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CHARLES RIVER

ARTIFICIAL DESTRATIFICATION PROJECT

BOSTON, MASSACHUSETTS

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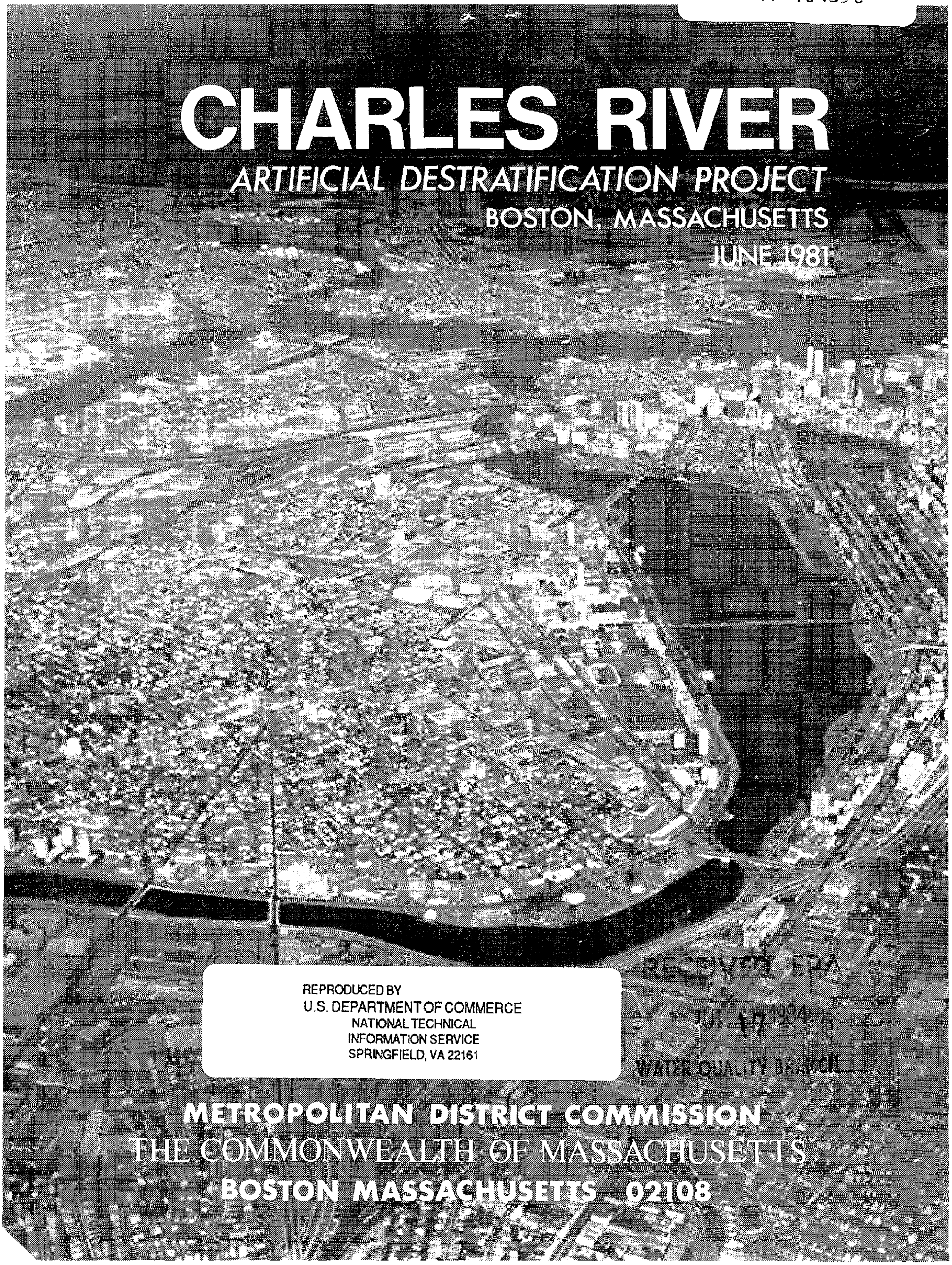

METROPOLITAN DISTRICT COMMISSION
THE COMMONWEALTH OF MASSACHUSETTS
BOSTON MASSACHUSETTS 02108

EPA Report No.
June 1981

CHARLES RIVER LOWER BASIN
ARTIFICIAL DESTRATIFICATION PROJECT

by

Alfred F. Ferullo
Paul J. DiPietro
Robert J. Shaughnessy
Metropolitan District Commission
Commonwealth of Massachusetts
Boston, Massachusetts 02108

Grant No. S804812

Project Officer

Ronald G. Manfredonia
Water Quality Branch
Boston, Massachusetts 02203

Water Program Division
Office of Research and Development
U.S. Environmental Protection Agency
Boston, Massachusetts 02203

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FOREWORD

The Charles River Basin (CRB) is a major recreational resource in the heart of metropolitan Boston. It is owned by the Metropolitan District Commission (MDC) a multi-city service agency providing water, sewer and parks services to up to fifty-four municipalities in the Boston metropolitan area.

The section of the Charles River addressed in this report is the downstream end between Watertown Dam (upstream) and the Charles River Dam (CRD) which separates the CRB from the marine waters of Boston Harbor. Since construction of the CRD in 1910, sea water infiltrating into the CRB has remained on the bottom as a stratified layer. Decomposing material in the sediments has resulted in the depletion of dissolved oxygen and production of varying concentrations of hydrogen sulfide.

The destratification of the CRB was undertaken to (1) eliminate the occasional release of hydrogen sulfide to the atmosphere (2) avoid a fishkill in Boston Harbor when the flood control pumps of a new Charlés River Dam are turned on in the future and (3) improve the fish habitat. This report covers the period between September 1976 to December 31, 1980.

ABSTRACT

The Charles River Basin (Basin) which was created by construction of a dam in 1910 has been stratified since that time with salt water intruding from Boston Harbor through a boat lock and leaky sluices. In order to eliminate nuissance conditions and fish kills caused by hydrogen sulfide from the anoxic bottom water, destratification by air-mixing was initiated in the spring of 1978. Six diffusers were installed on the bottom in the deep sections of the Basin and operated as necessary to induce sufficient circulation to maintain a minimum of 4.0 mg/l dissolved oxygen throughout the water column. After two and a half years of operation hydrogen sulfide has been eliminated and water quality has generally improved in the area of the Basin influenced by the diffusers.

Construction cost of the destratification system was $559,000. Annual operating cost was $24,000.

CONTENTS

TABLES

LIST OF ABBREVIATIONS

ABBREVIATIONS

BOD	--biochemical oxygen demand
DO	--dissolved oxygen
H_2S	--hydrogen sulfide
PPM	--parts per million or mg/l
^oC	--degrees Celsius
^oF	--degrees Fahrenheit
cfs	--cubic feet per second
cfm	--cubic feet per minute
psia	--pounds per square inch measured relative to absolute pressure
psig	--pounds per square inch measured relative to atmospheric or gage pressure (1 psig = 1 + 14.7 psia)
CR	--Charles River
CRB	--Charles River Basin
CRD	--Old Charles River Dam
NCRD	--New Charles River Dam
MDC	--Metropolitan District Commission

ACKNOWLEDGEMENTS

Recognition is due to the following organizations their staff and individuals for their assistance in providing the information required on the development and completing of this project:

Commonwealth of Massachusetts: Department of Fisheries, Wildlife and Recreational Vehicles, Division of Fisheries and Wildlife; The Department of Environmental Quality Engineering, Lawrence Experiment Station; Metropolitan District Commission; Sewage Division's Deer Island Laboratory, Water Division's Somerville Water Laboratory, The Construction Engineering Division, The Metropolitan Police (Lower Basin & Harbor District). The U.S.E.P.A. New England Regional Laboratory Surveillance and Analysis Division. The consulting firm of Camp, Dresser, McKee, Inc., Boston, Massachusetts.

INTRODUCTION

The Charles River (CR) located in eastern Massachusetts drains 307 Square miles of watershed over its 80 mile length and is the largest tributary draining into Boston Harbor. The Charles River Destratification Project involved the section commonly referred to as the Charles River Basin (CRB) which is the 8.6 mile portion of the river from Watertown Dam to the C.R. Dam The destratification units or diffusers were installed downstream of Deerfield Street (lower CRB).

During colonial days, the Basin was an estuary composed mainly of mud flats. The Charles River has been the site of many historic events since the beginning of the seventeenth century when it was visited by Samuel Champlain and Captain John Smith. Paul Revere looked across the Charles to receive signals that would send him on his way to Lexington on horseback. The first English speaking university was founded on its banks and the first remote telephone call took place across the C.R. from Alexander Graham Bell in Boston to Thomas Watson in Cambridgeport.

By the late 1800's it became clear that an acute public health nuisance had developed as a result of years of direct wastewater discharges to the Basin from an increasing urban population. A special legislative commission was appointed to investigate the problem and make recommendations on the desirability of constructing a dam across the river. The report stated that "the chief reasons for the construction of the dam are to be found in the sanitary betterment of the region and the betterment of the metropolitan park system".1 The legislative report which also addressed wastewater disposal recommended that remedial sewer work be done on both banks of the river and along the Back Bay Fens, a tributary of the Basin. While the report examined tha anticipated stratification of the Basin after construction of the dam it did not consider the magnitude of the slat water intrusion that would occur in later years.

The Craige Street Dam is now called the Old Charles River Dam (CRB); The recently constructed dam (1979) one-half mile downstream is called the New Charles River Dam (NCRD). Shortly after the old dam was in place the Boston Marginal Conduit was constructed to intercept wastewater overflows along the Boston shoreline for discharge downstream of the dam. Many of the reports written over the past 30 years on pollution of the Basin make reference to the stratified layer of saltwater that on occasion has extended as far upstream as Watertown Dam. Inasmuch as the shallow upstream section of the Basin is subject to turnover from wind, several fishkills and malodors from the release of hydrogen sulfide to the atmosphere have occurred.

CONCLUSIONS

1. Air-mixing has eliminated the extensive stratified anoxic bottom water and sulfides in the Lower Charles River Basin without creating any environmental problems. Stratification in the Upper Charles River Basin (beyond the influence of the air-mixers) has not changed.

2. Salinity in the water column is not uniform, a salinity gradient still exists.

3. Water quality has improved primarily because the high concentrations of sulfides, nutrients and oxygen-consuming materials in the anoxic zone have disappeared and oxygen is found through-out the water column.

4. Air-mixing has helped to flush salt water from the Basin.

5. The temperature gradient has been reduced downstream of Deerfield Street.

6. There were no significant changes in algal or coliform populations.

7. Air-mixing did not resuspend bottom sediments.

RECOMMENDATIONS

1. After the New Charles River Dam becomes operational, manipulate the flood control pumps and diffuser 5A to further reduce salt water intrusion to minimize the air-mixing.

2. Perform a fish survey to determine the effect of destratification on the diversity of fish species.

3. Examine bottom sediments to record changes in physical and chemical quality and the presence of benthic organisms.

THE PROBLEM

A major water quality problem affecting the Basin is the inability of the bottom stratified saltwater layer to become aerated. The saltwater infiltrating the Basin through the boat lock and leaky sluices has become a relatively stagnant bottom stratum devoid of oxygen and fishlife and containing varying concentrations of hydrogen sulfide. Several discharges of combined sewer overflows and several feet of accumulated organic sediment provide to oxygen demanding material and high concentrations of sulfates in seawater provide the source of sulfides. The depth of anoxic zone and its migration upstream is determined by number of boat lock openings and the fresh water flows. Because of the greater depth downstream of the B.U. Bridge any disturbance of the bottom salt water layer by the flow of overlying fresh water does not result in any detectable release of hydrogen sulfide to the atmosphere. This,of course,is not true in the shallower upstream section of the Basin. Hydrogen sulfide,on the other hand,has been detected at sluices at the dam in the summer during periods of high runoff.

