AN IMPACT ASSESSMENT OF THE NEW CHARLES RIVER DAM

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ABSTRACT

During the spring term of 1980 a group of MIT seniors conducted, as a class project, a critique of certain design features of the new Charles River Dam at Warren Avenue, Boston, Massachusetts. The project objective also included an assessment of the impact of the new dam on the Charles River Basin. Topics covered in detail were flood control, recreational navigation, land use, water quality, and aquatic life. The study resulted in:

— development of unit hydrographs for the Charles River watershed
— estimation of navigation times between basin and harbor
— evaluation of adjacent land development plans
— development of a mathematical model for changes in the salt water content of the basin
— discussion of basin water quality as affected by operation of air bubblers and chlorination/detention facilities
— consideration of the new fishway's potential success in establishing an American Shad population in the Charles River.

INTRODUCTION

An assessment of the new Charles River Dam was performed during the spring of 1980 by a group of MIT seniors in the Department of Civil Engineering. The objective of our study was to review the new dam and its possible effects as of 1980, taking into consideration the fact that the design of the new dam was completed in 1968. Our goal was to incorporate available new knowledge and to perform a critique of the project. Our study concentrated on five areas of impact by the new dam. These areas are: flood control, recreational navigation, land use, water quality and aquatic life.

The new Charles River Dam will bring about many changes to the surrounding environment. Most of these changes were expected to be beneficial, although how beneficial is not known. The major reason for

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the new dam was to prevent flooding during hurricane events, but several other factors were also considered in the design. These include the need to improve water quality in the basin, the need to improve the passage of boats between the basin and the harbor and the desire to re-establish an American Shad population in the Charles River.

The new dam has been completed and it will be in operation following completion of the new chlorination/detention plant downstream of the present dam. Fig. 1 shows the Charles River Basin and the two dams. Several features included in the new dam will be discussed later in the paper.

The different sections presented in this paper were investigated by individuals and combined to form a technical report [2]. The following are short summaries.

FLOOD CONTROL

When the decision was made in the early 1900's to build the original dam (at the Science Museum, see Fig. 1) across the Charles River, flood prevention was not the main objective. Replacing unsightly low tide mud flats with a fresh water pond, which could be enjoyed by the city residents, was a more important consideration. However, with the elimination of the tidal variation, people began to depend on a stable basin elevation of about 108 MDC. (The MDC datum is 105.6 feet below mean sea level, National Geodetic Vertical Datum of 1929). The design flood for the original dam was computed using the largest flow on record which occurred in 1886. This flow was measured at the Waltham dam and was increased to account for the drainage basin below the Waltham dam. It was observed [14] that maximum flow over the Waltham dam occurred about three days after the start of the storm. This slow reponse to rainfall was assumed to persist downstream to the location of the proposed dam.

The original dam was designed so that a basin elevation below 111 MDC would be maintained in the event of the design flood of 1886 [14]. The hurricanes of 1954 and 1955 resulted in much larger flows than the design flood. As a result of the flooding caused by these storms, it became obvious that the original dam could not prevent recurring damages due to high basin water levels. It was therefore decided to construct a new Charles River Dam at Warren Avenue approximately one-half mile below the original dam. The original dam discharges water through gravity discharge sluices. The result is that during periods of high tide, when the harbor elevation is higher than basin elevation, no water can be discharged from the basin. The new

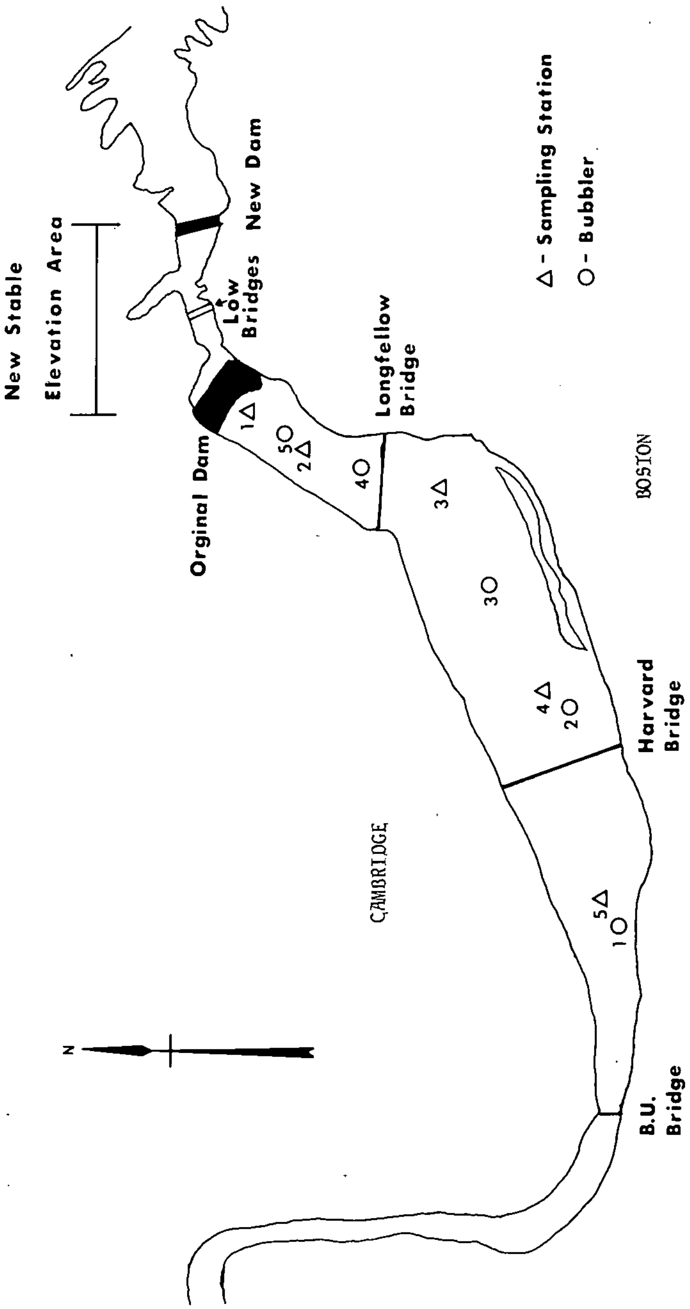

Figure 1: Plan View of Charles River Basin

dam is equipped with a pumping station so that discharge is possible at all harbor elevations.

