to assimilate nitrogen loading from its watershed, the Buzzards Bay Project funded a flushing study of the embayment in the summer of 1996 (Geyer et al., 1997). This study was compared to the nitrogen management approach outlined in the Buzzards Bay Comprehensive Conservation and Management Plan to establish the Critical Nitrogen Limit for the bay. This amount represents the extent of nutrient loading that can occur in Little Bay without the embayment suffering declines in water quality and living resources.

A buildout analysis and nitrogen loading evaluation were conducted. The buildout analysis indicated that there are currently 1,273 dwellings located in the Little Bay watershed. Under current zoning, these numbers could increase to 3,621 dwellings if all available land were built out.

The nitrogen loading assessment suggested that under existing conditions, the critical load to the bay has not been exceeded. However, the estimated nitrogen load to Little Bay from the watershed at buildout (22,281 kg/yr) is 1,001 kg/yr greater than the calculated critical load (21,280 kg/yr). This suggests that there must be 120 fewer residential dwelling units at buildout conditions than programmed under existing zoning, so that the nitrogen critical load is not exceeded in the future.

Based on this information, options for the management of the nitrogen inputs to Little Bay were examined and recommendations were made. With the exception of nitrogen inputs from atmospheric deposition, all of the sources of nitrogen entering Little Bay can be controlled by the Towns of Fairhaven and Acushnet. The two largest sources of nitrogen in the watershed were found to be

residential dwellings and dairy farms. Zoning techniques, such as increasing minimum lot size in the area to reduce build-out densities, were not recommended as absolutely necessary to reduce the future nitrogen load to the Bay. Greater benefits are likely to result from non-regulatory actions such as selective acquisition or transfer of undeveloped lands in the watershed to permanent open space, and through sewering additional portions of the watershed. Other specific examples of town actions to reduce nitrogen loading were presented.

Introduction

Background

In 1995 the Buzzards Bay Project, part of the National Estuary Program and a unit of Massachusetts Coastal Zone Management, completed a report entitled "A Buzzards Bay Embayment Subwatershed Evaluation: Establishing Priorities for Nitrogen Management Action." In this report, the existing and projected future nitrogen load to 30 embayments throughout the bay were evaluated relative to their capacity to assimilate nitrogen without suffering water quality degradation and declines in fish, shellfish, and other coastal habitats. The results of this evaluation provided our first estimate as to the extent of eutrophication in each embayment as well as the potential to effectively manage future nitrogen loadings. Nasketucket Bay, which included Little Bay (Fig. 1), was included in this evaluation.

In the Buzzards Bay CCMP, the Buzzards Bay Project recommended that before municipalities take action to manage nitrogen reaching embayments identified as threatened or impacted in the study, more detailed information should be collected. First, we recommended that a more detailed study of nitrogen be conducted using parcel information (zoning, wetlands, and actual acreages). Second, we recommended that a more detailed study of embayment flushing be conducted. These needs were particularly important for embayments that were either at or near their critical loading limit at the time of the report or had significant local conditions that merited additional investigation. Little Bay in Fairhaven was one of these areas.

The negative impacts of excessive nitrogen loading are usually most acute in the shallow, poorly flushed portions of an embayment. One of the limitations of the Subwatershed Evaluation's analysis was that it considered the several complex large bays in aggregate. In the case of Little Bay, it was included in a larger discussion of Nasketucket Bay which is well flushed with the waters of Buzzards Bay. For this reason, we recommended that the Town of Fairhaven work with the Buzzards Bay Project to focus in on Little Bay - the most sensitive portion of the Nasketucket Bay system - and conduct further investigations.

In 1996, the Town completed a preliminary build-out analysis of the watershed to Little Bay in order to estimate future nitrogen loads to the bay from residential development. In the same year, the Buzzards Bay Project contracted with Offshore and Coastal Technologies to perform field measurements to determine the tidal flushing rate in Little Bay. Both pieces of information were critical to the development of a thorough evaluation of

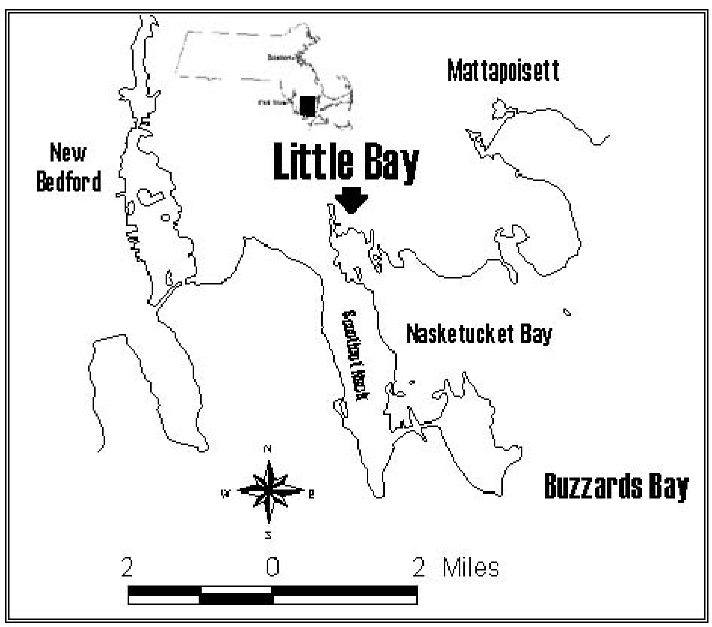

Figure 1. Locus map of Little Bay in the Town of Fairhaven.

the effects of anthropogenic nitrogen loading to Little Bay.

This study represents the synthesis of these planning and scientific investigations and describes nitrogen loading assessments for land uses within the watershed to Little Bay. The total nitrogen loads, both existing and future, are compared to the ability of the Bay to assimilate nitrogen without damage to natural resources. Finally, management options are presented.

The Problem with Nitrogen

In Buzzards Bay, as in most coastal waters, nitrogen is the nutrient that usually limits the growth of algae. Algae include macroalgae or "seaweeds," and microalgae such as phytoplankton, which form the base of many marine food webs. Increased supplies of nitrogen threaten many embayments within Buzzards Bay by stimulating rapid growth, or blooms, of both. These blooms can limit the transmission of light reaching eelgrass (*Zostera marina*) leaves, resulting in loss of eelgrass beds which are some important in providing habitat for shellfish and other animals. Dense layers of macroalgae accumulate on the bottom of some shallow bays and exclude and/or smother shellfish and other invertebrates, destroying valuable shellfish habitat. For example, quahogs cannot pump food and oxygen-bearing water through their body if a layer of algae covers the bottom. The effects of excessive nitrogen also include replacement of eelgrass beds with macroalgae, declines in water transparency, and loss of shellfish bed habitat.

In addition, decay of macroalgae causes unpleasant odors and depletes oxygen in the water. Severe oxygen depletion can kill fish and shellfish. There is also evidence that nutrient loading promotes (directly and indirectly) the survival of coliform bacteria which contributes to closures of shellfish areas. Algal blooms and accumulation of macroalgae also pose aesthetic problems and inhibit recreational uses such as swimming and boating. Overall, nitrogen loading is one of the most serious long-term problems threatening many embayments around Buzzards Bay.

High concentrations of nitrogen in groundwater are also a concern because of the effects on drinking water quality. Contamination of drinking water by nitrate-nitrogen has been linked to gastrointestinal health problems and the decreased capacity of infants to utilize oxygen. Because of these health concerns, state and federal regulations have established nitrogen limits for drinking water.

Sources of nitrogen entering Buzzards Bay include sewage treatment facilities, septic systems, acid rain, fertilizer used on lawns and golf courses, and agricultural areas. The nitrogen from these sources enters the Bay via streams, groundwater, and direct effluent discharge. Because Buzzards Bay is large and relatively well flushed, nitrogen from human activity does not affect the central portion of the Bay to the same degree that it does near coastal areas. In particular, shallow, poorly flushed embayments are most sensitive to new nitrogen additions because they are most likely to exhibit the symptoms described above.

Septic systems are the dominant source of nitrogen entering most moderately developed embayments
around Buzzards Bay. All septic systems (both properly operating and failing systems) release large amounts of nitrogen to groundwater as ammonia in a form which is rapidly converted to nitrate. It

is important to stress that conventional septic systems are designed to remove bacteria and are not very effective at reducing nitrogen loadings in residential wastewater. So while septic system upgrades may help reopen closed shellfish beds, they have little positive effect on improving the quality of eutrophic coastal systems. In general, nitrate levels in groundwater decline very little as groundwater flows to the Bay. Since embayments are typically most affected by nitrogen that is transported by groundwater and streams, the relative importance of the various nitrogen sources in any embayment depends largely on the land use in the drainage basin that surrounds that embayment.

Nitrogen Management Approach

In the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP), the Buzzards Bay Project proposed that local, regional, and state authorities adopt nitrogen loading rate limits to protect Buzzards Bay's more than 30 major coastal embayments from excessive inputs of nitrogen (EPA and EOEA, 1991). This action was recommended because excessive anthropogenic nitrogen inputs are causing, or have the potential to cause, declining water quality and loss of living resources in the embayments around Buzzards Bay.

To implement the Buzzards Bay Project's management strategy (see Fig. 2), it is necessary to determine whether nitrogen loading to an embayment's drainage basin currently exceeds the embayment's recommended maximum annual nitrogen load, or has the potential to exceed this annual load when the drainage basin reaches its full "build-out." This process requires:

- An evaluation of nitrogen loadings from both point source and nonpoint source discharges. Existing and potential nonpoint source nitrogen loadings are determined by performing a land use analysis on each parcel of land in the surrounding drainage basin. Point sources are quantified from information contained on state and federal discharge permits to surface water or groundwater or actual discharge data.

- A detailed flushing study to accurately calculate the acceptable maximum annual load.

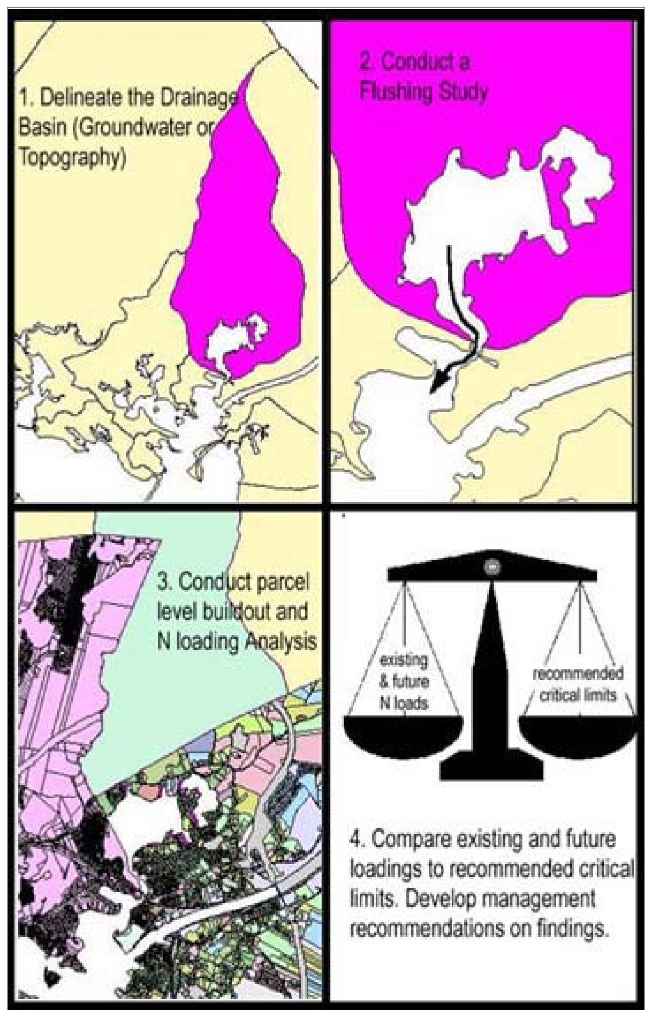

Figure 2. Buzzards Bay Project's nitrogen management strategy in four steps.

