NUTRIENT LOADING TO LAKE ANTHONY and SUNSET LAKE

July 2003

THE MARTHA'S VINEYARD COMMISSION

PROJECT CONDUCTED 2001-2003
DATA COLLECTED 2001

PREPARED FOR:

MASSACHUSETTS EXECUTIVE OFFICE OF
ENVIRONMENTAL AFFAIRS
MASSACHUSETTS WATERSHED INITIATIVE

And

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RESOURCE PROTECTION

PROJECT NUMBER 0105-MWI Volume 2

NUTRIENT LOADING TO
LAKE ANTHONY and SUNSET LAKE

0105-MWI Volume 2

PREPARED BY:

THE MARTHA'S VINEYARD COMMISSION
JO-ANN TAYLOR, PRINCIPAL INVESTIGATOR and PROJECT MANAGER

PREPARED FOR:

MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION

MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
Ellen Roy Herzfelder, Secretary

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Edward P. Kunce, Acting Commissioner

BUREAU OF RESOURCE PROTECTION
Cynthia Giles, Assistant Commissioner

DIVISION OF MUNICIPAL SERVICES
Steven J. McCurdy, Deputy Director

DIVISION OF WATERSHED MANAGEMENT
Glenn Haas, Director

ACKNOWLEDGEMENTS

The Town of Oak Bluffs, with the cooperation of Harbormaster John Todd Alexander, provided access to its facilities at the Harbormaster's Office and at the Sunset Lake culvert for installation of tide gauge equipment. Shellfish Constable David Grunden provided field bathymetry measurements for Sunset Lake, detailed town records regarding the Stormwater collection system, and the stormwater photographs. Former Highway Superintendent Herbert A. Combra, Jr. provided information regarding the stormwater collection system.

Jo-Ann Taylor, Coastal Planner, was principal investigator and project manager for the Martha's Vineyard Commission, and provided the boat used for fieldwork. Lisa Bowen was Quality Assurance Officer.

EOEA's Islands Watershed Team provided support and cooperation.

This project has been financed partially with Commonwealth Funds from the Massachusetts Department of Environmental Protection (DEP) under a Massachusetts Watershed Initiative grant. The contents do not necessarily reflect the views and politics of DEP, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LAKE ANTHONY (OAK BLUFFS HARBOR)
and SUNSET LAKE

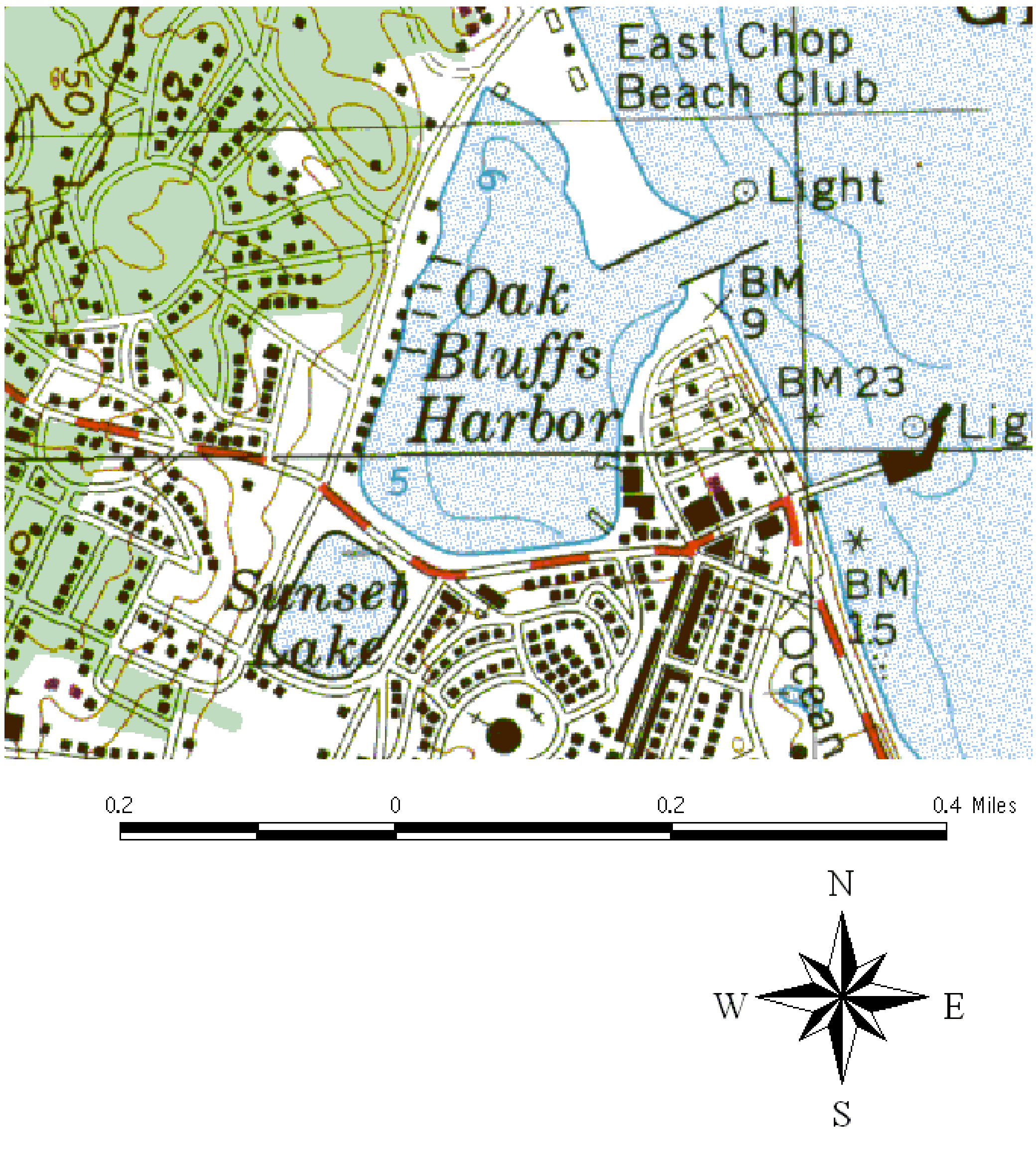

Figure 1

EXECUTIVE SUMMARY

The 30 acre Lake Anthony is situated on the northeast shore of the Island. Sometime prior to 1858, an artificial breach was made through the barrier beach between Lake Anthony and Nantucket Sound, creating Oak Bluffs Harbor. Wooden bulkhead was constructed along the shore of the commercial side, along with considerable dredging and other harbor improvements. Harbor jetties, constructed in 1899, stabilize the inlet for navigation. Sunset Lake drains into the harbor by means of a culvert under Lake Avenue. Surrounding land use includes dense residential and commercial development, much of it seasonal. The harbor itself is also used quite intensely in the summer season, primarily for berthing of transient recreational vessels, and for passenger ferry service. Much of the surrounding lands have recently been provided with new sewer service, in the fall of 2002. Those properties are identified in the land use investigation.

LOCUS
LAKE ANTHONY & SUNSET LAKE

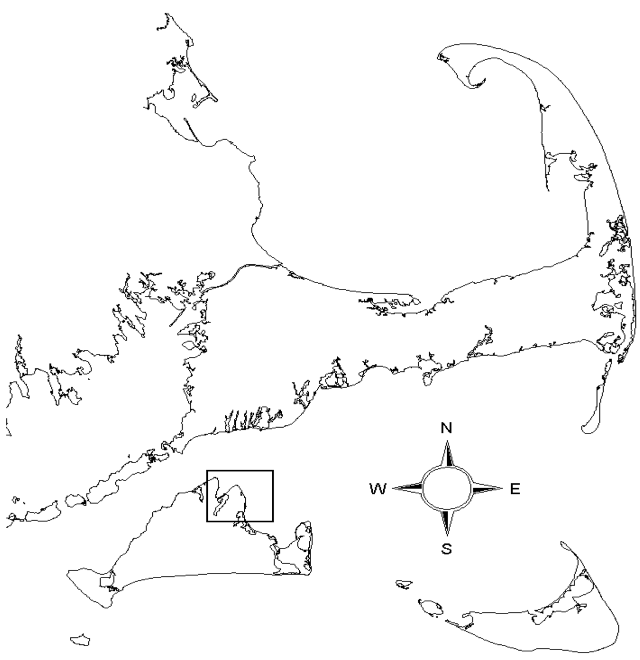

Figure 2

The harbor (Lake Anthony) supports commercially important shellfish resources. In recent years, the harbor has shown symptoms of stress that may reflect increased human activity in the watershed. The harbor is under an administrative closure during the summer months, based solely on the large numbers of boats in the harbor, not on any water quality data. There has been extensive residential and commercial development in the watershed. The issue of nitrogen loading is a key to developing an appropriate response to issues including the nature of future growth in the watershed. The unknowns which were evaluated include: dissolved oxygen levels and nutrient levels; the projected nitrogen loads based on buildout including various scenarios, and what effect they will have; the steps that should be taken to assure that the water quality is restored.

FLUSHING CHARACTERISTICS

Tide gauges were installed in order to assess the flushing characteristics of the pond. Both tide curves are semi-diurnal. The average tide range was 1.9 feet (.58 meters) in Lake Anthony and 1.84 feet (.56 meters) in Sunset Lake. The curve is flood-dominated, as indicated by the duration of each phase of the tidal cycle. Average flood stage ran 7:04 hours in Lake Anthony and 7:00 hours in Sunset Lake. On average, ebb tide ran 5:39 hours in Lake Anthony and 5:42 hours in Sunset Lake. On average, a tidal cycle required 12:43 hours to complete. There were approximately 1.89 tidal cycles per day.

Bathymetric measurements were made and were used to calculate the mid-tide volume of 326,405.89 cubic meters and the mean depth of 2.62 meters. The data from the circulation investigations were used to determine the flushing time of 12.2 tidal cycles and a residence time of 6.46 days, or .0177 year.

NITROGEN LOADING LIMIT AND COMPARISONS

The nitrogen-loading limit was calculated from the circulation characteristics. The limit recommended for Lake Anthony is **2,800** kilograms. None of the buildout scenarios would contribute less than the limit of 2,800 kilograms, but all represent a significant reduction from the present load of 12,818.8 kilograms. Existing load and load at buildout are summarized in the following table.

NITROGEN LOAD, DISTRIBUTION AND PROJECTIONS	
Existing Load	12,818.8 kg
Load at Low Growth Buildout	4,269.2 kg
Load at Moderate Growth Buildout	4,484.7 kg
Load at High Growth Buildout	4,772.8 kg
The present load is distributed as follows:	
SEPTIC SYSTEMS	
RESIDENTIAL	3,720.5
COMMERCIAL	7,592.8
LAWNS	953.3
RAINFALL	552.2
TOTAL	**12,818.8 kg**

Table 1

WATER QUALITY SAMPLING 2001

Six rounds of water quality sampling were made at four stations during 2001. A number of hydrographic parameters such as temperature and salinity were recorded at the surface, at mid-depth, and at the bottom. Surface water samples were analyzed for nutrients. The table below compares data from Lake Anthony with a number of other resource areas; Edgartown Great Pond, Oyster Pond and Buzzards Bay, as reported by the Island Ponds Consortium[1] in 1999, for Tisbury Great Pond, as reported by the Martha's Vineyard Commission[2] in 2000, and for Lake Tashmoo as reported by the Martha's Vineyard Commission[3]. The range of averages for each station over time is listed, not the absolute maximum and minimum records:

NUTRIENT VALUES FOR COMPARISON

Nutrient (uMoles)	Lake Tashmoo	Buzzards Bay	Tisbury Great Pond	Edgartown Great Pond	Oyster Pond	Lake Anthony
NH4	.6-1.4	2.33-5.39	.92-2.88	1.06-1.39	.9-1.21	1.5-3.9
PO4	.4-.63	.47-.72	.65-1.15	.04-.2	.12-.27	.4
SiO3	8.1-24.3	3.75-6.68	80.25-116.73	26.8-31.56	41.69-63.25	5.45-11.63
NO3	.1-.7	.62-.91	.05-5.075	2.83-5.06	.56-1.55	1.1-4.4

Table 2

[1] The Island Ponds Consortium, 1999, Island Coastal Ponds Water Quality Study
[2] Martha's Vineyard Commission, 2000, Nutrient Loading to Tisbury Great Pond
[3] Martha's Vineyard Commission, 2003, Nutrient Loading to Lake Tashmoo

PRIORITIZED MANAGEMENT MEASURES
(IN ORDER OF URGENCY)

ADOPT 2800 KILOGRAMS PER YEAR AS THE ANNUAL NITROGEN LOADING LIMIT FOR THE WATERSHED

According to the MVC calculations in this report, the nitrogen loading limit for Lake Anthony and Sunset Lake should be **2,800** kilograms. The 2000 load, 12,819 kilograms, was dominated by commercial septic flow representing 60% of the total. Most of that flow should be removed from the watershed by sewer service. There is very little difference between the low, moderate and high buildout scenarios, because so much of the watershed is already built. None of the buildout scenarios would contribute less than the limit of 2,800 kilograms, but all represent a significant reduction from the present load of 12,819 kilograms. With little potential to influence future growth, it appears that reduction of the existing load is the best means available to approach the loading limit.

ENCOURAGE ADVANCED NITROGEN REDUCTION FOR EXISTING AND FUTURE DWELLINGS

Encouragement of advanced nitrogen removal, particularly if funds could be discovered and provided, would remove existing load. Advanced nutrient removal can reduce nitrogen input by up to 50%.

IMPROVE STORMWATER TREATMENT

Because much of the watershed is impervious, stormwater has potential to contribute nutrients and other contaminants. Stormwater contribution is likely to not only add contaminants but also to “shock” the system by dumping suddenly after rainfall events. Although it is beyond the scope of this investigation, it is important to consider the impacts of bacterial contamination. Much of the stormwater from New York Avenue runs untreated through the stormwater system into the harbor. Treatment of the first flush of rainfall could be managed along the length of New York Avenue, so that the stormwater entering the harbor is reduced in velocity and in levels of contaminants.

REDUCE LOAD FROM LAWN CARE

Educate homeowners and professional landscapers about using native plants and about fertilizer impacts.

FURTHER ASSESSMENT AND MONITORING

It is important to follow up with additional sampling to monitor conditions over time. In order to assess the impacts of removal of the sewered systems, it is necessary to return after the pre-service flow has arrived at the harbor through the groundwater.

Investigate stratification in the deeper parts of the harbor, particularly in the southeastern area. Include some continuous recorded logs of dissolved oxygen over several daily cycles.

Measure and monitor chemistry of local rainfall, in order to properly assess the impacts of nitrogen from that source.

PROMOTE SHELLFISH

As filter feeders, shellfish "clean" the water of small particulate nutrients. According to the Chesapeake Bay Program, for every pound of commercial shellfish produced, 8,000 pounds of plankton are consumed[4]. Promote shellfish as nutrient consumers.

CONTINUE MAINTENANCE DREDGING AND BOATER SERVICES

Lake Anthony is used extensively for mooring and dockage of commercial and recreational vessels. Continue to provide pump out service and shore toilet and shower facilities. All associated flow should be included in the sewer service, rather than flow to the harbor.

Continue maintenance dredging; continue to consider extension of northern jetty.

[4] http://www.chesapeakebay.net/ecoint6a.htm

NITROGEN LOADING

The first step in assessment of nitrogen loading is to define the watershed. Topographic contours and groundwater contours (Whitman & Howard, Inc., 1994) were used to define the watershed for Lake Anthony and Sunset Lake. The "tail" was mapped using watershed boundaries for Lagoon Pond and Farm Pond as previously mapped by the Martha's Vineyard Commission. Much of the most densely developed portion of the watershed is extremely flat, and information regarding stormwater drainage was used there. The watershed was delineated[5] on the U.S.G.S. quadrangle sheets for the area, and area measured by Arc View. That measurement resulted in a value of 1,625,813.5 m^2, including the 137,239.461 m^2 surface areas of the ponds.

The average annual precipitation as recorded in Edgartown was 45.82 inches from 1945 to 1975 (New England Climatic Service-Climatological Summary). A portion of this rainfall reaches the water table and flows toward the pond. The remainder is lost to evaporation or is taken up by vegetation. The portion reaching the groundwater is not precisely known, but estimates have been made for various locations around Cape Cod and Martha's Vineyard. A recharge value of 22.2 inches from 45.82 inches of rainfall was used to calculate the volume of recharge:

For the surfaces of the ponds: 137,239.46 m^2 x 45.82" = 159,723.4m^3 =42,194,400 gal
For remainder of the watershed: 1,488,754m^2 x 22.2" = 839,377m^3 =221,740,000 gal

The following graphics illustrate the extent of the watershed for Lake Anthony and Sunset Lake, and information about the lots in the watershed.

The watershed is intensely developed; 1,242 of 4,419 lots in Oak Bluffs are located within the watershed. The M.V.C.M.A. property (the Campground) is built with tiny cottages sited on a family's tent site from the old revival meetings. Open space consists of the "circles" dispersed throughout the Campground and the Grand Circle in the center. The early subdivisions in Oak Bluffs were modeled after the Campground, consisting of small lots with community open space. Much of the original open space is now Town-owned parkland.