In this section, the design basis of the new dam is reviewed, an alternate design basis (which uses a unit hydrograph) is presented, a comparison is made between 1910 and 1950 storm response, and a simulation is made of a possible storm event to check the adequacy of the pumping station in the new dam.

New Dam Design

The design flood for the New Charles River Dam had its origin in the August 1955 hurricane. The peak inflow during the storm was estimated to be 12,400 cfs [17]. The shape of the design hydrograph was the same as that of the estimated 1955 hydrograph but design flows were increased by 25%. Thus the design peak inflow was 15,500 cfs. With the design flood and the new dam's pumping and sluicing capabilities, CE Maguire Inc. [6] has estimated a maximum basin elevation of 109.6 MDC, with no resultant flooding.

This design was based on a single past event which could present some problems. To remove individual storm characteristics, we chose to use a unit hydrograph approach. A unit hydrograph was not available for the Charles River so it was necessary to derive one. The unit hydrograph was applied in two ways: (1) as a means to compare basin response in 1910-1920 and 1950-1975, and (2) to simulate response to extreme storms such as the 1955 hurricane. Assumptions made during the derivation include uniform rainfall over the entire Charles River Watershed, a 12-hour rainfall duration, and accurate measurements. To derive the two unit hydrographs, storms with similar total rainfalls, intensities, and durations were selected. Four storms from the 1910-1920 period and their respective hydrographs were transformed into unit hydrographs. This was also done with five storms from the 1950-1975 period. The averages of these unit hydrographs give the unit hydrograph for each period. The computed unit hydrographs are shown in Fig. 2.

From the 1910-1920 unit hydrograph, it is seen that the peak flow, 15,900 cfs, was reached about 11.5 hours after runoff began. This is in disagreement with the assumption of slow response to storms that was made when the original dam was designed. The 1950-1975 unit hydrograph has a peak flow of 12,600 cfs reached 9.5 hours after start of runoff. Comparing the two unit hydrographs provides an indication of how the basin response has changed over time. To determine if this change was significant, we compared it with the variation in the individual storms that were used as our data base. The variation between storms was found to be two to three times larger than the change in unit hydrographs. Therefore, we concluded that no significant change in the hydrologic character of the drainage basin has occurred between the 1910-1920 and 1950-1975 periods.

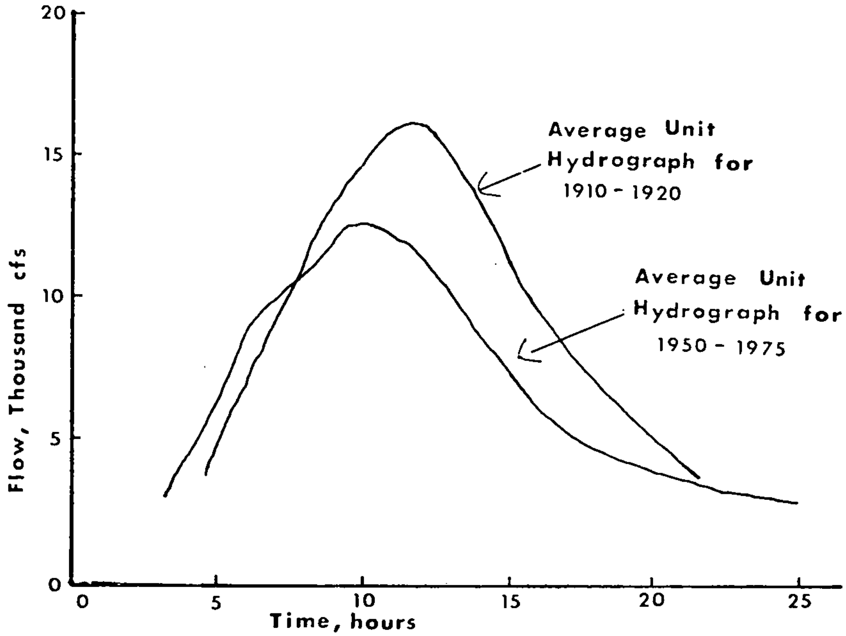

Figure 2: Unit Hydrographs for Charles River

Simulation of an Extreme Storm Event

The isohyetal map of the August 1955 storm is shown in Fig. 3 [1]. The center of the storm was not over the Charles River Watershed but was just west of the Connecticut River. During the three day storm this area received the maximum recorded rainfall of 19.75 inches while the Charles River Watershed received only 12 inches. As a simulation of an equally possible storm, the storm is translated so the maximum daily rainfall, 11.2 inches, occurs over the watershed. The isohyetal line of 16 inches encompasses roughly the same area as the Charles River Watershed. Therefore, the maximum daily rainfall for this region, 9.1 inches, was also used in our simulation. The simulations with 9.1 and

