MANAGEMENT OF DESIGN AND CONSTRUCTION PROCESSES

OF THE

BOSTON HARBOR PROJECT

by

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ABSTRACT

The Cleanup of the Boston Harbor is one of the largest public works projects ever undertaken in New England and one of the biggest of its kind in the nation. The Boston Harbor Project was initiated the primary consequence of the centuries long wastewater discharges into Boston Harbor. The extensive planning, design and environmental review of the Boston Harbor Project started in 1986 following a Federal Court order. The construction of the new plant on the selected site, Deer Island, started in 1989 and is expected to go through the beginning of the next decade. This thesis analyzes the issues related to the management of design and construction processes during the period when the construction reaches the halfway mark.

The first chapter describes the history of one of the dirtiest harbors in the U.S. along with the cleanup efforts. This chapter also includes an overview of the treatment facilities associated with the project. The next chapter explains and evaluates the planning and financing of the project. The third chapter analyzes the project's organization and structure. The last chapter concentrates on the overall management of the project including cost control, scheduling, and other management issues unique to the Boston Harbor Project.

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LIST OF ABBREVIATIONS

BHP..BOSTON HARBOR PROJECT
BOD..BIOLOGICAL OXYGEN DEMAND
CADD..COMPUTER AIDED DESIGN AND DRAFTING
CLF..CONSERVATION LAW FOUNDATION
CM..CONSTRUCTION MANAGER
CSO..COMBINED SEWER OVERFLOW
DEP..DEPARTMENT OF ENVIRONMENTAL POLICY
EPA..ENVIRONMENT PROTECTION AGENCY
ESDC..ENGINEERING SERVICES DURING CONSTRUCTION
LDE..LEAD DESIGN ENGINEER
MDC..METROPOLITAN DISTRICT COMMISSION
MWRA..MASSACHUSETTS WATER RESOURCES AUTHORITY
PDE..PROJECT DESIGN ENGINEER
PMD..PROGRAM MANAGEMENT DIVISION
TSS..TOTAL SUSPENDED SOLIDS

INTRODUCTION

The Boston Harbor Project is one of the single largest public works projects ever undertaken in New England's history and one of the biggest of its kind in the nation. The project involves the design and construction of a vast new wastewater treatment network expected to cost more than three billion dollars when completed by the end of 1999. The completed facilities will treat the wastewater generated by more than 2.5 million residents and 5,500 businesses in the Boston Metropolitan Area.

The magnitude of the project and its urban location have attracted widespread interest. From its inception, the Boston Harbor Project occupied a prominent place in the public eye, subject to scrutiny from elected officials, state and federal regulatory agencies, environmentalists and activists, and the media. This public project has unusual benefits and constraints: it is very visible - and eventually beneficial - to the public; it is subject to all of the laws governing public construction in Massachusetts; and it is funded almost entirely with local funds raised from water and sewer charges.

The public nature of the project does not affect what needs to be done to resolve the problem of restoring the Boston Harbor, but it does affect how the cleanup is accomplished. Successful management of this complex project requires a plan and structure that fully consider both the public nature of the project and the environment in which it will be built, as well as how best to organize resources to build one of the largest wastewater treatment plants in the world. Dozens of decisions depend on the framework used to view this challenge: it has to be realistic, flexible, and durable for both the short- and long-term. While the end of the project is still some years away, the plans and decisions of today's managers must withstand tests each day through out the next decade.

This thesis will analyze the issues related to the management of design and construction processes of the Boston Harbor Project. The first chapter of the thesis will provide the reader with a brief history of the Boston Harbor and will also describe the treatment facilities associated with the project. The second chapter will present the general planning and financing of the project. The third chapter will describe the project management structure of the project, along with analysis of some project management alternatives considered for the project. The last chapter deals with various project management issues, from information systems to change order process and cost control techniques.

Information for this thesis was gathered form diverse sources. Besides using the obvious sources such as library books and articles, the majority of the information was obtained directly from the Massachusetts Water Resources Authority, the owner of this large project. The research for this thesis was completed in January, 1995. when the project was 57.1 percent complete after six years of construction.

I. PROJECT OVERVIEW

The Boston Harbor Project was initiated as the primary consequence of the centuries long wastewater discharges into Boston Harbor. This section is intended to provide the reader with a brief history of wastewater discharges into harbor. The extensive planning, design and environmental review of the Boston Harbor Project started in 1986 following a Federal Court order. The construction of the new plant on the selected site, Deer Island, started in 1989. This section also describes the project's background and treatment facilities. Since it is a cleanup project of an harbor it is necessary to explain how the cleaning mechanism works.

A. History of Boston Harbor

Boston was settled in 1630, with its first sewer built before the turn of the 18th century. The earliest sewers carried waste from pumps, kitchen sinks, cellars, and rainwater from yards and roofs down to the harbor's shores. Only after 1833 were human wastes allowed for the first time to be dumped in the sewer. Between 1876 and 1904 three separate sewerage systems were built in Boston area. The Main Drainage System collected sewage from Boston and then conveyed it (through tunnels, interceptors and pumping facilities) to storage tanks on Moon Island, where the sewage was discharged, untreated, into the harbor with the outgoing tides. The North Metropolitan Sewerage System collected sewage from towns north of Charles River and transports it to Deer Island, where large solids were screened out before the sewage was discharged into the harbor. The South Metropolitan Sewerage System served areas to the south of Boston and discharged screened wastes into the harbor at Nut Island. Figure 1 shows all three discharge locations on the Boston map.

Figure 1: Map of Boston Harbor

Source: Leah MacGovern/ 1990

By 1939, there were already concerns and investigations to "urge immediate correction of pollution (in the harbor)[1]." Thus construction of treatment works on Deer, Nut and Moon Islands - the discharge points of the three sewage collection systems - was recommended. The same year the state legislature authorized the construction of a sewage treatment plant at Nut Island. The Metropolitan District Commission (MDC) was responsible for the overseeing of these projects. After the Second World War, the first primary treatment plant was built on Nut Island in 1952, and the second plant was constructed on Deer Island in 1968. The recommendation to built a treatment plant on Moon Island was never acted upon. Instead, Moon Island's old facilities continued to hold and discharge untreated sewage through 1968, when the Boston Main Drainage System was re-routed to feed into North Metropolitan Sewerage System. The two primary treatment plants reduced the total suspended solids concentrations by 60 percent and organic matter concentrations (such as fecal material) that contribute to biochemical oxygen demand (BOD) by 25 percent[2]. However, the Boston Harbor continued to be polluted and degraded as a result of the discharge of municipal waste, including sludge, into the harbor. Approximately 50 dry tons of digested sludge were being discharged into the harbor every day. In addition, in wet weather the system's hydraulic capacity (ability of the pipes to carry the water) was exceeded, allowing raw sewage to flow into the harbor through overflow pipes, causing frequent closings of nearby shellfish beds and bathing beaches.

In 1972 Congress passed the "Federal Water Pollution Control Amendments of 1972", commonly referred to as the *Federal Clean Water Act.* One of this Act's provisions requires Publicly Owned Treatment Works, such as the facilities on Nut and Deer Islands, to provide secondary treatment by mid-1977[3]. Secondary treatment means 85 percent removal of both suspended-solids concentrations and BOD concentrations. In December 1977 Congress passed amendments enabling Publicly Owned Treatment Works

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[1] Dolin, Eric Jay, Dirty Water/Clean Water - A Chronology of Events Surrounding the Degradation and Cleanup of Boston Harbor, MIT Sea Grant, 1990.
[2] Aubrey, David G. and Connor, Michael S., "Boston Harbor - Fallout Over the Outfall" Oceanus, Spring 1993, pp. 61-70.
[3] Dolin, Eric Jay, Dirty Water/Clean Water - A Chronology of Events Surrounding the Degradation and Cleanup of Boston Harbor, MIT Sea Grant, 1990.

to apply for a waiver. After unsatisfactorily exploring several other options of sewage treatment, in September 1979, MDC applied for the waiver from secondary treatment, proposing instead to discharge primary effluent into Massachusetts Bay via a 7-mile outfall pipe, and to stop discharging sludge into the ocean. The MDC studies on water quality claimed that secondary treatment would not achieve significant environmental benefits, and consequently was not cost effective[2]. In June 1983, the United States Environmental Protection Agency (EPA) denied the waiver. The main reason for this denial was EPA's concerns about maintaining the dissolved oxygen standard in the bay and protecting the organisms living in the sediments around the discharge site. MDC then modified its waiver request by relocating the outfall 9.2 miles into the Massachusetts Bay to provide better effluent dilution. The application was again denied by the EPA in March 1985. By this time, it was too late to apply for the federal grants for construction of sewage treatment facilities like the one needed in Boston. Today, over 90 percent of the project costs are borne by the local communities. Chapter 2 explains the financing of the project more in detail.

The city of Quincy and the Conservation Law Foundation, a public interest group, filed state and federal lawsuits for violations of the 1972 Clean Water Act. As a result, an independent agency, the Massachusetts Water Resources Authority (MWRA), was created in December 1984[4], to take over the control of regional sewer and water system from MDC. Another reason for the new authority's creation was that, after about 1960, the MDC was not given the resources necessary to maintain the water works and sewer system, and therefore the systems began to deteriorate. The MWRA was given a legislative mandate to upgrade and maintain the systems, and the power, as an independent authority, to raise water and sewer rates to pay for the necessary repairs[5]. The new authority began its formal existence on July 1st, 1985 and currently provides water supply and distribution services and wastewater collection and treatment services to nearly 60 cities and towns within Massachusetts.

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[4] Aubrey, David G. and Connor, Michael S., "Boston Harbor - Fallout Over the Outfall" Oceanus, Spring 1993, pp. 61-70.
[5] Levy, Paul F., "Sewer Infrastructure - An Orphan of Our Times" Oceanus, Spring 1993, pp. 53-60.

B. Project Background

The regional EPA administrator files suit in Federal Court, in 1985, against the MWRA alleging numerous violations of the Clean Water Act. On December 23, 1985, Judge A. David Mazzone of the Federal District Court ordered the MWRA to construct new treatment facilities, including secondary level wastewater treatment, in accordance with an aggressive schedule of court-ordered milestones. The court order ended years of political paralysis on what to do about the condition of Boston Harbor. Most observers, including the former Director of MWRA[6], agree that without EPA's intervention, the Conservation Law Foundation and the City of Quincy, the harbor cleanup would not have been undertaken even to this day.

The two primary treatment facilities, on Nut and Deer Islands, that the MWRA had already been operating were considered to have exceeded their respective useful lives and could not provide the level of treatment required to meet the Clean Water Act and court ordered standards. Consequently, new primary treatment facilities were required to replace both outdated plants and provide new secondary treatment facilities.

Before construction of new facilities began, a planning process was commissioned to identify the systems flows to be treated, the location of the treatment, and the necessary technologies and facilities to use. Out of several options considered, it was decided that all facilities were to be located in one large complex on Deer Island[7].

Although called an island and technically within the City of Boston, Deer Island is actually a peninsula connected to the mainland only by a small road through the town of Winthrop, which is in effect the host community. In order to minimize the traffic through this town, the MWRA decided that half of workers would be transported via ferry and all materials were to be barged. The town would have been affected significantly if 100

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[6] Interview with Mr. Paul Levy, Executive Director of the Massachusetts Water Resources Authority 1987-1992, December 1994.
[7] MWRA, Boston Harbor Program, 1988 - 1999, Design and Construction Consulting Briefing, June 1988.

trucks and 2000 cars a day had instead traveled through local streets[6]. A barrier, a small mountain, was created between the construction site and Winthrop by moving some 2 million cubic yards of earth from Deer Island's center to its northern border. The move was beneficial not only for Winthrop but also for the MWRA, which saved $14 million in transportation and disposal costs[8]. A concrete batch plant was constructed on-site for all construction needs. The site had to be prepared for the construction by the demolition of a prison and an old fort. The limited size of the site requires that new technologies, such as the use of stacked clarifiers and egg-shaped digesters, are incorporated into the design. These items and other facilities that make up the Project are described in the following section.

C. Treatment Facilities Associated with the Project

Many factors influenced the Boston Harbor Project's approach to wastewater treatment and the selection and application of technology for the facilities on Deer Island. The first factor relates directly to the size of the plant, the facility size and the limited available land space. Other factors include the effluent limitations imposed by regulatory requirements and the cost effectiveness and reliability of the process technology.

The primary treatment is applied universally in wastewater treatment due its low cost of operation, which results, in part, from the fact that it uses gravity (natural process), and has no chemicals or high energy requirements. The secondary treatment process selected for the Boston Harbor Project is a state-of-art process. Its design includes selectors ahead of the secondary reactors, such as high purity oxygen reactors and secondary clarifiers that had to be stacked due to the severe site size restrictions.

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[8] Armstrong, Walter G., Director, Program Management - MWRA, The Boston Harbor Project, The American Public Works Association, August 31, 1992.

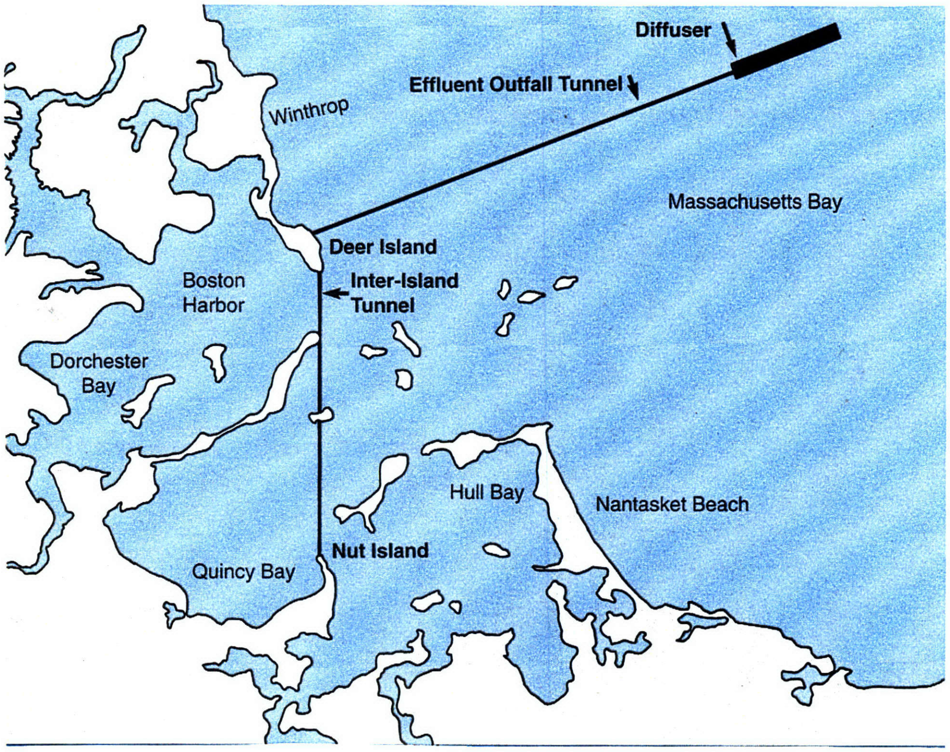
1. Preliminary Treatment

The new plant is designed to collect flows from the northern service area through the existing pump stations, headwork facilities, and tunnels going to Deer Island. The southern service area flows will also be collected as before. However, a new headworks facility at Nut Island and an inter-island tunnel from Nut Island to Deer Island will be constructed to transport the southern flow to Deer Island. The Nut Island head works facility will also remove grit through a centrifuge type process in order to further protect the inter-island tunnel and the pumping facilities on Deer Island.

Waste flow from the northern area is pumped to Deer Island through the existing facilities. Then two on-island force mains, constructed as part of this project, convey the wastewater from the pump stations to the north system grit facilities. Grit from the northern system is removed via the same type of centrifuge system utilized at Nut Island for the south system. The grid is then disposed of in a landfill. A new pumping station is under construction to bring the southern area wastewater from Nut Island through the new inter-island tunnel. This tunnel, as shown on figure 2, runs 200 to 300 feet below sea level in the solid bedrock under Boston Harbor for approximately 25,000 feet and is 14 feet in diameter after being lined with concrete[9].

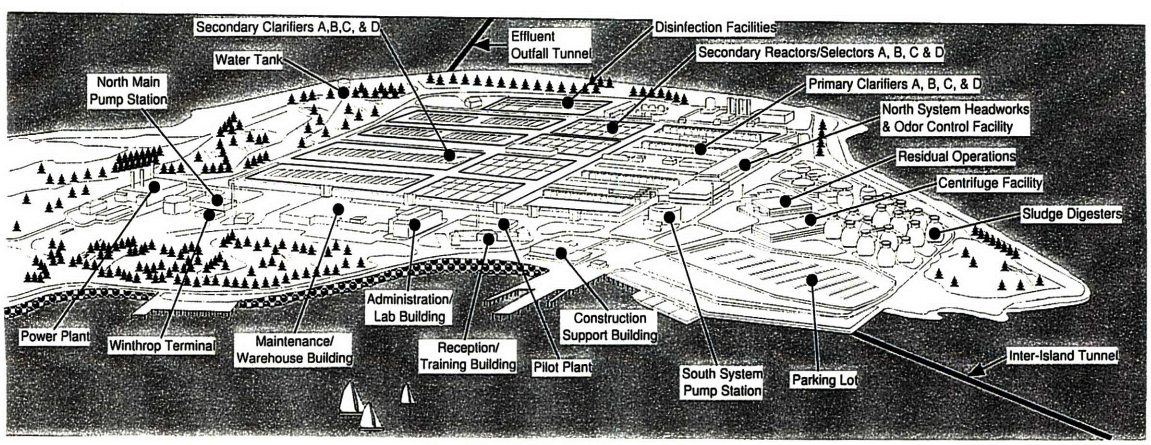
[9] F.W. Dodge - Profile, *Boston Harbor Cleanup*, The McGraw-Hill Construction News Publishing Network, July 20, 1992.

Figure 2: The Tunnels of the Boston Harbor Project[10]



After wastewater is pumped to Deer Island from both the north and south systems, it flows through the various treatment facilities by gravity, with no further pumping needed to continue the wastewater flow. Figure 3 shows the new treatment facilities on Deer Island.

Figure 3: Deer Island's Ultimate Site Plan[11]



[10] MWRA, Boston Harbor Project Facts - Tunnels, Fall 1993.
[11] MWRA, Boston Harbor Project Facts - Treatment Technologies, Spring 1994.

2. Primary Treatment

Upon removal of the grit, the wastewater goes to the primary treatment units called batteries. The wastewater sits for three to five hours while sludge settles to the bottom and scum floats to the top. During this process gravity helps to settle out approximately 35% of the human waste (sludge) and some of the toxic chemicals contained in the flow[12]. Meanwhile, scum and foam are removed from the surface of the wastewater. This primary treatment process is typical for nearly all wastewater facilities. The new primaries on Deer Island consist of four batteries which each contain 18 units. These units are stacked rectangular-shaped clarifiers, which differ from the typical common rectangular clarifiers in that a second level of units is stacked above the first. This 'stacked' arrangement is used in areas where space is limited, as is the case of Deer Island. The batteries are covered and air is drawn out and passed through a scrubber system prior to release for odor control. The four primaries under construction will be able to treat a wastewater flow of 1270 million gallons per day (mgd) that the collection system tunnels can bring to Deer Island. This capacity far exceeds the average daily flow, which is estimated at 400 mgd[13]. Accordingly, the planned excess capacity is intended to treat flows generated by storm events and the combined sewer systems, to help reduce the number of Combined Sewer Overflow (CSO) events per year and to accommodate future growth. The sludge extracted during primary treatment is sent via a piping system to further treatment - biodegradation - through a digestive process, or on the on-island residual treatment. The sludge is first sent to gravity thickeners , which handle the heavier solids resulting from primary treatment, where a portion of the excess water is removed and then returned to the start of the treatment stream. The sludge is then sent into eight egg-shaped digesters, where it is mixed and heated to reduce its overall volume, as sewage-eating microorganisms digest the sludge, and to kill disease-causing bacteria. This process lasts 12 to 22 days and reduces sludge weight by as much as 45%. Figure 4 shows the outline of the sewage treatment process.

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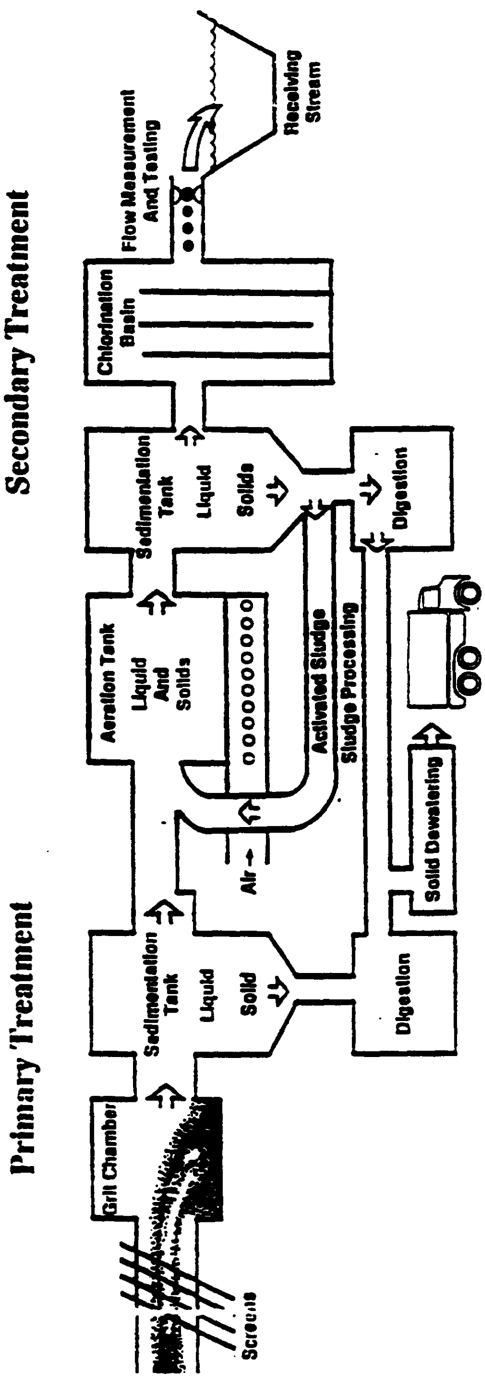
[12] Metcalf & Eddy, Wastewater Engineering: Treatment, Disposal, and Reuse - Third Edition, revised by George Tchobanoglous and Frank Burton, McGraw-Hill, 1991.
[13] F.W. Dodge - Profile, *Boston Harbor Cleanup*, The McGraw-Hill Construction News Publishing Network, July 20, 1992.

