LAKE COCHITUATE

PHASE II IMPLEMENTATION AND RESTORATION PROJECT

FINAL REPORT

1988

Massachusetts Department of Environmental Protection
Division of Water Pollution Control
Technical Services Branch
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ACKNOWLEDGMENTS

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ABSTRACT

The U.S. EPA Section 314 Phase II Restoration Grant was awarded in 1976 to the Department of Environmental Protection (DEP, formerly the Department of Environmental Quality Protection) for the purpose of identifying and analyzing the water quality problems of Lake Cochituate in Natick, Massachusetts. In addition, the Section 314 grant was to develop and execute recommendations to improve the water quality at Lake Cochituate. Analysis of the data collected under this grant revealed that the construction of a filter berm and two detention basins in the watershed would reduce the nutrient load to the lake. With the services of a professional engineer and a construction firm, the project was implemented and completed. Post construction monitoring and analysis evaluated the effectiveness of the project structures.

LIST OF FIGURES

INTRODUCTION

The Clean Lakes Program was established by Section 314, PL92-500, of the Federal Water Pollution Control Act of 1972, as amended under PL95-217, the Clean Water Act of 1977. This program directs the U.S. Environmental Protection Agency to assist states in controlling sources of pollution to publicly owned freshwater lakes, as well as, restoring lakes which have degraded water quality.

Both financial and technical assistance to the states is provided by this program. This assistance is to be used to:

1. classify publicly owned freshwater lakes according to trophic condition;

2. conduct diagnostic studies on lakes and develop feasible control and restoration programs from them; and

3. implement lake restoration and pollution control projects (U.S. EPA, 1980).

The Clean Lakes Program is an example of a cooperative governmental arrangement. The U.S. Environmental Protection Agency (EPA) has selected the DEP, Division of Water Pollution Control (DWPC) to be the state agency to administer the 314 Clean Lake grants in Massachusetts. In 1976 a Section 314 grant was awarded to DEP for the purpose of addressing the above stated points as they relate to Lake Cochituate in Natick, Massachusetts.

LAKE CHARACTERISTICS

Location & Morphometry

Lake Cochituate is a Great Pond of the Commonwealth of Massachusetts. It is located in the towns of Natick, Framingham, and Wayland. The entire lake is more than 3.5 miles long and approximately 0.5 miles wide at its maximum width. The approximate center of the lake is latitude 42°17'30" and longitude 71°2'30".

Lake Cochituate is a deep lake consisting of four basins; South Basin, Carling Basin, Middle Basin and North Basin with flow going from south to north. At a mean sea level of 138 feet, the total area of the lake is 561 acres with North Basin having the greatest storage volume of 5,371 acre-feet followed by South Basin with 4,639 acre-feet. The total length of shoreline is approximately 13 miles. A complete listing of morphometric data can be found in Table 1.

Table 1.

Lake Cochituate Morphometric Data

	South Basin	Carling Basin	Middle Basin	North Basin
Maximum Length (ft.)	5,083	1,198	4,625	5,868
Maximum Effective Length (ft.)	5,083	1,198	4,625	5,868
Maximum Width (ft.)	2,775	599	2,035	3,189
Maximum Effective Width (ft.)	2,775	599	2,035	3,189
Maximum Depth (ft.)	69	30	60	69
Mean Depth (ft.)	19.9	12.7	27.7	27.8
Mean Width (ft.)	422.2	139.8	252.3	436.7
Area (ac.)	233	12.9	130.6	194.8
Volume (ac.-ft.)	4,638.6	164.5	3,620.3	5,370.9
Length of Shoreline (ft.)	24,050	4,032	22,560	19,240
Development of Shoreline	2.1	1.5	2.6	1.8
Development of Volume	0.86	1.26	1.30	1.20
Mean to Maximum Depth Ratio	0.28	0.42	0.46	0.40

WATERSHED CHARACTERISTICS

General Description

The Lake Cochituate watershed is situated in the SuAsCo (Sudbury-Assabet-Concord) River Basin which is a sub-basin of the Merrimack River Basin. A map of the Lake Cochituate watershed is presented in Figure 1. The watershed covers 17 square miles (10,730 acres) and is located within the towns of Sherborn, Ashland, Framingham, Natick, and Wayland.

Water enters the lake via surface-water runoff from perennial and intermittent streams, storm drains, ground water, and direct precipitation onto the surface of the lake.

The Lake Cochituate drainage area can be subdivided into six sub-basins (Table 2). Four of the sub-basins are drained by tributaries (Figures 2 and 3). These tributaries are Snake Brook, Beaverdam Brook, Pegan Brook, and Course Brook. The remaining two sub-basins contribute to the lake via overland runoff.

The outlet is located at the northern end of the lake. Water leaves the lake via Cochituate Brook, which flows north into the Sudbury River.

Table 2

Lake Cochituate

Watershed and Sub-Basin Surface Areas

Sub-Basin	Square Miles	Acres
Beaverdam Brook	7.25	4,640.0
Course Brook	3.42	2,188.8
Ungaged Drainage Area Around Lake Cochituate	2.70	1,728.0
Snake Brook	2.10	1,344.0
Fisk Pond Ungaged Drainage Area	0.75	480.0
Pegan Brook	0.54	345.6
Total	16.76	10,726.4