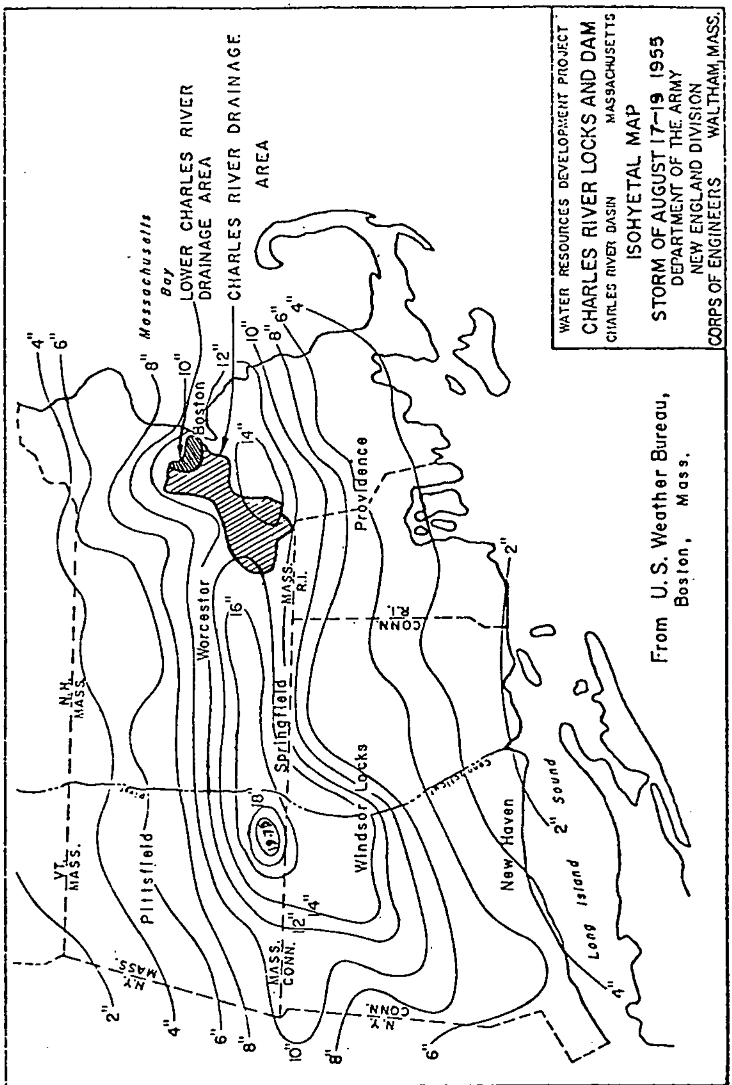

Figure 3: Isohyetal Map of August 1955 Storm [1]

11.2 inches of rainfall resulted in hydrographs with peak inflows of 17,200 and 21,200 cfs respectively. These peak inflows are both greater than the new dam's design peak inflow of 15,500 cfs. To use our unit hydrograph a relationship between rainfall and runoff is needed. This relationship is a runoff coefficient which, when multiplied by total rainfall, gives total runoff. An average runoff coefficient for the 1950-75 period was computed knowing rainfall and resulting from five storms. Using the 1950-1975 unit hydrograph and our average runoff coefficient of .15, the hydrograph corresponding to the translated 1955 storm was computed. Nine sensitivity simulations were then run varying four parameters: rainfall, harbor elevation at peak inflow (high or low tide), beginning basin elevation, and number of pumps. The resulting maximum basin elevations are given in Table 1.

Damage from flooding is estimated to start when basin elevation reaches 110.2 [6]. This elevation was exceeded in 7 of the 9 simulations; the highest elevation was 112.4 MDC, occurring in Run 6. The last simulation (Run 9) used the same worst case condition as Run 6, i.e., 11.2 inches of rain, high tide concurrent with peak flow, and a pre-storm basin elevation of 108 MDC, but with seven pumps instead of the design six. The resulting elevation was only 0.2 ft lower. To determine if the savings from this lower elevation would be greater than the cost of an additional pump requires an economic analysis which was beyond the scope of this paper. In conclusion, we found that the basin's response to storms has not changed significantly since 1910, and, in the event of an extreme storm, the new dam and pumping facilities may not prevent flooding.

TABLE 1. BASIN ELEVATIONS REACHED IN SIMULATIONS (MDC DATUM)

Run	Rainfall	Harbor Elev.	Initial Elev.	#of Pumps	Max. Basin Elev.
1	9.1 in.	113	107	6	110.8
2	9.1	113	108	6	111.3
3	9.1	102.5	107	6	107.7
4	9.1	102.5	108	6	108.1
5	11.2	113	107	6	112.3
6	11.2	113	108	6	112.4
7	11.2	102.5	107	6	110.7
8	11.2	102.5	108	6	111.0
9	11.2	113	108	7	112.2

RECREATIONAL NAVIGATION

Some of the benefits anticipated from the new dam are derived from the enhancement of recreational boating opportunities in the basin and improved navigation between the harbor and the basin. Although the primary purpose of the project is flood prevention, approximately fifteen percent of the estimated monetary benefits of the overall project are expected to accrue to the recreational boating category [1]. In this section we will review the use of the lock at the original dam, consider the expected benefits of the new dam with its three locks, and give recommendations to help alleviate the conflicts between users.

Users and Historical Trends

There are two groups of users of the lock in the original dam: commercial and recreational. The commerical group consists of tugs, barges, scows, and tankers. The recreational vessels are mostly power boats, which either commute from neighboring storage areas or are based in the basin. Other recreational vessels are very common in the basin but seldom use the locking facilities. These are sailboats and rowboats, which will also be affected by the new dam.

Fig. 4 is a plot of the number of recreational and commercial vessels passing through the lock at the old Charles River Dam in the years 1910-1979. Until about 1930, the primary use of the lock was for commercial users. Since then recreational use has dominated and commercial use has dropped to almost zero. These are annual figures but the use is not distributed evenly over the year. It was found that about 64% of the total yearly traffic occurs on about 30 days of the year. These days are the summer weekends and holidays. Along with a yearly variation there is a daily variation in the arrival rate. This variation can be seen in Fig. 5. There are two periods of heavy congestion at the locking facility: 10:00-1:00 and 4:30-7:30. The first period is caused by boats passing out to the harbor and the second is caused by boats returning to the basin. These periods of congestion have resulted in long waiting lines which the new dam was expected to relieve.

Benefits from the New Dam to Boats

The new dam is expected to benefit the boating community in 4 ways: (1) improved water quality, (2) more stable basin elevations, (3) added shoreline within the basin, and (4) time savings.

