Town of Acushnet
Acushnet, MA

Diagnostic/Feasibility Study of New Bedford Reservoir, Acushnet, Massachusetts

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ENSR INTERNATIONAL

December 2002
Document Number 8734-675

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1.0 EXECUTIVE SUMMARY

The Department of Environmental Management (DEM) has responded to concern over the condition of New Bedford Reservoir by providing a matching grant to the Town of Acushnet for a water quality management and improvement study. The purpose of the present project is to assess pond conditions, determine causative influences, and evaluate the feasible options for the rehabilitation and protection of the pond. Identified issues of concern in New Bedford Reservoir include excessive rooted plant growth, concern over pathogens related to waterfowl and watershed nutrient loading.

During 2002 ENSR investigated the physical, chemical and biological features of the Reservoir and its drainage area. New Bedford Reservoir is a 210-acre, four-pond system located in the Town of Acushnet, MA. The Reservoir system contains approximately 1078 acre-feet of water. It receives water from a 4160-acre predominately rural watershed located in the Towns of Acushnet, Rochester and Freetown. Overall, New Bedford Reservoir has many desirable attributes, but appears to be in sub-optimal condition for its desired uses.

Rooted plant growths present the major impediment to optimal habitat and recreational uses, and are dominated by two species with high nuisance potential. Management techniques could control these growths on at least a maintenance basis. Substantial plant growth is expected, however, in the expansive deposits of organic sediment located in shallow areas. The effective load of phosphorus exceeds the limit for optimal water clarity and quality, and is close to the limit for continual and severe productivity problems. Algal blooms were not observed, probably a consequence of light limitation, low phosphorus availability, and dense rooted plant growth. Although pathogenic bacteria were not assessed as part of the scope for this study, they have been an issue in the past.

These distinct problems relating to New Bedford Reservoir should be addressed if conditions are to be made consistent with desired use as a contact recreation resource.

Potential management actions with regard to control of rooted plant growths include a drawdown of the Reservoir. An initial drawdown of approximately 3 ft to assess Reservoir and plant response is recommended prior to a larger drawdown. Additional investigations into how much of a drawdown the outlet structure can support and potential affects on Reservoir users should be completed prior to a drawdown. A separate feasibility study may be necessary, as the number of considerations associated with planning, permitting and implementing a drawdown are many. The cost of planning and permitting would be on the order of $15,000.

The use of benthic barriers in limited areas of the North Pond to provide swimming and boating access and/or boat lanes within the Pond is a potential option for rooted plant control. A cost on the order of $40,000/acre for capital cost is to be expected, but this will provide material that is expected to last at least a decade.

Watershed management techniques to decrease nutrient loading to the Reservoir can take many forms, but should focus on abatement of storm water runoff. All possible actions to restrict further loading are recommended, including full application of the Wetlands Protection Act, the Riverways Act, and the Massachusetts Storm Water Policy in association with new or existing development projects. Limiting storm water runoff can best be accomplished by detention and infiltration facilities, but care should be taken to look for passive opportunities to detain and filter storm water, rather than taking a more involved and expensive engineering approach. A follow up survey to suggest a list of target areas and their relative priority would be appropriate.

Avian management focusing on keeping waterfowl away from swimming and boat access areas can be done in a variety of ways, generally by altering habitat in target areas to be less hospitable to waterfowl. Temporary fencing could be erected at access points during periods of limited use (fall through early spring). The fencing could be removed for the summer or on a daily basis. A cost on the order of $5000 is envisioned. The primary alternatives include trained dogs that chase waterfowl and noisemakers used to scare waterfowl, both of which have distinct drawbacks that may limit utility in this case. Selective plantings may be applicable in areas less actively used by humans.

This study represents the first comprehensive effort to develop a management plan for New Bedford Reservoir. The size of the system and complexity of its problems will necessitate further investigation and suggest that a phased approach to management is appropriate. Determination of the priority of uses and goals for Reservoir condition should be performed by the Town of Acushnet. This will help shape priorities for management. With what is known now of conditions and desired uses, it appears that management of rooted plants on at least a localized scale at beaches and boat launches has a high priority, followed by management of waterfowl and any other sources of bacteria and associated pathogens. Nutrient loading reductions, while important to long-term management, do not appear to require immediate reduction to meet perceived current use goals.

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2.0 INTRODUCTION

New Bedford Reservoir is a 210-acre, four-pond system located in the Town of Acushnet, MA. The watershed of 4160 acres is located in the Towns of Acushnet, Rochester and Freetown. The Keene River, Squam Brook and various wetland and cranberry bog areas drain the Reservoir watershed, which is a sub-watershed of the Buzzards Bay watershed. The predominantly rural watershed is comprised of forest, cranberry bogs, wetlands and residential housing. Several new roads and housing developments have been constructed in the past 10 to 15 years, especially near the South Reservoir basin. Industrial development in the watershed is light, but there are some barren areas associated with construction or mining. It is likely that these areas are associated with cranberry bog operations as most are near or adjacent to bogs.

New Bedford Reservoir has excessive growth of aquatic macrophytes, including one introduced species, variable milfoil (*Myriophyllum heterophyllum*). The colonization and excessive growth by aquatic plants have contributed to declining recreational and ecological values of the pond. Additionally, sampling by the town has recorded elevated levels of *Escherichia coliform* (E.Coli) and Enterococci.

The Department of Environmental Management (DEM) has responded to concern over the pond's condition by providing a matching grant to the Town of Acushnet for a water quality management and improvement study. ENSR was contracted to perform this investigation. The purpose of the present project is to assess pond conditions, determine causative influences, and evaluate the feasible options for the rehabilitation and protection of the pond.

3.0 WATERSHED HISTORY AND USE

3.1 History of Land and Pond Use

New Bedford Reservoir is located in the Town of Acushnet, Massachusetts, while the watershed extends into both the Towns of Freetown and Rochester. The Reservoir was created in 1869 by the construction of a dam on the headwaters of the Acushnet River, which discharges into New Bedford Harbor and ultimately into Buzzards Bay. The New Bedford Reservoir has also been known as Old New Bedford Reservoir, Acushnet Reservoir, Old Acushnet Storing Reservoir and Lake Street Pond. The water rights to the reservoir are owned by the City of New Bedford. The Town of Acushnet is currently in negotiations with the City to acquire the water rights to the Reservoir.

The Reservoir was originally created as a water supply reservoir for the City of New Bedford, although it has not been used for this purpose since 1899 (C.Kennedy pers. comm.) The multiple water bodies that comprise the Reservoir were also used to augment industry in the area, with the 1970s as the last recorded use. In July of 1959, the Reservoir was opened to public fishing by agreement between the New Bedford Water Works and the then Division of Fish and Game. The current uses of the Reservoir include fishing and boating. In the past the ponds were also used for swimming, but not since the 1970's. Numerous cranberry bogs also use the Reservoir for irrigation purposes.

Public access to the Reservoir is readily available on Lake Street where there are two sizable public parking lots with unimproved boat ramps to both the North Pond and the Northeast Pond. Shoreline fishing access to all four ponds is also available on Lake Street. Recently, The Town of Acushnet has purchased an area known as the Quaker Wells Conservation Land with access to the North Pond.

3.2 Previous Studies

The Department of Fisheries and Wildlife (DFW) in 1960 determined bathymetry of each of the four ponds. Data generally match those found by ENSR during their summer 2002 survey. The DFW study noted a flow of 25-30 gallons/minute at the inlet at Keene Road, values greater than the 12 gallons/minute noted during the ENSR study. The northern half of the North Pond was reported by the DFW to be heavily covered with emergent and submerged vegetation and it was difficult to tell the end of the pond from wetland areas. Several large ditches (3-4 ft deep and 10-25 ft wide) for cranberry bog use were noted along the shores of the North Pond. The muck bottom was determined to be from 2-4 ft in most areas of the upper reaches of the North Pond.

The Northeast Pond was reported to be about 50% open with dense submerged vegetation and 50% covered with emergent vegetation, with an emergent wetland on the east and north side. This pond discharges to the South Pond. The small Southeast Pond was mostly open water with dense submerged vegetation. The Pond discharged into adjacent cranberry bogs and then drained into the main South Pond section. During the 1960 DFW study, the elevation of the Southeast Pond appeared to be 2 or more feet about the main South Pond section. The South Pond contained 98% open water with no emergent wetland areas along the shore. Submerged vegetation was visible in shallow areas only. The findings of this study are similar to those of the ENSR 2002 plant survey.

Macrophyte and fish population surveys were completed by the Department of Environmental Protection (DEP) in 2000. The DEP macrophyte density map is similar to ENSR's 2002 survey. A total of 13 plants were found during the DEP study: *Wolffia sp.* (watermeal), *Utricularia sp.* (bladderwort)*, Nuphar sp*. (yellow water lily), *Nymphaea sp*.(white water lily*), Pontederia cordata* (pickerelweed), *Brasenia schreberi* (watershield), *Juncus sp.* (rush), *Myriophyllum heterophyllum* (variable milfoil), *Potamogeton robbinsii* (Robbins or ribbonleaf pondweed), *Potamogeton natans* (floatingleaf pondweed*), Potamogeton richardsonii* (Richardson's pondweed), *Typha latifolia* (cattail)*, and Potamogeton amplifolius* (broadleaf pondweed). The ENSR survey in 2002 identified 17 submerged macrophytes and 5 emergent aquatic plants. ENSR found all plants identified by the DEP except for *Potamogeton richardsonii* and *Potamogeton amplifolius*. Both were only found at one site each in the DEP study.

The fish survey completed by the Massachusetts DFW in 2000 identified herring (*Alosa sp*.), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), chain pickerel (*Esox niger*), golden shiner (*Notemigonus crysoleucas*), largemouth bass (*Micropterus salmoides*), pumpkinseed (*Lepomis gibbosus*), unidentified sunfish (*Lepomis sp.*), white perch (*Morone americana*) and yellow perch (*Perca flavescens*) in the North Pond. Basic water quality information for an un-named part of the pond, most likely the North Pond, recorded temperatures that decreased from a high at the surface of 23 °C to a low of 20.0 °C at 9 ft. The dissolved oxygen concentration decreased from 6.1 mg/L at the surface to 0.4 mg/L at 9 ft. A copy of this report is provided in the Appendix A.

Nutrients were collected from the culvert at Lake Street by the Coalition for Buzzards Bay (CBB) during 4 dates in 2001 and 2000. Data are attached in Appendix A. Data exhibit low levels of nutrients that are generally the same as those noted during the ENSR study for total phosphorus and total nitrogen. CBB ortho-phosphorus detection limits were lower than those obtained by the laboratory to which ENSR sent samples and therefore they were able to quantify ortho-phosphorus to lower levels. The average CBB ortho-phosphorus value was 0.0032 mg/L and the ENSR value was generally below the detection limit (0.01 mg/L). The Coalition for Buzzards Bay collects yearly samples from many bays and lakes in the Buzzards Bay watershed to provide long term environmental data required for the protection and remediation of coastal waters.

4.0 STUDY APPROACH

4.1 Physical Characteristics

4.1.1 Watershed Features

Field investigations and United States Geological Survey (USGS) 7.5 minute topographic maps were used to delineate the watershed draining to New Bedford Reservoir. Drainage patterns were used to further divide the watershed into sub-basins. Major land use categories in the watershed were obtained from the Massachusetts Geographic Information System (MASS GIS). Land use data were based upon aerial photographs recorded in 1999. Pond areas were determined from land use data.

4.1.2 Lake Features

For the purposes of this study the four ponds that make up the New Bedford Reservoir were referred to by their geographic orientation to one another (Figure 4-1). Water depth, sediment type and sediment depths in each pond were determined during a field survey. A graduated metal rod was used to measure water depth and soft sediment depths at 66 survey points on the North Pond, 47 survey points on the South Pond and 21 survey points on the Northeast pond. Plant biovolume and cover were also recorded at each survey point. Survey transects were spaced from approximately 160 to 850 ft apart (Figure 4-2). No transects were completed in the Southeast Pond and the upper reaches of the North Pond due to excessive plant growth. The north section of the Northeast Pond was inaccessible due to floating islands of lilies.

The resulting bathymetric map was used to determine average water depth, maximum water depth, and total lake volume. Benthic substrate composition and depth were evaluated by probing the lake bottom with a metal rod. Sediment depth was measured in areas where the total depth (water plus sediment) was less than 10 ft.

Inlets, outlets and cranberry bog drainage were identified from field investigations and review of USGS 7.5 minute topographic maps. Tributary and outlet flow measurements were estimated during field visits.

Hydrologic loading was determined using actual measurements and estimated values based on watershed and lake features. Hydrologic inputs were divided into three categories: direct precipitation, surface water base flow, and surface water runoff. Average annual precipitation was estimated from the nearby Cranberry Experiment station in West Wareham, which has a long-term data set. Direct precipitation was estimated by multiplying average annual precipitation by the total lake area. Surface water base flow and runoff flow were estimated for each sub-basin by multiplying average annual precipitation by selected runoff and base-flow coefficients relating to land use.

New Bedford Reservoir
Figure 4-1: Water Quality Sampling Locations

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New Bedford Reservoir
Figure 4-2: Bathymetry, Soft Sediment and Plant Survey Points and Transects

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4.2 Chemical Characteristics

Surface water sampling was conducted on two occasions during the summer: June 19th and August 6th, 2002. The first sampling event occurred 2 days after a rain event and the second 7 days after a rain event. Lake level was estimated to have dropped 1 ft between the first and second sampling events. This was probably due to minimal precipitation, withdrawal from the reservoir to irrigate cranberry bogs adjacent to the reservoir, minimal tributary inflow and evaporation. During the first sampling event estimated flow at tributary station NBR7 was 12 gallons per minute, while during the second sampling event there was no flow.

Sampling was conducted at three locations in the North Pond, one in each the Northeast and South Ponds and one tributary (Figure 4-1). The small Southeast Pond was not sampled because of excessive plant growth. Measured in-lake parameters included; dissolved oxygen, temperature, pH, specific conductance, secchi transparency, turbidity, total alkalinity, nitrate and nitrite (06 August only), ammonia, total Kjeldahl nitrogen, total phosphorus and ortho-phosphorus. Dissolved oxygen, temperature, and specific conductance were determined using a YSI field meter. During the June sampling event pH was measured using a YSI field meter, and in August pH was determined using a Hach test kit. Turbidity was determined using a Hach turbidity meter. Secchi transparency was measured using a secchi disk. The remaining parameters (total alkalinity, nitrate and nitrite, ammonia, total Kjeldahl nitrogen, total phosphorus and ortho-phosphorus) were measured by Berkshire Envio-labs.

During the first field effort data were collected for dissolved oxygen, temperature, specific conductivity and pH every 1-2 ft from the surface of the pond to 1 ft from the bottom of the pond. This allowed depth gradients of dissolved oxygen, temperature, specific conductivity and pH to be detected. During the second sampling effort dissolved oxygen and temperature were taken at 1-2 ft intervals while pH and specific conductance were taken at surface and bottom at each site, because of the more homogeneous water column observed during the second sampling event. Turbidity samples were taken at the surface and bottom for sites greater than 7.0 ft and at mid-depth for shallower sites during both sampling dates.

The tributary samples were analyzed for the same parameters as the in-lake samples, with the addition of total suspended solids. Secchi depth for the tributary was not determined due to the shallow nature of the stream.

Nitrogen and phosphorus loading to New Bedford Reservoir was determined using a land use export coefficient model and an empirical model. The land use model uses nutrient export coefficients for land use types, tempered by known attenuation mechanisms, specific watershed features, and existing data, to predict nutrient loading. The model can be used to predict the impact of various management actions on in-lake water quality. The model was developed by ENSR as a spreadsheet that can be adapted to various uses, and incorporates the predictive capability of empirical models and the reality checks afforded by actual data for the target system.

The empirical models use hydrologic lake features and known in-lake concentrations to back-calculate the load that would yield the observed concentrations. A variety of such models are available; we have chosen a single three-part nitrogen model (Bachman, 1980) and several phosphorus models that tend to represent the range of possible conditions (Kirchner and Dillon, 1975; Vollenweider, 1975; Reckhow, 1977; Larsen and Mercier, 1976; and Jones and Bachman, 1976).

4.3 Biological Characteristics

Phytoplankton and zooplankton were collected from two locations, one in the North Pond (NBR5) and one in the South Pond (NBR4). Phytoplankton were collected as an integrated sample from the surface to the end of the photic zone, generally 3 x the secchi depth. At both stations the total depth was within the photic zone so the integrated sample consisted of water from the surface to the bottom of the Pond. Phytoplankton samples were preserved with Lugol's solution and identified in the laboratory under phase contrast optics at 400x magnification. Cell counts were converted to biomass based on size and species-specific biovolumes using a specific gravity of 1.0

Zooplankton were collected by towing a net with a mesh aperture of 53 micrometers through 30 meters of water, resulting in a concentrated sample representing 948 liters of lake water. Samples were preserved with formalin and identified in the laboratory under brightfield optics at 40X to 100X magnification to determine types, abundance and size of zooplankters present. Organism counts were converted to biomass based on size and species-specific relationships.

The aquatic vascular plant community was surveyed on August 6^{th} and 7^{th} of 2002 concurrently with the water/sediment depth survey and the second water chemistry survey. An underwater camera was used to view and identify the submerged plant community. At each station plant species present, plant cover, plant biovolume, water depth, soft sediment depth and sediment type were recorded. Plant biovolume was defined as the percentage of the water column from the bottom to the surface that was filled with plant material. The percentage of pond bottom covered with plants was recorded as plant cover. The percentages of plant cover and biovolume were expressed as a number from 0 to 4. A value of 1 represents a percentage in the range of 1-25%, a value of 2 = 26-50%, a value of 3 = 51-75% and a value of 4 = 76-100%. Absence of plants resulted in a value of zero. Shoreline emergent aquatic plants were also noted if present, but no effort was made to quantify the number of these plants along the shore.

5.0 STUDY RESULTS

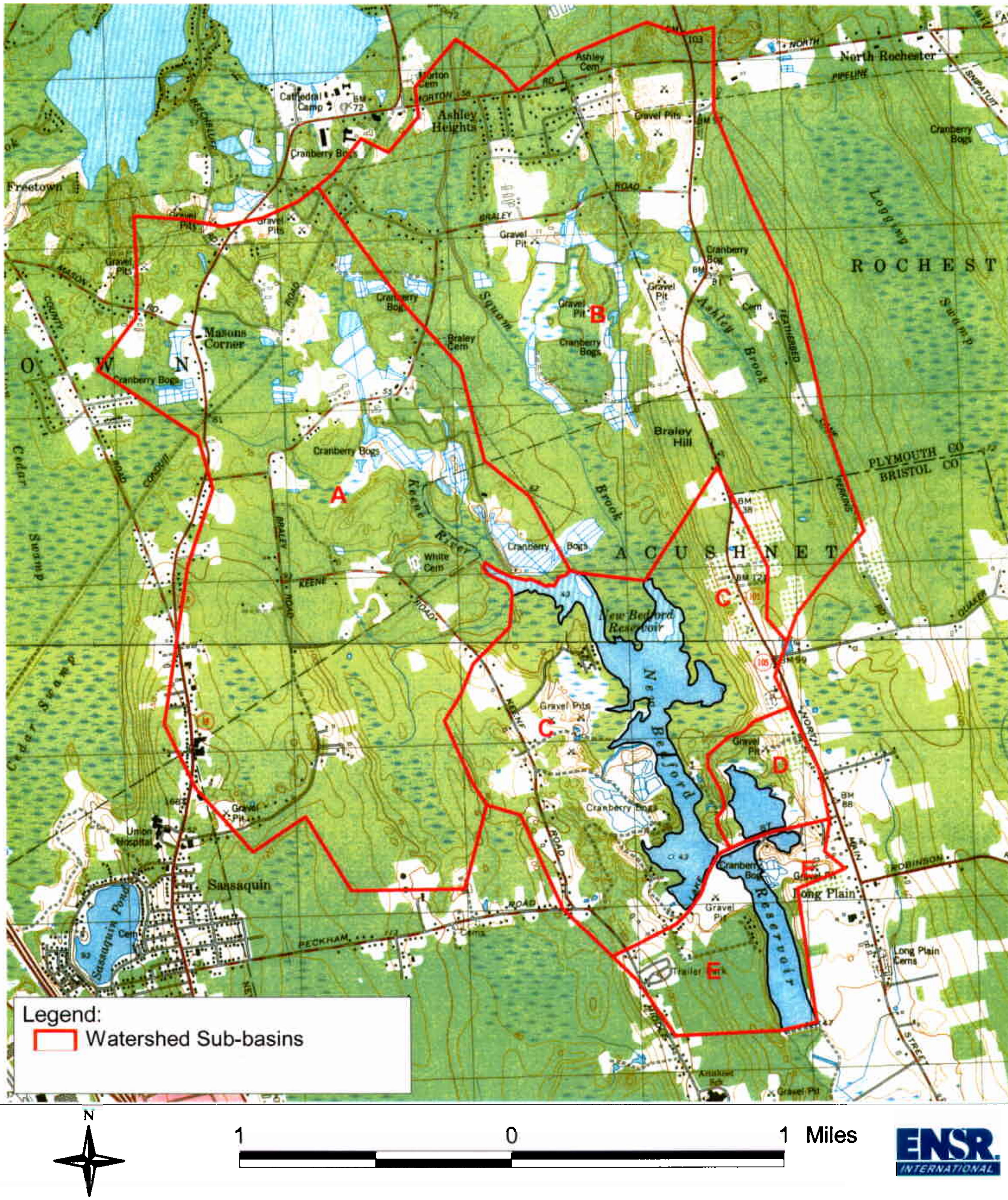
5.1 Watershed Features

The watershed draining to New Bedford Reservoir is approximately 4160 acres in size. Five sub-basins were delineated within the watershed and differentiated on Figure 5-1 as A, B, C, D and E. Sub-basin A (1666 acres) is drained by the Keene River and a smaller tributary to the south, sub-basin B (1567 acres) is drained by Squam Brook, sub-basin C (658 acres) drains directly into the North Pond, sub-basin D (74 acres) drains directly into the Northeast Pond and sub-basin E (195 acres) drains directly into the South Pond.

Mass GIS designations (LU21_codes) for each type of land-use were consolidated into larger descriptions to allow use of this information in the nitrogen and phosphorus export coefficient model discussed earlier. For the purposes of the model, there are 11 different categories (Table 5-1 & Figure 5-2). Due to the large amount of cranberry bogs located in the watershed, this landuse category was listed separately in Table 5-1, although in the model it was placed in the category of open 1 (wetland/lake). The area of the small plant infested Pond (Southeast Pond) was placed into the open 1 (wetland/lake) category and included as part of sub-basin E for the model.

The New Bedford Reservoir watershed is relatively undeveloped with 56% of watershed classified as forest and 20% as residential (14% low density). The balance of the land is agricultural, open land and a small percentage (<2%) is classified as industrial or mining/construction area. Although little of the watershed is developed, within the last 10 years several developments have been constructed, especially in the South Pond watershed (Sub-basin E). About 78% of sub-basin E is classified as residential, in comparison to 13-19% in sub-basins A, B, C and D.

New Bedford Reservoir
Figure 5-1: Watershed Boundary and Sub-Basins



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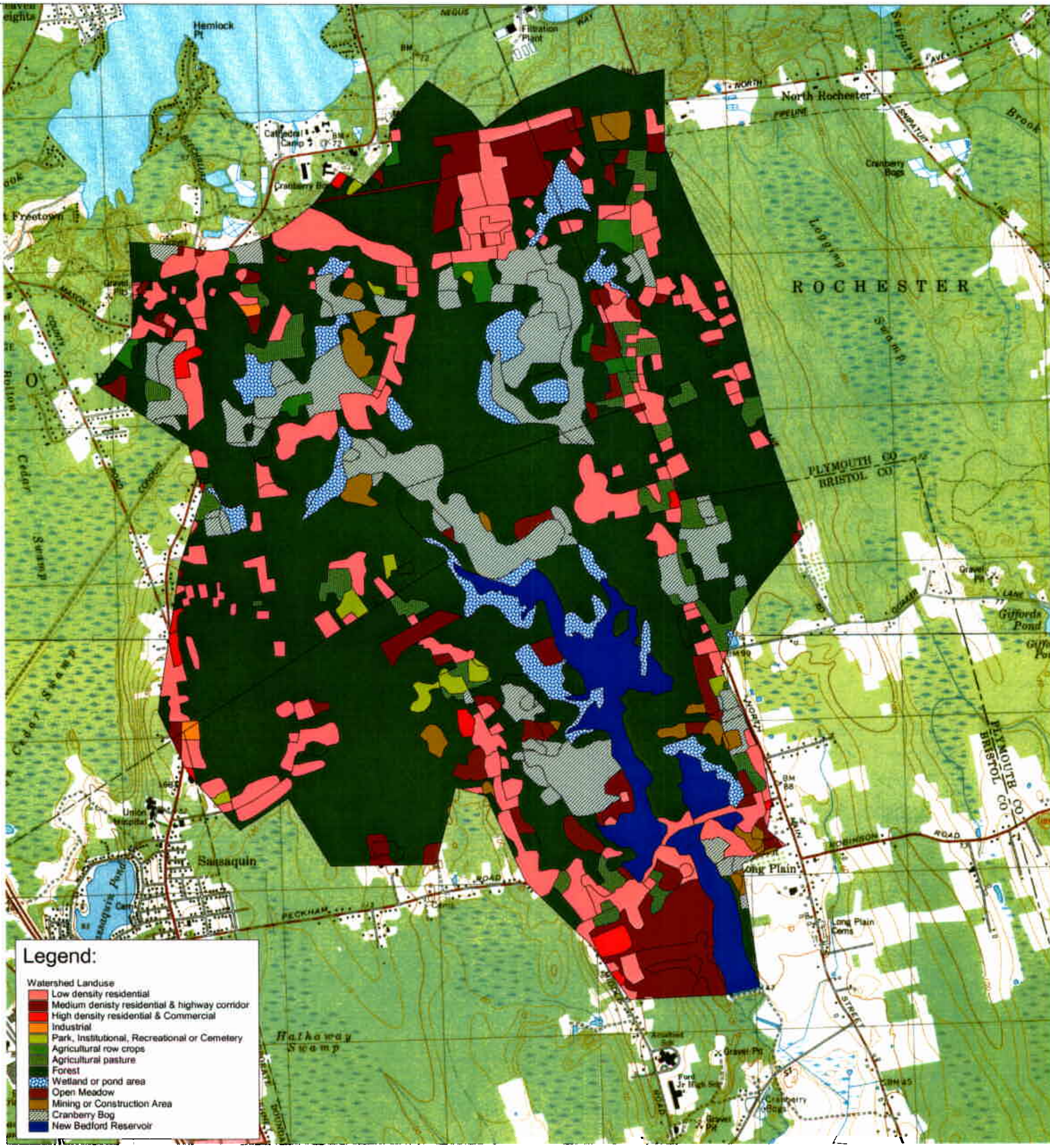
New Bedford Reservoir
Figure 5-2: Watershed Landuse



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Watershed Land-use from MASS GIS
NAD83 MA State Plane in m

Table 5-1 - New Bedford Reservoir Land Use by Watershed Sub-Basin

			Sub-basin	A	B	C	D	E		
Value	Abbreviation	Land Use Description	MASS GIS (LU21_CODE)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Area (HA)	Total (HA)	% of Total area
1	Urban 1 (LDR)	Low density residential (>1 acre lots)	13	87.3	91.2	36.2	4.1	18.5	237.3	14.1
2	Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 acre lots) and highway corridors	12,18	10.6	28.7	6.1	0.0	39.0	84.4	5.0
3	Urban 3 (HDR/Com)	High density residential (<0.3 acre lots) and commercial	10,11,15	4.3	0.6	2.3	0.0	4.4	11.7	0.7
4	Urban 4 (Ind)	Industrial	16	2.2	0.0	0.0	0.0	0.0	2.2	0.1
5	Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	7,8,17	5.3	1.7	5.7	0.0	0.0	12.7	0.8
7	Agric 2 (Row Crops)	Agricultural with row crops (some bare soil)	1	3.6	11.9	0.0	0.0	0.0	15.5	0.9
8	Agric 3 (Grazing)	Agricultural pasture with livestock	2	17.4	21.9	13.6	2.3	3.4	58.6	3.5
10	Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	3	429.2	366.6	128.0	7.9	3.2	934.9	55.5
12	Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	4,14,20,9	24.1	26.5	19.1	5.1	1.4	76.2	4.5
13	Open 2 (Meadow)	Open meadow area (not clearly wetland, but no canopy)	6	7.2	15.5	15.4	3.5	1.4	43.0	2.6
14	Open 3 (Barren)	Mining or construction areas, largely bare soils	5	10.9	4.8	3.6	3.6	3.3	26.1	1.6
16	Other 2	Cranberry bog	21	72.2	64.8	36.2	3.6	4.3	181.1	10.8
		Total	(HA)	674.4	634.1	266.2	30.0	79.0	1683.7	100.0
			(acres)	1666.4	1566.9	657.7	74.2	195.2	4160.4	

Note: SE basin considered open wetland in this table

5.1.1 Morphometry

Water depth was recorded at 66 survey points on the North Pond, 47 survey points on the South Pond and 21 survey points on the Northeast Pond. Tabular survey data is provided in Table 5-10 and survey points/transect locations are presented in Figure 4-2. Bathymetric contours are presented in Figure 5-3.

New Bedford Reservoir is approximately 210 acres in total size (Table 5-2). The North Pond is approximately 138 acres, the Northeast Pond: 21 acres, the South Pond: 47 acres and the Southeast Pond: 3 acres. The computed watershed : lake area ratio is 20:1. This is a moderate ratio, indicating that land use may be an important determinant of water quality. Average and maximum water depths recorded during the field surveys were 5 ft and 8.9 ft, respectively for the North Pond, 6 ft and 12 ft, respectively for the South Pond and 5 ft and 6.8 ft, respectively for the Northeast Pond. All volumetric calculations are estimates based upon average depths. Total lake volume is approximately 1078 acre-feet for the entire complex.

Table 5-2 - New Bedford Reservoir Pond Area and Volume

Pond	Pond Area (HA)	Pond Area (Acres)	Pond Volume (Acre-feet)
North	55.9	138.2	680.0
Northeast	8.6	21.3	104.9
South	19.1	47.3	279.2
Southeast	1.4	3.4	13.6
Total	85.1	210.2	1077.7

5.1.2 Benthic Sediment Quantity

Benthic sediment type (e.g. sand, muck or rock) and sediment depth were recorded at the bathymetric survey points (Table 5-10 & Figure 4-2). Benthic sediments were comprised mostly of muck and sand. Average and maximum sediment depths recorded during the field surveys were 1.5 ft and 4.4 ft, respectively for the North Pond, approximately 0.8 ft and 2.5 ft, respectively, for the South Pond and 1.9 ft and 3.2 ft, respectively, for the Northeast Pond. Soft sediment depths were determined to a combined water and soft sediment depth of 10 ft.

Generally soft sediment depths were not excessive (Figure 5-4). The nature of the sediment type (muck with sand and gravel) indicates most of the sediment is related to plant growth. Dense rooted plant production over many years provides large amounts of organic matter that can settle to the bottom and gradually fill a pond. Some organic matter is undoubtedly passed downstream from wetland areas and cranberry bogs in the watershed as well.

New Bedford Reservoir
Figure 5-3: Water Depth (Bathymetry)

Legend:

Water Depth in ft

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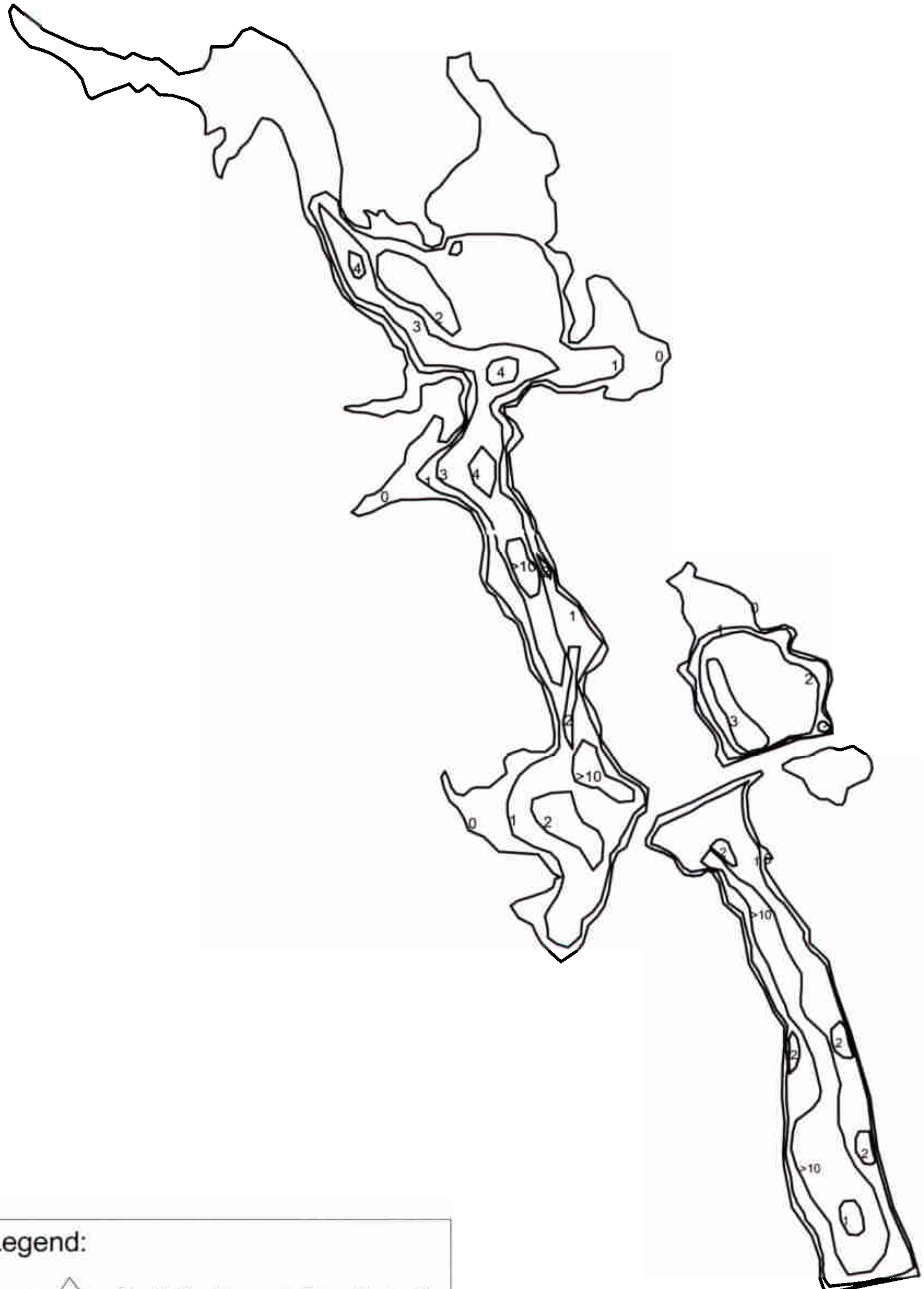
New Bedford Reservoir
Figure 5-4: Soft Sediment Depth



Legend:

Soft Sediment Depth in ft

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5.1.3 Hydrology

Three tributaries (Figure 5-1) discharge to the North Pond of New Bedford Reservoir. The Keene River and an un-named tributary to the western arm and Squam brook to the eastern arm of the North pond. No other tributaries discharge to the system, although inlet ditches and pump houses to irrigate cranberry bogs located on both the North and South Ponds were visible. The North Pond discharges to the South Pond through a culvert under the road. The Northeast Pond appears to discharge to the South Pond through a culvert as well. There was no direct communication between the Northeast and Southeast Ponds visible. Historic reports note a cranberry bog irrigation intake structure on the Southeast Pond, although it was not visible during the ENSR survey. The Reservoir outlet consists of a dam controlled by flashboards at the southern end of the South Pond. Dam flow is regulated to allow herring passage in the spring. Below the dam, the system becomes the Acushnet River, draining into New Bedford Harbor and ultimately into Buzzards Bay.

