Managing the Boston Harbor Project

A "modular" approach is one key to managing a large-scale project with a wide range of impacts that is conducted under severe time, siting and budget constraints.

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The Boston Harbor Project is one of the largest public works efforts ever undertaken in New England 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 $3.4 billion dollars when completed at the end of this century. The new facilities will treat the wastewater generated by 2.5 million residents and over 5,000 industries in the Boston metropolitan area.

In 1985, the newly-formed Massachusetts Water Resources Authority (MWRA) started the siting and facilities planning process for these new wastewater and residuals treatment facilities. Part of that process was to establish a management structure to oversee further planning, design and preliminary construction.

Within months of its creation, the MWRA was sued in federal district court by the U.S. Environmental Protection Agency for noncompliance with the Clean Water Act. U.S. District Court Judge A. David Mazzone found that the wastewater released into the harbor did indeed violate the law. The MWRA and the court parties entered into negotiations that resulted in a schedule for the new treatment facilities which was issued in 1986 (see Figure 1).

Management Structure

To provide the management capability necessary for a project as complex as the Boston Harbor Project, the MWRA created a team comprising three major entities: one was from in-house and two were from the private sector.

In 1988, the MWRA created a Program Management Division (PMD) outside its existing sewer management structure to focus exclusively on the Boston Harbor Project. Competitive salaries and the exciting nature of the job resulted in the recruitment of a talented group of managers with extensive private sector experience in wastewater engineering and construction management.

In addition, the MWRA conducted a competitive bidding process for a construction manager (CM) and a lead design engineer (LDE). The MWRA felt that hiring private sector firms would bring a number of benefits to the project, including staff with broad experience in managing major projects and handling

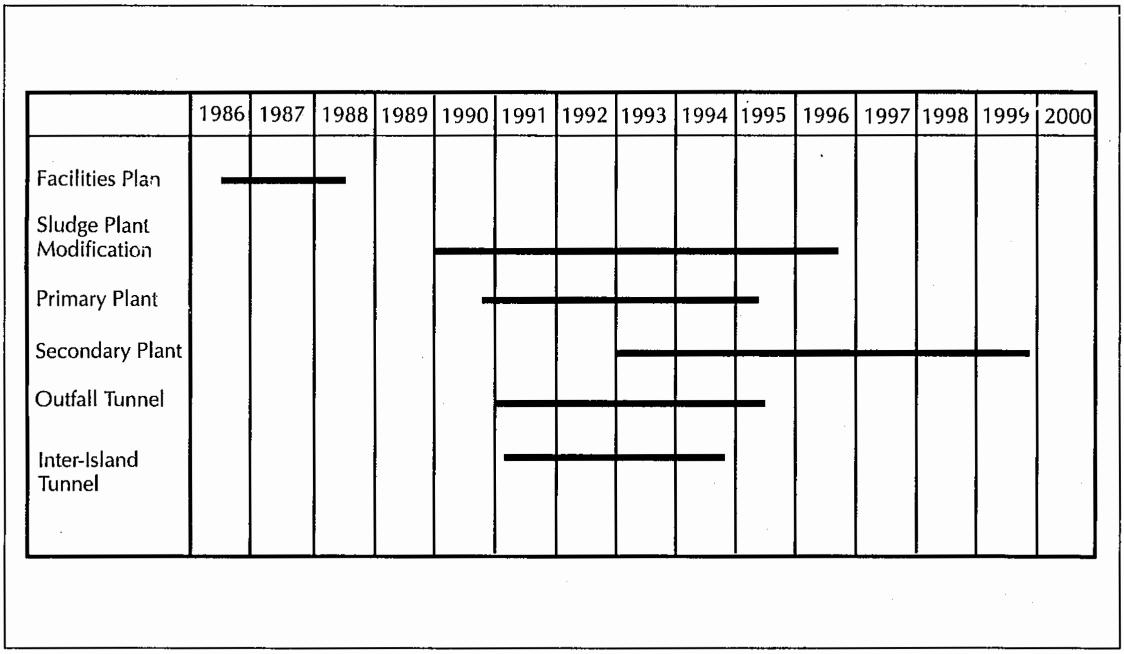

FIGURE 1. The court-ordered schedule for the Boston Harbor Project.

tried-and-true systems. These firms would have the management tools needed for such a project already in place. Another benefit of hiring in the private sector was that staff levels could be adjusted more freely as portions of the project were completed.