[5]Watershed delineated by MVC for this report

LAKE ANTHONY and SUNSET LAKE WATERSHED

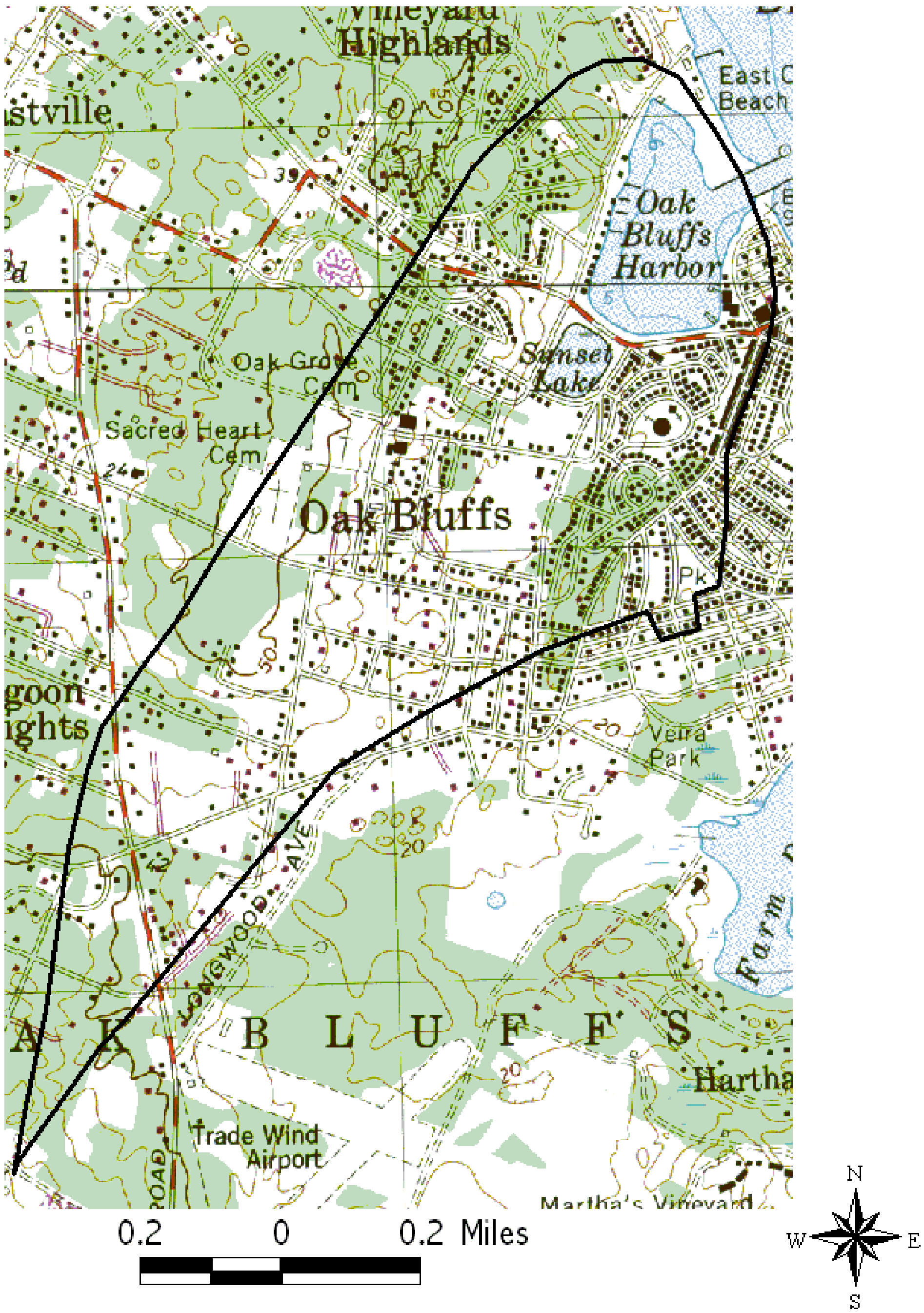

Figure 3

LAKE ANTHONY and SUNSET LAKE
Lots in the Watershed

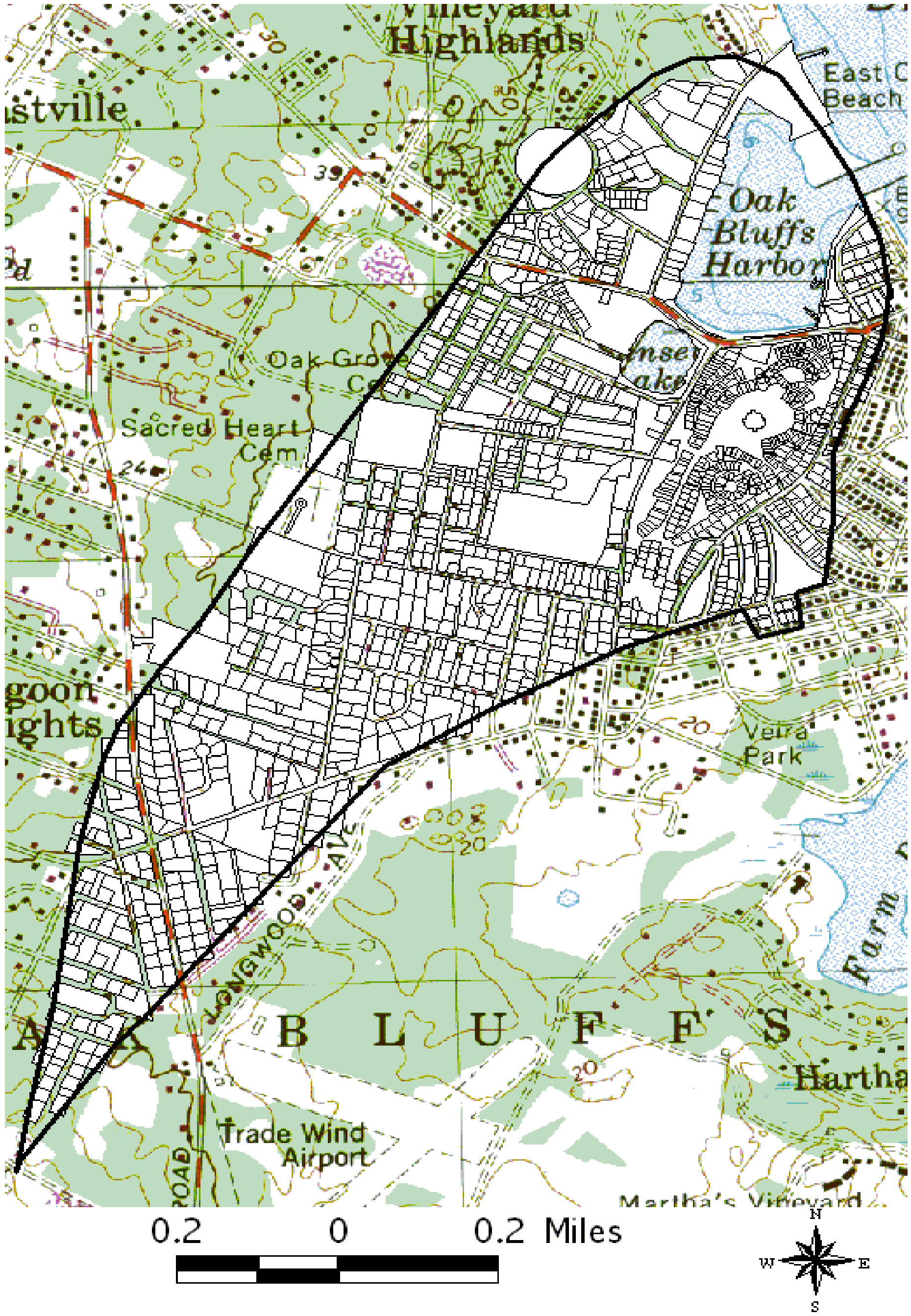

Figure 4

Of the 4419 lots in the Town of Oak Bluffs, 1242 are located within the densely developed Lake Anthony and Sunset Lake watershed.

