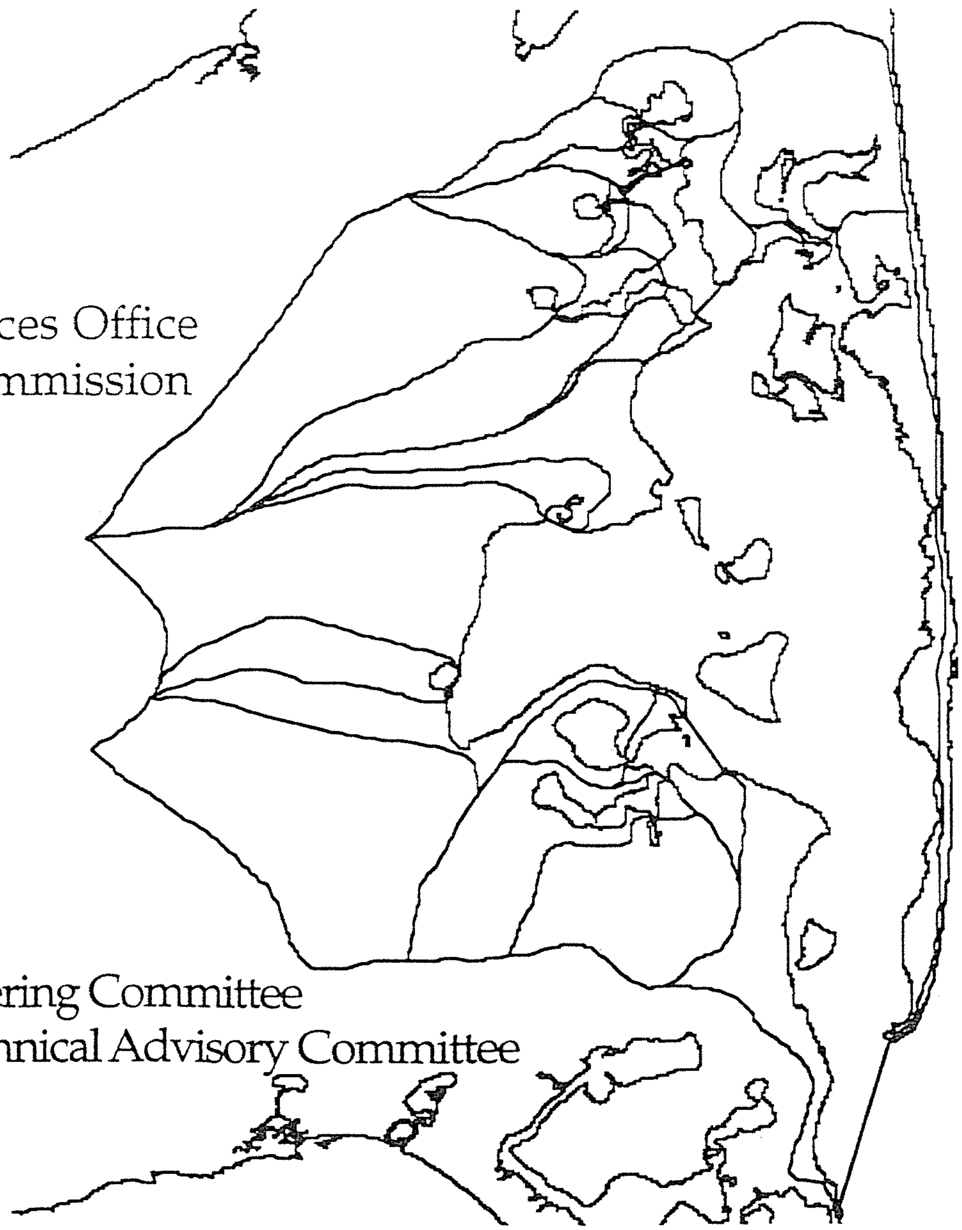
Pleasant Bay Nitrogen Loading Study

Final Report

May, 1998



Completed by:
Water Resources Office
Cape Cod Commission

Completed for:
Pleasant Bay Steering Committee
Pleasant Bay Technical Advisory Committee

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Pleasant Bay Nitrogen Loading Analysis

FINAL REPORT

(May, 1998)

prepared for

Pleasant Bay Steering Committee
Pleasant Bay Technical Advisory Committee

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Executive Summary

Pleasant Bay is the largest coastal embayment within Cape Cod and its resources are shared by the four towns along its coast: Orleans, Brewster, Harwich, and Chatham. In recent years, concerns have been expressed about the impact of development within these towns on the resources of the Bay. In order to address these concerns, the communities decided to develop a Resource Management Plan for the Bay. One of the primary issues selected to be addressed during the preparation of this plan was water quality and nitrogen loading impacts from development within the watershed to Pleasant Bay.

This Cape Cod Commission study documents the efforts undertaken to:

1) delineate the watershed to Pleasant Bay and its subwatersheds;
2) determine nitrogen loading limits for the Bay and its subembayments;
3) determine nitrogen loads coming from existing land uses within the watershed and subwatersheds and future potential nitrogen loads based on complete buildout within the watershed;
4) compare the nitrogen loading limits to the existing and buildout nitrogen loads; and
5) develop management options for watershed nitrogen loads that exceed nitrogen loading limits.

These efforts identify three subembayments with excess nitrogen loads coming from existing land uses within their subwatersheds: Muddy Creek, Areys Pond, and Round Cove. Two other subembayments (Pah Wah Pond and Ryders Cove) are identified as having the potential to exceed their nitrogen loading limits once all land is developed in their watersheds. In addition, the water quality of the whole system, including almost all the subembayments, has the potential to be jeopardized by the gradual natural movement of the Pleasant Bay inlet to a position similar to the configuration that existed prior to the 1987 break near the Chatham Lighthouse. How much water quality impact this inlet move has depends on the associated increase in background nitrogen concentrations that occurs as more tidal water is introduced into the system from the southern side of Chatham.

In order to help resolve some of these issues and better refine the nitrogen management options presented in the report, a number of recommendations are presented and discussed. These include a targeted water quality monitoring program, a watershed-wide lawn fertilizer education program, redesign of Route 28 at the mouth of Muddy Creek, evaluation of land purchase options, and development of information about existing wastewater treatment, potential locations and nitrogen-reducing capabilities of alternative septic systems, potential centralized wastewater applications, and associated costs.

I. INTRODUCTION

Pleasant Bay is the largest coastal embayment within Cape Cod, occupying more than 6,600 acres and bordered by the four towns of Orleans, Brewster, Harwich, and Chatham (Figure 1). These towns have long recognized the strong links between the resources of the Bay and their economies and community character. As the degree of development within these towns has increased, concerns have been expressed about the potential impacts upon the Bay and its resources. In order to address these concerns, the communities decided to develop a Resource Management Plan for the Bay. Among the many concerns the Management Plan is focussing on, one of the primary issues is water quality. The following Cape Cod Commission study evaluates the potential water quality impacts from development within the watershed to Pleasant Bay.

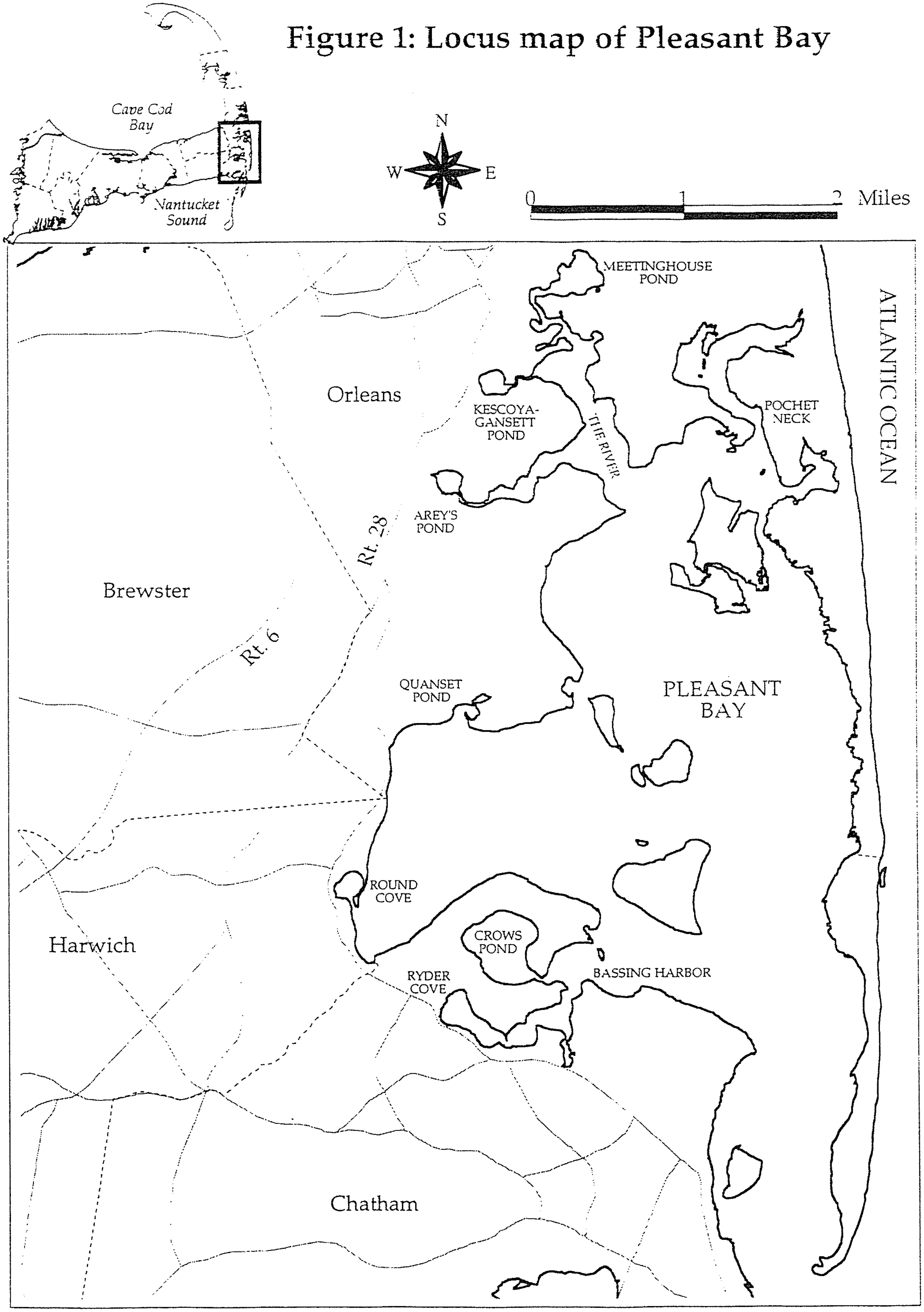
The primary contaminant of concern in this assessment is nitrogen. Nitrogen is introduced into coastal waters from atmospheric deposition and from water flowing from their watersheds. On Cape Cod, this nitrogen-bearing water is usually groundwater or groundwater-derived streams. The nitrogen that gets into the groundwater comes from wastewater, stormwater runoff, and fertilizers. The plants (algae and submerged) that form the base of embayment ecosystems can be "fertilized" by the addition of nitrogen (Ryther and Dunstan, 1971; Taylor, *et al.*, 1995a). Too much nitrogen in an embayment system increases the growth of these plants, which leads to diminished water clarity, losses of shellfish habitat, depressed dissolved oxygen levels, build-up of bottom sediments, and in extreme cases, fish kills (NRC, 1993; Valiela, *et al.*, 1992; Rosenburg, 1985; Taylor, *et al.*, 1995b; Howes and Goehringer, 1995). Long term exposure of shallow coastal waters to excessive nitrogen gradually alters their ecosystems, causing scallop and eelgrass populations to be replaced by dense algae or macroalgae, such as sea lettuce (Valiela, *et al.*, 1992; Costa, *et al.*, 1992; Nixon, *et al.*, 1986).