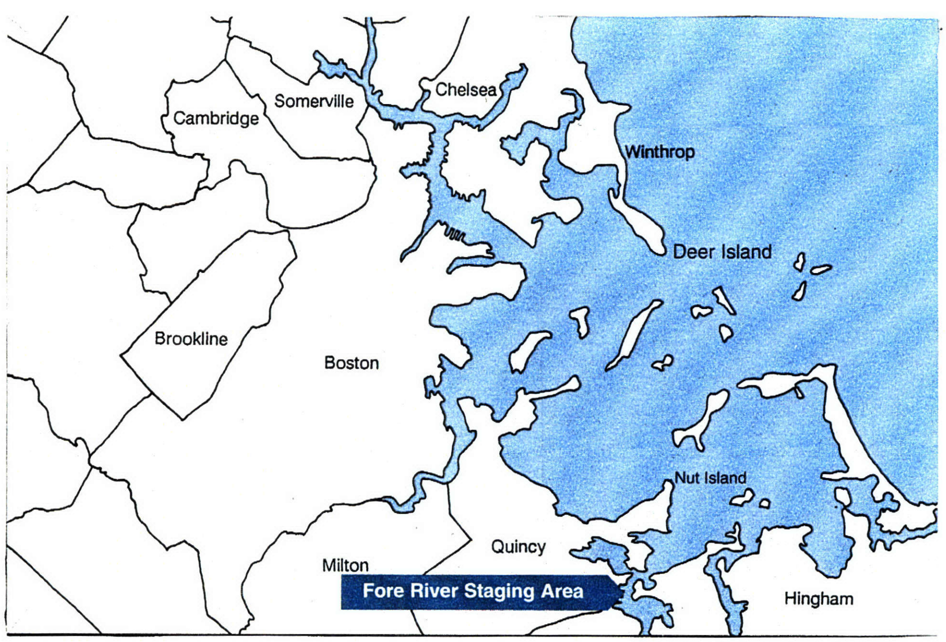
Figure 4: Outline of the Sewage Treatment Process[14]



[14] MWRA, Massachusetts Water Resources Authority Proposed Capital Improvement Program, Fiscal Years 1996-1998, December 30, 1994.

Although a relatively new technology in the United States, egg-shaped digesters have long been used in Europe and Japan. Such digesters use a smaller amount of land area, an attribute essential to the limited-size Deer Island site. This shape also allows for better mixing of the sludge and better self cleaning. The digested sludge, still approximately 95% water, is then conveyed to the new pelletizing plant at Fore River Staging Area (see Figure 5) in Quincy, currently via barge and, in later years of operation, by pipeline through the inter-island tunnel. At the pelletizing plant the sludge is dewatered further, heat dried and converted into a pellet fertilizer for use in agriculture, forestry, and land reclamation. This process for sludge is recommended by the EPA, as opposed to the alternatives of incineration, landfill, or ocean dumping. Prior to the construction of the pelletizing plant, which began operations in December 1991, sludge from the two treatment plants, almost 400,000 gallons or 70 tons of solids daily, had been pumped directly into the Boston Harbor.

Figure 5: Fore River Staging Area[15]



[15] MWRA, *Boston Harbor Project Facts - Fore River Staging Area*, Fall 1993.

3. Secondary Treatment

After the primary treatment, wastewater continues on for secondary treatment. The secondary treatment process is designed to further reduce the human waste and other solids as well as to remove a significant portion of toxic chemicals. Several options for secondary treatment exist and three alternatives for secondary treatment were considered for the Boston Harbor Project: air-activated sludge, oxygen-activated sludge, and the coupled system where the packed tower is followed by activated sludge. Ultimately, the oxygen-activated sludge system was selected for use on Deer Island, primarily for its lower capital, lower operation and maintenance costs, its smaller land area requirement, and its ability to handle the highly variable flows of wastewater expected at Deer Island according to the 1988 plan[16]. Four stacked rectangular batteries for secondary treatment were planned, each containing 18 units. These four batteries handle a flow of 1080 mgd. The capacity of the secondary treatment facilities are discussed to be reduced later on the project. These changes are discussed in detail in Chapter 2.

The first stage of secondary treatment is expected take the wastewater after flowing through the primary batteries and add oxygen to it, which is called the 'oxygen-activated' sludge process[17]. Adding oxygen to the wastewater speeds up the growth of micro-organisms (bacteria), which consume the wastes and settle to the bottom of the secondary clarifiers via gravity as in primary treatment. The settling of the waste is the second stage of the secondary treatment. Secondary treatment combined with primary treatment removes at least 85% of the human waste and other solids. Most of the facilities associated with secondary treatment, except the clarifiers, are covered where possible, with air being drawn off and passed through a scrubber system prior to release to assist in odor control.

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[16] MWRA, *Secondary Treatment Facilities Plan, Final Report*, Volume 1: Executive Summary, March 31, 1988.
[17] MWRA, Boston Harbor Project Facts - Treatment Technologies, Spring 1994.

The sludge accumulated in the secondary batteries will flow first to centrifugal thickeners, a screw-shaped core and outer shell which rotate in opposite directions, to remove some of the water. It is then sent to 8 egg-shaped digesters where it will be treated via the same process as explained for primary treatment. A total of 16 digesters were planned when combined with those used for primary sludge.

4. Wastewater Discharge

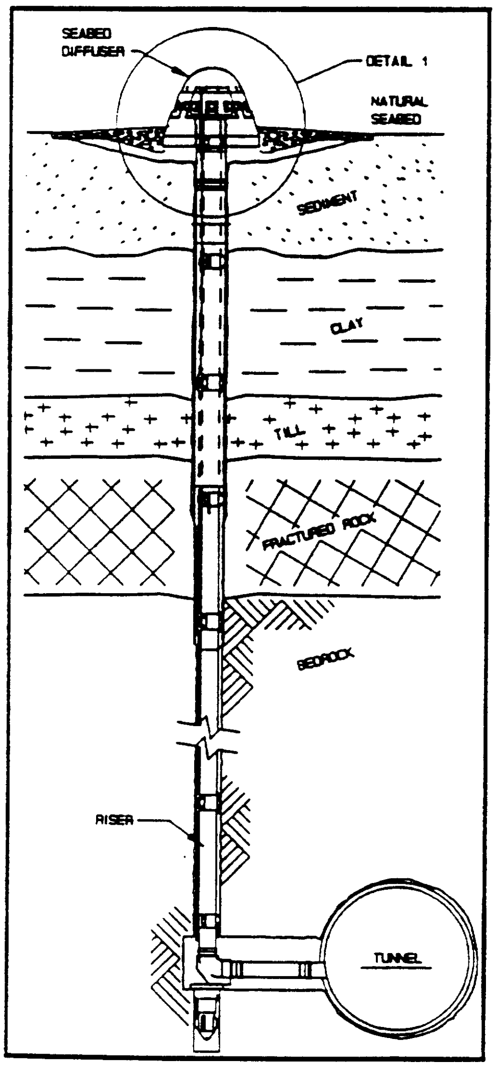
The wastewater resulting from secondary treatment is significantly cleaner than the wastewater after primary treatment. The next step is disaffection of wastewater before discharge. The Plant on Deer Island is designed to utilize liquid sodium hypochlorite which is very similar to household bleach. This chemical will be purchased and stored on the island, given that it is the only disinfectant alternative which could provide adequate disinfection to wastewater that has only received primary treatment. Department of Environmental Policy (DEP) guidelines state that the wastewater must be detained with the disinfectant for 30 minutes before discharge. The MWRA was able to reduce disinfection time down to 15 minutes due to the length of the effluent outfall tunnel, which will contain the effluent, the waste water, for at least 15 minutes before discharge. Also, a dechlorinating agent, sodium bisulfite, will be added to the effluent before its entering to the tunnel due to current regulations[18].

Disinfected and dechlorinated effluent will be sent through the 9.5 miles long effluent outfall tunnel into the Massachusetts Bay. The location of the outfall and diffusers was chosen after years of scientific investigation and public review and participation (refer back to Figure 2). The site takes advantage of ocean currents and circulation patterns so that the treated discharge will not affect beaches, fishing areas and other resources. The last 1.5 miles of the outfall tunnel is tapped by a system of 55 risers and diffusers (see Figure 6) spread 125 feet apart that will bring the effluent up out of the tunnel and disperse

[18] MWRA, Boston Harbor Project Facts - Tunnels, Fall 1993.

it into the bay through the 55 diffuser heads[19]. Each of these octopus-like diffuser heads is capped by an eight porthole manifold. The effluent will be mixed thoroughly with sea water, yielding better water quality, due to the location and the graduated nature of the release.

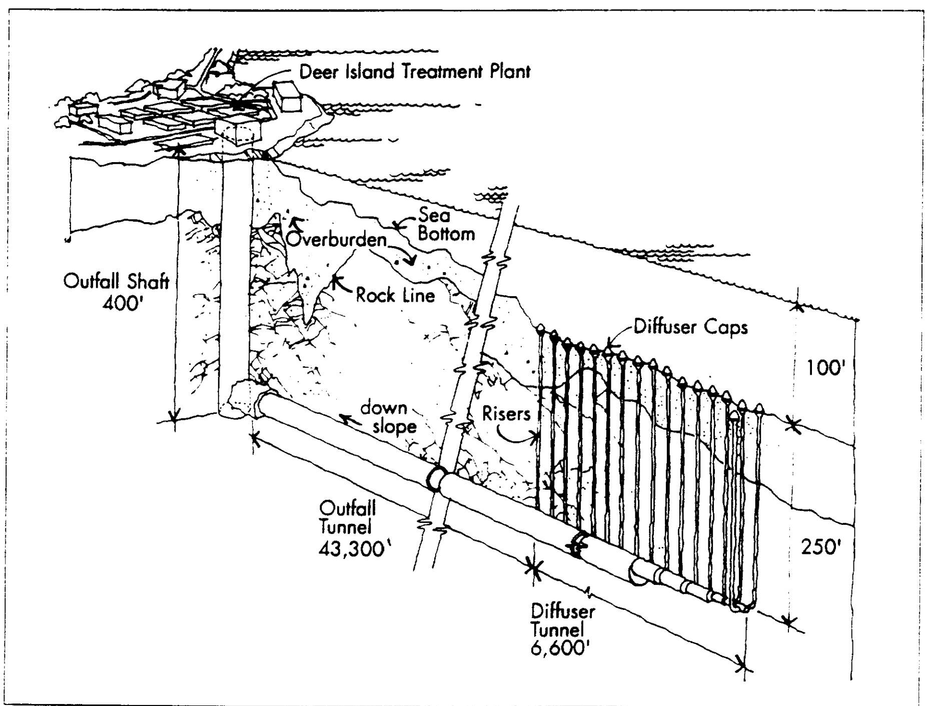
Figure 6: The System of Risers and Diffusers[20]



[19] F.W. Dodge - Profile, *Boston Harbor Cleanup*, The McGraw-Hill Construction News Publishing Network, July 20, 1992.
[20] F.W. Dodge - Profile, *Boston Harbor Cleanup*, The McGraw-Hill Construction News Publishing Network, July 20, 1992.

The tunnel is 400 feet below sea level, in bedrock, and will be 24 feet in diameter after being lined with concrete a foot thick. The outfall tunnel starts tapering down over the last 6,600 feet to a diameter of four to five feet at its terminus. The flow, which is pulled through the outfall tunnel by gravity, will be forced up the risers by differential heads (see Figure 7). According to the estimations[21], the normal transport time in the outfall tunnel will be at least 4.5 hours explaining the elimination of detention time associated with the disinfection.

Figure 7: The Outfall Tunnel[21]



[21] MWRA, Boston Harbor Project Facts - Tunnels, Fall 1993.

II. PLANNING AND FINANCING OF THE PROJECT

The Boston Harbor Project is, as stated previously, one of the largest wastewater construction projects being undertaken at this time. What complicates the task, besides the size of the project, is the timeframe. As part of the Court order to clean up the harbor, the parties, the judge and the MWRA, reached agreement and entered a schedule[22] of Milestones for portions of the project to be completed. This timeframe leaves little room for delays in construction.

The project was only made possible by the court's dictation under a decisive judge. The court wanted to monitor and control the project until it was successfully completed. And therefore implemented a schedule with milestones so that the project could be finished with no further bureaucratic delays. According to the MWRA's first director, Paul Levy, the secondary treatment facilities would have never been built without the court involvement[23].

A. *Planning Approach*

The facilities planning study[24] provides the foundation for the MWRA's program for the construction and operation of new primary and secondary treatment facilities at Deer Island. The planning was approached at early stages with the understanding that the facilities planning effort must secure and sustain the acceptance and support of the diverse

[22] MWRA's predecessor, MDC, brought in the environmental design firm Camp Dresser and McKee (CDM) to develop solutions for the problems of the Boston Harbor. CDM developed the schedule which was later chosen by the Federal Judge overseeing the cleanup. Although the schedule was tight it was workable and aggressive enough to be accepted.
[23] Interview with Mr. Paul Levy, Executive Director of the Massachusetts Water Resources Authority 1987-1992, December 1994.
[24] MWRA, *Secondary Treatment Facilities Plan, Final Report,* Volume 1: Executive Summary, March 31, 1988.

community, government and business interests that it effects. The process for planning was not only based on technical strength, but also on the reconciliation of political, environmental, economic and community interests.

After the final site selection (February 1986) of Deer Island for the wastewater treatment plant, a series of mitigation commitments were set to alleviate the impacts associated with the construction and operation of the new plant. The commitments covered the areas of flow and growth, operation and maintenance, noise, barging and busing, and use of liquid chlorine. The decision making process and these commitments made during the siting process were considered to be good guidance for the planning that was undertaken in the BHP.

1. Planning Period

The Planning period used in the facilities plan encompasses the period from 1988 through the year 2020. This represents the first twenty years of operation of the secondary treatment plant, which has been ordered by the Federal Court to be in operation no later than the end of 1999. A planning period of 20 years is the generally accepted practice in the engineering profession, and is required by construction grant regulations issued by the Environmental Protection Agency.

2. Recommended Plan[25]

In addition to the recommended plan, studies of alternate plans were also completed. The difference between the plans reflects alternate construction schedules for the secondary facilities, which are accelerated under the alternate plan. The plan for the

[25] MWRA, *Secondary Treatment Facilities Plan, Final Report*, Volume 1: Executive Summary, March 31, 1988.

treatment facilities on Deer Island was recommended in March, 1988, and consists of the following major components:

Preliminary Treatment

- Screening and grit removal at existing North System remote headworks.
- Screening at Winthrop Terminal.
- Additional grit removal of North System flow at new grit facilities on Deer Island.
- Screening and grit removal of South System flow at new Nut Island headworks.

Wastewater Pumping

- Replacement and modification of existing pumps at the North Main Pumping Station and the Winthrop Terminal to allow discharge to the new treatment facilities.
- Pumping of the South System flow at a new South System Pumping Station on Deer Island.

Primary and Secondary Treatment

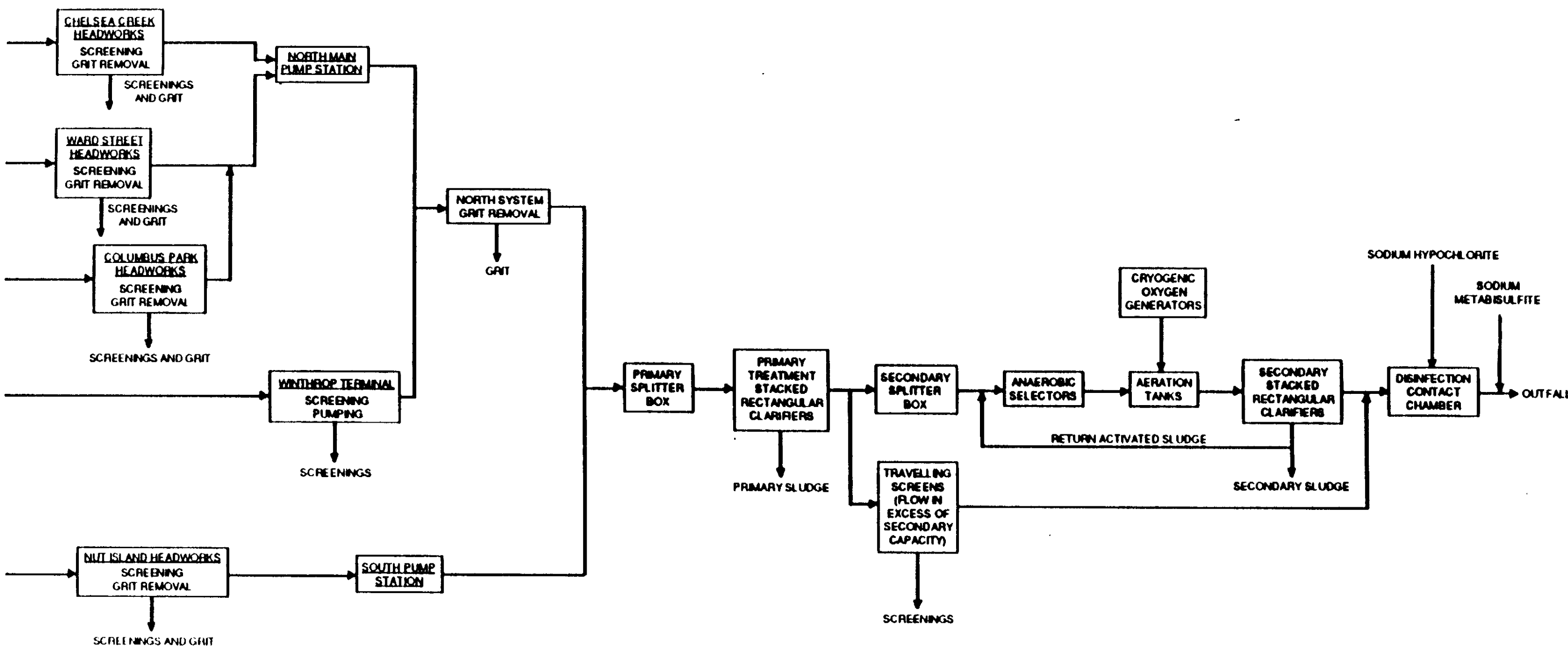
- Primary treatment to a flow rate of 1270 mgd in stacked rectangular clarifiers arranged in four batteries.
- Secondary treatment using the oxygen activated sludge process consisting of four parallel batteries of sequentially arranged anaerobic selectors, aeration basins and stacked rectangular clarifiers. The maximum flowrate in secondary treatment is 1080 mgd.
- Oxygen generation with two 300 ton per day cryogenic units with 1000 ton liquid oxygen storage capacity.
- Fine Screening of primary effluent in excess 1080 mgd with traveling water screens.

Disinfection

- Disinfection in chlorine contact basins with large barge-delivered sodium hypochlorite followed by dechlorination with sodium bisulfite.

The sequence of treatment is presented schematically in Figure 8. All of the treatment units are covered expect the disinfection contact basin and the secondary clarifiers. Exhaust air from the covered treatment units, and from pumping station wet wells and wet shafts, will be collected and treated with wet scrubbers (using sodium hypochlorite and caustic soda) followed by carbon adsorption.

Figure 8: Recommended Treatment Facilities Schematic[26]



[26] MWRA, *Secondary Treatment Facilities Plan, Final Report*, Volume 1: Executive Summary, March 31, 1988.

B. Court-Ordered Milestones

With the force of the court order behind them, a planning and construction process was able to be implemented that, under normal circumstances, would have been significantly slowed by bureaucracy. In May 1989 the Federal Court adopted 15 milestones for the Boston Harbor Project (as revisions to the initial Long Term Scheduling Order of May 1986). At the time of the initial milestones, the facilities to be built were not yet defined and technologies to be employed were not yet determined.

In October 1990 the Court allowed motions and amendments, which added 3 milestones relating to the construction of long-term residuals facilities, and amended existing milestones to clarify language relating to the long-term residuals facilities. Additionally, in September 1992, the Court allowed a revision to Milestone No.17, commencement of secondary residual facilities. This decision revised the milestone date from January 1993 to January 1994.

These eighteen milestones are listed below and the court ordered schedule is shown on figure 9. As of January 1995, completed milestones dates are bracketed following the milestone.

