ANNUAL REPORT
for
WHITMAN'S POND PROJECT 1997
TOWN OF WEYMOUTH, MASSACHUSETTS

Prepared by: Ambient Engineering Inc.
85 Main Street
Concord, MA 01742

and

Ocean Arks International
233 Hatchville Road
East Falmouth, MA 02536

February 1998

AMBIENT

ANNUAL REPORT
WHITMAN'S POND PROJECT 1997

TABLE OF CONTENTS

N

0 1/2 1 MILE

NOT A SURVEYED PLAN - ESTIMATED SCALE

FIGURE 1 SITE LOCATION

WHITMANS POND
WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT
ENGINEERING

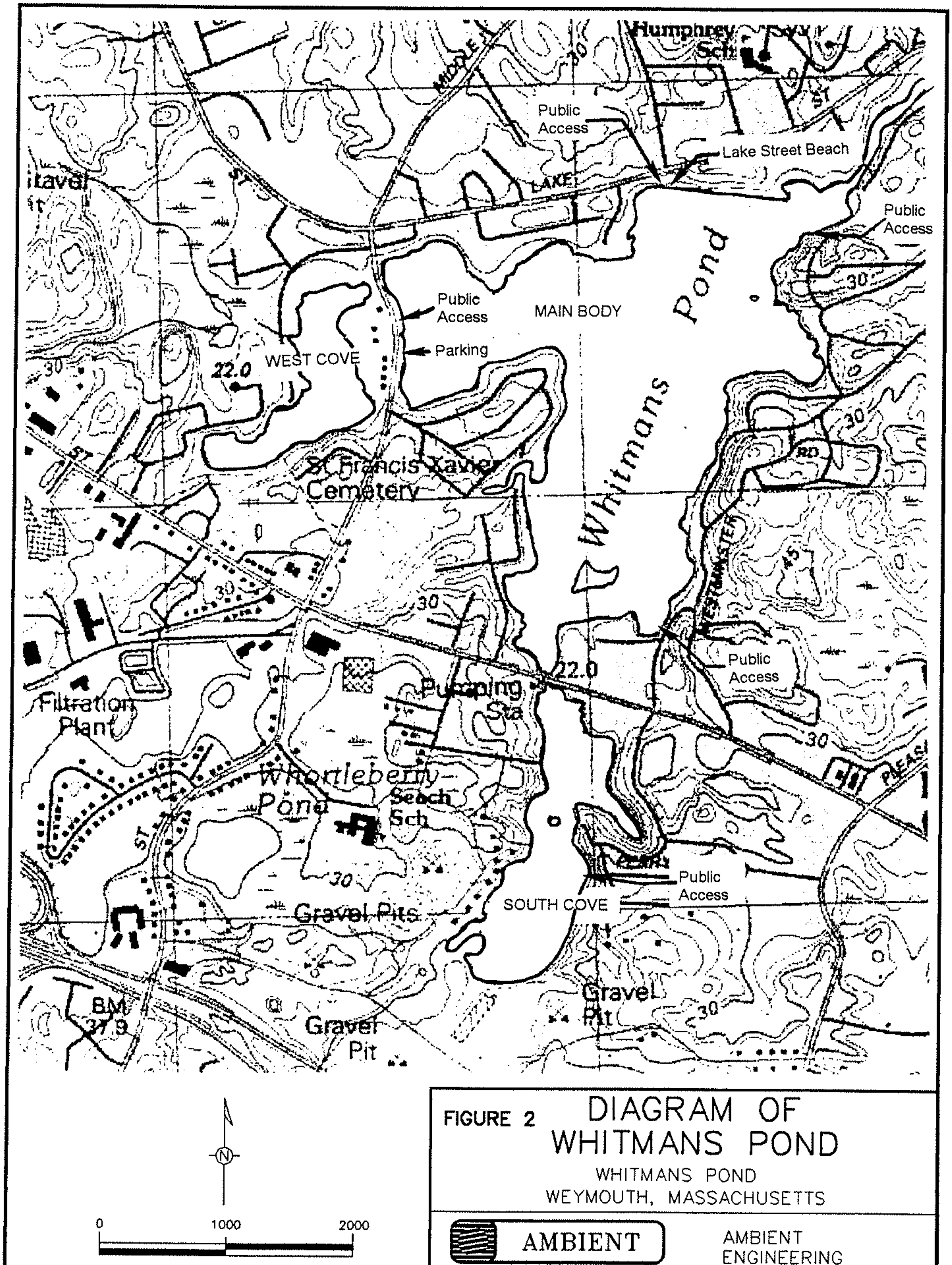
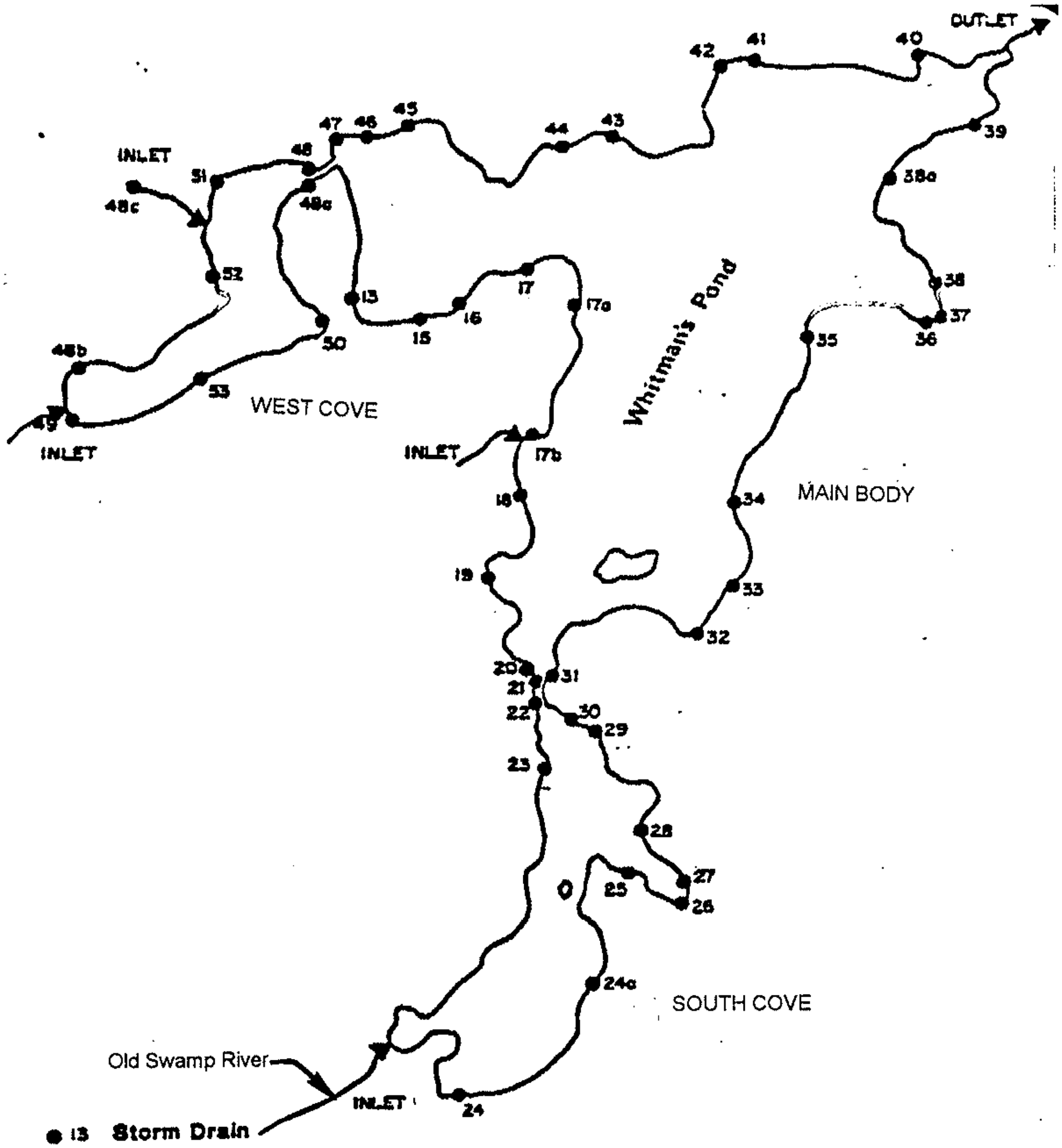


FIGURE 2 DIAGRAM OF WHITMANS POND

WHITMANS POND
WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT ENGINEERING



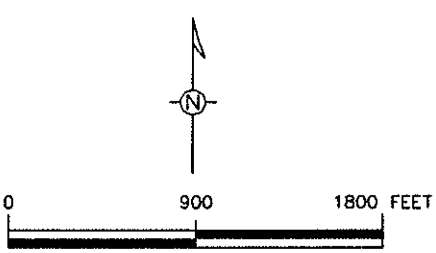


FIGURE 3 STORMWATER OUTFALL LOCATIONS

WHITMANS POND
WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT ENGINEERING

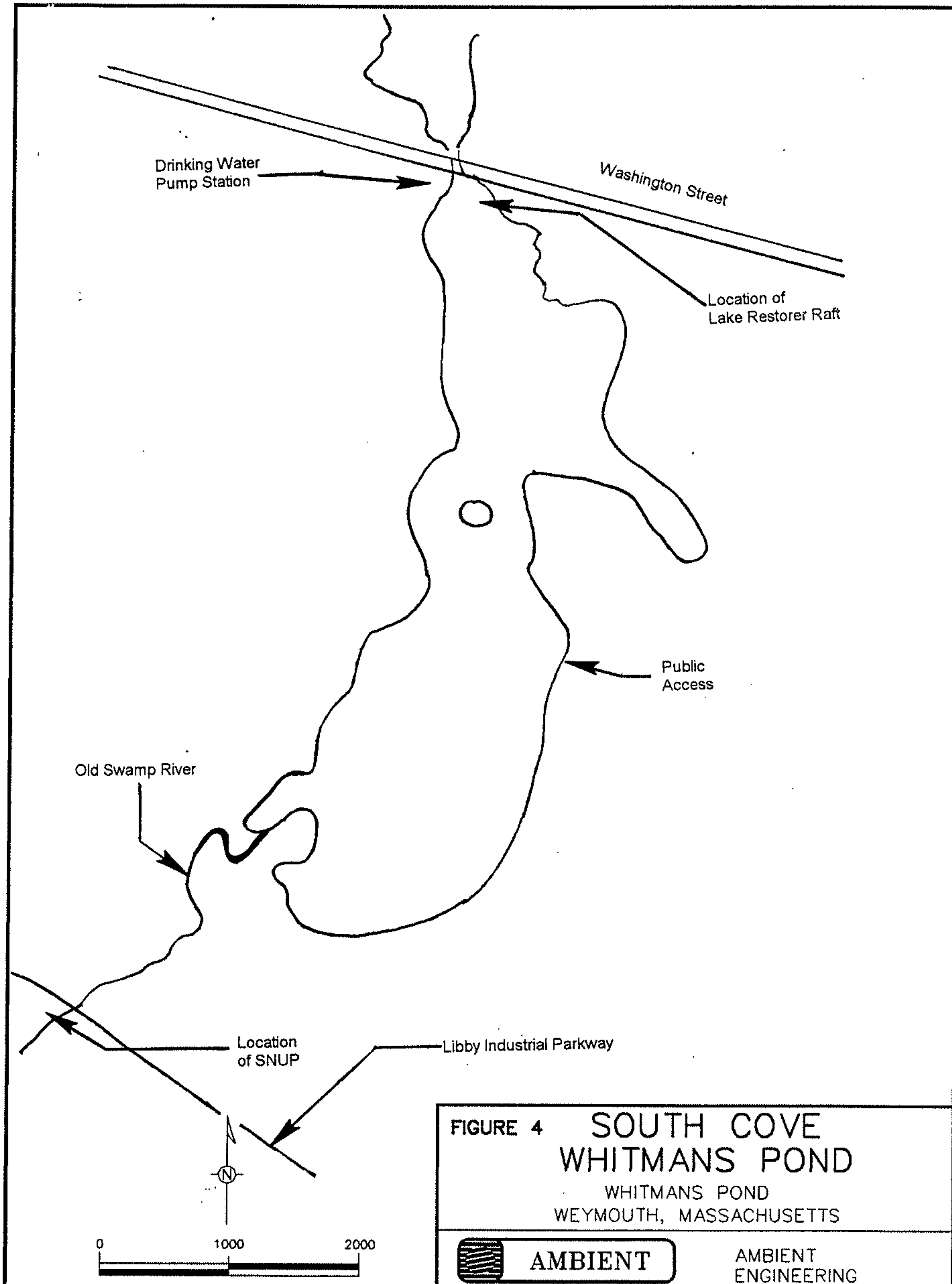


FIGURE 4 SOUTH COVE WHITMANS POND

WHITMANS POND
WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT
ENGINEERING

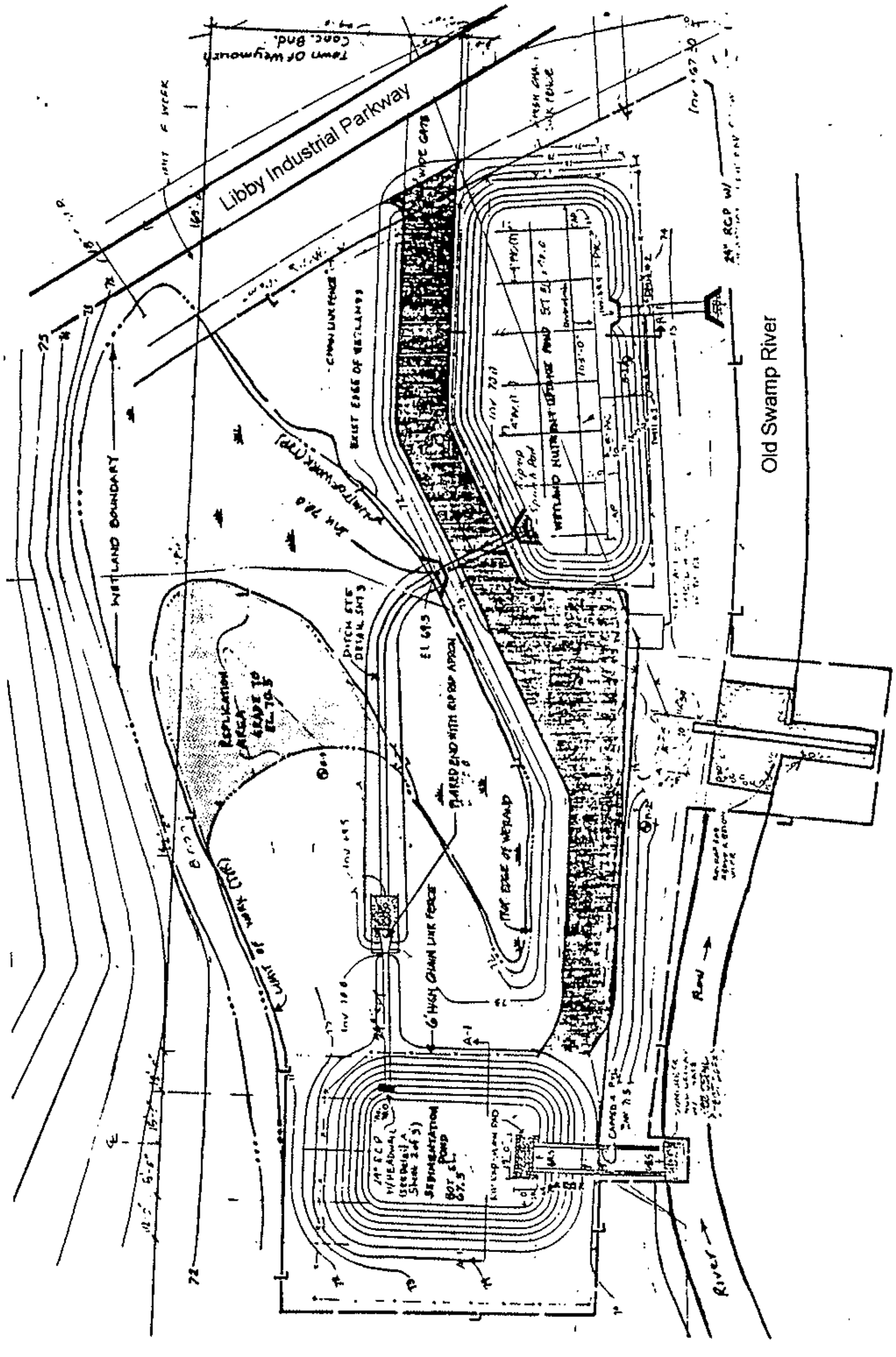


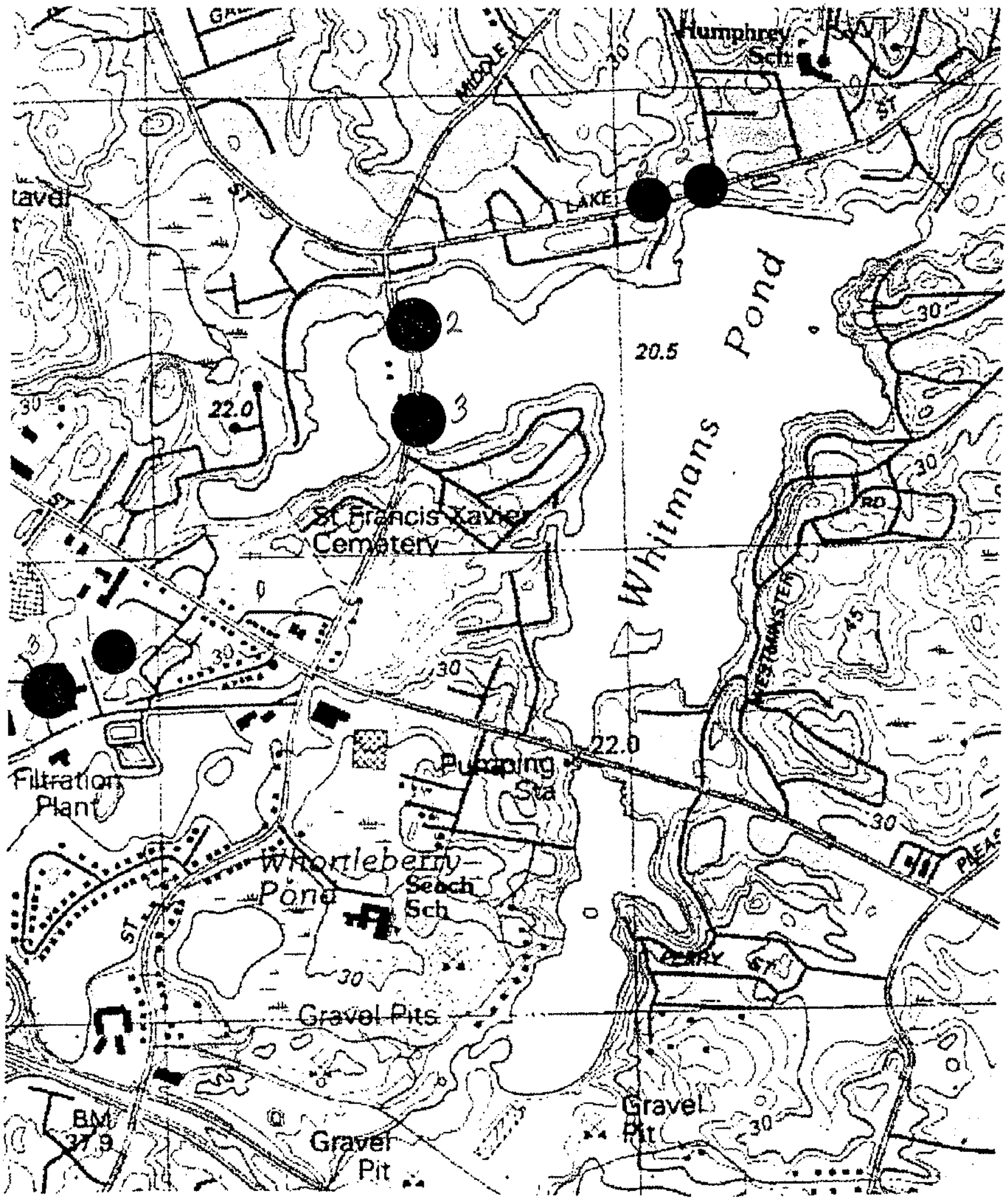
FIGURE 5 SEDIMENT NUTRIENT UPTAKE POND (SNUP)

WHITMANS POND

WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT ENGINEERING



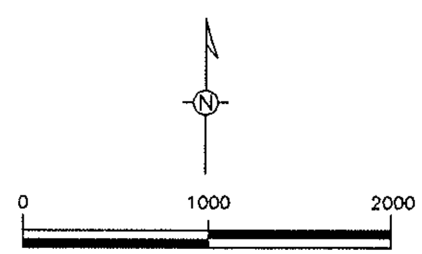


FIGURE 6 LOCATIONS OF STORMWATER TREATMENT INSERTS

WHITMANS POND

WEYMOUTH, MASSACHUSETTS

AMBIENT

AMBIENT ENGINEERING

ANNUAL REPORT
WHITMAN'S POND PROJECT 1997

1. EXECUTIVE SUMMARY

Whitman's Pond is a publicly owned water body located entirely within the Town of Weymouth Massachusetts. It covers an area of approximately 205 acres in a residential part of the town and is considered a significant resource. The pond consists of a large main basin and two shallow sub-basins designated as the South Cove and the West Cove . The main basin and the West Cove are listed as a Class "B" water bodies. The South Cove supplements the drinking water reservoir for the Town of Weymouth and is listed as Class A. The main basin is classified as an emergency water supply.

In addition to a wide range of recreational activities, Whitman's Pond also supports the second largest herring run on the eastern seaboard. Fish ladders on the Back River allow the herring to swim from Hingham Bay into the pond to spawn. Figure 1, Whitman's Pond, shows the location of the entire pond in the Town of Weymouth and its associated watershed.

In recent years the pond has grown eutrophic and the depth of silt on the bottom of all three sections of the pond has increased. Beach closings have increased during the past few summers due to high bacteria counts, and reported cases of "swimmer's itch", a water born parasite.

Ambient Engineering and Ocean Arks International were contracted by the Weymouth Department of Public Works to conduct a series of pond restoration projects. These projects focused on the South Cove and Main Body of Whitman's Pond. Separately, the Town engaged Lycott Environmental Inc. for herbicide application in the West Cove.

Work conducted by Ambient Engineering/Ocean Arks was in the following areas:

1. <u>Pond Treatment</u>
   Ocean Arks constructed, operated and monitored a "Lake Restorer" raft to biologically remove nutrients from the South Cove. The Ocean Arks report, including information regarding the Lake Restorer and data collected by Ocean Arks, is presented as Attachment A.

2. <u>Stormwater Management</u>
   Ambient Engineering wrote a Stormwater Management Plan for the South Cove watershed. The plan prioritized stormwater outfalls in terms of their contributions to stormwater contamination. Recommendations were made regarding suitable measures and devices.

3. Community Planning
Ocean Arks and Ambient Engineering participated in meetings with the local committees and associations as well as the Weymouth Department of Public Works. Articles regarding the projects were printed in local newspapers.

4. Sediment Nutrient Uptake Pond Management and Optimization Plan
Ambient Engineering conducted an audit and historical review of the planning, construction and operation of the of Sediment Nutrient Uptake Pond (SNUP) located on the Old Swamp River above the South Cove. The plan described the history and thought that went into the SNUP's original design as well as the modifications made. Adjustments to current operation of the SNUP were recommended to optimize its sediment and nutrient removal capabilities. Maintenance checklists and other information were also provided.

5. Grant Proposal and Agency Coordination
Several grants were pursued regarding Whitman's Pond. Ambient Engineering aided the Weymouth DPW in receiving Department of Environmental Management (DEM) Lakes and Ponds grant. The grant originally focused on implementing the recommendations of the South Cove Stormwater Management Plan. The DEM, however, determined that because funds were earmarked for recreational waters, and the South Cove was a drinking water supply, the grant could not be used on the South Cove.

   Ambient Engineering conducted an outfall survey on the main body of the pond. In conjunction with the Weymouth DPW, 13 catch basins were chosen, and stormwater treatment devices were installed into them. The evaluation of this project will be conducted in the spring of 1998.

   As part of an already existing CBGB Grant, Ambient Engineering conducted an evaluation of two catch basin stormwater treatment devices installed on Skelly Avenue. These were a different type of device than those installed as part of the Lakes and Ponds Grant.

6. Assessment and Annual Report
This report, issued after the first year of the program, summarizes activities conducted, discusses observed pond conditions and documents the progress made thus far. Based on observations, this report also makes recommendations for future steps to improve pond conditions.

Ambient Engineering was the lead contractor on this project and Ocean Arks International a subcontractor. However, since Ocean Arks' portion of the project was build, operate and maintain the Lake Restorer, each company focused on different aspects of the project. This report is presented in two Parts. The first, written by Ambient Engineering, discusses the portions of the contract covered by Ambient. The second part, written by Ocean Arks International discusses the Lake Restorer located in the South Cove.

2. BACKGROUND

2.1 Description of Whitman's Pond

Whitman's Pond covers an area of approximately 205 acres in a residential part of Weymouth and supports a large variety of activities and plant and animal species. It is classified as a "Great Pond" and is therefore owned by the State of Massachusetts. The Town of Weymouth, through the Board of Public Works in 1966, took ownership of the water rights, dams and flowage of the lake.

The pond consists of a large main basin and two shallow sub-basins. The southern sub-basin, called South Cove, supplements the drinking water reservoir for the Town of Weymouth. As necessary, water is treated and pumped over to Great Pond which is the town's main reservoir. The main basin is classified as an emergency water supply. The location of Whitman's Pond in Weymouth is shown in Figure 1. A diagram of the pond itself is provided in Figure 2.

The pond provides a wide range of recreational activities. The shoreline of the pond is mostly residential. There are four public access points, public parking and a public beach on Lake Street. The town maintains one public beach on the lake, which is shown in Figure 2. There is no resident requirement and no fees charged for parking or access. A gravel public boat ramp for small boats is available on Middle Street. Canoes and row boats are generally also carried to the water over the beach or at one of four public access points. Fishing and birdwatching are also activities supported by the pond, as is ice-skating, ice-fishing and ice-boating in the winter.

Whitman's Pond also supports the second largest herring run on the eastern seaboard. Fish ladders on the Back river allow the herring to swim from Hingham Bay into the pond to spawn. These ladders are well marked by signs and school groups use the pond as an educational resource.

Over the last several years the pond has grown eutrophic and the depth of silt on the bottom has increased. The beach has been closed during the past few summers due to high coliform bacteria counts, and "swimmer's itch," a parasite that now persists in the pond. Aquatic weeds choke some areas of the pond, and anoxic conditions exist at the lower depths. Overall, the water quality has been significantly degraded by development over several decades.

2.2 Previous Studies

In the early 1980's studies were conducted by the Massachusetts Department of Environmental Protection's (DEP) Division of Water Pollution Control and by Metcalf and Eddy, Inc. Both studies discovered that phosphorus was the major contributor to the algal blooms in the pond. The introduction of sediment containing heavy metals, oil and grease from stormwater releases were also considered a detriment to water quality, but were regarded as less important than phosphorus. Metcalf and Eddy (M&E) employed a nutrient budget mathematical model based on estimated annual delivery of phosphorus to the pond from tributaries and stormwater runoff. The major source of phosphorus delivery to the pond was determined to be via the Old Swamp River at the southern end of South Cove.