The poor water quality of the basin has damaged the boating community economically, healthwise, and aesthetically. If water quality can

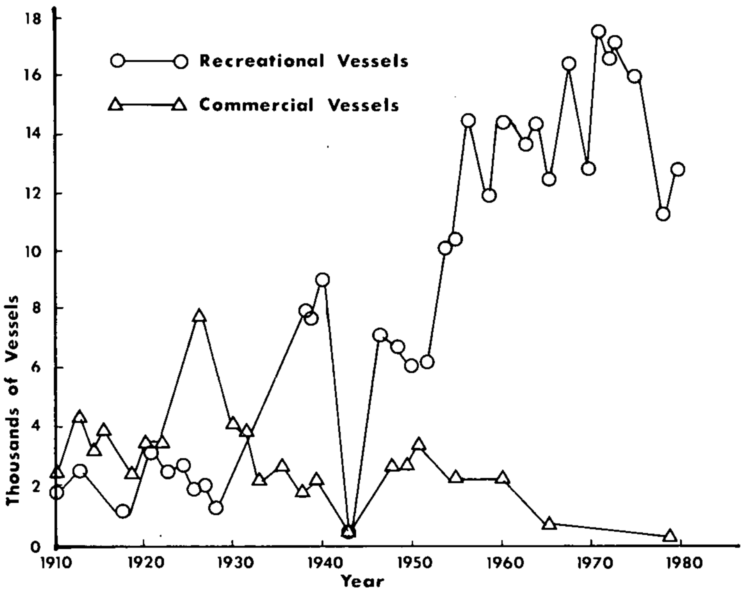

Figure 4: Historical Lock Usage - Annual Average

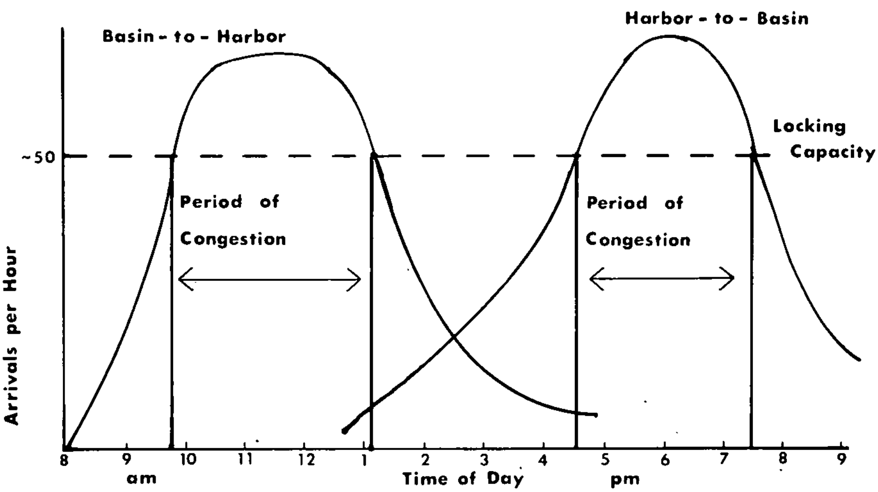

Figure 5: Daily Lock Usage

be improved one can reasonably expect greater recreational use of the basin, everything else being equal. This should benefit all users of the basin.

The new dam should result in a more stable basin elevation. This also will benefit the boating community because problems occur when the elevation varies. Among these problems are: difficulty in boarding and leaving boats at fixed-elevation docks; strained lines in high waters; slack lines in low waters; reduced clearance with high water; and grounding of boats with low water. If recreational boating on the basin is to grow in the future, additional mooring and launching space is needed. Since the new dam is extending the basin, the amount of shoreline is also increased. This is a source for the needed additional space.

The new dam is equipped with locking facilities to handle 140 boats per hour in one direction. There are three locks in the new dam — two 200 x 25 feet and one 300 x 40 feet in plan. The large lock is mainly for commercial use although recreational use may occur during times of heavy traffic. These locks represent an increase of almost three times the old dam's locking facilities. The increase was created to speed up the passage into the Boston Harbor. We considered the expected time savings. Three constrictions were analyzed: the old dam, the drawbridges between the two dams, and the new dam (see Fig. 1). Once the new dam is operational, boats will no longer have to lock through the old dam. A flow constriction will still exist, though, due to the size of the old lock; traffic will be allowed to pass through in only one direction and this could result in a waiting period. A study by Charles A. Maguire and Associates [7] estimated a 15 to 20 minute reduction in the time to pass through the old dam. The new dam and its resultant higher stable basin elevation will hinder passage under the drawbridges between the dams. The stable elevation will average almost 2.5 feet higher than mean sea level. This will cause the drawbridges to be opened more often for boats and thus it will take longer to pass between the dams. Finally, locking through the new dam is necessary. The locking cycle for the small lock is expected to take 20 minutes. An assumption of both small locks operating implies a ten-minute wait. A favorable assumption of a 20-minute reduction at the old dam, no increase due to the drawbridges, and a 10-minute wait at the new dam, gives a net time savings of only ten minutes.

User Conflicts

Conflicts between user groups is not a new problem, but if the groups grow in size, these conflicts become more pressing. To help alleviate conflicts we recommend that powerboat speed limits be reduced and more strictly enforced, and that powerboat facilities be developed in the newly formed part of the basin. Also the Lechmere Canal area could be used for powerboat facilities. New facilities in these lower areas of the basin would reduce the areas of conflict between powerboats and sailboats.

LAND USE

The new dam will extend the Charles River Basin about ½ mile northerly into downtown Boston, Cambridge, and Charlestown. Due to the present lack of flood control and a variety of other factors, these areas are currently underdeveloped. It may be expected that the completion of the new dam will be followed shortly by development of the area. The City of Boston, through the Boston Redevelopment Authority (BRA), has taken the largest role in the development plans. This section will present those plans.

Current Site Conditions

Fig. 6 shows the land adjacent to the newly formed basin area. Most of the large parcels on the Boston side are owned or partially controlled by public agencies. Publicly held land north of the Green Line comprises nearly 70% of the total area. A large area of the affected site is made up of parking lots and railyards; there is a low residential population of approximately 200.

The BRA has a plan for development of the site during the next fifteen years. The latest plan is shown in Fig. 7. Due to monetary constraints, it is expected that in the next three years there will be a slow, momentum-gathering phase. During the rest of the planning period several large construction projects should be carried out. These include a Northbound Storrow Tunnel Connector, a new Canal Channel (which would create an island in the basin), bridges to the island, a public building on the island, and other island buildings. The small size of the existing residential population means that the disruption of their lives will not be a major factor. This is a major difference between the current Charles River shoreline development, and, for example, the West End development of 1957.