Site Description

Little Bay, or Upper Nasketucket Bay, is a 208-acre shallow (6.28 ft mean depth at high water) embayment located on the eastern side of Sconticut Neck in the Town of Fairhaven, Massachusetts. The Nasketucket River, at the convergence of three small streams, is the primary source of freshwater flow entering Little Bay at its northwest corner. Most of the immediate shoreline in this

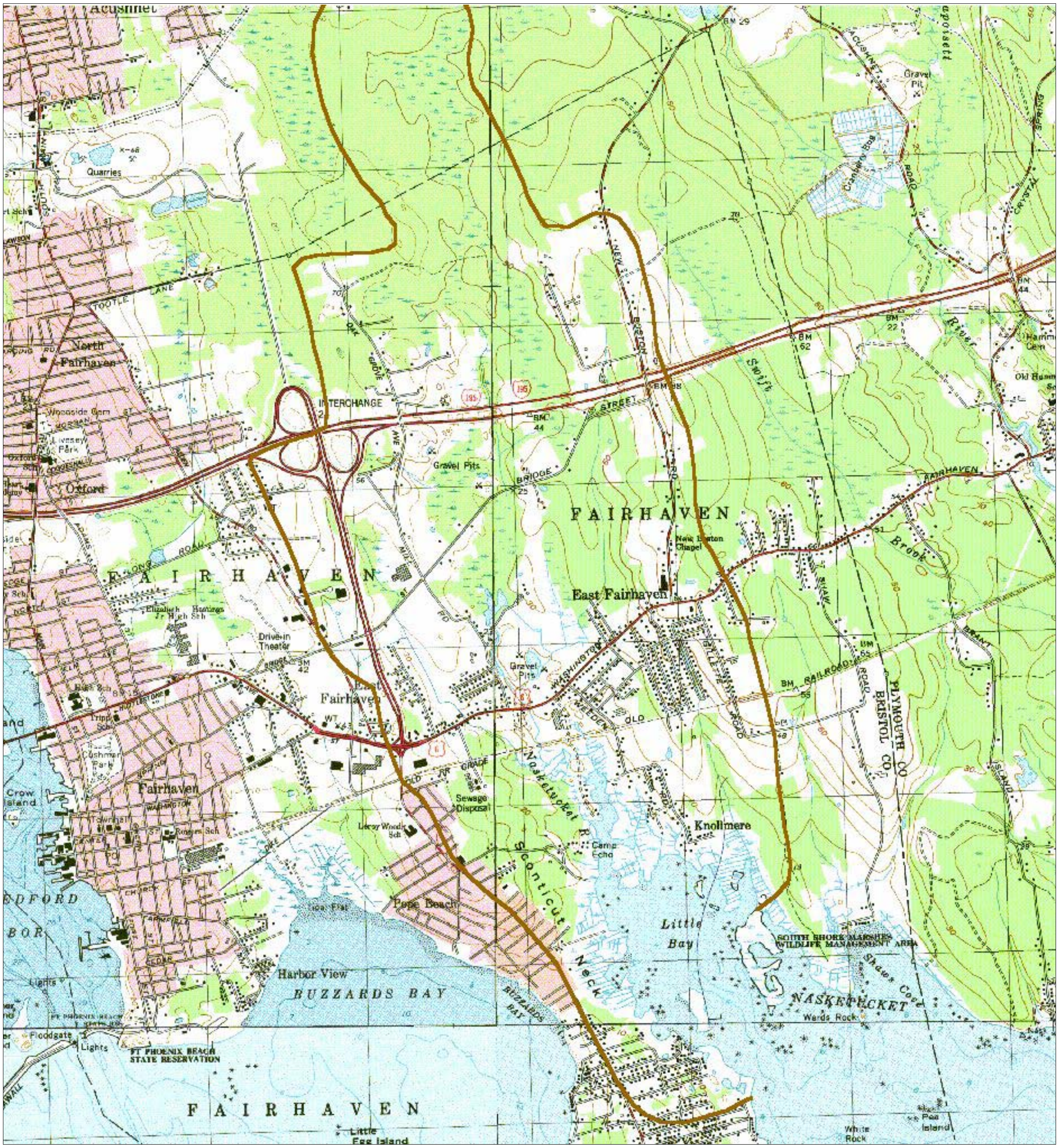

Figure 3. The watershed of Little Bay.

area is undeveloped, except a stretch along Sconticut Neck and an area at the head of the Bay known as Knollmere Beach. The shoreline of Little Bay is dominated by salt marsh and eelgrass (*Zostera marina*) habitat is widespread at its mouth and throughout Nasketucket Harbor. Eelgrass is absent from upper portion of the Little Bay, and this may be the result of eutrophication. The word "Nasketucket" in Wampanoag loosely translates to "our grass river place," most likely referring to the abundance of these estuarine habitats. Today, nearly 50% of the lands along the Little Bay shoreline are protected by the Fairhaven Conservation Commission, Massachusetts Division of Fisheries and Wildlife, or the private Fairhaven-Acushnet Land Preservation Trust as permanent open space.

Historically, Little Bay has supported good shellfish resources, primarily quahog (*Mercenaria mercenaria*) and soft shell clam (*Mya arenaria*). The American Oyster (*Crassostrea virginica*) has occurred in relative abundance in the Nasketucket River with a moderately-sized standing crop. Bay scallop (*Argopecten irradians*), lobster *(Homarus americanus*) and conch (*Busycon canaliculatus*) are also present and both recreationally and commercially fished. The area is listed as "Conditionally Approved" for the harvest of shellfish by the Massachusetts Division of Marine Fisheries due to elevated fecal coliform bacteria levels. Under an agreement with the Town of Fairhaven, the area is managed on the occurrence of rainfall. Whenever the area receives greater than 0.25" of rain in a 24-hour period, it is closed to shellfishing for five days. If no further rain exceeding this limit occurs during this 5-day period, it automatically opens. (DMF, Re-evaluation of Little Bay, Fairhaven, 1992)

Single family residential and retail commercial properties, farms, and open forest lands comprise the bulk of land uses in Little Bay's 3,006 acre watershed. Two large dairy farms are located approximately 1.5 miles north of the embayment along Interstate 195 which bisects the watershed west to east. Municipally owned forest lands dominate the upper reaches of the watershed in the Town of Acushnet and Fairhaven. In fact, 136 acres of the watershed within the Town of Acushnet are municipally owned and represents 40% of Acushnet's watershed contribution (344 acres) to Little Bay. There are no point source discharges of pollution in the Little Bay watershed.

The Little Bay watershed (Fig. 3) includes the Nasketucket River basin from which the Town of Fairhaven maintains its only municipal water supply well at Mill Pond. While not currently in use for public drinking water, this supply is protected by the town's regulations from hazardous land uses through the Nasketucket River Overlay District as a potential future source of potable water. A large fraction of the nitrogen load to the Nasketucket Bay system flows from the Nasketucket River into Little Bay. The town's regulations for the Nasketucket River basin do not, however, include nitrogen loading limits for wellhead protection. The goal of managing nitrogen for Little Bay then also benefits the Nasketucket water supply source.

Water Quality in Little Bay

Monitoring Stations

Six stations in Little Bay have been monitored at various times by the Buzzards Bay Project-Coalition for Buzzards Bay Citizens Water Quality Monitoring Program between 1992 and 1997 (see Fig. 4). These stations are Little Bay stations LT1, LT2, and LT3, and Nasketucket River Stations NR1 (Pierce Point Bridge), NR2 (Rt. 6), and NR3 (railroad bed). Stations NR2, NR3, and LT3 were monitored only in the first two years of the program. LT1 and LT2 were not monitored in 1997.

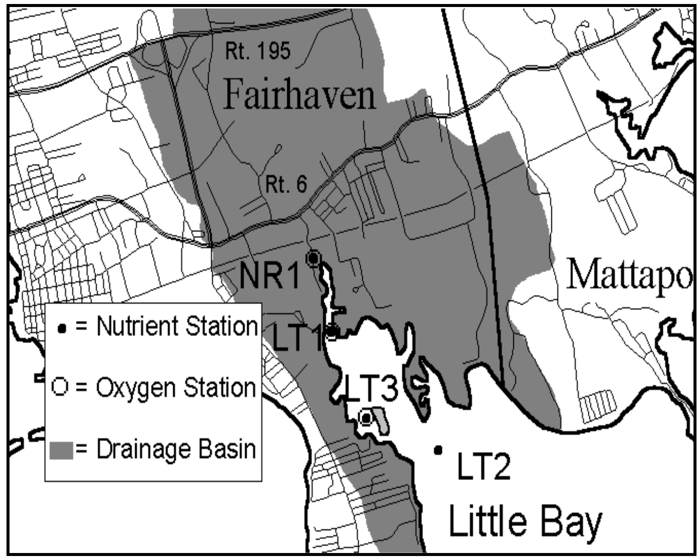

Figure 4. Location of monitoring stations in Little Bay. Only station LT1 was used to calculate the Eutrophication Index for the upper embayment.

Monitoring Results

River stations NR1 and NR2 were monitored for nitrogen on four dates in 1993 (the only year that nitrogen was measured at these stations). Station NR1, closest to the bay, had salinities ranging from 21-29 ppt. NR3, next upstream, had salinities between 4 and 12 ppt, and station NR2, most upstream, had salinities below 2 ppt. What is most interesting about the results of this survey was that inorganic nitrogen concentrations were considerably elevated midstream at station NR3, suggesting a large nitrogen source down gradient of Route 6. Concentrations of dissolved inorganic nitrogen approached a remarkably high 100 micromolar (=1.4 ppm)- a very high concentration for a Buzzards Bay stream.