No.1 October 1990
MWRA to have electrical power available on Deer Island sufficient to commence construction of the new tunnels and the primary plant. [May 1990]

No.2 December 1990
MWRA to commence construction of primary treatment facilities. [December 1990]

No.3 January 1991
MWRA to commence construction of new effluent outfall tunnel. [August 1990]

No.4 April 1991
MWRA to commence construction of inter-island wastewater transmission tunnel. [April 1991]

No.16 August 1991
MWRA to commence construction of residual facilities at Deer Island to support primary clarifier batteries. [August 1991]

No.5 January 1993
MWRA to commence construction of the first battery (Battery A) of secondary treatment. [November 1992]

No.6 December 1993
Parties to review need for exigency plan for use of existing outfalls for South System flows. [In December 1993, the parties agreed that an exigency plan[27] was needed and have begun to outline a procedure for its development.]

No.17 January 1994
MWRA to commence construction of secondary residuals facilities at Deer Island to support the first two batteries (Batteries A and B) of secondary treatment. [October 1993 - The construction Notice to Proceed was issued.]

No.7 July 1994
MWRA to complete construction and commence operation of first two primary clarifier batteries (Batteries A and B) and related facilities at Deer Island necessary for the operation of the first two primary clarifier batteries, including necessary facilities for the processing of residuals. [January 20, 1995][28]

No.8 December 1994 (projected August 1996)
MWRA to complete construction of inter-island wastewater transmission tunnel.

No.9 July 1995
MWRA to complete construction and commence operation of the second two primary clarifier batteries (Batteries C and D) and related facilities at Deer Island.

No.10 July 1995 (projected mid to late 1997)
MWRA to complete construction and commence operation of new effluent outfall tunnel.

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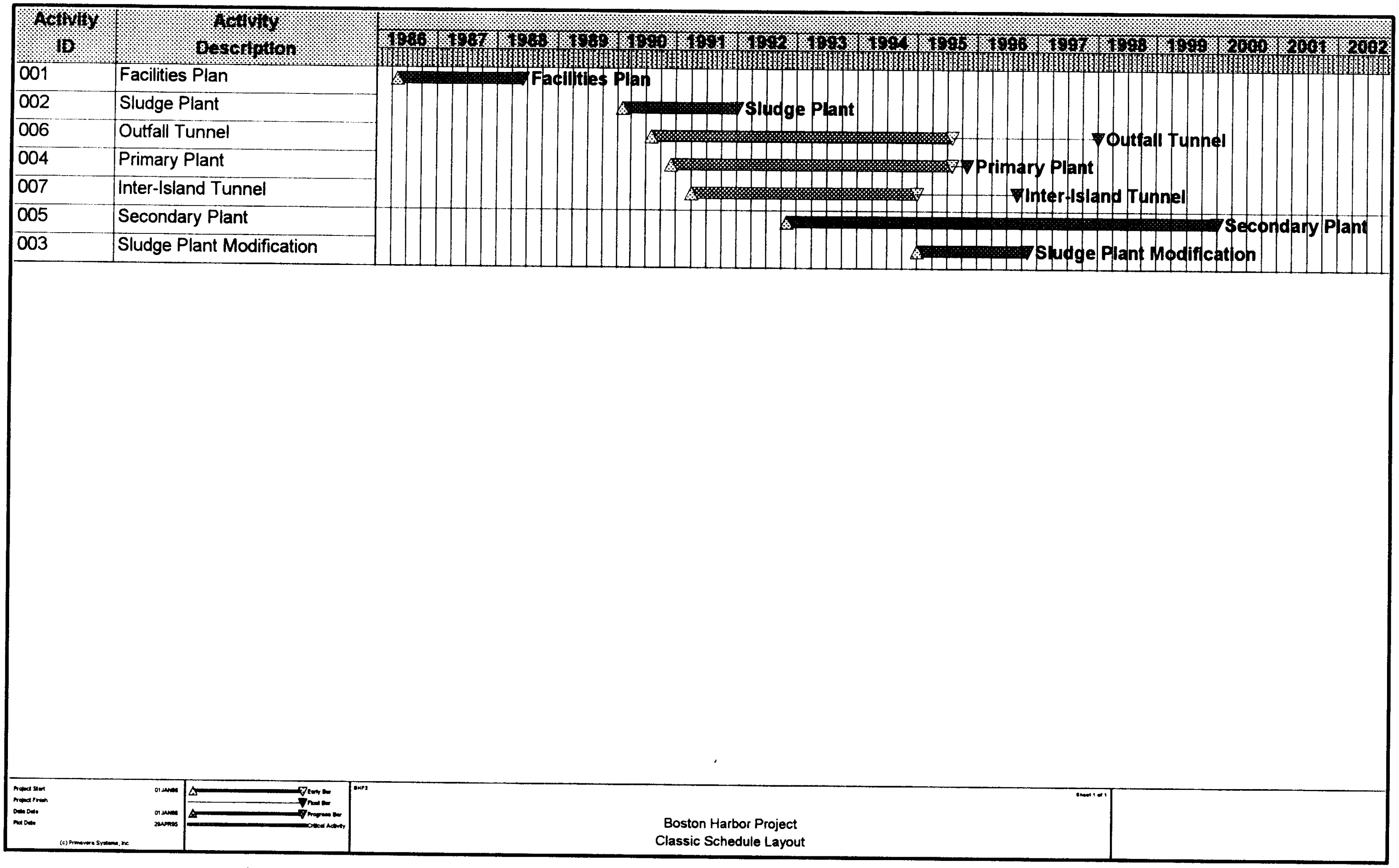
[27] The exigency plan will take into account an assessment of the water quality impacts and the feasibility of using the existing outfall system at Deer Island to handle the south system flows in the event that the Effluent Outfall Tunnel is not available in July, 1995. The tunnel will not be available until late 1997.
[28] The delay resulted primarily from the impacts of the severe winter weather, and the construction schedule of the Disinfection Facility (CP-204) was identified as the critical path item governing Phase I Startup.

Figure 9: Court-ordered Schedule of the BHP[29]



[29] This figure has been created using the scheduling software, Primavera.

No.11 July 1995 (projected October 1995)
MWRA to complete all other facilities necessary to permit acceptance of South System flows through the new primary facilities[30].

No.12 December 1995
MWRA to commence construction of secondary battery (Battery B).
[August 1993 - The construction Notice to Proceed was issued.]

No.13 October 1996 (projected December 1996)
MWRA to complete construction and commence operation[31] of first secondary battery (Battery A), and related facilities at Deer Island necessary for the operation of the first secondary battery, including facilities for processing residuals.

No.18 April 1997
MWRA to commence construction of secondary residuals facilities at Deer Island to support the second two batteries of secondary treatment (Batteries C and D).

No.14 June 1998 (projected July, 1997)
MWRA to complete construction and commence operation of second secondary battery (Battery B) and related facilities at Deer Island necessary for the operation of the second secondary battery, including facilities necessary for the processing of residuals.

No.15 December 1999 (subject to change)
MWRA to complete construction and commence operation of final two secondary batteries (Batteries C and D) and related facilities at Deer Island necessary for the operation of the final two secondary batteries, including facilities for the processing of residuals.

C. *Design and Construction Packages*

Because of its large size and long duration, the Boston Harbor Project, the stages of planning, design and construction are occurring concurrently. This is one of the reasons why the project is broken up into many design and construction packages (DP and CP).

[30] These facilities cannot be used prior to completion of the Inter-Island Tunnel. The MWRA will cease operation of the Nut Island treatment facility within six months following initiation of treatment of all South System flows at the new Deer Island primary facilities.
[31] "Complete construction and commence operation" means substantial completion of the secondary treatment facility, with the facility accepting flow. Substantial completion is expected to be followed by a period of start-up which will culminate in the consistent achievement of secondary treatment within six months of the above date.

Also, an initial MWRA decision to facilitate local economic benefit led to the breakup of the complete project, which in turn allows many local companies to work on the project as opposed to several large companies which would not have been local. There are around 25 design (DP) and 65 individual construction (CP) packages which comprise the Boston Harbor Project. The (CP)s are divided into five groups:

1. Group 000 General Site Facilities
2. Group 100 Primary Treatment Facilities
3. Group 200 Secondary Treatment Facilities
4. Group 300 Residuals Phase I and II
5. Group 400 Utilities (permanent)

The construction packages have been further grouped into 55 total facility construction packages. Table 1 presents a summary of the dollar value of these facility packages.

Table 1: Contract Packaging Summary

# of Packages	$ Value
23	Less than $10 Million
10	Between $10 and $25 Million
10	Between $25 and $75 Million
7	Between $75 and $100 Million
3	Between $100 and $150 Million
1	Between $150 and $200 Million
1	Greater than $200 Million

The design packages range from earthwork/landfills and fuel facilities to various environmental facilities such as primary and secondary clarifiers, screening facilities, headworks, residuals and finally two tunnels. The construction packages include largely the facilities associated with the sewage treatment plant and the two tunnels, and other site facilities. For a complete listing of all (DP)s and (CP)s along with their begin and end dates, vendors and total contract amounts, see Appendix A.

D. Project Critical Path

By definition, the critical path for a schedule network consists of the stream of activities with the longest path time-wise controlling project completion. The critical path is typically identified by those activities with a total float value equal to or less than zero: therefore, any delay to critical path activities will prolong the length of the project. However, since the schedule for the Boston Harbor Project is dictated by eighteen court-ordered milestones which mandate the commencement or completion of specific requirements as part of the Boston Harbor Clean-up, the Master Schedule has defined a critical path for compliance to each court-ordered milestones.

The critical path for selected court-ordered milestones[32] is summarized below:

No.7 (July 1994) - Complete Construction of Primaries A and B

Compliance with this milestone is currently dictated by the CP-102 schedule. Construction and start-up of some of the North Main Pump Station pumps and also construction and start-up of Winthrop Terminal Facility are required for the operation of Primary Batteries A and B. Completion of this work had around six months of negative float. Throughout 1994, completion of CP-204 required to support Phase I Start-up[33] remained the Milestone's critical path. The delay in physical progress in CP-204 hampered progress on the plant-wide instrumentation and control system (CP-450). The delayed physical progress provided no additional float in the substantial completion schedule.

No.8 (December 1994) - Complete construction of Inter-Island Tunnel

Substantial completion and start-up of inter-island tunnel CP-151 is forecasted for August 1996, or one and a half years behind schedule.

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[32] All dates, estimates, forecasts are taken from MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

[33] The Milestone 7, Phase I facilities include half the pumps in the North Main Pump Station/Winthrop Terminal Facility, Primary Batteries A and B, Module I of the Residual Facility, the Administration/ Laboratory, Maintenance Warehouse and Reception Training buildings plus portions of numerous other contracts such as island-wide utilities.

No.9 (July 1995) - Complete Construction of Primaries C and D

CP-130 - Construction and start-up of Primary Batteries C and D is forecasted for completion by June 1995 with one month of positive float.

No.10 (July 1995) - Commence operation of effluent tunnel

CP-282 - Substantial completion and start-up of effluent tunnel is forecasted for May 1997. The delay in the compliance to this milestone could potentially impact court milestones # 9 and 11.

No.11 (July 1995) - Complete facilities for Acceptance of South System Flows

CP-152 - Construction and start-up of the Nut Island Headworks and Odor Control facilities. Construction Notice to Proceed was issued in July 1992 with construction forecasted for completion by October 1995.

1. Milestone # 7 - Complete First Two Primary Batteries

As of December 31, 1994, construction physical progress toward the successful completion of Milestone # 7 is estimated at 99.5%. Commencement of operation of the first two primary clarifier batteries occurred on January 20, 1995. This achievement is six months later than originally scheduled Court-ordered Milestone. The delay resulted primarily from the impacts of the severe winter weather, and the construction schedule of the Disinfection Facility (CP-204) was identified as the critical path item governing Milestone # 7.

The following 17 construction contracts on Table 2, listed with their contract value and physical progress in the completion of Milestone # 7 related construction, are required in whole or in part to support this Milestone.

Table 2: The CP's of Milestone # 7[34]

CP #	Description	Contract Amount	Progress Completed 12/31/94
CP-024	Admin/Lab/Warehouse	$ 44,634,000	100.0%
CP-101	North System Tunnels	$ 20,230,000	100.0%
CP-102*	North Main Pump Station	$ 59,240,000	100.0%
CP-103	North System Headworks	$ 87,900,100	100.0%
CP-105	Primary Clarifiers A & B	$ 96,997,000	100.0%
CP-130*	Primary Clarifiers C & D	$ 82,858,000	100.0%
CP-202*	Secondary Reactor Batteries A & B	$ 109,980,000	100.0%
CP-204*	Disinfection Phase I / Seawall	$ 39,577,000	97.0%
CP-205	Water Storage Tank	$ 8,630,096	99.0%
CP-241*	Disinfection Facilities Phase II	$ 35,190,000	100.0%
CP-301*	Residuals Treatment Primary Phase I	$ 188,807,000	97.0%
CP-401	Water Supply Through Winthrop	$ 9,474,208	100.0%
CP-402	Yard Utilities	$ 19,846,200	100.0%
CP-428	On-Site Thermal / Power Plant	$ 53,650,000	80.0%
CP-450*	Process Information / Control System	$ 20,994,892	95.0%
CP-452*	Fire/ Telephone/ CCTV/ Comm. / Security	$ 9,854,707	93.0%
	Total	$ 887,863,203	99.5%

* Only portion of CP required for Milestone # 7.

E. Factors for Success[35]

The Boston Harbor Project has a duration of more than fifteen years, from 1985 when the project plan was first formulated until the year 2000 when the construction is expected to be completed. This long duration requires the management of the project to take into account the probability of change. The environment at the time the project was planned does not resemble the environment today while the project is being built. The best means of recognizing the environment is for the management to define project specific

[34] PMD, MWRA.

[35] Fox, Richard D., Director, Program Management Division, *Planning and Organization Of the Boston Harbor Project*, MWRA, 1991.

factors for success over the life of the project. These factors for success heavily influence all decisions to be made concerning the management of the project. Managers need to create a realistic set of goals and clearly see the future environment for these factors.

The Program Management Division (PMD) led by Richard Fox identified five factors required for completing the Boston Harbor Project successfully. Table 3 shows these factors at the three points in time: as they were listed in 1985 at the time of the initial project plan; as they were viewed by the PMD in 1991; and as they are viewed today by the author. The five factors remained unchanged, but their rank order of importance to project success has evolved over ten years.

Table 3: Changes in the Project Environment

Factors for success of Boston Harbor Project	Initial 1985	Then 1991	Current 1994
Meet or Beat Schedule	1	3	1
Start Actual Construction ASAP	2	1	5
Cut Costs	3	2	2
Develop a "Good Business" Reputation	4	4	4
Make it Work	5	5	3

In 1985, according to the first project team (1) meeting or beating the court-ordered schedule was the most important factor for the project success, followed by (2) starting actual construction as soon as possible, (3) cutting costs, (4) developing a "good business" reputation, and (5) making the completed project work. At the time, these factors were chosen after analyzing both the external and internal environments and drove the management structure and the decision-making process. The project team felt a strong need to keep up with the schedule in order to meet the MWRA's obligations as a defendant, to prove its ability to succeed and build credibility as a team. Starting the construction was a good way to show visible progress to justify the ratepayers' investment and to control the steady effects of inflation on project costs. Cutting costs was a good sign for the appreciation of the high financial burden of the project on the MWRA's member communities. A "good business" reputation was needed to make the project attractive to investors, suppliers and contractors. Making it work was the least important factor at the time since it was ten years distant.

After six years, the changes in the environment caused some changes in the order of importance. In 1985, the Massachusetts economy was in a booming stage and the slowdown at the end of decade was not foreseen. Also, the project had evolved from the planning and design stage to the beginning of construction. In 1991, starting the construction became the most important factor for success. The MWRA accelerated bidding on several projects to take advantage of a slowdown in the construction industry, saving tens of million dollars on original construction cost estimates. Cutting costs became more feasible by taking advantage of the economic slowdown and became the second most important factor. After the success in meeting or beating the first milestones of the project, the project team became comfortable with the schedule shifting that factor to the third place. The remaining two factors of developing a "good business" reputation and making the project work held their ranks of fourth and fifth. The changes in the environment at that time of the project life did not effect their ranks.

Today, with more than half of the actual construction of the project completed, the environment seems to have changed again. Because of major delays in construction of the tunnels which also effects other milestones, meeting the schedule has once again become the most important factor for success after ten years. Every milestone following Milestone No.7 seems to be either delayed or just barely making its court-ordered completion date. These delays attract a lot of attention and detract from the MWRA's previous successes in the project. Cutting costs has taken second place since delays threaten increases in the forecasted construction costs. Making it work has moved to the third place. Operation of the first primary clarifier batteries started on January 20, 1995. The MWRA has been working to implement training programs for more than 300 Deer Island staff. Developing a "good business" reputation ranks fourth as construction work peaks and operation and maintenance of the new facilities assume greater importance. Starting the actual construction falls to last place from its position of most important factor in 1991. Most contracts are in place. Most of the construction notices to proceed for the milestones have been issued in advance of their deadlines.

F. Changes in Project Design

In 1993, the MWRA determined that, when the Boston Harbor Project was nearing halfway to completion, plans for project components not yet designed should be reviewed in light of extensive new flows and loads data and advances in wastewater technology. In 1994, there were discussions regarding the potential for construction-related reductions in the original Boston Harbor Project design. Milestone #15 which is the complete construction and commence construction of the final two Secondary Batteries C and D, scheduled for October 1999, is the subject of a current Secondary Design Reassessment (DP-29) study [36]. This study provides evidence that peak and average flows are likely to be 25 percent less than anticipated in 1988 when the sewage treatment plant facilities plan was completed.

Secondary treatment regulations are clear as to the required effluent limits to be achieved for the non Combined Sewer Overflows (CSO) and waste loads. The limitations on CSOs are set by the states and vary for each state and by the option for CSO removals. The limits are assessed based on environmental concerns, costs and attainability. For the BHP, the State has imposed limits of 50 milligrams per liter (mg/l) of biochemical oxygen demand (BOD) and 50 mg/l of total suspended solids (TSS) on a peak day for the entire wastewater and storm flows[37].

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[36] The study is performed by Camp Dresser & McKee under $2.5 million contract.
[37] MWRA, *Secondary Treatment Facilities Plan, Final Report*, Volume 1: Executive Summary, March 31, 1988.

Establishment of a revised, long-term CSO remedial program by the MWRA, EPA and DEP, as part of an integrated master plan for wastewater collection and treatment, affects the extent to which Secondary Batteries C and D can be scaled down. Important to the equation is the amount of flow considered as a part of the secondary or non-CSO contributions. The present modular design for the oxygen activated sludge process and secondary clarifiers is for 540 million gallons per day (mgd) into Batteries A and B. The actual secondary treatment flow contribution will determine the portions of Battery C and D that must be constructed.

The cost of Batteries C and D is approximately $250 million for the oxygen reactors, clarifiers and cryogenic plant expansion[38]. A portion of this amount may be deleted based on the work of the DP-29 consultant, Camp Dresser and McKee (CDM) and the master plan by Lead Design Engineer (LDE) Metcalf and Eddy. The results of pilot plant performance and flow and waste load reductions resulting from the new CSO study work will form the basis for the MWRA presentation to the DEP and the resultant standards set for handling CSO related flows.

According to MWRA's last BHP - Annual Report, 1994, the MWRA is likely to recommend the removal of Secondary Battery D (CP-261). Currently, efforts are underway to select a design consultant to complete the remaining secondary facilities in light of the ultimately determined sizing and configuration of the secondary treatment facilities. A recommendation drawing for secondary treatment facilities is shown in Appendix B.

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[38] MWRA, Massachusetts Water Resources Authority Capital Improvement Program, Fiscal Years 1995-1997, June 30, 1994.

G. *Financing of the Project*

The Boston Harbor Project was estimated to cost around six billion dollars by the time it was completed in 1999. Actually, the project was calculated to cost not more than three and one half billion dollars in 1989 dollars before the construction had started. Since the project was going to be funded by ratepayers of MWRA and therefore was going to attract a lot of public attention due to the expected rate increases for the following decade, the former director Paul Levy decided, in 1989, to advertise the cost of the project in 1999 dollars. So the cost of three and one half billion dollars became six billion dollars when an inflation rate of five percent was included for the following eleven years[39]. Therefore the project seemed to be proceeding under budget in the first three years thus indicating that MWRA was very successful in its project management.

According to the July 1994 MWRA Capital Investment Summary, the ultimate total cost of the Boston Harbor Project is estimated at around 3.4 billion dollars. This amount excludes the residuals management and CSO screening costs. A small portion of the project is funded from through state and federal dollars. The remainder is funded by bond issues that will be paid off over the next 20-35 years by funds raised by the rates charged to wholesale customers of the MWRA. These wholesale customers, such as the Boston Water & Sewer Commission and individual cities and towns, then pass MWRA costs, as well as their own operating costs, on to their residential and commercial customers.

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[39] Taking 5 % inflation for eleven years causes about 71 % increase in the initial amount:
5% interest factor for discrete compounding, n=11, P=$3.5 billion results in F=$6 billion.
The factor (F/P,5,11) = 1.71.
Actual Inflation Factors:

FY 89	5.50 %
FY 90	1.50 %
FY 91	6.90 %
FY 92	3.10 %
FY 93	6.10 %
FY 94-2000	5.00 %

The MWRA updates its capital facilities programs for its capital expense budgets in order to implement and finance programs such as the BHP. It prepares periodically a series of capital improvements programs covering rolling three-years budget periods. At the end of the 1994, the MWRA approved the Proposed FY96-98 Capital Improvement Program for the BHP[40]. This program reflects the potential cost savings from the reduced secondary treatment facility, as recommended in DP-29 study.

