NUTRIENT LOADING TO LAKE TASHMOO

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THE MARTHA'S VINEYARD COMMISSION

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PREPARED FOR:

MASSACHUSETTS EXECUTIVE OFFICE OF
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MASSACHUSETTS WATERSHED INITIATIVE

And

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RESOURCE PROTECTION

NUTRIENT LOADING TO
LAKE TASHMOO

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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

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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.

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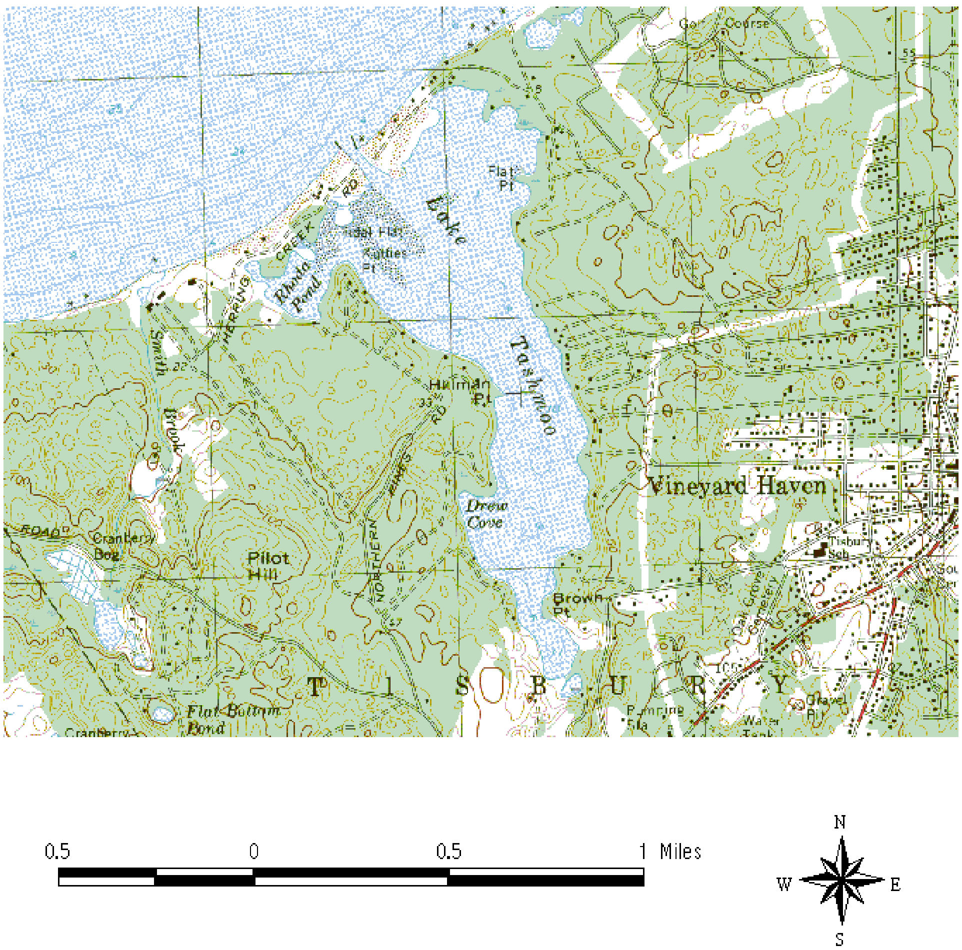


Figure1

EXECUTIVE SUMMARY

Lake Tashmoo is a 270-acre coastal pond situated on the north shore of Martha's Vineyard. Surrounding land use is predominantly residential. Depths range to twelve feet. Fresh water enters the pond via groundwater and via groundwater-fed springs at the head. In the late 1800's, the spring, named by the Wampanoags "Kuttashimmoo" (the great spring), became the source of supply for commercially bottled water and for the Town's first public water supply system. A meandering inlet connected the pond to Vineyard Sound until the U.S. Army Corps of Engineers dredged the inlet and constructed jetties to stabilize the opening for navigation.

The pond supports important shellfish resources and diverse fish populations, including herring, which are an important food source for both commercial offshore fish species and near shore recreational fish species such as bluefish and striped bass. In recent years, shellfish closures may reflect increased human activity in the watershed. There has been very little research or data-gathering done, and very little is known about water quality. The issue of nitrogen loading is a key to developing an appropriate response to issues including the nature of future growth in the watershed. Assessment includes: the projected nitrogen loads based on buildout, including various scenarios, and what effects they will have, and the steps that should be taken to assure that water quality will not be compromised by use at buildout.

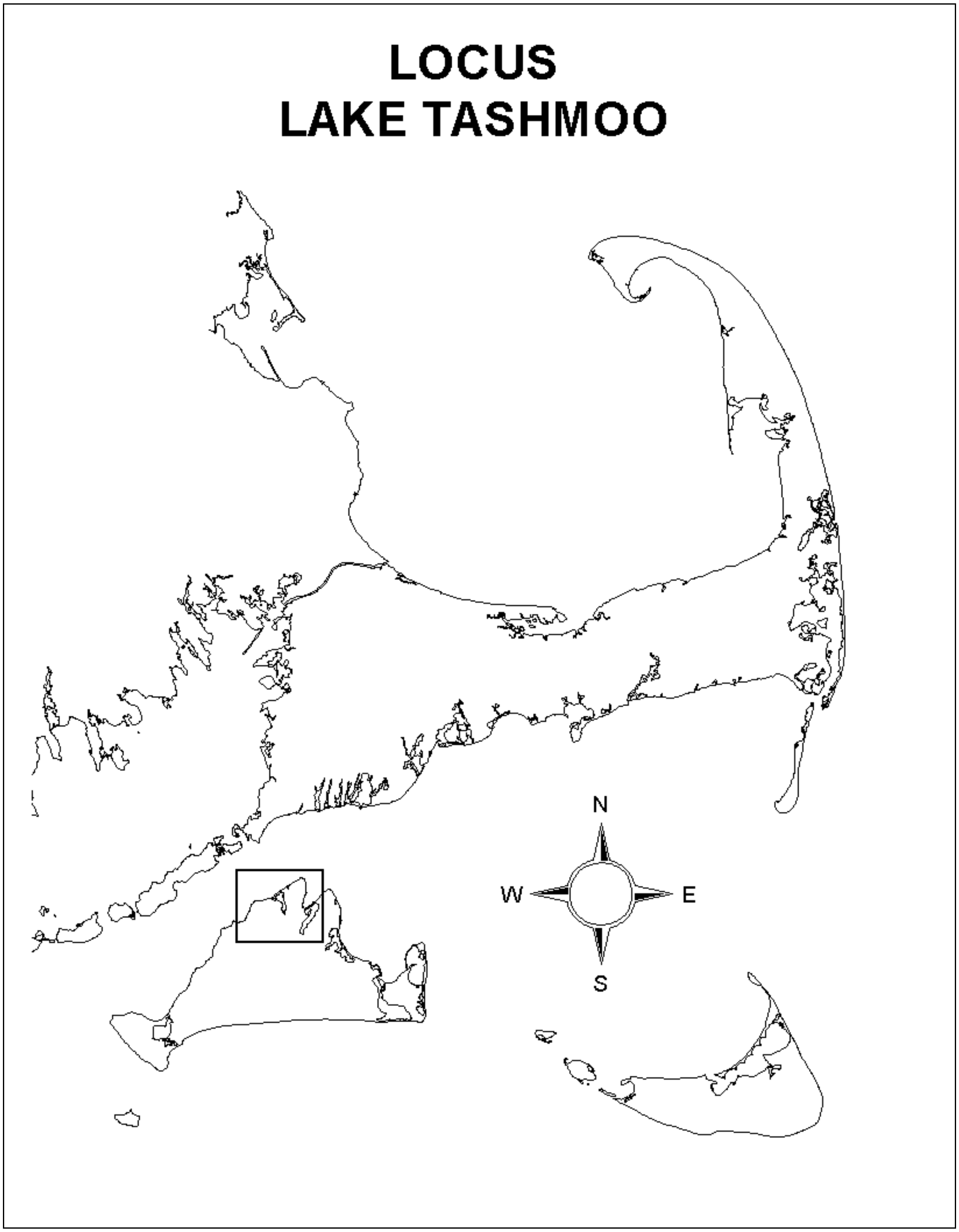


Figure 2

FLUSHING CHARACTERISTICS

Tide gauges were installed in order to assess the flushing characteristics of the pond. Both tide curves are semi-diurnal and show strong similarities of the tidal hydrograph. The average tide range recorded was 2.00 feet (0.61 meters) for both stations. The curve is strongly ebb-dominated, in contrast to the flood-dominated curves recorded at several other ponds on Martha's Vineyard. Average flood stage ran 5:06 hours at the Town Landing and 5:04 at Packers'. On average, ebb tide ran 7:16 hours at the Town Landing and 7:12 at Packers'. On average, a tidal cycle required 12:22 hours to complete. There were approximately 1.94 tidal cycles per day.

Bathymetric measurements were made and were used to calculate the mid-tide volume of 1,601,310.495 cubic meters, the mid-tide mean depth of 1.3 meters and median depth of 2.1 meters. The data from the circulation investigations were used to determine the flushing time of 6.22 tidal cycles, and residence time of 3.206 days.

NITROGEN LOADING LIMIT AND COMPARISONS

The nitrogen loading limit was calculated from the circulation characteristics. The recommended nitrogen loading limit is **9,000** kilograms per year.

Existing load and load at buildout are summarized below from the final NDWRCDP report[1]:

NITROGEN LOAD AND PROJECTIONS	
Existing Load	6,326.5 kg
Load at Low Growth Buildout	7,233.3 kg
Load at Moderate Growth Buildout	8,129.9 kg
Load at High Growth Buildout	11,561.0 kg

Table 1

[1] Heigis, W., B.Douglas, M. Hoover and Dennis Luttrell, 2001, "Application of a Risk-Based Approach to Community Water Resources Capacity Development Project" Final Report to the National Decentralized Water Resources Capacity Development Project.

WATER QUALITY SAMPLING 2001

Four rounds of water quality sampling were made at six stations in the pond 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 Tashmoo with a number of other resource areas; Edgartown Great Pond, Oyster Pond and Buzzards Bay, as reported by the Island Ponds Consortium[2] in 1999, for Tisbury Great Pond, as reported by the Martha's Vineyard Commission[3] in 2000, and for Lake Anthony (Oak Bluffs Harbor) as reported by the Martha's Vineyard Commission[4]. 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

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

PRIORITIZED MANAGEMENT MEASURES

1. ADOPT 9,000 KILOGRAMS AS AN ANNUAL LOAD LIMIT FOR THE WATERSHED

Continue Zoning and Board of Health regulations in place that support the 9,000 kilogram limit.

Encourage advanced nitrogen removal septic systems for new commercial or residential development, or both

Use existing licensing authority of the Board of Selectmen to restrict commercial development of high nitrogen producers such as restaurants.

Maximize effort to increase open space from remaining undeveloped land.

Educate homeowners and professional landscapers about reducing the load from lawns and landscaping.

2. FOCUS SHORT-TERM MANAGEMENT ON IMPACTS OF BOATING

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

Assess maintenance needs in vicinity of Town Landing; instruct boaters to clear trailers of vegetation.

Manage numbers of vessels, particularly live-aboards.

Manage mooring and anchorage areas and general navigation to minimize impacts to eelgrass beds.

3. FURTHER ASSESSMENT AND MONITORING

Continue surface water sampling for nutrients. Include weather data from the Martha's Vineyard Coastal Observatory, when available, in analysis.

Continue to investigate stratification in the pond. Include some continuous recorded logs of dissolved oxygen over several daily cycles.

Measure and monitor chemistry of local rainfall.

Reexamine eelgrass beds periodically to assess health of the crop over time.

Investigate plankton populations to determine whether the low levels of silica indicate a low level of input or the utilization of silica for the skeletons of diatoms.

4. PROMOTE SHELLFISH AND HERRING

Promote shellfish as nutrient consumers, along with herring. Ensure that their habitats are protected, particularly eelgrass beds.

Support efforts to maintain the newly established herring run at the head of the pond.