Lake Cochituate Phase II

Restoration Project

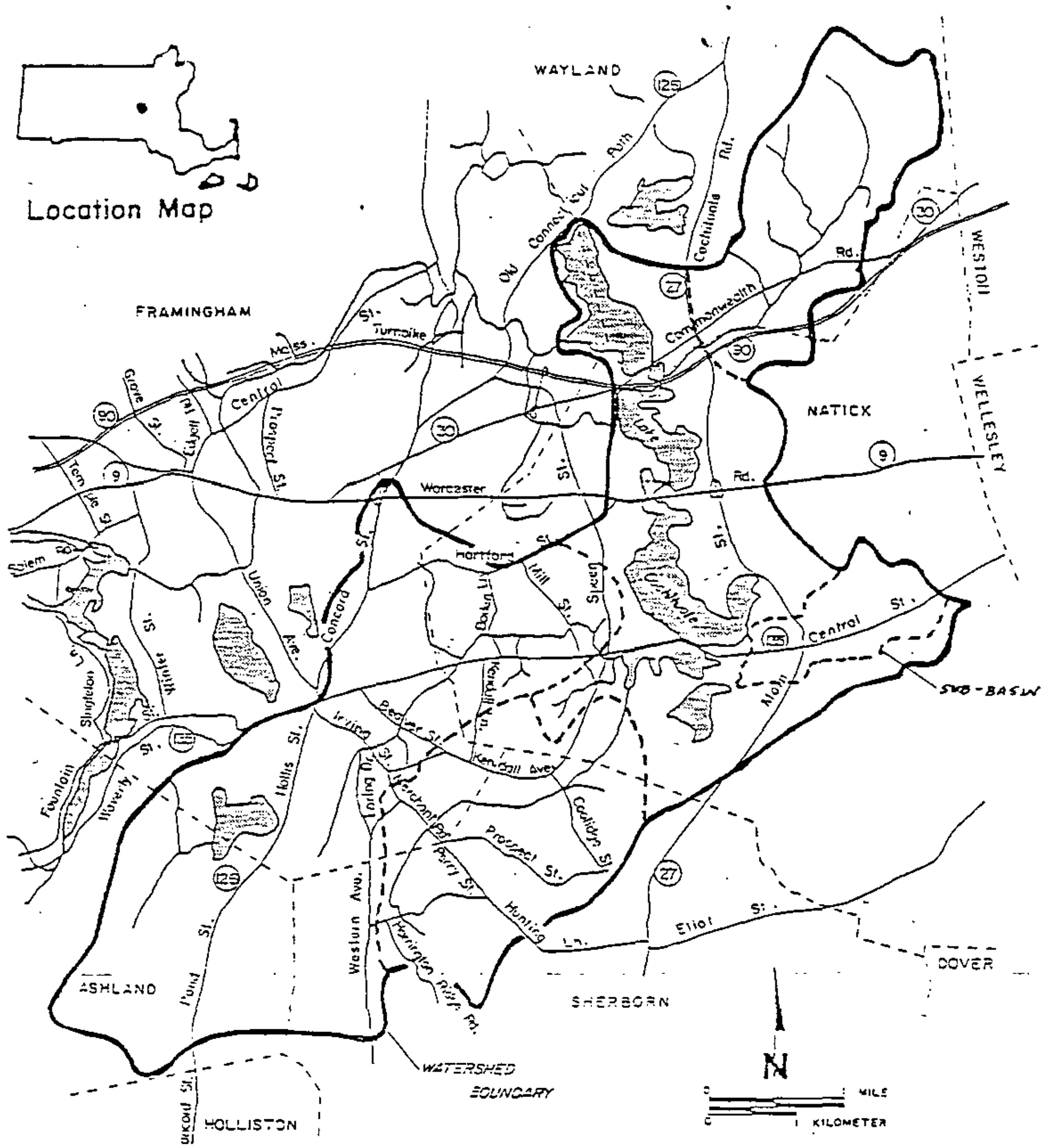

Figure 1

Lake Cochituate Watershed Map

Lake Cochituate Phase II Restoration Project

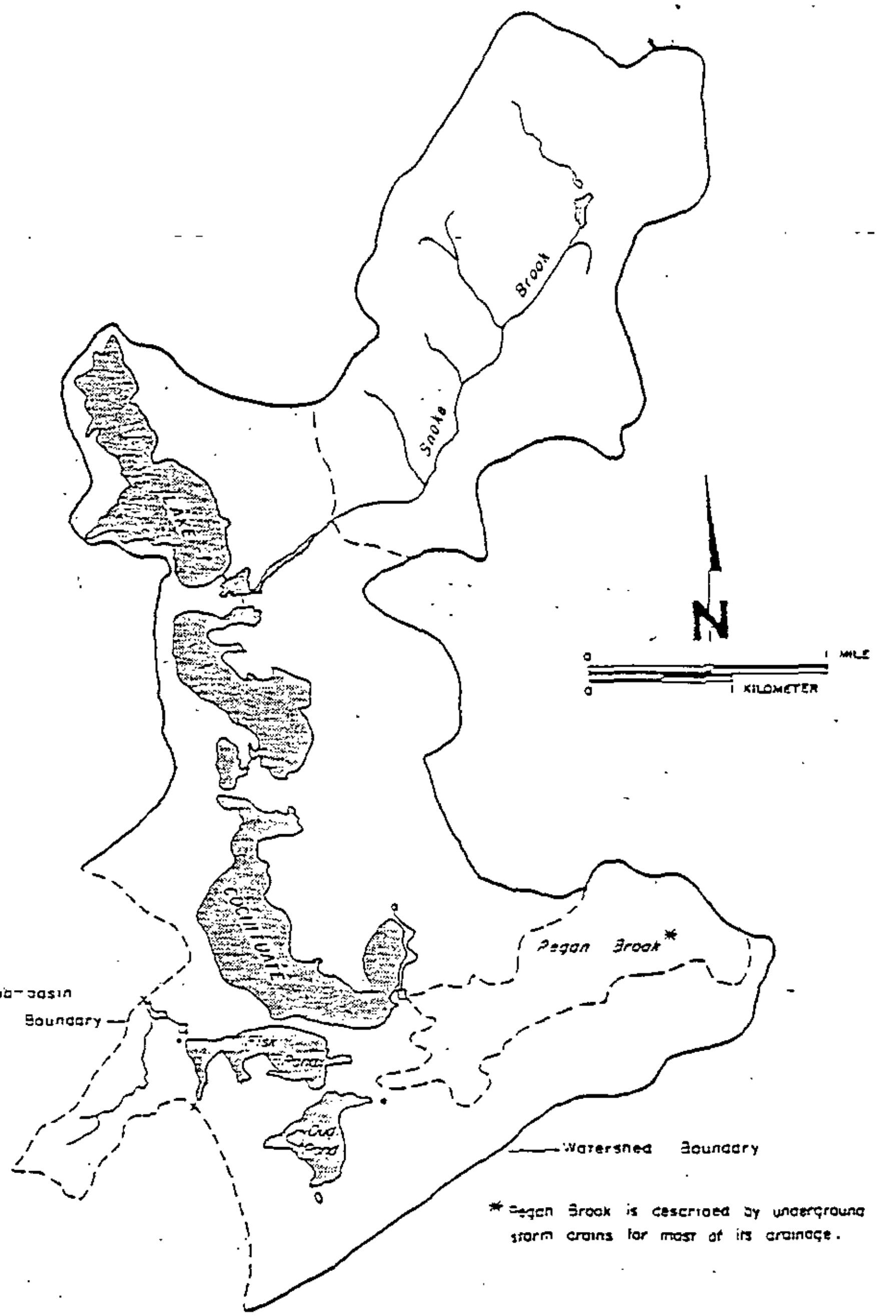

Figure 2

Lake Cochituate Sub-Basins Map (Snake Brook and Pegan Brook)

Lake Cochituate Phase II
Restoration Project

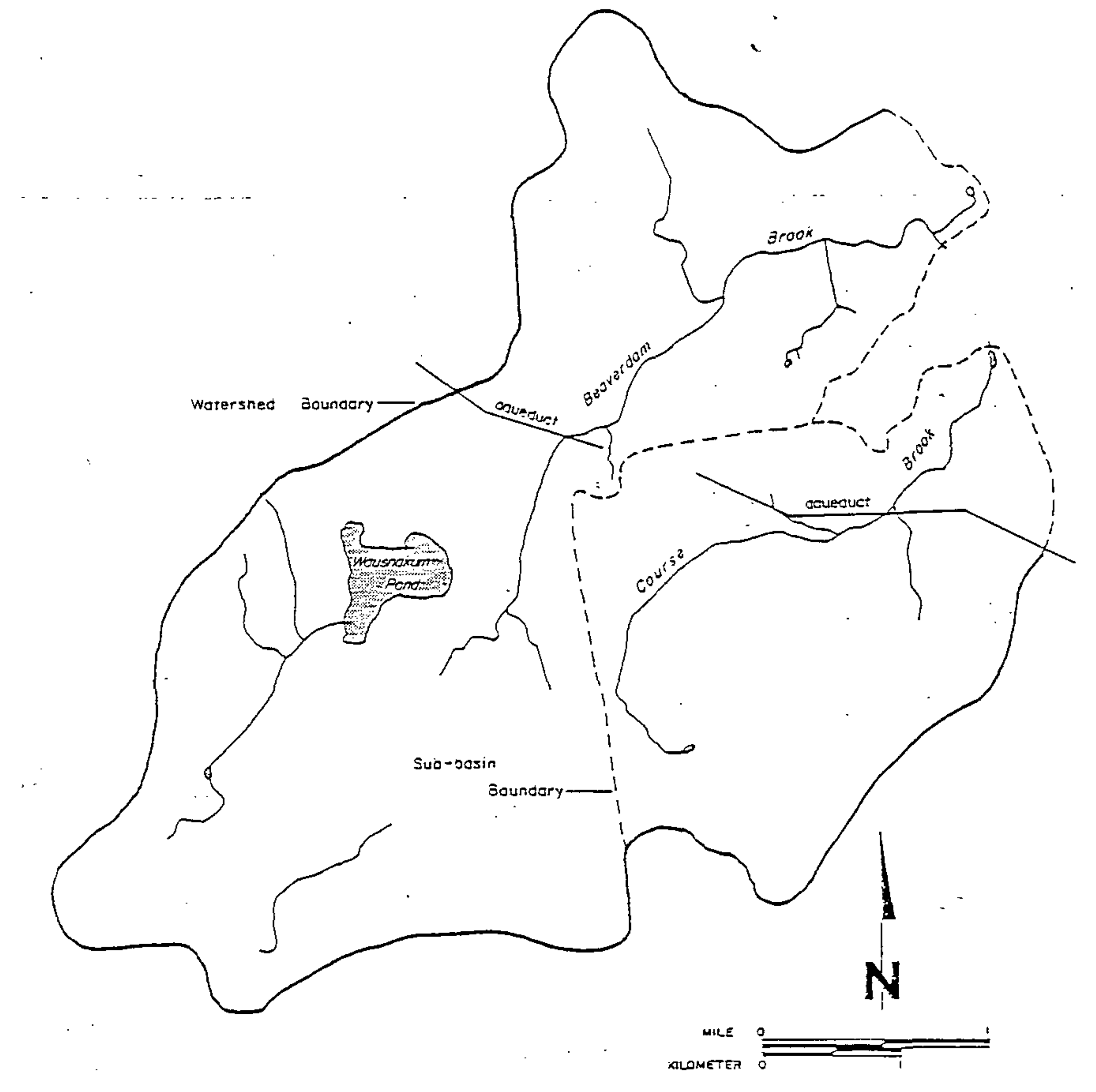

Figure 3

Lake Cochituate Sub-Basins Map (Beaverdam Brook and Course Brook)