To support the costs of the project, Funds have been raised to finance the BHP from the following sources:

1. Federal grants
2. State revolving loan funds
3. State grants
4. Long-term bond financing

The breakdown of the grant and loan funding to date (FY86 - FY94) is provided below:

Table 4: Grants and Loans[41]

State Grant	**$27,753,000**
Federal Grant	**$532,068,000**
State Loan	**$280,242,000**
	$840,062,000

1. Federal Grants

The BHP construction began after the phase out of the EPA Construction Grant program. On a national level, Federal money for wastewater programs has declined since

[40] The fiscal years for the BHP are from budget the beginning of July until the end of June of the following year.
[41] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

the early 1980's. Therefore, BHP was not afforded the benefit of substantial federal grant funding that was generally available for waste water projects throughout the 1970's and early to mid -1980's[42]. Only a small portion of the project is funded through federal dollars. Only for FY 1994, the project received a special federal grant of $100 million from the US Congress which increases the amount of total Federal Grants to over $531 million.

2. State Funding

Massachusetts is providing subsidy assistance to MWRA for the financing of BHP in the following forms:

- 20 % match of Federal capitalization grants used for the state loans
- Subsidies of MWRA's revenue bond and state loan bond debt service payments
- Grants for the BHP

Grants for BHP provided by the State have diminished as a percent of the total project, down from 7% 1986-93 to 1% for 1986-1999[43]. The total State Funding to date is around $ 308 million.

3. Bond Program

MWRA has had to rely on revenue bond financing for the large majority of its financing program for the BHP and will continue to do so in the future. Over the past seven years, MWRA has issued around $2 billion of revenue bonds. Since interest rates

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[42] During the 1970s and 1980s, there was a "Sewer America" program to get the wastewater from the cities and towns sufficiently treated to meet Clean Water Act standards. The federal government paid for 90 percent of the design, engineering, pipes, treatment plants, and outfall and discharge pipes for these systems. Cities with inadequate collection and treatment systems were able to upgrade to adequate systems, and direct discharges of raw waste into lakes, rivers and oceans stopped. Large systems were built because community leaders assumed they had only one chance to obtain federal dollars for these projects, so they built in 1975 what they might need in 2015. Expensive systems were built because the municipal portion of the cost was less than 10 percent (sometimes less than 5 percent) of the real cost.
[43] MWRA - Finance Division

have dropped over the past year, MWRA has been refinancing much of the older, more costly debt at lower rates.

This financing structure caused extreme increases in water and sewer rates for the communities in the Boston area. In 1985 water and sewer service cost per average ratepayer was $140 in Boston. In 1992 those services had quadrupled to $535. Boston became one of the cities with the highest water and sewer rates in the nation. By 1998 water and sewer service are expected to cost $850 in current dollars. Figure 10 and 11 shows the historical and future rate revenue increases.

The BHP has been perceived in the municipal bond community as a complex and expensive project. The investor and rating community have in the past expressed several concerns about the project's complexity and size, rate impacts on customers and delays in construction. Standard and Poor's has historically rated MWRA municipal bonds at a grade of A^{-}. The rating was increased to A in November 1993 because of efforts of MWRA and the Massachusetts to address some of the risk issues. The grade of A is Standard and Poor's third best grade after AAA and AA.

The MWRA and the State must maintain a continuous effort to keep addressing the legislative, construction, and financing issues to maintain the positive momentum achieved over the last years. The effort should even be increased due to extreme delays in tunnel construction. MWRA should also continue with the investor outreach programs addressing the construction status and progress of BHP.

Figure 10: Historical Rate Revenue and Percentage Increases[44] [1]
(dollar amounts in millions)

Fiscal	Water		Sewer		Combined	
Year	Amount	Increase	Amount	Increase	Amount	Increase
1985[2]	$21.1	-	$ 24.9	-	$ 46.0	-
1986[3]	24.8	17.5%	33.9	36.1%	58.8	27.8%
1987	30.4	22.6	60.3	77.9	90.7	54.3
1988	33.4	9.9	66.8	10.8	100.2	10.5
1989	45.2	35.3	92.5	38.5	137.8	37.5
1990	49.3	9.1	121.8	31.7	171.1	24.2
1991	50.6	2.6	134.7	10.6	185.3	8.3
1992	58.3	15.2	185.0	37.3	243.3	31.3
1993	60.3	3.4	230.2	24.4	290.5	19.4
1994[4]	63.9	5.9	240.5	4.5	304.4	4.8
1995[5]	63.4	-0.7	240.9	0.2	304.4	0

1 Does not include revenues received by the Authority from Local Bodies pursuant to contracts or special act which are accounted for as other charges for service rather than as rates and charges. See "Local Bodies - Special Arrangements."

2 Last fiscal year in which assessments were made by the MDC.

3 First fiscal year in which rates and charges were established by the Authority and first full fiscal year of operation of the Authority.

4 Based upon unaudited records of the Authority for Fiscal Year 1994.

5 Based upon the Fiscal Year 1995 Current Expense Budget.

Figure 11: Estimated Future Rate Revenue Requirements and Percentage Increases[45]
(dollar amounts in millions)

	BASELINE		ADJUSTED	
Fiscal Year	Rate Revenue	Percentage Increase	Rate Revenue	Percentage Increase
1995	$304.4		$304.4	
1996	358.2	17.7%	341.6	12.2%
1997	427.8	19.4	402.6	17.8
1998	520.4	21.7	479.7	19.1
1999	584.8	12.4	536.8	11.9

44 MWRA, General revenue Bonds - 1994 Series A

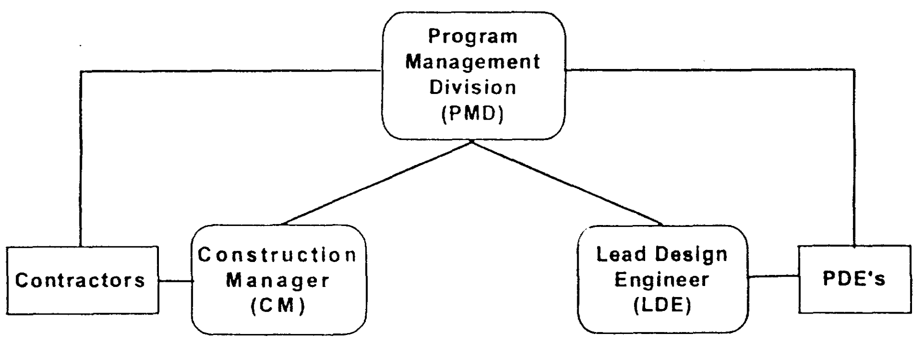
45 MWRA, General revenue Bonds - 1994 Series A

III. PROJECT ORGANIZATION

A. Project Management Structure

The BHP is administered by MWRA's Program Management Division (PMD) that oversees a Lead Design Engineer (LDE) and Construction Manager (CM). This management structure is depicted in the organization chart in Figure 12. The respective missions and responsibilities of these principal Boston Harbor Project management parties are described in the following sections.

Figure 12: BHP Organizational Structure[46]



[46] Source: PMD - MWRA

1. A New Division at MWRA: PMD

During the development of the Court-ordered schedule, MWRA felt that CM services could ensure that the adopted schedule was achieved or even accelerated. Thus, the Federal Court, in May 1986, directed the MWRA to investigate and evaluate the efficiency of construction management services for the project. The Secondary Treatment Facilities Plan reviewed CM concepts and recommended a model that provided a management team consisting of a comparatively small in-house oversight team. In September 1987, the MWRA approved a special management approach for the project that included the development of the Program Management Division (PMD). This new division within the MWRA reports to the Executive Director and functions as a consultant to the Sewerage Division. The organizational chart of MWRA in the appendix shows the relationship of this unit to other divisions.

There were several advantages to an independent program management structure[47]:

1. An in-house team dedicated to the harbor cleanup would allow other divisions to meet their requirements, such as the capital rehabilitation and replacement program, without distraction.

2. Considering the fast pace of design and construction required to meet the aggressive court order, an independent team could focus all of its resources on the BHP rather than being occupied by other responsibilities.

3. The formation of a new division permitted MWRA to recruit new management personnel, from both public and private sectors, with proven management skills, but with a finite commitment, since the positions would be eliminated upon completion of the project by the year 2000.

Some project functions, such as personnel, law, procurement and budget, were thought to be more effective if they remained interrelated with other departments. The reason for this decision was that these functions were subject to external review and have a

[47] Fox, Richard D., Director, Program Management Division, *Planning and Organization Of the Boston Harbor Project*, MWRA, 1991.

significant need for consistency across MWRA. The project's management information systems were decided to be operated independent of MWRA's management information systems since the project's information needs differ significantly from MWRA's requirements. Given the size and complexity of the project, an original system, dedicated to the project, was more preferable[48]. Chapter 4, Section A, discusses this system more in detail.

The essential mission of the Program Management Division (PMD) is to provide the management and coordination required for the execution and completion of BHP, resulting in operable and reliable facilities within court scheduled deadlines. PMD is responsible for transmitting the MWRA's objectives to all its consultants and contractors, including the Construction Manager, the Lead Design Engineer, and Project Design Engineers. PMD will monitor the performance of all its consultants and contractors and serve as the liaison between them and other MWRA divisions. The MWRA retains sole authority and responsibility with regard to all contractual matters including without limitation the following:

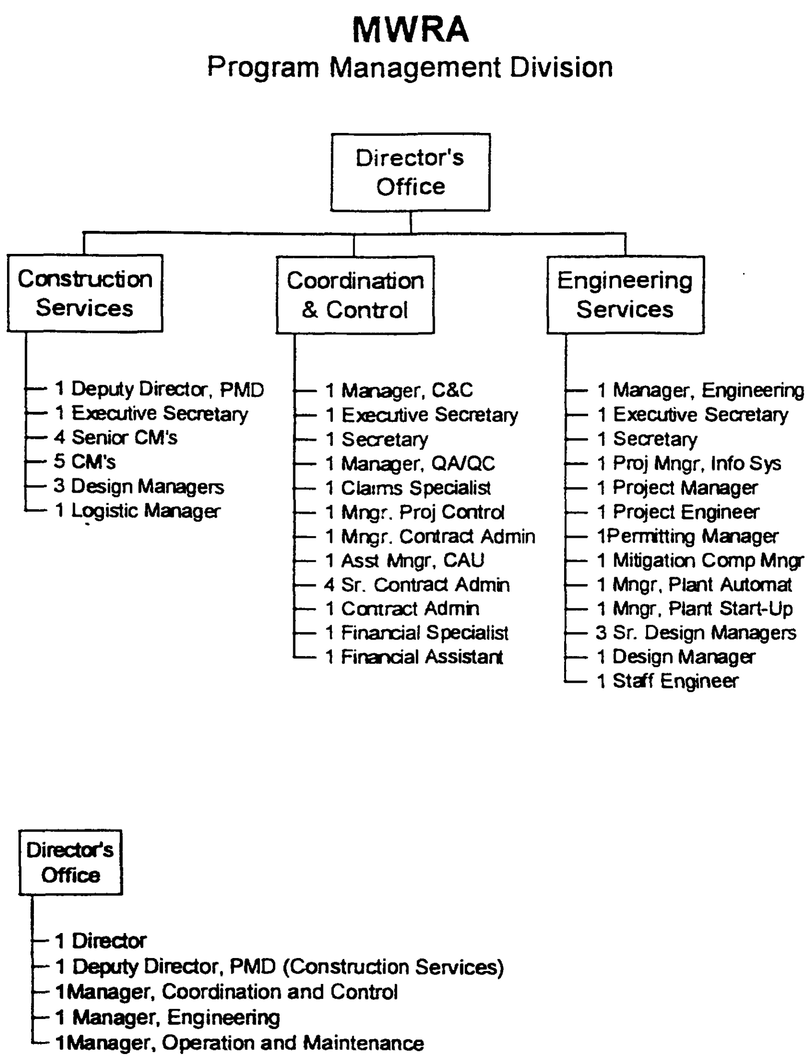
Advertising design and construction contracts
Selecting consultants and contractors
Authorizing amendments, change orders, and payments
Approving completion certificates
Approving partial and final acceptance
Issuing Authority position on claims

Figure 13 shows the organization chart of PMD. The PMD Engineering Services Department consists of 16 engineers who manage the LDE team and oversee the management of principal design firms. The PMD Construction Services Department consists of 15 engineers/construction managers who manage the CM construction team and oversee the activities of prime contractors and subcontractors. The PMD

[48] Fox, Richard D., Director, Program Management Division, *Planning and Organization Of the Boston Harbor Project*, MWRA, 1991.

Coordination and Control Department consists of 15 engineers, contract administrators, claims specialists, financial specialists and permitting specialists. This Department is supported by the CM team in expediting all professional and construction procurements and directing, invoicing, permitting, scheduling, budgeting, auditing, contract close-outs, and general contract administration.

Figure 13: Organization Chart of PMD[49]



[49] Source: PMD - MWRA.

2. The Construction Manager

Most of the activities prior to June 1990 were pre-construction planning and preparation, such as developing safety programs, change order and claims procedures and labor relations programs. Therefore the title of program/construction manager (P/CM) was chosen rather than a construction manager (CM). ICF Kaiser Engineers, Inc. served as the P/CM from April 1988 to March 1991 with a contract valued at $18.4 million[50]. In April 1989, the MWRA adopted a model for construction management services and authorized the use of the model on the early site preparation contracts. The selection of the certain model is discussed later in this chapter. The procurement for a CM for the entire project began in February 1990. A 66 month contract was awarded to ICF Kaiser for CM services. The total contract amount was $ 171.1 million[51]. The contract also provided for three, three-year extensions of CM services. ICF Kaiser has a chief consultant which is another large engineering firm called Stone & Webster and based in Boston. Although ICF Kaiser was chosen alone initially as the CM, Stone & Webster joined later using its influence as a major construction firm headquartered in Boston.

The CM is responsible for scheduling, cost estimating, cost control, permitting, water transportation, logistics, value engineering, constructability reviews, operability reviews, equipment prepurchase, testing, startup, training, safety, technical support for contractor selection, change orders, progress payments, inspection and final acceptance. The organization chart of the CM is shown in figure 14. A summary of the CM contract is in Appendix D.

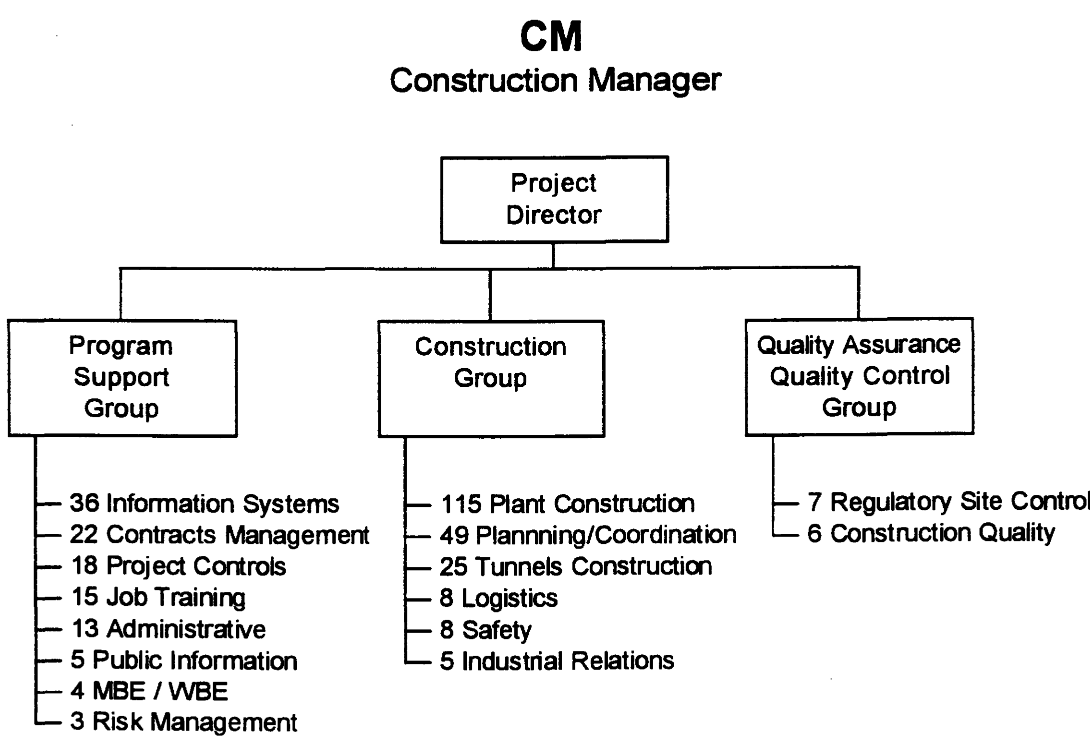
Since the BHP is in the construction phase, the construction management team is active trying to ensure timely completion of a high quality project within established budget levels. To accomplish this goal, much of the CM team is located on Deer Island in

[50]MWRA, Massachusetts Water Resources Authority Proposed Capital Improvement Program, Fiscal Years 1990-1992, January 18, 1989.
[51] MWRA, Massachusetts Water Resources Authority Proposed Capital Improvement Program, Fiscal Years 1996-1998, December 30, 1994.

construction support buildings close to the site of the major construction and support effort. The complexity of the project and the limited size of the construction site requires more on-site management than usual construction projects. The management of the project is discussed further in Chapter 4.

The following figure shows the organizational chart of the Construction Management for BHP. It has three different groups; Program Support Group with a staff of 116, Construction Group with a staff of 210, and the QA/QC Group with a staff of 13. The total staff is 339, which is an average figure over the course of the project. The Staffing of CM is analyzed on Section C - 1. The roles of each group are described in Appendix D.

Figure 14: The Organizational Chart of CM[52]



[52] Source: PMD - MWRA.

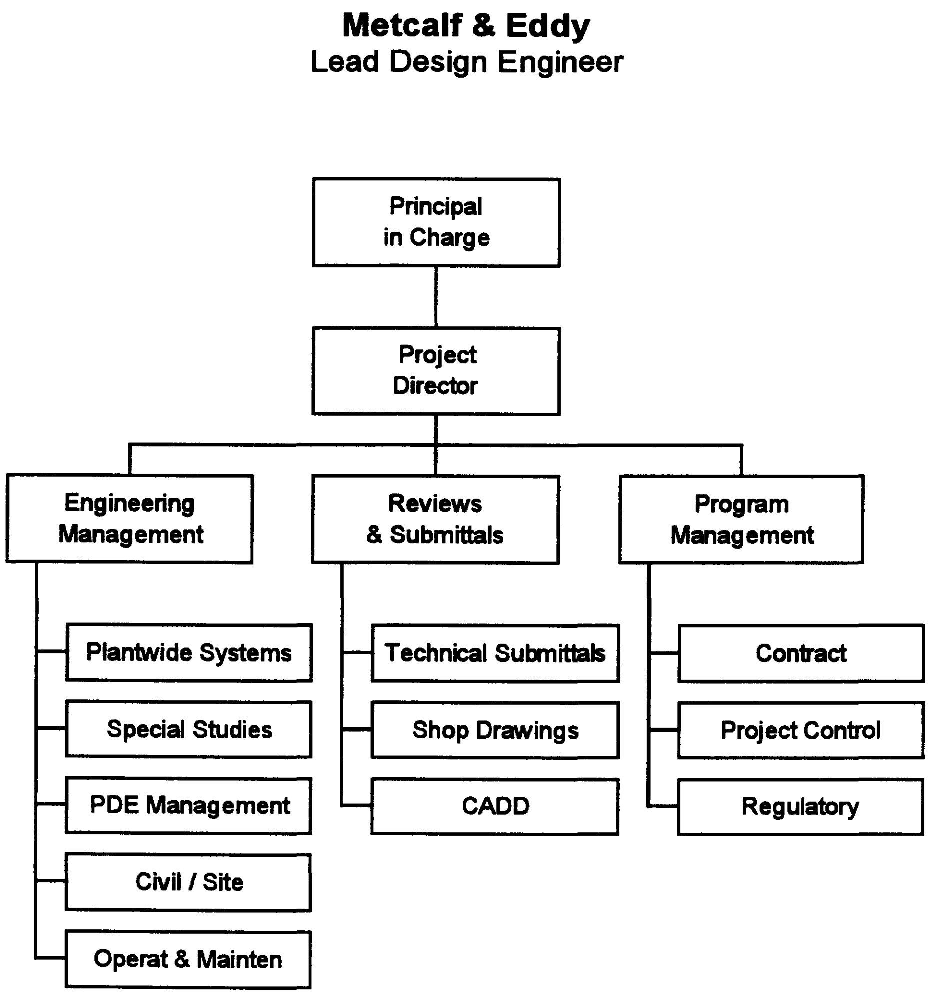
3. The Lead Design Engineer

The Lead Design Engineer (LDE) function is performed by a team led by the design firm Metcalf and Eddy, Inc. The LDE has developed project-wide design standards, implemented an overall CADD system, and prepared designs for the earliest project contracts. It provided all services required to prepare, in part, and to manage the design of the primary and secondary treatment facilities and associated project components. Presently, the LDE directs the design of major project components, coordinates all design work, develops design to the 10% - 15% level and, provides oversight for Project Design Engineers (PDEs). The LDE is also providing Engineering Services During Construction (ESDC) focusing on the integrity of plant-wide systems, the components of which were designed by a variety of firms. The PMD staff provides overall functional direction to the LDE. The total contract amount of LDE services provided by Metcalf & Eddy, from August 1988 to June 1996, is $77.7 million[53].

