Chapter 4

Characterization of Pollution Sources

Buzzards Bay is an important segment of the Massachusetts coastline for both its economic and aesthetic resources. The economic resources of the Bay range from the harvest of its fisheries to its use as a transit route for shipping traffic through the Cape Cod Canal. Its aesthetic resources include recreational opportunities such as bathing beaches, boating, hunting, and fishing.

Buzzards Bay is an estuary in transition. Along its shores, communities are faced with widespread coastal development. The legacy of industrial pollution from greater New Bedford combined with widespread accelerated development threaten the Bay's environmental and economic health and typify the stresses placed on many estuaries of the Northeastern United States by conflicting uses. The wise management of Buzzards Bay requires an increasingly sophisticated knowledge of estuarine processes and an understanding of the effect of land use on water quality.

Contamination or pollution sources entering a body of water are divided into point and nonpoint sources. Point sources occur at discrete and identifiable points, usually through pipeline discharges or direct dumping. Obvious point-source discharges into estuarine and coastal waters include sewage treatment plants, industrial discharges, and combined sewer overflows (CSOs). Nonpoint sources are diffuse, often intermittent, and sometimes ill-defined inputs to an estuary. These sources include surface runoff, rainfall, atmospheric deposition, underground transport, and leaching of materials to the estuary.

The Buzzards Bay Project has focused its efforts on three priority pollution problems — pathogen contamination, toxic contamination, and increasing nitrogen inputs — and how they affect water quality and living resources in Buzzards Bay. These pollution problems were selected because it was determined that they had the greatest impact on the economic , ecological, and aesthetic values of Buzzards Bay. This chapter is an overview of the findings on which the management actions in this document are based. These findings are the result of the many studies conducted by the Buzzards Bay Project during the past five years.

Pathogen Contamination

Degradation of water quality due to contamination by pathogens represents a serious health risk and economic loss to many parts of Buzzards Bay. The pathogens associated with sanitary waste disposal that are of primary concern to humans are disease- causing bacteria and viruses. Some bacteria are free-living organisms able to survive on their own and grow in an aquatic habitat; viruses, on the other hand, can grow only inside of a suitable host. Of the many different viruses associated with human wastes, most are responsible for causing gastrointestinal illness, but some cause significant illnesses such as hepatitis and polio. Pathogenic bacteria found in waste material are responsible for a variety of diseases.

The presence of human pathogens in waters overlying shellfish harvesting areas has historically been the primary index of the "health" of Buzzards Bay. Because public health agencies are not able to measure the entire host of human pathogens directly, they have relied on "indicator" organisms to assess the probability of the presence of pathogens. The indicator organisms presently used to evaluate the status of overlying waters are a group of bacteria called fecal coliform. This fecal coliform indicator test has been in use since the early 1980s. Formerly 'total coliforms' a superset of fecal coliform, had been used as the basis of regulatory action back to the 1920s.

Large numbers of fecal coliform bacteria are present in the fecal material of warm-blooded animals. For the most part, fecal coliforms are not themselves pathogenic, but are often found associated with other organisms that do cause disease in humans. When predetermined concentrations of fecal coliforms are reached, the area is considered unsafe for certain uses. Shellfishing is prohibited when concentrations reach 14 fecal coliforms per 100 milliliters (ml); bathing may be forbidden at levels of 200 fecal coliform per 100 ml by the public health agency overseeing the beach.

