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STRAITS POND RECLAMATION STUDY AND PROGRAM

TOWNS OF HULL AND COHASSET

APRIL 1980

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iEP

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1.0 INTRODUCTION

Straits Pond is located in the southeasterly area of Hull and the northwestern part of Cohasset where it forms a portion of the boundary between the two towns (Figure 1.1). The Pond has a surface area of about 92 acres, an average depth of 3.3 feet, a maximum depth of 4 feet and an elevation which varies between 3 and 4 feet (MSL).

Straits Pond was originally a tidal marsh representing the upward extent of tidal activity of the Weir River. Records indicate that during the nineteenth century the tidal marsh was dammed and used as a reservoir for the operation of a mill located near the existing outlet on Nantasket Avenue in Hull. Later in the century when the Mill closed, the Pond was drained and the area used for the growing of grass crops.

As early as 1900 the state Board of Health was directed to investigate complaints of nuisance weed growth and foul odors at Straits Pond (Mass. Dept. of Public Health, et al, December 2, 1953). At that time the Pond's average depth was listed as 5 feet and the bottom sediments characterized as "mud."

The state Board of Health proposed several ways of improving this situation. One involved the placement of pipes connecting the easterly end of the Pond with the Atlantic Ocean and replacing the water in the Pond two or three times a month. Apparently sewage and other waste materials were being discharged to the Pond at that time, as the Board of Health cited as essential the elimination of all such material from entering the Pond. Further recommendations included removal of the mud and organic matter and replacing this with sand and gravel (Mass. Dept. of Public Health, et al, December 2, 1953). Apparently little or no action was taken to effectuate the Mass. DPH recommendations.

In the early 1940's interest in correcting problems at Straits was once again sparked. The Hull Highway Department contracted the services of Mr. Howard Bailey, consulting engineer, to recommend appropriate corrective actions. Mr. Bailey proposed that a tide gate be installed at the outlet of the Pond in order to raise and stabilize water levels in the Pond. It was felt that raising the water level would remedy some of the problems. A sluice gate and tide gate were later constructed according to Mr. Bailey's plans. Mr. Bailey echoed the recommendations made some 40 years earlier by suggesting that one or more openings to the Atlantic Ocean be made at Gun Rock. The anticipated cost at that time was listed at $13,000.00 (Mass. DPH, et al, December 2, 1953). Further interest was directed towards the Pond when, in 1943, discharges of pollution were found entering at various locations.

In 1952 the state Board of Health was once again called to respond to numerous complaints regarding the conditions at Straits Pond. By this time, appropriations for the construction of sewerage in Hull had been made. The state Board of Health encouraged the Town of Hull to proceed with construction of sewerage facilities and to flush the Pond to the extent possible by means of the existing outlet structure. An additional sanitary survey revealed numerous storm drains which discharge runoff from Hull and Cohasset to Straits Pond. Along Richards Road in Hull sewage was found to be entering the Pond from private property via pipes.

Figure 1-1

Project Location

IEP

IEP was directed to a storm drain system on Richards Road which was continuing to discharge sewage. An overflowing cesspool at 739 Jerusalem Road in Cohasset was observed in 1953 by the survey group. Several areas of septic system over-flow were also noted by IEP in April, 1980.

In an attempt to control the nuisance weeds and midge problems at Straits Pond, the Town of Hull began chemical treatments in the early 1950's. Chemicals known to have been used included DDT and lead arsenate.

The conclusion of the 1953 Mass. Dept. of Public Health report restated earlier conclusions regarding the need for increased circulation in the Pond through a conduit to the Atlantic Ocean at Black Rock. Also suggested was placing the responsibility of control of the outlet gates in the hands of the Port of Boston Commission who would coordinate raising and lowering of the Pond so as to permit exposure of sediments, chemical treatment of midge larvae and weeds and exchange of water. Either filling or dredging the Pond were also considered as possible solutions. It was concluded that both of these alternatives would likely be too costly to implement.

Since 1953 numerous studies and seasonal chemical treatments have been undertaken at Straits Pond. Frequent chemical treatment for control of weeds has been funded by the Towns through the state Reclamation Board and treatment of midges and mos-quitoes has been effectuated by the South Shore Mosquito Control Project. Chemicals used include sodium arsenite and kuron (Mr. Boschetti, memorandum, October 20, 1960), hydrothol-47 (Mr. Boschetti letter, October 1, 1971), heptachlor (Dr. Cohen, memorandum February 3, 1954), aqualin (Mr. Boschetti, memorandum, November 20, 1961, princep 80W (Mr. Boschetti, memorandum, March 2, 1971), and arsenic trioxide (Mr. Boschetti, memorandum, January 5, 1970).

In response to the continuing problems at Straits Pond and the added problems resulting from the severe winter storm of February, 1978, the current study was initiated by the Towns of Hull and Cohasset with a Community Assistance Grant from the Massachusetts Office of Coastal Zone Management. During the course of the study, past reports, documents and data were reviewed; interviews were held with local and state officials; and additional water quality, hydrologic, sediment, land use, topographic and other applicable data were collected. Data and resultant findings are included as are recommendations for a long term recla-mation program.

2.0 APPROACH AND METHODOLOGY

Eutrophication is the natural aging process which all waterbodies undergo, whereby a pond or lake gradually "fills in" and through ecological succession, eventually becomes a marsh, bog or even dry land. If undisturbed by human activities this process is normally very slow and may take many thousands of years. However, in an enhanced, or dammed waterbody such as Straits Pond, the shallow water depth combined with a fertile bottom substrate, provides suitable conditions for aquatic weed and algae growth almost regardless of the quality of inflowing waters. Various land use types such as high population densities associated with residen-tial or urban development, as well as some open space and rural activities generate additional nutrients. These materials may then be transported via the flow of surface water, groundwater, or through the air, to a receiving point at a lower elevation. Upon entering the Pond, silt and sediment settle out and nutrients (nitrogen and phosphorus) contained in the inflowing waters and attached to soil particles become available for assimilation by aquatic plant life. Therefore, it is vitally important to examine and quantify both internal (in pond) and external (watershed) nutrient contributions as part of the overall pond study. In order to locate and quantify sources of eutrophication which are responsible for nuisance weed and algae growth, this study was initiated to deal with the identification, significance of and interaction among the natural resource disciplines which determine eutrophic conditions. This approach more carefully analyzes the "whys" or the reasons for the eutrophic conditions and nuisance midge and odor problems which plague the Straits Pond area.

Much useful data was available for use by IEP in the preparation of this report. Where applicable this information has been incorporated into the study and updated as necessary. Baseline environmental conditions were assessed through the use of much of this existing data. Various informational maps on surface water features, land use, geologic features and others were prepared by the Consultant based on data interpretation of the literature available and additional field investigation carried out by the IEP staff. Because of certain gaps in the existing data, field surveys were conducted to locate of confirm various geologic, hydrologic and land use elements. Water quality and biological sampling were determined to be a necessary element of the study. Sections 3.0 through 9.0 of the report describe and discuss the interrelationships of the various disciplines and the ramifications in terms of correcting existing eutrophic and nuisance conditions.

Finally, an evaluation of potential reclamation strategies for Straits Pond was undertaken. In-lake as well as watershed management techniques have been considered and assessed. Due to the degradation that the Pond has suffered over the years, reclamation work within the Pond itself is necessary and emphasis has been placed on an examination of in-lake strategies. It was found, however, that there are significant nutrient loadings entering the Pond via Rattlesnake Run making consideration of long-term watershed management techniques essential. Another source of nutrients to the Pond includes several direct sewage discharges via pipes or storm drains and overland from overflowing septic systems. Portions of Hull are scheduled for sewering in the near future and this should alleviate some of the problem. However, other areas of Hull where discharges occur are not scheduled in the near future for sewering. In these areas Board of Health action will be required. In Cohasset, where there is no potential for future sewering within the Straits Pond watershed, Board of Health action will be necessary and provision for continued maintenance or management of septic systems should be made.

3.0 LAND USE

Various land use types (e.g. residential, commercial, open space, agricultural) have the capacity of generating varying amounts of runoff and nutrient loadings to a given hydrologic system. Absent major mitigative measures, urban uses typically produce higher levels of nutrients and contaminants than do less intensive uses, such as a low density residential area or open space. There are, of course, exceptions to this general rule. Such is the case where a number of homes, even in a rural area, are discharging sewage directly to a receiving waterbody. Where this situation is known to exist and the number of discharges can be reasonably estimated, then nutrient loadings may be reasonably predicted.

The first step in determining areas and uses which may impact a given waterbody is to delineate, on a map, the area, or watershed, which contributes drainage to the waterbody under study, e.g., Straits Pond. Figure 3-1 shows the watershed and associated land uses which ultimately drain into Straits Pond. The area comprises some 765 acres inclusive of the 92 acre water surface of the Pond. Approximately 5/6 of the watershed area occurs in the Town of Cohasset with the remaining 1/6 lying in Hull.

On a rising tide the Weir River will contribute flow to Straits Pond through cracks in the mortar and granite dam, by overriding the outlet gate and, occasionally, by flooding over Nantasket Avenue. Under normal tidal conditions, however, water elevation in Straits Pond is affected very little (<0.2') by the tidal influence of the Weir and it is, therefore, felt that the drainage area of the Weir River should not be included as part of the Straits Pond watershed.

Table 3-1 lists in acreages and percentages the distribution of various land use types within the Straits Pond watershed. Four densities of residential/institutional development are delineated, Marsh or wetland areas, forest, golf course, open land, landfill and open water are also included.

Table 3-1. Land Use Categories Within the Straits Pond Watershed

Land Use Category	Approximate Area in Acres	% of Total Watershed
R1 (High Density Residential/Institutional)	30.90	4.0
R2	32.33	4.2
R3	117.73	15.4
R4 (Low Density Residential/Institutional)	33.25	4.3
Landfill	9.44	1.2
Golf Course	40.23	5.3
Forest	345.54	45.2
Marsh (Wetlands)	58.88	7.7
Open Land	5.28	0.7
Open Water	91.42	12.0
	765.00	100.0

As is indicated in Figure 3-1 virtually all of the high density development which exists within the watershed occurs in the Town of Hull, as does the majority of the R2 use category. Lesser density development occurs wtihin the watershed in Cohasset, though the developed area occupies more land than in Hull. The majority of forested land and all major wetlands within the watershed are found in Cohasset as is a golf course and a landfill.

The capacity for nutrient or contaminant generation of each of these land use types is discussed in Section 7.0.

4.0 PHYSIOGRAPHY, GEOLOGY, AND GROUNDWATER HYDROLOGY

The nature of the topography in the Straits Pond watershed is best described as highly variable and inconsistent. The highest point occurs just west of Tad Lane in Cohasset where an elevation of approximately 102 feet above mean sea level is reached. The lowest elevation in the watershed is, of course, Straits Pond which varies between 3 and 4 feet above mean sea level. Much variation, particularly on the Cohasset side, exists between these two extremes. The only relatively flat sections occur in the large wetland areas, the golf course, and on top of several of the, otherwise, fairly rounded hills.

The Straits Pond watershed is characterized by numerous bedrock outcroppings, generally shallow soils (<6 feet) with occasional deeper unconsolidated deposits occurring in the large wooded swamps of Cohasset, under the golf course, and at places along the Straits Pond shoreline.(Figure 4-1).

The bedrock which is seen exposed at numerous locations throughout the majority of the watershed, including along the shore and within Straits Pond is the Brookline Member of the Roxbury Conglomerate (Billings in Cameron, 1976). The rock is fairly typical of the "puddingstone" appearance, associated with all Members of the Roxbury Conglomerate found at various locations throughout the Boston Basin. The Brookline Member has a matrix of fine-to-medium grained gray feldspathic sandstone with the well-rounded pebble and cobble clasts consisting predominantly of quartzite, quartz monzonite, granite felsite and lesser amounts of melaphyre and argillite (Billings in Cameron, 1976). Thickness of the Brookline Member has been found elsewhere in the Boston Basin as great as 4300 feet, however, in the neighboring Town of Hingham the unit is approximately 500 feet thick (Billings in Cameron, 1976). It is felt that the Brookline Member in Hull and Cohasset is of similar or shallower thickness to that found in Hingham. The Roxbury Conglomerate is believed to be of Pennsylvanian age (270,000,000 - 310,000,000 years before present) at least, and probably older.

In the southernmost portion of the watershed the Dedham Granodiorite may be exposed. This rock unit is light pinkish gray or green in color, is one of the most common formations in eastern Massachusetts and forms the outer geologic border of the Boston Basin metasedimentary formations. It is of pre-Cambrian age (greater than 600,000,000 years before present).

Within 0.5 mile to the north and within 1.5 miles to the south of Straits Pond exist two fault zones which tend, generally, east-west. The northern fault is called the Blue Hills thrust and creates the contact between the Roxbury Conglomerate and the Cambridge Argillite which underlies Nantasket Beach and the majority of the Hull peninsula. The fault to the south is called the

Ponkapoag fault and is a major thrust which creates the boundary between the Boston Basin to the north and the older Dedham Granodiorite to the south.

Atop the bedrock exists remnants of glacial advance over the area and subsequent deposition by meltwater as the glacier retreated some 12,000 to 15,000 years ago. Glacial till, a nonsorted, unstratified homogenized material ranging in particle size from clay to cobbles and occasionally boulders, lies immediately over the bedrock and may be as thick, locally, as eight to ten feet.

The large swamps and golf course in Cohasset are believed to be underlain by glaciofluvial (sand) deposits up to ten feet to fifteen feet in thickness. Peat and muck soils lie atop the glacial outwash material.

The Straits Pond shoreline is composed of several areas which are made up of unconsolidated beach and tidal marsh sediments. Crescent Beach, between Gun Rock and Green Hill appears to be true marine beach deposits between the ocean and Straits Pond except where some filling may have occurred. Other areas along the west and south shoreline of Straits appear to be shallow silt and muck deposits which were originally layed down in a tidal marsh environment prior to damming of the Pond.

Due to the nature of the underlying geology, three different hydrogeologic conditions exist within the watershed. The first occurs by surface water percolating through the very thin soils and unconsolidated surficial geologic deposits until bedrock is reached. At this point the water moves along the bedrock/surface deposit interface until it either emerges as a spring or finds an opening in the bedrock.

The second hydrogeologic situation occurs primarily along Rattlesnake Run and in the Crescent Beach area. In these two areas the surface deposits are deep enough to lie below the groundwater table. Conventional recharge occurs and groundwater would be expected to move through the unconsolidated sediments to a point of discharge which would be the brook or Straits Pond.

The final condition that exists involves groundwater penetrating bedrock through the process described previously or by direct recharge into fractures. It is expected that there are numerous fractures and small subsidiary faults in the bedrock of the Straits Pond watershed due to the presence of major faults nearby both to the north and to the south. This would afford some recharge to the Pond via springs as has been reported in the past. It is believed that the hydrologic contribution to Straits Pond by groundwater discharge, while not insignificant, is not enough to afford adequate flushing or dilution.