LAKE ANTHONY /SUNSET LAKE WATERSHED
Open Space

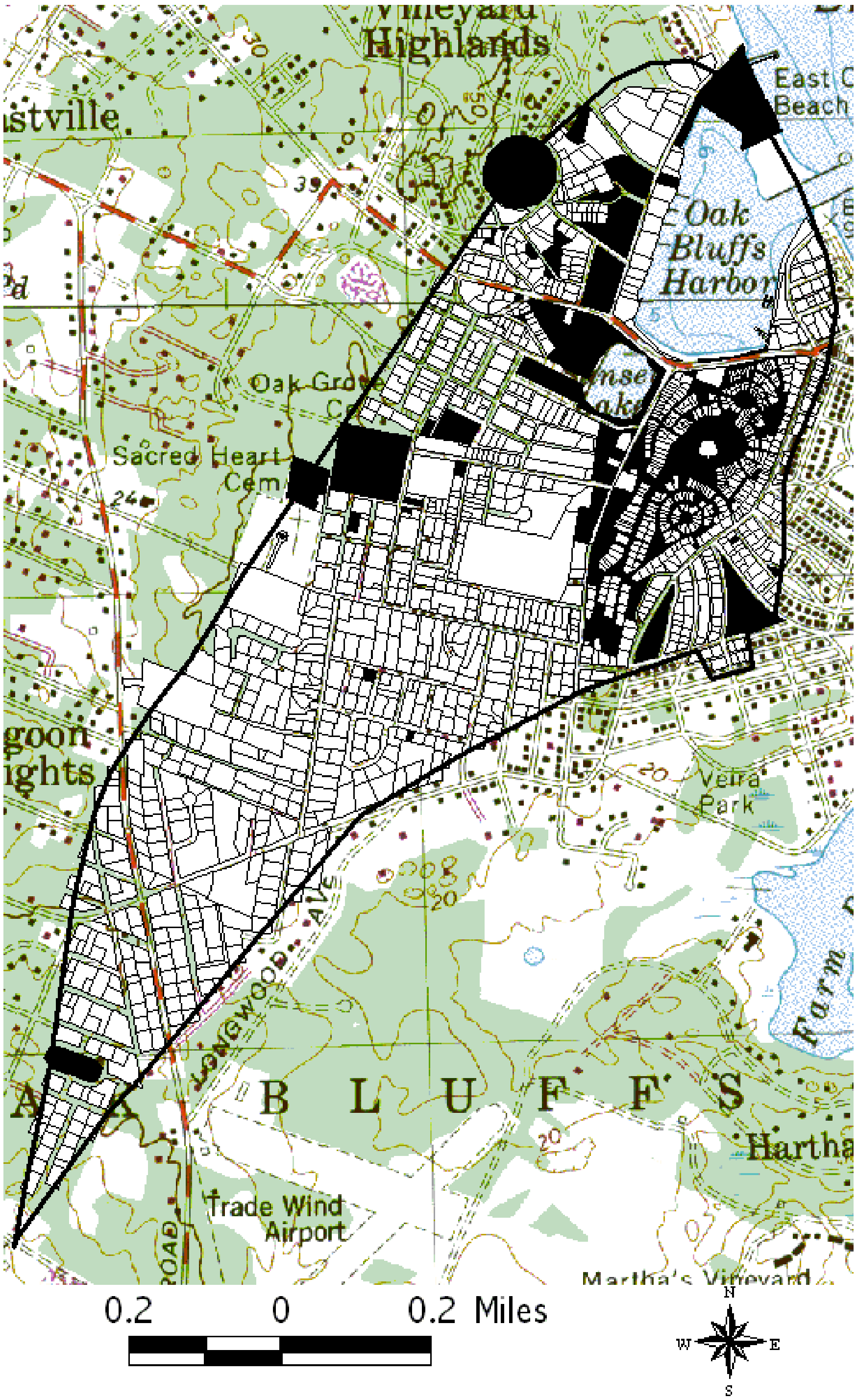

Figure 5

LAKE ANTHONY /SUNSET LAKE WATERSHED
Residential Land Use

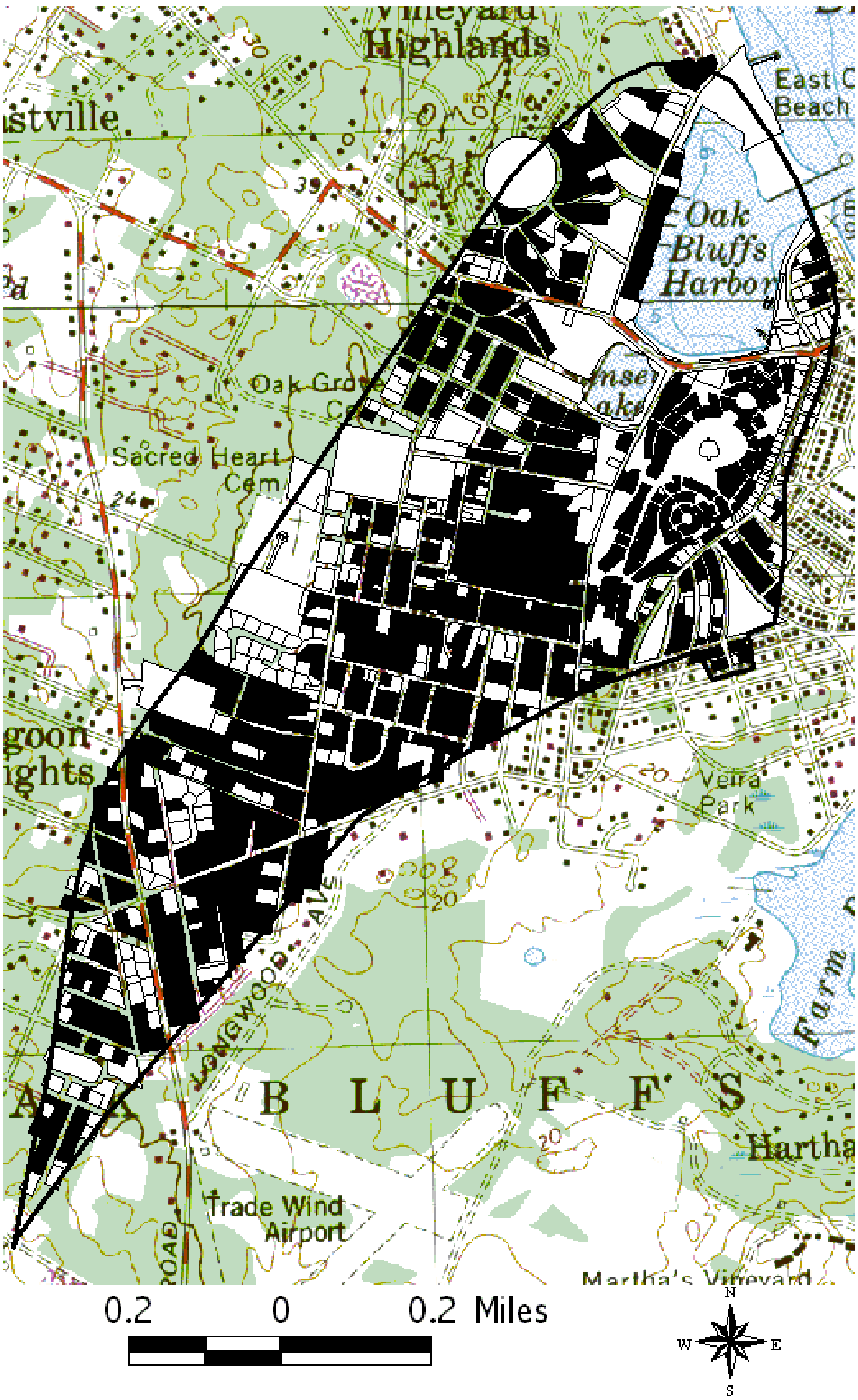

Figure 6

LAKE ANTHONY /SUNSET LAKE WATERSHED
Commercial Land Use

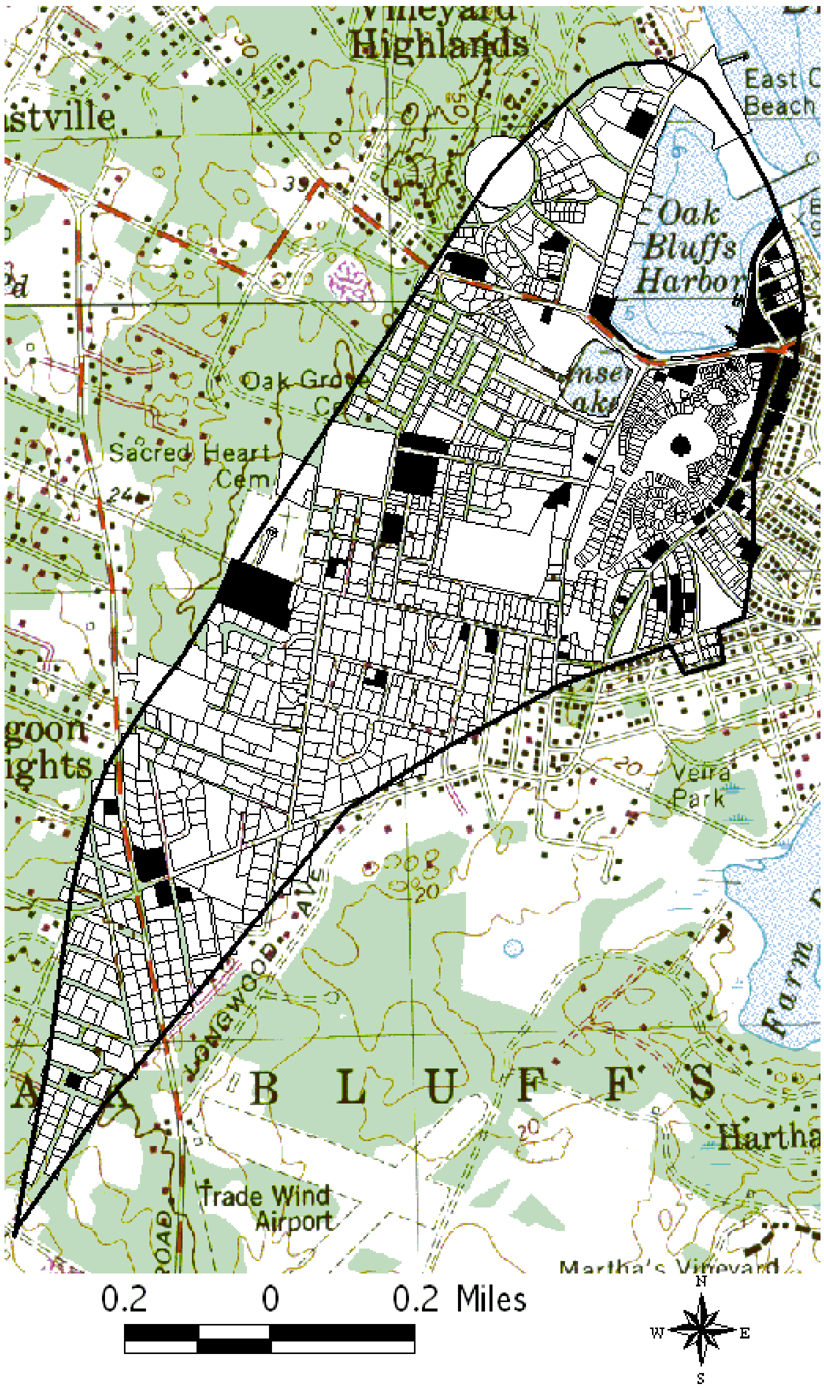

Figure 7

LAKE ANTHONY /SUNSET LAKE WATERSHED

Sewer Service Area

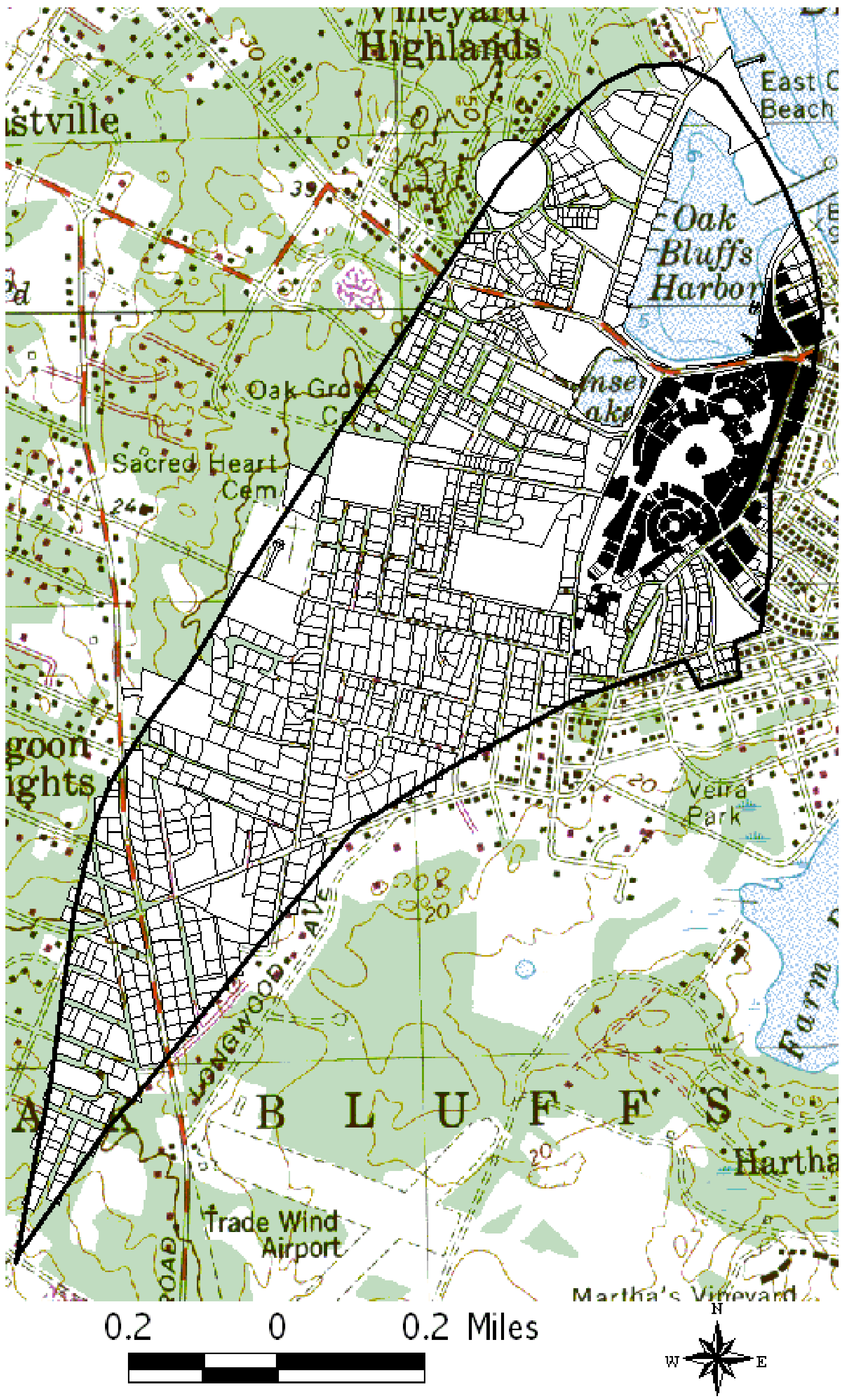

Figure 8

LAKE ANTHONY /SUNSET LAKE WATERSHED

Vacant Lots

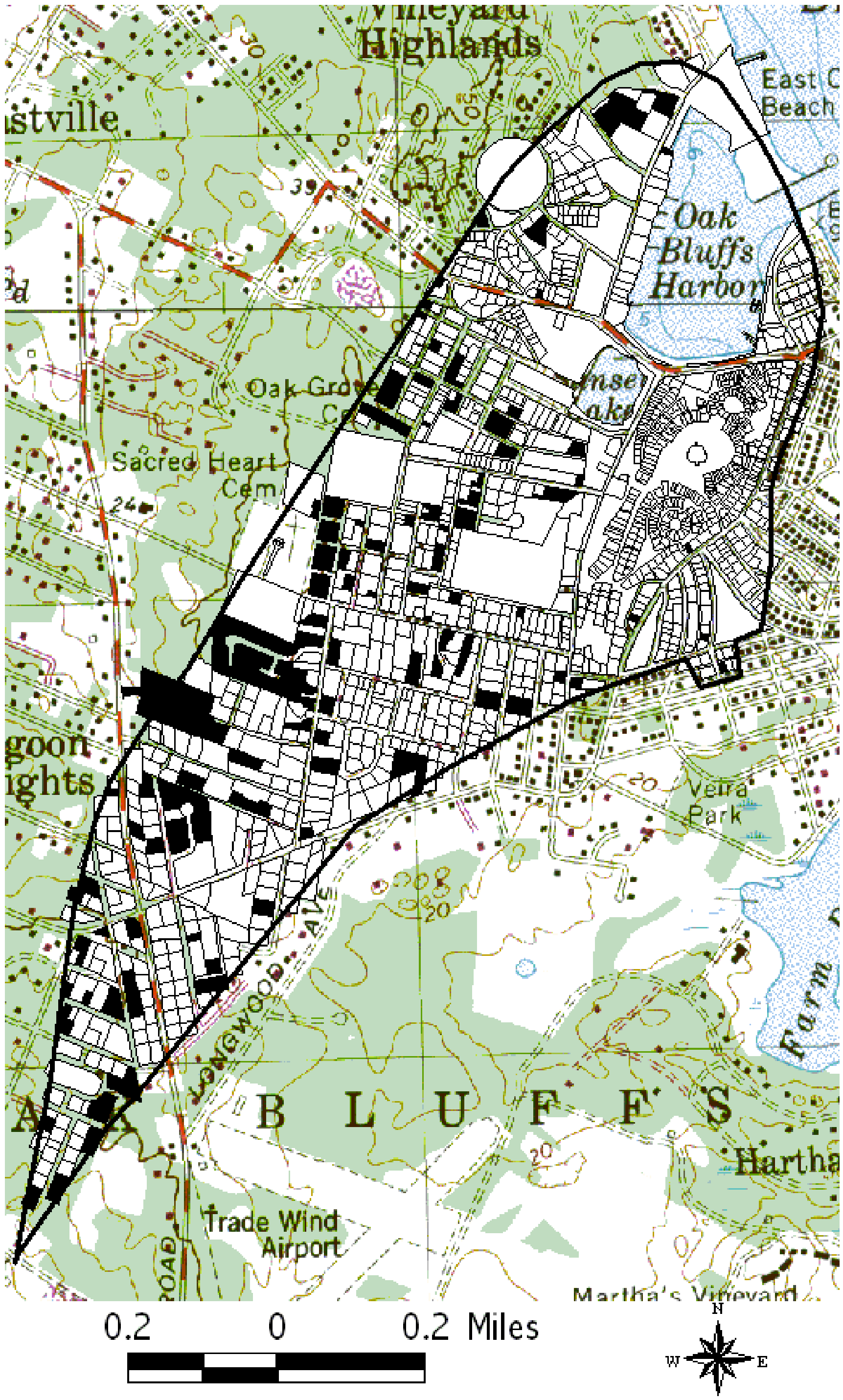

Figure 9

SEPTIC SYSTEMS

All lots within the watershed were identified by superimposing the watershed over the town assessors' parcel map with ArcView GIS. Land use codes from the Martha's Vineyard Commission's land use database were used to identify land use, also with ArcView. The loading from septic systems was estimated based on annual occupation patterns to provide a loading that takes into consideration the seasonal use of many houses. This information was derived from the MISER data (Mass. Institute for Social & Economic Research). In Oak Bluffs, 2.26 persons reside in each year 'round dwelling, and 49% of dwellings are seasonally occupied. The recent Oak Bluffs Master Plan survey[6] reported that an average of 4.77 persons resides in each seasonal dwelling. It is assumed that each year 'round dwelling is occupied by guests for 25 days. Seasonal dwellings are assumed to be occupied by 4.77 persons for 75 days and by the year 'round number for an additional 30 days of shoulder season. Septic load was calculated based on 35 mg/l nitrogen and 48 gal/person/day, as was use for the Edgartown Great Pond watershed[7]. The daily water use was assumed to be 60 gpd. Evaporation and transpiration in the leach area was assumed to remove 20% of the water discharged such that the net recharge is 48 gallons per capita per day.

EXISTING LOAD FROM SEPTIC SYSTEMS

RESIDENTIAL

for 909 residential units, 49% seasonal are 4.77 persons/house x 75 days + 2.26 persons/house x 30 days

445 houses x 425.55 persons/year x .00622 = 1,179 kilograms seasonal

for year 'round, 51% of 909 = 464 year 'round homes
2.26 persons/house x 365 days + 2.26 persons x 25 days

464 year 'round houses x 881.4 persons/year x .00622 = 2,541.5 kilograms

Total residential load = 1,179 + 2,541.5 = 3,720.5 kilograms nitrogen

---

[6] Town of Oak Bluffs, 1998, Oak Bluffs Master Plan

[7] Martha's Vineyard Commission, 1999, Edgartown Great Pond: Nutrient Loading and Recommended Management Program

COMMERCIAL

The 114 parcels in commercial use, including government offices, are assumed to consume 71,635,658 gallons of water annually. Water usage was calculated based on a survey as part of the Town's sewer planning project, with estimates for unsurveyed properties, based on the average for that category of commercial land use.

71,635,658 gallons, less 20% loss, x 35 mg/l nitrogen = 7,592.8 kg

Total from septic systems = 3,720.5 + 7,592.8 = **11,313.3 kilograms** nitrogen

LAWNS

Lawn calculations include lawn area for all lots outside of the Martha's Vineyard Camp Meeting Association lots (the Campground). Each Campground lot represents a tent site from the early revival meetings, and the tiny lots have no room for lawn. Lawn size and fertilizer application rates for the remaining 598 lots were taken from the Martha's Vineyard Commission's in-depth study of lawns in neighborhoods of similar small-lot subdivisions in the Lagoon Pond watershed[8], where lawn size averaged 3300 square feet and average fertilizer application rate was determined to be approximately 1.42 lb/1000 square feet. A 25% leaching loss was assumed.

Existing load from lawns:

598 lots x 3300 ft^2 x 1.42 lb/1000 ft^2 x .75 = 1480 lb = **953.3 kilograms**

RAINFALL

Rain and rainfall contribute atmospheric nitrogen to the watershed. After extensive literature review and consideration of wet deposition data at Provincetown since 1981, the Boston University Marine Program[9] uses a value of 15 kilograms per hectare for total nitrogen in rainfall. Using the value of 15 kg per hectare, the load to the surface areas of the ponds is 137,239.46 m^2 x 15 kg/10,000 m^2 = 205.9 kg.

---

[8] Martha's Vineyard Commission, 2000, Nutrient Loading to Lagoon Pond

[9] Jennifer Bowen, BU Marine Program, 2000, personal communication

Rain also falls on the landward portion of the watershed. Earlier in this section, groundwater recharge was calculated to be 839,377 m^3. For this densely developed watershed, it may be assumed that approximately 25% of the watershed is impervious surfaces such as roofs and pavement. It is further assumed that the rain falling on the impervious surfaces will be discharged as runoff, and that the rain falling on permeable surfaces such as open parkland will be discharged through the groundwater. The Buzzards Bay Project recommends using values of .05 mg/l and 1.5 mg/l, respectively, for nitrate nitrogen in rainfall discharged through groundwater and rainfall discharged as runoff[10]. For the total groundwater recharge of 839,377 m^3 (exclusive of the surface areas of the ponds themselves), 75% of the area will discharge rainfall through groundwater, and 25% of the area will discharge rainfall as runoff. Load from the landward portion of rainfall may be calculated as follows:

75% 839,377 m^3 x .05 mg/l = 31.5 **kg nitrate nitrogen discharged through groundwater**

25% 839,377 m^3 x 1.5 mg/l = 314.8 kilograms **nitrate** nitrogen **discharged as runoff**

Total load from rainfall = 205.9 + 31.5 + 314.8 = **552.2 kilograms.**

It is readily apparent from the calculations that runoff is providing nutrients to the system. It is also likely that runoff is contributing some bacteria. At one of the public sessions for this project, Shellfish Constable David Grunden supplied some information about the pipes discharging into the harbor: that there are 16 pipes going into the harbor; the largest are the two 16" diameter pipes on Lake Avenue. He noted that there was no dry-weather flow from any of the pipes (that would indicate septic intrusion. He later provided hard copies of several reports from bacterial testing to MVC staff. Most counts were low (ranging from 0 to less than 14) throughout the harbor, except for the time of the unknown incident, assumed an isolated episode.

AGRICULTURE

Cut flowers are grown on one 8,576.95 square foot parcel in the watershed. Agricultural load is assumed to be zero.

---

[10] J.E. Costa et al, 1999, Buzzards Bay Project Technical Report, "Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay"

TOTAL EXISTING LOAD

Total existing load = 11,313.3 + 953.3 + 552.2 = **12,818.8 kg**

BUILDOUT PROJECTIONS

The Town's new sewer treatment plant began operation in April 2002. The sewer service area includes properties that do not include space or depth to groundwater adequate for installation of a Title V septic system. The system is not designed to accommodate additional growth on lots where Title V compliance is achievable on-site. There is a 10% increase in flow figured for suppressed water use in both the commercial and residential sectors, but nothing for additional commercial or residential hookups in the design, according to the 1998 facilities plan[11].

312 residences are or will be served. 68 commercial properties , accounting for 70,418,758 gallons, are or will be served, leaving 46 commercial properties consuming 1,216,900 gallons. It is unlikely that future growth of the commercial sector will focus on the lots that are not served by the sewer system. The growth scenarios at buildout may be assumed to be identical. Sewer service will reduce the commercial load, under low, moderate or high growth scenarios, to the following:

Commercial load after sewer service =
1,216,900 gallons, less 20% loss, x 35 mg/l = 128.98 kg, representing a savings of 7,464 kilograms annually compared to the present load.

Residential buildout projections will include the removal of 312 residences that are or will be served by sewer service. The load savings may be calculated as follows:

For 312 residential units, 49% seasonal, 4.77 persons/house X 75 days + 2.26 persons/house X 30 days

153 houses X 425.55 persons/year X .00622 = 405 kilograms seasonal load

for year 'round, 51% of 312 = 159 houses
2.26 persons/house x 365 days + 2.26 persons x 25 days

159 year 'round houses x 881.4 persons/year x .00622 = 872 kilograms

---

[11]Horsley & Witten, Inc. and Wright-Pierce, 1998, draft Town of Oak Bluffs, Massachusetts, Phase III Wastewater Facilities Plan and Environmental Impact Report

The total residential savings is 872 + 405 = 1,277 kilograms saved. Added to the commercial savings of 7,464 kilograms, the total saved by sewer service is 8,741 kilograms. Assuming groundwater flow of approximately 1m per day, it should take about two years for nitrogen from the farthest Campground house, about 725 m, to reach Sunset Lake. The distance from the bottom of Circuit Avenue is more like 300 m, so it should take about one year for the last of nitrogen originating from the business area prior to April 1, 2002 to arrive at Sunset Lake. The commercial contribution of 7,464 kilograms is much greater in volume, roughly six times greater than the residential component of 1,277 kilograms.

Total vacant land includes 153 parcels totaling 162,963.5 m^2, including 150 parcels less than 1 acre in size, 2 between 1 and 2 acres in size, and one between 2 and 3 acres in size, and one lot greater than 3 acres in size. Eight vacant parcels are located within the R2 zoning district, requiring a minimum of 20,000 square feet. Of the 8 vacant parcels, only 3 include at least 20,000 square feet; one of those is large enough for two 20,000 square foot parcels. The remaining 145 parcels are located within the R1 zoning district, requiring at least 10,000 square feet. Seventy parcels include at least 10,000 square feet. Of those, twelve include more than 20,000 square feet, 4 include more than 30,000 square feet, 2 include more than 40,000 square feet, and one includes 177,635 square feet. Another 36 parcels include at least 5,000 square feet, and could conceivably be built as non-conforming pre-existing lots. It is possible that some of the parcels, although of minimum size, would not be built because of wetlands limitations or unclear title.

The vacant land could arrive at buildout contributing the following numbers of new dwellings in low, moderate and high growth scenarios:

	Low growth	moderate growth	high growth
R2	0	2	4
R1	35	70	119
Total	35	72	123

Recall that the existing scenario includes 909 residential units, of which 312 will be removed from the load by sewer service. Total contributing residential units at buildout would then include the following numbers:

Low growth	moderate growth	high growth
632	669	720

Using the same formulas that were used to determine existing load, the load from the three buildout scenarios may be calculated as follows:

Low growth scenario, 632 residential units

309 houses x 425.55 persons/year x .00622 = 813.9 kilograms seasonal

for year 'round, 51% of 632 = 322 year 'round homes

322 year 'round houses x 881.4 persons/year x .00622 = 1,767 kilograms

for the moderate growth scenario, 669 residential units

327 houses x 425.55 persons/year x .00622 = 867.7 kilograms seasonal

for year 'round, 341 year 'round houses x 881.4 persons/year x .00622 = 1,869.5 kilograms

for the high growth scenario, 720 residential units,

352 houses x 425.55 persons/year x .00622 = 931.7 kilograms seasonal

for year 'round, 51% of 720 = 367 year 'round homes
367 year 'round houses x 881.4 persons/year x .00622 = 2,012 kilograms.

Total septic load for 3 growth scenarios would be as follows:

	Low growth	moderate growth	high growth
Res	2,581	2,737	2,944
Com	129	129	129
Total	2,710 kg	2,866 kg	3,073 kg

Total load from lawns would be as follows:

Low growth	moderate growth	high growth
1,007 kg	1,066.5 kg	1,147.6 kg

Total load from rainfall would remain:

Low growth	moderate growth	high growth
552.2 kg	552.2 kg	552.2 kg

TOTAL LOAD FROM 3 GROWTH SCENARIOS:

Low growth	4,269.2 kg
Moderate growth	4,484.7 kg
High growth	4,772.8 kg

FLUSHING CHARACTERISTICS

A number of factors determine the extent to which seawater influences the pond. Tidal flushing is defined by bathymetry and other physical characteristics within the pond itself and by the size and nature of the inlet. Between 1856 and 1858, an artificial breach was created through the barrier beach between Lake Anthony and Vineyard Sound, thus creating Oak Bluffs Harbor. The 1856 Whiting map shows "Meadow Pond" as a landlocked feature with no outlet. The Whiting map also shows Sunset Lake as a separate feature, not connected to Lake Anthony. In 1985, the 30" round culvert was replaced with a 3' X 10' box culvert, which extends 90' under Lake Avenue[12]. The new culvert was considered a great improvement, and appears to be adequately sized for the flow. Were the culvert size inadequate, there might be a sloshing effect that is not seen under the existing circumstances. After creation of the artificial connection to Nantucket Sound, wooden bulkhead was built along much of the shore. A number of dredging and wooden bulkhead construction projects followed.

TIDAL EXCHANGE

In 2001, MVC recorded tidal data throughout a lunar cycle in the pond. Two Global water level recorders were placed in the pond in September. The dates were chosen to reflect mean tide conditions with respect to the phases of the moon at apogee and perigee. In other words, tide was recorded when the full and new moon extremes did not coincide with the extremes associated with the moon's position relative to the earth. The two locations selected were at the Harbormaster's dock in the harbor (Lake Anthony) and in Sunset Lake, at the culvert connecting it to Lake Anthony. The gauges were programmed to record the water depth over the pressure transducer at 10 minute intervals. The devices are temperature, pressure and salinity compensated. The manufacturer indicates .2% accuracy. There were several days of high winds at the end of September. There were no other unusual weather events.

Both tide curves are semi-diurnal. The average tide range was 1.9 feet (.58 meters) in Lake Anthony and 1.84 feet (.56 meters) in Sunset Lake. The curve is flood-dominated, as indicated by the duration of each phase of the tidal cycle. Average flood stage ran 7:04 hours in Lake Anthony and 7:00 hours in Sunset Lake. On average, ebb tide ran 5:39 hours in Lake Anthony and 5:42 hours in Sunset Lake. The slight difference is understandable; the tide ran flood for slightly longer in Lake

[12] C.E. Maguire, Inc., October 31, 1985, plan for Oak Bluffs Harbor Improvements

Anthony, then after turning ebbed for a bit longer in Sunset Lake. On average, a tidal cycle required 12:43 hours to complete. There were approximately 1.89 tidal cycles per day.