This report documents the work completed by the Cape Cod Commission to evaluate the nitrogen loads coming into Pleasant Bay and their potential impacts on the resources of the bay. This work was completed at the request of the Steering and Technical Advisory committees working on the Resource Management Plan. This project was designed to: 1) assist the Pleasant Bay Technical Advisory Committee in the preparation and review of Requests For Proposals (RFPs) for flushing studies for Pleasant Bay; 2) delineate subwatersheds to Pleasant Bay; 3) determine critical nitrogen loads for the subembayments of the Bay based on the results from the flushing studies; 4) determine cumulative non-point source nitrogen loads for the watershed and subwatersheds and 5) develop potential nitrogen management options for subwatersheds where existing or future cumulative nitrogen loads will exceed the recommended critical loads.

II. EVALUATION PROCESS/FINDINGS

In order to determine the amount of nitrogen getting into Pleasant Bay, the Cape Cod Commission utilized a four step process. These steps include: 1) conducting a flushing study to determine how long it takes for water within an embayment and its subembayments to be exchanged by the tides and the amount of nitrogen that the

Figure 1: Locus map of Pleasant Bay



ecosystems can assimilate (usually referred to as "critical loads"); 2) delineating the watershed to the embayment and subembayments; 3) evaluating the steady-state nitrogen load coming from existing development within its watershed and subwatersheds and the potential future load based on the complete development of undeveloped land under existing zoning; and 4) comparing the nitrogen loads from existing and future development in the watershed(s) to the critical loads from the flushing study and developing nitrogen management strategies based on this comparison (Figure 2).

A. Flushing Study and Critical Loads

i. Flushing Study

In 1995, the Cape Cod Commission provided $25,000 to conduct a flushing study of Pleasant Bay. These funds were held by the Town of Orleans as the selected town to administer the Resource Management Plan funds. In 1996, the Commission provided a grant of $15,000 to the Town of Chatham to conduct a tidal flushing study of the Bassing Harbor system, including Ryders Cove and Crows Pond. In 1997, with the start of the Management Plan efforts, these funds were combined to conduct a comprehensive flushing study of the entire Pleasant Bay system. After the preparation of a Request for Proposals (RFP), Aubrey Consulting, Inc. (ACI) was selected to complete the flushing study of Pleasant Bay.

In general, a flushing study begins with a bathymetric (depth) survey of the embayment. This survey establishes where sub-basins are located within the embayment system and the volume of water in these sub-basins. ACI collected bathymetric information in April 1997; details of their techniques are included in ACI (1997). At the same time, nine temperature-depth recorders (TDRs) were deployed at selected locations within Pleasant Bay. These TDRs collected tidal elevations for at least 30 days and this tidal data was incorporated and calibrated within a two-dimensional model of the Bay.

Once the details of how water moves with the tides are accurately modeled, the next question is how quickly is the water exchanged within the sub-basins and out of the whole system. Determining how quickly the water is exchanged, or flushed, from a sub-basin and system is a key to determining how long nitrogen introduced from a watershed is available for use, or uptake, by the plants in an embayment ecosystem.

One key consideration in determining how to evaluate flushing information is deciding on the appropriate flushing time. If the water quality within the larger embayment (*e.g.*, the main portion of Pleasant Bay) is worse than the water quality within a subembayment (e.g., Ryders Cove), one would want to evaluate how long the water within a subembayment takes to flush all the way out of the larger embayment. This flushing time is know as a system residence time (Figure 3). If the water quality is better in the larger embayment, one would want to evaluate the flushing time to get water out of the subembayment and into the larger embayment. This is known as a local residence time (see Figure 3). Since Pleasant Bay is flushed with relatively unimpacted waters of the Atlantic Ocean and/or Nantucket Sound, this review focussed on evaluations based on the local residence times of the

Figure 2. Four step approach to nitrogen management of coastal waters.

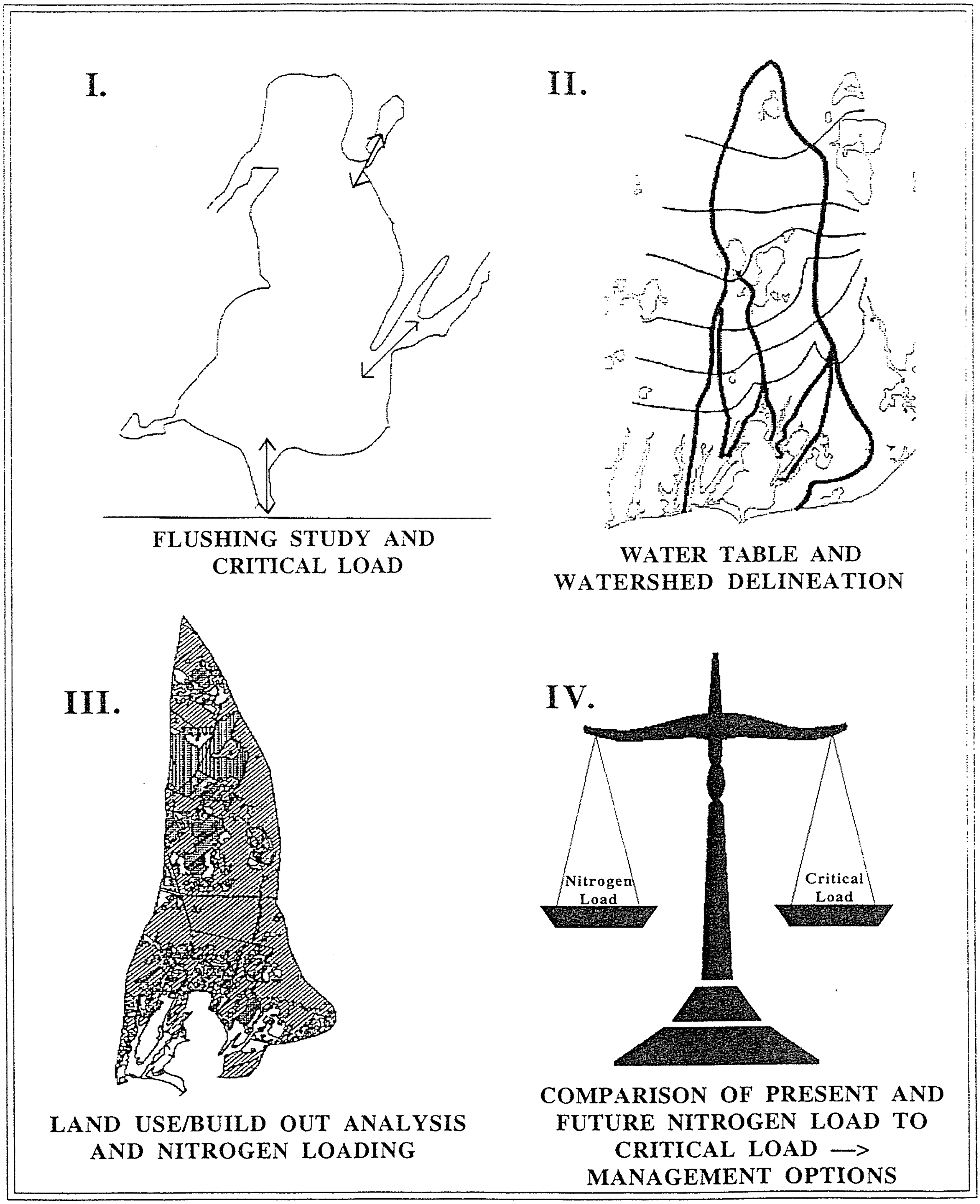
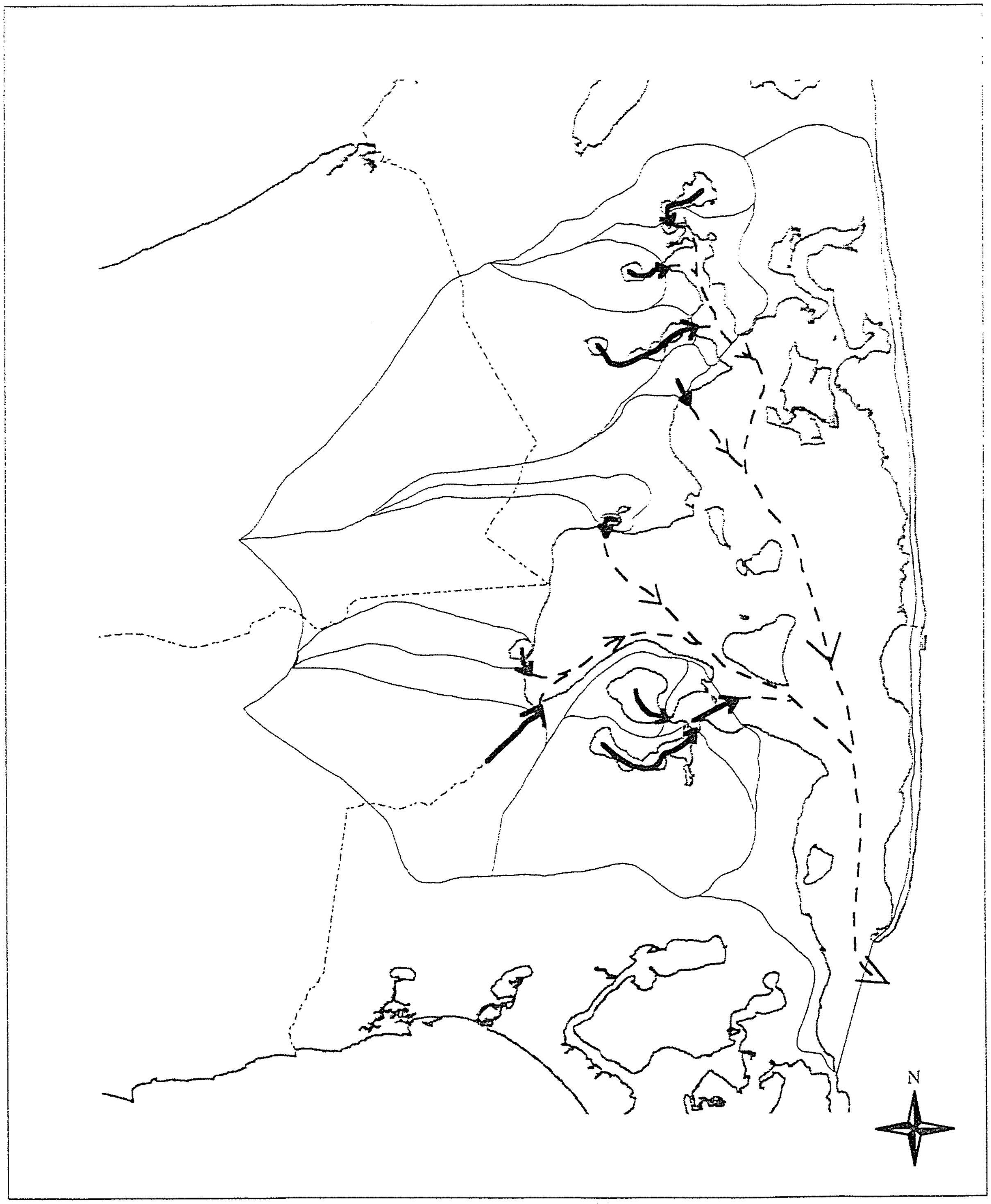


Figure 3: Local and System Residence Times in Pleasant Bay



= Local residence time flowpath

= System residence time flowpath

subembayments (Table 1).