The M&E study utilized a nutrient budget mathematical model which estimated that the Old Swamp River contributes 60 % of the total phosphorus loading to Whitman's Pond. The study also the amount of total phosphorus attributable to direct storm drain runoff to Whitman's Pond to be 54 kilograms or 15 % of the total. Recommendations made in the M&E report were largely directed towards controlling the delivery of phosphorus from the Old Swamp River inlet to Whitman's Pond.

2.3 Sediment Nutriment Uptake Pond (SNUP)

In accordance with the reports' recommendations, the Town of Weymouth's Planning Board authorized the construction of a Sediment Nutriment Uptake Pond (SNUP) at the Old Swamp River's entrance to South Cove. The recommended SNUP was designed to remove nutrients and sediment from the Old Swamp River before the water reached South Cove. This was the first engineering project undertaken to improve water quality in Whitman's Pond.

2.4 Nonstructural and Source Controls

Also recommended by the M&E plan were the enactment of non-structural controls and "source controls" to reduce phosphorus delivery by the storm drain system by 25%. The non-structural controls consist of a litter control program, control of fertilizer application, public education programs, improved enforcement of construction site erosion control, and land use zoning . The recommended "source controls" consist of more frequent street sweeping, more frequent catch basin cleaning, use of sedimentation basins and stormwater retention ponds as well as vegetative buffers for new construction.

With the combined phosphorus removal efficiencies of the SNUP and the non-structural and source controls on phosphorus delivery in storm drain runoff, it was proposed that the annual maximum total in-lake phosphorus concentration could be reduced from 0.6 to 0.4 milligrams per liter. This reduction of the phosphorus concentration in the lake would be adequate to prevent summer algae problems.

The combined SNUP and proposed controls on phosphorus entering storm drains were intended to reduce the total loading to Whitman's Pond by approximately 33 % from 365 kilograms per year to 241 kilograms per year.

3. AMBIENT ENGINEERING STORMWATER MANAGEMENT PLAN

The South Cove of Whitman's Pond became the focus for stormwater control measures because the Town's secondary water supply source intake is located in this part of the lake. The surface area of the South Cove is approximately 33 acres. The subcatchments drain directly to South Cove through 10 identified discharge pipes and encompass an area of approximately 95 acres. Approximately 80 acres, consisting largely of moderate density residential land use, are drained by the stormwater catchment system. The remaining area of approximately 15 acres drains to South Cove through surface runoff which is not collected by a formal drainage system.

→ WHICH ONES?

Previous reports noted that in addition to nutrients, the influx of sediment, heavy metals and oil are also identified as significant pollutants in stormwater discharged to South Cove. Suspended sediment contributes to the creation of depositional deltas as well as increased turbidity within South Cove. All of the above negatively impact the water quality of the pond. ←

3.1 Determination of Stormwater Pollutant Contribution

Based on the results and background provided by previous studies, Ambient Engineering produced a Stormwater Management Plan for the South Cove. The estimates of nutrient loading in the M&E report were based on results taken from two sampling locations during two storm events. Ambient Engineering utilized two alternative approaches to estimate the phosphorous concentrations in stormwater runoff. An estimated 15% of the phosphorous loading to the South Cove was reportedly due to stormwater runoff.

The first utilized the "Simple Method" for pollutant runoff calculation developed by Schueler (1987) and incorporated the national average of phosphorous in stormwater determined the EPA's National Urban Stormwater Program. The M&E runoff concentration is considerably less than the national average. Runoff calculations were based on an estimated average lot size and an estimated percentage of impervious area. This method determined that direct stormwater runoff contributes 61 % of the total phosphorus loading.

(SEE REPORT)

→ NO TESTING DONE TO CONFIRM THESE NOS. !

An additional set of calculations were performed using a literature value for the runoff coefficient based on the land use in the watershed. This alternative approach predicted the loading of phosphorus from storm drain systems to be 36% of the total. Both alternative approaches estimated a much greater portion of phosphorous entering the pond to be due to stormwater.

3.2 Determination of Targeted Outfalls

The South Cove watershed area was divided into subwatershed areas corresponding to the stormwater outfall pipes which drained them. Drainage areas were estimated using the Town "Drain Atlas", in conjunction with USGS topographic maps. Land uses were estimated from the MASS GIS land use maps of Weymouth. After calculating a phosphorus loading each storm drain entering the South Cove, storm drains leading to outfalls No. 23 and No. 29 were shown to be the largest sources.

ASSUMPTION (WHAT SUPPORTS IT ?)

Although sediment loadings were not estimated due to lack of available data, it is expected that drainage catchments with high phosphorus loadings would also have high amounts of sediment. The two storm drains were prioritized for possible implementation of sediment control structures on the basis of proximity to the potable water intake structure, and relative

magnitude of phosphorus loading. The locations of Outfalls No. 23 and 29 are shown in the diagram of Whitman's Pond, Figure 3.

3.3 Recommended Stormwater Control Technologies

At the time M&E developed its recommendations for Whitman's Pond, the technology for addressing phosphorus in stormwater was limited to filtration or sedimentation holding basins with the capacity to retain a "design storm" usually set at 0.5 inch of runoff. Current technology for pollution attenuation of stormwater runoff from urban areas can be divided into two basic approaches:

- Storm drain inserts which can be installed in existing catch basin inlets
- Sedimentation-enhancing precast in-ground concrete units which minimize the re-suspension of trapped material during large storms. This is sometimes referred to as an end-of-pipe approach.

Ambient Engineering researched and evaluated several different products of each approach as well as possible future modifications. While the end-of-pipe devices appeared showed promise, the cost of the purchase and installation of an appropriately sized unit was greater than the $20,000 allotted for the project. Suntree Isles storm drain inserts were recommended for installation in catchbasins leading to outfalls No.23 and No.29.

4. AMBIENT ENGINEERING SNUP MANAGEMENT AND OPTIMIZATION PLAN

Metcalf and Eddy in 1986 concluded that approximately 60% of the phosphorous loading into the Pond entered through the Old Swamp River via the South Cove. This was determined to be the largest point source of phosphorous into Whitman's Pond. The report recommended that a Sediment and Nutrient Uptake Pond (SNUP) be constructed on the river to capture and retain some of the nutrient, primarily phosphorous, and sediment before it entered the South Cove. The original design was meant to remove 50% of the phosphorus loading being delivered to South Cove by the Old Swamp River.

Whitman and Howard designed the SNUP and conducted an extensive approval process with various state and federal agencies. A natural wetland already present in the site chosen for the SNUP would have to be partially filled, and an adjacent are converted into a new wetland. A net gain of approximately 2,000 ft^2 of wetland would be produced. Approval for the project was rejected the US EPA on the grounds that a natural wetland would be compromised.

The SNUP was quickly redesigned and considerably scaled down. Adjustments to the design were made with respect to the hydraulic capacities of the basins that could be created with the available land. The modified design incorporated the existing wetland as an overflow holding area.

4.1 SNUP Design and Construction

Whitman and Howard designed a man-made wetland THAT was to use settling and natural plant systems to remove phosphorous and other nutrients from the Old Swamp River. A series of three basins comprised the wetland; one sedimentation basin followed by two successive shallow basins filled with wetland plants. A site was chosen adjacent to the Libby Industrial Park approximately 1/4 mile upstream of a town drinking water well and the mouth of the river at South Cove. The series of man-made basins or ponds was collectively referred to as the Sediment Nutrient Uptake Pond, or SNUP. Figure 4 shows the location of the SNUP in relation to the Old Swamp River and South Cove.

The EPA rejected the design of the SNUP in the final portion of the approval process. A natural wetland already present in the site chosen for the SNUP would have to be partially filled, and an adjacent area converted into a new wetland. A net gain of wetland area would be produced but approval was rejected on the grounds that a natural wetland would be compromised by the installation of an man-made wetland, even if the man-made wetland would be larger.

Whitman and Howard redesigned the SNUP to bypass the existing wetland as much as possible. Instead of two artificial wetlands, only one would be built. A channel through a portion of the natural wetland was designed to carry water from the sedimentation basin to the artificial wetland. At times of high flow the channel would overflow and the natural wetland would then be used for storage capacity. Both the sedimentation basin and the remaining wetland were scaled down in size. Adjustments to the design were made with respect to the hydraulic capacities of the basins that could be created with the available land. A diagram of the SNUP as constructed is presented in Figure 5.

The SNUP was originally designed to remove 50% of the phosphorus loading being delivered to South Cove by the Old Swamp River. No study was conducted to assess the effectiveness of the SNUP after it was built. Although the area has been cleared of trees and vegetation at times, no scientific evaluation has been conducted to assess the effectiveness of the SNUP, or regular maintenance program incorporated.

4.2 Ambient Engineering Investigation and Recommendations

Ambient Engineering conducted research into the original design and the actual design of the SNUP and evaluated the dimensions of basins, hydraulics, settling enhancements and vegetation selected. Current practices and operation were also considered. Very little documentation is available pertaining to the SNUP as it was constructed. When possible, telephone interviews were conducted with informed parties to gather relevant information.

The SNUP Management and Optimization Plan was written as an operational document. It incorporates the design history, the effects of changes made to the original design, and the problems which resulted. The Plan then recommends changes to the operation of the SNUP to enhance the removal of sediments and nutrients from the Old Swamp River. The introduction of different plant species is discussed, and a maintenance schedule and checklists are provided. Since there has been no comprehensive evaluation of the SNUP's effectiveness in removing sediment and nutrients, the Plan also recommends an influent/effluent study be undertaken.

WATER (?)

Copies of the Management and Optimization Plan were distributed to the Department of Public Works, Town Engineer, Sewer Department, Whitman's Pond Committee, Whitman's Pond Association and the Weymouth Planning Board.

SAME ?

5. GRANT PROPOSAL AND AGENCY COORDINATION

During 1997, both Ambient Engineering and Ocean Arks International pursued several grant opportunities pertaining to the restoration of Whitman's Pond:

- Department of Environmental Management Lakes and Ponds Grant
  Ambient Engineering assisted the town in applying for this matching grant to install the recommendations of the Stormwater Management Plan. The grant was awarded and implemented as discussed in Section 5.1

- Costal Zone Management Coastal Pollution Remediation (CPR) Grant
  Ambient Engineering assisted the town in applying for this grant to install and end-of-pipe stormwater treatment device at outfall No. 47 along Middle Street. The previous year this grant was awarded for the installation of such a device on the Back River. Upon further investigation of the location the water table was found to be too high to allow for the hydraulics of the unit. The project was canceled and the grant rescinded.

  The Ambient Engineering application therefore requested funding for a siting and feasibility study to be conducted at outfall No. 47. If feasible, funding would then be requested the following year for the unit's purchase and installation. The application was rejected however, because Coastal Zone Management (CZM) concluded that a Stormwater Management Plan for the Main Body of the Lake was necessary before grants for the installation of large end-of-pipe treatment devices would be funded. A copy of the CZM letter is provided in Appendix A. MISSING

- EPA Section 604(b) Program Water Quality Assessment and Management Grants
  These grants are targeted towards watershed non-point source assessment, and water supply projects. Priority was given to the Blackstone, Chicopiee, Connecticut and Nashua River watersheds and sub-watersheds. Upon investigation by Ambient Engineering, it was determined that funding for Whitman's Pond projects was unlikely. The grant application was therefore dropped.

- EPA Section s.319 Program Non-point Source Pollution Grant
  Ocean Arks International assisted the town in applying for funding through this grant to extend the operation of the Lake Restorer. The current contract with the Town of Weymouth funded the operation of the Lake Restorer through 1997. Grant funding was not approved.

- Private Foundation Grants
  To assist the town in gathering funding to support the operation of the Lake Restorer, Ocean Arks International also applied for additional grants through the Clowes Foundation, the Alden Trust, and the Allen Foundation. As of this date, grant monies are not forthcoming.

5.1 Lakes and Ponds Grant Application

Funding provided by the Lakes and Ponds Grant were to be used to implement the recommendations of South Cove Watershed Management Plan. The Plan called for the installation of catch basin inserts in the subwatershed which drained to outfalls No. 23 and No.29.

The DEM grant was earmarked for recreational waters. The South Cove of Whitman's Pond is a drinking water supply for Weymouth, and although most of the shoreline is private property, public access is available and canoeing and fishing allowed, the DEM did not consider this portion of the pond eligible for funding. The West Cove and Main Body of the Pond however, were recognized as recreational waters.

In order to evaluate where catchbasin inserts should be installed, Ambient Engineering conducted an outfall survey on the main body of the pond. The survey attempted to locate each outfall from both the shore and the lake. Each location was evaluated for sediment deposition, excess nutrient loading, evidence of petroleum pollution, accessibility, and drainage area. Also considered were land use and the proximity of the outfall to the Lake Street Beach.

In conjunction with the Weymouth DPW, thirteen catch basins were chosen for stormwater treatment devices. Catch basin inserts manufactured by Suntree Isles of Cape Canaveral, Florida, were selected as the most appropriate for this project. The two stage inserts can easily be lifted out of the catch basin and cleaned. The first stage contains a petroleum absorbent sock and the second a sediment filter. All inserts were installed by January 14, 1998, by the DPW with Ambient Engineering assistance. Their locations are shown in Figure 6.

SEE R. LYNCH'S LIST OF PROBLEMS

An evaluation of the effectiveness of these inserts must be conducted as part of the grant requirements. Since frozen winter conditions make stormwater sampling difficult, Ambient Engineering and the DPW applied for, and received, an extension for the final report. The insert evaluation will be conducted in the spring of 1998 and the report issued by June 30, 1998.

5.2 Evaluation of Stormwater Inserts on Skelly Avenue

As part of a CBGB Grant, the Weymouth DPW installed Fossil Filter catchbasin inserts manufactured by KriStar Enterprises of Santa Rosa, California, into two catchbasins on Skelly Avenue. Fossil Filters are a different type of insert than those installed as part of the Lakes and Ponds Grant. They are designed to collect oil and grease, not sediment.

Ambient Engineering conducted an evaluation of two catch basin inserts as part of the CBGB Grant requirements. Stormwater was sampled on June 2, 1997, after two weeks of dry weather. Samples were taken from before and after the Fossil Filter and analyzed for oil and grease, total suspended solids (TSS), and nutrients.

The evaluation found no significant reduction in nutrient or sediment concentrations in the filtered stormwater. The oil and grease concentration however, did appear to have been somewhat reduced. ← VERY MINIMALLY (BOTH IN & OUT CONCENTRATIONS WERE LOW).

6. CONCLUSIONS AND OBSERVATIONS

Excess phosphorus, as well as nitrogen compounds and sedimentation have been identified as the major contributors to the eutrophic conditions noted in Whitman's Pond. Ambient Engineering and Ocean Arks have conducted a multi-phased approach to combating this problem. Most of this effort focused on the South Cove because of the impact eutrophication can have on the Weymouth back-up water supply.

Sampling of the water and sediment from the South Cove was performed by Ocean Arks. Water samples were taken from the influent and effluent of the Lake restorer raft, and from a "remote" (or "adjunct") location approximately 20 feet from the raft, estimated to be the edge of the Lake Restorer's influence. Sediment samples were taken at the remote location except for the December 30, 1997 sample, which was taken from under the Lake Restorer. The Lake Restorer however, was taken out of service at the end of October 1997.

During mid-summer, water was pumped out of the South Cove into Weymouth's Great Pond reservoir. The water level dropped to a point where the Lake Restorer could not operate. Therefore no influent and effluent samples are reported for July 31, and August 8, 1997. A summary of the South Cove data collected is provided in Table 1.

6.1 Nutrient Loading

Sampling of lake water in the South Cove has shown that nutrients present are quickly incorporated into new plant growth. No significant pattern of nutrient removal could be derived from the comparison of the Lake Restorer's influent and effluent results. Most samples taken showed nutrients below detectable concentrations.

To characterize the nutrient concentrations present in Whitman's Pond, previous studies

TABLE 1. Lake Restorer Monitoring Results
Whitman's Pond Weymouth

(surface /bottom)

	6/5/97	6/12/97	6/19/97	6/26/97	7/2/97	7/10/97	7/17/97	07/31/97	08/08/97	08/12/97	08/22/97	08/27/97	09/12/97	09/18/97	09/26/97	10/16/97	12/30/97*
Inluent	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
NH4	< 0.1	< 0.1	0.1	< 0.1	< 0.1	0.17	0.18			< 0.10	1.24	< 0.1	0.075	0.23	0.55	0.12	
NO3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4			< 0.4	0.34	< 0.4	1.03	< 0.4	0.1	< 0.4	
TKN	0.88				1.63		1.9									1.2	
total Coliform	0				9							16				23	
PO4	0.03	< 0.02	< 0.02	< 0.02	0.02	0.02	0.04			< 0.02	0.04	< 0.02	0.13	< 0.02	< 0.02	< 0.02	
Total P	0.22	0.06	< 0.02	< 0.02	0.06	0.28	0.27			0.06	0.32	0.1	0.06	0.03	0.02	0.04	
Alkalinity	26	33	29	31	29.6	31	34			34.4	20	12.4	31	22	21.6	26	
TSS	5				3											4	
Dissolved oxygen	9.2 / 9.0	7.5 / 3.1	6.4 / 0.2	6.4 / 4.8	8.2 / 4.2	8	6.2	8	8.2	4.8	5.43			8.5	9.6	9.3	
Temperature	17 C	26.5 / 20.5 C	25.0 / 23.3 C	26.0 C	28.8 / 25.2	25 C	26	26	26	27	25	22	20	24	17		
pH	7.8	7.81	7.28	6.89	7.08	7.01	26			7.34							
Effluent																	
NH4		< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.36			0.64	1.08	< 0.1	0.024	0.034	0.1	< 0.1	
NO3		< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4			< 0.4	0.45	< 0.4	1.05	< 0.4	< 0.1	< 0.4	
TKN					1.33		1.28									1.42	
total Coliform					15							80				0	
PO4		< 0.02	< 0.02	< 0.02	0.02	0.05	0.13			0.16	0.02	0.02	0.13	0.02	< 0.02	< 0.02	
Total P		0.08	< 0.02	< 0.02	0.07	0.06	0.17			0.3	0.06	0.06	< 0.02	0.08	< 0.02	0.02	
Alkalinity		41	29	31	30.6	54	50			56.4	18	27.6	26	22	16.4	24	
TSS					4											1.5	
Dissolved oxygen		7.5	6.85	8.3 / 5.6	7.65 / 1.4	5	5.25	9.6	8.8	5.65				7.5	9.3	11.9	
Temperature		26.5	25	26.0 / 25.5	29.0 / 26.0	26 C	29	29	29	29	24	24	22	23	16		
pH		7.89	7.16	6.77	7.03	6.68	28.5			6.56							
Remote																	
NH4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.10	< 0.1	0.05	< 0.10	1.28	< 0.1	0.125	< 0.1	0.15	0.12	0.26
NO3	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.04	< 0.4	< 0.4	< 0.4	< 0.4	0.49	< 0.4	1.03	< 0.4	0.01	< 0.4	0.6
TKN	0.4				1.13		0.9	0.43								1.18	0.48
total Coliform	1				10			0			12					60	
PO4	0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.02	< 0.02	< 0.02	0.02	< 0.02	< 0.02	0.02	0.18	< 0.02	< 0.02	< 0.02	< 0.02
Total P	0.22	0.16	< 0.02	< 0.02	0.04	0.09	0.02	0.07	0.12	0.13	0.09	0.03	< 0.02	0.02	< 0.02	0.04	< 0.02
Alkalinity	26	33	31	31	32.8	32	30	31.6	35.2	32.8	32	12.4	14.3	22	22	24	31
TSS	4				3								Possible contamination -------->			9	
Dissolved oxygen	9.9 / 9.6	8.0 / 8.8	8.0 / 0.85	6.8 / 4.0	11.0 / 2.35	8.8 / 6.1	7.8 / 3.2		8.8 / X	11 / X	4.5 / X	9.6 / X	10.2 / X	8.4 / X	10 / X	8.2 / X	
Temperature	17 / 16 C	26.0 / 21.5 C	24.0 / 20.5	27.0 / 22.0	28.1 / 27.0 C	27.5 / 26.0	28 / 26 C	30 / 28 C	30 / 28 C	29 / 27 C	24 / 23 C	23 / 23 C	23 / 20 C	25 / 24 C	18 / X C		
pH	7.29	7.92	7.16	6.85	7.39	8.79 / 6.69	7.38 / 6.89			7.59							6.81
Sediment																	
NH4	719				1121			740				490				485	155
NO3	140				47			9.7				340				26.7	31.3
TKN	5500				11500			10150								27700	3650
PO4	41.7				1.31			2.47				1.55				0.01	< 0.02
Total P	1098				1040			1341				524				339	< 0.5
Iron	18333				21000							11100				25577	110829.5

Alkalinity = 6143

* December 30, 1997 sediment sampling conducted under Lake Restorer, not at Remote Location.

utilized sampling data taken from stations along the Old Swamp River, and from stations distributed throughout the three portions of the lake. The data collected in the South Cove over the summer of 1997 can be averaged to provide a comparable picture of the nutrient concentrations. Average South Cove nutrient concentrations are shown in Table 2. These average concentrations were calculated from the Lake Restorer Influent and Remote locations.

Table 2. Average South Cove Summertime Nutrient Concentrations

Water		mg/l
Ammonia	NH_4	0.18
Nitrate	NO_3	0.27
Total Kjeldahl Nitrogen	TKN	0.92
Phosphate	PO_4	0.05
Total Phosphorous	Total P	0.08
Sediment		
Ammonia	NH_4	618
Nitrate	NO_3	99
Total Kjeldahl Nitrogen	TKN	11,700
Phosphate	PO_4	7.84
Total Phosphorous	Total P	724

Total nitrogen can be considered the sum of the TKN and Ammonia concentrations. At first glance, the resulting average total nitrogen concentration of 1.1 mg/l appears to agree well with the 1981 M&E average of 1.06 mg/l from the Old Swamp River station, and the estimated average total pond concentration of 1.0 mg/l.

Phosphorous, considered the limiting nutrient in Whitman's Pond, also demonstrates similar good agreement. The average total phosphorous concentration determined over the summer sampling period is 0.08 mg/l. The M&E study found the concentration over the whole pond to be 0.05 mg/l. the concentration taken from the Old Swamp River during the analogous June to October period in 1980 was 0.058 mg/l.

Most of the results obtained by the Ocean Arks sampling program however, were below detection limit for phosphorous and ammonia. To obtain average concentrations, one-half the detection limit value was used as an estimate of below detection level concentration. Therefore, statistical analysis of any small differences between the averages can not be made.

6.2 Sediment Phosphorous

Iron present in the water and sediments of a pond combine with dissolved phosphorous under aerobic conditions. The ferric-phosphorous complex settles on the sediment surface, forming part of an oxidized microzone. Under conditions where the dissolved oxygen concentration of the water over this microzone drops below 1.0 mgO_2/l, iron becomes an alternate electron acceptor to oxygen. This can rapidly solubilized the iron and release the phosphorous back into the water column.
Sediment results from the remote location show a steady decline in total phosphorous from June to October 1997. This decrease however, does not coincide with the phosphate (PO4) concentrations.

Dissolved oxygen readings at the lake bottom were not taken consistently from any location. Readings which were taken however, show the water at the lake bottom varies widely between oxygen saturation and anoxic conditions. If the decrease in sediment total phosphorous were due to anoxic conditions, the iron concentration in the sediments would also be expected to vary with the total phosphorous. Since the correlation between iron and total phosphorous is not close, some phosphorous uptake from the sediment may have occurred over the course of the season. The December 30 sample was taken from a different location and two months after the Restorer had ceased operation. This data set is more indicative of natural seasonal processes than the effects of the Lake Restorer.

SEEMS TO SUPPORT THE LACK OF RELIABLE DATA FOR LAKE RESTORER EVALUATION

6.3 Buffering Capacity

The alkalinity of the South Cove was found to vary between 12.4 and 54.0 mg $CaCO_3/l$ which corresponds to low to moderately alkalinity. Therefore the buffering capacity of the soft water in South Cove was also determined to be low to moderate. As a result, during eutrophic conditions, the primary production and respiration occurring in the water body may decrease its pH. Acidic conditions were not observed although a significant macrophyte density was observed throughout the South Cove.

The South Cove is shallow, the average depth of the water body is approximately 4 feet. The deepest area is adjacent to the outlet of the cove, and the drinking water intake. Dissolved oxygen measurements showed that while water at the bottom in this area would become anoxic at times, much of the lake remained well aerated. The fact that the pond is shallow may allow it to remain well mixed and oxygenated overall; thereby limiting the growth of anoxic or anaerobic organisms which would reduce the cove's pH.

6.4 Bacterial Contamination

Coliform bacteria counts in the Main Body of Whitman's Pond have led to the closure of the Lake Street Beach. The test for Fecal coliform is often used as an indicator of raw sewage entering a water body. Since the South Cove is a drinking water supply, Total coliform analysis was conducted. The Total coliform test will detect fecal coliform as well as other similar bacteria. The Total coliform counts in all analyses were less than 100 colonies per

100 ml, which is well below the ambient water quality standard of 1000 colonies per 100 ml. Therefore, bacterial contamination does not appear to be a significant problem in the South Cove.

6.5 Observations on West Cove and Main Body

While conducting the Outfall Survey on the Main Body of the pond, the West Cove was observed to be a significant source of nutrients and possibly fecal coliform. The greatest concentration of plant and algae growth observed in the Main Body was at the West Cove inlet. The West Cove itself is eutrophic, and there are reports of raw sewage entering the water body during periods of heavy rainfall.

BASED ON WHAT?

THIS ?

The Lake Street Beach is directly between the West Cove inlet, and the Main Body's outlet to the Back River. High coliform counts and algae observed at the beach may be a result of impacts from the West Cove.

Lycott Environmental applied herbicide to the West Cove to combat the Eurasian water milfoil. The non-native plant species had infested the entire West Cove. While the herbicide application was effective, the nutrient loading in the water body was not affected. Excessive populations of other plant species, such as water lilies, were observed by August.

Roads on the west shore of Whitman's Pond are sanded more heavily in the winter due to their steep hills. At the time of the Outfall Survey, storm drain catch basins on these roads were observed to be completely covered with sand not yet cleared from the previous winter. Outfalls from this side of the pond were noted to have released greater amounts of sediments than other portions of the Main Body.

UNCONFIRMED (CHK. W/ R.O'C. OR R. LYNCH)

R.O'C., 4/6: NO; APPROXIMATELY EQUAL.

7. RECOMMENDATIONS

7.1 Recommendations Based on Ambient Engineering's Work

The following recommendations to the Town of Weymouth are meant to sustain the effectiveness of projects completed by Ambient Engineering.

7.1.1 Incorporate the Recommendations of the SNUP Management and Optimization Plan

The SNUP, designed by Whitman and Howard, was meant to absorb nutrients and sediment from the Old Swamp River. The SNUP Management and Optimization Plan identified several improvements which could be made to the operation of the artificial wetland system. Incorporating these recommendations and the proposed maintenance schedule should improve the water quality entering the South Cove.

7.1.2 Maintain the Stormwater Catch Basin Inserts.

The grant received from the DEM Lakes and Ponds program allowed the Suntree Isles Stormwater catch basins to be installed in various catch basins around the pond. The inserts were sized to fit the space available in the catch basins, and some are not very large. They will collect sediment and petroleum products and must be cleaned periodically. Until the frequency of cleaning has been determined for each location, the status of the inserts should be checked weekly.