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. The Wampanoag name, *Ashappaquonsett*, means "where the nets are spread" to dry. Nineteenth-century historian Banks suggested that "the name seems to belong to the creek which forms the outlet of Tashmoo Lake, and the definition applies perfectly to the low sandy formation of that region, where the Indians once had one of their chief fishing stations"[5]. Banks continued on to describe the herring run at Tashmoo as historically a rich and significant resource for the people "The fine herring run and fishery at Ashappaquonsett has been a famous and prolific domestic industry from time immemorial, and it is a common heritage of the townsmen unto this day". Belding[6] reported that the alewife fishery at Tashmoo Lake, or Chappaquonsett Pond, "…formerly flourished, and more fishing vessels were baited at Vineyard Haven than in Edgartown. In the palmy days there were some 155 houses on the beach near the outlet for the accommodation of persons who desired to share in the catch". The descriptions imply a historic inlet, hence the fishery. The 1856 chart by Whiting shows such inlet in existence at that time, a meandering creek. Apparently, the inlet was not always evident. No inlet appears on the 1777 Des Barres chart. According to a U.S. Army Corps of Engineers study[7], Lake Tashmoo was landlocked in 1930. A narrow opening appeared through the barrier beach, and a wooden bulkhead was constructed, only to be destroyed in the hurricane of 1938. In 1941, the Massachusetts Department of Public Works dredged an entrance channel and constructed stone revetments and a stone jetty. In 1946, the D.P.W. widened and deepened the channel, and added additional stone riprap on the channel slopes. The westerly jetty was extended in 1941, and the channel dredged. D.P.W. dredged the channel again in 1972 and in 1990. The federal government has made no improvements. Although the feasibility study recommended that the Corps of Engineers perform dredging and reconstruction and realignment of the existing jetties and further extension of the westerly jetty, the improvements were not undertaken. Shoaling inside the westerly jetty remains a maintenance problem, addressed by means of repeated maintenance dredging.

[5] Banks, Charles Edward M.D., 1966 by Dukes County Historical Society, History of Martha's Vineyard Dukes County Massachusetts
[6] C.E. Maguire, 1975, Lake Tashmoo Feasibility Study Martha's Vineyard

TIDAL EXCHANGE

In 2001, MVC recorded tidal data through a lunar cycle in the pond. Two Global water level recorders were placed in the pond from March 29 through April 30. Those 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 Town Landing, mid-pond, and at the private residence of Ralph and Dorothy Packer, near the head of the pond. 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 no storms or other unusual weather events.

Both tide curves are semi-diurnal and show strong similarities of the tidal hydrograph. The average tide range was 1.99 feet at the Town Landing and 2.01 feet at Packers', an average of 2.00 feet (0.61 meters) for both stations. There is significant coincidence of the time of high and low water at both stations. The curve is strongly ebb-dominated, as indicated by the duration of each phase of the tidal cycle. Average flood stage runs 5:06 hours at the Town Landing and 5:04 at Packers'. On average, ebb tide runs 7:16 hours at the Town Landing and 7:12 at Packers'. M.V.C. tidal investigations in various other ponds on Martha's Vineyard have produced flood-dominated tide curves for most. The ebb-dominated curve for Lake Tashmoo is an anomaly among the Martha's Vineyard ponds studied to date. On average, a tidal cycle requires 12:22 hours to complete. There are approximately 1.94 tidal cycles per day.

Nearly coincident rise and fall of the tide and approximately equal tide ranges at both stations indicate good tidal circulation. Perhaps the good circulation comes from the depth and elongation of the main body of the pond. Prevailing southwest and northwest winds cut across the pond diagonally, and are tempered by the bluffs on either side of the pond. Tidal circulation in the pond is not expected to be impacted by the prevailing winds, as might occur in a broad and shallow pond.

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

LAKE TASHMOO
TIDE GAUGE STATIONS
2001

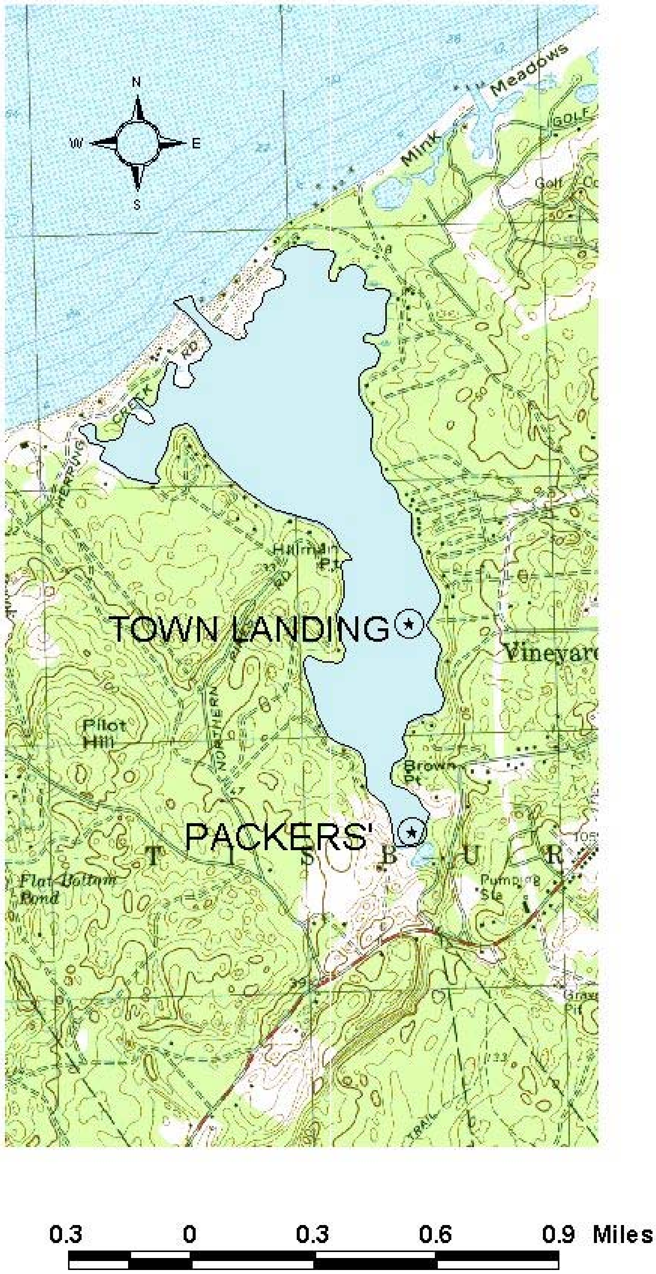
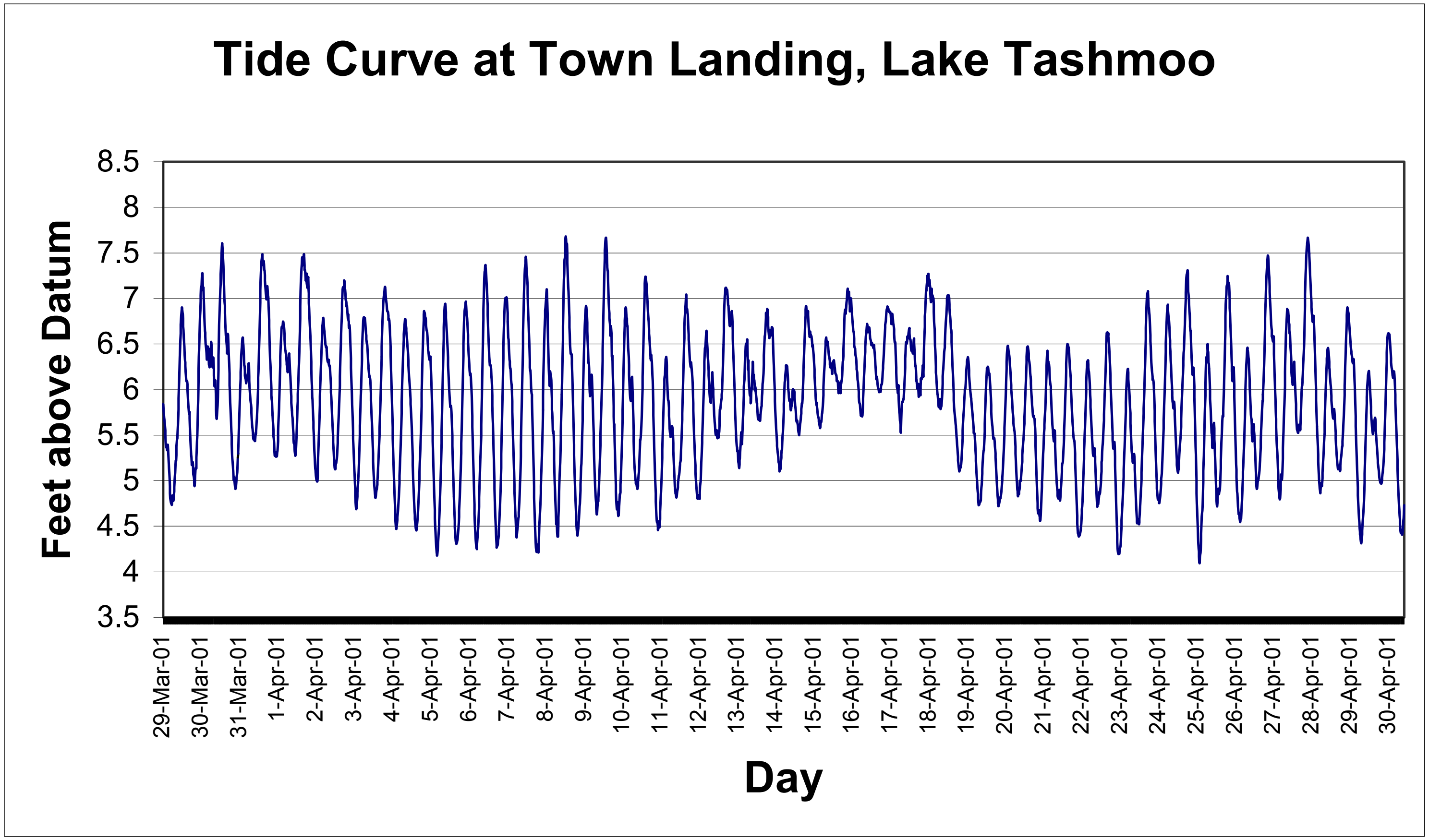


Figure 3



Tide Curve at Town Landing, Lake Tashmoo
Feet above Datum
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
29-Mar-01
30-Mar-01
31-Mar-01
1-Apr-01
2-Apr-01
3-Apr-01
4-Apr-01
5-Apr-01
6-Apr-01
7-Apr-01
8-Apr-01
9-Apr-01
10-Apr-01
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22-Apr-01
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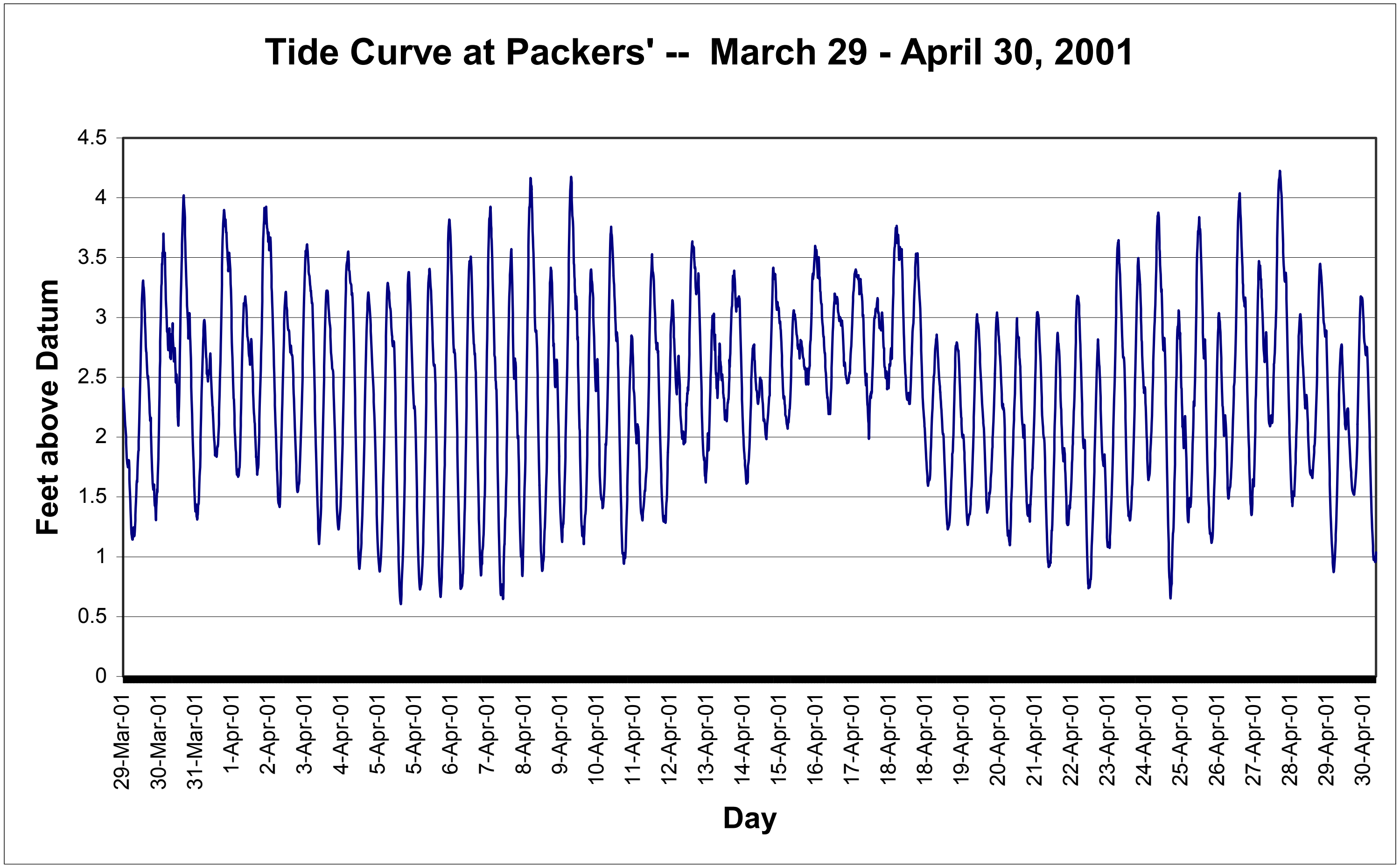
29-Apr-01
30-Apr-01
Day

Figure 4


Tide Curve at Packers' -- March 29 - April 30, 2001
Feet above Datum
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
29-Mar-01
30-Mar-01
31-Mar-01
1-Apr-01
2-Apr-01
3-Apr-01
4-Apr-01
5-Apr-01
5-Apr-01
6-Apr-01
7-Apr-01
8-Apr-01
9-Apr-01
10-Apr-01
11-Apr-01
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22-Apr-01
23-Apr-01
24-Apr-01
25-Apr-01
26-Apr-01
27-Apr-01
28-Apr-01
29-Apr-01
30-Apr-01
Day

Figure 5

BATHYMETRY

Bathymetry measurements were made in Lake Tashmoo 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.

