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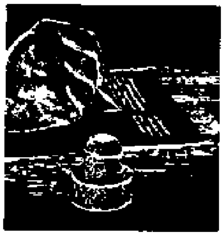

WHITE PAPER SERIES

COASTAL ISSUES IN NEW ENGLAND

The Cleanup of Boston Harbor: Another Viewpoint

Based on a R.I. Sea Grant Coastal Issues in New England Lecture at URI BAY CAMPUS 1991

by

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I am sure that most of you are aware that one of the most publicized debates about Boston Harbor took place during the 1988 presidential election campaign between Michael Dukakis and George Bush. I can tell you that neither of them knew what they were talking about. I am here to set the record straight, and to relate the *true* story about Boston Harbor.

The waste treatment facilities that empty into Boston Harbor serve a population of about 2.5 million people. This population is distributed over 45 cities and towns in the metropolitan Massachusetts Water Resource Authority (MWRA) area. Governing such a large area causes decision-making to be politically complex. In addition, the large area comprising the old inner city is of particular concern, because it is this part of the city that has combined sewer overflows (CSOs)—meaning that there is a single pipe for all stormwater and sewage waste products combined. But CSOs are only part of the Boston Harbor problem. Superimposed on the CSO problem is the problem that, with a population of 2.5 million people, the average annual waste discharge is 500 million gallons per day (mgd)—which translates into 200 gallons per person per day. This is an awful lot of waste. The normal U.S. average waste production is about 100 gallons per person per day. Why is it so high in Boston? It is high because the groundwater, which in most places is higher than the sewer pipes, leaks into the pipes. This causes a lot of infiltration, which is exacerbated in the wet times of the year. The CSO problem is completely separate from the groundwater problem. The first is a storm-buffer type of problem, while the other is a groundwater seepage problem. Therefore, the treatment plants for Boston that are designed to handle capacity at twice the average flow—about 1,200 mgd—makes them among the largest, single-treatment plants in the world.

Boston currently has two aging, primary-treatment plants—one located at Nut Island, and one at Deer Island. The interesting thing about the present situation is that the two plants obviously remove something in their processing. What they remove is sludge. Until January 1992, the sludge was put back into the Harbor via the existing effluent-discharge lines. One might ask, "What kind of a system has treatment plants that remove something and then return it?" But that is what actually happened. The only consolation was that the sludge was theoretically discharged on the outgoing tide.

There are about 80 CSO pipes around the perimeter of the Harbor. When there is rainfall—about once per week—the capacity of the treatment plants is exceeded, the storm water is mixed with untreated sewage in the CSO pipes, and the untreated waste is discharged around the perimeter of Boston Harbor, close to bathing beaches and shallow water shellfish areas. The reason why Boston Harbor is considered unclean, and why there are frequent closures of beaches and shellfishing areas, is primarily related to the weekly CSO events. During the summer, many bathing beaches are closed more than 50 percent of the time because of high coliform counts resulting directly from the CSO problem.

History of the Boston Harbor Cleanup Effort

The Boston Harbor cleanup effort began in 1972 with the passage of the first federal Clean Water Act. The Clean Water Act mandated secondary wastewater treatment standards for all municipally owned treatment plants in the country. This uniformity approach was chosen because it would be easy to enforce from a legal standpoint—there were to be no exceptions; everyone was to do the same thing. The federal government combined the uniformity approach with a generous construction-grant program, which would pay for 75 percent of the cost of treatment plant construction required under the Clean Water Act. At the time the Clean Water Act was passed, most of the large coastal cities—New York, Boston, San Diego, Los Angeles—were not in compliance with the new regulations. But for Boston to construct a full secondary treatment plant for treated waste was not going to clean up the Harbor, because the Clean Water Act made no provisions to address the CSO problem. For many coastal cities, a viable alternative to building a secondary-treatment plant would be to construct a long ocean outfall into deeper water, utilizing the benefits of the tides and currents in mixing and diluting primary-treated waste; upgrade primary treatment to a good level; and finally, rather than going to full secondary treatment, devote energies to the CSO problem. The reaction in Boston was that going to full secondary-treatment really meant going to high levels of carbon removal, and that the benefits of carbon removal were minor in comparison with the CSO issue.