During the late summer of 1975 sea water covered 80% of the bottom and up to 50% of the total vertical depth was anoxic. This was assumed to be a "worst case" and indicates the magnitude of volume of the Basin that was "off limits" to fish and their food organisms. Fishkills however were only noticed when the anoxic bottom water mixed with the surface waters.

The New Charles River Dam with its tighter boat locks and sluices will result in an 80% reduction in salt water intrusion when it becomes operational. Questions raised during the design phase of the new dam regarding the release of sulfide laden bottom waters downstream when it became necessary to use the large capacity flood control pumps in the dam provided the stimulus for addressing the stratification problem. The intakes of the pumps are located near the bottom. Discharge of water high in hydrogen sulfide could cause a fishkill and the release of hydrogen sulfide to the atmosphere in the center of a very active commercial section of Boston .

The Old Charles River Dam contains one relatively large boat lock whose water elevation is controlled by exploiting the hydraulic head on either side of the dam. When the upstream gate is opened, salt water within the lock flows into the Basin and freshwater flows over it to fill the lock. During high tide seawater is used to raise the level of the lock before the downstream gate is opened. This "gravity" method of operating the lock in the old dam permits considerable exchange of salt and fresh water.

Salt water intrusion and loss of freshwater shown in table 1 is based on estimates of the number of lock cycles. Some factors influencing quantities are tidal elevations, time of lock opening and density differences between salt and freshwater. Table 1 compares volumes of salt and fresh water exchanged by lock operations through the Old and New Charles River Dams and the percentage of monthly uses during the year. Future quantities are based on year 2025 estimates.

LEAKAGE

Losses associated with leakage are due mainly to old sluice gate seals; lesser losses occur at the lock seals. The Basin's surface elevation will be increased from 107.5 (MDC datum) to 108.0 when the New Charles River Dam becomes operational. The harbor elevations generally range from 100' to 110'. Estimates indicate that an average of 16 cfs of saltwater enter and 35cfs of fresh water leave the Basin through leakage during a 24 hour day. Faulty tide gates on the major combined sewer outlets have on occasion permitted seawater to enter the Basin during high tide. However, a major sewer reconstruction project will eliminate this source of infiltration.

BASIN MORPHOLOGY

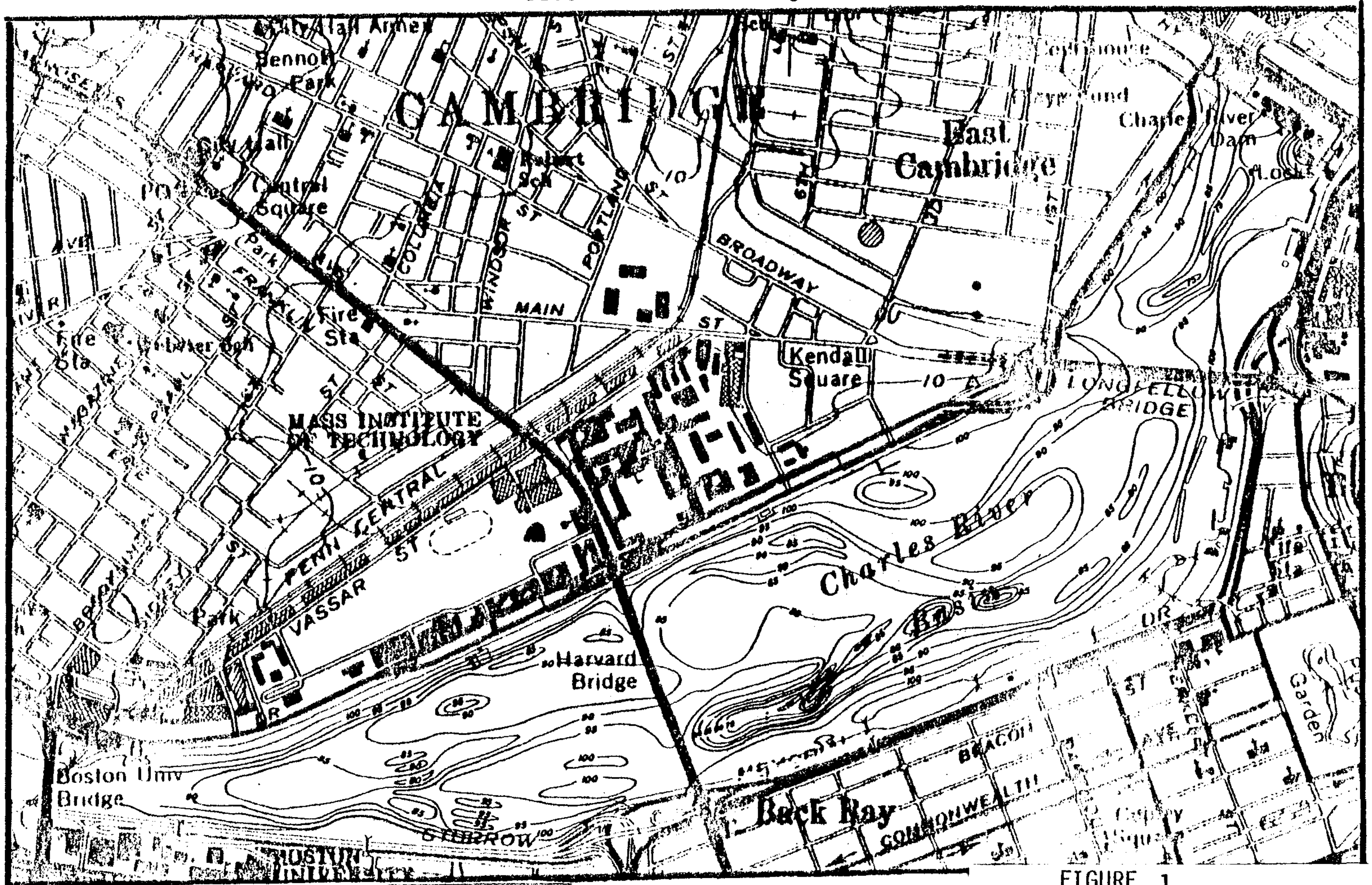
The bottom features of the Basin, particularly in the downstream section, aggravates the stratification problem by entrapping seawater. The river bed has deep depressions which are well below the average river bottom elevation. It is suspected that the depressions along the Boston side of the Basin were created to provide fill for construction or the proper depth for navigation. Close inspection of the river bottom reveals fairly steep walls at some locations.

The overall mean depth of the downstream section of the Basin is 20 feet with maximum depths exceeding 35 feet. A bathymetric map (figure 1) showing elevations was prepared from depth information collected during various river surveys. The mean and maximum depth profiles in figure 2, reveal deep pockets as well as elevated mounds. The bottom configuration is important to the stratification problem insofar as it is able to collect and store seawater and prevent it from being flushed from the river. An important barrier to the downstream flow of saltwater exists at the Longfellow Bridge where a ridge about 20 feet below the water surface extends from one side of the river to the other. Thirty-five foot troughs follow the ridge on both the upstream and downstream sides of this barrier which has been very effective in holding back the downstream flow of saltwater. The highest concentrations of hydrogen sulfide were recorded just upstream of the barrier. Not only seawater but organic solids collect in the depressions thereby providing the necessary ingredients for the generation of hydrogen sulfide.

TABLE 1 ESTIMATED VOLUMES OF SALTWATER INTRUSION AND WASTED FRESH WATER FROM BOAT LOCK OPERATIONS, CU FT x 10^6

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Totals
Percentage of total number of cycles per year	1	1	1	7	7	14	23	23	14	7	1	1	100
Initial Estimates													
Old Charles River dam													
Saltwater intrusion	10.9	10.9	10.9	78.8	78.8	154.0	245.0	245.0	154.0	78.8	10.9	10.9	1,088.9
Freshwater outflow	12.2	12.2	12.2	88.9	88.9	172.0	274.0	274.0	172.0	88.9	12.2	12.2	1,219.7
New Charles River dam													
Saltwater intrusion	5.2	5.2	5.2	17.4	17.4	18.7	29.2	29.2	18.7	17.4	5.2	5.2	174.0
Freshwater outflow	6.5	6.5	6.5	22.2	22.2	26.6	43.6	43.6	26.6	22.2	6.5	6.5	239.5
Future Estimates													
New Charles River dam													
Saltwater intrusion	7.8	7.8	7.8	26.1	26.1	28.3	43.6	43.6	28.3	26.1	7.8	7.8	261.1
Freshwater outflow	10.5	10.5	10.5	36.6	36.6	43.6	71.4	71.4	43.6	36.6	10.5	10.5	392.3

Charles River Basin
Destratification Project



Note: Contours shown are elevations (ft.)
Normal Basin elevation is 108 ft.

FIGURE 1
Charles River Lower Basin
Bathymetric Map (see note)

Charles River Basin
Destratification Project

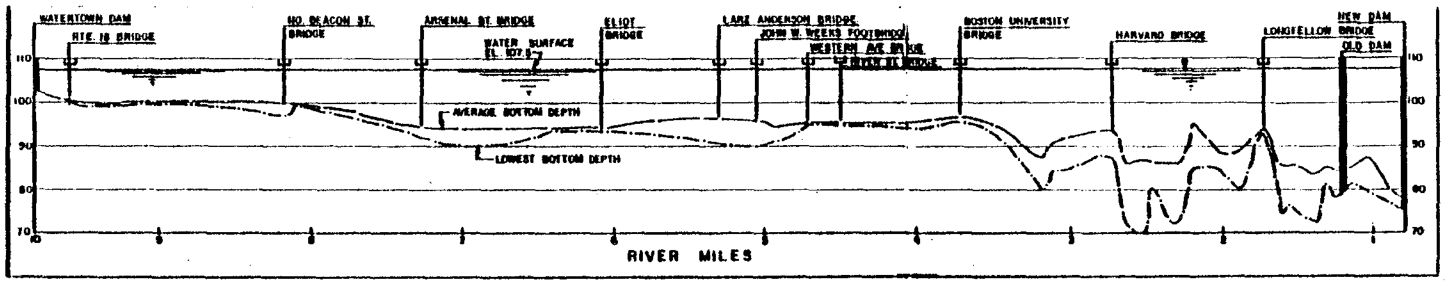


FIGURE 2

Charles River Basin
Basin Profile

ALTERNATIVE SYSTEMS

Several schemes were evaluated for eliminating salt water stratification and the hydrogen sulfide problems it caused. The alternatives were:

1. Baffling to induce mixing

   This was not considered practical because of the interference to boating.

2. Pumping bottom waters to sewer

   This scheme was rejected because it provided no advantage to pumping bottom waters to the harbor with the flood control pumps at the new dam.

3. Creating a barrier at the existing dam

   The purpose of the barrier would be to limit the amount of salt reaching the Basin. This alternative was rejected because the barrier would restrict flood flows passing through the old dam and create a hazard to navigation because of the increased velocities.

4. Installing an air barrier

   The air barrier would be installed at (a) the upstream end of the boat locks of the new dam or (b) just upstream of the new dam. This alternative was rejected because the currents caused by the air barriers within the boat locks would make maneuvering of boats difficult. The cost of providing the proper amount of air for the barrier further upstream would be prohibitive.

5. Excavation of channels through existing barriers

   The ridges on the Basin bottom would be cut to promote the downstream flow of saline waters. This scheme would not work during periods of low flow and was therefore discarded.