The performance of the LDE relative to the master schedule and project cash flow implications is managed from an overall program perspective by the CM. In addition, the CM works closely with the LDE and provides site coordination and logistics information to the LDE for use in all design activities. However, the LDE reports directly to PMD on design and engineering issues. The PMD has the responsibility for the management of design-related activities performed by the LDE and PDE teams. Figure 15 shows the organization chart of LDE.

[53] MWRA, Massachusetts Water Resources Authority Proposed Capital Improvement Program, Fiscal Years 1996-1998, December 30, 1994.

Figure 15: The Organizational Chart of LDE[54]



[54] Source: PMD - MWRA.

B. The Analysis of CM Alternatives

In early 1989, the PMD wanted to clearly define the role of the CM before the project moved into construction the spring of the same year. Eight different project management models which have been used for large projects were analyzed. The eight different project management models are described in the following[55]:

1. **Single Prime:** Two contracts with the owner are established, one with the architect/engineer(A/E) for design services only and one with a prime construction contractor(PC) who is responsible for all construction management services and contracts and is responsible for all other work being completed.

2. **Multiple Primes (AE as Owner's Representative):** Multiple contracts are established directly with the owner. The A/E's are responsible for design and construction management services and the PC's are responsible for their contracted construction work. This is the traditional way of procuring construction projects for many, smaller public agencies and is MWRA's current model.

3. **General Contractor as Coordinator:** Multiple contracts are established directly with the owner. The A/E's are responsible for design services only. The construction management services are provided by one PC who coordinates all construction work to be done by the other PC's who are contracted directly to the owner.

4. **CM as Owner's Agent:** Multiple contracts are established directly with the owner. The construction management services are contracted directly with the owner and provided by a firm(CM) specializing in construction management. A/E's are contracted directly with the owner and are responsible for design services. PC's are contracted directly with the owner and are responsible for their construction work.

5. **CM as independent contractor (without design):** Two contracts with the owner are established, the A/E contract and the CM contract. The A/E is responsible for design services. The CM contracts with all other PC's and performs all construction management services, does no work directly, and guarantees budget and schedule.

6. **CM as independent contractor (including design):** One contract with the owner and CM is established. The CM contracts with all the A/E's and PC's. The CM performs no work and performs all construction management services including design services oversight.

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[55] MWRA - Staff Summary to the Board of Directors, *Proposed Construction Management Model*, April 6, 1989.

7. **Owner design/manage:** The owner manages all A/E's and CM work and contracts with all the PC's.

8. **Turnkey Construction:** The owner establishes a contract where a PC is responsible for all financing, design, construction management services and construction. The PC owns the project until the project is complete and turns it over to the owner.

There is no definite and common standard to be applied in the selection of a project management structure. Rather, the nature and requirements of the respective construction project drive this selection. For the BHP, the PMD evaluated each of the eight alternatives against the criteria of

- size and number of contractual awards
- competitiveness and potential contractual opportunities (large number of contract awards encourages more competition)
- responsibility and delegation of PMD (the contractual responsibility to PMD and the level of authority PMD delegates to a construction management firm)

Based upon the above criteria, all eight models were examined[56]:

Model 1 requires bidding and award of a multi-billion dollar contract with one prime construction contractor. In order to meet Court Schedule requirements, fast-track construction was to be used and that required the design to be sequenced over time. Since the entire Deer Island Facilities design would not be ready for bid at one time, a single contractor seemed impractical. It would be nearly impossible to assemble a team with adequate bonding and thus competitive bidding would be severely limited.

Model 3 is similar to Model 1 but would allow the multi-billion dollar contract to be split into several contracts. This would allow for more competitive bidding and would allow staggered construction contract awards when designs were completed. The prime construction contractor is still responsible for all construction work and all construction management services. Limited authority is delegated. Many prime construction

[56] MWRA - Staff Summary to the Board of Directors, *Proposed Construction Management Model*, April 6, 1989.

contractors do not have the requisite skills to provide what would amount to construction management services and would likely require a joint venture to provide this service.

Models 5 and 6, like Model 1, required that the MWRA - PMD award a multi-billion dollar contract directly to either one, or a small handful of firms. A sequenced design again precluded this approach. Award to one or a small handful of firms severely limited competition. Models 5 and 6 offer the purest true construction management models but would leave the lowest level of PMD control. All PMD staff has been delegated to the construction manager in the case of Model 6, or to both the CM and the A/E's in Model 5. Model 6 offered the PMD the strongest managerial control to accomplish the Deer Island Facilities, since CM contratually received the sole source of responsibility. The key difference between the two alternatives is that in Model 6, the CM must include professional liability insurance to cover the A/E designs, which is a large risk for the CM to assume and insure; in Model 5 the A/E's and the CM are contractually independent, making the A/E's responsible for their designs and the CM an independent reviewer of the A/E's design.

Model 7 offers the highest level of PMD control, for under this model, the PMD maintains all authority, and does not delegate any control to another party. However, this model was eliminated, since it would require a very large PMD staff of highly specialized employees to be hired for the duration of the project. It was believed to be unreasonable to expect the MWRA to recruit the workforce needed to implement this model.

Model 8 was eliminated because it requires a change in current legislation to allow its use and because the high cost of the project would be very difficult for any prime contractor to bond and finance. Model 8 involves the award of a single multi-billion dollar contract to design and construct the facilities. Competition is limited as discussed in Models 1, 5 and 6. Also all authority is delegated, leaving the lowest PMD control. Current state laws do not permit turnkey construction in the absence of special legislation.

Only Models 2 and 4 meet all established criteria and were recommended for further analysis.

Model 2 is an approach typically used by municipalities and smaller public works projects, and is the approach currently used by the MWRA. This model does not delegate any authority to the construction manager (the A/E's) and the construction management is performed by the various A/E's, acting as the Owner's Representatives, with oversight by PMD staff.

Although adequate for needs in 1989, this alternative would present major problems with the envisioned multiple (20 to 30) A/E's involved in the Deer Island Project. There would be no consolidated responsibility within the A/E contracts for overall management and coordination. Each A/E would be responsible only for the construction services that would be associated with its respective projects. No single entity would be responsible for coordinating on-island construction with water transportation, busing, concrete batch plant operations, site security and safety, labor agreement administration, mitigation compliance, program schedule and budget, temporary construction facilities. Although the need for construction management was evident, no mechanism would exist to accomplish it.

A lack of an independent construction manager means that the A/E's function in the paradoxical role of defending their design while concurrently serving as the Owner's Representative, including inspecting the contractors' work, reviewing payment requests, and recommending the acceptance of work. The real construction management role would fall upon the PMD, requiring a large project-specific staff for the duration of the BHP construction. The traditional approach to construction administration would be a cumbersome model for managing the construction.

Model 4 provides the same contracting mechanism as Model 2 with the construction contracts awarded by the MWRA, but it also includes the role of a construction manager, acting as the Owner's Agent. The role of the A/E differs from that in Model 2. The A/E role during construction is limited to office engineering support, shop drawing review, and plan interpretation. Construction management services are provided by a firm specializing in construction management, the CM. The CM assumes the responsibilities as previously outlined in the "Required services of a Construction Manager" section of this document. Because all contracts are directly with the MWRA, only a limited amount of delegation is required.

Model 4 offered significant cost savings. In Model 2, where the A/E's are providing both office engineering and resident inspection (field services), a difference may or may not exist between office rates (overhead multipliers) and field rates. Many firms do not have field capabilities or field rates. With Model 4, the PMD can insist that only field rates be used. Cost savings were estimated to be in the order of $15 to $20 million by using Model 4, because all construction management services would be performed using project specific field rates. Therefore, it was recommended Model 4, the Construction Manager as the Owner's Agent, be chosen as the construction management method to coordinate the Boston Harbor Project construction.

To find about the appropriateness of an organizational structure, one must view from a standpoint of the achievement of stated goals, effectiveness and efficiency. There is also the issue of accountability. In each of these areas, the current project organization approach (PMD / CM / LDE) for BHP seems to be acceptable.

C. The BHP Staffing

The BHP's staffing approach uses a small number of highly qualified staff in a stand-alone organization (PMD), coupled with the extension of that staff through the use of the CM, LDE, and PDEs. The PMD manager organization mirrors that of the LDE and CM. For example, the PMD has an Engineering Manager who directly communicates with the LDE, while the Construction Manager and Controls Manager of the PMD mirror the CM organization.

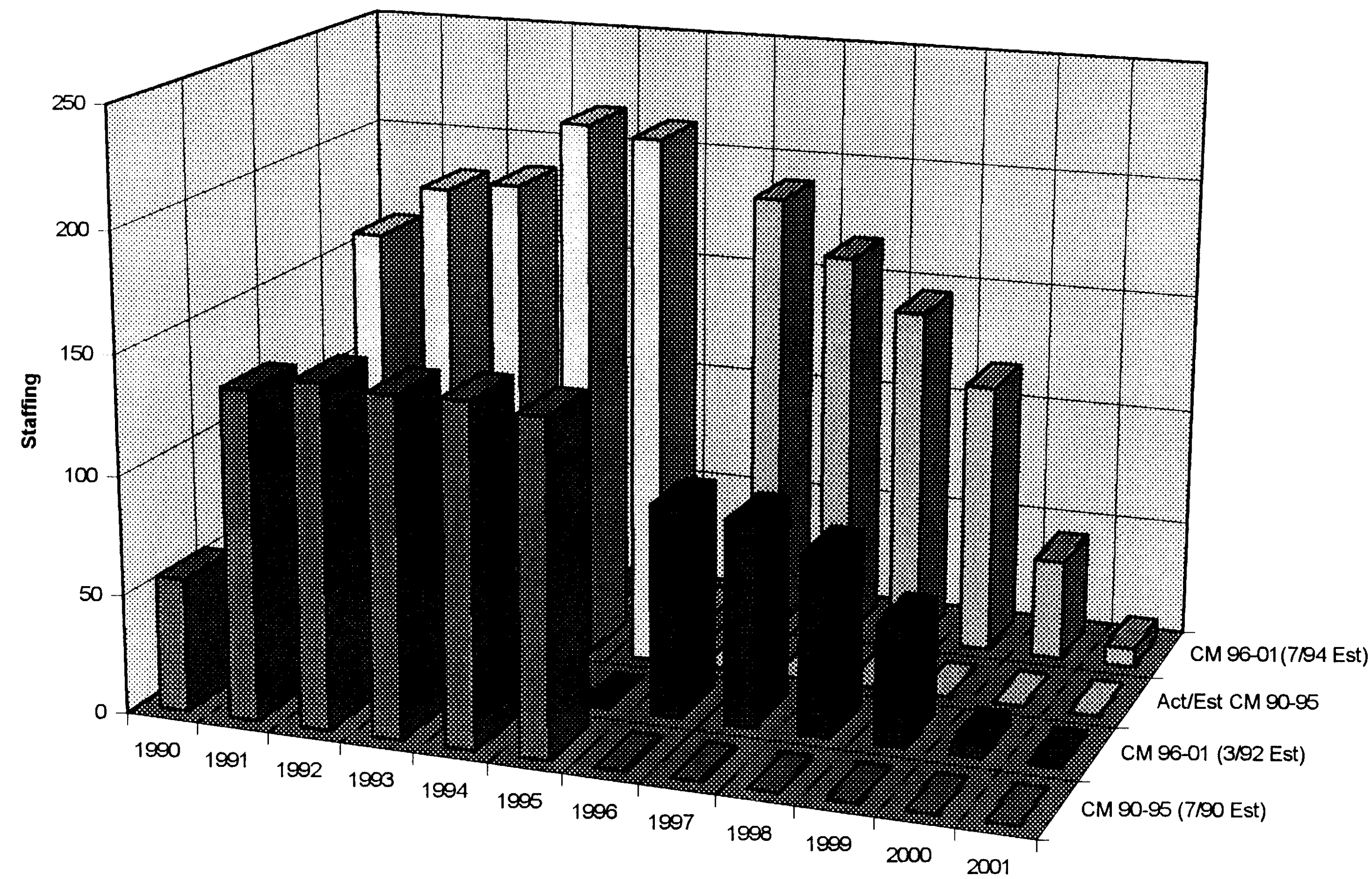
Support of the project is also provided by staff in other departments of the MWRA organization such as legal, purchasing and internal auditing. This approach meets the objectives set forth by the MWRA to streamline its staffing and optimize decision making by the MWRA.

The combined PMD, LDE and CM management staff for the Boston Harbor Project is approximately 350 persons (1994), with PMD at 46, the LDE around 5O and the CM at approximately 250. A review takes place annually for the purpose of determining the next year's staffing needs. CM Contract Needs Analysis - CM Services (92-95) Backup is an example of such a negotiation with the CM. Also, a long-term plan of the BHP linking staffing, operations, cashflow, and the reduction of the LDE, CM and PMD should be developed in order to better manage the BHP.

1. CM Staffing

The planning and forecasting in the staffing, especially for CM, seems to have caused some unexpected costs. The CM Services costs, for the period 1996 to 2000, have increased from a forecasted $38 million (FY95-97) to $74.5 million (Proposed FY96-98). The major reason, for this 96 percent increase, is the unforeseen staffing increases for CM. The Figure 15 shows the CM staffing analysis.

Figure 16: CM Staffing Analysis[57]



[57] Practical Experience, *Capital Planning and Budgeting, Finance Division, MWRA*, supervised by Miriam Maxian and Timothy Popejoy, 1994-1995.

D. Comparison to Other Projects

The "CM as Owner's Agent" form of construction management is commonly used in the municipal environmental sector. Professional oversight of construction, a second unit looking over the design product and a high level of project accountability of all project participants to the owner are made possible with this form. As a result, this form is used where public accountability is important and project complexity is of concern, such as in the Boston Harbor Project. The cities of New York, Milwaukee and San Diego each have large environmental projects and each has also used "CM as Owner's Agent" construction management.

According to the 1994 Management Review[58] of BHP (independent review commissioned by state) , a driving force in the level of effort exerted by an outside CM is the size and quality of the municipal environmental staff at the time the project is undertaken. In the case of San Diego, the city has an environmental program which is up and running; therefore, the outside staffing needs are not as great as those of the BHP project at its inception.

There is a high level of complexity in the Boston Harbor Project. The tunneling portions of this project are unique and very complex. Operations such as these require highly professional input and oversight. The policy of the MWRA to spread the construction work around within the local economy further complicates the project. There are currently more than 50 individual contractors and 3000 employees working on the site[59].

In the opinion of the Management Review, the BHP management structure compares favorably with other large governmental projects. Given the complexity of the

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[58] MWRA, *Management Review of the Boston Harbor Project*, prepared by KPMG Peat Marwick, May 1994.
[59] Source: PMD - MWRA.

project, and necessity of public accountability, the present structure was a sound choice. Further, when the efficiency rates of management personnel to million dollars spent on construction are compared with other municipal projects, the BHP project is efficient. See Table 3.

In order to determine efficiency of the project staffing levels, a comparative analysis was performed to compare the staffing levels per million dollars in total project costs for the Boston Harbor Project and the City of San Diego. The results of this analysis shows that the Boston Harbor project management staffing appears to be consistent with the San Diego project, although this project has nearly half the total cost of BHP. Table 5 shows the staffing comparison including the other largest construction project in the region: The Central Artery Project.

Table 5: The Staffing Comparison

	Total Project Cost	**Management Staff** (during construct.)	**Comparison Ratio***
BHP	$3.4 billion	450	0.13
San Diego Project	$2.0 billion	434	0.22
The Central Artery Project[60]	S7.7 billion	approx. 1200**	0.16

*** Comparison Ratio: Management Personnel per Million Dollars Project Cost**

**** This figure represent the design stage not the construction stage like the others, accordingly the ratio should rise as construction activity increases.**

[60] Information reported by the Massachusetts Highway Department for the Central Artery Project.

The ratio of PMD staff to the private sector units of CM and LDE is approximately one to ten. This comparison follows the objective of the MWRA in initially formulating the project management approach for this project. Each construction project and its owner have unique circumstances and objectives for developing the project structure and ratios. The ratio of one to ten on a municipal project is low according to the 1994 Management Review of BHP. The underlying reason is believed to be that other municipalities had large existing staffs prior to project initiation or a less intensive construction effort. This does not conclude that the one to ten ratio is incorrect. If one views the management of the CM and LDE as a professional development project, a 1 or 1.5 to 10 ratio is well within the industry standard for project management effort.

Table 6: Cost Comparison[61]

	Project Cost	Design as a % of Construction Cost	Management as a % of Project Cost
BHP	$3.4 billion	6%	10% Target* 9.1% in 1993
San Diego Project	$2.0 billion	9.4%	10.71%

* These numbers are taken from Figure 17 shown on the following page.

As shown in Table 6, the Boston Harbor Project costs compare favorably with the San Diego Project. According to the 1994 Management Review, the design costs as a percentage of construction costs are favorable and in line with industry standards. It should also be pointed out that even with design costs at this reasonable level, construction change orders to date are approximately 7.11%[62]. This is also within the industry standards for efficient municipal projects.

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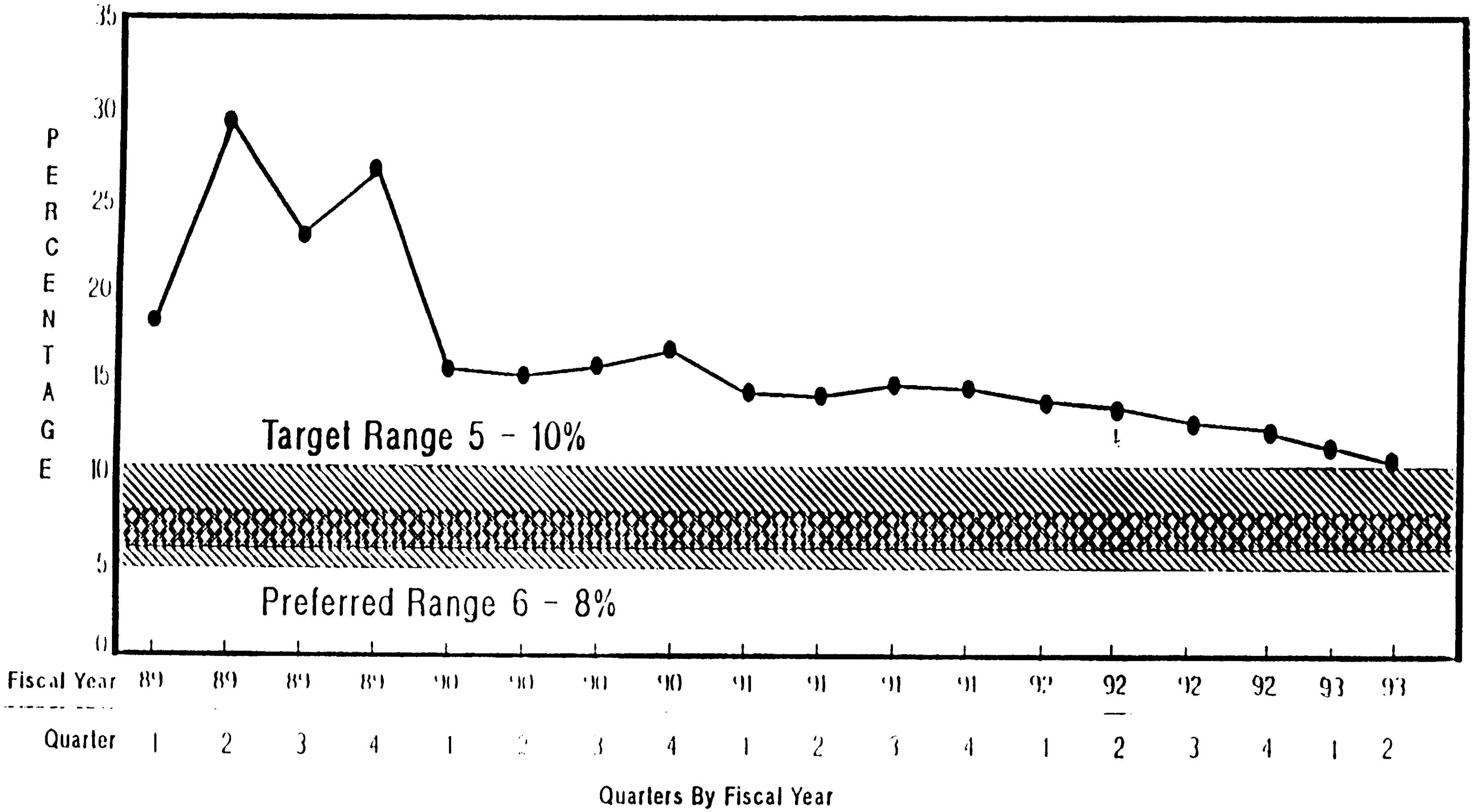
[61] Data adapted from MWRA, *Management Review of the Boston Harbor Project*, prepared by KPMG Peat Marwick, May 1994.
[62] MWRA, *Boston Harbor Project - 1994 Annual Report*, January 25, 1995.

Figure 17: Project Management Budget as a % of Cumulative Capital Cost[63]



[63] MWRA, *Boston Harbor Project - Annual Progress Report*, January 22, 1993.

E. Cost-Effectiveness of the Management Structure

With 92% of the project design completed and the project standing at 57.1% (as of December 1994) of overall completion, and contract awards (with 86.4% being awarded) averaging 12.8% below the engineer's estimate for the entire project, the project management structure seems to be functioning to achieve cost effective results. In the measurement of meeting its mission, the PMD has performed well and has met its goals. Except the two tunnels, construction progress seems to be under way and court imposed milestones have, to date (December 1994), been met. Significant and challenging completion milestones are upcoming in the following several months and years. Finally, costs have been within budget. Both the management structure of the project and its design and construction seems to be cost effective at the 57.1% completion level.