Table 1. Residence Times and Volumes in the Pleasant Bay Embayment System

	Local Residence Time (days)		Volume (ft3)
	Existing	Pre-Break	
Pleasant Bay Estuary	0.98	1.10	1,997,780,000
Bassing Harbor System	1.38	1.56	100,580,000
Ryder Cove	0.93	1.03	30,386,000
Crows Pond	1.77	2.01	51,465,000
Muddy Creek	5.83	7.50	5,391,000
Round Cove	0.80	0.93	3,202,000
Quanset Pond	0.68	0.76	2,436,000
Pah Wah Pond	0.68	0.78	1,246,000
Pochet Channel	*0.43*	*0.48*	*17,850,000*
The River System	0.77	0.87	80,724,000
Upper River System	*1.12*	*1.27*	*3,774,000*
Areys Pond System	0.54	0.61	12,138,000
Areys Pond	*1.52*	*1.75*	*2,898,000*
Kescayo Gansett Pond System	1.06	1.15	4,782,000
Kescayo Gansett Pond	*0.68*	*0.79*	*3,774,000*
Meeting House Pond	1.15	1.31	17,447,000
Meeting House Pond (revised)	*0.87*	*0.99*	*13,322,000*

Table 1 shows two local residence times: existing and pre-break. One of the tasks requested of ACI during their evaluation of flushing times and tidal characteristics in Pleasant Bay was to evaluate the potential change expected in flushing times once the system reconfigures itself back to conditions more closely approximating those before the 1987 break near the Chatham Lighthouse. The movement of the inlet to a pre-break, more southern, position makes the tidal flow into the system less efficient, reducing the amount of tidal water reaching the upper portions and increasing the residence times. The evaluation of these pre-break conditions is carried through the rest of the nitrogen loading analysis.

Selected portions of Pleasant Bay that are identified in Table 1 are italicized. Following the draft flushing study, the Pleasant Bay Technical Advisory Committee suggested alternative segmentation of Pleasant Bay based on local observations and experiences. This resegmentation allowed for additional focus on the parts of Pleasant Bay most likely to experience the impacts of excessive nitrogen loads. Based on assessments completed in the draft nitrogen loading analysis, project staff selected certain of these altered subembayments for additional nitrogen loading assessments. Following sections discuss the level of analysis selected for these alternative segments.

A flushing study was previously conducted for the Round Cove portion of Pleasant Bay (ASA, 1992). This study involved the release of dye on the surface of Round

Cove followed by periodic measurements of its declining concentration. Using this method, ASA found that the residence time for Round Cove was 2.4 days. This is a significantly different than the 0.80 days estimated by ACI (1997) for existing conditions. ACI reviewed weather patterns during ASA's data collection and found that a sustained east/northeast wind was blowing during the first two days of the dye study. This wind would tend to lengthen the estimated residence time since the wind would hold water, and its accompanying dye, in Round Cove. Dye concentrations did not appreciably decrease during the two days and ASA did not take another reading until 4 days later. Although this reading found that dye concentrations had decreased, a northeast storm had overwashed the sand spit protecting Round Cove during this period and no interim measurements had been taken. Based on the data collection difficulties associated with the ASA dye study, project staff have decided to utilize the ACI (1997) readings in all the following analyses and recommendations.

ii. Critical Loads
Studies of coastal systems around the world have indicated that increased nitrogen loading can dramatically increase the productivity and alter the ecosystem characteristics of coastal waters (USEPA and EOEA, 1991; Nixon, 1983; Nixon, *et al.*, 1986; NRC, 1993; Valiela, *et al.*, 1992). However, determining the appropriate level of nitrogen loading tends to be rather site-specific and can become more complicated by factors that will alter the expected nitrogen load, its measurement, or its impacts. These factors can include: internal nitrogen loads to the embayment from its sediments (deposited by growth during previous years), carbon-rich soils in the embayment watershed (can allow denitrification of nitrogen loads within groundwater prior to discharge), and coastal wetlands (can denitrify watershed nitrogen loads if they flow through the wetland). Even with these concerns about variability, ultimately, a community needs to make a decision about whether conditions within an embayment are desirable and how much it is willing to spend to either restore the embayment or preserve its condition.

Desirability is a difficult questions for coastal water quality scientists to answer; any ecosystem will adapt to its inputs. In the case of a nitrogen overloaded system, the ecosystem's function will result in: low or absent dissolved oxygen concentrations, loss of shellfish due to lack of oxygen, bottom sediments may start producing hydrogen sulfide (rotten egg) odors, herring will not advance into the system because of low dissolved oxygen, eelgrass will disappear, and macroalgal mats will become the dominant plant species. However, in this system, people will still be able to moor their boats and the water will still look good from a distance, although most people probably would not want to go swimming in this water. On the other hand, a less impacted system will look good close up, shellfish will be abundant, swimming will be inviting, and a more diverse and stable ecosystem will be sustained. The acceptability of the condition of coastal water ecosystems needs to be addressed by the involved communities, hopefully with information from scientists. This type of discussion about the consequences of our decisions does not regularly occur. We generally make decisions about water quality in coastal waters without considering water quality or ecosystem impacts.

Rather than trying to address the desirability of one system over another, most coastal water quality scientists try to determine what sort of ecosystem conditions will be seen at various nitrogen loading levels. These conditions tend to focus on one parameter or species that is a key determinant for the stability or "health" of the ecosystem. This key factor could be dissolved oxygen, chlorophyll concentrations, or eelgrass coverages. Much research has been focussed on determining the relationship between these factors and nitrogen loads.

Unfortunately, this research has not been able to provide "crystal clear" results that most people desire. As with most relationships in nature, the factors and nitrogen loads are interrelated in complex and variable ways. Local conditions, such as tidal ranges, watershed geology, or background nitrogen concentrations, will cause different balancing points in different embayments. On Cape Cod, these factors vary within smaller ranges, but there is still variability between embayment systems. A flushing study helps to determine some of the conditions, but other details will still contribute toward some sense of uncertainty. The analyses completed below focus on trying to make recommendations about management with an acknowledgement of the uncertainties and recommendations about where additional information will be useful.

In order to begin the process of defining an appropriate amount of nitrogen for each of the subembayments, staff reviewed available water quality information and recommended nitrogen loading limits in other areas and evaluated qualitative measures of surface waters and their ecosystems.

a. Massachusetts Coastal Water Quality Regulations

Current Massachusetts regulations do not directly address nitrogen limits for coastal water quality, but the Surface Water Classification regulations suggest the use of best available treatment technologies for direct discharges of wastewater into the cleanest waters (310 CMR 4.04 (5)) and Title 5 requires density limitations for septic systems within watersheds to "nitrogen sensitive coastal embayments" (310 CMR 15.214-15.217). The state surface water regulations (310 CMR 4) also contain a classification system for coastal waters.

The state classification system designates three types of coastal waters: SA, SB, and SC (Table 2). Each designation has numerical water quality criteria for selected parameters: dissolved oxygen (DO), temperature, pH, fecal coliform, solids, color and turbidity, oil and grease, and taste and odor. These numerical water quality standards tend to focus on conditions surrounding a wastewater outfall and do not correspond to eutrophication impacts, ecosystem health, or the impact of nonpoint source pollution commonly associated with septic systems. Pleasant Bay is designated by the state as a SA water, with an additional Outstanding Resource Water (ORW) designation (310 CMR 4.06).

Table 2. State Coastal Waters Classification System (310 CMR 4.05(4))	
Classification	Criteria
SA	- "suitable for shellfish harvesting without depuration" - "excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation" - "have excellent aesthetic value"
SB	- "suitable for shellfish harvesting with depuration" - "habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation" - "have consistently good aesthetic value"
SC	- "habitat for fish, other aquatic life and wildlife and for secondary contact recreation" - "have good aesthetic value" - "suitable for certain industrial cooling and process uses"

The ORW designation (310 CMR 4.04) can be added to any water classified under the SA/SB/SC system. These waters are recognized as being "an outstanding resource as determined by their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these water shall be protected and maintained." Degradation of these waters is not allowed unless authorized by the Director of the state Division of Water Pollution Control.

As with the SA/SB/SC system, the ORW designation tends to focus on direct point sources; restricting additional pollutant discharges. Nonpoint pollution sources of nutrients (*i.e.*, septic systems) "shall be provided with all reasonable best management practices for nonpoint source control." Coastal ORWs on Cape Cod tend to be within special state area designations, such as Areas of Critical Environmental Concern (ACECs). Pleasant Bay is specifically listed as an ORW water because of the ACEC designation (310 CMR 4.06).

In summary, the state regulations include a coastal water quality classification system that tends to focus on point source discharges of pollutants and shellfish bed conditions. These regulations do not include coastal nitrogen standards.

b. Recommended Coastal Nitrogen Limits

Although there is little debate about the impacts of excessive nitrogen in coastal waters, there has been some debate about the most appropriate basis for establishing nitrogen loading limits. Some studies of nitrogen sensitivity have recommended that a nitrogen load per unit area of an embayment is the most appropriate measure in determining eutrophication effects (*e.g.*, Nixon, 1983). Other studies have suggested that in rapidly flushed shallow embayments, determining how quickly water in the embayment is exchanged with the surrounding ocean water is a more appropriate measure for determining coastal eutrophication effects (*e.g.*, Valiela and Costa, 1988; Nixon and Pilson, 1980).

The Buzzards Bay Project (BBP) reviewed water quality and ecosystem eutrophication information for a number of coastal embayments throughout the world in the process of putting together the Comprehensive Conservation and Management Plan for Buzzards Bay (USEPA and EOEA, 1991). Based on this review, the BBP suggested that eutrophication effects of nitrogen loads in rapidly-flushed shallow embayments are better correlated with assessments that include measures of flushing or turnover time, while embayments with longer flushing time should have limits based on their area (Costa, *et al.*, in preparation). The turnover time idea is very similar to a concept established by Vollenweider (1976) for determining acceptable phosphorus loads within freshwater lakes and has been supported by water quality monitoring in coastal systems (*e.g.*, Paerl, *et al.*, 1995). Based on their review, the BBP recommended a tiered nitrogen loading limit system for shallow and deep embayments that incorporates flushing times for rapidly flushed systems and areal measures for less rapidly flushed systems (USEPA and EOEA, 1991) (Table 3). These limits are based on nitrogen added to the system from its watershed, not the total amount of nitrogen within the system. The total amount would include internal nitrogen loads and background nitrogen from the ocean or bay. The BBP used a modified version of the coastal classification system used by the state, but as stated above, coastal nitrogen limits are not included in Massachusetts regulations.

Table 3. Buzzards Bay Project Recommended Nitrogen Loading Limits

Embayment	ORW/SA	SA	SB
Shallow			
-flushing: 4.5 days or less	100 $mg/m^3/Vr$	200 $mg/m^3/Vr$	350 $mg/m^3/Vr$
-flushing: greater than 4.5 days	5 $g/m^2/yr$	15 $g/m^2/yr$	30 $g/m^2/yr$
Deep			
- select rate resulting in lesser annual loading	130 $mg/m^3/Vr$ 10 $g/m^2/yr$	260 $mg/m^3/Vr$ 20 $g/m^2/yr$	500 $mg/m^3/Vr$ 45 $g/m^2/yr$
Note: Vr= Vollenweider flushing term	Vr= r/(1+sqrt(r))	r= flushing time (yrs) source: USEPA and MA EOEA, 1991	

The tiered limits in Table 3 use the state classification designations, but the meaning of the ORW designation is not similar in both cases. The state uses the ORW designation for "anti-degradation" areas; areas where water quality should not be further degraded by pollutants. Since the BBP used the ORW designation as a limit, waters that have nitrogen loads below the limit could theoretically accommodate more pollutants up to the limit. This concept is contrary to the state use of the ORW designation.

Once the flushing time for an embayment or subembayment system is established, this value and the appropriate BBP limit is inserted into a calculation form with information about the bathymetry and volume of the system (Table 4). The calculation results in a "critical load" or an annual mass of nitrogen that the system can assimilate at the recommended limit without becoming more eutrophic or impaired. In some cases, the flushing time for an embayment or subembayment is longer than 4.5 days recommended as a cutoff by the BBP (see Table 3). In these cases, the surface area of the embayment determines the critical load (see Method 2 in Table 4). The only subembayment in Pleasant Bay with a flushing time longer than 4.5 days is Muddy Creek (see Table 1).