6. Artificial destratification

   Destratification by (a) mechanical pumping or (b) air-mixing would provide oxygen throughout the water column and enhance flushing of salt water out of the Basin.

This alternative was selected as the best for the Charles River Basin. It could be accomplished at reasonable cost and would provide considerable control. The air-mixing system with compressed air was found to be preferable to mechanical pumping inasmuch as the latter would have to be mounted on rafts.

7. Removal or covering bottom sediments

The removal or covering of the bottom sediments to reduce its oxygen demand and other possible adverse water quality impacts was investigated. Dredging to remove the material was estimated to be at over 4 million dollars (1976) and was rejected. Covering of bottom sediments was also abandoned due to the fluid nature of the benthic deposits. Past surveys have shown that the uppermost section is colloidal in nature and grows denser as one proceeds downward. This alternative was also rejected because of the cost.

DESTRATIFICATION FACILITIES DESCRIPTION

The compressed air mixing system provides for the artificial destratification of the water column and the maintenance of aerobic conditions in the Charles River Basin. Compressors are located in the Upper Lockhouse at the Old Charles River Dam and in the Fens Gatehouse, both structures situated along the Boston shoreline. Three miles of three inch plastic piping convey the compressed air to six duffuser locations in the deepest sections of the CRB. Each compressor system supplies three diffusers.

Mixing is induced by the release of compressed air from each diffuser which entrains water on its upward movement to the surface. The rising plume produces a distinctive surface water boil which at full capacity is up to six inches above the water surface and twenty feet in diameter. The result is a blending of salt and fresh water, a significant increase in dissolved oxygen in the entire water column and the virtual elimination of hydrogen sulfide.

Design Criteria

The Destratification Facilities were designed not only to destratify but also maintain 4 mg/l dissolved oxygen throughout the Basin. These goals will be met when the New Charles River Dam is operational. The system was designed to provide sufficient oxygen to satisfy the oxygen demands of benthal deposits, local combined sewer overflows and upstream pollution. These factors provided the input to the sizing of the air mixers. There is sufficient flexibility in the rate at which air is supplied to the diffusers to respond to changing conditions in both salinity and organic loads. The average oxygen demand of the bottom sediments was estimated at 6,000 lbs per day in the undisturbed state. The average ultimate BOD loading from combined sewer overflows and upstream sources was estimated at 15,500 pounds per day. The total oxygen demand was estimated to increase tenfold under worst case conditions, e.g. when sewage is released from overflowing combined sewers during storms. These discharges will be reduced drastically in the next five years when new facilities will be constructed to contain or treat combined flows from storms of one year frequency or less.

Air Compressor Systems

The Compressed Air Systems are located in two existing buildings eliminating the need for any new structures on MDC parkland (Figure 3). Diffusers 1, 2, and 3 are supplied from the Fens Gatehouse and diffusers 4, 5 and 5A from the Upper Lockhouse at the Old Charles River Dam. Diffuser 5A is located between the Old and New Charles River Dams and will be used once the

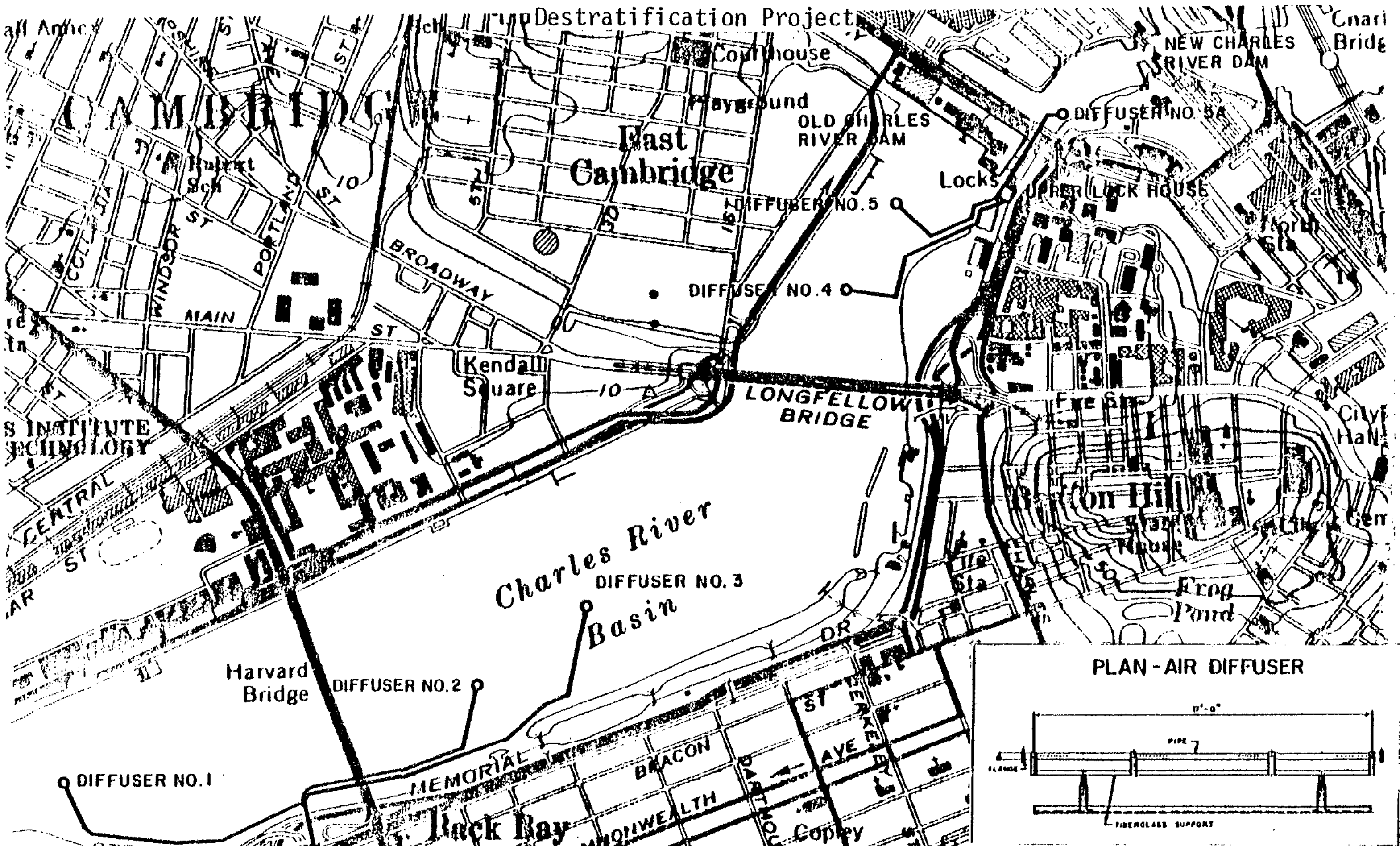


FIGURE 3
Charles River Basin
Diffuser Location and Plan

new dam becomes fully operational.

The Fens Gatehouse is on the Boston side of the CRB at the intersection of Storrow Drive and Charlesgate Interchange. Built in 1910 and owned by the MDC this building houses sluice gates which control the flow of combined wastewater from upstream conduits. During dry weather, flow is conveyed to the Boston Marginal Conduit and the Deer Island Wastewater Treatment Plant and during wet weather combined wastewater discharges directly into the Charles River. Three compressors supply air to three diffusers in the upstream section of the Basin. The total system consists of three air intake filters, three air intake silencers, three air compressors, three pressure relief valves, three temperature controls, one air-water after-cooler, one oil and moisture separator, one air receiver tank, and three air flow meters.

The remaining two compressors are located in the Upper Lockhouse at the Old Charles River Dam. The building was built around 1910 and houses the upstream boat lock with necessary mechanical equipment and controls used in the dam's locking operations. Sluice gates that control flows in the downstream end of the Boston Marginal Conduit are found in this building. The equipment is similar to the upstream system except that only two compressors are involved.

Each of the five compressors consists of six cylinders arranged in a paired radial pattern which reduces vibration. Each compressor has its own air filter and air intake silencer and is capable of delivering 350 cfm of air at 35 psig. Pressure relief valves are set at 55 psig. A separate fifty horsepower electric motor drives a six-v-belt system powering each compressor at 500-600 rpm. The compressors are oil lubricated and water cooled. Their control panels consist of operation switches and malfunction indicator lights. A sensing system triggers the warning light and shuts down the compressors if oil pressure is low, or air pressure, air temperature and cooling water temperatures too high. After the malfunction is corrected the switches are reset manually and operation resumed. Air from each compressor is passed through a water after-cooler and a moisture and oil separator before entering the air storage tank. The separator is of a cyclone design with an automatic drain tap. The cylindrical storage tanks have a design capacity of 400 and 240 gallons for the Fens Gatehouse and Upper Lockhouse system, respectively. The compressed air is sent through a header pipe to a distribution manifold system which consists of three sets of control valves and three air flow meters. This system allows independent air flow regulation to each of the diffusers in the river.

The operating compressors are pressure regulated by a master control panel located next to the air flow meters in each building. An adjustable pressure sensing device electronically signals the solenoid valves to open, unloading the compressors. In the unloaded mode the compressors run, but air is not compressed thereby reducing the energy requirement. As the air pressure in the storage tank drops the solenoid valves are closed and the compressors run in the loaded mode filling the tank with compressed air until the upset pressure setting is reached. Then the compressors are again unloaded. There are two pressure sensing relay systems at each compressor location. This permits either presetting two different operating pressure ranges or using one as a standby. Only one unit is needed for the control of all the compressors at each location. A selector switch provides ease in transferring from one system to the other when needed. The compressed air leaves the buildings through air piping to the six diffuser sites in the river. The location of the six diffusers are shown in figure 3. Diffuser 1 is between the Cottage Farm Bridge and Mass. Ave. Bridge off Deerfield St. at an approximate depth of 25 feet. Diffusers 2 and 3 are situated between the Mass. Ave. Bridge and the Longfellow Bridge. Diffuser 2 is located off Gloucester Street and diffuser 3 off Exeter Street both in water 30-35 feet deep. Diffusers 4 and 5 are located between the Longfellow Bridge and the Old Charles River Dam in 25 feet of water in a tidal section of the river which will become part of the CRB when the New Charles River Dam becomes operational. Air from the Fens Gatehouse and Upper Lockhouse flows through 3 inch polyethylene pipes to each diffuser. The piping is either buried or shielded before entering the river approximately two and one-half miles of polyethylene piping were installed along the river bed weighted to the bottom by 2,400 steel collar weights, twenty-two pounds each spaced five feet apart. Submerged marker floats attached to one hundred foot intervals identify the sunken airlines. A bed of crushed stone supports each diffuser assembly consisting of a fiberglass cradle and an adjustable rack. The rack holds the diffuser in place and is so constructed that it can be adjusted vertically two to three feet to provide equal air distribution along the entire length of the diffuser. The diffuser is the seventeen foot long end of the 3 inch diameter polyethylene pipe with four rows of one-eight inch diameter air holes placed at quarter points around the pipes circumference. The holes are spaced two inches on center and each row is aligned off center with the adjacent row.

A reverse flow check valve is at the intake end of the diffuser and a cleanout flange is provided at the other end.

OPERATION

Operating Criteria

The destratification system was designed to mix the downstream part of the CRB i.e. from Deerfield Street to the New Charles River Dam (NCRD) and provide a minimum of 4.0 mg per liter of oxygen throughout the water column under conditions anticipated after the NCRD becomes operational. Salt water intrusion at that time will be reduced by 80%. It is understood that a 4.0 mg/l DO cannot be maintained during those infrequent periods when heavy rains cause the release of sewage-stormwater (combined sewer overflow) at various locations in the Basin. While the upper section of the Basin i.e. upstream of Deerfield Street will not be influenced directly by the diffusers, it should show improvement because of the reduced amount of salt water migrating upstream.