Planimeter measurements were made of the area within each bathymetric contour. Using the depth, those measurements were converted to volumes and added to calculate the mid-tide volume of 1,601,310.495 cubic meters. The following hypsographic curve represents those measurements and was used to calculate the mid-tide mean depth of 1.3 meters and median depth of 2.1 meters.

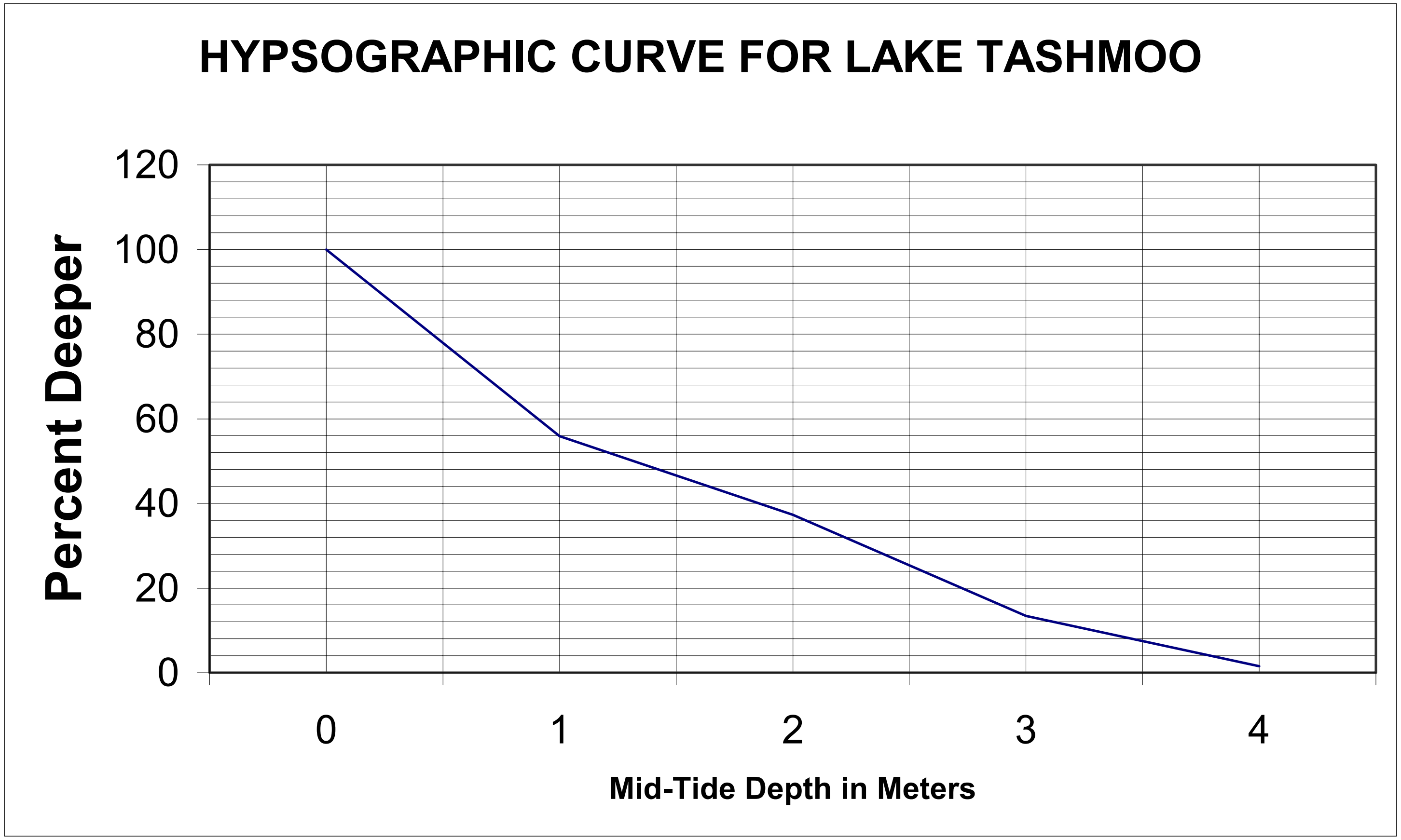
HYPSOGRAPHIC CURVE FOR LAKE TASHMOO
Percent Deeper
120
100
80
60
40
20
0
0
1
2
3
4
Mid-Tide Depth in Meters

Figure 6

LAKE TASHMOO
Mid-Tide Depth (m)

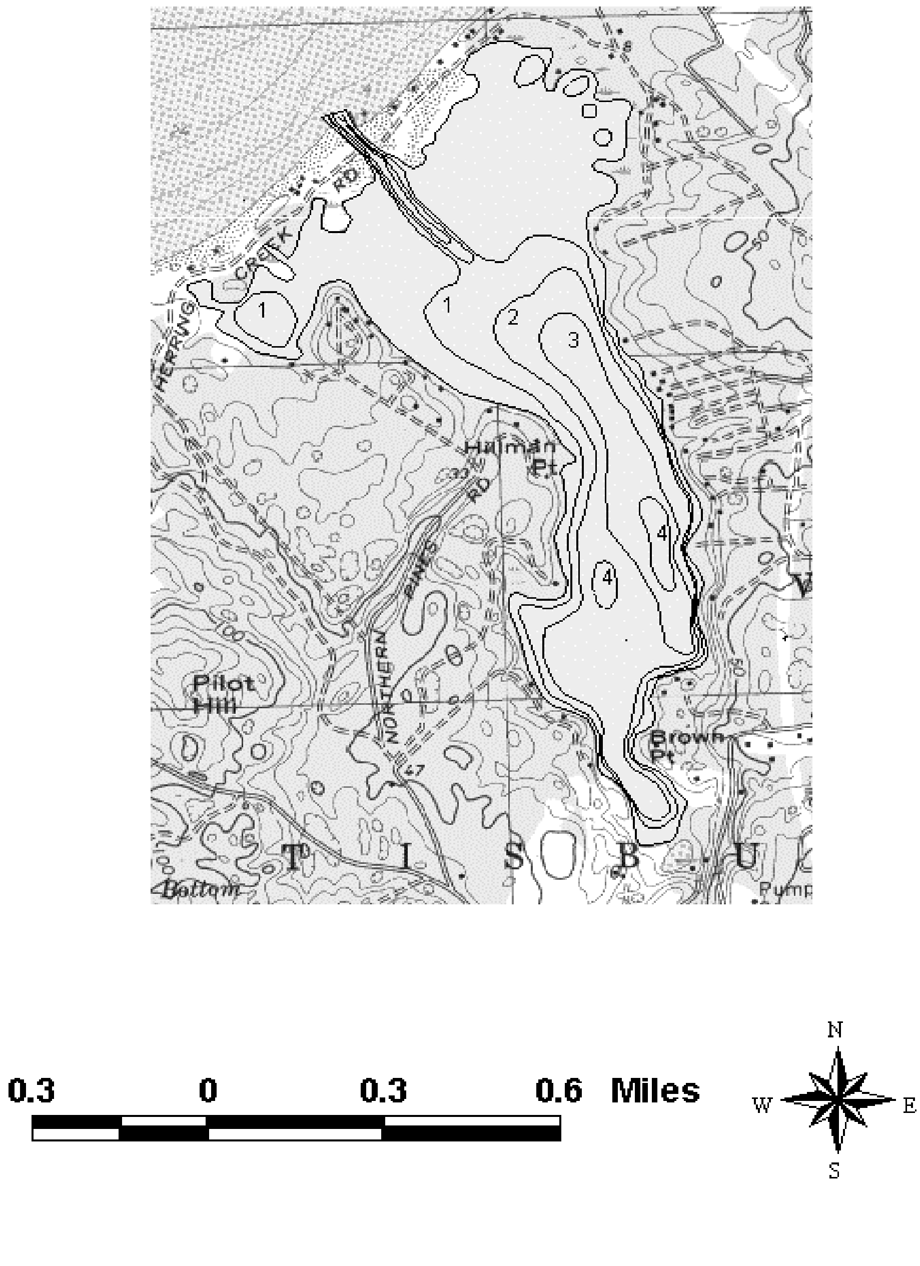

Figure 7

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 1.3 meters for mean depth at mid-tide and the MVC tidal range measurement of .62 meters results in a flushing estimate of 2.097 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 6.29 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 M.V.C.'s planimeter measurements and depth calculations, the Mean Low Water Volume is 1,287,323.99 cubic meters and the tidal prism is 627,975.01 cubic meters. Computing flushing time from those volume estimates results in an estimate of 2.05 tidal cycles, which corresponds to 6.15 cycles estimated to exchange 95% of the pond's water.

The two flushing estimates of 6.29 and 6.15 cycles are quite consistent with one another. Averaging the two results in an estimate of 6.22 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 6.22 tidal cycles for flushing time and the M.V.C. measurement of 1.94 tidal cycles per day results in a residence time of 3.206 days, or .00898 year.

NITROGEN LOADING LIMIT AND COMPARISONS

MVC has used the formulas developed by the Buzzards Bay Project, as recently modified[8], to determine the nitrogen loading limit for the pond. The Buzzards Bay Project formula will be 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. These formulas provided a nitrogen loading limit based on pond characteristics and desired use of the pond. The formulas make reference to water quality classifications of the Massachusetts Water Quality Standards, although those standards do not associate a nitrogen loading limit with a particular classification. In order to avoid confusion, the following calculations use the terms “good” and “excellent” in place of the Buzzards Bay Project’s references to water quality classifications.

Volume at mid-tide = 1,601,310.495 m^3
Residence time = .00878 yr.

for excellent water qualtiy:

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

$$= \frac{(50\ \text{mg/m}^3)(1{,}601{,}310.495\ \text{m}^3)(1+\text{sqrt}\ .00878)}{(.00878)(1{,}000{,}000)}$$

= **9,119.17** kilograms limit for excellent water quality

[8] 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

For good water quality:

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

$$= \frac{(150\ mg/m^3)(1{,}601{,}310.495\ m^3)(1+\ sqrt\ .00878)}{(.00878)(1{,}000{,}000)}$$

= **27,357.52** kilograms limit for good water quality

The limit of 27,357.52 kilograms should maintain the pond at good qualitly. The more restrictive limit of 9,119.17 kilograms should maintain excellent water quality.

COMPARISONS

Heigis et al investigated the existing load and projected the load at three different scenarios of buildout. The results are summarized below from the 2002 NDWRCDP report[9]:

NITROGEN LOAD WITH GROWTH SCENARIOS						
	Rain	Commercial	Residential	Lawns	Farms	Total
Existing Load	2,499.1	513.7	2,505.4	241.0	633.2	6,326.5 kg
Low Growth	2,433.0	735.5	3,148.4	273.1	633.2	7,233.3 kg
Moderate Growth	2,447.0	953.0	3,791.3	305.3	633.2	8,129.9 kg
High Growth	2,452.9	2,440.1	5,461.8	573.0	633.2	11,561.0 kg

Table 3

It would appear from the data and calculations that, even at the highest growth potential, nitrogen from the watershed should not compromise the water quality of the pond beyond "good" quality. In fact the more restrictive limit for "excellent" water quality would fall between the moderate and high growth scenarios.