However, some of the most difficult areas of the project remain, as the PMD begins to close out construction contracts and typically, at the end of a contract, claims for additional compensation are made by the contractor. The tunneling operations have already proved of being areas of high liability and potential claims are expected. Careful monitoring of these activities should continue to be a central focus of the PMD.

IV. PROJECT MANAGEMENT

A. *Project Management Information Systems*

The MWRA has a documented system which uses the software; Kaiser Engineers Management System (KEMS) for scheduling, tracking and cost control and a CADD system for overall design development.

A wide variety of data and reports are provided by the management system. Each report has a certain distribution list and it appears that necessary information is provided to those who have project responsibilities for the items reported. Detail diminishes as the reporting moves up the management chain. Significant numbers of reports are prepared monthly which results in a large amount of documentation. The project is driven by a large Project Management Information System (PMIS), which meets industry standards. This system contains ten (10) subsystems covering the following functional areas[64]:

1. Project Controls System (Cost & Schedule)
2. Office Automation/Document Preparation System
3. Document Control System
4. Contracts Management System
5. Human Resources Information Systems
6. Master Equipment Reference System
7. Logistics Support System
8. Quality Assurance Support System
9. Risk Management Information System
10. PMIS Operation and Control System

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[64] MWRA, *Management Review of the Boston Harbor Project*, prepared by KPMG Peat Marwick, May 1994.

PMIS is a very detailed system of scheduling, cost and information control and is consistent with industry standards for managing a construction project. PMD's ability to respond quickly with data and reports for questions that are raised about the project plays an important role for the success of management.

The data generated by the project team are used to manage and direct the project. It enables the project team to anticipate problems before they occur and act to minimize the potential delays or extra costs on the project. An example of this approach is the MWRA's policy of requiring a recovery schedule from the contractor when the contract is 20 days behind schedule. Through KEMS, early finish and late finish curves are calculated and plotted for review by the project management team. As the construction progress curve begins to move in the direction of the late finish curve, the project team will more closely review construction progress. This focus serves to keep the contract on schedule. If the project begins to fall behind schedule, the PMD goes into a recovery mode posture. The recovery mode may be very simple, such as a meeting with the contractor, or very complex, such as appointing and organizing a recovery task force to return the project to schedule.

B. Project Control[65]

The Construction Manager is using an estimating, budgeting and project control system for the project. The system, if used properly, leads to a cost effective product. The BHP Program Management Information System (PMIS), as discussed earlier, is a collection of ten (10) computerized modules and procedures implemented by the Project Construction Manager (CM) to assist in the management of the construction process. The

[65] MWRA, *Management Review of the Boston Harbor Project*, prepared by KPMG Peat Marwick, May 1994.

"Project Management PMIS Handbook" describes the project control system module as follows[66]:

"Project Control Systems enable the project to provide cash flow (budget), estimate costs, update and maintain the master schedule and the construction baseline schedules, and prepare progress reports in compliance with federal court-ordered milestone dates and the MWRA's Board of Director's annual approved master schedule and project cash flow." Project Control Systems utilize the ICF-Kaiser Engineers proprietary Kaiser Engineers Management System software (KEMS) and the ICF-Kaiser Interactive Estimating System (IEST). Costs are controlled with IEST and schedules are controlled by KEMS. Cost data may be imported from IEST to KEMS. Costs are developed, tracked and maintained by the Cost Estimating subsystem and the Project Cash Flow subsystem. The cost estimating subsystem maintains, monitors, analyzes, forecasts and controls costs associated with the project. The subsystem is used to establish the baseline (first) budget, measure actual costs against the baseline, and identify deviations from the budget. The Project Cash Flow subsystem provides the project with a mechanism to plan for cash needs during the life of the project. It provides a prediction of the net flow of dollars into or out of the project. This subsystem also monitors progress by comparing actual expenditures against period estimates.

For project control, monthly reports are produced which bring together detailed cost information with physical progress. Deviations from forecast are identified and exception charts are produced. The construction budget awarded (as planned compared to actual) and construction cash flow (as planned compared to actual) is produced in graphic format.

Cost estimates are presently prepared by Kaiser for each stage of the project. These estimates should be used proactively by the design firms to assure that the estimates are working tools to refine design cost effectiveness as the project progresses. Figure 18 shows the engineer's estimate versus the bid price for construction contracts awarded. The

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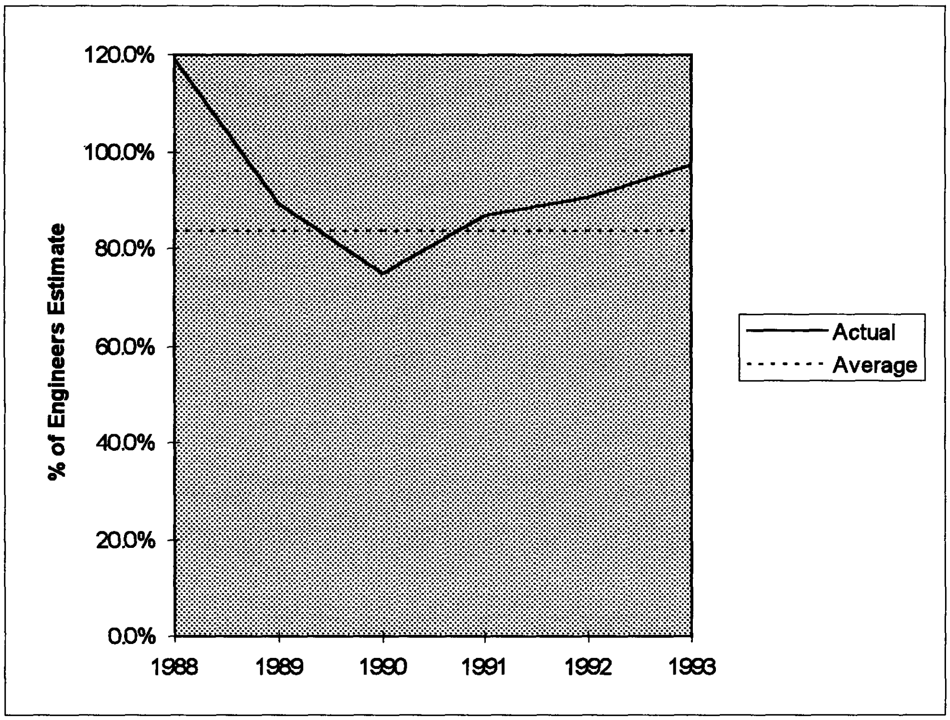
[66] PMD - MWRA.

average bid price is around 83% of the engineers estimate. From this graph it appears that the bids were lower than the engineers estimates during the years 1989-1993.

Figure 18: Engineers Estimate vs. Bid Price at BHP[67]



In the reporting format of the MWRA, the project costs are viewed on an annual basis with variances and causes shown in a year end report. These variances are not accumulated from year to year. This makes it difficult to see how much the Cost of a particular project contract package has risen from the original estimate. It was found that the data available does not easily report current project costs (estimates) compared to original concept costs or to design estimates. In order to better forecast project spendings, a document should be available which outlines the changes in the estimated project cost

[67] PMD - MWRA.

(by components of the project) showing original concept estimate, final design estimate and current construction cost estimates.

The contingency levels being carried on the BHP (FY95-97) are reasonable given the size and scope of the project. The contingencies for the non-tunneling, portions of the project drop from 12.5% for FY95 to 10% in the out years; while the tunnel portions carry 15%. Overall, these contingencies average to a level which appears appropriate at this stage of the project. As the BHP moves forward, these contingency levels should continue to be reassessed and adjusted as needed.

C. *Project Scheduling*

The CM does the scheduling and updating and PMD reviews them. The CM is using a scheduling subsystem of PMIS which provides the project with detailed project schedules for planning, monitoring, controlling, and charting the activities needed to achieve project goals and milestone set forth in the planning stage. The project schedule is used to generate charts, highlight critical paths, key project milestones, network logic, scheduling calculations, resource loading and leveling. PMIS is linked with the other information system KEMS (Kaiser Engineers Management System).

As stated earlier, on BHP, construction work is divided up into Contract Packages (CP). Each CP is bid and awarded through a competitive bidding process. Prior to award, the overall project cash flow uses the engineer's estimated value for the CP. After award, this is replaced by the amount of the successful bid. Once the CP is awarded, the master schedule is updated to reflect the successful contractor's schedule. Each Contract Package is controlled separately. The contractor provides a schedule of values and a detailed construction schedule, which are reviewed by CM staff. Once they are approved by PMD, the construction schedule becomes the baseline (first) schedule and the schedule of values become the original budget to the contract. All subsequent expenditures on the contract will be measured against the baseline (first) budget. The baseline (first) budget for the contract will only be changed by an approved change order.

The baseline (first) schedule is the main source of information used during the life of a contract package to predict project progress. The schedule is updated each period to reflect the current situation and the status as compared against the baseline (first). If the contractor falls significantly behind schedule (a month or more) he will be required to provide a recovery plan and schedule. This may include additional personnel, extra working hours (i.e., double shifts), or other measures designed to bring the contract back on schedule. A potential change order may be initiated requesting additional terms or an extension of the contract end date. The potential change order will be reviewed by PMD, and either approved or denied depending upon the circumstances.

As the contract progresses, cash flow reports and graphs are prepared. When change orders are approved, the effect can be seen in the variance columns of the cost reports. The additional funding requirement for the change orders is allocated as part of the change order approval process. Cash flow reports are prepared until the contract is complete and all costs of the contract are documented.

Progress measurement works clearly with both cost control and scheduling. If progress is falling behind, this can be an early indication that the baseline schedule may not be met or the budgeted costs may be increasing. The schedule is also used to predict progress goals for each project.

D. Value Engineering Program

ICF Kaiser Engineers prepared a value engineering program (VE) in the form of a "Guidance Document for Value Engineering Program" in March 1989. This document, following established EPA guidelines, sets out all procedures to be followed and provides guidelines for preparation of the report. Although current published guidelines state that VE reviews should take place at the 30% and 60% design stages, the PMD does reviews at design concept (0%) and 50% to better effect changes. This is not uncommon within the industry.

The VE program provides recommendations for change that will improve the life cycle costs of the project by construction package or group of related packages. VE also offers recommendations that may not affect cost but will result in a functionally improved facility, a more constructable facility, or a better maintainable facility. Several groups associated with the project review the VE recommendations including the PMD project manager, other members of the PMD group, MWRA Sewerage Division Operations and Maintenance personnel, the LDE and the PDE. Areas covered by the reviews include technical feasibility, effect on construction schedule, constructability and capital cost and life cycle cost implications. Comments from each review are included in the final Value Engineering Report for a particular construction package. A meeting is held to review the comments prepared by the reviewers and determine which recommendations are to be taken into account. Based on these data, the PMD project manager decides which recommendations are to be implemented. The decision to implement some recommendations could be deferred based on incomplete knowledge of future conditions or requirements to obtain approvals from regulatory agencies. Value engineering study results at the end of the implementation meeting indicate the status of recommendations. There has been no effort to revisit projects to determine whether or not pending decisions were ever implemented[68].

So far, there has been more than $250 million capital cost savings resulted through VE recommendations. VE savings opportunities on the BHP are also available through the use of value engineering change proposals (VECPs) which allow construction contractors to share in the savings from their accepted ideas.

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[68] MWRA, *Management Review of the Boston Harbor Project*, prepared by KPMG Peat Marwick, May 1994.

E. Change Order Process

1. Design Change Orders

The PMD receives a full description of the design change, its history and its project impacts. This is in the form of letters from the PDE and/or LDE to the PMD Design Project Manager. Included in the package are the construction cost and schedule impacts, future operations and maintenance impacts, and design budget and schedule impacts for each design change request submitted. This process is for design contracts, before bid, during bidding, and engineering during construction.

After receiving a review by the LDE PDE manager, PMD's Design Project (DP) Manager reviews the information and produces a "Design Change Request" form. The DP Manager justifies the change and approves all design changes which affect the PDE design schedule and budget. PMD's Project Controls group reviews and approves all design changes which delay the design schedule by more than one month and/or increase the construction cost estimate by more than $1 million.

As stated above, the PMD Directors of both Coordination and Control and Engineering must approve changes which will delay the design schedule by more than two months and/or increase the construction cost by more than $2 million. The Director - PMD must approve design changes that increase construction cost estimates by more than $4 million. Included in the review is the O&M Director/Manager to assure that O&M considerations are taken into account.

2. Construction Change Orders

The PMD has a documented construction change order process which meets accepted standards and provides for review of, as with the design change order process, necessary affected departments, and, limits of authority have been established for the approving persons. The construction change order percentage of slightly over 3% is considered good.

According to the BHP - 1994 Annual Report, the average time for processing change orders for construction was 100.9 days increasing From 96.1 days. The PMD staff pointed out that change orders are prioritized to expedite the most critical. It should also be noted that since claims usually result from unresolved change orders, there could be exposure to contractors from the cumulative effect of this processing time.

3. Change Order Management (by December 1994)

Since peak construction took place in 1994 and is expected to continue in 1995, aggressive scrutiny and management of change orders and claims are significant factors in controlling costs. There has been a significant increase in the volume of change orders processed at BHP. See Table 7.

Table 7: Executed Change Orders (1990-1994)[69]

Year	Change Orders Executed
1990	52
1991	126
1992	252
1993	237
1994	412
Total	**1079**

Due to concerns about increases in the time required to process change orders, a number of steps were implemented during early 1994 which were designed to streamline the change order process. A number of management initiatives, not requiring MWRA approval, were undertaken to reduce the change order processing time. These included procedures to expedite review and approval of change orders within the MWRA, as well as, conducting training sessions with PMD, Procurement, and CM staff to improve change order quality and minimize redrafting of change orders.

As a result of these changes, the average processing time on BHP change orders has declined despite a substantial increase in the number of change orders being processed. The average MWRA in-house processing time for BHP change orders decreased form 26.5 days prior to changes to 18.8 days after the implementation of changes, a reduction of 8 days (or 29.1 %).

The change orders as a percent of awarded value for construction contracts is below the target of less than 10% for the BHP. Table 8 shows a breakdown for completed and ongoing construction contracts as of December 31, 1994.

[69] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

Table 8: Construction Change Orders[70]

	Awarded Budget	% Increase Approved Change Orders	% Increase Pending Change Orders	Total % Change
Construction in Progress	$1,631,017,000	5.69%	1.71%	7.40%
Construction Completed	$276,503,000	6.20%	(0.76%)	5.44%
Total Project	$1,907,520,000	5.76%	1.35%	7.11%

F. Some Cost Control Techniques

The scale of the project and the financial burden it presents for local ratepayers provide the MWRA , as the owner of the project, with an overwhelming mandate to control the cost of BHP. The following approaches have been adopted to achieve control over BHP's costs[71]. These approaches exclude the project management structure's and other project management roles in cost control since they have been discussed in other sections of this thesis.

1. The Role of CADD System

One of the major factors in controlling design costs is the creative application of computer assisted design and drafting (CADD) technology. Standardization is enhanced by the use of a single CADD system to be used by all designers and to serve eventually as the management information system by which the operating facilities are managed. The

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[70] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

[71] Armstrong, Walter G., Deputy Director, Program Management - MWRA, *Controlling the Costs of the Boston Harbor Project*, The 1990 National Construction Management Conference, September 25, 1990.

MWRA took an aggressive step in determining that a single CADD system would be used by all designers and furnished the requisite hardware and software to the firms. According to the former Director of MWRA, Paul Levy, this was the first time on a major sanitary engineering project in the US that a single CADD system was used[72].

This unusual step was motivated by the desire to achieve the following advantages: (1) timely completion of design by facilitating the use of multiple designers; (2) ensuring consistency of design and quality control while using multiple designers; (3) tapping the resources of design firms throughout the nation in order to complete the massive design effort within the highly constrained timetable; and (4) creating the information system for the ongoing management of the completed facilities.

2. Project Promotion

Competition has been enhanced through project promotion. A special effort has been made to make design and construction firms aware of upcoming opportunities associated with the Boston Harbor Project. A quarterly newsletter, Harbor Prospects, is produced especially for potential bidders. The centerfold of the newsletter provides a complete list of the design, construction and construction support contracts with information as to the bid date and the estimated contract value. More than five thousand copies are distributed to interested parties.

In addition to the newsletter, an annual contractors' forum has been held to provide information on the upcoming contracts. Special forums also have been held for small and local contractors and for contracts that require specific expertise such as water transportation, concrete supply and the construction of the project's tunnels.

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[72] Interview with Mr. Paul Levy, Executive Director of the Massachusetts Water Resources Authority 1987-1992, December 1994.

3. Stabilizing Construction Support Costs

a) Water and Bus Transportation

The cost of BHP exceeds that of comparable wastewater plants because of the location of its facilities on a peninsula to which road access has been severely reduced in order to mitigate the construction impacts on the neighboring community. As part of the Project's mandatory environmental mitigation requirements, the MWRA must move at least fifty percent (50%) of the total workforce to the site by ferry and the remainder by bus from a remote parking site. In addition, construction vehicles, equipment and materials with the exception of eight trucks per day - must be transported to the site by water.

The water transportation system consists of ten vessels making movements between five terminals. The fleet is composed of two barges, two tugboats, five passenger ferries and a water taxi. Today, during the peak period of construction activity, two barges each make twice daily trips across the harbor transporting a total of 90 trucks. The personnel ferry system transports 1200 workers and operates around-the-clock, six days per week during the project's most intense period of activity in 1994. As many as 30 busses transport another 1,200 workers per day.

To stabilize the cost of the transportation system, three separate contracts (barge, personnel ferry and bus transportation) were bid each for a five and one-half year term. The bids were let in a particularly poor economic climate for the maritime industry and prior to bids requiring similar services for the other major local public works project, the Central Artery/Third Harbor Tunnel. As a result, MWRA managed to lock-in the cost of its transportation system, except for a fuel escalation clause, for a five and one-half year period.

b) Concrete and Power

The on island location of the wastewater treatment facilities requires that a concrete batch plant be present on-site and that electric power be delivered on-site.

The contract for the supply and delivery of concrete is an essential project component, with almost one million cubic yards of concrete needed for the facilities. Given the environmental requirements restricting truck traffic and the remote location of the island, an on-site single source of supply was necessary. Given the fact that the supplier was, in effect, being given a monopoly, bidders were asked to set fixed unit prices for various types of concrete. The fixed price would be used by all purchasers of concrete for the duration of the construction. Inflationary escalation in the supplier's cost over the project duration will be offset by quarterly escalation payments made directly by the MWRA according to a formula based on the index provided by the Engineering News Record.

The arrangements made by the Authority to obtain construction and long-term electric power supply were even more innovative. The MWRA entered in an agreement with the local utility, Boston Edison under which the company would supply power to Deer Island by financing, through a new subsidiary, the construction of a submarine transmission cable from the mainland to substation facilities on Deer Island. This arrangement is a departure from the standard practice which is to require an up-front payment in full from the customer before construction of any substantial new facilities that are required solely for service to the customer. This arrangement provided savings to BHP, because it avoids the substantial tax liability which an upfront payment in full would create for Boston Edison. Under Massachusetts Utility Policy, Boston Edison would have required MWRA to reimburse the company for this liability.

The contract is estimated to have saved the BHP a minimum of $3.3 million, in 1990 dollars. It provides the BHP a guaranteed cost ceiling of $46 million for the submarine cable, and thus avoids the risk of construction cost increases. Any construction cost savings on these facilities generated by a required value engineering review would be split by the MWRA and Boston Edison. In addition, the proposal avoids financing on MWRA's part. Payment for the facilities is spread over a 25 year period. Finally, the contract secures power for BHP at very favorable rates compared to those charged to Boston Edison's other large customers.

4. Labor Harmony

In formulating the labor relations policy for BHP, the most significant concern was the avoidance of delay. Any delay in the construction schedule will significantly increase the total cost of the Project. 1990 estimates were that a one week delay in construction would result in a $2,000,000 increase in costs.

Labor disputes have a particularly significant potential for causing delay because of the geographic limitations involved. As a result of the close proximity of the workers on the job site and the common use of buses and boats, any disputes can spread quickly throughout the project. Similarly, picketing at the limited number of access points, such as the personnel ferry sites and barge transportation terminals, also has the potential to disrupt the Project.

To respond to this potential problem, the CM entered into a Project Labor Agreement[73] that ensures labor harmony with more than 15 International and 25 local unions represented by the Building and Construction Trades Council of the Boston Metropolitan District. The Project Labor Agreement is designed to avoid delay by assuring, to the extent legally and practically possible, that labor disputes will not occur. Moreover, if they do occur, the Agreement contains procedures to resolve disputes quickly and efficiently. The Agreement establishes written rules for the employment of all construction workers and standardizes certain working conditions for all workers (such as work hours and travel

[73] MWRA, *Boston Harbor Wastewater Treatment Facilities Project Labor Agreement*, May 22, 1989.

allowances). The Agreement contains a 10-year, no-strike guarantee from the unions which prohibits all of the employees covered under the Agreement from striking, picketing or other disrupting the Project.

Although Project Labor Agreements have been used in major construction projects in the United States during the past 25 years, the Boston Harbor Project Labor Agreement is the first negotiated in the Boston area and among the few involving publicly sponsored construction projects.