HISTORICAL and RECREATIONAL BACKGROUND

According to the History of Framingham (Temple, 1877) the lake originally "presented the appearance of two bodies of water united by a narrow strait." It was at this strait that Indians would fish for salmon, shad or alewives, all common at that time. Early settlers made this strait into a passable road by dumping in large quantities of small stones. A second forging place was later filled in and a road from Framingham to the village of Cochituate was built. Lake Cochituate is presently crossed by U.S. Route 9, Interstate Route 90 and U.S. Route 30 and has the appearance of four interconnected basins.

Cochituate is an Indian word meaning "place of falling waters." This name referred to a point just downstream of Saxonville Falls where Indians once paddled into Cochituate Brook to reach the lake before the dams were constructed.

Fishing was first regulated on the lake in 1743 (Temple, 1877). In 1748, Brown's Dam was built on Cochituate Brook to provide water for a mill. The threat to fishing posed by the dam was temporarily relieved when Mr. Brown put in a fishway. Fishing from boats was later restricted on Lake Cochituate when the lake was turned over to the state for use as a public water supply for Boston.

In 1839 the state legislature established Lake Cochituate as a public water supply. Besides the recreational changes brought about by the water supply designation, the lake was also physically changed. The water level was raised nine feet in 1846 and then another four feet in 1859. The increase in water level necessitated building a lower dam to relieve pressure on the upper dam.

The first flow of water from Lake Cochituate to Boston began on October 14, 1848. In 1872, a temporary connection between Lake Cochituate and the Sudbury River was constructed to supplement the lake water flow to Boston. With the completion of Quabbin Reservoir in western Massachusetts as a drinking water supply for Boston, the use of Lake Cochituate waned. Finally, in 1947 the management of Lake Cochituate was turned over to the Department of Environmental Management (DEM) for public recreation.

Recreational use returned slowly to Lake Cochituate. For the first half of this century boating was not allowed and fishing from the side banks was described as fair. As recreational restrictions were lifted the Division of Fisheries and Wildlife (previously the Division of Fisheries and Game) began stocking rainbow and brown trout to add to the indigenous population of white perch, pumpkinseeds, and bullheads.

Swimming and boating use have increased steadily over the second half of this century. According to the DEM, Cochituate State Park located on the shore of Middle Basin receives several hundred thousand visitors each year. Several town beaches and private camps also exist on the shores of Lake Cochituate, (DWPC, 1982).

HISTORICAL INVESTIGATIONS and FINDINGS

The first study of Lake Cochituate by the DWPC was conducted during the period of July 1970-February 1973. Two objectives of this study were: 1) to demonstrate a methodology for lake eutrophication studies, algal counts and other work deemed necessary to develop a long-term lake management strategy; and 2) to demonstrate the effects of lake destratification by artificial mixing with a static aerator in South Basin. The first objective was met utilizing the sampling regime developed by DWPC for further study of Lake Cochituate. The second objective was not obtained because of vandalism to the aerator.

In 1976 programs for control of eutrophication received added impetus with the advent of the Federal Clean Lakes Program PL92-500 Section 314. Under this program federal monies were made available for lake restoration activities. The DEP, applied for and received a Section 314 grant for $250,000 to develop restoration techniques for use on Lake Cochituate. Work under this grant included water quality monitoring, feasibility studies for lake restoration, and educational programs for the public. The DWPC conducted the water quality monitoring on Lake Cochituate. The consulting firm of Jason M. Cortell and Associates did the feasibility studies and the Lake Cochituate Watershed Association completed the public information work.

The water quality monitoring program included sampling of all four basins, as well as, some tributary sampling. For two years, DWPC took physical, chemical, and biological samples on a monthly basis from spring until fall and at least once during ice cover. The data from this sampling program was published in a 1982 report (DWPC, 1982).

The Lake Cochituate Watershed Association (LCWA) developed a public education program specifically dealing with lake eutrophication and watershed practices. Some of the methods employed to educate the public were posters, workshops, radio spots, and local mailings. The LCWA also produced a watershed map depicting points of interest and sources of pollution. In addition three pamphlets were published: <u>Detergents and Your Lake</u>, <u>Fertilizers and Your Lake</u>, and <u>Septic Systems and Your Lake</u>. Although their contracted tasks are completed, the LCWA continues its long-standing effort to improve watershed practices.

In 1977, the DWPC allocated $61,000 to study the feasibility of dredging Snake Brook, reducing nutrient input from Fisk Pond to Lake Cochituate and rehabilitating the filter beds at Pegan Brook. Concurrently, the USGS and DWPC entered into an agreement for a separate study on Lake Cochituate. The purpose was to estimate nutrient loadings from ground water and surface sources to the lake and its tributaries. This study also included sediment analysis, phytoplankton and chlorophyll <u>a</u> analysis and algal assay tests. USGS also examined sources of nutrients to the lake from stormwater runoff. DWPC used the flow and nutrient data gathered by USGS to determine nutrient loadings to Lake Cochituate.

Through these studies a substantial body of information was collected on Lake Cochituate and its watershed. A thorough analysis of those data documented the following water quality conditions:

1. Lake Cochituate was thermally stratified and characterized as a weakly buffered mesotrophic pond;

2. The average epilimnetic total phosphorus concentration often exceeded the U.S. EPA suggested criterion of 0.025 mg/l. In addition, hypolimnetic concentrations of total phosphorus were very high;

3. The hypolimnion was typically anoxic during the summer months. Occasionally conditions of supersaturated dissolved oxygen in the epilimnion would exist during the winter and summer. This was the direct result of coincident diatom blooms;

4. The transparency of South Pond, as measured by Secchi disk, was the worst of the four basins in the lake. However, transparency improved downstream peaking in the North Basin;

5. Conductivity values were generally high and varied little from year to year;

6. Diatom blooms of <u>Asterionella</u> sp. and <u>Tabelleria</u> sp. often occurred, as well as, blue-green algae blooms of <u>Oscillatoria</u> sp. and <u>Anabaena</u> sp.; and

7. The aquatic macrophytes <u>Potamogeton</u> <u>robbinsii</u> and <u>Potamogeton</u> <u>crispus</u> were dominant in the lake during the study period.

The studies also showed that the sources of pollution to Lake Cochituate were:

1. stormwater runoff from the drainage area, including a considerable urbanized area;

2. leachate from malfunctioning septic systems, dumps, and former industrial sites; and

3. the sediments of the lake and its tributaries. These sediments had accumulated contaminants from a long history of prior pollution to the waterbody.

In addition, the studies investigated several techniques for reducing nutrient availability and nutrient influx. Structural or chemical control measures tended to be expensive so every effort was made to use existing structures, which included the inactive settling basins on Beaverdam Brook near the inlet to Fisk Pond and the abandoned slow sand filter beds on Pegan Brook near the inlet to South Basin. The alternatives also included measures that would utilize highly eutrophic Fisk Pond as a natural settling basin or treatment system for the rest of the lake.