The MWRA's PMD acts as the policy and oversight group, while day-to-day construction management and design tasks are handled by the project's CM and LDE.

The CM is responsible for scheduling, cost estimating, cost control, resident engineering and inspection, public information, quality control, safety oversight, permitting, water transportation, value engineering, pre-purchase of equipment, facility testing, startup and staff training. The CM also provides technical support for agency decisions regarding contractor selection, change orders, progress payments and final acceptance.

The responsibilities of the LDE include conceptual design and management of the detailed design of the new plant (which is broken down into 29 detail design packages), the detailed design of some of the elements of the new wastewater treatment plant (including parts of the primary treatment plant, utilities, roads, landscaping, earthwork and berms), and management of the design of other components of the project.

The Project

The Boston Harbor Project is a massive undertaking. The actual design and construction of the project involves the execution of 29 design contracts as well as 87 construction and construction support contracts. All activities must be scheduled, coordinated and tracked to minimize delays relative to the court-ordered schedule as well as to control costs.

The centerpiece of the project is a new primary and secondary wastewater treatment plant with the capacity to handle a peak flow of 1.3 billion gallons a day. This plant is being built on Deer Island, a 210-acre site that forms the northern edge of Boston Harbor, approximately five miles from downtown Boston. The site was an actual island until a storm in the late 1930s filled in a narrow strait of water, Shirley Gut, and joined the island to the mainland by a thin strip of land. The fact that only a single, narrow road connects Deer Island to Winthrop greatly limits access to the island.

The Boston Harbor Project also includes a new headworks, or screening facility, being built south of Boston on Nut Island, a peninsula connected to Quincy. Wastewater from the Nut Island headworks will be conveyed north to the Deer Island treatment plant via a 4.5-mile-long, 11-foot-diameter deep-rock tunnel, one of two deep-rock tunnels in the project. Another tunnel, 9.5 miles long and 25 feet in diameter, will carry treated effluent into the deep waters of Massachusetts Bay where it will be dispersed into the ocean through a series of 55 riser pipes. Sixteen egg-shaped sludge digesters, each as tall as a 15-story building, are being constructed on Deer Island. Two intra-island tunnels completed in 1992 on Deer Island will bring wastewater from communities north and west of Boston (now being treated at the existing plant) to the new plant for treatment.

One of the most important components of the project began operating at the end of December 1991. A processing plant at the Fore River Staging Area in Quincy is now turning 60 tons of sludge a day into pellets that are marketed as a soil conditioner. The startup of the plant allowed the MWRA to meet a federal requirement, with a week to spare, to end sludge dumping in coastal waters.

Management Approach

The MWRA's PMD, the CM and the LDE hit the ground running. During the first two years of the project, contracts were signed with nearly two dozen design firms and the design of all the components of the new wastewater treatment facility, except the secondary plant, got under way. The team devised several strategies to answer the challenges of the project.

Packaging Construction Tasks. Construction contracts were packaged to create maximum price competition and to provide opportunities for small local firms to bid on project work. Various facilities (such as the concrete batch plant, fuel facility and roads) were required to support the construction. The project was subdivided into 87 construction and construction support packages:

- 48 packages of less than $10 million;
- 17 packages between $10 and $25 million;
- 10 packages between $25 and $75 million;
- 6 packages between $75 and $100 million; and
- 6 packages in excess of $100 million.

Breaking up construction into a number of contracts has allowed work to begin in sequence once designs were completed. Because of the accelerated schedule mandated by the court, the MWRA could not wait until the entire plant was designed before beginning to advertise for construction.

To further encourage local, small-firm participation, the CM held regular contractors' forums during the first two years of the project and published a newsletter, *Harbor Prospects*, to keep the contracting industry informed about the project.

Permitting. Any environmental project (and especially one of this size) involves extensive permitting. In order to keep the project on its tight schedule, the CM and designers worked with regulatory agencies to expedite their reviews. Permitting schedules were incorporated into the overall program schedule. Applications were consolidated into logical packages. Also, all permitting activities were coordinated through the construction management team.

Even with all that extra effort, however, the application process has not been entirely smooth. Since the approval process could take such a long time, permits might not be available at the time of the contract award (thereby causing delays for the contractor). To solve this problem, permit applications are generated at approximately the 90 percent design completion stage rather than at design completion.