The following illustrations represent the locations of the tide gauges and the tide curves from each station:

TIDE GAUGE STATIONS
LAKE ANTHONY & SUNSET LAKE
2001

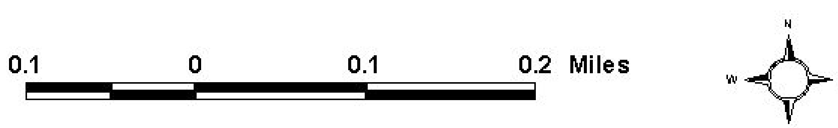

Figure 10

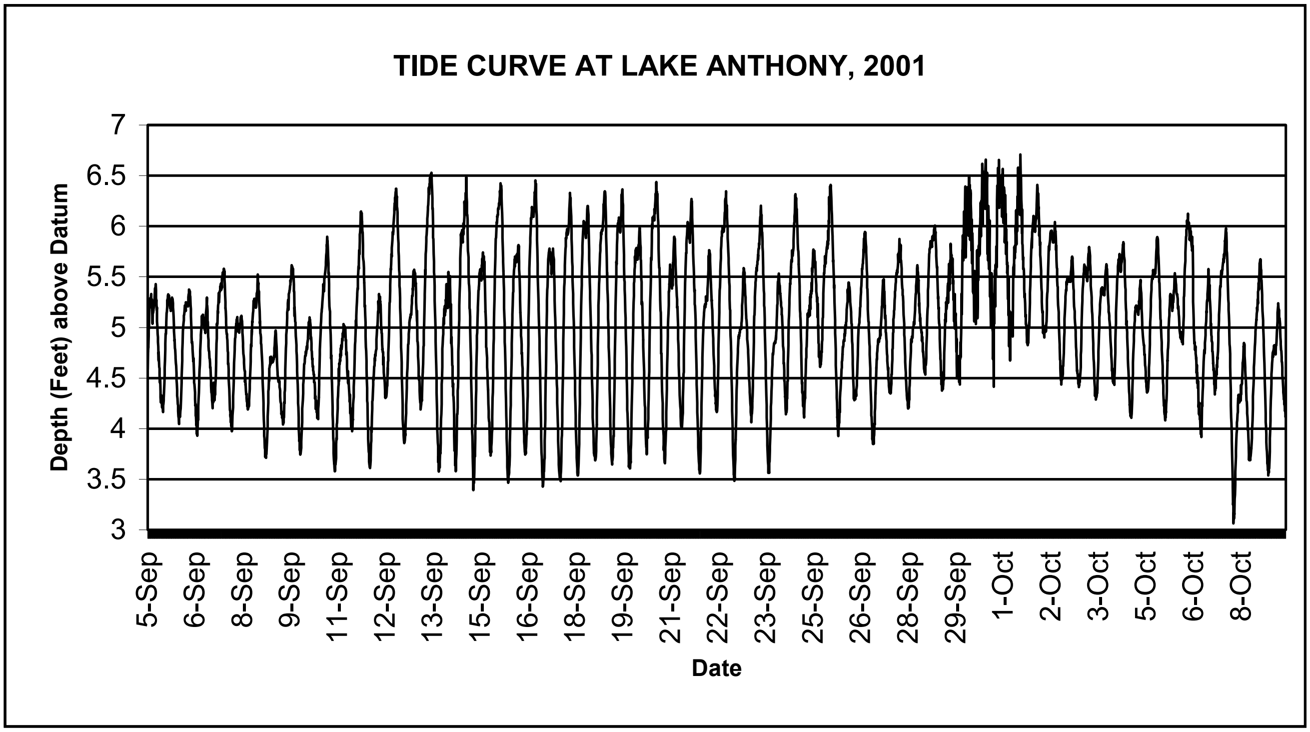

Figure 11

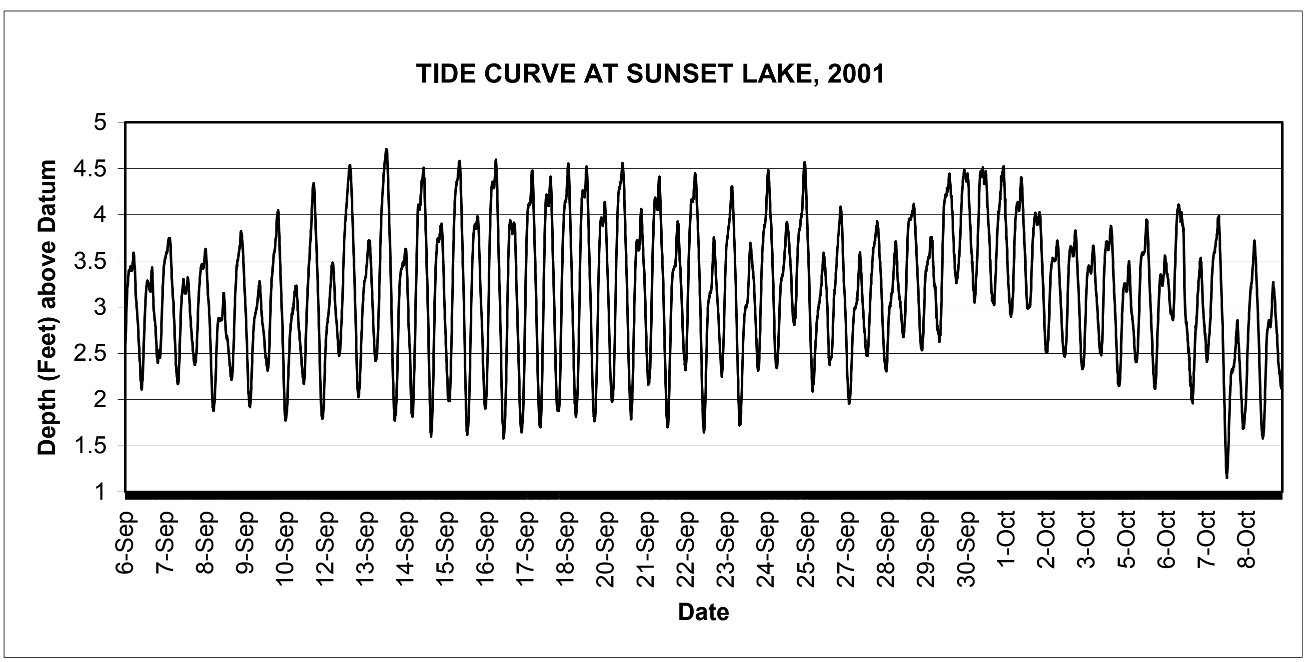

Figure 12

BATHYMETRY

Bathymetry measurements were made in Lake Anthony on October 3, 2001, by means of a Speedtech hand-held gauge. Measurements were recorded with a Trimble GeoExplorer 3 data collector and were corrected for tidal variations by comparison with the tide gauge data collected at the same time. The mid-tide bathymetry was plotted and contoured. ArcView was used to measure the area within each bathymetric contour. Using the depth, those measurements were converted to volumes and added to calculate the mid-tide volume of 315,714.85 cubic meters.

Bathymetry measurements were made in Sunset Lake on December 12, 2001, by Oak Bluffs Shellfish Constable David Grunden. Measurements were made with a Speedtech hand-held gauge at mid-tide (12:20-12:50 P.M.). The pond bottom was found to be predominantly flat, approximately .6 meters in depth. The area of 17,818.398 m^2 was calculated by ArvView and used with the depth measurement of .6 m to calculate the mid-tide volume of 10,691.04 cubic meters.

The tidal data leads to the conclusion that the two ponds essentially function as one. Therefore, the two volumes may be added, for a total mid-tide volume of 326,405.89 cubic meters.

The hypsographic curve below represents the Lake Anthony and Sunset Lake measurements together and was used to calculate the mean depth of 2.62 meters at mid-tide.

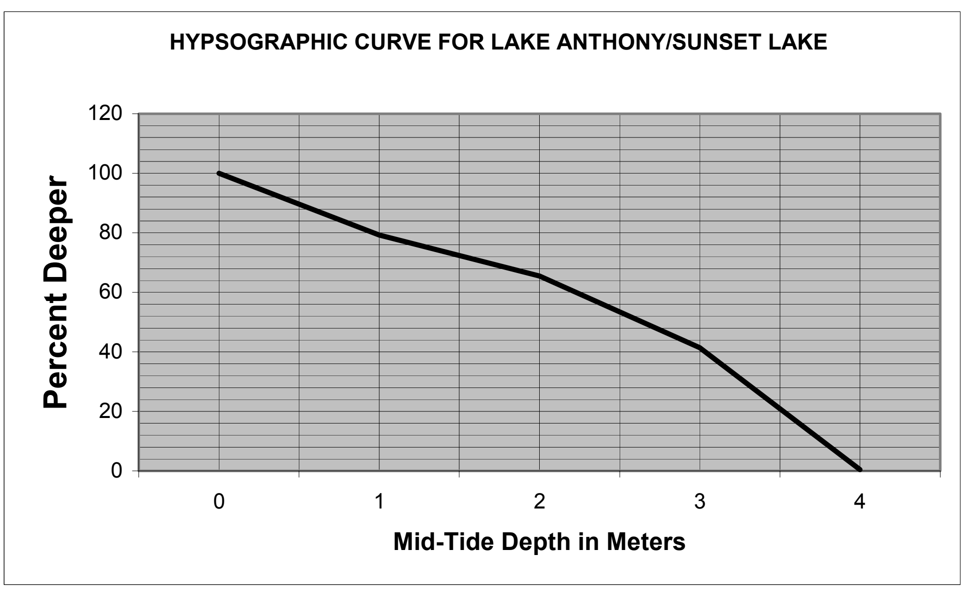

Figure 13

LAKE ANTHONY / SUNSET LAKE
Mid-tide Depth (meters)

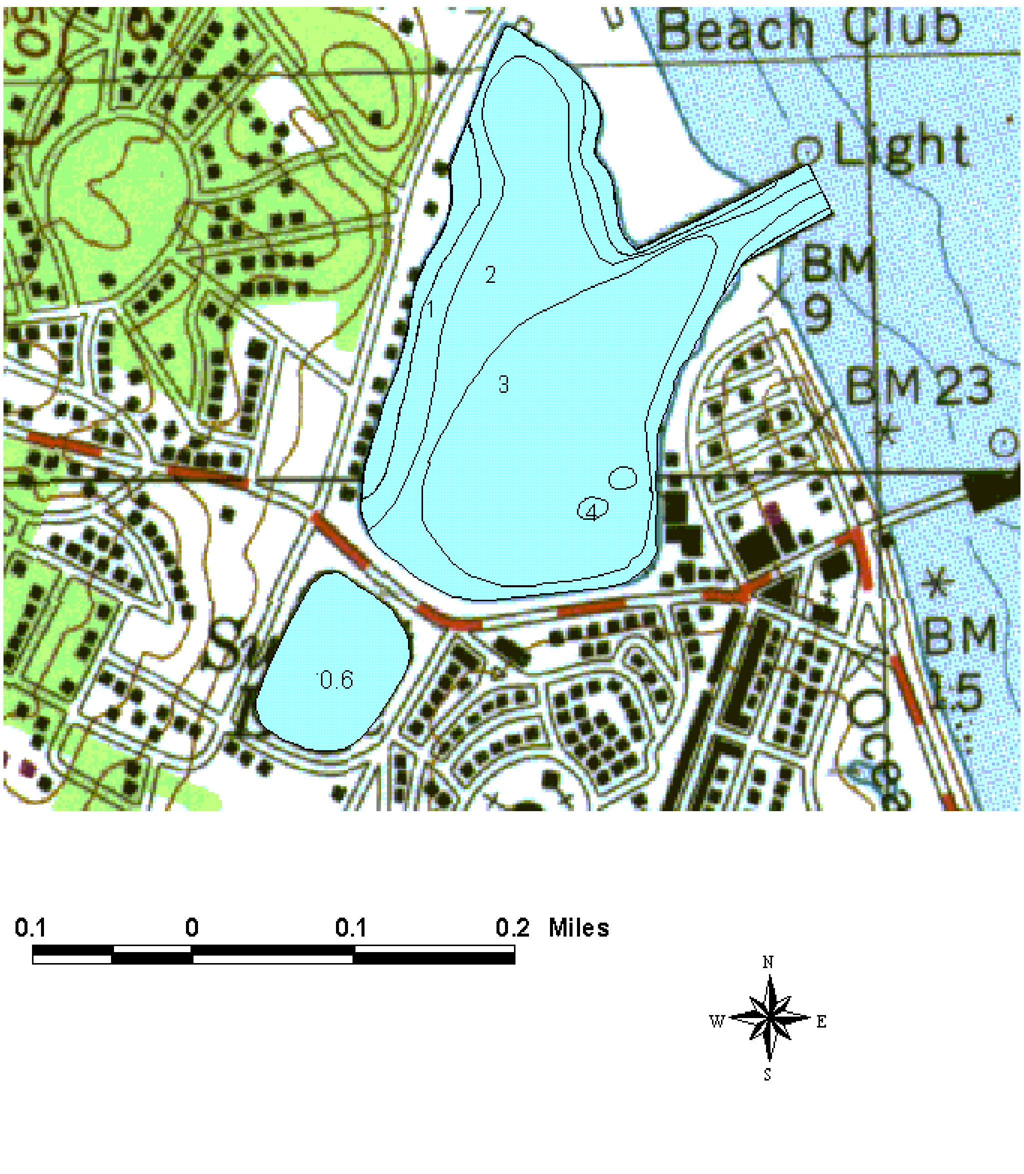

Figure 14

TIDAL FLUSHING AND RESIDENCE TIME

There are two simple ways to compute tidal flushing. The average depth at mid-tide may be divided by the tidal range. Using M.V.C.'s estimate of 2.62 meters for mean depth at mid-tide and the MVC tidal range measurement of .58 meters results in a flushing estimate of 4.52 tidal cycles. Assuming that not all water indicated in the tide range is actually completely new water exchanged for old water, this figure can be modified to give the estimated time to exchange 95% of the old water. This is three times the calculated flushing time, or 13.55 tidal cycles.

Another method to calculate flushing involves dividing the Mean Low Water volume by the difference in volume between Mean High Water and Mean Low Water. According to ArcView's area measurements and M.V.C.'s depth calculations, the Mean Low Water Volume is 286,784.61 cubic meters and the tidal prism is 79,242.56 cubic meters. Computing flushing time from those volume estimates results in an estimate of 3.62 tidal cycles, which corresponds to 10.9 cycles estimated to exchange 95% of the pond's water.

The two flushing estimates of 13.56 and 10.9 cycles are quite consistent with one another. Averaging the two results in an estimate of 12.2 tidal cycles for flushing time. **Residence time** is the number of days of tidal flushing required to completely exchange old water for new, or the time it takes for newly input fresh water to arrive at and exit the pond through the inlet. Residence time is calculated by dividing flushing time by the number of tidal cycles per day. Using the M.V.C. calculation of 12.2 tidal cycles for flushing time and the M.V.C. measurement of 1.89 tidal cycles per day results in a residence time of 6.46 days, or .0177 year.

NITROGEN LOADING LIMIT AND COMPARISONS

MVC has used the formulas developed by the Buzzards Bay Project, as recently modified[13], to determine the nitrogen loading limit for the pond. The Buzzards Bay Project formulas were used because several of the water bodies used to devise the method were tributaries of nearby Buzzards Bay, although San Francisco Bay, Long Island Sound and experimental mesocosms were also used. The model is based on the capacity of coastal waters to assimilate added nitrogen. The technical basis for the process involved identifying indicators of environmental quality (such as oxygen levels, chlorophyll concentration and eelgrass coverage), identifying water bodies exhibiting critical changes in those qualities (such as hypoxia, excessive turbidity, or loss of eelgrass beds); and estimating the nitrogen loading rate associated with that condition. From that information an attempt was made to prepare a generalized nitrogen loading scale, identify thresholds of nitrogen loading that could be used as guides for managing anthropogenic nitrogen additions, or as goals for mitigation of nutrient impacts on degraded estuaries and coastal ponds. This formula provided a nitrogen loading limit based on pond characteristics and desired use of the pond. Although the Buzzards Bay Program used the Commonwealth's water quality ratings to distinguish desired uses, the Commonwealth's water quality classification system includes no specific nitrogen loading limits In order to avoid confusion, the following calculation uses the term "good" in place of the Buzzards Bay Project's reference to "SA" waters. The revised formula, further modified as described above, was used for the following calculation, where volume at mid-tide = 326,405.89 m^3, and residence time = .0177 year:

$$\frac{\text{(loading rate)(volume at mid-tide)(1+sqrt residence time)}}{\text{(residence time)(1,000,000)}}$$

$$= \frac{(150\ \text{mg/m}^3)(326{,}405.89\ \text{m}^3)(1+\text{ sqrt }.0177)}{(.0177)(1{,}000{,}000)}$$

= **2,766.28** kilograms limit

---

12 J. E. Costa et al, 1999, Buzzards Bay Project Technical Report, Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay

COMPARISONS

Existing load and load at buildout are summarized below:

Existing Load	12,818.8 kg
Load at Low Growth Buildout	4,269.2 kg
Load at Moderate Growth Buildout	4,484.7 kg
Load at High Growth Buildout	4,772.8 kg

None of the buildout scenarios would contribute less than the limit of 2,800 kilograms, but all represent a significant reduction from the present load of 12,818.8 kilograms.

WATER QUALITY SAMPLING

Six rounds of sampling were made in Lake Anthony/Sunset Lake from May through September, at four stations. All sampling rounds were made in the early morning hours in order to record dissolved oxygen levels, and on an ebb tide in order to sample the outgoing water rather than the incoming seawater. The water quality sampling program included chemical composition parameters. The water quality data should assist in identifying nutrient loading problems that may exist in the pond during present loading conditions, thus providing a "snapshot" of existing nutrient loading conditions as well as possibly pointing out local indications in various parts of the pond. As such, the water sampling data may be useful in development of management recommendations, helping to identify source areas of nutrients in the groundwater discharging to the ponds. The water chemistry data included nitrate, ammonia, dissolved organic nitrogen, particulate nitrogen, particulate organic carbon, conductivity, orthophosphate, chlorophyll *a* and silicate. Hydrographic data (physical parameters as opposed to water chemistry data) included: depth & water transparency, temperature, conductivity, salinity, and dissolved oxygen. Hydrographic data was gathered for each station and surface water chemistry samples taken at each station. Details of methodologies may be found in the Quality Assurance Project Plan.

The four sampling stations are shown on the following graphic. Station OBH 1 was located at the culvert to Sunset Lake, in order to sample nutrient exchange between Sunset Lake and the harbor. Station OBH 2 was located in a deep area of the harbor, near the commercial side. Station OBH 3 was located across the harbor, near the residential side. Station OBH 4 was located in deep water adjacent to the inlet.

Hydrographic data were recorded with a Trimble GeoExplorer 3, at the surface, mid-depth and the bottom. Those data are printed in Appendix 2, along with the results of laboratory analysis of the surface water samples.