5.0 SURFACE WATER

5.1 Investigative Methods

Two fundamental aspects of the surface water hydrology of the Straits Pond watershed were investigated: the quantities of water flowing into and out of the Pond and the quality of that same water. The quantities of water were estimated by determining the "hydrologic budget" of the watershed. In its simplest form, the budget represents the balance between water entering the watershed's hydrologic regime and water leaving the regime.

The quality of the waters entering and leaving the hydrologic regime was determined by monitoring the quality of the surface waters entering and leaving Straits Pond. By selectively locating sampling points it is possible to determine both qualitatively and quantitatively the natural, background quality of all waters as well as the source(s) of possible degradation. Sampling results yield concentrations of various chemical constituents at specified sampling sites. Two kinds of water quality sampling were undertaken - base flow and storm runoff.

Flow measurements carried out at the same time that water samples were collected provide information on "pollutant loading" with respect to time or rainfall. The water quality sampling program at Straits Pond was conducted by IEP, Inc. A core of six sampling stations was established at key locations of the watershed. These locations are shown in Figure 5-1. All samples were collected approximately one foot below the water surface. Sample stations 1, 2 and 3 were located on the east, middle and west end of Straits Pond, respectively. Station 4 was sited on Rattlesnake Run just upstream of Jerusalem Road. Station 5 was on the Weir River. Station 6 is a storm drain that directly enters the Pond which was suspected of transporting sewage. Station 7 was taken from a plume of leachate that was observed to enter the Weir River from the Hull sanitary landfill. Stations 8 and 9 were located at Black Rock and Gun Rock Beaches, respectively. Storm sampling was undertaken on April 10, 1980. Those sampling locations are also indicated in Figure 5-1.

5.2 Results and Discussion

5.2.1 Hydrology

Under the existing flow regime wherein the tidal waters of the Weir River do not enter Straits Pond, the watershed of the pond is relatively small (764 acres) and is mostly confined by Hull Street, North Main Street, and Forest Avenue in North Cohasset. There is only one surface tributary, Rattlesnake Run, which is fed by two upstream drainage subareas: (1) from the southeast through the sanitary landfill and a large wooded swamp, and (2) from the southwest through the Cohasset Golf Club and a small wooded swamp which forms the headwaters at Rattlesnake Run. Many storm drains from the peripheral residential areas of Cohasset are also tributary to the Pond.

The area of Straits Pond is 91.4 acres (3,982,250 sq.ft.) with a mean depth of 3.3 feet. The water surface is currently maintained by the tidegate at an elevation of 3.0^{+} feet MSL (7.7 ft. MLW). The volume of water in the Pond is

98,310,000 gallons or 13,140,000 cubic feet. Because the Pond area is large relative to the watershed area, the existing flushing time (the time it takes one pond volume of water to discharge from the pond) is long, 71 days.

The average annual precipitation at Hull is 44.2 inches of which about 25 inches becomes surface runoff. This translates into an average annual discharge rate of 2.21 CFS of surface water (stream and storm drain) into the Pond. A greater proportion of the rainfall becomes runoff in the residential areas surrounding the Pond than in the upstream undeveloped areas.

Table 5-1 shows the average monthly precipitation at Hull and the average monthly surface water discharge to the Pond. The monthly variation of precipitation is fairly uniform with moderately greater amounts falling in the autumn and winter months. Runoff discharge is substantially greater in the winter and spring than in summer owing to frozen ground conditions (less pervious surface) in the winter, snowmelt in the spring, and increased evapotranspiration during the summer.

Table 5-1. Monthly Discharge to Straits Pond

Month	Average Precipitation/Inches	Average Discharge to Straits Pond - CFS
January	3.65	2.71
February	3.62	3.81
March	3.94	4.38
April	3.63	3.21
May	3.60	2.87
June	2.66	1.10
July	2.76	0.67
August	4.34	0.76
September	3.28	0.56
October	3.55	1.00
November	4.87	2.24
December	4.34	3.26
Annual Total	44.24	--
Annual Average	3.69	2.21

5.2.2 Surface Water Quality

Baseline water quality testing of Straits Pond, the Weir River and Rattlesnake Run was conducted during seven sampling rounds. A number of additional samples were also collected and analyzed from Gun Rock and Black Rock Beaches in addition to a storm drain that was found to flow continuously along the west end of the Pond. Table 5-2 summarizes the test results as analyzed by Reitzel Laboratories of Boylston, Massachusetts. Figure 5-1 shows the sampling locations.

Parameters Tested

Certain physical, chemical and biological constituents of water provide indices for measuring the quality and "health" of a naturally occurring aquatic ecosystem. In areas where influence or contamination attributable to human systems is expected, concentrations of certain chemical constituents, presence or absence of various biological forms, and combinations of the two can provide an investigator with suitable information from which to draw a conclusion concerning the nature, severity and cause of a deterioration in health and, therefore, quality and use of a water resource.

Chemical parameters tested at Straits Pond and its tributaries were chosen on the basis of the expected nature of the problems affecting the Pond and the future water quality goals of a continuing management program. The future intended usages of the Pond include limited recreation and aesthetics. Because of excessive aquatic plant growth these goals have been impeded. Therefore, the sampling program reflected parameters which would yield information regarding nutrient loading to the Pond and nutrient concentrations within the Pond and its bottom sediments as well as bacteria and other indicators of pollution.

Stations 1, 2 and 3 - Straits Pond

Salinity in Straits Pond was found to vary between 10.48 ppt - 23.49 ppt. No significant difference in salinity was detected from the surface to the bottom. The Pond is brackish by definition. Substrate composition and other factors, rather than salinity, currently preclude shellfish from inhabiting the Pond. The total coliform bacteria counts did not exceed the "class SB" criteria of 1,000 colonies/100 ml, however, the fecal coliform counts were quite high during the October 2nd, sampling round. Total phosphorus was quite high at stations 1-3, well in excess of the minimum phosphorus levels required to support algal blooms and dense growth of aquatic vascular plants at inland pond and lakes.

The Massachusetts Division of Water Pollution Control (DWPC) assigns a maximum severity point rating of "3", to those fresh water ponds and lakes where phosphorus >0.10 mg/l. A direct comparison between the DWPC lake classification system and Straits Pond water quality data, however, must be approached with caution. The DWPC classification scheme is designed to compare and classify inland lakes according to their "trophic condition" from data collected during mid-late summer or during peak biological production. Unfortunately, our contract to proceed with this study of Straits Pond was not approved until September, 1979. Never-the-less, we feel that the high total phosphorus, ortho phosphorus and kjeldahl nitrogen levels observed in mid-May reflect the highly eutrophic condition of Straits Pond. We believe it is quite probable that even druing July and August, a surplus of available (inorganic) P and N exists within the Pond and that other micronutrients and/or light intensity limit aquatic plant productivity. The extremely shallow water depth combined with a lack of water circulation result in high water temperatures as observed on May 16, 1979. Discussions with Mario Boschetti, DEQE Bio-Engineer, and a review of past reports, document surface water temperatures reaching the mid to upper 80's during July and August.

The dissolved oxygen content in Straits Pond was not recorded by IEP to drop below the critical limit of 3.0 mg/l necessary to sustain a warm water fish population. However, we were not able to monitor the Pond during the summer months over a 24 hour period when oxygen concentrations are most likely to be at their lowest. Sampling through the ice during mid-February revealed an ample concentration of dissolved oxygen from the water surface to the bottom, a vertical distance of only 4.0 feet. Further winter sampling performed after a period of prolonged ice and snow cover might well show an oxygen deficit.

Station 4 - Rattlesnake Run

Rattlesnake Run is the only fresh water stream that flows year-round into Straits Pond. Despite the relatively rural nature of the watershed, phosphorus and nitrogen concentrations were moderate to high. Total coliform bacteria exceeded 1,000 colonies/100 ml. on two occasions. Further investigations of the existing nutrient and bacteriological inputs and sources to Rattlesnake Run should be performed by the Towns. During the course of our studies, we did not observe any surface water flows entering the Brook from the golf course, although the Cohasset Golf Club has been included within the Straits Pond watershed. However, land-clearing and the construction of new single family dwellings was observed in the upper, western portion of the Rattlesnake Brook watershed along with the Cohasset sanitary landfill.

Station 5 - Weir River

Water quality entering Straits Pond from the Weir River is of importance, whereas the Weir has been previously though to "cleanse or flush" through dilution, the contaminated water in Straits Pond. Contrary to what may have been anticipated, we found that Weir River water was quite high in both its phosphorus and nitrogen content although it currently does not contribute significantly to the Pond's water volume. On three of the four occasions when station 5 was sampled on the incoming tide, fecal coliform densities exceeded 360 colonies/100 ml. Very high total coliform counts were also observed in October and January. Salinity varied from 11.21 - 29.39 ppt which was similar to the range of salinity found in Straits Pond. Based upon our sampling data and personal communication with DWPC personnel, water quality in the Weir River does not meet its assigned "SB" classification. Although beyond the scope of this study to determine the origin and sources of contamination to the Weir River, a single grab sample was collected from a plume of leachate observed to be entering the River from the Hull Sanitary Landfill (Site 7). That leachate sample was found to be of poor quality as might be expected. We understand that the Town and its consulting engineers are currently working with DEQE to correct the problems that now exist with the Hull Landfill.

Station 6 - Storm Drain

Three rounds of sampling were collected and analyzed from a storm drain that discharges directly into Straits Pond. The results for total and fecal coliform testing confirm the Hull Board of Health's belief that untreated sewage is entering the drainage system, probably from illegal connections in the area of Richards Avenue.

Stations 8 and 9

Two rounds of samples were collected from both Black Rock and Gun Rock beaches. Salinity of the ocean water was considerably higher (33.27 - 35.32 ppt) than at sites 1-7 as expected. Fecal and total coliform counts were low, as was the ortho phosphorus and nitrogen content of the water. The total phosphorus content of the water at stations 8 and 9 was somewhat higher than had been anticipated. We are not aware of any significant pollution sources in proximity to stations 8 or 9, however, and feel that the overall quality of the ocean water is much better for purposes of flushing or dilution. Visually, excellent clarity and low turbidity were noted in the samples collected near Gun Rock.

Black Rock Beach is a "shingle," pebble and cobble beach reflecting a high energy environment. Its northeast exposure and frequent turbid waters near shore, are important considerations that must be addressed as part of an engineering feasibility study, if a conduit to the ocean, as discussed in section 8.0, is pursued by the Towns at some future time.

5.2.3 Storm Water Sampling Results

On April 10, 1980, IEP undertook storm runoff sampling at eight discharge locations on the Pond's periphery and at two in-lake stations as well (Figures 5-1). Sampling followed a six hour period of intermittent showers and occurred during continuous rain. Approximately 14 storm discharge culverts were located along the Pond's edge, the majority of which occurred in Cohasset. Records indicate as many as 21 such discharge points actually exist, 11 in Hull and 10 in Cohasset.

In general, the existing storm drain systems which discharge to Straits Pond are of two sizes. The first, typified by the systems on the Cohasset side, drain fairly large areas (5-12 acres) of predominantly residential development. Of the six stations sampled in Cohasset, four (A,B,C,E) were taken at the termination of closed storm drain systems. Sample D was taken at the discharge point of Rattlesnake Run into Straits Pond. Approximately 1/7 mile of Jerusalem Road drains into this system via twin catch basins which connect directly to two 24 inch culverts which carry the brook under Jerusalem Road. Sample F was taken from an ephemeral stream which apparently "flashes" during periods of rain or snow melt. The stream is located approximately 700 feet west of the intersection of Jerusalem Road and Forest Avenue extension. It drains an area of roughly 10 acres adjacent to an unnamed lane south of Jerusalem Road and a short (400 feet) section of Jerusalem Road.

The majority of storm runoff discharges in Hull drain considerably smaller areas (<2 acres) mostly along Atlantic Avenue. Due to this situation runoff occurs almost simultaneously with the rain event. Runoff quality is effected most by silt, sand, trash and residue on roofs and paved surfaces along Atlantic Avenue. The poorest quality results at the beginning of a rain event, particularly following an extended dry period. Due to the small area drained by most of these systems along Atlantic Avenue in Hull and due also to the presence of municipal sewerage, it is not felt that the majority of these systems are major contributors to water quality problems in Straits Pond.

Two exceptions to this general storm drain situation in Hull were found. Sample station G, located at the east end of the Pond was found to be discharging a significant amount of runoff water which was apparently bypassing catch basins on Green Hill. The quality of the water, though apparently not degraded, was not representative of a "first flush" and would be expected to be worse at the beginning of a rain event.

The second example occurred on Richards Avenue where sanitary sewage is apparently being piped directly through a storm drain system and into the west end of Straits Pond. Water quality at this station (SS6, H) has been found to be consistently poor with parameters indicative of domestic sewage consistently elevated.

Table 5-3, summarizes the findings of storm water sampling undertaken by IEP at Straits Pond. Stations A, C, E, F and H show abnormally high nutrient levels and bacteria counts. It is felt that the cause of these problems in Cohasset is the result of malfunctioning subsurface sewage disposal systems which are entering the storm drain systems either by over land flow or via groundwater. Several obvious and apparent overflowing systems were observed in the field on April 10, 1980 by IEP personnel. Septic odors were also noted by IEP at stations C,E,F, and H. This last station (H) is the Richards Avenue discharge in Hull which was discussed previously.

Several solutions exist for remedying the existing storm water runoff problems in the Straits Pond watershed. One problem which deserves immediate attention is the direct sanitary sewage discharge on Richards Avenue. This is occurring all of the time and not just during storm events. It constitutes a significant, controllable source of nutrients and contaminants to the Pond. Sewering of this area is not scheduled for the near future but would offer the only lasting remedy to this situation. Temporary solutions would consist of conventional septic systems or holding tanks.

Maintenance of the existing storm drain systems in Cohasset and Hull including catch basin cleaning on a biennial basis, street sweeping, and street repair is essential. In Hull where there are discharges resulting from street drainage, catch basins should be installed where they currently do not exist. In Cohasset, particularly in the Black Road area of Jerusalem Road, catch basins and pipes appeared to be running at or very near capacity on April 10. Little, if any, settling was occurring. This system may be in need of upgrading, separation or complete redesign.

The major concern in Cohasset storm water sampling results was the apparent influence by domestic sewage of storm runoff waters entering Straits Pond. This seemed to be a continuous problem during and following the rain event and not just a phenomenon of the "first flush" of the system. There are numerous homes within each of these storm drainage areas and to pinpoint which systems are contributing would not be easy to ascertain using conventional dye sampling techniques. Other methods, such as use of a device called a Septic Snooper, further sampling, etc. may be feasible and should be further explored in order to determine which homes may be responsible for the discharges. Mandatory annual maintenance of all subsurface sewage disposal systems within the Straits Pond watershed should be effectuated. Flow reduction techniques and other methods to reduce hydraulic overloads should also be implemented.