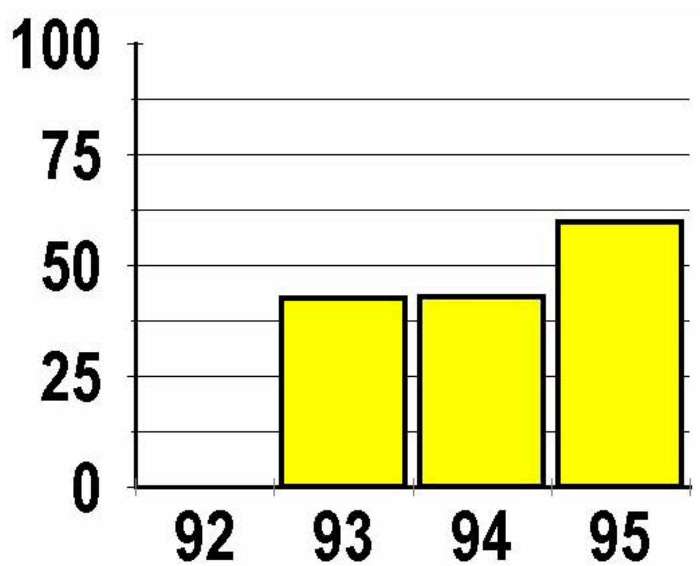

Figure 5. Eutrophication Index scores for Little Bay 1993 to 1995 from the Citizens Water Quality Monitoring Program.

The Buzzards Bay Project's Eutrophication Index scores for inner Little Bay (Fig. 5, based on the data for station LT1) for 1993 to 1995 were 42, 43, and 59 respectively, only fair scores compared to other Buzzards Bay embayments. Our Eutrophication Index is based on a scoring system for five water quality parameters: mean summertime oxygen concentrations, water transparency, phytoplankton pigments, inorganic nitrogen, and total organic nitrogen.

The apparent improvements in water quality during the monitoring period were largely driven by a big reduction in inorganic nitrogen levels in 1995, together with improvements in the amount of chlorophyll and organic nitrogen in the water.

The improved water quality demonstrated by the Eutrophication Index for station LT1 is clearly demonstrated by one of the EI components, phytoplankton pigment concentration in the water (Fig. 6). Unsurprisingly, stations LT2 and LT3 do not show this distinct trend apparently because they are less influenced by nitrogen sources up the Nasketucket River. Station LT1 is typical of the less well flushed portion of an embayment with higher phytoplankton concentrations than outer embayment stations.

When dissolved inorganic nitrogen (DIN) concentrations are examined (Fig. 7), the 1992 to 1996 trend of improving water quality is not true with station LT1. However, DIN concentrations alone are not a good indicator of loading since inorganic nitrogen is so readily taken up by algae, and DIN concentrations in any embayment are strongly influenced by the amount of, and time since, the last rainfall. None-theless, DIN concentrations in 1995 and 1996 were clearly lower than in 1992 and 1993, despite the fact that 1993 experienced a summer drought.

In Figure 8, total nitrogen concentrations are similarly shown. Total nitrogen, which is the combined total of dissolved inorganic nitrogen, particulate nitrogen (e.g., plankton, detritus, etc.) and dissolved organic nitrogen, is often viewed as one of the best indicators of nitrogen. Stations LT2 and LT3

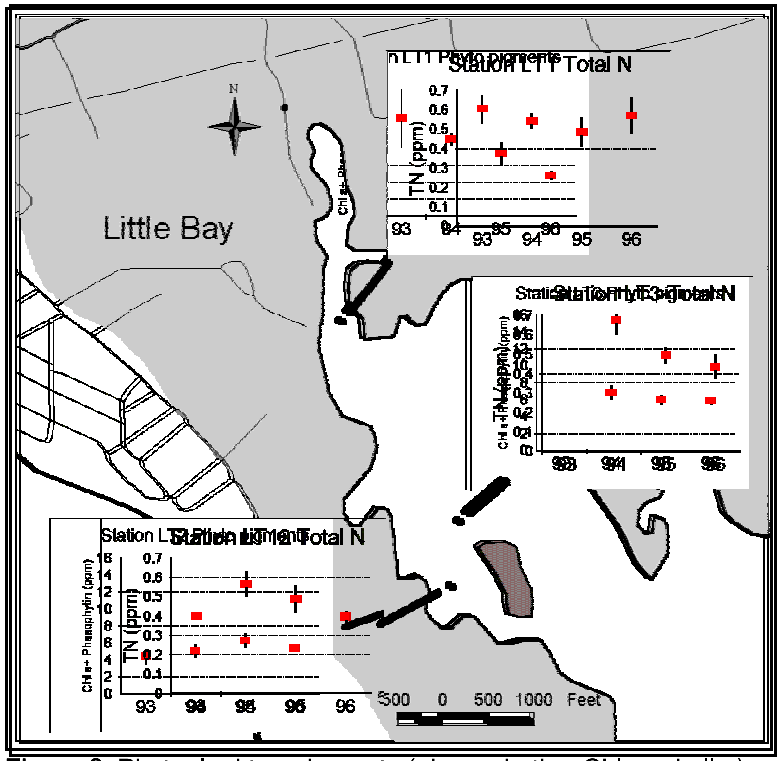

Figure 6. Phytoplankton pigments (phaeophytin+ Chlorophyll a) for stations LT1, LT2, and LT3.

Figure 8: Total Nitrogen concentrations (ppm) at three stations.

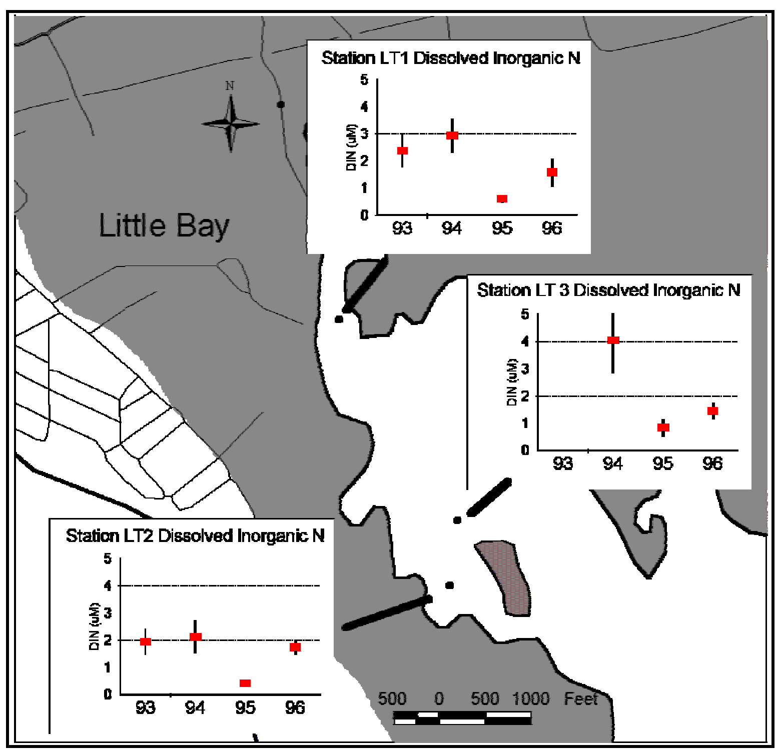

Figure 7. Dissolved inorganic nitrogen concentrations at the three Little Bay stations.

were consistent in improved water quality between 1994 and 1996. Station LT1 on the other hand showed a steady improvement from 1993 to 1995 but inexplicably showed a marked increase in total nitrogen concentrations in 1996. Also somewhat unexpected was the fact that station LT3 had higher total nitrogen concentrations than station LT1, since upper embayment stations tend to have higher total nitrogen. Several explanations are possible for this but one of the most likely is that very close to the mouths of streams in this sort of estuary, there is too short of a residence time of the water for phytoplankton and algae to respond to the source of DIN to the river. Nitrogen sources from Sconticut Neck septic system discharges may also be influencing water quality at the station.

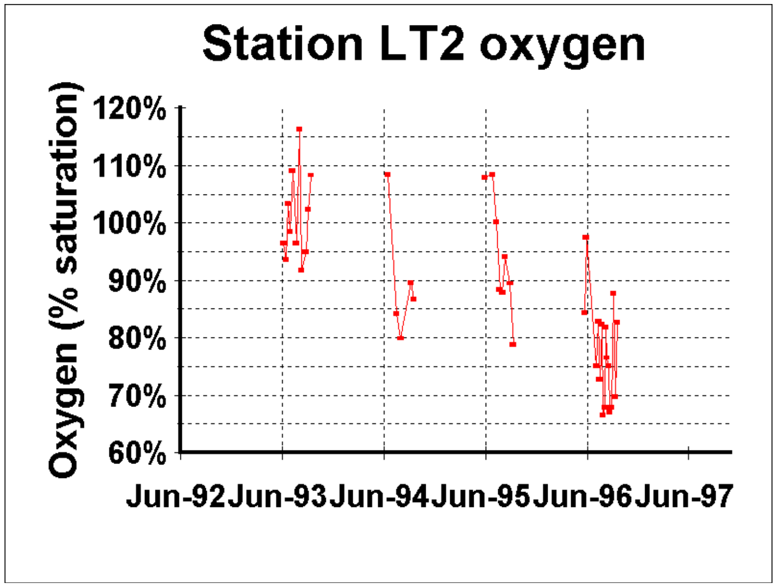

Figure 10. Oxygen percent saturation at station LT2.

Oxygen concentrations were monitored at station LT 1 in 1992, 1994, 1995, and 1996 and at station LT2 in 1993 1994 1995 and 1996 (Figs. 9 and 10 respectively). Neither station was monitored in 1997. Oxygen saturation values showed a similar decline during the 1993 to 1995 monitoring period. This trend was consistent at station LT2 since 1993.

The upper bay station unexpectedly showed higher concentrations than the lower station, but this may be the result of the fact that station LT1 is a shallow station near the edge of shore and freshwater flow, and exposed more to wind driven circulation and flushing by the Nasketucket River. Station LT2, on the other hand, is a deeper station at the end of a dock. Oxygen concentrations here probably reflect the lower oxygen concentrations to be expected in the deeper more quiescent central portions of a small embayment with somewhat higher total nitrogen (and organic matter) in the water.

In general, oxygen concentrations were typically above 80% saturation at both sites, but in 1992, an exceptionally wet summer that would have

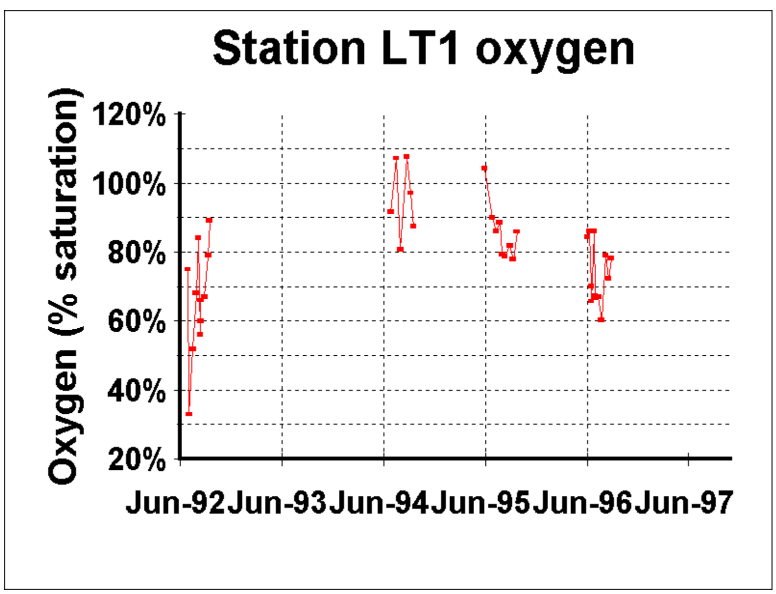

Figure 9. Oxygen percent saturation at station LT1.

washed considerable nitrogen off the watershed of this embayment, most oxygen saturation values were below 70%, with one observation at 33%. This poor water quality was manifest in other water quality measures that year. In that year station NR1 (not shown) was even with the lowest 1/3 saturation values hovering around only 45% saturation.