SAMPLING STATIONS

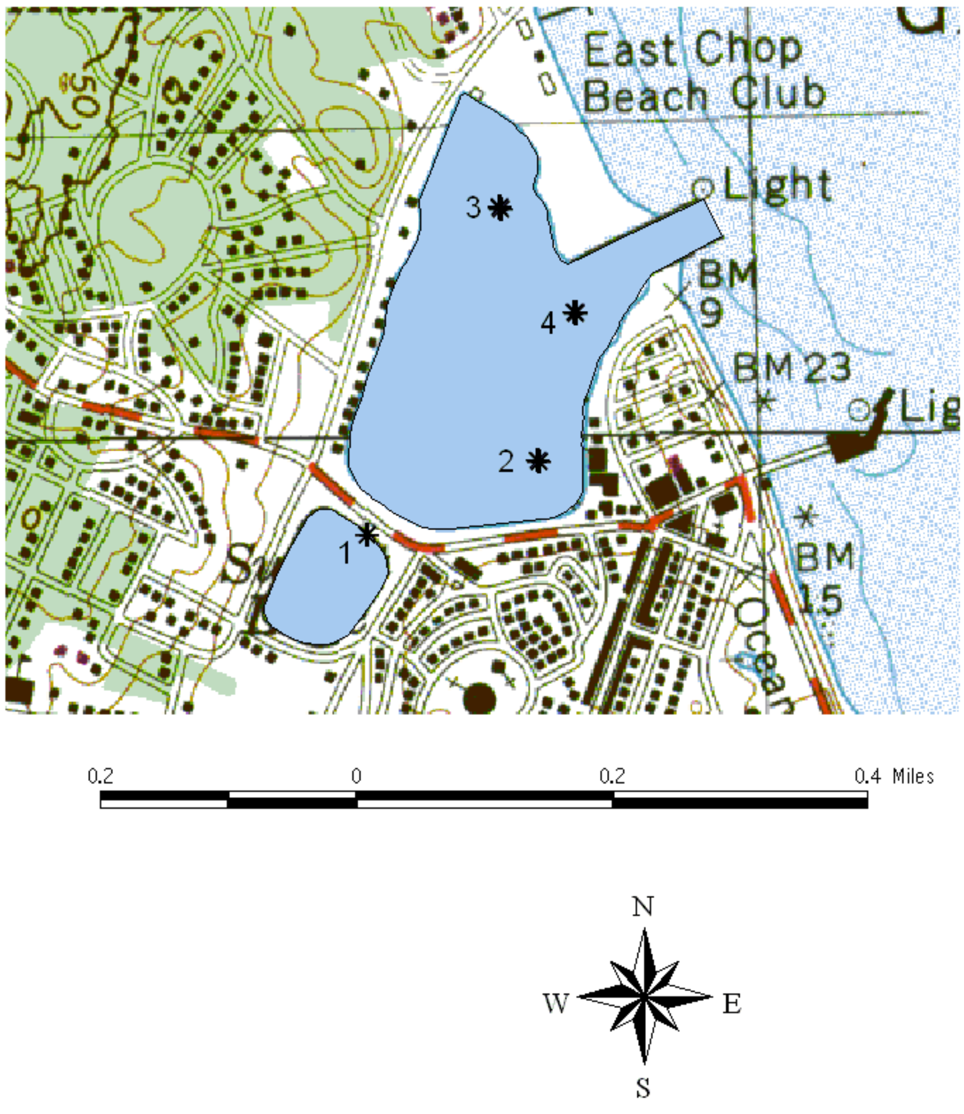

Figure 15

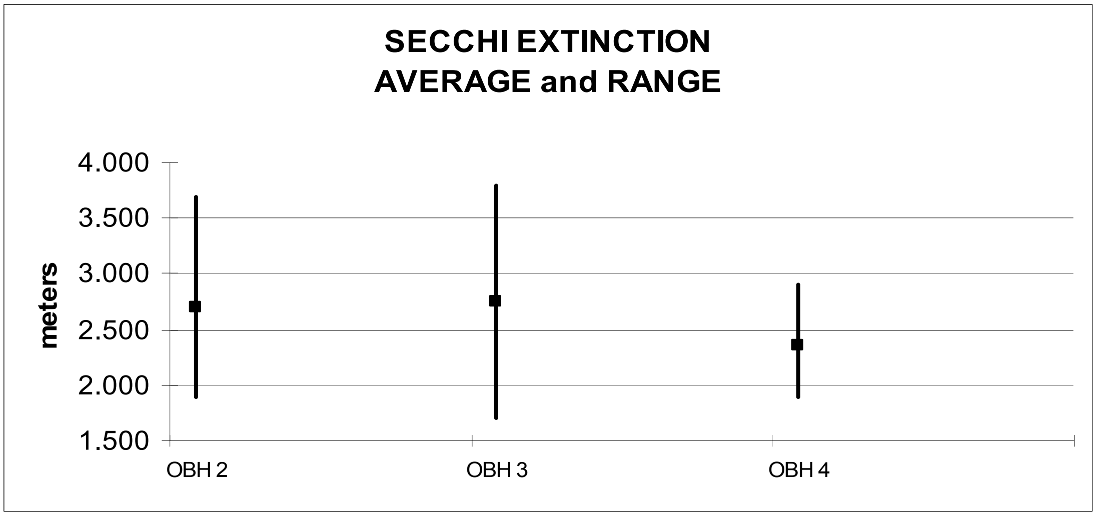

Figure 16

Water clarity was high, as recorded with a Secchi disc. Extinctions are plotted above for Stations 2-4 in the harbor. Clarity was highest at Station 4 near the inlet; lower and more variable at the stations farther from the inlet. Station one, at the culvert to Sunset Lake, does not appear on the chart. The shallow depth there precluded measurement of extinction, except for on May 1, when extinction was measured at .5 meter, indicating a very low level of water clarity. Surface conductivity is illustrated below. The Sunset Lake samples reflect slightly less influence of seawater. Sunset Lake and harbor samples showed similar variability.

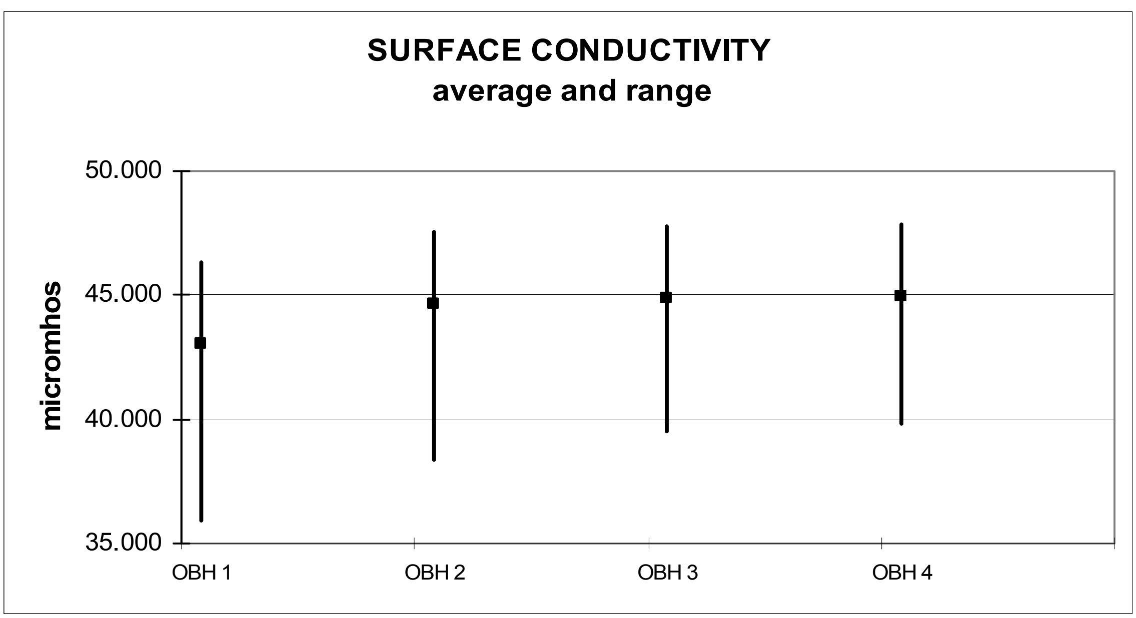

Figure 17

The following graphs illustrate values of various parameters as measured from surface water samples throughout the pond. The graphs represent the range and average values:

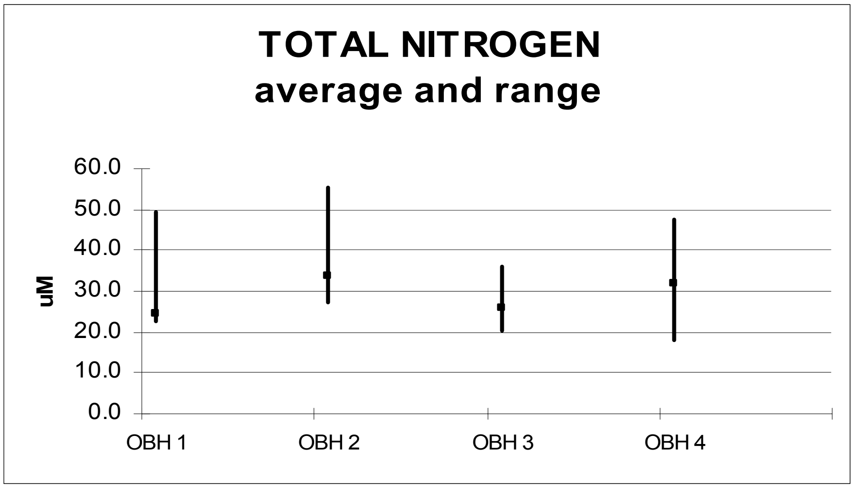

Figure 18

The value of total nitrogen includes all forms of nitrogen, including dissolved nitrogen and that found in particulate matter such as phytoplankton, bacteria and organic debris. Values for total nitrogen were markedly higher at Station 1, at the culvert to Sunset Lake than at the harbor stations. High values of total nitrogen commonly indicate eutrophication. Total Dissolved Nitrogen measures all the nitrogen that is free in the water, including inorganic forms such as nitrate and ammonium and organic forms such as urea, which are released by decaying organic matter.

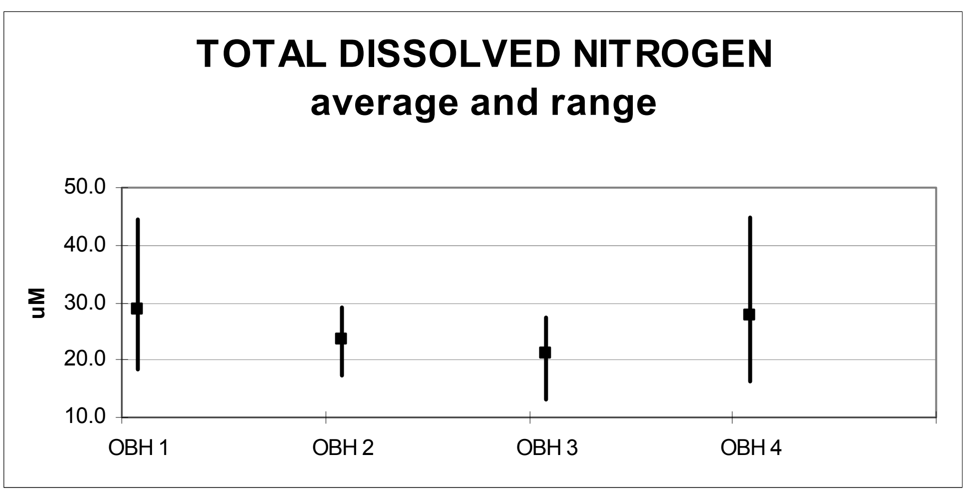

Figure 19

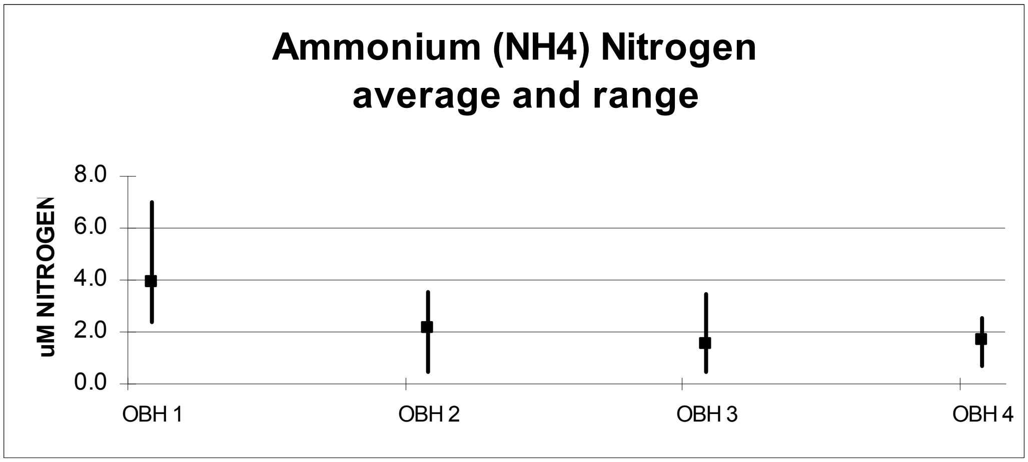

Figure 20

Values for ammonium and nitrate were distinctly higher at Station 1, at the culvert to Sunset Lake, more consistently so for ammonium. Together, ammonium and nitrate make up dissolved inorganic nitrogen.

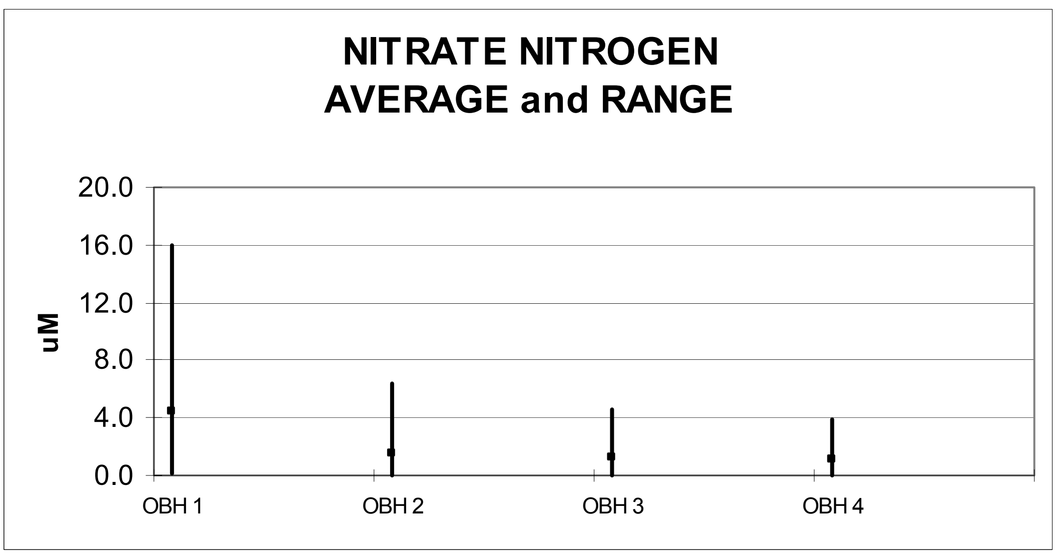

Figure 21

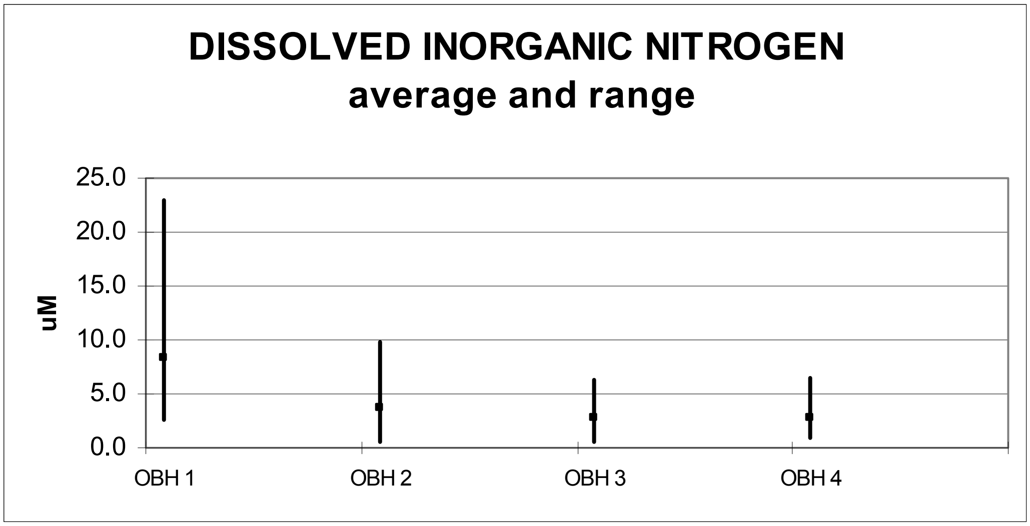

Figure 22

Dissolved Inorganic Nitrogen includes nitrate and ammonium. DIN is normally found at low concentrations in coastal waters; high levels indicate eutrophication. DIN is instantly and readily available for phytoplankton growth. DIN values were markedly higher at the culvert to Sunset Lake. Dissolved Organic Nitrogen values were markedly higher at Station OBH 4, near the inlet.

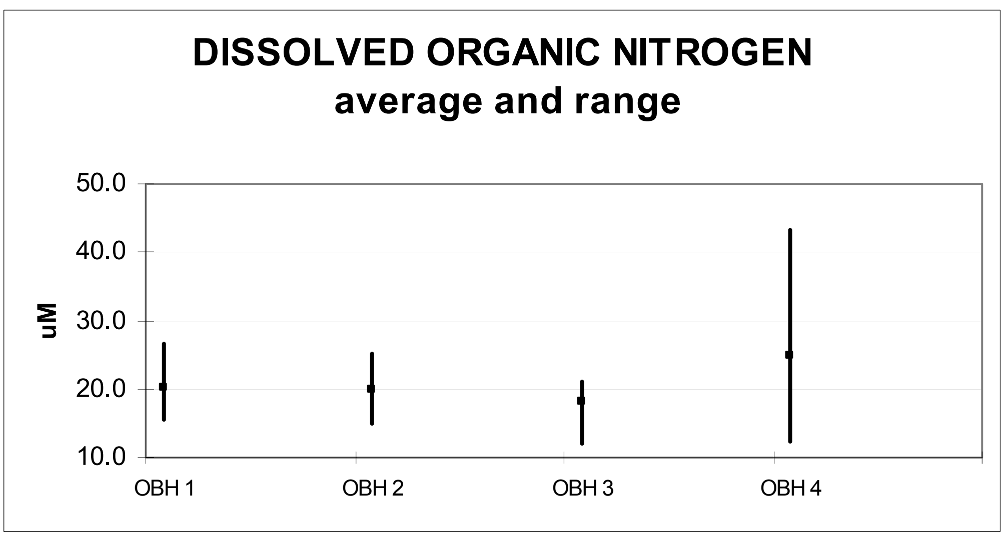

Figure 23

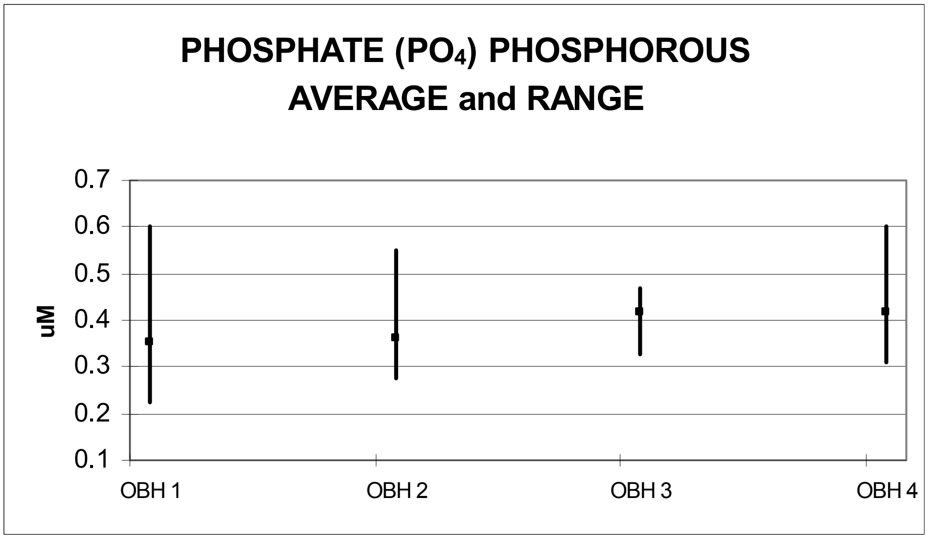

Figure 24

Values for phosphate increased with proximity to the inlet. The ratio of inorganic nitrogen to phosphate is an indication of whether nitrogen or phosphorous is the limiting factor for growth. According to Redfield (Redfield et al, 1963), the average ratio of phosphorous to nitrogen to silica to carbon is 1:16:16:106 in phytoplankton. Major nutrients deficient according to the Redfield Ratio are said to be the limiting nutrients. On the graph below, with the threshold of 16 shown on the y-axis, nitrogen appears as the limiting factor most often in the harbor samples; while phosphorous was the limiting factor more often in the Sunset Lake samples (OBH 1).