The City of Cambridge, which borders the opposite shore, has also conducted a development study for its side of the basin. The plans are, however focused more on the improvement of the Lechmere Canal and adjacent area, and on provision of a linear park along the river's edge.

The benefits from these planned new developments were not included in the original cost-benefit analysis of the new dam. These plans require a stable basin elevation which the new dam will provide and perhaps some of the expected benefits should have been included.

WATER QUALITY

The Charles River Basin has been designated by the Massachusetts Department of Water Pollution Control as a Class C water body, which means "for the uses of protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation." At present, however, the water is Class U (unsatisfactory), not meeting any of the existing standards. Two major contributors to the poor quality of the basin water are stratification caused by salt water intrusion, and combined sewer overflows. Both of these problems are being addressed by the Metropolitan District Commission (MDC) in conjunction with the new Charles River Dam, and will be discussed in this section.

Role of Salinity Stratification

Vertical diffusion of oxygen through the water column is necessary to maintain good water quality. Oxygen diffusion is aided by natural mixing processes caused by the wind and by fresh water inflows. However, mixing is hampered by density stratification. Density variation can be dependent upon several factors, but in the Charles River Basin it is almost entirely a function of salt concentration. Density and elevation differences cause salt water to leak into the basin through the various gates in the dam. This type of intrusion occurs throughout the year. Additional salt intrusion occurs through the boat locks, mostly during the summer. Once this higher-density water enters the Basin, it fills the deepest pockets of the river bottom. Vertical diffusion to the fresher upper layers helps to flush the salt, especially during spring flows.

To supplement the natural flushing of salt, a program for bubbling the basin was started in spring of 1978. This program was proposed by Camp, Dresser and McKee (CDM) in 1976 [4]. Fig. 1 shows the five air bubblers which have been placed between the Boston University Bridge and the old dam. Bubbling is designed to reduce the salt mass in the basin and thereby reduce the occurrence of anoxia near the bottom. Measurements (discussed below) of salinity and dissolved oxygen taken by MDC before and after bubbler operation show this to be the case. Operation of the new dam will also lead to a reduction, but not an elimination, of the salt intrusion problem.

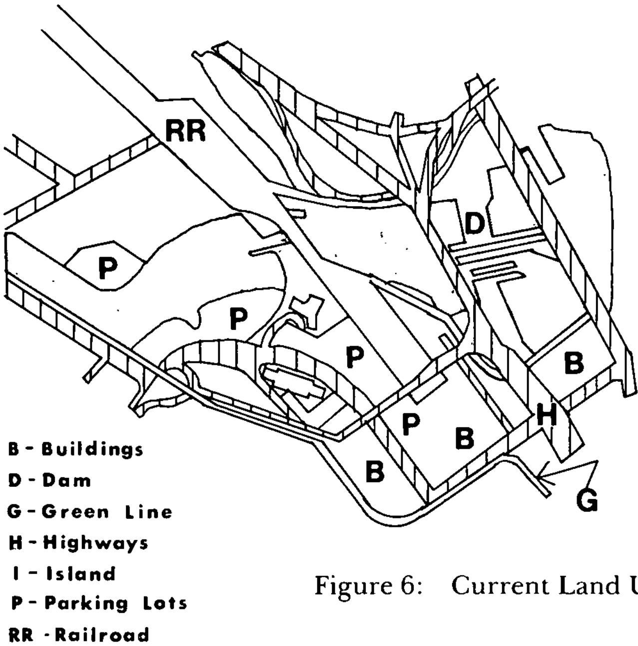

Figure 6: Current Land Use

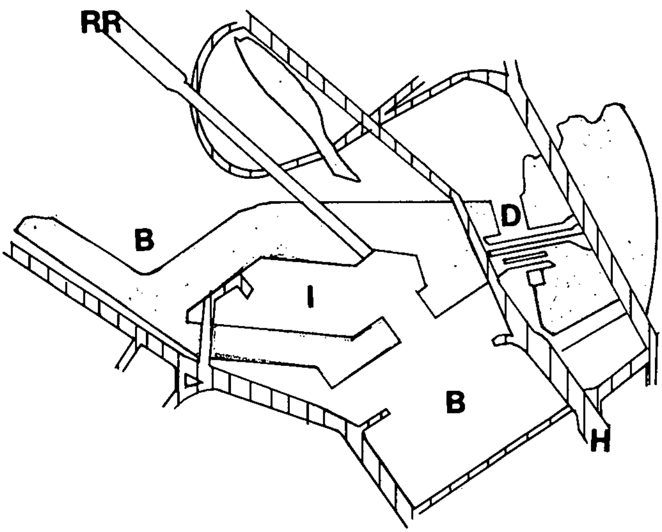

Figure 7: Latest Development Plan

Empirical Results With and Without Bubblers

The MDC has prepared quarterly reports describing measurements of salinity, dissolved oxygen, biochemical oxygen demand (BOD), and phytoplankton production at the stations within the basin, shown in Fig. 1. Fig. 8 compares measured profiles of dissolved oxygen, BOD and salinity taken before bubbler operation (August 18, 1977) and after 1.5 years of bubbler operation (August 9, 1979) as measured at sampling site#2. The profiles in Fig. 8 show that there have been substantial decreases in both the average concentration and the vertical gradients of salinity and BOD since the bubblers have been operational. There has also been an increase in dissolved oxygen concentrations at lower depths while the dissolved oxygen at the surface has decreased slightly. These data clearly indicate improvement in water quality. However, it should be noted that all but one of the sampling sites are located within 100 feet of the bubblers. The one sampling site located 1000 feet away from a bubbler (station#3) shows less improvement than the other stations. The MDC claims that this discrepancy results from the location of bubbler#3 a few feet above a depression, and that the bubbler is unable to mix the deep water in this depression. Since there are no data on water quality at other locations away from the bubblers, it is recommended that such samples be taken to determine whether water quality improvements are occurring throughout the basin, or if improvement is localized around each bubbler.