Conclusions

Interpretation of the water quality data

Taken together, the nutrient data and oxygen data support two major conclusions. First, in comparison to other Buzzards Bay embayments, nutrient concentrations and chlorophyll concentrations are higher in Little Bay. Eutrophication Index scores are also below most of the embayments monitored. The summertime average total nitrogen concentrations above 0.6 ppm observed at some Little Bay stations in certain years are comparable to other eutrophic Buzzards Bay embayments.

The other major conclusion is that most water quality indicators suggest that Little Bay appears to be experiencing slight to marked improved water quality depending upon which indicator and station is considered. Mean oxygen concentrations are not consistent with these observations, but because oxygen is so dependent upon wind, light, and temperature conditions each summer, this pattern is difficult to interpret without addition years of monitoring data.

There are several possible factors which may explain the decline in inorganic nitrogen in the Nasketucket River and general improved water quality in the bay. For example, a large corn field in the watershed was converted to a soccer field and park in the Spring of 1994. Another contributing factor could have been the fact that the Weeden Road area (just a few hundred feet from the bay) was sewered in the Fall of 1993. Finally, a nursery along the Nasketucket River was reported to have changed its management practices relating to compost storage, and this may have contributed to reduced nitrogen loads. We also presumed in our assessment that the soccer field received considerably less or no fertilizer applications as compared to its former cornfield use, and that there was a sizeable decline in overland runoff of inorganic nitrogen from all these sources.

Flushing Study Results

A flushing study determines the amount of time, referred to as "residence time," it takes for a given volume of water in different portions of the bay to be exchanged through tidal cycles. The flushing rate for Little Bay (43.2 hours) is 44% longer than that of outer Nasketucket Bay (30 hours) which is open to the waters of Buzzards Bay. This means that the average gallon of water in Little Bay takes approximately 1.8 days to return to the greater Buzzards Bay system. The longer the residence time, the less nitrogen an embayment can assimilate from its surrounding watershed without suffering declines in water quality and living resources.

Aubrey Consulting Flushing Estimates

In 1994, the Buzzards Bay Project funded the calculation of flushing estimates for 27 embayments within the Buzzards Bay ecosystem by Aubrey Consulting, Inc. of Cataumet, MA. The flushing estimates produced in their January 1995 report (Aubrey Consulting Inc., 1995) were among the first numbers calculated for the Bay's shallow, poorly flushed harbors and coves and provided the basis for the Buzzards Bay Project's early work in estimating the impacts of nitrogen loading to individual embayments. While these numbers continue to provide our best estimates regarding flushing rates and thus direct our attention to those areas requiring management, the Buzzards Bay Project has sought more detailed field surveys of flushing to develop better estimates of nitrogen loading impacts.

In the Aubrey study, a simple tidal prism box model was used to estimate residence times in each embayment. Because it was assumed that none of the water returned with the incoming tide, in general this estimate is an underestimate of actual water turnover. The second method employed a simple one-dimensional spatial analytical model that incorporated the size and geometry of the estuary, and used assumed "dispersion coefficients." This method probably arrives at more realistic turnover estimates than the tidal prism method, except for very small embayments, or embayments with very wide openings. In the smallest embayments, calculated turnover times were often less than found with the tidal prism method. Finally, a simple one dimensional numerical computer model, probably gave the best estimates of tidal flushing, but may also be inadequate for those embayments with wide openings. The estimates of flushing by ACI are shown in Table 1.

The Aubrey report suggested that the estimates of residence time could be improved by more complete bathymetry, better knowledge of the tide, and more accurate numerical modeling to define the hydrodynamics of the system. Additionally, dye studies should also be used to estimate local dispersion coefficients more accurately.

The Aubrey Report did not attempt to detail variabilities in flushing rates within individual embayments. Often it is the upper, tidally-restricted, shallower portions of a bay that suffer most acutely from excessive nitrogen loading from the surrounding watershed. These areas should be used in making land use decisions to protect coastal water quality. The estimates of flushing in the Aubrey report using the latter two methods for the upper 1/3 of the embayment. This limitation was particularly evident in the case of Little Bay where the report had only provided estimates for greater Nasketucket Bay - most of which is exposed and receives significant mixing with the open waters of Buzzards Bay. In short, the 1995 Aubrey report coupled with the land use analysis contained within the Buzzards Bay Project's "Subwatershed Evaluation" report made clear the fact that, for one, Little Bay should be managed as a separate - more sensitive - unit from Nasketucket Bay, and further that in order to do so, more detailed estimates of flushing in the embayment were needed to make informed land use decisions.

Table 1. Residence Times for “inner” Nasketucket Bay (Aubrey Consulting, Inc., 1995).

Embayment	Technique 1	Technique 2
Nasketucket Bay	30 hours	31-48 hours

Offshore and Coastal Technologies Field Study

Following the early compilation of the build-out potential of the Little Bay watershed by the Town of Fairhaven, the Buzzards Bay Project contracted with Offshore and Coastal Technologies, Inc. (OCT) of Sandwich, MA for the development of detailed field studies of flushing in three Buzzards Bay embayments - Onset Bay, Little Bay and Allen's Pond (Geyer et al., 1997).

The flushing rate of Little Bay was determined by releasing known amounts of Rhodamine WT dye into the embayment and measuring the change in dye concentration and distribution using a fluorometer. The dye was injected in vertically well-mixed bands extending across the embayment close to its landward end. Successive surveys were used to determine the seaward spreading of the dye and the decrease in mass of the dye within each of the bays. Background fluorescence caused by phytoplankton and organic matter was measured prior to the dye releases. The background level was subtracted from the fluorescence measurements. In addition to fluorescence, the salinity distributions of the bays were measured with a conductivity-temperature-depth (CTD) instrument. The salinity provided an alternative method of residence time estimation, based on estimating the freshwater inflows to the bay.

Dye injections were conducted in Little Bay on August 9 and 10, 1996. The tidal conditions were intermediate between spring and neap during the surveys. Winds were light. There were 0.25 inches of rain early on August 10, but because it had been dry for the previous week, there was little runoff associated with the rain. These forcing conditions should have produced average summertime flushing conditions.

The estimated residence times based on the dye studies and the freshwater budget estimates were 1.8 days from the dye measurements and 1.1 days from the freshwater method (Table 2). The uncertainty of the estimates comes from natural variability as well as measurement error. For the dye estimates, the largest source of error is the natural background of fluorescence. The freshwater residence time is hampered by only rough estimates of the freshwater input based on precipitation data. In spite of the uncertainty, these two approaches yield similar estimates of residence time (Geyer et al., 1997). For management purposes, the Buzzards Bay Project used the longer estimate to establish the critical nitrogen loading limit for Little Bay.

Table 2. Residence Time - Offshore & Coastal Technologies, Inc. (Geyer et al., 1996).

Embayment	Residence Time from Dye	Residence Time from Freshwater
Little Bay	43.2 hours	26.4 hours

Critical Nitrogen Load for Little Bay

With the information collected through the Offshore and Coastal Technologies Flushing Study for Little Bay, the Buzzards Bay Project was able to calculate the maximum capacity of the Bay to assimilate nitrogen inputs from its surrounding watershed without suffering serious declines in water quality and living resources such as loss of eelgrass beds, shellfish beds, and anoxic events. This point is known as the 'Critical Limit' and it represents the "carrying capacity" of Little Bay. For embayments that have not yet exceeded their Critical Limit, it is possible to plan future growth and land uses within the watershed so that the embayment will not suffer from excessive nutrient loading at full development build-out.

Table 3 shows the theoretical nitrogen loading limit for Little Bay at the two separate hydraulic residence times developed in the flushing study based on Buzzards Bay Project methodologies. As discussed above, the two flushing estimates were developed using different field techniques and mathematical models - one tracking the diffusion of a dye released into the bay, the other using mathematical calculations estimating freshwater inputs. For the purposes of planning for water quality protection in Little Bay, we have chosen to use the slower Turnover Rate (or Residence Time) in this analysis (1.8 days) for a more conservative (lower) allowable nitrogen loading limits for the bay.

Table 3. Little Bay - Critical Nitrogen Loading Limits*

Residence Time (days)	1.8
Area	
Acres	183
Area (m^2)	740,010
Area (hectares)	74
Mean Depth (m) high	1.9
Tidal Range (m)	1.15
Mean Depth (m) mid	1.3
Mid Tide volume (m^3)	981,000
High Tide volume (m^3)	1,410,000
Reported high tide volume	1,400,000
Critical Loading Limits**	
ORW limit	21,280
SA limit	42,560
SB limit	74,480

* Date from Offshore &Coastal Technologies (Geyer et al. 1997). Area and other hydrographic features based on Little Bay excluding the lower reaches of the Nasketucket River and 2 small coves.
**ORW= Outstanding Resource Waters with exceptional habitat, aesthetic, and ecological values, SA= High water quality areas that have excellent habitat and ecological and aesthetic values, SB= Areas that have good habitat and ecological and aesthetic values, shellfish areas are restricted and require depuration.

Water quality classifications

Loading limits proposed by the Buzzards Bay Project are tiered to reflect existing or proposed surface water quality standards. The Massachusetts Department of Environmental Protection (DEP) classifies harbors and bays in the Commonwealth as either SA (high standard), SB, or SC (severely degraded). No Buzzards Bay embayments have been classified as SC, two have been classified as SB (New Bedford Harbor & East Branch, Westport River) and the remainder are either classified as SA or not classified. A number of embayments are also designated as "Outstanding Resource Waters" (ORW). According to the Massachusetts Surface Water Quality Standards (314 CMR 4.0) "These waters constitute an outstanding resource as determined by their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained."

The choice of a water quality goal is a crucial decision in establishing the recommended loading limits. In the case of Little Bay, as the following loading evaluation shows, the town is fortunate to be in a position to consider Outstanding Resource Waters (ORW) status for the Bay which will maintain it at near pristine quality. We have, therefore, recommended that ORW be established as the target water quality level for Little Bay.

Nitrogen Loading Evaluation

As part of this study, the Buzzards Bay Project evaluated all sources of nitrogen within the watershed to Little Bay and assigned loading rates to each source based on accepted standard loadings. The sources of nitrogen to Little Bay are comprised entirely of non-point sources of pollution. In other words, the nitrogen sources are generated from many diffuse sources of ground and surface runoff and not a single or series of pipe discharges such as wastewater treatment plants. Although the Fairhaven Wastewater Treatment Facility lies close to the Bay on Nasketucket Creek, it discharges to Inner New Bedford Harbor and does not appear to contribute nitrogen to Little Bay. Exfiltration of sewage from pipes or structures into groundwater is conceivable under certain circumstances, but has not been demonstrated for this watershed. Industrial and commercial sources of nitrogen contribute relatively small nutrient loads through stormwater runoff from large parking lots in the Route 6/Alden Road area.