Flow at the un-named stream located on the western arm of the North Pond at station NBR7 was 12 gallons per minute during the first sampling event and during the second event there was no flow. The other two tributaries were not accessible near the pond because of wetland areas, private property and no nearby road access. The summer of 2002 was considered to be extremely dry. Lack of precipitation and withdrawals for cranberry bog irrigation from either the tributaries or wells that affect the tributaries could have contributed to the no-flow conditions seen in August.

5.1.4 Hydrologic Loading

Estimated hydrologic loading to the New Bedford Reservoir system (Table 5-3) was derived from the land use export coefficient model. Direct precipitation was estimated assuming average 10-year precipitation conditions (Cranberry Experiment Station, West Wareham, MA). Surface water load includes both runoff and baseflow and contributes the most to each pond.

According to morphometric features and hydrologic data, the North Pond has a flushing rate of 11 times/yr, the Northeast Pond 2 times/yr and 31 times/yr for the South Pond. The flushing rate is the actual number of times in a given year that the entire water volume could be replaced by inputs. The inverse of flushing rate is detention time or the average length of time that water remains in the lake. The detention time for the North Pond is estimated to be 0.09 years (33 days), 0.5 yrs (182 days) for the Northeast Pond and 0.03 yrs (12 days) for the South Pond. However, prolonged detention is expected during extended dry periods, such as those observed in 2002.

Table 5-3 - New Bedford Reservoir Estimated Hydrologic Loading

Pond	Direct Precipitation (m^3/yr)	Surface Water (m^3/yr)	Total (m^3/yr)
North	670,800 (7%)	8,800,738 (93%)	9,471,583
Northeast	103,200 (37%)	177,163 (63%)	280,363
South	229,200 (2%)	10,325,305 (98%)	10,554,505

Note: This assessment assumes that ground water seepage is largely accounted for by baseflow, which is part of the surface water load as estimated here.

5.2 Chemical Characteristics

5.2.1 Surface Water Chemistry

Water quality monitoring locations are presented in Figure 4-1. Values for field parameters (temperature, dissolved oxygen, specific conductance, pH, turbidity and secchi depth) are presented in Table 5-4. Values for laboratory water quality parameters (alkalinity, nutrients and total suspended solids) are presented in Table 5-5.

Dissolved oxygen (DO) is the amount of oxygen dissolved in the water column. Values below 5.0 mg/L are generally considered undesirable for many species of aquatic life. Low oxygen (<1.0 mg/L) or anoxic (no oxygen) conditions may cause fish and benthic organisms to die and/or release of phosphorus from benthic sediments. Dissolved oxygen was lowest during both sampling events at station NBR6. This station was located in dense aquatic macrophytes and was sampled in the early morning on both sampling dates. Often, dissolved oxygen values are low in the morning due to plant respiration. During the night plants take in oxygen, dropping DO levels, and then build-up oxygen levels during the day through photosynthesis. The North Pond exhibited the lowest DO values in the Reservoir system during both sampling events. The North pond also had the most intense macrophyte growth in the system, potentially one of the reasons for low DO values. During the second sampling event, when water temperatures were fairly high (up to 26.8 °C), surface DO still maintained at least 80% saturation in both the Northeast and South Ponds. In contrast, the DO in the North Pond was less than 50% of saturation at each site, with site NBR6 having a saturation of only 14.6%. Stations in both the Northeast and South Pond exhibited minimal DO change with depth, with DO levels greater than 4.5 mg/L at the bottom of the pond (up to 11 ft for the South Pond). In contrast, the North Pond exhibited stratification in regards to DO, with values near zero at the bottom of the Pond at each site. The tributary exhibited high oxygen values for the June sampling as the stream was flowing, and lower DO (5.4 mg/L) during its stagnant period. This was expected since decomposition can overwhelm aeration in stagnant waters.

The temperature regime of an aquatic ecosystem is important in determining community structure. Temperatures in excess of 20 °C are stressful to coldwater fish (such as trout), while temperatures greater than 28-30 °C are stressful to most fish species. Tributary temperatures ranged from 14.0 to 20.0 °C. During the first tributary sampling the stream was flowing and during the second sampling there was no flow, allowing for stream temperatures to rise in the sampled pool. During the June sampling event temperature stratification was apparent in all three Ponds sampled, but in August no stratification was detected. Early spring temperatures ranged from 18-21 °C at the surface to 15-19 °C near the bottom. During the August sampling, the temperature ranged from 22-27 °C, with the lowest temperatures at site NBR6. There was a general pattern of increasing temperature from the northern half of the North Pond to the South pond. This pattern was most likely due to heat absorption as water moved from the North Pond to the South Pond and out the dam. The stained color of the Reservoir water also allows for greater heat absorption from sunlight, especially near the surface. The shallow nature of the ponds allows for mixing during wind events, generally keeping the pond unstratified.

The pH of the reservoir is a measure of it's acidity. It is measured in Standard Units (SU) with 7.0 as neutral, 1 as extremely acidic and 14 as extremely basic. Average North Pond values were 6.0 S.U. during both sampling events, while in the South Pond the pH averaged 6.0 S.U. in June and 6.9 S.U. in August. The pH in the Northeast Pond averaged 6.9 S.U. and 7.1 S.U. during the June and August sampling events, respectively. In the tributary, pH was 5.4 S.U. in June and 6.3 S.U. in August. Biological activity will raise pH levels in a water body as plant photosynthesis and algal blooms take up CO_2, an acidic molecule. Values seen in the Reservoir system are not abnormal.

Total alkalinity is a measure of buffering capacity or the ability of water to neutralize acids. Mean values for the North and South Ponds ranged from 7 to 12 mg/L during the June and August sampling events. In the Northeast Pond alkalinity were 18 and 24 mg/L during the June and August sampling events, respectively. Tributary alkalinity values were 4 and 7 mg/L during June and August sampling events, respectively. Values greater than 20 mg/L are generally indicative of waters that are well buffered and not highly susceptible to acid precipitation. The higher alkalinity values for the Northeast Pond probably allow for the more neutral pH's seen in the pond, but are not entirely consistent with area geology and soils. The alkalinity and pH values exhibited in the other ponds are more typical. The reason for differing values in the Northeast Pond is unknown.

Specific conductance is a measure of the amount of dissolved solids in the water column. Average ranges for the conductance during both sampling events in the North and South Ponds were 88-105 uS/cm and 49-69 uS/cm at the tributary. In the Northeast Pond, average specific conductivity values ranged from 140-169 uS/cm. Generally, values less than 100 uS/cm are indicative of infertile conditions and values in excess of 300 uS/cm are considered high enough to warrant investigation of the source of the dissolved solids that impart conductivity to the water. Values recorded in the Reservoir system are not abnormal.

Turbidity is a measure of the amount of particulate matter in the water column. Mean values ranged from 1.9-2.5 NTU for all the sampling sites including the tributary. Values greater than 10 NTU are cause for some concern in aquatic systems, but the turbidity values for New Bedford Reservoir are low. Extensive plant cover, while a nuisance for recreation and possible habitat impairment, does minimize sediment resuspension and limit turbidity in this shallow system. Total suspended solids (TSS) is a measure of the amount of particulate matter in the water column as determined by weight. Unlike turbidity which is an optical unit, TSS provides values in the units of mass / volume. TSS samples were collected at the tributary station to evaluate the amount of particulates entering the Reservoir system. TSS values ranged from <1 mg/L to 14 mg/L for the tributary, these values are considered low.

Secchi transparency is a measure of water clarity and also a useful indicator of trophic state. This value is obtained by lowering a circular disk into the water column until it is no longer visible. The most critical time of the year to evaluate Secchi transparency is during the summer, when algal blooms most often occur and recreational use is highest. Measurements less than 6.6 ft (2.0 meters) are generally considered indicative of eutrophic conditions, although non-algal turbidity can also cause Secchi transparency values to decline to low levels. Contact recreation is not encouraged under state law at values <4 ft (1.22 m). Values recorded in New Bedford Reservoir ranged from 2.5-3.5 ft in the North Pond, 4.5-5.0 ft in the South Pond and 5.5-7.0 ft in the Northeast Pond. In the Reservoir system, the brown stained water contributes to the low Secchi disk readings.

Nitrogen and phosphorus are essential plant nutrients. Excessive concentrations in the water column can fuel undesirable growths of algae, and accumulations in the sediment can promote the growth of rooted aquatic plants. The mean concentration of ammonium-nitrogen in all the ponds was 0.02 mg/L for both sampling events. The tributary concentration was <0.01 mg/L (below detection limit) during the flowing period, and slightly higher (0.06 mg/L) during the August sampling event. The elevation was probably due to the stagnation of the system, but all values are low, relative to ecological impacts.

Average nitrate-nitrogen ranged from 0.02 mg/L in the North and Northeast Ponds to 0.04 mg/L in the tributary and South Pond during the June sampling. During the August event, nitrite and nitrate were both assessed and all values were at or below the detection limit (0.01 mg/L). Tributary samples were slightly higher, but this was probably due to stream stagnation; values were still low in terms of ecological effect.

Total Kjeldahl nitrogen (TKN), a measure of ammonium nitrogen and organically bound nitrogen averaged 0.5 mg/L during both sampling events throughout the Reservoir system. As ammonium nitrogen values are low, most of the TKN is organically bound nitrogen, but these values are still low in terms of ecological indications. Nitrogen is not abundant in this system, a situation common to many southeastern Massachusetts aquatic systems with limited watershed development.

Concentrations of ortho-phosphorus, or readily available phosphorus, were at or below the detection limit (0.01 mg/L). Concentrations of total phosphorus (dissolved plus particulate) averaged 0.03 mg/L during both sampling events for all the ponds. Total phosphorus was elevated during the second tributary sampling, possibly due to the stagnant conditions. Values of total phosphorus exceeding 0.025 mg/L are generally considered elevated. Often in environments with thick plant growth it is difficult to obtain a water column sample without plant particles, and inclusion of such particles in a sample can elevate total phosphorus sample values. This was probably the case at station NBR6, which exhibits the highest total phosphorus value (0.08 mg/L).

The nutrient concentrations in New Bedford Reservoir and the tributary are low. The nitrogen to phosphorus ratio was 18 (N:P) by weight. This moderate N:P ratio does not strongly favor green or blue-green algae, and slight shifts in the N:P ratio over time may cause shifts in the phytoplankton assemblage.

Measurements of DO, specific conductivity, pH, alkalinity and secchi depth exhibit a marked difference between the Northeast Pond and the other ponds in the system (North and South Ponds), although nutrient data are generally the same between ponds. These differences are most likely due to differences in the feed waters between ponds. The Northeast Pond has a small watershed that drains directly into the pond with no tributaries, while the other ponds have larger watersheds and more tributaries.

Table 5-4 - Field Water Quality Parameters

Site	Date	Depth (ft)	Temp.(C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen Saturation (%)	sp. Cond (uS/cm)	pH[2]	Turbidity[1] NTU	Secchi Disk (ft)	Total Depth (ft)	Notes
North Pond											
NBR1	6/19/02	1	19.93	6.99	76.8	82.0	6.3	1.4			
		2	17.71	4.25	44.5	84.0	6.0				
		3	17.03	3.30	33.9	83.0	5.5				
		5	15.93	0.89	8.8	82.0	5.4				
		6	15.90	0.71	7.1	105.0	5.7	2.5	2.5	7.5	
NBR1	8/6/02	1	25.00	3.70	45.7	103.1	6.1	3.2			
		3	25.00	3.90	47.2						
		5	25.00	4.00	49.7						
		7	25.10	2.70	38.0	103.5	6.1	3.3	2.5	6.5	
NBR5	6/19/02	1	20.94	7.12	79.9	81.0	6.4				
		2	16.51	0.78	7.9	84.0	6.2	2.4			
		4	15.10	0.38	4.0	86.0	6.0		3.0	5.0	
NBR5	8/6/02	1	24.70	3.00	36.2	102.0	5.9				
		2	24.60	2.70	32.3	103.1		3.1			
		4	24.00	0.60	7.0	119.4	5.9		2.6	4.3	
NBR6	6/19/02	1	18.97	2.38	24.5	90.0	6.1	1.5			Plants so thick Secchi disk not visible, turbidity may be high due to plant material
		3	17.20	0.36	4.1	104.0	6.2		NA	4.0	
NBR6	8/6/02	1	23.90	1.20	14.6	99.0	5.7	2.0			
		3	21.90	0.20	3.2	104.8	5.9		3.5	4.2	

Table 5-4 – Field Water Quality Parameters (Continued)

Site	Date	Depth (ft)	Temp.(C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen Saturation (%)	sp. Cond (uS/cm)	pH[2]	Turbidity[1] NTU	Secchi Disk (ft)	Total Depth (ft)	Notes
North East Pond											
NBR2	6/19/02	1	21.46	9.26	104.9	140.0	7.3				
		2	21.35	9.28	104.8	141.0	7.3				
		3	21.26	9.35	105.5	140.0	7.2	0.9			
		4	20.65	10.01	111.5	140.0	7.2				
		5	20.17	10.17	112.5	140.0	7.0				
		6	19.42	9.39	98.0	140.0	6.9		7.0	7.0	
NBR2	8/6/02	1	26.80	6.50	83.5	168.0	7.0				
		2	26.80	6.70	83.5						
		3				168.1	7.0	2.1			
		4	26.80	6.50	83.4						
		6.5	26.20	4.60	57.9	172.1	6.7		5.5	6.5	
South Pond											
NBR4	6/19/02	1	21.46	8.13	92.0	88.0	6.5	1.2			
		2	20.99	8.09	90.8	88.0	6.5				
		3	20.67	7.96	88.8	88.0	6.5				
		4	20.46	7.70	85.4	89.0	6.4				
		5	19.56	7.25	78.7	88.0	6.1				
		6	18.66	6.52	69.8	87.0	5.8				
		7	17.98	6.33	67.0	87.0	5.8				
		8	17.79	6.49	68.5	88.0	5.7				
		9	17.61	6.11	63.9	88.0	5.7				
		10	17.39	5.62	58.1	87.0	5.7				
		11	17.20	5.38	55.9	87.0	5.6	1.7	5.0	12.0	
NBR4	8/6/02	1	26.40	7.00	88.0	103.7	7.0	2.2			
		3	26.50	7.10	88.6						
		5	26.50	7.10	89.6	103.7	7.0				
		7	26.50	7.20	91.8						
		10	26.30	6.70	86.6	103.8	6.7	2.6	4.5	10	

Table 5-4 – Field Water Quality Parameters (Continued)

Site	Date	Depth (ft)	Temp.(C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen Saturation (%)	sp. Cond (uS/cm)	pH[2]	Turbidity[1] NTU	Secchi Disk (ft)	Total Depth (ft)	Notes
Tributary											
NBR7	6/19/02		14.04	10.32	100.2	49.0	5.43	1.57		0.5	3 ft wide, 6 inches deep, orange colored, estimated flow 12 Gallons per minute
NBR7	8/6/02		20.40	5.40	58.6	68.7	6.30	2.6		0.5	No flow (0 Gallons per minute), small pool

Notes:

[1]Turbidity was obtained using a Hach turbidity meter

[2]pH was obtained using a YSI field meter on 6/19/02 and a Hach pH test kit on 8/6/02

[3]Physical samples taken using YSI field meters for all other parameters

[4]No samples were taken in the Southeast pond due to excessive plant growth

Table 5-5 - Laboratory Water Quality Data

		North Pond				NE Pond		South Pond		Tributary
Sampling Date: 19-Jun-02		NBR1 Surf	NBR1 Btm	NBR5 Mid	NBR6 Surf	NBR2 Mid	NBR2-Dup Mid	NBR4 Surf	NBR4 Btm	Trib1
Alkalinity	mg/L	7	7	7	6	16	19	8	8	4
Ammonia (as N)	mg/L	0.01	0.02	0.01	<0.01	<0.01	<0.01	0.02	0.03	<0.01
Nitrite (as N)	mg/L									
Nitrate (as N)	mg/L	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.04	0.04	0.04
Total Kjeldahl (as N)	mg/L	0.5	0.4	0.6	0.8	0.4	0.5	0.5	0.4	0.4
Ortho-Phosphorus	mg/L	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Phosphorus	mg/L	0.04	0.02	0.04	0.08	<0.01	0.02	0.02	0.02	0.02
Total Suspended Solids	mg/L									<1

		North Pond				NE Pond		South Pond		Tributary	
Sampling Date: 6-Aug-02		NBR1 Surf	NBR1 Btm	NBR5 Mid	NBR6 Surf	NBR2 Mid		NBR4 Surf	NBR4 Btm	Trib1	Trib1 Dup
Alkalinity	mg/L	12	14	12	10	24		12	12	6	8
Ammonia (as N)	mg/L	0.03	0.02	0.02	<0.01	0.02		0.02	0.01	0.06	0.06
Nitrite (as N)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01
Nitrate (as N)	mg/L	<0.01	0.01	<0.01	<0.01	<0.01		<0.01	<0.01	0.13	0.13
Total Kjeldahl (as N)	mg/L	0.6	0.5	0.5	0.4	0.5		0.4	0.4	0.4	0.5
Ortho-Phosphorus	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	0.02	0.01
Total Phosphorus	mg/L	0.03	0.04	0.03	0.03	0.03		0.02	0.02	0.07	0.08
Total Suspended Solids	mg/L									14	10

Notes: [1] No samples were taken in the Southeast pond due to excessive plant growth

5.2.2 Nitrogen and Phosphorus Loading

Nitrogen and phosphorus loads to New Bedford Reservoir were derived by calculation from a land use-based model calibrated with actual data and empirical models that back calculate total loads from in-lake conditions. The land use model was run for each of the three main Ponds with the results from the North and Northeast Ponds linked to the model for the South Pond. In the land-use model the small Southeast Pond was placed into the watershed of the South Pond. The influent and effluent phosphorus concentrations and water inflow numbers where then put into the empirical model with current nutrient concentrations to back calculate loads using the empirical model.

These models are an approximation of the New Bedford Reservoir system, especially due to the presence of cranberry bogs in the watershed. Bog systems seasonally affect the pond system as tributary inputs are diverted for irrigation and then discharged after use. Discharge of organic materials from the bogs is generally on a seasonal pulse and will affect the quality of the water downstream. The scope of this project was limited and therefore minimal data were collected and used to calibrate the model. The data provides a small “snap-shot” of the system and therefore year to year conditions may be substantially different than those observed. Although models are only representations of reality, they can provide insights into the magnitude and range of loading and temper judgements made based on a limited set of actual data.

5.2.2.1 Nitrogen Loading

The nitrogen load to New Bedford Reservoir as predicted by the land use model is 5335 kg/yr to the North Pond, 175 kg/yr to the Northeast Pond and 6553 kg/yr to the South Pond. The complete output from the land use model is presented in Appendix B. There are many assumptions that go into loading predictions, including the accuracy and treatment of data, choice of models, selection of export coefficients, and assignment of attenuation factors. Furthermore, loading does not occur at a constant rate and can vary substantially among seasons and years. As a consequence, the uncertainty of such estimates can be quite large and no single number should be relied upon too heavily.

The total nitrogen load to the Reservoir estimated from the empirical model approach was 6410 kg/yr for the North Pond, 225 kg/yr to the Northeast Pond and 5465 kg/yr to the South Pond. This model back-calculates the loading from known lake characteristics such as area, volume and current concentrations of nutrients. The estimates for the two models return loading values for each pond that are relatively close.

5.2.2.2 Phosphorus Loading

The phosphorus load to the New Bedford Reservoir as predicted by the land use model is 508 kg/yr for the North Pond, 8 kg/yr for the Northeast Pond and 383 kg/yr for the South Pond (Table 5-6). The phosphorus load to the reservoir using the empirical model is 432 kg/yr for the North Pond, 14 kg/yr for the Northeast Pond and 251 kg/yr for the South Pond. The values for the two models are relatively close. As with the nitrogen loading estimates, the many assumptions inherent in the predictive process can lead to substantial variability of estimates.

5.2.2.3 Discussion of Loading Limits

The land use and empirical models provide a reasonable approximation of the New Bedford Reservoir system and the model therefore provides an acceptable basis for evaluating the impact of possible management scenarios. Permissible and critical limits for phosphorus loading were estimated based upon an approach developed by Vollenweider (1968). The permissible load is the amount of phosphorus that could enter a system without obvious or continual detrimental effects. As values exceed the permissible load and get closer to the critical load, nuisance algal blooms often become a problem. Lakes exceeding the critical load usually experience serious productivity problems. Permissible and critical phosphorus loads for the North Pond were calculated to be 230 kg/yr and 460 kg/yr, respectively (Table 5-6). The calculated South Pond permissible and critical phosphorus loads are 142 kg/yr and 285 kg/yr, respectively and for the Northeast Pond 16 and 31 kg/yr, respectively.

Phosphorus loading estimates to the North and South Ponds from both the land-use and empirical models exceed the permissible load limit. Loading estimates for the North and South Ponds based on the land use model exceed the critical load. Estimated loading in the Northeast pond does not exceed the permissible load. Excessive amounts of algae growth are not noted in either the North or South ponds as would be expected looking only at the model results. This is probably because the Vollenweider model predicts that high levels of phosphorus are directly related to algae biomass. In this model, the only control on algae biomass is nutrients. Light limitation due to turbidity or staining and rooted aquatic plants are not taken into account in the model. The Reservoir system may experience algae problems if the rooted aquatic plants are removed from the system because there are enough dissolved nutrients to support their growth and without competition for nutrients from the rooted plants, the nutrients will be available for the algae. However, the low light induced by natural color in the water may still limit algal growth.

Table 5-6 - Phosphorus Loading Estimates from Models

Pond	P Loading – Land Use Model (kg/yr)	P Loading – Empirical Model (kg/yr)	Permissible P Load (kg/yr)	Critical P Load (kg/yr)
North	508	432	230	460
Northeast	8	14	16	31
South	383	251	142	285

5.3 Biological Characteristics

5.3.1 Phytoplankton

The phytoplankton community of New Bedford Reservoir was sampled on 06 August, 2002 at 2 sites, one in the North Pond (NBR 1) and one in the South Pond (NBR 4). The sample represented a composite from the surface to the bottom of the pond at the sampling location.

The phytoplankton of the New Bedford Reservoirs includes representatives of six algal divisions, with one common division (Cryptophyta) not represented (Table 5-7). Numerically, the algal count was dominated by green algae (Chlorophyta) at NBR-1 (North Pond) and by blue-green algae (Cyanophyta, or more properly, cyanobacteria) at NBR-4 (South Pond). As cell size varies among phytoplankters, cell counts are converted to biovolume and then biomass to provide a better evaluation of relative abundance and importance to the aquatic system. Euglenoid algae dominated at NBR-1 in terms of biomass, while golden algae (Chrysophyta) were dominant at NBR-4, owing to the larger size of the cells of the genera from these divisions. Green algae were the next most abundant algal group in both samples.

Overall, biomass was moderate at 1036 ug/L at NBR-1 and 3706 ug/L at NBR-4. Values in excess of 10,000 ug/L are possible in lakes, and values <1000 ug/L are usually considered low for ecological purposes. However, values >100 ug/L may be problematic in water supplies, depending upon which species are present and how the water is treated prior to distribution. As the New Bedford Reservoir system is no longer used as a water supply, the values seen are not problematic. Ecologically, moderate algal biomass is generally a positive factor, fueling fish production without greatly impairing recreational uses.

Many of the algal forms present are indicative of high organic content. This does not mean the lakes are “polluted” in any gross sense, but that dissolved organic matter concentrations are high. This could be caused by discharges of wastewater, but no such discharges are known for this system. Rather, this is a likely consequence of plant decay and interaction of the water column with highly organic sediments. Diversity and evenness were moderate, suggesting no major ecological imbalance.

The Coalition for Buzzards Bay (CBB) reported chlorophyll and phaeophyton values during their 2000 and 2001 sampling seasons to be less than 10 ug/L (see Appendix A for data).

Table 5-7 - New Bedford Reservoir Phytoplankton Data

PHYTOPLANKTON DENSITY	(CELLS/ml)		(ug/L)	
TAXON	NBR-1 8/6/02	NBR-4 8/6/02	NBR-1 8/6/02	NBR-4 8/6/02
BACILLARIOPHYTA				
Asterionella	0	20	0.0	4.0
Eunotia	30	0	30.0	0.0
Fragilaria	40	0	12.0	0.0
Gomphonema	10	0	10.0	0.0
Melosira	10	160	3.0	48.0
Nitzschia	10	0	8.0	0.0
CHLOROPHYTA				
Closterium	10	0	40.0	0.0
Closteriopsis	10	0	5.0	0.0
Crucigenia	0	320	0.0	32.0
Eudorina	0	80	0.0	32.0
Gloeocystis	0	40	0.0	216.0
Paulschultzia	40	40	16.0	16.0
Quadrigula	0	40	0.0	8.0
Scenedesmus	40	40	4.0	4.0
Schroederia	30	0	75.0	0.0
Sphaerocystis	320	240	64.0	48.0
CHRYSOPHYTA				
Chrysosphaerella	0	100	0.0	100.0
Dinobryon	30	1030	90.0	3090.0
Mallomonas	50	30	25.0	50.0
CRYPTOPHYTA				
CYANOPHYTA				
Chroococcus	0	3840	0.0	38.4
EUGLENOPHYTA				
Euglena	20	0	255.0	0.0
Trachelomonas	120	20	378.0	20.0
PYRRHOPHYTA				
Peridinium	10	0	21.0	0.0
RHODOPHYTA				

Table 5-7 - New Bedford Reservoir Phytoplankton Data (Continued)

PLANKTON DENSITY	(CELLS/ml)		(ug/L)	
SUMMARY STATISTICS	**NBR-1 8/6/02**	**NBR-4 8/6/02**	**NBR-1 8/6/02**	**NBR-4 8/6/02**
DENSITY				
BACILLARIOPHYTA	100	180	63.0	52.0
CHLOROPHYTA	450	800	204.0	356.0
CHRYSOPHYTA	80	1160	115.0	3240.0
CRYPTOPHYTA	0	0	0.0	0.0
CYANOPHYTA	0	3840	0.0	38.4
EUGLENOPHYTA	140	20	633.0	20.0
PYRRHOPHYTA	10	0	21.0	0.0
RHODOPHYTA	0	0	0.0	0.0
TOTAL PHYTOPLANKTON	780	6000	1036.0	3706.4
TAXONOMIC RICHNESS				
BACILLARIOPHYTA	5	2		
CHLOROPHYTA	6	7		
CHRYSOPHYTA	2	3		
CRYPTOPHYTA	0	0		
CYANOPHYTA	0	1		
EUGLENOPHYTA	2	1		
PYRRHOPHYTA	1	0		
RHODOPHYTA	0	0		
TOTAL PHYTOPLANKTON	16	14		
S-W DIVERSITY INDEX	0.91	0.56		
EVENNESS INDEX	0.75	0.49		

5.3.2 Zooplankton

The zooplankton of the New Bedford Reservoir in Acushnet was sampled by towing a net with a mesh aperture of 53 micrometers through 30 meters of water, resulting in a concentrated sample representing 948 liters of lake water. Samples were collected at two locations, one in the North Pond (NBR-1) and one in the South Pond (NBR-4) on 06 August 2002. The samples were examined at 40X to 100X magnification under brightfield optics to determine types, abundance and size of zooplankters present. Composition included three species of rotifers, three types of copepods, and four genera of cladocerans, all forms commonly found in this region (Table 5-8). Density as number of individuals was low and biomass per liter values were low to moderate, suggesting that the zooplankton are only a minor component of the aquatic system. Biomass was distinctly higher at NBR-1 as a function of more and larger Diaptomus copepods and the presence of a small-bodied *Daphnia cladoceran* not found at NBR-4. Average size was moderate, indicating no more than moderate grazing pressure on algae and significant but not optimal potential as a fish food source. Diversity and evenness were high, suggesting that no one genus of zooplankter was strongly dominant.

Table 5-8 - New Bedford Reservoir Zooplankton Data

ZOOPLANKTON DENSITY	(#/L)		(ug/L)	
TAXON	**NBR-1 8/6/02**	**NBR-4 8/6/02**	**NBR-1 8/6/02**	**NBR-4 8/6/02**
PROTOZOA	0.0	0.0	0.0	0.0
ROTIFERA				
Asplanchna	0.3	0.6	0.8	1.3
Conochilus	0.0	0.5	0.0	0.1
Keratella	0.4	0.5	0.1	0.1
COPEPODA				
Copepoda-Cyclopoida				
Cyclops	0.5	0.2	1.3	0.4
Mesocyclops	1.0	0.1	4.4	0.1
Copepoda-Calanoida				
Diaptomus	3.8	1.4	44.7	0.7
Copepoda-Harpacticoida	0.0	0.0	0.0	0.0
Other Copepoda-Adults	0.0	0.0	0.0	0.0
Other Copepoda-Copepodites	0.0	0.0	0.0	0.0
Other Copepoda-Nauplii	0.7	1.2	2.4	3.8
CLADOCERA				
Bosmina	0.7	0.1	2.1	0.3
Ceriodaphnia	0.8	1.9	5.6	13.0
Daphnia ambigua	1.9	0.0	10.9	0.0
Diaphanosoma	0.4	0.1	2.0	0.3
OTHER ZOOPLANKTON				
Chironomidae	0.0	0.0	9.0	0.0
SUMMARY STATISTICS				
DENSITY				
PROTOZOA	0.0	0.0	0.0	0.0
ROTIFERA	0.6	1.5	0.9	1.4
COPEPODA	6.0	2.9	52.8	5.0
CLADOCERA	3.8	2.1	20.7	13.5
OTHER ZOOPLANKTON	0.0	0.0	9.0	0.0
TOTAL ZOOPLANKTON	10.4	6.5	83.4	20.0
TAXONOMIC RICHNESS				
PROTOZOA	0	0		
ROTIFERA	2	3		
COPEPODA	4	4		
CLADOCERA	4	3		
OTHER ZOOPLANKTON	1	0		
TOTAL ZOOPLANKTON	11	10		
S-W DIVERSITY INDEX	0.85	0.82		
EVENNESS INDEX	0.81	0.82		
MEAN LENGTH: ALL FORMS (MM)	0.86	0.58		

5.3.3 Aquatic Vascular Plants

Most of the sediment surface of each pond in New Bedford Reservoir is covered with plants with most growths extending upward substantially toward the water surface (Figures 5-5 & 5-6). The percentage of cover of a given area is the portion of the sediment surface area occupied by plants (a two-dimensional measure), while biovolume is an estimate of how much of the water column is filled by those upward-extending growths (a three-dimensional measure). Only small areas of the North Pond (9%) and about 35% of the South Pond exhibited areas of no plants, generally in a corridor following the deepest portions of these ponds (Table 5-9). Below approximately the 6 ft bathymetric contour in both the North and South Ponds there was no plant growth. This corresponds to about 2 times the secchi depth for the North Pond and 1.3 times the secchi depth for the South Pond. The North Pond also had 88% and 71% of the percentage of pond area rated in the 76-100% cover and biovolume categories, respectively, while the South Pond had only 14% of the pond area in the category of 76-100% cover and no areas with biovolume in this category.

In the Northeast Pond almost the entire area (94%) was extensively covered (76-100%), but only 23% of the area exhibited biovolume in the highest category. The Southeast Pond was not surveyed, but from visual inspection the surface was completely (100%) covered with plants and the biovolume was probably also 75-100%.

The North Pond supported 13 different species of aquatic plants, while the South Pond exhibited 11 species and the Northeast Pond contained 10 species (Table 5-10). In no pond was the average biovolume of one species greater than 40%. However, *Utricularia sp*. and *Myriophyllum heterophyllum* were present in all the surveyed ponds at greater than 50% of the transect points, making up the largest percentage of the biovolume in each of the ponds. All the plants identified, with the exception of *Myriophyllum heterophyllum,* are considered native plants. *Myriophyllum heterophyllum* has been in the Northeast possibly since the mid-1800's and therefore may also be considered a native aquatic plant by some.

Table 5-9 - New Bedford Reservoir Plant Biovolume and Cover

Pond	Area of No Plants (acres)	Area of 76-100% Plants (acres)	
	Cover = 0	Cover = 4	Biovolume = 4
North	13 acres (9%)	121 acres (88%)	98 acres (71%)
Northeast	0 (0%)	20 acres (94%)	5 acres (23%)
South	16 acres (35%)	7 acres (14%)	0 acres (0%)
Southeast	0 (0%)	3.4 acres (100%)	3.4 acres (100%) (estimated)

Certain plants have the potential to completely dominate a system by filling the water column and/or outcompeting other plants to create a monoculture of the plant, thereby decreasing diversity. Plants with this ability are considered potential nuisance plants. In the New Bedford Reservoir several of the identified species are potential nuisance plants including: *Brasenia schreberi* (watershield), *Ceratophyllum demersum* (coontail), *Lemna sp.* (duckweed), *Myriophyllum heterophyllum* (variable milfoil), *Nymphaea sp.* (white water lily), *Nuphar sp.*(yellow water lily), *Utricularia geminiscapa or vulgaris* (bladderwort), *Utricularia purpurea* (bladderwort) and *Wolffia sp*. (watermeal) As can be seen by the plant data, most of these species are present in large quantities in the ponds, except *Brasenia schreberi.*

Phytoplankton blooms and floating algal mats were not observed. Blue green algal mats were limited to a few deeper locations in the North Pond and one location in the Northeast Pond. At these sites, less than 5% of the species composition was blue green algae mats.