During the spring thaw, an evaluation of the insert's effectiveness will be conducted. If the results of the evaluation are favorable, another grant request may be submitted to buy and install more.

7.2 Reccomendations for Future Projects

7.2.1 Evaluation of SNUP Efficiency

Over all, the relative benefits of structural stormwater controls on the South Cove, versus improved maintenance of the SNUP, must be evaluated by examining the cost per kilogram of phosphorus and other pollutants that can be removed by each method. No study or evaluation has been made concerning the current effectiveness of the SNUP since it has been built. Observations and interviews suggest that SNUP performance has not met expectations. Since the Old Swamp River provides 26%-60% of the phosphorus loading into Whitman's Pond, any overall strategy for the pond's restoration must take its redemption into account.

Ambient Engineering also recommends that an investigation into nutrient concentrations in the river and the SNUP be undertaken. These results could be compared to the M&E report's 1986 findings and would provide further information on inputs to the South Cove as well as SNUP effectiveness.

7.2.2 Improved Monitoring Program

The sampling program conducted by Ocean Arks over the summer found many of the nutrient results to be below the detection limits of the analytical methods used. This indicates that nutrients in the South Cove are quickly incorporated into the vegetation present. An improved monitoring program for the Lake Restorer's effectiveness would involve the utilization of different analytical methods capable of achieving lower detection limits.

WHY COULDN'T THE NUTRIENTS JUST NOT BE PRESENT (IN GREATER CONCENTRATIONS)?

7.2.3 Main Body Stormwater Management Plan

As previously stated, the application for a Coastal Zone Management (CZM) grant to site an end of pipe sediment treatment device was rejected because a Stormwater Management Plan had not been written. Before grants for any major construction projects on the Main Body, or West Cove, will be funded, a comprehensive stormwater management plan which addresses the inputs and treatment options available must be produced.

PART OF LAKE MGMT. PLAN W.P.C. IS PREPARING?

7.2.4 <u>West Cove Stormwater Management Plan</u>

A significant portion of the nutrient and bacterial loading into the Main Body appears to originate from the West Cove. Reportedly, sedimentation in the water body is also increasing. Some members of the community have proposed dredging the West Cove as the solution to both the eutrophication and sedimentation problems. However, dredging is one of several approaches which should be evaluated, and is not looked upon favorably by some regulatory agencies.

WHY STORMWATER? (SEWAGE NOT INCLUDED)

Before any project is undertaken, a stormwater management plan should be written for the West Cove. This plan should contain an investigation of the sources of pollutants into the West Cove, including sewage overflows and stormwater runoff. Different pond management and restoration options should then examined with resect to effectiveness, environmental impact, and cost. the findings of this plan would then be used as the basis for grant and permit applications.

Recommendations pertaining to the Lake Restorer are included in the Ocean Arks Section of the report.

PART 2

OCEAN ARKS LAKE RESTORER

A major portion of the annual contract work involved the construction and operation of a "Lake Restorer" raft which was anchored in the South Cove of Whitman's pond during the summer of 1997. The raft provided a platform for microbial and vegetative systems to remove nutrients from the water column. The Lake Restorer was designed, built and operated by Ocean Arks International, which also conducted the monitoring to evaluate its effectiveness.

The Lake Restorer is located in South Cove, approximately 30 meters from the pump house for the secondary drinking water supply intake, and 20 meters from the Washington Street bridge. The Lake Restorer operated from June through October 1997. It is still anchored in the South Cove, but has been taken out of service.

The following section of the report, written by Ocean Arks International, discusses the construction and operation of the Lake Restorer. Ocean Arks also provides an independent evaluation of the data collected as part of the Restorer Monitoring Program. The recommendations offered in this section pertain only to future projects regarding Lake Restorer technology, and should be considered part of the recommendations discussed in Section 7 above.

OCEAN ARKS INTERNATIONAL
Ecological Solutions for the 21st Century

Table of Contents

A 501(c)(3) Not-for-Profit Organization
233 Hatchville Road, East Falmouth, MA 02536 • (508) 563-2792 Fax (508) 563-2880

Summary

The Lake Restorer at Whitman's Pond began operation in June of 1997. The Restorer is a floating Living Machine, a biological filtration and incubation system for water quality enhancement. From the period of June to December of 1997 quantitative and qualitative data about the South Cove of the Pond and the operation of the Restorer were collected. Ammonia and nitrates in the sediments declined by nearly 80% each at an adjunct sampling station between the outset of this project and December 1997. Phosphorous levels declined by more than 99% in these sediments. Over the same time period, the area around the Lake Restorer was observed to support gradually smaller populations of the nuisance plant, water milfoil. Finally, water quality analysis indicated that populations of coliform bacteria decreased following the Restorer's installation. From these data we surmise that the Restorer reduced quantities of macronutrients in the sediments, aided in the retreat of water milfoil, and helped to control populations of pathogenic bacteria, as indicated by measurements of coliform bacteria. Additionally, improvements in water clarity were observed over the course of Restorer operations. The Lake Restorer acted as a focal point for education about Whitman's Pond water quality issues, and the need for community involvement and water conservation.

The future of water restoration at the South Cove of Whitman's Pond could proceed at several levels. With minimal modifications and maintenance, the Restorer could run for the next several years. This report contains recommendations for future operations and water quality monitoring programs, including a direct quantitative analysis of water milfoil growth patterns. Particularly, citizens living near Whitman's Pond have the potential to become more involved with the activity of the Restorer. Additionally, there is a potential need for similar units in both the West Cove and the main body of the pond.

KEY WORD

JAY HAS BRUCE GETTING

— WATER DEPTH/LEVEL?
— RAIN EVENTS?
— O.S. RIVER FLOW?

JAY WILL CHECK ON WWW.

OAI Staff & Volunteers for the Whitman's Pond Project

Living Machines and Lake Restorers were initially designed by Dr. John Todd, President of OAI.

At the beginning of the Whitman's Pond Project, and through the design & construction phases, Beth Josephson worked as OAI assistant director, and project manager. Amanda Ludlow worked as research assistant. Both Beth and Amanda left OAI in June of 1997.

In June of 1997, Christine Graziano returned to OAI to begin work as full-time staff, and to take over as project manager. She coordinated the ramp-up of the system, and all subsequent operations. During the summer, she worked with two interns from Warren Wilson College, Jill Stevens and Stacey Greco.

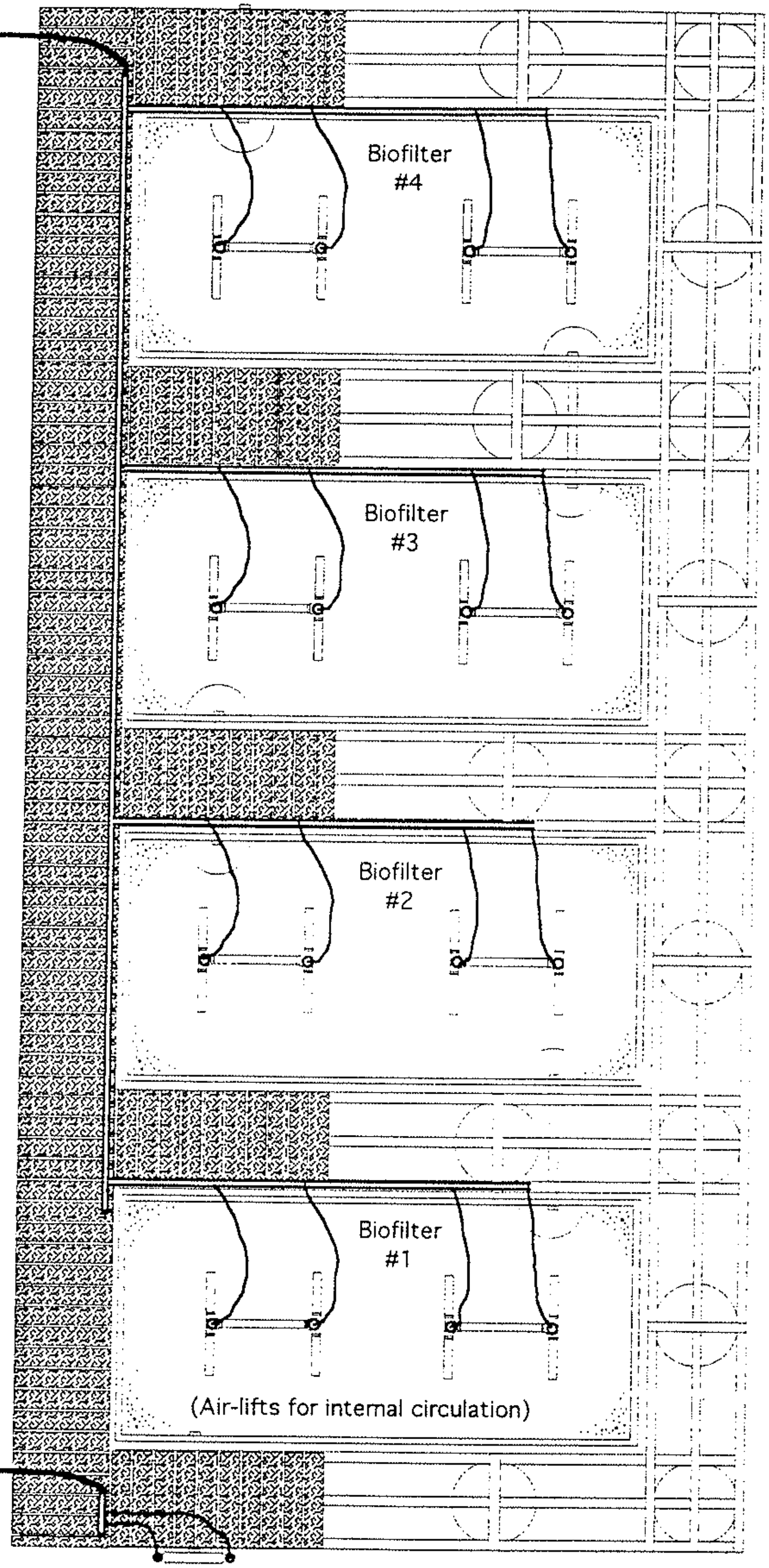
Richard Boylan assisted the Whitman's Pond project for a portion of the final phase of construction. He returned to Ocean Arks full-time beginning in September, working on sampling, education, and other aspects of the project.

Acknowledgments:
The Restorer project could not have gone forward without the advice, support, communication and interest of many individuals and organizations. In particular, Ocean Arks staff would like to extend our appreciation to Lorraine Larraby, Jim Cunningham, the Whitman's Pond Association, the Whitman's Pond Commission, Jim Leary and Jay Fink at the Water Department, untold others in the Department of Public Works, the staff at SciLab Boston, Inc., Ambient Engineering, the Weymouth Board of Health, the Weymouth Board of Selectmen, the staff at That's Italian Too, The Patriot Ledger and the many residents of Weymouth who attended our tours and contributed to the restoration process of Whitman's Pond.

Whitman's Pond Restorer

Weymouth, MA

A floating *Living Machine* for nutrient uptake, and ecologically-sound lake restoration.



Structure:
Framing-grade lumber, treated with non-toxic wood preservative

Floatation:
28 polyethylene "Sea Cell" cylinders

Water Pumping/ Initial Aeration :
3/4 hp, rotary vane compressor (shore-mounted)

Internal Circulation/ Continuous Aeration:
1 hp, rotary vane compressor (shore-mounted)

Biofilter Media:
100% recycled, nylon monofilament matrix, covered with native, wetland plant species for rhizofiltration and direct uptake (not shown)

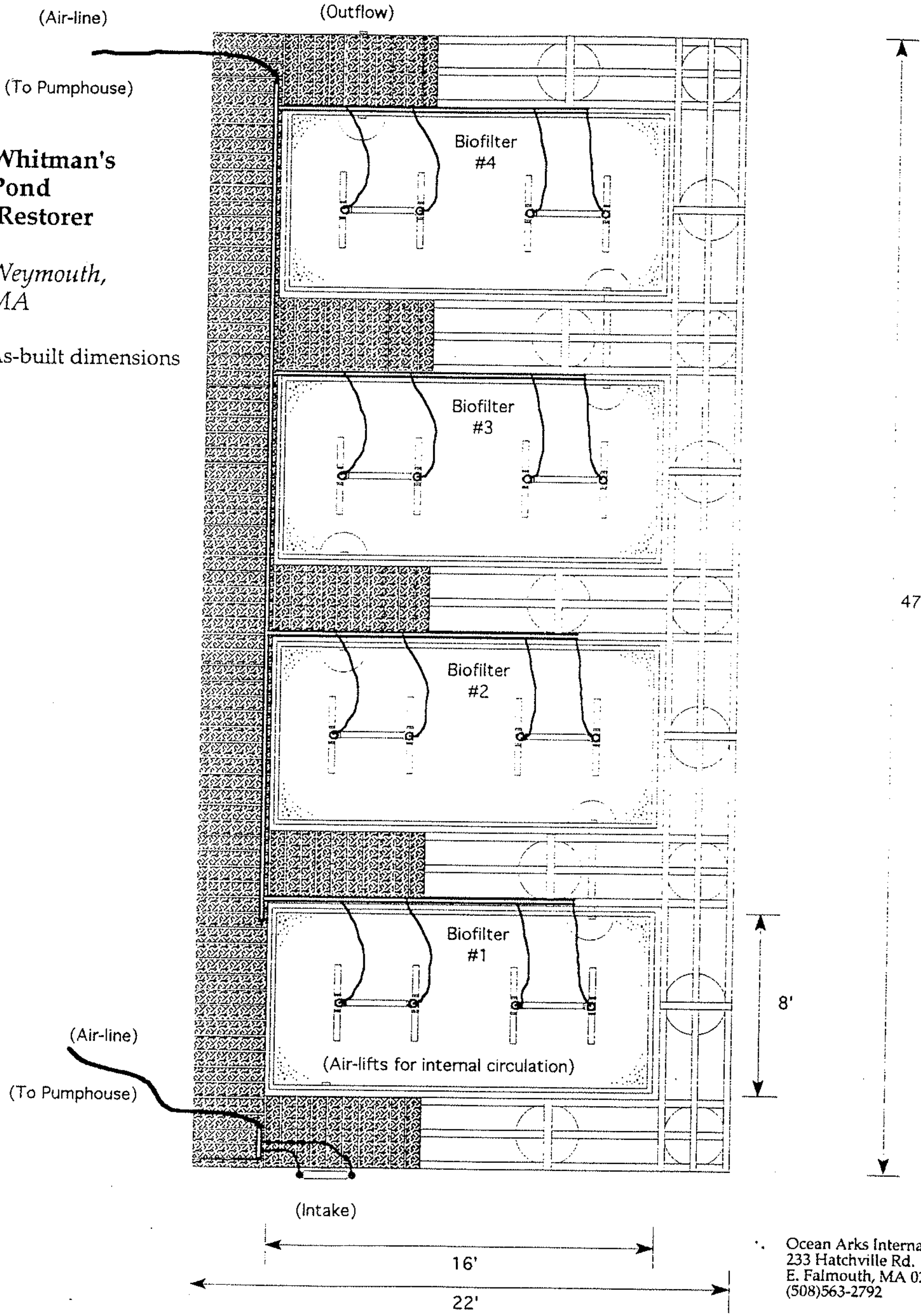
Throughput:
Aproximately 200,000 gallons per day

Ocean Arks International
233 Hatchville Rd.
E. Falmouth, MA 02536
(508)563-2792

Whitman's Pond Restorer

Weymouth, MA

As-built dimensions



Ocean Arks International
233 Hatchville Rd.
E. Falmouth, MA 02536
(508)563-2792

Characteristics of the South Cove of Whitman's Pond

Whitman's Pond, an enhanced "Great Pond", is located in the northern-central region of Weymouth. It is part of a watershed located in the Boston Harbor Drainage Area. The watershed encompasses 12.6 square miles with 75% of that land located in Weymouth, MA. Whitman's Pond covers an area of 72 hectares and a total volume of 1,246 acre-feet. The pond is fed by two major tributaries entering into the South Cove. The tributaries are Old Swamp River and Mill River. Ground water is also a source of water for the pond. The pond is divided into three sections. South Cove, the main body, and West Cove are separated from one another by busy roadways. The water moves from South Cove to the main body through a series of gated mechanisms. The water moves from the main body to West Cove. After water exits at the northeast corner of the pond through a sediment control structure, a constructed fish passage, and the Iron Hill Reservoir, the Pond drains into the Back River. This connects to Boston Harbor's Outer Harbor.

Ocean Arks International's work remained focused on South Cove, the chosen location of our Lake Restorer. The morphometric data compiled in 1981 recorded the Southern Basin or Cove as constituting an area of 12.1 hectares or 29.9 acres. The volume of this area totals 60 acre-feet (72,671 m^3). The depth in this cove reaches a maximum of six feet. The Restorer operated in this deeper area of the cove.

USE OF THE POND

The pond is heavily impacted by, and relied upon for recreation, and is also a source of the town's secondary drinking water supply. One source indicated 40% of the town's water is taken from South Cove in a year. A 1980 census report estimated 62,000 people would reside in Weymouth at the end of two decades with the population numbers already at 55,601 in the census year. The population expected to use Whitman's Pond exceeds three million people.

The public beach in the main body of the pond is now closed to swimming year round due to the presence of swimmer's itch parasite. In Whitman's Pond, water is pumped from South Cove into a pumping station on the shore where the water is then piped to Great Pond in the southeast area of town. The water is moved from Great Pond to a water treatment facility and then to Weymouth businesses and residences.

Whitman's Pond is important as a complex ecosystem and wildlife habitat. It is particularly important since it is the major spawning ground for a species of herring, *Alosa psuedoharengus* , or alewives. The fish migrate from Hingham into Whitman's Pond by the Back River during April and May. The fish have been accommodated with fish ladders, modified culverts and additional shoring of the river banks by the town.

SOURCES OF POLLUTION

The principal problems identified have been urban stormwater runoff and seepage from subsurface disposal systems. Industry in the area, including Quincy Steel, an iron foundry in operation on Old Swamp River, may have had significant impact on the pond in the past, with iron levels in the main body registering in high concentrations. Other minor land uses include agriculture, mining and waste, highway and outdoor recreation. Located near the southern border of Whitman's Pond is Libbey's Industrial Park. It was developed after 1971 and encompasses 0.25 miles. ?

With a large percentage of the watershed in an urban setting (industrial, commercial, residential) precipitation tends to run off impervious surfaces, rapidly carrying pollutants into storm drains or surface waters. Additional problems stem from the use of storm drains as waste disposal sites by a small minority of area residents.

Septic tank leakage poses a significant problem as residences ring the waters of South Cove. Septage acts as a source of nutrients for another major problem in the pond, aquatic weed infestation. The most immediate problem in Whitman's Pond is the very dense aquatic macrophyte, *M. spicatum L.* or Eurasian water milfoil. For the practical need of pumping water from South Cove to Great Pond, the weed could present a significant problem with clogging. Another growing concern is the increase in the lily pad population. Both plants add to the sedimentation of the pond, accelerating its transition to marsh habitat.

HOW WILL THE LAKE RESTORER REDUCE MILFOIL?

Restorer Design, Installation and Operations

The Whitman's Pond Restorer consists of a rectangular raft which floats in the south cove of Whitman's Pond, approximately 30 meters from the pump house for the secondary drinking water supply intake, and 20 meters from the Washington St. bridge. The raft itself is approximately 7 meters by 12 meters in size. Structural framing is of conventional 2x4 and 2x6 lumber, with PVC pool liners lining the four open cells that form the biologically active areas of the Restorer. The liners are supported by a criss-crossed framework of lumber, suspended by chains attached to the main structure of the raft.

In April, 1997 Ocean Arks International installed the Lake Restorer in the deepest available section of South Cove, measured at 6 ft. in depth. On June 5, 1997 the Restorer was connected via air-hose to the pump station, electrical circuits and compressors, and began its biological ramp-up and operation.

All plumbing on the Lake Restorer is 4 inch diameter standard pipe, with the exception of the two vertical intake pipes, which are 3 inch. Intake pipes and connections between cells are schedule-40 PVC, while internal circulation pipes are schedule-20 PVC. Water enters the raft at its south-west corner, and flows both laterally and vertically through each of the four biofilter cells. Two "H"-shaped air-lift circulators per cell insure that water recirculates through each cell several times before exiting to the next cell. At the same time, these circulators reoxygenate water that has become anaerobic due to the oxygen demands of the nitrification process.

FLOWS

Compressed air for the intake and recirculator air-lifts is provided by two rotary vane compressors that are located in the Weymouth DPW pump-house at the edge of the south cove. On June 5, 1997 flows began at approximately 100,000 gallons per day. At that time, a single 3/4 horse power compressor was used to drive both the intake and recirculators. The addition of a second compressor on June 21, rated at 1 hp, increased internal aeration and also increased the throughput to 200,000 gpd. The 3/4 hp compressor draws approximately 7.0 amps of electric current, while the 1 hp compressor draws approximately 7.4 amps of current. Both compressors are operated on a 24-hour per day basis, allowing the Restorer to function around the clock. Continuous functioning allows the greater survival of beneficial aerobic nitrifying bacteria (see "Biological" section, below for more details).

On July 10, 1997 the water table in the pond dropped significantly without warning. By July 31, water levels were approximately 2.5 ft. The Restorer, designed to float in six feet of water, experienced structural and operational difficulties due to the shallower waters. During the period of 7/31/97 - 8/8/97, the Restorer was disconnected from the compressor while undergoing repairs. Water began to flow again through the Restorer on August 8. It is worthwhile to note that sampling at influent and effluent stations did not occur on both July 31 and August 8. The adjunct station was sampled for continuity.

During the ramp-up and early operations period, muskrats began inhabiting the wetland cells. On July 31, 1997 a hole chewed in the liner appeared near the intake. It was patched successfully. Throughout the month of August, various other holes were made by the animals and dealt with similarly. The flow was therefore diverted slightly from its course of influent to effluent.

On August 8,1997 water flow had stopped at the intake pipes. The problem appeared to be a punctured airhose connecting to the airlift mechanisms (the muskrat had chewed through the hose). By the twenty -sixth of August, the Restorer was again pumping at maximum capacity. Flows through the Restorer were terminated at the end of November, due to ice formation in the biofilter cells. Data points for December 17 were taken approximately two weeks after the Restorer had ceased flows for the season. This variation is represented by the presentation of two different tables in the section "Quantitative Data and Results".

MEDIA AND BIOFILTRATION

Each cell is filled with approximately three-hundred-eighty-four cubic feet (384 $ft.^3$) of nylon monofilament biofilter media that provides habitat for beneficial microorganisms, including nitrifying and denitrifying bacteria. Using a conservative estimate of 250 square feet of surface area per cubic foot of monofilament matrix, this results in approximately 96,000 square feet of biologically active filtration surfaces per treatment cell. The Restorer therefore contains approximately 384,000 square feet of filter area. From the period of June 5 to June 21, quantities of nylon monofilament biofilter media were added to the Restorer to increase the volumes in the four cells to full capacity, a depth of three feet. A plasticcovered, heavy-gauge wire ("Bartlett Wire") screen creates a small, open water area near each pipe inlet and outflow, and prevents biofilter media from entering the plumbing.

MICROBIOLOGICALS

A lake such as Whitman's Pond already contains a vast array of microorganisms, both beneficial and harmful (note the high levels of coliform bacteria at the outset of the Restorer project). However, not all types of beneficial bacteria are present in any given environment at any given time. For example, it has been shown in lakes, that peak occurrence of bacteria degrading fats and bacteria degrading protein may be several months apart. To contribute, in part, to efficient water purification, the presence of all appropriate strains at one time is necessary. If one of the members of the necessary community is lacking, bacterial action can be limited.

For this reason. OAI adds Bacta-Pur live bacteria, cultured by Aquaresearch Ltd., to all of our Lake Restorers. The bacteria added to the biofilters include seventeen strains, primarily *Nitrosomonas* spp. and *Nitrobacter winogradskyi*, as well as a number of other heterotrophic and lithotrophic bacterial species. Other heterotrophic and lithotrophic species of bacteria in the Bacta-Pur mixture are identified as *Aerobacter aerogenes, Bacillus subtilis, Cellulomonas biazotea, Psuedomonas denitrificans,* and*P. stutzeri.*

These diverse bacteria combine their efforts to reduce (through denitrification) or oxidize (through nitrification) ammonia, and digest oils, sludges, hydrocarbons, and other pollutants. The Restorer acts both as a self-contained treatment system, and as a biological incubator that helps to seed the entire pond with these desirable organisms. We believe the Restorer acts as a catalyst for natural reactions in the pond and can initiate or maintain processes in the larger pond body that can regulate substances such as toxic ammonia. Nitrification of ammonia definitively took place in the Flax Pond Restorer as measured from a mass balance perspective. The data was unavailable to calculate removal rates for the Weymouth Restorer, but we assume nitrification by bacteria occurred in the cells. Nitrification is the conversion of ammonia to nitrate nitrifying bacteria. In the presence of oxygen, autotrophic *Nitrosomonas* initiates the first step of the conversion to nitrites. Nitrobacter completes the process by converting toxic nitrites to nitrates. Anaerobic bacteria change nitrates to nitrogen gas. On Flax Pond in Harwich, MA the Restorer exhibited a fifty percent conversion of nitrate to nitrogen gas as nitrogen passed through the Restorer. Again, measurements taken at Whitman's pond for the influent and effluent stations were often below detection limits. It may be that water flowing in and out of the Restorer through holes in the liner interfered with the quantification of such processes in this Restorer. Two additional principle steps bacteria affect in the water purification process, aside from denitrification and denitrification, include the solubilization of organic solids and the removal of soluble carbonaceous pollution (BOD). These processes are accomplished through the aerobic and anaerobic respiration of the bacteria.

By creating conditions favorable to these helpful bacteria, the Restorer ecosystems eliminated harmful species such as the coliform species, through a process known as competitive exclusion. Anti-microbial exudates from the roots of particular plant species on the raft (*i.e. Iris versicolor*) also contribute to the reduction of similarly pathogenic organisms. Nucleated algae, water molds, slime molds, slime nets and protozoa are organisms, although less metabolically diverse than bacteria, that can also play a role in nutrient breakdown. For coliform removal from sewage, protozoans are useful. They can remove moribund bacteria and improve system efficiencies.

To ensure biological and chemical activity in the Restorer, bacteria was added to each cell in 4-8 Liter quantities every week from the period of June to September. Lime was added to the system on three different occasions to increase alkalinity concentrations necessary for the metabolic processes of denitrifying bacterial species. The combination of root masses, biofilter media, and beneficial bacteria facilitates the growth of complex biofilms and protozoans. These microbial communities attach to the vast surface area provided by the nylon monofilament matrix. This area provides the primary location for the biologically-induced oxidation of ammonia to less toxic forms. In areas of the biofilter that lack oxygen, anaerobic communities of microbes convert ammonia to nitrogen gas. All of the bacteria added to the Restorer are EPA-certified as safe for use in food establishments and drinking water supplies.

HIGHER PLANTS

Over the biofilter media, mats of wetland plant species, planted into a coconut-fiber substrate, provide the areas for phytoremediation of pond waters. Each of its four cells contains a variety of wetland plant species, that work together to form an engineered ecosystem, designed specifically for water purification. The plants actually incorporate pollutants, such as phosphorous and ammonia that enter the pond through leaky septic systems. Within the plants' tissues, nitrogen becomes a component of proteins in seeds and other areas, thereby changing from a waste to a living resource. Ammonia can also volatilize to the atmosphere.

