how will the discharge affect **the health** of the Bays?

Using computer modeling, MWRA has predicted that increased pollutant removals by secondary treatment, combined with improved dilution of effluent provided by the new outfall, will improve the health of Boston Harbor and Massachusetts and Cape Cod Bays.

Computer model

Scientists assisting MWRA have developed a detailed computer model to predict impacts on Boston Harbor and the Massachusetts and Cape Cod Bays from discharges of secondary-treated effluent at the new 9.5-mile outfall location. This forecast is contrasted with modeled impacts from the discharges of primary effluent at the outfall location near Deer Island within Boston Harbor. The model is a time-variable, three-dimensional, hydrodynamic and water quality model called the Bays Eutrophication Model. It was developed by the U. S. Geological Survey and Hydroqual, Inc., the company that also developed water quality models for the Chesapeake Bay and Long Island Sound.

Verifying the model

In the course of developing and testing the model, modeling results were compared to actual environmental observations in the Massachusetts Bay system made in 1989-1992. The model results agreed quite well with observed data, and reproduced the major processes affecting the Bays system: the annual cycle of surface water heating and stratification; the spring freshet associated with the Merrimack River and other northern rivers discharging to the Gulf of Maine; the annual cycle of phytoplankton growth; the annual cycle of nutrients in the surface and bottom waters; and the effect of stratification on the minimum dissolved oxygen concentrations observed in October.

After the usefulness of the computer model was established by these tests, scientists used the model to predict the likely impacts of discharging secondary effluent through the new outfall into Massachusetts Bay. Figures 19-21 show the model predictions for three major components of concern: surface chlorophyll *a*, bottom dissolved oxygen, and particulate organic carbon flux.

Chlorophyll a

Because primary and secondary treatment do little to remove nutrients from sewage effluent, one of the major questions regarding relocation of the effluent discharge to the 9.5-mile site offshore is what effect nutrients would have on phytoplankton growth: would adding nutrients offshore promote blooms of phytoplankton? One important measure of the status of eutrophication in the Bays system is the concentration of chlorophyll *a*, a major algal pigment that is a good measure of phytoplankton abundance.

Figures 19a and 19b show concentrations of chlorophyll *a* at the surface for Boston Harbor and Massachusetts Bay predicted by the Bays Eutrophication Model. The figures show a five-day average in August, when the Bays are stratified. There is a large decrease in surface chlorophyll *a* levels in Boston Harbor and no increase in Massachusetts Bay after the 9.5-mile outfall and secondary treatment are on-line. This is largely because of improved dilution, and because at the new deeper location, discharged nutrients will mostly be below the summer pycnocline in the Bay. Nutrients will not be available to phytoplankton at the surface, where there is enough light to support vigorous growth.

Dissolved oxygen in bottom water

Animals and plants living in the marine environment need adequate dissolved oxygen (DO) in the water for respiration. If DO levels fall too low, fish and other animals may die. Bottom waters, because they are not in contact with the atmosphere, are most likely to experience low DO. Factors that decrease the levels of DO in the water are: high water temperature—oxygen is less soluble at warmer temperatures, and respiration rates of all life increase; too much oxygen-demanding organic matter in the sediment; and stratifica-

Figure 19. Modeled surface chlorophyll *a*, August

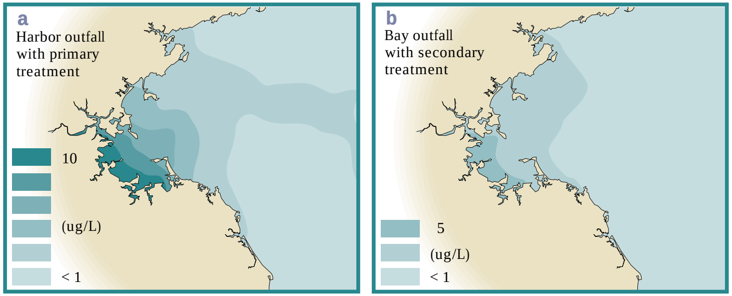
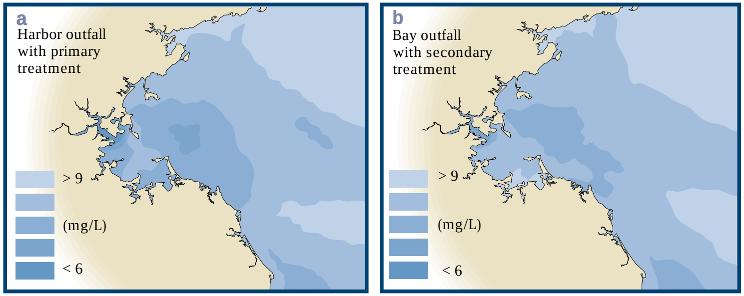


Figure 20. Modeled dissolved oxygen in bottom water, October



tion of the water column, which prevents more highly oxygenated surface waters from reaching the bottom. Concerns about the outfall related to dissolved oxygen are whether inputs of materials that use up oxygen (measured as biochemical oxygen demand, or BOD) and nutrients might cause bottom DO to violate the water quality standard. Monitoring has shown that bottom water DO has occasionally fallen below the standard at the new outfall site. The state standard for DO is 6 mg/l in Massachusetts Bay, and 5 mg/l in most of Boston Harbor.

Bottom DO levels are generally lowest in October because the water column has been stratified since April (see page 12). The model shows that with the Harbor discharge and primary treatment (Figure 20a), the lowest DO is in the Inner Harbor, and DO is also depressed near the future outfall area. This offshore DO depression is partly natural, and partly reflects the present export of nutrients and BOD from Boston Harbor. Figure 20b shows that secondary treatment and the long outfall result in improved bottom DO, both in the Harbor and near the outfall. Most of this improvement is explained by increased removal of BOD through secondary treatment.

Particulate organic carbon flux

The animal community living on the ocean floor relies for food on organic matter deposited to the sediment through the overlying water column—the particulate organic carbon (POC) flux. However, deposition of too much organic matter in the sediments can deplete sediment DO. Excess food as POC will destabilize the normal community structure, leading to decreased diversity, as has happened in Boston Harbor. POC can be contributed directly by an effluent discharge, or indirectly by increased phytoplankton and zooplankton abundance, some of which ultimately deposit in the sediments. A concern with the 9.5-mile outfall location has been the potential effect of adding POC to the sediments near the new outfall.

The model shows a high deposition rate in Boston Harbor with the present outfall and primary treatment (Figure 21a). With the new outfall and secondary treatment, POC flux is dramatically reduced in both the Harbor and the Bay (Figure 21b).

Figure 21. Modeled deposition of particulate organic carbon