Table 5-3
Storm Water Quality Sampling Results

Station Parameter	A	B	C	D	E	F	G	H	I	J
pH	5.8	6.0	6.2	6.1	6.1	6.6	5.9	6.2	8.1	7.4
Total Coliform Bacteria (org./100ml)	7550	1300	3650	700	3800	16000	300	4850	100	2450
Fecal Coliform Bacteria (org./100ml)	4650	600	750	800	1950	5750	100	2850	50	800
Total Phosphorus (mg/l)	0.01	0.07	0.28	0.05	0.07	0.15	0.01	0.19	0.04	0.02
Ammonia-Nitrogen (mg/l)	0.15	0.11	0.65	0.04	0.13	0.22	0.06	0.23	0.04	0.04
Kjeldahl-Nitrogen (mg/l)	0.79	0.79	1.60	0.64	0.79	1.28	0.87	1.28	0.92	0.68
Nitrate-Nitrogen (mg/l)	0.83	1.20	1.20	0.54	0.64	1.30	0.06	1.60	0.03	0.16
Temperature (°C)	9.5	9.0	10.5	9.0	9.5	9.0	11.5	11.0	11.0	11.5
Flow (cfs)	0.8	0.5	1.0	4.4	0.4	2.0	4.0	5.0	-	-

Diversion of all urban storm runoff waters from the watershed has been suggested as a possible means of greatly reducing nutrient loadings from this source. Several difficulties impede effectuation of this option. Initially, the cheapest and most logical means for diverting storm water would be to tie the existing systems in Hull to one main line running down Atlantic Avenue and doing the same in Cohasset along Jerusalem Road. Discharge could be either to the Weir River or the Ocean. The major problem with this solution appears to be the difficulty which would be encountered in maintaining proper grades to a discharge point. As it exists, the systems have been designed to discharge to Straits Pond at an elevation considerably lower than high tides in the Ocean and Weir River. Discharge to the Weir, for example, would require an invert elevation of the discharge pipe to be approximately 5 feet higher than the average elevation of storm drains currently discharging to Straits Pond. This is significant difference necessitating considerable engineering study and design.

Another problem includes rerouting of a pollution source(s) to another body of water. This would not be recommended, and probably not approved, when it is suspected that domestic sewage is entering the storm drain system.

An additional reason for not pursuing this alternative is that implementation of other options, such as watershed managment strategies and in-lake solutions, will reduce the impact of storm runoff on water quality in Straits Pond.

6.0 AQUATIC ECOLOGY

The biological communities inhabiting a waterbody reflect the past physical and chemical conditions unique to that area over an extended period of time. In eutrophic waters such as Straits Pond, high concentrations of nutrients, and warm water temperatures are often manifested by dense "blooms" of microscopic algae and/or abundant growth of aquatic vegetation. A knowledge of the species composition, diversity, density and seasonal distribution of these communities is an integral part of a Pond or Lake reclamation study. Thus, biological sampling and interpretive analysis are desirable in conjunction with water quality monitoring, as they augment each other for ascertaining "short" and "long term" aquatic environmental conditions.

6.1 Investigative Methods

Samples for examination of plankton or microscopic algae were collected concurrently with the water samples obtained for routine physical and chemical testing. A single "grab" sample was obtained one foot below the water surface for plankton analyses at in-lake Station 2. The plankton samples were normally examined on the day of collection by IEP personnel utilizing a Sedgewick-Rafter counting chamber according to the procedures described in Standard Methods (APHA, 1976). Transparency measurements at Station 2 were conducted with a standard 20 cm. Secchi disc.

A semi-quantitative survey of aquatic vegetation (macrophytes) present in Straits Pond was carried out on May 16, 1979. IEP's aquatic biologist conducted a visual survey of rooted, floating and emergent macrophytes. A grappling device was used to survey the bottom for determining the species composition and relative abundance of submerged vegetation.

6.2 Results and Discussion

6.2.1 Aquatic Vegetation and Macroscopic Algae

An aquatic plant survey of Straits Pond was performed on May 16, 1979 by IEP's aquatic biologist. Although May is relatively early in the "normal" aquatic growing season, vegetation was at or near the water surface throughout more than 50% of the Pond area. Widegongrass *(Ruppia maritima)* was the dominant macrophyte observed, virtually infesting the entire 92 acre Pond surface area. A few sprigs of sago pondweed *(Potamogeton pectinatus)* were found floating amongst the *Ruppia* and an emersed species, reedgrass *(Phragmites communis)* was frequently observed in dense stands along shore.

Clumps of filamentous algae *(Cladophora sp.)* were beginning to form, along with free-floating *(Enteromorpha spp.)* which is a green marine alga belonging to the *Chlorophyceae*. Three different species of *Enteromorpha* were identified in Straits Pond with *E. intestinalis* comprising approximately 50%. *E. prolifera* and *E. clathrata* were found in similar densities or about 25% each. *Enteromorpha* is a brackish water or marine alga commonly found along the New England coast. A small amount of sea lettuce *(Ulva)* was observed in the southeast portion of the Pond near the tide gate at Nantasket Avenue.

The dominant nuisance species widgeongrass, is an annual, rooted macrophyte belonging to the pondweed *(Potamogeton)* family. It is seldom found inland, occurring mostly in brackish and saline waters. Richardson (personal communication) has found that *R. maritima* will tolerate a wide range of salinity, varying from 2-60 ppt. Its ability to survive in such highly saline environments, suggests that introducing ocean water to Straits Pond will do little to control its growth. Furthermore, *R. maritima* is a submersed, rooted macrophyte that can be expected to obtain the bulk of its nutrients from the bottom sediments rather than the surrounding water. Introducing large volumes of "nutrient depauperate" ocean water will do little to reduce the existing phosphorus and nitrogen content of the sediments in Straits Pond. Nutrient recycling between the rooted plants *(R. maritima* and *P. pectinatus)* and the sediments would sustain nuisance weed populations for many years to come, despite increased water circulation. Improved water movement, either through modification of the existing tide gate or conduit to the ocean, might, however, reduce the foul odors that emanate from the decomposing vegetation and sediments in the summer.

R. maritima reproduces almost exclusively by seed. Effective control by means of an "overwinter drawdown" or lowering the water level to expose the plants to dessication and freezing temperatures is questionable. At Straits Pond, the *Ruppia* normally dies off by late August or early September even without any chemical treatment.

6.2.2 Plankton

Microscopic examination of water samples from Straits Pond for phytoplankton was undertaken by IEP. During each round of base-line water quality sampling at at station 2, one additional sample was collected specifically for algal identification and density counts. During the winter and spring months, diatoms and green algae were most abundant. Diatom genera such as *Navicula, Melosira* and *Gyrosigma* were the most common forms. Among the green algae, *Closterium* was dominant. Transparency or water clarity in the Pond was "fair," usually to the bottom or a depth of about 3.0 ft. at Station 2. During IEP's late summer (October 10th) round of sampling, transparency was reduced to only 2.2 ft. in the Pond. Macroscopic green algae *(Cladophora)* was also prevalent in May and October.

Unfortunately, due to a time delay in the Towns procuring the CZM grant monies used to fund most of this study, no samples were taken during the summer. However, previous surveys and investigations at Straits Pond do reveal that blue-green algal "blooms" typically develop during the summer. Miscellaneous algae counts performed during the 1960's in June and July, report high densities of *Anabaena, Microcystis and Lyngbya*. Mario Boschetti, DEQE bio-engineer, informed IEP that there is an on-going "algal bloom" most of the summer at Straits Pond in addition to the prolific weed growth. The Pond is colored a bright green and transparency is minimal. The advanced eutrophic condition of Straits Pond is further substantiated by the fact that both weed and algal nuisances occur there each summer. Nutrients released from the decomposing macrophytes, principally *R. maritima* during August and September, are rapidly assimilated by the planktonic algae.

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6.2.3 Midges and Other Aquatic Life

The emergence of tremendous numbers of adult non-biting midges from the sediments of Straits Pond are a serious nuisance to Pond abuttors during the summer. Entomologists working for the Massachusetts Department of Public Health in 1953, identified the problem midge species as *Tendipes decorus* or according to current taxonomic nomenclature, *Chironomus decorus*. This particular group of midges contain a special respiratory pigment called "erythrocruorin," which enables them to survive in waters very low in dissolved oxygen. This dissolved pigment imparts a deep, reddish color to the body of the midge, hence these midges are commonly referred to as "bloodworms."

IEP scientists reviewed the literature regarding the environmental requirements of this particular midge species, in an effort to evaluate alternative methods of control. Of particular concern, was the maximum salinity tolerance of *C. decorus*, in the event that introducing large volumes of seawater to the Pond through a conduit or siphon from the ocean might prove to be viable, non-chemical control technique. According to Beck (April, 1977) and telephone conversations with several Chironomid experts, the occurrence of this particular midge *(C. decorus)* has only been documented in low salinity waters, less that 0.5 ppt. Salinity in Straits Pond is much higher, varying from 14-23 ppt. In other words, based upon the literature, *C. decorus* is not known to inhabit brackish water ponds of even moderate salinity such as Straits. This unexpected report, prompted IEP's aquatic biologist to obtain a number of midge larvae "first-hand" from Straits Pond for verification. The sampling was carried out in early March, 1980. All of the midge larvae collected from the Pond sediments, keyed out to *Chironomus riparius* and not *C. decorus* as reported in 1953. (Stephen Travis, an expert in midge taxonomy employed by the Massachusetts Division of Water Pollution Control, verified our identification of *C. riparius*).

This discrepancy between the previous and current identification suggests that either, (1) a change in species has occurred during the past 27 years, (2) the earlier (1953) identification was incorrect, or (3) revisions of the taxonomic keys since 1953, now used to identify midges, have assigned a different name to the same species. Whether a different species *(C. riparius)* currently infests Straits Pond is of little consequence for both *C. decorus* and *C. riparius* have been reported only to occur in low salinity waters. They are also very similar with respect to other water chemistry, feeding and habitat requirements.

The density of midge larvae in the sediments of Straits Pond was estimated at $\geq 500/m^2$ during March, 1980. No other macroinvertebrate insect larvae, nymphs or worms were observed in the main body of the Pond other than *C. riparius*. Along the Pond shoreline, however, amphipods *(Gammarus sp.)* were common. The oxygen deficit that reportedly occurs in the Pond during the summer is a harsh environment for most macroinvertebrates. On the other hand, both *C. decorus* and *C. riparius* are known to thrive under organically enriched conditions (low oxygen, high ammonia and BOD levels, etc.) and their occurrence in large numbers is a good indication of severe organic enrichment.

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Fisheries inventory data for Straits Pond is apparently limited to a one-day survey conducted by the Massachusetts Division of Marine Fisheries (MDMF) on August 15, 1978. Utilizing a 60 ft. haul seine, MDMF biologists found the following species of finfish to be present: white perch, alewife, atlantic silverside, American eel, mummichog, striped killifish, threespine stickleback and fourspine stickleback. Straits Pond is of some importance for providing nursery habitat for these species as indicated by the observed presence of juveniles. Eel traps are set in the Pond and smelt fishing is reportedly good on the Weir River side of the tidegate. Herring also run in the River during spring.

Recreational sport or commercial fishing in the Pond itself is limited or nonexistent. The low dissolved oxygen content of the water at certain times during the summer, is felt to preclude the majority of finfish species from inhabiting the Pond for any prolonged length of time. The high coliform bacteria counts that presently exist in Straits Pond, exceed the permissible state criteria of 70/100 ml. for the harvesting of shellfish. Mr. Russell Iwanowicz, the MDMF biologist who surveyed Straits Pond in 1978, concluded his report by saying that in his opinion, Straits Pond is not a good area for either finfish or shellfish aquaculture at the present time. He felt that emphasis should be directed towards eliminating domestic pollution sources and insuring that adequate water exchange is maintained through the tidegate.

6.2.4 Bottom Sediments

Sediment sampling at Straits Pond was performed through the ice during mid-February, 1980. The sediment sample locations were the same as the "in-lake" water quality sites (Figure 5-1). The purpose of the sampling was two-fold: one, to obtain data on the physical and chemical properties of the bottom sediments and secondly, to determine the volume of "unconsolidated" material, in order to evaluate dredging as a reclamation alternative.

A total of three sediment samples were collected and analyzed from Straits Pond. The samples were 1.5" diameter, surface cores taken from the top 8" of substrate. The surface sediments are more likely to contain potentially toxic substances than at greater depths, whereas the pesticides used to control both the midge and aquatic weed nuisances were applied during the past 20-30 years. This "upper" layer of sediments is also in direct contact with the overlying water. Furthermore, rooted species of aquatic plants such as widgeongrass *(Ruppia maritima)*, obtain the bulk of their nutrients from this surface layer.

The results for the physical, nutrient and residual metal analyses are provided below.

Table 6.1

Results of Physical, Nutrient and Metals Analyses Sediment Stations 1-3

	Percent Moisture	Percent Organics	Chemical Oxygen Demand (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Total Phosphorus (mg/kg)	Total Nitrogen (mg/kg)
Station 1	74.1	15.3	24,200	63	93	<10	4,400
Station 2	77.2	20.9	25,900	38	89	38.7	6,700
Station 3	77.7	20.0	28,000	62	77	28.2	7,000

A gas chromatograph scan for 25 different pesticide compounds was performed on sediment core no. 2. The purpose of this analysis was to determine the concentration of certain residual insecticides that may have been applied to Straits Pond through the years, to control midges. The results for those compounds found to be present are listed below. The remaining 25 compounds that were also analyzed, but were not found to be present, are reported as "not detected" (Appendix A).

Table 6-2. Results of Sediment Pesticide Scan, Station 2

	Dieldrin*	4,4'-DDE*	4,4'-DDD*	PCB-1260*
Station 2	5	25	39	33

** ng/g (ppb) dry weight*

The surface sediments at Stations 1-3 possessed a uniform, high moisture content, ranging from 74.1 - 77.7%. Substantial consolidation of the sediments would be expected if the water level in the Pond was lowered and "dry romoval" of the sediments was to occur with conventional excavating equipment. A thorough discussion of the feasibility and alternative methods for dredging Straits Pond is provided in Section 8.1.9.

The organic content of the sediments is characterized as low to moderate in comparison with other pond and lakes sampled by IEP scientists. This implies that "filling-in" of Straits Pond is largely due to inputs of inorganic materials such as silt and fine sand from erosion, roadway runoff or during major storm events such as the Blizzard of February, 1978. However, the tremendous biomass of aquatic vegetation that presently exists in the Pond from May - August and "dies-off" in September, can be expected to elevate the percentage of organics in those surface sediments in subsequent future years.

The total phosphorus and total nitrogen sediment concentrations were quite low in comparison with other Massachusetts waterbodies, yet adequate to meet the nutrient requirements of rooted, aquatic vascular plants. The Massachusetts Division of Water Pollution Control (April, 1978) reported total P and total kjeldahl nitrogen concentrations for the sediments in eutrophic Pontoosuc Lake of 1,300 mg/kg and 10,300 mg/kg, respectively.