G. Other Project Management Issues

1. Facility Management

Current MWRA plans call for the facilities on Deer Island, once operational, to be staffed and maintained in full by MWRA personnel. This raises the question whether opportunities for cost savings exist through privatization of facility operations.

None of the large and complex municipal environmental projects (comparable to BHP) across the country seems to have completely privatized day-to-day operations or have even privatized significant portions of their operations; except the sludge disposal portion, which has already been privatized in BHP. A number of smaller projects, on the other hand, have privatized operations, either entire operations or portions. There are several reasons why privatization has been pursued for smaller operations. For any operation, regardless its size, there is a need to keep up with training, certification, and regulatory requirements, which are sometimes difficult for smaller municipalities and authorities to manage. Therefore they usually turn to private firms which have the appropriate resources in these areas.

Some opportunities exist for privatization within the facilities on Deer Island of BHP. Specific portions of the facility might be applicable to privatization; for example, laboratory, facility upkeep and custodial maintenance, training, and administration support services. In order to explore whether savings could be achieved from privatization in any of these areas, the conduct of a specifications and bid process is required. Such a process would generally entail development of detailed specifications of the needs and requirements of the specific area under consideration, followed by the MWRA and private sector companies bidding on the area of work. Through this type of process, it could be seen whether significant savings could be achieved through the use of the private sector or if the MWRA is competitive enough.

2. Mitigation Agreements

Mitigation agreements between the MWRA and various municipalities and other public entities cause part of the costs of BHP. Mitigation agreements, largely, are entered into to provide compensation for interruption or inconvenience caused by the MWRA to a concerned party in order for the project to continue on a timely basis. Approximately $55.5 million in mitigation costs are expected during the BHP duration (1988 to 2000).

Two of the concerned parties are the Towns of Winthrop and Quincy. As part of the effort to mitigate the decision to site a wastewater-treatment plant at Deer Island, the MWRA agreed to pay $25 million in cash[74] to the Town of Winthrop, since the Deer Island peninsula is attached to the town. The second controversial site, a plant to process sludge from liquid form into pellet fertilizer used in agriculture, is located on a former shipyard in Quincy. This site is no more popular with local residents than the treatment plant has been in Winthrop. The mitigation agreement with Quincy provides the city with payments of $2 million a year as compensation for hosting the plant.

[74] Armstrong, Walter G., Director, Program Management - MWRA, *The Boston Harbor Project*, The American Public Works Association, August 31, 1992.

Perhaps the most contentious siting was the MWRA's effort to place a landfill for grit and screenings on a 94-acre plot next to a state prison in Walpole. That landfill would also take sludge in cake or liquid form in the event of malfunction at the sludge-processing plant. The siting process for the Walpole landfill lasted five years, and was finally resolved in 1991. Or so the MWRA thought. However, Governor Weld's incoming administration urged the MWRA to reopen the siting process to ensure that other locales in and out of state were given due consideration. In August 1993, the Walpole Landfill was set aside. The commercial landfill capacity is substituted for a planned MWRA-owned landfill in Walpole.

3. One Step Permitting

An One Step Permitting agreement exists between the Department of Public Safety and the MWRA, dated May 22, 1991, for the purpose of "a coordinated, expedited and prioritized process for the review, approval, permitting, licensing, inspection and enforcement of all construction related matters within the exclusive jurisdiction of the Department of Public Safety."[75] In order to staff the Department of Public Safety to provide this expedited process, the MWRA prepaid $1.5 million in permit fees, with a planned total of $3.5 million to be paid. To date, One Step Permitting has not been implemented. According to the MWRA, it is not obligated to pay the balance, $2 million, if the program is not implemented.

Delays in permitting has the potential to delay the overall construction schedule. Obtaining occupancy permits in a timely manner, probably caused some difficulty for the MWRA as Milestone 7 (Complete First Two Primary Batteries) approached to finishing early 1995. Generally, these permits are not applied for until construction is substantially complete. Some finished units, such as the Pilot Plant, have temporary occupancy permits.

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[75] PMD - MWRA

H. Some CM Analyses from the 1994 Annual Progress Report[76]

This last section includes first the analysis on the progress of one the most important milestones of the project, completion of the outfall tunnel. The outfall tunnel along with the inter-island tunnel are the two parts of BHP where extensive delays already took place and more delays are expected due to the difficulty of the work. The progress on the outfall tunnel could affect the project's outcome significantly in terms of both the cost and the schedule.

The other three analyses of safety, construction quality and regional benefits are also included in this section due to their importance in BHP since the project's is very unique with a timeframe of more than 10 years and a cost of more than three billion dollars. It employs a great number of workers where the safety becomes an even more important issue than a regular construction project and where the impact on the local economy and the engineering society is substantial.

1. Analysis of Milestone # 10 (Outfall Tunnel)

The Effluent Outfall Tunnel is a 9.5 mile tunnel which will convey treated effluent through a series of 55 risers and diffusers, which were completed in November 1992. By the end of December 1994, the General Contractor (GC) has advanced 28,677 feet of the total 49,677 feet to be mined[77]. In 1994, the GC mined a total of 13,446 feet and reached the 5-mile mark on December 1, 1994.

In the first half of the year, the GC improved mining operations, increasing average weekly production. Subsequently, in June 21, 1994, the GC ceased work due to general

[76] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.
[77] The mining started on Deer Island advancing out to the already built risers and diffusers at the discharge point.

safety concerns raised in the aftermath of the Inter-Island Tunnel fire[78]. Production was stopped by an Abatement Order issued by Boston Fire Department for approximately two months and mining did not resume until September 9th, after a number of safety recommendations were implemented and a second Abatement Order was addressed. Table 9 shows the monthly Tunnel Boring Machine (TBM) advancements since production resumed in September 1994.

Table 9: TBM Advancements[79]

Month	Linear Feet
September	1,212
October	956
November	879
December	1,672

During the year, PMD has met with senior management from the firms constructing the outfall tunnel to discuss matters of construction quality and productivity with the goal of achieving a higher and more consistent rate of progress and improved quality standards. The outfall tunnel is currently forecasted for completion in mid to late 1997.

2. Safety

Construction safety is one of the top priorities in the management of BHP. The contractors and the CM have the following responsibilities for implementing a successful

[78] On June 15, 1994, the vertical conveyor system was destroyed by fire and power was lost to the pumps, and the tunnel flooded. Damage from the fire and flooding were extensive. Most of the electrical and communication systems were damaged. Mechanical equipment had to be rebuilt. The dewatering, restoration, and construction effort continued from June 15 until September 6, when mining operations resumed.
[79] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

safety program. Construction contractors who directly employ craftworkers have the primary responsibility to provide a safe work site and ensure that all activities are conducted in a safe manner. The CM has a responsibility to coordinate safety on a site-wide basis. It may issue stop work orders and has the authority to remove any personnel who refuse to comply with safety standards. To enhance safety awareness the CM conducts monthly site safety inspections, performs mock drills, and distributes monthly safety statistics. Table 10 compares BHP safety statistics with national safety statistics compiled by the US Department of Labor.

Table 10: Labor Safety Statistics[80]

	Lost Time Incidence Rate (Frequency)	Days Lost Incidence Rate (Severity)
Boston Harbor Project	4.80	152.1
National Average	6.48	150.4

Overall, the 375 lost time injuries compares favorably to the national average in terms of the frequency of injuries, with the frequency of lost time injuries on BHP approximately 258 below the national average, but slightly exceeds the national average in terms of the severity (days lost) of lost time injuries. While 79.28 of the injuries have been of a minor nature (contusions, lacerations or strains), the days lost associated with these injuries are slightly greater than the national average. The Days Lost Incidence Rate has decreased dramatically over the past six months when the previously reported Days Lost Incidence Rate was 190.4. This is attributed to more aggressive efforts by general and lower tier subcontractors in pursuing the timely return of injured workers, as well as, successfully implementing other methods to reduce the lost days incident rate. PMD

[80] MWRA, Boston Harbor Project - 1994 Annual Report, January 25, 1995.

continues working with the BHP contractors and suggesting ways to further reduce their rates.

In December 1994, the contractor and crew for the water transportation system received a nation-wide union award for compiling the best safety record in the nation. This safety record is a national best for Local 25 of the Maritime Trades Division of the International Union of Operating Engineers. The ferries have carried more than 2 million passengers since 1990 without an injury.

3. Construction Quality

Building quality in from the start is a critical element of BHP. The tight sequencing of multiple contracts on a small site, the need to ensure that the completed facilities would meet the requirements of state and federal law, and dependence on building quality into each facility as a cost control measure (as opposed to inspecting it in after it is completed) made quality assurance/quality control (QA/QC) an essential management goal.

While contractors have primary responsibility for construction quality control on the project, the CM oversees construction activity to insure that it is performed in compliance with the PMD's quality criteria. The CM's Quality Department has reviewed 33 general contractor quality control programs for application to 40 construction contracts. 89 quality audits have been performed on CM, contractor, subcontractor, and vendor quality-related activities. These consist of 82 audits on BHP construction activities, and 7 audits on vendor manufacturing and fabrication activities. Out of a total 18,500 observations made during the 82 construction site audits only 1,557, approximately 8.4%, identified items which were unsatisfactory and required contractor correction.

4. Regional Benefits

In December 1989, the Board of Directors of MWRA approved a Buy American/Buy Massachusetts policy. As of December 1994, 87 of 101 (86%) of the prime construction contracts for the project have been awarded to local Massachusetts firms. In addition, 86.7% of the subcontractors are local Massachusetts firms. These awards have had favorable impacts on the economy by providing jobs for both construction firms and local manufacturing and supply companies.

During construction, the Boston Harbor Project is generating a significant amount of economic activity within the Boston metropolitan area, in terms of increased sales, employment, personal income, and tax revenues. By the end of 1994, over $2 billion have been expended on engineering, construction, and related contracts and total expenditures exceed $3 billion. More than half ($1.6 billion) of total project expenditures will be purchased within the Boston metropolitan region. These expenditures will include hiring construction and support workers, purchasing materials and equipment from local suppliers, and the procurement of engineering and other services from firms within the region. The $1.6 billion in project spending which remains in the Boston metropolitan area will generate an additional $1.4 billion in economic 'spin-off' activity within the region, resulting in a total local economic impact of $3 billion. In total, the project will generate $1.9 billion in income to households within the Boston metropolitan region in the form of wages and other forms of personal income.

During construction, the project will directly create an average of 1,500 full and part-time jobs each year. These jobs will be in construction, engineering and professional services, and industries supplying construction materials and equipment to the project. The project is expected to generate an average of 900 additional jobs per year in indirect and induced employment, resulting in an average total employment impact of 2,400 jobs per year.

Finally, the increase in local economic activity resulting from construction of the Boston Harbor project will generate an estimated $130 million in additional sales and income tax revenues for the Commonwealth of Massachusetts.

CONCLUSIONS

As construction of the Boston Harbor Project reaches its halfway mark, there seems to be an effective overall management of the Boston Harbor Project. Despite the complexity of wastewater facilities construction, the challenge of constructing these treatment facilities on a very small and isolated peninsula, possibility and existence of extreme winter conditions, and the aggressive milestone-based Court schedule, the project is close to budget and generally close to schedule. The major problem for the construction schedule is the delays in the two tunnels. Although more than usual contingency factors were initially taken into account, the progress on the two tunnels fell significantly and they are around two years behind schedule beyond the limit of any risk factors.

The most important and visible proof of good construction management is controlling the costs. Since the cost of BHP presents a significant financial burden on local residents and businesses, it becomes the most important concern of any person or party associated with the project. In a project where the cost of delay is estimated to be $2 million per week[81], the ability to keep on schedule is a critical cost control factor. Contributing factors in maintaining the schedule include the ability to expedite regulatory reviews, the use of a master schedule by which to carefully monitor progress and identify slippages, and the commitment of organized labor to maintain labor harmony through the use of a project-wide labor agreement.

Creative and imaginative design, planning and management also have contributed to cost savings. Design costs are running below the industry standards, partly due to the adoption of project-wide design standards and the successful application of CADD. Value engineering reviews have saved significantly on conceptual designs. Constructability and operability reviews also yield savings after the construction progressed.

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[81] PMD - MWRA.

Substantial costs savings also have been generated by extremely competitive construction bids. Contributing factors for the competitive bids include the regional slowdown in the construction industry, combined with the PMD - MWRA attempts to maximize competition through an aggressive outreach program and by desegregating the Project into smaller, discrete construction contracts. In addition, the PMD worked on reducing bid contingencies by collecting a substantial amount of geotechnical data and including risk-sharing provisions in its construction contracts. However, this has not worked for the case of the outfall tunnel. Additional cost savings were also reached from an aggressive project-wide safety program conducted by the CM, as well as CM's rigorous construction inspection program.

To continue with an effective overall management during the remaining half of the project is not a simple task. The different members of the BHP team, the PMD of MWRA, the CM and the LDE, must use he best and most up-to-date construction management techniques available. However, experience in many large and complex projects has shown that, after planning the best of all construction projects in the best of all possible worlds, the BHP organization adjust their planning and expectations for the world they live in: For the halfmark date, Boston in 1995. In those cases where the planning fails to anticipate the "real world" they live in - as is the case of the tunnels - the BHP organization team must be ready to respond to external issues, e.g. political issues, as they rise, and to adjust its plans and expectations accordingly. Rigidity has no place in construction management.

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Appendix A: The Design and Construction Packages[82]

PROJECT SCHEDULE & COST ESTIMATE
($000)

FMS Sub Phase	Contract Number		VENDOR	Begin Date	End Date	Total Contract Amount	Projected Payments Thr. FY95	Remaining Balance 6/30/95
	14 D.I. PRIMARY & SECONDARY TREATMENT FACILITY							
FACILITIES PLANNING								
17981	5540	Surveying		Jul-85	Jul-85	15	15	0
18621	5526	Facilities Plan	CDM	May-86	May-88	16,518	16,518	0
		Project Total:				16,533	16,533	0
SITE FACILITIES CONSTRUCTION								
18020	5536 CP-020	Asbestos Rmvl Ft Dawes-SPS	Dec - Tam	Jun-89	Jan-90	518	518	0
18021	5599 CP-021	Demo Ft. Dawes Bunkers	J.M. Cashman	Aug-89	Apr-90	4,617	4,617	0
18022	5601 CP-022	Earthworks/Lndfl/Roadwys	J.M. Cashman	Jan-90	Nov-91	17,107	17,107	0
18023	5600 CP-023	Pump Sta Mods & Sewers	Modern	Jan-90	Nov-90	5,713	5,713	0
18024	5740 CP-024	Admin/Lab:Maint/Whse/Trn&Supt Hs	Modern	Apr-92	Nov-94	48,186	48,186	0
18027	5728 CP-027	Maint Shops Facil. Ph. I	Sciaba	Sep-91	Apr-92	265	265	0
18028	5841 CP-028	Maint Shops Facil. Ph. II	J.M. Cashman	Dec-91	Sep-92	1,970	1,970	0
18030	5640 CP-030	Disposal of Excess Till	J.M. Cashman	Aug-90	Dec-91	14,137	14,137	0
18040	5739 CP-040	DI Demo/Late Drumlin Excv	J.M. Cashman	Dec-91	Jun-94	16,905	16,905	0
18042	5481 CP-042	* Remov of Temp Facilities		Jun-88	Jun-2000	702	34	668
18043	5474 CP-043	* Site Prep/Dem Exst Trmt Plnt	Modern	Feb-94	Mar-97	36,611	20,254	16,357
		* Western Shoreline Protection		Aug-96	Mar-98	15,617	0	15,617
18044	CP-044	* Final Paving and Landscaping		Jun-98	Dec-99	20,195	0	20,195
18045	CP-045	* Dry Storage Building		Dec-96	Dec-98	3,847	0	3,847
18049	5719 CP-049	Hazardous Mtl Rem Ph I	Tricil	Jun-91	Jun-94	7,429	7,429	0
18050	5729 CP-050	* Hazardous Mtl Rem Ph II	Enviro Waste	Apr-94	Apr-96	2,896	1,854	1,042
18051	CP-051	* Hazardous Mtl Rem Ph III		Feb-96	Feb-98	2,385	0	2,385
18905	5537 CP-905	* Supply & Del. Consrete	Boston S&G	Apr-90	Dec-99	13,423	6,298	7,125
18430	5633	Int. Xfmr. & Switchgear	Lasden/WESCO	Sep-89	May-90	216	216	0
25923	5649 CP-805	D.I. Sludge Transfer Fac	Sciaba	Aug-90	Sep-91	4,514	4,514	0
		Project Total:				217,253	150,017	67,236
PRETREATMENT & PRIMARY CONSTRUCTION								
18101	5707 CP-101	North System Tunnels	Kwt/Atkn/Knny	Dec-90	Jul-92	20,578	20,578	0
18102	5722 CP-102	* North Main Pump Stations	J.F. Whte/PKF	Jun-91	Sep-95	76,127	66,929	9,198
18103	5720 CP-103	North System Headworks	Britta/O'Cnnll	May-91	Dec-94	95,205	95,205	0
18104	5733 CP-104	South System Pump Station	Dick Corp	Nov-91	May-95	40,005	40,005	0
18105	5700 CP-105	Primary Clarifier Bttrys A&B	Gust Newberg	Mar-91	Dec-94	99,673	99,673	0
18107	CP-107	* Gallery (CP-24 & Pri X-Gal. W)		Jul-96	Jun-99	1,108	0	1,108
18130	5742 CP-130	Primary Clarifers Bttry C&D	George Hyman	Mar-92	May-95	83,632	83,632	0
18151	5541 CP-151	* Inter-island Tnl/Ext Otfl	Hearly/Modern	Apr-91	Jul-96	103,135	81,375	21,760
18152	5850 CP-152	* Nut Isl. Headworks	Modern/SAE	Jul-92	Dec-96	64,396	43,618	20,778
18153	5639	Nut Island HW Equip	Southworth Mach	Mar-91	Mar-92	347	347	0
18160	5454 CP-160	* Ancil. D. I. Mods Ph. I		Jan-95	Dec-95	9,942	4,347	5,595
		Project Total:				594,148	535,709	58,439

* denotes project phases included in the proposed three year capital budget.

[82] MWRA, Massachusetts Water Resources Authority Proposed Capital Improvement Program, Fiscal Years 1996-1998, December 30, 1994.

PROJECT SCHEDULE & COST ESTIMATE
($000)

FMS Sub Phase	Contract Number		VENDOR	Begin Date	End Date	Total Contract Amount	Projected Payments Thr. FY95	Remaining Balance 6/30/95
SECONDARY CONSTRUCTION								
18201	5743 CP-201	Permanent Pilot Plant	Peabody	Dec-91	Sep-94	11,826	11,826	0
18202	5484 CP-202	* Secondary Reactor Bttry A&B	J.F. White/PKF	Nov-92	Aug-96	112,748	85,809	26,939
18203	5492 CP-203	* Secondary Clarifier Bttry A&B	J.F. White/PKF	Aug-93	Jul-97	142,725	69,066	73,659
18204	5744 CP-204	* Disinfect Fclty Ph I/Seawall	Newberg/Walsh	Aug-92	Jul-95	41,120	40,720	400
18205	5604 CP-205	Water Storage Tank	R. Zoppo	Dec-92	Dec-94	9,016	9,016	0
18210	CP-210	* Ancil D.I. Mods Ph II		Jun-95	Apr-96	2,430	313	2,117
18241	5544 CP-241	* Disinfect Fclty / Hydro Plant Ph. II	Walsh	Jul-93	Jul-96	35,866	29,888	5,978
18242	CP-242	* Disinfect Facility Ph. III		Feb-96	Mar-98	12,598	0	12,598
18260	CP-260	* Secondary C Reactor and Clarifier Bttry		Dec-96	Jun-99	135,265	0	135,265
18270	5548	* Prepurchase		Jun-93	Jul-96	959	642	317
18282	5637 CP-282	* Effluent Outfall Tunnel	Kwt/Atkn/Knny	Aug-90	May-97	209,529	165,993	43,536
18283	5638 CP-283	Effluent Outfall Diffusers	Cashman/Intrb	Aug-90	Nov-92	77,065	76,842	223
18285	5724 CP-285	Effl Otfl Tnl Muck Proc&Disp	Pr&Cashman	Sep-91	Nov-94	15,732	15,118	614
18286	CP-286	* Effl Otfl Tnl Muck Proc&Disp PHII		Nov-94	Jun-97	6,900	1,380	5,520
		Project Total:				813,779	506,613	307,166
ON-ISLAND RESIDUALS CONSTRUCTION								
18301	5723 CP-301	Res Trt Fac Ph I Pri A,B,C&D	Perini/Eastern	Aug-91	Jun-95	199,620	196,985	2,635
18303	5493 CP-303	* Res Trt Fac Ph I Sec A&B	Hyman	Oct-93	Jul-96	97,703	49,620	48,083
		Project Total:				297,323	246,605	50,718
PERMANENT UTILITIES CONSTRUCTION								
18401	5615 CP-401	* Off Island Water Line	LinGioioso	Jan-93	Jul-95	16,157	16,157	0
18427	5710 CP-427	Mn 13.8 Swgr,Bld&Dist/Yd Util	Sciaba	Jun-91	Jan-95	20,858	20,858	0
18428	5745 CP-428	* On-Site Power Plant for DI	BECo	Jan-93	Nov-95	62,174	59,913	2,261
18431	5768 CP-431	BECO CTG	BECo	Oct-94	Dec-94	31,721	31,721	0
18450	5546 CP-450	* Instrumentation & Cntrl Ph 1	Bailey	Dec-92	Oct-99	20,345	11,539	8,806
18460	5590	* Facility Information System		Dec-92	Dec-99	7,848	5,945	1,903
18452	5589 CP-452	* Plant Communication System	Fschbch&Moore	Jan-93	Oct-99	10,217	7,859	2,358
		Project Total:				169,320	153,992	15,328
CONSTRUCTION SUPPORT SERVICES								
17979	5964	* Technical Assistance		Apr-90	On-Going	374	374	0
18429	5711	* Construction Power	Boston Edison	Jan-90	Jun-2000	7,511	5,027	2,484
18940	5746	* Construction Water @ D.I.		Jul-91	Jun-97	615	615	0
18425	5458	Interim Utilities	Indeck Power	Oct-94	Jun-95	3,455	3,455	0
18901	5516 CP-901	Construction Spport Bldg	Sciaba	Sep-90	Jul-91	4,067	4,067	0
18902	5696 CP-902	Construction Rds & Utilities	Welch	Nov-90	Jan-92	5,123	5,123	0
18903	5695 CP-903	Fuel Facility	Sciaba	Oct-90	Sep-91	1,665	1,665	0

* denotes project phases included in the proposed three year capital budget.