The following is a summary of the alternatives investigated by DWPC and the results thereof.

Rehabilitation of the Beaverdam Brook Settling Basins

The rehabilitation of the settling basins on Beaver Brook was an obvious choice of study since particulate forms of phosphorus comprised over one-half of the total phosphorus loading to Lake Cochituate. To reactivate the settling basins, dredging would have been required to remove years of accumulated sediment. Analysis of the sediments revealed extremely high concentrations of pesticides, heavy metals, oil, and grease. The lack of a disposal site and the high cost of redredging precluded the settling basins as a viable nutrient removal option.

Instream Nutrient Precipitation

Nutrient precipitation by chemical treatment was considered for Beaverdam Brook and Course Brook. The costs, estimated in 1979, were $130,000 for facility construction and $140,000 in annual operation and maintenance costs. The major drawback with this option was the fate of the chemical floc which would be formed as a result of chemical addition. Unless the floc could be captured there would be adverse impacts to biota downstream. Capturing the floc would require periodic dredging and thus, made this a very costly option.

Reactivation of the Filter Beds on Pegan Brook

The use of the Pegan Brook slow sand filters for improving water quality from Fisk Pond and possibly South Basin was also investigated. The filters were found to be capable of removing high percentages of turbidity, suspended solids, and algae. However, the filters would not remove dissolved nutrients to a degree that would significantly benefit the lake. A pilot test of rapid sand filtration was also conducted. However, this test did not achieve good removal of dissolved nutrients or algae. In general, a literature search revealed that sand filtration (slow, intermittent, or rapid) would not remove nutrients to the concentrations necessary to restore a natural waterbody. Additionally, sand filtration was not considered because of the high maintenance cost involved.

Physical/Chemical Treatment

Physical/chemical treatment would have provided a proven, but expensive means of removing nutrients from the lake water. One process, High Gradient Magnetic Separation had a slightly lower cost than conventional treatments and a very high removal of algae and nutrients. However, the capital cost of 3.5 to 4 million for a full scale facility and over $400,000 in annual operation and maintenance costs would have been beyond the project.

Snake Brook Dredging

Periodically the sediments of Snake Brook release nutrients to Lake Cochituate. This release supports massive growths of algae that produced nuisance odors and stimulated aquatic weed growth that hindered boat traffic in the summer.

The design called for dredging and disposal of 40-45,000 cubic yards of sediment. The total cost of the project was estimated to be $250,000-300,000 and thus, was determined not to be cost effective.

Best Management Practices

Best Management Practices (BMP) are techniques for controlling nonpoint sources of pollution by means of political controls (i.e., rigid zoning laws), maintenance controls (i.e., street sweeping, leaf collection), and some passive structural measures (i.e., berm detention ponds). In general these practices are used as a means of preservation rather than restoration of a lake. Thus, it was concluded that BMP's would reduce but not reverse the cultural eutrophication of the lake.

Swirl Concentrator

A swirl concentrator at the outlet of Fisk Pond with pumping of the concentrated flow to the M.D.C. sewer line, and diversion of the overflow to the filter beds at Pegan Brook was considered. However, the variability of flow was too great for proper sizing of the concentrator. Flows from Beaverdam Brook can vary from 90 cfs (January 1978) to 1.1 cfs (September 1978). In addition, pumping of water from the Fisk Pond outlet to the Pegan Brook filter beds was too expensive. Given these considerations, the alternative was dropped from further consideration.

Floating Tank System

A floating tank system for settling and equalizing the flow of discharge from Beaverdam Brook and Course Brook was not pursued because of the high capital costs associated with it.

Alum Precipitation

To produce a short term improvement in the water quality of Lake Cochituate, a series of alum applications to Fisk Pond, South Basin, and Middle Basin were considered. This alternative would have been utilized as a stopgap measure until watershed management techniques became effective in reducing the runoff of nutrients into the lake. Nutrient reduction in Fisk Pond would also have had a large influence on the water quality of the Lake Cochituate since it contributes the largest percentage of nutrients. Cost estimates for the application of alum by boat would been $7,500 in 1980 dollars for labor and material.

Berm Filtration and Alum Precipitation

Nutrient removal from the Fisk Pond discharge by utilizing alum precipitation within a filter berm was considered to be a cost effective method of controlling nutrient influx from this area. The multi-media alum-sludge berm was planned for construction at the outlet of Fisk Pond. The berm was to filter approximately 25 cfs at maximum head. The intended effect was to raise the pond level approximately 1.5 feet, increasing both the storage capacity of the pond and the detention time for waters that enter it.

RESTORATION ALTERNATIVES

Many ideas have been suggested and examined for restoring water quality at Lake Cochituate. However, the various studies indicated that no single measure, short of a full scale physical/chemical treatment plant, would reduce nutrient inputs to an acceptable level. More than one treatment method was necessary. Large scale treatment methods would quicken and enhance the reduction of nutrients to the lake, but long term management techniques would also be essential to improve and maintain the water quality at Lake Cochituate to be improved and remain so.

Since Lake Cochituate was determined to be phosphorus limited, (USGS memo, 1979) the restoration alternatives seriously considered for implementation at Lake Cochituate were those that could reduce the annual phosphorus loading to South Pond to 0.020 - 0.025 mg/l (VanArsdale, 1979). Also considered were those alternatives having low capital costs combined with low operating and maintenance costs.

To provide the best methods currently available for controlling nutrient inputs to Lake Cochituate, DWPC (1982) recommended the following implementation projects. These implementation projects encompassed not only in-lake alternatives but also actions that could be taken in the watershed.

1. Utilize best management practices (BMPs) in the Course Brook and Beaverdam Brook watersheds. These BMPs might include public education, increased street sweeping, improved maintenance of subsurface disposal systems, more frequent catch basin cleaning, and improved use and storage of road salts.

2. Coordinate agricultural and soil controls with the Soil Conservation District to improve practices, manure storage, fertilizer applications, and plantings which will improve water retention and the uptake of nutrients.

3. Strategically utilize retention basins, detention basins, and percolation ponds to store and filter stormwaters. Location of the watershed controls will rely on the subsequent input of the local conservation commissions and watershed associations. Further description of these control methods are found in Appendix G.

4. Build the Framingham Extension Sewer to reduce loading to Beaverdam Brook.

5. Build an in-situ demonstration (one-tenth size) filter berm at the outlet of Fisk Pond to reduce nutrient loading. Monitor the berm to determine its effectiveness in controlling nutrient influx to South Pond while remaining free of alga clogging problems. The design and discussion of the berm is presented in Appendix G of the 1982 DWPC report.

6. Construct a full size filter berm at the outlet of Fisk Pond, if the 1/10 scale berm is effective in reducing the nutrient load to South Pond.

Based upon subsequent discussions between the U.S. EPA and DEP, two other restoration alternatives were recommended. These were a retention/detention pond at the discharge of a stormwater drain in the Fisk Pond watershed, and a stormwater detention/filter device upstream of the Pegan Brook confluence with Lake Cochituate. These latter two project elements were added to reduce stormwater loading to Lake Cochituate and, to develop and use innovative technology that could be "tested" as part of the project.

A CHRONOLOGY OF THE LAKE COCHITUATE PHASE II IMPLEMENTATION PROJECT

In July 1980 the Lake Cochituate Restoration Project was transferred from the DEP Office of Planning in Boston to the DWPC Technical Services Branch (TSB) in Westborough. Following this transfer of the project, the TSB published four years of chemical, biological, and physical data gathered on Lake Cochituate. In addition, a limnalogical analysis, conclusions, and recommendations for restoration were made a part of this report.

On November 3, 1981 the DEP submitted a grant amendment request totaling $945,000.00 to EPA for the implementation of restoration alternatives recommended in the above report. This request was not granted until September 14, 1982 due to difficulties in documenting the non-federal matching funds.