Residual copper varied from 38 - 63 mg/kg at Stations 1-3. These concentrations are well below DEQE's (1979) suggested maximum permissible limit of 150-300 mg/kg dry weight. Arsenic concentrations, however, were very high in all three sediment samples. The Division of Water Pollution Control classifies sediments to one of three categories depending upon the materials physical and chemical quality. The high (20 mg/kg) arsenic content of the sediments in Straits Pond place it in Category III. Materials falling within Category III are usually subject to more stringent regulations as to the method of removal and placement of the dredge spoils material.

The pesticide content of the sediments at Station 2 (Table 6-2) was fairly low. The presence of chlorinated hydrocarbon pesticides in Straits Pond sediment including DDE, DDE and Dieldrin, is probably linked to certain compounds that were used to controlmidges. These "hard" pesticide compounds are no longer approved by the USEPA or State Pesticide Board for aquatic usages.

Approximately 90 holes were driven through the ice covering Straits Pond in February, enabling the IEP study to determine the "thickness" of the unconsolidated bottom sediments. At each hole, the depth of water was measured with a hand-line. Five foot connecting lengths of stainless steel rod were pushed down by hand to "refusal." Where the sediment thickness exceeded 12 ft., the rods could no longer be pulled-out by two men (Figure 6-1). Sediment thickness in certain areas of the Pond is therefore reported as >12 ft. Straits Pond bathymetry is shown in Figure 6-2.

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7.0 NUTRIENT BUDGET

7.1 Investigative Methods and Permissible Supplies

The trophic status of a waterbody may be defined by nutrient concentrations in the lake water during the spring over-turn. The National Academy of Sciences (NAS) has defined the oligotrophic/mesotrophic borderline at a phosphorus concentration of 0.015 mg/l and the mesotrophic/eutrophic borderline at 0.030 mg/l. By using these boundary concentrations and certain hydrologic characteristics of the pond, the annual supplies of phosphorus (kg/yr) which would lead to each trophic state may be calculated.

The formula for calculating permissible phosphorus supplies, derived from the Dillon-Rigler Model:

$$J = \frac{[P] - Q}{(1-R)} \quad \text{and } R = \frac{13.5}{13.5 + q_s}$$

where J = annual phosphorus supply, kg/yr
[P] = average spring phosphorus concentration in late, ug/l
Q = annual volume of water passing through lake, m^3/yr
R = phosphorus retention coefficient
q_s = areal water load, m/yr

By substituting the NAS borderline trophic level concentrations for [P] and extrapolating clearly oligotrophic and clearly eutrophic concentrations, the trophic states for Straits Pond are defined by the annual phosphorus supplies:

1. Clearly Oligotrophic J = 51 kg/yr
2. Oligotrophic/Mesotrophic J = 102 kg/yr
3. Mesotrophic/Eutrophic J = 204 kg/yr
4. Clearly Eutrophic J - 408 kg/yr

Hence, to achieve and maintain oligotrophy in Straits Pond, the annual supply of phosphorus entering the Pond from all sources must be less than 102 kg/yr.

In the current hydrologic condition wherein the existing tidegate excludes the inflow of Weir River tidal waters, all phosphorus sources are contained within the delineated watershed and hence may be identified and quantified.

7.2 Existing Phosphorus Supply

By comparison of the actual existing phosphorus supply to the permissible supplies calculated in section 7.1, the magnitude of eutrophication may be determined. In addition, the supplies from each source within the watershed may be quantified thereby permitting evaluation of remedial measures which could be implemented to eliminate or reduce the supplies from the individual sources. The supplies are calculated from methodologies developed by CEM (1979).

Phosphorus Supply From Runoff and Erosion

The phosphorus contained in the soils within the watershed are released to Straits Pond via the surface runoff from precipitation. The quantification of the phosphorus supply is a complex function of land use, land management practices, soil types, topography, and hydrology of the watershed. It involves the use of the Universal Soil Loss Equation, a sediment delivery formula, and soils and land use (see figure 3-1) mapping.

By this methodology, the annual average phosphorus supply from erosion was calculated to be 295 kg/yr. Table 7-1 itemizes the supplies from each land use area within the watershed.

Table 7-1. Runoff/Erosion Phosphorus Supply

Land use	Area (acres)	Annual Phosphorus Supply to Straits Pond (kg/yr)
Forest	346	24.6
Golf course	40	1.0
Wetland	59	0.0
Urban Residential, R1	31	30.3
R2	32	52.8
R3	118	167.5
Rural Residential, R4	33	18.9
Landfill	9	see next section
		295.1

Most of the supply from the golf course and forest areas is transported to Straits Pond via Rattlesnake Run. The wetlands act as a sink by vegetative uptake of phosphorus release from upstream areas. The gulf course and forested areas are relatively minor sources of phosphorus and control would be difficult.

The developed areas are, however, a major source of erosion-related phosphorus because the rate of erosion increases with the density of development. The residential areas comprise only 33% of the contributing watershed yet contribute 91% of the total erosion related phosphorus supply. This portion (270 kg/yr) could ideally be controlled by diverting the storm drain outfalls away from the pond if such were feasible.

Phosphorus Supply From the Landfill

The Cohasset sanitary landfill on Cedar Street is located within the Straits Pond watershed. Phosphorus in the leachate is directed to the pond via the wooded swamp which abuts the landfill. Due to the age of the landfill, as well as its proximity to the surface water course, it is a significant contributor of phosphorus. The calculated annual phosphorus supply from the landfill is 41 kg/yr. The control of this source would be difficult because leaching would continue even if the landfill operation was ceased.

Phosphorus Supply From the Atmosphere

Phosphorus exists in the ambient atmosphere and will reach Straits Pond through precipitation and dry fallout directly on the pond surface. The amount falling on land surfaces within the watershed has been included in the erosion-related supply computation.

Measurement of atmospheric fallout is very difficult. The typical ambient fallout and precipitation rate for this region is estimated at 100 kilograms per square kilometer of lake surface per year. Hence, the annual atmospheric supply to Straits Pond is calculated to be 37 kg/yr. This source is, of course, not controllable.

Phosphorus Supply From Septic Systems

Septic systems generally contain large amounts of phosphorus. A septic system from one typical dwelling (occupied year-round) receives about 4.78 kg/yr of phosphorus, itemized by contributor in Table 7-2.

Table 7-2. Phosphorus Contributions to a Typical Septic System

*Contributor and Approximate Percentage of Dwellings With This Contributor	Phosphorus Supply Per Capita, kg/yr	Phosphorus Supply Per Dwelling, 3.5 Occupancy Rate, kg/yr
Toilet, 100%	0.77	2.70
Bathroom Sink, 100%	0.05	0.18
Kitchen Sink, w/o Disposal, 100%	0.02	0.07
Disposal, 5%	0.11	0.22
Clothes Washer, 80%	0.57	1.60
Dish Washer, 35%	0.17	0.21
TOTAL per dwelling		4.78 kg/yr

*CEM (1977)

All septic systems within 300 feet up-gradient of Straits Pond or surface water tributaries are potential sources. The proportion of septic leachate actually reaching the surface water is dependent on soil characteristics, actual distance from the system to the water, and the age of the system as it dictates its effectiveness.

Most of the residences on the Hull shoreline are on a town sewerage system and are presumed not to contribute to the Pond, though some leakage is possible. However, some Hull residences and all Cohasset residences are not sewered.

Approximately 74 unsewered residences (total) are within the 300 foot, up-gradient zone. It is assumed that most systems are old enough to have breeched the attenuating capacity of the intervening soils, thus exceeding their effective lives. The more recently installed systems, if any, were possibly rendered ineffective by the 1978 storm.

By this account, an estimated 354 kg of phosphorus reaches Straits Pond from septic systems each year.

7.3 Results and Conclusions

In summary, the total annual phosphorus supply to Straits Pond, itemized by source:

Land Surface Erosion/Runoff	295 kg/yr	41% of total
Cohasset Landfill	41 kg/yr	6% of total
Atmospheric	37 kg/yr	5% of total
Septic Systems	354 kg/yr	48% of total
TOTAL ANNUAL SUPPLY	727 kg/yr	100%

As determined by the permissible supply calculations, the total supply would have to be limited to less than 200 kg/yr to maintain a mesotrophic state and to less than 100 kg/yr for an oligotrophic state. Ideally, source controls such as 100% sewering and storm drain diversion would afford a reduction of 624 kg/yr of the annual supply. The remaining supply would be 103 kg/yr which could maintain a trophic level between oligotrophy and mesotrophy.

8.0 EVALUATION OF STRAITS POND TROPHIC STATUS AND RECLAMATION ALTERNATIVES

Lake reclamation techniques are of two general types and include "in-lake" and watershed management. More often than not, a successful lake reclamation program will employ a combination of both strategies.

In-lake techniques, as the term implies, include methods which focus on work within the affected waterbody. Typical in-lake techniques include dredging, harvesting, herbicide/algicide application, biological control, aeration, nutrient inactivation, drawdown, and others. In-lake methods are generally capital intensive and also require a continuing, periodic (usually seasonal) program.

Watershed management, as a lake reclamation technique, utilizes land use and environmental planning concepts and engineering practices in order to reduce present loadings and minimize future loadings attributable to cultural influences. Zoning, subdivision control, health regulations, increased enforcement, heightened awareness, additional maintenance, sewering, etc. are all included under the general heading of Watershed Management. These approaches are typically long-term, incremental measures but do focus on limiting the source(s) of nutrient input. In-lake techniques, while outwardly much more effective, are limited in their ability to control nutrient sources. This is why a combination of the two is generally favored and is recommended for Straits Pond.

The specific methods which should be applied to reclamation of a particular waterbody are dependent upon the nature of the problem, hydrologic and nutrient parameters, nutrient sources, management objective(s), proposed use(s), feasibility, social acceptance, effectiveness of method and cost. It is most cost/effective to attack those sources of nutrients which are contributing most to the problem and which are easiest to control. For example, atmospheric fallout has been found to be an increasing source of nutrients (particularly nitrogen). It would not, however, be practical for the Towns of Hull and Cohasset to attempt to control this source of nutrients whose origin may likely be hundreds of miles away. More applicable would be increasing maintenance of storm drains and septic systems in Cohasset and eliminating sanitary/storm sewer cross connections in Hull.

Additional concern results in the proposition of alternatives which would result in questionable benefit but whose cost may be significant. Apparent panaceas must be closely scrutinized before the decision is made to implement. Extenuating environmental and social circumstances must also be considered. Reinstituting complete tidal flushing of Straits Pond, for example, may accomplish water quality objectives but would also adversely impact adjacent drainage systems, homes and sewage disposal facilities. Rerouting storm runoff or sewage flows may be helpful to Straits Pond but may pose water quality problems elsewhere or may require costly engineering solutions, discordant to local taxpayers. Proposed reclamation strategies must address environmental, social and fiscal concerns, as well as in-lake and inflowing water quality conditions.

8.1 Watershed Reclamation Techniques

8.1.1 Land Use Planning

The Straits Pond watershed lies within two different municipalities and as a consequence, land use types and densities are governed by two separate sets of regulations. This situation is somewhat muted by the fact that much of the developable land in Hull which occurs in the Straits Pond watershed has been built upon and there is little opportunity for any major new development. The only area where extensive contiguous open land occurs is at the western end of Straits Pond and east of Nantasket Avenue. This area is currently zoned commercial Recreation A. Recent zoning amendments appear to allow for single family residential use of this area but prohibit multi-family dwellings. Much of this area is characterized by outcropping bedrock or low, poorly drained land.

Additional zoning changes have recently been made in Hull which further restrict the extent of multi-family and business usage within the Straits Pond watershed. These changes appear to be linked more to future usage of existing structures than to any potential major development within the watershed.

A different situation exists in Cohasset, however, where the majority of the Straits Pond watershed lies. There is a substantial amount of land which is forested or open where future development could occur. Fortunately, the existing Cohasset Zoning Bylaw and Subdivision control regulations are, for the most part, compatible with water quality goals.

There exists a Floodplain and Watershed Protection District which is designed to maintain water quality and flood protection. This District includes major wetland areas, Rattlesnake Run, and within the 10 foot contour around Straits Pond. One special permitted use within this District which is not compatible with water quality objectives is section 9.7.2 which allows for public sewer facilities and public solid waste disposal. One such area has been established north of Cedar Street in a large wooded swamp. This use is not permitted by the underlying (RC) zone.

The applicable use/density districts which exist within the Straits Pond watershed in Cohasset include RB and RC. The two districts are split about evenly in terms of area occupied by each. The RB zone provides for single family residential usage with a minimum lot size of 20,000 square feet and 50 feet frontage. The zone permits coverage of up to 30% of the lot not including area used for accessory buildings. Two family residential uses are permitted with increases in lot size. This zone occupies the area in Cohasset closest to Straits Pond.

The RC zone requires a minimum lot size of 30,000 square feet and a 50 foot frontage with a maximum of 30% coverage not inclusive of accessory buildings. As in the RB zone two family dwellings are permitted with increases in lot size.

Due to the potential for future increases in development in the Cohasset portion of the Straits Pond watershed and due also to the reliance on subsurface sewage disposal systems in that area, it is recommended that minimum lot sizes be increased to 40,000 square feet. This recommendation is made in light of the current nutrient loadings found in Rattlesnake Run, the observation or other evidence of several overflowing septic systems, the poor soil and shallow bedrock conditions, and the fact that residential development has been shown to cause as much as a ten to twelve-fold increase in nutrient loadings over formerly forested land area. Due to the presence of large areas of shallow soils and high groundwater conditions in the Cohasset portion of the watershed, provision for cluster development would encourage development of the more suited sites while leaving open those areas less amenable to development.

Additional provision for water quality maintenance could be made within section 9 - Special Floodplain and Watershed Protection District, of the Cohasset Zoning By-Law. Regulations for the establishment of lake and stream buffers, wetland protection, erosion and sedimentation control, etc. may also be included within an overlay zoning bylaw.

Additionally, any proposed development within the Floodplain and Watershed Protection District should invoke the Site Plan Review process as provided in section 11.6 of the Town's Zoning Bylaw. Although a fairly comprehensive review by the Board of Appeals is required in situations where a special permit is being sought, it is felt that a full review under Section 11.6 would be more thorough. In some communities (e.g. Weston) site plan review is provided by all of the various boards, similar to the state's MEPA process, for example.