Carbon removal has always been of interest as a surrogate for dissolved oxygen depletion. For example, if you remove high levels of organic carbon, then the oxidation of that organic carbon (occurring in the receiving water as dissolved oxygen is depleted) would be less. This is a perfectly good rationale for inland waters. The Ohio River is a prime example of inland water that was completely devoid of oxygen, because of high levels of organic carbon in the river.

It was because of situations like the Ohio River example that Congress passed a Waiver Act in 1977, which said that coastal cities could request a waiver from full secondary treatment in order to address problems such as CSOs. In 1979, after publication of the guidelines, Boston filed an application to upgrade the primary-treatment plant and build a nine-mile outfall; to fix the CSOs; and to stop dumping sludge into the Harbor.

Nobody knew at that time how long it was going to take EPA to review all the waivers—and they were inundated with them. It took six years to get through all of the requests. The unfortunate thing was that during the six years between 1979 and 1985, while the waiver request was pending, nothing happened. There was also no provision made for spending money on the first, or primary, stage of the new treatment plant, which would have to be done regardless of the waiver decision. In 1985, the waiver was denied. In retrospect, Boston would have been better off in 1980 if it had used the money allocated from the construction-grant program and made the upgrade, but it didn't. It was now 1985, nothing had been done, and there was no plan made for what needed to be done. One year later, following a federal court order to bring Boston into compliance with the Clean Water Act, planning finally began, environmental impact statements were written, and construction plans began. Construction finally started in 1990.

Boston had originally proposed a nine-mile outfall to discharge primary effluent, but the plans were changed to have a nine-mile outfall that discharged secondary-treated effluent, which scientifically is a bit of an overkill. Nevertheless, politically, it might have been a good decision. Until the residents on Cape Cod started to get excited about what was planned, everybody else in the metropolitan area was satisfied that the effluent was going out nine miles, and that was better than *not* going out nine miles. A big controversy has ensued since Cape Cod became aware of the planned outfall, because they fear that the effluent will close their beaches. I don't feel that this will be the case because the discharge will be well-treated. The question of whether additional treatment—to remove nutrients causing eutrophication—will be necessary remains an issue.

Unfortunately, by the time planning was underway, the federal construction-grant program was phased out. The Boston metropolitan area then found itself in a situation where it had to meet federal requirements, but the federal government was no longer paying for it. My argument is that if the metropolitan area has to bear the cost, it should be done in the most cost-effective way to meet the federal objectives. Ideally, this would involve employing innovative technologies that would be less expensive, and then using the savings to resolve the CSO problem—currently not in the schedule. There are a number of obstacles to this point of view. For example, there is no incentive built into the way that consultants are employed for them to be innovative and to save money. Their fee for designing what is built is based on the cost of it—at a certain fixed percentage. Therefore, to save money is to cut their fee. I think that concerned public citizens who recognize this problem should have the ability to exert the pressure on the consultants to try to make them be innovative.

Sewage Treatment

I have mentioned primary and secondary treatment, and this is not an audience that I would expect would be conversant in the details of the differences between them. In order to understand the innovative process in getting to secondary treatment, it is important to know something about the conventional way of dealing with sewage treatment. Primary treatment is very simple. There is one chamber that removes the big rocks and large debris, called grit, and then a second settling chamber that allows particulates of a certain size to settle out. This is a very simple process called primary settling. The amount of material that is removed during this process is measured by two quantities—total suspended solids (TSS) and biochemical oxygen demand (BOD), which is a measure of organic carbon. The carbon is in both particulate and dissolved form. Primary treatment, which involves particulate settling, can normally remove about 60 percent of the TSS and about 30 percent of the BOD.

Secondary treatment, as the name implies, follows upon conventional primary treatment. In conventional secondary treatment, called activated sludge, the first thing that follows is the aeration tank, which is nothing more than a big tank where bacteria are grown—bacteria that are happy to chew on organic carbon as their food supply. The process is very simple: Bacteria eat organic carbon and produce club soda; that is, $CO_2 + H_2O$. Consider a solution of sugar water—$C_6H_{12}O_6$ + bacteria $\rightarrow CO_2 + H_2O$. Under this reaction, club soda (an inorganic carbon) and additional bacteria are produced. The aeration tank is able to remove more of the dissolved carbon, because bacteria are able to more readily break down smaller fractions of dissolved organic carbon fractions. The problem is that a soupy mixture of bacteria (5,000 milligrams per liter) is produced, making it necessary to separate the bacteria from the water in order to remove carbon, which is now inside the bacteria.