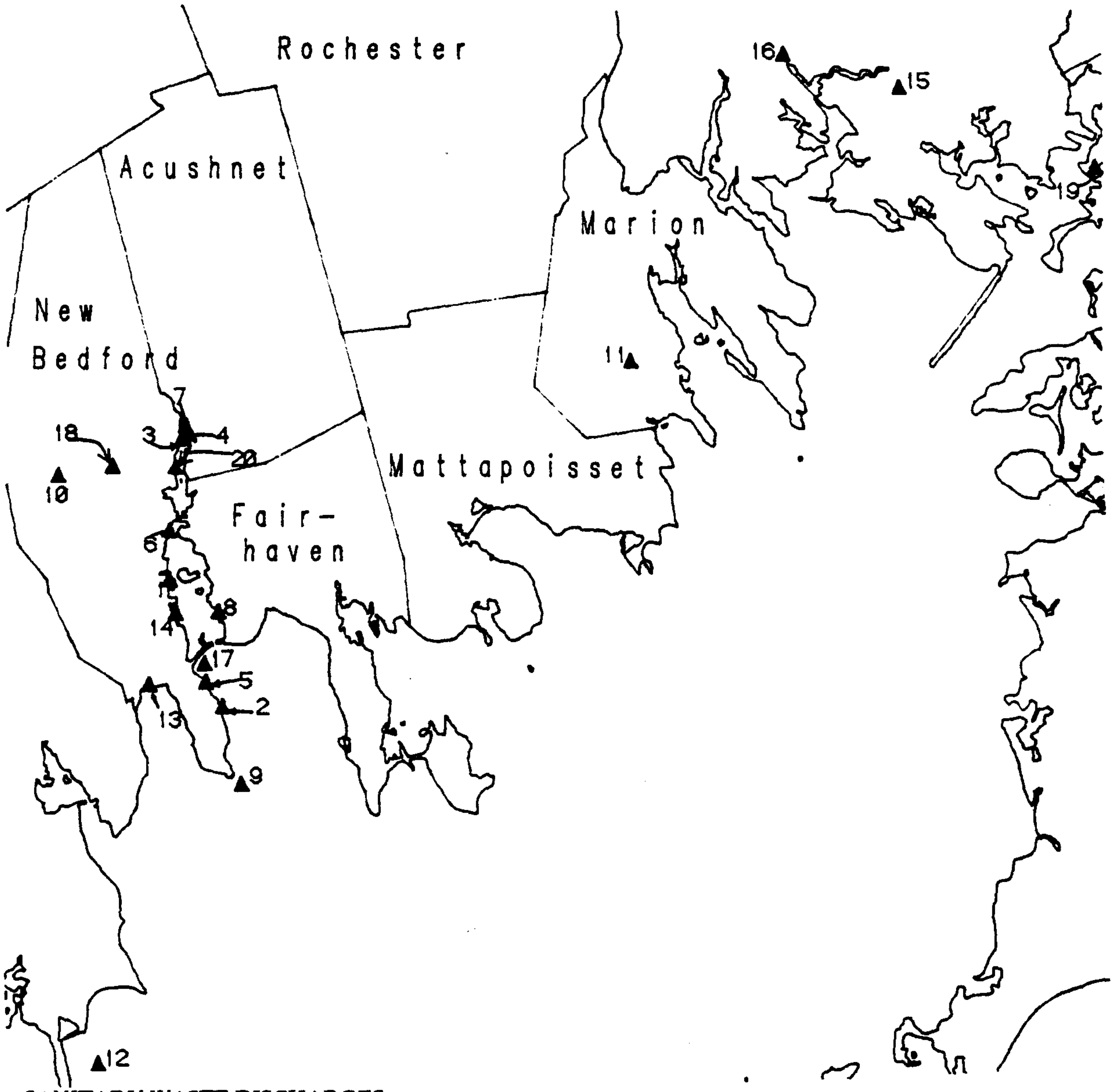
A number of problems are associated with the use of fecal coliform as an indicator of public-health risk. Although this method may protect human health from bacterial pathogens, the same may not be true for viral pathogens. Under certain circumstances, fecal coliforms bear little, if any, quantifiable association with pathogens of concern, including viruses such as hepatitis A. In addition, the fecal indicator does not differentiate between human and animal wastes. The health risk and implications of the presence of fecal coliform originating from nonhuman sources have not been determined.