It is felt that several large wetland areas which occur in Cohasset are contributing beneficially to water quality by means of their pollution attenuation or "living filter" functions. The location of two large wooded swamps just downstream of the golf course and the landfill is very fortunate in terms of attenuation of nutrients or possibly contaminants from these two land use types which are potential degraders of water quality. While wetland protection is afforded somewhat by MGL C.131, s.40, the Massachusetts Wetlands Protection Act, this is seen more as a regulatory and not a restrictive law. Further protection may be garnered by enactment of a local Wetland Protection Zoning District or a Wetland Protection Bylaw. Recently, the Town of Dennis' Wetland Protection Bylaw was challenged and tested within the Massachusetts court system. The Commonwealth's Supreme Judicial Court upheld the Dennis Bylaw, which is currently looked upon as a model for other towns to follow. Advantages of General Bylaw over a zoning District are several. Initially, only a majority town meeting vote is required for passage of a General Bylaw whereas a two thirds majority is required for zoning approval. Interests protected under a Bylaw may include more than the seven statutory wetland values covered under C.131, s.40. The authority to deny a project is clear. Appeal is to the Superior Court, not DEQE. For these and other reasons as well it is recommended that a Wetlands (non-zoning) Bylaw be adopted in Cohasset.

Due to the large contribution of nutrients by means of erosion within the watershed it is highly recommended that an Earth Removal or Mineral Excavation ordinance be instituted which will be enforced. Most communities have regulations governing earth removal, however, these are either very narrow in scope or are not enforced. In Cohasset earth removal is allowed only where such is defined as an "exempt operation." The regulations are enforced by the Building Inspector.

The Town of Boylston has overcome some of the traditional problems with enforcement of Earth Removal Bylaws by adopting an Earth Removal Board who is charged with the responsibility of reviewing applications for earth removal within the Town and granting a permit for such activity if it is so determined by the Board. Though there are limits to what sorts of activities the Board may regulate, the system has apparently worked well in Boylston and should be considered for application in Cohasset absent passage of more stringent controls on earth disturbing activities, such as an amendment to the Floodplain and Watershed Protection Bylaw which would prohibit major earth removal activities within the Straits Pond watershed, or an Erosion Control Bylaw which would specify limitations and impact mitigation measures for all earth disturbing activities allowed in the Town.

Local subdivision control regulations may also provide for flexibility in cases where environmental sensitivity or water quality goals are an important consideration in development of a large tract of land. For example, a town Planning Board through subdivision control regulations may require that runoff rates from a site not be increased, that permeable pavement, oil/gas traps, etc. be used in road and catch basin construction in critical areas, that ground cover be maintained, and that subdivision ways be designed so as to minimize erosion and subsequent siltation. The Cohasset subdivision rules and regulations specify, for instance, that streets be a certain width and that sidewalks be constructed on both sides of the street. Standard design criteria are specified for street construction and drainage as well. There may be situations, however, where standard street widths and curbing are not essential and where discharge of storm runoff to the "nearest natural water course" is not desired.

Local health regulations may also serve to afford better protection to water resources. Title V, the State Environmental Code, provides minimum requirements for location, design and construction of septic systems. Title V is written to apply statewide and therefore provides that local regulations may be effectuated which go further than the state Code in certain cases. Many towns have, in fact, done just this. Examples of applying more stringent requirements include 100 to 150 foot set back distances from reservoirs, waterbodies, wetlands and tributaries in watershed protection areas; establishing a maximum percolation rate limit (e.g., 3 minutes per inch) atop water supply aquifers or adjacent to waterbodies; allowing groundwater testing in only three months of the year or as designated by the Board of Health for years in which groundwater levels vary significantly from the norm; requiring water conserving fixtures to be installed in situations where there exist marginal soil conditions (greater than 20 minutes per inch), where a chronic sewage disposal problem exists, or in critical water resource protection areas (legislation has recently been filed which would revise the state building and plumbing codes so that water conserving fixtures would be required in all new or replacement construction); and requiring septic system maintenance (pumping) on a regular basis in critical resource areas. In areas of poor soil where septic system problems are known to occur, sewering is not imminent, and impacts to water resources result, it is highly recommended that a septic system maintenance program be implemented. Such a program would mandate that septic systems located within the watershed be pumped a minimum of once every two to three years.

The value of wetlands in the maintenance of water quality has been well documented and has been previously referred to as an important function within the Straits Pond watershed. Regulation under C.131, s.40 (The Massachusetts Wetlands Protection Act) requires that the local Conservation Commission ensure that the wetland values enumerated within the Act are maintained or adequately replaced as development occurs. Values include water supply (public and private), groundwater, pollution prevention, flood control, storm damage prevention, fisheries, and shellfish. Any activity which is proposed within 100 feet of a wetland may fall under the jurisdiction of the local Conservation Commission. In its regulatory capacity under C.131, s.40, the Conservation Commission may require, within reason, that certain runoff quality and quantity criteria are met.

Land use planning and other local regulatory techniques may provide the basis for protection of water resource values over the long term. As with any regulatory controls, however, there are two sides to the coin. After the applicable regulations have been drafted and are on the books, enforcement must take over. If the adopted regulations over-tax the ability of the Town to enforce these regulations, then they have accomplished very little and may, in fact, be counter-productive. If they can be enforced, it is by far and away better to prepare regulations which will plan for and afford protection to valuable resources before development occurs.

8.1.2 Urban Runoff Controls

EPA (1975) and others have found runoff from urban and suburban areas to be considerably higher in concentrations of nutrients and contaminants than runoff generated from less densely developed areas. In fact, comparison of urban runoff water quality is frequently compared with that of domestic sewage (see Table 8-1).

Table 8-1. Characteristics of Urban Runoff

Constituents	Raw Domestic sewage (lb/day/acre)	Raw Domestic sewage (lb/yr/acre)	Urban runoff loads as percentage of sewage loads: During runoff	Urban runoff loads as percentage of sewage loads: Annually
Suspended solids	1.5	540	2400	160
COD	2.6	960	520	33
BOD_5	1.5	540	110	7
Total PO_4	0.19	68	70	5
Total N	0.23	82	200	14

Source: Amy, et. al. Water Quality Management Planning for Urban Runoff, USEPA-440/9-75-004

Sources of urban runoff are numerous and varied and include grit, sand, salt, auto emissions, animal waste, trash, fertilizers, etc. Besides the increase in waste production attributable to urbanization, there is also an increase in the amount and rate of runoff waters generated. Increased impervious services - roofs, roads, sidewalks, etc. - result in less infiltration of storm water. Typically, this water is captured by a catch basin/storm sewer system and discharged to a brook or pond, as is the case at Straits Pond. This system acts as a vector for the transfer of contaminated runoff water and provides little or no opportunity for renovation prior to discharge. This is precisely the situation which exists in the Straits Pond watershed and where storm water sampling has shown elevated levels of bacteria and nutrient input to the Pond.

Two general approaches are applicable in dealing with the storm water runoff problems in the Straits watershed. These include both remedial and preventive measures. Section 8.1.1 of this report discusses preventive approaches to reducing degraded storm water runoff. The following discussion will concentrate on remedial measures for dealing with poor quality storm runoff. The storm water collection systems in Hull and Cohasset are dissimilar in one major factor, that being drainage area. In Hull there exist several small systems along Atlantic Avenue which collect water from very small areas. As a result, discharge to Straits Pond is almost coincidental with a rain event with runoff being generated principally from short stretches of the roadway and adjacent yards. Two of these systems, though very small and insignificant in terms of total nutrient loadings to Straits Pond, do not appear to have sufficient grates and sumps to allow for entrapment and settling of sticks, trash, sand and silt. These systems should be upgraded to provide adequate catch basin facilities. Water quality samples taken on 4/10/80 at one storm drain at the east end of Straits Pond in Hull showed fairly good quality, low in nutrients and bacteria. Runoff waters entering this particular drain were emanating from overflow of an undersized or blocked drain system from the Green Hill area of Hull.

A storm drain system on Richards Avenue in Hull was also sampled during the rain event on April 10, 1980. The sampling station corresponded with baseline station, SS-6. Bacterial counts and nutrient levels confirm earlier findings that one or more domestic sewage discharges are connected to this storm drain system which enters Straits Pond. Although sewerage upgrading and expansion is currently underway in Hull, the Richards Avenue area is not scheduled for work for at least another five to ten years. Immediate dye testing should be undertaken in order to determine contributors to this grave health hazard and emergency sewage disposal alternatives adopted. If long term alternatives do not appear feasible then amendment should be made of the Town's sewerage facilities plan schedule to allow an adequate long term solution to be implemented.

In Cohasset there are approximately ten storm sewer outfalls to Straits Pond. Each of the systems drain fairly large areas on the south side of Jerusalem Road. On April 10, 1980, six of these outfalls were sampled. Of the six, four had elevated bacteria counts and nutrient levels suggesting influence from domestic sewage. The four stations included discharge points to Straits Pond at, approximately the intersection of Hyde Lane and Jerusalem Road; the intersection of Windy Hill Road and Jerusalem Road; the intersection of Black Rock Road and Jerusalem Road; and an ephermeral stream between Black Rock Road and an unnamed private way just off of Jerusalem Road. It is assumed that the degraded water quality is attributable to overflowing septic systems and to direct domestic sewer connections to the storm drain system. Several additional overflowing septic systems were observed in Cohasset within 50 feet of the shoreline.

It is recommended that a sanitary survey be undertaken in the areas drained by the storm drain systems referenced above and at homes located north of Jerusalem Road. Because sewering of this area is not contemplated, septic system rehabilitation, installation of water conserving plumbing fixtures and appliances,

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and required periodic pumping and maintenance of systems should be effectuated in identified problem areas in Cohasset.

Though septic system overflow appeared to be the major contributor from Cohasset of storm related nutrient loadings to Straits Pond, several of the storm drain systems examined appeared to be ineffective in removing suspended materials and floatables. This problem appeared to result from hydraulically over-loaded systems and was most acute in the drain system which collects runoff from the Black Rock Road area.

Due to the steep gradient on the south side of Jerusalem Road and the development which has occurred on both sides of Jerusalem Road there is little opportunity for construction of detention basins or enhancing shallow marsh areas for the purpose of trapping and neutralizing storm runoff water from Cohasset before reaching Straits Pond. In cases such as this, less cost-effective measures such as increased street sweeping, street maintenance, catch basin cleaning and storm sewer flushing may be the only source and in-line measures available. Effectuation of these methods, particularly flushing and cleaning, would be advisable within all closed drainage system(s) discharging to Straits Pond.

Another approach to neutralizing the effects of storm water runoff involves the use of end-of-pipe remedies. Treatment by conventional means has been attempted but this tends to be very costly. Artificial methods of phosphorus and sediment removal would include treatment of the inflow with a suitable flocculant such as aluminum sulfate or ferric chloride. The installation of such a treatment system on one or more of the major inflowing storm systems to Straits Pond would not be cost/effective. Chemical costs alone are estimated to run approximately \$5.00 - \$10.00/day/cfs (EPA, 1976). To this daily chemical cost would also be added an estimated initial capital outlay of \$5,000 - \$10,000 for the purchase and installation of an automatic-flow proportional dosing system.

8.1.3 Other Watershed Management Measures

Besides the regulatory and engineering type measures which may be taken to reduce nutrient loadings to a lake, there are others which may be effectuated by residents of the lake front and watershed. Most of the recommended procedures discussed below are not conducive to regulation and enforcement at the local level but are probably most effective when put into practice by a strong watershed group or homeowners association in the form of "pier" pressure.

Shore and bank erosion can contribute significantly to nutrient input to a lake or pond. In addition, water clarity and other quality parameters are lessened. Though much of the shoreline of Straits Pond is either sand or bedrock, there is a significant area of water front which is protected by walls, rip-rap, or other erosion prevention measures. At various locations around the Pond, particularly in Hull, these structures were found to be in disrepair and in need of fixing. Therefore, one major way lakefront owners may contribute to water quality objectives at Straits Pond is to maintain these erosion prevention structures.

A major source of phosphorus in wastewater from a domestic septic system is phosphate detergent. Several states and municipalities have banned phosphate detergents due to their impacts on local waterbodies. Because of the ease in obtaining phosphate detergents in non-participating neighboring municipalities; local prohibitions are usually not effective. However, a watershed, or lake group can serve to inform neighbors of the benefit of using low or non-phosphate clothe's and dishwashing detergents. Through such an educational and local effort reduction in the use of phosphate detergents will occur. This is of particular concern in Cohasset where septic systems are used for domestic waste treatment.

Other common sense approaches to landscaping and lawn maintenance practice can help to curb Pond nutrient loadings. For example, lawn or garden fertilizers should be applied in prescribed dosages for the soil on which they are being used. Leaves, grass clippings, pet droppings and other waste or organic material should not be dumped along the pond's edge or in the pond as was observed along several stretches of shoreline and sand or other fill material should not be brought in to extend a private yard or beach.

While these various approaches will not, in and of themselves, correct the eutrophication problems plaguing Straits Pond, they will help. Formation of a strong neighborhood, homeowners, or watershed group would help to effectuate these and other measures and to forward attempts to reclaiming Straits Pond.

8.2 In-Lake Reclamation Techniques

A variety of in-lake restoration and reclamation techniques have been used throughout the country with varying degrees of success. The discussion below presents the most commonly applied techniques and reviews each in light of the unique characteristics of Straits Pond.

8.2.1 Chemical Control - Aquatic Vegetation and Midges

Aquatic Vegetation

This short-term in-lake management technique is aimed at the elimination or reduction of growth of rooted aquatic macrophytes. Control may be provided for several species with a single application of a herbicide, or may be directed at the specific unwanted specie or species by the use of certain formulations of species-selective herbicides.

Straits Pond has a long history of herbicide treatments dating back to the late 1950's. During the past 30 years a variety of chemical compounds have been used to control the predominant nuisance plant, widgeongrass (*Ruppia maritima*). Sodium arsenite (active ingredient arsenic trioxide) was repeatedly used during the early and mid 1960's. This compound was applied to the Pond surface at a dosage of 10 ppm or a total application of roughly 2,500 gallons of concentrated material per year. According to memoranda obtained from the DEQE and the State Reclamation Board offices in Boston, the arsenic treatments successfully controlled both the weed and algae growth for the remainder of the summer following its application. However, sodium arsenite was banned for aquatic usages by the USEPA during the late 1960's due to its recognized toxic effects on non-target organisms and the realization that high residual levels of arsenic could accumulate in the sediments.

Other herbicides used at Straits Pond include Kuron, Aqualin, Aquazine, Hydrothal 47 and Aquathol K. In recent years, however, Aquathol K and Hydrothol 47 were most frequently applied. Both compounds contain Endothall as the primary active ingredient and both are generally considered among the "safer" herbicides currently approved for aquatic vegetation control by the State Pesticide Board and USEPA. Unlike sodium aresenite, the Endothall formulations are thought to breakdown to harmelss salts, although there is always some degree of risk or doubt regarding the long-term effects of any pesticide.