Maximum efficiency has been achieved during the period covered by this report by taking full advantage of the flexibility of the system in reacting to changes in existing water quality. Experimentation during the first year of operation has helped in establishing a fairly stable mode of operation where from 700 to 1000 cfm air (total) is provided in the summer months and 200-400 cfm during the winter. Electrical power costs have been $1200-$1800 per month for each compressor running at the maximum rate of 360 cfm. These costs will be lower when the NCRD becomes operational.

Since 1979 two compressors have provided sufficient air for destratification. The other three compressors have been used in rotation to equalize wear. Daily measurements of temperature, pressure, air flow and operating time are recorded and analyzed periodically to determine the need for replacement of parts. No major mechanical failures have occurred in almost three years of operation.

The operational strategy has been to provide mixing of the water column in the CRB to the degree necessary to maintain satisfactory oxygen levels and preclude nuisance conditions using the minimum amount of energy. Destratification has also helped to remove sea water from the Basin.

Initial Operation

Diffuser start-up was scheduled to take place during early spring to coincide with the Basin's lowest hydrogen sulfide (H_2S) concentrations and avoid interfering with the upstream migration of anadromous fish. The plan was to turn on the downstream diffuser first and progress upstream. Historically the areas in which these diffusers (4 and 5) are located have had lower H_2S values than upstream sections. The staggered operation would allow resident fish to escape downstream to waters free of H_2S.

The installations of diffusers 4 and 5 located downstream of the Longfellow Bridge were completed in April 1978. On the day of start-up, May 1, 1978, oxygen was present down to the twenty-five foot depth at both diffusers. Diffuser 5 was turned on at 8 a.m. at an air flow rate of 100-150 cfm. At 10 a.m. after a short initial burst of H_2S no odors were detected. Diffuser 4 was turned on at 10 a.m. at 100 cfm. Although weather conditions on the first day favored atmospheric dispersion, H_2S readings over diffusers 4 and 5 were 2.0 - 4.0 and 0.2 - 0.6 ppm respectively. After a brief run at maximum air flow, H_2S concentrations at diffuser 4 ranged from 4.0 to 10.0 ppm. At 100 cfm H_2S readings onshore downwind of diffuser 4 were 0.4 ppm. Operations ceased at 12 noon in compliance with restrictions imposed by local conservation commissions. Both diffusers were turned back on at 9 p.m. May 1, 1978 at 75 cfm. On the morning of May 2, 1978 no odors were detected downwind of both diffusers. Permission therefore was granted by local authorities to operate the diffusers around-the-clock.

Start-up of diffusers 1, 2, and 3 had to be postponed because their construction extended into the fish migration season. Diffuser 2 was of particular concern because of its location in the deepest hole in the Basin just downstream of the largest source of combined sewer overflows.

Diffuser 2 was started in January 1979 to take advantage of high flows. Ten inches of rain fell during this month with readings of 3000 cfs recorded at the U.S. Geological Survey gage in Waltham. The "boil" broke through the ice ultimately forming an ice-free zone up to 500 feet in diameter. Hydrogen sulfide measurements recorded on shore exceeded 10 ppm during the first day's operation at 100-175 cfm. Three weeks of intermittent day-time operations were required to eliminate sulfide odors and continuous operation was established by mid-February.

Diffusers 1 & 3 were turned on in mid-March when the Basin was free of ice. Hydrogen sulfide odors at these diffusers were minimal at start up and disappeared quickly. These odors have been virtually eliminated in the CRB downstream of the Cottage Farm Bridge since that time.

While the design of the destratification system was based on conditions anticipated in the Basin after the construction and operation of the NCRD, the data show that even with large amounts of sea water in the Basin in 1978-80, oxygen levels seldom dropped below 4.0 mg/l downstream of Deerfield St. The operating plan has been to vary the air supplied to each diffuser to respond to changes in water quality. Mixing was increased as salinity increased and DO concentrations dropped. The Basin was considered adequately mixed when the DO was greater than 4.0 mg/l and the salinity differed less than 5 parts per thousand through the entire water column.

Insufficient mixing has resulted in a rapid drop in bottom DO. Dissolved oxygen values above 4.0 mg/l not only preclude H_2S generation but sustains fish life and encourages the growth of benthic organisims. Water quality monitoring at regular intervals determines operating procedures.

An ongoing construction program to reduce combined sewer discharges into the CRB to only those that occur during storms of one year or less frequency, should be completed by 1986. The oxygen demand in the Basin immediately following storms should therefore be drastically reduced.

Spring and Summer Operation

Diffuser 1 and 3 are turned on in the spring as soon as the Basin is free of ice. Since diffusers 2,4, and 5 have been in operation during the winter no H_2S is released at this time. During the summer air flow rates are adjusted to maintain at least 4.0 mg/1 DO. In the summer of 1980 this was accomplished with 140 cfm of air at each diffuser. "Worst conditions" occur in the middle of the summer when the boat locks are opened frequently forcing salt water into the Basin, when temperatures are high and river flows low.

Fall and Winter Operation

Air flow rates at all diffusers are reduced in the fall as water temperatures drop and river flows increase. Diffusers 2,4, and 5 run all winter to ensure that the Basin remains aerobic; this is accomplished with less than 100 cfm of air at each diffuser. A sign posted on shore warns ice skaters and others of thin ice around the diffusers.

Emergency Operation

An electrical outage in 1980 prompted the installation of a quick-connect coupling with pressure reducing valve at each air receiver tank. On two occasions portable air compressors were used at the Fens Gatehouse to provide air and preclude oxygen depletion in the Basin during outages by simply connecting a standard air compressor hose to the new coupling. The compressor was able to deliver about 100 cfm to diffuser 2.

New Charles River Dam

Unlike the Old Charles River Dam, the NCRD whose primary purpose is flood control has the capability of pumping water out of the Basin. This capability as well as tighter boat locks and sluices are expected to reduce salt water intrusion into the Basin by 80%. The intakes of the sluices and pumps are located near the bottom. Diffuser 5A located between the old and new dams has not been operated during the report period but will be put to use as needed after the NCRD becomes operational. It will ensure satisfactory bottom DO concentrations and enhance flushing of salt water from the Basin.

Impact on Recreation

Inasmuch as the CRB is used intensively for recreation (boating, fishing)* there was concern about the impact of the diffusers on the occupants of boats. At the request of the management of one of the boating clubs, the location of diffuser 3 was moved further upstream for this reason.

* The Basin is classified "C" under the Massachusetts Water Quality Standards i.e. the water is suitable for boating and fishing but not swimming.

The effects of a diffuser boil were tested by attempting to row a 12 foot aluminum row boat through it several times. The boat was unable to overcome the force of the waves radiating from the boil and was turned away in every instance. The same effect was experienced by a person trying to swim through the boil. Since the time of the tests, sail boats have been observed cutting through the boils with no apparent danger of capsizing.

Even though ice-skating or walking on the ice in the Basin is prohibited, the effects of the upstream diffusers on the thickness was a consideration in winter operations. Inasmuch as diffusers 4,5 and 5A are located in a section of the Basin kept open for commercial boat traffic, this was not a problem with the downstream diffusers. Because diffuser 2 was located in a deep section of the Basin just downstream of a largest source of combined sewer overflows and this site has historically had high concentrations of hydrogen sulfide, this diffuser had to be operated year-round. It not only ensured adequate DO but avoided the release of hydrogen sulfide to the atmosphere each spring during start-up. Therefore only diffusers 2,4 and 5 have been left on all winter. A sign warning the public of thin ice was placed on the shore near diffuser 2.

WATER QUALITY

Monitoring

Water Quality monitoring in this report covers the period between May 1975 and December 1980 i.e. 2½ years before destratification and two and a half years after destratification. Samples were collected throughout the water column to reflect water quality characteristics that would change as a result of destratification. Most of the sampling stations were located in the deeper sections of the CRB (figure 4 & 5). They are identified as follows:

Station No.*	Location
1	Old Charles River Dam
2	Downstream of Longfellow Bridge
3	Upstream of Longfellow Bridge
4	Opposite Storrow Lagoon
5	Opposite Boston University
6	Elliot Bridge
7	Arsenal Street Bridge
8	Watertown Dam

In general, sampling was conducted twice monthly during spring, summer, and fall and monthly during winter. Temperature, chloride, salinity, dissolved oxygen and secchi disc measurements were made in the field; pH, ammonia, nitrates, total kjeldahl nitrogen, sulfide, phosphorous, suspended solids, color, turbidity, coliforms and plankton counts were performed in the laboratory. The results appear in the appendix.

Pre-Destratification

The following are water quality characteristics observed in the CRB prior to installation of the destratification units:

1. Water quality deteriorated with depth; the greatest surface to the bottom differences occurred in the section downstream of the Boston University Bridge,

2. The quantity of salt water in the CRB varied with the seasonal fluctuation in river flows and lock usage. The highest salinities therefore appeared in the late summer. Sustained high river flows reduced salinity to negligible levels except in the deep trough located between the Longfellow and Harvard Bridges. A halocline was clearly recognizable in this area,