Sewage Treatment Plants

The most significant potential point sources of human pathogens into Buzzards Bay is discharge of sanitary wastes from sewage treatment plants (Figure 4.1). The combined capacity of all such discharges to the Bay exceeds 37 million gallons per day (MGD). Although these plants should be discharging only disinfected wastewater, occasional plant malfunctions and failures do occur. In general, closed "safety zones" around the immediate discharge areas are designed to protect the public from exposure to pathogens and are sized to allow adequate time to close adjacent shellfishing areas in the event of plant failure. However, a growing body of scientific evidence strongly suggests that, in some cases, traditional fecal indicator organisms are not adequately portraying real pathogen risks. For example, following chlorination, many pathogens, as well as fecal coliforms, may enter a state where they are viable but non-recoverable or detectable using standard assay methods. Fecal coliforms may also die off more rapidly than some viruses. Because of the high volume of untreated sewage that they release, CSOs in New Bedford are a major source of fecal coliforms to Buzzard Bay. The impacts of bacteria and pathogens from both sewage treatment facilities and CSOs are largely localized in the vicinity of these discharges.

Vessel Sanitary Wastes

Discharge of sanitary wastes from marine craft is a locally significant direct source of pathogens to Buzzards Bay. The more than 4,300 slips and moorings in the Bay and



SANITARY WASTE DISCHARGES

1. Glen Petroleum Corp.
2. Teledyne-Rodney Metals
3. Aerovox Corporation
4. Acushnet Co. - Rubber Division
5. Cornell-Dublier Electric
6. Revere Copper Products
7. Acushnet Co. - Golf Division
8. Fairhaven Wastewater Treatment Plant
9. New Bedford Wastewater Treatment Plant
10. Shawmut Avenue Landfill
11. Marion Wastewater Treatement Plant
12. Dartmouth Wastewater Treatment Plant
13. Goodyear Tire and Rubber
14. Commonwealth Electric
15. Wareham Wastewater Treatment Plant
16. Tremont Nail Company
17. Berkshire Hathaway Company
18. Chamberlain Manufacturing Corp.
19. Massachusetts Maritime Academy
20. Acushnet Capacitor

Figure 4.1. Selected surface wastewater discharge locations (NPDES permitted[1]) to Buzzards Bay

[1] Data source: NPDES permit files, Massachusetts Division of Marine Fisheries sanitary survey, and staff of pemitted entities.

the nearly 20,000 vessels passing through the Cape Cod Canal yearly create a considerable potential for waters to be contaminated by untreated sanitary waste from boats. Because of the intermittent and often covert nature of disposal from vessels, the overall impact of sanitary wastes on Buzzards Bay is difficult to assess. Few marinas in Buzzards Bay provide pump-out facilities. Marinas that do have these facilities report that they are seldom used.

The impact of sanitary waste pollution from boats tends to be site specific. In poorly flushed areas that have low dilution, the effect may be substantial and unpredictable. Health implications are difficult to evaluate from such unpredictable, and usually undetectable, changes. Nonetheless, direct illegal discharge of human wastes is a potential threat that must be addressed because of the large number of boats using Buzzards Bay.