However, early application presents its own set of problems. In addition to the permitting of any changes made to the design after the 90 percent stage, there may be regulatory changes as well as changes in site conditions. The Boston Harbor Project will take place over more than ten years, and a great deal can happen during that time. In 1991, for example, two hurricanes caused significant damage to a seawall and sedimentation ponds on Deer Island. Proposed repairs had to be permitted before work to repair the damage could begin, thus causing unforeseen delays.

Computer-Aided Design & Drafting (CADD). A single CADD system was implemented for use by all designers. This system was also to serve as the project information system to manage operations and maintenance of the completed facilities. The MWRA furnished CADD hardware and software to all Boston Harbor Project design firms. The decision to have a single CADD system was motivated by the desire to:

- Achieve a timely completion of design by facilitating the use of multiple designers;
- Ensure consistency of design, design details and quality control while using multiple designers;
- Tap the resources of design firms throughout the nation in order to complete the design effort within the extraordinarily tight timetable; and,
- Create an information system for the operation and management of the completed facilities.

Project Labor Agreement. A project labor agreement was negotiated with the Building and Construction Trades Council of the Metropolitan District to ensure that the harbor project would not be interrupted by labor disputes. The CM felt that this was a critical need because delays could jeopardize the ability to meet the schedule and increase the cost of the project. To date, with millions of hours of work already put into the project, no time has been lost because of labor disputes.

The implementation of the agreement was not accomplished without problems, however. The MWRA was sued by Associated Builders and Contractors which maintained that federal law prohibits public agencies such as the MWRA from requiring contractors to abide by the terms of such an agreement as a condition to being awarded a contract. The First Circuit Court of Appeals concurred. The MWRA then appealed to the U.S. Supreme Court. In the spring of 1993, the Supreme Court decided in favor of the MWRA. In addition to protecting labor harmony on the Boston Harbor Project, that decision extended the right to negotiate similar agreements to other public entities and projects across the country.

Transportation System. Project-generated traffic had the potential to cause major difficulties — those who are familiar with Boston will understand why. In order to construct the project without imposing hardships on neighboring communities and the narrow, wandering and congested regional traffic network, the CM devised a transportation system to move construction vehicles, equipment and materials by barge as well as to transport project construction workers by water and bus.

Work on Deer Island begins at 7:00 a.m. and ends at 3:30 p.m. for most workers. No private vehicles are allowed on the construction site (a hardship for some construction supervisors who have company vehicles as a job "perq"), and workers are required to bring their own food. At peak construction, over 3,000 workers will be on site.

Half of all project workers travel to Deer Island by bus from a terminal at the Suffolk Downs Race Track in Revere, a community north of Boston. The other half travel by personnel ferry from downtown Boston, a site on the Mystic River in Charlestown or from the South Shore community of Quincy.

A traffic mitigation agreement worked out with the neighboring town of Winthrop allows only eight project-related vehicles (excluding personnel buses) per day to come onto the island via the town. Due to that agreement, almost all equipment, materials and vehicles must travel to the island by barge from the Fore River staging area in Quincy where areas have been set aside for the laydown and storage of construction materials. Off-site laydown and storage were essential because there is almost no room on Deer Island for construction-related storage.

Barges, which can carry up to two dozen 35-foot-long trailers, make a total of four trips to the island each day after loading at roll-on/roll-off piers that were constructed for the project. Each trip takes approximately two hours. The system is working very well, although it requires that contractors do a lot of planning. For example, contractors cannot run out to a local hardware store to buy a hammer or make a last-minute call for an extra load of rebar.

Centralized Services. To further accommodate construction on Deer Island, on-site electrical power was made available by laying a cable under Boston Harbor from South Boston to the island that is capable of conveying 70 megawatts of power. A solid waste transfer facility allows the centralization of trash removal. An on-site concrete batch plant will produce nearly a million cubic yards of concrete during the course of the project (enough to repave the entire 134-mile length of the Massachusetts Turnpike). Also, service areas for contractors complete with electricity, telephone lines, water and toilets are provided, along with a fuel storage and distribution facility.

Quality Control/Assurance. The CM has developed a quality control/assurance program that reflects a shift from the traditional build-inspect-rework approach to quality management. The theory behind this new quality management program is that if you build a project right the first time, and only build it once, both time and money will be saved for the client and for the contractor. Success in this regard is critical to a project where time lines and funding are extremely tight.