The separation step requires a secondary settling tank, which makes the process more complicated because the bacteria do not settle out as well as the first stage of particles because they are lighter. In any event, if the primary and secondary processes are combined, it is possible to increase the removal of solids from 60 to about 85 percent, and BOD from about 30 to 85 percent, bringing the figures up to the specifications of the Clean Water Act.

Another question in many people's minds is the concern over heavy-metal concentrations and other toxins. But metals and other toxins tend to be adsorbed to particles; and therefore, tend to be removed in proportion to the solids removed. This means that most of the metals and toxins are contained in the sludge, which then creates a sludge-disposal problem. That is no small problem. EPA is opposed to sludge disposal in the ocean, and to burning the sludge because of the effects on the atmosphere. This leaves the land as a sludge-dumping alternative, which may not be the best solution since the potential for seepage into groundwater is high. At this time, it is not clear what the best solution for sludge disposal is.

Innovative Technology

Innovative technologies can be incorporated into the primary- or the secondary-treatment stages. In primary treatment, it is possible to be much more efficient by adding very small quantities of coagulants to the "soup," which alters the electric charge of the particles and allows them to clump together, forming larger particles that settle out more readily. Typical coagulants used are alum and ferric chloride—trivalent metal salts that have this coagulating/flocculating property—supplemented by innocuous polymers that also aid in charge-alteration and clumping. This technique, called "chemically enhanced primary treatment," is quite an old one, but it is very surprising that 1,200 million–gallon conventional primary plants are built today—as in Boston—without making use of this technology. This is one of my big arguments with Boston. Why is Boston building a monstrous plant and not taking advantage of what can be gained by increasing the efficiency of that monster plant? It should be obvious that anything that can be done to increase the efficiency at the primary stage is going to reduce the size and cost of what is done at the secondary stage in meeting the final objective.

I am going to talk about two innovations—one in the primary stage and the other as a process that eliminates the two-step process of secondary treatment and combines it into one, eliminating the need for the secondary clarifiers, which cost and occupy about two-thirds of the area of a secondary plant. The first of these technologies, chemically enhanced primary treatment, is prac-