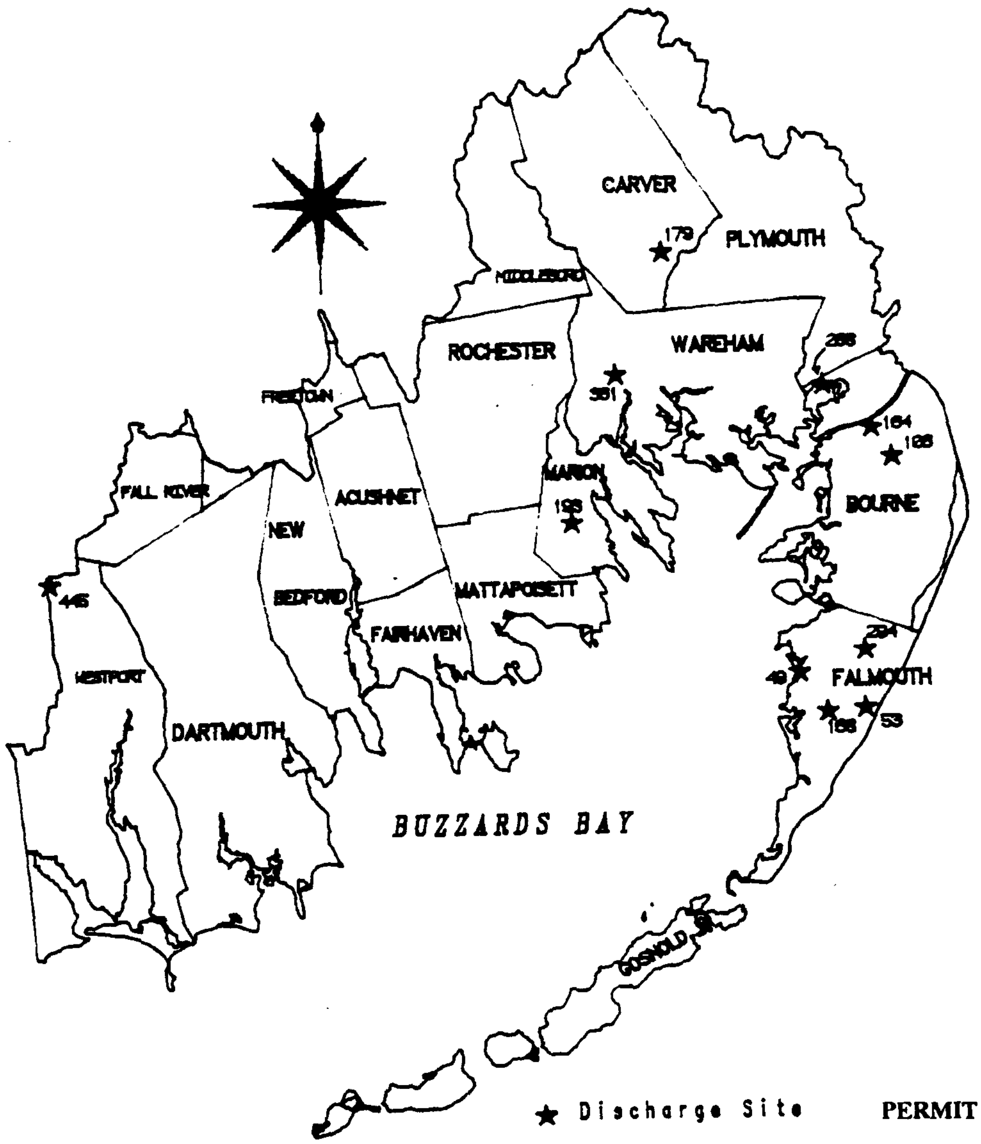
On-Site, Sub-Surface Sewage Disposal

Approximately half of the residents of the Buzzards Bay watershed use on-site, subsurface sewage disposal systems (cesspools or septic systems) to dispose of sanitary wastes. Construction of these systems is regulated by the state's sanitary code, known as Title 5, which sets minimum standards for design and placement. Pathogens are removed from septic-system wastes by two mechanisms — physical retention (or straining) by the receiving soil, and adsorption (or adherence) of pathogens onto soil particles. Groundwater discharges of over 15,000 gallons per day must have state permits issued by the Massachusetts Department of Environmental Protection (Figure 4.2). Many other large groundwater discharges exist, but were planned for less than 15,000 GPD to avoid permit requirements.

Pathogen contamination of Buzzards Bay from septic systems can occur in at least three ways. The most obvious threat to public health is an overt system failure. Such a failure results when soils can no longer receive septic effluent, and sewage collects on top of the septic system, often breaking out onto the surface of the ground. Sewage may then be transported into the receiving waters by stormwater drainage systems or overland flows. Overt system failure during dry weather probably plays a minor role in the overall pathogen contamination of Buzzards Bay. During heavy rains, many inadequately designed or maintained systems overflow, and this may be a significant source of coliforms in some areas. Many of these failures can be prevented by routine maintenance such as pumping out the solids that collect in the tank.

Closely related to overt failure is the existence of overflow pipes. Such pipes were once connected to the leaching component of septic systems to prevent failure and subsequent surface break-out. Overflow pipes were often designed to empty directly into a major water body or connecting ditch or stream. This practice of connecting overflow pipes is thought to have been quite common in past years, but is now illegal. A recent survey by state and local authorities has documented the locations of many of these overflow pipes around Buzzards Bay.