The carpets of plants include water-tolerant woody species, such as willows (*Salix sp.*) and buttonbush (*Cephalanthus* sp.). There are also wetland plants, including sedges (*Carex* sp.), grasses (*Glyceria* sp.,*Poa* sp.), reeds, and rushes (*Scirpus* sp.). All species are native to new England. The willows send deep tap roots downward, reaching into the water column. The root surfaces of the sedges, grasses and other soft-stemmed plants provide a filter media thousands of times more effective than even the best man-made products. Because all of the filtering systems are alive, they require very little maintenance. Root masses also form an extremely fine natural media for symbiotic microorganisms. Plants can exude up to 40% of their net primary productivity as photosynthates and secondary compounds through their roots to sustain these microbial communities. In exchange, these microbes assist in the uptake of nitrogen, phosphorous, and other trace nutrients.

The Whitman Pond Restorer has four distinct cells of such plants and biofilters. This multicellular structure allows the breakdown of more complex pollutants, such as oils and organic wastes that enter the pond from roadways and surrounding yards. As long-chain hydrocarbons pass through successive cells they are broken down in stages, passing through aerobic and anaerobic areas, through light and dark, and bacterially- and photosynthetically-dominated systems, eventually becoming carbon dioxide and water.

MINERAL DIVERSITY

Autotrophic bacteria form the basis of entire biologically rich food chains. They derive food and energy from inorganic mineral sources. Bacteria use carbonate, phosphate, iron oxide, manganese oxide and sulfide minerals in the metabolic process. Some minerals such as iron are critical in enzymatic systems. Colloid formation, extremely small clay and humus particles, may be dependent on mineral diversity. Such particles are a crucial link between higher plants, bacteria, water and soil as they regulate the exchange of ions.

In the Weymouth Living Machine Lake Restorer we added 40 kg of finely ground rock powders to the filtration cells over the course of the summer season. In one OAI experiment, 19,000 m^3 of bottom sediments were digested in a 4 ha pond with the application of 7,200 kg of rock powders from glacial materials. This application was in combination with a Restorer circulating 40,000 gallons of water per day. The mineral addition may increase the Restorer's capacity of the system in self-design and optimization. Mineral reservoirs provide a long-term foundation for nutrient diversity in the system.

Quantitative Results - Discussion of sediment and water analyses

SAMPLING TECHNIQUES

Sampling stations were located at the influent and effluent ends of the raft. A third adjunct station was chosen within the sphere of influence of the Restorer approximately twenty feet off the south side of the raft. The location was marked with an anchored buoy.

Water samples were generally taken at all three sites from June - October once per week. At the influent station, samples were collected from the water flow moving directly into the first cell through a PVC intake pipe. These samples were collected in bottles provided by certified lab SciLab Boston, Inc. After collection, samples were placed directly into a cooler for transport.

Parameters for DO, pH and temperature were collected from the water column directly outside the uptake pipe to approximate the conditions of the water flowing into the raft. These measurements were taken with OAI equipment. In August, our pH meter failed. This parameter was then measured by SciLab Boston for the duration the season.

Effluent water samples were taken from a pocket of water immediately prior to the entrance of the exit pipe. All parameters were measured here. Sample bottles were provided by the local laboratory. Collected samples were placed immediately into a cooler for delivery to the laboratory.

In July, OAI began doing their own water chemistry analysis with CHEMetrics spectrophotometer kits. This was done to double check laboratory results. Samples were collected in glass jars cleaned in a solution of diluted HCL and ionized water. Samples were transported in a cooler to our facilities in Falmouth where they were analyzed within a 24 hr. period.

Sediment samples were taken from the bottom of the pond once per month from June-December at the adjunct station. An Eckman Grab was used to collect sediment samples. Bottles were provided by SciLab Boston.

INTRODUCTION

Data were collected at three locations in the South Cove of Whitman's Pond, in order to quantitatively assess the impact of the Lake Restorer. Water samples were collected at the intake pipe to the first cell of the Restorer ("influent"), and near the final opening in the fourth cell of the Restorer ("effluent"). These two sample areas are grouped into the section entitled "Restorer." Water samples were also collected from the epilimnion of an adjunct sampling station ("adjunct"), located approximately 30 meters from the Restorer, and marked by an anchored buoy. Sediment samples were taken from the hypolimnion, directly below the adjunct station buoy, once per month.

It is important to note that all three of the sampling sites were located within the zone of influence of the Restorer. Results of the Whitman's Pond analysis are further qualified by the fact that while water flowed primarily from the "influent" toward the "effluent," several holes in the liners of the biofilter cells allowed water to enter and exit the Restorer at several points. These holes, chewed by a muskrat, did not significantly impede the biological functioning of the Restorer, but may have masked contrasts between influent and effluent chemistries. Due to the holes, approximately 20 cm in diameter, and located in cells one, three, and four, the constructed wetlands and biological filtration beds of the Restorer operated as semi-independent modules. Water was exchanged from cell to cell, but also from cell to lake. Nonetheless, water movement and filtration continued due to the action of the internal circulators, two of which were located in each cell.

The results that follow, presented in the form of charts, spreadsheets, and narrative discussion, are grouped into three sections that correspond to the sampling areas. All data presented were analyzed and reported by the state-certified laboratory Aqua-Air Analytical (A^3, now Sci-Lab Boston, 25 Matthewson Drive, Weymouth, MA), unless otherwise noted.

The most significant results are in the first section: *Sediment Chemistry Data. Unlike* direct water measurements, sediment samples are able to illustrate broad, long-term trends in the ecology of Whitman's Pond. Quantities of nutrients, pollutants, and dissolved gases in the water column can vary drastically over weeks, days, and even hours, due to diurnal cycles, temperature changes, and plant and animal activity. Alternately, sediment chemistries remain fairly stable over short periods of time. Changes in the quantities of major nutrients and pollutants within the sediments serves as evidence of significant changes in the ecology of the area. Furthermore, sediment reservoirs of nitrogen and phosphorous are the most important sources of these nutrients to Eurasian water milfoil as well as to other aquatic plants.

The second section of this Results chapter focuses on the water samples taken at the Adjunct sampling station, entitled *Adjunct Station Data*. These samples illustrate both short-term and longer-term impacts of the Restorer, within the raft's zone of influence. The adjunct station is close enough to the Lake Restorer to be affected by the biological filtration and ecological augmentation of the Restorer, yet water at the adjunct station is not likely to have passed directly through the Restorer for some time (the exact period would depend on recent rainfall events, whether the pump station is active at the time, and a host of other variables).

The third section. *Restorer Data*, looks at measurements taken at the influent and effluent sites of the Restorer itself. Both of these points are within the immediate influence of the Lake Restorer. As the Restorer cycles water through its four cells, any given unit of water may cycle through the Restorer several times, again depending on weather, the activity of the pump station. etc. This, combined with the fact that the liners contained several holes, caused the influent and effluent data to closely resemble each other in most instances.

SUMMARY OF SEDIMENT RESULTS

Over the course of the 1997 season, sediments were monitored for concentrations of ammonia-nitrogen, nitrate-nitrogen, total kjeldahl nitrogen (TKN), orthophosphate (PO4), total phosphorous (TP), and iron. In all instances, these parameters declined between June and December, in some cases quite precipitously. While a variety of factors may have contributed to this decline, including seasonal changes and the growth of water milfoil, it is likely that the Restorer also played a role in this reduction. These declines are consistent with the impacts of other Restorers on sediment nutrient levels at other ponds, including at Flax Pond in Harwich, MA; and also at Canadian Goose Pond in Irvington, NY.

Changes in Sediment Chemistry (mg/kg)

Parameter	**Initial Concentration**	**October Concentration**	**Percent Change**
Ammonia - N	719	485	32.55
Nitrate - N	140	26.7	80.93
TKN	5500	27700	-403.64
PO4	41.7	0.01	99.98
TP	1098	339	69.13
Fe	18333	25577	-39.51

Changes in Sediment Chemistry (mg/kg) ...Continued

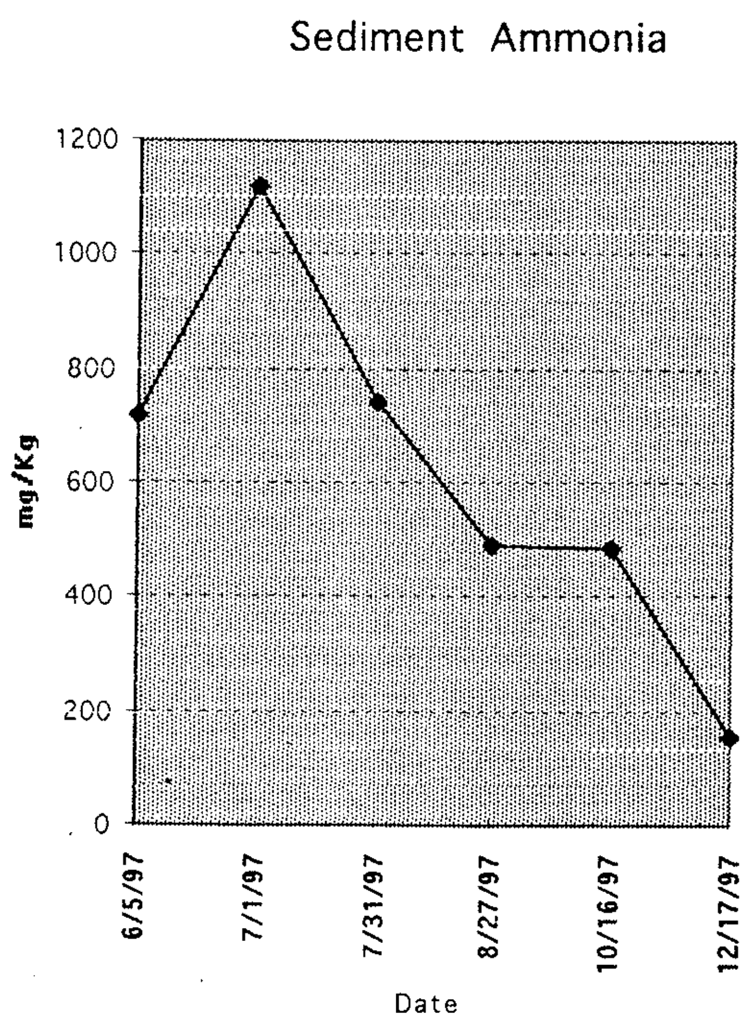
Parameter	**December Concentration**	**Percent Reduction**
Ammonia - N	155	78.44
Nitrate - N	31.3	77.64
TKN	3650	33.64
PO4	0.01	99.98
TP	0.025	100.00
Fe	10829.5	40.93

Note that for the parameters TKN and Fe, concentrations had increased in the October analysis, resulting in negative values for the "reductions."

Also Note: All sediment data was analyzed by Aqua-Air Analytical, a licensed and state-certified laboratory.

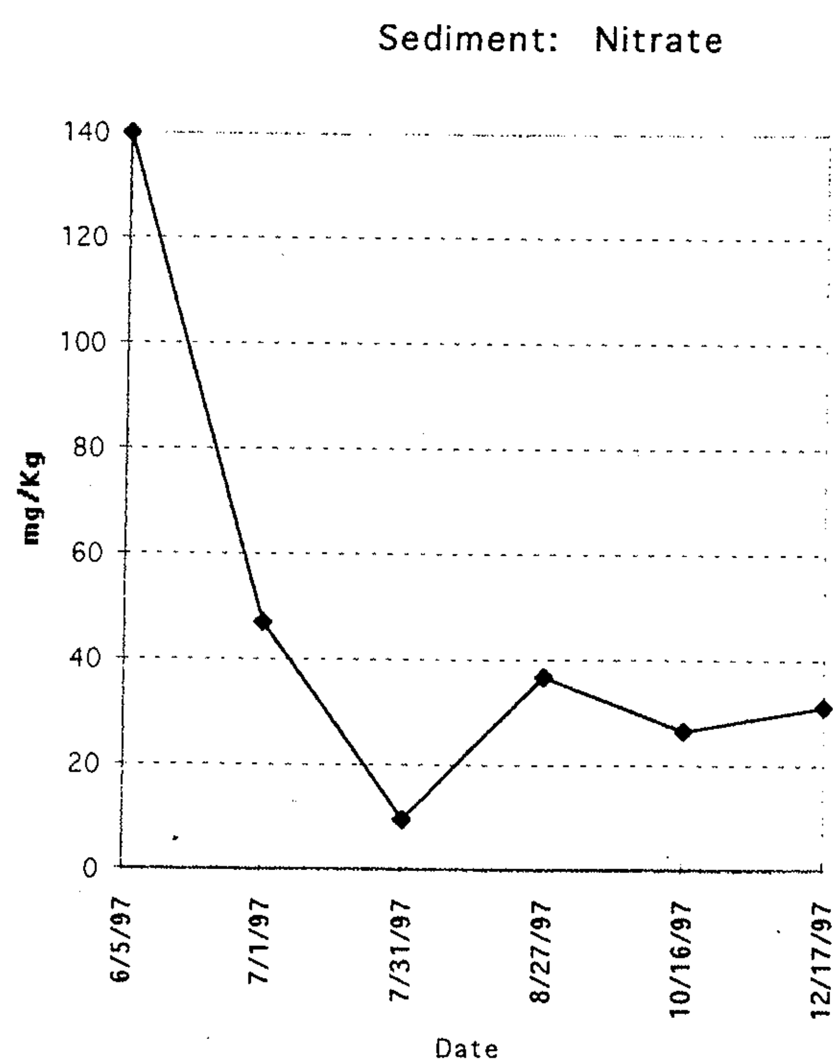
Ammonia - Nitrogen

Ammonia is a reduced form of nitrogen found in animal wastes. Throughout the operation of the Whitman's Pond Restorer, ammonia levels declined steadily in sediment samples. This toxic form of nitrogen threatens fish and other aquatic animal life when found in high concentrations, especially in the presence of more alkaline waters. The decline of ammonia in Whitman's Pond sediments decreases the likelihood of future fish die-offs and will also help to minimize algal blooms and milfoil growth.



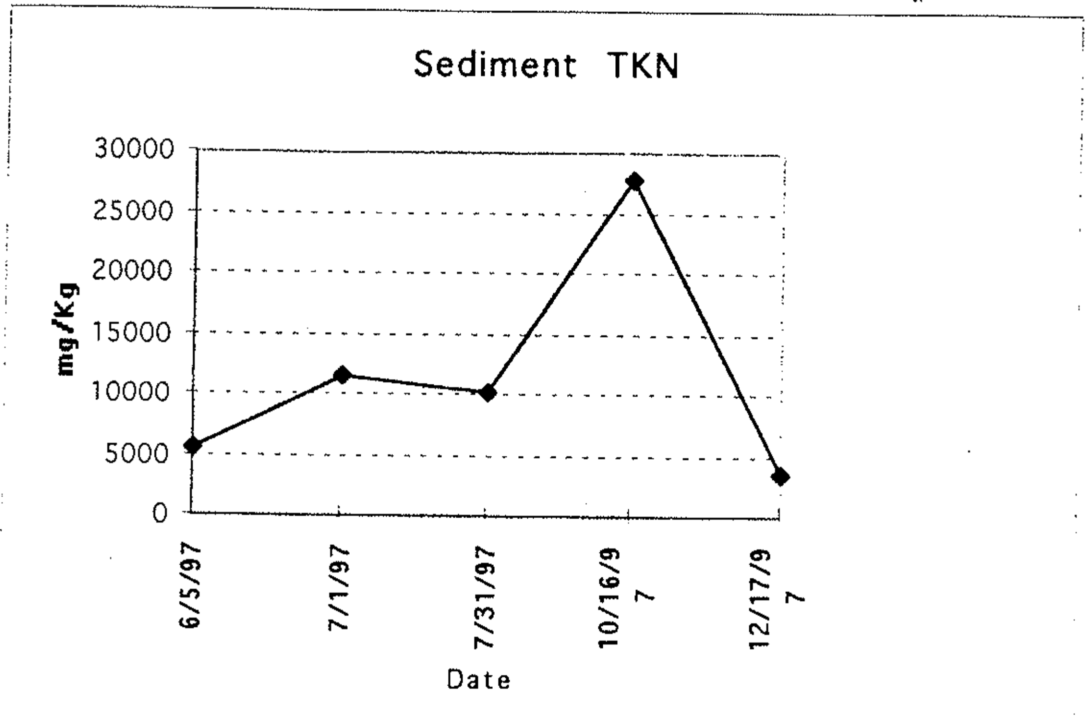
Nitrate - Nitrogen

The decline of nitrate-nitrogen in pond sediments indicates a reduction in the fertilizer available to algae and aquatic plants, especially water milfoil. The initial peak of 140 mg/kg was quite high, indicating a nutrient reservoir in the sediments. The decline indicates that the Restorer, in conjunction with natural pond processes, has reduced this reservoir, thereby limiting algal blooms and nuisance plant growth.



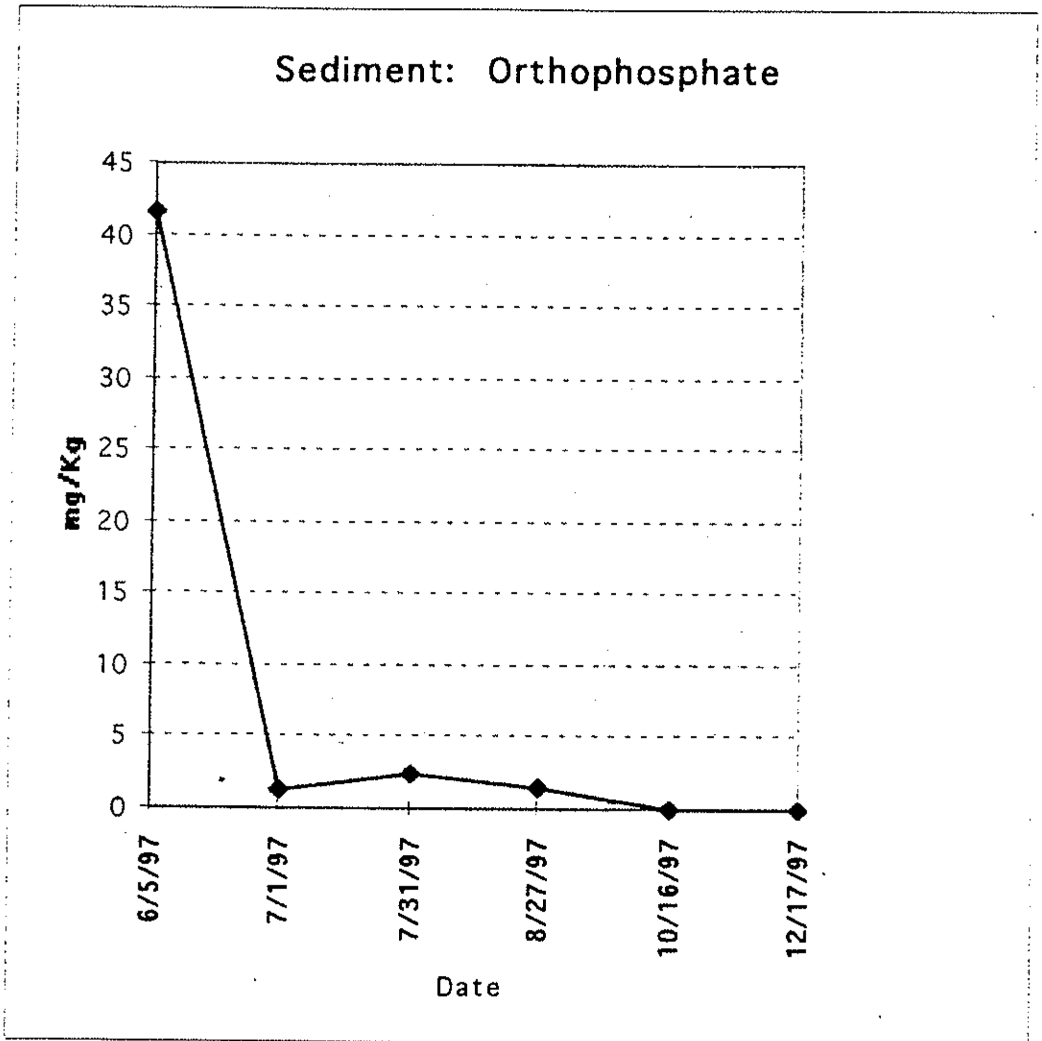
Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen measures the organic nitrogen bound with ammonia. The trend for TKN is less clear than for ammonia and nitrates, but TKN levels in the sediments in December were approximately 1/3 less than the June measurements. The cause of the spike on October 16 remains unclear.



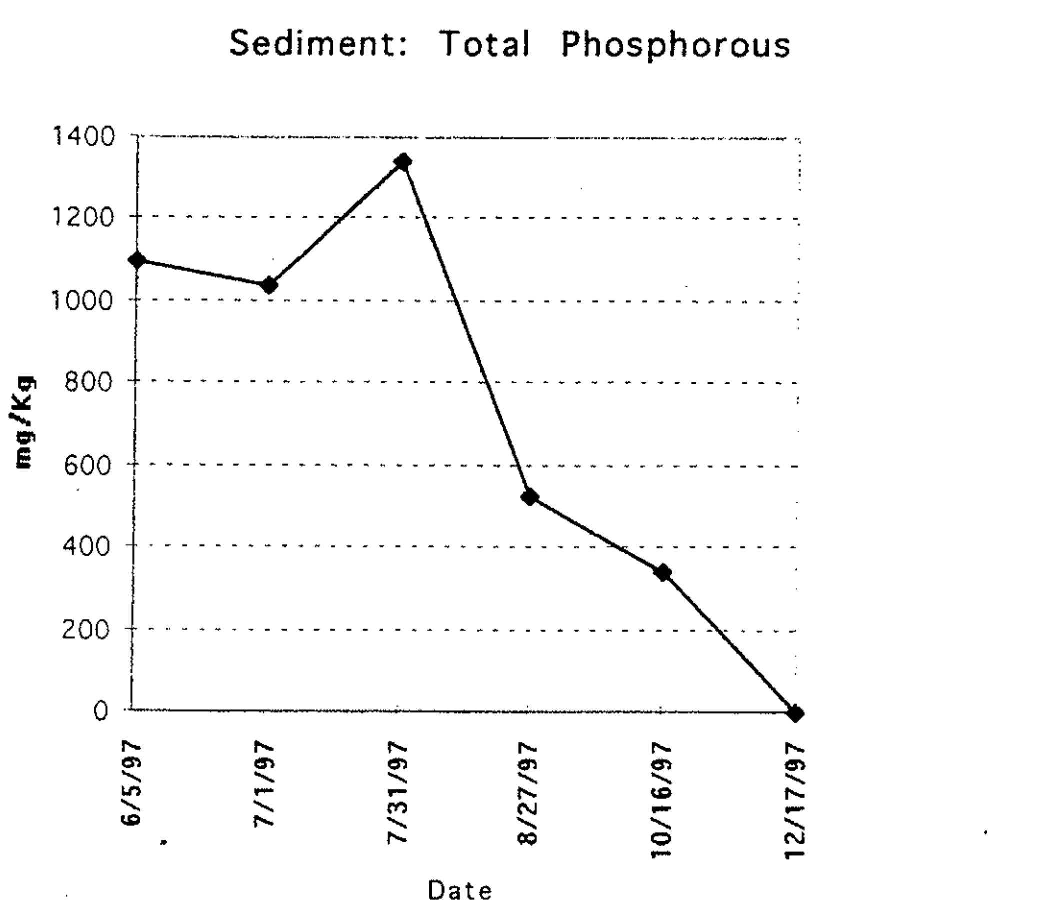
Orthophosphate

In freshwater bodies, phosphorous constitutes the least available macro-nutrient. Therefore it limits the productivity of plants and the entire food web of the lake. The oxidized form of phosphorous, orthophosphate, is found in many fertilizers, and is the biologically available form of this element. The dramatic reduction, by more than 99%, of orthophosphates in the sediments at the adjunct station offers hope that water milfoil and other plants in the area will experience limited growth in the future.



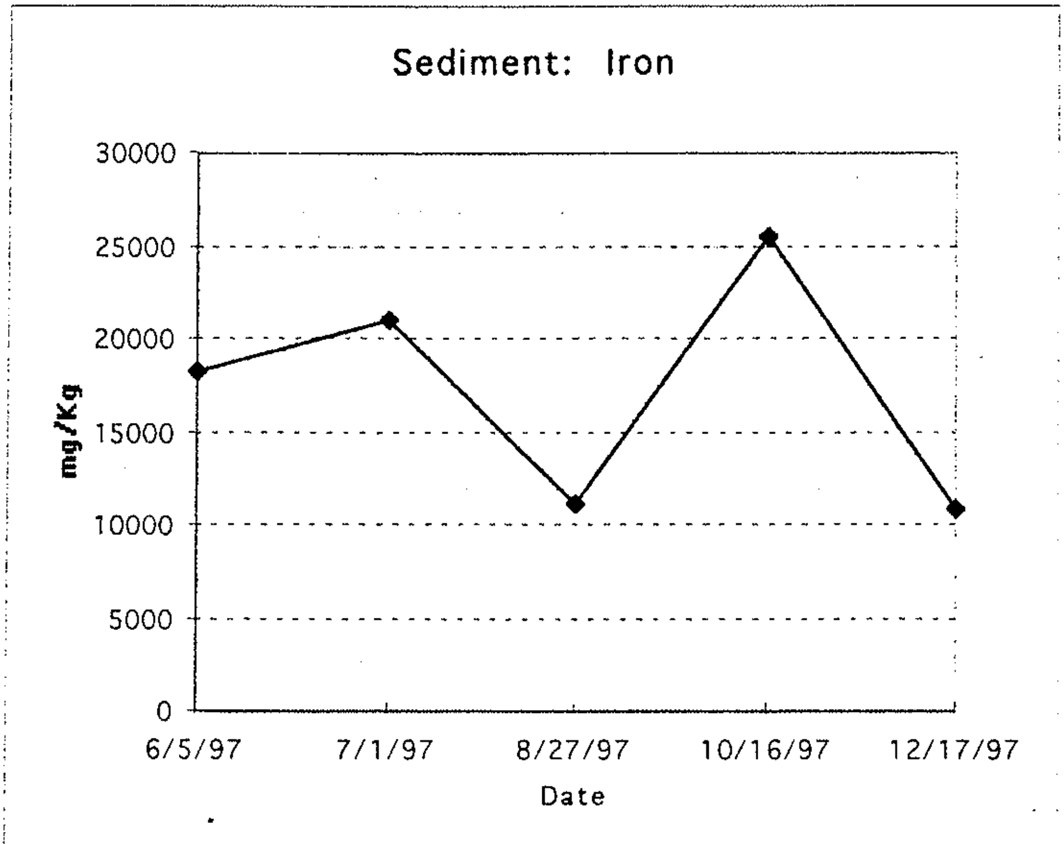
Total Phosphorous

Like orthophosphates, levels of total phosphorous in sediments declined by more than 99% in 1997. These declines, if maintained, should limit the future growth of nuisance plants. It is important to note that the slight midsummer rise in total phosphorous, observed on 7/31/97, coincided with the temporary shut-down of the Restorer for repairs. While a direct cause-and-effect cannot be established from the data, the two events could be linked.