The two largest sources of nitrogen to Little Bay are residential dwellings and dairy farms in the watershed. Non-animal agricultural land uses such as cropland, primarily feed corn, and hay or pasture lands were also evaluated and assigned loading values (Table 4). Minor sources include nitrogen compounds in acid rain falling onto the surface of Little Bay, reported here as atmospheric deposition. The following discussion describes each of the sources and loads in more detail.
The estimation of future nitrogen loads are based on the important assumption that all agricultural lands will be residential in the future. As written, the Fairhaven Zoning Bylaw has "programmed" most of the Town for such a land use conversion. Local real estate market forces will ultimately determine when these changes will occur. While land conservation alternatives for both forest and agricultural lands may deter some undeveloped lands from their residential development fate, we did not plan for this unknown. Therefore, the potential watershed sources of nitrogen in the future

will be residential homes, roads, and parking areas.

Residential Loading

Build-out Method

The build-out analysis followed a three step process. First, the subwatershed drainage area for Little Bay as well as the extent of municipal sewer service in Fairhaven were transferred to Assessors Maps for each town. Existing land uses within these areas were documented and the potential for further development was determined. Existing and potential development for each parcel was determined based on lot area, road frontage and local zoning requirements.

All data used in the analysis were entered into a spreadsheet program (Quattro Pro) which was programmed to perform the necessary calculations. The assumptions and calculations within the spreadsheet were based on an overall build-out methodology developed for Buttermilk Bay by Horsley, Witten, Hegemann, Inc. in 1991 for the Buzzards Bay Project. Data summaries tabulating existing and potential development within each town are provided below. Further details on methodology are also provided below.

Table 4. Annual nitrogen loading rates used for preliminary loading assessments using MassGIS data for Buzzards Bay subwatershed evaluations. Parcel data is used for actual residential loadings for the Little Bay subwatershed.

Category #	Category Name (typical examples)	N loading rate (kg ha-1 y-1)
1	Cropland (corn, nurseries)	20.0
2	Pasture (hay, dairy)	10.0
3	Forest	0.0
4	Non-forested wetland (freshwater marshes)	0.0
5	Mining (sand and gravel pits)	7.3
6	Open land	0.0
7	Participatory recreation (golf courses)	29.3
8	Spectator recreation (baseball diamonds)	29.3
9	Water based recreation (beaches)	0.0
10	R0: Residential-multi-family[a] (condominiums, dormitories, etc.)	106.5
11	R1: Residential-<3 acre lots[a]	83.6
12	R2: Residential-3 - 2 acre lots[a]	51.8
13	R3: Residential->2 acre lots[a]	24.6
14	Salt marsh	0.0
15	Commercial (business districts)	121.0
16	Industrial	15.1
17	Urban open (parks, etc.)	0.0
18	Transportation (interstate highway, medians)	15.1
19	Waste disposal (landfills)	15.1
20	Water (freshwater ponds and rivers)	0.0
21	Woody perennial (cranberry bogs, orchards,)	18.0
NA	Embayment surface (atmospheric deposition)	7.3
NA	Roads (also included in other land classes)	15.1

[a] Assumed loadings with unit occupancy = 3.0. Loadings rates for these land use categories would differ with different occupancy rates.

Existing Conditions

The number of existing residential and commercial structures was determined from recent assessor's records provided by the two towns. Land use codes included on the tax printouts for each town were used to differentiate between developed and undeveloped land and to determine the land use category for each parcel (e.g., single-family residential dwelling, commercial uses, agriculture, tax-exempt open space). All undeveloped parcels which were restricted from development were identified, including those owned by the towns, state and federal government, and the private Fairhaven-Acushnet Land Preservation Trust.

Buildout Conditions

Zoning districts in the two towns (Table 5) were traced onto Assessors Maps described above. This information, combined with recent tax records, was used to compute the number of units which could potentially be constructed within each contributing area. Development options included vacant lots and vacant parcels which could be divided through an "Approval Not Required" (ANR) process (MGL, Chapter 41, 81-P), or a Definitive Subdivision Plan (MGL, Chapter 41, 81-L), or through a combination of the two processes as allowed under the Massachusetts Subdivision Control Law. "Grandfathered" lots were defined as vacant lots with an area of at least 5,000 square feet, but which

Table 5. Minimum Zoning Requirements for Residential Development

TOWN	ZONING DISTRICT	MINIMUM LOT SIZE	MINIMUM FRONTAGE
Fairhaven	RA - Single Family	15,000 sf	100 ft
	RR - Rural Residence	30,000 sf	140 ft
	A - Agricultural	50,000 sf	200 ft
	B - Business	15,000 sf	100 ft
	I - Industrial	15,000 sf	140 ft
	P - Park & Recreation	100,000 sf	200 ft
Acushnet			
	General	60,000 sf	150 ft.

contained less than twice the minimum lot size required in the relevant zoning district. The number of grandfathered lots was tabulated on a map-by-map basis and entered into the spreadsheet program.

Larger vacant parcels of land were subdivided in the following manner:

a) Each parcel was checked for development potential. In determining whether a lot was potentially developable, the following criteria were used: Did the lot meet the required zoning for minimum lot area and minimum road frontage for the zoning district in which the land was located?

b) If the residential lot (i.e., a lot with an existing dwelling unit) met all zoning requirements for its district, but was less than twice the minimum lot size, then the lot was considered fully developed since it could be subdivided no further, and one (1) dwelling unit was recorded in the data base for that lot.

c) If a residential lot was greater than two (2) times the minimum lot size, the remaining undeveloped land was considered subdividable. To determine the number of developable acres on the lot, the minimum lot size was multiplied by the number of existing dwelling units, and the resultant developed acreage was subtracted from the total lot area. The remaining undeveloped acreage was then subdivided according to d) and e) below.

d) Property having at least twice the minimum required road frontage on an existing public way was divided into "Approval Not Required" (ANR) lots first, followed by the creation of additional lots on the remaining "back" land through subdivision. To determine the number of ANR lots possible, the total length of road frontage was divided by the minimum frontage required per lot. If, once the ANR lots were determined, there remained a large back lot with at least fifty (50') feet of frontage once the ANR lots were determined, then the total number of ANR lots possible was decreased by one lot in order to provide the access frontage needed for the subdivision of the back tract of land.

e) For subdividable parcels (including "back lots"), 10% of the total lot area was deducted to account for interior infrastructure such as roadways, sidewalks, utilities, etc. In addition, each lot was analyzed for the extent of "undevelopable" wetland resource areas within the parcel. The extent of wetlands on each parcel was developed in two ways. First, individual parcels were classified with approximate percent wet from the Town of Fairhaven's buildout table completed by the town (Pat Fowle, pers. comm.). Second, aerial orthophotographs of Fairhaven and Acushnet interpreted by the Massachusetts DEP Wetlands Conservancy Program for wetland extent and types were overlayed with Assessors parcel data through the use of a Geographic Information System (GIS) to develop a wetland percentage for every lot within the study area (see Fig.11). A standard wetland percentage of 10% was then applied to all lots within the watershed to account for underestimates of wetland area in the Wetlands Conservancy Program data. The remaining land area (80% of total site size) was then divided by the minimum required lot size within the zoning district to determine a conservative estimate of the potential number of dwelling units. A summary of this buildout analysis is shown in Table 6.

Table 6. Buildout Analysis Summary for Little Bay

	Fairhaven	Acushnet	Totals
Existing Land Uses			
Residential Units - Sewered	725	0	725
Residential Units - Septic Systems	524	19	543
Total Existing Dwelling Units	1,254	19	1,273
Protected Open Space	239	136	375
Potential Land Use			
Vacant Grandfathered Lots	344	29	373
ANR lots			718
Subdivision Lots			2,101
Total Lots			
Expected new Dwelling Units	2,253	105	2,358
Total Dwelling Units at Full Build-Out			3,631

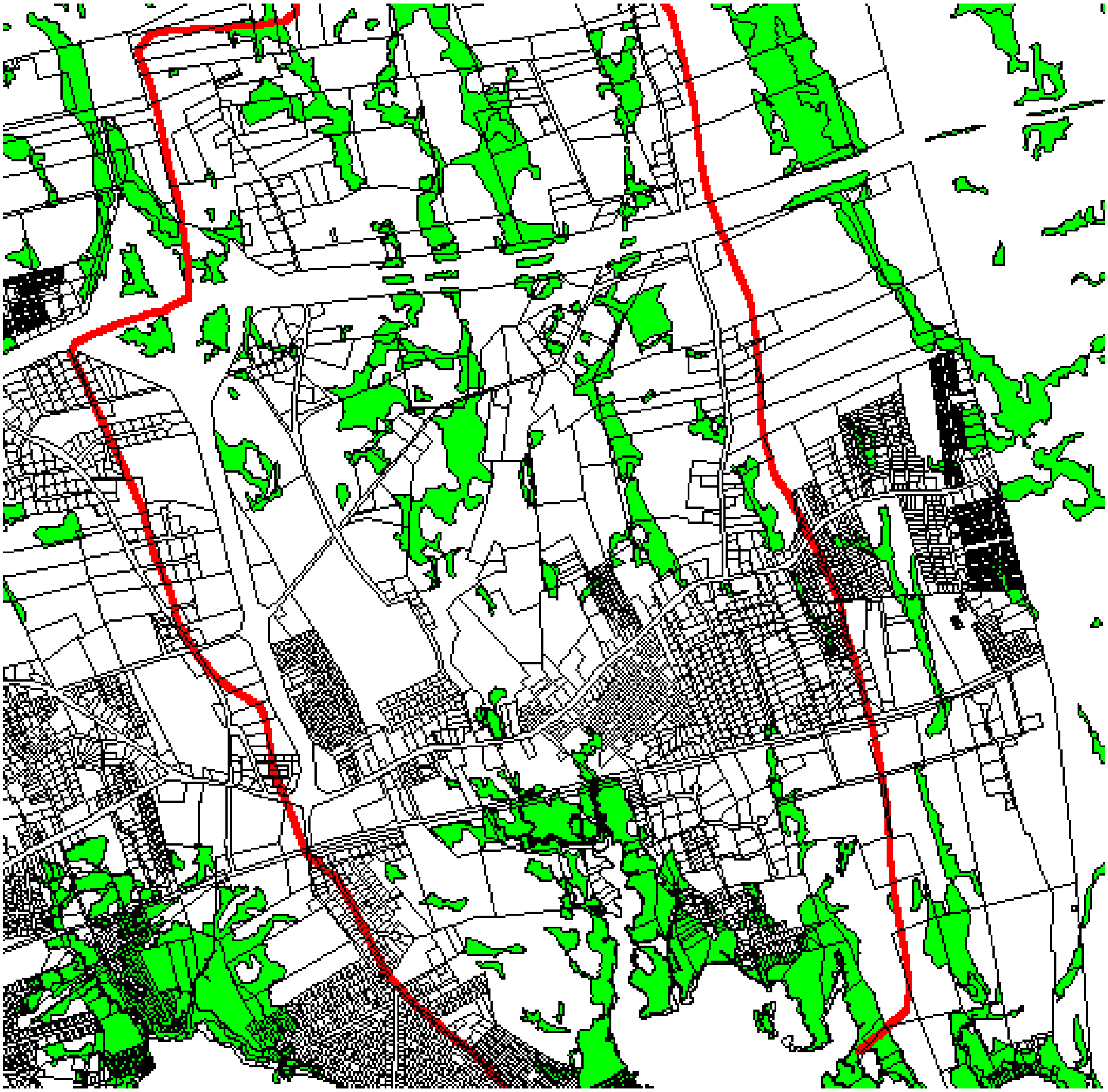

Figure 11. Wetland coverage from the DEP Wetland Conservancy Program overlain with parcel data for the central portion of the watershed. Conservancy Wetland Program maps represent only "core" wetlands. Actual wetland coverage is more extensive, and local official information was used to supplement the degree of wetland coverage in other areas.