Measurements (not shown) also indicate that phytoplankton production has remained constant over this period. CDM felt that the mixing caused by the bubblers would circulate phytoplankton out of the euphotic zone, reducing photosynthesis and thus phytoplankton production. Recent studies [16, 19] show that mixing may actually be enhancing phytoplankton growth by reducing photoinhibitory effects of intense light exposure.

Effects of the New Dam on Salinity

The closing of the new dam is expected to have a positive effect on basin water quality through a further decrease in salinity. Several factors can be cited: (1) reduced salinity intrusion through more efficient locking and gate operation (CDM [4] estimates a reduction of about 80% in the annual salt water intrusion with the new dam.), (2) low level pumping and sluicing capability (drawing water from depths of about 20 ft rather than the approximately 5 ft of the existing sluices), (3) a modest increase in basin volume (approximately 3%) and (4) enhanced vertical diffusion due to the decreased salt content. Based on mass bal-

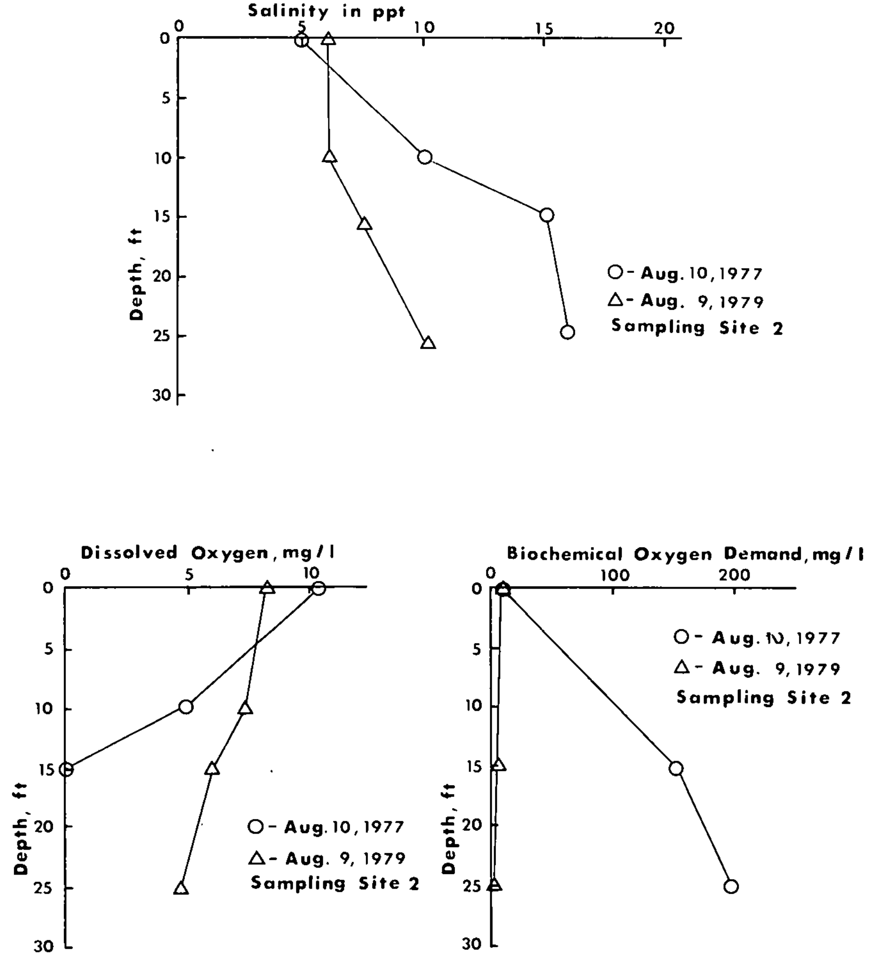

Figure 8: Vertical Profiles of Water Quality Parameters Before and After Bubbler Operation

ance estimates, these combined factors should result in at least a 90% decrease in both the total salt content and the vertical salinity gradient.

To quantify the impact of reduced salinity on water quality parameters such as dissolved oxygen requires a more complete mathematical model including coupled conservation equations representing salinity, dissolved oxygen and BOD. Such an effort is being contemplated as part of another student project. The first step in such an exercise is model verification based on measured profiles for the existing conditions (Fig. 8).

Combined Sewer Overflows

Combined sewer overflows (CSO) occur when rainfall or high tides cause combined sewers to become surcharged and overflow into the Charles River or the inner harbor. The MDC's priorities for treatment of CSO are the removal of floatables and the reduction of coliform bacteria concentrations. One of the efforts involved in combating this problem is the construction of chlorination and detention plants. One of these, Cottage Farm Chlorination and Detention Center, has been in operation since 1971. A similar facility is being constructed in conjunction with the new Charles River Dam. This station, the Charles River Estuary Pollution Control Facility (CREPCF) will collect overflows that are now being discharged into the area between the old and the new dams.

Operation of the CREPCF

The CREPCF will serve as both a pumping station and a chlorination/detention facility. Its total capacity, designed for a 5-year storm, is 323 mgd. The CREPCF has two modes of operation: a dry weather mode and a wet weather mode. In the dry weather mode (inflows of 5 mgd or less) the plant can pump inflows into the Charlestown sewer. When inflows exceed 5 mgd the facility operates in a wet weather mode. Operation during the design peak inflow will cause 44% of the inflow to be pumped into the Charlestown sewer, 50% to be treated at the facility and discharged to the harbor, and 6% of the inflow detained and returned to the sewer system. Treatment of wastewater at the facility consists of screening and chlorination [4]. This treatment has a removal efficiency of 19% for BOD, 23% for suspended solids, and 34% for settleable solids [5]. Coliform removal by the addition of a 15% sodium hypochlorite solution is estimated to be 99.9% [9]. The concentration of chlorine in the effluent will be controlled by a chlorine residual analyzer which will sample total residual chlorine (TRC). The amount of chlorine added to the water during the process will be adjusted so that the residual is 1 mg/l. If the inflow to the plant should exceed 323 mgd, the excess will overflow directly into the Charles.