[9] Heigis, W., B.Douglas, M. Hoover and Dennis Luttrell, 2001, "Application of a Risk-Based Approach to Community Water Resources Capacity Development Project" Final Report to the National Decentralized Water Resources Capacity Development Project.

LAKE TASHMOO
WATER QUALITY STATIONS
2001

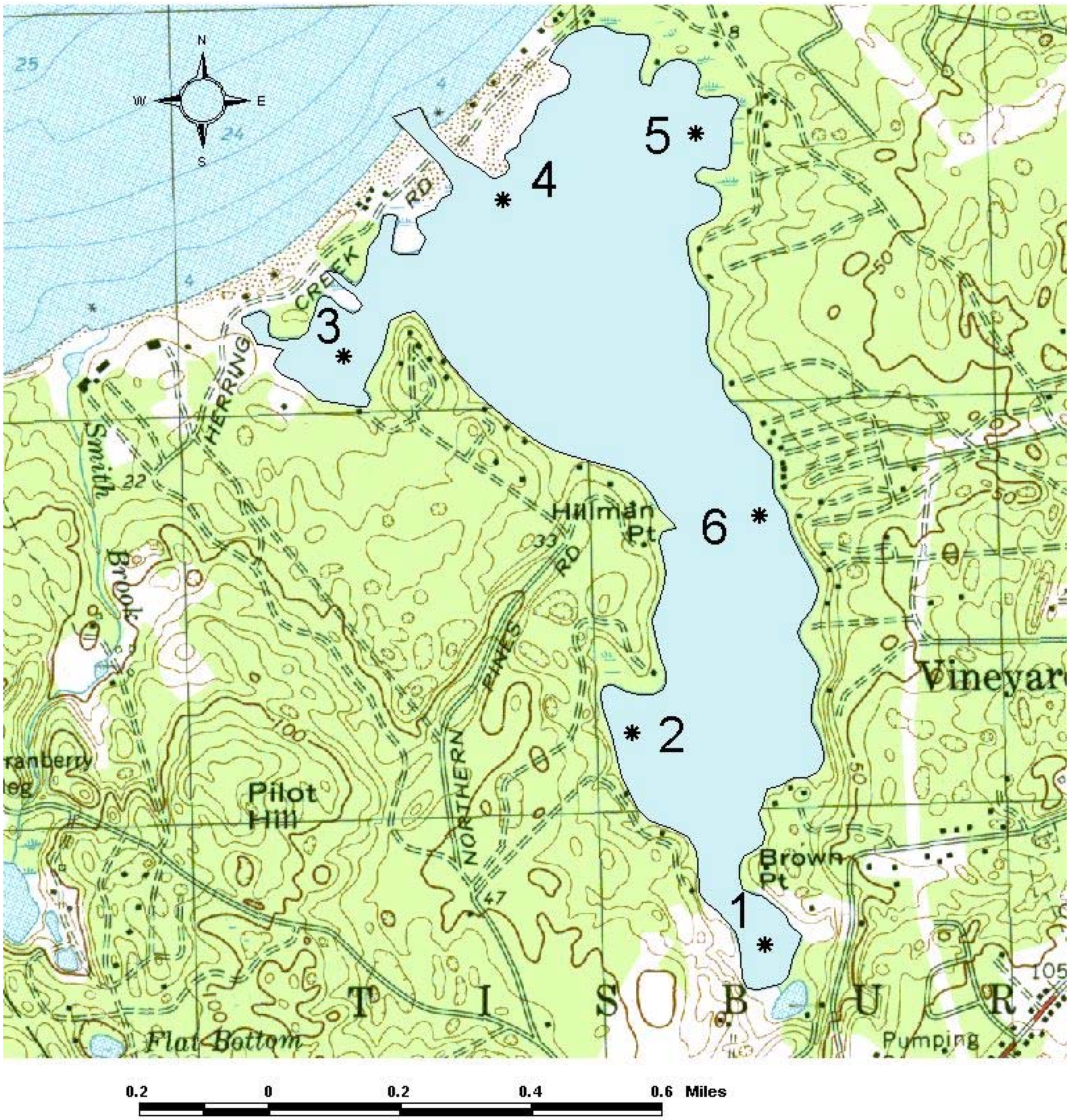

Figure 8

WATER QUALITY SAMPLING

Four rounds of sampling were made in Lake Tashmoo between July and September, 2001 at six stations: Head of Pond (1), Drew Cove (2), Rhoda Pond (3), Inlet (4), near Flat Point (5) and at the Town Landing (6). 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.

FIELD OBSERVATIONS

On **July 1**, a Southwest breeze was sometimes as strong as 20-25 mph. Minor rainfall (.07”) was recorded at Falmouth on the previous day. The tide turned at 7:11, and sampling was done 8:23-12:32. Water clarity was high, as measured by extinction depth of a Secchi disc. The pond water was clear to the bottom at stations 2-6, and no extinction was recorded at those stations. At Station 1, near the head of the pond, extinction was recorded at 2 meters. On **July 30**, the tide turned at 5:53, and sampling was done 7:46-10:43. There was a strong southwest breeze, particularly strong at stations 3-5. No rain had been recorded at Falmouth for the past four days. Water clarity was high, with no Secchi extinction at stations 2-6, and extinction at 2.1 meters for station 1. On **September 12**, there was a light North wind. The tide turned at 4:23 and sampling was done 7:37-10:47. No rain had been recorded at Falmouth since August 20. Water clarity was highest of any sampling day, with no extinction at stations 2-6 and an extinction of 2.8 meters at station 1. On **September 26**, the field notes recorded “heavy rain” for the previous day, when .49” was recorded at Falmouth. At stations 1 and 2, the sky was overcast and there was a light WSW breeze; at stations 3-5, it was sunny, with a stiff WSW breeze (15-25 mph); and at station 6 it was sunny with a 10-15 mph WSW breeze. The tide turned at 5:01 and sampling was done 7:41-10:53. On this, the only sampling day that followed rainfall, water clarity was least of any day. Extinction was recorded at 1.8 meters at station 1. At the other stations, the water column was clear to the bottom.

STRATIFICATION

The graph below illustrates conductivity at the surface, mid-depth and at the bottom. The four values for each station represent measurements on July 1, July 30, September 12 and September 26.

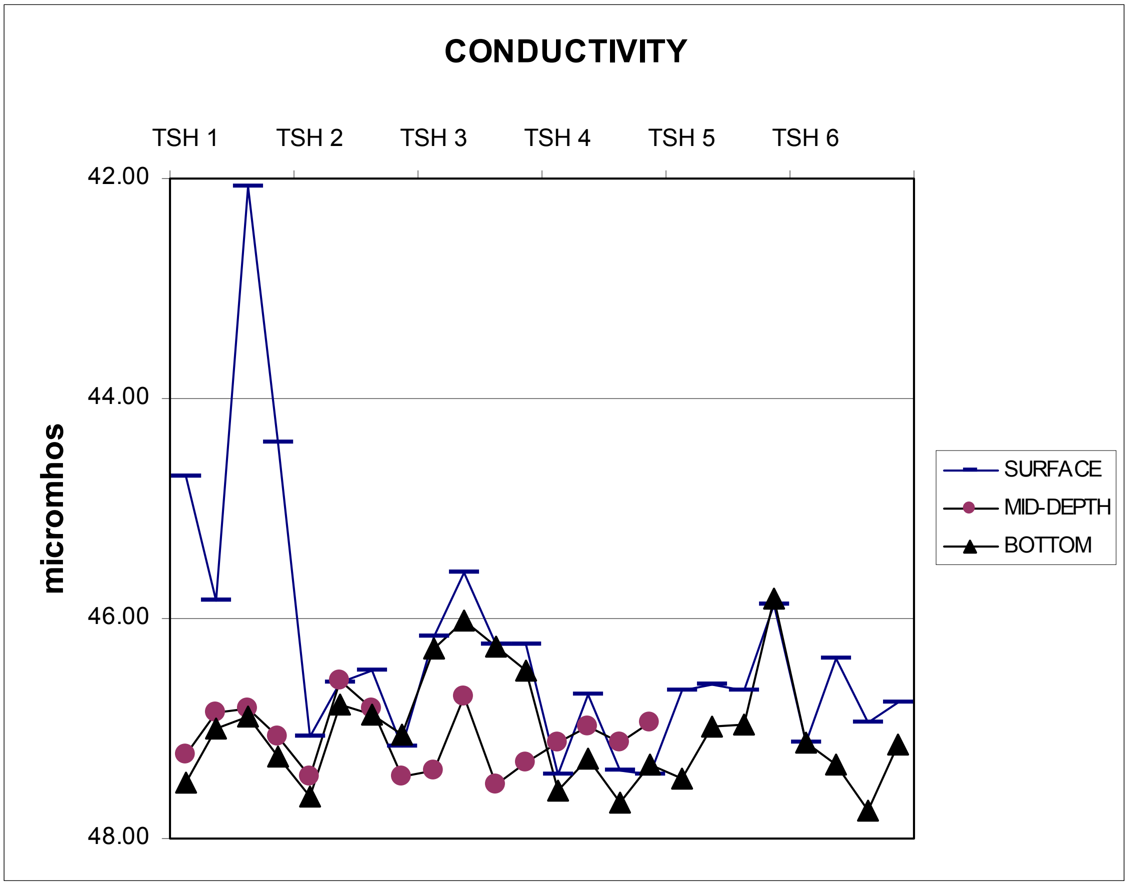

Figure 9

At station 1, near the head of the pond, there was some degree of stratification on all sampling days. This station, at the head of the pond, may be expected to display the effects of freshwater input more readily than do the other stations. At Station 4, at the inlet, there was some stratification on July 1 and on July 30, which was easily identified as a short-term reflection of tidal conditions. On July 1 and July 30, sampling was done very soon after the tide had turned, and the stratification on those days reflects that. No stratification was seen on the other days, when the tide turned 2-3 hours before sampling began. Stratification was seen on July 1 in Drew Cove. Stratification was seen at station 6, at the Town Landing, on one occasion, on July 30.

Although the pond is well-circulated overall, there may be a tendency for some stratification at the head of the pond, and possibly also at Drew Cove and at the Town Landing. Stratification is important from a management perspective, because there is potential for dissolved oxygen levels to drop to dangerous levels during the night. During the hours of darkness, plants and animals alike consume oxygen. A confined layer may be especially prone to oxygen depletion.

Often, the confined layer is found at the pond's bottom. Much of the stratification seen in Lake Tashmoo consisted of a middle layer disparate from the surface and bottom conditions.

SURFACE WATER QUALITY DATA

Surface water samples were analyzed for nutrients including: nitrate, ammonia, dissolved organic nitrogen, particulate nitrogen, particulate organic carbon, conductivity, orthophosphate, chlorophyll *a* and silicate. The raw data may be found in Appendix II. 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.

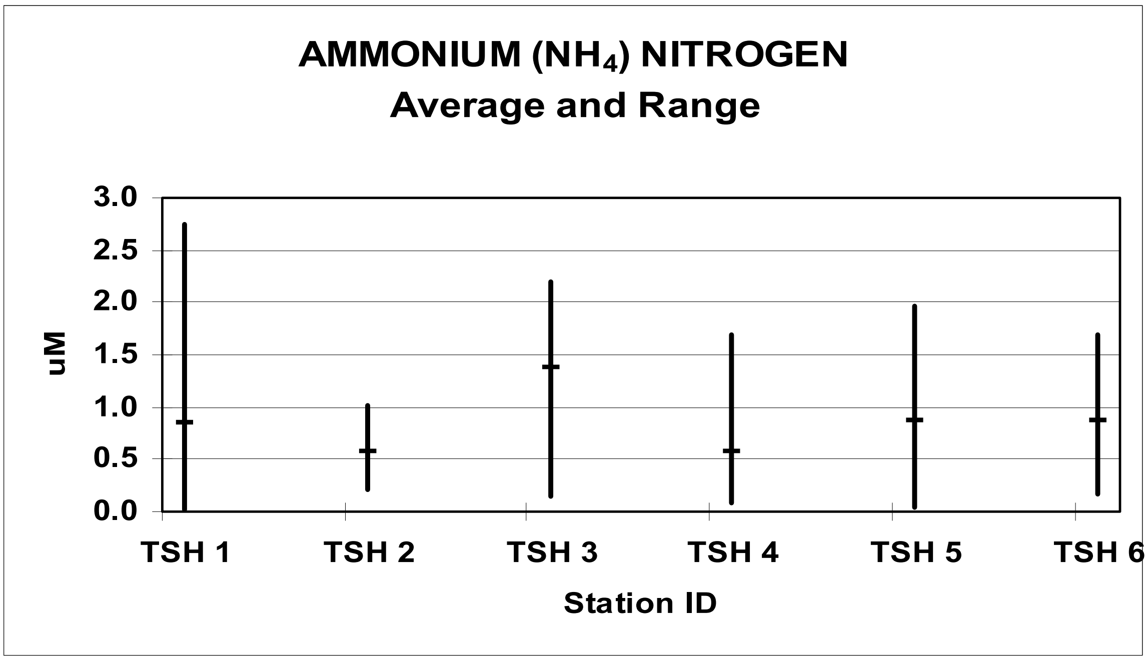

Figure 10

Ammonium (NH_4), an inorganic compound of nitrogen, Values for ammonium (NH_4) were overall lower than those in the other Island ponds used for comparison. Random spikes could indicate isolated sources such as birds or boats.