Two species of potentially nuisance floating plants (*Lemna sp*. and *Wolffia sp*.) were only noted in the North Pond. These species are generally indicative of higher nitrogen levels, although nitrogen levels in all the ponds were low.

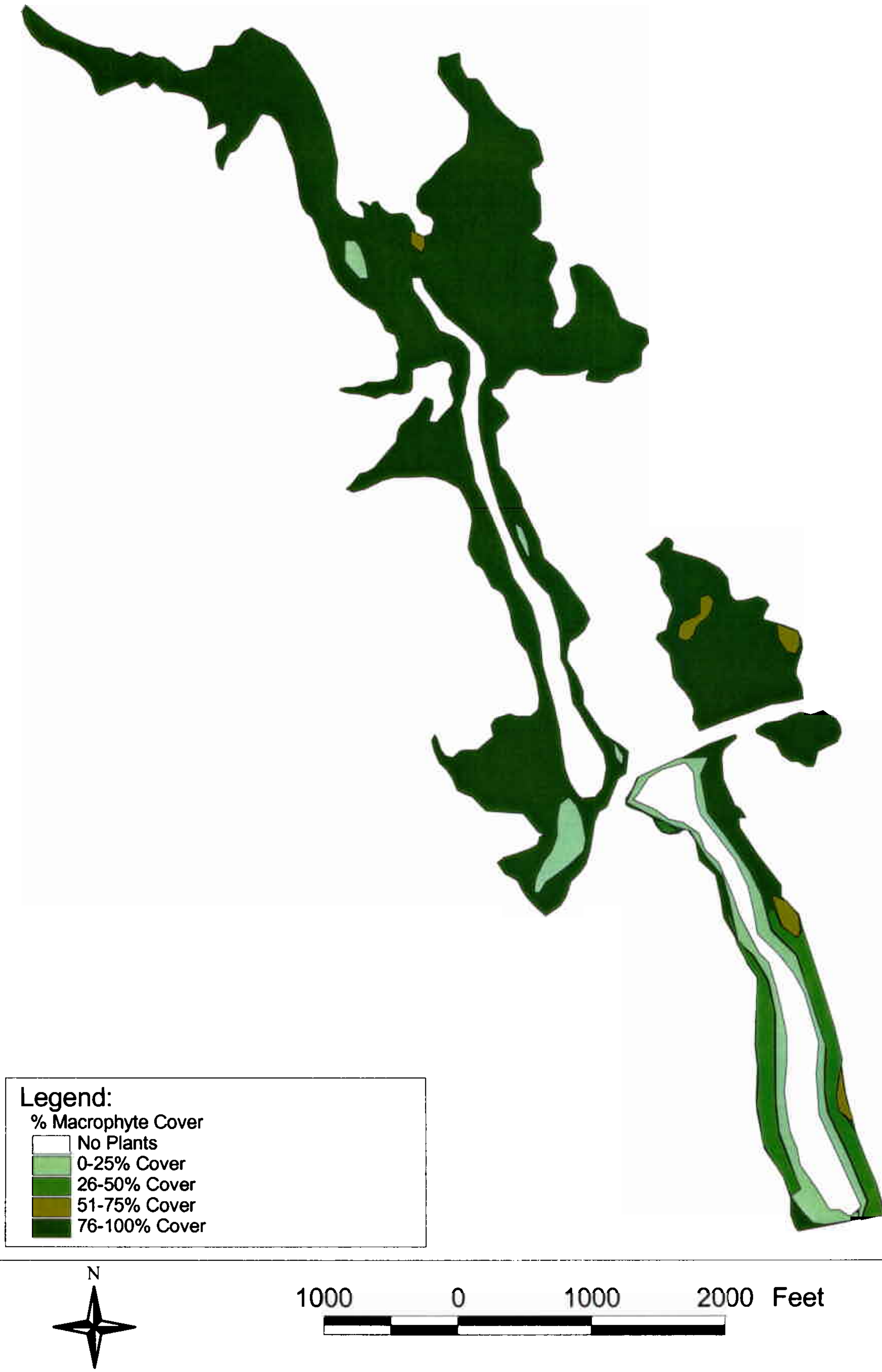
Although *Nymphaea sp.* and *Nuphar sp*. did not make up large percentages of the biovolume in surveyed areas, they did make navigation in the shallower and near shore areas of all the ponds difficult. In all Ponds, most of the embayments were completely covered with lilies. In the North Pond and Northeast Pond the entire upper northern sections were covered with lilies. In the Northeast Pond floating islands of lily rhizomes were noted. In the South Pond, areas along the eastern shore toward the north supported dense lily populations, due to the shallower nature of these areas. Mixed in with the lilies, *Brasenia schreberi* was often present, although not at the densities of the lilies.

Ceratophyllum demersum is a potential nuisance plant but was only noted at a few sites in the North Pond. *Myriophyllum heterophyllum* was present in all ponds and in some areas in dense monocultures. At least three species of *Utricularia w*ere identified. One species was identified either as *Utricularia geminiscapa or Utricularia vulgaris*; positive species identification was not possible since a flower was needed for this determination and none were visible. *Utricularia purpurea* was identified and *Utricularia radiata (or inflata)* was visually identified in the North Pond during the first water column survey but not identified during the plant survey. Species of *Utricularia* are potential nuisance plants and were present in all the ponds, in some areas as dense monocultures.

Potamogeton (pondweed) species were noted in small densities at a few sites throughout each pond. Native species of *Potamogeton* are not considered to be nuisance plants in most cases.

Several emergent wetland species were identified along the edges of the ponds, including *Decodom verticillatus* (water willow), *Pontederia cordata* (pickerelweed), *Lythrum virgatum* (swamp loosestrife), *Scirpus sp.* (Sedge), *Tyhpa sp*. (cattail). *Phragmities sp.* (reed grass), although not recorded, was noted to be present along the edges of Lake Street, bordering the ponds as well as on the edges of several of the wetland areas. *Phragmities sp.* is a nuisance plant that can out compete native plants and form dense monoculture stands that are difficult to remove. Cattail and swamp loosestrife can reach nuisance densities under favorable conditions.

New Bedford Reservoir
Figure 5-5: Macrophyte Cover



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New Bedford Reservoir
Figure 5-6: Macrophyte Biovolume

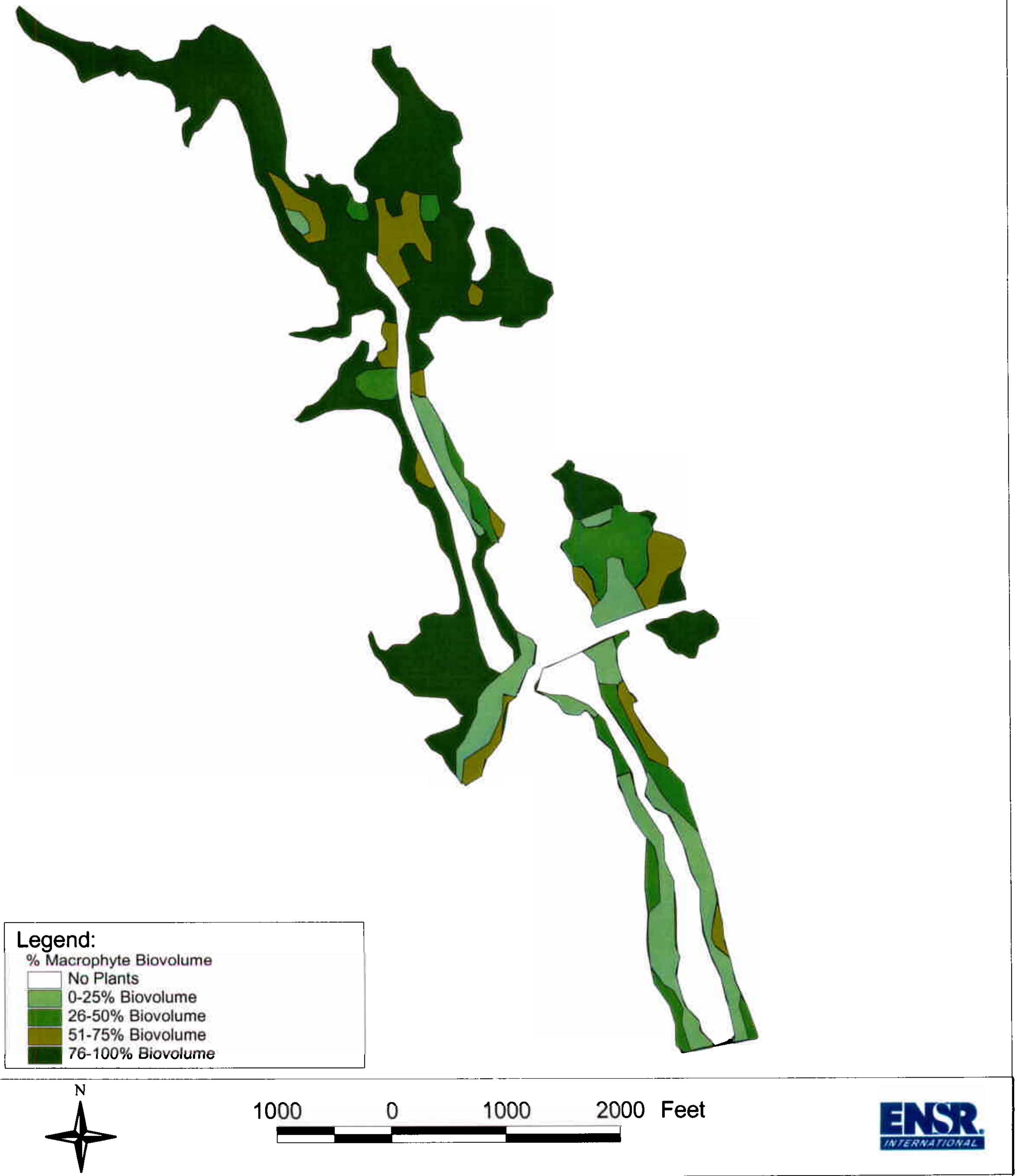

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Table 5-10 - Bathymetric, Soft Sediment and Plant Survey Data

Transect Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition / Aquatic Macrophyte Taxa (% of biovolume) Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Emergent Aquatic Plants (P=Presence) Wet1	Wet2	Wet3	Rush	Tf
North Pond																												
A1	3.5	0.7	M	4	4	20					5		5	25		<5	<5	15	15	10				P				
A2	4.5	0.3	M/Hp	4	4	30	20							25		<1	<1	10	5	10				P				
A3	4.0	2.5	M/Hp	4	3	20	20		5					20		<5	<5	10	5	15			<1					
A4	2.0	0.9	M/Hp	4	4	25								40		<1	<5	5	20	10				P	P	P		
B1	1.9	1.6	M&S	4	4	15	25							30		<5	<5	5	15	5				P	P			
B2	4.0	3.5	M	1	1		55							45									<5					
B3	4.5	2.4	M	4	3		40						5	30		<5	<5	20										
B4	2.1	1.8	M	4	4		20						20	5		<5	<5	20	20	10								
B5	3.8	0.7	M	3	2				15		5			25		<5	<5	35	5	10			<5					
B6	4.3	2.5	M	4	3		65							30		<1	<5											
B7	2.0	1.1	M&S	4	4		30		5		5			30		<5	<5	10	15								P	
B8	2.5	1.0	M	4	3		20				5			35		<5	<5	25	5	5					P		P	
B9	4.5	0.7	S&M	4	2		25				20			35				10	5	5								
B10	1.5	1.4	S&M	4	4		10				5		5	40		<5	<5	15	20						P	P	P	
C1	1.5	1.0	S&M	4	4		10				5		5	35			5	10	30						P		P	
C2	3.6	0.4	S&M	4	4		60							30			5	5										
C3	5.0	0.1	S&M	4	3		60							25			5	10										
C4	4.0	0.3	S&M	4	4		60							15			5	20										
C5	5.3	0.9	M	4	3		85							10		<5	<5											
C6	5.0	2.2	M	0	0																							
C7	4.5	2.5	M/Hp	4	4		30		15				<5	20		<5	<5	20	5	5								
C8	3.5	0.6	M&S	4	4		25							40			5	5	20	5					P		P	

Transect Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition																						
						Aquatic Macrophyte Taxa (% of biovolume)																		Emergent Aquatic Plants (P=Presence)				
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Wet1	Wet2	Wet3	Rush	Tf
D1	3.5	1.4	G/R	4	4		30		<5					30		<5	<5	20	10	5					P	P		
D2	4.5	4.4	M	0	0																							
D3	4.5	4.0	M	4	4		50							45		<5	<5											
D4	5.5	2.5	M/Hp	4	4		50		15					30		<5	<5											
D5	4.9	3.1	M/Hp	4	4		50							30		<5	<5	10	5									
D6	4.5	0.3	M&S/Hp	4	3				10		15			50		<5	<5	20										
D7	4.4	0.2	M/Hp	4	4		5				5			40		<5	<5	15	10	20								
D8	3.5	1.0	M/Hp	4	4		20						5	20		<5	<5	10	10	30								
E1	2.0	1.5	M&S/R	4	4		25		5		5			40		<5	<5	10	5	5					P	P	P	
E2	6.5	2.5	M	0	0																							
E3	4.5	2.8	M/Hp	4	3		15							55		<5	<5	25							P	P	P	
F1	2.0	1.1	M&S	4	4		10						5	30		<5	<5	15	20	15								
F2	5.2	2.7	M/Hp	4	2		50						5	25		<5	<5	15										
F3	5.5	3.0	M&S/Hp	4	2		70						5	15		<5	<5		5									
F4	5.5	4.0	m	0	0																							
F5	3.8	0.7	M&S	4	3		40		5					25		<5	<5	20	5									
G1	2.1	1.8	M&S	4	2		25		15		5			35		<5	<5	5	5	5					P	P		
G2	6.0	*4.0**	M	1	1														100									
G3	6.8	*3.2**	M	0	0																							
G4	4.8	0.1	M&S	4	3		70									<5	<5	10	15									
G5	2.0	0.5	M/Hp	4	4		10						5	25		<5	<5	30	15	10							P	
H1	2.5	1.4	M&S	4	4		20		10				5	25		<5	<5	15	15	5						P	P	
H2	6.0	3.0	M/S	0	0																							
H3	7.2	2.3	M/S	0	0																							
H4	4.5	0.5	M/S&R	4	2		30		10		15		25	5				15										
H5	4.5	0.6	M&R	4	3		25							50		<5	<5	10	5	5					P			
I1	2.0	0.5	M&R	4	4		30		10			5	5	25		<1	<1	15	10	<5					P	P	P	

Transcept Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition — Aquatic Macrophyte Taxa (% of biovolume): Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Emergent Aquatic Plants (P=Presence): Wet1	Wet2	Wet3	Rush	Tf
I2	8.0	*2.0**	M	0	0																		<1					
I3	6.2	2.3	M	0	0																		<1					
I4	2.5	1.0	M&S	4	4		15		5				5	35		<5	<5	25	5	5								
J1	1.5	1.5	M&S	4	4	5	20							40		<5	<5	20	5	5						P		
J2	2.8	1.7	M&S&R	4	4		30						<5	30		<5	<5	30	5									
J3	5.5	0.5	S	0	0																		<1					
J4	8.9	*1.1**	M	0	0																		<1					
J5	4.5	1.5	M/S	1	1		30		20					50														
K1	0.9	1.0	G/S	4	4		25							55		<5	<5	<5	10	5								P
K2	5.8	1.2	M	1	1									50				50										
K3	6.0	1.8	M	1	1		10						10	10					70									
K4	6.3	1.9	M	1	1		40												60									
K5	4.5	0.5	S/R/Hp	4	3		15							60		<5	<5	5	10	5					P			P
L1	2.7	0.7	M/Hp	4	3		25							60		<5	<5	5	5						P			P
L2	5.0	1.4	M	4	3		50							40					10									
L3	5.9	1.0	M/S	1	1		100																					
L4	3.5	0.8	S/Hp	4	4		10							60		<5	<5	20	5									
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG					
Pond wide average						19	34	0	10	0	7.9	5	7.7	33	0	<5	<5	16	16	9	0	0	<1					
SOUTH PD																												
A1	3.4	0.2	S	2	2		10				10	10		10				60							P		P	P
A2	8.6	0.4	M	0	0																							
A3	>10	>10	M	0	0																							
A4	>10	>10	M	1	1		50					50																
A5	6.0	0.3	S/Hp	4	2		10				10	5		50				20	5						P		P	

Transect Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition: Aquatic Macrophyte Taxa (% of biovolume) Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Emergent Aquatic Plants (P=Presence) Wet1	Wet2	Wet3	Rush	Tf
B1	3.9	0.7	S	2	2		45				45	5								5					P			
B2	10.0	*0**	S/M	0	0																							
B3	7.3	0.7	S/M	0	0																							
B4	>10	>10	NA	0	0																							
B5	5.9	0.2	S	2	1		75				20			5	<5										P		P	
C1	2.3	1.5	S	3	3		40							40				20										
C2	>10	>10	NA	0	0																							
C3	2.7	2.5	S/M	2	1		20				20	10		20				20		10					P			
D1	2.1	0.3	R/S/G	2	2		40				10	10						30	5	5					P			
D2	6.8	1.0	M	1	1		100																					
D3	>10	>10	NA	0	0																							
D4	8.5	0.8	M	0	0																							
D5[1]	3.5	0.6	S/Hp	2	1		18	18			18	18							18	10					P			
E1	2.1	2.4	S	2	1		30					20						30	20								P	
E2	>10	>10	NA	0	0																							
E3	4.2	1.9	S/M	2	2		40					10		10				20	20									
F1	2.7	0.8	S/R	2	1		34												33		33				P			
F2	>10	>10	NA	0	0																							
F3	8.5	0.3	M/S/R	0	0																							
F4	6.4	0.5	M/S	1	1									100														
F5	2.7	0.8	S	2	2		35	5			10	5	20					15	10								P	
G1	1.9	1.1	S/M/R	3	2		5	5			10	5	5	50				10	10								P	
G2	4.4	0.2	S/Hp	3	2		30							70														
G3	9.3	*0.7*	S/M	1	1									100														
G4	>10	>10	NA	0	0																							
G5	2.6	0.6	S/R	1	1		70											30										
H1	3.2	0.2	R	4	2		10							55				5	30									

Transect Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition: Aquatic Macrophyte Taxa (% of biovolume)																		Emergent Aquatic Plants (P=Presence)				
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Wet1	Wet2	Wet3	Rush	Tf
H2	9.7	*0.3**	NA	0	0																							
H3	10.0	>10	NA	0	0																							
H4	3.5	1.4	S/R	4	3		25	5		5		5		20				25	15								P	
H5	1.0	1.0	M/S/G	4	3		20			10	10		10	35				5	5	5					P		P	
I1	0.5	0.5	S/G	4	3		25	20				5		20				5	10	5	10				P			
I2	2.7	0.5	S/Hp	4	2		50	10						20				10	10									
I3	6.0	1.5	S&M	0	0																							
I4	>10	>10	NA	0	0																							
I5	3.7	0.3	S/G&R	2	1		35	5					10	25				25										
J1	6.5	1.4	M/R	0	0																				P		P	
J2	8.7	1.1	M	0	0																							
J3	6.8	0.8	M	0	0																							
J4	6.9	0.1	R&Hp	0	0																							
J5	6.1	0.6	S/R	1	1									34				33	33									
J6	4.5	0.8	M&S	4	2		20	<5					30	30					10	10					P			P
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG					
Pond wide average						0	35	10	0	8	16	12	15	39	0	0	0	21	16	7	22	0	0					
North East Pond																												
A1	4.5	1.0	M	4	2								33	33					34									
A2	6.2	2.4	M	4	1		35				5		10	35					10	5								
A3	5.4	1.6	M	3	1						20		35	35					10									
A4	3.5	1.3	M	4	2		10				20		45	5					10			10						
B1	3.1	1.7	M	4	2								40	40					20								P	
B2	5.2	1.9	M	4	2		40							50					10									
B3	6.1	2.0	M	4	2		10				40			40					10									

Transect Point	Water Depth (ft)	Sediment Depth[5] (ft)	Sediment Type[6]	% Cover	% biovolume	Species Composition																		Emergent Aquatic Plants (P=Presence)				
						Aquatic Macrophyte Taxa (% of biovolume)																						
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG	Wet1	Wet2	Wet3	Rush	Tf
B4	5.6	3.2	M	3	2		10				5		10	65						10								
B5	3.5	1.1	M	4	2		30				10			50					10									
C1	3.4	1.1	M&S	4	3		20							40				5	35						P			
C2	6.1	2.7	M	4	2								35	50					15									
C3	6.9	2.4	M	4	1		70				10			10					10									
C4	6.6	2.4	M	4	2		10				30			40					10	10								
C5	5.9	2.2	M	4	3		60				10			10					20									
C6[2]	3.5	1.8	M/Hp	3	3		10					5	10	38					38						P			
D1	3.3	2.7	M	4	4		20				10		10	20					20	20								
D2	3.4	2.2	M/Hp	4	4		20						20	30					30									
D3	6.2	1.0	M	4	3		40					20	10	20					10				<5					
D4	6.5	2.7	M	4	1						15	10	15	60														
D5	6.8	2.6	M	4	1							40	30	30														
D6	4.9	0.2	S/Hp	4	1		10					40	10	20					20									
						Cd	Mh	Pe	Pg	Pn	Pp	Pr	Up	Usp	Ssp.	Lm	Wf	Bs	No	Nv	Moss	Scsp.	BG					
Pond wide average						0	26	0	0	0	16	23	22	34	0	0	0	5	18	11	0	10	<5					

Legend and Abbreviations:

Transect Points: Transects are identified by a latter; points on transect by a number

Plant Abundance:

% Cover:	% biovolume:	Sediment Type	
0- No plants	0- No plants	M	Muck
1- 1-25% areal coverage	1- 1-25% of water column filled	S	Sand
2- 26-50% areal coverage	2- 26-50% of water column filled	Hp	Hard Pan
3- 51-75% areal coverage	3- 51-75% of water column filled	R	Rock
4- 75-100% areal coverage	4- 76-100% of water column filled	G	Gravel

Aquatic Macrophyte taxa

BG	Blue Green algae matts
Moss	*Bryophyte* (moss/leafy liverwort)
Bs	*Brasenia schreberi*
Cd	*Ceratophyllum demersum*
Lm	*Lemna sp.*
Mh	*Myriophyllum heterophyllum*
No	*Nymphaea sp.*
Nv	*Nuphar sp.*
Pe	*Potamogeton epihydrus*
Pg	*Potamogeton bicupulatus*
Pn	*Potamogeton natans*
Pp	*Potamogeton pulcher*
Pr	*Potamogeton robbinsii*
Ssp.	*Sparganium sp.*
Usp	*Utricularia geminiscapa* or *U. vulgaris* (need flower for positive species ID)
Up	*Utricularia purpurea*
Wf	*Wolffia sp.*

Terrestrial Aquatic Plants

Wet 1	*Decodom verticillatus* (Water willow)
Wet 2	*Pontederia cordata* (Pickerelweed)
Wet 3	*Lythrum virgatum* (Swamp Loosestrife)
Scsp.	*Scirpus sp*. (Bulrush)
Rush	Rush
Tf	*Tyhpa sp*. (cat tail)

Notes:

[1] Leaf Litter on bottom

[2] *Phragmities sp*. Along shore

[3] Plant percentages add to 100% assuming that two values of <5% will equal 5%. One value of 5% is not counted.

[4] P = plant is present

[5] * and Italics denote that sediment and water depth were greater than 10ft, therefore sediment depth is estimated

[6] NA = Water depth greater than 10ft, sediment type is unknown (NA)

6.0 DIAGNOSTIC SUMMARY

New Bedford Reservoir is a 210-acre reservoir consisting of 4 ponds. Located in Acushnet, Massachusetts with mean depths of 5 ft for the North and Northeast Pond, 6 ft for the South Pond and 5 ft for the Southeast Pond, these water bodies receive water from a 4160 acre watershed which includes 3 tributaries and many cranberry bogs. The combined reservoir system holds approximately 1078 acre-feet of water with 680 acre-feet in the North Pond, 105 acre-feet in the Northeast Pond and 279 acre-feet in the South Pond. The water in each pond is replaced on average about 11 times/yr for the North Pond, 2 times/yr for the Northeast Pond and 31 times/yr for the South Pond. However, prolonged detention is expected during extended dry periods, such as those observed in the summer of 2002.

The watershed is primarily forested, with low to medium density residential housing and cranberry production areas scattered throughout, except along the South Pond where 78% of land use is residential housing. Crop and livestock farming are minor uses (on an areal basis) within the watershed.

Specific conductivity, pH, alkalinity and nutrients were detected at low to moderate levels in each pond. Dissolved oxygen was adequate for a healthy aquatic community throughout the summer in both the Northeast and South Ponds, although values in the North Pond were low and at the bottom were often below 1 mg/L. Measurements of dissolved oxygen, specific conductivity, pH, alkalinity and Secchi depth exhibit a marked difference between the Northeast Pond and the other ponds in the system (North and South Ponds), although nutrient data were generally similar between Ponds. These differences are most likely due to differences in the feed waters between Ponds, but the precise reason for such differences is not clear.

The nitrogen load to New Bedford Reservoir as predicted by the land use model is 5335 mg/L to the North Pond, 175 kg/yr to the Northeast Pond and 6553 kg/yr to the South Pond. The total nitrogen load to the Reservoir estimated from the empirical model approach was 6410 kg/yr for the North Pond, 225 kg/yr for the Northeast Pond and 5465 kg/yr for the South Pond. These estimates suggest reasonable agreement between the land use model and the empirical model for all the ponds.

The phosphorus load to New Bedford Reservoir as predicted by the land use model is 508 kg/yr for the North Pond, 8 kg/yr for the Northeast Pond and 383 kg/yr for the South Pond. The phosphorus load to the reservoir using the empirical data is 432 kg/yr for the North Pond, 14 kg/yr for the Northeast Pond and 251kg/yr for the South Pond. Phosphorus loading estimates for both the North and South Ponds exceed the permissible load limit. Estimates based on the land use model for those two Ponds exceed the critical load. Loading in the Northeast Pond does not exceed the permissible load. Excessive amounts of algae growth are not noted in either the North or South Ponds as would be expected from model results alone. Light limitation due to turbidity or staining and rooted aquatic plants are probably controlling the algae. The Reservoir system could experience algae problems if the rooted aquatic plants are removed from the system because there are enough dissolved nutrients to support their growth and without competition for nutrients from the rooted plants, the nutrients will be available for the algae. However, natural color in the water may maintain a light limitation on algal growth.

Phytoplankton biomass, diversity and evenness were moderate, suggesting no major ecological imbalance. A variety of forms were present, but bloom-forming species were not common. Density of zooplankton as number of individuals was low and biomass per liter values were low to moderate, suggesting that the zooplankton are only a minor component of the aquatic system. Diversity and evenness were high, suggesting that no one genus of zooplankter was strongly dominant.

The aquatic plant community of New Bedford Reservoirs is dominated by two nuisance species: *Utricularia* sp. (bladderwort) and *Myriophyllum heterophyllum* (variable milfoil), although neither species has an average biovolume of more than 40%, but both are present at over 50% of survey sites. Both *Nuphar sp*. (yellow water lily) and *Nymphaea sp*.(white water lily*)* grew in dense profusion near shore in all ponds. A variety of other native species were present. Rooted plant densities were high over much of the area of all the ponds. The only areas devoid of surface cover were areas greater than about 6 ft deep in both the North and South Ponds; this was probably due to light limitation.

Overall, New Bedford Reservoir has many desirable attributes, but appears to be in sub-optimal condition for its desired uses. Although pathogenic bacteria were not assessed as part of the scope for this study, they have been an issue in the past. The effective load of phosphorus exceeds the limit for optimal water clarity and quality, and is close to the limit for continual and severe productivity problems. Algal blooms were not observed, however, probably a consequence of light limitation, low phosphorus availability, and dense rooted plant growth. Rooted plant growths present the major impediment to optimal habitat and recreational uses, and are dominated by two species with high nuisance potential. Management techniques could control these growths on at least a maintenance basis. Substantial plant growth is expected, however, in the expansive deposits of organic sediment located in shallow areas.

Additional studies of sources of biological contamination and use of the reservoir by the cranberry industry should be undertaken to further define areas of potential concern. Also, areas of Lake St. were noted to directly drain into the ponds during storms. This direct runoff is a direct pathway for biological and chemical contaminants.

7.0 MANAGEMENT OBJECTIVES

Based on discussions with the Town of Acushnet and on ENSR's experience with the management of aquatic systems for habitat and recreation, logical objectives for the management of New Bedford Reservoir include:

- Minimization of deleterious inputs from the watershed, including sediments, nutrients, fecal bacteria (and associated pathogens), and anthropogenic compounds (e.g. hydrocarbons and pesticides), especially from any areas of direct runoff into the ponds. To maintain a high quality habitat in New Bedford Reservoir, and potentially support contact recreation, reduction in current loads and prevention of future undesirable loading appears appropriate.

- Control of rooted aquatic vegetation, especially nuisance species. To maximize both habitat and recreational value, a reduction in rooted plant biomass is appropriate.

- Decrease the presence of swans, ducks and geese in the Reservoirs to manage the nutrient levels, enhance aesthetics of the public launch areas, and decrease bacterial loading.

Continuing discussion of management objectives among interested parties to more clearly define goals and priorities is encouraged. The above objectives are the result of discussions held to date in which ENSR has been involved; additional objectives are certainly possible, and no priority order has been established or intended in this report.

8.0 MANAGEMENT OPTIONS

Management options for New Bedford Reservoir can be broken down into two broad categories, watershed management and in-lake management. Watershed management options will focus on pollutant loading in general, with particular emphasis on the control of phosphorus and fine sediment additions. Most techniques are covered in more detail in several watershed management manuals (e.g., Schueler 1987, Dennis et al. 1989, Scheuler et al. 1992, Claytor and Scheuler 1996), but are summarized here for the purpose of evaluating applicability to the New Bedford Reservoir watershed. In-lake management options will focus on mitigation of low levels of dissolved oxygen and rooted plant control. The most detailed reference on this topic is by Cooke et al. (1993), with additional useful information available in Baker et al. (1993), Hoyer and Canfield (1997), NYSDEC/FOLA (1990), McComas (1993), Westerdahl and Getsinger (1988a, 1988b), and WDNR (1989).

8.1 Watershed Management Options

8.1.1 Source Reduction

8.1.1.1 Agricultural Best Management Practices

Agricultural Best Management Practices (BMPs) incorporate techniques in forestry, animal science, and crop science to minimize adverse impacts to water resources. This management approach actually relies upon a combination of techniques in source reduction and transport mitigation. Such practices include manure management, fertilizer management, use of cover crops, and use of buffer zones. The use of agricultural BMP's is highly recommended in the New Bedford Reservoir watershed. However, with the reduced amount of land in agriculture, this is not likely to provide a major change in the water quality of New Bedford Reservoir. Rather, this is mainly a protective measure to be encouraged. The movement of contaminants from cranberry bogs is generally limited in a modern operation, but BMPs for cranberry farming are also advisable to limit nutrient and possibly pesticide movement downstream to the New Bedford Reservoir.

8.1.1.2 Bank and Slope Stabilization

Erosion control is an important component of an overall management plan designed to decrease pollutant loading to aquatic ecosystems. This is especially important in areas of new development, where soils are both exposed and susceptible to erosion. Other critical areas include riparian zones and stream banks. This is a recommended management technique in the New Bedford Reservoir, as a matter of protection, especially in areas where the pond abuts the roadway, at unimproved boat launch areas and areas of new development noted along the eastern side of the South Pond.

8.1.1.3 Behavioral Modifications

Behavioral modifications involve changing the actions of watershed residents and lake users to improve water quality. Such changes may include conversion to non-phosphate detergents (already the case in MA), elimination of garbage grinders, limits on lawn fertilization, and eliminating illegal dumping in roadways and watercourses. Behavioral modifications can be brought about in two principal ways, through public education and/or the implementation of local bylaws and bans. Education is a critical first step and should precede any attempt at regulation.

Public education can be accomplished by mailing an informative brochure on watershed management to all residents in the watershed, through the use of video programs on local access television, by placing informative billboards in high access areas, or by holding public meetings for watershed residents. Public education relies heavily upon cooperation from residents and other lake users, and is not likely to result in major improvements in water quality by itself. However, some level of improvement has been noted in other studies and the education process sets the stage for community involvement and cooperation. Public education is a recommended management technique for New Bedford Reservoir.

The focus of education and behavioral modifications in this watershed should be on storm water management. The recent past development in the watershed and probable future development will increase loads of sediment, nutrients, and other residential contaminants, including fecal coliform, metals, hydrocarbons, and pesticides. Adherence to the Massachusetts Storm Water Policy will greatly reduce potential loads, but residential BMPs can also provide major load reductions. Appropriate septic system management should also be described.

8.1.1.4 Land Use Conversion

Land use conversion involves purchasing properties that contribute excessive amounts of pollutants and converting these properties to less deleterious land uses. For example, the Town might decide to purchase an agricultural property and convert the land to open space, thus reducing pollutant generation from this parcel of land. This is a very expensive proposition and is not practical on a large scale in most cases, but may be practical for targeting specific properties that generate excessive amounts of pollutants, which eventually discharge into New Bedford Reservoir. This is not a recommended management technique for New Bedford Reservoir as there no parcels that really threaten the Reservoir at this time.

8.1.1.5 Storm Water Diversion

Re-routing a discharge away from a target water-body is one of the most effective ways to change the quality of incoming water. It suffers from the philosophical drawback of passing the problem downstream without dealing with the source of the pollution, and is not feasible in many areas where downstream uses must be protected. This is not a recommended management technique for New Bedford Reservoir as no storm-water discharge to the Reservoir were noted except the direct runoff from Lake St, which can be dealt with in other ways.

8.1.1.6 Waste Water Management

A properly functioning on-site waste disposal system (e.g., septic system) can be an effective means of reducing pollutant loading to an aquatic ecosystem. Of particular concern are those systems where septic effluent is breaking out above ground and is transported to the lake or a tributary during storm events. Residences and businesses in the watershed of New Bedford Reservoir are generally serviced by on-site waste disposal systems. There is no evidence to suggest that any major contaminant inputs are attributable to ground water.