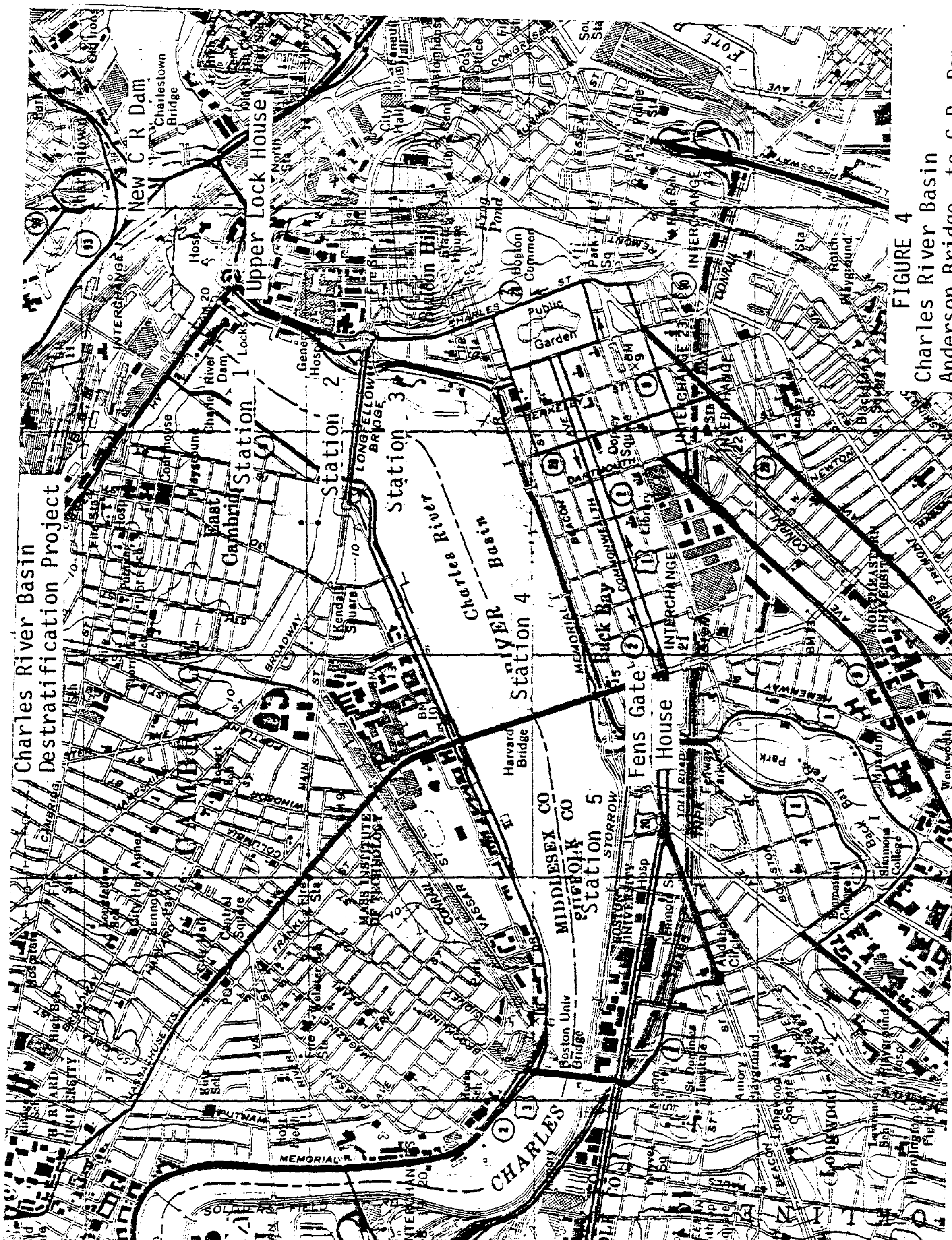


FIGURE 4
Charles River Basin
Anderson Bridge to C.R. Dam

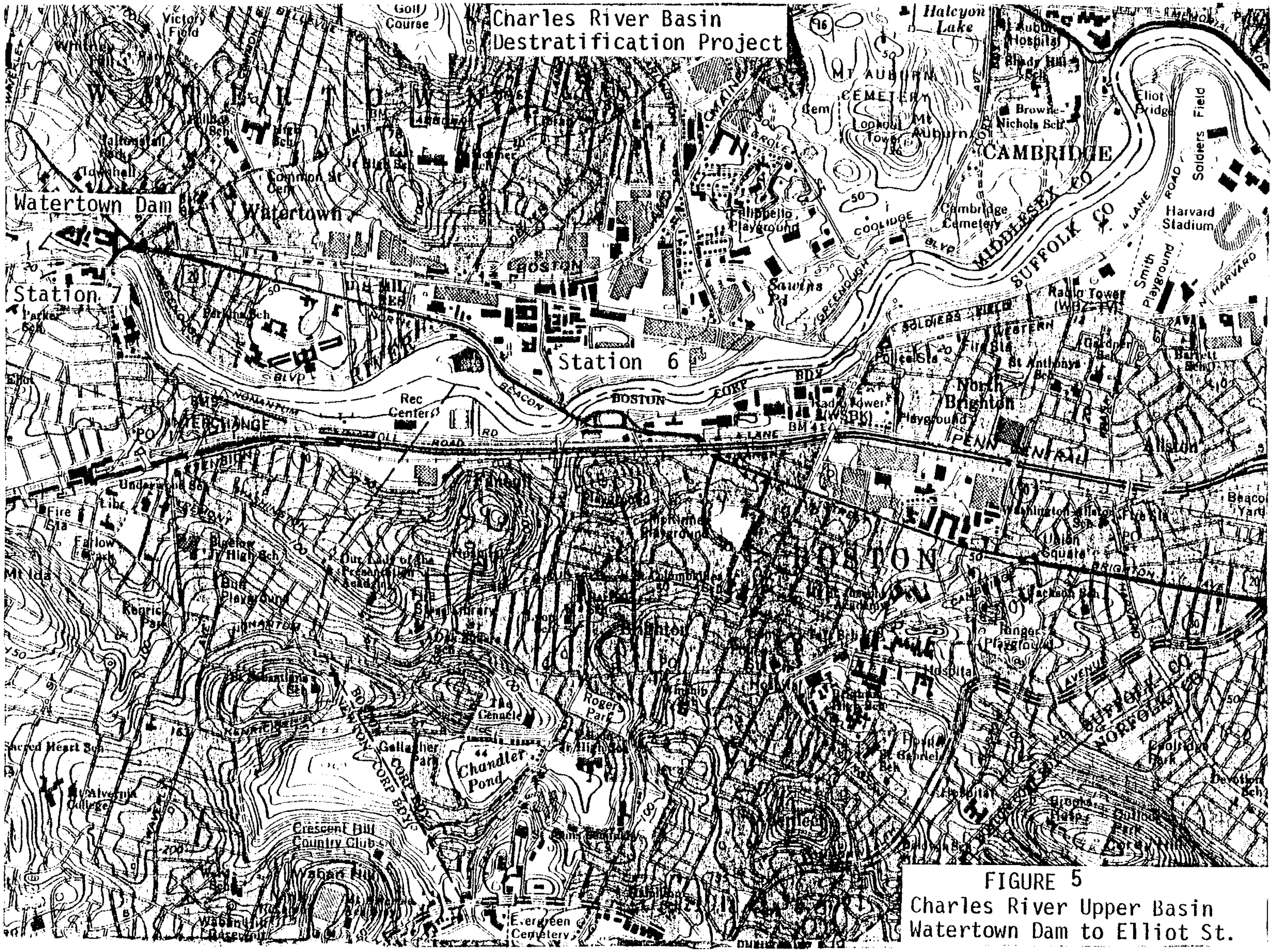


FIGURE 5
Charles River Upper Basin
Watertown Dam to Elliot St.

3. Temperature differences between the surface and bottom were greater in the lower CRB (Stations 1-5) than in the Upper CRB.

4. Sulfides were found only in water with salinities in excess of 3 parts per thousand and increased with depth within the bottom salt water layer. They occasionally were found as far upstream as station 7, about 8.5 miles above the Old Charles River Dam.

5. Surface water D.O. values were generally above 5.0 mg/l. Occasionally concentrations in excess of saturation occurred in the upper CRB during periods of high algal activity.

6. Abrupt decreases in dissolved oxygen were attributable to combined sewer discharges during and after rainstorms.

7. Bottom salt water immediately upstream of the Old Charles River Dam never become anoxic because of frequent mixing with incoming harbor water.

8. Algae counts were higher in the upper CRB than in the lower CRB.

9. Coliform bacterial counts were higher in the lower CRB than the upper CRB.

Post-Destratification

The following are water quality observations after installation of the destratification system:

1. The total quantity of salt in the CRB was reduced. The salinity of the surface waters increased and that of the bottom waters decreased in the lower CRB. No effect on salinity was seen in the upper CRB. Figure 6 shows the impact of mixing on salt distribution.

   The 1980-81 drought accounts for the upstream migration of sea water.

2. Surface to bottom temperature variations were within 2-3 C in both the upper and lower CRB despite the great difference in

*North Beacon Street added in 1977 (station No. 6). Elliot Bridge and Arsenal Street Bridge were dropped.

river depths. This was achieved while suppling only 40% of the total available air flow to the diffusers.

3. Sulfides have been virtually eliminated in the lower CRB. However, bottom samples collected just upstream of Longfellow Bridge in 1979 did contain sulfides which were attributed to recent upstream combined sewer discharges. No sulfides were detected at the same site in 1980.

   On several occasions there was evidence of sulfides in the upper CRB.

4. A minimum of 4.0 mg/l DO in the lower CRB contrasts with the extremely low DO values at identical locations before destratification. The lowest DO's were found at station 3 upstream of Longfellow Bridge and station 6 in the upper CRB beyond the influence of the diffusers.

5. There was little variation in phosphorus and ammonia concentrations throughout the water column.

6. The biochemical oxygen demand measurements were lower after destratification. This was not unexpected inasmuch as the anoxic bottom waters were eliminated. The increase in the assimulative capacity of the CRB is a significant incidental benefit of the destratification project.

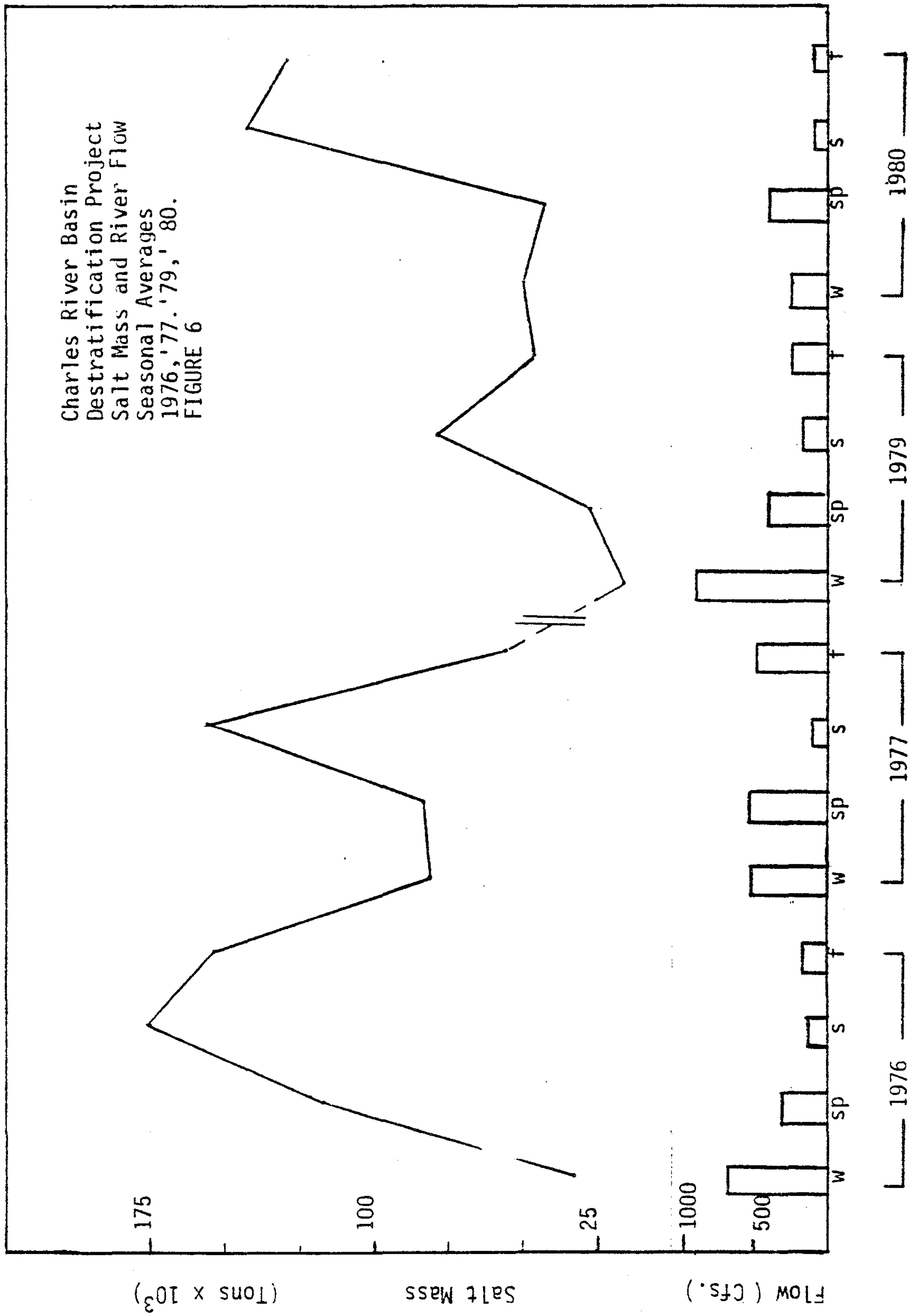
7. No change in the populations or distribution of coliform bacteria was noticed.