Table 4. Sample Critical Load Calculation Form	
1. Embayment: Example Subembayment	
2. Area of Bay (hectares):	4.7
3. Mean Depth of Embayment at MLW (meters):	1.92
4. Tidal Prism volume (m^3):	
5. Volume at mid-tide (m^3):	90,682
6. Flushing time or residence period (days):	0.80
7. Flushing time or residence period (years):	0.00219178
8. Critical loading rate for this embayment (select 8a or 8b):	
8a. Volume-flushing adjusted limit ($mg*m^{-3}*Vr^{-1}$):	100
8b. Area-adjusted limit ($g*m^{-2}*yr^{-1}$):	Not Applicable in this Case

9. Critical loading limit to embayment:

9a. METHOD 1- (volume-flushing adjusted limit as in 8a):

$$\frac{100*90{,}682*(1+\sqrt{0.00219178})}{0.00219178*1{,}000{,}000}=$$

= 9,528 lbs Nitrogen/year to the embayment

= 4,321 kg Nitrogen/year to the embayment

9b. METHOD 2 - (area adjusted limit as in 8b):

$X * 1.92 * 10 * 2.2 =$ NOT APPLICABLE IN THIS CASE

= X lbs Nitrogen/year to the embayment

= X kg Nitrogen/year to the embayment

The idea inherent in the Massachusetts surface water and wastewater regulations is that ORW waters should not be allowed to degrade. This idea runs contrary to the idea of setting a limit and allowing nitrogen loading up to the limit. Since any additional nitrogen will necessarily enrich or encourage more growth in a coastal ecosystem, a question arises whether enrichment of a system constitutes degradation.

In order to try to evaluate this question, project staff also evaluated the water quality parameters found by the Falmouth Pond Watchers in their regular monitoring of Falmouth's coastal embayments. Staff focussed on the average nitrogen concentrations, the other ecosystem measures in these ponds (*i.e.*, dissolved oxygen and chlorophyll concentrations), the average nitrogen concentrations under the BBP recommended limits, and how the concentrations relate to the qualitative categories in the state regulatory classification strategy for coastal waters.

If one were to take the average nitrogen concentration along the southern and western coasts of Cape Cod (approximately 0.3 ppm) and add this to the recommended BBP limits, the corresponding concentration limits in Table 3 for shallow quick-flushing embayments would be: ORW, 0.4 ppm; SA, 0.5 ppm; and SB, 0.75 ppm. After reviewing the Pond Watchers data, it appears that waters with average nitrogen concentrations less than or equal 0.35 ppm generally have the highest dissolved oxygen concentrations in bottom waters and ecosystems that are nearly pristine. Nitrogen concentrations between 0.35 and 0.45 ppm are generally associated with relatively high dissolved oxygen concentrations in bottom waters, although depressed concentrations (in the 2 to 4 ppm range) have been detected (Howes and Goehringer, 1995); clearly these waters are impacted. Systems with nitrogen concentrations around 0.5 ppm have more regular occurrences of low dissolved oxygen conditions in bottom waters and nitrogen concentrations greater than 0.75 ppm consistently have low dissolved oxygen concentrations in bottoms waters with occasional anoxic events. Low oxygen concentrations are associated with lower species diversity and less stable ecosystems. Embayments with higher nitrogen concentrations also tend to have extensive phytoplankton populations, which restrict light penetration (<3 m) and shade out eelgrass.

Comparing the BBP designations and recommended limits to the Falmouth Pond Watchers review of impacts, it would appear that the BBP limits are associated with greater impacts than one would associate with the state regulatory descriptions of coastal water quality. For an additional comparison, the Town of Falmouth uses the Pond Watchers data within its zoning regulations and has the following categories and concentration limits for its embayments: High Quality Areas (< 0.32 ppm), Stabilization Areas (0.32 to 0.5 ppm), Intensive Water Quality Areas (0.5 to 0.75 ppm) (Falmouth Zoning Bylaws, Article IV). Based on these comparisons, if one were to assign adjectives to the BBP limits, they would probably be: "excellent" for the ORW limit; "impacted" for the SA limit; and "impaired" for the SB limit. Clearly, these are different qualitative assessments than one would associate with the state regulatory classifications.

In summary, the BBP ORW limit generally results in a nitrogen load equivalent to 0.1 ppm addition over background concentration, which staff have assumed to be 0.1 ppm in Pleasant Bay. During a review of water quality in Falmouth coastal embayments, this addition seems to be associated with greater impacts than one would associate with waters meant to be the most pristine (*i.e.*, designated ORW). The Falmouth Pond Watchers data tends to support a smaller concentration addition (~0.05 ppm) for the maintenance of water quality in the most pristine waters. Staff have labelled a limit based on this smaller addition as "ORW-N".

c. Pleasant Bay Critical Nitrogen Loads

Since Pleasant Bay is a state-designated ORW water, the analyses below have been guided by the idea of preserving or attaining excellent or near pristine water quality in the Bay. Because water quality information in Pleasant Bay is relatively sparse, project staff determined (Table 5) and evaluated critical nitrogen loads based on both the BBP ORW limit and the ORW-N limit, as well as considering both inlet configurations (labeled "existing" and "pre-break" in Table 5).

Table 5. Pleasant Bay Critical Loads

	BBP ORW Critical Load (kg/yr)		ORW-N Critical Load (kg/yr)	
	Existing	Pre-Break	Existing	Pre-Break
Pleasant Bay Estuary	2,211,417	1,975,943	1,053,627	938,686
Bassing Harbor System	79,792	70,843	37,670	33,324
Ryder Cove	35,399	32,042	16,887	15,248
Crows Pond	32,076	28,367	15,028	13,234
Muddy Creek	662	662	478	372
Round Cove	4,321	3,730	2,069	1,780
Quanset Pond	3,854	3,457	1,852	1,657
Pah Wah Pond	1,971	1,724	947	826
Pochet Channel	44,283	39,744	21,455	19,220
The River System	113,090	100,368	54,185	47,957
Upper River System	3,668	3,246	1,742	1,536
Areys Pond System	24,074	21,361	11,618	10,284
Areys Pond	2,093	1,826	985	856
Kescayo Gansett Pond System	4,904	4,529	2,332	2,149
Kescayo Gansett Pond	5,971	5,156	2,869	2,469
Meeting House Pond	16,525	14,559	7,841	6,884
Meeting House Pond (revised)	16,564	14,601	7,914	6,955

Table 5 includes the alternative subembayments identified following the review of the draft flushing study. Following the determination of the critical loads in Table 5, project staff consulted with Technical Advisory Committee (TAC) members about which of the new subembayments would be rigorously reviewed. Project staff reviewed the nitrogen loads previously determined in the areas of the new subembayments, estimated watersheds, and the critical loads in Table 5. Areys Pond was chosen for additional review based on the significant increase in its nitrogen sensitivity (*i.e.*, decrease it its critical loads). Kescayo Gansett Pond was selected because the nitrogen load within the Kescayo Gansett Pond System is relatively close to its critical load and it was determined that the TAC wanted to document the nitrogen loading impact of only a portion of the Pond System watershed. Pochet Channel was not selected for additional review based on its relatively high critical nitrogen loads and relatively small amount of development its watershed. The Upper River system was not selected for additional review because its very small watershed should not approach its critical nitrogen loads. The revised Meeting House Pond was not selected for additional review because its watershed decreased in size, while its critical nitrogen loads remained essentially the same (see Table 5).

B. Watershed Delineation

The porous and highly permeable characteristics of the glacial-derived sand deposits of Cape Cod allow rapid infiltration of precipitation. This rapid recharge and absence of exposed bedrock (Oldale, 1969) means that watershed delineations on Cape Cod are determined by the elevation of the groundwater and its direction of flow, rather than by the land surface topography (Cambareri and Eichner, 1998). Each coastal watershed is defined as the land area that captures recharge that eventually discharges into an embayment.

In order to determine a watershed to Pleasant Bay, project staff needed to have an accurate and regionally consistent groundwater map. Staff obtained groundwater elevations from previously completed regional, subregional, and parcel groundwater studies. The predominant studies used for this effort are Johnson and Davis (1988) water table map of Harwich and Brewster, the Cape Cod Commission's water table map of Orleans (Leab, *et al.*, 1995), and unpublished water table information provided by Whitman and Howard for Chatham. The water table elevations of all studies were adjusted to the time of the Harwich and Brewster mapping to prepare a composite water table map of the watershed area around Pleasant Bay.

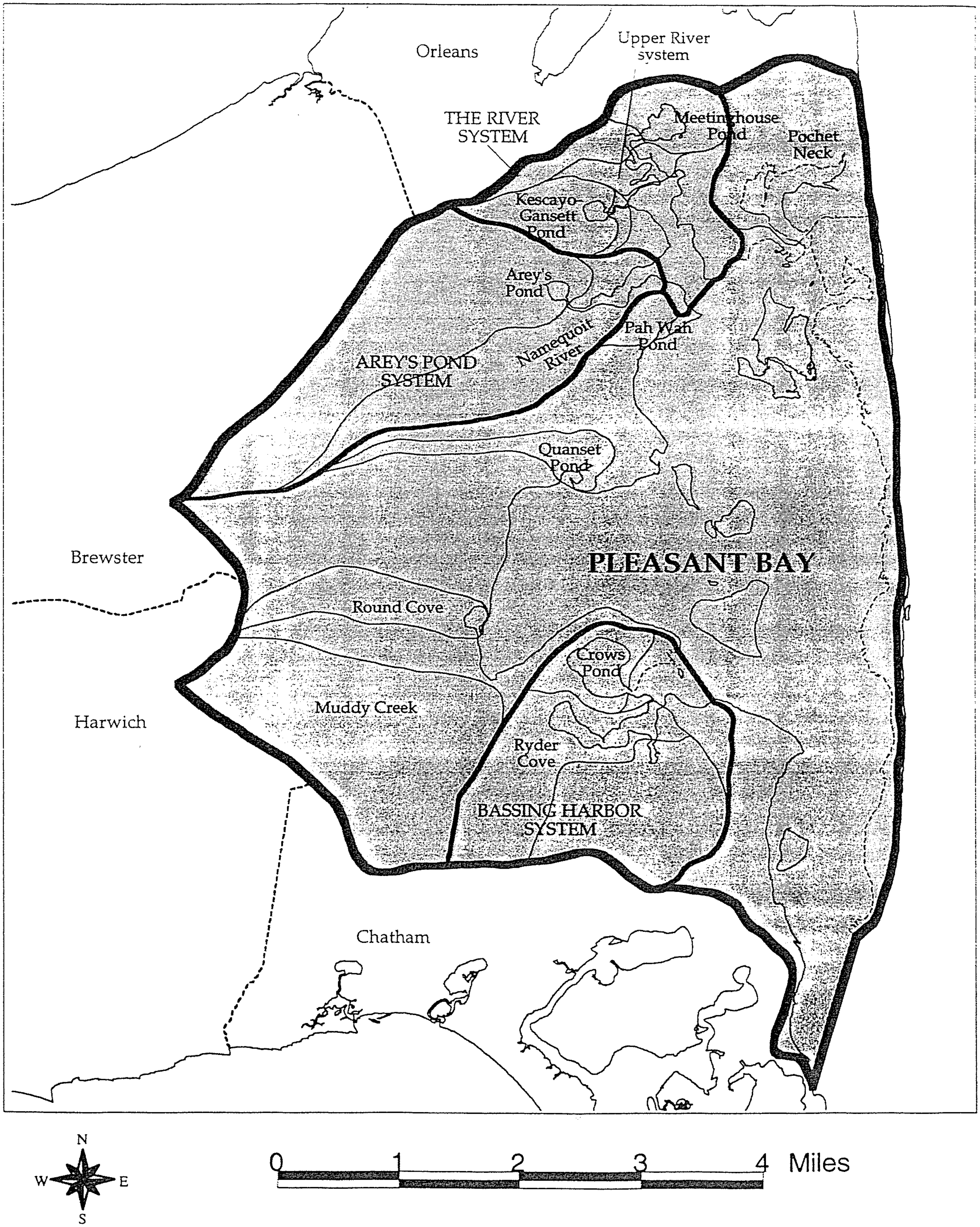
Once the composite map was completed, the outer watershed boundary to Pleasant Bay was delineated. Following this delineation, subwatersheds were delineated based on the segmentation of the Bay system in the draft flushing study (ACI, 1997). Once the Bay system was resegmented with input from the Technical Advisory Committee, subwatersheds were redelineated to selected portions of the Bay system. Figure 4 shows the subwatershed delineations, including the watersheds to the newly identified subembayments.