Maintenance and inspection of on-site waste disposal systems is a recommended management technique for the New Bedford Reservoir watershed. Education is the first step in alerting residents to this need. Consideration of a bylaw that requires proof of septic system inspection and maintenance on an every other year basis is worthwhile. Adherence to current Title V regulations will eventually improve conditions, but will be a slow process. As there is no clear and present threat, a prolonged improvement process may be quite acceptable.

8.1.1.7 Zoning and Land Use Planning

Zoning and land use planning are very important elements in controlling watershed inputs to aquatic resources. A strong relationship exists between land use type and pollutant generation, with developed lands (including agriculture) typically generating greater pollutant loads than non-developed lands. Preserving undeveloped land in the New Bedford Reservoir watershed is highly recommended, with particular emphasis on preserving areas of land that form buffer zones along the lake and its tributaries. The zoning laws of Acushnet, Lakeville and Rochester should be reviewed with maintenance of buffer strips in mind, and the Rivers Protection Act provisions for control over development along permanent streams should be strongly enforced. Where development does occur, adherence to the Massachusetts Storm Water Policy is strongly advised. While current conditions in New Bedford Reservoir are not optimal, increased pollutant loading could lead to much more severe degradation.

Agricultural operations, especially cranberry bog discharges and water use should be assessed. Development need not be curtailed, but proper controls on source generation and on-site capture are essential to protect the pond; the focus should be on storm water management for no loss of water and no gain in pollutant load.

8.1.2 Transport Mitigation

8.1.2.1 Buffer Strips

Buffer strips (or vegetated filter strips or grassed buffers) are areas of grass or other dense vegetation that separate a waterway from an intensive land use. These vegetated strips allow overland flow to pass through vegetation that filters out some percentage of the particulates and decreases the velocity of the storm water. Particulate settling and infiltration of water often occurs as the storm water passes through the vegetation. Buffer strips need to be at least 25 ft wide before any appreciable benefit is derived, and superior removal requires a width >100 ft. This can create land use conflicts, but creative planting and use of buffer strips can be a low cost, low impact means to minimize inputs to the aquatic environment.

This management technique is highly recommended for the New Bedford Reservoir watershed. Application is especially important for areas of new development along the Ponds and tributaries. This technique also has applicability to the South Pond cranberry bogs, near Pond developments and along Lake St to mitigate direct runoff from the roadway. Assessment of current buffer zones in place along the cranberry bogs and agricultural areas of the Ponds will also be helpful.

8.1.2.2 Catch Basins with Sumps and Hoods

Deep sump catch basins equipped with hooded outlets can be installed as part of a storm water conveyance system. Deep sumps provide capacity for sediment accumulation and hooded outlets prevent discharge of floatables (including non-aqueous phase hydrocarbons). Catch basins are usually installed as pre-treatment for other BMP's and are not generally considered adequate storm water treatment as a sole system. Volume and outlet configuration are key features, which maximize particle capture, but it is rare that more than the coarsest fraction of the sediment/pollutant load is removed by these devices. This is a recommended management technique for the New Bedford Reservoir watershed, but is not expected to be sufficient by itself to make an appreciable difference. Rather, this will be an important pre-treatment mechanism for infiltration or detention strategies. This method may be appropriate to re-direct and treat direct runoff from Lake St into the Reservoir.

8.1.2.3 Oil/Grit Chambers

A number of oil/grit chamber designs are currently on the market. These self-contained units include an initial settling chamber for sediment removal, typically have hooded internal passages to remove oil and other floatables, and often incorporate some form of outlet pool to control exit velocity. Several rely on a vortex design to enhance sediment removal (e.g., Vortechnics, Storm Defender). Such systems are most applicable as pre-treatment for other BMPs, and are generally well suited as retrofits for relatively small areas in developed watersheds. Installing these devices as off-line systems may enhance pollutant removal, but their more common use as on-line pre-treatment could benefit New

Bedford Reservoir in combination with infiltration technologies. This method may be appropriate to re-direct and treat direct runoff from Lake St into the Reservoir.

8.1.2.4 Street Sweeping/Catch Basin Cleaning

Removal of pollutants before they are washed into New Bedford Reservoir or its tributaries could be accomplished by frequent street sweeping and catch basin cleaning. Both techniques provide only limited benefits by themselves, but could be effective tools in combination with other Best Management Practices. Truly effective street sweeping is accomplished with vacuum equipment, which costs in excess of $100,000/vehicular unit. Maintenance costs can also be substantial. Catch basin cleaning should be a semi-annual activity, but rarely is; restoration of catch basin capacity is essential to the proper function of drainage systems, and costs about $50/catch basin per year when basins are cleaned on a bulk basis. Street sweeping and catch basin cleaning are recommended management techniques for the New Bedford Reservoir watershed, as part of normal road maintenance and storm water drainage system management, but neither can be counted on as a primary pollutant control technique, especially since limited areas of its tributaries and ponds border road-ways.

8.1.2.5 Created Wetlands

Created wetlands are shallow pools that create conditions suitable for the growth of marsh or wetland plants. These systems maximize pollutant removal through vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and enhanced settling. Alternatively, a treatment system may combine created wetlands with detention ponds. Created wetlands are suitable for on-line or off-line treatment (assuming maintenance of adequate hydrology with off-line systems to support the wetland). Natural wetlands already fulfill this function on the tributaries, and areas of both the North and Northeast Ponds. Created wetlands as part of the direct discharges from the cranberry bogs into New Bedford Reservoir could be used to decrease loading due to bogs.

8.1.2.6 Detention

Detention ponds are essentially basins that are designed to hold a portion of storm water runoff for at least 12-24 hours. Pollutant removal is accomplished mainly through settling and biological uptake. Wet detention ponds are more effective than dry detention ponds as the latter have a greater risk of sediment re-suspension and generally do not provide adequate soluble pollutant removal. Although effective, the land requirement is typically large; the area should be at least 2% of the drainage area it serves, and preferably as much as 7% of that area. This technique is very useful in association with new development, and might be used in some retrofit scenarios. In the New Bedford Reservoir watershed, detention systems may be largely infiltration systems due to porus soils (see below).

8.1.2.7 Infiltration Systems

Infiltration systems may include trenches, basins or dry wells, and involve the passage of water into the soil or an artificial medium. Particles are filtered by the soil matrix and many soluble compounds are adsorbed to soil particles. Such systems require sufficient storage capacity to permit the gradual infiltration of runoff. Pre-treatment of the runoff allows larger particles to be removed, thereby aiding in the prevention of infiltration system failure due to clogging and sediment accumulation.

Site constraints such as shallow depth to groundwater table or bedrock and poorly drained soils often limit the effective use of infiltration. In sites with suitable conditions, off-line infiltration systems are generally preferred. The key to successful infiltration is providing adequate pre-infiltration settling time or other treatment to remove particles that could clog the interface at which infiltration occurs. This is a recommended management technique for the New Bedford Reservoir watershed in areas with appropriate soils and ground water elevations.

The soils in the New Bedford Reservoir watershed are mainly A soils, having high permeability and great potential for infiltration. Each chosen site must be carefully evaluated for soil strata and permeability, much the way one would evaluate an area for a septic system. As infiltration can occur in subsurface chambers, no major impact to surface uses is necessary, but open infiltration basins or trenches will be easier to clean. Typical road runoff or inputs from residences and small farms should be easily treatable in this watershed by infiltration. The primary drawback in this case will be high groundwater table in some areas; it would be preferable to have at least 4 vertical feet of distance between the infiltration point and the groundwater table.

8.1.2.8 Chemical Treatment

In-stream chemical treatment involves the dosing of stream flows with alum or other coagulants to bind phosphorus and coagulate sediments to promote settling. During this process, phosphorus permanently complexes with aluminum or another binding agent, rendering it unavailable for biological uptake by algae. This in-stream treatment technology has been successfully applied in other regions, especially Florida. A pilot application was performed on the primary tributary to a drinking water supply reservoir in Ohio, and another was conducted for the main inlet of a lake in Wellesley, MA, both with moderate success. The primary application of this technology has been for phosphorus removal where other BMPs were not viable. Phosphorus removal rates ranging from 50-95% have been reported. Removal rates ranging from 50-99% have also been documented for other pollutants such as suspended solids, nitrogen, color, and bacteria.

Although effective, this technique is not recommended for New Bedford Reservoir due to high operational and maintenance costs and low phosphorus concentrations. A dosing station would be needed for each discharge point, and with substantial sub-watershed areas, the first flush concept has limited applicability. Virtually all storm flows would have to be treated at substantial long-term cost. Other methods are preferable in this case.

8.2 In-Lake Management Options - Rooted Plant Control

Macrophytes (vascular plants and visible algal mats) are generally grouped into classes called emergents (represented by pickerelweed and cattails), floating-leaved (water chestnut and water lilies), and submergents (pondweeds, milfoil, fanwort and waterweed), plus mats of filamentous algae. Understanding the factors that control plant growth is the first step in controlling weeds.

Macrophytes reproduce by producing flowers and seeds and/or by asexual propagation from various fragments and shoots extending from roots. The primary means of reproduction is an extremely important feature of a plant, and will greatly affect the applicability of control methods.

Growth rates of macrophytes, especially non-native species like fanwort and milfoil, can be very high, but is a function of suitable substrate and available light. Submergent plants will grow profusely only where underwater illumination is sufficient. Highly turbid lakes and reservoirs are unlikely to have dense beds of submerged plants. Significant reductions in algal blooms can enhance light penetration and allow weeds to grow more extensively and densely. High silt loads to a lake can create a favorable plant substrate, but the silt loading may also create severe turbidity that limits growth. Rock, gravel and coarse sand provide limited rooting opportunity, while finer sands, silts and organic mucks can support substantial plant growths. Steep-sided lakes support a much smaller plant community as a consequence of both peripheral substrate and light limitations. A few plants, including water hyacinth, water lettuce, duckweed, and watermeal, can float on the surface with no roots in the sediment, nearly eliminating substrate and light as key control factors.

Most macrophytes obtain most of their nutrition via roots that extend into the sediment. This is an important ecological feature, as they can therefore be abundant in lakes in which nutrient concentrations in the water column have been reduced through watershed management or in-lake measures. When the sediments are either highly organic (very loose mucks) or inorganic (rock to coarse sand), macrophyte growth may be poor because it is more difficult for roots to take hold and to obtain nutrients in these sediment types. In these two extremes, emergent plants may replace submergents in shallow water because their more extensive root systems are better adapted to these conditions.

Setting goals for rooted plant control is a critical planning step and the choice of management technique(s) will be highly dependent upon those goals. A certain amount of plant growth is an ecological necessity in most lakes. Where fishing is the primary objective, substantial littoral bottom coverage is desirable, with some vertical and horizontal structure created by different species of plants to enhance the habitat for different fish species or life stages. For swimming purposes, having no macrophytes seems desirable from a safety perspective, but a low, dense cover in shallow lakes with silty bottoms can minimize turbidity, another safety concern.

Perhaps the simplest axiom for plant management is that if light penetrates to the bottom and the substrate is not rock or cobble, plants will grow. A program intended to eliminate all plants is both unnatural and maintenance intensive, if possible at all. A program to structure the plant community to meet clear goals in an ecologically and ethically sound manner is more appropriate, although potentially still quite expensive.

Table 8-1 provides an overview of the techniques used to control rooted plants, with notes on the mode of action, advantages, and disadvantages of each technique. Additional details are provided in narrative form below.

Table 8-1 - Management Options for the Control of Rooted Aquatic Plants

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Physical Controls			
1) Benthic barriers	♦ Mat of variable composition laid on bottom of target area, preventing plant growth ♦ Can cover area for as little as several months or permanently ♦ Maintenance improves effectiveness ♦ Not often intended for use in large areas, usually applied around docks, in boating lanes, and in swimming areas	♦ Highly flexible control ♦ Reduces turbidity from soft bottoms ♦ Can cover undesirable substrate ♦ Can improve fish habitat by creating edge effects	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species
1.a) Porous or loose-weave synthetic materials	♦ Laid on bottom and usually anchored by sparse weights or stakes ♦ Removed and cleaned or flipped and repositioned at least once per year for maximum effectiveness	♦ Allows some escape of gases which may build up underneath ♦ Panels may be flipped in place or removed for relatively easy cleaning or repositioning	♦ Allows some growth through pores ♦ Gas may still build up underneath in some cases, lifting barrier from bottom

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
1.b) Non-porous or sheet synthetic materials	♦ Laid on bottom and anchored by many stakes, anchors or weights, or by layer of sand ♦ Not typically removed, but may be swept or "blown" clean periodically	♦ Prevents all plant growth until buried by sediment ♦ Minimizes interaction of sediment and water column	♦ Gas build up may cause barrier to float upwards ♦ Strong anchoring makes removal difficult and can hinder maintenance
1.c) Sediments of a desirable composition	♦ Sediments may be added on top of existing sediments or plants. ♦ Use of sand or clay can limit plant growths and alter sediment-water interactions. ♦ Sediments can be applied from the surface or suction dredged from below muck layer (reverse layering technique)	♦ Plant biomass can be buried ♦ Seed banks can be buried deeper ♦ Sediment can be made less hospitable to plant growths ♦ Nutrient release from sediments may be reduced ♦ Surface sediment can be made more appealing to human users ♦ Reverse layering requires no addition or removal of sediment	♦ Lake depth may decline ♦ Sediments may sink into or mix with underlying muck ♦ Permitting for added sediment may be difficult ♦ Addition of sediment may cause initial turbidity increase ♦ New sediment may contain nutrients or other contaminants ♦ Generally too expensive for large scale application

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
2) Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering/disposal ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Plants and seed beds are removed and re-growth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging ♦ Usually very expensive
2.a) "Dry" excavation	♦ Lake drained or lowered to maximum extent practical ♦ Target material dried to maximum extent possible ♦ Conventional excavation equipment used to remove sediments	♦ Tends to facilitate a very thorough effort ♦ May allow drying of sediments prior to removal ♦ Allows use of less specialized equipment	♦ Eliminates most aquatic biota unless a portion left undrained ♦ Eliminates lake use during dredging

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
2.b) "Wet" excavation	♦ Lake level may be lowered, but sediments not substantially dewatered ♦ Draglines, bucket dredges, or long-reach backhoes used to remove sediment	♦ Requires least preparation time or effort, tends to be least cost dredging approach ♦ May allow use of easily acquired equipment ♦ May preserve most aquatic biota	♦ Usually creates extreme turbidity ♦ Tends to result in sediment deposition in surrounding area ♦ Normally requires intermediate containment area to dry sediments prior to hauling ♦ May cause severe disruption of ecological function ♦ Usually eliminates most lake uses during dredging
2.c) Hydraulic removal	♦ Lake level not reduced ♦ Suction or cutterhead dredges create slurry which is hydraulically pumped to containment area ♦ Slurry is dewatered; sediment retained, water discharged	♦ Creates minimal turbidity and limits impact on biota ♦ Can allow some lake uses during dredging ♦ Allows removal with limited access or shoreline disturbance	♦ Often leaves some sediment behind ♦ Cannot handle extremely coarse or debris-laden materials ♦ Requires sophisticated and more expensive containment area ♦ Requires overflow discharge from containment area
3) Dyes and surface covers	♦ Water-soluble dye is mixed with lake water, thereby limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system. ♦ Opaque sheet material applied to water surface	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water ♦ Covers inhibit gas exchange with atmosphere

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
4) Mechanical removal	♦ Plants reduced by mechanical means, possibly with disturbance of soils ♦ Collected plants may be placed on shore for composting or other disposal ♦ Wide range of techniques employed, from manual to highly mechanized ♦ Application once or twice per year usually needed	♦ Highly flexible control ♦ May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Non-selective removal of plants in treated area ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity
4.a) Hand pulling	♦ Plants uprooted by hand (“weeding”) and preferably removed	♦ Highly selective technique	♦ Labor intensive
4.b) Cutting (without collection)	♦ Plants cut in place above roots without being harvested	♦ Generally efficient and less expensive than complete harvesting	♦ Leaves root systems and part of plant for re-growth ♦ Leaves cut vegetation to decay or to re-root ♦ Not selective within applied area
4.c) Harvesting (with collection)	♦ Plants cut at depth of 2-10 ft and collected for removal from lake	♦ Allows plant removal on greater scale	♦ Limited depth of operation ♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ More expensive than cutting

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
4.d) Rototilling	♦ Plants, root systems, and surrounding sediment disturbed with mechanical blades	♦ Can thoroughly disrupt entire plant	♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial turbidity ♦ More expensive than harvesting
4.e) Hydroraking	♦ Plants, root systems and surrounding sediment and debris disturbed with mechanical rake, part of material usually collected and removed from lake	♦ Can thoroughly disrupt entire plant ♦ Also allows removal of stumps or other obstructions	♦ Usually leaves fragments which may re-root and spread infestation ♦ May impact lake fauna ♦ Not selective within applied area ♦ Creates substantial turbidity ♦ More expensive than harvesting
5) Water level control	♦ Lowering or raising the water level to create an inhospitable environment for some or all aquatic plants ♦ Disrupts plant life cycle by desiccation, freezing, or light limitation	♦ Requires only outlet control to affect large area ♦ Provides widespread control in increments of water depth ♦ Complements certain other techniques (dredging, flushing)	♦ Potential issues with water supply ♦ Potential issues with flooding ♦ Potential impacts to non-target flora and fauna

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
5.a) Drawdown	♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds ♦ Timing and duration of exposure and degree of dewatering are critical aspects ♦ Variable species tolerance to drawdown; emergent species and seed-bearers are less affected ♦ Most effective on annual to once/3 yr. basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ Impacts vegetative propagation species with limited impact to seed producing populations	♦ Possible impacts on contiguous emergent wetlands ♦ Possible effects on overwintering reptiles and amphibians ♦ Possible impairment of well production ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ Possible overwinter water level variation ♦ Possible shoreline erosion and slumping ♦ May result in greater nutrient availability for algae
5.b) Flooding	♦ Higher water level in the spring can inhibit seed germination and plant growth ♦ Higher flows which are normally associated with elevated water levels can flush seed and plant fragments from system	♦ Where water is available, this can be an inexpensive technique ♦ Plant growth need not be eliminated, merely retarded or delayed ♦ Timing of water level control can selectively favor certain desirable species	♦ Water for raising the level may not be available ♦ Potential peripheral flooding ♦ Possible downstream impacts ♦ Many species may not be affected, and some may be benefited ♦ Algal nuisances may increase where nutrients are available

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
Chemical controls 6) Herbicides	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic poisons kill plants or limit growth ♦ Typically requires application every 1-5 yrs	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve some algae control as well	♦ Possible toxicity to non-target species of plants/animals ♦ Possible downstream impacts; may affect non-target areas within pond ♦ Restrictions of water use for varying time after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths
6.a) Forms of copper	♦ Contact herbicide ♦ Cellular toxicant, suspected membrane transport disruption ♦ Applied as wide variety of liquid or granular formulations, often in conjunction with polymers or other herbicides	♦ Moderately effective control of some submersed plant species ♦ More often an algal control agent	♦ Toxic to aquatic fauna as a function of concentration, formulation, and ambient water chemistry ♦ Ineffective at colder temperatures ♦ Copper ion persistent; accumulates in sediments or moves downstream

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
6.b) Forms of endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid)	♦ Contact herbicide with limited translocation potential ♦ Membrane-active chemical which inhibits protein synthesis ♦ Causes structural deterioration ♦ Applied as liquid or granules	♦ Moderate control of some emersed plant species, moderately to highly effective control of floating and submersed species ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to aquatic fauna (varying degrees by formulation) ♦ Time delays on use for water supply, agriculture and recreation ♦ Safety hazards for applicators
6.c) Forms of diquat (6,7-dihydropyrido [1,2-2',1'-c] pyrazinediium dibromide)	♦ Contact herbicide ♦ Absorbed by foliage but not roots ♦ Strong oxidant; disrupts most cellular functions ♦ Applied as a liquid, sometimes in conjunction with copper	♦ Moderate control of some emersed plant species, moderately to highly effective control of floating or submersed species ♦ Limited toxicity to fish at recommended dosages ♦ Rapid action	♦ Non-selective in treated area ♦ Toxic to zooplankton at recommended dosage ♦ Inactivated by suspended particles; ineffective in muddy waters ♦ Time delays on use for water supply, agriculture and recreation
6.d) Forms of glyphosate (N-[phosphonomethyl glycine)	♦ Contact herbicide ♦ Absorbed through foliage, disrupts enzyme formation and function in uncertain manner ♦ Applied as liquid spray	♦ Moderately to highly effective control of emersed and floating plant species ♦ Can be used selectively, based on application to individual plants ♦ Rapid action ♦ Low toxicity to aquatic fauna at recommended dosages ♦ No time delays for use of treated water	♦ Non-selective in treated area ♦ Inactivation by suspended particles; ineffective in muddy waters ♦ Not for use within 0.5 miles of potable water intakes ♦ Highly corrosive; storage precautions necessary

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
6.e) Forms of 2,4-D (2,4-dichlorophenoxyl acetic acid)	♦ Systemic herbicide ♦ Readily absorbed and translocated throughout plant ♦ Inhibits cell division in new tissue, stimulates growth in older tissue, resulting in gradual cell disruption ♦ Applied as liquid or granules, frequently as part of more complex formulations, preferably during early growth phase of plants	♦ Moderately to highly effective control of a variety of emersed, floating and submersed plants ♦ Can achieve some selectivity through application timing and concentration ♦ Fairly fast action	♦ Variable toxicity to aquatic fauna, depending upon formulation and ambient water chemistry ♦ Time delays for use of treated water for agriculture and recreation ♦ Not for use in water supplies
6.f) Forms of fluridone (1-methyl-3-phenyl-5-[-3-{trifluoromethyl} phenyl]-4[IH]-pyridinone)	♦ Systemic herbicide ♦ Inhibits carotenoid pigment synthesis and impacts photosynthesis ♦ Best applied as liquid or granules during early growth phase of plants	♦ Can be used selectively, based on concentration ♦ Gradual deterioration of affected plants limits impact on oxygen level (BOD) ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna	♦ Impacts on non-target plant species possible at higher doses ♦ Extremely soluble and mixable; difficult to perform partial lake treatments ♦ Requires extended contact time

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
6.g Forms of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid)	♦ Systemic herbicide, registered for experimental aquatic use by cooperators in selected areas only at this time ♦ Readily absorbed by foliage, translocated throughout plant ♦ Disrupts enzyme systems specific to plants ♦ Applied as liquid spray or subsurface injected liquid	♦ Effectively controls many floating and submersed plant species ♦ Can be used selectively, more effective against dicot plant species, including many nuisance species ♦ Effective against several difficult-to-control species ♦ Low toxicity to aquatic fauna ♦ Fast action	♦ Impacts on non-target plant species possible at higher doses ♦ Current time delay of 30 days on consumption of fish from treated areas ♦ Necessary restrictions on use of treated water for supply or recreation not yet certain
Biological Controls			
7) Biological introductions	♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses biological interactions to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of non-native species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
7.a) Herbivorous fish	♦ Sterile juveniles stocked at density which allows control over multiple years ♦ Growth of individuals offsets losses or may increase herbivorous pressure	♦ May greatly reduce plant biomass in single season ♦ May provide multiple years of control from single stocking ♦ Sterility intended to prevent population perpetuation and allow later adjustments	♦ May eliminate all plant biomass, or impact non-target species more than target forms ♦ Funnels energy into largely unused fish biomass and algae ♦ May drastically alter habitat ♦ May escape to new habitats upstream or downstream ♦ May not always be sterile; population control uncertain ♦ Grass carp currently not permitted for use in MA
7.b) Herbivorous insects	♦ Larvae or adults stocked at density intended to allow control with limited growth ♦ Intended to selectively control target species ♦ Milfoil weevil is best known, but still experimental	♦ Involves species native to region, or even targeted lake ♦ Expected to have no negative effect on non-target species ♦ May facilitate longer term control with limited management	♦ Population ecology suggests incomplete control likely ♦ Oscillating cycle of control and re-growth likely ♦ Predation by fish may complicate control ♦ Other lake management actions may interfere with success
7.c) Fungal/bacterial/viral pathogens	♦ Inoculum used to seed lake or target plant patch ♦ Growth of pathogen population expected to achieve control over target species	♦ May be highly species specific ♦ May provide substantial control after minimal inoculation effort	♦ Largely experimental; effectiveness and longevity of control not well known ♦ Infection ecology suggests incomplete control likely ♦ Possible side effects not well understood

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES
7.d) Selective plantings	♦ Establishment of plant assemblage resistant to undesirable species ♦ Plants introduced as seeds, cuttings or whole plants	♦ Can restore native assemblage ♦ Can encourage assemblage most suitable to lake uses ♦ Supplements targeted species removal techniques	♦ Largely experimental at this time; few well documented cases ♦ Nuisance species may eventually outcompete established assemblage ♦ Introduced species may become nuisances

8.2.1 Benthic Barriers

The use of benthic barriers, or bottom covers, is predicated upon the principles that rooted plants require light and cannot grow through physical barriers. Applications of clay, silt, sand, and gravel have been used for many years, although plants often root in these covers eventually, and current environmental regulations make it difficult to gain approval for such fill deposition. An exception may exist in the reverse layering technique (KVA 1991), in which sand is pumped from underneath a muck or silt layer and deposited as a new layer on top of the muck or silt. This is technically a re-organizing of the sediments, not new filling. Although expensive on a large scale and not applicable where the muck is not underlain by suitable materials, this technique restores the natural lake bottom of some previous time without sediment removal.

Artificial sediment covering materials, including polyethylene, polypropylene, fiberglass, and nylon, have been developed over the last three decades. A variety of solid and porous forms have been used. Manufactured benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants.

In theory, benthic barriers should be a highly effective plant control technique, at least on a localized, area-selective scale. In practice, however, there have been many difficulties in the deployment and maintenance of benthic barriers, limiting their utility in the broad range of field conditions. Benthic barriers can be effectively used in small areas such as dock spaces and swimming beaches to completely terminate plant growth. The creation of access lanes and structural habitat diversity is also practical. Large areas are not often treated, however, because the cost of materials and application is high and maintenance can be problematic.

Benthic barrier problems of prime concern include long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. Additionally, benthic barriers are non-selective, killing all plants over which they are applied. Oxygen depression and related chemical changes under the barrier result in reductions in the density and diversity of the benthic invertebrate community, but recovery is rapid once the barrier is removed. One final problem is the tendency of products to come and go without much stability in the market. Few of the barrier materials on the market at any time continue to be available for more than 5 to 10 years; most need to be made in bulk to keep costs down, yet cost remains high enough to hinder demand and reduce bulk use.

Successful use is related to selection of materials and the quality of the application. As a result of field experience with benthic barriers, several guidelines can be offered:

- ♦ Porous barriers will be subject to less billowing, but will allow settling plant fragments to root and growth; annual maintenance is therefore essential.

- Solid barriers will generally prevent rooting in the absence of sediment accumulations, but will billow after enough gases accumulate; venting and strong anchoring are essential in most cases.
- Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant; barriers of sufficient tensile strength can then be moved to a new location, although continued presence of solid barriers restricts recolonization.
- Proper application requires that the screens be placed on the sediment surface and staked or securely anchored. This may be difficult to accomplish over dense plant growth, and a winter drawdown can provide an ideal opportunity for application. Late spring application has also been effective, however, despite the presence of plant growths at that time, and barriers applied in early May have been removed in mid-June with no substantial plant growth through the summer. Scuba divers normally apply the covers in deeper water, which greatly increases labor costs. Bottom barriers will accumulate sediment deposits in most cases, which allows plant fragments to root. Barriers must then be cleaned, necessitating either removal or laborious in-place maintenance.

Despite application and maintenance issues, benthic barriers are a very effective tool. On a localized scale in New Bedford Reservoir, at a swimming area or around docks and landing areas, bottom barriers could be an effective means to control rooted plant growths. Except where the substrate is gravelly, plant growths can be expected and may require control to limit interference with recreation. Bottom barriers offer a smaller scale, localized approach to managing plant nuisances and would have minimal consequences on the overall lake ecosystem. They will not, however, provide economical control on a large-scale basis.

8.2.2 Dredging

Dredging works as a plant control technique when either a light limitation on growth is imposed through increased water depth or when enough “soft” sediment (muck, clay, silt and fine sand) is removed to reveal a less hospitable substrate (typically rock, gravel or coarse sand). The only exception may be suction dredging, whereby a target species can be reduced or possibly eliminated by removing whole plants and any associated seed banks. Suction dredging might more appropriately be considered a form of harvesting, however, as plants are extracted from the bottom by SCUBA divers operating the suction dredge and sediment is often returned to the lake.

The amount of sediment removed, and hence the new depth and associated light penetration, is critical to successful long-term control of rooted, submerged plants. There appears to be a direct relation between water transparency, as determined with a Secchi disk, and the maximum depth of colonization (MDC) by macrophytes. Canfield et al. (1985) provided equations to estimate MDC in Florida and Wisconsin from Secchi disk measurements:

State	Equation
Florida	$\log MDC = 0.42 \log SD + 0.41$
Wisconsin	$\log MDC = 0.79 \log SD + 0.25$

where SD = Secchi depth in meters

Using the Wisconsin equation, growths would be expected to a depth of 5 ft in the North Pond, 8 ft in the Northeast Pond and 9 ft in the South Pond. Growth in the North Pond and South Pond is observed to about 6 ft and throughout the Northeast Pond (max depth 7ft). The differences observed for the South pond may be due to watercolor, as the stained water decreases secchi depth.

If the soft sediment accumulations that are supporting rooted plant nuisances are not especially thick, it may be possible to create a substrate limitation before a light-limiting depth is reached. If dredging exposes rock ledge or cobble, and all soft sediment can be removed, there will be little rooted plant growth. Yet such circumstances are rare to non-existent; either the sediments grade slowly into coarser materials, or it is virtually impossible to remove all fine sediments from the spaces around the rock or cobble. Consequently, at least 25% re-growth is to be expected when light penetrates to the bottom.

Dredging can be accomplished by multiple methods, which can be conveniently grouped into four categories:

- Dry excavation, in which the lake is drained to the extent possible, the sediments are dewatered by gravity and/or pumping, and sediments are removed with conventional excavation equipment such as backhoes, bulldozers, or draglines.
- Wet excavation, in which the lake is not drained or only partially drawn down (to minimize downstream flows), with excavation of wet sediments by various bucket dredges mounted on cranes or amphibious excavators.
- Hydraulic dredging, requiring a substantial amount of water in the lake to float the dredge and provide a transport medium for sediment. Hydraulic dredges are typically equipped with a cutterhead that loosens sediments. The sediments are then mixed with water and transported as a pumped slurry of 80 to 90% water and 10 to 20% solids through a pipeline that traverses the lake from the dredging site to a disposal area.
- Pneumatic dredging, in which air pressure is used to pump sediments out of the lake at a higher solids content (reported as 50 to 70%). This would seem to be a highly desirable approach, given containment area limitation in many cases and more rapid drying with higher solids content. However, few of these dredges are operating within North America, and there is little freshwater experience upon which to base a review. Considerations are much like those for hydraulic dredging, but no further text will be devoted to this technique.

Experience with dredging for rooted plant control has had mixed results. As with dredging for algal control, failures are invariably linked to incomplete pre-dredging assessment and planning. Control through light limitation appears more successful than control through substrate limitation, largely as a function of the difficulty of removing all soft sediment from shallow areas. Dry dredging projects appear to result in more thorough soft sediment removal, mainly because equipment operators can visually observe the results of dredging as it takes place. Hydraulic dredging in areas with dense weed beds can result in frequent clogging of the pipeline to the slurry discharge area, suggesting the need for some form of temporary plant control (most often herbicides or harvesting) prior to hydraulic dredging.

The potential for serious negative impacts by dredging on the lake and surrounding area is very high. Many of these problems are short-lived, however, and can be minimized with proper planning. It should be kept in mind, however, that dredging represents a major re-engineering of a lake, and should not be undertaken without clear recognition of its full impact, positive and negative.

Dredging of New Bedford Reservoirs to control rooted plants would probably focus on the North Pond. The South Pond has limited plant growth problems due to its depth and the Northeast Pond does not experience the high densities that the North Pond does. Dredging of the North Pond would involve creating a substrate limitation in shallow waters <4 ft deep assuming that the substrate below the organic layer would not support growth or removing sediment down to a depth of >6 ft. Either option would not be cost effective due to the large amount of sediment that would need to be removed and there are other options that should provide the desired level of control.

8.2.3 Light Limitation with Dyes and Surface Covers

Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. They tend to reduce the maximum depth of plant growth, but have little effect in shallow water (<4 ft deep). They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which a stem could reach the lighted zone). In lakes with high transparency but only moderate depth and ample soft sediment accumulations, dyes may provide open water where little would otherwise exist. Repeated treatment will be necessary, as the dye flushes out of the system. Dyes are typically permitted under the same process as herbicides, despite their radically different mode of action.

Surface shading has received little attention as a rooted plant control technique, probably as a function of potential interference with recreational pursuits, which are a goal of most rooted plant control programs. Polyethylene sheets, floated on a lake surface for two to three weeks may be sufficient to eliminate many species for the summer if the sheets were applied in spring before plants grow to maturity. This procedure should be a useful and inexpensive alternative to traditional methods of weed control in small areas such as docks and beaches, and could be timed to yield results acceptable to summer human users with minimal negative impacts to system ecology.

The artificial color imparted by dyes will do little more for New Bedford Reservoir than the natural color that pond already provides. The potential interference of surface covers with recreation limits their utility. However, surface covers might be used on a localized basis much like bottom barriers. The key would be to have the surface cover in place during the spring to retard growths, then remove it for the swimming and boating season.

8.2.4 Mechanical Removal

There are many variations on mechanical removal of macrophytes. Table 8-1 breaks these varied techniques into hand pulling, cutting without collection, harvesting with collection, rototilling, and hydroraking. Suction dredging, addressed in the dredging section, could also be included here, as it is primarily intended to remove plant biomass. Other classification systems are undoubtedly applicable; this is a diverse collection of methods linked by the commonality of physically attacking the targeted plants. These techniques are often cited as being analogous to mowing the lawn (cutting or harvesting), weeding the garden (hand pulling), or tilling the soil (rototilling or hydroraking), and these are reasonable comparisons. Mechanical management of aquatic plants is not much different from managing terrestrial plants, except for the complications imposed by the water.

Hand pulling is exactly what it sounds like; a snorkeler or diver surveys an area and selectively pulls out unwanted plants on an individual basis. This is a highly selective technique, and a labor intensive one. It is well suited to vigilant efforts to keep out invasive species that have not yet become established in the lake or area of concern. Hand pulling can also effectively address non-dominant growths of undesirable species in mixed assemblages, or small patches of plants targeted for removal. This technique is not suited to large scale efforts, especially when the target species or assemblage occurs in dense or expansive beds.