Assessment of the CREPCF and Recommendation for Improved Efficiency

The top priority of the combined sewer overflow control program has been given to the removal of visual pollution (floatables) and the destruction of coliform bacteria in the overflows entering the Charles River. Second priority is to remove organic material and suspended solids in order to help control the oxygen demand and the benthic deposits in the river.

The CREPCF will be successful in controlling these parameters with respect to the combined sewer overflows which now empty between the two dams. It will also be successful in achieving its aim of providing drainage for the combined sewers that would be continuously surcharged when the basin is maintained at a constant level of 108 feet.

Thus the CREPCF will clearly reduce the level of pollutants discharged into the lower Charles River Basin. This should improve the water quality; however, several questions are raised concerning the proposed mode of operation and the assessment of its impact.

First, in analyzing the CREPCF, the level of bacteria kill has been commonly equated with the total residual chlorine in the effluent. The correlation of TRC and bacterial kill is dubious. Many compounds in wastewater react with chlorine and rob it of its disinfecting capacity [8]. Contact time with chlorine in the CREPCF is to average 8-10 min. when operating at capacity, as compared with recommended minimum contact time for primary treated sewage of 15-45 min. [20]. With these variables to consider, disinfection efficiency cannot be measured by a single parameter such as TRC. Some system of accurate and complete water quality sampling should be used to monitor disinfection level.

Second, it might also be mentioned that chlorination as a means of disinfectant for wastewater is under attack. Carcinogenic chlorinated hydrocarbons are formed by the chlorination of sewage. An alternative to chlorination is to simply discharge the screened wastewater into ocean water. Contact with salt water has been shown to kill 90% of the bacteria within 1-3 hours.

Third, removal efficiencies for BOD, suspended and settleable solids in the wastewater treated at CRECPF could be improved. A cleaner effluent could be achieved by changes in operation. Detention tanks could be used to hold the "first flush", treating and discharging the later flow. This would improve effluent because during low flow, solids are deposited in the sewer system and initial water from a rainstorm picks up these additional solids. It would be advantageous to hold this first flush until it could be returned to the sewer system. Treatment and discharge of succeeding cleaner flows will result in a better quality discharge to the harbor. One problem with this method of operation would be that fewer tanks would be available for chlorination and settling. However, flocculating chemicals could be added to speed up sedimentation, and exposure to sea water could provide disinfection. Another plan would be to flush the sewer during low flow by injecting water. This operation would keep solids from building up in the sewers.

Finally, the concept of chlorination and detention plants as a way of coping with combined sewer overflow might, in fact, be questioned. Possible dangers to aquatic and human life resulting from chlorination have already been mentioned, and while such plants are consistent with the current effort to achieve Class C water, the rise in demand for good water quality, may result in a higher ultimate goal. Perhaps the MDC should consider a higher water quality goal when planning programs for water quality improvements.

AQUATIC LIFE

The new Charles River Dam includes a vertical slot fishway designed to allow passage of anadromous fish past the dam. This fishway was specially designed for the use of American shad, which cannot pass fishladders and locks as easily as other anadromous fish. The MDC hopes to restore shad to the Charles along with alewife and blueback herring, which have already been observed to be migrating in the basin. In assessing this fishway, other factors affecting shad habitation and migration should be considered. In particular, water quality in the basin and the inner harbor could affect shad populations.

Life Cycle of the Shad

American shad are anadromous. They spend the majority of their life in the ocean, ascending fresh water streams to spawn. Fry are hatched upstream in fresh water during the spring and remain there until water temperatures drop in the fall. The juveniles migrate to the ocean where they will remain until reaching sexual maturity (3-5 years). Adult shad complete the cycle by returning to their home stream to spawn [23].

Adult shad have been stocked in the Charles at Mother Brook. These operations were begun in 1978 by the Department of Marine Fisheries.

Reasons for Decline of Shad

Impassable dams are cited as the major reason for the decline of shad along the East Coast [23]. In the Charles, fish ladders are provided as far upstream as the Newton Lower Falls Dam. Fig. 9 shows dams on part of the Charles River and areas with suitable spawning grounds. The water quality levels at these grounds are poor, but will not severely hamper shad development [11].

Poor water quality in the lower Charles River Basin and the inner harbor may affect shad habitation. Shad spawning in the Charles must pass through this area during their migrations. Although levels of individual pollutants are not high enough to cause fish kills, the synergistic effects of the pollutants may place stress on migrating fish.

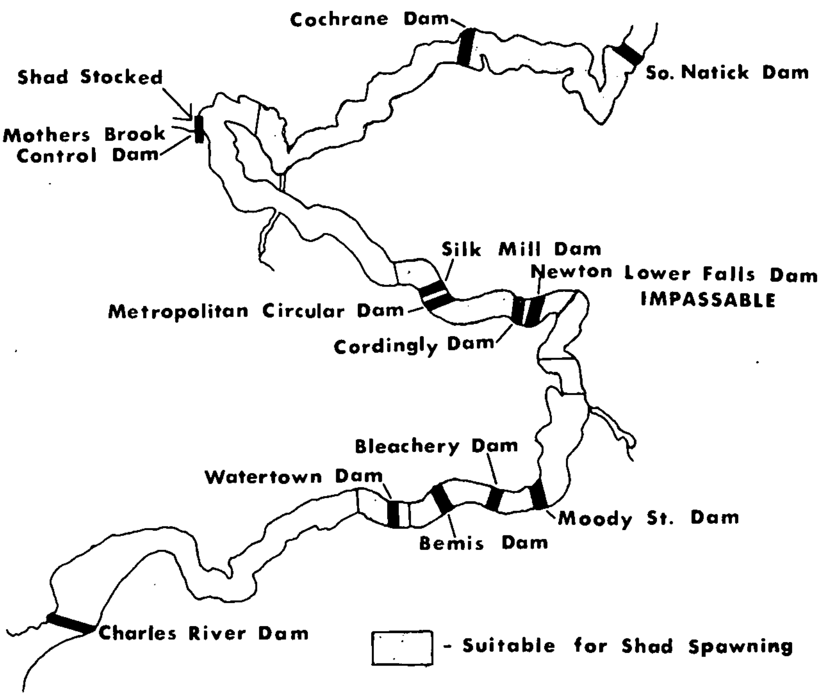

Figure 9: Upstream Dams and Spawning Areas in the Charles River

The largest water quality barrier that shad will encounter is the drastic change in salinity between the inner harbor (20-30 ppt) and the basin (0-5 ppt). In natural (undammed) estuaries, shad spend one or two days in the region of salt water-fresh water interface [12]. The shad meander back and forth with the tide as shown in Fig. 10. This action allows the fish to adjust to the decreased salinity. To pass the new Charles River Dam the shad must undergo a rapid change in salinity. This may cause fish kills or discourage upstream migration. A study by Tagatz [22] showed that a salinity change from 27 ppt to 0 ppt results in 50% mortality of adult shad. In another experiment [18] shad were