Iron

Iron levels in the sediments sampled at the adjunct station fluctuated within a narrow range, but were overall quite high. These levels could be from historic discharges by Quincy Steel. However, the results of the December sampling were approximately 40% lower than iron levels in June. The Restorer likely played a role in this reduction, through the complexation of iron in plant tissues, and the adsorption of iron onto organic matter and root masses.



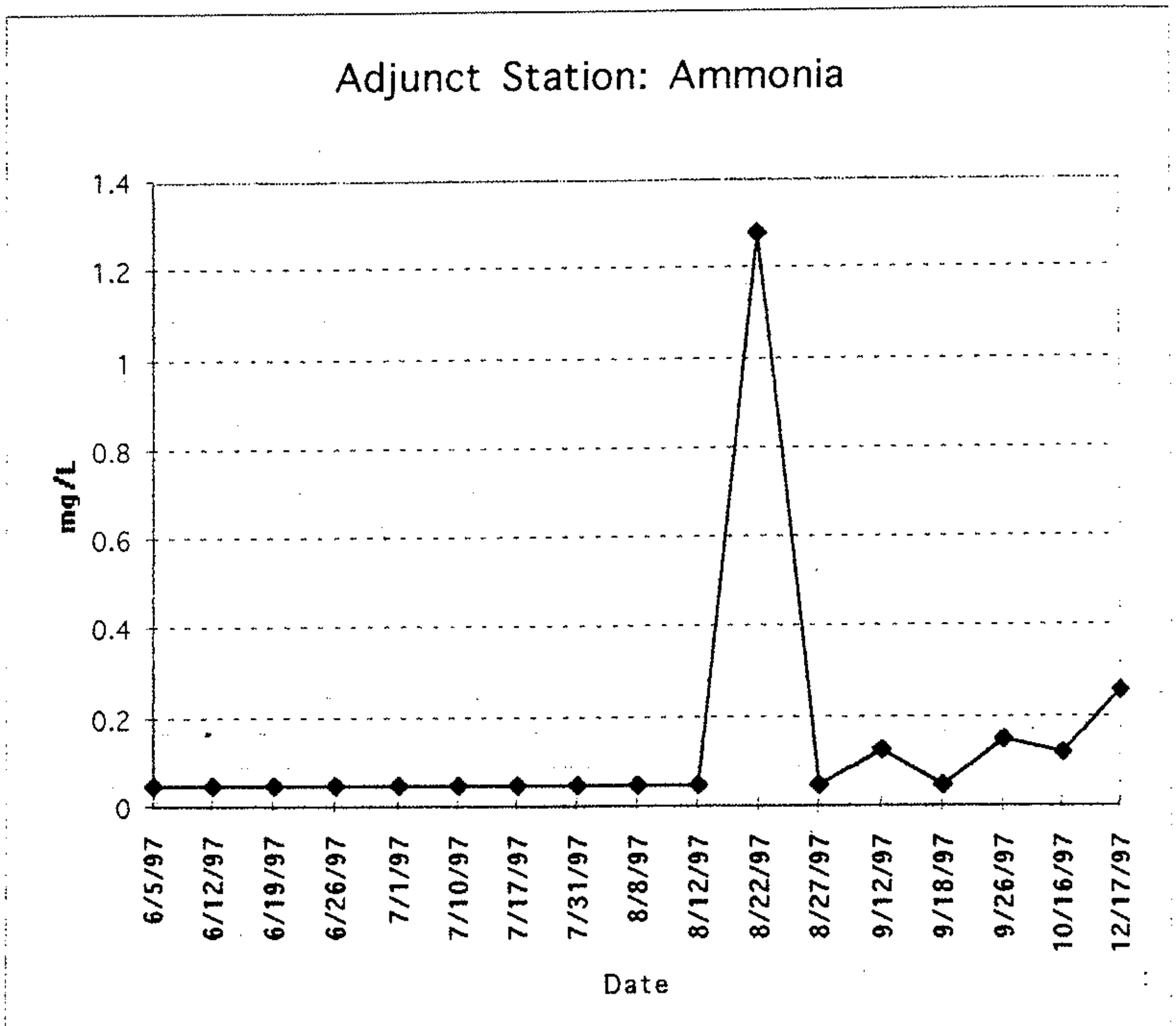
SUMMARY OF ADJUNCT STATION WATER CHEMISTRY

Measurements of water quality at the adjunct station showed fewer distinct trends, compared to the those observable in the sediment data. Nutrient levels remained low in the water column, probably mostly due to the large populations of aquatic plants in Whitman's Pond. The Restorer plants and beneficial bacteria also played a role in removing nutrients from the water, and introduced a powerful competitive pathway for the uptake of these nutrients. This competitive pathway may have played a role in the retreat of water milfoil populations from around the Restorer (see Qualitative Observations section for more details). The Restorer also may have played a role in reducing fecal coliform levels, although more analysis of this parameter would be necessary to establish this as a fact.

All Adjunct Station water quality analysis was conducted by Aqua-Air Analytical, unless otherwise noted.

Ammonia

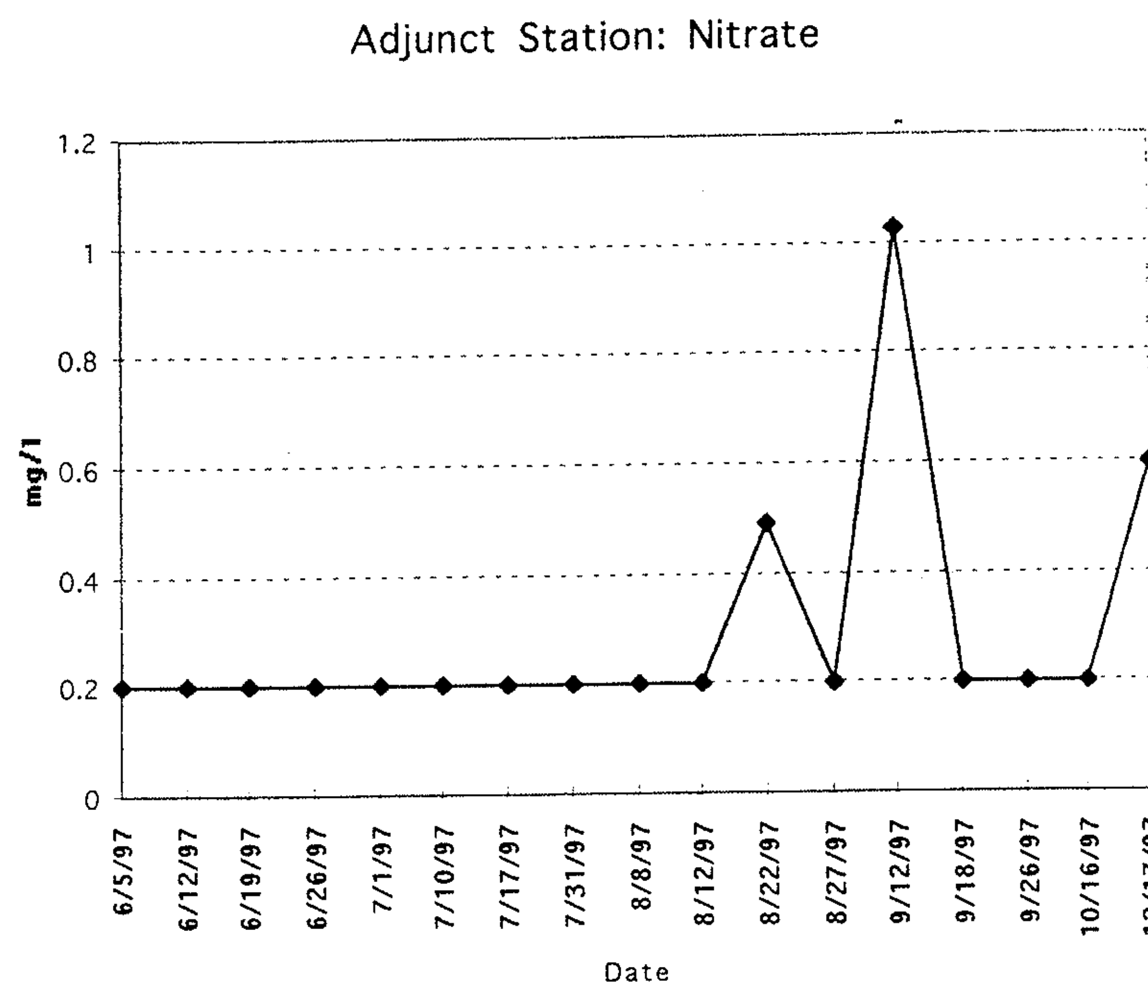
For most of the summer, ammonia levels in the water column remained below the laboratory detection limit of 0.1 mg/l. This indicates that dissolved ammonia was quickly metabolized by aquatic life forms. The slight rise in ammonia beginning in September is probably attributable to the slower metabolic rates of plants and bacteria that follows cooling water temperatures. The cause of the spike on 8/22/97 is unknown, but could be from a duck, goose, or other animal defecating in the water shortly before sampling, or it could have resulted from an error in the instrumentation (see note below).



Note: Ammonia levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR 1000 spectrophotometer was used.

Nitrate Nitrogen

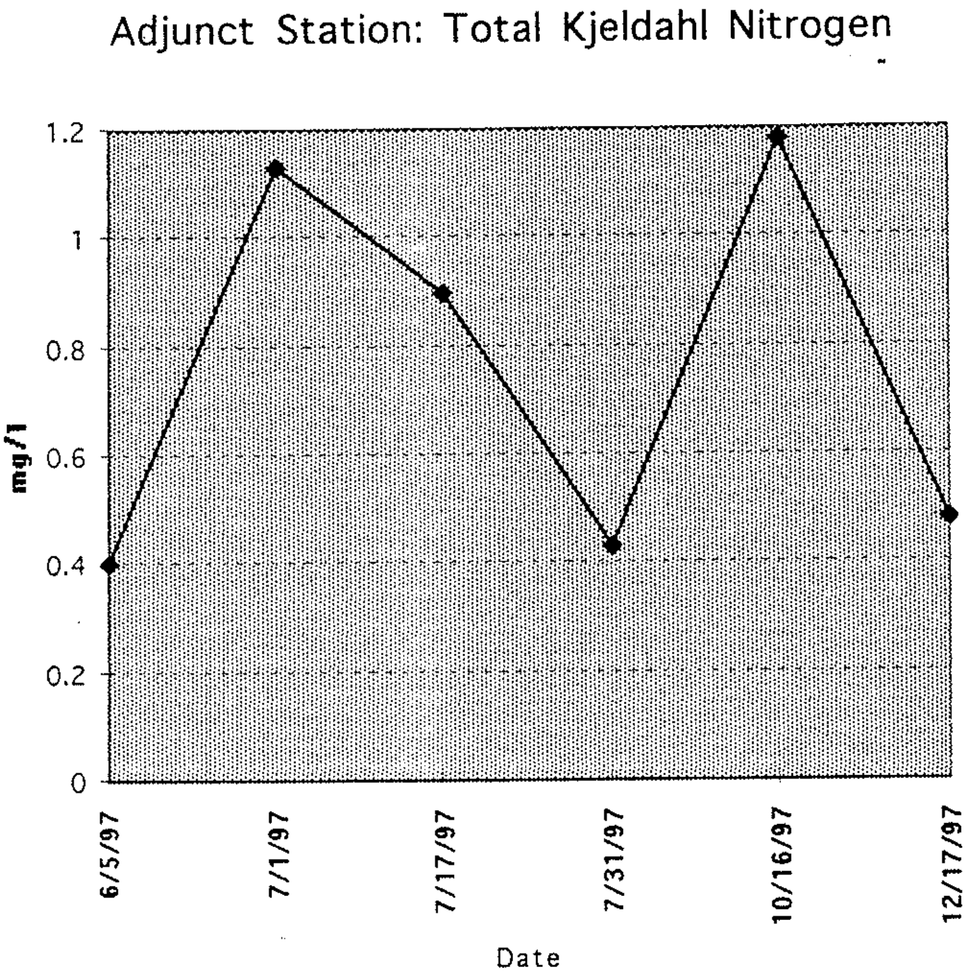
Nitrate levels also remained quite low in the water column for most of the sampling season.



Note: Nitrate levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR 1000 spectrophotometer was used.

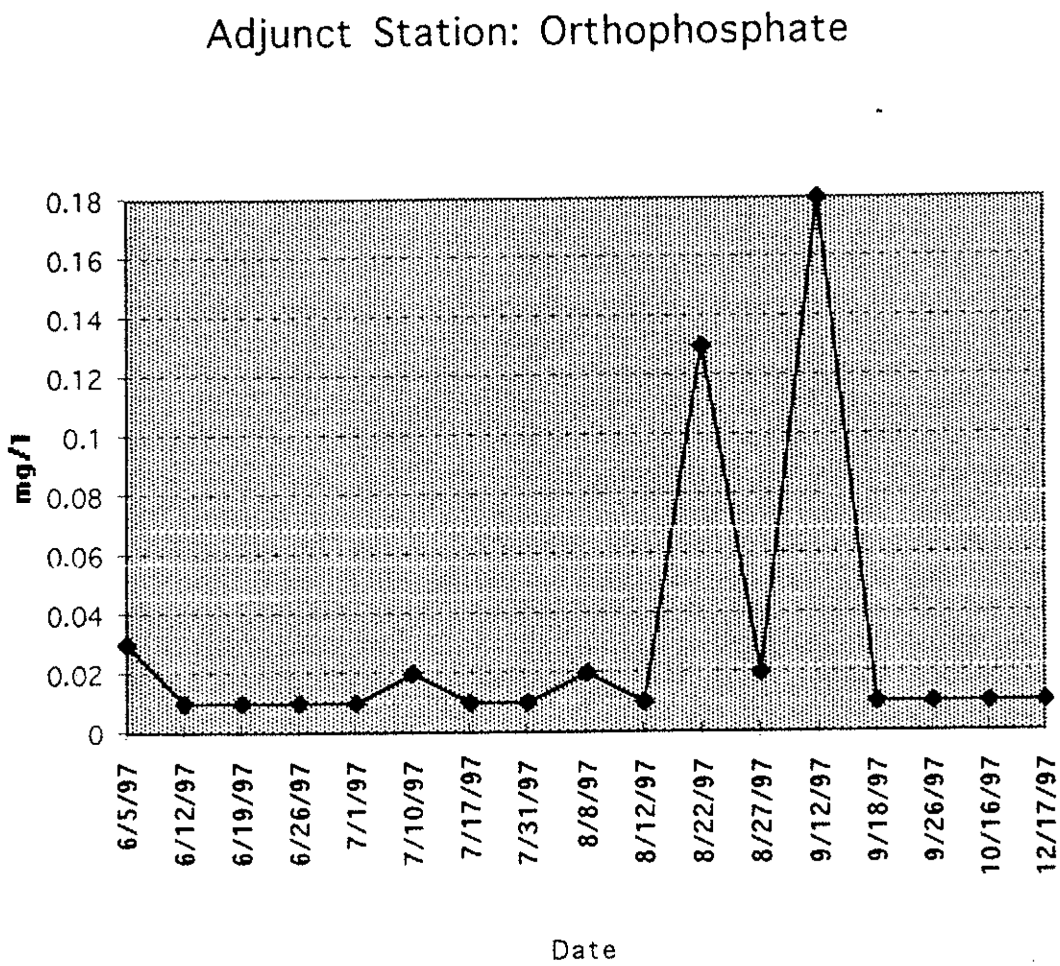
Adjunct Station: TKN

Total Kjeldahl Nitrogen levels in the pond water did not exhibit any readily-observable trend during this sampling season. Overall levels remained low.



Orthophosphate

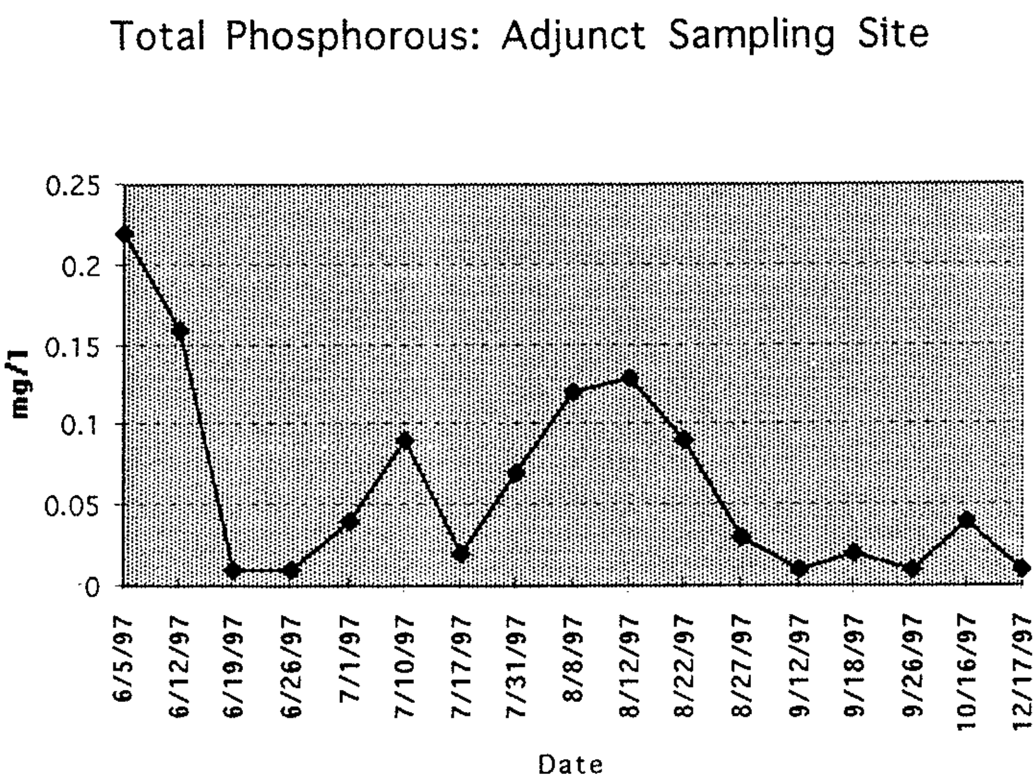
Orthophosphate levels exhibited no clear trends in the water column.



Note: Orthophosphate levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR V-1000 spectrophotometer was used.

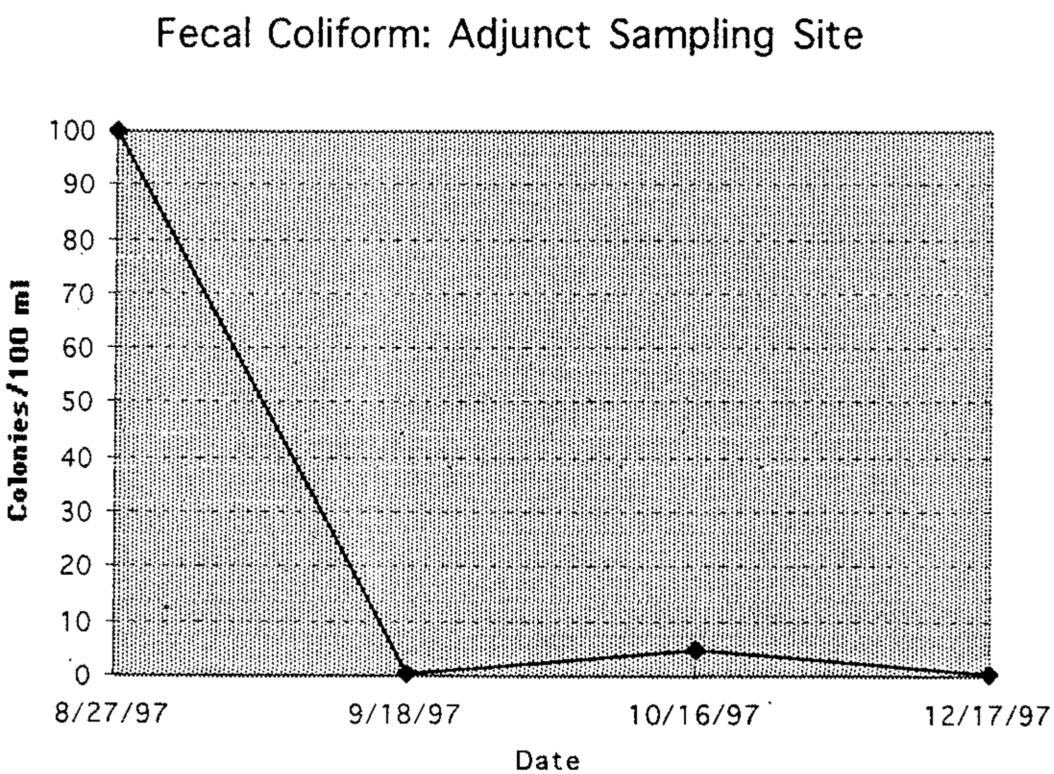
Total Phosphorous

Total Phosphorous levels exhibited a general decline throughout the season. The temporary shut down of the Restorer in late July and early August may have triggered the brief increase of Total Phosphorous from that time until September.



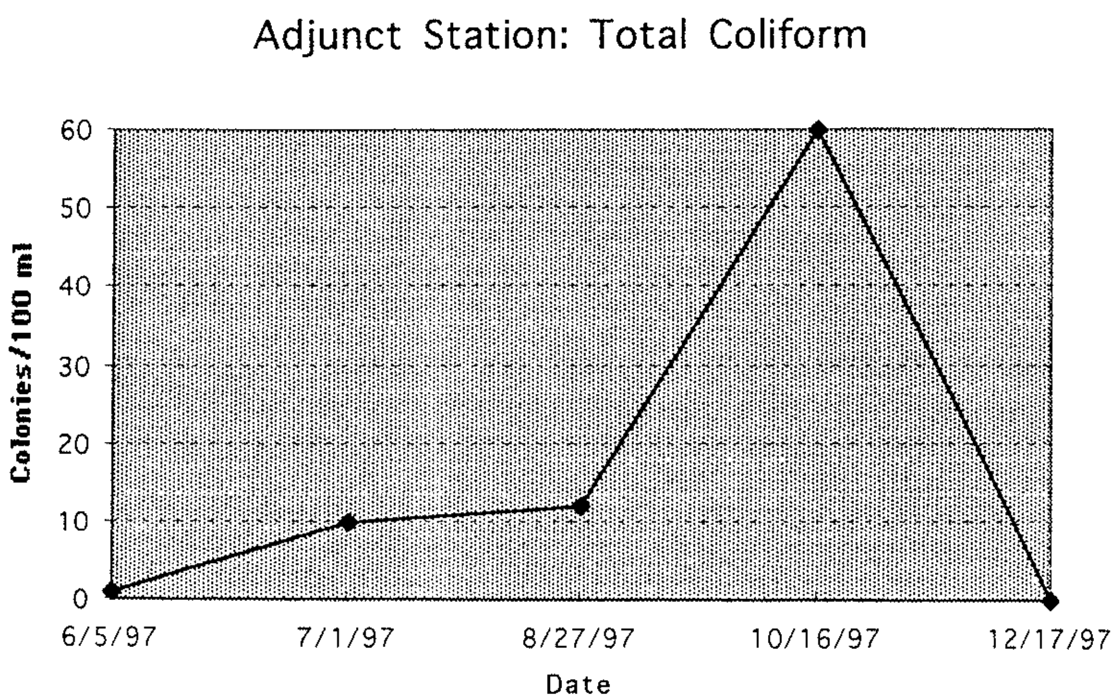
Fecal Coliform

Measures of coliform bacteria are used to estimate the presence of pathogens in the water supply due to their ease of analysis. The presence of fecal coliforms in the water could implicate leaky septic systems, an overload of animal wastes, or other biological pollution of Whitman's Pond. Although only a few water samples were analyzed for fecal coliforms, the decline of fecal coliforms after August is encouraging, and may indicate that the Restorer helped to reduce contamination in Whitman's Pond. Water samples were analyzed for coliform populations only after Weymouth residents contacted OAI with concerns about fecal coliform numbers, as the original contract did not specify monitoring for coliforms. In future years, a more regular and frequent measurement of coliform levels could help to assess the effectiveness of the Restorer, as well as the overall health of the pond.



Total Coliform

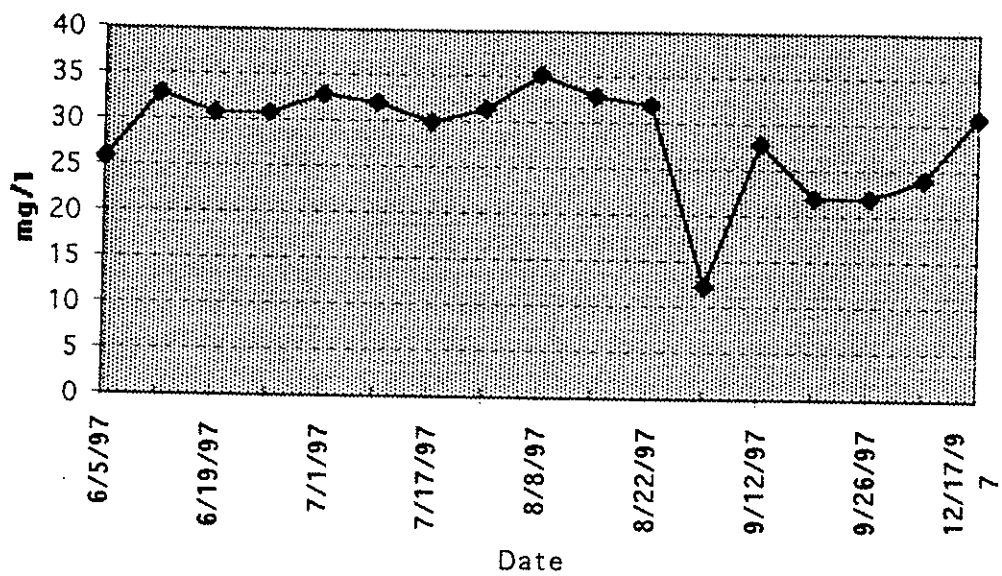
Total coliform measurements show higher populations than measurements of fecal coliforms. One possible reason for this is that the non-fecal variety of coliform bacteria are generally more tolerant to air, light, and other environmental conditions known to kill fecal coliforms. The cause of the spike on October 16 is unknown, but could be related to precipitation, or to the presence of a muskrat or other animal capable of spreading coliform bacteria in its wastes.



Alkalinity

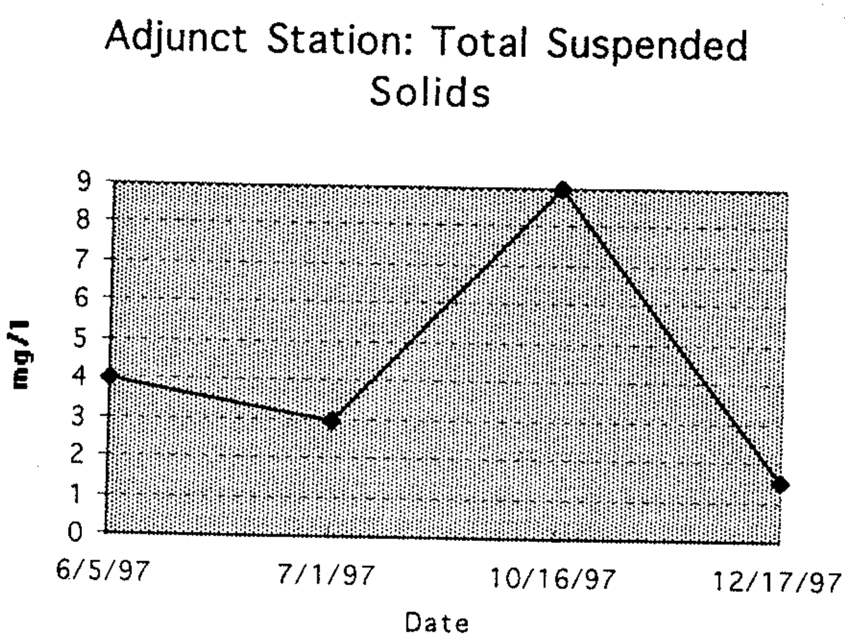
Alkalinity remained low during the 1997 season. These low levels may have limited denitrification on board of the Restorer. Denitrifying bacteria need dissolved carbon (as measured in alkalinity) to reduce ammonia to nitrogen gas.