Hand pulling can be augmented by various tools, including a wide assortment of rakes, cutting tools, water jetting devices, nets and other collection devices. McComas (1993) provides an extensive and enjoyable review of options. Use of these tools transitions into the next two categories, macrophyte cutting and harvesting. Suction dredging is also used to augment hand pulling, allowing a higher rate of pulling in a targeted area, as the diver/snorkeler does not have to carry pulled plants to a disposal point.

Cutting is also exactly what it appears to be. A blade of some kind is applied to plants, severing the active apical meristem (location of growth) and possibly much more of the plant from the remaining rooted portion. Regrowth is expected, and in some species that regrowth is so rapid that it negates the benefits of the cutting in only a week or two. If the plant can be cut close enough to the bottom, or repeatedly, it will sometimes die, but this is more the exception than the rule. Cutting is defined here as an operation which does not involve collecting the plants once they are cut, so impacts to dissolved oxygen are possible in large scale cutting operations.

The most high technology cutting technique involves the use of mechanized barges normally associated with harvesting operations, in which plants are normally collected for out-of-lake disposal. In its use as a cutting technology, the “harvester” cuts the plants but does not collect them. A recent modification in this technique employs a grinding apparatus, which ensures that viable plant fragments are minimized after processing. There is a distinct potential for dissolved oxygen impacts as the plant biomass decays if it is not removed from the pond, much like what would be expected from most herbicide treatments.

Harvesting may involve collection in nets or small boats towed by the person collecting the weeds, or can employ smaller boat-mounted cutting tools which haul the cut biomass into the boat for eventual disposal on land, or can be accomplished with larger, commercial machines with numerous blades, a conveyor system, and a substantial storage area for cut plants. Offloading accessories are available, allowing easy transfer of weeds from the harvester to trucks that haul the weeds to a composting area. Choice of equipment is really a question of scale, with most larger harvesting operations employing commercially manufactured machines built to specifications suited to the job. Some lake associations choose to purchase and operate harvesters, while others prefer to contract harvesting services to a firm specializing in lake management efforts.

Cutting rates for commercial harvesters tend to range from about 0.2 to 0.6 acres per hour, depending on machine size and operator ability, but the range of possible rates is larger. Even at the highest conceivable rate, harvesting is a slow process that may leave some lake users dissatisfied with progress in controlling aquatic plants. Weed disposal is not usually a problem, in part because lakeshore residents and farmers often will use the weeds as mulch and fertilizer. Also, since aquatic plants are more than 90 percent water, their dry bulk is comparatively small. Key issues in choosing a harvester include depth of operation, volume and weight of plants that can be stored, reliability and ease of maintenance, along with a host of details regarding the hydraulic system and other mechanical design features.

Rototilling and the use of cultivation equipment are newer procedures with a limited track record. A rototiller is a barge-like machine with a hydraulically operated tillage device that can be lowered to depths of 10-12 ft for the purpose of tearing out roots. Also, if the water level in the lake can be drawn down, cultivation equipment pulled behind tractors on firm sediments can achieve 90 percent root removal. Potential impacts to non-target organisms and water quality are substantial, but where severe weed infestations exist, this technique could be appropriate.

Hydroraking involves the equivalent of a floating backhoe, usually outfitted with a York rake, which looks like certain farm implements for tilling or moving silage. The tines of the rake attachment are moved through the sediment, ripping out thick root masses and associated sediment and debris. A hydrorake can be a very effective tool for removing submerged stumps, water lily root masses, or floating islands. Use of a hydrorake is not a delicate operation, however, and will create substantial turbidity and plant fragments. Hydroraking in combination with a harvester can remove most forms of vegetation encountered in lakes.

Most mechanical plant removal operations are successful in producing at least temporary relief from nuisance plants and in removing organic matter and nutrients without the addition of a potentially deleterious substance. Plant regrowth can be very rapid (days or weeks). Harvesting may reduce plant diversity in some cases, and resultant open areas are candidates for colonization by invasive species, but most potential problems can be avoided by proper program planning.

Harvesting could be used in New Bedford Reservoir to control rooted plants on a maintenance basis, but the long-term costs may not be favorable.

8.2.5 Water Level Control

Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat. It has also been a common fishery management method. Until a few decades ago, drawdowns of recreational lakes were primarily for the purpose of flood control and allowing access for clean ups and repairs to structures, with macrophyte control as an auxiliary benefit. While this technique is not effective on all submergent species, it does decrease the abundance of some of the chief nuisance species, particularly those that rely on vegetative propagules for overwintering and expansion. If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control some macrophytes. Additional benefits may include opportunities for shoreline maintenance and oxidation or removal of nutrient-rich sediments.

The ability to control the water level in a lake is affected by area precipitation pattern, system hydrology, lake morphometry, and the outlet structure. The base elevation of the outlet or associated subsurface pipe(s) will usually set the maximum drawdown level, while the capacity of the outlet to pass water and the pattern of water inflow to the lake will determine if that base elevation can be achieved and maintained. In some cases, sedimentation of an outlet channel or other obstructions may control the maximum drawdown level.

Several factors affect the success of drawdown with respect to plant control. While drying of plants during drawdowns may provide some control, the additional impact of freezing is substantial, making drawdown a more effective strategy during late fall and winter. However, a mild winter or one with early and persistent snow may not provide the necessary level of drying and freezing. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on target submergent species by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring or new and equally undesirable plant species. Recolonization from nearby areas may be rapid, and the response of macrophyte species to drawdown is quite variable.

Desirable side effects associated with drawdowns include the opportunity to clean up the shoreline, repair previous erosion damage, repair docks and retaining walls, search for septic system breakout, and physically improve fish spawning areas. The attendant concentration of forage fish and game fish in the same areas may be viewed as a benefit of most drawdowns, although not all fishery professionals agree. The consolidation of loose sediments and sloughing of soft sediment deposits into deeper water is perceived as a benefit in many cases, at least by shoreline homeowners.

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fishkills if oxygen demand exceeds re-aeration during a prolonged drawdown, altered littoral habitat for fish and invertebrates, mortality among hibernating reptiles and amphibians, impacts to connected wetlands, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after refill in some cases, reduction in water supply, impairment of recreational access during the drawdown, and downstream flow impacts. Careful planning can often avoid many of these negative side effects, but managers should be aware of the potential consequences of any management action.

Desirable flood storage capacity will increase during a drawdown, but associated alteration of the downstream flow regime may have some negative impacts. Once the target drawdown level is achieved, there should be little alteration of downstream flow. However, downstream flows must necessarily be greater during the actual drawdown than they would be if no drawdown was conducted. The key to managing downstream impacts is to minimize erosion and keep flows within an acceptable natural range.

Inability to rapidly refill a lake after drawdown is a standard concern in evaluating the efficacy of a drawdown. There must be enough water entering the lake to refill it within an appropriate timeframe while maintaining an acceptable downstream flow. In northern lakes, the best time for refill is in early spring, when flows typically peak as the snowpack melts and rainfall on frozen ground yields the maximum runoff.

Impairment of water supply during a drawdown is a primary concern of groups served by that supply. Processing or irrigation water intakes may be exposed, reducing or eliminating intake capacity. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake and Forge Pond in Massachusetts resulted in impairment of well water supplies (Wagner, pers. obs.), but there is little mention of impairment of well production in the reviewed literature.

Recreational facilities and pursuits may be adversely impacted during a drawdown. Swimming areas will shrink and beach areas will enlarge during a drawdown. Boating may be restricted both by available lake area and by access to the lake. Again, winter drawdown will avoid most of these disadvantages, although lack of control over winter water levels can make ice conditions unsafe for fishing or skating. Additionally, outlet structures, docks and retaining walls may be subject to damage from freeze/thaw processes during overwinter drawdowns, if the water level is not lowered beyond all contact with structures.

Carefully planned water level fluctuation can be a useful technique to check nuisance macrophytes and periodically rejuvenate wetland diversity. Planned disturbance is always a threshold phenomenon; a little is beneficial, too much leads to overall ecosystem decline. The depth, duration, timing and frequency of the drawdown are therefore critical elements in devising the most beneficial program.

It does appear that a drawdown could be an inexpensive means of gaining some control over rooted plants in New Bedford Reservoir. It seems unreasonable to assume that the ponds could be lowered sufficiently to kill most of the vegetation, as few areas are devoid of vegetation and completely draining the lake would not be likely to be permitted. It would be possible, however, to lower the ponds slightly (perhaps 2-4 ft) and observe what benefits and detriments accrue. Issues associated with drawdown such as impact on water supply or non-target flora and fauna could be evaluated in a phased program of increasing drawdown, up to the point where detrimental impacts become unacceptable. Drawdown does not cause irreversible impacts; only temporary impacts would be likely from a few years of experimental drawdown. Further research into the dam and outlet structure would be necessary to understand the potential drawdown capacity of the structure.

8.2.6 Herbicides

Killing nuisance aquatic weeds with chemicals is perhaps the oldest method used to attempt their management. Other than perhaps drawdown, few alternatives to herbicides were widely practiced until relatively recently. There are few aspects of plant control which breed more controversy than chemical control through the use of herbicides, which are a subset of all chemicals known as pesticides. Yet as chemicals are an integral part of life and the environment, it is logical to seek chemical solutions to such problems as infestations of non-native species which grow to nuisance proportions, just as we seek physical and biological solutions. Current pesticide registration procedures are far more rigorous than in the past. While no pesticide is considered unequivocally “safe”, a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when the chemical is used according to label restrictions.

There are only six active ingredients currently approved for use in aquatic herbicides in the USA today, with one additional ingredient in the experimental use phase of the approval process. Westerdahl and Getsinger (1988a, 1988b) provide a detailed discussion of herbicides and related plant susceptibilities.

Copper products have been around for a long time. Copper is not typically preferred as a primary herbicide for rooted aquatic plants, but is sometimes part of a broad spectrum formulation intended to reduce the biomass of an entire plant assemblage, especially if it includes a substantial algal component. Copper concentrations should not exceed 1 mg/L in the treated waters.

Endothall is a contact herbicide, attacking plants at the immediate point of contact. Only portions of the plant with which the herbicide can come into contact are killed. It is sold in several formulations: liquid (Aquathol K), granular dipotassium salt (Aquathol), and the di (N, N-dimethyl-alkylanine) salt (Hydrothol) in liquid and granular forms. Effectiveness can range from weeks to months. Most endothall compounds break down readily and are not persistent in the aquatic environment, but the potassium salt forms have been shown to persist in the water for 2 to 46 days.

Endothall acts quickly on susceptible plants, but does not kill roots with which it cannot come into contact, and recovery of many plants is rapid. Rapid death of susceptible plants can cause oxygen depletion if decomposition exceeds re-aeration in the treated area, although this can be mitigated by conducting successive partial treatments. Toxicity to invertebrates, fish or humans is not expected to be a problem at the recommended dose, yet water use restrictions are mandated on the label and it is not used in drinking water supplies. Depending upon the formulation, concentrations in treated waters should be limited to 1 to 5 mg/L.

Diquat, like endothall, it is a fast acting contact herbicide, producing results within 2 weeks of application. It is not an especially selective herbicide, and can be toxic to invertebrates, fish, mammals, birds and humans. A domestic water use restriction is normally applied, and this herbicide is not used in drinking water supplies. Regrowth of some species has been rapid (often within the same year) after treatment with diquat in many cases. Concentrations in treated water should not exceed 2 mg/L.

Glyphosate is another contact herbicide. Its aquatic formulation is effective against most emergent or floating-leaved plant species, but not against most submergent species. Its mode of action is not certain, but it appears to disrupt synthesis of necessary compounds within the cell. Rainfall shortly after treatment can negate its effectiveness, and it readily adsorbs to particulates in the water column or to sediments and is inactivated. It is relatively non-toxic to aquatic fauna at recommended doses, and degrades readily into non-toxic components in the aquatic environment. There is no maximum concentration for treated water, but a dose of 0.2 mg/L is recommended.

2,4-D, which is the active ingredient in a variety of commercial herbicide products, has been in use for over 30 years despite claims of undesirable environmental side effects and potential human health effects. This is a systemic herbicide; it is absorbed by roots, leaves and shoots and disrupts cell division throughout the plant. Vegetative propagules such as winter buds, if not connected to the circulatory system of the plant at the time of treatment, are generally unaffected and can grow into new plants. It is therefore important to treat plants early in the season, after growth has become active but before such propagules form.

2,4-D is sold in liquid or granular forms as sodium and potassium salts, as ammonia or amine salts, and as an ester. Doses of 50 to 150 pounds per acre are usual for submersed weeds, most often of the dimethylamine salt or the butoxyethanolester (BEE). This herbicide is particularly effective against

Eurasian watermilfoil (granular BEE applied to roots early in the season). 2,4-D has a short persistence in the water but can be detected in the mud for months. Recovery of the native community from seed has also been successful. 2,4-D has variable toxicity to fish, depending upon formulation and fish species. The 2,4-D label does not permit use of this herbicide in water used for drinking or other domestic purposes, or for irrigation or watering of livestock. Concentrations in treated water should not exceed 0.1 mg/L.

Fluridone is a systemic herbicide introduced in 1979 and in widespread use since the mid-1980's, although some states have been slow to approve its use. Fluridone currently comes in two formulations, an aqueous suspension and a slow release pellet, although an even slower release pellet is in the development stage. This chemical inhibits carotene synthesis, which in turn exposes the chlorophyll to photodegradation. Most plants are negatively sensitive to sunlight in the absence of protective carotenes, resulting in chlorosis of tissue and death of the entire plant with prolonged exposure to a sufficient concentration of fluridone. Some plants, including Eurasian watermilfoil, are more sensitive to fluridone than others, allowing selective control at low dosages. Fanwort is also sensitive to fluridone, but at higher doses than typically used for Eurasian watermilfoil.

For susceptible plants, lethal effects are expressed slowly in response to treatment with fluridone. Existing carotenes must degrade and chlorosis must set in before plants die off; this takes several weeks to several months, with 30-90 days given as the observed range of time for die off to occur after treatment. Fluridone concentrations should be maintained in the lethal range for the target species for at least three weeks, and preferably for six weeks. This presents some difficulty for treatment in areas of substantial water exchange, but the slow rate of die off minimizes the risk of oxygen depletion.

Fluridone is considered to have low toxicity to invertebrates, fish, other aquatic wildlife, and humans. It is not known to be a carcinogen, oncogen, mutagen or teratogen. Research on its degradation products initially suggested some possible effects, but further testing indicated no significant threat. Substantial bioaccumulation has been noted in certain plant species, but not to any great extent in animals. The USEPA has designated a tolerance level of 0.5 ppm (mg/L or mg/kg) for fluridone residues or those of its degradation products in fish or crayfish. The USEPA has set a tolerance limit of 0.15 ppm for fluridone or its degradation products in potable water supplies, although state restrictions are sometimes lower. Control of Eurasian watermilfoil has been achieved for at least a year without significant impact on non-target species at doses <0.01 mg/L. However, control of variable milfoil has not been consistent and requires more research before this herbicide can be considered reliable for control of that species.

The active herbicidal ingredient triclopyr is currently experimental for aquatic habitats. It is highly selective and effective against Eurasian watermilfoil at a dose of 1 to 2.5 mg/L. Experimental treatments of aquatic environments (Netherland and Getsinger 1993) have revealed little or no effect on most monocotyledonous naiads and pondweeds, which are mostly valued native species. Its mode of action is to prevent synthesis of plant-specific enzymes, resulting in disruption of growth processes.

This herbicide is most effective when applied during the active growth phase of young plants. It has just been registered with the USEPA, but does not yet have a MA state registration to allow its use within the Commonwealth.

Triclopyr is not known to be a carcinogen, oncogen, mutagen or teratogen, and all lethal effects on tested animal populations have occurred at concentrations over 100 times the recommended dosage rate. The experimental label calls for concentrations in potable water of no more than 0.5 mg/L, suggesting that care must be taken to allow sufficient dilution between the point of application and any potable water intakes.

A herbicide treatment can be an effective short-term management procedure to produce a rapid reduction in vegetation for weeks to months. In some cases involving fluridone, as many as five years of control can be gained. The use of herbicides to control a major plant nuisance is a valid element of long-term management when other means of keeping plant growths under control are also applied. Failure to apply alternative techniques on a smaller scale once the nuisance has been abated places further herbicide treatments in the cosmetic maintenance category; such techniques tend to have poor cost-benefit ratios over the long-term.

Important questions to be answered before adopting a management program involving herbicides include:

- What is the acreage and volume of the area(s) to be treated? Proper dosage is based upon these facts.
- What plant species are to be controlled? This will determine the herbicide and dose to be used.
- What will the long-term costs of this decision be? Most herbicides must be reapplied annually, in some cases two to three times per growing season.
- How is this waterbody used? Many herbicides have restrictions of a day to two weeks on water use following application.
- Is the applicator licensed and insured, and has a permit been obtained from the appropriate regulatory agency? All are necessary prior to treatment.

For New Bedford Reservoir treatment with multiple herbicides might be necessary to control the range of species present. Potential risks to cranberry bogs might outweigh the expected benefits, especially since the shallow ponds are expected to support substantial plant growths; any benefits from herbicide treatment are likely to be temporary.

8.2.6.1 Biological Introductions

Significant improvement in our future ability to achieve lasting control of nuisance aquatic vegetation may come from plant-eating or plant-pathogenic biocontrol organisms, or from a combination of current procedures such as harvesting, drawdown, and herbicides with these organisms. Biological control has the objective of achieving control of plants without introducing toxic chemicals or using machinery.

It suffers from one ecological drawback; in predator-prey (or parasite-host) relationships, it is rare for the predator to completely eliminate the prey. Consequently, population cycles or oscillations are typically induced for both predator and prey. It is not clear that the magnitude of the upside oscillations in plant populations will be acceptable to human users, and it seems likely that a combination of other techniques with biocontrols may be necessary to achieve lasting, predictable results.

Biological controls include herbivorous fish such as *Ctenopharyngidon idella* (the grass carp), insects such as the aquatic weevil (*Euhrychiopsis lecontei*), and experimental fungal pathogens. Aside from consumptive approaches (grazing, parasitism), it is also possible to exert competitive pressures, limiting invasive species by maintaining a healthy native assemblage.

The grass carp is a non-native fish (imported around 1962) known to be a voracious consumer of many forms of macrophytes. It has a very high growth rate. This combination of broad diet and high growth rate can produce control or even eradication of plants within several seasons. However, grass carp do not consume aquatic plant species without preference. These fish prefer plant species such as elodea, pondweeds and hydrilla. Low stocking densities can produce selective grazing on the preferred plant species while other less preferred species, including milfoil, may even increase. Overstocking, on the other hand, may eliminate all plants, contrary to the ecological axiom of oscillating population cycles described previously.

Grass carp are not approved for introduction in Massachusetts. Consequently, while some success has been achieved elsewhere, this is not an option for New Bedford Reservoir at this time. Additionally, the use of grass carp is likely to drastically alter the ecology of a lake. Stocked to reduce vascular plant density, grass carp typically cause a shift toward algal blooms and increased turbidity that becomes a self-sustaining alternative lake condition. This condition is often unsuitable for desirable gamefish production and may be more objectionable to human users than the original rooted plant density.

The use of insects to control rooted plants has historically centered on introduced, non-native species. Despite some successes, the track record for biological problem-solving through introduced, non-native species is poor (as many problems seem to have been created as solved), and governmental agencies tend to prefer alternative controls unless there is no practical choice. However, the use of native species in a biomanipulative approach is usually acceptable. Combining biological, chemical and mechanical controls is the basis of integrated pest control, and takes advantage of as many avenues of control as possible for maximum effectiveness. The development of native insects as aquatic plant controls is still in its infancy, but several promising developments have occurred in the last decade. The use of larvae of midgeflies, caddisflies, beetles and moths have been explored with some promise. However, the activities of the aquatic weevil *Euhrychiopsis lecontei* have received the most attention in recent years.

Euhrychiopsis lecontei is a native North American species believed to have been associated with northern watermilfoil (*Myriophyllum sibericum*), a species largely replaced by non-native, Eurasian watermilfoil (*M. spicatum*) since the 1940's. The weevil is able to switch plant hosts within the milfoil genus, although to varying degrees and at varying rates depending upon genetic stock and host history. It does not utilize non-milfoil species, and does not appear to affect variable milfoil, the dominant species in the New Bedford Reservoir. Its impact on Eurasian watermilfoil was been documented through five years of experimentation under USEPA sponsorship. In controlled trials, the weevil clearly has the ability to impact milfoil plants through structural damage to apical meristems (growth points) and basal stems (plant support). Adults and larvae feed on milfoil, eggs are laid on it, and pupation occurs in burrows in the stem.

Although weevils may be amenable to use within an integrated milfoil management approach, the milfoil weevil is not expected to control variable milfoil, or any other species present in New Bedford Reservoir.

Plant pathogens remain largely experimental, despite a long history of interest from researchers. Fungi are the most common plant pathogens investigated, and control of water hyacinth, hydrilla or Eurasian watermilfoil by this method has been extensively evaluated. Results have not been consistent or predictable in most cases, and problems with isolating effective pathogens, overcoming evolutionary advantages of host plants, and delivering sufficient inoculum have limited the utility of this approach to date. However, combination of fungal pathogens and herbicides has shown some recent promise as an integrated technique.

Although invasive nuisance plant species are just what the name implies, there is evidence that the presence of a healthy, desirable plant community can minimize or slow infestation rates. Most invasive species are favored by disturbance, so a stable plant community should provide a significant defense. Unfortunately, natural disturbances abound, and almost all common plant control techniques constitute disturbances. Therefore, if native and desirable species are to regain dominance after disturbance, it may be necessary to supplement their natural dissemination and growth with seeding and plantings. The use of seeding or planting of vegetation is still a highly experimental procedure, but if native species are employed it should yield minimal controversy. More research is needed in this area, but establishment of desired vegetation is entirely consistent with the primary plant management axiom; if light and substrate are adequate, plants will grow. Control of rooted plants should extend beyond the limitation of undesirable species to the encouragement of desirable plants.

8.3 In-Lake Management Options – Avian Control

Although ENSR did not notice large amounts of birds during their field surveys, fecal matter was noted along the shoreline and in boat-launch areas. The Town also has identified this to be of concern. Control of birds can be difficult; methods are limited and tend not to be continually effective.

8.3.1.1 Behavioral Modifications

Behavioral modifications involve changing the actions of watershed residents and lake users to improve water quality. The main behavioral change would be not to feed any birds. Behavioral modifications can be brought about in two principal ways, through public education and/or the implementation of local bylaws and bans. Education is a critical first step and should precede any attempt at regulation. The focus of education and behavioral modifications related to avian control should be on the detriment to the environment brought about by feeding animals and birds.

Public education can be accomplished in the same ways as discussed under watershed management techniques, mainly mailing informative brochures, through the use of video programs on local access television, by placing informative billboards in high access areas, or by holding public meetings for watershed residents.

8.3.1.2 Buffer zones

Minimization of shore line areas of direct movement of birds from the water to land areas such as beaches and launch areas will help deswade birds from using a specific area. Ducks, geese and swans prefer habitat that they can easily walk out of the water and onto land. This may be difficult in New Bedford Reservoir due to fluctuating water levels exposing additional beach areas as the summer progresses.

9.0 MANAGEMENT RECOMMENDATIONS

There are several distinct problems relating to New Bedford Reservoir that should be addressed if conditions are to be made consistent with desired use as a contact recreation resource. Primary among them are loading of nutrients and other contaminants from the watershed, excessive rooted plant growths in the reservoir, and interactions with waterfowl that may have health implications for human users of the reservoir. The recommended approach could take many forms, and each problem is likely to involve multiple management actions followed by further study to determine what progress has been made and what additional needs should be met. In light of the size of the system and the lack of highly detailed information on the Reservoir and its watershed, this investigation should be viewed as a first step toward developing an overall management program. The information gained thus far, however, does suggest several actions that could be taken in the near future to help establish the desired conditions in the Reservoir. It also suggests limitations on management actions that will eliminate some options.

Reduce loading of nutrients and related contaminants

The data and analysis provided in this study suggest that loads are higher than what would be desired for a contact recreation resource. Any actions that limit further inputs are viewed as desirable, but the balance between expense for loading reductions and benefits to be accrued is not clear. Despite slightly elevated phosphorus levels, phosphorus availability is not especially high and light limits the level of phytoplankton (algae) production. This is not unusual in slightly acidic, colored lakes, and suggests that major expense to reduce loading is not a high priority. All possible actions to restrict further loading are recommended, including full application of the Wetlands Protection Act, the Riverways Act, and the Massachusetts Storm Water Policy in association with new or existing development projects.

Wherever possible, it would also be desirable to limit the input of storm water runoff to the Ponds or their tributaries. This can best be accomplished by detention and infiltration facilities, but care should be taken to look for passive opportunities to detain and filter storm water, rather than taking a more involved and expensive engineering approach. A follow up survey to suggest a list of target areas and their relative priority would be appropriate. The Town of Acushnet should then seek creative and cooperative approaches to fund and implement these improvements, but with the recognition that no single area or action is likely to strongly influence Reservoir condition by itself. Enhancing water quality will require long-term effort, and current utility of the Reservoir is not substantially impaired by water quality issues.

Reduce the density of rooted aquatic plants

The coverage of Reservoir area by rooted plants is currently excessive, in terms of both supporting human uses and maximizing ecological habitat value. The aquatic plant assemblage is, however, a largely native group of plants, and substantial growths of plants are to be expected in shallow waters with suitable substrates. Variable milfoil, the native/non-native status of which is debatable, is the primary problem species, with bladderwort as a secondary problem and water lilies providing nuisance conditions on a more localized basis. The only techniques that deal with the plants on a whole-lake basis are dredging and herbicides, neither of which appears particularly well suited to the circumstances of the reservoir at this time. It might be possible to treat portions of the reservoir with herbicides without major risk to cranberry operations, but that eliminates the lakewide appeal of that approach. In contrast, drawdown, bottom barriers, surface covers can be used on selected parts of the ponds to achieve the desired conditions. Drawdown is particularly appealing, as it carries little cost and will most affect peripheral areas where human use is most intense. Bottom barriers and surface covers have highly localized applicability, however, where a swimming area is to be established or maintained.

The key question to be answered involves the desired level of use for these ponds and the associated level of plant density that is tolerable. Realistically, these ponds are not naturally well suited as motorized watercraft resources, being too shallow and having easily resuspended soft sediments, and no indication has been given that there is any strong interest in such use. Use of motors for fishing is possible now, albeit with limitations, and reduced plant abundance would be desirable. However, the primary species for which one would fish in ponds such as these (pickerel, bass) are tolerant of high plant density and may actually require more plant coverage than desirable for most human uses. Canoeing and other non-motorized uses are possible now, but would be better served with fewer plants. Swimming requires a much lower density of plants, but not over the whole area of the reservoir.

It is suggested that a drawdown would open peripheral areas such that improved swimming, fishing, and non-motorized boating would result. A drawdown of perhaps 3 ft would be a logical starting target, with monitoring to determine just what effects such a drawdown would have. A separate feasibility study may be necessary, as the number of considerations associated with planning, permitting and implementing a drawdown (Table 9-1) is second only to dredging projects. From the data collected in this study, however, there is no indication that a 3 ft drawdown could not be supported. The cost of planning and permitting would be on the order of $15,000.

The use of bottom barriers is recommended for any smaller areas where low plant biomass is needed. This would include swimming areas and possibly access lanes for boats. This approach is too expensive on a larger scale, but could provide longer-term relief with proper planning and maintenance. A cost on the order of $40,000/acre for capital cost is to be expected, but that will provide material that is expected to last at least a decade.

It should be kept in mind that several invasive species are currently absent (most notably fanwort, or *Cabomba caroliniana*), and that any management of the existing plant community may constitute a disturbance favoring invasions. The use of drawdown and bottom barriers offers the least potential for such invasions, and has worked well in other cases.

Reduce waterfowl use of beach and boat launch areas

This is a tricky area of management, as habitat for waterfowl would appear to be a goal of reservoir management in this and many similar cases. The key is keeping the waterfowl away from the swimming and boat access areas. This can be done a variety of ways, as described previously, but is best accomplished on a longer term basis by altering the habitat in the target areas to make it less hospitable to waterfowl, particularly geese. This poses a challenge, as what limits access for geese may also limit access for humans and boats. It is suggested that temporary fencing be erected at any access point during periods of limited use (e.g., fall through early spring) to discourage waterfowl use of those areas. The fencing would be removed, either for the summer season or on a daily basis (as at beaches), to facilitate human access. A cost on the order of $5000 is envisioned.

The primary alternatives include trained dogs that chase waterfowl and noisemakers used to scare waterfowl, both of which have distinct drawbacks that may limit utility in this case. Selective plantings may be applicable in areas less actively used by humans.

Table 9-1 - Key Considerations for Drawdown

Reasons for Drawdown
- Access to structures for maintenance or construction
- Access to sediments for removal (dredging)
- Flood control
- Prevention of ice damage to shoreline and structures
- Sediment compaction
- Rooted plant control
- Fish reclamation

Water Quality
- Possible change in nutrient levels
- Possible change in oxygen levels
- Possible change in pH levels
- Other water quality issues

Sediments
- Particle size distribution (or general sediment type)
- Solids and organic content
- Potential for sloughing
- Potential for shoreline erosion
- Potential for dewatering and compaction
- Potential for odors
- Access and safety considerations

In-Lake Vegetation
- Composition of plant community
- Areal distribution of plants
- Plant density
- Seed-bearing vs. vegetative propagation
- Impacts to target and non-target species

Macroinvertebrates, Fish and Wildlife
- Composition of fauna
- Association with areas to be exposed
- Breeding and feeding considerations
- Expected effects on target and non-target species

Access to the Pond
- Alteration of normal accessibility
- Possible mitigation measures

Other Mitigating Factors
- Monitoring program elements
- Watershed management needs
- Ancillary project plans (dredging, shoreline stabilization)

Drawdown Information
- Target level of drawdown
- Pond bathymetry
- Area to be exposed
- Volume to remain
- Timing and frequency of drawdown
- Outlet control features
- Climatological data
- Normal range of outflow
- Outflow during drawdown and refill
- Time to drawdown or refill

Water Supply
- Use of lake water as a supply
- Presence/depths of wells in zone of influence
- Alternative water supplies
- Emergency response system
- Downstream flow restrictions

Flood Control
- Anticipated storage needs
- Flood storage gained
- Effects on peak flows

Protected Species
- Presence of protected species
- Potential for impact
- Possible mitigative measures

Vegetation of Connected Wetlands
- Composition of plant community
- Areal distribution of plants
- Plant density
- Temporal dormancy of key species
- Anticipated impacts to target and non-target species

Downstream Resources
- Erosion or flooding potential
- Possible habitat alterations
- Water quality impacts

Associated Costs
- Structural alteration to facilitate drawdown by gravity
- Pumping or alternative technology
- Monitoring program

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APPENDIX A

Historic Data

New Bedford Reservoir

Acushnet
Bristol County
Buzzards Bay Watershed

219 Acres
Average Depth 4 ft.
Maximum Depth 14 ft.
Primary Gamefish:
Largemouth Bass

General Information:

New Bedford Reservoir is a 219-acre artificial impoundment of the Acushnet River. The reservoir was created in 1869 and was formerly used as a water supply reservoir for the City of New Bedford. This waterbody is also known as Old New Bedford Reservoir, Acushnet Reservoir, Old Acushnet Storing Reservoir or Lake Street Pond. The reservoir is fed by Roaring Brook and Squam Brook (also known as Squinn Brook), cranberry bogs and swamplands. The reservoir is generally shallow (average depth 4 feet) and has a maximum depth of 14 feet; it is heavily vegetated with both emergent and submerged vegetation and has a muck and sand bottom. The water color is stained. The reservoir consists of two main sections divided by Lake Street, another pond (sometimes called East Pond) lies slightly east of the two main sections. A small lily pond (sometimes called Tom Davis Pond) lies south of Lake Street and East Pond.

Access:

New Bedord Reservoir is readily accessible from Lake Street which can be reached off Route 105 (Main Street) in Acushnet. Ample parking is available on the north side of Lake Street between the northern section and East Pond. Unimproved boat ramps are available from these parking areas into the northern sections and car top boats and canoes can be launched readily into the southern section.
Ample shore fishing is available along Lake Street.

Management History:

The Reservoir was created in 1869 and was owned by the New Bedford Water Works. In July, 1959 the pond was opened to public fishing by an agreement between the New Bedford Water Works and the then Division of Fisheries and Game. A fisheries and depth survey was performed on the pond in July of 1960. The area on the north side of Lake Street was used as a town beach by the town of Acushnet but is now posted - no swimming, polluted area.

Fish Populations:

New Bedford Reservoir was last surveyed on August 17, 2000 and contained abundant bluegill, yellow perch, largemouth bass and golden shiner as well as black crappie, pumpkinseed, white perch, chain pickerel, American eel and river herring. A survey on July 12 1960 identified eleven species: yellow perch, largemouth bass, chain pickerel, brown bullhead, pumpkinseed, bluegill, golden shiner, white perch, banded sunfish, bridle shiner, and American eel.

Fishing:

New Bedford Reservoir has a reputation as a good largemouth bass pond and regularly produces some trophy sized largemouth bass. Panfishing for sunfish and other species should be good but the thick growth of aquatic vegetation may interfere with boating and fishing during the summer months.

Updated: May, 2002 S.T. H.