Occupancy rates and use of US Census data

To estimate population within the Little Bay watershed, the existing and future dwelling unit estimates were multiplied by U.S. census occupancy rates documented for all the Fairhaven and Acushnet 1990 Census "block group" data as contained on the MassGIS system. In the case of Little Bay, a rate of 2.5 persons per household was used. This is an important factor as nitrogen loading rates are not assigned per household, but rather per person. In regard to future loadings, the build-out projects that living density will increase in Fairhaven and Acushnet to 3.0 persons per household.

Lawns

In addition to nitrogen loads generated by wastewater, our evaluation of residential sources also considered the contribution of fertilizer applications to watershed loadings. Reported application rates of lawn fertilizers vary widely and equally variable are estimates of nitrogen that leaches into groundwater or that runoff lawns following application. Fertilizer leaching rates from lawns have been the subject of increasing debate. The amount of fertilizer that ultimately leaches into groundwater is a function of the type of ground cover, soil characteristics, climate, type of fertilizer used, application rate, and the degree of irrigation or rainfall. Estimates developed for Buttermilk Bay in Bourne and Wareham in 1991 by Horsely & Witten assumed 146.7 kg/hectare/year as the annual application rate and a 30 percent leaching rate, or 73 kg/hectare/year loading to groundwater. Nevertheless, local soil conditions will greatly affect the amount of nitrogen that will enter groundwater and the amount that will be lost as surface runoff. Buttermilk Bay soils are very permeable while the soils of most of the Little Bay watershed are derived from glacial till and are substantially less permeable. Therefore, we assumed that retention of nitrogen was greater and that only 10% of the nitrogen applied to lawns would enter the bay through groundwater. An additional 10% was estimated to run off the surface and be transported to the bay. Finally, in calculating total lawn area per dwelling in the Little Bay watershed, we used a standard lawn area per dwelling of 5,000 sq. ft. for lots more than 30,000 sq. ft. in size and proportionally reduced lawn areas for smaller lots.

Impervious Surfaces

The extent of impervious surface area associated with each dwelling was estimated based on roof and driveway sizes. These sources represent a very small portion (0.2 kg/yr/hectare) of the total nitrogen load per dwelling unit. For purposes of this analysis, 5,000 sq. ft. of impervious roof and driveway areas was used as an average within the Little Bay watershed.

Sewer versus Septic

There are currently 725 dwellings within the Little Bay watershed serviced by municipal sewer service through the Fairhaven Wastewater Treatment Plant. The homes, while physically within the Little Bay watershed, contribute the vast majority of their nitrogen load to the Inner New Bedford Harbor ecosystem via the treatment plant outfall. While this works to the benefit of Little Bay, it amounts to greater than watershed contributions to New Bedford Harbor which must assimilate the nitrogen from within its own drainage area as well as loadings from other coastal watersheds such as Little Bay and Mattapoisett Harbor. Despite this transfer of wastewater nitrogen loads out of the Little Bay system, these sewered dwellings still contribute lawn and impervious surface nitrogen loadings, and these lesser contributions are included in the calculated loadings in our build-out/loading spreadsheet.

In making assumptions about the extent of future development in the watershed, we assumed that all new development would use on-site septic systems. This obviously represents the worst case from a nitrogen loading perspective, but is supported by current town planning for sewer extensions which seeks to sewer existing homes on West Island and Sconticut Neck instead of extending to undeveloped areas for new growth. Additionally, most of the neighborhoods proposed for sewering are outside of the Little Bay watershed.

It is also important to note that our analysis assumes that in the future all soils will pass percolation tests and be capable of meeting state and local regulations for on-site septic system disposal. This is based on a long-term view that new technologies for on-site disposal as well as possible longer percolation times under Title 5, the state sanitary code, will allow new areas thought unbuildable today to support residential development in the future. The exception to this assumption is those areas defined as core wetlands as shown on the Wetlands Conservancy Maps.

Non-animal Agricultural Uses - Pasture and Cropland

Based on aerial photography and field surveys, we determined that there are approximately 279 acres (or 111.6 hectares) of open fields and pasture lands as well as 63 acres (or 25.2 hectares) of land in active crop production within the Little Bay watershed. The vast majority of cropland is in the production of corn. Using the standard fertilizer application rates for nitrogen, it was determined that 10% of watershed nitrogen loadings were generated by agricultural uses. Estimated loadings from cropland is shown in Table 7.

Table 7. Summary of Cropland loadings.

Agricultural Use	Area	N Loading Rate	Total N Loadings
Hay/Pasture fields	279 acres or 111.6 hectares	10 kg/hectare/year	1,116 kg/year
cropland - cornfields	63 acres or 25.2 hectares	20 kg/hectare/year	504 kg/year
TOTALS	342 acres		1,620 kg/year

Farm Animals

The total number of farm animals permanently residing in the Little Bay watershed was obtained from the USDA Natural Resources Conservation Service in January 1998. Using an annual excretion rate for nitrogen of 65 kg N/animal unit/year (USDA-SCS, 1992), a per year loading was assigned to each of the two principal dairy farms in the watershed. Livestock loadings were calculated as a separate source in addition to land use loadings which are typically pasture in this case. The amount of nitrogen reaching groundwater and eventually the Bay depends on many factors including the extent to which agricultural Best Management Practices (BMPs) are employed on the farm. It is also worth noting that farm animals (primarily dairy cows) play a far more important role in fecal coliform bacterial loading and shellfish bed closures than they are a cause for coastal eutrophication.

Each farm is located approximately 1.6 miles from Little Bay. In the case of the Costa Farm at New Boston Road & Interstate 195, we estimated that only 10% of the nitrogen load created at the farm would enter groundwater as nitrate and reach Little Bay. The farm sits on the watershed divide with the majority of the property draining through Swift Brook to Mattapoisett Harbor. The Deterra Farm at Oak Grove Lane and Interstate 195 lies completely within the watershed and drains through the main branch of Nasketucket Creek to Little Bay. We recognize that surface runoff sources of nitrogen, such as manure, are diminished somewhat by attenuation through natural wetland systems before entering coastal waters. Combined with the distance of the cows from the bay, we assumed that only 50% of the nitrogen load produced by the Deterra herd would reach the bay. Farm animal loadings are summarized in Table 8.

Table 8. Summary of Farm Animal Nitrogen Loadings

Watershed Dairy Farm	Costa Dairy Farm	Deterra Dairy Farm
attenuation assumption	10% reaches Little Bay	75% reaches embayment
Milking cows (1.4 au each)	140 Holsteins	80 Holsteins
Heifers (.5 au each)	135 heifers	10 heifers
Total # of cows	275	90
Animal Units (1 au /1000lbs.)	264 animal units (au)	117 animal units (au)
Animal Nitrogen Loading	17,160 kg/year	7,605 kg/year
Loading w/ watershed attenuation	10% = 1,716 kg/year	75% of load = 5,704 kg/year
Total Farm Animal N Load =		**7,420 kg/year**

Road Runoff

Sources of nitrogen in road runoff include precipitation, soil erosion, leaf litter, automobile exhaust, and animal wastes. Nitrogen concentrations in road runoff can vary by an order of magnitude, depending on spacing between storms, the intensity and duration of the storm, and the timing of sample collection. The highest nutrient concentrations are generally found in the "first flush" (Horsely & Witten, 1991).

The extent of roads presently constructed in the Little Bay watershed was estimated using Geographic Information Systems (GIS) coverages based on USGS Quadrangle maps of the area. This analysis yielded that there are approximately 120,607 feet of road in the watershed. Assuming that these roads are on average 25 ft wide, this translates to 3,015,175 sq. ft. or 69.22 acres or 27.69 hectares of impervious roadway surface in the watershed. Based on the standard road nitrogen loading, approximately 418 kg/year of nitrogen are generated from roads.

Estimations of future roads in the watershed required that we make some assumptions about the construction of new subdivision roads. Using the 2,363 anticipated new dwellings estimate generated through the build-out analysis we concluded that each new dwelling in a subdivision (1,990 new homes) would bring with it 1,875 sq. ft. of new road surface. It was assumed that grandfathered units will be constructed on existing roads and therefore produce no new road based nitrogen load.

Based on an average minimum lot frontage of 150 feet and 25 foot wide roads, future residential development in the Little Bay watershed is projected to create 34.3 hectares of new impervious road surface and contribute 517 kg/yr of nitrogen to the bay.

Commercial Runoff

Based on aerial photography and field surveys, it was determined that there are approximately 30 acres (or 12 hectares) of impervious commercial space (i.e., parking lots) in the watershed. Using the same loading standard applied to roads (15.1 kg/hectare), commercial land uses are generating 181.2 kg/year nitrogen through stormwater runoff.

Estimates of future commercial loads were developed assuming full build-out of the commercially zoned land area in the watershed. This will create an additional 15 acres (or 18 hectares) of impervious area with a total nitrogen loading of 272 kg/year.

Atmospheric Deposition

In the atmosphere, nitrogen oxides from power plants and automobiles are transformed to nitrate and nitric acid - a form of "acid rain" - both of which land often far downwind from where they are discharged. Nitrogen sources to Buzzards Bay were estimated in the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP) to represent 12% of the total load to the bay. Fortunately, this is one nitrogen source which is likely to improve in the future as more stringent air pollution laws stimulate the use of cleaner fuels and technologies. For this reason, the future nitrogen load provided in this report may be somewhat conservative.

The atmospheric deposition loading standard used in this analysis is 7.3 kg/hectare/year. For the surface area of Little Bay (74 hectares or 185 acres), this translates to 540 kg/yr nitrogen loading to the bay from atmospheric deposition. This represents the only "out of watershed," non-land-based source of nitrogen to the Little Bay system.

Summary of Nitrogen loading

Figures 12 and 13 show a bar chart of existing and future potential nitrogen sources. At buildout, total nitrogen loading to the bay will increase by 50% and residential dwellings will nearly double. The most important implication of the buildout analysis is that not only will agricultural sources diminish in importance, but residential sources (septic systems and lawns) will greatly dominate nitrogen inputs to the bay.