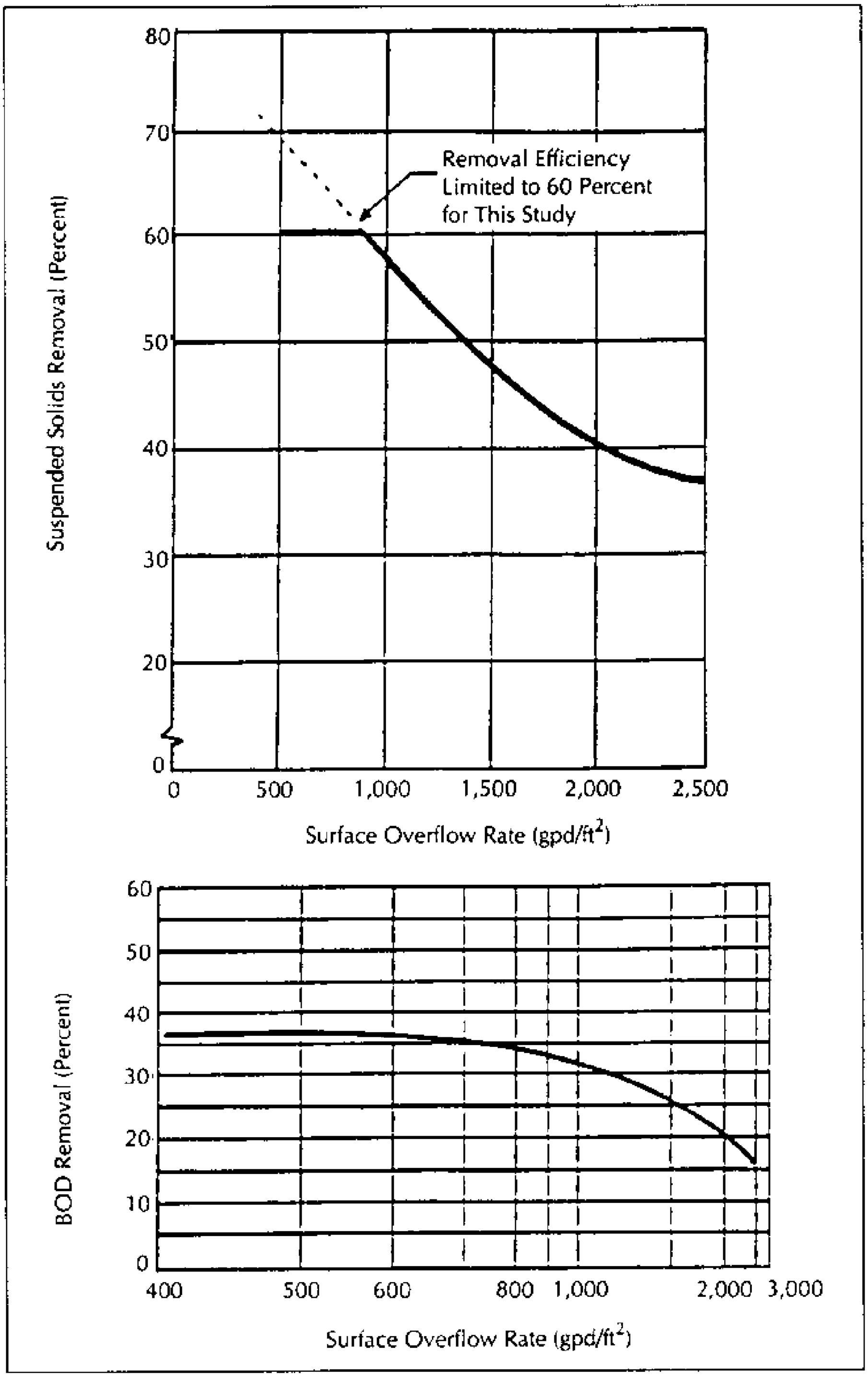


Figure 1. *Suspended solids and BOD removal for conventional primary treatment.*

ticed widely in southern California. One of the benefits of adding coagulants is that there is a high degree of phosphorus removal. Unfortunately, the mind-set is that if EPA hasn't said to remove phosphorus, then don't add chemical coagulants. One of the byproducts of the removal of phosphorus is that it puts more phosphorus in the sludge, making it a potentially better fertilizer.

To get slightly more technical, it is necessary to first look at two things—the TSS and the BOD removal as functions of what is called the "overflow rate." The overflow rate is the flow through the plant divided by the surface area of the primary tanks. Conventional primary-treatment plants are designed to have overflow rates of about 1,000 gallons per day per square foot (gpd/ft^2), based on the average annual flow through the plant. At this rate, about 60 percent of TSS and 35 percent of BOD may be removed. It is common for treatment plants to experience daily flows twice the annual average. Under these conditions, treatment efficiency is reduced to less than 40 percent for TSS and 20 percent for BOD because the residence time within the settling tanks is decreased. Expected removals of TSS and BOD for conventional primary treatment in relation to overflow rates are shown in Figure 1. The large decrease in efficiency is a big problem because, although the size of the plant is calculated for average flows, the plant will be operating at twice-the-average flows during any rainy season. This problem is something that is often not addressed. But I am going to show that by adding coagulants, the overflow rate can be doubled without causing a decrease in removal efficiency.

Experience With Chemically Enhanced Primary Treatment

The first experience with chemically enhanced treatment that I want to discuss is one that I call the "Scandinavian Experience." The VEAS treatment plant in Oslo, Norway (160 mgd wet-weather flow) is one of a large group of Scandinavian plants that have eliminated biological secondary- and tertiary-treatment stages in favor of single-stage, chemically enhanced primary treatment. Chemical plants of this type meet, or come very close to meeting, U.S. EPA secondary treatment requirements. However, it must be noted that these plants are not designed for TSS or BOD removal.