The FREQ Procedure

Table of species by gear

species(species) gear(gear)

Boat fishz — Experimental Gill Net

Frequency	ANG	ELEC tric	EXGN	Total
American Eel	0	1	0	1
BBH (Alosa sp.)	0	1	0	1
Black Crappie	2	14	2	18
Bluegill	0	66	0	66
Chain Pickerel	1	6	0	7
Golden Shiner	0	14	8	22
Largemouth Bass	1	23	1	25
Pumpkinseed	0	15	0	15
SUN (Lepomis sp.)	0	2	0	2
White Perch	0	5	5	10
Yellow Perch	1	23	10	34
Total	5	170	26	201

Angling

MDFW Pond Survey

The FREQ Procedure

Table of lencm by species

lencm species(species)

Frequency	American Eel	BBH	Black Crappie	Bluegill	Chain Pickerel	Golden Shiner	Largemouth Bass	Pumpkinseed	SUN	White Perch	Yellow Perch	Total
2	0	0	0	4	0	0	0	0	2	0	0	6
3	0	0	0	7	0	0	0	1	0	0	0	8
4	0	0	0	0	0	1	0	0	0	0	0	1
5	0	0	0	1	0	0	2	0	0	0	0	3
6	0	0	0	0	0	0	5	0	0	0	0	5
7	0	0	0	5	0	0	7	0	0	0	0	12
8	0	0	0	4	0	0	1	2	0	0	1	8
9	0	0	0	7	0	1	0	1	0	0	1	10
10	0	0	0	7	0	2	0	1	0	0	3	13
11	0	1	2	6	0	0	1	1	0	0	4	15
12	0	0	0	1	0	3	1	0	0	0	2	7
13	0	0	0	4	0	2	0	0	0	0	2	8
14	0	0	0	5	0	1	0	1	0	0	0	7
15	0	0	0	3	0	3	0	1	0	0	0	7
16	0	0	0	4	0	1	0	1	0	0	0	6
17	0	0	0	1	0	0	0	3	0	0	0	4
Total	0	1	18	66	7	21	25	15	2	10	34	199

(Continued)

The FREQ Procedure

Table of lencm by species

lencm species(species)

Frequency	American Eel	BBH	Black Crappie	Bluegill	Chain Pickerel	Golden Shiner	Largemouth Bass	Pumpkinseed	SUN	White Perch	Yellow Perch	Total
18	0	0	0	3	0	0	0	2	0	0	0	5
19	0	0	0	2	0	0	1	1	0	0	1	5
20	0	0	3	1	0	0	0	0	0	0	4	8
21	0	0	2	0	1	0	0	0	0	0	1	4
22	0	0	2	1	0	1	0	0	0	0	2	6
23	0	0	4	0	1	1	0	0	0	3	5	14
24	0	0	3	0	0	3	0	0	0	3	6	15
25	0	0	2	0	0	2	1	0	0	3	1	9
26	0	0	0	0	0	0	0	0	0	1	0	1
27	0	0	0	0	1	0	0	0	0	0	0	1
28	0	0	0	0	0	0	1	0	0	0	1	2
33	0	0	0	0	2	0	0	0	0	0	0	2
34	0	0	0	0	2	0	1	0	0	0	0	3
37	0	0	0	0	0	0	3	0	0	0	0	3
43	0	0	0	0	0	0	1	0	0	0	0	1
Total	0	1	18	66	7	21	25	15	2	10	34	199

Frequency Missing = 2

New Bedford Reservoir — Acushnet 8-17-[illegible]
4:05 pm

Air 25.1 Cond 99.1 µS 22.4 C 6.04 pH
hot humid thunderstorms in distance

	T	DO
surface	23.0	6.1
3 ft	23.0	5.6
4 ft	22.0	3.8 ← <5
5 ft	21.8	3.3
6 ft	21.3	2.0
7 ft	21.2	1.9
8 ft	21.0	1.4 ← <1 ppm
9 ft	20.0	0.4 ppm

1.0 meter Secchi
— Stained water

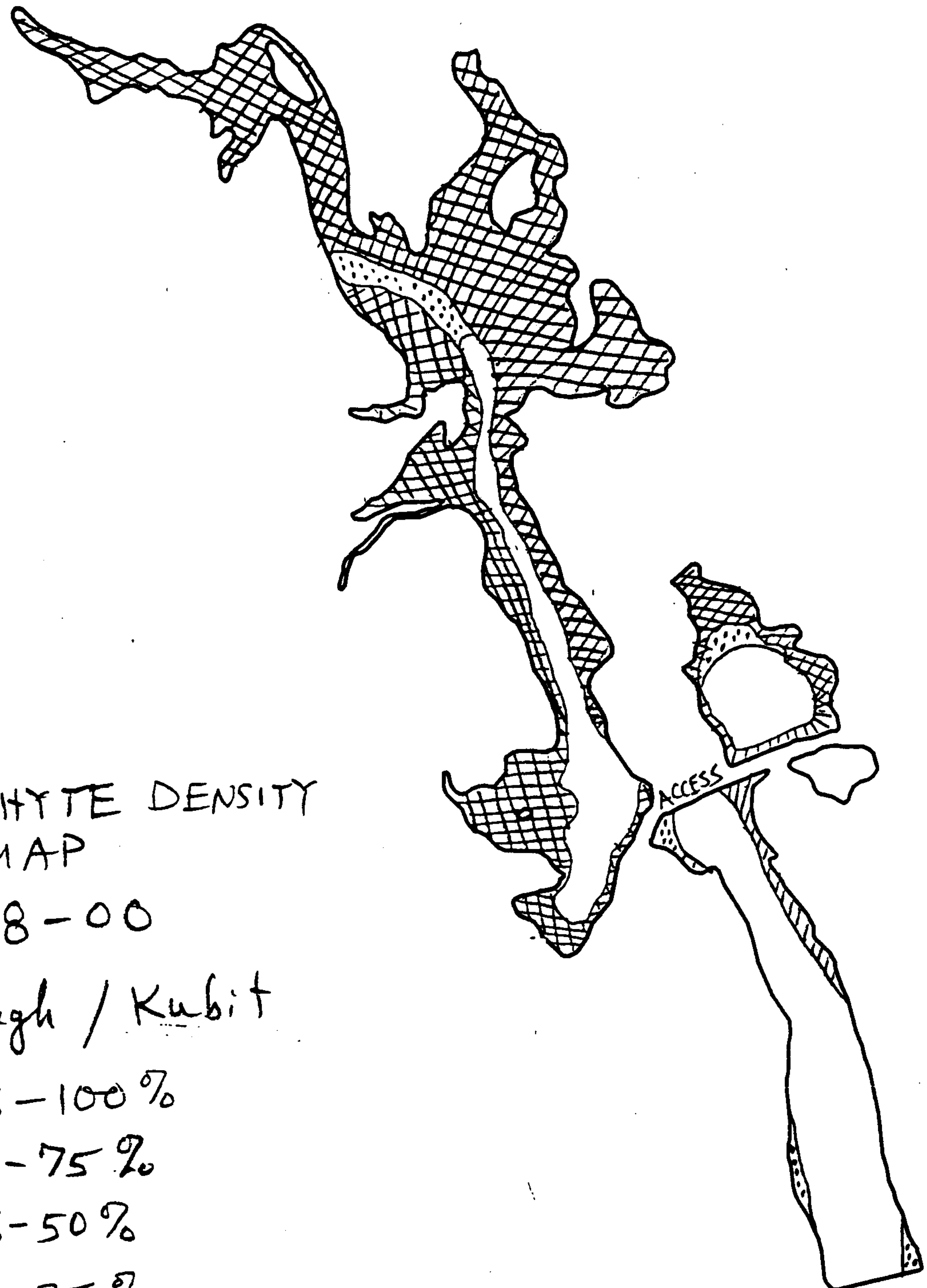
deepest 9.4 ft

soft muck bottom

Bladderwort
Millfoil Eurasian
Yellow + white water lily
Wolffia
Bulrushes

- sparsely developed north basin with houses cranberry
- unimproved boat ramps (BOG)
- ample shorefishing at Lake Street
- Ample parking area

DEP data



MACROPHYTE DENSITY MAP

9-8-00

Chesebrough / Kubit

- 76-100%
- 51-75%
- 26-50%
- 0-25%

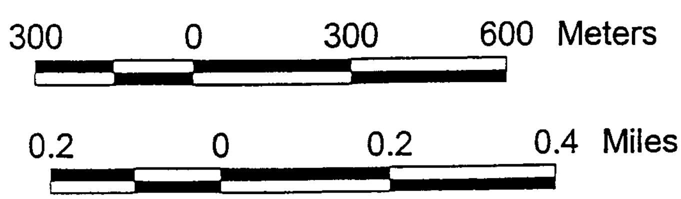
New Bedford Reservoir

Acushnet

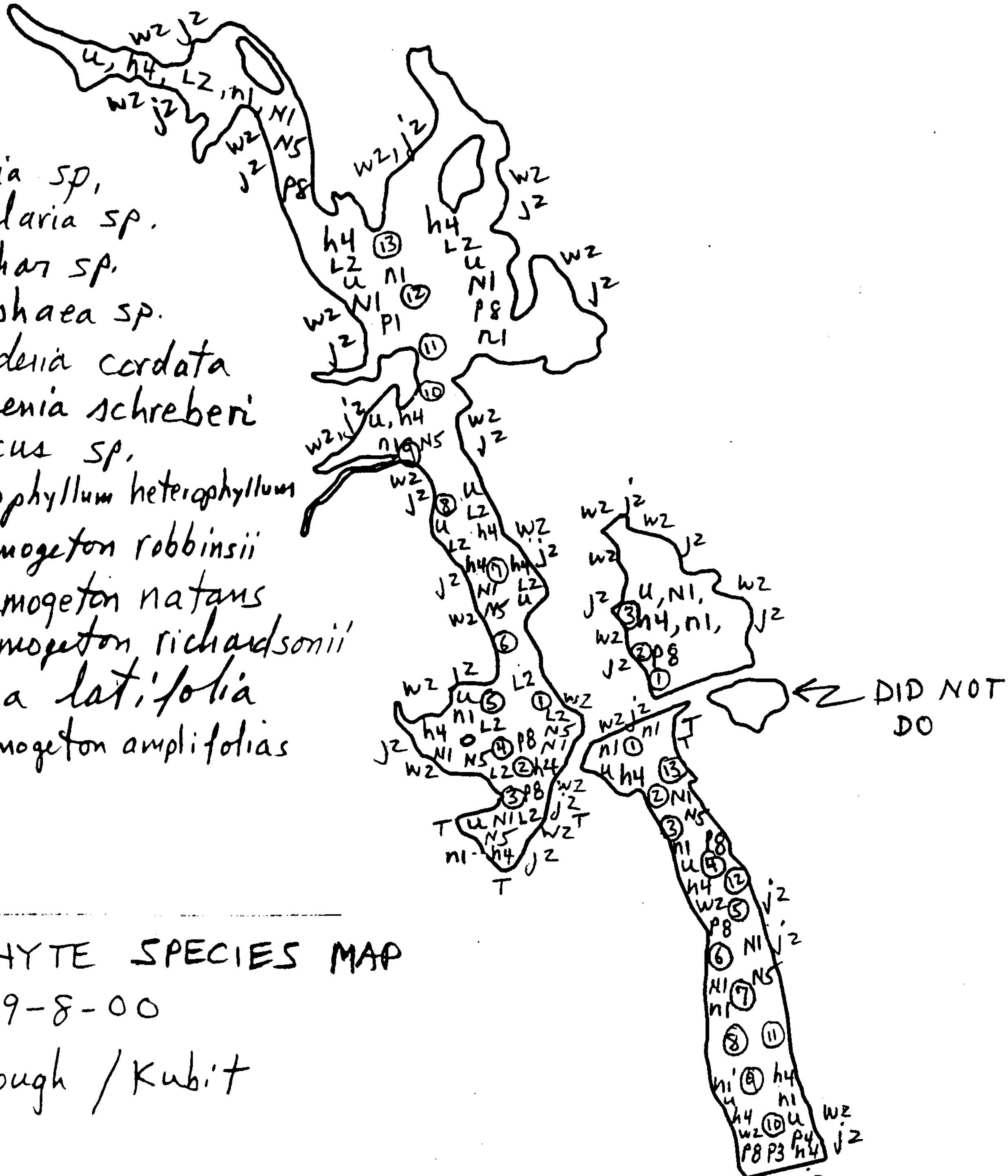
N

date:

observers:



L2 Wolffia sp.
u Utricularia sp.
N5 Nuphar sp.
N1 Nymphaea sp.
W2 Potedeiia cordata
n1 Brasenia schreberi
j2 Juncus sp.
h4 Myriophyllum heterophyllum
P4 Potamogeton robbinsii
P8 Potamogeton natans
P3 Potamogeton richardsonii
T Typha latifolia
P1 Potamogeton amplifolias



MACROPHYTE SPECIES MAP
9-8-00
Chesebrough / Kubit

New Bedford Reservoir
Acushnet
date:
observers:

N

300 0 300 600 Meters

0.2 0 0.2 0.4 Miles

NEW BEDFORD RESERVOIR
ACUSHNET

North section – WEST

Most of the area north of the neck A-A (NOTE MAP) is covered with emergent vegetation. Submerged vegetation is very heavy also. Floating islands are numerous in upper sections especially left arm or Keene river cove.

Right side of Keene cove has been ditched out for bog use. There are upwards to 1 mile of ditches 3 to 4 feet deep, 10 to 25 feet wide. Difficult to tell edge of pond from swamp in much of upper area.

Squam brook cove similar but shoreline more distinct. Upper section seemed all grass but could not reach by boat because of vegetation.

Muck in entire section from 1 ft up, 2 to 4 ft in most areas.

From lake area to A-A mostly open water. Most of vegetation noted in areas of less than four feet depth. Bottom muck 1 foot or more.

A series of ditches on and above Keene river inlet on right side of inlet used for C.B. flowing. All bogs seem to pump out of pond and drain into it

North of road, east section

About 50% open water with heavy submerged vegetation. Rest of pond covered with emergent vegetation and brush. Wet swamps on east and north sides.

No connection visible between this area and small area on southeast corner across road.

Culvert between this section and large south section

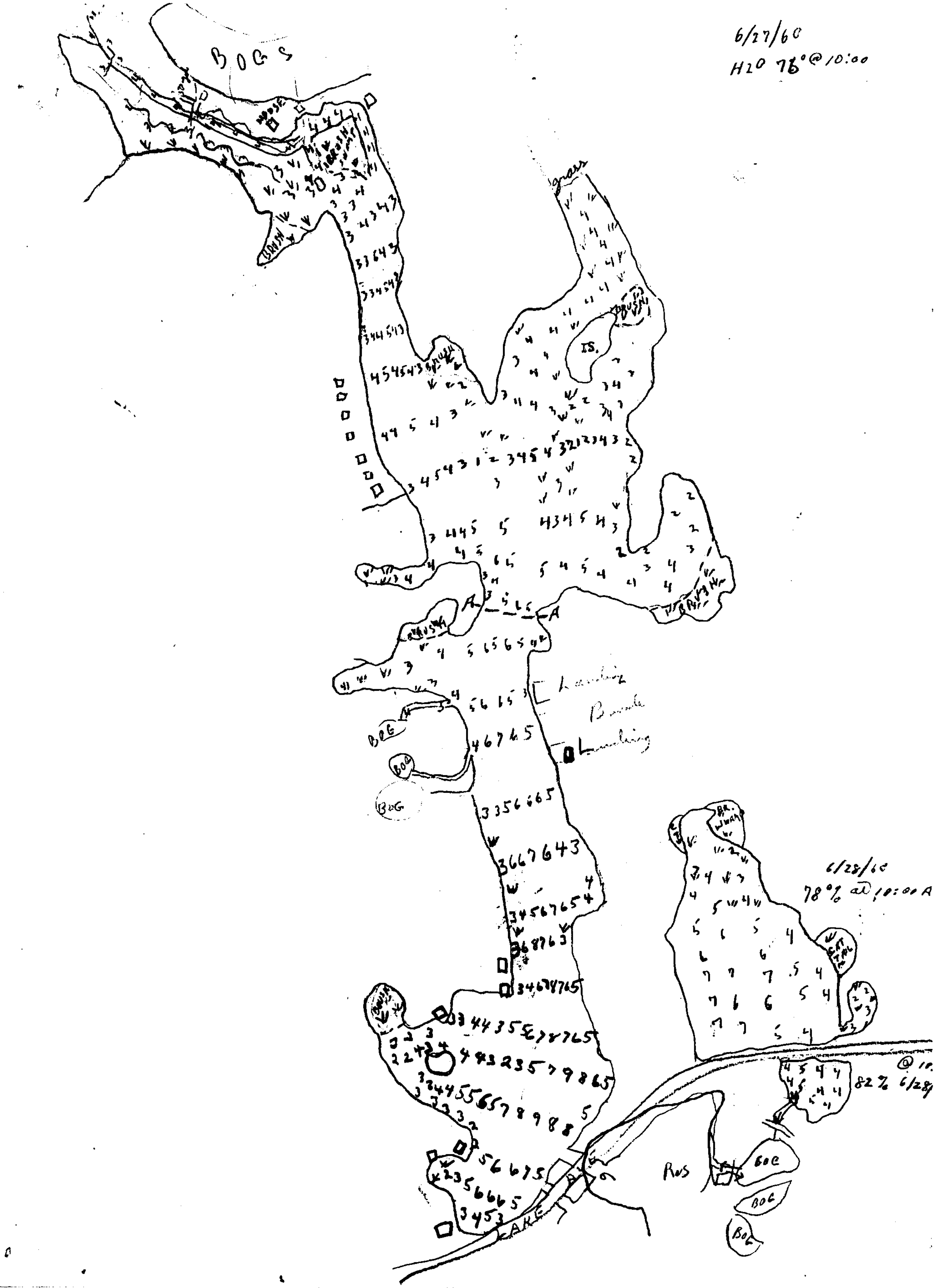
SOUTH of Road, small east section

Mostly open water with heavy submerged vegetation. Water flows into bogs and drains into main south section. Elevation seems to be 2 or more feet above main section.

South of road, main section

98% open water. No swamp areas along shore. Submerged vegetation visible in shallow areas only. Shore line woody, section of land on south west side being taken by town for taxes.

North and south main sections connected by stone culverts under road.


6/27/60
H2O 76°@10:00
BOGS
HOUSE
grass
IS.
A
Landing
Boat
Landing
BOG
BOG
BOG
6/28/60
78% @ 10:00 A
@ 10
82% 6/28
Rus
BOG
BOG
BOG
LAKE

6/28/60

Inlet - Keene road, Acushnet - 25-30 G.P.M

Kendrick road Freetown 1 G.P.M.

Bogs 50 G.P.M

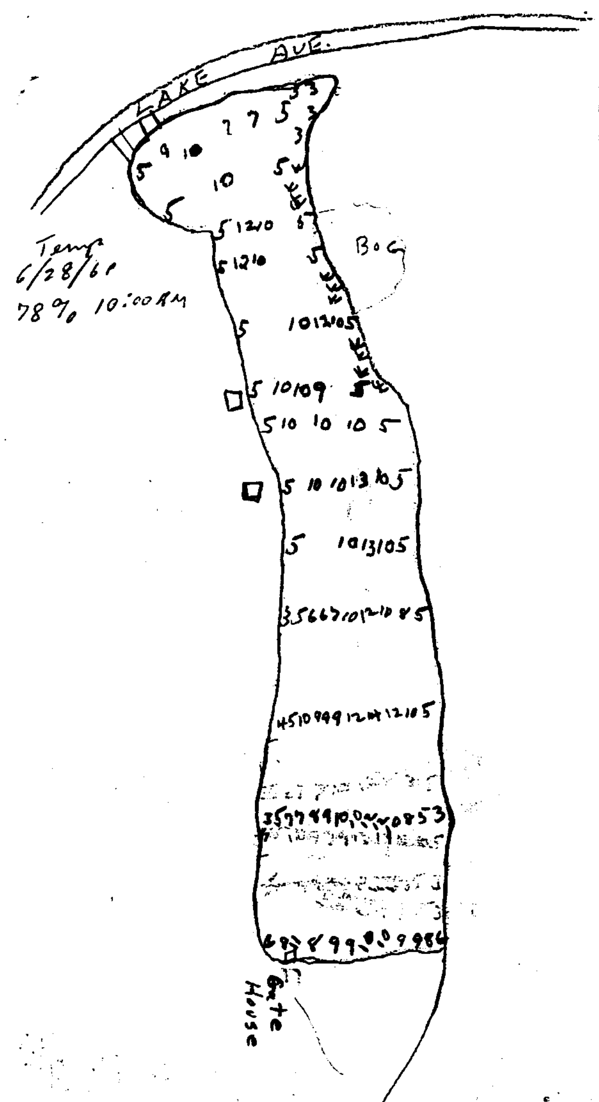
Squam brook

outlet 75° at Leonard St.

71° Pumphouse outlet

76° Pine hill farm

78° Hamblin road



Coalition for Buzzards Bay Data

Acushnet Estuary: Acushnet River, New Bedford Hbr, New Bedford Outer Hbr

Embayment	Nuts Station	In/Outer	S/B	Information	Depth (m)	Date	Year	DO/Secchi Station	D.O. mg/L	All Secchi m	Nutrient Secchi m	Total Depth	Temp C	Salt ppt	PO4 uM	NH4 uM	NO3 uM	DIN uM	DON uM
=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
JSHNET RIV	ARL		S	UPPER RIVER	0.15	07/11/00	2000					1.3	24	2	0.1	2.7	2.58	5.3	58.6
JSHNET RIV	ARL		S	UPPER RIVER	0.15	07/27/00	2000				1.1	1.5	22	1	0.0	2.5	0.80	3.3	59.7
JSHNET RIV	ARL		S	UPPER RIVER	0.15	08/09/00	2000				1	1.5	26	3	0.1	1.3	1.23	2.5	39.0
JSHNET RIV	ARL		S	UPPER RIVER	0.15	08/25/00	2000				1.3	1.5	22	1	0.1	2.8	2.17	5.0	73.8
JSHNET RIV	ARL		S		0.15	07/18/01	2001					1.1	24	2	0.0	8.5	6.3	14.9	40.5
JSHNET RIV	ARL		S		0.15	07/31/01	2001				1	1.3	23	2	0.1	7.3	6.5	13.8	37.1
JSHNET RIV	ARL		S		0.15	08/15/01	2001				1.2	1.5	23	2	0.1	4.8	5.3	10.1	34.7
JSHNET RIV	ARL		S		0.15	08/29/01	2001				1.4	1.5	24	2	0.0	2.5	4.0	6.5	27.9

Nuts Station	Date	DIN ppm	DON ppm	TDN uM	POC uM	POC ppm	PON uM	PON ppm	C/N Ratio	TON uM	TON ppm	Total N ppm	Chl a ug/L	Pheo ug/L	Chl/Pheo Ratio	la+Ph ug/L	mmer	TP uM	TN uM
=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=
ARL	07/11/00	0.07	0.82	63.84	80.6	0.968	7.91	0.111		66.5	0.93	1.005	4.98	0.06	0.99	5.0			
ARL	07/27/00	0.05	0.84	63.05	78.6	0.943	6.63	0.093		66.4	0.93	0.976	6.74	2.20	0.75	8.9		0.5	
ARL	08/09/00	0.03	0.55	41.44	66.3	0.796	7.66	0.107		46.6	0.65	0.687	10.04	0.14	0.99	10.2		0.8	
ARL	08/25/00	0.07	1.03	78.73	51.1	0.613	6.08	0.085		79.8	1.12	1.187	3.08	1.56	0.66	4.6		0.4	
ARL	07/18/01	0.21	0.57	55.4	51.19	0.61	5.45	0.08	9.39	45.9	0.64	0.851	2.93	3.18	0.48	6.11		1.5	60.8
ARL	07/31/01	0.19	0.52	50.9	65.32	0.78	6.18	0.09	10.57	43.3	0.61	0.800	2.48	2.66	0.48	5.14		1.0	57.1
ARL	08/15/01	0.14	0.49	44.8	75.41	0.90	10.23	0.14	7.37	44.9	0.63	0.771	6.54	1.02	0.87	7.55		1.0	55.0
ARL	08/29/01	0.09	0.39	34.4	85.99	1.03	10.39	0.15	8.27	38.3	0.54	0.627	5.63	2.75	0.67	8.38		0.8	44.8

The Coalition for Buzzards Bay, a nonprofit citizens education and advocacy organization utilizes citizen volunteers to gather long term environmental data on the ponds and bays in Buzzards Bay.

APPENDIX B

LAND USE MODELS

ENSR INTERNATIONAL

LAND USE MODELS
North Pond

EXPORT MODEL VARIABLES AND INPUT RANGES

VARIABLE	DESCRIPTION	FOR SOUTHERN NE AREA HIGH	MEDIUM	LOW
Standard Water Yield	Rate of water yield in CFS/Sq.Mi. by watershed Increases with increased runoff	2.0	1.7	1.5
Precipitation	Annual rainfall in M Increases with wet year	1.53	1.14	0.81
Runoff Coefficient	Portion of rainfall converted to overland flow Increases with steeper slope and lowered permeability	0.95	0.40	0.10
Baseflow Coefficient	Portion of rainfall converted to baseflow Increases with flatter slope and higher permeability	0.40	0.20	0.01

P, N AND TSS EXPORT COEFFICIENTS FOR RUNOFF

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 4 (Ind)	Industrial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	2.90	1.08	0.80	0.10	7.82	5.19	6.08	0.97	500	100	100	20
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50
Agric 3 (Grazing)	Agricultural pasture with livestock	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	500	100	100	20
Agric 4 (Feedlot)	Concentrated livestock holding area	795.20	300.70	224.00	21.28	7979.90	3110.70	2923.20	680.50	40000	15000	15000	3500
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 3 (Barren)	Mining or construction areas, largely bare soils	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	10000	1000	1000	100
Other 1	Define:	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Other 2	Define:	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Other 3	Define:	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50

P, N AND TSS EXPORT COEFFICIENTS FOR BASEFLOW

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	0.050	0.010	0.010	0.001	40.00	10.00	10.00	2.00	1.0	0.3	0.3	0.1
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1
Urban 4 (Ind)	Industrial	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 3 (Grazing)	Agricultural pasture with livestock	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 4 (Feedlot)	Concentrated livestock holding area	0.100	0.030	0.030	0.001	100.00	25.00	25.00	5.00	1.0	0.3	0.3	0.1
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 3 (Barren)	Mining or construction areas, largely bare soils	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 1	Define:	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 2	Define:	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Other 3	Define:	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
OTHER AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Atmospheric Deposition	Wet and dry deposition from aerial sources												
from Forested Area	Deposition originating in largely forested area	0.54	0.27	0.20	0.07	11.30	5.96	6.52	0.99	55	30	32	5
from Agricultural/Rural Area	Deposition originating in largely agricultural area	0.97	0.45	0.30	0.12	38.00	20.98	13.13	10.49	190	105	66	52
from Urban/Industrial Area	Deposition originating in largely urban area	3.67	1.27	1.00	0.26	24.80	18.51	21.36	7.40	124	93	107	37
Internal Loading	Release from sediments or macrophytes, oxic or anoxic (assumes anoxia for 90 days - adjust as needed)	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10

		PHOSPHORUS LOAD				NITROGEN LOAD				SUSPENDED SOLIDS LOAD			
NON-AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Waterfowl	Direct inputs from birds (kg/bird/yr)	0.50	0.20	0.20	0.09	5.80	1.00	0.95	0.48	29.0	5.0	5.0	2.0
Point Sources	Direct discharge from facility												
	Wastewater - primary treatment (ppm)	6.00	4.00	4.00	1.00	70.00	45.00	45.00	20.00	100.0	50.0	50.0	10.0
	Wastewater - secondary treatment (ppm)	4.00	2.00	2.00	0.40	10.00	5.00	5.00	1.00	10.0	5.0	5.0	1.0
	Wastewater - tertiary treatment (ppm)	1.00	0.50	0.50	0.10	5.00	2.00	2.00	1.00	10.0	5.0	5.0	1.0
	Cooling water (ppm)	5.00	1.00	1.00	0.05	1.00	0.05	0.05	0.02	1.0	0.5	0.5	0.1

EXPORT MODEL INPUT AND CALCULATIONS

STD. WATER YIELD (CFS/SQ.MI)	1.7	
PRECIPITATION (in M)	1.20	(From Cranberry Expt station, E.Wareham)

COEFFICIENTS			RUNOFF EXPORT COEFFICIENTS			BASEFLOW EXPORT COEFFICIENTS		
	Runoff	Baseflow	P Export	N Export	TSS Export	P Export	N Export	TSS Export
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
LAND USE	(Fraction)	(Fraction)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)
Urban 1 (LDR)	0.40	0.25	1.10	5.50	93	0.010	5.00	0.3
Urban 2 (MDR/Hwy)	0.50	0.15	1.10	5.50	93	0.010	10.00	0.3
Urban 3 (HDR/Com)	0.60	0.05	1.10	5.50	93	0.010	20.00	0.3
Urban 4 (Ind)	0.60	0.05	1.10	5.50	93	0.010	5.00	0.3
Urban 5 (P/I/R/C)	0.40	0.25	1.10	5.50	93	0.010	5.00	0.3
Agric 1 (Cvr Crop)	0.15	0.30	0.80	6.08	100	0.010	2.50	0.3
Agric 2 (Row Crop)	0.30	0.30	2.20	9.00	250	0.010	2.50	0.3
Agric 3 (Grazing)	0.30	0.30	0.80	5.19	100	0.010	5.00	0.3
Agric 4 (Feedlot)	0.45	0.30	224.00	2923.20	15000	0.030	25.00	0.3
Forest 1 (Upland)	0.20	0.40	0.20	2.46	16	0.004	0.50	0.3
Forest 2 (Wetland)	0.05	0.40	0.20	2.46	16	0.004	0.50	0.3
Open 1 (Wetland/Lake)	0.05	0.40	0.20	2.00	16	0.004	0.50	0.3
Open 2 (Meadow)	0.15	0.30	0.20	2.46	16	0.004	0.50	0.3
Open 3 (Excavation)	0.40	0.20	0.80	5.19	1000	0.004	0.50	0.3
Other 1	0.10	0.40	0.20	2.46	16	0.004	0.50	0.3
Other 2	0.35	0.25	1.10	5.50	93	0.010	5.00	0.3
Other 3	0.60	0.05	2.20	9.00	250	0.010	20.00	0.3

OTHER AREAL SOURCES				
	Affected	P Export	N Export	TSS Export
	Lake	Coefficient	Coefficient	Coefficient
Atmospheric Deposition	Area (ha)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)
from Forested Area	28.0	0.20	6.52	32.0
from Agricultural/Rural Area	28.0	0.30	13.13	66.0
from Urban/Industrial Area	0.0	1.00	21.36	107.0
Internal Loading	20.9	1.00	1.00	1.0

NON-AREAL SOURCES								
	Number of	Volume	P Load	N Load	TSS Load	P Load	N Load	TSS Load
	Source Units	(cu.m/yr)	(kg/unit/yr)	(kg/unit/yr)	(kg/unit/yr)	(ppm)	(ppm)	(ppm)
Waterfowl	20		0.20	0.95	5			
Point Sources								
PS-1		0				0.00	0.00	0.0
PS-2		0				0.00	0.00	0.0
PS-3		0				0.00	0.00	0.0

Basin in which Point Source occurs (0=NO 1=YES)

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
PS-1	0	0	0	0	0	0	0	0	0	0
PS-2	0	0	0	0	0	0	0	0	0	0
PS-3	0	0	0	0	0	0	0	0	0	0

BASIN AREAS

LAND USE	BASIN A AREA (HA)	BASIN B AREA (HA)	BASIN C AREA (HA)	BASIN 4 AREA (HA)	BASIN 5 AREA (HA)	BASIN 6 AREA (HA)	BASIN 7 AREA (HA)	BASIN 8 AREA (HA)	BASIN 9 AREA (HA)	BASIN 10 AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	87.3	91.16	36.25	0	0	0	0				214.71
Urban 2 (MDR/Hwy)	10.63	28.66	5.1	0	0	0	0				45.39
Urban 3 (HDR/Com)	4.35	0.62	2.33	0	0	0	0				7.3
Urban 4 (Ind)	2.21	0	0	0	0	0	0				2.21
Urban 5 (P/I/R/C)	5.31	1.67	5.69	0	0	0	0				12.67
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0				0
Agric 2 (Row Crop)	3.58	11.94	0	0	0	0	0				15.52
Agric 3 (Grazing)	17.42	21.88	13.55	0	0	0	0				52.85
Agric 4 (Feedlot)	0	0	0	0	0	0	0				0
Forest 1 (Upland)	429.2	366.58	128	0	0	0	0				923.78
Forest 2 (Wetland)	0	0	0	0	0	0	0				0
Open 1 (Wetland/Lake)	95.26	91.33	55.28	0	0	0	0				242.87
Open 2 (Meadow)	7.2	15.5	15.38	0	0	0	0				38.08
Open 3 (Excavation)	10.9	4.75	3.58	0	0	0	0				19.23
Other 1	0	0	0	0	0	0	0				0
Other 2	0	0	0	0	0	0	0				0
Other 3	0	0	0	0	0	0	0				0
TOTAL	674.36	634.1	266.16	0	0	0	0	0	0	0	1574.62

WATER LOAD GENERATION: RUNOFF

LAND USE	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	419040	437568	174000	0	0	0	0	0	0	0	1030608
Urban 2 (MDR/Hwy)	63780	171960	36600	0	0	0	0	0	0	0	272340
Urban 3 (HDR/Com)	31320	4464	16776	0	0	0	0	0	0	0	52560
Urban 4 (Ind)	15912	0	0	0	0	0	0	0	0	0	15912
Urban 5 (P/I/R/C)	25488	8016	27312	0	0	0	0	0	0	0	60816
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	12888	42984	0	0	0	0	0	0	0	0	55872
Agric 3 (Grazing)	62712	78804	48780	0	0	0	0	0	0	0	190296
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	1030080	879792	307200	0	0	0	0	0	0	0	2217072
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	57756	54798	33168	0	0	0	0	0	0	0	145722
Open 2 (Meadow)	12960	27900	27684	0	0	0	0	0	0	0	68544
Open 3 (Excavation)	52320	22800	17184	0	0	0	0	0	0	0	92304
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1784256	1729086	688704	0	0	0	0	0	0	0	4202046
Total (cfs)	2.00	1.94	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.71
Area * Water Yield (cell b7)	4.4	4.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4

LOAD GENERATION: RUNOFF P

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	96.03	100.275	39.875	0	0	0	0	0	0	0	236.181
Urban 2 (MDR/Hwy)	11.693	31.526	5.71	0	0	0	0	0	0	0	49.929
Urban 3 (HDR/Com)	4.785	0.682	2.563	0	0	0	0	0	0	0	8.03
Urban 4 (Ind)	2.431	0	0	0	0	0	0	0	0	0	2.431
Urban 5 (P/I/R/C)	5.841	1.837	6.259	0	0	0	0	0	0	0	13.937
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	7.876	26.268	0	0	0	0	0	0	0	0	34.144
Agric 3 (Grazing)	13.936	17.512	10.84	0	0	0	0	0	0	0	42.288
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	85.84	73.316	25.6	0	0	0	0	0	0	0	184.756
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	19.252	18.266	11.056	0	0	0	0	0	0	0	48.574
Open 2 (Meadow)	1.44	3.1	3.076	0	0	0	0	0	0	0	7.616
Open 3 (Excavation)	8.72	3.8	2.864	0	0	0	0	0	0	0	15.384
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	257.8	276.6	108.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	543.3