Importance of Watershed Nitrogen Attenuation Assumptions

There is growing scientific interest in research that has attempted to quantify to what extent nitrogen is removed from ground and surface waters as it moves from its source to a receiving water body. To date, the Buzzards Bay Project, as well as coastal scientists, have considered the loss of nitrogen in groundwater as negligible and therefore not considered in its nitrogen management efforts. However, recent research performed on Cape Cod in sandy, well-drained soils suggests that there is the potential for anywhere from 5-30% of nitrogen to be removed from septic system effluent in

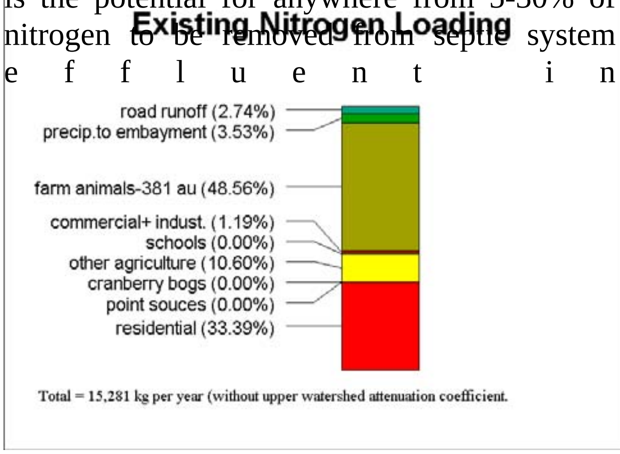

Figure 12. Percent contribution of all existing nitrogen sources.

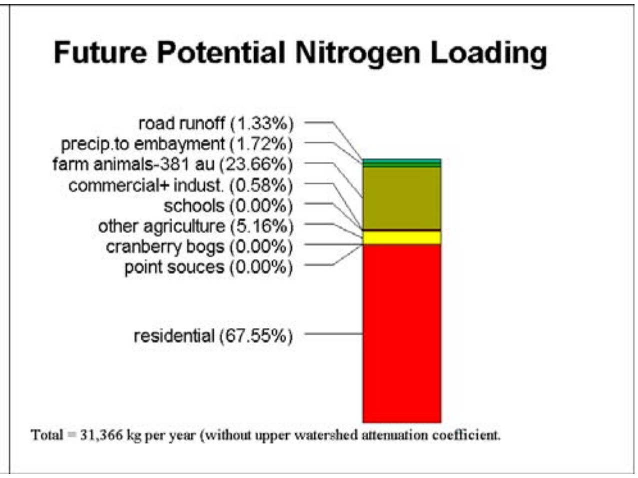

Figure 13. Percent contribution of all future potential nitrogen sources.

groundwater during what may be decade-long transits to the coast. There is also agreement that where groundwater enters wetlands, ponds, or the root zone of forests, opportunities exist for nitrogen removal. Despite this new information, there remains a lack of a consensus among the scientific community regarding what nitrogen attenuation rates managers should use.

Due to the Little Bay watershed's geology and landscape characteristics, the Buzzards Bay Project assigned nitrogen attenuation rates to residential sources north of Interstate 195 as well as dairy cow inputs in the watershed. It was assumed that approximately 30% of the nitrogen from these residential sources would be absorbed by the large forested wetland systems which characterize the upper drainage basin for the Nasketucket River. No groundwater sampling was performed as part of this study to establish an attenuation rate based on field research and these numbers are largely theoretical. If this approach is applied to the Little Bay watershed, nitrogen

Table 9. Existing and Future Nitrogen Loading to Little Bay

Existing Loadings	kg N/yr*	kg N/yr
Residential Loading	5,048	4,848
Point Sources	0	0
Cropland	504	504
Hay/Pasture	1116	1116
Commercial & Industrial	181	181
Farm Animals (lbs/animal unit)	7,420	7,420
Atmospheric Deposition	540	540
Road Runoff	418	418
TOTAL	15,227	15,027
Future Loadings	kg N/yr	kg N/yr*
Residential Loading	20,534	18,597
Point Sources	0	0
Hay/Pasture	0	0
Cropland	0	0
Commercial & Industrial	272	272
Farm Animals	0	0
Atmospheric Deposition	540	540
Road Runoff	935	935
TOTAL	22,281	20,344

* assumes some watershed attenuation

loading at building would be 2,000 kg (7%) less, and be slightly below recommended limits. However, because of the uncertainty of the degree of attenuation in this watershed, the authors have recommended that nitrogen management in the Little Bay Watershed be based on the full, non-attenuated, loading rate.

In the case of the dairy cow loadings, however, we did include attenuation rates for these loadings since there is a substantial body of research to show that animal sources of nitrogen in surface runoff will be taken up by forests and wetlands as they are transported to streams, particularly in areas of poorly drained soils. Therefore, the authors believe that the surface runoff attenuation rates included in this report are fair estimates of what can be expected to be removed by natural processes. Again, as in the case with the residential loading assumptions, no field sampling was performed as part of this study to quantify nitrogen attenuation rates.

Discussion of Nitrogen Management Options

The estimated nitrogen load to Little Bay at watershed buildout (22,281 kg/yr) is 1,001 kg/yr greater than the calculated critical load (21,280 kg/yr). This equals the equivalent of 120 residential dwelling units that must not be built at buildout conditions, or about 200 existing homes that must be sewered (a larger number is required to account for nitrogen from lawns and paved areas), so that the critical load for Outstanding Resource Waters is not exceeded in the future. The 120 homes represent only 3.3% of the 3,631 dwellings projected for the watershed at full build-out. This is a manageable number which can be achieved by taking a few important actions to reduce the total load.

If we take into account the watershed attenuation that may occur with development in the upper watershed, Little Bay is projected not to exceed its critical limit at full build-out. As discussed above, if we assume that approximately 30% of the nitrogen load from residential land uses north of Interstate 195 will never reach Little Bay and be absorbed by watershed wetlands, the full build-out loading is reduced to 20,344 kg/yr - 936 kg/yr under our estimated critical limit. The equivalent of 112 homes under the limit.

While these findings are encouraging, the closeness of these numbers to the estimated critical limit test the accuracy of the flushing studies as well as the methods and assumptions used to calculate the critical limit, future build-out density, and watershed nitrogen loading. To account for any error in these analyses, we suggest that the Town use the greater of the two estimates, without the 30% watershed attenuation, to plan for the protection of water quality in Little Bay.

For embayments such as Little Bay that have not yet been critically impacted by excessive nutrient loading municipalities can typically avoid exceeding their critical nitrogen loading limit. This can be accomplished in a number of ways including increasing minimum lot sizes on unsubdivided land, sewering portions of the drainage basin, requiring implementation of Agricultural Best Management Practices, limiting lawn sizes, purchasing either land or conservation restrictions to prevent development of open space, or by requiring the use of nitrogen reducing septic systems. With the exception of nitrogen inputs from atmospheric deposition, all of the sources of nitrogen entering Little Bay can be controlled by the Towns of Fairhaven and Acushnet.

Because existing water quality conditions are not critically impaired now, or expected to be so in the future, drastic steps are not required to protect Little Bay. However, because existing water quality can be characterized as somewhat below average compared to other Buzzards Bay embayments, and at buildout, nitrogen loadings to the bay will increase by 50%, management action is warranted. Without action, recommended nitrogen limits will be exceeded, and water quality and living resources in Little Bay will become degraded.

Because there is always a certain amount of uncertainty in a nitrogen loading analysis like the one presented here, one can pose the question “Can Little Bay truly handle 22,000 kg of nitrogen per year with experience critical declines in water quality and living resources?” In a very practical sense, political decisions are made as to what regulatory or non-regulatory goals should be adopted for a watershed. That is, if the recommended limit is perceived as too high because of existing water quality conditions, or if better ecosystem modeling predictions become available, a lower loading limit could be adopted. For example, in our buildout prediction, we assume that dairy farms are replaced by residential homes. Suppose instead that the dairy farms remain in production, and other parcels in the watershed continue to be developed. Such a future scenario would result in considerable overloading of Little Bay with nitrogen.

Recommendations for Nitrogen Management in Little Bay

Below are Buzzards Bay Project management recommendations that will reduce either present and future potential nitrogen loads to Little Bay to 22,000 kg/yr at buildout using the assumptions of our buildout and loading models. These recommendations represent the minimum action required to protect Little Bay.

1) Zoning and Health Regulations should be maintained

Zoning changes can have a dramatic impact on the future development potential in the Little Bay watershed. Existing zoning ranges from 15,000 to 60,000 sq. ft. for new subdivision. Without zoning changes, 2,338 more residential units can be expected to be built. However, if the minimum lot size on unsubdivided lots were increased to 30,000 sq. ft., only 1,940 new residences could be built, reducing potential future inputs by approximately 4,000 kg annually. If minimum lot size were further increased to 60,000 sq. ft., only 1,140 new residences could be built, resulting in a reduction of potential future inputs by 12,000 kg annually! Despite these reductions, changes in zoning in portions of this watershed may be very difficult to achieve, and may not be justified by either the Buzzards Bay Projects nitrogen loading methodology or water quality data alone. Zoning changes would be more achievable to implement in selected areas, such as north of Rt. 195. Overall, procurement of open space may be a more politically feasible approach for achieving modest to sizeable reductions in future growth potential, and these purchases would have other environmental benefits.

While we do not recommend upzoning at this time, it is important to note that our recommendations assume that local zoning and health regulations such as the minimum lot size, frontage requirements, septic system rules, etc. are not only not reduced, but fully enforced, to allow for more future development in the watershed than is currently allowed. Such, a loosening of land development rules in Fairhaven and Acushnet are likely to contribute to an increase in nitrogen loads beyond the ability of Little Bay to assimilate this growth without negative impacts on the coastal environment. Similarly, the location of industrial or municipal point source discharges in the watershed have the potential to drastically alter future nitrogen loadings to the bay. Thus, all land use and regulatory decisions or changes made in the Little Bay watershed should take into account alterations of loadings to Little Bay.

2) Fairhaven sewer extensions should continue

The densest concentration of homes on the Little Bay shoreline is located at the bay's northern edge in an area known as Knollmere Beach. Currently 31 homes in the Knollmere area are unsewered and many of these are served by substandard septic systems or cesspools. The area also has the potential to support an additional 12 houses on grandfathered lots. Sewering of this area should be made a priority of town officials in Fairhaven. Not only does this area contribute nitrogen unattenuated to the waters of Little Bay, it is also the most significant source of bacterial contamination contributing to the rainfall closure of Little Bay for the harvest of shellfish.

The upper eastern side of Sconticut Neck, north of Edgewater Street, should also be provided with municipal sewer since the septic systems of these homes, which are constructed on small lots near the bay, are an immediate source of nitrogen inputs to Little Bay. There are approximately 72 unsewered homes in this area. When added to the Knollmere Beach area, sewer extensions have the potential to reduce the number of homes contributing wastewater nitrogen loads to Little Bay by 105 homes. This will reduce future and existing nitrogen loads to the bay by at least 850 kg annually.