Pathogens from septic systems can also enter Buzzards Bay through groundwater. Studies conducted by the Buzzards Bay Project examined the potential for pathogen transport by this route. Results support the contention that, in most instances, soils filter pathogenic bacteria out of wastewater over a distance of only a few yards.



PERMIT HOLDERS

49 - Seacrest Hotel
53 - Falmouth Septage#
106 - Bourne Septage Disposal
164 - Bourne Laundromat
168 - Falmouth DPW
179 - Ocean Spray
193 - Town of Marion
288 - Hideaway Village
294 - Whitney - Cape Cod
361 - Spring Born Bionomics
445 - Old Colony Petroleum #
- Ceased Discharge

Sites discharging more than 15,000 gpd to groundwater must have a state permit. These permits are issued by the Mass. Dept. of Env. Protection's Div. of Water Pollution Control, Groundwater Section (DWPC-GW). The computer map of site locations was provided by DWPC-GW. The town and basin boundaries were provided by MassGIS. The Cape Cod side basin boundary was delineated by USGS based on water table elevation contours published in hydrologic atlas HA-692. This map was produced by the Buzzards Bay Project in March 1990, using ARC/INFO software.

Figure 4.2. Groundwater discharges (with state permits) in the Buzzards Bay drainage basin

Although properly functioning (no observed overflow) septic systems were generally not found to contribute to the indicator levels in the Bay, there is still concern that the much smaller pathogenic viruses may pass through the soil and reach the Bay, even when state requirements are being met (see review in Heufelder, 1988).

Stormwater Runoff

Stormwater refers to that portion of precipitation that is returned to a water body via surface routes from an adjacent land mass. Although precipitation when it falls is generally devoid of fecal indicator organisms, as it flows over the ground, it washes debris and sediments into surface waters. This debris may be composed of, or contaminated with, human or animal wastes.

Stormwater is managed to reduce or eliminate local flooding or to drain road surfaces for safety. Roadways and other developments are often designed so that excess water collects in drainage basins, ditches, and pipes and is then directed to the nearest river, stream, estuary, or other surface water body. An additional component of stormwater runoff that is of particular significance in agricultural areas is the sheet flow from land masses. In this case, instead of being collected and discharged through pipes, the flow is unconsolidated and enters the receiving water in broader, less defined areas. Generally, development further contributes to the amount of runoff by increasing the amount of paved or impervious surfaces and reducing the surface area available for precipitation to naturally percolate into the ground.

Investigations by the Buzzards Bay Project confirm the findings of the National Urban Runoff Program indicating that stormwater runoff is a major contributor of fecal indicators to surface waters. Agricultural runoff, which dominates the western portion of the Bay near Westport, and urban runoff, which dominates New Bedford and other residential areas near cities and town, enter the Bay both at discrete points such as pipes and open ditches and in broader, less defined areas of sheet flow.

Two distinct classes of urban runoff enter Buzzards Bay. Many older cities such as New Bedford built their storm and sewer systems using a single pipe, or combined sewer, approach that combines sewage wastes from households with stormwater. During heavy rainstorms, the waste treatment facility in New Bedford is unable to handle both the sewage and stormwater, and the untreated excess flow is discharged directly into Buzzards Bay through overflow pipes. These pipes are called combined sewer overflows (CSOs). There are 38 such discharges into the Acushnet River Estuary and Clarks Cove (see Figure 4.3). Data show that the highest densities of fecal coliform from all storm pipes investigated generally come from CSOs.