WATER LOAD GENERATION: BASEFLOW

	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	261900	273480	108750	0	0	0	0	0	0	0	644130
Urban 2 (MDR/Hwy)	19134	51588	10980	0	0	0	0	0	0	0	81702
Urban 3 (HDR/Com)	2610	372	1398	0	0	0	0	0	0	0	4380
Urban 4 (Ind)	1326	0	0	0	0	0	0	0	0	0	1326
Urban 5 (P/I/R/C)	15930	5010	17070	0	0	0	0	0	0	0	38010
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	12888	42984	0	0	0	0	0	0	0	0	55872
Agric 3 (Grazing)	62712	78804	48780	0	0	0	0	0	0	0	190296
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	2060160	1759584	614400	0	0	0	0	0	0	0	4434144
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland)	462048	438384	265344	0	0	0	0	0	0	0	1165776
Open 2 (Meadow)	25920	55800	55368	0	0	0	0	0	0	0	137088
Open 3 (Excavation)	26160	11400	8592	0	0	0	0	0	0	0	46152
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2850788	2717406	1130682	0	0	0	0	0	0	0	6798876
Total (cfs)	3.30	3.04	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.000	7.61

LOAD GENERATION: RUNOFF N

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	480.15	501.38	199.375	0	0	0	0	0	0	0	1180.905
Urban 2 (MDR/Hwy)	58.465	157.63	33.55	0	0	0	0	0	0	0	249.645
Urban 3 (HDR/Com)	23.925	3.41	12.815	0	0	0	0	0	0	0	40.15
Urban 4 (Ind)	12.155	0	0	0	0	0	0	0	0	0	12.155
Urban 5 (P/I/R/C)	29.205	9.185	31.295	0	0	0	0	0	0	0	69.685
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	32.22	107.46	0	0	0	0	0	0	0	0	139.68
Agric 3 (Grazing)	90.4098	113.6091	70.3245	0	0	0	0	0	0	0	274.3434
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	1055.832	901.7868	314.88	0	0	0	0	0	0	0	2272.4988
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	192.52	182.66	110.56	0	0	0	0	0	0	0	485.74
Open 2 (Meadow)	17.712	38.13	37.8348	0	0	0	0	0	0	0	93.6768
Open 3 (Excavation)	56.571	24.6525	18.5802	0	0	0	0	0	0	0	99.8037
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2049.2	2039.9	829.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4918.3

LOAD GENERATION: BASEFLOW P											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	0.873	0.9115	0.3625	0	0	0	0	0	0	0	2.1471
Urban 2 (MDR/Hwy)	0.1063	0.2866	0.061	0	0	0	0	0	0	0	0.4539
Urban 3 (HDR/Com)	0.0435	0.0062	0.0233	0	0	0	0	0	0	0	0.073
Urban 4 (Ind)	0.0221	0	0	0	0	0	0	0	0	0	0.0221
Urban 5 (P/I/R/C)	0.0531	0.0167	0.0569	0	0	0	0	0	0	0	0.1267
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0.0358	0.1194	0	0	0	0	0	0	0	0	0.1552
Agric 3 (Grazing)	0.1742	0.2189	0.1355	0	0	0	0	0	0	0	0.5286
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	1.7168	1.46632	0.512	0	0	0	0	0	0	0	3.69512
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	0.38504	0.36532	0.22112	0	0	0	0	0	0	0	0.97148
Open 2 (Meadow)	0.0288	0.062	0.06152	0	0	0	0	0	0	0	0.15232
Open 3 (Excavation)	0.0436	0.019	0.01432	0	0	0	0	0	0	0	0.07692
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3.5	3.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4

ROUTING PATTERN (Which basin flows to which)										
	PASSES THROUGH...									
1=YES 0=NO XXX=BLANK	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	1	1	1	0	0	0	0	0	0	0
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX

WATER ROUTING AND ATTENUATION											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
SOURCE	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	
INDIVIDUAL BASIN	4735044	4446492	1819386	0	0	0	0	0	0	0	
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0	
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0	
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0	
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0	
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0	
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0	
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0	
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0	
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0	
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX	
CUMULATIVE TOTAL	4735044.0	4446492.0	1819386.0	0.0	0.0	0.0	0	0	0	0	
BASIN ATTENUATION	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
OUTPUT VOLUME	3788035.2	3557193.6	1455508.8	0.0	0.0	0.0	0	0	0	0	
Reality Check for Indiv. Basin	3957414.2	3721152.4	1561933.3	0.0	0.0	0.0	0	0	0	0	0.0
(Based on std water yield)											

LOAD GENERATION: BASEFLOW N											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (LDR)	436.5	455.8	181.25	0	0	0	0	0	0	0	1073.55
Urban 2 (MDR/Hwy)	106.3	286.6	61	0	0	0	0	0	0	0	453.9
Urban 3 (HDR/Com)	87	12.4	46.5	0	0	0	0	0	0	0	146
Urban 4 (Ind)	11.05	0	0	0	0	0	0	0	0	0	11.05
Urban 5 (P/I/R/C)	26.55	8.35	28.45	0	0	0	0	0	0	0	63.35
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	8.95	29.85	0	0	0	0	0	0	0	0	38.8
Agric 3 (Grazing)	87.1	109.45	67.75	0	0	0	0	0	0	0	264.3
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	214.6	183.29	64	0	0	0	0	0	0	0	461.89
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	48.13	45.665	27.64	0	0	0	0	0	0	0	121.435
Open 2 (Meadow)	3.6	7.75	7.69	0	0	0	0	0	0	0	19.04
Open 3 (Excavation)	5.45	2.375	1.79	0	0	0	0	0	0	0	9.615
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1035.2	1141.5	486.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2662.9

LOAD ROUTING AND ATTENUATION: PHOSPHORUS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	261.3	280.1	110.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	261.3	280.1	110.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.75	0.70	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	196.0	196.0	77.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	196.0	196.0	77.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT (MG/L)	0.052	0.055	0.053	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC.	0.056										
(Based on real data)											
TERMINAL DISCHARGE?	1	1	1	0	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	8800738
PHOSPHORUS (KG/YR)	196.0	196.0	77.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	469.2
PHOSPHORUS (MG/L)	0.052	0.055	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053

LOADING SUMMARY FROM MODEL

DIRECT LOADS TO LAKE	P	N	TSS		WATER
ATMOSPHERIC (KG/YR)	14.0	549.2	2739.1	(CU.M/YR)	670800.0
INTERNAL (KG/YR)	20.9	20.9	20.9	(CU.M/YR)	0.0
WATERFOWL (KG/YR)	4.0	19.0	100.0	(CU.M/YR)	0.0
WATERSHED LOAD (KG/YR)	469.2	4746.0	76971.7	(CU.M/YR)	8800737.6
TOTAL LOAD TO LAKE (KG/YR)	509.1	5335.2	79831.7	(CU.M/YR)	9471537.6
(Watershed + direct loads)					
TOTAL INPUT CONC. (MG/L)	0.054	0.563	8.429		

LOAD ROUTING AND ATTENUATION: NITROGEN

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	3084.4	3181.4	1315.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	3084.4	3181.4	1315.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.60	0.60	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	1850.6	1908.9	986.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: NITROGEN

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	1850.6	1908.9	986.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	0.489	0.537	0.678	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC	0.4										
(Based on real data)											
TERMINAL DISCHARGE	1	1	1	0	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	8800738
NITROGEN (KG/YR)	1850.6	1908.9	986.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4746.0
NITROGEN (MG/L)	0.489	0.537	0.678	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.539

No Data On This Page

LOAD GENERATION: RUNOFF TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	8118.9	8477.88	3371.25	0	0	0	0	0	0	0	19968.03
Urban 2 (MDR/Hwy)	988.59	2665.38	567.3	0	0	0	0	0	0	0	4221.27
Urban 3 (HDR/Com)	404.55	57.66	216.69	0	0	0	0	0	0	0	678.9
Urban 4 (Ind)	205.53	0	0	0	0	0	0	0	0	0	205.53
Urban 5 (P/I/R/C)	493.83	155.31	529.17	0	0	0	0	0	0	0	1178.31
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	895	2985	0	0	0	0	0	0	0	0	3880
Agric 3 (Grazing)	1742	2189	1355	0	0	0	0	0	0	0	5286
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	6867.2	5865.28	2048	0	0	0	0	0	0	0	14780.48
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	1540.16	1461.28	884.48	0	0	0	0	0	0	0	3885.92
Open 2 (Meadow)	115.2	248	246.08	0	0	0	0	0	0	0	609.28
Open 3 (Excavation)	10900	4750	3580	0	0	0	0	0	0	0	19230
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	32271.0	28854.8	12798.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73923.7

LOAD GENERATION: BASEFLOW TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	26.19	27.348	10.875	0	0	0	0	0	0	0	64.413
Urban 2 (MDR/Hwy)	3.189	8.598	1.83	0	0	0	0	0	0	0	13.617
Urban 3 (HDR/Com)	1.305	0.186	0.699	0	0	0	0	0	0	0	2.19
Urban 4 (Ind)	0.663	0	0	0	0	0	0	0	0	0	0.663
Urban 5 (P/I/R/C)	1.593	0.501	1.707	0	0	0	0	0	0	0	3.801
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	1.074	3.582	0	0	0	0	0	0	0	0	4.656
Agric 3 (Grazing)	5.226	6.567	4.065	0	0	0	0	0	0	0	15.858
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	128.76	109.974	38.4	0	0	0	0	0	0	0	277.134
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	28.878	27.399	16.584	0	0	0	0	0	0	0	72.861
Open 2 (Meadow)	2.16	4.65	4.614	0	0	0	0	0	0	0	11.424
Open 3 (Excavation)	3.27	1.425	1.074	0	0	0	0	0	0	0	5.769
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	202.3	190.2	79.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	472.4

LOAD ROUTING AND ATTENUATION: SUSPENDED SOLIDS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	32473.3	29045.0	12877.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	32473.3	29045.0	12877.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	1.00	1.00	1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	32473.3	29045.0	15453.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: SUSPENDED SOLIDS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	32473.3	29045.0	15453.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	8.573	8.165	10.617	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC	6.5										
(Based on real data)											
TERMINAL DISCHARGE	1	1	1		0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	3788035	3557194	1455509	0	0	0	0	0	0	0	8800738
TSS (KG/YR)	32473.3	29045.0	15453.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76971.7
TSS (MG/L)	8.573	8.165	10.617	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.746

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE TERMS

PHOSPHORUS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Phosphorus Load to Lake	kg/yr	From export model	508	
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A	0.909	
TPin	Influent (Inflow) Total Phosphorus	ppb	From export model	54	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available	35	Enter Value (TP out)
I	Inflow	m3/yr	From export model	9471538	
A	Lake Area	m2	From data	559200	Enter Value (A)
V	Lake Volume	m3	From data	838800	Enter Value (V)
Z	Mean Depth	m	Volume/area	1.500	
F	Flushing Rate	flushings/yr	Inflow/volume	11.292	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.652	
Qs	Areal Water Load	m/yr	Z(F)	16.938	
Vs	Settling Velocity	m	Z(S)	0.979	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.295	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.229	

NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TN	Lake Total Nitrogen Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Nitrogen Load to Lake	kg/yr	From export model	5335	
L1	Nitrogen Load to Lake	g N/m2/yr	KG*1000/A	9.54	
L2	Nitrogen Load to Lake	mg N/m2/yr	KG*1000000/A	9541	
C1	Coefficient of Attenuation, from F	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	2.65	
C2	Coefficient of Attenuation, from L	fraction/yr	2.7183^(0.71(ln(L2))-6.426)	1.08	
C3	Coefficient of Attenuation, from L/Z	fraction/yr	2.7183^(0.594(ln(L2/Z))-4.144)	2.88	

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE MODELS

PHOSPHORUS

NAME	FORMULA	PRED. CONC. (ppb)	PERMIS. CONC. (ppb)	CRITICAL CONC. (ppb)
Mass Balance (Maximum Conc.)	TP=L/(Z(F))*1000	54		
Kirchner-Dillon 1975 (K-D)	TP=L(1-Rp)/(Z(F))*1000	38	17	34
Vollenweider 1975 (V)	TP=L/(Z(S+F))*1000	51	23	46
Larsen-Mercier 1976 (L-M)	TP=L(1-Rlm)/(Z(F))*1000	41	19	37
Jones-Bachmann 1976 (J-B)	TP=0.84(L)/(Z(0.65+F))*1000	43	19	39
Average of Model Values (without mass balance)		43	20	39
Reality Check Conc.		38.8		
From Vollenweider 1968				
Permissible Load (g/m2/yr)	Lp=10^(0.501503(log(Z(F)))-1.0018)	0.41		
Critical Load (g/m2/yr)	Lc=2(Cp)	0.82		

PREDICTED CHL AND WATER CLARITY

MODEL	Value	
Mean Chlorophyll (ug/L)		
Dillon and Rigler 1974	17.1	
Jones and Bachmann 1976	19.8	
Oglesby and Schaffner 1978	21.9	
Modified Vollenweider 1982	20.8	19.9
"Maximum" Chlorophyll (ug/L)		
Modified Vollenweider (TP) 1982	66.6	
Vollenweider (CHL) 1982	61.8	
Modified Jones, Rast and Lee 1979	67.8	65.4
Secchi Transparency (M)		
Oglesby and Schaffner 1978 **(Avg)**	1.3	
Modified Vollenweider 1982 **(Max)**	3.4	

NITROGEN

NAME	FORMULA	PRED. CONC. (ppb)
Mass Balance (Maximum Conc.)	TN=L/(Z(F))*1000	563
Bachmann 1980	TN=L/(Z(C1+F))*1000	456
Bachmann 1980	TN=L/(Z(C2+F))*1000	514
Bachmann 1980	TN=L/(Z(C3+F))*1000	449
Average of Model Values (without mass balance)		472.9
Reality Check Conc.		538

Nitrogen and Phosphorus Loading to New Bedford Reservoir (North Pond) Estimated from Empirical Models

PART 1: THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From data or model	33	Enter Value
L	Phosphorus Load to Lake	g P/m2/yr	From data or model		
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	54	Enter Value
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	35	Enter Value
I	Inflow	m3/yr	From data	9471538	Enter Value
A	Lake Area	m2	From data	559200	Enter Value
V	Lake Volume	m3	From data	838800	Enter Value
Z	Mean Depth	m	Volume/area	1.5	
F	Flushing Rate	flushings/yr	Inflow/volume	11.29177	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.648148	
Qs	Areal Water Load	m/yr	Z(F)	16.93766	
Vs	Settling Velocity	m	Z(S)	0.972222	
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.351852	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.294963	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.229341	
	ADDENDUM FOR NITROGEN				
TN	Lake Total Nitrogen Conc.	ppb	From data or model	548	Enter Value
L	Nitrogen Load to Lake	g N/m2/yr	From data or model		Enter Value
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	2.654314	

Nitrogen and Phosphorus Loading to New Bedford Reservoir (North Pond) Estimated from Empirical Models - Continued.

PART 2: THE MODELS					*LOAD ANALYSIS*	
		PREDICTION				ESTIMATED
		CONC.	LOAD			LOAD
NAME	FORMULA	(ppb)	(g/m2/yr)		MODEL	(kg/yr)
Mass Balance	TP=L/(Z(F))*1000	0			***Phosphorus***	
(minimum load)	L=TP(Z)(F)/1000		0.56		Mass Balance (no loss)	313
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	0				
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.79		Kirchner-Dillon 1975	443
Vollenweider 1975	TP=L/(Z(S+F))*1000	0				
(V)	L=TP(Z)(S+F)/1000		0.59		Vollenweider 1975	331
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	0				
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		1.05		Reckhow 1977 (General)	589
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	0				
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.73		Larsen-Mercier 1976	406
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	0				
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.70		Jones-Bachmann 1976	394
Average of Model Values		0			Model Average	
(without mass balance)			0.77		(without mass balance)	432
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	0				
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.64		Reckhow 1977 (Anoxic)	358
From Vollenweider 1968						
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.41		Permissible Load	230
Critical Load	Lc=2(Lp)		0.82		Critical Load	460
Mass Balance	TN=L/(Z(F))*1000	0			***Nitrogen***	
(minimum load)	L=TN(Z)(F)/1000		9.28		Mass Balance (no loss)	5190
Bachmann 1980	TN=L/(Z(C+F))*1000	0				
	L=TN(Z)(C+F)/1000		11.46		Bachmann 1980	6410

LAND USE MODELS
South Pond

EXPORT MODEL VARIABLES AND INPUT RANGES

VARIABLE	DESCRIPTION	FOR SOUTHERN NE AREA HIGH	MEDIUM	LOW
Standard Water Yield	Rate of water yield in CFS/Sq.Mi. by watershed Increases with increased runoff	2.0	1.7	1.5
Precipitation	Annual rainfall in M Increases with wet year	1.53	1.14	0.81
Runoff Coefficient	Portion of rainfall converted to overland flow Increases with steeper slope and lowered permeability	0.95	0.40	0.10
Baseflow Coefficient	Portion of rainfall converted to baseflow Increases with flatter slope and higher permeability	0.40	0.20	0.01

P, N AND TSS EXPORT COEFFICIENTS FOR RUNOFF

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 4 (Ind)	Industrial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	2.90	1.08	0.80	0.10	7.82	5.19	6.08	0.97	500	100	100	20
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50
Agric 3 (Grazing)	Agricultural pasture with livestock	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	500	100	100	20
Agric 4 (Feedlot)	Concentrated livestock holding area	795.20	300.70	224.00	21.28	7979.90	3110.70	2923.20	680.50	40000	15000	15000	3500
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 3 (Barren)	Mining or construction areas, largely bare soils	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	10000	1000	1000	100
Other 1	Define:	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Other 2	Define:	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Other 3	Define:	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50

P, N AND TSS EXPORT COEFFICIENTS FOR BASEFLOW

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	0.050	0.010	0.010	0.001	40.00	10.00	10.00	2.00	1.0	0.3	0.3	0.1
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1
Urban 4 (Ind)	Industrial	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 3 (Grazing)	Agricultural pasture with livestock	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 4 (Feedlot)	Concentrated livestock holding area	0.100	0.030	0.030	0.001	100.00	25.00	25.00	5.00	1.0	0.3	0.3	0.1
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 3 (Barren)	Mining or construction areas, largely bare soils	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 1	Define:	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 2	Define:	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Other 3	Define:	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
OTHER AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Atmospheric Deposition	Wet and dry deposition from aerial sources												
from Forested Area	Deposition originating in largely forested area	0.54	0.27	0.20	0.07	11.30	5.96	6.52	0.99	55	30	32	5
from Agricultural/Rural Area	Deposition originating in largely agricultural area	0.97	0.45	0.30	0.12	38.00	20.98	13.13	10.49	190	105	66	52
from Urban/Industrial Area	Deposition originating in largely urban area	3.67	1.27	1.00	0.26	24.80	18.51	21.36	7.40	124	93	107	37
Internal Loading	Release from sediments or macrophytes, oxic or anoxic (assumes anoxia for 90 days - adjust as needed)	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10

		PHOSPHORUS LOAD				NITROGEN LOAD				SUSPENDED SOLIDS LOAD			
NON-AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Waterfowl	Direct inputs from birds (kg/bird/yr)	0.50	0.20	0.20	0.09	5.80	1.00	0.95	0.48	29.0	5.0	5.0	2.0
Point Sources	Direct discharge from facility												
	Wastewater - primary treatment (ppm)	6.00	4.00	4.00	1.00	70.00	45.00	45.00	20.00	100.0	50.0	50.0	10.0
	Wastewater - secondary treatment (ppm)	4.00	2.00	2.00	0.40	10.00	5.00	5.00	1.00	10.0	5.0	5.0	1.0
	Wastewater - tertiary treatment (ppm)	1.00	0.50	0.50	0.10	5.00	2.00	2.00	1.00	10.0	5.0	5.0	1.0
	Cooling water (ppm)	5.00	1.00	1.00	0.05	1.00	0.05	0.05	0.02	1.0	0.5	0.5	0.1

EXPORT MODEL INPUT AND CALCULATIONS

STD WATER YIELD (CFS/SQ MI) 1 7
PRECIPITATION (in M) 1 20 (From Cranberry Expt station, E Wareham)

COEFFICIENTS			RUNOFF EXPORT COEFFICIENTS			BASEFLOW EXPORT COEFFICIENTS		
	Runoff Coefficient	Baseflow Coefficient	P Export Coefficient	N Export Coefficient	TSS Export Coefficient	P Export Coefficient	N Export Coefficient	TSS Export Coefficient
LAND USE	(Fraction)	(Fraction)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)
Urban 1 (LDR)	0 40	0 25	1 10	5.50	93	0 010	5.00	0.3
Urban 2 (MDR/Hwy)	0 50	0 15	1.10	5.50	93	0.010	10.00	0.3
Urban 3 (HDR/Com)	0 60	0.05	1.10	5.50	93	0 010	20.00	0.3
Urban 4 (Ind)	0 60	0 05	1 10	5.50	93	0 010	5.00	0.3
Urban 5 (P/I/R/C)	0.40	0 25	1 10	5.50	93	0 010	5.00	0.3
Agric 1 (Cvr Crop)	0 15	0 30	0 80	6 08	100	0.010	2.50	0.3
Agric 2 (Row Crop)	0 30	0 30	2.20	9.00	250	0.010	2.50	0.3
Agric 3 (Grazing)	0 30	0 30	0 80	5 19	100	0.010	5.00	0.3
Agric 4 (Feedlot)	0 45	0 30	224.00	2923.20	15000	0 050	25.00	0.3
Forest 1 (Upland)	0 20	0.40	0 20	2 46	16	0 004	0.50	0.3
Forest 2 (Wetland)	0 05	0.40	0.20	2.46	16	0 004	0.50	0.3
Open 1 (Wetland/Lake)	0 05	0.40	0 20	2.00	16	0 004	0.50	0.3
Open 2 (Meadow)	0.15	0.30	0 20	2.46	16	0.004	0.50	0.3
Open 3 (Excavation)	0 40	0 20	0 80	5.19	1000	0.004	0.50	0.3
Other 1	0 10	0.40	0.20	2.46	16	0 004	0.50	0.3
Other 2	0 55	0.25	1 10	5.50	93	0.010	5 00	0.3
Other 3	0 60	0 05	2.20	9 00	250	0 010	20.00	0.3

OTHER AREAL SOURCES	Affected Lake Area (ha)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	TSS Export Coefficient (kg/ha/yr)		
Atmospheric Deposition						
from Forested Area		0.20	6.52	32 0		
from Agricultural/Rural Area	9 6	0.30	13 15	66.0		9 56
from Urban/Industrial Area	9 6	1.00	21 36	107 0		
Internal Loading	0 0	1 00	1 00	1.0		

NON-AREAL SOURCES	Number of Source Units	Volume (cu m/yr)	P Load (kg/unit/yr)	N Load (kg/unit/yr)	TSS Load (kg/unit/yr)	P Load (ppm)	N Load (ppm)	TSS Load (ppm)
Waterfowl	10		0.20	0 95	5			
Point Sources								
PS-1		0				0 00	0.00	0.0
PS-2		0				0 00	0.00	0.0
PS-3		0				0 00	0.00	0 0

Basin in which Point Source occurs (0=NO 1=YES)

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
PS-1	0	0	0	0	0	0	0	0	0	0
PS-2	0	0	0	0	0	0	0	0	0	0
PS-3	0	0	0	0	0	0	0	0	0	0

BASIN AREAS

LAND USE	BASIN A AREA (HA)	BASIN B AREA (HA)	BASIN C AREA (HA)	BASIN 4 AREA (HA)	BASIN 5 AREA (HA)	BASIN 6 AREA (HA)	BASIN 7 AREA (HA)	BASIN 8 AREA (HA)	BASIN 9 AREA (HA)	BASIN 10 AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	214.71	4.11	18.5	0	0	0	0				237.32
Urban 2 (MDR/Hwy)	45.39	0	39.02	0	0	0	0				84.41
Urban 3 (HDR/Com)	7.3	0	4.35	0	0	0	0				11.65
Urban 4 (Ind)	2.21	0		0	0	0	0				2.21
Urban 5 (P/I/R/C)	12.67	0		0	0	0	0				12.67
Agric 1 (Cvr Crop)	0	0		0	0	0	0				0
Agric 2 (Row Crop)	15.52	0	0.02	0	0	0	0				15.54
Agric 3 (Grazing)	52.86	2.26	3.44	0	0	0	0				58.56
Agric 4 (Feedlot)	0	0		0	0	0	0				0
Forest 1 (Upland)	923.78	7.9	3.23	0	0	0	0				934.91
Forest 2 (Wetland)	0	0		0	0	0	0				0
Open 1 (Wetland/Lake)	298.79	17.29	5.73	0	0	0	0				321.81
Open 2 (Meadow)	38.08	3.47	1.41	0	0	0	0				42.96
Open 3 (Excavation)	19.23	3.53	3.29	0	0	0	0				26.15
Other 1	0	0	0	0	0	0	0				0
Other 2	0	0	0	0	0	0	0				0
Other 3	0	0	0	0	0	0	0				0
TOTAL	1630.54	38.66	78.99	0	0	0	0	0	0	0	1748.19

WATER LOAD GENERATION: RUNOFF

LAND USE	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	1030608	19728	88800	0	0	0	0	0	0	0	1139136
Urban 2 (MDR/Hwy)	272340	0	234120	0	0	0	0	0	0	0	506460
Urban 3 (HDR/Com)	52560	0	31320	0	0	0	0	0	0	0	83880
Urban 4 (Ind)	15912	0	0	0	0	0	0	0	0	0	15912
Urban 5 (P/I/R/C)	60816	0	0	0	0	0	0	0	0	0	60816
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	55872	0	72	0	0	0	0	0	0	0	55944
Agric 3 (Grazing)	190296	8136	12384	0	0	0	0	0	0	0	210816
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	2217072	18960	7752	0	0	0	0	0	0	0	2243784
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	179274	10374	3438	0	0	0	0	0	0	0	193086
Open 2 (Meadow)	68544	6246	2538	0	0	0	0	0	0	0	77328
Open 3 (Excavation)	92304	17424	15792	0	0	0	0	0	0	0	125520
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4235598	80868	396216	0	0	0	0	0	0	0	4712682
Total (cfs)	4.74	0.09	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.28
Area * Water Yield (cell b7)	10.7	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5

LOAD GENERATION: RUNOFF P

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	236.181	4.521	20.35	0	0	0	0	0	0	0	261.052
Urban 2 (MDR/Hwy)	49.929	0	42.922	0	0	0	0	0	0	0	92.851
Urban 3 (HDR/Com)	8.03	0	4.785	0	0	0	0	0	0	0	12.815
Urban 4 (Ind)	2.431	0	0	0	0	0	0	0	0	0	2.431
Urban 5 (P/I/R/C)	13.937	0	0	0	0	0	0	0	0	0	13.937
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	34.144	0	0.044	0	0	0	0	0	0	0	34.188
Agric 3 (Grazing)	42.288	1.808	2.752	0	0	0	0	0	0	0	46.848
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	184.756	1.58	0.646	0	0	0	0	0	0	0	186.982
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	59.758	3.458	1.146	0	0	0	0	0	0	0	64.362
Open 2 (Meadow)	7.616	0.694	0.282	0	0	0	0	0	0	0	8.592
Open 3 (Excavation)	15.384	2.904	2.632	0	0	0	0	0	0	0	20.92
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	654.5	15.0	75.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	745.0

WATER LOAD GENERATION: BASEFLOW

	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	644130	12330	55500	0	0	0	0	0	0	0	711960
Urban 2 (MDR/Hwy)	81702	0	70236	0	0	0	0	0	0	0	151938
Urban 3 (HDR/Com)	4380	0	2610	0	0	0	0	0	0	0	6990
Urban 4 (Ind)	1326	0	0	0	0	0	0	0	0	0	1326
Urban 5 (P/I/R/C)	38010	0	0	0	0	0	0	0	0	0	38010
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	55872	0	72	0	0	0	0	0	0	0	55944
Agric 3 (Grazing)	190296	8136	12384	0	0	0	0	0	0	0	210816
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	4434144	37920	15504	0	0	0	0	0	0	0	4487568
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland)	1434192	82992	27504	0	0	0	0	0	0	0	1544688
Open 2 (Meadow)	137088	12492	5076	0	0	0	0	0	0	0	154656
Open 3 (Excavation)	46152	8712	7896	0	0	0	0	0	0	0	62760
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	7067292	162582	196782	0	0	0	0	0	0	0	7426656
Total (cfs)	7.91	0.18	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.000	8.32

LOAD GENERATION: RUNOFF N

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	1180.905	22.605	101.75	0	0	0	0	0	0	0	1305.26
Urban 2 (MDR/Hwy)	249.645	0	214.61	0	0	0	0	0	0	0	464.255
Urban 3 (HDR/Com)	40.15	0	23.925	0	0	0	0	0	0	0	64.075
Urban 4 (Ind)	12.155	0	0	0	0	0	0	0	0	0	12.155
Urban 5 (P/I/R/C)	69.685	0	0	0	0	0	0	0	0	0	69.685
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	139.68	0	0.18	0	0	0	0	0	0	0	139.86
Agric 3 (Grazing)	274.3434	11.7294	17.8536	0	0	0	0	0	0	0	303.9264
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	2272.4988	19.434	7.9458	0	0	0	0	0	0	0	2299.8786
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	597.58	34.58	11.46	0	0	0	0	0	0	0	643.62
Open 2 (Meadow)	93.6768	8.5362	3.4686	0	0	0	0	0	0	0	105.6816
Open 3 (Excavation)	99.8037	18.8397	17.0751	0	0	0	0	0	0	0	135.7185
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	5030.1	115.7	398.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5544.1

LOAD GENERATION BASEFLOW P

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	2.1471	0.0411	0.185	0	0	0	0	0	0	0	2.3732
Urban 2 (MDR/Hwy)	0.4539	0	0.3902	0	0	0	0	0	0	0	0.8441
Urban 3 (HDR/Com)	0.073	0	0.0435	0	0	0	0	0	0	0	0.1165
Urban 4 (Ind)	0.0221	0	0	0	0	0	0	0	0	0	0.0221
Urban 5 (PA/R/C)	0.1267	0	0	0	0	0	0	0	0	0	0.1267
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0.1552	0	0.0002	0	0	0	0	0	0	0	0.1554
Agric 3 (Grazing)	0.5286	0.0226	0.0344	0	0	0	0	0	0	0	0.5856
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	3.69512	0.0316	0.01292	0	0	0	0	0	0	0	3.73964
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	1.19516	0.06916	0.02292	0	0	0	0	0	0	0	1.28724
Open 2 (Meadow)	0.15232	0.01388	0.00564	0	0	0	0	0	0	0	0.17184
Open 3 (Excavation)	0.07692	0.01452	0.01316	0	0	0	0	0	0	0	0.1046
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	8.6	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5

LOAD GENERATION: BASEFLOW N

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	1073.55	20.55	92.5	0	0	0	0	0	0	0	1186.6
Urban 2 (MDR/Hwy)	453.9	0	390.2	0	0	0	0	0	0	0	844.1
Urban 3 (HDR/Com)	146	0	87	0	0	0	0	0	0	0	233
Urban 4 (Ind)	11.05	0	0	0	0	0	0	0	0	0	11.05
Urban 5 (PA/R/C)	63.35	0	0	0	0	0	0	0	0	0	63.35
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	38.8	0	0.05	0	0	0	0	0	0	0	38.85
Agric 3 (Grazing)	264.3	11.3	17.2	0	0	0	0	0	0	0	292.8
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	461.89	3.95	1.615	0	0	0	0	0	0	0	467.455
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	149.395	8.645	2.865	0	0	0	0	0	0	0	160.905
Open 2 (Meadow)	19.04	1.735	0.705	0	0	0	0	0	0	0	21.48
Open 3 (Excavation)	9.615	1.815	1.645	0	0	0	0	0	0	0	13.075
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2690.9	48.0	593.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3332.7

ROUTING PATTERN (Which basin flows to which)

PASSES THROUGH...