Alkalinity: Adjunct Sampling Site



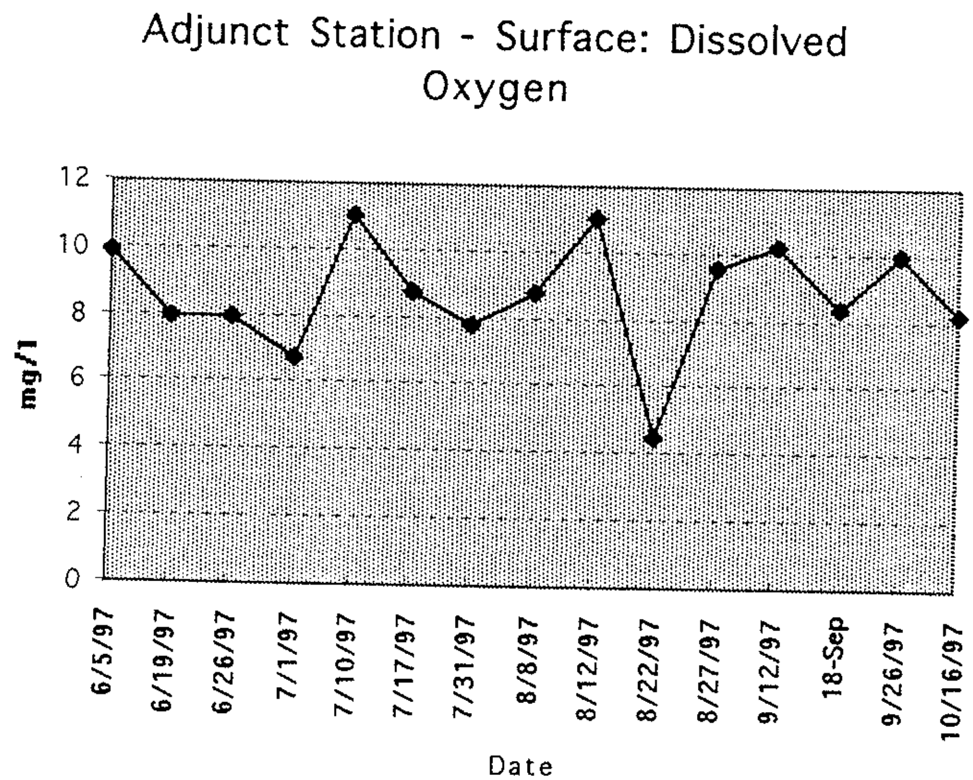
Total Suspended Solids

Suspended solids were generally low in the water column. The peak on October 16 was most likely caused by a sampling error, at which time the bottom sediments were disturbed prior to water sampling.



Dissolved Oxygen - Surface

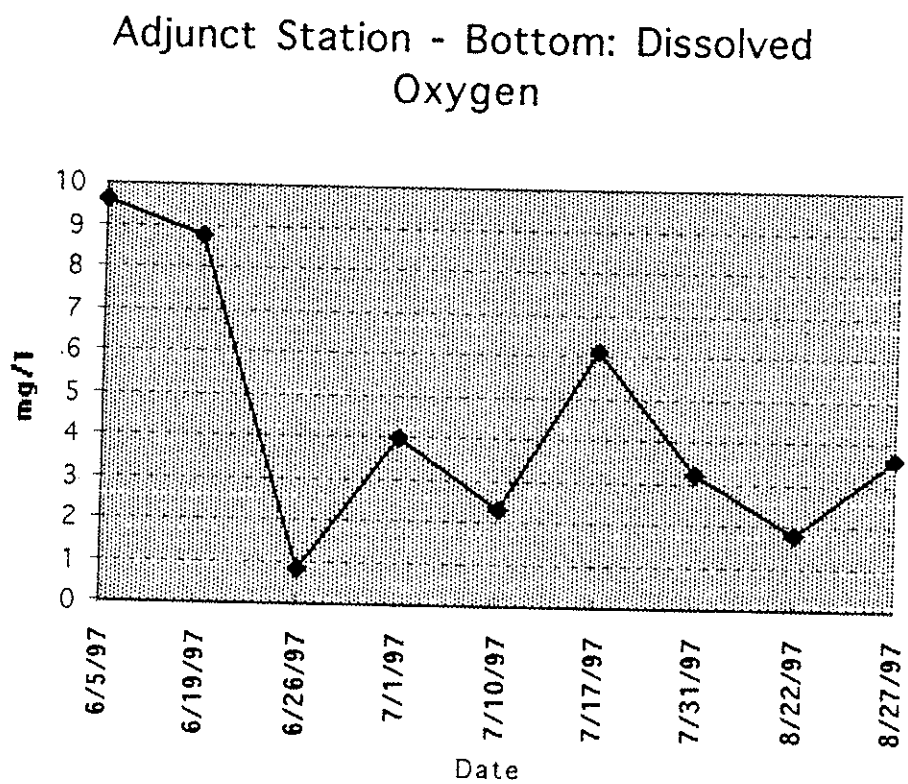
Dissolved oxygen levels at the surface of the pond remained adequate to sustain aquatic life at all sampling times. However, it is important to note that DO levels may have dropped at night, when aquatic and terrestrial plants respire but do not photosynthesize. Because all sampling was conducted during daylight hours, the dissolved oxygen levels in the pond at night remain unknown.



Note: All dissolved oxygen measurements taken in the field by OAI staff using a YSI (Yellow Springs Instruments) 51-B dissolved oxygen meter.

Dissolved Oxygen - Bottom

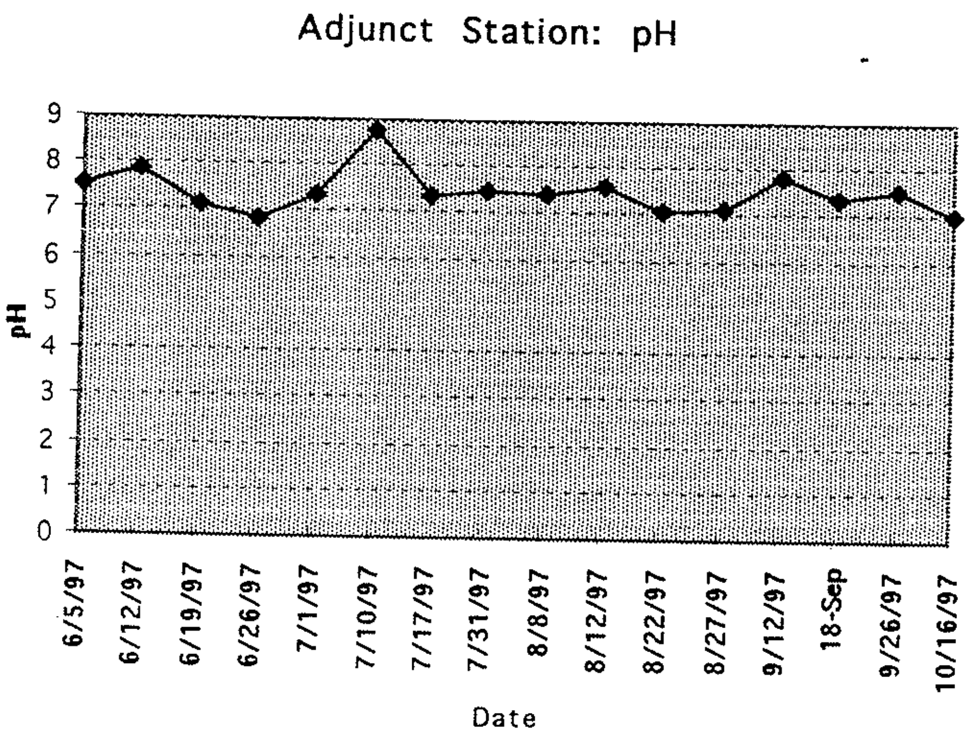
Measurements of dissolved oxygen at the benthic, or bottom, area of the adjunct station fluctuated widely. On June 26, they dipped to a level that, if sustained, could threaten benthic life. Fortunately, oxygen levels climbed shortly thereafter, due to the Restorer, climate, aquatic plant activity, water movement, or some combination thereof.



Note: All dissolved oxygen measurements taken in the field by OAI staff using a YSI (Yellow Springs Instruments) 51-B dissolved oxygen meter.

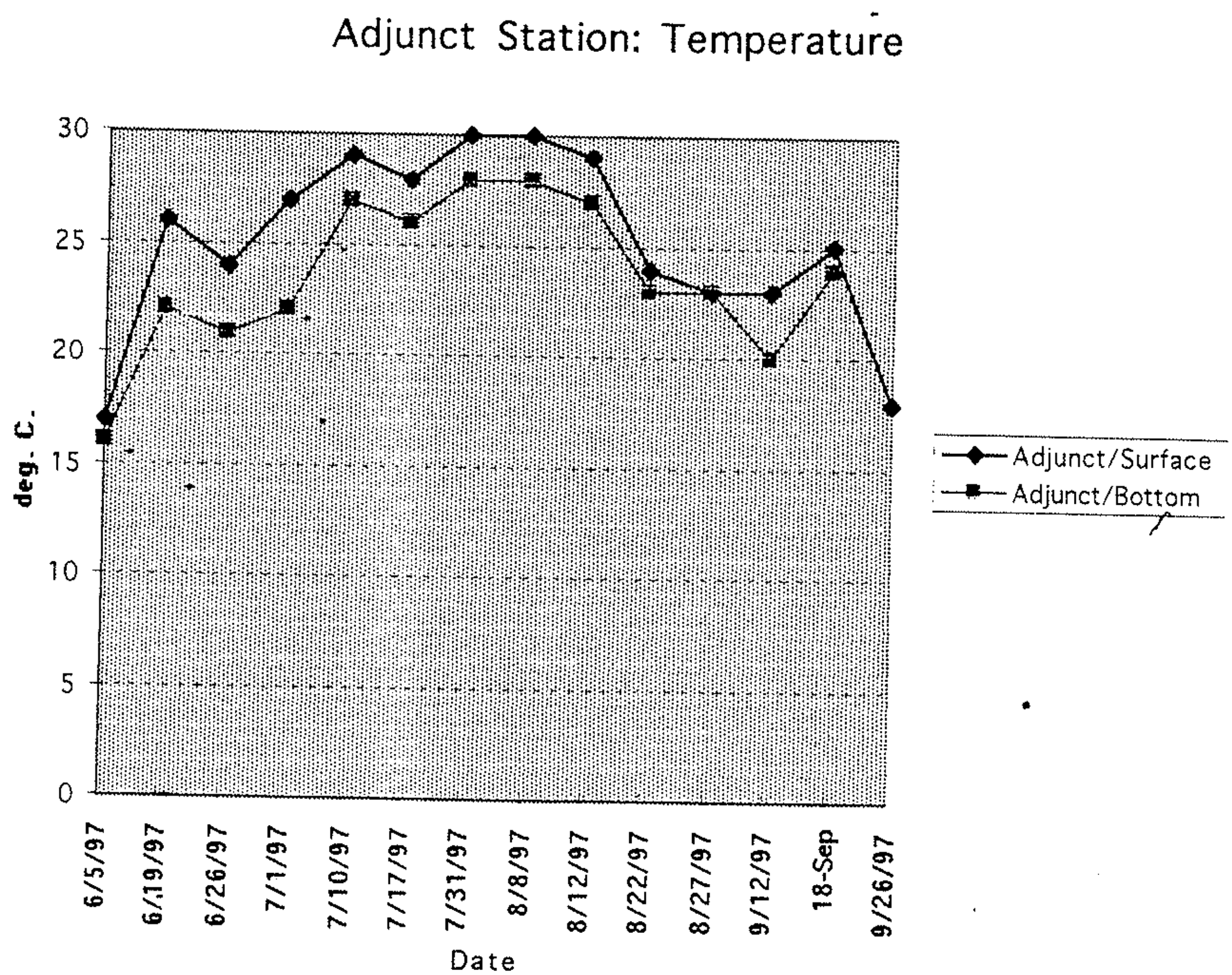
pH

The pH levels in Whitman's Pond remained neutral to slightly alkaline. The Restorer did not appear to affect pH levels in the Pond.



Temperature

Temperatures in the pond varied as expected over the seasons. At most times during the sampling period, the bottom (approximately 2 meters below the surface) remained slightly cooler than the surface.



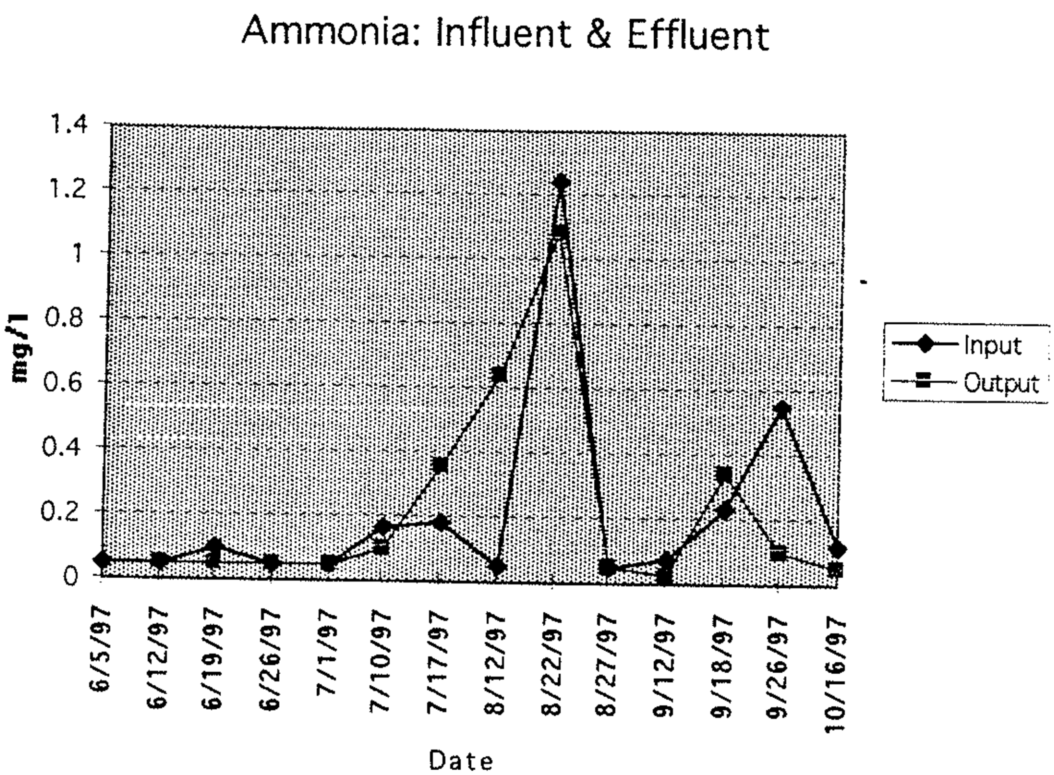
Note: All temperature measurements were made by OAI staff using a YSI 51-B meter.

INTRODUCTION TO RESTORER CHEMISTRY DATA

In most cases, the analysis of water parameters yielded results similar to those found at the adjunct station. This is consistent with our expectations of how a Restorer affects its aquatic surroundings, and compounded by the fact that this particular Restorer exchanged water with the pond at several junctures in addition to the influent and effluent pipes. However, there are some important differences as well. Like a natural wetland, the Restorer functioned as both a source and as a sink for nutrients as they cycled through the pond system over time. When viewed in conjunction with water and sediment data from the adjunct station, Restorer data confirms that nutrients moved rapidly through the aquatic environment, and that water measurements show shorter-term trends than sediment data.

Ammonia-Nitrogen

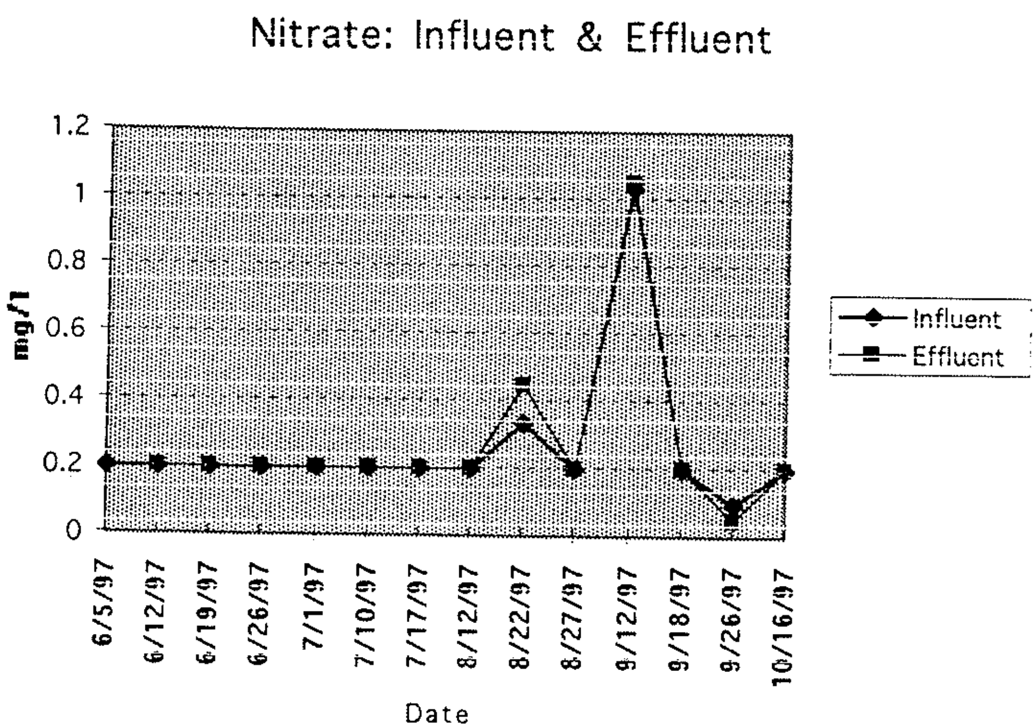
Ammonia levels in water passing through the Restorer remained generally low throughout the 1997 season, with the exception of a peak in parts of July and August. We believe that this peak results from several ammonifying influences existing on the Restorer at this time. These influences include one or more muskrats, that grazed wetland plants, chewed holes in the biofilter liners, and presumably excreted directly into the biofilter cells. Also, the Restorer raft was used as a landing point for geese and other waterfowl, that also excreted onto the decking and into the biofilters. While these animal wastes caused ammonia levels in the effluent to actually exceed ammonia levels in the influent (and on most dates, also exceed ammonia levels in adjunct water samples), the overall impact on the pond is probably minimal. By concentrating animal wastes in the biofilters, these wastes were deposited where they could be most rapidly broken down and/or assimilated. Had the muskrats and geese been living away from the Restorer, the total addition of ammonia to the pond due to their presence would likely have been greater, as their excrement would have entered the water directly. Additionally, Ocean Arks staff were able to initiate some measures to control these animals, including the use of a Hav-a-hart trap, which captured several muskrats. The muskrats were then relocated outside the Whitman's pond watershed. Following the successful trapping of several muskrats, ammonia levels declined in Restorer water samples.



Note: Ammonia levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR 1000 spectrophotometer was used.

Nitrate-Nitrogen

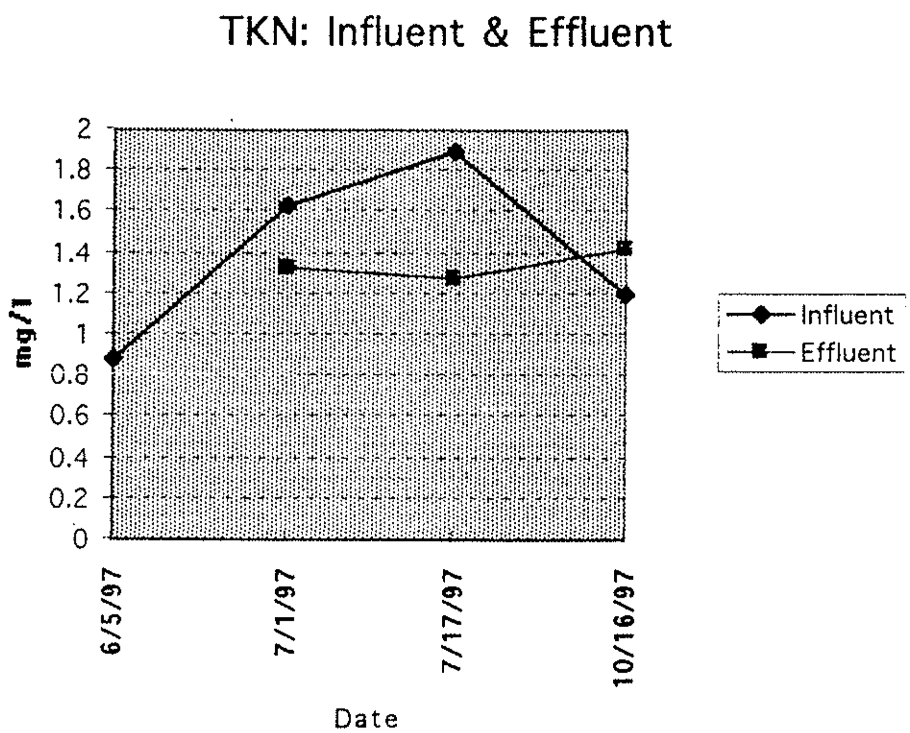
Nitrate-nitrogen fluctuated less than ammonia-nitrogen, reinforcing the notion that muskrats, geese, and other animals (that excrete ammonia-rich wastes) were the cause of ammonia-peaks in the data. The fairly consistent nitrate data indicates that nitrates are rapidly assimilated in Whitman's Pond, both by plants on the Restorer, and by the water milfoil and other wild plants. The cause of the spike on September 12 is not known.



Note: Nitrate levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR V-1000 spectrophotometer was used.

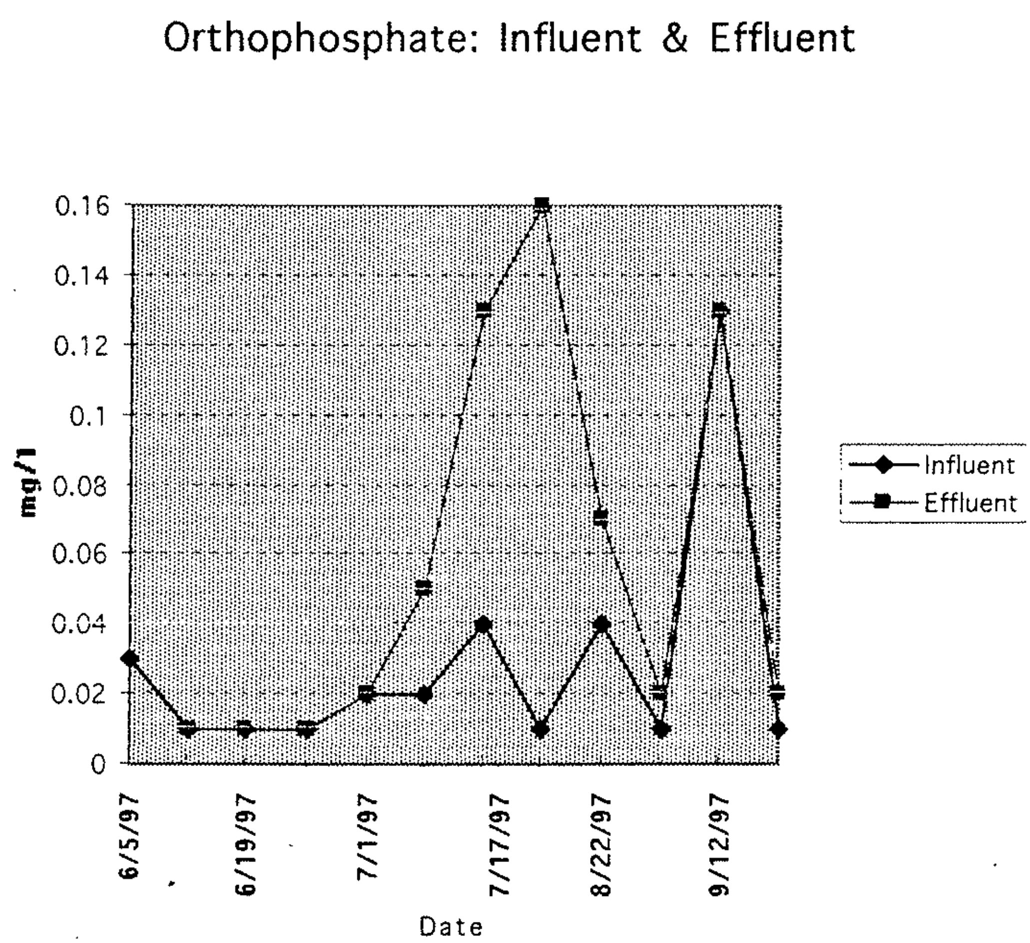
Total Kjeldahl Nitrogen

TKN was measured on only four occasions: an insufficient sample size from which to draw any definite conclusions. However, it appears that the Restorer played a role in reducing the quantity of organically-bound nitrogen, probably through mineralization carried out by heterotrophic bacteria.



Orthophosphate

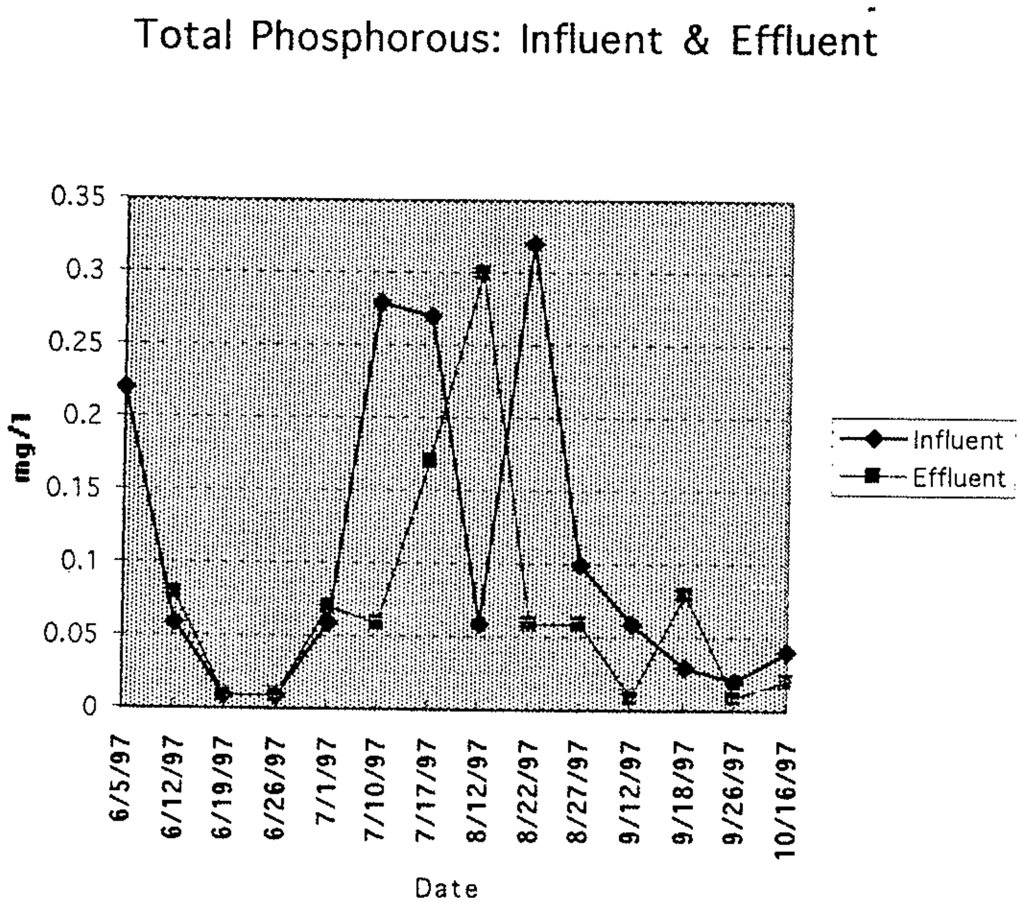
During part of July and August, the Restorer actually released orthophosphates. The exact cause of this is not known, but it could be that the wetland plants contained excess fertilizers in their coconut-fiber substrates. However, levels never reached even two-tenths of a part-per-million.