8. The increase in pH moving downstream is attributed to the increasing percentage of seawater. Destratification eliminated thelow pH values caused by hydrogen sulfide in the bottom stratum.

9. The water of the CRB has always had a natural brown coloration characteristic of the waters of the large wetland areas in the watershed. The drop in color and increase in transparency noted after destratification are attributed to improved mixing of the harbor water within the CRB.

   There was concern before installation of the diffusers that the soft bottom sediments would be dispersed throughout the water column while they were operating. This has not occurred. Changes in color intensities and turbidity are caused by variations in flow, algae populations, stormwater discharges and combined sewer overflows in addition to sea water.

10. The effects of the diffusers on algae populations do not appear significant. The changes in types from the upper CRB to the lower CRB may be due to osmotic differences and availability of macronutrients and micronutrients. There may not have been sufficient changes in these characteristics in the surface waters


Charles River Basin
Destratification Project
Salt Mass and River Flow
Seasonal Averages
1976,'77.'79,' 80.
FIGURE 6
Salt Mass (Tons x 10^3)
Flow (Cfs.)
175
100
25
1000
500
w
sp
s
f
1976
1977
1979
1980

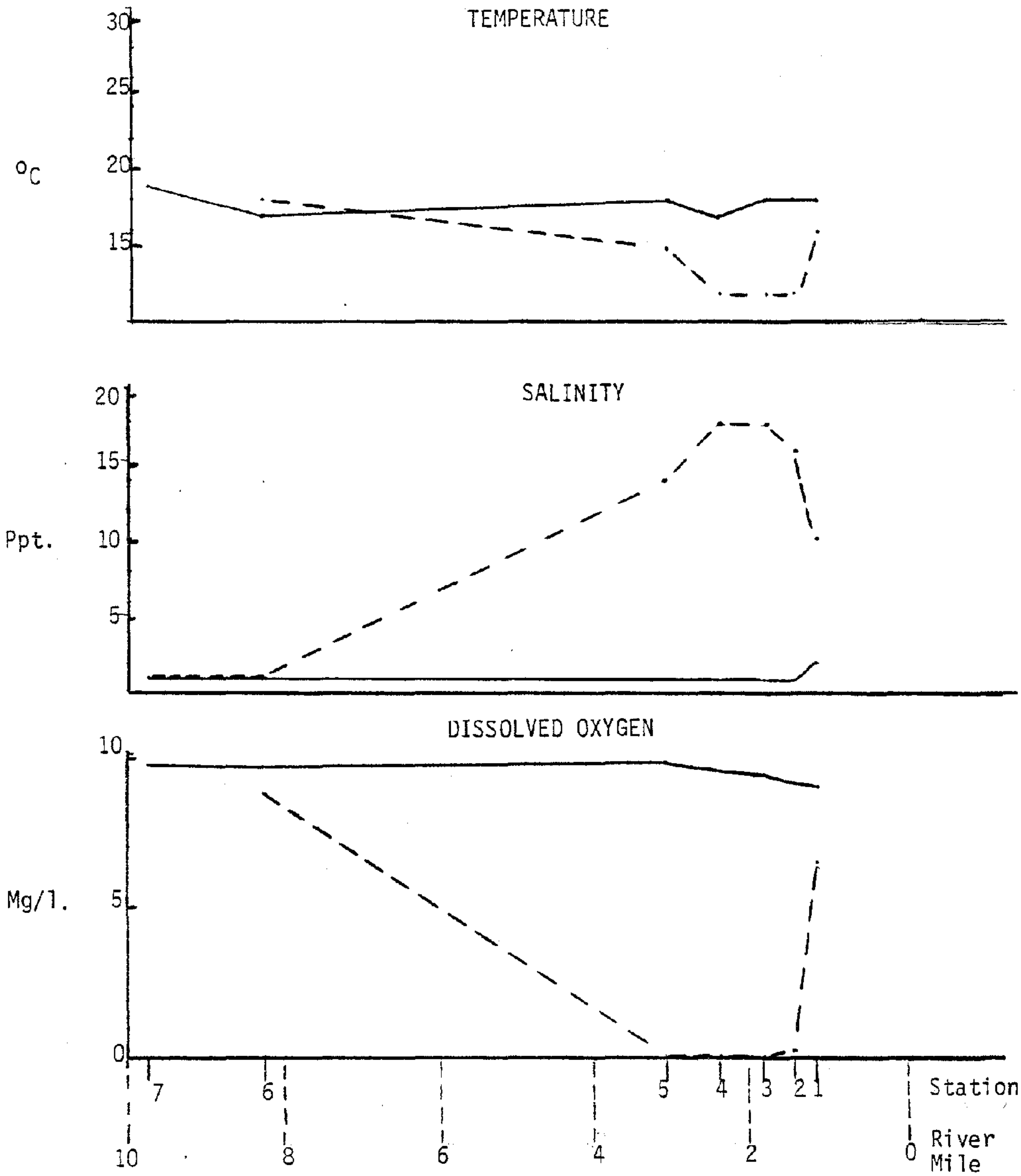
to affect the algae.

Reduced salt water intrusion when the New Charles River Dam becomes operational and the control of combined sewer discharges to the CRB may change the pattern of algae distribution in the future.

The following graphs were prepared to improve the comparative representation of water quality differences that occurred before and after destratification. The seasonal surface and bottom averages for temperature, salinity and dissolved oxygen are shown in figures 7, 8, 9, and 10.

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

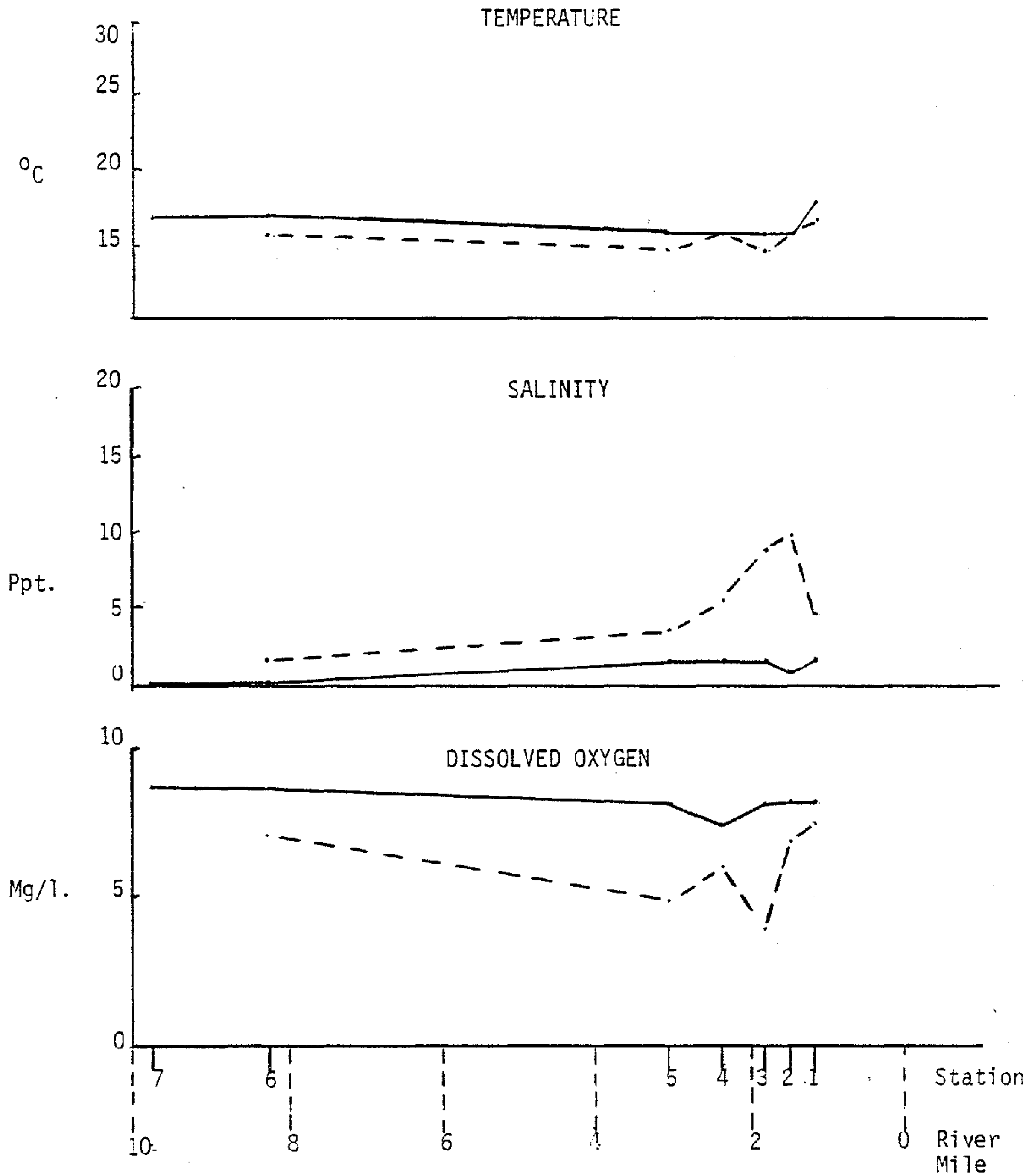
TEMPERATURE, SALINITY
DISSOLVED OXYGEN AVERAGES
APRIL, MAY, JUNE 1977.
Surface
Bottom
FIGURE 7



CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY
DISSOLVED OXYGEN AVERAGES
APRIL, MAY, JUNE 1980.
______________ Surface
-------------- Bottom