C. Land Use and Nitrogen Loading Analysis

In order to determine the potential water quality impacts of development upon coastal embayments, one needs to estimate the amount of nitrogen (or "load") that is currently getting into an embayment and then estimate how much nitrogen can get into the embayment once all the land within a watershed is developed. In order to estimate the loads, project staff determined the various land uses within the subwatersheds and projected the potential future development based on current zoning in the watershed towns.

Project staff determined the land uses within the watershed to Pleasant Bay by initially combining parcel and tax assessors information within the Commission's Geographic Information System (GIS). Since Massachusetts town assessors classify land uses by a common code (MADOR, 1991), land uses in the various towns in the different watersheds can be combined. Once this is accomplished, staff obtained assistance from town planning, water, and health departments to estimate wastewater flows from commercial, industrial, and governmental land uses. In some cases, this required field checks of land uses and/or determination of Title 5 flows.

Figure 4: Pleasant Bay watershed and subwatersheds



Once all the land use information had been determined, staff used the Cape Cod Commission's Technical Bulletin 91-001 (TB91-001) (Eichner and Cambareri, 1992) as the basis for determining Pleasant Bay watershed nitrogen loads. Each residential dwelling is assumed to have three bedrooms and each residence is assumed to be occupied at the current occupancy rate within the town (Table 6). These two factors are combined to estimate a wastewater flow that is lower than a Title 5 estimate (110 gallons per day per bedroom) and more closely approximates actual water use. In addition, the nitrogen loading estimates also account for the seasonal nature of residential dwellings in the Pleasant Bay watershed (see Table 6). The total number of residential dwellings is multiplied by the year-round occupancy percentage, based on 1990 US Census data, and seasonal dwellings are assumed to be occupied for 3 months at an occupancy of 5 people per residence. This summer occupancy results in a tripling of year-round population, which is the estimated population increase associated with summer visitors on Cape Cod (CCC, 1996). Condominium units are also evaluated with consideration of known deed restrictions that limit occupancy. Depending on the information available, the wastewater estimates for commercial, industrial, and governmental land uses are based on Title 5 flow estimates or actual measured water use.

Table 6 - Occupancy Factors for Towns in the Pleasant Bay Watershed

Town	Persons per Househould	Total Housing Units	Occupied Housing Units on April 1st	% Occupied Year Round
Brewster	2.42	6367	3383	53.1%
Chatham	2.10	6301	3023	48.0%
Harwich	2.27	8325	4505	54.1%
Orleans	2.09	4593	2722	59.3%

Future development potential within the Pleasant Bay watersheds is based on the number of parcels classified as "developable" by the town assessors. The total number of potential residential units is determined by evaluating each parcel; if a parcel can be subdivided into two or more parcels under current zoning, it is counted as having the highest number of potential parcels based strictly on lot size. This evaluation method does not account for other zoning issues, such as frontage requirements, but it is a reasonable first approximation of potential residential lots. Staff evaluated development of future residential parcels based on both seasonal and year-round occupancy. No subdivisions of commercial and industrial developable parcels are assumed and future wastewater nitrogen loads from these lots are assumed to be equal to the average of existing commercial and industrial land uses within the Pleasant Bay watershed or specific subwatershed.

Once all the land uses and wastewater estimates had been determined in each of the Pleasant Bay subwatersheds, staff used the TB91-001 nitrogen loading factors (Table 7) to estimate nitrogen loads within each subwatershed and to the system as a whole (Table 8).

Table 7. Technical Bulletin 91-001 Nitrogen Loading Factors for Pleasant Bay			
NITROGEN CONCENTRATIONS (mg/l):		RECHARGE RATES (in/yr):	
Wastewater	35	Impervious Surfaces	40
Road Run-off	1.5	Natural Areas	
Roof Run-off/Direct Precipitation on Embayment	0.75	Brewster, Harwich	17
Natural Area Run-off	0.05	Chatham, Orleans, Eastham, Wellfleet, Truro, Provincetown	16
BEDROOMS PER SINGLE FAMILY HOUSE	3		
AVERAGE LAWN SIZE (ft2)	5,000		
NITROGEN FERTILIZER RATE (lbs/1,000 ft^2 of lawn)	3		

Table 8 - Existing and Future Nitrogen loads within the Pleasant Bay Watershed and Subwatersheds (kg/yr)

	Existing	Buildout		% Seasonal
	Seasonal	Seasonal	Year-round	Increase
Pleasant Bay Estuary	92218	116932	123572	27%
Bassing Harbor System	18878	22254	23451	18%
Bassing Harbor	1469	1889	2065	29%
Ryder Cove	15343	18048	18964	18%
Crows Pond	2066	2317	2422	12%
Muddy Creek	10947	19402	20847	77%
Round Cove	3608	4837	5274	34%
Quanset Pond	927	1170	1248	26%
Pah Wah Pond	487	916	1045	88%
The River System	2845	3566	3783	25%
Areys Pond System	6623	8631	9246	30%
Areys Pond	3217	4600	5677	43%
Kescayo Gansett Pond System	1423	1677	1753	18%
Kescayo Gansett Pond	1334	1616	1943	21%
Meeting House Pond	3967	4969	5101	25%

Table 8 also shows the expected increase in nitrogen load at buildout based on continued seasonal occupancy. The greatest percentage increases in nitrogen loading due to buildout are within the watersheds to Muddy Creek (77%) and Pah Wah Pond (88%).

D. Development and Implementation of Management Strategies

During the final step of the four step process, the nitrogen loads developed in Step III are compared to the critical nitrogen loads developed in Step II (see Figure 2). If the nitrogen load from either existing or future development within the embayment watershed exceeds a critical load, management strategy options have been developed to reduce the nitrogen load to the critical load. This report presents potential nitrogen management strategies to meet both the BBP ORW and ORW-N limits. Implementation and adoption of management strategies will require further discussions within and among the communities within the various subwatersheds.

i. Comparison of Nitrogen Loads to Critical Loads

a. Existing Loads

Figure 5 compares the existing seasonal nitrogen loads in Table 8 to the two critical loads (ORW-N and BBP ORW) developed for the Pleasant Bay subwatersheds based on both inlet configurations (existing and pre-break) (see Table 5). If a bar in this figure is above the "Critical Load" line, the existing loading is exceeding the nitrogen loading limit for the respective subembayment. Muddy Creek and Areys Pond exceed both critical loads based on both inlet configurations. Round Cove exceeds the ORW-N limit based on both inlet configurations. Ryders Cove exceeds the ORW-N limit based on the pre-break inlet configuration. All other subembayments and the system as a whole are below the two critical loads based on both inlet configurations.

b. Buildout Loads (Seasonal)

Figure 6 compares the buildout seasonal nitrogen loads in Table 8 to the two critical loads (ORW-N and BBP ORW) developed for the Pleasant Bay subwatersheds based on both inlet configurations (existing and pre-break) (see Table 5). If a bar in this figure is above the "Critical Load" line, the buildout loading is exceeding the nitrogen loading limit for the respective subembayment. Since Muddy Creek and Areys Pond exceed both critical loads based on both inlet configurations under existing conditions, buildout nitrogen loads further exceed the critical loads. Similarly the buildout nitrogen load from the Round Cove subwatershed further exceeds the ORW-N limit based on both inlet configurations, while also exceeding the BBP ORW limit in both inlet configurations. Buildout nitrogen load within the Ryders Cove subwatershed further exceeds the ORW-N limit based on the pre-break inlet configuration, while also exceeding the ORW-N limit based on the existing inlet configuration. The buildout nitrogen load within the Pah Wah Pond subwatershed exceeds the ORW-N limit based on the pre-break inlet configuration. All other subembayments and the system as a whole are below the two critical loads based on both inlet configurations.

c. Discussion of Nitrogen Loads

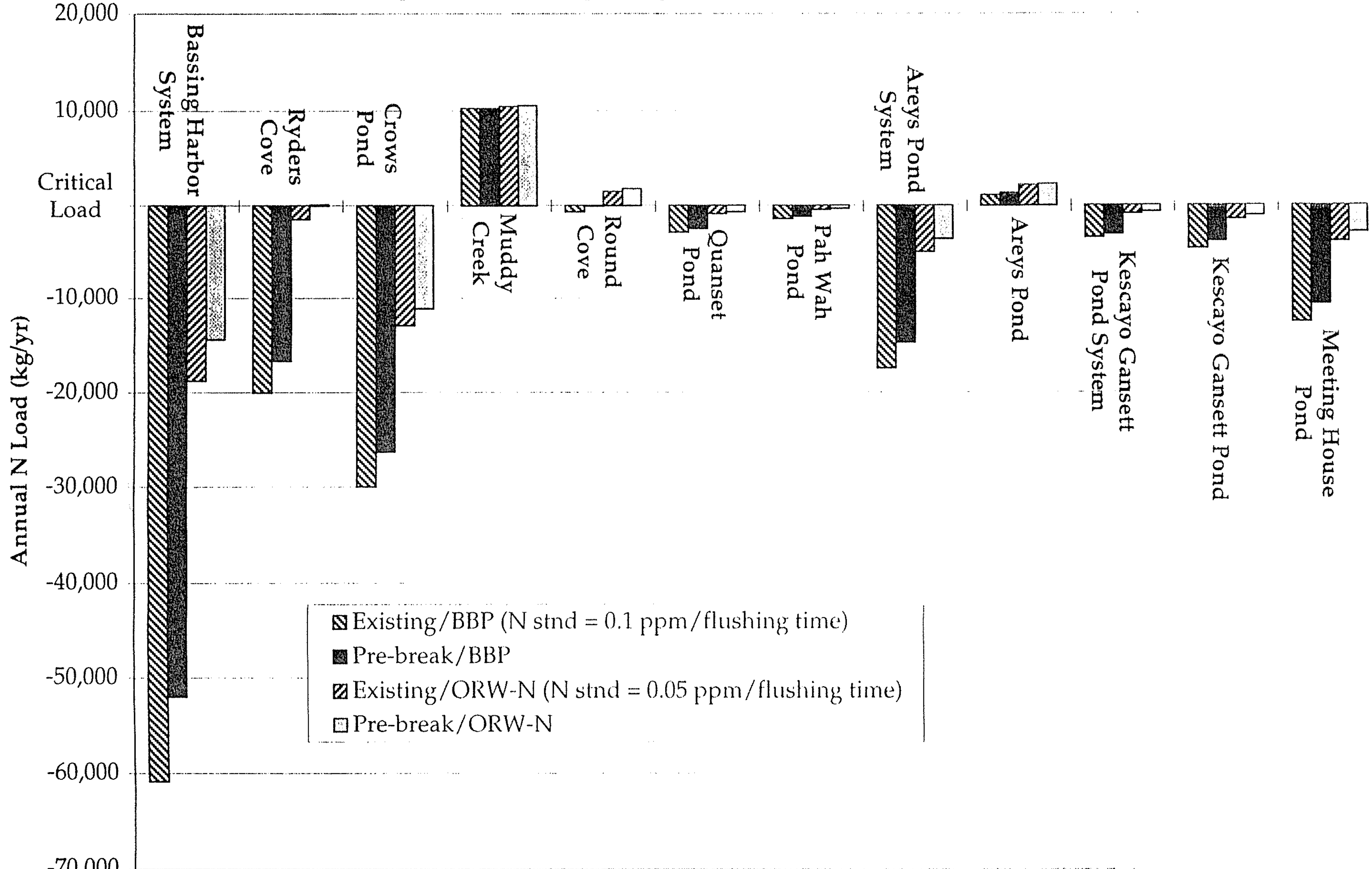
Based on the above analysis, management options should be developed to address nitrogen loading coming from the watersheds to Muddy Creek, Areys Pond, Pah Wah Pond, Ryders Cove, and Round Cove. This analysis also indicates that nitrogen management options are not necessary for the other subwatersheds or the Pleasant Bay system as a whole.