The CM has a three-tiered approach to building quality into the project:

- A contractor develops a program to ensure that work meets MWRA plans and specifications;
- The CM reviews and approves the plans and provides ongoing and final work inspection; and,
- The CM's quality assurance group oversees day-to-day quality control by performing regular surveillance and audits on each contract.

Construction Management

To date, the project has met or bettered ten major court-ordered milestones. Keeping a project this size on schedule and within budget requires management skills and sophisticated management tools. There are two primary keys to performing work on this scale: hiring the best people available; and, breaking the project into parts that can be more easily managed. The CM brought people to the Boston Harbor Project from major projects all over the world and also subcontracted with some of the finest smaller, local businesses in the industry.

To create manageable construction contracts, the Boston Harbor Project has been broken down by facilities. The facilities are then grouped into construction contract packages. Each facility within a contract is then divided into construction activities. It is at this lowest level — the individual construction activity — where project control must start. Each construction activity is cost-loaded based on the contractor's schedule of values and is tied to other activities that must be done before, or cannot start until, a unit of work is completed.

Activities are not always tied together sequentially, but can be done simultaneously, thereby creating numerous chains or paths of activities that are needed to complete a contract. The longest chain of activities required to complete a contract defines a "critical path."

Critical Path. Scheduling is an important management tool, both for the contractor planning its work and the CM monitoring progress and identifying slippages as quickly as possible. The critical path method allows all project participants to focus on the most time-sensitive (critical) area of the work in a logical, continuous process.

The primary treatment plant provides an example. It has a number of components, including galleries where the piping will be installed, and numerous large clarifiers. Because the galleries contain more equipment and will take longer to build and equip than the clarifiers, the galleries make up the critical path for the construction of the primary treatment plant.

Ideally, there is only one critical path. However, there are also interim milestones and each of those milestones has its own critical path. Critical paths can change as the contractor progresses with the work and encounters and resolves problems that affect schedules on a contract.

Constructing the two North System tunnels provided a good example of a shift in the critical path. After the excavation of the first tunnel was completed, the critical path was the excavation of the second tunnel. Since the lining of the first tunnel was taking longer than anticipated, the critical path shifted from the second tunnel excavation to the lining of the first tunnel.

Computer-Based Management System. Without the aid of computer-based management tools, keeping track of a $3.4 billion project with its 87 major and hundreds of minor contracts would be a nightmare. An engineering