FIGURE 8

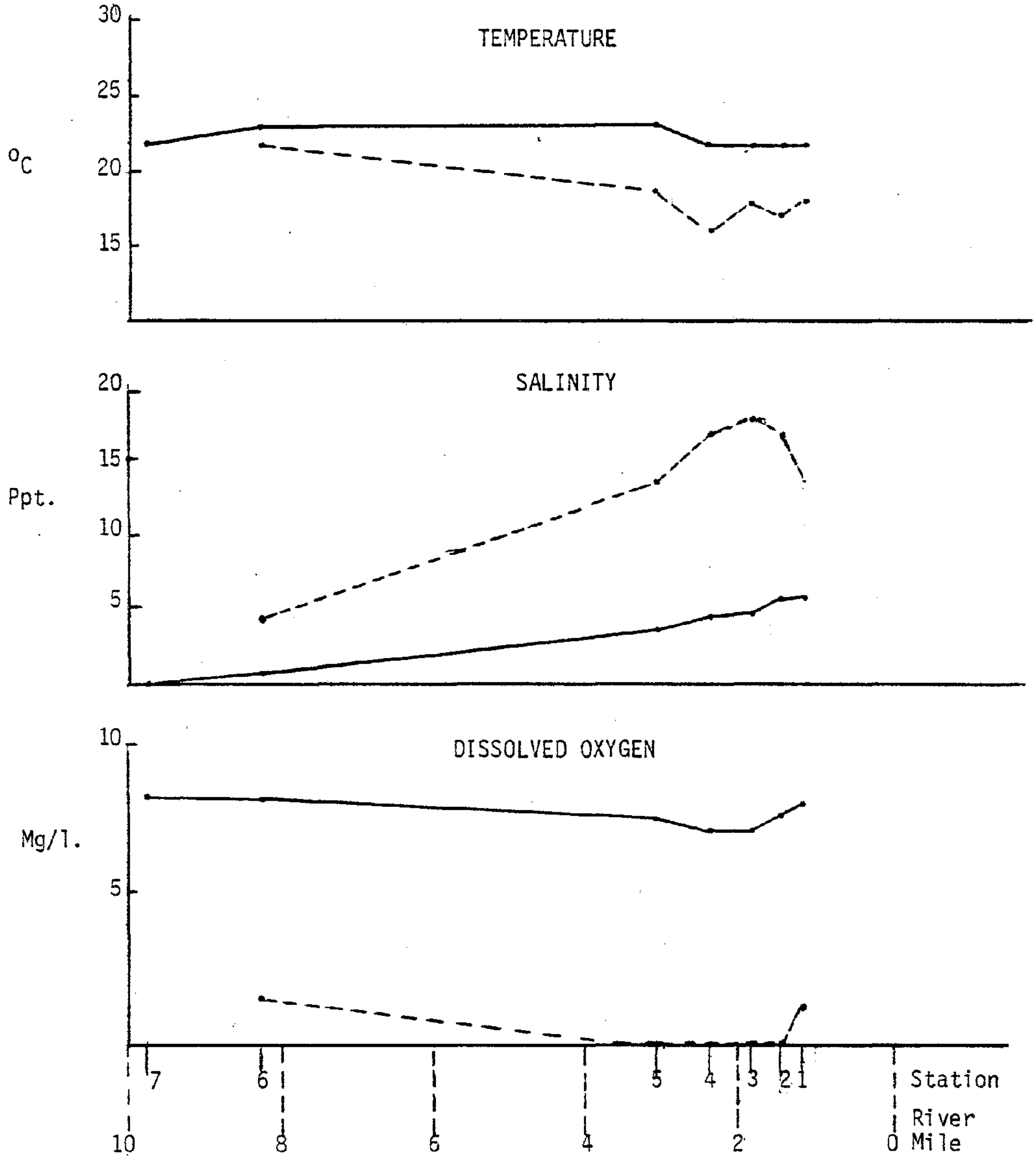


CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY,
DISSOLVED OXYGEN AVERAGES
JULY, AUG. SEPT. 1977.

——— Surface
- - - - - Bottom

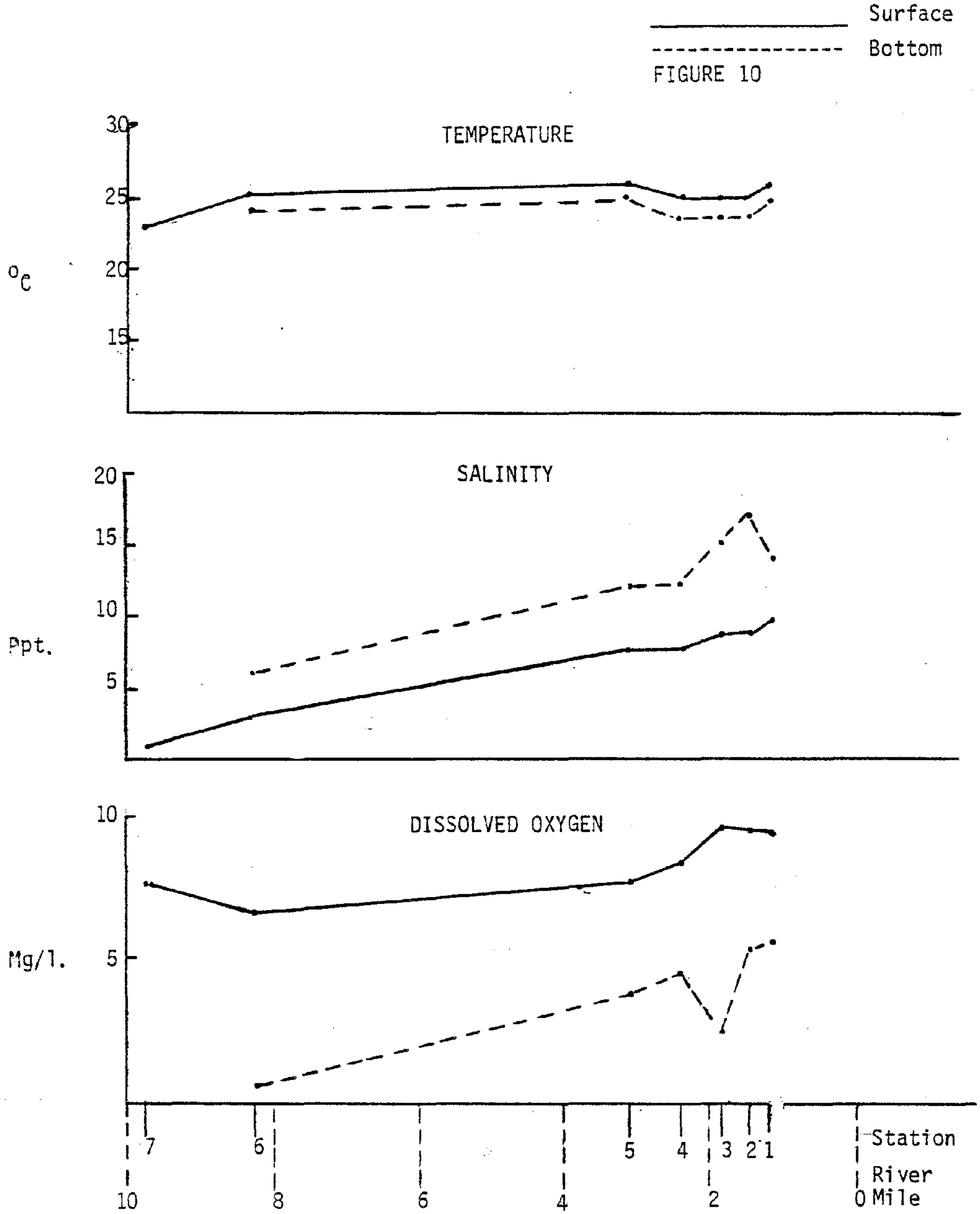
FIGURE 9



CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY
DISSOLVED OXYGEN AVERAGES
JULY, AUG. SEPT. 1980

FIGURE 10



CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY,
DISSOLVED OXYGEN
AVERAGES (JAN-MARCH)
TABLE 2

TEMPERATURE C°

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980* Surface	1980* Bottom
One	-	-	4.0	4.0	6.0	4.0	8.0	6.0
Two	-	-	3.0	4.0	4.0	5.0	8.0	6.0
Three	6.0	8.0	3.0	5.0	4.0	4.0	8.0	6.0
Four	6.0	10.0	3.0	5.0	4.0	4.0	7.0	6.0
Five	6.0	7.0	4.0	4.0	8.0	8.0	6.0	6.0
Six	-	-	9.0	8.0	11.0	10.0	8.0	7.0
Seven	-	-	9.0	8.0	10.0	-	7.0	-

SALINITY P.P.T.

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980* Surface	1980* Bottom
One	0.0	4.0	1.0	6.0	1.0	2.0	2.0	4.0
Two	0.0	6.0	1.0	14.0	1.0	5.0	2.0	8.0
Three	1.0	10.0	1.0	14.0	0.0	5.0	2.0	8.0
Four	1.0	12.0	1.0	17.0	0.0	2.0	1.0	5.0
Five	1.0	7.0	1.0	18.0	0.0	1.0	2.0	4.0
Six	-	-	1.0	1.0	0.0	0.0	0.0	0.0
Seven	-	-	1.0	1.0	0.0	-	0.0	-

DISSOLVED OXYGEN mg/l

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980* Surface	1980* Bottom
One	10.9	10.7	12.3	8.6	12.0	11.6	11.6	11.2
Two	11.9	9.3	10.2	3.9	11.8	11.5	11.5	10.9
Three	12.1	0.0	11.6	4.4	12.4	6.7	11.2	8.8
Four	12.7	0.0	12.4	0.0	12.4	12.2	11.1	10.0
Five	12.7	10.8	12.1	2.0	11.8	11.4	10.4	8.9
Six	-	-	12.6	12.6	11.6	11.2	11.6	11.7
Seven	-	-	-	-	-	-	11.6	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

* One set of values only

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY,
DISSOLVED OXYGEN
AVERAGES (APRIL-JUNE)
TABLE 3

TEMPERATURE C°

	1976		1977		1979		1980	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	12.0	10.0	18.0	16.0	18.0	17.0	18.0	17.0
Two	11.0	9.0	18.0	12.0	17.0	16.0	16.0	16.0
Three	12.0	8.0	18.0	12.0	17.0	16.0	16.0	15.0
Four	12.0	12.0	17.0	12.0	17.0	17.0	16.0	16.0
Five	13.0	8.0	18.0	15.0	17.0	16.0	16.0	15.0
Six	-	-	17.0	18.0	19.0	18.0	17.0	16.0
Seven	-	-	19.0	-	16.0	-	17.0	-

SALINITY P.P.T.

STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	1.0	10.0	2.0	10.0	2.0	4.0	2.0	5.0
Two	1.0	16.0	1.0	16.0	2.0	7.0	1.0	10.0
Three	1.0	17.0	1.0	18.0	2.0	5.0	2.0	9.0
Four	1.0	22.0	1.0	18.0	2.0	3.0	2.0	6.0
Five	1.0	18.0	1.0	14.0	2.0	2.0	2.0	4.0
Six	-	-	1.0	1.0	0.0	0.0	0.0	2.0
Seven	-	-	1.0	-	0.0	-	0.0	-

DISSOLVED OXYGEN mg/l

STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	9.8	8.0	9.1	6.4	7.7	7.4	8.2	7.5
Two	10.2	3.0	9.2	4.0	8.0	7.0	8.3	7.0
Three	10.0	0.0	9.5	0.0	8.0	7.8	8.3	4.1
Four	10.0	0.0	9.6	0.0	7.7	6.8	7.6	6.1
Five	10.2	0.0	9.8	0.0	7.9	6.0	8.2	5.0
Six	-	-	9.7	8.9	9.0	7.9	8.8	7.2
Seven	-	-	9.8	10.1	8.8	-	8.3	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY,
DISSOLVED OXYGEN
AVERAGES (JULY-SEPT)
TABLE 4

TEMPERATURE C°

	1976		1977		1979		1980	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	26.0	20.0	22.0	18.0	23.0	22.0	26.0	25.0
Two	25.0	20.0	22.0	17.0	23.0	21.0	25.0	24.0
Three	24.0	20.0	22.0	18.0	22.0	22.0	25.0	24.0
Four	24.0	18.0	22.0	16.0	22.0	22.0	25.0	24.0
Five	25.0	20.0	23.0	19.0	23.0	22.0	26.0	25.0
Six	22.0	22.0	23.0	22.0	23.0	22.0	25.0	24.0
Seven	22.0	22.0	22.0	-	22.0	-	23.0	-

SALINITY P.P.T.

STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	6.0	17.0	6.0	19.0	5.0	8.0	10.0	14.0
Two	6.0	20.0	6.0	20.0	5.0	11.0	9.0	17.0
Three	5.0	17.0	5.0	18.0	5.0	10.0	9.0	15.0
Four	4.0	16.0	5.0	17.0	5.0	8.0	8.0	12.0
Five	2.0	8.0	4.0	14.0	4.0	7.0	8.0	11.0
Six	1.0	6.0	1.0	5.0	1.0	5.0	3.0	8.0
Seven	1.0	-	0.0	-	0.0	-	1.0	-

DISSOLVED OXYGEN mg/l

STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	9.1	1.9	8.0	1.2	8.5	6.9	9.5	5.5
Two	9.1	0.0	7.7	0.0	8.5	5.6	9.7	5.3
Three	10.8	0.0	7.2	0.0	8.2	1.3	9.8	2.6
Four	10.9	0.0	7.2	0.0	7.3	5.4	8.4	4.4
Five	10.5	0.0	7.5	0.0	6.8	6.0	7.7	3.6
Six	10.4	1.0	8.1	1.8	9.2	3.1	6.7	0.6
Seven	-	8.3	-	8.6	-	-	7.7	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

TEMPERATURE, SALINITY
DISSOLVED OXYGEN
AVERAGES (OCT.-DEC.)
TABLE 5

TEMPERATURE C°

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	10.0	11.0	9.0	10.0	12.0	12.0	9.0	8.0
Two	9.0	13.0	9.0	10.0	12.0	12.0	8.0	8.0
Three	10.0	14.0	9.0	11.0	12.0	12.0	8.0	8.0
Four	9.0	16.0	9.0	13.0	12.0	12.0	8.0	9.0
Five	9.0	14.0	8.0	12.0	12.0	13.0	8.0	9.0
Six	-	-	12.0	10.0	12.0	11.0	9.0	9.0
Seven	-	-	10.0	-	12.0	-	7.0	-

SALINITY P.P.T.