Negotiations were initiated in September 1982 between the DEP and the DEM for a Memorandum of Understanding (MOU). With the DEP as project proponent and DEM as project owner, an MOU was needed to clarify the responsibilities of each party. The MOU outlined all major aspects of the project and assigned one or the other agency various tasks. Specifically, the DEP was to design the restoration alternatives, solicit bids for construction, oversee and carry-out construction, implement post-construction monitoring, and provide funding for the aforementioned activities. DEM was to provide for the operation and maintenance of the completed projects and the costs associated with them. Both parties were to mutually review and approve of all project documents. The MOU was signed on May 31, 1983.

While the MOU was being negotiated, the DEP issued a Request for Proposals (RFP) for design services of the Lake Cochituate restoration project on September 27, 1982. The due date for proposals was October 22, 1982. A total of five consulting firms submitted bids in response to the RFP. However, due to unavoidable delays in the review process and associated problems, the DEP withdrew the RFP on December 9, 1982 and immediately reissued it with a due date of December 31, 1982.

Five bids were received in response to the second RFP, with dollar amounts ranging from $59,640 to $104,099. In February 1983, DEP awarded the contract for consulting services to Whitman & Howard, Inc. of Wellesley, MA for $59,640. As a result of delays in the contract review process at the Department of Administration and Finance, the contract with Whitman & Howard was not signed until July 27, 1983. The "Notice to Proceed" was issued on August 8, 1983.

By December 30, 1983, Whitman & Howard had completed 90% of the project design. However, final site selection and the filing of project permits were not completed until August 1984. It was during this period that Pegan Brook was selected as the site for the filter chamber. Also, a retention/detention basin was added by EPA with the final site selected off Cemetary Street. Additionally, it was decided that a full scale filter berm would be constructed at Fisk Pond instead of the originally proposed one-tenth scale structure (to save repetition of efforts). Finally, a mixture of limestone and sand was selected as the most appropriate media for the Fisk Pond filter berm.

Whitman & Howard, Inc. submitted a Notice of Intent for the Lake Cochituate project to the Natick Conservation Commission (NCC) in September 1984. By October 11, 1984 the NCC had issued its Order of Conditions to DEP. In addition, the DEM notified DEP in January 1985 that a Chapter 91 Waterways permit was not needed for the project. Because of requests for clarification and additional information (and EPA review and modification), the Army Corps of Engineers (ACOE) did not issue DEP a Section 404 permit until June 26, 1985. The DEP received a Water Quality Certificate at approximately the same time as the ACOE 404 permit. Review of the Environmental Notification Form by MEPA unit went smoothly and it was determined that an EIR would not be necessary for the project.

In March of 1985, a Request for Proposals for project construction was issued by DEP with a due date of May 2, 1985. This due date was later postponed to May 23, 1985 and then to July 25, 1985 because of ACOE permit delays. Because of a bid protest raised by a prospective bidder, the RFP due date was delayed a third time to September 3, 1985.

Of the five companies determined to be eligible, only two submitted bids. These were WES Construction of Dedham, MA for a bid of $624,900.00 and R. Zoppo Co., Inc. of Lynnfield, MA for a bid of $467,606.00. The project consultant, Whitman & Howard, Inc., reviewed the bids and recommended Zoppo as the lowest qualified bidder. On October 21, 1985 the DEP issued a Notice of Award to Zoppo Co., Inc. Because of delays in the contract review process, a Notice to Proceed was not issued to Zoppo, Inc. until July 7, 1986. These delays at the Department of Administration and Finance made it necessary for DEP to obtain a time extension of the Order of Conditions from the Natick Conservation Commission.

Shortly after a pre-construction conference at the project site, work began and continued to October 28, 1986. Construction proceeded smoothly and was completed within the time and budgetary limits of the contract. However, there were two notable change orders issued during the project. First, was a rip-rap channel extension of approximately eighty (80) feet from the Cemetary street detention basin outlet to Fisk Pond. The second was a change in filter media from the proposed limestone and sand mixture to a mix of alum and sand. By December 5, 1986 Whitman & Howard had drawn up a final project punch list of tasks to be completed and submitted them to Zoppo Co., Inc. for completion.

Through the spring and summer of 1987, difficulties developed in obtaining state approval of a time extension to Whitman & Howard's contract. As a result, the amendment was not executed and the contract was subsequently terminated. Another consequence was that Whitman & Howard did not initiate post-construction monitoring during the delay and it eventually had to be assumed (fall of 1988) by the DEP.

Unusually heavy rains and subsequent run-off in the spring of 1988, caused the emergency overflow of the Pegan Brook filter chamber to become obstructed and backed-up. Soon, these waters circumvented the headwall on its southern end, by-passing the structure and creating a significant erosion channel. This channel turned northward and rejoined the outflow from the sturcture roughly forty feet downstream.

Presently, remediation and mitigation of the erosion at Pegan Brook is the focus of the Department's efforts at Lake Cochituate. Specifically, the DEP has retained the services of Hayward-Boynton & Williams Inc. to design alternatives for addressing the erosion at Pegan Brook.

POST-CONSTRUCTION
WATER QUALITY MONITORING

Responsibility for post-construction monitoring of the project elements was shifted to DEP after problems arose in executing a time amendment to the Whitman & Howard, Inc. contract. As a result of the delays and confusion associated with the shift in responsibility, no immediate pre-construction or post-construction data were collected. When monitoring was conducted it was designed to determine whether the chemical cores of the Fisk Pond filter berm and the Pegan Brook detention/filter device had exceeded their useful lifetime and would require regeneration. Monitoring of the retention/detention pond at Cemetary Street was not included because it would have required ground water monitoring which was beyond the scope of the study. Since the monitoring program focused upon the effectiveness of the project structures, in-lake sampling was not conducted.

Post-Construction Sample Regime

Two stations were sampled at both the Fisk Pond filter berm and Pegan Brook detention/filter project sites (see Figure 4, locus map of project sites). One station was located directly upstream and the other located directly downstream of each project site (see Figures 5 and 6).

Discrete water samples were collected (in accordance with DWPC's Standard Operating Procedures) at each station on an approximately weekly interval from October 25 to November 23, 1988. There was little differential in time between the collection of samples at the two stations for each project site. Water samples were transported to the Lawrence Experiment Station immediately after collection, and analyzed for the following parameters: total phosphorus, total Kjeldahl-nitrogen, nitrate-nitrogen, ammonia-nitrogen, total alkalinity, total hardness, suspended solids, and total solids. Samples for total phosphorus and nitrogen forms were taken in triplicate.

Temperature, dissolved oxygen, specific conductivity, and pH were measured in situ with a Hydrolab Model 4000 unit. The Hydrolab unit was standardized on the morning of each sampling trip according to the manufacturer's recommendations.

On October 25, 1988 the Fisk Pond filter berm and the Pegan Brook detention/ filter devise were sampled for heavy metals following the procedures specified above. Samples were assayed at the Lawrence Experiment Station for the heavy metals cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc.

Sample Station Location

Four separate sample stations were established for the monitoring program. The location of these sample stations are shown in Figures 5 and 6, and are described in more detail below.

FP31 - This surface water station is upstream from the Fisk Pond filter berm at the gate valve mechanism. The station is accessed via a catwalk over the filter berm off Rt. 135.