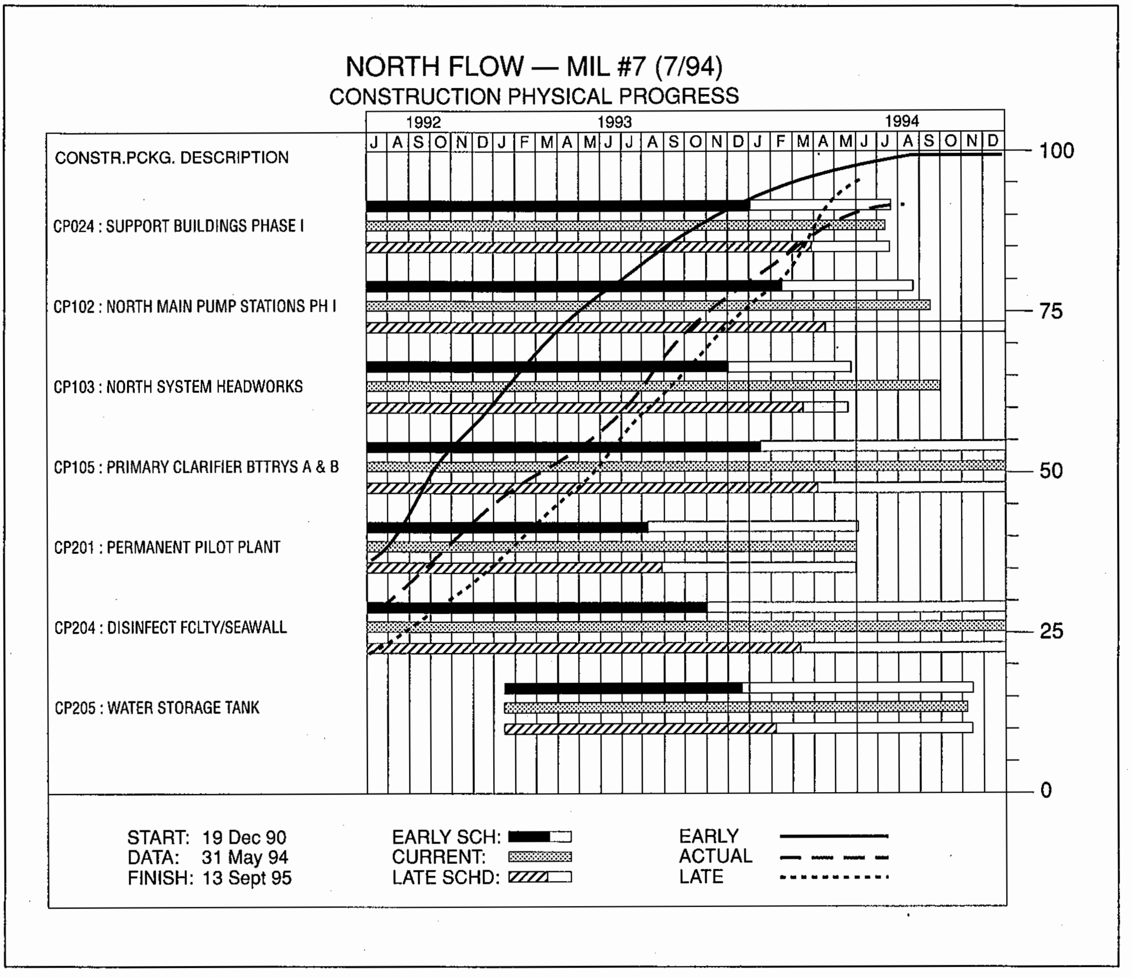

FIGURE 2. A chart of construction progress for work at the Deer Island plant.

management system takes the schedule and integrates the cost element of the work to create a complete management tool. The work progress curve shows how well a contractor is doing on elements of work that require the most person hours. Work progress in the field can best be measured by looking at the number of hours it takes to accomplish a task rather than the cost of a task.

Consider, for example, the installation of an expensive piece of equipment. The equipment costs a lot of money, but the installation does not take much effort. Forming, placing and finishing concrete, on the other hand, is relatively labor-intensive, making installation expensive when compared to the cost of concrete. Monitoring the manpower needs of installation gives the CM a better picture of progress than looking only at the cost of the work.

The next step is to compare the progress of each element against a base-line curve, by actual measurement of quantities in place (see Figure 2). The progress must take place within the envelope that is defined by early and late progress curves.

Construction Site Congestion

In August 1993 the Boston Harbor Project reached its peak level of construction activity. Nearly 3,000 craftspeople, engineers, designers, managers and others were on the job during the height of construction. What makes this project different from other major public works projects is the very limited space for construction, the high number of

FIGURE 3. A view of the construction of the primary wastewater treatment plant on Deer Island. (Photo courtesy of Karen-Jayne Dodge.)

contractors and construction workers and the tight schedule. Figures 3 and 4 show the scope of the construction activity as well as the site limitations.

The main construction of the Boston Harbor Project takes place on just two-thirds of Deer Island. In addition, the construction must be carried out without interfering with the operations of the existing primary wastewater treatment plant that must continue to operate until the new primary plant is phased into operation in 1994.

Until the end of December 1991, construction on Deer Island had to occur around another operating facility: a century-old prison complex of 11 buildings that housed over 800 inmates. The inmates were moved to the new Suffolk County House of Correction in the South Cove section of Boston in early December 1991 and the keys of the facility were turned over to the MWRA. The prison, which was located on the site of the future secondary treatment plant and power plant, was demolished in the spring of 1992.

Site congestion is a major challenge on the Boston Harbor Project. One of the CM's strong points is the harbor project management staff's ability to coordinate the scheduling and sequencing of construction contracts under these difficult site conditions. Construction of just one section of this enormously complicated project — the utility and piping galleries that run throughout the plant — provides a vivid example of Boston Harbor Project construction challenges.

The three main portions of the plant — primary treatment clarifiers A through D; secondary reactor batteries A through D and secondary clarifiers A through D; and gravity thickeners and digesters — are connected by a series of galleries.