Nitrate values were similarly low, compared to those for other ponds on Martha's Vineyard. Nitrate values at Station 5 (Flat Point) were distinctly higher than at the other stations.

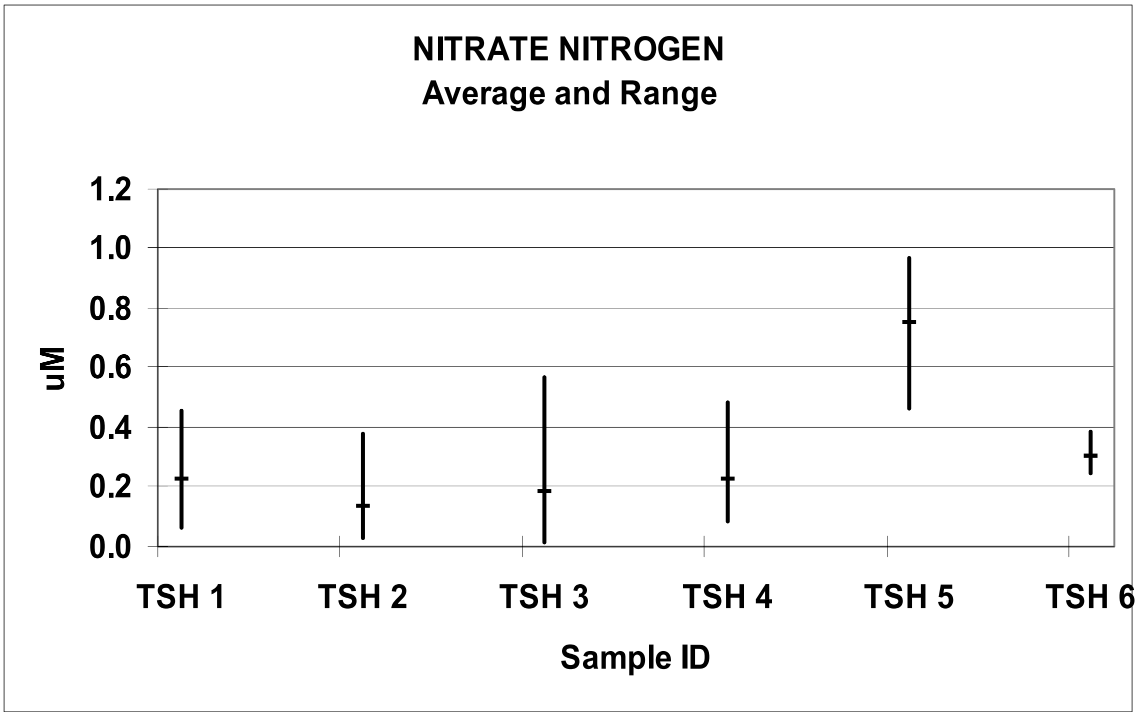

Figure 11

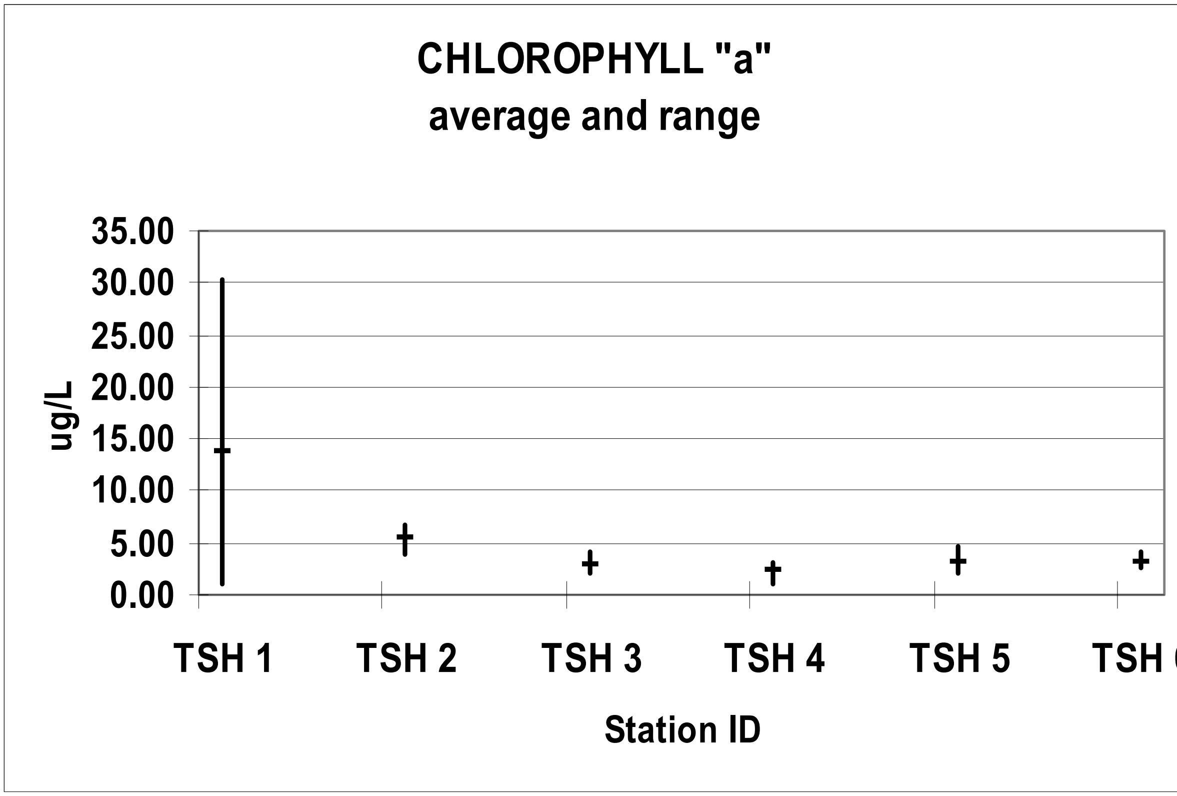

Figure 12

The above graph illustrates the range of values and average values of Chlorophyll "a" throughout the pond. There was more variability at the head of the pond (TSH1), and the highest values were recorded there.

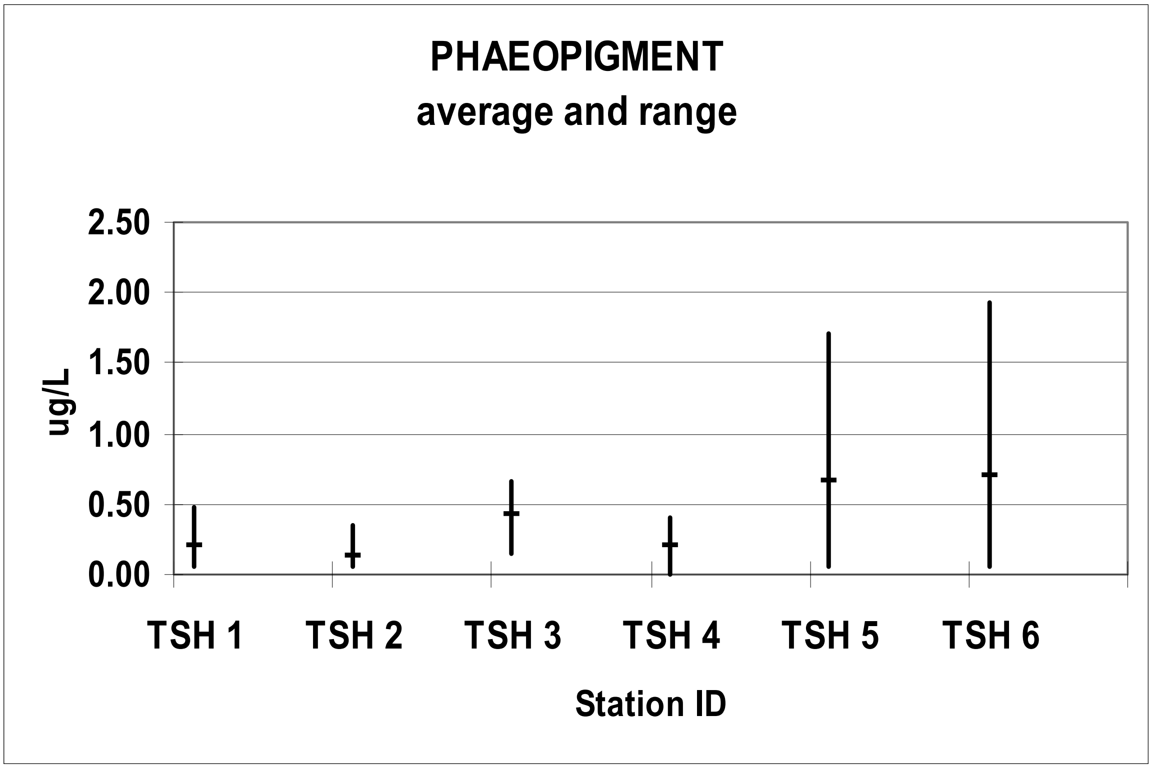

Figure 13

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. Phaeopigment values were higher and varied more at Station 5, near Flat Point, and at Station 6, near the Town Landing.

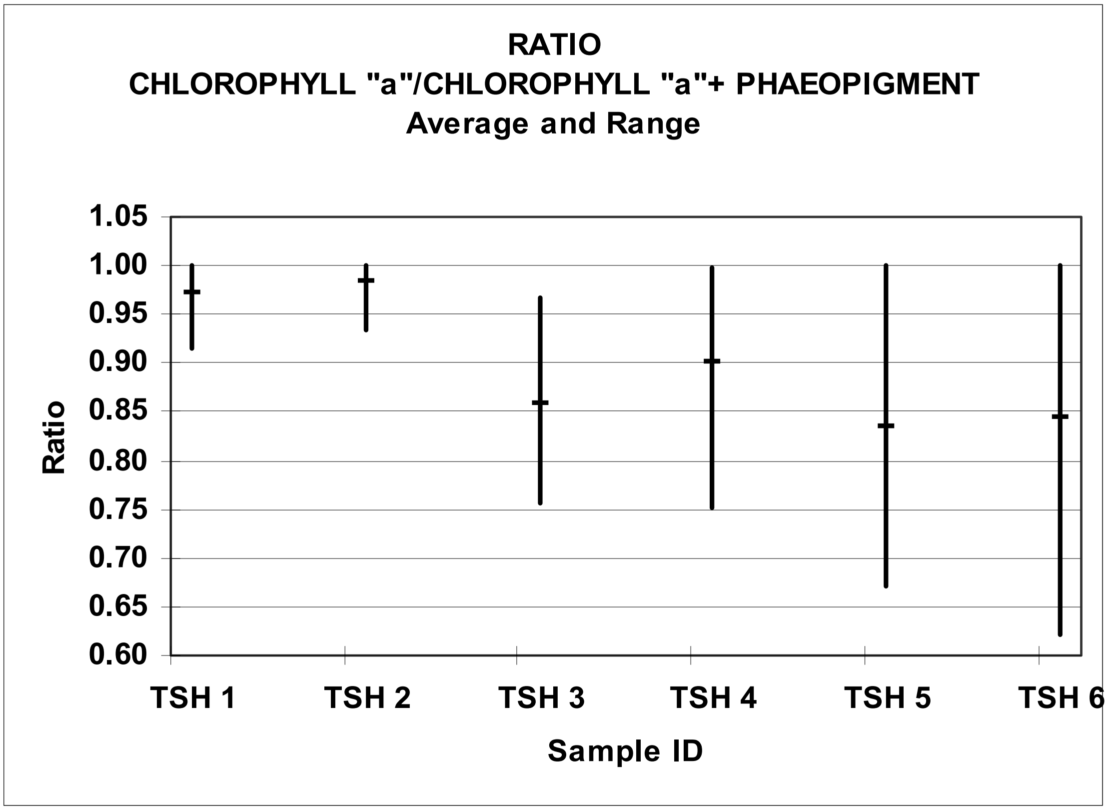

Figure 14

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 head of the pond, but that a higher proportion of dead algae was found closer to the inlet.