Until other long term aquatic vegetation control techniques are implemented (sections 8.2.7), chemical treatments may be required. The major herbicide application should be scheduled early in the summer, preferably in late May or June. The decay of the *Ruppia*, 7-10 days following treatment does allow for improved water circulation within the Pond. However, the Towns should also be aware that the decomposing vegetation is also likely to reduce the dissolved oxygen content of the Pond water during bacterial decomposition of the organic matter. The benefit of the chemical treatments in reducing the odors that emanate from the Pond during the summer, should be carefully weighed against the number of complaints received last year when no treatment was performed. Chemical treatment is a "cosmetic," short-term management technique that affords no permanent solution for the control of either the weed or midge nuisance. Based upon a review of the literature, the dominant midge species infesting Straits Pond will lay its eggs and the larvae will thrive independent of the vegetative density or species composition. We understand the annual cost for the chemical weed control program at Straits Pond currently runs between $3,500.00 - $5,000.00 per year. This cost can be expected to increase at a rate of 15 - 20% per year or more, should a second additional treatment be necessary later in the summer to control the algae.

Midges

The "hard" chlorinated hydrocarbon pesticides such as DDT, that were once used to control the midge nuisance at Straits Pond have since been banned by the state and federal regulatory agencies. The pesticide currently applied to Straits Pond is an organophosphate larvicide sold under the trade-name "Abate." Since this insecticide is formulated to kill the larvae and not the adult midges, this chemical is normally applied during the spring, before the mature adults emerge from the Pond. According to Lewis Wells, Director of the Massachusetts Pesticide Board, the optimal time for treating Straits Pond is during the first two weeks of April. Adult midges reportedly will begin to emerge from the Pond as early as April 15th.

Like the herbicides that are used to control nuisance aquatic vegetation, the Abate treatments must be repeated each year. In view of the severe nuisance to Pond abuttors reportedly posed by the emergence of the adult midges, the insecticide treatment does afford some temporary relief, although Wall (personal communication), cited that the larvae will eventually become resistant to the Abate insecticide. We understand the Pond is to be treated within the next week. However, next year (1981) we are recommending that the Pond be emptied during the winter, in order to kill the midge larvae inhabiting the bottom sediments (section 8.2.7) rather than using chemicals.

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8.2.2 Mechanical Harvesting of Aquatic Vegetation

Weed harvesting is used considerably in other parts of the country to both improve the utility of a lake made inaccessible or unusable by dense growths of aquatic macrophytes and secondly, to remove nutrients from a lake subsequent to removal of cut weeds from the waterbody. Compared with the use of chemicals, the mechanical approach does not add potentially toxic substances to the environment. Furthermore, since the cut weeds and macroscopic algae are removed from the water during the harvesting operation, the dissolved oxygen content of the water is not significantly lowered. Estimates of nutrient removal, based upon values reported in the literature are in the range of 2.7 kg of phosphorus and 22.7 kg of nitrogen per acre per harvest. If we assume that two weed harvests per summer were to occur over the entire 92 acre surface area of Straits Pond, roughly 552 kg of phosphorus and 4,181 kg of nitrogen could potentially be taken out. This removal estimate for phosphorus reporesents 75.9% of the total phosphorus supplied annually to the Pond, exclusive of the nutrient input from the Weir River. On the basis of the figures presented above, mechanical harvesting appears to be a promising management technique for use at Straits Pond. However, harvesting alone, could not be considered "restorative" until specific action is taken to reduce nutrient inputs from the watershed as discussed in section 8.1.

There are a number of difficulties associated with mechanical harvesting at Straits Pond that prevent us from recommending its use there. The shallow water depth combined with debris (tires, lumber, etc.) along the Pond shoreline would inhibit harvesting in these areas. A large mechanical harvester such as Aquamarine Corporation's H-650 model, requires a reasonable working depth of roughly 1.5 ft. The major problem that we foresee with harvesting Straits Pond, is the high potential for nutrient release from the bottom sediments. The force of the harvester paddle wheels will create excessive turibdity in water depths less than 1-2 feet. The release of inorganic phosphorus and nitrogen from the disturbed sediments could provide additional nutrients for utilization by the floating filamentous or microscopic algae. Furthermore, the visibility of the harvester operator would be greatly impaired due to such turbid conditions.

The current price of the H-650 mechanical harvester is approximately $72,000.00 including the necessary modifications for use in salt or brackish water. A single cutting of the Pond would require approximately 30 operating days assuming a harvesting productivity rate of three acres per day. In addition to a harvester operator, one other man and a dump truck would be required to haul the weeds away to a disposal site. Amortizing the purchase price of the equipment over a 10 year anticipated life expectancy yields an annual cost of $7,200.00. To this sum, we have estimated annual operating and maintenance expenses of $8,000.00 - $10,000.00 or a real cost of perhaps $17,000.00 per year. In view of the limitation,s anticipated problems and high cost of mechanical harvesting, we do not recommend its use at Straits Pond.

8.2.3 Aeration

Use of aeration can be for several objectives ranging from nutrient, iron and manganese inactivation, to elevate low concentrations of dissolved oxygen for fisheries management or for the control of microscopic algae.

There are two basic types of aeration systems, one being total aeration/destratification of the waterbody and a second method whereby only the hypolimnion (bottom water) of a lake is aerated to prevent thermal destratification. Hypolimnetic aeration is preferred in most ponds or lakes especially where the maintenance of a "cold water" (trout or salmon) fishery is an important consideration.

The installation of an aeration system at Straits Pond, either by laying perforated hose along the entire length of the bottom or utilizing several plastic mixers, might possibly help to reduce the hydrogen sulphide odors emitted from sediment. Due to the extreme shallowness of Straits Pond, water temperatures do not differ significantly between the surface and bottom. In other words, aeration will not alter either the existing temperature or salinity profiles in Straits Pond. We do not believe that aeration will significantly reduce the existing weed or algal nuisance either. Aeration might possibly lead to a more diverse community of bottom dwelling insect larvae, nymphs and worms. However, it is doubtful that an increase in the diversity and density of these other organisms in Straits Pond would result in a concomitant reduction in the nuisance midge population. Capital expenditures for an aeration system are likely to range between $25,000 - $50,000 with annual operating and maintenance costs approximated at $5,000. We do not recommend aeration at Straits Pond.

8.2.4 Lake Bottom Sealing or Shading

Lake bottom sealing is used to prohibit or reduce the nutrient exchange between bottom sediments and the overlying water column. Commonly used materials for lake bottom sealing include plastic and sand. "Flocs" produced by use of alum may also be considered a variant of the lake bottom sealing technique.

A complete sealing of the bottom of Straits Pond based upon past nation-wide experiences, is not possible to attain. Flocculants such as aluminum sulfate would probably become resuspended due to the shallow water depth. On the other hand, the application of sand would provide limited benefit for perhaps three to five years before silt or muck would cover the bottom once again. Black plastic sheeting layed along the bottom to prevent rooted vegetation from growing in the Pond would rapidly be up-lifted due to the release of hydrogen sulphide gas from the sediments. A recently developed, fine-meshed screening material (Aquascreen™) would effectively control the *Ruppia,* however the material cost alone is roughly $8,712.00 per acre. The cost/benefit projected for any of these sealing alternatives does not justify their use at Straits Pond.

8.2.5 Nutrient Inactivation

Nutrient inactivation encompasses a variety of materials that are used to remove or render unavailable, nutrients that are found within a lake's water column. Most commonly used is alum, chemically, aluminum sulfate, although experimentation is ongoing with such materials as ferric chloride and potassium permanganate.

Use of these chemicals results in removal of other elements within the water column in addition to nutrients. Iron, a micronutrient that favors the growth of blue-green algae is effectively removed by potassium permanganate. Alum has been found to remove particulate organic matter, as well as phosphorus and trace metals. It also flocculates unicellular algae and removes them from the water column.

As with dilution/flushing this management technique is intended for the control of microscopic algae and would yield little or no benefit towards the reclamation of Straits Pond. A pond or lake must also have a comparatively long hydraulic retention time (preferably one year or more) in order for alum treatments to be effective. Again, Straits Pond does not meet this criteria.

8.2.6 Biological Controls

Biological controls used in fresh water lakes include the introduction of aquatic plant-eating fish such as the White Amur, or mammals such as the Manatee. Other biological controls include the use of insects which attack weeds or algae. We are not aware of any brackish water environments where any of the above biological controls have been used successfully.

We understand that large numbers of alewives were once stocked in Pilgrim Lake, Truro, in an effort to control midges in that brackish waterbody. Wells (personal communication) reported an apparent reduction in the density of midge larvae after the alewives were brought in; however, chemical treatments were also necessary. After a period of several months the alewives apparently moved out of the Lake. In recent years, a naturally occurring population of carp has moved into Pilgrim Lake, reportedly keeping the midge population under control (Van Arsdale, personal communication).

Based upon the available fisheries data for Straits Pond, resident populations of brackish water species are apparently limited by low oxygen concentrations and high water temperatures during the summer. Without first improving water circulation and quality throughout the Pond, it is doubtful that either a native or artificially introduced finfish population of sufficient magnitude could be established.

8.2.7 Fall/Winter Drawdown

This in-lake reclamation technique seeks to expose sediments and aquatic weeds to freezing temperatures and the effects of dessication by lowering water levels in a lake such that the majority of the weed infested shoreline is exposed. The same process often results in consolidation of loose, "muck" bottom sediments and will, if consolidation is substantial enough, result in an increase in the water volume of the lake once refilled.

At Straits Pond, we view repetitive fall/winter drawdowns as offering the most cost/effective method by which to control the nuisance midge population. The potential benefit of drawdown for reducing rooted aquatic vegetation (*Ruppia*) is unclear.

The proposed drawdown would be initiated in the fall (mid-late October), when foul odors from the exposed sediments are not apt to be a problem, due to the cooler air temperatures. Lowering of the water level should be in increments of

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of one foot thereby enabling Town personnel to check the permeability of the sediments. Prior to lowering the water level further, the exposed bottom should be firm enough to walk upon to avoid possible danger to children who may venture out on the exposed sediments. Lowering of the Pond can be accomplished by opening the tidegate and removing the flashboards during the outgoing tides while closing both fixutres on the rising tide. Once the Pond is emptied, some effort will still be necessary to let out the fresh-water that enters the Pond from surface and groundwater flow from the watershed. The volumes of water that have been calculated to enter Straits Pond on a monthly basis are shown in section 5.2. Mr. Raymond Cowen, Hull DPW Director, told us that the water level will drop approximately one foot in roughly 72 hours if the tide and sluice gate are manned continuously.

The elevation of the bottom of the tide gate and sluiceway is approximately five feet below the normal surface elevation of the Pond. The elevation of these structures will not be an impediment to total drawdown of the Pond. While we believe that water depths extending easterly from the tidegate out into the Pond are sufficient to draw off at least 2.0 - 2.5 ft. of water, some trenching and excavation work may be required to lower the Pond the desired depth of at least 3.5 ft. or to its maximum. The specific location and existing depth of the Weir River channel that formerly extended into what is now called Straits Pond, is precisely unknown despite a detailed bathymetric survey by IEP. We will not know exactly how large an area of the Pond can be drained until it is first attempted.

As cited previously, it would be desirable to keep the Pond emptied through the winter until the spring thaws. Based upon our hydrologic calculations, the Pond should be refilled within a matter of 33 days from watershed flows alone, if the refilling process starts on March 15th. Naturally, this figure is an estimate only based upon average monthly flows. The time for refilling, will, of course, be accelerated by allowing water into the Pond from the Weir River.

Based upon our discussions with W. Wall and L. Wells (personal communications) on the proposed plan for drawdown presented above, they felt that perhaps within a period of only several weeks following exposure of the sediments, the midge larvae would be killed. We feel it is most important that the Towns retain a qualified expert to monitor the response of the midge larvae during the drawdown process. Larval counts performed just prior to the start of the project and again several weeks following sediment exposure, will help to provide data on larval mortality and the necessity of keeping the Pond drained throughout the entire winter.

The response of the predominant nuisance weed species (*R. maritima*) to drawdown is speculative. Whereas *Ruppia* reproduces primarily by seed, there has been some question as to whether germination of dormant seeds that currently occur in the sediments might be enhanced during drawdown. The answer to this question is difficult without first conducting a series of experiments. In view of the extremely high density of *Ruppia* that presently exists in Straits Pond, we do not believe that the weed nuisance can, for all practical purposes, increase in severity. The ensuing freezing and drying of the *Ruppia* roots and seeds may, in fact, help reduce its growth during the following summer.

The sediments in Straits Pond may also consolidate significantly during drawdown and remain partially consolidated following refill in the spring. Muck sediments (50% inorganic material) such as occur in Straits Pond, have a greater potential for water loss and shrinkage than do organic peat materials (Fox et al, 1977).

Draining Straits Pond during the winter will temporarily displace whatever species of finfish normally inhabitat its waters. The significance of Straits Pond as a spawning area for finfish has not been established although it is known to provide nursery habitat for juveniles of several species. Iwanowicz (personal communication) suggested that additional survey work be performed. We do not believe that Straits Pond is a critical spawning habitat for any particular species and feel that the high potential benefit of drawdown for midge, flood control and possible weed reduction far outweighs the anticipated impact upon finfish. Our suggested plan calls for refilling the Pond in March. Consequently, species that are likely to spawn in Straits Pond, such as white perch, will still be able to do so.

8.2.8 Permanent Draining of Straits Pond

Completely emptying Straits Pond and maintaining that condition appears feasible through the installation of a float operated tidegate designed to let water out on the falling tide but closes on the incoming tide. In a theory, only freshwater from Rattlesnake Brook, stormwater flows and precipitation would enter the Pond.

We are hesitant to recommend permanent draining of Straits Pond for several reasons. First, it is not known whether, or to what extent, isolated pools of water will remain after the Pond is lowered. The proposed fall/winter drawdown will answer the question. Secondly, if large pools remain and accumulate water from the many stormwater discharges, these pools would be excellent breeding habitat for mosquitoes and other nuisance insects. Furthermore, reed grass (*Phragmites communis*) is likely to recolonize the entire Pond bottom within a matter of several years. We believe the eventual decay and accumulation of *Phragmites* would necessitate a great deal of maintenance dredging/channelizing in order to prevent the impounding of water. Without keeping these channels open, we believe a severe insect nuisance will develop.

A monotypic stand of *Phragmites* would completely eliminate the existing habitat provided for finfish and would not afford a high quality wildlife habitat at either. Expansive stands of *Phragmites* are often lit on fire by children, while rats and other vermin may also become a problem. For these reasons, we do not believe that permanent draining of Straits Pond is a desirable alternative.

8.2.9 Dredging

Dredging of lake bottom sediments is used (1) to remove bottom substrate upon which nuisance aquatic macrophytes thrive, (2) to remove sediments that have high concentrations of undesirable chemical constituents, and which liberate nutrients to the overlying water column, and (3) to deepen a lake to gain both total water volume and depth.

Due to the potential in Straits Pond for accomplishing each of these three objectives through dredging much attention was focused upon this in-lake reclamation technique.