FP32 - This surface water station is downstream from the Fisk Pond filter berm where a large stone culvert channels flow under the railroad tracks and into the south basin

Lake Cochituate Phase II

Restoration Project

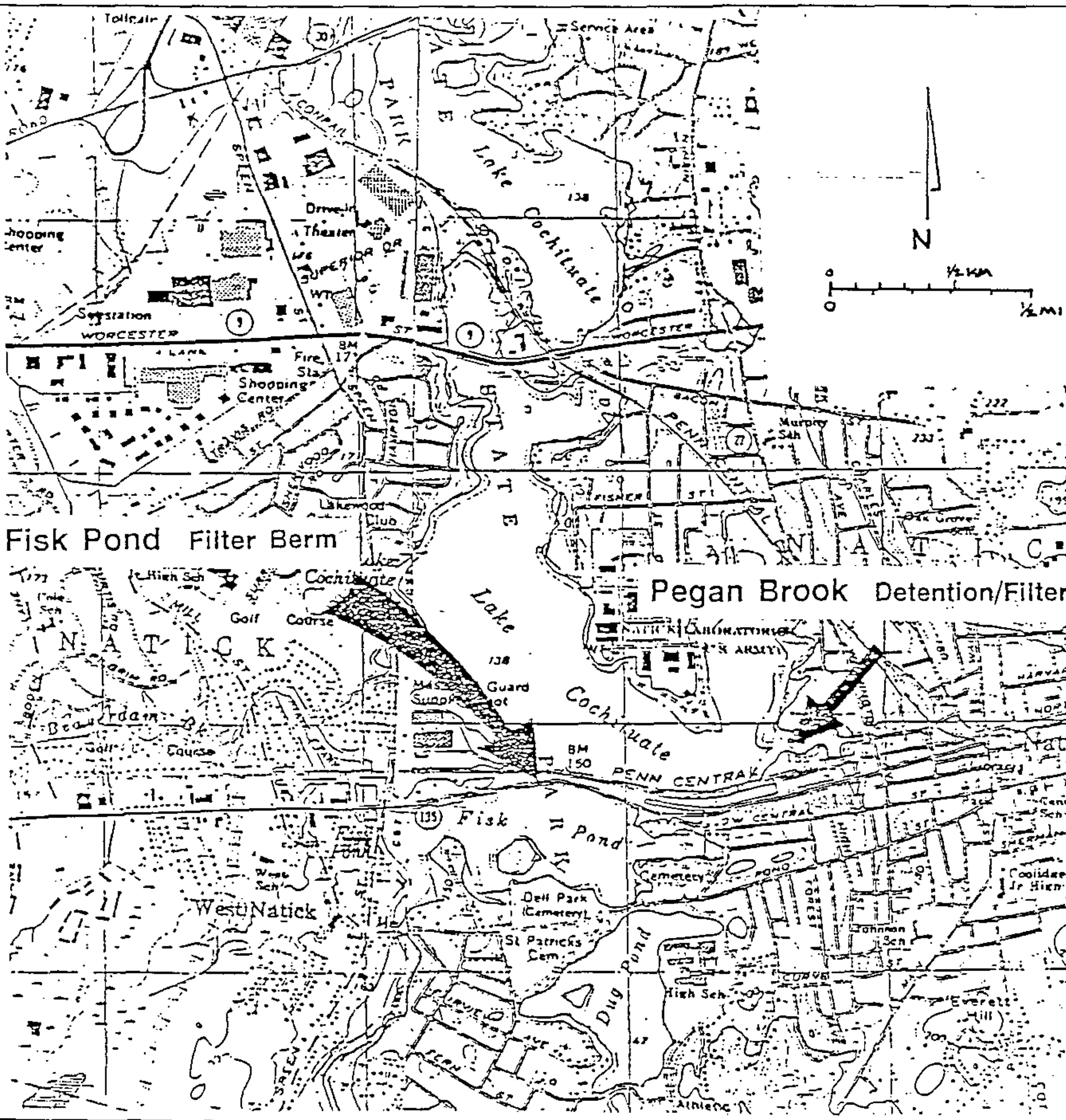

Figure 4

Locus Map

Lake Cochituate Phase II
Restoration Project

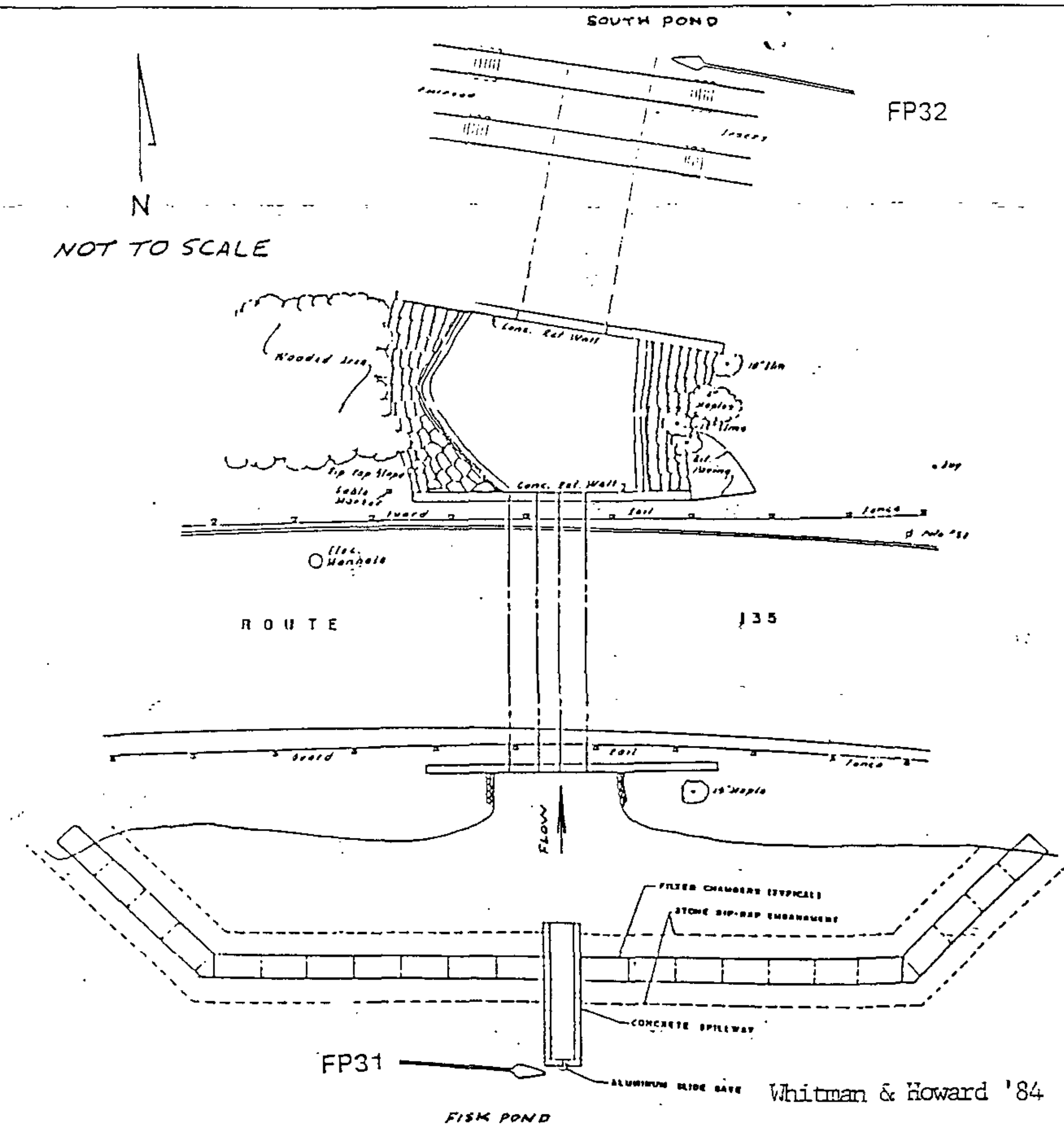

Figure 5

Fisk Pond Sample Station Location

Lake Cochituate Phase II
Restoration Project

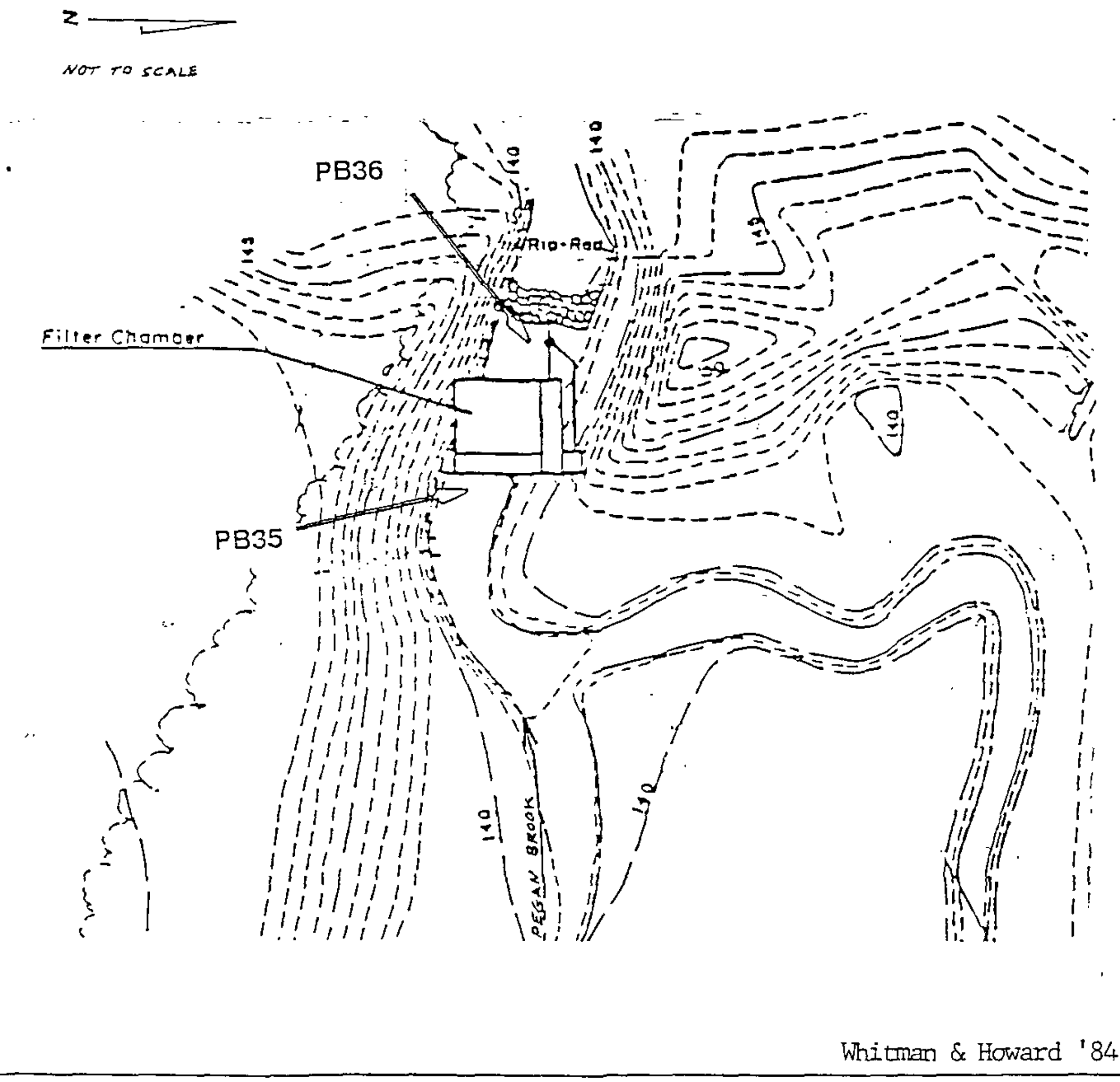

Figure 6
Pegan Brook Sample Station Location

of Lake Cochituate. The station is accessed via a railroad embankment and culvert riprap off Rt. 135.

PB35 - This surface water station is upstream from the headwall where Pegan Brook enters the Pegan Brook detention/filter device. The station is accessed via DEM land at the end of Bellevue Road.

PB36 - This surface water station is downstream from the Pegan Brook detention/filter device where Pegan Brook exits through the downstream headwall. The station is accessed in the same manner as Station PB35.

Sample Period and Exceptions

The stations described above were sampled on four occasions: 25 October, 31 October, 9 November, and 22 November of 1988. All stations were sampled as indicated in the previous section, Post-Construction Water Quality Monitoring, with the following exceptions:

- triplicate analyses are not available for Station PB35 on 9 November 1988 due to breakage of two sample bottles in transit;
- pH was measured on 23 November 1988 rather than the 22nd due to a meter malfunction in the Hydrolab unit; and
- stations FP31 and FP32 could not be sampled on 22 November 1988 due to excessively high water levels following a rainfall event several days earlier.

Results

Metals- Metal data are presented in Table 3. Cadmium, chromium, copper, lead, and nickel were all below the limit of detection. Little difference was observed between the concentration of the other metals upstream and downstream at each project site. There was, however, an increase in iron and to a lesser degree, manganese, below the Pegan Brook detention/filter devise. This is probably insignificant due to the complexed/particulate nature of these metals, which would allow a very small particle or "clump" of material to skew the data.

Temperature- Table 4 presents the water temperature data from the post-construction survey. On most of the water sampling dates, temperature dropped slightly across the project element at both sites. The magnitude of the temperature differential was greater between stations FP31/FP32 ($\leq$1.1 ^{o}C) than stations PB35/PB36 ($\leq$0.3 ^{o}C). In both cases, however, it probably represents a slight energy transfer as water passes through the respective project elements.

Dissolved Oxygen- Dissolved oxygen data are presented in Table 5. At Fisk Pond, the increase in dissolved oxygen from FP31 to FP32 ranged from 0.2 to 1.2 mg/L. The Pegan Brook data sets show greater increases, ranging from 0.6 to 3.9 mg/L. Reaeration of the water passing through the two filter devices is the most likely explanation for these results.