non-text page

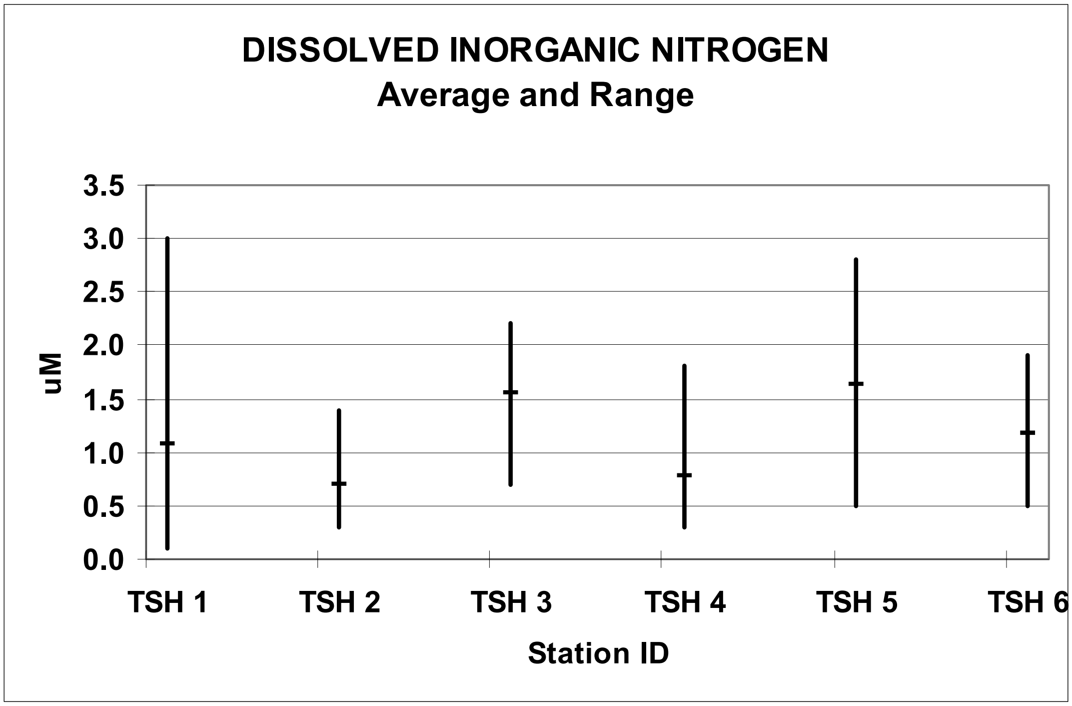

Figure 15

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. Average values were low and were similar throughout the pond.

Dissolved Organic Nitrogen includes organic forms such as urea, which are released by decaying organic matter. DON values were higher and more variable, particularly near the head of the pond and near the inlet.

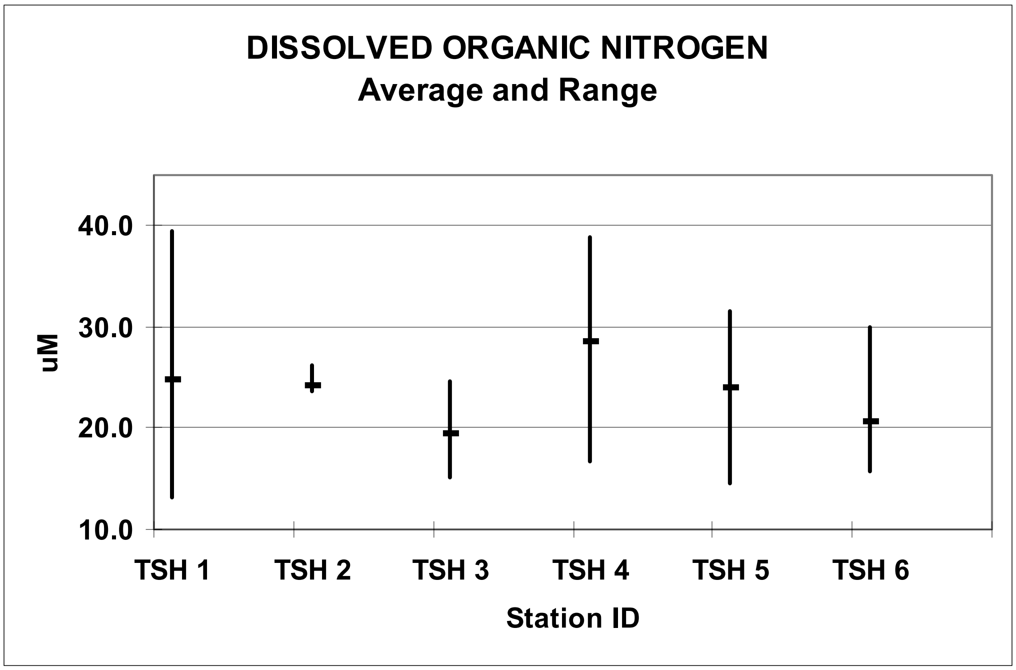

Figure 16

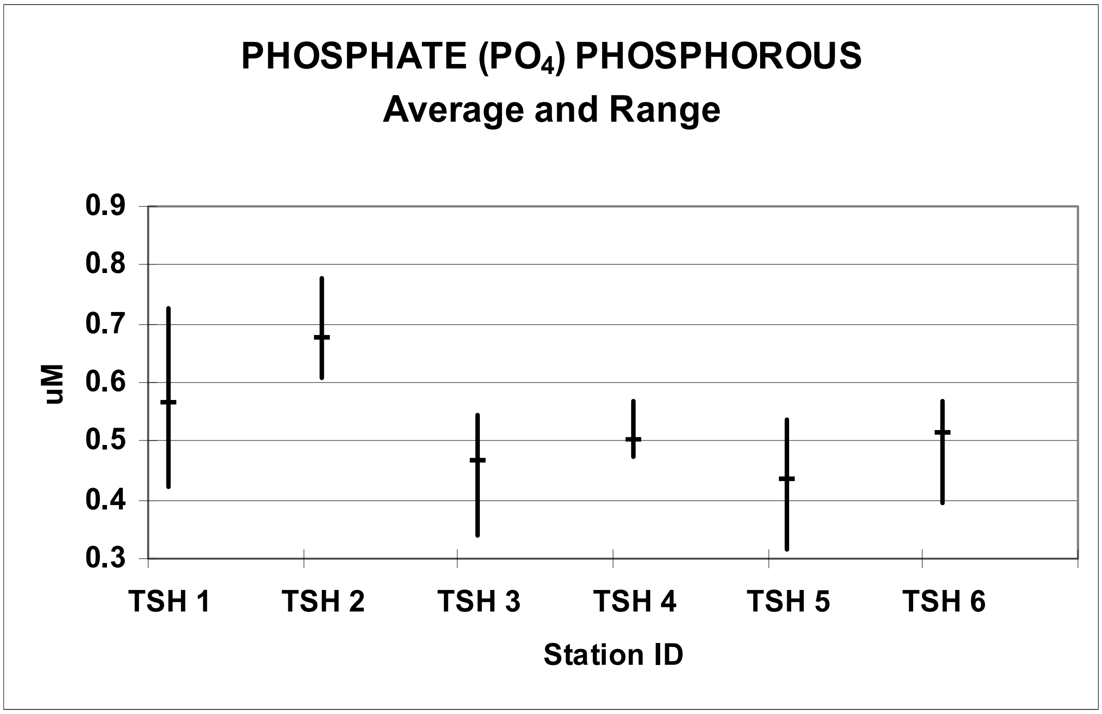

Figure 17

Values for phosphate were fairly uniform across the pond, slightly elevated at station 2, Drew Cove.

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 was clearly the limiting nutrient throughout the pond and on all sampling dates.

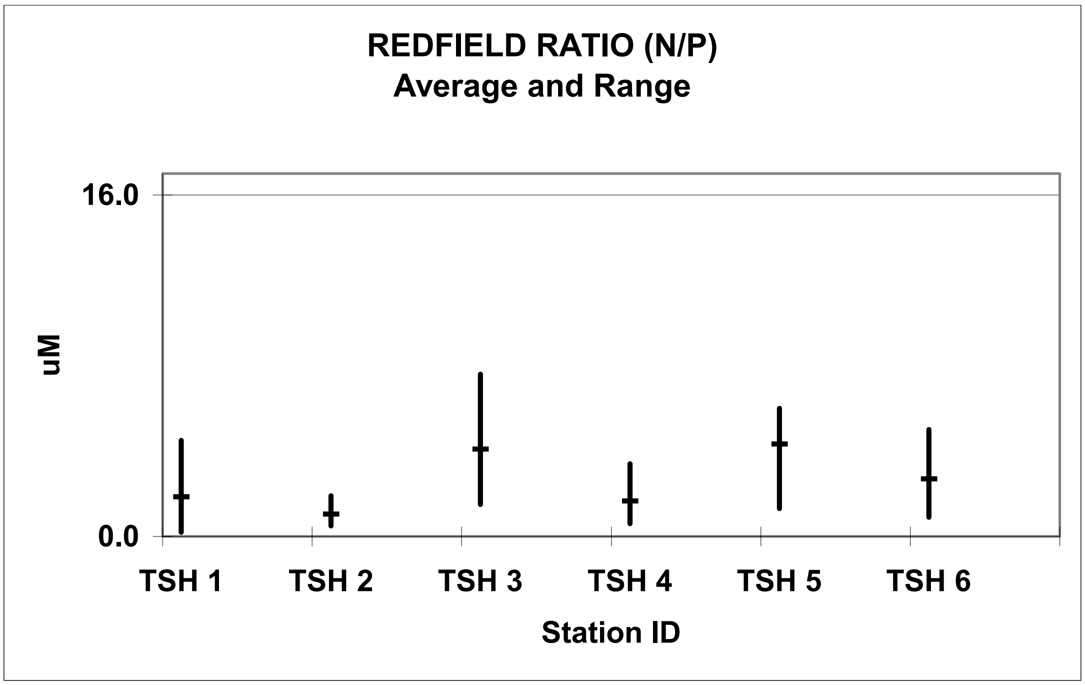

Figure 18

The graph below illustrates the values for Silica:

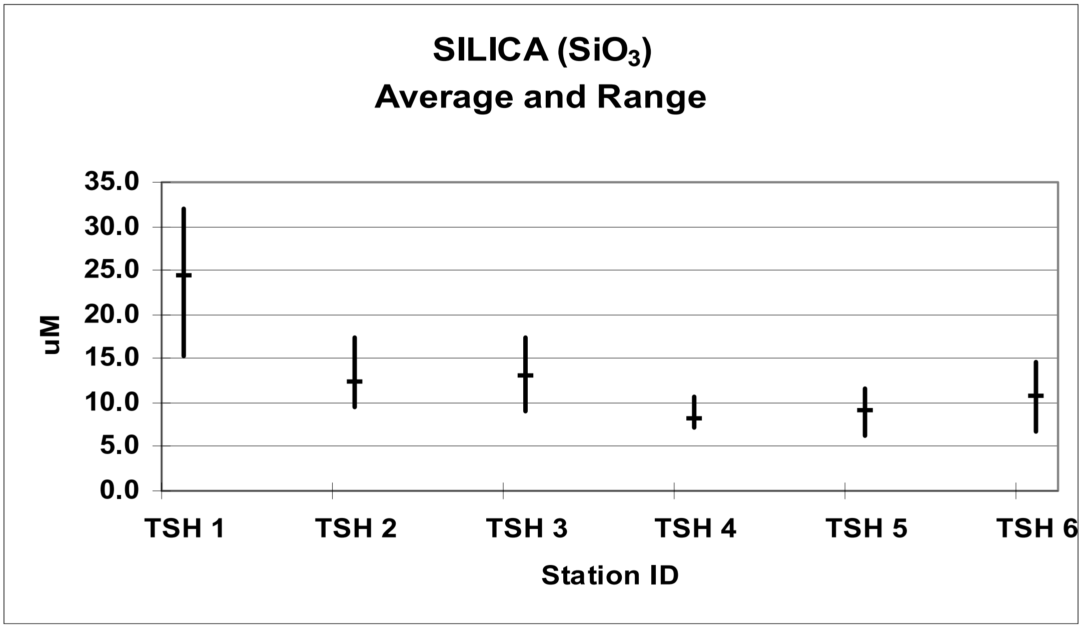

Figure 19

Higher concentrations of silica generally indicate input of fresh water, through runoff or streamflow. Only at the head of the pond were silica levels elevated, where higher concentration may be expected. All values were lower than those for other ponds on Martha's Vineyard. The low levels throughout the main body of the pond could indicate a low level of input, or could indicate that the silica was utilized for growth of diatoms. This warrants further investigation of the plankton population.