The distribution and thickness of the unconsolidated sediments in Straits Pond * are shown in Figure 6-1. The sediments possess an average thickness of 6.0 ft. with a total volume exceeding 884,752 yd^3.

Dredging projects are usually a complex undertaking that requires careful planning relative to determining (1) method of sediment removal, (2) locating a suitable spoils area, and (3) the environmental effects upon aquatic life, surface water and groundwater supplies. The removal of four feet of sediment over the entire 92 acre Pond surface area would increase the average water depth to approximately 7.3'. Naturally, more material would be removed in certain portions of the Pond than in others. Sediment removal at Straits Pond allowing for a post-dredging water depth averaging 7.3' is probably necessary to prevent rooted aquatic plants from growing, due to the attenuation of sunlight. Four feet of sediment over 92 acres represents a volume of approximately 590,000 yd^3.

There are a number of methods by which dredging can be accomplished. In the case of Straits Pond, its proximity to the coast, sugests that ocean disposal could be a viable alternative. Hydraulic cutter-head dredging equipment, whereby the spoil material is pumped to barges waiting off-shore or to a suitable land disposal site, are options that have been considered. A dredging project of this nature would be extremely expensive and potentially complicated due to the fact that the sediments contain high concentrations of arsenic. The closest ocean dredge spoils location to Straits Pond is an area called the Boston Foul Site located approximately 17 miles northeast of Hull. Whereas the Pond is surrounded by steep sloped uplands to the south and ocean to the north and west, the only remaining possibility for a spoils site is west of the Pond. Once again, however, we do not believe there is a suitable parcel of land that could begin to handle the tremendous volumes of sediment that must be removed in order for dredging to be effective. A possible spoils area, however, might be found by constructing a dike across the northwest cove, essentially filling in the cove with sediment from other portions of the Pond. This same procedure might be explored for the eastern end of Straits Pond. This alternative would reduce the overall surface area of the Pond while adding depth to the remaining portions. This option is attractive from an economic viewpoint because the high cost for land acquisition off-site or the transport cost associated with ocean disposal do not appear to be economically feasible. Partial filling of the Pond should also reduce the cost of the engineering design work, construction costs and would simplify the procurement of permits required from the state and federal regulatory agencies.

The unit cost of dredging varies tremendously depending upon the geographic location, method of removal, and disposal as well as a host of other factors. Two dredging projects recently funded under the USEPA "Clean Lakes Program," are Morses Pond in Wellesley and Nuttings Lake in Billerica. A breakdown of costs for these two projects follows (Table 8-2).

Table 8-2. Dredging Case Histories

Name	Morses Pond	Nutting Lake
Town	Wellesley	Billerica
Lake area (acres	107	89
Spoils area (acres	1.3	11
Storage depth (ft)	20	10
Spoils area cost	49K	158K
Dredging (cubic yards)	74,000	360,000
Dredging method	Large Commercial	Small Purchase
COSTS: Mobilization	50K	--
Purchase	--	80K
Aux. Pump/Equip	--	81K
Operation/Maintenance	--	79K
Manpower	--	105K
Dredging	287.5K	335K
Raw $/yd^3	$3,83	$0.93
Land Acquisition	--	11K
Off-site disposal	74K	5K
Administration	--	25K
Permits, Eng., EPA Study	133K	79K
	$593.5K	$614.5K
Real Cost/yd^3	$8.02	$1.71

The figures presented for Nutting and Morses show a wide range for hydraulic dredging costs. Utilizing a portion of the Pond for the spoils area with a hydraulic dredge, should place the unit cost of dredging at Straits Pond on the low end of the scale, perhaps in the vicinity of the $1.71 yd^3 reported at Nuttings Lake.

Based upon further examination of the costs associated with dredging projects reported in the literature, "dry dredging" with conventional excavating equipment may well be the least costly method. This dredging method assumes that the Pond can be lowered and that the sediments will dry and consolidate enough, such that bulldozers and other equipment can operate without getting bogged down. The consolidation of the sediment upon dewatering may well, in fact, appreciably reduce the volume of sediment that needs to be removed.

We have presented the foregoing discussion relative to dredging Straits Pond, for sediment removal is viewed by many as a "cure-all" for any waterbody plagued by weed and algae growths. We do not recommend dredging Straits Pond at this time. Without first reducing the nutrient load entering the Pond from storm runoff and malfunctioning septic systems, Straits would still be plagued by free-floating algae even after dredging was completed. Dredging alone, without improved water circulation or annual drawdown is not likely to control the midge nuisance either. The proposed, recommend drawdown should answer many questions pertaining to the feasibility and cost/benefit of "dry dredging" at some future time.

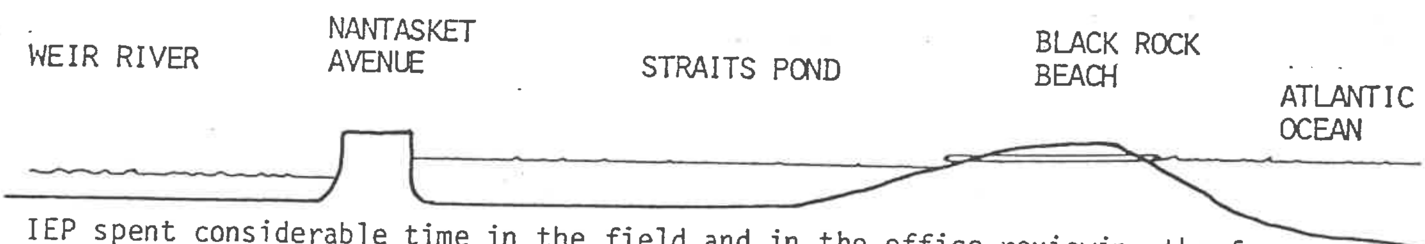
8.2.10 Flushing

The concept of increased flushing of a waterbody is founded on the premise that replacing poor quality, stagnating water on a fairly frequent basis with that of higher quality water will improve the quality of the waterbody - i.e., the solution to pollution is dilution. Where a major source of water quality problems is degraded inflowing water and stagnation, and where an adequate supply of additional water for flushing is available at a reasonable economic and environmental cost, then flushing may be regarded as a viable lake rehabilitation option. At Straits Pond such conditions, among others, do exist, thus lending appeal to a reclamation strategy which includes induced flushing.

Originally, Straits Pond was a tidal marsh, raising and lowering with the tide in the Weir River. This ensured complete replacement, or flushing, of the entire waterbody twice daily. Damming of the area in order to create the Pond restricted this option. Management as a pond and not a tidal marsh has reduced the amount of water available in flushing the Pond to the flow from the main tributary (Rattlesnake Run), groundwater inflow and land runoff. Instead of flushing twice daily, the Pond currently flushes once every 71 days.

It has long been suspected that Straits Pond suffers from a stagnation of sorts, owing to its reduced flushing time. While its current flushing rate is not exceptionally slow for an inland fresh water lake with a fairly small watershed, brackish water and highly enriched sediment conditions at Straits coupled with the slow flushing rate and amount of incoming nutrients, makes water quality and nuisance weed and insect conditions uninhabitable for most life forms and almost unbearable for abuttors.

One solution that has been cited repeatedly is creating an opening to the ocean through which incoming, relatively clean salt water would enter at high tide. It was assumed that due to the lag time in tidal elevations in the Weir River, a natural gradient would be established wherein on a rising tide ocean water would flow into Straits, through the Pond and empty into the Weir River. Below is a conceptualized sketch of this idealized situation.



IEP spent considerable time in the field and in the office reviewing the feasibility of this seemingly ideal solution and variations thereof. Relative elevations were measured by transit at various times during several tidal cycles, tide charts were studied, water quality data gathered, geological and land use conditions examined.

It was concluded that this ideal situation does not occur for a long enough time period to allow a significant amount of water to enter from the Atlantic Ocean and flow, by gravity, through the Pond and out the Weir River. The time lag between the ocean and the Weir is not enough to allow adequate flushing by gravity, alone (see Figure 8-1).

Several further problems also add difficulty to implementation of a flushing alternative. Initially, the elevation of Straits Pond is crucial. Storm drain systems, septic systems, basements, etc. have been established around the Pond based on an elevation of between 3 and 4 feet MSL of the static water level in Straits. Therefore raising of the Pond is not possible without first lowering it. Tides cannot be allowed to enter Straits on an unchecked basis due to these elevational restrictions. Lowering of the Pond in its current state, however, also presents problems particularly in summer, due to odors generated from the exposed sediments and decaying vegetation. Summer, however, is the time when flushing would be of most benefit to the Pond.

Other problems involve the engineering and construction costs of a conduit to the ocean. Any option where continuous flushing by either gravity or pumping is examined, favors an opening at Black Rock Beach. This particular area, however, is underlain by shallow bedrock and is a very high energy environment, open to northeast storms. Any intake structure at Black Rock would have to be specially designed and constructed to meet these conditions. An opening at Gun Rock would be preferable from the viewpoint of increased protection, however, bedrock is still a concern as is the amount and density of development between Gun Rock and the Pond.

Variations of the gravity flushing option were also considered. These include the use of pumps, flushing by the Weir River only, and a gradual lowering and fill-up of the Pond through several tidal cycles. The various flushing options considered are outlined below.

Alternative 1: Gravity Flushing

This would include construction of a conduit to Straits Pond from the Atlantic Ocean at either Gun Rock or Black Rock. The existing tidegate (manually operated) at the Weir River would not be altered except to assure dependable operation.

There is typically a 15 to 30 minute time lag from high tide at the ocean to high tide at the Weir River tidegate. The theory behind the operation of this system is that the time lag would create a hydraulic gradient from the ocean through the Pond and to the River, thus effecting a flush by flow through of the ocean water.

As a result of the time lag, the ocean water elevation would only be 0.4 to 0.7 feet higher than the River during the flood phase of the tide cycle. The conduit could effectively introduce ocean water to the Pond during the high tide phase, yet the gradient to the River would not be enough to allow outflow. Flooding
* of Straits Pond would result. Hence, this is not a feasible alternative.

Alternative 2: Two-Stage Flushing by Existing Tidegate

By manual operation of the existing tidegate (no conduit from ocean), Straits Pond could be drawn down during low tide phases and filled to normal elevation during high tide phases. The Weir River would serve as the sole source of exchange water.

The hydraulic effectiveness (i.e., the ability of the tidegate to drawdown and fill substantial water volume) of this system is highly dependent upon the magnitude of the tide range during the period of operation. Lunar phases (primarily lunar) create alternating cycles of higher high tides with lower low tides (spring ranges) and lower high tides with higher low tides (neap ranges). Figure 8-2 shows these fluctuations with respect to the normal Straits Pond surface elevation of 3.0+ feet MSL. Substantially greater volumes of water can be exchanged during the spring ranges, occurring semimonthly, than during the neap ranges due to the high head elevations. In addition to the phases of the moon, its distance from the earth causes tidal magnitude fluctuations on a 28 day cycle. Tides of decreased range are experienced when the moon is in apogee (farthest from the earth) and tides of increased range occur with the moon in perigee (nearest to the earth). Therefore, drawdown and fill-up of Straits Pond can be accomplished most rapidly during spring and perigean tidal range periods.

The rate of natural inflow to the Pond of runoff waters from within the watershed will also have a large influence on the time required to flush the Pond. Drawdown can be completed more rapidly during dry periods.

This alternative is the most economical because it does not require the construction and manual operation of any other outlet-inlet structures. Effective flushing could be accomplished over several days during periods with large tidal ranges. The drawback to this system is the water quality of the Weir River water during the flood cycle. Although hydraulically feasible, Straits Pond would be flushed with Weir River water which has been shown to be of fair or poor quality. Additionally, since this involves a two-stage process with drawdown being required prior to inflow, the Pond sediments would be exposed during the drawdown periods. This exposure could lead to odor problems during the summer, worse than currently experienced. Dredging of the sediments may be necessary prior to implementation of this alternative. Due to these compounded short comings, this alternative is not recommended at this time. However, if a flushing alternative is later pursued, this option should be attempted before an opening is made to the ocean, due to the relative costs involved.

Alternative 3: Two-Stage Ocean Flushing

A manually controlled conduit to Straits Pond would be constructed at either Gun Rock or Black Rock. The Pond would be drawn down during low tide periods by discharging water through the existing Weir River tidegate. The discharged volume would then be replaced by ocean water through the conduit during high tide periods.

By manipulation through tide cycles, this system would create an artificial hydraulic gradient and could effectively replace Pond water with ocean water of high salinity and better water quality. Gun Rock would be the preferrable site because it would allow greater areal flushing of the Pond and the conduit structure would be more protected from wind and wave action than at Black Rock.

The primary drawbacks to this system are the construction costs of the conduit (inflow) structure and operational costs of control of both inflow and outflow structures through tide cycles. Displacement of one or more homes may also be required in order to effectuate this alternative. Additionally, dredging may be necessary to alleviate odor problems as cited with Alternative 2. Similarly, again flushing would be most effective (i.e., greatest volume exchange) during spring and perigean tide range periods. In summary, this alternative is effective and feasible, yet costly. While this may be the best option for improving * water quality within Straits Pond, cost and operational problems prevent this option from being recommended for initial implementation.

Alternative 4: Flushing by Ocean Inflow and Pumped Outflow

This system would also permit inflow through a conduit from the ocean, yet outflow would be accomplished by pumping Pond water into the Weir River.

One advantage to this system is that the outflow is not dependent on tide cycles. Pumping could continue constantly regardless of the elevation of the Weir River. The existing tidegate could remain closed except in preparation for storm floods. Also, since this is not a two-stage process (drawdown not required) dredging may not be necessary as with Alternative 3.

Under this alternative flushing would be slower than with Alternative 3. Inflow from the ocean would be less because of the lesser head elevations at the conduit and the outflow rate would be limited by the capacity of the pump. The pumping capacities needed to discharge a 2-foot volume of Pond water are specified in Table 8-3.

Table 8.3. Time Required to Drawdown of Fill-up a Two-Foot Volume of Straits Pond

Time (hours)	Required Discharge or Inflow* CFS	GPM
1	2212	993,000
2	1206	541,000
3	737	441,000
4	553	248,000
5	442	198,000
6	369	166,000
7	316	142,000
8	276	124,000
9	246	110,000
10	221	99,000
11	201	90,000
12	184	82,500
18	123	55,000
24 (1 day)	92	41,500
30	74	33,000
36	61	27,500
42	53	24,000
48 (2 days)	46	20,500
72 (3 days)	31	14,000
96 (4 days)	23	10,500
120 (5 days)	18	8,100
144 (6 days)	15	6,700

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This system is costly, requiring construction and operation at both the conduit from the ocean and the pump to the River. Although pumps with 20,000 GPM capacities are available, the purchase cost would be approximatley $100,000.00. The two pumps (1600 GPM combined capacity) currently owned by the Town of Hull, would require about two months to remove the 2-foot volume. Other problems associated with pumping include noise, energy requirements, and location and construction of the pumping facility. A discharge pipe would also have to be cited and laid under Atlantic Avenue.