These major galleries are 50 feet wide and 25 feet high, and they run north-south and east-west within the plant. The galleries are de-

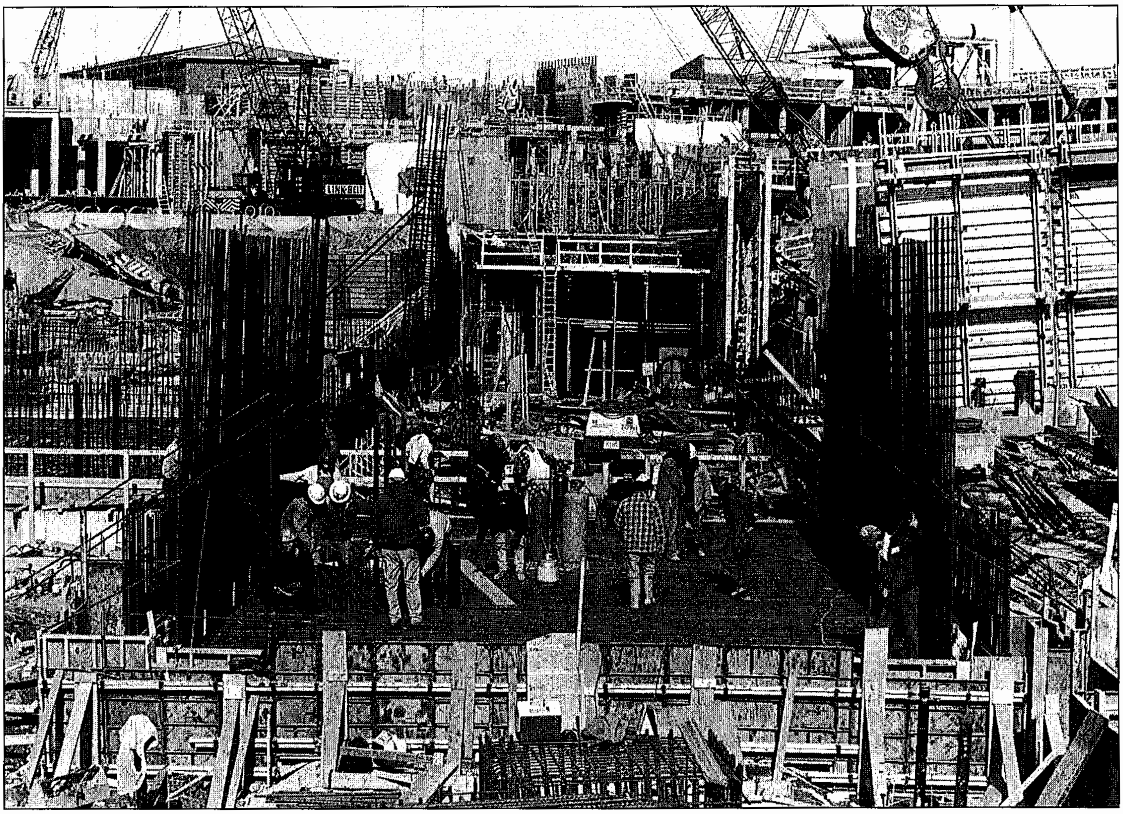

FIGURE 4. A view of the construction of the primary wastewater treatment plant on Deer Island. (Photo courtesy of Karen-Jayne Dodge.)

signed to carry all the utilities that serve the plant as well as process piping throughout the plant. The galleries interconnect at each construction package starting with sludge digesters in the south, through the North System headworks, to primary clarifiers A and B onto secondary reactor batteries A and B, through secondary clarifiers A and B to the disinfection facilities.

Work on each of these connecting or interfacing locations must be carefully planned and coordinated so that deep excavations and construction by one contractor can be accomplished in time for the next contractor to come in to perform more deep excavation and physically join a new section of the gallery to the existing construction.

It is critical that all piping and electrical systems meet at the proper location and elevation at each interface point. Timing and coordination at each of the five separate contracts' limit lines assures that the system will operate as one unit on startup day.

The LDE reviews transitions at all interfaces to ensure that plant-wide system integrity is not lost, that operable system components are available for the court-ordered startup dates, and that "generic" design assumptions are continuously updated based on approved contractor submittals.

The in-ground, buried piping and ductwork that carry the utilities to the facilities are being constructed at the same time as the 2,500-foot utility gallery. The utility and cable-pulling contract will interface with over half a dozen contracts in as many facilities. What makes this work a particular challenge is that the utilities contract was prepared, bid and awarded before the designs of the facilities themselves were completed.