However, the change in the Pleasant Bay inlet configuration also introduces another nitrogen-associated water quality concern to the above analyses. Atlantic Ocean

Figure 5.

Existing Nitrogen Loading Capacity within Pleasant Bay and selected Subembayments

Comparison of Existing Nitrogen Loads to Various Critical Loads



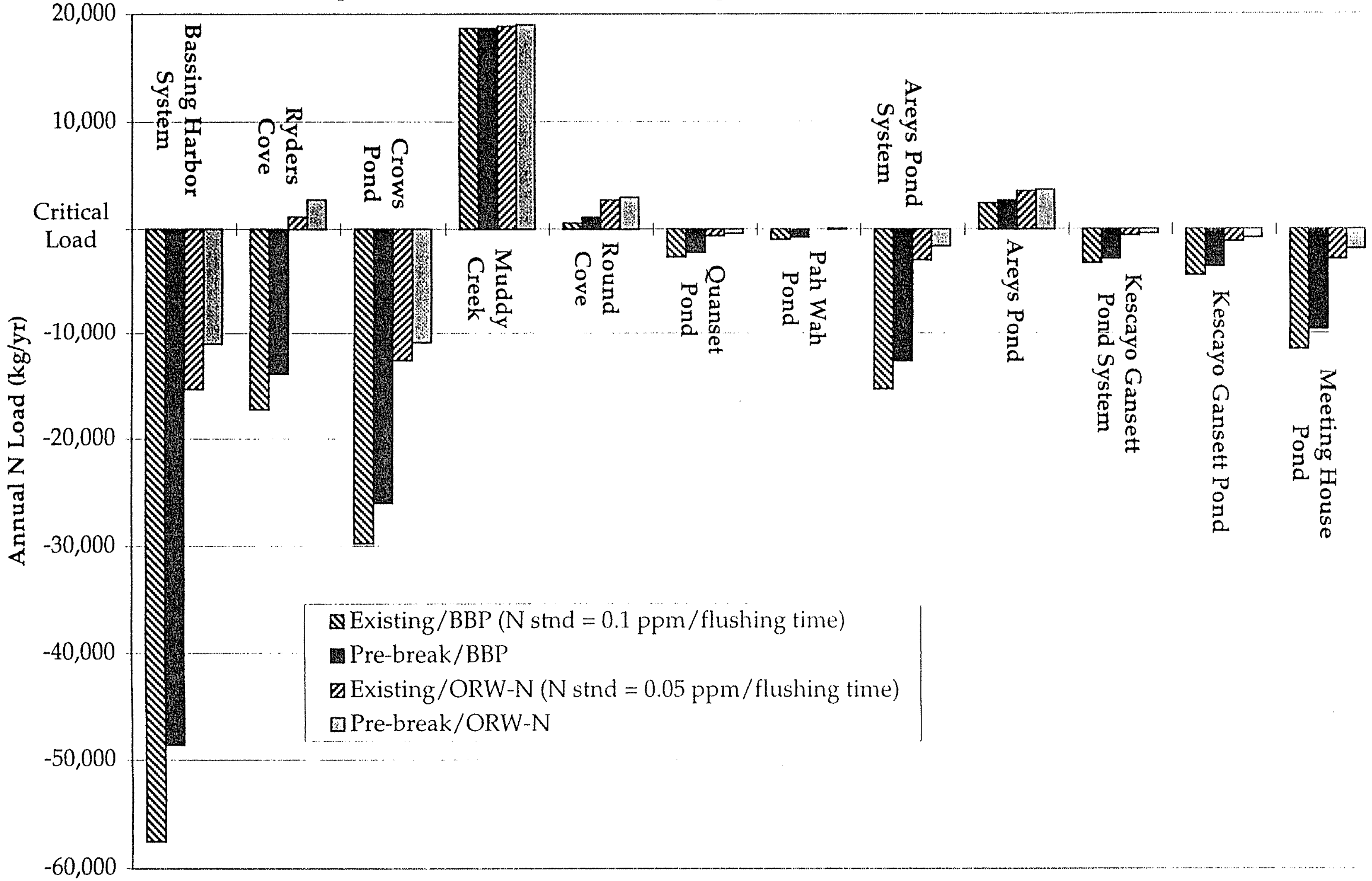
BBP = Buzzards Bay Project
ORW = Outstanding Resource Water

N loads based on seasonal occupancy.
Whole system loads are at least 860,000 kg/yr below critical loads.
The River System loads are at least 45,000 kg/yr below critical loads.

Figure 6.

Buildout Nitrogen Loading Capacity within Pleasant Bay and selected Subembayments

Comparison of Buildout (Seasonal) Nitrogen Loads to Various Critical Loads



BBP = Buzzards Bay Project
ORW = Outstanding Resource Water

N loads based on seasonal occupancy.
Whole system loads are at least 821,000 kg/yr below critical loads.
The River System loads are at least 44,000 kg/yr below critical loads.

water which enters Pleasant Bay from the current inlet should have nitrogen concentrations approximating the nitrogen concentrations measured near the mouth of Wellfleet Harbor (~ 0.1 ppm) or perhaps even lower. As the Bay inlet moves further to the south, into more of a pre-break configuration, the background nitrogen concentration would be expected to rise as more tidal water comes from Nantucket Sound. Although water quality measurements have not been collected along the southern coast of Chatham, nitrogen background concentrations further to the west along the southern coast of Cape Cod are generally around 0.3 ppm (personal communication, Brian Howes, UMASSD/CMST).

An increase in the background nitrogen concentration would be equivalent to an addition of nitrogen from the watershed to the bay. Figure 7 shows what the impacts of a 0.05 ppm and 0.1 ppm increase in background concentrations would do to the nitrogen loading analysis completed for the BBP ORW critical load in the pre-break inlet configuration. At the 0.05 ppm addition level, the areas of concern are: Ryders Cove, Muddy Creek, Round Cove, Pah Wah Pond, and Areys Pond. These are the same areas of concerns identified in the analysis completed above for existing conditions. At the 0.1 ppm addition level, however, the impacts are seen throughout the Pleasant Bay system. All subembayments, save the River System, exceed their critical loads at buildout and all, but the River System and the whole Pleasant Bay system, exceed the critical load based on existing development within their watersheds.

Since the relatively small change in background concentration of between 0.05 and 0.1 ppm has such a significant projected impact on the whole Pleasant Bay ecosystem, there is a genuine need to collect water quality samples to confirm the actual water quality conditions within the Bay and its subembayments both now and during the transition of inlet configuration. Collection of this information can also be used to confirm the other analyses of nitrogen loading within the subembayments projected to have excessive impacts. Nitrogen sampling is also paramount because the lack of reliable water quality analyses within Pleasant Bay, opens much of the nitrogen loading analyses to the criticism that they are simply "paper exercises." Although similar analyses in other embayments on Cape Cod have shown that these analyses predict concentrations and impacts very well (*e.g.*, West Falmouth Harbor, Popponesset Bay), the confirmation offered by actual water quality analyses can help to support the implementation of nitrogen management options.

ii. Nitrogen Management Options

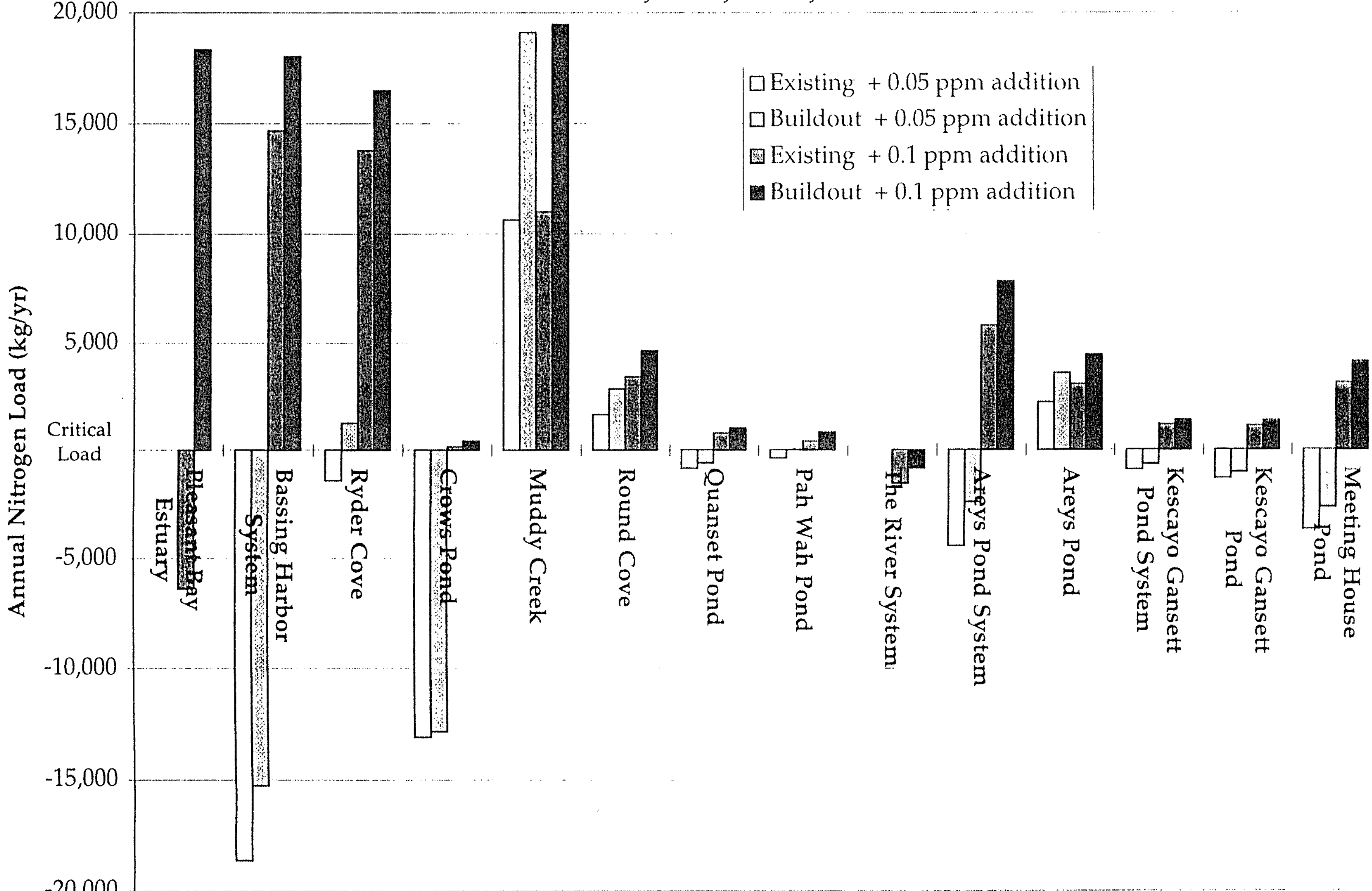
After reviewing the nitrogen analyses for existing and buildout conditions, project staff developed nitrogen management options in the watersheds to Muddy Creek, Pah Wah Pond, Ryders Cove, and Round Cove. These are the subembayments to Pleasant Bay where existing and/or buildout nitrogen loads from their watersheds exceed their critical loads (see Figures 5 and 6).

Staff focussed most attention on nitrogen loads from wastewater, since wastewater is

Figure 7.

Impact of Increase in Background Nitrogen Concentration on Nitrogen Loading Capacity

Pleasant Bay Embayment System



All N loads based on seasonal occupancy and BBP ORW critical load.
Whole estuary and River System loads for 0.05 ppm increase are not included in figure (these loads are at least 920,000 kg and 48,000 kg less than their respective critical loads).

usually the largest contributor to the overall nitrogen load. Staff also looked at reductions in fertilizer applications. For cases where buildout nitrogen loads exceed the critical load, staff also developed options that involved the permanent preservation of developable land as open space. Wastewater reductions of the nitrogen load can be accomplished through the use of on-site denitrifying septic systems or through the use of centralized collection (*i.e.*, sewer systems) with denitrification occurring at a large or small wastewater treatment facility. DEP currently allows a 25 ppm nitrogen effluent concentration for recirculating sand filters (RSFs) septic systems and a 19 ppm nitrogen effluent concentration for proprietary denitrifying septic systems (Ruck, Bioclere, FAST).