Note: Orthophosphate levels were measured by Aqua-Air Analytical, except on the dates 8/22, 9/12, and 9/26. On these dates, a CHEMetrics (Rt 28A, Calverton, VA 22016, Phone: 800 356 3072) VVR V-1000 spectrophotometer was used.

Total Phosphorous

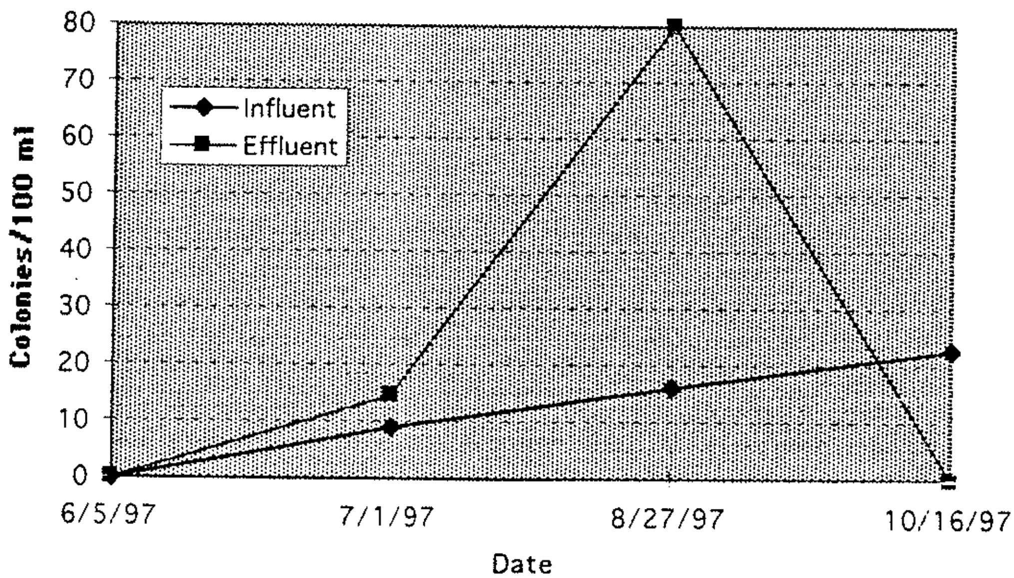
Total phosphorous levels also fluctuated over a narrow range, but tended to decline as the season progressed. Again, the Restorer appeared to act as both a source and sink for this nutrient at various times.



Total Coliform

Total coliform populations increased steadily throughout the season at the influent point. The cause of the effluent spike of 8/27 is not known, but could be related to muskrats or other animals within the Restorer. Because both the Influent and Adjunct data for 8/27 do not contain such spikes, the source must have been highly localized. To establish clear causes and effects, more data should be taken in coming years. What little background data there is on coliform levels shows that coliform levels fluctuated widely, probably due to a combination of weather and localized sources of biological pollution.

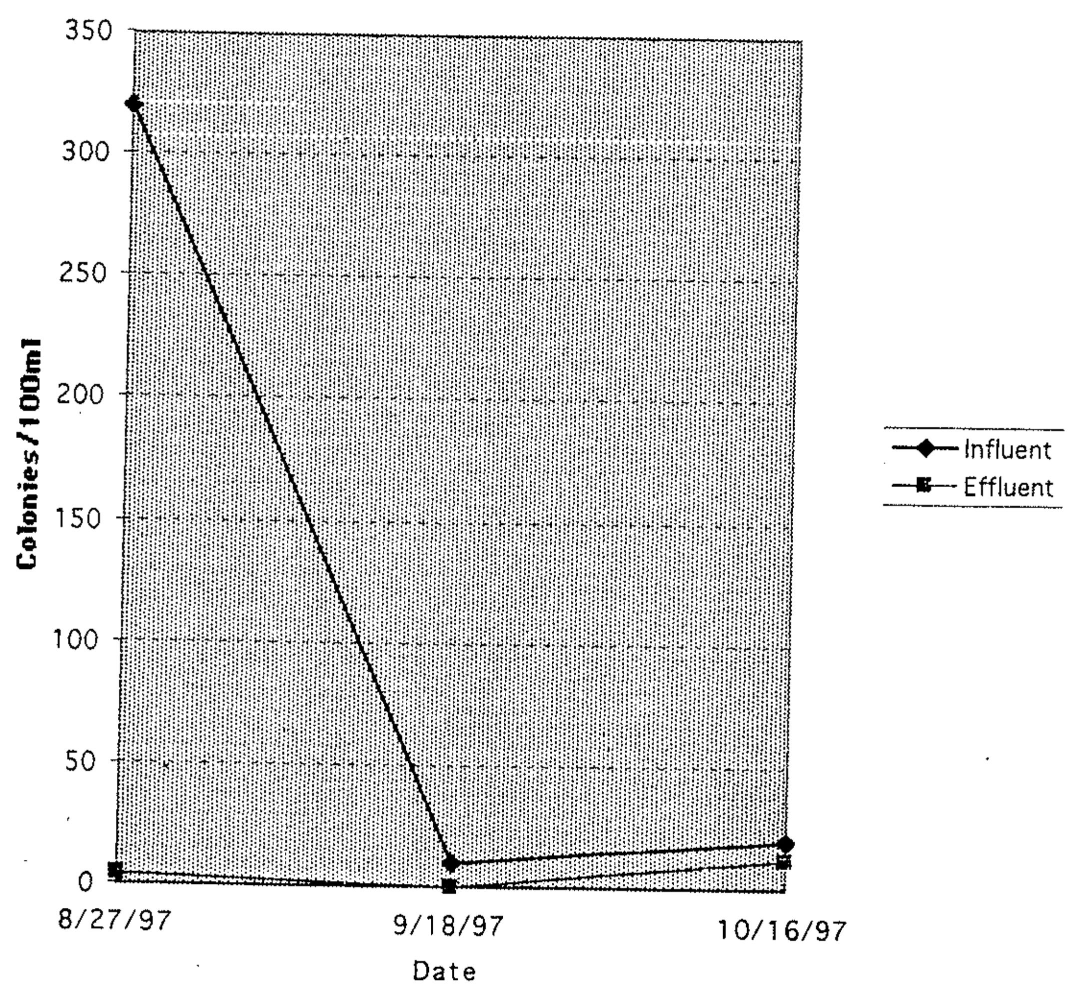
Total Coliform: Influent & Effluent



Fecal Coliform

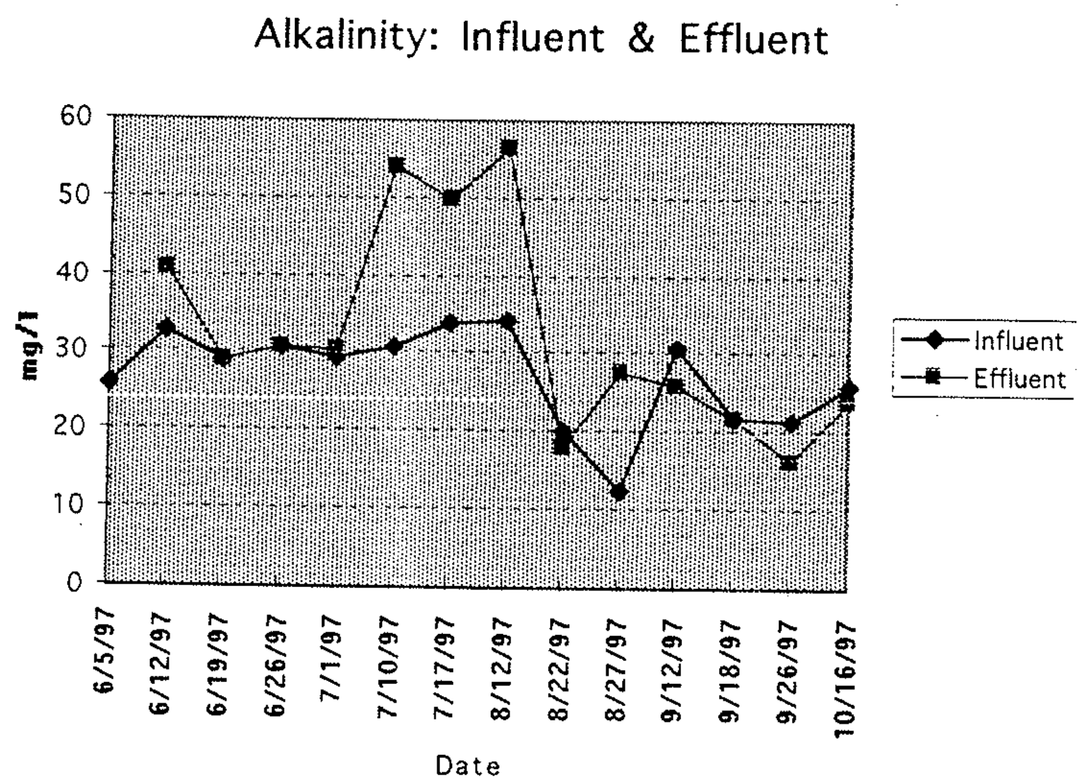
Fecal coliform measurements were only made on three sampling days; more data is clearly necessary to draw any definite conclusions. Nonetheless, the sharp contrast between influent and effluent data is encouraging, as are the consistently low measurements of both influent and effluent thereafter.

Fecal Coliform: Influent & Effluent



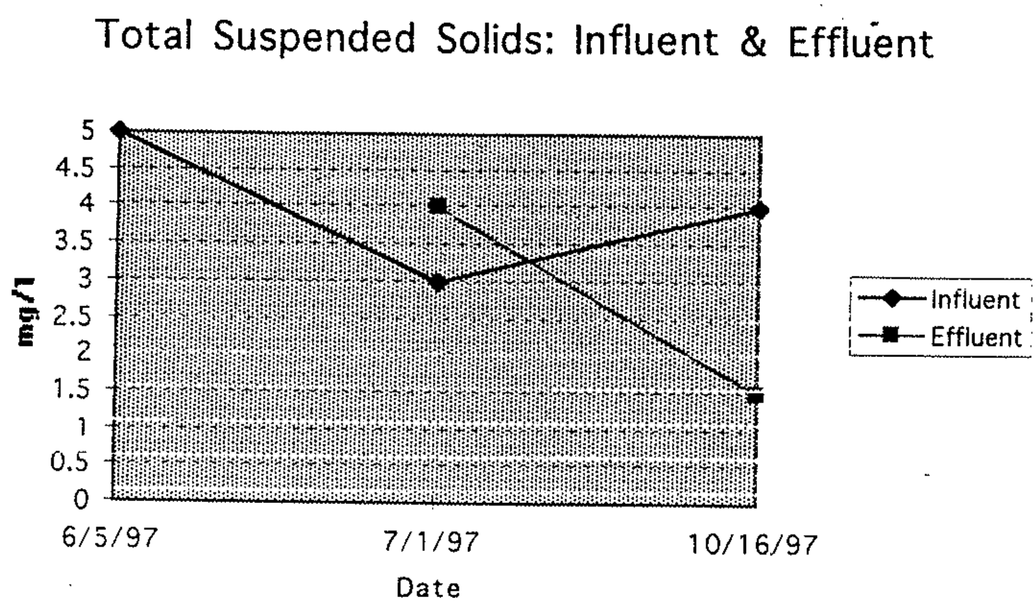
Alkalinity

The high alkalinity measurements in Restorer effluent between 7/1 and 8/12 resulted from the addition of horticultural lime to the biofilter cells. This addition was made in an effort to boost denitrification in the anaerobic zones of the Restorer. Otherwise, alkalinity remained low.



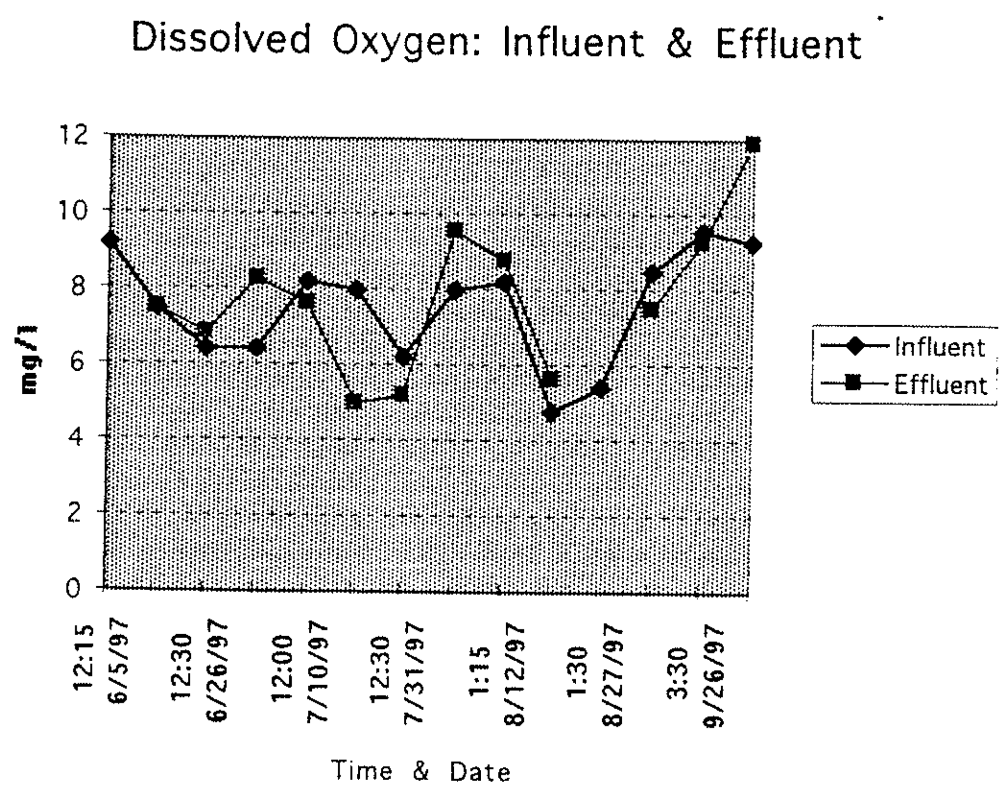
Total Suspended Solids

TSS was measured on too few occasions to draw any meaningful conclusions. The graph is nonetheless included in order to complete the data set in a graphic format. Furthermore, the downward trend in effluent TSS levels may warrant future sampling for this parameter.



Dissolved Oxygen

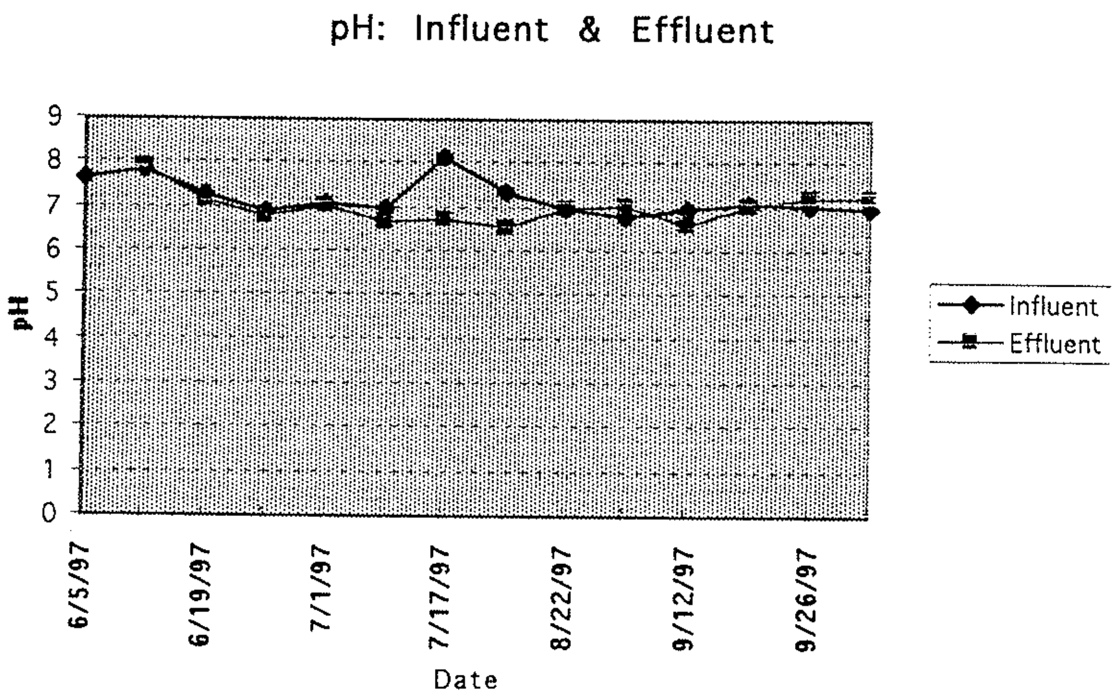
Dissolved oxygen levels did not vary widely between influent and effluent. Although many microbes living within the Restorer consume oxygen, the airlifts and internal circulators constantly replenish the supply.



Note: All dissolved oxygen measurements taken in the field by OAI staff using a YSI (Yellow Springs Instruments) 51-B dissolved oxygen meter.

pH

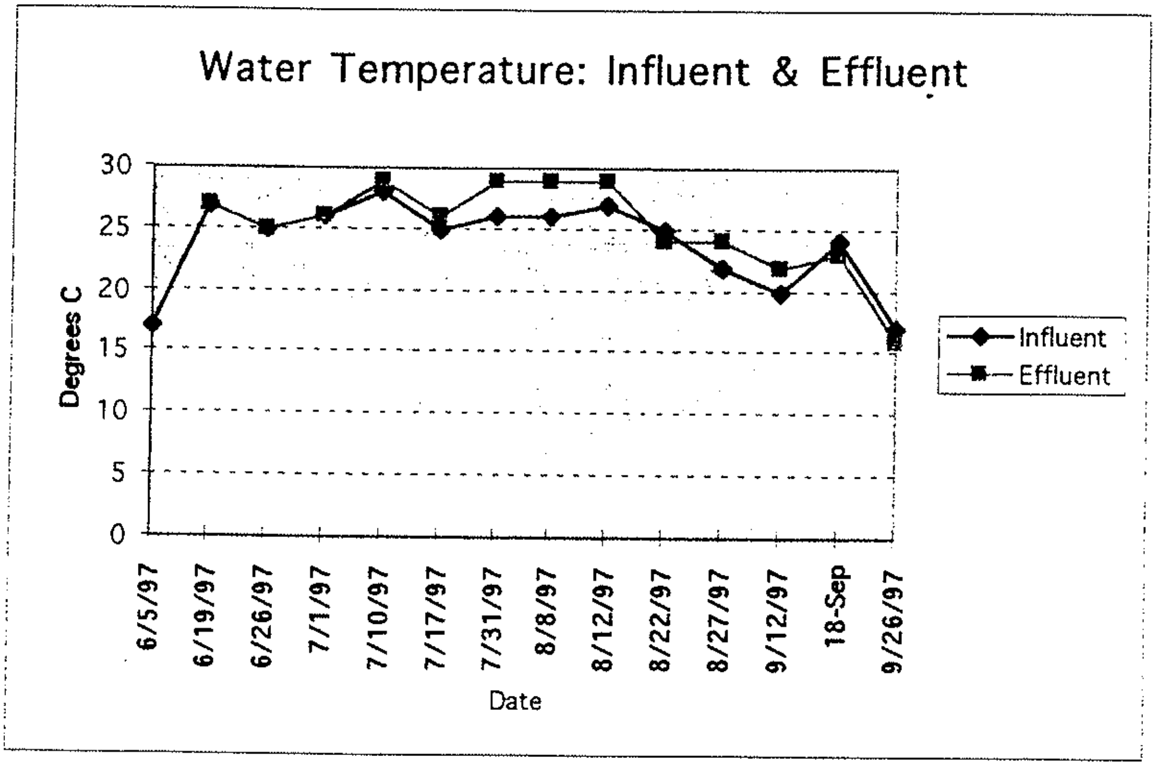
Levels in pH did not appear to change significantly as water passed through the Restorer. In general, bacterial metabolic activity tends to acidify water, while the photosynthetic activity of algaes and plants tends to shift pH toward the alkaline. These processes appear to be close to equilibrium within the Restorer.



Note: Measurements for pH were initially conducted by OAI staff, using a Hanna Instruments HI 9025 pH meter. Beginning on 8/8/97 and through the end of the season, pH was measured by Aqua-Air Analytical.

Temperature

As water passed through the Restorer, it tended to warm slightly, but never more than a few degrees Celsius.



Note: All temperature measurements taken in the field by OAI staff using a YSI (Yellow Springs Instruments) 51-B meter.

Qualitative Assessment of the Pond & Restorer Operations

EURASIAN WATERMILFOIL

THE PROBLEM

In Whitman's pond, Eurasian watermilfoil presents a significant problem to the future use of the waterway for recreation and as a drinking water resource. In South Cove, the waterway appears substantially clogged. *Myriophyllum spicatum L.* is a nuisance species. A perennial submergent, it can out-compete most native plant species, particularly in nutrient-rich waters. In South Cove, and in much of the Whitman's Pond ecosystem, the milfoil dominates aquatic plant populations. The ability of the plant to tolerate a wide range of conditions, including fluctuating weather conditions and varying depths, allows its presence from early spring to late fall in high abundance. Associated with milfoil excess are problems of accelerated eutrophication due to rapid sedimentation.

Milfoil infestations are typically controlled with a range of options such as herbicide application, mechanical harvesting, insect and invertebrate control, and the manipulation of habitats by varying water levels. All have been partially successful and considerably expensive. The choice for a solution to the milfoil populations in South Cove becomes even more restricted due to the use of the body as a secondary drinking water source.

OBSERVATIONS

In June, with the ramp up of the Restorer, milfoil populations were in abundance with meristems submerged approximately a foot from the surface of the water. As the summer progressed and water levels dropped, the stems and leaves were closer to the surface. Within an observed fifteen foot radius around the Restorer, milfoil was in high abundance and very few patches of bare sediment could be seen (1-2 at most, no greater than the size of a frisbee).

As the operating season for the Restorer progressed, a marked retreat of milfoil from the Restorer was observed. Sandy patches of lake bottom appeared on the north, south and west side of the raft. The first observations were made over an area radiating from the north west corner of the raft and towards shore. This area was well traveled by canoe throughout the season so the area was observed continually during the summer. On 8 August, the first marked reduction in milfoil was noted. Each week, larger and more varied patches were disappearing on different sides of the raft. Patches were approx. 3-10 ft. away from the perimeter of the raft.

During this same period, a tremendous improvement in water clarity was observed, first on 10 July. Communities of bryozoans (*Pectinatella magnifica*) , colonies of fresh water animals, appeared on the sea-cell floatations of the raft. These organisms, not present at the start of the season, are filter-feeders that only tolerate clear, non-turbid and warm water conditions. The colonies are able to harbor a large, diverse number of protozoans, rotifers, gastrotrichs, microcrustaceans and other small animals. Most of these organisms are useful in controlling populations of waterfoil as they are grazers. These consumers may have combined to eat both the milfoil's nutrients, and in the case of grazing protozoans, the milfoil itself. They have also been observed at the site of another restoration project initiated by OAI in Flax pond, Harwich, MA. As water quality improved there we began to observe colonies of the organisms clinging to components of the Restorer.

RATIONALE

It appears that Restorer diminished milfoil populations through several methods. First, the Restorer created and maintained a constant flow of water. This augmented the flows of water toward the pump house, when water was drawn into the drinking supply (these flows - upwards of 1 million gpd - dwarfed flows through the Restorer). As water flowed through the Restorer, it was stripped of many of its nutrients, limiting the opportunity for milfoil populations to access these nutrients. Furthermore, it is possible that the wetland and aquatic plants aboard the Restorer secreted allelopathic and antibiotic natural chemicals that hindered the growth of the milfoil.

OAI associate and Canadian renowned scientist, Dr. Karl Ehrlich, conducted research on the affects of biomanipulation and watermilfoil populations. In two 4-month trials, bioaugmentation of sediments and the water column, repeatedly demonstrated reductions in Eurasian watermilfoil populations up to 90%. The bacterial suspension used in the experiments, Bact-pur, is the same mixture used to inoculate the living systems of the Restorer. The Restorer acts as an incubator for these organisms. The water leaving the raft disseminates these populations throughout the pond. By harboring billions of bacteria and protozoans, the Restorer may have been able to shift the local food chain toward a heterotrophically-dominated system. It cannot be assumed that healthy populations of bacteria exist in an ecosystem (refer to above discussion on bacteria in section "Media and Biofiltration").

Sediments are the most important source of nitrogen and phosphorous for Eurasian water milfoil and other aquatics. The Restorer seems to have reduced these nutrients in the sediment significantly. This may also have contributed to the decline in milfoil abundance. Bacterial augmentation, with balanced bacterial communities, has been shown to be able to more than double bacterial counts in wastewater treatment plants and in lake sediments.

ZONE OF INFLUENCE

In the South cove of Whitman's Pond, OAI sampled the influent and effluent sites on the raft and a site approximately 30 meters off the south side of the raft. Changes in sediment chemistry were observed at the adjunct station. We believe the Restorer acts as a catalyst for natural reactions in the pond, and can initiate or maintain processes in the larger pond body. On Flax Pond in Harwich, MA, a Restorer is treating a 15 acre pond. The area sampled comprised from eight to six (varied depending on the year) stations throughout the entire area of the pond. Significant changes in sediment chemistry and depth reductions were recorded at all stations over a five year period. Such results suggest that the influence of the Restorer affected change in the entire pond body. Continuing Whitman Restorer operations would allow the opportunity to sample points beyond the adjunct point monitored in 1998.

PUBLIC OUTREACH

One measure of success for the Restorer project is indicated by the levels of interest in our technology by the community. In June, community members and media representatives visited our launch site. Throughout the summer season, media coverage on the South Cove restoration project remained fairly continuous. Residents contacted our office with frequency to inquire about Restorer operations and the state of the water. In late August, OAI attended a Weymouth Association meeting to update the community on the technology and the data collected to date. The turnout was large, and led to an organized tour of the raft in October. At that juncture, OAI staff met a school teacher in a neighboring town curious about integrating lessons of ecology, water conservation and living machines into an after school program. This meeting is now evolving into a potential school aged program.