3) Acushnet forestlands should be protected

Today, 136 acres of the Little Bay watershed within the Town of Acushnet are municipally owned and managed by the Board of Selectmen. This represents 40% of Acushnet's watershed contribution (344 acres) to Little Bay. While undeveloped lands held by a local Conservation Commission are permanently protected under the Conservation Commission Act (MGL, Chapter 40 ss.8C), lands held by the Selectmen are held at their will and could be sold for development or converted to non-open space uses at any time. The Fairhaven Town Forest lands just south and contiguous to the Acushnet properties are held by the Conservation Commission and therefore permanently protected.

We did not include these lands in our build-out projections. Should these lands be developed, they have the potential to increase the number of residential units and therefore nitrogen loads considerably. For this reason, as well as the preservation of forest resources, wildlife habitats, and future recreational trail opportunities between Fairhaven and Acushnet, the Acushnet Board of Selectmen should transfer control of these properties to the Acushnet Conservation Commission.

4) A minimum of 200 undeveloped acres should be targeted for conservation

The acquisition of undeveloped open space in the Little Bay watershed most simply limits the opportunity for the watershed to reach its maximum build-out potential as outlined in the Fairhaven and Acushnet Zoning Bylaws. Based on the 30,000 sq. ft. minimum lot size in the Fairhaven portion of the upper Little Bay watershed, the preservation of 200 addition acres of developable land has the potential to remove more than 200 homes and their accompanying nitrogen load from the watershed at build-out. This will reduce future nitrogen loads to the bay by at least 2,000 kg annually.

As with sewering, the acquisition of open space serves a multitude of other public needs. For example, purchase of lands surrounding the Mill Road wellhead area will help preserve the quality of potential future in-town water supply sources. The preservation of farmlands and road frontage will also serve to maintain the rural character of East Fairhaven. Additional fiscal benefits will be gained through the reduction in school demand and town services in the fastest growing portion of the town. Fig. 14 shows existing open space parcels in the watershed, as well as the public wellhead recharge area (preliminary).

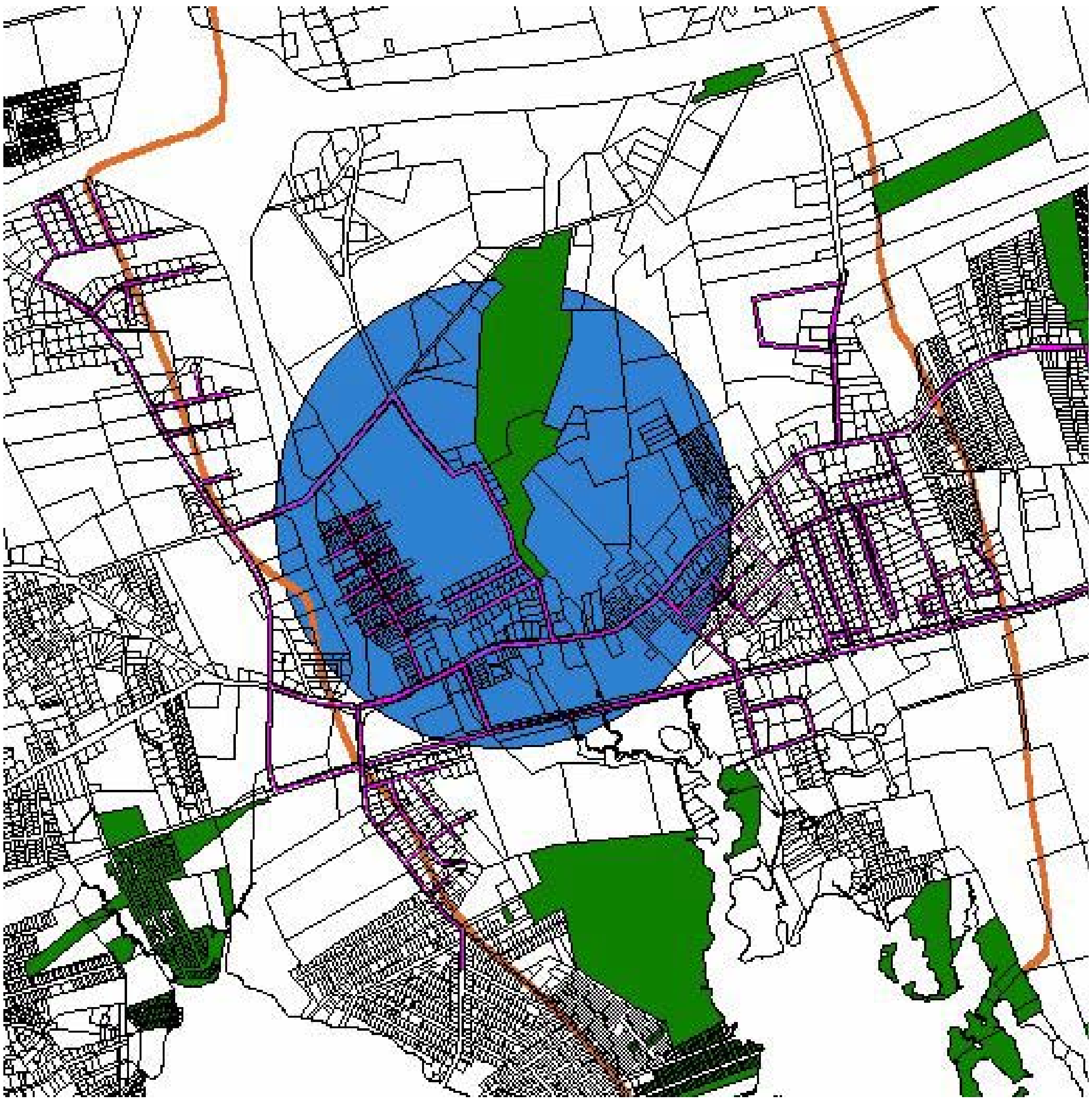

Figure 14. Open space and well recharge area in the Little Bay watershed. Circle shows preliminary well recharge areas. Highlighted roads are sewered.

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Glossary

Anoxic: A condition is which dissolved oxygen is absent. Anoxic water quality conditions often result in fish kills and shellfish mortality.

Algal bloom: A condition resulting from excessive nutrient levels or other physical and chemical conditions that enable algae to reproduce rapidly.

Anthropogenic: Human related effects. Anthropogenic impacts to water quality include wastewater from septic systems and treatment plant discharges, road and agricultural runoff, and acid rain.

Bathymetry: Measure of the depth of a water body. Important in determining the total volume of water in an embayment which is critical to nitrogen loading analysis.

Build-out Analysis: A parcel-by-parcel analysis to estimate the total number of existing and developable units, based on current zoning and other land use regulations. Such an analysis is essential for managing and limiting impacts of growth.

Carrying Capacity: The limit of a natural or man-made system to absorb perturbations, inputs, or population growth without suffering declines in quality and abundance.

Combined Sewer Overflows (CSO): A pipe that, during rain storms, discharges untreated wastewater from a sewer system that carries both sewage and stormwater. The overflow occurs because a system does not have the capacity to transport and treat the increased flow caused by stormwater runoff. New Bedford is the only Buzzards Bay municipality with CSO discharges.

Critical Limit: The carrying capacity of a coastal embayment to absorb nitrogen inputs from its watershed without suffering the negative effects of eutrophication.

Eelgrass (*Zostera marina*): A marine flowering plant that grows subtidally in sand and mud. In Buzzards Bay, eelgrass is widespread and grows to depths of 20 feet in clear waters. Eelgrass beds are an important habitat and nursery for fish, shellfish, and waterfowl.

Embayment: A small bay or any small semi-enclosed coastal water body whose opening to a larger body of water is restricted. In Buzzards Bay there are over 30 major embayments in the form of harbors, coves, coastal lagoons (or salt pond), and river mouths.

Estuary: A semi-enclosed body of water having a free connection with the open ocean and within which seawater is measurably diluted with fresh water.

Eutrophication (coastal): The process of nutrient enrichment in aquatic ecosystems. In marine systems, eutrophication results principally from nitrogen inputs from human activities such as sewage disposal and fertilizer use. The addition of nitrogen to coastal waters stimulates algal blooms and growth of bacteria, and can cause broad shifts in ecological communities present and contribute to anoxic events and fish kills. In freshwater systems and in parts of estuaries below 5 ppt salinity, phosphorous is likely to be the limiting nutrient and the cause of eutrophic effects.

Fecal Coliform: Bacteria that are present in the intestines and feces of warm-blooded animals and that are often used as indicators of the sanitary quality of water. Their degree of presence in water is expressed as the number of bacteria per 100 milliliters of the sample. The greater the number of fecal coliforms, the higher the risk of exposure to human pathogens. The indicator is used by the Massachusetts Division of Marine Fisheries in determining shellfish bed classification and local Boards of Health on swimming beach conditions.

Flushing Time (or Rate): The mean length of time for a pollutant entering a water body to be removed by natural forces such as tides and currents; also referred to as residence time or turnover time, although there are important technical distinctions in their definitions.

Hectare: A unit for measuring land area. Equals 2.5 acres.

Hypoxic: A condition in which dissolved oxygen is low or deficient. Hypoxic conditions stress marine plants and animals.

National Estuary Program: A state grant program within the US Environmental Protection Agency established under Section 320 of the Clean Water Act to designate estuaries of national significance and to incorporate scientific research into planning activities. Buzzards Bay was designated an Estuary of National Significance in 1985, thereby creating the Buzzards Bay Project.

Non-Point Source Pollution: Pollution that is generated over a relatively wide area and despersed rather than discharges from a pipe. Common sources of non-point source pollution include stormwater runoff, septic systems, and marinas.

Nutrients: Essential chemicals needed by plants and animals for growth. Excessive amounts of nutrients such as nitrogen and phosphorous can lead to degradation of water quality and growth of excessive amounts of algae. Some nutrients can be toxic at high concentrations.

Phytoplankton: Microscopic algae suspended in the water column. They contains pigments known as chlorophylls and phaeophytons which make eutrophic waters look green or brown.

Point Source Pollution: Pollution originating at a particular place, such as a sewage treatment plant, outfall, or other discharge pipe.

Polychlorinated Biphenyls (PCB): A class of chlorinated aromatic compounds composed of two fused benzene rings and two or more chlorine atoms used in heat exchange, insulating fluids and other applications. There are 209 different PCBs. PCBs are present in marine sediments in New Bedford Harbor where their cleanup is being coordinated by the US EPA Superfund Program. They, as well as other toxic contaminants, are not monitored as part of the Buzzards Bay Citizens Water Quality Monitoring Program.

Ulva: A green sheet-like seaweed commonly called "sea lettuce". Enteromorpha is another green algae that typically grows in long, thin green tubes. Both are found in eutrophic areas.

Watershed: The land that surrounds a body of water and contributes freshwater, either from streams, groundwater or surface water runoff, to that body of water.

Appendix A- Buildout Calculations

to the report:

Assessment of Nitrogen Loading and Nitrogen Management Alternatives for the Little Bay Watershed (Fairhaven & Acushnet, MA)

February 1999

by

Joseph E. Costa, Ph.D. Executive Director
Mark P. Rasmussen[2], Regional Planner

Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, East Wareham, MA 02538

[2] Current Address: Coalition for Buzzards Bay, 17 Hamilton St., New Bedford, MA 02740