Other Project Challenges

Deer Island was also part of a World War II harbor defense system. One of the first tasks in preparing the island for construction was the removal of five military bunkers, one of which was built with 18-foot-thick reinforced-concrete walls.

A four-million-cubic-yard drumlin was, until recently, located in the middle of the island at the site of the future primary treatment plant. Most of that hill has been moved to the north side of Deer Island where the earth is being used to created a landform that will shield the community of Winthrop from the noise of the construction and operation of the new plant.

Three centuries of human occupation mean that almost anything can be found on Deer Island, sometimes when least expected. Human bones were turned up far outside the known site of the New Resthaven Cemetery. That discovery stopped the project for a day until a "work-around" program could be developed with the Massachusetts Historical Commission. Work in that area was reorganized and an expert was brought in to sift the disturbed materials for analysis and supervise the removal of the bones from the site. The remains will be reinterred after construction is completed with an appropriate ceremony.

As with most public works jobs, a certain percentage of the contracts have been set aside for minority business enterprises (MBE) and woman business enterprises (WBE). Typically, contracts require 8.25 percent MBE and 2.09 percent WBE involvement. In addition, MWRA contracts require each contractor and subcontractor to provide a workforce by trade consisting of ten percent minority and 6.9 percent female workers.

The CM monitors contracts to make sure that MBE and WBE subcontractors are actually on the job doing work they were contracted to perform with their own workforces. Besides providing its own labor, the MBE or WBE subcontractor is expected to supervise its own work as well as supply and operate equipment and purchase and install material.

Environmental Issues

The harbor project is being constructed under very strict guidelines governing such issues as noise, dust, hazardous waste and impact on coastal resources. Because the construction project is taking place at several locations in and around Boston Harbor, the work is subject to review by conservation commissions in Winthrop, Boston and Quincy. Some of the key environmental concerns being dealt with for the project include:

- Because hazardous materials are in use on the construction site, a plan to contain spills is in place for the unloading of fuel and sodium hypochlorite, as well as to prevent oil leaks from machinery.
- Hay bales and silt curtains are placed around the construction site to prevent suspended matter associated with runoff from washing into the harbor. In addition, runoff from roads and construction areas is channeled to settling ponds where solids are settled out before the flow is released.
- Construction site roads are regularly sprayed with water to control dust.
- Soil on Deer Island that has been contaminated with oil by a long line of public facilities — including the old prison, the old military complex and the existing primary treatment plant — is being mixed with asphalt and recycled as subgrade, road base material.
- No dredging takes place between February and May to accommodate the spawning season of winter flounder.
- Construction activities that take place in the inter-tidal zone (such as work on seawalls and storm drains) are performed during low tide. Doing the work on dry land makes it easier to prevent any impacts on water quality.
- Noise levels for day and night construction activities are defined in an agreement worked out with the neighboring community of Winthrop and monitored at the Winthrop line around the clock. Particular attention is paid to such activities as blasting, pile driving and night-time work.

Project Progress

Construction is proceeding on all major components of the Boston Harbor Project. As of the end of June 1994, every court-ordered milestone has been met, and about 90 percent of the design and 50 percent of construction has been completed. More than 13 million hours have been put in by over 3,000 workers. With approximately 2,500 craftspeople on the job, the project is currently the largest construction employer in New England. The employment level is good for the construction industry and for the economic health of the region. The fact that the project is presently around $700 million under fiscal year 1988 estimates is also good for the MWRA's ratepayers.

Early steps in the Boston Harbor Project have already resulted in improvements. Boston Harbor is cleaner than it has been in 60 years. A recent report found that the harbor generally meets federal water quality standards most of the time. The MWRA has made more than $100 million in interim improvements to existing treatment facilities, which has paid off with the following benefits:

- Effluent from the MWRA's existing sewage treatment plants is chlorinated more efficiently and reliably;
- Pumping capacity at Deer Island has improved; and,
- Floating pollution, called scum, has been removed from the effluent.

The most significant contribution yet to improved water quality has been the end of sludge dumping. In December 1991, the MWRA opened its $87 million pelletizing plant at the Fore River staging area in Quincy to handle up to 500,000 gallons of liquid sludge each day that were previously dumped into the harbor.

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