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	4.0	18.0	1.0	6.0	3.0	6.0	8.0	9.0
Two	4.0	20.0	1.0	12.0	2.0	8.0	8.0	12.0
Three	4.0	20.0	1.0	12.0	2.0	8.0	8.0	13.0
Four	4.0	21.0	1.0	13.0	2.0	8.0	7.0	10.0
Five	3.0	15.0	1.0	11.0	4.0	4.0	7.0	10.0
Six	-	-	0.0	0.0	0.0	0.0	1.0	10.0
Seven	-	-	0.0	-	0.0	-	0.0	-

DISSOLVED OXYGEN mg/l

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	10.0	3.9	8.1	7.1	8.7	8.0	8.4	7.6
Two	10.1	0.0	8.4	4.9	8.6	7.7	8.2	7.2
Three	10.1	0.0	8.3	6.5	8.6	5.2	8.3	5.5
Four	9.9	0.0	8.1	3.0	8.5	7.8	8.4	7.0
Five	9.3	0.0	8.4	6.8	8.6	7.0	8.1	6.6
Six	-	-	8.9	8.8	9.8	9.1	10.0	2.9
Seven	-	-	9.0	-	9.8	-	10.4	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

BIOCHEMICAL OXYGEN DEMAND, TOTAL PHOSPHOROUS, AMMONIA-NITROGEN, AVERAGES (JAN-MARCH)
TABLE 6

BIOCHEMICAL OXYGEN DEMAND mg/l

	1976		1977		1979		1980 *	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	5.0	4.0	3.3	16.6	5.3	2.4	4.0	3.5
Two	5.0	3.0	2.9	81.0	5.0	3.2	3.0	4.6
Three	3.0	117.0	5.8	60.0	8.9	8.4	4.2	3.6
Four	2.0	90.0	4.0	81.0	9.0	4.0	3.5	3.8
Five	4.0	109.0	3.8	91.0	7.4	10.0	3.3	4.0
Six	-	-	-	-	4.0	4.0	3.4	2.7
Seven	-	-	-	-	10.0	-	2.9	-

TOTAL PHOSPHOROUS mg/l

	1976		1977		1979		1980 *	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	-	-	0.66	1.24	0.25	0.29	0.14	0.14
Two	0.3	0.4	0.65	2.25	0.28	0.32	0.22	0.23
Three	0.4	3.1	0.94	0.60	0.19	0.60	0.14	0.22
Four	0.2	4.2	1.00	2.60	0.43	3.00	0.04	0.05
Five	0.3	2.3	1.04	2.49	0.50	0.90	0.05	0.25
Six	-	-	2.38	1.97	0.20	0.40	0.15	0.03
Seven	-	-	0.95	-	0.40	-	0.02	-

AMMONIA - NITROGEN mg/l

	1976		1977		1979		1980 *	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	-	0.8	1.24	1.01	0.54	0.50	0.60	0.54
Two	0.6	8.9	1.30	1.08	0.48	0.48	0.60	0.60
Three	0.2	11.5	1.17	1.56	0.20	1.70	0.44	0.72
Four	0.3	7.2	1.04	10.32	0.35	15.00	0.60	0.90
Five	0.3	-	1.13	10.60	0.40	1.20	0.76	0.84
Six	-	-	0.33	0.46	0.20	1.00	0.60	0.50
Seven	-	-	0.35	0.27	-	-	0.62	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

* One Set of values only

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

BIOCHEMICAL OXYGEN DEMAND, TOTAL PHOSPHOROUS, AMMONIA-NITROGEN AVERAGES (APRIL-JUNE)
TABLE 7

BIOCHEMICAL OXYGEN DEMAND mg/l

	1976		1977		1979		1980	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	2.0	0.0	2.7	13.0	3.3	3.1	2.0	1.30
Two	1.0	90.0	3.1	71.0	2.8	2.6	1.4	0.97
Three	1.0	130.0	2.8	50.0	2.9	4.6	1.2	1.50
Four	2.0	110.0	2.5	129.0	3.1	2.2	1.8	1.10
Five	2.0	90.0	5.9	94.0	3.3	2.2	5.0	4.00
Six	-	-	4.0	6.0	4.9	4.5	2.1	1.50
Seven	-	-	4.2	-	5.4	-	2.4	-

TOTAL PHOSPHOROUS mg/l

	1976		1977		1979		1980	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	-	-	0.18	0.70	0.12	0.13	0.60	0.15
Two	0.30	0.60	0.28	0.98	0.09	0.12	0.15	0.13
Three	0.50	1.50	0.48	2.20	0.09	0.13	0.13	0.17
Four	0.50	4.20	0.42	3.00	0.10	0.10	0.15	0.17
Five	0.50	0.60	0.32	2.10	0.10	0.14	0.17	0.20
Six	-	-	0.51	0.22	0.09	0.11	0.12	0.24
Seven	-	-	0.49	-	0.09	-	0.47	-

AMMONIA - NITROGEN mg/l

	1976		1977		1979		1980	
STATION	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
One	-	-	0.18	0.46	0.23	0.23	0.37	0.20
Two	0.0	2.0	0.47	2.50	0.21	0.23	0.28	0.24
Three	0.0	4.0	0.16	5.80	0.23	0.50	0.18	0.13
Four	0.0	11.0	0.40	9.40	0.26	0.26	0.10	0.24
Five	7.0	29.0	1.00	8.20	0.21	0.32	0.60	0.40
Six	-	-	1.20	0.43	0.11	0.27	0.25	0.12
Seven	-	-	1.00	-	0.11	-	0.15	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

BIOCHEMICAL OXYGEN DEMAND,
TOTAL PHOSPHOROUS,
AMMONIA-NITROGEN, AVERAGES
(JULY-SEPT)
TABLE 8

BIOCHEMICAL OXYGEN DEMAND mg/l

	1976		1977		1979		1980	
STATION	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**
One	6.0	36.0	4.1	52.6	4.2	3.2	3.7	4.2
Two	5.0	77.0	3.7	78.1	3.8	2.7	2.9	3.0
Three	21.0	61.0	4.0	139.4	4.3	6.7	3.8	3.5
Four	10.0	186.0	6.0	238.0	2.6	3.1	3.3	3.0
Five	6.0	78.0	7.0	197.0	2.6	2.6	3.3	2.7
Six	-	-	6.2	-	4.6	3.7	3.7	4.9
Seven	-	-	14.3	-	4.5	-	2.7	-

TOTAL PHOSPHOROUS mg/l

STATION	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**
One	-	-	0.51	0.57	0.22	0.09	0.34	0.22
Two	1.2	2.3	0.46	0.69	0.22	0.14	0.21	0.16
Three	1.2	1.5	0.34	1.70	0.09	0.11	0.20	0.29
Four	1.8	42.0	0.43	3.80	0.10	0.11	0.22	0.20
Five	1.5	22.8	0.26	2.10	0.19	0.24	0.24	0.24
Six	-	-	0.21	-	0.12	0.47	0.17	0.18
Seven	-	-	0.35	-	0.10	-	0.16	-

AMMONIA --NITROGEN mg/l

STATION	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**	**Surface**	**Bottom**
One	-	-	0.59	1.6	0.39	0.10	-	-
Two	-	1.1	0.35	2.9	0.27	0.19	-	-
Three	0.0	1.6	0.48	7.0	0.26	0.25	-	-
Four	0.8	10.6	0.56	13.0	0.32	0.33	-	-
Five	0.5	6.2	0.60	9.0	0.39	0.48	-	-
Six	-	-	0.32	-	0.36	1.20	-	-
Seven	-	-	0.30	-	0.13	-	-	-

Note:
1976, 1977 **Diffusers not operational.**
1979, 1980 **Diffusers operational**

CHARLES RIVER BASIN
DESTRATIFICATION PROJECT

BIOCHEMICAL OXYGEN DEMAND,
TOTAL PHOSPHOROUS,
AMMONIA-NITROGEN, AVERAGES
(OCT.-DEC.)
TABLE 9

BIOCHEMICAL OXYGEN DEMAND mg/l

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	2.6	4.3	3.4	5.2	3.8	2.4	3.5	3.2
Two	2.7	26.7	2.8	66.0	3.2	2.2	3.5	2.7
Three	2.6	40.8	3.0	91.5	3.8	4.3	3.5	2.6
Four	2.7	60.0	3.5	212.5	3.6	3.4	3.0	2.5
Five	2.4	39.2	3.2	99.0	5.0	3.5	2.9	3.0
Six	-	-	3.0	3.3	2.6	3.5	2.8	6.2
Seven	-	-	4.8	-	2.3	-	2.6	-

TOTAL PHOSPHOROUS mg/l

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	-	-	0.64	0.60	0.21	0.08	0.18	0.14
Two	0.02	0.38	0.62	0.67	0.14	0.19	0.14	0.16
Three	0.18	0.47	0.66	2.85	0.11	0.06	0.16	0.15
Four	0.22	0.72	0.35	8.34	0.09	0.12	0.16	0.12
Five	0.10	-	0.37	3.85	0.28	0.25	0.12	0.13
Six	-	-	0.16	1.70	0.22	0.66	0.14	0.13
Seven	-	-	0.23	-	0.11	-	0.11	-

AMMONIA - NITROGEN mg/l

STATION	1976 Surface	1976 Bottom	1977 Surface	1977 Bottom	1979 Surface	1979 Bottom	1980 Surface	1980 Bottom
One	-	-	1.03	4.50	0.35	0.08	-	-
Two	0.06	1.79	0.92	2.58	0.28	0.27	-	-
Three	0.43	3.09	1.02	8.20	0.29	0.27	-	-
Four	-	6.83	0.66	11.80	0.26	0.17	-	-
Five	0.54	4.98	0.52	6.03	0.36	0.42	-	-
Six	-	-	0.60	0.56	0.22	1.30	-	-
Seven	-	-	0.45	-	0.18	-	-	-

Note:
1976, 1977 Diffusers not operational.
1979, 1980 Diffusers operational

Charles River Lower Basin
Destratification Project

Plankton Analysis *
Seasonal Averages
(Stations 1,3,5)

TABLE 10

	1976	1977	1979	1980
		CHRYSOPHYTES		
Winter		300	1760[1]	990[1]
Spring		1800	1600	2500
Summer		300	450	330
Fall	600	300	910	590
		CHLOROPHYTES		
Winter		60	310[1]	540[1]
Spring		1400	3500	540
Summer		840	1700	2000
Fall	700	190	630	660
		CYANOPHYTES		
Winter		60	500[1]	-
Spring		50	60	220
Summer		860	1200	620
Fall	600	330	30	360

Note: * Standard Areal Units Per Milliliter
1 One Sampling Event.

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(3) Ibid.

(4) Ibid.

(5) Ibid.

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