1=YES 0=NO XXX=BLANK	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)
INDIVIDUAL BASIN	1	1	1	0	0	0	0	0	0	0
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX

WATER ROUTING AND ATTENUATION

SOURCE	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	
INDIVIDUAL BASIN	11302890	243450	592998	0	0	0	0	0	0	0	
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0	
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0	
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0	
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0	
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0	
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0	
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0	
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0	
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0	
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX	
CUMULATIVE TOTAL	11302890.0	243450.0	592998.0	0.0	0.0	0.0	0	0	0	0	
BASIN ATTENUATION	0.85	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
OUTPUT VOLUME	9607456.5	243450.0	474398.4	0.0	0.0	0.0	0	0	0	0	
Reality Check for Indiv. Basin (Based on std water yield)	9568660.9	226872.3	463544.9	0.0	0.0	0.0	0	0	0	0	0.0

LOAD ROUTING AND ATTENUATION: PHOSPHORUS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	663.1	15.2	76.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	663.1	15.2	76.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.50	0.40	0.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	331.5	6.1	30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	331.5	6.1	30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT (MG/L)	0.035	0.025	0.064	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC (Based on real data)	0.0388	0.0225									
TERMINAL DISCHARGE? (1=YES 2=NO)	1	1	1	0	0	0	0	0	0	0	
LOAD TO RESOURCE											
WATER (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	10325305
PHOSPHORUS (KG/YR)	331.5	6.1	30.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	368.1
PHOSPHORUS (MG/L)	0.035	0.025	0.064	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036

LOADING SUMMARY FROM MODEL

DIRECT LOADS TO LAKE	P	N	TSS		WATER
ATMOSPHERIC (KG/YR)	12.4	329.4	1652.2	(CU.M/YR)	229200.0
INTERNAL (KG/YR)	0.0	0.0	0.0	(CU.M/YR)	0.0
WATERFOWL (KG/YR)	2.0	9.5	50.0	(CU.M/YR)	0.0
WATERSHED LOAD (KG/YR)	368.1	6213.7	89598.5	(CU.M/YR)	10325304.9
TOTAL LOAD TO LAKE (KG/YR) (Watershed + direct loads)	382.5	6552.6	91300.7	(CU.M/YR)	10554504.9
TOTAL INPUT CONC. (MG/L)	0.036	0.621	8.650		

LOAD ROUTING AND ATTENUATION: NITROGEN

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	7721.0	163.7	992.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	7721.0	163.7	992.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.70	0.70	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	5404.7	114.6	694.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: NITROGEN

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	5404.7	114.6	694.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	0.563	0.471	1.464	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC (Based on real data)	0.538	0.475									
TERMINAL DISCHARGE? (1=YES 2=NO)	1	1	1	0	0	0	0	0	0	0	
LOAD TO RESOURCE											
WATER (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	10325305
NITROGEN (KG/YR)	5404.7	114.6	694.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6213.7
NITROGEN (MG/L)	0.563	0.471	1.464	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.602

No Data On This Page

LOAD GENERATION, RUNOFF TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	19968.03	382.23	1720.5	0	0	0	0	0	0	0	22070.76
Urban 2 (MDR/Hwy)	4221.27	0	3628.86	0	0	0	0	0	0	0	7850.13
Urban 3 (HDR/Com)	678.9	0	404.55	0	0	0	0	0	0	0	1083.45
Urban 4 (Ind)	205.53	0	0	0	0	0	0	0	0	0	205.53
Urban 5 (P/R/C)	1178.31	0	0	0	0	0	0	0	0	0	1178.31
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	3880	0	5	0	0	0	0	0	0	0	3885
Agric 3 (Grazing)	5286	226	344	0	0	0	0	0	0	0	5856
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	14780.48	126.4	51.68	0	0	0	0	0	0	0	14958.56
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	4780.64	276.64	91.68	0	0	0	0	0	0	0	5148.96
Open 2 (Meadow)	609.28	55.52	22.56	0	0	0	0	0	0	0	687.36
Open 3 (Excavation)	19230	3630	3290	0	0	0	0	0	0	0	26150
Other 1.	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	74818.4	4696.8	9558.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89074.1

LOAD GENERATION: BASEFLOW TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	64.413	1.233	5.55	0	0	0	0	0	0	0	71.196
Urban 2 (MDR/Hwy)	13.617	0	11.706	0	0	0	0	0	0	0	25.323
Urban 3 (HDR/Com)	2.19	0	1.305	0	0	0	0	0	0	0	3.495
Urban 4 (Ind)	0.663	0	0	0	0	0	0	0	0	0	0.663
Urban 5 (P/I/R/C)	3.801	0	0	0	0	0	0	0	0	0	3.801
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	4.656	0	0.006	0	0	0	0	0	0	0	4.662
Agric 3 (Grazing)	15.858	0.678	1.032	0	0	0	0	0	0	0	17.568
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	277.134	2.37	0.969	0	0	0	0	0	0	0	280.473
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	89.637	5.187	1.719	0	0	0	0	0	0	0	96.543
Open 2 (Meadow)	11.424	1.041	0.423	0	0	0	0	0	0	0	12.888
Open 3 (Excavation)	5.769	1.089	0.987	0	0	0	0	0	0	0	7.845
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	489.2	11.6	23.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	524.5

LOAD ROUTING AND ATTENUATION: SUSPENDED SOLIDS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	75307.6	4708.4	9582.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	75307.6	4708.4	9582.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	75307.6	4708.4	9582.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: SUSPENDED SOLIDS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	75307.6	4708.4	9582.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	7.838	19.340	20.199	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC (Based on real data)											
TERMINAL DISCHARGE? (1=YES 2=NO)	1	1	1		0	0	0	0	0	0	
LOAD TO RESOURCE											
WATER (CU.M/YR)	9607457	243450	474398	0	0	0	0	0	0	0	10325305
TSS (KG/YR)	75307.6	4708.4	9582.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	89598.5
TSS (MG/L)	7.838	19.340	20.199	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.678

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE TERMS

PHOSPHORUS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Phosphorus Load to Lake	kg/yr	From export model	383	
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A	2.000	
TPin	Influent (Inflow) Total Phosphorus	ppb	From export model	36	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available	20	Enter Value (TP out)
I	Inflow	m3/yr	From export model	10554505	
A	Lake Area	m2	From data	191300	Enter Value (A)
V	Lake Volume	m3	From data	344340	Enter Value (V)
Z	Mean Depth	m	Volume/area	1.800	
F	Flushing Rate	flushings/yr	Inflow/volume	30.651	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.552	
Qs	Areal Water Load	m/yr	Z(F)	55.173	
Vs	Settling Velocity	m	Z(S)	0.993	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.114	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.153	

NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TN	Lake Total Nitrogen Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Nitrogen Load to Lake	kg/yr	From export model	6553	
L1	Nitrogen Load to Lake	g N/m2/yr	KG*1000/A	34.25	
L2	Nitrogen Load to Lake	mg N/m2/yr	KG*1000000/A	34253	
C1	Coefficient of Attenuation, from F	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	4.62	
C2	Coefficient of Attenuation, from L	fraction/yr	2.7183^(0.71(ln(L2))-6.426)	2.68	
C3	Coefficient of Attenuation, from L/Z	fraction/yr	2.7183^(0.594(ln(L2/Z))-4.144)	5.52	

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE MODELS

PHOSPHORUS / *PREDICTED CHL AND WATER CLARITY*

NAME	FORMULA	PRED. CONC. (ppb)	PERMIS. CONC. (ppb)	CRITICAL CONC. (ppb)	MODEL	Value	Avg
Mass Balance	TP=L/(Z(F))*1000	36					
(Maximum Conc.)					**Mean Chlorophyll (ug/L)**		
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	32	12	24	Dillon and Rigler 1974	11.1	
(K-D)					Jones and Bachmann 1976	12.8	
Vollenweider 1975	TP=L/(Z(S+F))*1000	36	13	26	Oglesby and Schaffner 1978	15.5	
(V)					Modified Vollenweider 1982	15.6	13.8
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	31	11	23	**"Maximum" Chlorophyll (ug/L)**		
(L-M)					Modified Vollenweider (TP) 1982	48.8	
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	30	11	22	Vollenweider (CHL) 1982	41.9	
(J-B)					Modified Jones, Rast and Lee 1979	47.0	45.9
					Secchi Transparency (M)		
Average of Model Values		32	12	24	Oglesby and Schaffner 1978 **(Avg)**	1.6	
(without mass balance)					Modified Vollenweider 1982 **(Max)**	3.7	
Reality Check Conc.		20					
From Vollenweider 1968							
Permissible Load (g/m2/yr)	Lp=10^(0.501503(log(Z(F)))-1.0018)	0.74					
Critical Load (g/m2/yr)	Lc=2(Cp)	1.49					

NITROGEN

NAME	FORMULA	PRED. CONC. (ppb)
Mass Balance	TN=L/(Z(F))*1000	621
(Maximum Conc.)		
Bachmann 1980	TN=L/(Z(C1+F))*1000	540
Bachmann 1980	TN=L/(Z(C2+F))*1000	571
Bachmann 1980	TN=L/(Z(C3+F))*1000	526
Average of Model Values		545.5
(without mass balance)		
Reality Check Conc.		425

Nitrogen and Phosphorus Loading to New Bedford Reservoir (South Pond) Estimated from Empirical Models

South Pond

PART 1: THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From data or model	20	Enter Value
L	Phosphorus Load to Lake	g P/m2/yr	From data or model		
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	36	Enter Value
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	20	Enter Value
I	Inflow	m3/yr	From data	10554505	Enter Value
A	Lake Area	m2	From data	191300	Enter Value
V	Lake Volume	m3	From data	344340	Enter Value
Z	Mean Depth	m	Volume/area	1.8	
F	Flushing Rate	flushings/yr	Inflow/volume	30.65141	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.555556	
Qs	Areal Water Load	m/yr	Z(F)	55.17253	
Vs	Settling Velocity	m	Z(S)	1	
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.444444	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.114015	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.15299	
	ADDENDUM FOR NITROGEN				
TN	Lake Total Nitrogen Conc.	ppb	From data or model	450	Enter Value
L	Nitrogen Load to Lake	g N/m2/yr	From data or model		Enter Value
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	4.615944	

Nitrogen and Phosphorus Loading to New Bedford Reservoir (South Pond) Estimated from Empirical Models - Continued.

PART 2: THE MODELS					*LOAD ANALYSIS*	
		PREDICTION				**ESTIMATED**
		CONC.	**LOAD**			**LOAD**
NAME	**FORMULA**	**(ppb)**	**(g/m2/yr)**		**MODEL**	**(kg/yr)**
Mass Balance	TP=L/(Z(F))*1000	0			***Phosphorus***	
(minimum load)	L=TP(Z)(F)/1000		1.10		Mass Balance (no loss)	211
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	0				
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		1.25		Kirchner-Dillon 1975	238
Vollenweider 1975	TP=L/(Z(S+F))*1000	0				
(V)	L=TP(Z)(S+F)/1000		1.12		Vollenweider 1975	215
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	0				
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		1.56		Reckhow 1977 (General)	298
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	0				
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		1.30		Larsen-Mercier 1976	249
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	0				
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		1.34		Jones-Bachmann 1976	257
Average of Model Values		0			Model Average	
(without mass balance)			1.31		(without mass balance)	251
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	0				
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		1.25		Reckhow 1977 (Anoxic)	240
From Vollenweider 1968						
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.74		Permissible Load	142
Critical Load	Lc=2(Lp)		1.49		Critical Load	285
Mass Balance	TN=L/(Z(F))*1000	0			***Nitrogen***	
(minimum load)	L=TN(Z)(F)/1000		24.83		Mass Balance (no loss)	4750
Bachmann 1980	TN=L/(Z(C+F))*1000	0				
	L=TN(Z)(C+F)/1000		28.57		Bachmann 1980	5465

LAND USE MODELS
Northeast Pond

EXPORT MODEL VARIABLES AND INPUT RANGES

VARIABLE	DESCRIPTION	FOR SOUTHERN NE AREA HIGH	MEDIUM	LOW
Standard Water Yield	Rate of water yield in CFS/Sq.Mi. by watershed Increases with increased runoff	2.0	1.7	1.5
Precipitation	Annual rainfall in M Increases with wet year	1.53	1.14	0.81
Runoff Coefficient	Portion of rainfall converted to overland flow Increases with steeper slope and lowered permeability	0.95	0.40	0.10
Baseflow Coefficient	Portion of rainfall converted to baseflow Increases with flatter slope and higher permeability	0.40	0.20	0.01

P, N AND TSS EXPORT COEFFICIENTS FOR RUNOFF

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 4 (Ind)	Industrial	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	2.90	1.08	0.80	0.10	7.82	5.19	6.08	0.97	500	100	100	20
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50
Agric 3 (Grazing)	Agricultural pasture with livestock	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	500	100	100	20
Agric 4 (Feedlot)	Concentrated livestock holding area	795.20	300.70	224.00	21.28	7979.90	3110.70	2923.20	680.50	40000	15000	15000	3500
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Open 3 (Barren)	Mining or construction areas, largely bare soils	4.90	1.50	0.80	0.14	30.85	8.65	5.19	1.48	10000	1000	1000	100
Other 1	Define:	0.83	0.24	0.20	0.02	6.26	2.86	2.46	1.38	40	15	16	4
Other 2	Define:	6.23	1.91	1.10	0.19	38.47	9.97	5.50	1.48	250	77	93	14
Other 3	Define:	18.60	4.46	2.20	0.26	79.60	16.09	9.00	2.10	2000	200	250	50

P, N AND TSS EXPORT COEFFICIENTS FOR BASEFLOW

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
LAND USES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Urban 1 (LDR)	Low density residential (>1 ac lots)	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 2 (MDR/Hwy)	Medium density residential (0.3-0.9 ac lots) + highway corridors	0.050	0.010	0.010	0.001	40.00	10.00	10.00	2.00	1.0	0.3	0.3	0.1
Urban 3 (HDR/Com)	High density residential (<0.3 ac lots) + commercial	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1
Urban 4 (Ind)	Industrial	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Urban 5 (P/I/R/C)	Park, Institutional, Recreational or Cemetery	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 1 (Cvr Crop)	Agricultural with cover crops (minimal bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 2 (Row Crop)	Agricultural with row crops (some bare soil)	0.050	0.010	0.010	0.001	10.00	2.50	2.50	0.50	1.0	0.3	0.3	0.1
Agric 3 (Grazing)	Agricultural pasture with livestock	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Agric 4 (Feedlot)	Concentrated livestock holding area	0.100	0.030	0.030	0.001	100.00	25.00	25.00	5.00	1.0	0.3	0.3	0.1
Forest 1 (Upland)	Land with tree canopy over upland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Forest 2 (Wetland)	Land with tree canopy over wetland soils and vegetation	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 1 (Wetland/Lake)	Open wetland or lake area (no substantial canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 2 (Meadow)	Open meadow area (no clearly wetland, but no canopy)	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Open 3 (Barren)	Mining or construction areas, largely bare soils	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 1	Define:	0.010	0.004	0.004	0.001	1.00	0.50	0.50	0.05	1.0	0.3	0.3	0.1
Other 2	Define:	0.050	0.010	0.010	0.001	20.00	5.00	5.00	1.00	1.0	0.3	0.3	0.1
Other 3	Define:	0.050	0.010	0.010	0.001	80.00	20.00	20.00	4.00	1.0	0.3	0.3	0.1

		PHOSPHORUS EXPORT (KG/HA/YR)				NITROGEN EXPORT (KG/HA/YR)				SUSPENDED SOLIDS EXPORT (KG/HA/YR)			
OTHER AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Atmospheric Deposition	Wet and dry deposition from aerial sources												
from Forested Area	Deposition originating in largely forested area	0.54	0.27	0.20	0.07	11.30	5.96	6.52	0.99	55	30	32	5
from Agricultural/Rural Area	Deposition originating in largely agricultural area	0.97	0.45	0.30	0.12	38.00	20.98	13.13	10.49	190	105	66	52
from Urban/Industrial Area	Deposition originating in largely urban area	3.67	1.27	1.00	0.26	24.80	18.51	21.36	7.40	124	93	107	37
Internal Loading	Release from sediments or macrophytes, oxic or anoxic (assumes anoxia for 90 days - adjust as needed)	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10	10.00	1.00	1.00	0.10

		PHOSPHORUS LOAD				NITROGEN LOAD				SUSPENDED SOLIDS LOAD			
NON-AREAL SOURCES		MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM	MAXIMUM	MEAN	MEDIAN	MINIMUM
Waterfowl	Direct inputs from birds (kg/bird/yr)	0.50	0.20	0.20	0.09	5.80	1.00	0.95	0.48	29.0	5.0	5.0	2.0
Point Sources	Direct discharge from facility												
	Wastewater - primary treatment (ppm)	6.00	4.00	4.00	1.00	70.00	45.00	45.00	20.00	100.0	50.0	50.0	10.0
	Wastewater - secondary treatment (ppm)	4.00	2.00	2.00	0.40	10.00	5.00	5.00	1.00	10.0	5.0	5.0	1.0
	Wastewater - tertiary treatment (ppm)	1.00	0.50	0.50	0.10	5.00	2.00	2.00	1.00	10.0	5.0	5.0	1.0
	Cooling water (ppm)	5.00	1.00	1.00	0.05	1.00	0.05	0.05	0.02	1.0	0.5	0.5	0.1

EXPORT MODEL INPUT AND CALCULATIONS

STD. WATER YIELD (CFS/SQ.MI)	1.7	
PRECIPITATION (in M)	1.20	(From Cranberry Expt station, E.Wareham)

COEFFICIENTS			RUNOFF EXPORT COEFFICIENTS			BASEFLOW EXPORT COEFFICIENTS		
	Runoff Coefficient	Baseflow Coefficient	P Export Coefficient	N Export Coefficient	TSS Export Coefficient	P Export Coefficient	N Export Coefficient	TSS Export Coefficient
LAND USE	(Fraction)	(Fraction)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)
Urban 1 (LDR)	0.40	0.25	0.80	5.50	93	0.010	5.00	0.3
Urban 2 (MDR/Hwy)	0.50	0.15	1.10	5.50	93	0.010	10.00	0.3
Urban 3 (HDR/Com)	0.60	0.05	1.10	5.50	93	0.010	20.00	0.3
Urban 4 (Ind)	0.60	0.05	1.10	5.50	93	0.010	5.00	0.3
Urban 5 (P/I/R/C)	0.40	0.25	1.10	5.50	93	0.010	5.00	0.3
Agric 1 (Cvr Crop)	0.15	0.30	0.80	6.08	100	0.010	2.50	0.3
Agric 2 (Row Crop)	0.30	0.30	2.20	9.00	250	0.010	2.50	0.3
Agric 3 (Grazing)	0.30	0.30	0.80	5.19	100	0.010	5.00	0.3
Agric 4 (Feedlot)	0.45	0.30	224.00	2923.20	15000	0.030	25.00	0.3
Forest 1 (Upland)	0.20	0.40	0.20	2.46	16	0.004	0.50	0.3
Forest 2 (Wetland)	0.05	0.40	0.20	2.46	16	0.004	0.50	0.3
Open 1 (Wetland/Lake)	0.05	0.40	0.20	2.46	16	0.004	0.50	0.3
Open 2 (Meadow)	0.15	0.30	0.20	2.46	16	0.004	0.50	0.3
Open 3 (Excavation)	0.40	0.20	0.40	5.19	1000	0.004	0.50	0.3
Other 1	0.10	0.40	0.20	2.46	16	0.004	0.50	0.3
Other 2	0.35	0.25	1.10	5.50	93	0.010	5.00	0.3
Other 3	0.60	0.05	2.20	9.00	250	0.010	20.00	0.3

OTHER AREAL SOURCES				
	Affected Lake	P Export Coefficient	N Export Coefficient	TSS Export Coefficient
Atmospheric Deposition	Area (ha)	(kg/ha/yr)	(kg/ha/yr)	(kg/ha/yr)
from Forested Area	4.3	0.20	6.52	32.0
from Agricultural/Rural Area	4.3	0.30	13.13	66.0
from Urban/Industrial Area	0.0	1.00	21.36	107.0
Internal Loading	0.0	1.00	1.00	1.0

NON-AREAL SOURCES								
	Number of Source Units	Volume (cu.m/yr)	P Load (kg/unit/yr)	N Load (kg/unit/yr)	TSS Load (kg/unit/yr)	P Load (ppm)	N Load (ppm)	TSS Load (ppm)
Waterfowl	3		0.20	0.95	5			
Point Sources								
PS-1		0				0.00	0.00	0.0
PS-2		0				0.00	0.00	0.0
PS-3		0				0.00	0.00	0.0

Basin in which Point Source occurs (0=NO 1=YES)

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
PS-1	0	0	0	0	0	0	0	0	0	0
PS-2	0	0	0	0	0	0	0	0	0	0
PS-3	0	0	0	0	0	0	0	0	0	0

BASIN AREAS

LAND USE	BASIN A AREA (HA)	BASIN B AREA (HA)	BASIN C AREA (HA)	BASIN 4 AREA (HA)	BASIN 5 AREA (HA)	BASIN 6 AREA (HA)	BASIN 7 AREA (HA)	BASIN 8 AREA (HA)	BASIN 9 AREA (HA)	BASIN 10 AREA (HA)	TOTAL AREA (HA)
Urban 1 (LDR)	4.11	0	0	0	0	0	0				4.11
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0				0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0				0
Urban 4 (Ind)	0	0	0	0	0	0	0				0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0				0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0				0
Agric 2 (Row Crop)	0	0	0	0	0	0	0				0
Agric 3 (Grazing)	2.26	0	0	0	0	0	0				2.26
Agric 4 (Feedlot)	0	0	0	0	0	0	0				0
Forest 1 (Upland)	7.9	0	0	0	0	0	0				7.9
Forest 2 (Wetland)	0	0	0	0	0	0	0				0
Open 1 (Wetland/Lake)	8.66	0	0	0	0	0	0				8.66
Open 2 (Meadow)	3.47	0	0	0	0	0	0				3.47
Open 3 (Excavation)	3.63	0	0	0	0	0	0				3.63
Other 1	0	0	0	0	0	0	0				0
Other 2	0	0	0	0	0	0	0				0
Other 3	0	0	0	0	0	0	0				0
TOTAL	30.03	0	0	0	0	0	0	0	0	0	30.03

WATER LOAD GENERATION: RUNOFF

LAND USE	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	19728	0	0	0	0	0	0	0	0	0	19728
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	8136	0	0	0	0	0	0	0	0	0	8136
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	18960	0	0	0	0	0	0	0	0	0	18960
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	5196	0	0	0	0	0	0	0	0	0	5196
Open 2 (Meadow)	6246	0	0	0	0	0	0	0	0	0	6246
Open 3 (Excavation)	17424	0	0	0	0	0	0	0	0	0	17424
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	75690	0	0	0	0	0	0	0	0	0	75690
Total (cfs)	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Area * Water Yield (cell b7)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

WATER LOAD GENERATION: BASEFLOW

	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	TOTAL (CU.M/YR)
Urban 1 (LDR)	12330	0	0	0	0	0	0	0	0	0	12330
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	8136	0	0	0	0	0	0	0	0	0	8136
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	37920	0	0	0	0	0	0	0	0	0	37920
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland)	41568	0	0	0	0	0	0	0	0	0	41568
Open 2 (Meadow)	12492	0	0	0	0	0	0	0	0	0	12492
Open 3 (Excavation)	8712	0	0	0	0	0	0	0	0	0	8712
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	121158	0	0	0	0	0	0	0	0	0	121158
Total (cfs)	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.14

LOAD GENERATION: RUNOFF P

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	3.288	0	0	0	0	0	0	0	0	0	3.288
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	1.808	0	0	0	0	0	0	0	0	0	1.808
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	1.58	0	0	0	0	0	0	0	0	0	1.58
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	1.732	0	0	0	0	0	0	0	0	0	1.732
Open 2 (Meadow)	0.694	0	0	0	0	0	0	0	0	0	0.694
Open 3 (Excavation)	1.452	0	0	0	0	0	0	0	0	0	1.452
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6

LOAD GENERATION: RUNOFF N

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	22.605	0	0	0	0	0	0	0	0	0	22.605
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	11.7294	0	0	0	0	0	0	0	0	0	11.7294
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	19.434	0	0	0	0	0	0	0	0	0	19.434
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	21.3036	0	0	0	0	0	0	0	0	0	21.3036
Open 2 (Meadow)	8.5362	0	0	0	0	0	0	0	0	0	8.5362
Open 3 (Excavation)	18.8397	0	0	0	0	0	0	0	0	0	18.8397
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	102.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	102.4

LOAD GENERATION: BASEFLOW P

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	0.0411	0	0	0	0	0	0	0	0	0	0.0411
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	0.0226	0	0	0	0	0	0	0	0	0	0.0226
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	0.0316	0	0	0	0	0	0	0	0	0	0.0316
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	0.03464	0	0	0	0	0	0	0	0	0	0.03464
Open 2 (Meadow)	0.01388	0	0	0	0	0	0	0	0	0	0.01388
Open 3 (Excavation)	0.01452	0	0	0	0	0	0	0	0	0	0.01452
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

ROUTING PATTERN (Which basin flows to which)

1=YES 0=NO XXX=BLANK	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)
					PASSES THROUGH...					
INDIVIDUAL BASIN	1	0	0	0	0	0	0	0	0	0
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX

WATER ROUTING AND ATTENUATION

SOURCE	BASIN 1 (CU.M/YR)	BASIN 2 (CU.M/YR)	BASIN 3 (CU.M/YR)	BASIN 4 (CU.M/YR)	BASIN 5 (CU.M/YR)	BASIN 6 (CU.M/YR)	BASIN 7 (CU.M/YR)	BASIN 8 (CU.M/YR)	BASIN 9 (CU.M/YR)	BASIN 10 (CU.M/YR)	
INDIVIDUAL BASIN	196849	0	0	0	0	0	0	0	0	0	
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0	
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0	
BASIN 3 OUTPUT	0	0	XXX	0	0	0	0	0	0	0	
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0	
BASIN 5 OUTPUT	0	0	0	0	XXX	0	0	0	0	0	
BASIN 6 OUTPUT	0	0	0	0	0	XXX	0	0	0	0	
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0	
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0	
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0	
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX	
CUMULATIVE TOTAL	196848.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	
BASIN ATTENUATION	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
OUTPUT VOLUME	177163.2	0.0	0.0	0.0	0.0	0.0	0	0	0	0	
Reality Check for Indiv. Basin (Based on std water yield)	176228.1	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0

LOAD GENERATION: BASEFLOW N

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	20.55	0	0	0	0	0	0	0	0	0	20.55
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	11.3	0	0	0	0	0	0	0	0	0	11.3
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	3.95	0	0	0	0	0	0	0	0	0	3.95
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	4.33	0	0	0	0	0	0	0	0	0	4.33
Open 2 (Meadow)	1.735	0	0	0	0	0	0	0	0	0	1.735
Open 3 (Excavation)	1.815	0	0	0	0	0	0	0	0	0	1.815
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	43.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.7

LOAD ROUTING AND ATTENUATION: PHOSPHORUS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT (MG/L)	0.030	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC.											
(Based on real data)											
TERMINAL DISCHARGE?	1	0	0	0	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	177163
PHOSPHORUS (KG/YR)	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
PHOSPHORUS (MG/L)	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030

LOADING SUMMARY FROM MODEL

DIRECT LOADS TO LAKE	P	N	TSS		WATER
ATMOSPHERIC (KG/YR)	2.2	84.5	421.4	(CU.M/YR)	103200.0
INTERNAL (KG/YR)	0.0	0.0	0.0	(CU.M/YR)	0.0
WATERFOWL (KG/YR)	0.6	2.9	15.0	(CU.M/YR)	0.0
WATERSHED LOAD (KG/YR)	5.4	87.7	4567.7	(CU.M/YR)	177163.2
TOTAL LOAD TO LAKE (KG/YR)	8.1	175.0	5004.1	(CU.M/YR)	280363.2
(Watershed + direct loads)					
TOTAL INPUT CONC. (MG/L)	0.029	0.624	17.849		

LOAD ROUTING AND ATTENUATION: NITROGEN

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	146.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	146.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	87.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: NITROGEN

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	87.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	0.495	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC.											
(Based on real data)											
TERMINAL DISCHARGE	1	0	0	0	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	177163
NITROGEN (KG/YR)	87.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.7
NITROGEN (MG/L)	0.495	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.495

No Data On This Page

LOAD GENERATION: RUNOFF TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	382.23	0	0	0	0	0	0	0	0	0	382.23
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	226	0	0	0	0	0	0	0	0	0	226
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	126.4	0	0	0	0	0	0	0	0	0	126.4
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	138.56	0	0	0	0	0	0	0	0	0	138.56
Open 2 (Meadow)	55.52	0	0	0	0	0	0	0	0	0	55.52
Open 3 (Excavation)	3630	0	0	0	0	0	0	0	0	0	3630
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4558.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4558.7

LOAD GENERATION: BASEFLOW TSS

LAND USE	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)	TOTAL (KG/YR)
Urban 1 (LDR)	1.233	0	0	0	0	0	0	0	0	0	1.233
Urban 2 (MDR/Hwy)	0	0	0	0	0	0	0	0	0	0	0
Urban 3 (HDR/Com)	0	0	0	0	0	0	0	0	0	0	0
Urban 4 (Ind)	0	0	0	0	0	0	0	0	0	0	0
Urban 5 (P/I/R/C)	0	0	0	0	0	0	0	0	0	0	0
Agric 1 (Cvr Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 2 (Row Crop)	0	0	0	0	0	0	0	0	0	0	0
Agric 3 (Grazing)	0.678	0	0	0	0	0	0	0	0	0	0.678
Agric 4 (Feedlot)	0	0	0	0	0	0	0	0	0	0	0
Forest 1 (Upland)	2.37	0	0	0	0	0	0	0	0	0	2.37
Forest 2 (Wetland)	0	0	0	0	0	0	0	0	0	0	0
Open 1 (Wetland/Lake)	2.598	0	0	0	0	0	0	0	0	0	2.598
Open 2 (Meadow)	1.041	0	0	0	0	0	0	0	0	0	1.041
Open 3 (Excavation)	1.089	0	0	0	0	0	0	0	0	0	1.089
Other 1:	0	0	0	0	0	0	0	0	0	0	0
Other 2:	0	0	0	0	0	0	0	0	0	0	0
Other 3:	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	0	0	0	0	0	0	0	0
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0

LOAD ROUTING AND ATTENUATION: SUSPENDED SOLIDS

	BASIN 1 (KG/YR)	BASIN 2 (KG/YR)	BASIN 3 (KG/YR)	BASIN 4 (KG/YR)	BASIN 5 (KG/YR)	BASIN 6 (KG/YR)	BASIN 7 (KG/YR)	BASIN 8 (KG/YR)	BASIN 9 (KG/YR)	BASIN 10 (KG/YR)
BASIN 1 INDIVIDUAL	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN ATTENUATION	1.00	1.00	1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OUTPUT LOAD	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LOAD AND CONCENTRATION SUMMARY: SUSPENDED SOLIDS

	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
OUTPUT (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	
OUTPUT (KG/YR)	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OUTPUT MG/L	25.783	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC.											
(Based on real data)											
TERMINAL DISCHARGE	1	0	0	0	0	0	0	0	0	0	
(1=YES 2=NO)											
LOAD TO RESOURCE											
WATER (CU.M/YR)	177163	0	0	0	0	0	0	0	0	0	177163
TSS (KG/YR)	4567.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4567.7
TSS (MG/L)	25.783	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25.783

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE TERMS

PHOSPHORUS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Phosphorus Load to Lake	kg/yr	From export model	8	
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A	0.094	
TPin	Influent (inflow) Total Phosphorus	ppb	From export model	29	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available	20	Enter Value (TP out)
I	Inflow	m3/yr	From export model	280363	
A	Lake Area	m2	From data	86300	Enter Value (A)
V	Lake Volume	m3	From data	129450	Enter Value (V)
Z	Mean Depth	m	Volume/area	1.500	
F	Flushing Rate	flushings/yr	Inflow/volume	2.166	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.692	
Qs	Areal Water Load	m/yr	Z(F)	3.249	
Vs	Settling Velocity	m	Z(S)	1.038	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.687	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.405	

NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TN	Lake Total Nitrogen Conc.	ppb	From in-lake models	To Be Predicted	Dependent Variable
KG	Nitrogen Load to Lake	kg/yr	From export model	175	
L1	Nitrogen Load to Lake	g N/m2/yr	KG*1000/A	2.03	
L2	Nitrogen Load to Lake	mg N/m2/yr	KG*1000000/A	2028	
C1	Coefficient of Attenuation, from F	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	1.06	
C2	Coefficient of Attenuation, from L	fraction/yr	2.7183^(0.71(ln(L2))-6.426)	0.36	
C3	Coefficient of Attenuation, from L/Z	fraction/yr	2.7183^(0.594(ln(L2/Z))-4.144)	1.15	

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions

THE MODELS

PHOSPHORUS

NAME	FORMULA	PRED. CONC. (ppb)	PERMIS. CONC. (ppb)	CRITICAL CONC. (ppb)
Mass Balance (Maximum Conc.)	TP=L/(Z(F))*1000	29		
Kirchner-Dillon 1975 (K-D)	TP=L(1-Rp)/(Z(F))*1000	9	17	35
Vollenweider 1975 (V)	TP=L/(Z(S+F))*1000	22	42	84
Larsen-Mercier 1976 (L-M)	TP=L(1-Rlm)/(Z(F))*1000	17	33	66
Jones-Bachmann 1976 (J-B)	TP=0.84(L)/(Z(0.65+F))*1000	19	36	72
Average of Model Values (without mass balance)		17	32	64
Reality Check Conc.		20		

From Vollenweider 1968

Permissible Load (g/m2/yr)	Lp=10^(0.501503(log(Z(F)))-1.0018)	0.18
Critical Load (g/m2/yr)	Lc=2(Cp)	0.36

PREDICTED CHL AND WATER CLARITY

MODEL	Value	Avg
Mean Chlorophyll (ug/L)		
Dillon and Rigler 1974	4.3	
Jones and Bachmann 1976	5.0	
Oglesby and Schaffner 1978	6.7	
Modified Vollenweider 1982	8.4	6.1
"Maximum" Chlorophyll (ug/L)		
Modified Vollenweider (TP) 1982	24.6	
Vollenweider (CHL) 1982	17.6	
Modified Jones, Rast and Lee 1979	20.9	21.1
Secchi Transparency (M)		
Oglesby and Schaffner 1978 **(Avg)**	2.7	
Modified Vollenweider 1982 **(Max)**	4.4	

NITROGEN

NAME	FORMULA	PRED. CONC. (ppb)
Mass Balance (Maximum Conc.)	TN=L/(Z(F))*1000	624
Bachmann 1980	TN=L/(Z(C1+F))*1000	419
Bachmann 1980	TN=L/(Z(C2+F))*1000	535
Bachmann 1980	TN=L/(Z(C3+F))*1000	408
Average of Model Values (without mass balance)		453.9
Reality Check Conc.		538

Nitrogen and Phosphorus Loading to New Bedford Reservoir (North-east Pond) Estimated from Empirical Models

North-east pond

PART 1: THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From data or model	20	Enter Value
L	Phosphorus Load to Lake	g P/m2/yr	From data or model		
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	29	Enter Value
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	20	Enter Value
I	Inflow	m3/yr	From data	280363	Enter Value
A	Lake Area	m2	From data	86300	Enter Value
V	Lake Volume	m3	From data	129450	Enter Value
Z	Mean Depth	m	Volume/area	1.5	
F	Flushing Rate	flushings/yr	Inflow/volume	2.165801	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.689655	
Qs	Areal Water Load	m/yr	Z(F)	3.248702	
Vs	Settling Velocity	m	Z(S)	1.034483	
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.310345	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.686599	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.404585	

ADDENDUM FOR NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TN	Lake Total Nitrogen Conc.	ppb	From data or model	538	Enter Value
L	Nitrogen Load to Lake	g N/m2/yr	From data or model		Enter Value
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	1.063115	

Nitrogen and Phosphorus Loading to New Bedford Reservoir (North-east Pond) Estimated from Empirical Models - Continued.

PART 2: THE MODELS					*LOAD ANALYSIS*	
		PREDICTION				**ESTIMATED**
		CONC.	**LOAD**			**LOAD**
NAME	**FORMULA**	**(ppb)**	**(g/m2/yr)**		**MODEL**	**(kg/yr)**
Mass Balance	TP=L/(Z(F))*1000	0			***Phosphorus***	
(minimum load)	L=TP(Z)(F)/1000		0.06		Mass Balance (no loss)	6
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	0				
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.21		Kirchner-Dillon 1975	18
Vollenweider 1975	TP=L/(Z(S+F))*1000	0				
(V)	L=TP(Z)(S+F)/1000		0.09		Vollenweider 1975	7
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	0				
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		0.31		Reckhow 1977 (General)	27
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	0				
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.11		Larsen-Mercier 1976	9
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	0				
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.10		Jones-Bachmann 1976	9
Average of Model Values		0			Model Average	
(without mass balance)			0.16		(without mass balance)	14
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	0				
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.08		Reckhow 1977 (Anoxic)	7
From Vollenweider 1968						
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.18		Permissible Load	16
Critical Load	Lc=2(Lp)		0.36		Critical Load	31
Mass Balance	TN=L/(Z(F))*1000	0			***Nitrogen***	
(minimum load)	L=TN(Z)(F)/1000		1.75		Mass Balance (no loss)	151
Bachmann 1980	TN=L/(Z(C+F))*1000	0				
	L=TN(Z)(C+F)/1000		2.61		Bachmann 1980	225