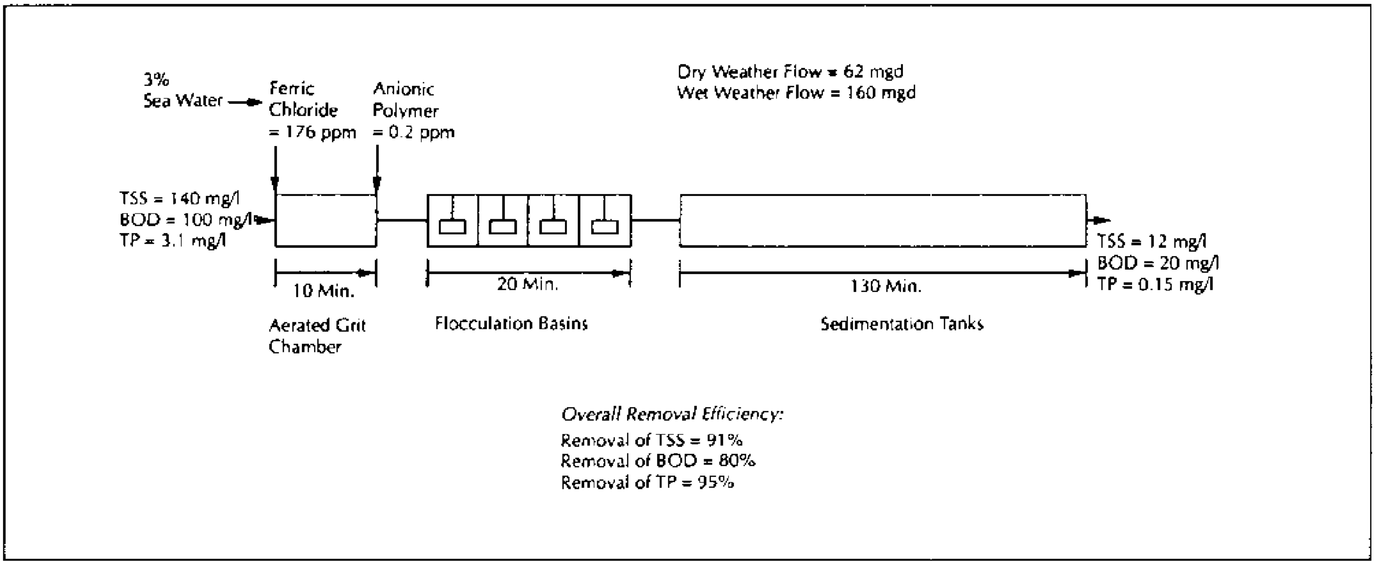
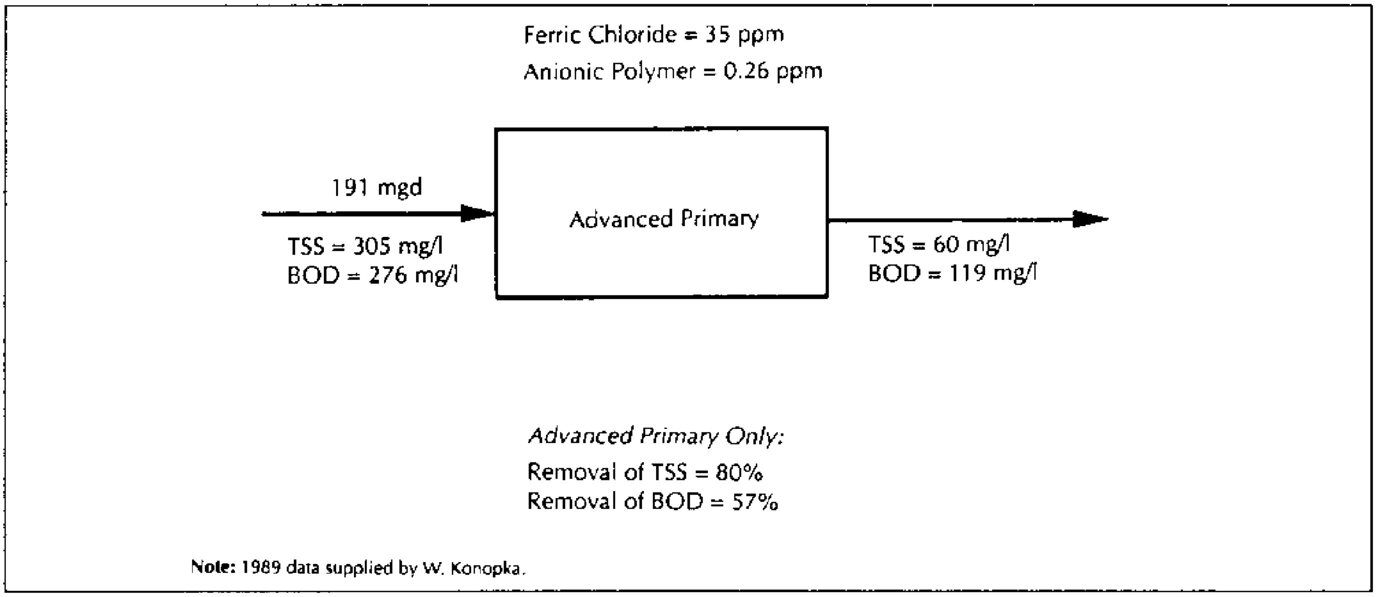