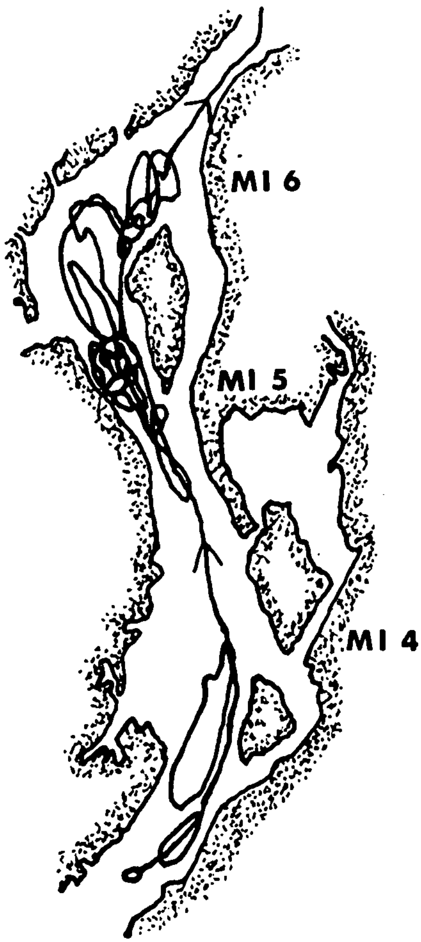

Figure 10: Observed Upstream Migratory Pattern of Shad while Acclimating to Reduced Salinity (after [12])

towed in cages from Long Island Sound up the Connecticut River. This transition took 2.5 hours and the salinity change was 31 ppt to 1 ppt. A control cage was towed in salt water for 5 hours. The result: of the 18 fish experiencing the salinity change 17 died while all fish in the control cage survived. While these experimental methods place significant stress on the fish, they suggest that the abrupt changes in salinity may be a critical inhibition to successful fish migration. We believe that this barrier should be investigated further.

SUMMARY OF CONCLUSIONS

This paper has discussed five impact areas associated with operation of the new Charles River Dam. The conclusions derived for each are summarized below.

Flood control is the major objective of the new dam. Our studies conclude that the basin's response to storms has not changed significantly since 1910 and that the new dam and pumping facilities cannot be expected to prevent all flooding in the event of an extreme storm similar in total rainfall to the 1955 hurricane.

Recreational navigation has been suggested as another major objective. Here, the major benefit is believed to be decreased passage time between basin and inner harbor. However, we found that the time savings will not be significant.

Development of adjacent land was not a stated objective of the new dam, but in fact, new areas can now be developed. Plans have been made for this development.

Water quality is adversely affected at present by salinity intrusion and combined sewer overflow. Data from the MDC indicate that operation of the five air bubblers in the lower Charles River Basin has had a positive effect in reducing salinity and attendant anoxic conditions. Mass balance predictions indicate that further improvement will be possible due to the lower salt intrusion with operation of the new dam. However, it is recommended that sampling be conducted at locations farther from the individual bubblers to verify that the improvement is general rather than local and that additional sampling be conducted in the upper basin. The MDC might also consider operation of one or more bubblers in the upper area. The new chlorination/detention plants should be effective in removing virtually all of the combined sewer overflow between the two dams. However, they could be made more effective by establishing a method to retain the first flush of a storm. This would result in a cleaner effluent into the harbor. Also the use of chlorine as a disinfectant should be carefully reconsidered.

The new fishway in the dam will physically provide for the passage of American shad. However, the shad will have to pass through a very sharp saline gradient which could prove to be detrimental. The poor water quality of the Boston inner harbor and concentrations of pollutants could also prevent a shad population from forming in the Charles River.

ACKNOWLEDGMENTS

This paper resulted from a class project undertaken by ten seniors during their last semester at MIT (Spring 1980). This project resulted in a final report [2] which was then edited into manuscript form by Alice Godbey and Sandy McCarley. Project supervision was provided by Dr. Eric Adams and Professor Donald Harleman.

Appreciation is expressed to a number of individuals who offered assistance in the form of guest lectures, data, critiques, etc. These individuals include: Jekabs Vittands and David Bingham of Metcalf and Eddy, Inc.; Clayton Stokes, superintendent of the Charles River Dam; Frank Notordonato and Richard Doherty of the New England Division, U.S. Army Corps of Engineers; Peter Devenis and Edward Dunn of CE Maguire; and John Bennett of the MIT Writing Program.

Preparation of the final report was facilitated through use of text editing facilities at MIT's Joint Computer Facility, with assistance from Elizabeth Schumacker of the Civil Engineering Department. Financial assistance in the preparation of the paper was provided by the John R. Freeman Fund of the Boston Society of Civil Engineers Section, ASCE. This assistance and the cooperation of Mr. Lee Wolman of the fund committee is gratefully acknowledged. Final typing of the manuscript was performed by Elizabeth Quivey.

We would like to dedicate this paper to the memory of John R. Freeman, Chief Engineer of the 1903 Committee on the Charles River Dam.

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Conversion Factors

Multiply	*By*	*To Give*
cfs	.0283	m^3/s
miles	1.609	kilometers
ft	.3048	meters
inches	2.54	centimeters

MDC Datum is 105.625 below Mean Sea Level