Most of these systems are currently being monitored to ensure that they can consistently discharge at these concentrations and to develop information for future review and updates of these concentrations. In preliminary evaluations of these systems, they appear to denitrify better in aggregated wastewater situations (>2,000 gpd). Centralized wastewater treatment technologies are generally assigned lower total nitrogen effluent concentration limits (10 ppm) in DEP groundwater discharge permits. These technologies can attain 5 ppm discharge if closely maintained. Staff considered these concentrations, additional reductions in nitrogen loads from wastewater and lawn fertilizers, and purchase and preservation of developable land as open space, in the development of the following potential nitrogen management strategies.

a. Muddy Creek

As stated above, existing development within the Muddy Creek watershed exceeds both critical loads in both inlet configurations (see Figure 5) and this condition is exacerbated by buildout conditions within the watershed (see Figure 6). Largely because of the constrictions at the culvert at Route 28, Muddy Creek has the longest residence times of any of the subembayments (see Table 1). Because of the relative potential ease in increasing flow in the creek by redesigning the culvert, staff also considered the impact of improved flushing on the water quality in Muddy Creek.

Table 9 presents the management options to meet either the BBP ORW or ORW-N nitrogen limit under the existing inlet configuration. In order to meet either of the limits with the level of existing development, wastewater concentrations throughout the watershed need to be significantly reduced, usually to concentrations at or below those attainable by the best centralized wastewater technologies. These reductions need to be coupled with reductions or elimination of fertilizer applications and increases in tidal flushing. In order to accommodate the additional nitrogen associated with buildout within the watershed, additional reductions are necessary.

Table 9. Selected Nitrogen Management Options Reviewed (Muddy Creek - Existing Inlet Configuration)					
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space	% Reduction in Existing Residence Time
		Wastewater Concentration	Fertilizer Load		
BBP ORW	Existing	93% (2.5 ppm discharge)	100%	-----	50
BBP ORW	Existing	71% (10 ppm discharge)	80%	-----	75
ORW-N	Existing	95% (1.75 ppm discharge)	100%	-----	75
BBP ORW	Buildout	98% (0.75 ppm discharge)	100%	312 of 407	50
BBP ORW	Buildout	86% (5 ppm discharge)	100%	none	75
All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 5 g/m2/yr. ORW-N = Critical Load for Outstanding Resource Waters based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.					

The management options to attain the critical loads in the pre-break inlet configuration are more stringent than the existing inlet configuration options because the pre-break inlet configuration increases the residence time in Muddy Creek (see Table 1). Table 10 presents the management options to meet either the BBP ORW or ORW-N nitrogen limit under the pre-break inlet configuration.

Table 10. Selected Nitrogen Management Options Reviewed (Muddy Creek - Pre-Break Inlet Configuration)					
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space	% Reduction in Existing Residence Time
		Wastewater Concentration	Fertilizer Load		
BBP ORW	Existing	99% (0.5 ppm discharge)	100%	-----	50
BBP ORW	Existing	79% (7.5 ppm discharge)	100%	-----	75
Can't achieve ORW-N (existing) even with no wastewater and fertilizer load & 75% residence time					
BBP ORW	Buildout	89% (4 ppm discharge)	100%	357 of 407	75
All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 5 g/m2/yr. ORW-N = Critical Load based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.					

b. Pah Wah Pond

Nitrogen loading within the Pah Wah Pond subwatershed only exceeds the ORW-N limit when full buildout is reached (see Figure 6) and then only in the pre-break inlet configuration. Table 11 presents the management options to meet the ORW-N nitrogen limit under the pre-break inlet configuration. As can be seen by reviewing the options in Table 11, the management strategies to meet the ORW-N limit at buildout for Pah Wah Pond are readily achievable.

Table 11. Selected Nitrogen Management Options Reviewed (Pah Wah Pond - Pre-Break Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
ORW-N	Buildout	none	65%	none
ORW-N	Buildout	14% (30 ppm discharge)	none	none
ORW-N	Buildout	none	none	9 of 44
ORW-N	Buildout	none	50%	3 of 44
All analyses assume current seasonal development. ORW-N = Critical Load for Outstanding Resource Waters based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.				

c. Ryders Cove

Nitrogen loading within the Ryders Cove subwatershed exceeds the ORW-N limit at buildout when the both existing and pre-break inlet configurations are considered (see Figure 6) and is slightly above the ORW-N limit given a pre-break inlet configuration and existing nitrogen loads (see Figure 5). Table 12 presents the management options for build out to meet the ORW-N nitrogen limit under the existing inlet configuration. These options suggest that the ORW-N limit can be met by slightly reducing the nitrogen effluent from all septic systems, reducing all fertilizer applications, or preserving slightly more than half of the projected future residential lots as undeveloped open space.

Table 12. Selected Nitrogen Management Options Reviewed (Ryders Cove - Existing Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
ORW-N	Buildout	none	45%	none
ORW-N	Buildout	none	none	130 of 244
ORW-N	Buildout	11% (31 ppm discharge)	none	none
All analyses assume current seasonal development. ORW-N = Critical Load for Outstanding Resource Waters based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.				

Table 13 presents the management options to meet the ORW-N nitrogen limit under the pre-break inlet configuration. In order to meet the limit at the existing level of development, the fertilizer load could be reduced by 5%, but once buildout occurs, all fertilizer applications would have to be eliminated to meet the ORW-N limit without additional reductions in wastewater contributions or protection of residential lots as permanent open space.

Table 13. Selected Nitrogen Management Options Reviewed (Ryders Cove - Pre-Break Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
ORW-N	Existing	none	5%	-----
ORW-N	Buildout	none	100%	none
ORW-N	Buildout	11% (31 ppm discharge)	50%	none
ORW-N	Buildout	none	50%	174 of 244
All analyses assume current seasonal development. ORW-N = Critical Load for Outstanding Resource Waters based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.				

d. Round Cove

Nitrogen loading within the Round Cove subwatershed exceeds the ORW-N limit under existing and buildout conditions for both inlet configurations (see Figures 5 and 6, respectively). Buildout nitrogen loads also exceed the BBP ORW limit in both inlet configurations. Table 14 presents the management options to meet the nitrogen limits under the existing inlet configuration. These options include wastewater nitrogen effluent reductions that are attainable by existing technologies, fertilizer application reductions and preservation of projected future residential lots as undeveloped open space.

Table 14. Selected Nitrogen Management Options Reviewed (Round Cove - Existing Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
ORW-N	Existing	63% (13 ppm discharge)	none	-----
ORW-N	Existing	51% (17 ppm discharge)	50%	-----
ORW-N	Existing	40% (21 ppm discharge)	100%	-----
BBP ORW	Buildout	17% (29 ppm discharge)	none	none
BBP ORW	Buildout	none	70%	none
BBP ORW	Buildout	none	none	55 of 129
ORW-N	Buildout	79% (7.5 ppm discharge)	none	none
ORW-N	Buildout	69% (11 ppm discharge)	50%	none
ORW-N	Buildout	57% (15 ppm discharge)	50%	85 of 129
All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 0.1 ppm nitrogen addition. ORW-N = Critical Load based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.				

Table 15 presents the management options to meet the nitrogen limits under the pre-break inlet configuration. These options also include combinations of wastewater nitrogen effluent reductions that are attainable by existing technologies, fertilizer application reductions and preservation of projected future residential lots as undeveloped open space.

Table 15. Selected Nitrogen Management Options Reviewed (Round Cove - Pre-Break Inlet Configuration)

Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
ORW-N	Existing	71% (10 ppm discharge)	none	-----
ORW-N	Existing	63% (13 ppm discharge)	50%	-----
ORW-N	Existing	51% (17 ppm discharge)	100%	-----
BBP ORW	Buildout	31% (24 ppm discharge)	none	none
BBP ORW	Buildout	11% (31 ppm discharge)	100%	none
BBP ORW	Buildout	29% (25 ppm discharge)	none	13 of 129
ORW-N	Buildout	86% (5 ppm discharge)	none	none
ORW-N	Buildout	76% (8.5 ppm discharge)	50%	none
ORW-N	Buildout	71% (10 ppm discharge)	50%	47 of 129

All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 0.1 ppm nitrogen addition. ORW-N = Critical Load based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.

e. Areys Pond

Nitrogen loading within the Areys Pond subwatershed exceeds the ORW-N limit under existing and buildout conditions for both inlet configurations (see Figures 5 and 6, respectively). Buildout nitrogen loads also exceed the BBP ORW limit in both inlet configurations. Table 16 presents the management options to meet the nitrogen limits under the existing inlet configuration. These options include wastewater nitrogen effluent reductions that are attainable by existing technologies, fertilizer application reductions and preservation of projected future residential lots as undeveloped open space.

Table 16. Selected Nitrogen Management Options Reviewed (Areys Pond - Existing Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
BBP ORW	Existing	60% (14 ppm discharge)	none	-----
BBP ORW	Existing	46% (19 ppm discharge)	50%	-----
ORW-N	Existing	91% (3 ppm discharge)	100%	-----
BBP ORW	Buildout	60% (14 ppm discharge)	100%	none
BBP ORW	Buildout	71% (10 ppm discharge)	50%	none
BBP ORW	Buildout	54% (16 ppm discharge)	100%	43 of 143
ORW-N	Buildout	96% (1.5 ppm discharge)	100%	none
ORW-N	Buildout	94% (2 ppm discharge)	100%	68 of 143

All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 0.1 ppm nitrogen addition. ORW-N = Critical Load based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.

Table 17 presents the management options to meet the nitrogen limits under the pre-break inlet configuration. These options also include combinations of wastewater nitrogen effluent reductions that are attainable by existing technologies, fertilizer application reductions and preservation of projected future residential lots as undeveloped open space.

Table 17. Selected Nitrogen Management Options Reviewed (Areys Pond - Pre-Break Inlet Configuration)				
Nitrogen Limit	Existing or Buildout	% Nitrogen Reduction Necessary		Future residential parcels preserved as open space
		Wastewater Concentration	Fertilizer Load	
BBP ORW	Existing	74% (9 ppm discharge)	none	-----
BBP ORW	Existing	60% (14 ppm discharge)	50%	-----
BBP ORW	Existing	49% (18 ppm discharge)	100%	-----
ORW-N	Existing	99% (0.5 ppm discharge)	100%	-----
BBP ORW	Buildout	69% (11 ppm discharge)	100%	none
BBP ORW	Buildout	80% (7 ppm discharge)	50%	none
BBP ORW	Buildout	71% (10 ppm discharge)	50%	80 of 143
BBP ORW	Buildout	86% (5 ppm discharge)	none	68 of 143
ORW-N	Buildout	100% (0 ppm discharge)	100%	8 of 143

All analyses assume current seasonal development. BBP ORW = Buzzard Bay Project Outstanding Resource Water Recommended Critical Load = 0.1 ppm nitrogen addition. ORW-N = Critical Load based on Falmouth Pond Watcher data = 0.05 ppm nitrogen addition.

III. DISCUSSION

Five subembayments (Muddy Creek, Pah Wah Pond, Ryders Cove, Areys Pond, and Round Cove) are identified by the above analysis as either having existing water quality problems or having the potential for water quality problems in the future. Among these, Round Cove, Areys Pond, and Muddy Creek are identified as having excessive nitrogen loading now, with Muddy Creek having the highest exceedances.

A. Water Quality Sampling

As mentioned above, similar nitrogen loading analyses have been shown to be good predictors of actual nitrogen concentrations and impacts in other embayments around Cape Cod. However, the significant changes in wastewater management that are currently indicated and the potential impacts of changes in the source of background flushing waters (see Figure 7) require documentation. With this in mind, staff recommends that a comprehensive water quality sampling program be instituted for the Bay.