Figure 2. VEAS treatment plant at Oslo.



Note: 1989 data supplied by W. Konopka.

Figure 3. Point Loma treatment facility.

Their sole regulatory requirement is nutrient removal, and currently, they are achieving 95 percent phosphorus (TP) removal. Nevertheless, the VEAS plant obtains 91 percent TSS and 80 percent BOD removal, as indicated in Figure 2. The raw-sewage influent to the VEAS plant is somewhat weaker than the influent going into the planned MWRA plant, and significantly high ferric chloride concentrations—176 parts per million (ppm)— are being used to obtain the very high phosphorus removal. Treatment efficiency is improved by adding 3 percent sea water (a natural coagulant) to the inflow. The annual average overflow rate for the VEAS plant is 2,500 gpd/ft^2—almost three times the standard flow for conventional primary treatment. Flocculation basins are located ahead of the primary sedimentation tanks; however, their effectiveness appears to be diminished by the high chemical dosage and inadequate screening of the raw waste. Other Norwegian plants indicate that flocculation basins are very effective. The high phosphorus removal makes sludge from the VEAS plant attractive as a land additive and soil conditioner. The chemically enhanced treatment process is actually the same process that is used to treat cloudy drinking water. If you are taking water from the Mississippi River for drinking purposes—water that contains a large amount of suspended sediments—this is the process that uses ferric chloride or alum to clarify the drinking water.

Southern California provides two additional examples of successful experiences with chemically enhanced primary treatment. Under the California Oceans Plan of 1985, those coastal plants that had not yet converted to secondary treatment were required to increase solids-removal efficiency to 75 percent, because suspended solids tend to adsorb heavy metals to particulates. These plants were immediately required to use chemical additives to increase the solids removal. The Point Loma, San Diego, plant treats raw waste, about 200 mgd, from the city of San Diego, Calif. It has operated as an advanced primary plant for more than five years. The operating conditions and annual averages for 1989, shown in Figure 3, indicate 80 percent TSS removal and 57 percent BOD removal, obtained with only 35 ppm of ferric chloride and 0.26 ppm of polymer at an overflow rate of 1,700 gpd/ft². During a 30-day test in which the plant overflow rate was increased to an average of 2,800 gpd/ft², the treatment efficiency dropped by only 2 percent for both TSS and BOD. Figure 4 shows the significant increase in the Point Loma plant's performance compared to conventional primary-treatment expectations. The concentration of the raw waste at Point Loma is about twice as high as that for the planned MWRA plant. What the 30-day study shows is that if one were to build a conventional plant today, as they are doing in Boston, one could presumably double the capacity by going to small amounts of additives, thereby saving half the capital cost of the plant.

The San Diego story is in many ways a parallel of Boston, except for one small difference: San Diego is under a federal court order to build a full secondary plant. But San Diego had six years of monitoring experience with chemically enhanced primary treatment, and scientists have testified that there are no ill effects in coastal waters due to the present level of treatment. They have also stated that nothing would be gained by going to full secondary treatment. The logical thing for San Diego to do at this time would be to build a tertiary-treatment plant for 25 percent of the flow, and use that reclaimed water to replace the consumption of fresh water that is in short supply throughout the entire region.