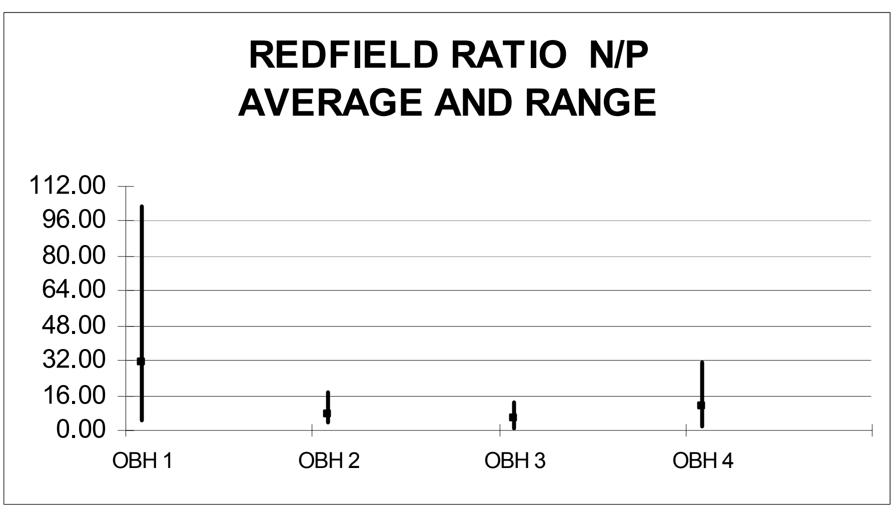

Figure 25

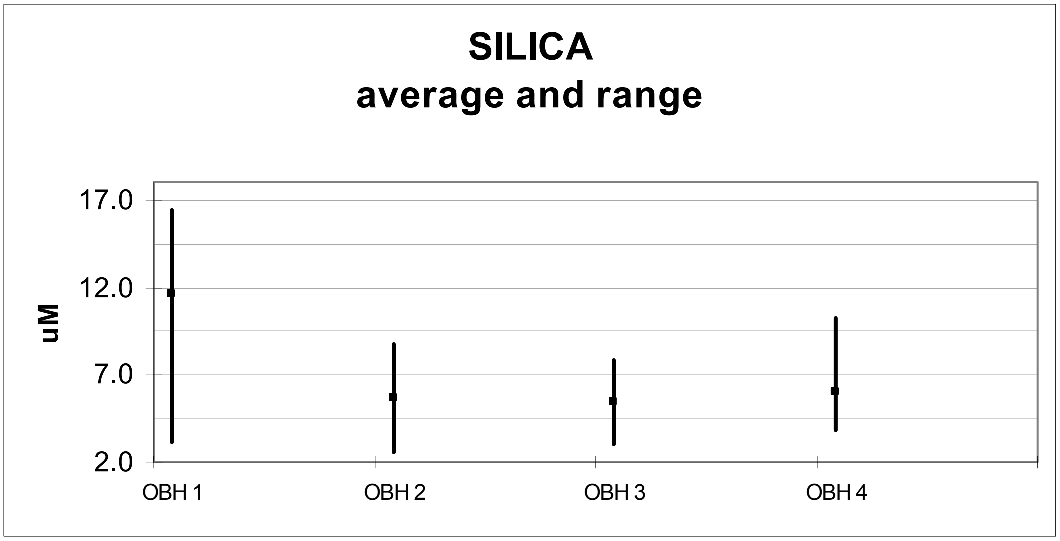

Figure 26

Silica values were low throughout; somewhat higher in the Sunset Lake samples. The Redfield Ratio for silica to orthophosphate is also 16 to one. The graph below illustrates that relationship. The average ratio for the harbor samples (OBH 2 – OBH 4) was quite close to 16. On the days that the ratio was more than 16, growth of algae was limited by the shortage of phosphate. On the other days, growth of algae was limited by the supply of silica. The ratio routinely exceeded 16 in the Sunset Lake samples, indicating that the greater supply of silica there ensured that orthophosphate was more often the limiting factor.

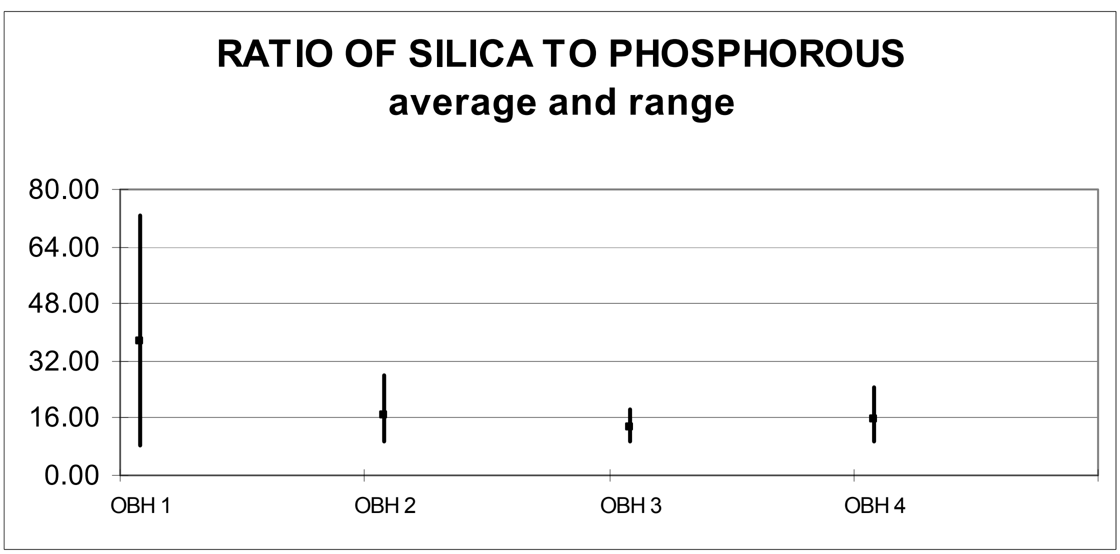

Figure 27

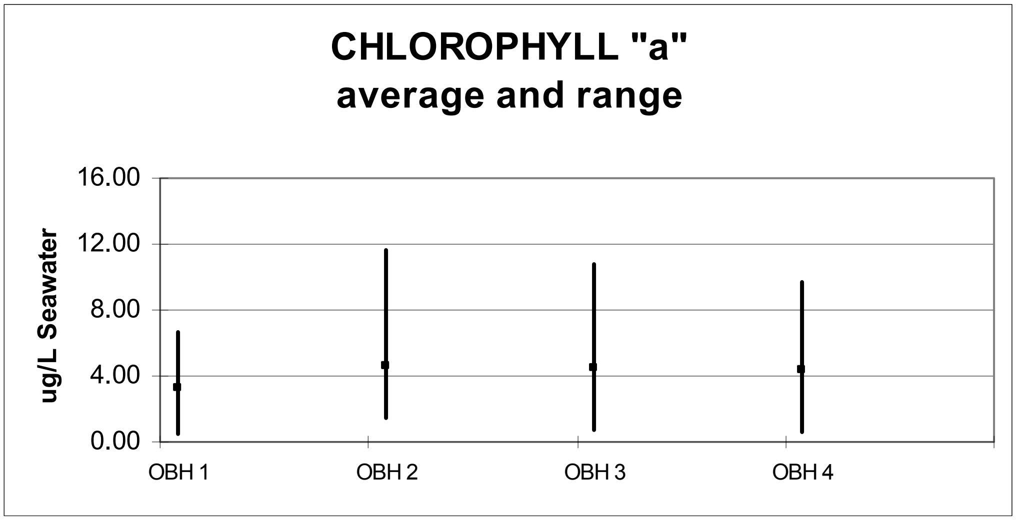

Figure 28

The above graph illustrates the range of values and average values of Chlorophyll "a". There was more variability at harbor stations (2-4), and the highest values were recorded there. Phaeopigment values measure how much dead and decaying vegetation is in the water, as opposed to the Chlorophyll "a" values that measure living plant life. Values were distinctly higher and more variable at the culvert (Station 1).

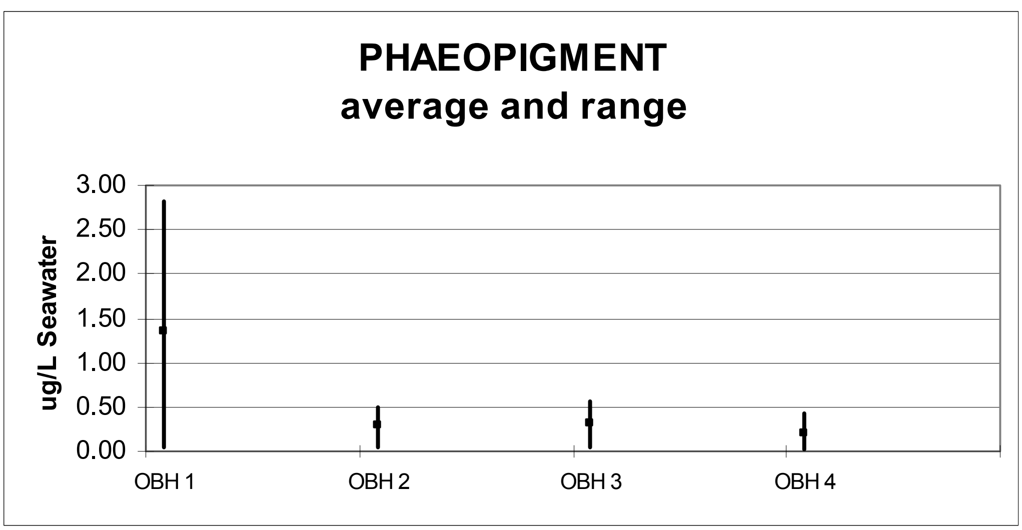

Figure 29

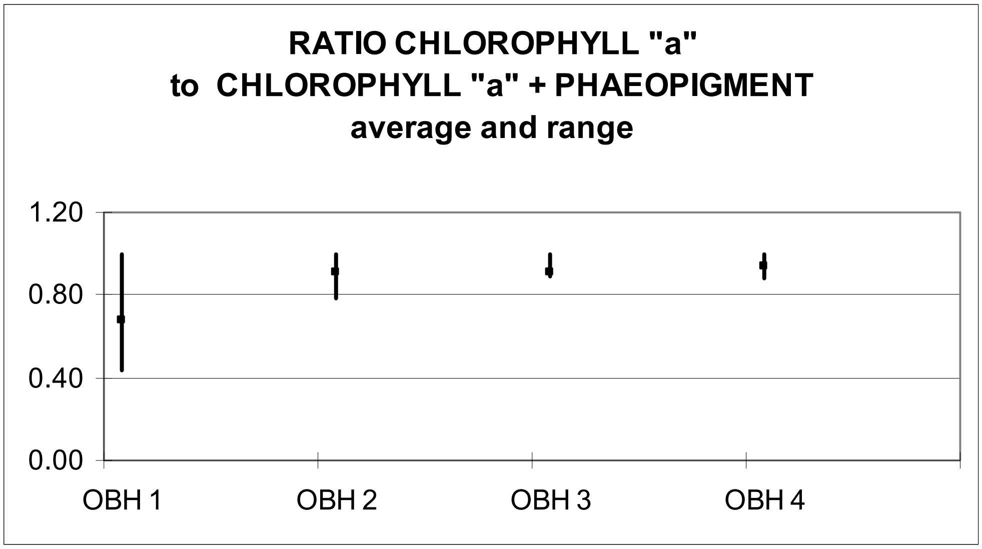

Figure 30

The ratio of Chlorophyll "a" to the sum of Chlorophyll "a" and Phaeopigment represents the portion of the mass of algae that is living. Values close to 1 represent primarily living populations, while lesser values indicate more mass of dead algae. The graphs above show that more Chlorophyll “a” was found at the harbor stations, but that a higher proportion of dead algae was found at the culvert to Sunset Lake.

COMPARISONS AND CONCLUSIONS

The results of the 2001 sampling may be viewed in terms of 6 snapshots of water conditions as they varied spacially throughout the area and depth of the pond, and over time. Much can be learned about nutrients entering the pond, and also about how the dynamics of the pond determine the ultimate fate of those nutrients. This round also will serve as a baseline nutrient data set, particularly appropriate for comparison with sampling subsequent to the impacts of sewering and other modifications.

For comparison of some major nutrients, the following table compares the Lake Anthony set to MVC data for several Island ponds and from Buzzards Bay; Edgartown Great Pond, Oyster Pond and Buzzards Bay, as reported by the Island Ponds Consortium[14] in 1999, for Tisbury Great Pond, as reported by the Martha's Vineyard Commission[15] in 2000, and for Lake Tashmoo as reported by the Martha's Vineyard Commission[16]. The range of averages for each station over time is listed, not the absolute maximum and minimum records:

NUTRIENT VALUES FOR COMPARISON

Nutrient (uMoles)	Lake Tashmoo	Buzzards Bay	Tisbury Great Pond	Edgartown Great Pond	Oyster Pond	Lake Anthony
NH4	.6-1.4	2.33-5.39	.92-2.88	1.06-1.39	.9-1.21	1.5-3.9
PO4	.4-.63	.47-.72	.65-1.15	.04-.2	.12-.27	.4
SiO3	8.1-24.3	3.75-6.68	80.25-116.73	26.8-31.56	41.69-63.25	5.45-11.63
NO3	.1-.7	.62-.91	.05-5.075	2.83-5.06	.56-1.55	1.1-4.4

Table 3

[14] The Island Ponds Consortium, 1999, Island Coastal Ponds Water Quality Study
[15] Martha's Vineyard Commission, 2000, Nutrient Loading to Tisbury Great Pond
[16] Martha's Vineyard Commission, 2003, Nutrient Loading to Lake Tashmoo

Reviewing the data overall, nitrogen values [ammonium (NH_4) and nitrate (NO_3)] were found to be higher than for various other Island ponds used for comparison, except for the higher nitrate vales in Edgartown Great Pond. Phosphate values were lower, and silica values were considerably lower.

Water clarity was high; highest at Station 4 near the inlet, lower and more variable at the stations farther from the inlet. The shallow depth precluded measurement of extinction at OBH 1, at the culvert to Sunset Lake, except for on May 1, when extinction was measured at .5 meter, indicating a very low level of water clarity. The Sunset Lake samples reflected slightly less influence of seawater; Sunset Lake and harbor samples showed similar variability in conductivity.

Values for total nitrogen were markedly higher at Sunset Lake than at the harbor stations. Values for ammonium and nitrate were distinctly higher at Sunset Lake, more consistently so for ammonium. Together, ammonium and nitrate make up dissolved inorganic nitrogen. Dissolved Organic Nitrogen values were markedly higher at Station OBH 4, near the inlet. Values for phosphate increased with proximity to the inlet, perhaps indicating the inlet as a source. Nitrogen was the limiting factor most often in the harbor samples; while phosphate was the limiting factor more often in the Sunset Lake samples (OBH 1). Silica values were low throughout; somewhat higher in the Sunset Lake samples. The average ratio of silica to orthophosphate was quite close to 16 for the harbor samples (OBH 2 – OBH 4). On the days that the ratio was more than 16, growth of algae was limited by the shortage of phosphate. On the other days, growth of algae was limited by the supply of silica. The ratio routinely exceeded 16 in the Sunset Lake samples, indicating that orthophosphate was more often the limiting factor.

There was more variability of Chlorophyll "a" at harbor stations (2-4), and the highest values were recorded there. Phaeopigment values were distinctly higher and more variable in Sunset Lake. More Chlorophyll “a” was found at the harbor stations, but a higher proportion of dead algae and plant material was found in Sunset Lake.

MANAGEMENT MEASURES

ADOPT 2800 KILOGRAMS PER YEAR AS THE ANNUAL NITROGEN LOADING LIMIT FOR THE WATERSHED

According to the MVC calculations in this report, the nitrogen loading limit for Lake Anthony and Sunset Lake should be **2,800** kilograms. As the following graphic illustrates, the present load, 12,819 kilograms, is dominated by commercial septic flow representing 60% of the total. Most of that flow should be removed from the watershed by sewer service. Sewer service should remove 7,464 kilograms from 68 commercial properties and 1,277 kilograms from 312 residential properties, for a total of 8,741 kilograms.

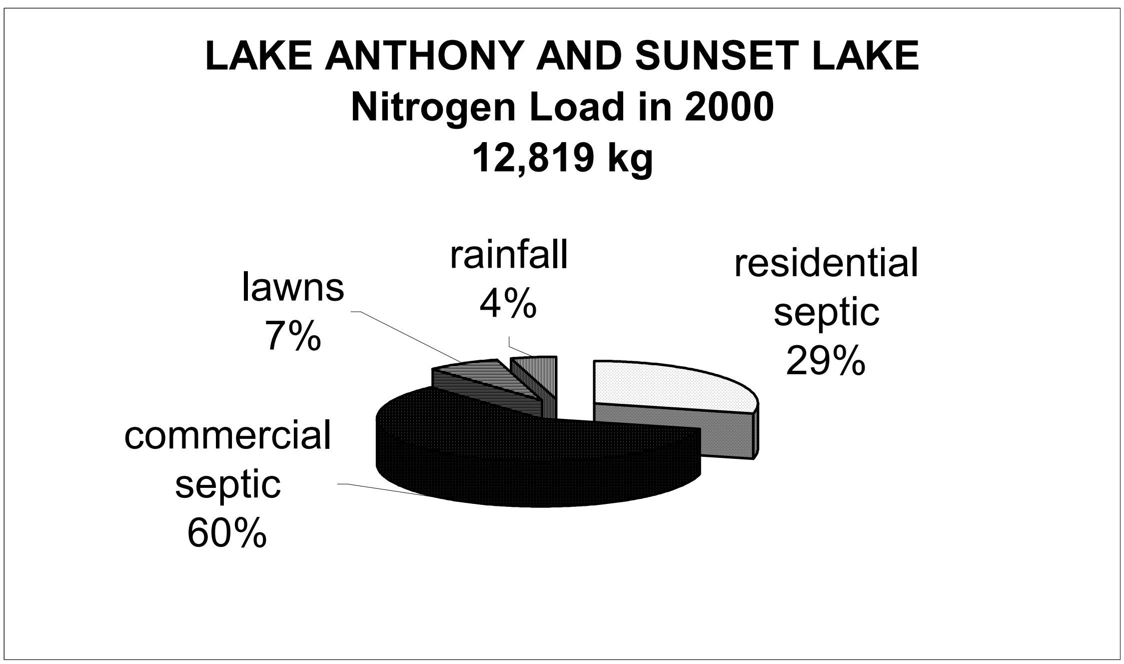

Figure 31

There is very little difference between the low, moderate and high buildout scenarios. This is because so much of the watershed is already built, and because most of the remaining vacant space has already been subdivided into small lots. It is unlikely that growth management in the form of subdivision control could significantly impact nitrogen loading to this watershed. The following graphics illustrate the high degree of similarity between the components of the low, moderate and high buildout scenarios:

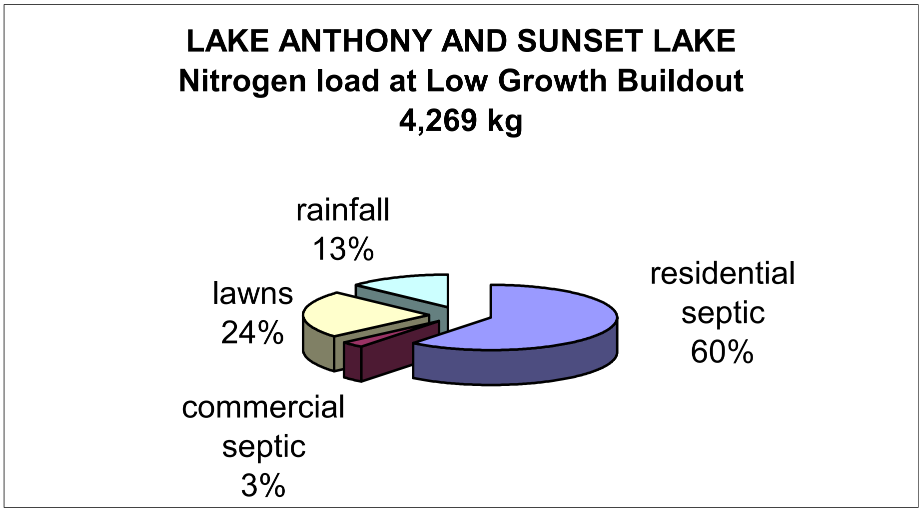

Figure 32

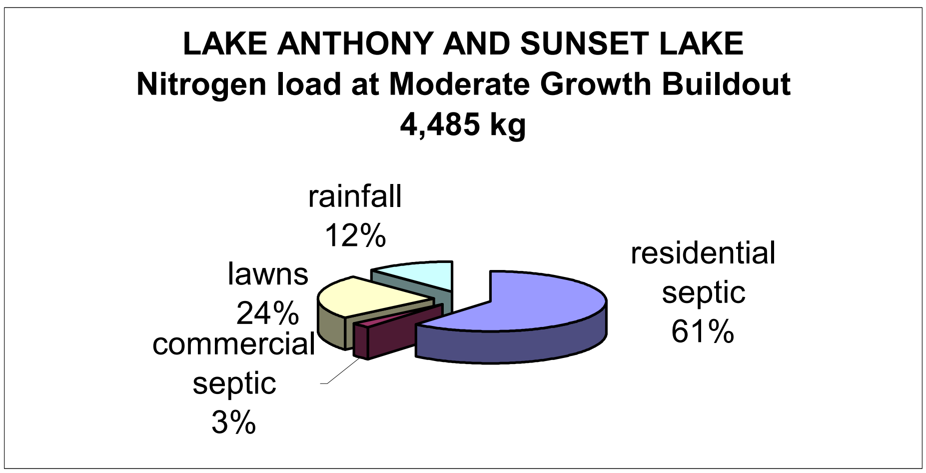

Figure 33

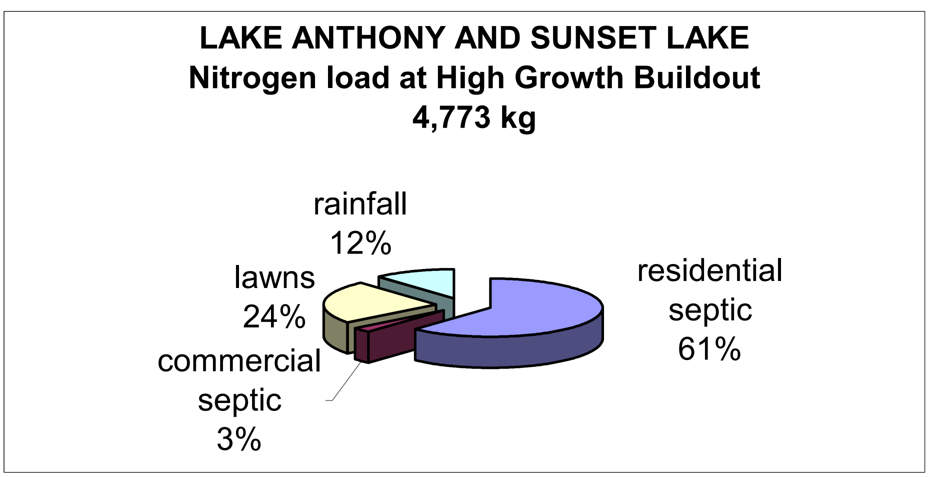

Figure 34

None of the buildout scenarios would contribute less than the limit of 2,800 kilograms, but all represent a significant reduction from the present load of 12,819 kilograms. With the removal of most of the commercial flow, the proportions change significantly. The residential component increases in impact from 29% to 60-61% of flow. The impact of lawns also increases from 7% of flow to 24% of flow.

With little potential to influence future growth, it appears that reduction of the existing load is the best means available to approach the loading limit. The dramatic impact of sewer service is an example. It is unlikely that more load will be reduced from sewer service, at least not from the sewer service as planned. The new sewer is designed to serve inadequate systems with no potential for on-site remediation. Those systems are removed from the watershed by the sewer service. The remaining septic load is from functional septic systems or systems on lots that could accommodate a Title V system.

ENCOURAGE ADVANCED NITROGEN REDUCTION FOR EXISTING AND FUTURE DWELLINGS

Encouragement of advanced nitrogen removal, particularly if funds could be discovered and provided, would remove existing load. There are many aging systems in the watershed that will require replacement with at least Title V compliance (load calculations are based on Title V capacity). Advanced nutrient removal can reduce nitrogen input by up to 50%. The Town of Oak Bluffs participates in the Septic Repair Loan Program, administered by the Martha's Vineyard Commission. It is a revolving loan fund for repair of septic systems, used to bring failed and inadequate systems up to Title V compliance. It could not be used for advanced nitrogen removal for a functional system in compliance.

IMPROVE STORMWATER TREATMENT

Because much of the watershed is impervious, stormwater has potential to contribute nutrients and other contaminants. Stormwater contribution is likely to not only add contaminants but also to "shock" the system by dumping suddenly after rainfall events. Of particular concern are the storm drains along the length of New York Avenue, which discharge to the harbor at Lake Avenue.

The nitrogen load contributed by runoff has been calculated here to be 314.8 kilograms, including the stormwater discharged through the sixteen pipes around the harbor. Because the watershed is relatively small, the impact of nitrogen in rainfall is also low, constituting 4% of the present load and 12-13% of the buildout load. Although it is beyond the scope of this investigation, it is important to consider the impacts of bacterial contamination. The harbor is under an administrative closure from May 15 through October 31, based solely on the number of boats berthed there. For the remainder of the year, there is little or no recreational boating in the harbor, and the harbor remains open to shellfishing based on actual bacterial sampling results. It is important to keep the harbor open for shellfishing in the winter, particularly when the scallop resources of the other ponds in town have been exhausted for the season and the harbor's quahogs are the only option for the town's commercial shellfishermen. An isolated episode of very high counts of coliform bacteria (Too Numerous To Count) occurred late in 2001. Although the source was never identified, the stormwater discharge system has the potential to be the source of such a concentrated slug of contaminants.

It is important to address the source of the discharge to the pipes. Much of the stormwater from New York Avenue runs untreated through the stormwater system into the harbor. Treatment of the first flush of rainfall could be managed along the length of New York Avenue, so that the stormwater entering the harbor is reduced in velocity and in levels of contaminants.

REDUCE LOAD FROM LAWN CARE

Educate homeowners and professional landscapers about using native plants and about fertilizer impacts. Application of fertilizers is a practice that is difficult to regulate. Education is probably the effective tool to persuade homeowners to follow label instructions regarding application, to use fertilizers with slow-release nitrogen, or to abstain altogether. Landscaping with native plants is an attractive and low-maintenance alternative to suburban turf. Local nurseries carry native plants in stock.

FURTHER ASSESSMENT AND MONITORING

It is important to follow up with additional sampling to monitor conditions over time. In order to assess the impacts of removal of the sewered systems, it is necessary to return after the pre-service flow has arrived at the harbor through the groundwater. Most of the commercial flow should have arrived at the harbor one year after the September, 2002 startup date. Inputs from the farthest Campground houses should arrive at the harbor within two years. Continue surface water sampling for nutrients, annually in 2003, 2004 and 2005. Include weather data from the Martha's Vineyard Coastal Observatory, when available, in analysis.

Investigate stratification in the deeper parts of the harbor, particularly in the southeastern area. Include some continuous recorded logs of dissolved oxygen over several daily cycles.

Measure and monitor chemistry of local rainfall, in order to properly assess the impacts of nitrogen from that source.

PROMOTE SHELLFISH

As filter feeders, shellfish "clean" the water of small particulate nutrients. According to the Chesapeake Bay Program, for every pound of commercial shellfish produced, 8,000 pounds of plankton are consumed[17]. Promote shellfish as nutrient consumers. The Town maintains an active shellfish management program, seeding and rotation of open areas. In the off-season, quahogs are harvested from the open areas, while other areas are closed for seeding and other management considerations. Harvesting of quahogs is an excellent means of "working" the bottom to keep it in good condition for future sets.

CONTINUE MAINTENANCE DREDGING AND BOATER SERVICES

Lake Anthony is used extensively for mooring and dockage of commercial and recreational vessels. Continue to provide pump out service and shore toilet and shower facilities. All associated flow should be included in the sewer service, rather than flow to the harbor.

Continue maintenance dredging; continue to consider extension of northern jetty. Northeast storms tend to batter the harbor and introduce considerable sediment. In order to keep the inlet clear, routine maintenance dredging is needed. It has been suggested that modifications to the northern jetty would reduce storm impacts from the northeast and help to keep the inlet functioning.

---

[17] http://www.chesapeakebay.net/ecoint6a.htm

REFERENCES

J. E. Costa et al, 1999, Buzzards Bay Project Technical Report, Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay

Whitman & Howard, Inc., 1994, "A Numerical Groundwater Flow Model and Zone II Delineation for the Farm Neck Well, Oak Bluffs, Massachusetts"

Horsley & Whitten, Inc. and Wright-Pierce, 1998, "Town of Oak Bluffs, Massachusetts, Draft Phase III Wastewater Facilities Plan and Environmental Impact Report"

Horsley & Whitten, Inc., 1996, "Town of Oak Bluffs, Massachusetts Wastewater Facilities Plan, Phase I, Needs Analysis"

Former Oak Bluffs Highway Superintendent Herbert A. Combra, Jr., December 20, 2001, personal communication regarding Stormwater facilities

MISER – Mass. Institute for Social and Economic Research

Town of Oak Bluffs, 1998, Oak Bluffs Master Plan

Martha's Vineyard Commission, 1999, Edgartown Great Pond: Nutrient Loading and Recommended Management Program

Martha's Vineyard Commission, 2000, Nutrient Loading to Lagoon Pond

Jennifer Bowen, BU Marine Program, 2000, personal communication

Massachusetts Geographic Information System

J.E. Costa et al, 1999, Buzzards Bay Project Technical Report, "Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis and evaluation of a management strategy adopted for Buzzards Bay"

http://www.chesapeakebay.net/ecoint6a.htm

C.E. Maguire, Inc., October 31, 1985, plan for Oak Bluffs Harbor Improvements

The Island Ponds Consortium, 1999, Island Coastal Ponds Water Quality Study

Martha's Vineyard Commission, 2000, Nutrient Loading to Tisbury Great Pond

Martha's Vineyard Commission, 2003, Nutrient Loading to Lake Tashmoo

APPENDIX I

PUBLIC PARTICIPATION

Town and other interested parties were informed early in the program, by letter, and invited to participate. The press was informed, and an introductory article was printed in the February 9, 2001 edition of the Vineyard Gazette.

After completion of the field studies of bathymetry, tidal flow and circulation, and sampling, preliminary results were presented at a public session on January 16, 2002. Laboratory results from the surface water sampling were not yet available. Results from the bathymetric and tidal flow measurements were presented, with implications regarding circulation, and development of a nitrogen-loading limit. Much of the discussion focused on the nitrogen loading limit and its derivation from the field data. A separate session is needed in order to properly present these complex relationships. Handouts were provided, with highlights from the field data and calculations.

The participants in the January session raised concerns regarding the impacts of bacteria on the water quality of the harbor, in addition to the impacts of nitrogen loading. Concerns were raised about the impacts of boats and of stormwater.

Shellfish Constable David Grunden explained that there are 16 pipes going into the harbor. The largest are the two 16" diameter pipes on Lake Avenue. He noted that there was no dry-weather flow from any of the pipes (that would indicate septic intrusion). The session followed an incident of high coliform counts, originally attributed to the dumping of several deer carcasses in the harbor. It was later determined that the deer carcasses were not to blame, and the source was never identified. Shellfish Constable David Grunden explained that coliform counts were high on December 3, 2001 (something happened between November 27 and December 3) and the following week and then were only high at the boat ramp in the northwest corner of the harbor and at the inlet; that the highest were recorded at Sunset Lake. He later provided counts to MVC staff.

The public was invited to a second session on June 21, 2002. Water sampling results were presented and management recommendations were discussed. Handouts were provided, with review of the field data and calculations, and draft management recommendations.

Questions raised concerned the size of the culvert to Sunset Lake, potential expansion of the sewer service area, and length of time needed for last inputs from sewer service area to arrive at the harbor via groundwater. Answers were provided at the session and in the revised final report.

Draft reports were provided to town boards and other interested parties and to DEP for comment. Mr. Grunden wrote with some comments: suggesting emphasis on the fact that the existing load is already 4.57 times greater than the recommended limit, and for determination of the load that will be removed by sewer service. DEP wrote comments focusing on the need to upgrade the display of the graphs and tables, and the need to differentiate between loading limit and the Commonwealth's water quality standards, which include no such limits. All comments were gratefully accepted and precipitated revision of the draft report.

APPENDIX II

WATER QUALITY DATA

LAKE ANTHONY AND SUNSET LAKE SURFACE WATER QUALITY 2001

Sample ID	Sampling Date	uM PO4	uM NH4	uM NOx	uM DIN	uM DON	uM SiO3	Salinity (ppt)	POC ug/L	POC uM C	PON ug/L	PON uM N	C/N	** ug/L Seawater ** Chla	Phaeo	Chla/ Chl+Phaeo
OBH1	5/1/01	0.2	7.0	16.0	23.0	21.6	16.4	26.8	374.34	31.20	66.22	4.73	6.59	0.46	0.46	0.50
OBH2	5/1/01	0.4	3.6	6.4	9.9	15.0	6.3	29.8	1252.73	104.39	78.38	5.60	18.64	1.42	0.40	0.78
OBH3	5/1/01	0.4	1.7	4.6	6.3	21.1	4.5	27.7	220.18	18.35	25.71	1.84	9.99	0.78	0.10	0.89
OBH4	5/1/01	0.4	2.6	3.9	6.5	12.4	3.8	30.5	311.70	25.97	51.17	3.65	7.10	0.60	0.08	0.88
OBH1	6/4/01	0.4	2.4	0.2	2.6	26.5	3.1	23.1	448.69	37.39	33.22	2.37	15.75	3.00	0.61	0.83
OBH2	6/4/01	0.3	3.1	0.9	4.0	25.1	2.6	22.8	411.08	34.26	74.11	5.29	6.47	3.95	0.10	0.98
OBH3	6/4/01	0.3	1.2	0.5	1.7	20.4	3.0	22.4	416.05	34.67	71.12	5.08	6.82	3.60	0.29	0.92
OBH4	6/4/01	0.4	1.7	0.7	2.4	16.9	3.9	22.52	459.54	38.29	90.19	6.44	5.94	4.19	0.32	0.93
OBH 1	7/2/01	0.3	3.2	2.3	5.5	18.4	10.6	24	696.19	58.02	115.83	8.27	7.01	6.66	0.05	1.00
OBH 2	7/2/01	0.3	1.3	0.0	1.4	21.7	3.5	23.9	653.51	54.46	116.65	8.33	6.53	11.67	0.05	1.00
OBH 3	7/2/01	0.5	1.7	0.5	2.1	19.5	4.4	23.9	653.39	54.45	128.58	9.18	5.93	10.78	0.05	1.00
OBH 4	7/2/01	0.3	1.6	0.0	1.7	43.2	3.9	22.1	818.09	68.17	150.11	10.72	6.36	9.64	0.05	1.00
OBH 1	7/24/01	0.3	1.7	1.3	3.0	15.5	11.0	22	472.33	39.36	81.06	5.79	6.80	4.19	2.83	0.60
OBH 2	7/24/01	0.4	0.4	0.1	0.5	16.9	6.9	23.9	322.79	26.90	43.78	3.13	8.60	3.55	0.38	0.90
OBH 3	7/24/01	0.5	0.5	0.0	0.5	19.1	7.9	24.1	392.81	32.73	61.50	4.39	7.45	4.52	0.56	0.89
OBH 4	7/24/01	0.5	1.0	0.0	1.0	15.0	10.2	24.1	428.58	35.71	118.11	8.44	4.23	3.90	0.43	0.90
OBH 1	9/5/01	0.6	4.9	1.0	6.0	22.2	17.0	20.9	754.72	62.89	109.73	7.84	8.02	2.13	2.73	0.44
OBH 2	9/5/01	0.6	3.0	0.3	3.3	16.4	8.7	23.8	516.94	43.08	86.21	6.16	6.99	3.87	0.49	0.89
OBH 3	9/5/01	0.5	3.5	1.2	4.7	17.4	7.5	21.4	505.90	42.16	77.37	5.53	7.62	4.11	0.49	0.89
OBH 4	9/5/01	0.6	2.6	0.4	3.1	36.4	8.3	22.4	772.18	64.35	112.24	8.02	8.02	4.07	0.03	0.99
OBH 1	10/9/01	0.3	4.1	5.6	9.7	17.8	13.6	20	824.05	68.67	107.06	7.65	8.98	3.53	1.38	0.72
OBH 2	10/9/01	0.3	1.3	1.5	2.8	24.2	8.5	18.7	301.13	25.09	55.05	3.93	6.38	3.04	0.37	0.89
OBH 3	10/9/01	0.4	0.5	0.8	1.3	11.9	7.2	17.8	357.98	29.83	66.79	4.77	6.25	2.84	0.36	0.89
OBH 4	10/9/01	0.4	0.7	1.5	2.2	24.8	8.8	18.7	277.31	23.11	48.06	3.43	6.73	3.66	0.32	0.92

LAKE ANTHONY AND SUNSET LAKE STATIONS 2001
HYDROGRAPHIC PARAMETERS

Date	Time	station_ID	depth_in_r	secchi_m	conductivi	temperatur	salinity	dissolved_	dissolved2
5/1/01	03:57:52pr	obh-1-s	0.5	0.500	35.900	15.900	29.600	9.540	117.200
5/1/01	04:04:09pr	obh-1-d	0.4	0.000	36.000	15.800	29.700	9.490	115.900
5/1/01	01:08:03pr	obh-2-s	0.0	2.400	38.400	12.700	21.200	9.220	105.700
5/1/01	01:07:17pr	obh-2-m	1.0	0.000	39.400	12.200	21.800	9.350	106.600
5/1/01	01:08:35pr	obh-2-d	2.2	0.000	30.300	11.500	22.400	8.980	100.300
5/1/01	02:46:40pr	obh-3-s	3.8	3.800	39.500	11.500	21.900	9.540	109.000
5/1/01	02:53:46pr	obh-3-m	2.0	0.000	30.000	11.700	22.300	9.650	108.800
5/1/01	02:57:17pr	obh-3-d	3.6	0.000	30.700	10.900	22.600	9.600	106.100
5/1/01	01:52:25pr	obh-4-s	2.9	2.900	39.800	12.400	22.200	9.220	105.100
5/1/01	01:53:14pr	obh-4-m	1.5	0.000	30.100	11.600	22.300	9.150	102.500
5/1/01	01:54:03pr	obh-4-d	2.7	0.000	30.500	11.200	22.200	8.770	98.000
6/4/01	11:40:14ar	obh-1-s	0.0	0.000	39.250	16.400	30.600	8.040	98.600
6/4/01	11:49:21ar	obh-1-d	0.8	0.000	39.250	16.400	30.700	6.340	80.500
6/4/01	12:35:34pr	obh-2-s	0.0	3.700	39.650	16.500	30.900	6.950	88.600
6/4/01	12:48:20pr	obh-2-m	2.0	0.000	39.670	16.400	30.900	6.910	85.900
6/4/01	12:50:23pr	obh-2-d	4.0	0.000	39.520	15.800	31.200	6.000	70.400
6/4/01	02:05:56pr	obh-3-s	0.0	3.700	39.840	16.800	30.800	7.100	86.000
6/4/01	02:05:19pr	obh-3-m	2.0	0.000	39.700	16.400	30.900	7.000	86.000
6/4/01	02:01:19pr	obh-3-d	3.8	0.000	39.470	16.100	31.100	7.510	91.500
6/4/01	01:39:55pr	obh-4-s	0.0	2.700	40.000	17.000	30.700	6.630	83.400
6/4/01	01:45:27pr	obh-4-m	1.5	0.000	39.780	16.500	31.000	6.800	84.200
6/4/01	01:47:39pr	obh-4-d	2.5	0.000	39.650	16.300	31.000	6.720	82.300
7/2/01	03:52:11pr	obh-1-s	0.0	0.000	46.330	23.400	30.100	7.640	106.100
7/2/01	03:54:55pr	obh-1-d	0.8	0.000	46.200	22.800	30.000	7.090	98.600
7/2/01	02:52:04pr	obh-2-s	0.0	2.800	47.510	22.600	30.900	6.310	88.600
7/2/01	02:54:10pr	obh-2-m	1.5	2.800	47.480	22.600	30.900	6.270	85.600
7/2/01	02:56:14pr	obh-2-d	3.4	2.800	47.520	22.400	31.000	5.800	77.900
7/2/01	03:25:49pr	obh-3-s	0.0	1.700	47.420	22.800	30.900	6.620	91.400
7/2/01	03:27:30pr	obh-3-m	2.0	1.700	47.420	22.600	30.900	6.390	89.600
7/2/01	03:29:33pr	obh-3-d	4.1	1.700	47.520	21.900	31.000	5.540	72.500
7/2/01	03:15:00pr	obh-4-s	0.0	1.700	47.410	22.700	30.900	6.420	91.200
7/2/01	03:17:01pr	obh-4-m	1.5	1.700	47.400	22.500	30.900	6.470	88.800
7/2/01	03:19:07pr	obh-4-d	3.1	1.700	47.560	21.900	31.000	6.210	82.300
7/24/01	11:18:21ar	obh-1-d	0.7	0.000	45.800	22.900	29.700	4.110	56.900
7/24/01	11:12:38ar	obh-1-s	0.0	0.000	45.300	22.800	29.200	5.110	70.400
7/24/01	11:47:07ar	obh-2-s	0.0	2.400	47.250	22.900	30.800	6.330	87.300
7/24/01	11:51:32ar	obh-2-m	1.5	2.400	47.290	22.800	30.800	6.280	86.000
7/24/01	11:53:17ar	obh-2-d	2.9	2.400	47.450	22.400	30.900	5.690	77.000
7/24/01	12:10:33pr	obh-3-s	0.0	2.400	47.280	22.800	30.800	5.940	83.700
7/24/01	12:11:53pr	obh-3-m	2.0	2.400	47.320	22.800	30.800	6.080	83.800
7/24/01	12:13:44pr	obh-3-d	4.2	2.400	47.580	21.800	31.000	4.890	70.500
7/24/01	12:31:35pr	obh-4-s	0.0	2.400	47.160	23.300	30.700	5.810	82.100
7/24/01	12:33:16pr	obh-4-m	2.0	2.400	47.230	23.200	30.800	5.830	82.600
7/24/01	12:35:18pr	obh-4-d	2.5	2.400	47.270	23.200	30.800	5.810	82.400