The sampling program should initially focus on Muddy Creek, Areys Pond, Pah Wah Pond, Ryders Cove, and Round Cove. At a minimum, one sampling location should be selected within each of the embayments and one outside of each of the embayments. These locations should be sampled, at a minimum, every other week between the months of April and September. The water samples should be collected to account for, at a minimum, various nitrogen species, chlorophyll *a*, phosphate, salinity, and chloride. The samples should be analyses by a laboratory capable of analyzing low nitrogen concentrations typical of saline waters. If possible, it would be very useful to establish continuous dissolved oxygen monitors in bottom waters within these embayments. The UMASS-Dartmouth Center for Marine Science and Technology has these monitors and the experience of their staff and scientists would be very helpful in establishing the monitoring program, possibly including a citizen monitoring component, which could complement the more detailed sample collection. Assistance with the citizen portion of a monitoring program could also be provided by staff at the Waquoit Bay Estuarine Research Reserve or the Buzzards Bay Coalition.

If additional funds are available, this program should be expanded to include a one year snap-shot of the system, including a characterization of the nutrient release and storage in bottom sediments. In some embayments, nitrogen loading from bottom sediments can significantly increase nitrogen concentrations and ecosystem impacts. These bottom sediments represent nitrogen loads and algal growth from previous years. These nitrogen loads are released as the sediments decay. Thick sediment layers in Duck Creek in Wellfleet Harbor account for two times the watershed nitrogen load during the summer growing season (personal communication, Brian Howes, UMASS/CMST).

Whether an expanded or more limited sampling program is begun, the sampling program should also include a provision to assess the change in the background concentrations in the Bay. One sampling location removed from more localized impacts should be monitored on the same schedule as the subembayments and the sampling program should also note the configuration of the inlet. The sampling location should be selected following a review of flow direction and magnitude within the Bay.

B. Muddy Creek
There are over 55 acres of watershed for every acre of Muddy Creek. This is the largest ratio among any of the subembayments to Pleasant Bay, which by comparison has 2 acres of watershed to every acre of embayment. This high ratio for Muddy Creek means that there is a significant potential to overwhelm the nitrogen capacity of the Creek. In fact, converting the Muddy Creek critical loads to kg of nitrogen per acre of watershed range between 0.20 and 0.35 kg/ac. These levels are roughly equivalent to one three bedroom house per 60 to 35 acres, respectively. So it is not surprising to see that the above analysis indicates that both of the nitrogen limits evaluated have been exceeded and that the management options to attain either of the limits represent significant changes in wastewater treatment.

All the management alternatives for Muddy Creek also include an improvement in the flushing of the creek (see Tables 9 and 10). This provision is included for Muddy Creek because tidal movement in Muddy Creek is inhibited by the culvert installed for Route 28, which passes over the mouth of the creek. Since this culvert is a constructed, rather than a natural, feature, it can be redesigned and reconstructed to facilitate greater tidal flushing in the creek. If this culvert is reconstructed to allow greater tidal movement, the nitrogen loading capacity of the creek would increase, although it appears that any improvement due to reconstruction will have to be linked to an appropriate nitrogen reduction strategy.

Project staff suggest that wastewater improvements in this watershed should await better documentation of the improvements in flushing that could occur with the redesign of the Route 28 culvert. In the interim, we encourage the Towns of Harwich and Chatham to begin an homeowner landscaping education campaign which encourages elimination and/or reductions in fertilizer applications and lawn areas. Once the flushing improvements due to the culvert redesign have been determined and water quality monitoring has confirmed the impact of internal nitrogen loading from sediments, the management options can be refined and move closer to implementation. In addition, the towns should also begin to catalog the septic systems in this area and evaluate where aggregation of wastewater flows into smaller treatment facilities would be possible; the Chatham portion of the watershed could be addressed through the town Facilities Planning process. The towns may also want to consider making the purchase of developable properties in this watershed a priority since any purchases will help to reduce the reductions in wastewater nitrogen that will be required. The towns may also want to explore the availability of changes in zoning to increase minimum lot sizes. These latter options are particularly important because the large number of potentially developable residential lots in the subwatershed (407) can increase the existing load to the Creek by 77% (see Table 8).

C. Pah Wah Pond

The exceedances of Pah Wah Pond's ORW-N limit will occur in the future: if complete buildout is attained and if the pre-break inlet configuration is similar or if the pre-break configuration introduces higher background nitrogen levels to Pleasant Bay. Because the lags caused by groundwater flow, even at full buildout, the impacts of the exceedance may not be expressed for a number of years. If the background concentration increase is substantial, the measures to meet the ORW-N limit will be more extensive than those indicated in Table 11.

These factors seem to support implementation of a long-term monitoring of the water quality within the system. If background concentrations rise and/or Pah Wah Pond is showing the signs of excessive nitrogen impacts, management efforts can be refined based on the monitoring data. In the interim, since the ORW-N limit can be readily achieved, the Town of Orleans may want to begin an homeowner landscaping education campaign which encourages elimination and/or reductions in fertilizer applications and lawn areas and evaluate potential purchase and permanent preservation of developable parcels within this watershed.

D. Ryders Cove

Since existing nitrogen loading to Ryders Cove slightly exceeds the ORW-N limit with the inlet in the pre-break configuration (see Table 13), Ryders Cove should be the most susceptible subembayment to any increases associated with increases in background nitrogen concentrations accompanying the changes in the inlet. This susceptibility reinforces the need to have an adequate monitoring plan in place. If there are no increases associated with the change in inlet configuration, loading exceeds the ORW-N limit when approximately half of the potential new houses are built (see Table 12).

Aside from water quality monitoring, the management options in Tables 12 and 13 suggest that the Town of Chatham should begin an homeowner landscaping education campaign which encourages elimination and/or reductions in fertilizer applications and lawn areas for parcels within the watershed. Since the other management options focus on the number of future residential lots and improvements in wastewater treatment, the town should also evaluate the benefits of increasing minimum lot sizes within this watershed to decrease the number of potential future residential units and use its Facilities Planning Process, which is just getting underway, to evaluate wastewater treatment options within this watershed. This planning process can evaluate potential locations for improved treatment of aggregated wastewater flows from numerous residences and evaluate potential connections to the existing municipal wastewater treatment facility. If water quality information is also collected concurrently, this information can be used to help refine the potential management strategies. In the interim, Chatham may want to evaluate potential purchase and permanent preservation of developable parcels within this watershed.

E. Round Cove

Public observations have noted that a significant portion of the bottom of Round Cove is covered with macroalgae (leafy rooted plants) (CCC, 1995), which is an indication of excessive nitrogen loads. This observation supports the appropriateness of the ORW-N limit, over the BBP ORW limit, since it is the limit that is exceeded under existing conditions (see Figure 5). However, both limits are exceeded under buildout conditions under both inlet configurations (see Figure 6).

As with the other areas, water quality sampling is important to help refine the management options that will be implemented. In the interim, the Town of Harwich should consider beginning a homeowner landscaping education campaign which encourages elimination and/or reductions in fertilizer applications and lawn areas and evaluate potential purchase and permanent preservation of developable parcels within this watershed. In addition, since most of the management options identified in Tables 14 and 15 require significant reductions in wastewater effluent concentrations, the town should begin the process of identifying potential areas for the aggregation of wastewater flows and use of on-site denitrifying septic systems. This effort should include evaluation of wastewater flows in areas of smaller lots and potential sites for treatment and discharge of aggregated flows.

F. Areys Pond

Existing nitrogen loading from the watershed to Areys Pond exceeds both the BBP ORW and ORW-N limits under both inlet configurations (see Figure 5). The management options evaluated to meet either of these limits, require significant reductions in both wastewater and fertilizer loads (see Tables 16 and 17). The addition of nitrogen loads from full buildout require more stringent reductions in order to meet either of the ORW limits.

As with the other watersheds identified as having nitrogen loading concerns, water quality sampling is important to help refine the management options that will be implemented. In the interim, the Towns of Brewster and Orleans should consider beginning a homeowner landscaping education campaign which encourages elimination and/or reductions in fertilizer applications and lawn areas and evaluate potential purchase and permanent preservation of developable parcels within this watershed. In addition, since most of the management options identified in Tables 16 and 17 require significant reductions in wastewater effluent concentrations, the towns should begin the process of identifying potential areas for the aggregation of wastewater flows and use of on-site denitrifying septic systems. This effort should include evaluation of wastewater flows in areas of smaller lots and potential sites for treatment and discharge of aggregated flows.

G. Implementation

Implementation of the any of the management options will require additional information and discussions to determine the most appropriate course of action. Existing provisions and processes can facilitate the development of this information and these discussions. Towns can use existing provisions within the Title 5 regulations (310 CMR 15), the provisions within the Cape Cod Commission Act for establishment of a District of Critical Planning Concern (Sections 10 and 11 of the Act), and/or a Facilities Planning Process to develop the necessary information.

Title 5 allows Boards of Health (BOHs) to adopt more stringent on-site septic system regulations if local conditions suggest they are required (MGL c.111 §31, MGL c.21A §13, and Title 5 (310 CMR 15.003)). Title 5 (310 CMR 15.215) recognizes nitrogen sensitive areas, including embayments, and that these areas may be "particularly sensitive to discharge from on-site sewage disposal systems." DEP has not prepared a process to designate nitrogen sensitive areas, but based on the language in Title 5, project staff suggest that this designation can be approved by a local BOH under the "local conditions" provision. Project staff suggest that the efforts described in this report are sufficient for the towns in the watershed to adopt any or all of the watersheds to Pleasant Bay as nitrogen sensitive areas.

If a BOH designated a watershed to an embayment as a nitrogen sensitive area, all septic systems within that watershed would be limited to 440 gallons per day per acre (4 bedrooms per acre). While this limitation would be insufficient to fully protect water quality in most of the Pleasant Bay watersheds of concern, it would limit development in areas not already addressed through wellhead protection regulations and may hasten study of wastewater aggregation options and public discussion of other implementation efforts.

Adoption of a DCPC under the CCC Act could also be a way for communities to address nitrogen loading concerns. The towns and CCC have authority under the CCC Act to propose DCPCs for watersheds to nitrogen sensitive embayments. Preparation of a DCPC nomination would bring town boards, development and business interests, and other members of the public together to focus on coastal water quality issues and potential management solutions to preserve or remediate water quality. Although some have focussed on the permit moratorium imposed by a DCPC nomination, project staff suggest that careful development of nomination materials, including what permits could proceed during the moratorium period, would allow the community to concentrate on the development permits that will have the most effect. Once a DCPC has been adopted all town regulations would need to conform to the intent of the district and grandfathered protections can be removed. The power of the DCPC process to focus all town boards on crafting complementary regulations is powerful benefit.

Local examples of facilities plans are those in the Towns of Barnstable, Provincetown, and Chatham. These plans generally focus only on wastewater, but the process can be used to evaluate some of the key information necessary to select the best nitrogen management options. Facilities plans can be used to establish the age, condition, and size of septic systems and evaluate where aggregated systems can be sited. In addition, the engineering firms hired to conduct the facility plan can be used to evaluate existing technologies ability to be sited on particular parcels and attain desired denitrification levels. Funds in the form of low-interest loans are available to communities through the State Revolving Fund (SRF) to conduct facility planning studies.

Discussion of the appropriateness of next steps to protect and restore water quality within Pleasant Bay will have to occur among all involved parties: local boards, homeowners, business owners, and state officials. Cape Cod Commission staff are available to assist in facilitating these discussions.

IV. CONCLUSIONS

Based on the above analysis, Muddy Creek, Areys Pond, and Round Cove have existing water quality problems. Pah Wah Pond and Ryders Cove have the potential for water quality problems in the future. If background nitrogen concentrations increase throughout Pleasant Bay due to expected changes in the inlet configuration, nitrogen loading problems could be experienced throughout the Bay.

In order to confirm the above water quality concerns, it is recommended that a water quality monitoring program be instituted for the Bay. This program should initially focus on Muddy Creek, Pah Wah Pond, Ryders Cove, Areys Pond, and Round Cove and changes in the Pleasant Bay's background concentration. It is also recommended that the towns in the watersheds to the five subembayments should begin to evaluate the management options presented in this report. Cape Cod Commission staff are available to assist in facilitating these discussions.

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