pH- The pH data from the surveys are tabulated in Table 6. The three sets of data from Fisk Pond are inconclusive. Increases of slightly more than 1 pH unit on two dates were followed by a slight decrease (0.1 pH unit) on the 3rd date. The four sets of data from Pegan Brook all show increases (range 0.3 - 1.1 pH units). These fluctuations show some relatively large changes in hydrogen ion concentration across each of the project elements. However, a specific trend is not apparent and they do not indicate any important impact of the project elements.

Specific Conductance - Table 7 contains the specific conductance data from the survey. The levels at both sites are relatively high, particularly those at Pegan Brook. However, there was little difference between upstream and downstream values. Slightly elevated values were recorded at the downstream stations on most sampling dates.

Chloride- The chloride data in Table 8 also show relatively high concentrations at both sites with little distinction between upstream and downstream stations. However, the three-fold difference in chloride concentrations between the Fisk Pond and Pegan Brook sites corresponds to the measured difference in specific conductivity described above. The Fisk Pond site shows slight (2-7 mg/L), but insignificant, increases below the filter berm, whereas no such distinction is evident at Pegan Brook.

Total Alkalinity- Table 9 presents the total alkalinity data from the survey. Both sites show little variation between upstream and downstream sampling stations. The Pegan Brook alkalinity levels are slightly higher than those recorded for Fisk Pond.

Total Solids- The total solids data (Table 10) also show virtually no variation between upstream and downstream sampling stations at either site. The total solids in Pegan Brook are relatively concentrated and, in comparison with the Table 9 data, indicate a large dissolved solids load in this watercourse.

Suspended Solids- The suspended solids at both sites were all relatively low, and slight variations between upstream and downstream sampling stations were evident (Table 11). The filter berm at Fisk Pond appears to retain approximately 50% of the suspended solids load, whereas no effect is evident for the Pegan Brook detention/filter device. However, the lack of precision in this gravimetric method may account for station-to-station differences.

Hardness- The hardness data in Table 12 show a pattern similar to total alkalinity. Pegan Brook exhibited nearly twice the hardness that was recorded for Fisk Pond, but there was little or no variation between upstream and downstream sampling stations at either site.

Ammonia Nitrogen- All the ammonia nitrogen data sets (except 25 October at Fisk Pond) show a slight, but consistent increase downstream of the project element at both sites (Table 13). It is difficult to put much weight on this increase due to the fact that the data are all so close to the limit of detection (0.02 mg/L). This slight increase, however, may be the result of the enzymatic breakdown of organic matter by fungi and bacteria as the water passes through the filter elements.

Nitrate Nitrogen- No trend in nitrate nitrogen was evident above and below the project elements, but a major difference existed in the nitrate levels between the two sites (Table 14).