LAKE ANTHONY AND SUNSET LAKE STATIONS 2001
HYDROGRAPHIC PARAMETERS

Date	Time	station_ID	depth_in_r	secchi_m	conductivi	temperatui	salinity	dissolved_	dissolved2
9/5/01	10:37:22ar	obh-1-s	0.0	0.000	45.390	21.300	29.400	4.910	65.900
9/5/01	10:39:04ar	obh-1-d	0.7	0.000	42.540	21.300	29.700	4.000	53.000
9/5/01	11:47:59ar	obh-2-s	0.0	1.900	47.410	22.100	30.900	6.310	87.300
9/5/01	11:49:33ar	obh-2-m	1.5	1.900	47.370	22.100	30.900	6.350	86.800
9/5/01	11:51:23ar	obh-2-d	3.8	1.900	47.420	22.200	30.700	5.470	68.800
9/5/01	11:22:31ar	obh-3-s	0.0	1.900	47.450	22.100	30.900	6.010	84.400
9/5/01	11:24:51ar	obh-3-m	1.5	1.900	47.430	22.200	30.900	6.040	80.600
9/5/01	11:27:16ar	obh-3-d	3.5	1.900	47.650	22.000	31.100	6.090	81.300
9/5/01	11:01:36ar	obh-4-s	0.0	1.900	47.430	22.200	30.900	5.690	80.700
9/5/01	11:07:42ar	obh-4-m	1.0	1.900	47.400	22.300	30.900	5.760	77.000
9/5/01	11:05:12ar	obh-4-d	2.1	1.900	47.390	22.300	30.900	5.590	75.300
10/9/01	12:26:36pr	obh-1-s	0.0	0.000	46.120	12.400	29.700	6.440	72.600
10/9/01	12:28:55pr	obh-1-d	0.7	0.000	45.460	11.600	29.400	6.750	74.700
10/9/01	02:02:04pr	obh-2-s	0.0	3.000	47.520	13.300	30.900	7.110	83.300
10/9/01	02:03:30pr	obh-2-m	1.5	3.000	47.630	13.400	31.000	7.350	86.900
10/9/01	02:06:06pr	obh-2-d	3.3	3.000	47.790	13.600	31.100	7.130	85.600
10/9/01	02:08:35pr	obh-3-s	0.0	3.000	47.760	13.600	31.100	7.320	84.400
10/9/01	02:08:55pr	obh-3-m	2.2	3.000	47.810	13.600	31.100	7.310	83.700
10/9/01	02:09:24pr	obh-3-d	4.4	3.000	48.260	14.000	31.500	6.890	80.500
10/9/01	01:06:08pr	obh-4-s	0.0	0.000	47.850	13.700	31.200	6.880	79.000
10/9/01	01:09:35pr	obh-4-m	1.2	0.000	47.870	13.800	31.200	6.340	79.000
10/9/01	01:11:35pr	obh-4-d	2.5	0.000	47.870	13.800	31.200	6.580	75.300

APPENDIX III

LAND USE DATA TABLES

LAKE ANTHONY AND SUNSET LAKE WATERSHED
COMMERCIAL PROPERTIES

AREA (m^2)	LINK_ID	LAND_USE	GALLONS (metered)	SEWER	FEATURE_ID	GALLONS (estimated)_
2549.93867	3-4	800	0			7000
1888.26588	8-293	400	0	FALSE		0
1812.70806	8-75	604	0	FALSE		226800
815.74560	9-57	999	0	FALSE		49000
1481.90563	8-55	603	0	FALSE		70700
781.14093	8-56	400	0	FALSE		0
986.32705	8-298	999	0	FALSE		49000
679.66168	8-299	800	0	FALSE		7000
715.55874	8-291	999	14000	TRUE	23 cir ave ext	0
1768.15104	8-288	999	21660	TRUE	fishbones	0
281.36717	8-68	603	0	FALSE		70700
587.70066	9-53	602	0	FALSE		44000
588.63869	8-290	999	0	TRUE	15 cir ave ext	49000
2174.70793	8-137	999	0			49000
192.85313	8-296.1	400	0	FALSE		0
685.54060	8-289	603	28230	TRUE	dockside inn	0
993.50771	9-42	604	4000	TRUE	surfside gift	0
555.11735	8-141	800	0			7000
1155.14586	9-43	999	31710	TRUE	game room	0
530.11096	9-45	602	17250	TRUE		0
1166.14123	8-139	400	0	TRUE	Lake Ave comfort sta	260890
537.30325	8-287	999	56130	TRUE		0
606.89768	9-44	603	0	TRUE	11 ob ave strand theat	70700
721.83839	8-286	998	9800	TRUE	6 cir ave ext	0
187.88903	8-285	400	0	FALSE		0
274.79087	8-284.1	400	0	TRUE	church's pier	0
1412.47818	8-283	602	13962	TRUE	cottage city tex	0
522.30480	8-282	604	31000	TRUE	mad martha's	0
701.96878	8-284	604	555850	TRUE	nancy's	0
122.06053	9-32	998	9800	TRUE		0
562.45694	8-281	603	0	TRUE	island theater	70700
188.26320	81-93	998	9800	TRUE	26 lake ave	9800
221.53781	81-1.1	602	0	TRUE	30 lake ave	44000

AREA (m^2)	LINK_ID	LAND_USE	GALLONS (metered)	SEWER	FEATURE_ID	GALLONS (estimated)_
183.93724	81-93.1	998	9800	TRUE	28 lake ave	0
590.72877	9-31	999	248250	TRUE		0
321.71261	81-164	603	46000	TRUE	attleboro house	0
358.93002	8-280	602	14000	TRUE	murdick's fudge	0
252.16655	9-59	999	87000	TRUE	ritz	0
1923.70943	81-607	603	95000	TRUE	wesley	0
874.49485	8-278	602	202796	TRUE	david's	0
553.82488	9-22	604	199020	TRUE	lamppost,rare duck	0
70.56271	8-279	999	41540	TRUE	neptune's grill	0
504.48465	81-606	603	65000	TRUE	wesley annex	0
112.41959	9-21	602	6120	TRUE	8 circuit ave	0
260.53502	9-20	602	98000	TRUE	6 circuit ave	0
380.92953	8-277.1	999	26000	TRUE	sub	0
247.12132	9-12	999	31000	TRUE	mad martha's	0
118.19275	9-11	999	51830	TRUE	14 cir/sunglaass	0
612.77139	8-277	604	219050	TRUE	atlantic connection	0
135.90903	9-10	604	0	TRUE	vacant lot?	226800
1154.83855	9-9	998	8400	TRUE	eastaway	0
206.86968	8-276	604	196970	TRUE	linda jean's	0
104.07347	8-275	602	0	TRUE	27 cir ave	44000
833.19475	8-273	998	11110	TRUE	corner store	0
185.40231	8-274	602	12970	TRUE	mary's linen	0
367.92303	8-271	999	56000	TRUE	arcade	0
594.46762	8-272	602	3070	TRUE	phillips hardware	0
135.42026	8-270	602	6000	TRUE	laughing bear	0
328.73293	8-269	602	0	TRUE	take it easy baby	44000
3196.80590	11-293	800	0			7000
1347.27653	81-3.1	800	0	TRUE		7000
269.37048	11-2	999	24830	TRUE	leather	0
237.08462	11-7	999	37000	TRUE	39 cir ave	0
202.44449	11-6	602	0	TRUE	craftworks? 40 cir	44000
129.30243	11-8	999	3000	TRUE	secret garden	0
7967.21124	11-292	800	0			0
232.29209	11-9	602	0	TRUE	murray's of mv	44000
418.20964	11-10	602	3400	TRUE		0
432.81145	81-280	800	0	FALSE		7000

AREA (m^2)	LINK_ID	LAND_USE	GALLONS (metered)	SEWER	FEATURE_ID	GALLONS (estimated)_
205.02714	11-14	999	9000	TRUE	army barracks	0
230.33377	11-15	999	0	TRUE	47 cir ave	49000
115.56591	11-16	999	0	TRUE	49 cir ave	49000
118.82212	11-17	999	14000	TRUE	hilliard's	0
235.89945	11-18	999	75700	TRUE	papa's	0
216.67474	11-21	604	382000	TRUE	circuit cafe	0
189.21266	11-22	602	5000	TRUE	3rd world	0
439.88883	11-35	602	186720	TRUE		0
1949.47384	11-339	400	0			0
203.22144	11-36	602	0	TRUE	61 cir ave	44000
523.85742	11-24	999	0	TRUE		49000
412.47263	11-37	999	86800	TRUE	sweet life cafe	0
243.54036	11-38	999	0	TRUE	67 cir ave	49000
671.41490	11-34	603	119250	TRUE	o b inn	0
187.81924	11-39	999	10000	TRUE	cousen rose	0
167.51931	11-40	602	0	TRUE	penacook studios	44000
260.30018	11-32	800	0			7000
520.46567	11-89	999	0	TRUE		49000
2710.09205	11-272	800	0			7000
218.17511	11-88	800	6950	TRUE	library	0
1729.63242	11-50	800	0	FALSE		7000
504.03686	11-172	0	0			0
626.96469	11-174	602	0			0
424.53938	11-175	999	0			49000
1130.42708	12-150.3	999	0			49000
16274.80197	12-176	800	0			7000
696.71505	11-158	602	0			44000
507.64747	11-154	601	0		6 Hiawatha	0
2091.12698	11-159	500	0		Comm. Elect.	0
884.55846	11-153	650	0			0
891.48948	11-164	800	0			7000
347.56094	11-181	603	0			70700
624.11097	11-234	999	0			49000
1160.51001	11-232	999	0			49000
147.98069	81-2.1	602	0	TRUE		44000
294.07105	11-192	602	0			44000

AREA (m^2)	LINK_ID	LAND_USE	GALLONS (metered)	SEWER	FEATURE_ID	GALLONS (estimated)_
1192.73124	11-256	999	0			49000
913.19316	16-8	999	0			49000
819.23995	16-181	800	0			7000
1833.64337	16-180	800	0			7000
898.67050	16-179	800	0			7000
904.60293	16-178	800	0			7000
1555.79481	16-107.1	800	0			7000
977.56288	16-123	602	0			44000
998.02372	21-21	999	0			49000

LAKE ANTHONY & SUNSET LAKE OPEN SPACE

AREA (m^2)	LINK_ID
21333.09510	3-27
2146.40837	3-114.1
19388.86883	8-97
5724.43070	8-119
970.28722	8-126
1465.04781	8-119
8708.88609	8-123
2765.48324	8-76
564.22331	8-37
564.47384	8-88
7947.15939	8-134
341.50008	8-83
230.94765	8-162
22239.17281	8-141.1
743.54211	8-284.2
66259.47907	81-1
6126.94190	8-259
4834.49678	8-249
701.68089	8-248
21825.82733	12-144
5865.15859	11-337
6837.78280	12-142
706.98234	11-294
143.34203	81-1
185.11892	81-1
4049.35862	11-338
487.34940	11-267
230.65006	11-268
914.86283	12-148
65.78375	12-141
239.38474	11-86
9095.90541	11-91
294.23067	11-57
5141.41702	11-144
294.51909	12-167
334.13247	12-168
290.68667	17-100
5464.07839	21-20

LAKE ANTHONY AND SUNSET LAKE VACANT LOTS IN WATERSHED

AREA (m^2)	LINK_ID	PERIMETER (m^2)
1254.14573	3-6	204.51796
4145.50518	3-4.1	283.00096
999.82614	3-5	135.19395
1891.72415	3-3.1	185.08822
293.53964	3-2	75.99745
637.66607	8-36.1	102.64321
1358.28175	8-79	163.03404
634.64491	8-80	126.53395
302.92316	8-171	72.39365
245.28805	8-62	63.62597
395.04101	8-169	80.36837
252.11826	8-295	66.07965
136.95402	8-217	57.06108
484.25329	8-215	88.08192
444.37242	8-226	87.31399
478.90754	8-227	87.51431
1180.98920	8-202.1	151.16711
773.25106	8-230	135.03224
979.00908	8-207	133.50706
1138.07402	8-202	149.51613
930.21201	8-202.1	128.97276
309.18643	8-239	72.50393
633.79940	8-240	101.70856
241.29623	7-215	66.32109
661.71144	8-261	103.43626
472.44077	8-197	87.13001
720.91729	8-198	109.22791
2369.79993	8-255	195.78221
1242.90908	8-200	156.44216
223.28920	8-247	63.78361
946.92608	11-334	124.52295
1125.45470	11-332	140.47906
228.60693	11-320	63.59697
383.48643	11-336	81.43895
222.27369	11-319	65.68146
1949.43043	11-340.1	236.70727
460.59665	11-315	86.34576
1781.16592	12-145	168.71130
204.40602	11-313	61.46239
584.08653	12-146	108.92792
274.61592	11-314	71.23702
167.65897	11-289	54.32448
400.17766	11-290	89.54747
381.81343	11-291	88.76602
439.17065	11-310	110.02820
798.69886	11-309	136.21659
196.11241	11-287	57.43217
437.83346	11-270	83.52503

AREA (m^2)	LINK_ID	PERIMETER (m^2)
228.05170	11-307	63.40054
1818.99817	12-147	170.33019
212.29723	12-149.1	61.31791
436.98848	11-305	110.71010
203.79575	11-300	62.07372
873.29311	11-263	124.95742
268.68503	11-171.1	68.47691
1161.84258	11-302	158.06321
2169.23532	12-152	187.08006
905.40641	12-151	127.83396
1959.42409	12-153	176.33043
682.12207	12-150.2	106.99435
956.11122	11-280	131.13291
231.50857	11-261	63.35210
589.71206	11-382	97.26142
302.15839	11-368	72.99777
332.82591	11-182	74.33492
1383.33038	12-177.09	152.52703
1112.91211	12-154.2	151.80425
131.56357	11-381	48.84106
986.25618	12-177.08	132.55444
939.25344	12-177.07	122.48312
931.13352	12-177.06	122.06535
885.98889	11-239.1	131.66482
920.65879	12-177.03	119.21150
1336.37003	12-177.10	160.28104
867.23801	12-177.02	117.25426
308.22533	11-162	70.98566
1542.74261	11-235	218.92404
932.90389	12-177.05	122.18430
1372.82100	12-163	160.04896
927.11250	12-177.04	119.11314
1017.02215	12-177.13	124.79629
934.81154	12-177.14	123.91018
925.94649	11-242.1	125.25128
966.67130	12-177.15	123.99249
878.69157	11-239.4	133.84883
1213.65381	12-177.11	141.82116
1161.32783	12-177.19	137.49457
1256.85712	12-177.12	149.43919
367.58716	11-110	78.11653
1301.90170	12-177.16	151.06499
16502.75382	12-126	646.60214
954.44301	11-241	125.37880
1280.34959	12-172.1	191.63795
639.85032	11-216.1	101.28853
983.87181	12-177.17	130.06570
1344.33360	12-177.18	154.30104
563.57615	11-193	95.06574
968.95541	12-172.2	133.83031
1922.86887	11-229	179.12080

AREA (m^2)	LINK_ID	PERIMETER (m^2)
1174.71097	12-165	137.91009
959.44225	12-171.3	163.65931
1955.11399	11-226	180.81878
987.52734	12-171.1	163.20756
1491.49444	12-182	154.95528
887.83880	16-163	119.27052
1481.64243	16-210.1	173.41465
4370.85959	17-102	365.51024
939.43163	16-165	122.43786
289.14739	16-210	73.12586
931.71245	16-162.1	123.05063
920.69792	16-204	121.30560
1263.97206	16-192	165.09371
839.51046	16-205	115.78156
2977.30595	16-177.09	226.91238
949.22762	16-177.08	136.98030
373.69351	16-6	78.97094
1510.39681	16-214	178.42769
1009.44207	16-177.07	137.86158
877.36380	16-214.1	118.25187
1080.15303	16-177.06	133.08792
1124.01285	16-177.11	139.90665
846.46175	16-186	125.41559
1047.17561	16-177.05	130.96758
642.40657	16-171	105.48222
1924.84466	16-177.12	170.94500
1087.44926	16-184	133.41463
2309.40533	16-40	243.39004
1380.03110	16-131	151.27847
1140.69251	16-106	133.57705
394.31205	16-65	93.04942
470.00163	16-122.1	92.28837
965.06718	16-68	123.76410
456.65651	16-69	90.85283
935.70292	16-119.1	121.87692
1027.62298	16-104	130.44069
2011.66067	16-225	196.45789
483.68190	16-95	92.94007
789.18706	16-100	117.69177
454.69687	16-103	89.68217
454.68595	16-98	91.13587
1378.81283	16-102	151.58857
1416.98156	16-101	159.02261
470.71353	16-93.1	91.36388
990.91543	21-13	125.82582
2901.17872	21-19	270.79516
1621.66402	21-22	206.34025
938.10206	21-22.2	122.18507
922.53927	21-51	121.38607
925.49606	21-46	121.49541
918.52856	21-46.1	121.39142

AREA (m^2)	LINK_ID	PERIMETER (m^2)
503.72642	21-41	94.75338
1438.60503	21-40	154.17039
1408.73375	21-57	155.40351