OAI staff learned a great deal from the Weymouth residents we were in contact with this season. Often, conversations provided clues to a holistic approach to restoration that would stretch far into the future. These ideas as applied to Weymouth and the Restorer are outlined briefly in the section "Recommendations for the Future."

Recommendations for the Future

Option 1: The continued operation of the Restorer

The Whitman's Pond Restorer Living Machine has functioned well in its first year of operation. The successes and obstacles throughout the season have been outlined extensively above. With minor repairs and modifications, it is possible to continue the operation of the Restorer. Our contract terminated in December, Ocean Arks staff have not had the funds to continue maintenance or running of the Restorer since that time.

1) repairs

If the Whitman's Pond Restorer were to continue operating in 1998 a number of maintenance repairs would be needed. Structural reinforcement of the cells and repairs to the liner would be essential for the long term viability of the raft. Also, additional flotation should be added, particularly to the influent side of the Restorer (currently much lower in the water than the rest of the raft due to unequal weight, depth variability and a punctured floatation device).

2) biology

With the onset of warm weather in Springtime, the entire system requires pulsing of new biologicals. Although some of the perennial higher plant species will survive the winter, new populations will need to be introduced. Microorganisms will also be added as temperatures warm. Extra emphasis on the monitoring and adjustment of alkalinity concentrations will ensure the beneficial bacteria and other organisms are living in conditions optimal for their metabolism. Fresh water mussels, clams and snails can also be collected for incorporation into the system.

It is possible to plant the cells with butterfly and hummingbird attracting plant species. This would increase both the aesthetics and biodiversity of the system.

The pond will see the added benefit of a second year of Restorer operations with the system opened in April rather than June. The biology of the Restorer will then have two more months running time in which to establish and affect the quality of the water.

3) new measurements

In addition to water and sediment sampling, the monitoring regime would include quantitative measurements of the Eurasian watermilfoil populations in a determined radius around the raft. The number of sampling stations could be increased to better monitor the sphere of influence of the Restorers filtration activities. Biomass measurements and photography are options. The parameters chosen for data collection in 1998, should be altered to provide a more complete picture of water quality and the effects of the Restorer on Whitman's Pond South Cove.

Two laboratories in the area have donated laboratory testing services for water and sediment parameters. One laboratory has donated particular services of metal, pesticide and herbicide testing. Metals have been tested in the past for South Cove, with some of the last data compiled in the 1980's. As a secondary drinking water supply, it should be important to measure such parameters, particularly with a previous history of industry discharge and illegal dumping.

To further monitor changes in sediment chemistry and possible depth reductions, we propose incorporating a schedule of sediment core sampling over the year.

4) cost

We estimate the above to cost $50,000.00.

<u>Option 2:</u> An additional restorer in south cove

Part 1: restorer

Conclusions from the data collected in the summer season 1997, suggest water quality for the parameters tested in Whitman's Pond South Cove compliant with the standards for a healthy lake in Massachusetts. Of course, the major problem in South Cove remains the milfoil infestation and the rapid sedimentation the cove currently experiences. As suggested in this report, milfoil growth may be stemmed by bacterial manipulation accomplished by the Restorer. Sediment quality also benefited from Restorer operations. Toward this end, and to enhance the other discussed benefits of the Restorer, the construction of a second

Restorer in South Cove can be considered. With the volumes of water in South Cove, a second Restorer would be a good idea.

Over the past year, Ocean Arks has developed plans for an improved Restorer design (*see diagram attached*). Compiling the knowledge gained from the construction of five different Restorers since 1992, this Restorer combines only the most successful and effective components of our designs. Using modular components made of high quality, structurally sound materials, the Restorer is quickly and easily assembled and disassembled. Modules can be added and subtracted over time as needed to vary the volume of surface area the water flows over within the filter. This allows for an adjustment to the technology as knowledge of the ecosystem and the problem at hand are accumulated or as conditions change.

Part 2: education and community

A more holistic restoration approach builds on our experiences with the community of Weymouth and other project locales. Whether a new Restorer is built or last year's model preserved, the interested community of Weymouth will be incorporated into the process. A training program will be initiated prior to the ramp-up of the system. Interested and qualified residents of varying age will be taught the principles and theories behind the work of the Restorer. During the operating season, the participants will learn how to maintain the Living Machine Lake Restorer, respond to observations and data and take accurate water and sediment samples. Such a process will facilitate community wide involvement in their drinking water supply and local ecosystem through education and the decentralization of a technology potentially effecting thousands of residents. Coupled with coordinated media coverage and a link to area school programs, issues of ecology and water conservation may become prevalent enough to drive changes in behavior and world view. Ocean Arks has experience linking their water treatment technology to local education systems through an EPA funded project in Vermont. The project is coordinated by our for-profit sister company, Living Technologies. Extensive work has been completed on curriculums and desk top models of Living Machines for schools. This work and the associated contacts are available for OAI staff to draw upon and apply in Weymouth.

Providing the skills to local residents for the maintenance and monitoring of the Restorer will also decrease operation costs for future years. The role Ocean Arks could provide in the years beyond 1998, if funds are low, may include independent consulting. We also offer a yearly maintenance package which will allow open contact with OAI technical staff and a number of site visitations.

1) cost

A premium estimate for the cost of an additional Restorer as described above equals approximately $75,000.00. Approximately $10,000.00 would additionally be needed to implement the community and education program.

Option 3: A restorer for the restoration of west cove and the main body of Whitman's Pond

The West cove and main body of Whitman's Pond appear in need of restoration. A Restorer in West Cove was decided against in 1997. Instead, applications of the herbicide Sonar were opted for to control aquatic infestations. Ambient Engineering has concluded this section of the pond to be the most heavily impacted of the Whitman's Pond ecosystem. A Restorer in this area could be beneficial to improved water quality, aquatic plant and sediment reductions. Particularly, in areas where the swimming beaches remain closed due to high coliform counts and swimmer's itch parasite, a Restorer may be able to aid in improving the ecosystem.

A Restorer in the main body of the pond situated near swimming beaches could potentially deal with problems of parasites and coliform bacteria through biological augmentation, competitive exclusion and trophic manipulation. Cultured plant species within the Restorer chosen for antimicrobial properties in combination with the overall filtration capacities of the Restorer would reduce coliform numbers significantly.

References

Barnes, R.W. 1968. **Invertebrate Zoology**. Philadelphia, PA: W.B. Saunders Co.

Cooke, G.D., Welch, E.B., Peterson, S.A., & Newroth, P.R. 1993. **Restoration and Management of Lakes and Resrvoirs.** Lewis Publishers.

Ehrlich, K.F., Cantin, M.C. & Horsfall, F.L. in **Aquaculture Engineering Technologies for the Future** (ed. K. Murray), 329-341. (Institute of Chemical Engineering, U.K. Symposium Series #111).

Ehrlich, K.F., 1990. *Biotechnology in Aquaculture: Letting Mother Nature Work for You.* (Presented to Scottish fish farming conference).

Greenburg, A.E., Clesceri, L.s., & Eaton, A.D. (*eds.*) 1992. **Standard Methods for the Examination of Water and Wastewater:** 18th Edition.EPS Group, Inc.

Ocean Arks International.1995. **The Flax Pond Restoration Project: 1990-1995:** Annual Report to the Town of Harwich.

Thorp, J.H., & Covich, A.P. (*eds.*) 1991. **Ecology and Classification of North American Freshwater Invertebrates.** Academic Press, Inc.

Thunhorst, G., 1993. **Wetland Planting Guide for Northeastern United States.** Environmental Concern Inc.

Todd, J., and Josephson, B., 1996. *The design of living technologies for waste treatment.* Ecological Engineering 6 (1996) 109-136.

Turcotte, A.C., Dery, C.V., & Ehrlich, K.F. 1990. *Manipulation of Microbial Ecosystems to Control the Aquatic Plant Eurasian Water Milfoil*. unpublished data.

Whitman's Pond, Weymouth, MA			
Water chemistry			
Nitrogen, Ammonia - Influent, Effluent, Remote			
	(mg/l)	(mg/l)	(mg/l)
Date	Input	Output	Adjunct
6/5/97	0.05		0.05
6/12/97	0.05	0.05	0.05
6/19/97	0.1	0.05	0.05
6/26/97	0.05	0.05	0.05
7/1/97	0.05	0.05	0.05
7/10/97	0.17	0.1	0.05
7/17/97	0.18	0.36	0.05
7/31/97			0.05
8/8/97			0.05
8/12/97	0.05	0.64	0.05
8/22/97	1.24	1.08	1.28
8/27/97	0.05	0.05	0.05
9/12/97	0.075	0.024	0.125
9/18/97	0.23	0.34	0.05
9/26/97	0.55	0.1	0.15
10/16/97	0.12	0.05	0.12

Whitman's Pond, Weymouth, MA
Water Chemistry
Nitrogen, Nitrate

Date	Influent	Effluent	Adjunct
6/5/97	0.2		0.2
6/12/97	0.2	0.2	0.2
6/19/97	0.2	0.2	0.2
6/26/97	0.2	0.2	0.2
7/1/97	0.2	0.2	0.2
7/10/97	0.2	0.2	0.2
7/17/97	0.2	0.2	0.2
7/31/97			0.2
8/8/97			0.2
8/12/97	0.2	0.2	0.2
8/22/97	0.34	0.45	0.49
8/27/97	0.2	0.2	0.2
9/12/97	1.03	1.05	1.03
9/18/97	0.2	0.2	0.2
9/26/97	0.1	0.05	0.01
10/16/97	0.2	0.2	0.2

Whitman's Pond, Weymouth, MA					
Water Chemistry					
Nitrogen, Kjieldahl					
Date	Influent	Effluent	Adjunct		
6/5/97	0.88		0.4		
7/1/97	1.63	1.33	1.13		
7/17/97	1.9	1.28	0.9		
7/31/97			0.43		
10/16/97	1.2	1.42	1.18		

Whitman's Pond, Weymoth, MA
Water Chemistry
Total Coliform - Influent, Effluent, Remote
Measured in Units of Colonies

Date	Influent	Effluent	Adjunct
6/5/97	0		1
7/1/97	9	15	10
7/31/97			0
8/27/97	16	80	12
10/16/97	23	0	60
12/17/97			0

Background Bacteria - Colonies

Date	Influent	Effluent	Remote
6/5/97	TNTC		TNTC
7/1/97	TNTC	TNTC	TNTC
7/31/97	TNTC	TNTC	0
8/27/97	TNTC	TNTC	TNTC
10/16/97	TNTC	TNTC	TNTC
12/17/97			TNTC

Note: TNTC = Too numerous to count

Whitman's Pond, Weymouth, MA
Water Chemistry
Fecal Coliform - Col/100mL

Date	Influent	Effluent	Adjunct
8/27/97	320	4	100
9/18/97	10	0.5	0.5
10/16/97	20	12	5
12/17/97			0.5

Whitman's Pond, Weymouth, MA
Water Chemistry
Orthophosphate

Date	Influent	Effluent	Adjunct
6/5/97	0.03		0.03
6/12/97	0.01	0.01	0.01
6/19/97	0.01	0.01	0.01
6/26/97	0.01	0.01	0.01
7/1/97	0.02	0.02	0.01
7/10/97	0.02	0.05	0.02
7/17/97	0.04	0.13	0.01
7/31/97			0.01
8/8/97			0.02
8/12/97	0.01	0.16	0.01
8/22/97	0.02	0.02	0.01
8/27/97	0.01	0.02	0.02
9/12/97	0.13	0.13	0.18
9/18/97	0.01	0.02	0.01
9/26/97	0.01	0.01	0.01
10/16/97	0.01	0.01	0.01
12/17/97			0.01

Whitman's Pond, Weymouth, MA					
Water Chemistry					
Total Phosphorus - mg/L					
Date	Influent	Effluent	Adjunct		
6/5/97	0.22		0.22		
6/12/97	0.06	0.08	0.16		
6/19/97	0.01	0.01	0.01		
6/26/97	0.01	0.01	0.01		
7/1/97	0.06	0.07	0.04		
7/10/97	0.28	0.06	0.09		
7/17/97	0.27	0.17	0.02		
7/31/97			0.07		
8/8/97			0.12		
8/12/97	0.06	0.3	0.13		
8/22/97	0.32	0.06	0.09		
8/27/97	0.1	0.06	0.03		
9/12/97	0.06	0.01	0.01		
9/18/97	0.03	0.08	0.02		
9/26/97	0.02	0.01	0.01		
10/16/97	0.04	0.02	0.04		
12/17/97			0.01		

Whitman's Pond
Water Chemistry
Alkalinity - mg/L

Date	Influent	Effluent	Adjunct
6/5/97	26		26
6/12/97	33	41	33
6/19/97	29	29	31
6/26/97	31	31	31
7/1/97	29.6	30.6	32.8
7/10/97	31	54	32
7/17/97	34	50	30
7/31/97			31.6
8/8/97			35.2
8/12/97	34.4	56.4	32.8
8/22/97	20	18	32
8/27/97	12.4	27.6	12.4
9/12/97	31	26	28
9/18/97	22	22	22
9/26/97	21.6	16.4	22
10/16/97	26	24	24

Whitman's Pond, Weymouth, MA
Water Chemistry
Total Suspended Solids -mg/L

Date	Influent	Effluent	Adjunct
6/5/97	5		4
7/1/97	3	4	3
10/16/97	4	1.5	9
12/17/97			1.5

Whitman's Pond, Weymouth, MA
Water Chemistry
Dissolved Oxygen

Date	Time	Influent	Effluent	Remote/Surface
6/5/97	12:15	9.2		9.9
6/19/97	12:15	7.5	7.5	8
6/26/97	12:30	6.4	6.85	8
7/1/97	1:15	6.4	8.3	6.8
7/10/97	12:00	8.2	7.65	11
7/17/97	2:20	8	5	8.8
7/31/97	12:30	6.2	5.25	7.8
8/8/97	12:20	8	9.6	8.8
8/12/97	1:15	8.2	8.8	11
8/22/97	12:30	4.8	5.65	4.5
8/27/97	1:30	5.43		9.6
9/12/97				10.2
18-Sep	1:30	8.5	7.5	8.4
9/26/97	3:30	9.6	9.3	10
10/16/97	4:00	9.3	11.9	8.2

Whitman's Pond, Weymouth, MA
Water Chemistry
pH

Date	Influent	Effluent	Adjunct
6/5/97	7.65		7.55
6/12/97	7.81	7.89	7.92
6/19/97	7.28	7.16	7.16
6/26/97	6.89	6.77	6.85
7/1/97	7.08	7.03	7.39
7/10/97	7.01	6.68	8.79
7/17/97	8.15	6.76	7.38
7/31/97			7.49
8/8/97			7.45
8/12/97	7.34	6.58	7.59
8/22/97	6.97	6.98	7.08
8/27/97	6.77	7.02	7.16
9/12/97	7	6.62	7.86
18-Sep	7.1	7.02	7.4
9/26/97	7.03	7.25	7.52
10/16/97	6.96	7.22	7.01

Whitman's Pond, Weymouth, MA
Water Chemistry
Temperature - Celsius

Date	Influent	Effluent	Remote/Top	Remote/Bottom
6/5/97	17		17	16
6/19/97	27	27	26	22
6/26/97	25	25	24	21
7/1/97	26	26	27	22
7/10/97	28	29	29	27
7/17/97	25	26	28	26
7/31/97	26	29	30	28
8/8/97	26	29	30	28
8/12/97	27	29	29	27
8/22/97	25	24	24	23
8/27/97	22	24	23	23
9/12/97	20	22	23	20
18-Sep	24	23	25	24
9/26/97	17	16	18	

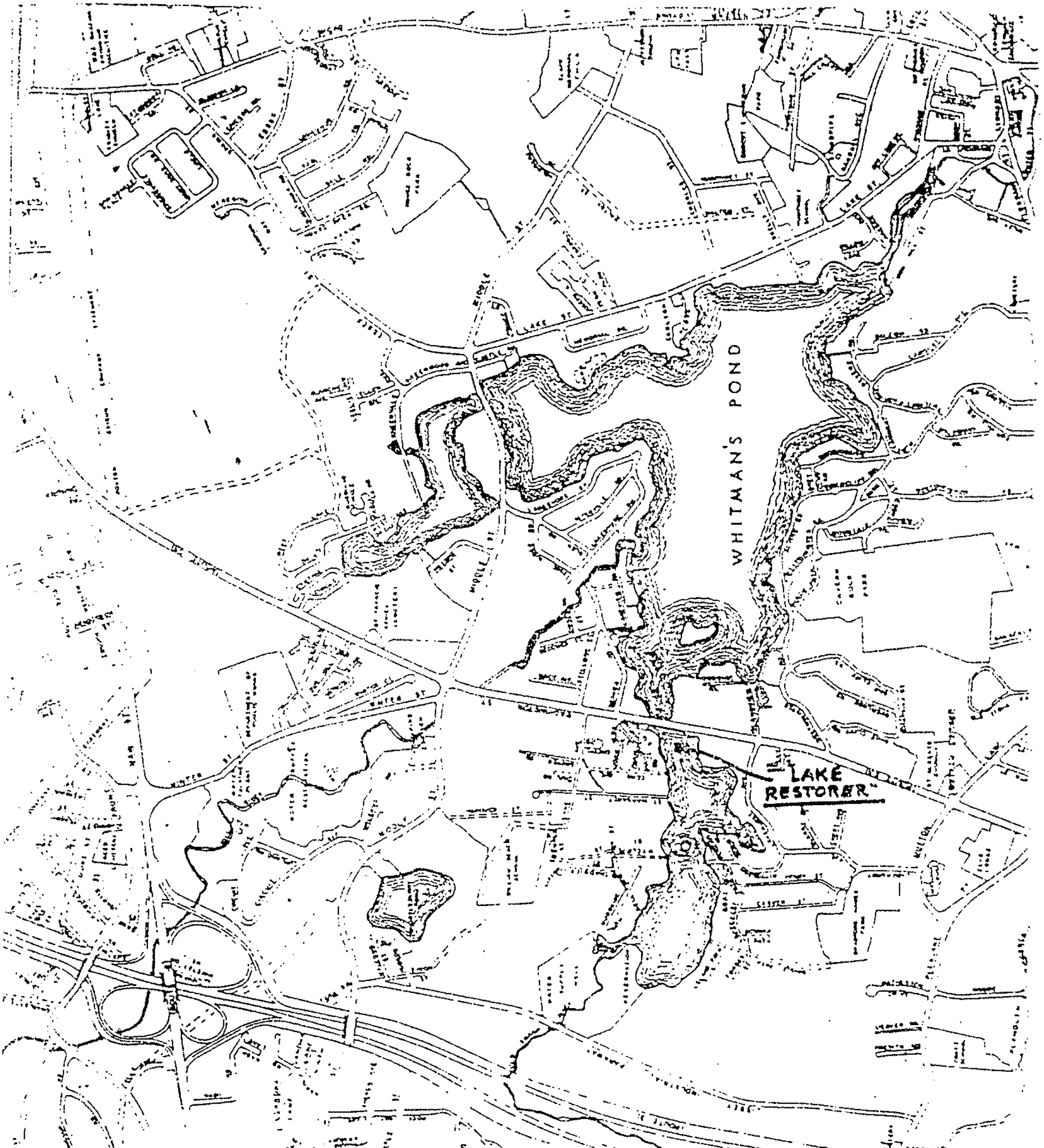
Whitman's Pond, Weymouth, MA

Sediment Chemistry

Nitrogen, Ammonia - mg/Kg		Nitrogen, Nitrate - mg/Kg	
Date	Adjunct	Date	Adjunct
6/5/97	719	6/5/97	140
7/1/97	1121	7/1/97	47
7/31/97	740	7/31/97	9.7
8/27/97	490	8/27/97	37
10/16/97	485	10/16/97	26.7
12/17/97	155	12/17/97	31.3

Total Kjeldhal, Nitrogen		Sediment Chemistry Orthophosphate - mg/Kg	
Date	Adjunct	Date	Adjunct
6/5/97	5500	6/5/97	41.7
7/1/97	11500	7/1/97	1.31
7/31/97	10150	7/31/97	2.47
10/16/97	27700	8/27/97	1.55
12/17/97	3650	10/16/97	0.01
		12/17/97	0.01

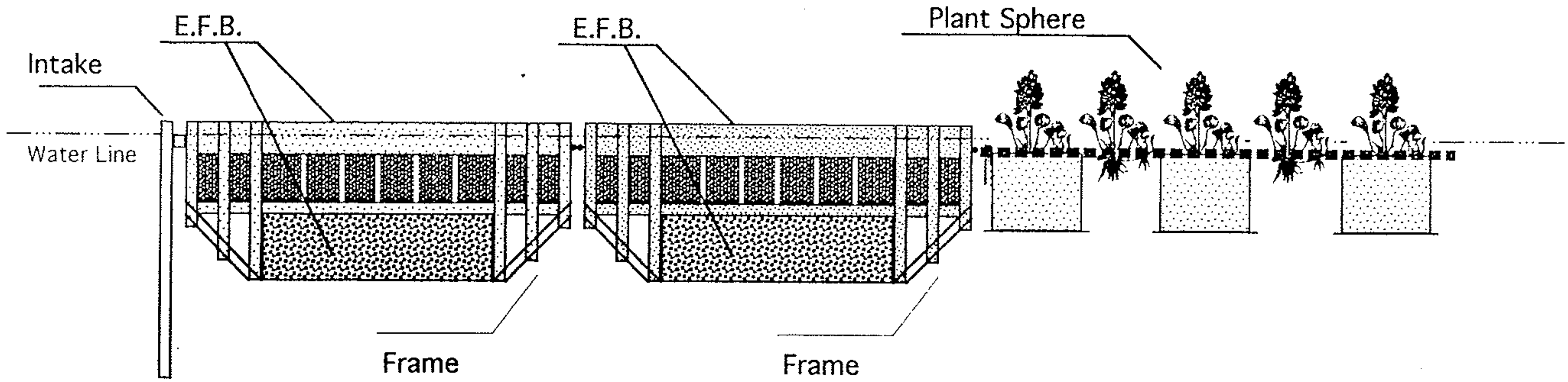
Sediment Chemistry Total Phosphorus		Sediment Chemistry Iron - mg/Kg	
Date	Adjunct	Date	Adjunct
6/5/97	1098	6/5/97	18333
7/1/97	1040	7/1/97	21000
7/31/97	1341	8/27/97	11100
8/27/97	524	10/16/97	25577
10/16/97	339	12/17/97	10829.5
12/17/97	0.025		



WHITMAN'S POND
IN
WEYMOUTH, MASS.

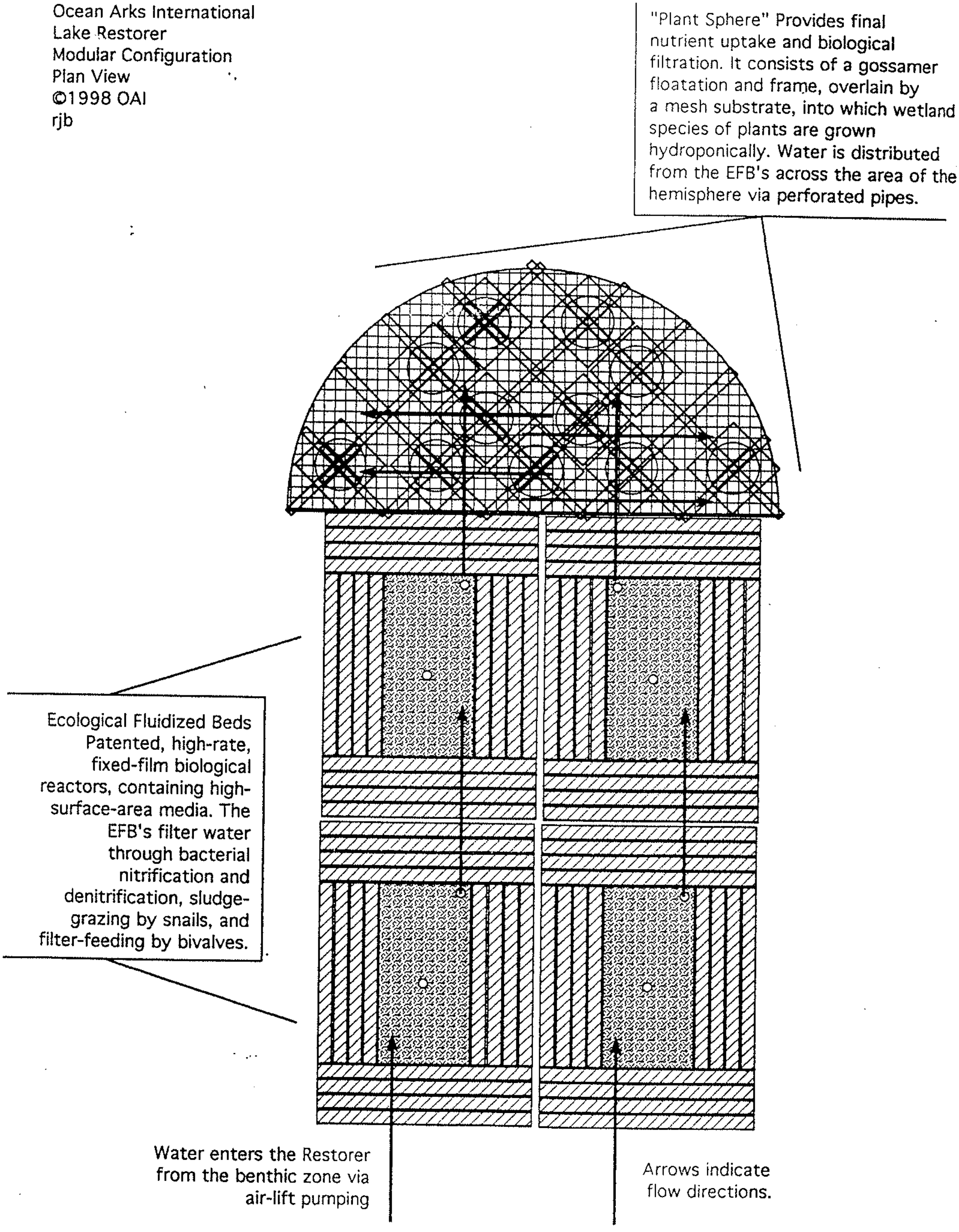
Lake Restorer
Modular Configuration

rjb



Ocean Arks International
Lake Restorer
Modular Configuration
Plan View

rjb



ERRATA

After the final printing of the report, the following errors and ommissions were noted.

1. On pg. 11, in the third paragraph, second sentence: ..." to increase alkalinity concentrations necassary for the metabolic processes of *denitrifying* bacterial species"; denitrifying should be changed to *nitrifying.*

2. On pg. 20, in the section on Sediment Chemistry Data/TKN, the last sentence states " The cause of the spike on October 16 remains unclear. " To this sentence it is important to stress the unliklihood of this data point. A more reasonable data point might be *2700*, rather than the *27000* as reported. OAI staff believe this point as it stands is not a valid data point.

3. On pg. 32, in Adjunct Station Water Chemistry/Alkalinity section, the words *denitrifying and denitrification* should be changed to *nitrifying and nitrification.*

4. On pg. 58, in the Reccomendations Section, the second paragraph indicates new Restorer designs were attached. They are included now after the ERRATA.

APPENDIX A

Associated Documentation