In addition to the CSOs of the New Bedford area, stormwater from other urban or suburban areas around the Bay often shows high fecal coliform counts, even where storm and sewer systems are not tied together. The source of coliforms in non-CSO discharges is the subject of considerable speculation. Pathogens may originate from

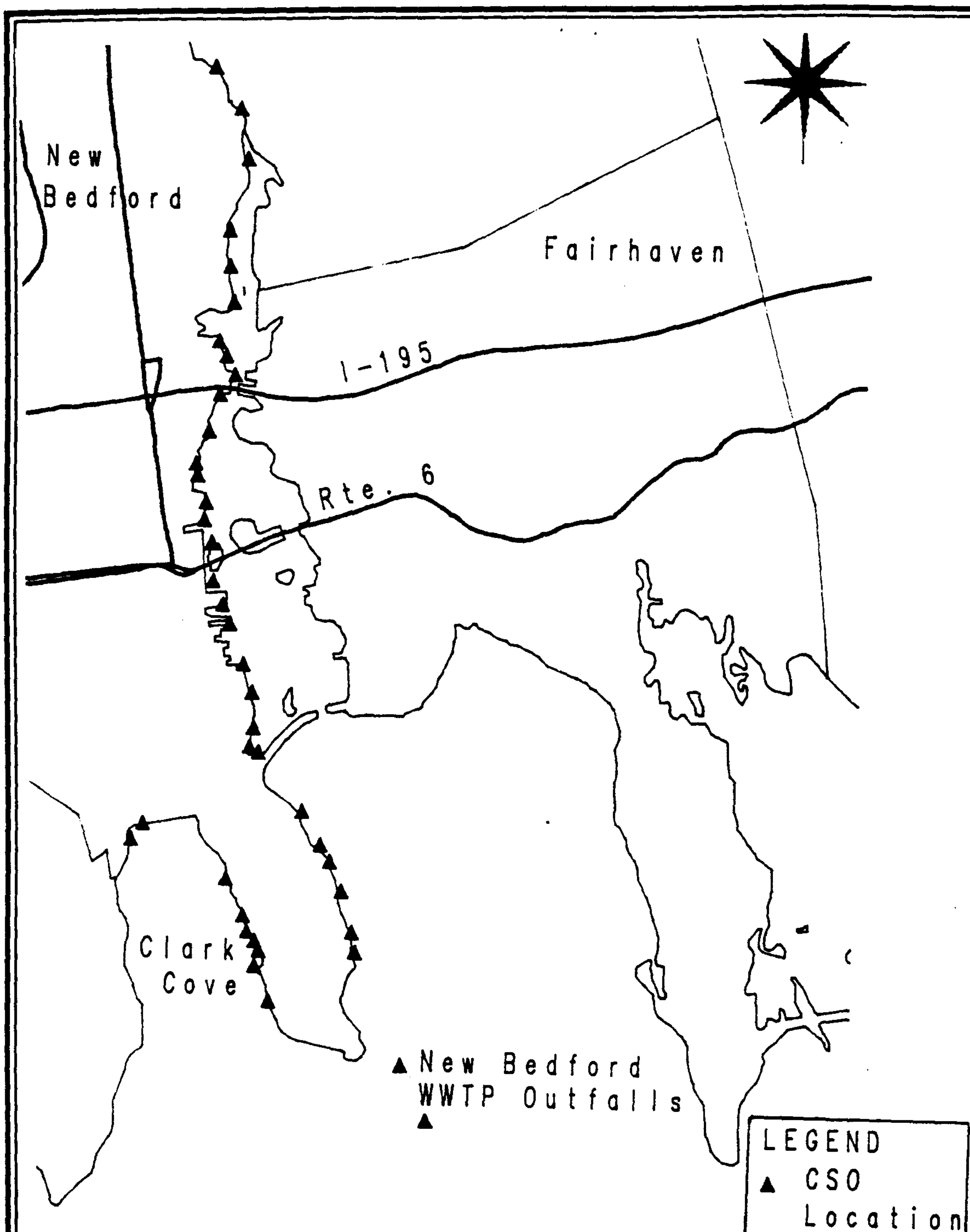


Figure 4.3. Location of CSOs and New Bedford wastewater discharge

(CSO locations provided by Massachusetts Department of Environmental Protection, Divison of Water Pollution Control) illegal home hook-ups or domestic and wild animals, or from failing septic systems whose sanitary wastes may pool on the top of the ground and find a surface pathway to the receiving water during a rain event. The Massachusetts Division of Marine Fisheries has recently completed sanitary surveys in Buzzards Bay under the Shellfish Sanitation Program[2] , and has identified more than 500 discharge pipes in open shellfish resources in Buzzards Bay and ranked their potential for contamination. This information is being used by the Buzzards Bay Project and Buzzards Bay municipalities to prioritize stormwater pipes and other sources for remediation.