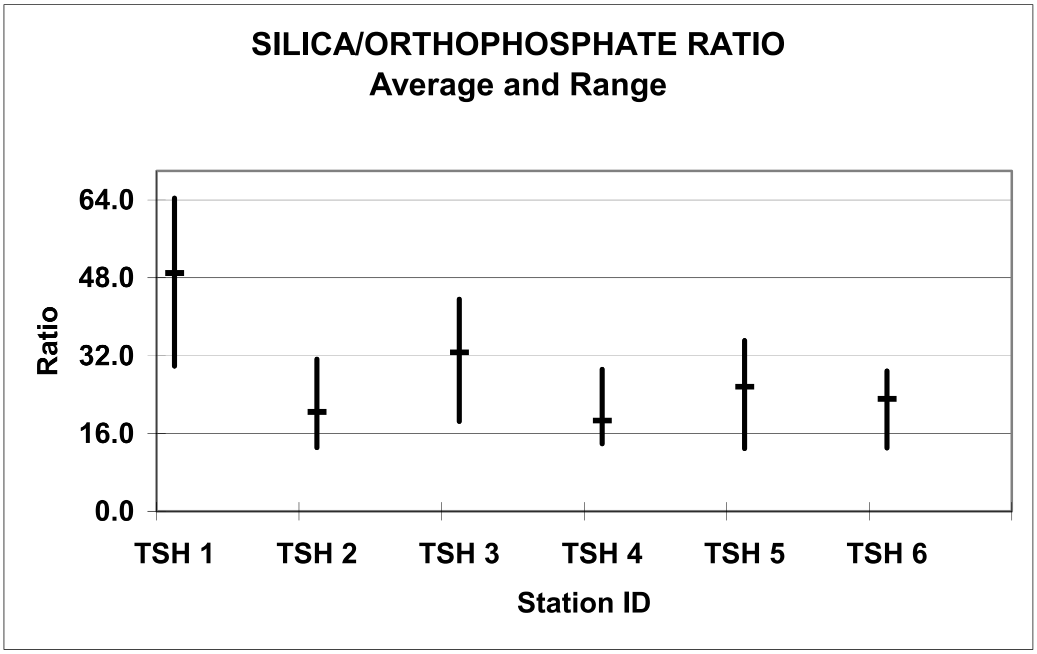

Figure 20

The Redfield Ratio for silica to orthophosphate is 6 to one. The graph above illustrates that relationship. The average ratio routinely exceeded 16 at all stations. 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 always exceeded 16 at the head of the pond (TSH 1), indicating that the greater supply of silica there ensured that orthophosphate was more often the limiting factor.

COMPARISONS AND CONCLUSIONS

The results of the 2001 sampling may be viewed in terms of 4 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.

In 1999, students from Martha's Vineyard Regional High School sampled groundwater adjacent to the shore of the pond and found total nitrogen concentrations averaging .93 mg/l, with slightly higher values on the eastern shore, reflecting the greater density of development there[10]. Those findings are consistent with the MVC data.

Reviewing the data overall, nutrient values were found to be lower than for various other Island ponds used for comparison, a general indication of high quality groundwater entering the pond from the existing load, and with the good circulation found in the pond. For comparison of some major nutrients, the following table compares the Lake Tashmoo 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[11] in 1999, for Tisbury Great Pond as reported by the Martha's Vineyard Commission[12] in 2000, and for Lake Anthony (Oak Bluffs Harbor) as reported by the Martha's Vineyard Commission[13]. 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 4

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10 Martha's Vineyard Regional High School, 1999, Water Quality Learning Project – Water Quality Monitoring Project

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

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

13 Martha's Vineyard Commission, 2003, Nutrient Loading to Lake Anthony and Sunset Lake

In 1995-6, the Martha's Vineyard Commission surveyed the health of the eelgrass crop in the pond, as shown in the following illustration, taken from the survey report[14].

Figure 21

[14] Martha's Vineyard Commission, 1997, A Survey of the Eelgrass Beds of Lake Tashmoo, Vineyard Haven, Massachusetts

From the survey, eelgrass was found to be generally abundant and healthy. The low nutrient levels and high water clarity found in the data from this study are consistent with those findings. The water column was clear to the bottom at stations 2-6 at all times, with extinctions ranging from 1.8 to 2.8 meters at the head of the pond. An exception to the abundancy note in the eelgrass survey was recorded in areas heavily impacted by boating. Note the large gap in eelgrass coverage, coincident with the large mooring field in the vicinity of the town landing. Eelgrass beds are susceptible to damage from increased turbidity associated with boating.

PRIORITIZED MANAGEMENT MEASURES

ADOPT 9,000 KILOGRAMS PER YEAR AS THE ANNUAL NITROGEN LOADING LIMIT FOR THE WATERSHED.

Lake Tashmoo is presently classified "SA", which indicates that these waters are suitable for fishing, for shellfishing in designated areas, and for primary contacts such as swimming, and aesthetically pleasing. Existing load and load at buildout are summarized below from the final NDWRCDP report[15]:

Existing Load	6,326.5 kg
Load at Low Growth Buildout	7,233.3 kg
Load at Moderate Growth Buildout	8,129.9 kg
Load at High Growth Buildout	11,561.0 kg

During discussion at the public session devoted to nitrogen loading, there was strong support among the public to strive for the "excellent" water quality limit of 9,000 kilograms, particularly since the limit appears to be achievable without much of a struggle. The management recommendation is to adopt a nitrogen-loading limit of 9,000 kilograms per year for the watershed. Existing land use controls in place would easily support the "good" quality limit of 27,000 kilograms, and would probably support the "excellent" quality limit of 9,000 kilograms. That amount would be between the values estimated for moderate growth and high growth scenarios at buildout. Although the highest growth scenario could exceed the limit, it is highly unlikely that the very maximum growth would be the final buildout condition. However, should the Town and Commonwealth choose to rely strictly on the 9,000 kilogram limit, there are ways to ensure that: encourage advanced nitrogen removal septic systems for new commercial or residential development, or both; use existing licensing authority of the Board of Selectmen to restrict commercial development of high nitrogen producers such as restaurants; maximize effort to increase open space from remaining undeveloped land; educate homeowners and professional landscapers about reducing the load from lawns and landscaping.

[15] Heigis, W., B.Douglas, M. Hoover and Dennis Luttrell, 2001, "Application of a Risk-Based Approach to Community Water Resources Capacity Development Project" Final Report to the National Decentralized Water Resources Capacity Development Project.

ENCOURAGE ADVANCED NITROGEN REDUCTION FOR FUTURE DEVELOPMENT

Advanced nitrogen removal can reduce nitrogen input by up to 50%.

MANAGE NEW COMMERCIAL GROWTH

Use the existing licensing authority of the Board of Selectmen to restrict commercial development of high nitrogen producers such as restaurants. There is much variability in the future for the commercial sector. High nitrogen producers could be discouraged.

MAXIMIZE OPEN SPACE PRESERVATION

Maximize efforts to increase open space from remaining undeveloped land. Much open space in the watershed remains unprotected.

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.

FOCUS SHORT-TERM MANAGEMENT ON THE IMPACTS OF BOATING

Lake Tashmoo is used extensively for mooring and anchorage of commercial and recreational vessels. It is important to minimize the impacts of boating, in order to maintain water quality and to protect the eelgrass beds. Manage numbers of vessels, particularly live-aboards. Manage mooring and anchorage areas and general navigation to minimize impacts to eelgrass beds. Assess maintenance needs in the vicinity of the Town Landing; instruct boaters to clear trailers of vegetation.

Continue maintenance dredging; continue to consider extension of western jetty. In order to keep the inlet clear, routine maintenance dredging is needed. Day-to-day longshore transport carries sand from west to east along the shore. With the present jetty configuration, much sand enters the inlet. It has been suggested that modifications to the western jetty would keep some of the sand offshore, and help to keep the inlet functioning.

PROMOTE SHELLFISH AND HERRING

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[16]. Promote shellfish as nutrient consumers. They can exert strong top-down controls on nutrients: feeding prodigiously on algae, they use and bind up nitrogen and phosphorus that would otherwise contribute to further degredation of water quality. Promote shellfish as nutrient consumers. Ensure that their habitats are protected, including protection of eelgrass beds that are an important habitat for juveniles.

Herring should be promoted along with shellfish, for the same top-down nutrient consumption benefits. Support efforts to maintain the newly established herring run at the head of the pond.

FURTHER ASSESSMENT AND MONITORING

Having identified a high level of water quality and exceptional clarity, it is important to follow up with additional sampling to monitor conditions over time. Continue surface water sampling for nutrients. Include weather data from the Martha's Vineyard Coastal Observatory, when available, in analysis. Continue to investigate stratification in the pond. 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.

Reexamine eelgrass beds periodically to assess health of the crop over time. The Wetlands Conservancy Program mapped the locations of the beds, from arial photos, in 1994 and again in 1999, with plans to update the maps every five years. In 1997, The Martha's Vineyard Commission performed a survey of the status of the health and productivity of the beds, using a diver to collect samples for analysis. The survey was intended to form a baseline database. There are no plans to repeat the survey. Perhaps performing such a survey every ten

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

years would be a good idea, with more or less of a time interval as indicated from the 5-year coverage maps.

Silica values were lower than those for other ponds on Martha's Vineyard. This warrants investigation of plankton populations, to determine whether the low levels of silica indicate a low level of input or the utilization of silica for the skeletons of diatoms.

REFERENCES

Heigis, W., B.Douglas, M. Hoover and Dennis Luttrell, 2001, “Application of a Risk-Based Approach to Community Water Resources Capacity Development Project” Final Report to the National Decentralized Water Resources Capacity Development Project.

Banks, Charles Edward M.D., 1966 by Dukes County Historical Society, History of Martha’s Vineyard Dukes County Massachusetts

C.E. Maguire, 1975, Lake Tashmoo Feasibility Study Martha’s Vineyard

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

Martha’s Vineyard Regional High School, 1999, Water Quality Learning Project – Water Quality Monitoring Project

The Martha’s Vineyard Commission, 1997, “A survey of the eelgrass beds of Lake Tashmoo, Vineyard Haven, Massachusetts”

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 Anthony and Sunset Lake

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

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 9, 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 public was invited to a second session on June 11, 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.

Concern was expressed for the condition of the eelgrass beds and the pond bottom. Tisbury Shellfish Constable Derek Cimeno reported that the bottom was in bad condition near the town landing and throughout the most congested mooring area, roughly the upper half of the main body of the pond, and into the upper pond area; there are about 600 moorings in the pond. He noted that boats anchor near the flats all summer, so that they can board without a dinghy. He reported that the Town had completed its work to restore the historic herring run, but in a new location at the upper end of the pond. There was concern about the impacts of the moorings, and suggestion to grid the whole mooring field and keep the moorings out of the eelgrass beds altogether.

There was strong support to set the nitrogen-loading limit at 9,000 kilograms rather than the alternative 27,000 kilograms of the range proposed in the draft report. There was strong support for keeping the highest possible water quality, and concern for the loss of water quality. One participant, Melinda Lohberg, stated that it would be a feather in the Town's cap to hold to the highest level of water quality.