The hydraulically preferable site for the inlet conduit would be at Black Rock to permit more complete areal flushing. Wave and storm energy problems at Black Rock further complicate the potential effectiveness and practicality of this alternative.

Alternative 5 - Flushing by Pumped Inflow and Outflow

This would involve pumped outflow to the Weir River as in Alternative 4 and pumped inflow from the ocean at Gun Rock or Black Rock.

This system could be totally independent of all tidal fluctuations if the pump inlet in the ocean is located where it would be submerged at low tide. Hence, it could operate continuously. Since no prior drawdown would be required, there would be no intensified odor problems associated with exposed sediments.

The drawbacks to this system are the purchase and operating costs of two high capacity pumps, the logistical problems of locating and constructing the pumps with intake and otuflow pipes, and pump noise.

As with Alternative 4, the Black Rock site for the ocean inflow pump would be hydraulically preferrable.

Should a flushing alternative be adopted as a reclamation strategy, it is recommended that flushing via the Weir River be first attempted due to the relative costs involved. It is felt that efforts to improve water quality within the Weir River basin will eventually prove fruitful, thereby removing poor water quality as an impediment to flushing of Straits Pond by the Weir.

9.0 SUMMARY AND RECOMMENDATIONS

Straits Pond is a brackish, eutrophic waterbody plagued by dense growth of aquatic vegetation and the release of noxious hydrogen sulphide gas during the summer. Furthermore, the bottom sediments provide rearing habitat for a large population of nonbiting midge larvae that are a nuisance to Pond abuttors upon emergence of the adults in late spring and summer. With these problems in mind, the preceeding report discusses the findings of the IEP study team and the Firm's recommended solutions to alleviate the aforementioned, undesirable conditions.

Field investigations of water quality, aquatic ecology, hydrology and land-use were performed by IEP scientists between May, 1979 and April, 1980. Both the Town of Hull and Cohasset along with the Massachusetts Office of Coastal Zone Management agreed that additional technical data was first necessary prior to implementing any of the reclamation techniques that may have been suggested in past reports. Although Straits Pond has been the focus of a great number of surveys and studies in previous years, the scope of these reports was largely limited to "one-day" biological surveys where the effects of eutrophication were described, however the origin and sources of the nutrient enrichment to the Pond were not identified. A successful, long-term lake or pond reclamation program usually necessitates both in-lake and watershed based strategies.

The extreme shallow water depth (avg. 3.3 ft.) of Straits Pond combined with the lack of inflowing water during the summer, means that even moderate inputs of phosphorus to the Pond will result in nuisance algal populations and poor water clarity. The permissible, annual phosphorus supply to Straits Pond in order to avoid eutrophic conditions was calculated to be 204 kg/yr yet the actual loading figures were modelled at 727 kg/yr. In other words, the current phosphorus inputs to the Pond exceed the permissible or desirable supply figures by a factor >3.5. The major sources of phosphorus to the Pond are surface water runoff from urban and residential development along with the discharge of untreated sewage from residential dwellings. The latter source was especially prevalent along the western shoreline where contaminated water from a storm drain continuously enters Straits Pond.

Water quality in the Pond reflects high nutrient concentrations and at certain times of the year, fecal coliform bacteria levels in excess of the state's class B standards. Inflowing water to the Pond from the Weir River, though not a great volume, was also of marginal quality, with moderate to high bacteria and nutrient concentrations the norm rather than the exception. Circulation of Weir River water to the Pond through the existing tidegate, may help to yield a slight reduction in the odor problem during the summer by replenishing the Pond with water of lesser temperature and a higher dissolved oxygen content. Based upon the available data, however, water circulation alone through the tidegate will not control either the midge or weed nuisance. The dominant vascular plant at Straits Pond (*Ruppia maritima* or widgeongrass) is tolerant of a wide range of salinity and is likely to obtain the bulk of its nutrient from the bottom sediments.

The midge larvae inhabiting the Pond would probably also survive even if improved circulation of water from the Weir River was achieved. However, it is unlikely that the midge larvae could withstand high salinity water (33-34 ppt) from the Atlantic Ocean.

In-lake weed/algae control techniques such as mechanical harvesting, nutrient inactivation, aeration, shading and biological controls have not been recommended for use at Straits Pond due to their: (1) inapplicability in brackish water situations,(2) high capital outlay, maintenance and operating costs, or (3) the short-term benefit to be derived versus potential adverse effects on non-target organisms. Hydraulic or mechanical dredging of the sediments utilizing ocean disposal or property off-site for the containment of the spoils material is not recommended, primarily due to its high cost and secondly because of potential problems with the high residual arsenic content of the sediments. Dry-dredging with conventional excavating equipment may be cost/effective at some future time after the proposed fall/winter drawdown provides information as to the extent of muck consolidation and potential to control the midge and vascular plant nuisances. Utilizing a portion of the existing Pond for the disposal of the spoils material seems attractive from the viewpoint of cost while mitigating impacts to water quality and aquatic life off-site.

Upon a thorough review of the available in-lake techniques, we feel that draining the Pond during the fall and winter has a high probability of killing the nuisance midge larvae and partial consolidation of the surface sediments. Exposure of the sediments to air may also possibly reduce the hydrogen sulphide odors emitted during the following summer. The effect of drawdown upon vasular plant growth (*R. maritima*) is not known, although an increase in weed density is unlikely. Drawdown is not apt to have a significant adverse effect upon finfish that may utilize Straits Pond for spawning or nursery habitat. However, more detailed fisheries inventory data would be desirable.

The bottom elevation of the tidegate and sluiceway should enable maximum drawdown of Straits Pond. Dredging or deepening the channel that leads to the Pond outlet, however, may be required to attain maximum lowering of the water level. Based upon our calculations, the Pond will refill, within approximately 33 days of closing the tidegate and sluiceway in mid-March. Cracks in the rock wall that house the outlet control structures may be an impediment to maintaining drawdown. We understand that the Hull DPW has received a proposal and cost estimate for correcting this problem. This should be effectuated.

Drawdown will also provide benefit for flood control during major storm events which, obviously, occur periodically. Exposure of the Pond bottom during the fall will enable clean-up of the lumber and miscellaneous debris washed into the Pond during the Blizzard of 1978.

It is not felt that flushing alternatives should be pursued at this time due to anticipated costs and the desirability of accomplishing other in-lake and watershed management objectives prior to flushing. Improvement in Weir River water quality may increase the potential effectiveness of using this source for flushing. An alternative which uses the Weir for flushing would be substantially less costly than one which requires construction of a conduit to the ocean or one which makes essential the use of pumps.

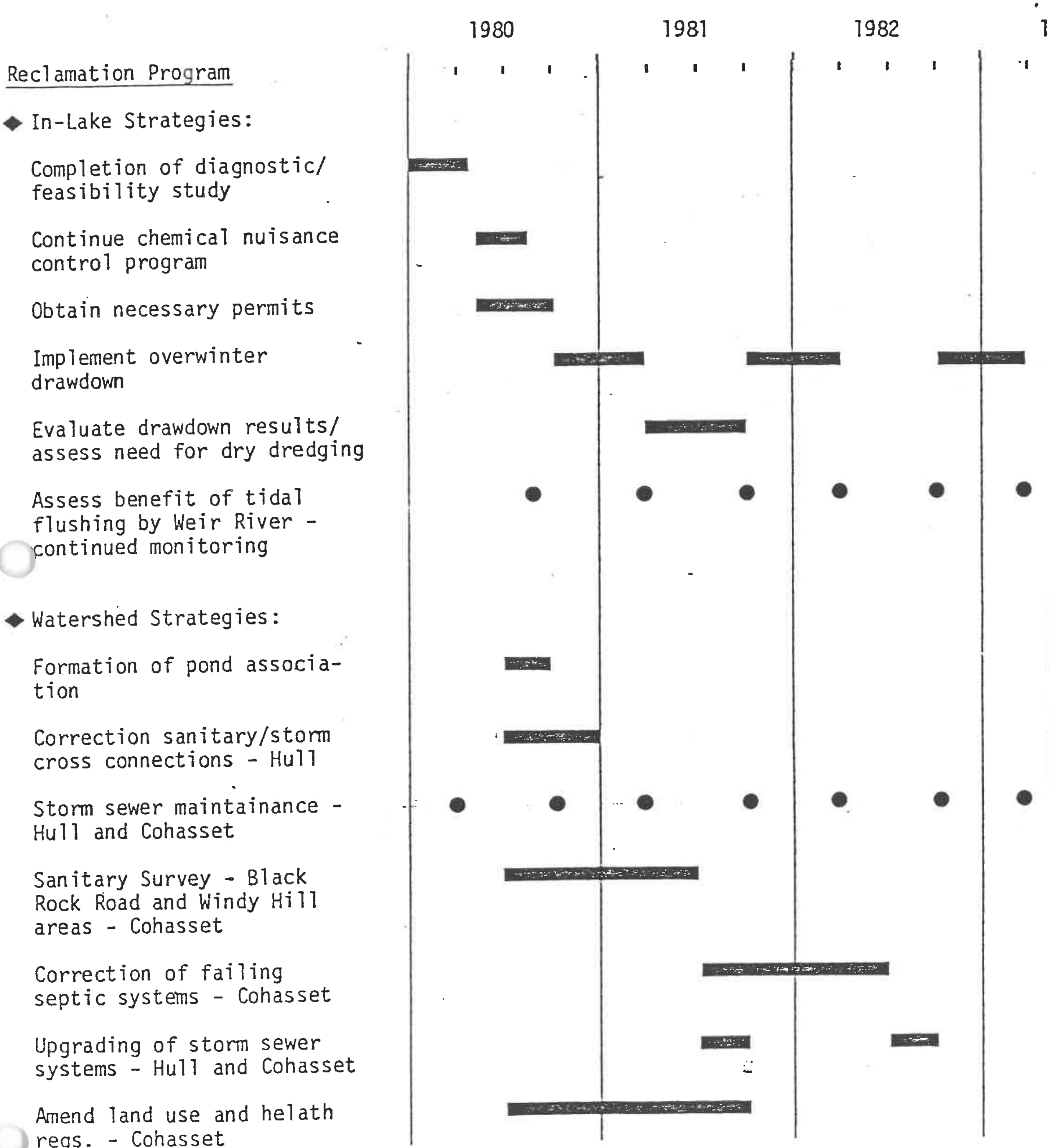
Watershed management options should, again, proceed from least to more costly solutions. Initiation of an active watershed or homeowners group is possibly most critical in keeping a lake rehabilitation program moving. This should be undertaken even if it requires initiation by local officials.

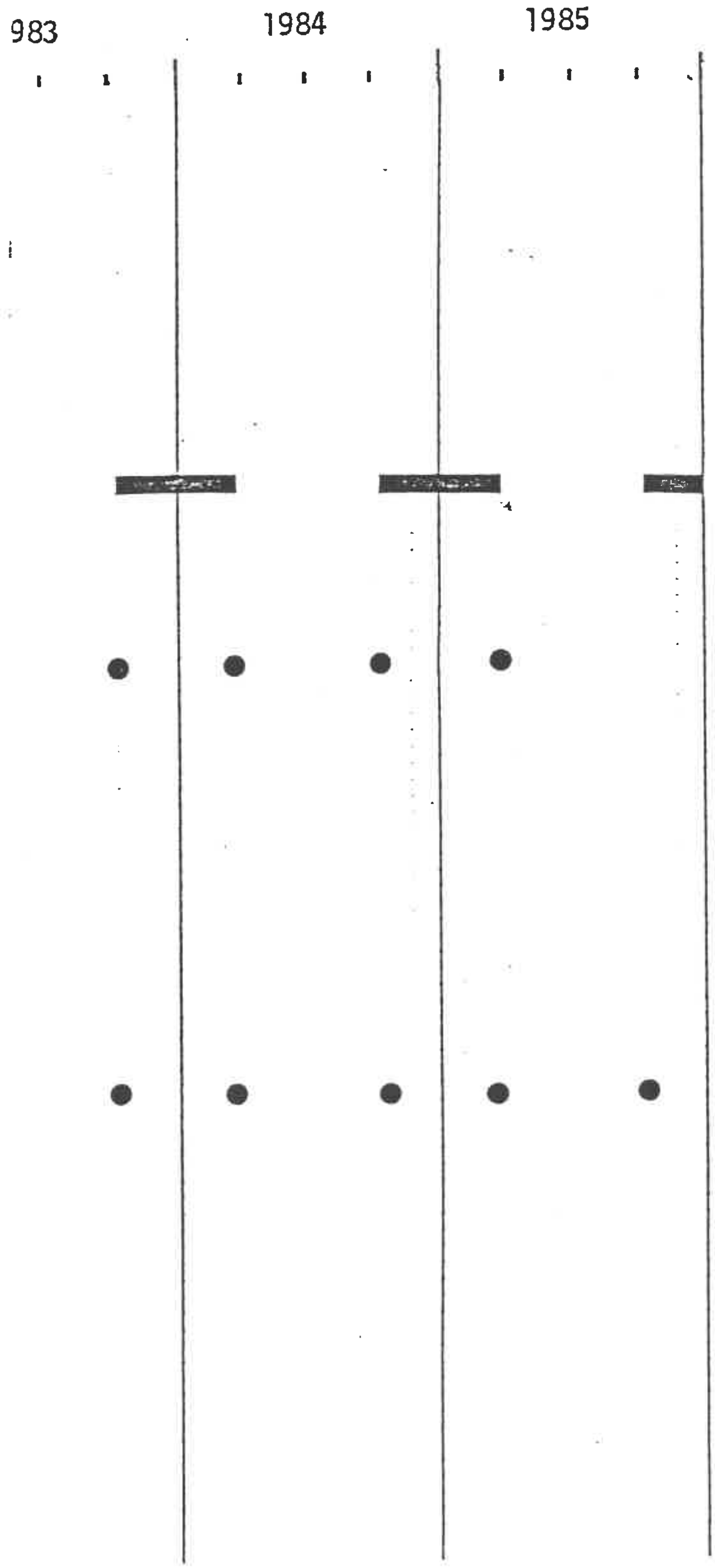
In Hull, separation of the cross connection on Richards Avenue has highest priority. Installation of functioning catch basins along Atlantic Avenue and continued maintenance of the storm drain systems along Atlantic Avenue should next be undertaken.

In Cohasset, amendments and additions to local land use and health regulations should be effectuated. Regular maintenance of storm drain systems and sweeping of Jerusalem Road and adjacent side streets should be continued.

Continued monitoring of storm runoff waters and follow-up sanitary surveys in areas expected of having failing subsurface sewage disposal systems should be undertaken. Regular maintenance of all septic systems within the watershed should be ensured. Replacement or upgrading of failing systems should be required. Enlargement of undersized drain systems should also be undertaken. Table 8-4 summarizes the proposed implementation schedule.

Table 8.4. Straits Pond - Recommended Implementation Schedule

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