The extensive use of the western shore of Buzzards Bay, particularly near Westport, for agricultural purposes makes this area highly susceptible to agricultural runoff. Fecal coliforms from this type of runoff originate primarily in animal feces, resulting from animal raising and crop-management practices (i.e., manure spreading).

Wildlife, Waterfowl, and Domestic Animals

Animal wastes enter Buzzards Bay in at least two ways. Stormwater, previously discussed, periodically washes animal wastes from both wildlife and domestic animals into the Bay. A more continuous input is from aquatic birds such as Canada geese and other shore birds. The effects from these inputs vary. Generally, the impact is less in well-flushed areas and greater in poorly flushed areas with organic sediment where the longevity of bacterial species is enhanced. A Buzzards Bay Project study in Buttermilk Bay has indicated that waterfowl waste can accumulate in other protected environments such as beach wrack (the free-floating plant material that washes up with the tide), which appears to prolong bacterial survival (Heufelder, 1988). Thus it is believed that wildlife, waterfowl, and domestic animals may be locally important sources of coliform contributing to the closure of resource areas.

Other Sources of Coliforms and Pathogens

Although not an original source, certain sediments in Buzzards Bay may act as a protective sink for fecal coliform and pathogens, releasing them back into the water column when the sediment is disrupted during storms or tidal fluxes. It is likely that in areas close to point-source discharges, such as CSOs and stormwater pipes, the sediments provide a protected habitat for settled microorganisms and prolong their survival. Soft organic sediments (e.g., muds) are more able to support bacterial survival and viral stability than are inorganic sediments such as sand and gravel. The introduction of nutrients from septic systems or sewage treatment plants may also play a role in the proliferation of pathogens harbored in sediments (Heufelder, 1988).

In addition to coliforms and pathogens stored in protective sediments, a number of human pathogens have been found to be normal inhabitants of estuaries elsewhere. No attempt has been made to document the presence of these pathogens in Buzzards Bay, but it is presumed they exist.

2 DMF is responsible for conducting shellfish area sanitary surveys in Massachusetts waters to identify existing and potential sources of coliform and pathogens in shellfish resource areas. A detailed explanation of the program is given on page 49.

Toxic Contamination to Buzzards Bay

Buzzards Bay receives a wide range of chemical contaminants from industrial and municipal wastes, dredged material, atmospheric fallout, river inputs, and other nonpoint pollution sources. Chemical contaminants enter Buzzards Bay through accidental oil spills, effluent discharges, river discharges, atmospheric transport and deposition to the Bay, or deposition to land and direct runoff to the Bay. Chemical pollutants associated with urban and industrial activities enter Buzzards Bay primarily in the western portion near the New Bedford, Fairhaven, and Dartmouth urban areas. Chemicals associated with agricultural activities are more likely to enter the Bay from runoff, creeks, and small rivers in the Westport, Dartmouth, Fairhaven, Mattapoisett, Marion, Wareham, Bourne and Falmouth areas.

The greater New Bedford area is clearly the major contributor of chemical contaminants to Buzzards Bay. The Harbor itself is extremely polluted with polycyclic aromatic hydrocarbons (PAHs), trace metals, and polychlorinated biphenyls (PCBs) as a result of industrial discharges between the 1940s and 1970s and stormwater runoff. On a regional scale, however, stormwater runoff, particularly from paved surfaces, is a major source of hydrocarbons to Buzzards Bay.

Evaluation of the fate and effects of chemical contaminants in the marine environment requires an understanding of the temporal and spatial distribution of contaminants; the partitioning of contaminants in the ecosystem among the sediment, the water column, and the living resources; and the level of damage imposed by accumulation of contaminants in the living resources.