Hyperion, which is located in the city of Los Angeles, is a primary plant that was highly overloaded in 1985. They had only 10 percent BOD removal, and 30 percent solids removal. They started adding 25 ppm ferric chloride in 1985, and now they have increased their solids removal to 83 percent and BOD to 52 percent. When I relate this to the Boston consultants, who designed this conventional primary-treatment plant, and ask, "Why not add chemicals?" The usual reaction is, "Oh, we don't need phosphorus removal."

Sludge Disposal

The next issue to consider is the sludge, because, as I said, whatever you remove increases the amount of sludge, and that has to go somewhere. In the case of Boston, about 100 dry tons per day are produced as sewage sludge—not a negligible thing that can be tucked away in a landfill. If one looks at advanced primary treatment, like that being used in San Diego, about 45 percent more sludge is produced—30 percent due to the removal of more solids, and 15 percent due to the additives that are added to produce coagulation. If these figures are compared with conventional biological secondary-treatment methods, which the Clean Water Act requires, twice as much sludge is produced—50 percent more than advanced primary treatment. Advanced primary treatment, as is done in Oslo, I call "chemical secondary" because it approaches biological secondary treatment in its removal efficiency, and does so in a single-stage process.

Innovations in Biological Treatment

Biological treatment innovations, such as the aerated bio-filter, have become quite common in Europe. These innovations, in principle, have been around for 100 years as a way of removing carbon compounds. The only difference is that the little organisms that digest the sewage material grow on the filter media, rather than being mixed into a "soup." If the media are large enough, the passages will remain unsaturated, and will get enough air to keep the organisms happy, because in order to work, the bacteria need to turn oxygen to soda water. However, the problem with using large media, such as rocks, is that little clumps of sludge break off, making a secondary settling tank necessary.

The European technology has gone to very fine media, which is too small to be naturally aerated, but if air is forced through it, the bacteria can be maintained under aerobic conditions. The nice thing about using fine media is that the bacteria clumps are retained in the media until the system is backwashed—about once a day. The advantage of this technology is that the same levels of biological treatment are attained with the same general levels of removal, and secondary clarifiers are not required.