Total Kjeldahl Nitrogen- Table 15 contains the total Kjeldahl nitrogen data from the surveys. The data are fairly erratic in comparing upstream and downstream samples at the two sites. No clear pattern is noticeable and the values do not indicate any significant impact of the project elements.

Total Phosphorus- The data of most interest to the study, total phosphorus, are presented in Table 16. As stated previously, each datum listed is an average of three replicate samples (Water Quality Monitoring Program). The total phosphorus levels were remarkably stable over time at the two sites, but they were nearly twice as concentrated at the Fisk Pond stations. The data in Table 14 do not indicate any discernible pattern and, more specifically, no detectable reduction in total phosphorus taking place across either of the project elements.

Summary of Water Quality Monitoring

Upon examining all of the data sets (Tables 3-16), it is evident that the quality of inflowing water to Lake Cochituate from both Fisk Pond and Pegan Brook remained largely unchanged. This is especially true for total phosphorus, ammonia nitrogen, and nitrate nitrogen. Thus, assuming no significant change in flow volume at these two inputs, the loading of these nutrients to Lake Cochituate remained unaffected by the structures being monitored.

The range and average values of the same parameters from previous monitoring surveys at both Fisk Pond and Pegan Brook are presented in Table 15 for historical perspective. Some parameters, notably pH, specific conductance, and suspended solids, monitored in 1988 exhibited deviations from historical data. For example, the historical Pegan Brook pH average was 7.0 (Table 17), whereas a range of ph 4.3 to 5.6 is recorded for the 1988 monitoring program (Table 6) at the upstream sampling location (PB 35). Either the buffering capacity of Pegan Brook has changed over time, which is not reflected in total alkalinity (Table 9) or hardness (Table 12) data, or the pH values in Table 6 are may be erroneous.

The data presented in Tables 3-16 indicate that neither the filter berm at Fisk Pond nor the detention/filter device at Pegan Brook were having a noticeable or measurable impact on the quality of the water entering Lake Cochituate at the time of the monitoring. Nutrient levels, specifically phosphorus, were not being reduced by either project element. This lack of nutrient reduction was probably the result of alum loss from the chemically active cores of the filtering devices. The alum loss would occur over time as water flowing through the filter slowly dissolved it away. Additionally

CONCLUSIONS

The water quality data show no significant reduction in either nutrients or other water quality parameters when the data from above and below the project elements is compared. Thus, neither the Fisk Pond filter berm nor Pegan Brook detention/filter devise were removing nutrients or other chemical constituents at the time of the study. Also, the water quality at both project sites appears to have changed very little from the historical data produced by DWPC. Since post-construction in-lake monitoring was not undertaken, it is not possible to document improvements to the water quality of Lake Cochituate.

It should be noted that although the aforementioned project structures have become expended, the third project element remains viable as of this writing. The detention/retention pond at Cemetary Street, by current estimates (Hayward, 1990), continues to function as designed and should do so for several more years. Presently at 30 to 40 percent capacity, it requires only periodic maintenance (weed removal and stone raking) before full scale rehabilitation will be needed. Because no monitoring was conducted at the site, the effectiveness of the Cemetary Street detention pond cannot be quantified. Qualitatively though, the structure has and continues to remove sediments and thus contributes positively to the water quality of Fisk Pond.

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APPENDIX

Water Quality Data

TABLE 3

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
METALS (mg/L)

OCTOBER 25, 1988

METAL/STATION I.D.	FP31	FP32	PB35	PB36
Cadmium	<0.02	<0.02	<0.02	<0.02
Chromium	<0.03	<0.03	<0.03	<0.03
Copper	<0.02	<0.02	<0.02	<0.02
Iron	0.51	0.50	0.34	0.72
Lead	<0.05	<0.05	<0.05	<0.05
Manganese	0.10	0.11	0.15	0.19
Nickel	<0.03	<0.03	<0.03	<0.03
Zinc	0.04	0.03	0.08	0.07

TABLE 4

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
TEMPERATURE (°C)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	10.0	9.4	8.6	8.5
10/31	8.0	6.9	4.8	4.8
11/9	7.3	6.5	5.3	5.1
11/22	—	—	6.2	5.9

TABLE 5

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
DISSOLVED OXYGEN (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	8.5	8.7	7.3	11.2
10/31	8.4	9.6	8.0	12.6
11/9	8.6	9.3	9.0	10.4
11/22	—	—	8.7	9.3

TABLE 6

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
pH (standard units)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	7.4	7.3	5.6	6.3
10/31	6.1	7.2	4.3	5.4
11/9	5.9	7.1	5.6	5.9
11/23	—	—	4.8	5.5

TABLE 7

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
SPECIFIC CONDUCTANCE (micromhos/cm)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	247	262	692	697
10/31	279	284	724	734
11/9	292	290	608	622
11/22	—	—	536	533

TABLE 8

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
CHLORIDE (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	44	46	140	140
10/31	51	53	150	150
11/9	45	52	140	140
11/22	—	—	100	100

TABLE 9

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
TOTAL ALKALINITY (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	30	30	54	54
10/31	34	35	57	56
11/9	29	29	58	58
11/22	—	—	58	48

TABLE 10

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
TOTAL SOLIDS (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	150	150	400	410
10/31	170	170	420	420
11/9	200	200	400	400
11/22	--	--	300	300

TABLE 11

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
SUSPENDED SOLIDS (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	4.0	2.5	1.5	2.5
10/31	1.5	1.0	2.0	2.5
11/9	2.5	<1.0	1.5	1.0
11/22	--	--	1.0	1.0

TABLE 12

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
HARDNESS (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	43	44	82	82
10/31	44	46	77	73
11/9	44	46	73	71
11/22	—	—	65	65

TABLE 13

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
AMMONIA-N (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	BDL	BDL	BDL	0.02
10/31	BDL	0.06	0.02	0.06
11/9	0.06	0.09	0.03	0.06
11/22	—	—	0.05	0.08

BDL = below detection limit

TABLE 14

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
NITRATE-N (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	BDL	BDL	1.0	1.0
10/31	BDL	BDL	1.1	1.1
11/9	0.1	0.1	1.0	0.6
11/22	—	—	1.3	1.2

BDL = below detection limit

TABLE 15

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
TOTAL KJELDAHL-N (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	0.48	0.67	0.56	0.62
10/31	0.81	0.63	0.60	0.79
11/9	0.61	0.71	0.44	0.65
11/22	—	—	0.42	0.41

TABLE 16

LAKE COCHITUATE 1988

POST-CONSTRUCTION SURVEY
TOTAL PHOSPHORUS-P (mg/L)

SURVEY DATE	SAMPLE STATION FP31	FP32	PB35	PB36
10/25	0.07	0.06	0.04	0.05
10/31	0.06	0.07	0.04	0.05
11/9	0.07	0.05	0.03	0.03
11/22	—	—	0.04	0.03

TABLE 17

LAKE COCHITUATE

HISTORICAL WATER QUALITY DATA*
APRIL 1976 - JUNE 1979
(Units in mg/L except as indicated)

PARAMETER	FISK POND		PEGAN BROOK	
	average	range	average	range
pH (standard units)	7.0	6.2-8.8	7.0	6.4-7.8
Total Alkalinity	29	13-36	38	30-46
Hardness	48	27-64	92	64-116
Suspended Solids	8.5	1.0-23	2.9	0.5-7.5
Total Solids	175	92-338	332	252-402
Specific Conductivity (micromhos/cm)	232	146-260	521	330-680
Total Kjeldahl-N	0.96	0.06-2.2	0.45	0.0-1.1
Ammonia-N	0.04	0.00-0.16	0.07	0.0-0.26
Nitrate-N	0.2	0.0-1.3	1.4	0.0-2.8
Total Phosphorus-P	0.07	0.03-0.14	0.04	0.01-0.09
Chloride	58	29-170	121	67-160

* The average of approximately 20 data sets from two Division of Water Pollution Control Reports (MDWPC, 1977 and 1979). The sample station location for the above data approximates FP32 and PB36, respectively.