PROJECT SCHEDULE & COST ESTIMATE
($000)

FMS Sub Phase	Contract Number		VENDOR	Begin Date	End Date	Total Contract Amount	Projected Payments Thr. FY95	Remaining Balance 6/30/95
18904	5692 CP-904	Fuel Supplier I	Grimes	Jul-90	May-92	126	126	0
18920	5866 CP-920	* Fuel Supplier II	Taylor Oil	Jun-92	May-96	50	39	11
18924	CP-924	* Fuel Supplier III		May-96	Dec-99	44	0	44
18909	5609 CP-909	Security I	N.E. Security	Oct-89	Oct-90	198	198	0
18917	5715 CP-917	Security II	N.E. Security	Nov-90	Dec-92	1,196	1,196	0
18930	5498 CP-930	Security III	Bview Security	Dec-92	Dec-94	1,304	1,304	0
18935	CP-935	* Security IV	Wackenhut Sec	Dec-94	Nov-96	1,534	345	1,189
18942	CP-942	* Security V		Oct-96	Dec-99	2,022	0	2,022
18910	5698 CP-910	Site & FRSA Maintenance	Sciaba	Oct-90	Nov-92	1,898	1,898	0
18931	5506 CP-931	Site & FRSA Maintenance II	Sciaba	Nov-92	Nov-94	2,831	2,831	0
18936	CP-936	* Site & FRSA Maintenance III		Nov-94	Nov-96	2,687	642	2,045
18943	CP-943	* Site & FRSA Maintenance IV		Aug-96	Dec-99	4,151	0	4,151
18911	5697 CP-911	Trash Disposal DI/FRSA	D&E/Jet	Jul-90	Jul-93	852	852	0
18933	5844 CP-933	Trash Handling & Disposal II	Vining	Jun-93	Jun-95	1,033	1,033	0
18938	CP-938	* Trash Handling & Disposal III		May-95	May-97	889	75	814
18944	CP-944	* Trash Handling & Disposal IV		Mar-97	Dec-99	698	0	698
18912	5699 CP-912	Off-Site Maint & CSB Hskp	Capital	Dec-90	Jan-93	205	205	0
18934	5511 CP-934	Off-Site Maint & CSB Hskp II	Sunshine	Feb-93	Feb-95	336	336	0
18939	CP-939	* Off-Site Maint & CSB Hskp III		Feb-95	Feb-97	332	61	271
18945	CP-945	* Off-Site Maint & CSB Hskp IV		Dec-96	Dec-99	470	0	470
18950	5747 CP-950	Construction Support Labor	Sciaba	Aug-91	Aug-92	735	735	0
18951	5520 CP-951	Const. Supt. Labor Ph. II	Zoppo	Aug-92	Jul-93	3,992	3,992	0
18952	5463 CP-952	* Const. Supt. Labor Ph. III	Zoppo	Jul-93	Jul-95	6,176	5,614	562
18953	CP-953	* Const. Supt. Labor Ph. IV		Jul-95	Jul-97	6,000	0	6,000
		* Construction Services		Aug-95	Sep-96	2,000	1	1,999
18960	5538 CP-960	Const. Supt Labor - Electrical	Fschbach&Moore	May-93	May-95	986	986	0
18961	5539 CP-961	* Const. Supt Labor - Plumbing	Patrick Kennedy	Jul-94	Jul-96	594	308	286
18962	5543 CP-962	* Const. Supt Labor - HVAC	HVAC Engr, Inc	Apr-94	Apr-96	429	216	213
18963	CP-963	* Const. Supt Labor - Ch. 149 Ph. II		Mar-96	Mar-98	750	0	750
18922	5717 CP-922	Ofst Snw Rltd Serv&Aspht Swp	Boston Zgrvng	Oct-90	Nov-92	134	134	0
18932	5530 CP-932	Ofst Snw Serv & Aspht Swp II	Boston GravDoc	Nov-92	Nov-94	682	682	0
18937	CP-937	* Ofst Snw Serv & Aspht Swp III		Oct-94	Oct-96	497	114	383
18946	CP-946	* Ofst Snw Serv & Aspht Swp IV		Aug-96	Dec-99	773	0	773
18913	5536BCP-913	Rodent Control	A-1	Jul-89	Jul-91	34	34	0
18919	5736 CP-919	* Rodent Control II	A-1	Sep-91	Sep-95	133	130	3
		* Rodent Control III		Sep-95	Dec-99	133	0	133
		Project Total:				69,714	44,413	25,301

CONSTRUCTION MANAGEMENT

18601	5535	P/CM Services	Kaiser	Apr-88	Dec-90	18,354	18,354	0
18602	5622	* CM Services (90-95)	Kaiser	Aug-90	Dec-95	171,104	141,233	29,871
		* CM Services (96-2000)		Jan-96	Dec-2001	74,514	0	74,514
18635	5455	* CM Add. R.I. (94-2000)		Jan-94	Aug-99	17,114	935	16,179
18603	5751	* Facilities Training	M & E	Jul-90	Jun-2000	3,575	1,870	1,705
18604	5496	* Project Offices	Flatley	Jul-88	Jun-98	6,083	5,039	1,044
18605	5889	Mgmt Support Services	HP	Jul-88	Dec-90	505	505	0
18606	5482	Consultant Computers	HP	Nov-88	May-94	600	600	0
18609	5488	Job Training		Jul-90	Sep-93	2,392	2,214	178
18611	5611	Legal Lien Fees		Jan-89	Jun-93	63	63	0
18612	5483	* Professional Services		Oct-89	Jun-2000	4,992	3,065	1,927
18613	5635	* Insur Gen Liab	Johnson Higgins	Jan-90	Jun-2000	3,246	1,083	2,163

* denotes project phases included in the proposed three year capital budget.

PROJECT SCHEDULE & COST ESTIMATE
($000)

FMS Sub Phase	Contract Number		VENDOR	Begin Date	End Date	Total Contract Amount	Projected Payments Thr. FY95	Remaining Balance 6/30/95
18614	5636	* Insur. Builders Risk	Alex & Alex	Jan-90	Jun-2000	5,839	1,457	4,382
18631	5734	* Insur Marine Liab	Johnson Higgins	Jan-90	Jun-2000	1,152	281	871
18616	5553	* Risk Management	Tallinghast	Sep-88	Jun-96	922	608	314
18620	5606	* Labor Agree. Admn. Serv.		Jan-90	Jun-2000	3,078	2,344	734
18623	5713	* Permit Fees	DEP	Jan-90	Dec-95	707	554	153
18624	5752	Outfall Admin		Aug-90	Apr-95	3,017	1,257	1,760
18625	5753	* Outfall Permits		Jul-90	May-97	100	0	100
18626		* Outfall Start-Up		Dec-96	Jun-98	10,000	0	10,000
18630	5754	Winthrop Easements		Jan-93	Mar-94	1,000	1,000	0
18632	5748	* Building Permits		Jul-91	Jun-98	3,500	2,098	1,402
18633	5749	* Misc. Facil Support		Sep-91	Jun-2000	3,466	1,926	1,540
18404	5457	Winthrop Road Reconstruction				1,602	1,602	0
18646	5581	MBE/WBE Assistance		Jul-94	Jun-95	250	250	0
18634	5865	* Construction Safety		Apr-92	Dec-95	1,330	1,087	243
18640	5694	* FO/RO - Rolling Stock	Hampden Engr	Mar-93	Jun-96	4,586	2,168	2,418
18641	5714	* FO/RO - Furnishings		Mar-93	Jun-96	949	814	135
18642	5730	* FO/RO - Shop & Maint. Equip.		Mar-93	Jun-96	1,592	1,578	14
18643	5761	* FO/RO - Lab. Equip.		Mar-93	Jun-96	2,526	953	1,573
18644	5762	FO/RO - Audio/Visual/ Supplies		Aug-93	Mar-95	149	149	0
18645	5763	* FO/RO - Misc. Fit Out/Supplies		Mar-93	Sep-96	2,552	1,363	1,189
		Project Total:				350,859	196,450	154,409

LEAD DESIGN SERVICES

18500	5534	* LDE Services	M & E	Aug-88	Jun-96	77,732	73,377	4,355
18607	5487	Cadd I	McDnnelDouglas	Aug-88	Mar-93	5,475	5,475	0
18629	5721	* Cadd II	McDnnelDouglas	Jul-89	Jun-99	3,554	1,419	2,135
18608	5486	Geotechnical Services	Warren George	Jan-89	Dec-89	9,707	9,707	0
18541	5575	* Engineering Svcs During Constr		Apr-93	Dec-99	15,724	6,864	8,860
		Project Total:				112,192	96,842	15,350

SITE FACILITY DESIGN

18501	5528 DP-1	Early Site Prep	Bryant	Oct-88	Mar-89	3,174	3,174	0
18507	5489 DP-7	* Support Buildings Ph.I	Tsoi/Kobus	Sep-90	Apr-92	6,570	6,570	0
18527	5629 DP-27	D.I. Haz Waste Eng Svcs	HMM Assoc.	Feb-90	Sep-93	2,805	2,805	0
	DP-34	* D.I. Haz Waste Eng Svcs II		Jul-97	Jun-99	1,080	154	926
		Project Total:				13,629	12,703	926

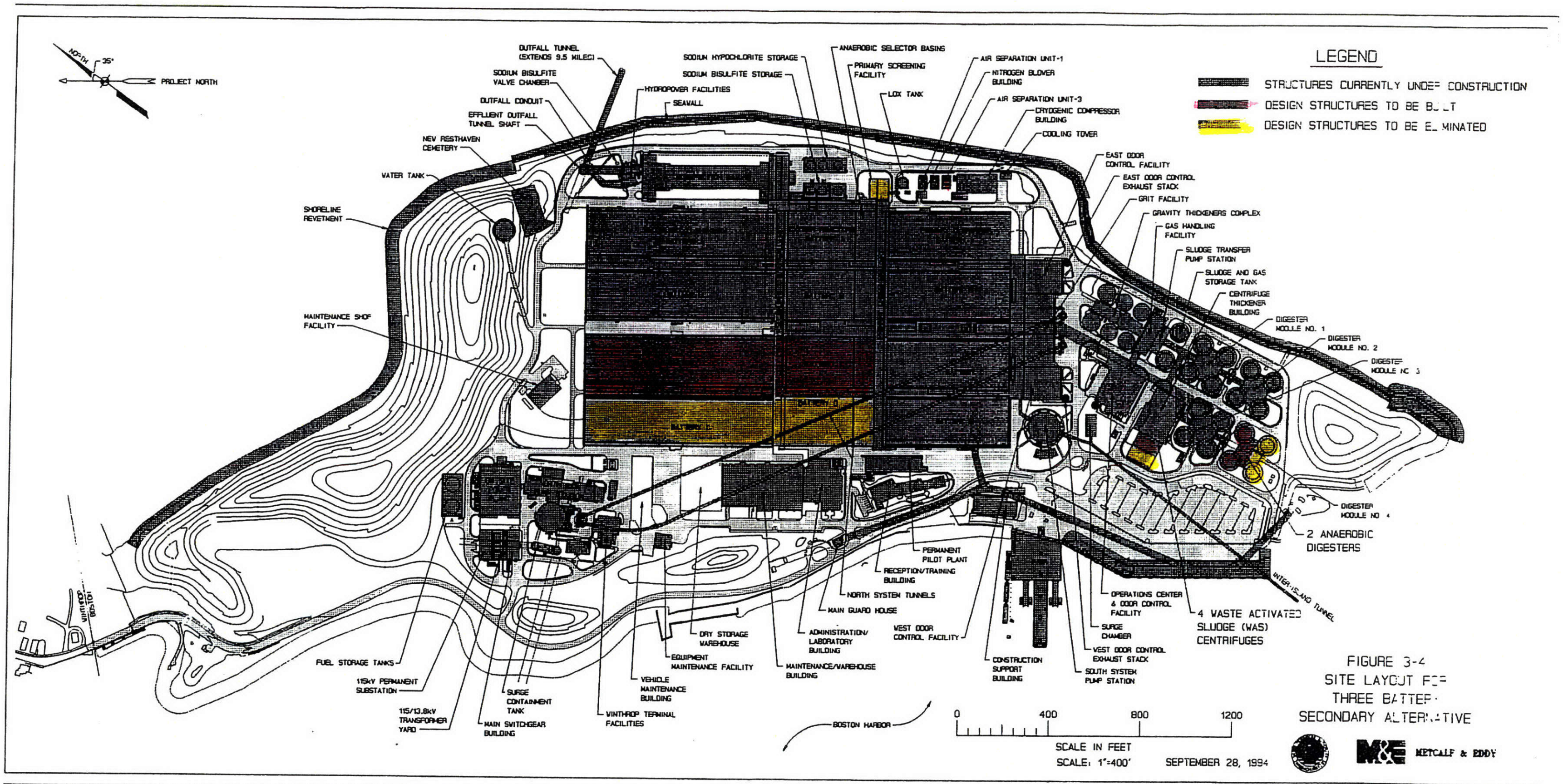
* denotes project phases included in the proposed three year capital budget.

PROJECT SCHEDULE & COST ESTIMATE
($000)

FMS Sub Phase	Contract Number		VENDOR	Begin Date	End Date	Total Contract Amount	Projected Payments Thr. FY95	Remaining Balance 6/30/95
PRETREATMENT & PRIMARY DESIGN								
18504	5532 DP-4	Nut Island Headworks	Havens&Emers	Jun-90	Sep-91	7,752	7,447	305
18505	5494 DP-5	Inter-Island Tunnel	Sverdrup	Feb-89	Oct-90	4,421	4,208	213
18509	5529 DP-9	Primary Phase I	Malcom Pirnie	Jun-89	Oct-91	8,444	8,444	0
		Project Total:				20,617	20,099	518
SECONDARY DESIGN								
18506	5531 DP-6	Effluent Outfall Tunnel	Parsons	Feb-89	Nov-90	8,269	8,269	0
18538	5570 DP-38	Ancil. D. I. Mods Design	Sverdrup	Apr-93	Dec-94	3,162	3,162	0
18519	5603 DP-19	Pilot Plant	CDM	Jun-89	Feb-90	425	425	0
18528	5701 DP-28	Sec. Treat. Fac. Ph. 1&2	Malcom Pirnie	Jan-91	Mar-95	25,806	23,741	2,065
18529	5585 DP-29	Sec. Treat. Fac. Ph. 3	CDM	Jan-94	Dec-94	2,498	2,498	0
	DP-40	* Sec. Treat. Fac. Ph. 4		Jan-95	Jun-96	16,970	2,817	14,153
		Project Total:				57,130	40,912	16,218
ON-ISLAND RESIDUALS DESIGN								
18513	5608 DP-13	Residuals Phase I	Black&Veatch	Nov-89	Mar-91	10,436	10,436	0
18514	5738 DP-31	Res Proc PH I DSDC	Havens&Emers	Oct-91	Jun-95	5,806	5,806	0
18516	5758 DP-32	Res Proc Ph IA	CDM	Jun-90	Jun-95	6,980	6,259	721
		Project Total:				23,222	22,501	721
PERMANENT UTILITIES DESIGN								
18503	5624 DP-3	Elec Distr Facilities	R.W. Beck	Feb-90	Dec-90	3,459	3,459	0
18523	5612 DP-23	Pwr & Hyd Plnt/Desl Tnk	R.W. Beck	Oct-90	Jul-92	14,534	14,534	0
18525	5630 DP-25	Plant I & C and Commun.	EMA	Jun-90	Jun-92	7,821	6,279	1,542
18534	5485	Rev/Chel/Win Util. Line	R.W. Beck	Apr-94	Dec-94	3,668	3,668	0
		Project Total:				29,482	27,940	1,542
CONSTRUCTION SUPPORT SERVICES DESIGN								
18522	5607 DP-22	Const. Support Facil.	Lin Assoc.	Aug-89	Jun-90	1,216	1,216	0
		* D.I Design Services		Mar-95	Mar-96	750	127	623
		Project Total:				1,966	1,343	623
		PROJECT TOTAL:				2,787,167	2,072,672	714,495

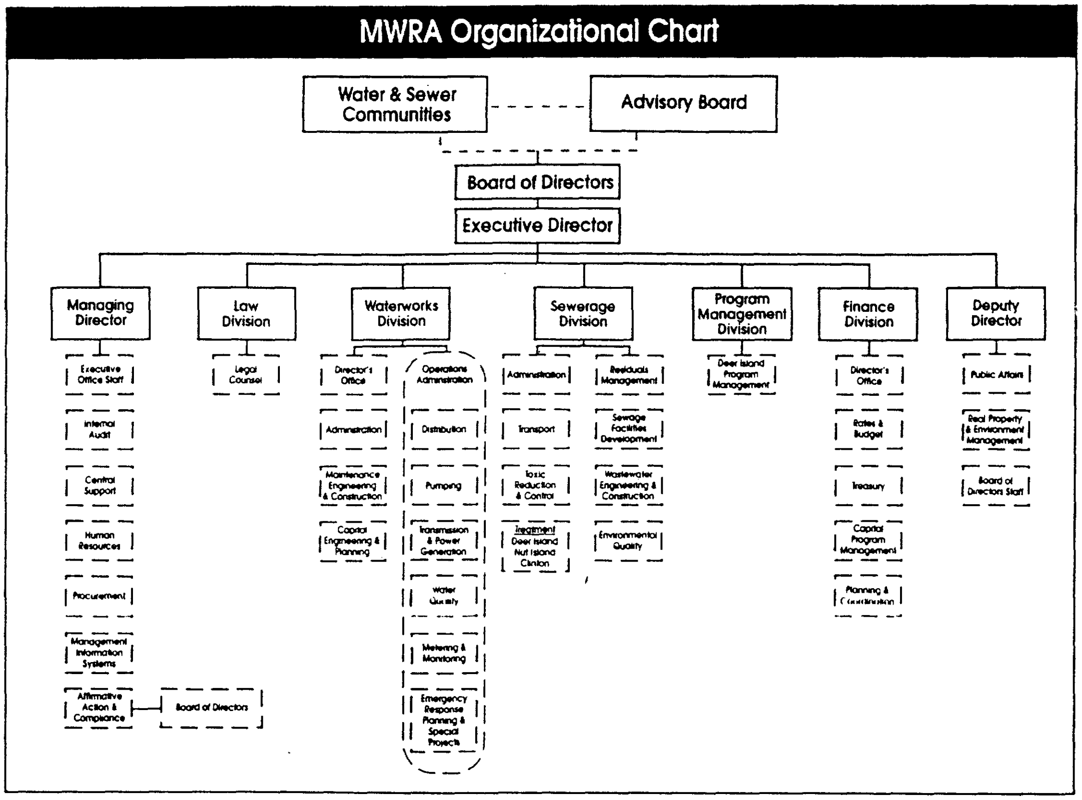
* denotes project phases included in the proposed three year capital budget.

Appendix B: Second. Treatment Facilities Recommendation for Sizing[83]



[83] MWRA, Secondary Treatment Strategies, Draft System Master Plan, prepared by Metcalf & Eddy, September 1994.

Appendix C: MWRA Organizational Chart[84]



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[84] MWRA, A Five Years Progress Report for the Years 1990-1994, December 31, 1994.

Appendix D: Summary of CM Contract[85]

Major elements of the CM scope of work are summarized below:

Program Support, which includes a variety of project management-related activities. These include project management, project controls, information systems, contracts management and administration, public information, risk management and insurance, and job training.

Construction Management, which includes those services directly and indirectly related to all Boston harbor Project construction activities. The CM will provide construction and site management, resident engineering and inspection services, contract bid support, logistical management, facilities management and support of Deer Island construction facilities, and industrial relations and safety management. Resident engineering and inspection services for contracts issued through 1991 are only included in this contract. Other required resident engineering personnel will be obtained through additional procurements and will either be contracted directly to the CM or directly to MWRA. In both cases, the CM will manage and coordinate the activities of all the project's resident engineering and inspection activities.

Quality Assurance/Quality Control, which includes the development of and management of an overall Boston Harbor Project quality assurance / quality control program. The CM will also provide design review services in constructability, operability and value engineering areas. Survey and field coordination, regulatory support, mitigation compliance and environmental compliance services will also be provided by the CM.

Technical Support, which includes engineering support and coordination services with design engineers during construction and start-up phases of the project. The CM will provide shop drawing administration services, record drawings, operation support and management of a limited number of design activities.

[85] PMD - MWRA.