These biological innovations are currently utilized by two large,

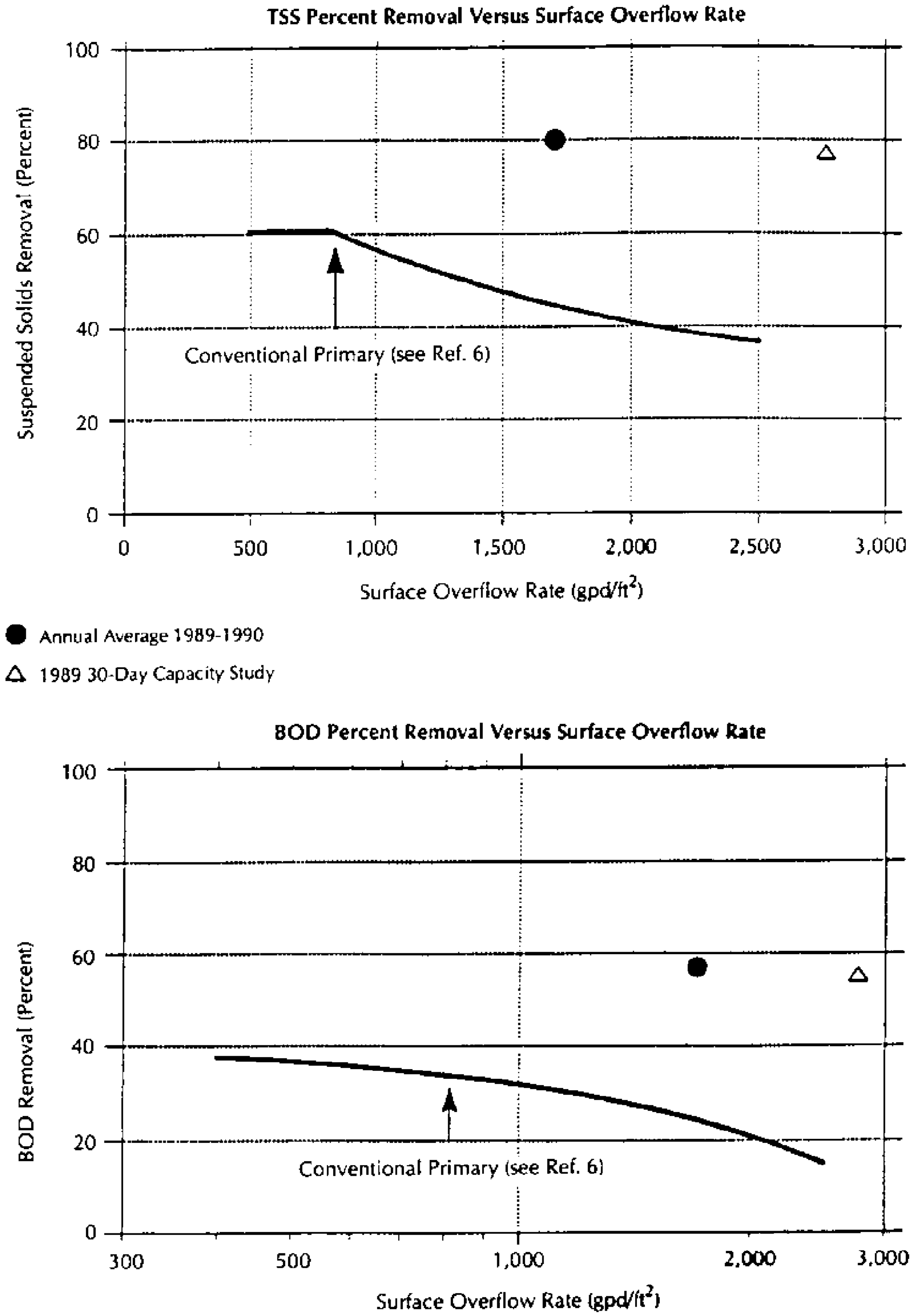


Figure 4. *Advanced primary performance at Point Loma. Above, TSS percent removal versus surface overflow rate; below, BOD percent removal versus surface overflow rate.*

TABLE 1
Boston Harbor Priorities

1986 Court-Ordered Schedule

1990	Begin construction of nine-mile ocean outfall and diffuser
1991	Begin construction of conventional primary-treatment plant
1994	Begin construction of biological secondary-treatment plant
1995	Complete ocean outfall and conventional primary plant
1999	Complete biological secondary plant
2000	Begin construction of CSO control facilities (not in court schedule)
2005	Estimated completion of CSO facilities
	Harbor cleanup completed

Proposed Schedule

1990	Begin construction of nine-mile ocean outfall and diffuser
1991	Begin construction of conventional primary-treatment plant
1994	Begin construction of CSO control facilities
1995	Complete ocean outfall and retrofitted chemically enhanced primary plant
1996	Begin construction of smaller secondary plant to meet EPA regulations
1999	Complete CSO control facilities and smaller secondary plant
	Harbor cleanup completed

French firms. The interesting part about the development of new innovations, like the bio-filter, is the way that municipalities interact with the consultants. In the United States, a municipality hires a consultant to design the whole treatment system, then the whole thing is sent out for competitive bidding on the building of the plant. There is no competitive part in the design stage. That is the big difference. In France, the municipality hires a consultant who only looks into a specific part of the plant's design, and says, "Here is the inflow; this is what is needed for the outflow to meet the required level of treatment." Then the competition comes in, sending out these requirements to the firms who are designing their innovative treatments, because they are now in competition for doing the job in the least-cost way. In most cases, the consultants operate the plant as well, so they have a vested interest in it. In the United States, the competition comes only in the plant construction. There, the competition comes in designing the plant, which includes the innovations. I must say, that if one looks back at the 1972 Clean Water Act, it unintentionally had the effect of stifling research in waste-treatment technology in this country. There was no incentive, because the Act specified a known technology, and all the consultants had to do was repeat that technology over and over again.

In summary, Table 1 reflects what the court said in 1985, regarding the cleanup of Boston Harbor. The MWRA recently said, "If we complete all of the goals by the year 2000, then maybe by the year 2005, we can have the money and time to fix the CSO problem." It is discouraging to me that the project will take another 15 years, and a total of $8 billion to complete, whereas a sensible alternative would be to complete the presently started new primary plant, to retrofit it to use the coagulants, to improve it for maximum efficiency, to increase its capacity, and to complete the CSO study. I think you could save hundreds of millions of dollars in this process to pay for the CSO fix-up.

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