Draft reports were provided to town boards and other interested parties and to DEP for comment. Oak Bluffs Shellfish Constable David Grunden noted surprise at the low level of silicates in the pond, especially when compared to other local salt ponds. He questioned if high diatom populations might be using up the silicates; he asked if the plankton populations had been investigated. He encouraged adoption of 9,000 kilograms for the loading limit, in order to maintain the highest water quality. He also suggested nomination as an Area of Critical Environmental Concern, in order to give the decision makers more control over the pond. 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

Field observations:

Date	Time	station_ID	depth_in_m	secchi_dow	secchi_up	specific_c	temperatur	salinity	dissolved_	dissolved2
7/1/2001	04:26:49pm	tsh-1-s	0.0	2.000	2.000	44.710	24.000	28.900	85.400	6.170
7/1/2001	04:30:18pm	tsh-1-m	1.0	2.000	2.000	47.230	23.000	30.800	77.800	5.400
7/1/2001	04:32:39pm	tsh-1-d	2.6	2.000	2.000	47.490	23.000	30.900	80.100	5.740
7/1/2001	03:40:58pm	tsh-2-s	0.0	0.000	0.000	47.080	23.800	30.600	94.600	6.560
7/1/2001	03:54:12pm	tsh-2-m	1.0	0.000	0.000	47.440	22.900	31.000	98.400	7.430
7/1/2001	03:56:51pm	tsh-2-d	2.2	0.000	0.000	47.620	23.000	31.000	83.400	6.150
7/1/2001	02:56:54pm	tsh-3-s	0.0	0.000	0.000	46.170	23.700	29.900	83.200	6.020
7/1/2001	02:59:01pm	tsh-3-d	0.9	0.000	0.000	46.270	23.700	30.000	86.000	6.090
7/1/2001	02:04:11pm	tsh-4-s	0.0	0.000	0.000	47.420	22.700	30.900	95.000	6.840
7/1/2001	02:07:52pm	tsh-4-m	1.5	0.000	0.000	47.390	22.700	30.900	88.900	6.630
7/1/2001	02:10:08pm	tsh-4-d	3.1	0.000	0.000	47.570	22.100	31.000	83.200	6.200
7/1/2001	01:18:27pm	tsh-5-s	0.0	0.000	0.000	46.660	23.100	30.400	74.700	5.350
7/1/2001	01:22:09pm	tsh-5-d	1.2	0.000	0.000	47.450	22.700	30.900	75.200	5.360
7/1/2001	12:23:30pm	tsh-6-s	0.0	0.000	0.000	47.120	23.100	30.700	95.500	6.760
7/1/2001	12:54:41pm	tsh-6-m	1.5	0.000	0.000	47.130	23.100	30.700	92.700	6.760
7/1/2001	12:57:09pm	tsh-6-d	3.4	0.000	0.000	47.130	23.100	30.700	93.000	6.730
7/30/2001	11:46:39am	tsh-1-s	0.0	2.100	2.100	45.830	21.500	29.900	79.500	5.970
7/30/2001	11:49:29am	tsh-1-m	1.5	2.100	2.100	46.860	22.000	30.500	83.400	6.220
7/30/2001	11:52:23pm	tsh-1-d	2.9	2.100	2.100	47.000	21.800	30.600	73.100	5.010
7/30/2001	12:20:22pm	tsh-2-s	0.0	0.000	0.000	46.580	21.600	30.300	86.500	6.460
7/30/2001	12:22:03pm	tsh-2-m	0.5	0.000	0.000	46.560	21.600	30.400	85.600	6.220
7/30/2001	12:23:44pm	tsh-2-d	1.1	0.000	0.000	46.790	21.800	30.400	82.100	6.000
7/30/2001	02:40:59pm	tsh-3-s	0.0	0.000	0.000	45.590	21.700	29.600	78.600	5.740
7/30/2001	02:43:08pm	tsh-3-d	1.0	0.000	0.000	46.010	21.600	29.900	79.000	6.310
7/30/2001	02:13:41pm	tsh-4-s	0.0	0.000	0.000	46.690	21.100	30.400	95.700	7.080
7/30/2001	02:15:03pm	tsh-4-m	1.5	0.000	0.000	46.700	21.100	30.400	93.600	6.940
7/30/2001	02:16:49pm	tsh-4-d	2.6	0.000	0.000	47.270	20.500	30.800	73.200	6.600
7/30/2001	01:46:48pm	tsh-5-s	0.0	0.000	0.000	46.600	21.300	30.300	69.900	5.170
7/30/2001	01:49:11pm	tsh-5-d	1.2	0.000	0.000	46.980	21.100	30.600	81.100	6.020
7/30/2001	12:58:57pm	tsh-6-s	0.0	0.000	0.000	46.370	21.300	30.100	96.100	7.210
7/30/2001	01:00:50pm	tsh-6-m	1.5	0.000	0.000	46.990	20.900	30.600	82.600	6.220
7/30/2001	01:02:09pm	tsh-6-d	3.4	0.000	0.000	47.320	20.400	30.900	78.400	6.000
9/12/2001	11:37:28am	tsh-1-s	0.0	2.800	2.800	42.080	19.600	27.200	90.400	7.180
9/12/2001	11:40:34am	tsh-1-m	1.5	2.800	2.800	46.820	22.000	30.400	82.800	6.010
9/12/2001	11:43:14am	tsh-1-d	3.2	2.800	2.800	46.890	21.700	30.500	76.100	5.400
9/12/2001	12:13:07pm	tsh-2-s	0.0	0.000	0.000	46.480	21.200	30.200	80.500	6.160
9/12/2001	12:15:29pm	tsh-2-m	0.8	0.000	0.000	46.820	21.600	30.400	77.700	5.650
9/12/2001	12:17:26pm	tsh-2-d	1.6	0.000	0.000	46.880	21.700	30.500	77.700	5.550
9/12/2001	01:05:51pm	tsh-3-s	0.0	0.000	0.000	46.240	19.900	30.100	76.800	5.770
9/12/2001	01:07:41pm	tsh-3-d	1.2	0.000	0.000	46.260	20.000	30.100	74.100	5.620
9/12/2001	01:34:18pm	tsh-4-s	0.0	0.000	0.000	47.390	20.700	30.900	88.400	6.590
9/12/2001	01:35:35pm	tsh-4-m	1.5	0.000	0.000	47.580	20.500	31.100	88.000	6.620
9/12/2001	01:38:11pm	tsh-4-d	3.1	0.000	0.000	47.680	20.400	31.100	81.300	6.150
9/12/2001	02:06:21pm	tsh-5-s	0.0	0.000	0.000	46.650	19.900	30.400	78.100	5.850
9/12/2001	02:08:35pm	tsh-5-d	1.0	0.000	0.000	46.970	20.000	30.600	80.200	6.020
9/12/2001	02:42:10pm	tsh-6-s	0.0	0.000	0.000	46.940	21.700	30.600	91.700	6.820
9/12/2001	02:43:43pm	tsh-6-m	1.0	0.000	0.000	47.130	21.400	30.700	87.900	6.540
9/12/2001	02:45:29pm	tsh-6-d	2.1	0.000	0.000	47.740	21.700	31.100	87.800	6.300

Date	Time	station_ID	depth_in_m	secchi_dow	secchi_up	specific_c	temperatur	salinity	dissolved_	dissolved2
9/26/2001	11:43:04am	tsh-1-m	1.5	1.800	1.800	47.080	21.000	30.700	79.300	6.030
9/26/2001	11:47:11am	tsh-1-d	2.9	1.800	1.800	47.250	20.800	30.800	36.800	2.960
9/26/2001	12:20:27pm	tsh-2-s	0.0	0.000	0.000	47.170	20.500	30.700	74.100	5.460
9/26/2001	12:22:33pm	tsh-2-m	1.0	0.000	0.000	43.220	20.600	30.700	71.600	5.430
9/26/2001	12:25:12pm	tsh-2-d	1.6	0.000	0.000	47.060	20.700	30.700	75.700	5.630
9/26/2001	01:10:54pm	tsh-3-s	0.0	0.000	0.000	46.230	20.500	30.000	74.800	5.370
9/26/2001	01:12:29pm	tsh-3-d	1.3	0.000	0.000	46.480	20.600	30.200	68.900	5.440
9/26/2001	01:40:06pm	tsh-4-s	0.0	0.000	0.000	47.420	20.100	30.900	86.800	6.550
9/26/2001	01:41:24pm	tsh-4-m	1.5	0.000	0.000	47.310	19.900	30.800	88.500	6.800
9/26/2001	01:42:42pm	tsh-4-d	3.2	0.000	0.000	47.320	19.900	30.800	91.800	6.650
9/26/2001	02:07:09pm	tsh-5-s	0.0	0.000	0.000	45.870	20.300	29.800	78.100	5.850
9/26/2001	02:08:15pm	tsh-5-d	1.0	0.000	0.000	45.820	20.300	29.800	78.400	5.790
9/26/2001	02:51:01pm	tsh-6-s	0.0	0.000	0.000	46.760	20.500	30.400	81.100	6.180
9/26/2001	02:52:45pm	tsh-6-m	1.0	0.000	0.000	46.940	20.500	30.500	78.000	5.940
9/26/2001	02:53:47pm	tsh-6-d	2.3	0.000	0.000	47.140	20.800	30.800	84.700	6.340

SURFACE WATER QUALITY DATA

Surface water samples were analyzed for nutrients, with the following results:

Sample ID	Sampling Date	uM PO4	uM NH4	uM NOx	uM DIN	uM DON	uM SiO3	Salinity (ppt)	** ug/L Seawater ** Chla	Phaeo	Chla/ Chl+Phaeo
TSH 1	7/2/2001	0.7	2.8	0.3	3	25	25.9	23.7	7.46	0.22	0.97
TSH 2	7/2/2001	0.7	1	0.4	1.4	26.2	9.5	23.6	6.66	0.05	1
TSH 3	7/2/2001	0.5	2.1	0	2.1	15.1	13.7	23.2	4.14	0.14	0.97
TSH 4	7/2/2001	0.5	1.7	0.1	1.8	16.8	7.2	24	3.21	0.01	1
TSH 5	7/2/2001	NS	NS	NS	NS	NS	NS	NS	2.07	0.55	0.79
TSH 6	7/2/2001	0.5	1.7	0.2	1.9	16.3	6.7	20.4	3.17	1.93	0.62
TSH 1	7/30/2001	0.5	0	0.1	0.1	39.5	15.3	21.1	5.31	0.49	0.92
TSH 2	7/30/2001	0.6	0.7	0.1	0.8	24.1	11.7	23.6	5.02	0.35	0.93
TSH 3	7/30/2001	0.5	0.2	0.6	0.7	24.7	9	20.1	1.99	0.64	0.76
TSH 4	7/30/2001	0.5	0.2	0.1	0.3	37.2	7.2	19.7	2.39	0.05	1
TSH 5	7/30/2001	0.5	2	0.8	2.8	31.6	6.3	20	2.14	0.32	0.87
TSH 6	7/30/2001	0.5	0.3	0.3	0.6	15.7	12	18.8	2.82	0.12	0.96
TSH 1	9/12/2001	0.5	0.3	0.1	0.4	21.8	32	21.8	11.76	0.05	1
TSH 2	9/12/2001	0.6	0.2	0.1	0.3	23.4	17.5	23.7	3.92	0.05	1
TSH 3	9/12/2001	0.4	1.1	0.1	1.2	21.9	17.3	21.9	2.59	0.27	0.9
TSH 4	9/12/2001	0.4	0.1	0.2	0.3	39	10.8	23.3	1.13	0.38	0.75
TSH 5	9/12/2001	0.4	0	0.5	0.5	14.5	11.5	23.7	4.62	0.05	1
TSH 6	9/12/2001	0.5	0.2	0.3	0.5	29.9	14.6	23.9	4.05	0.05	1
TSH 1	9/26/2001	0.4	0.3	0.5	0.7	13.1	23.9	19.3	30.44	0.05	1
TSH 2	9/26/2001	0.6	0.3	0	0.3	23.6	10.8	17.8	5.93	0.05	1
TSH 3	9/26/2001	0.3	2.2	0	2.2	15.8	11.9	15.3	2.75	0.67	0.8
TSH 4	9/26/2001	0.4	0.3	0.5	0.8	21.4	7.2	15.8	2.36	0.4	0.85
TSH 5	9/26/2001	0.3	0.6	1	1.6	25.9	9.3	18.6	3.51	1.71	0.67
TSH 6	9/26/2001	0.3	1.3	0.4	1.7	20.7	9	18.7	2.6	0.66	0.8

Sample ID	Sampling Date	POC ug/L	POC uM C	PON ug/L	PON uM N	C/N
TSH 1	7/2/2001	516.3	43.03	95.31	6.81	6.32
TSH 2	7/2/2001	429.9	35.83	73.89	5.28	6.79
TSH 3	7/2/2001	344.3	28.69	68.91	4.92	5.83
TSH 4	7/2/2001	259.4	21.61	56.45	4.03	5.36
TSH 5	7/2/2001	306.5	25.54	58.81	4.2	6.08
TSH 6	7/2/2001	266.2	22.18	60.63	4.33	5.12
TSH 1	7/30/2001	577.2	48.1	87.82	6.27	7.66
TSH 2	7/30/2001	359.9	29.99	67.89	4.85	6.18
TSH 3	7/30/2001	261.6	21.8	42.21	3.02	7.23
TSH 4	7/30/2001	273.6	22.8	50.62	3.62	6.3
TSH 5	7/30/2001	293.4	24.45	46.64	3.33	7.34
TSH 6	7/30/2001	379.4	31.61	78.52	5.61	5.63
TSH 1	9/12/2001	2437	203.1	230.6	16.47	12.3
TSH 2	9/12/2001	1042	86.81	120.6	8.61	10.1
TSH 3	9/12/2001	866.9	72.24	127.3	9.09	7.94
TSH 4	9/12/2001	285.1	23.76	32.47	2.32	10.2
TSH 5	9/12/2001	983.6	81.97	114.7	8.2	10
TSH 6	9/12/2001	373.1	31.09	65.61	4.69	6.63
TSH 1	9/26/2001	4998	416.5	628.5	44.89	9.27
TSH 2	9/26/2001	894.1	74.51	93.31	6.67	11.2
TSH 3	9/26/2001	388.7	32.39	62.9	4.49	7.21
TSH 4	9/26/2001	256.7	21.39	24.57	1.76	12.2
TSH 5	9/26/2001	832.2	69.35	76.78	5.48	12.6
TSH 6	9/26/2001	271.2	22.6	20.59	1.47	15.4