Concern about contaminant input to coastal waters is focused on the accumulation and transfer of metals and organic contaminants in marine food webs, including accumulation in seafood species and potential impacts on human health. Additional concerns include toxic effects of contaminants on the survival and reproduction of marine organisms and the resulting impact on marine ecosystems. Chemicals of concern are those that have known or potentially deleterious effects on populations of living marine resources and on humans. Chlorine residuals from disinfected sewage discharged from treatment plants may also represent a threat to marine organisms.

Petroleum and Fossil Fuel Hydrocarbons

Hydrocarbon inputs to Buzzards Bay are the result of accidental oil spills, industrial and municipal wastes, stormwater runoff, small boats and other marine craft, and creosote-treated wood pilings. Buzzards Bay and the Cape Cod Canal serve as a major transportation route for small tankers and barges carrying petroleum products to the Boston market. It has been estimated that over 260,000 gallons of fossil fuel hydrocarbons have been accidentally spilled into the Bay between 1973 and 1989. However, the everyday, more insidious inputs of hydrocarbons to the Bay — from stormwater and wastewater from industry and sewage treatment facilities — have been calculated to be equal to or greater than the inputs from accidental spills.

Pesticides

There is little doubt that chlorinated pesticides were used extensively in the Buzzards Bay area during the 1950s and 1960s. In coastal regions with large areas of wetland and marshes, these pesticides were used to combat insects such as mosquitos that were potential carriers of human diseases. Pesticides were also used to combat crop pests. Since that time, use of many of the persistent chlorinated pesticides has been reduced or banned, and these chemicals have been replaced by less damaging and less persistent forms.

It is estimated that approximately 33,000 pounds per year of pesticides are used in agriculture in the Buzzards Bay drainage basin, primarily on crops such as cranberries (almost 20,000 pounds of pesticides per year), feed corn, sweet corn, potatoes, and squash (Farrington and McDowell-Capuzzo, BBP in press). Pesticides from household use may enter municipal waste sewers and storm sewers, and eventually reach the Bay. Although this may be a cumulatively large input, the relatively nonpersistent nature of pesticides currently in use suggests that the effects may be nominal.

Polychlorinated Biphenyls (PCBs)

PCBs are a family of organic compounds used since 1926 in electrical transformers as insulation, and in liquid coolants, flame retardants, lubricants, carbonless copy paper, adhesives, caulking compounds, and marine paints. PCBs are extremely persistent in the environment because they do not readily break down into less harmful chemicals.

Extensive PCB contamination in the New Bedford Harbor area resulted from manufacturing operations that discharged PCBs directly into the Acushnet River Estuary and indirectly through the municipal sewage treatment plant between the 1940s and 1970s. Over 18,000 acres of productive fishing grounds around New Bedford remain closed due to PCB contamination.

Sediments in the Harbor continue to act as a major source of PCB contamination to Buzzards Bay. Other past sources include atmospheric transport from New Bedford and other industrial areas in the northeast, and the disposal of New Bedford Harbor dredged materials into the Bay.

The extent of PCB contamination in marine resources taken from areas outside of New Bedford has been studied. Results show that although edible tissues of the three species tested (lobster, flounder, and quahog) generally have PCB levels below the FDA Action Level of 2.0 ppm (parts per million), some samples are dangerously close to the FDA limit, especially lobster hepatopancreas, or tomalley (Schwartz, 1987).

Other Organic Pollutants

Analysis of the effluent from the New Bedford sewage treatment plant has shown that several of the synthetic organic compounds listed by EPA as priority pollutants are present in measurable quantities. These compounds are typical of what is found in sewage from urban industrialized areas.

Historically, a variety of industrial wastes containing chemicals of concern were discharged into New Bedford Harbor. More recently, research has shown that tributyltin (TBT), which is sometimes added to marine paint as an antifoulant, is toxic and harmful to marine organisms in coastal ecosystems, even at the extremely low concentrations observed when TBT leaches from boats. Recent federal legislation phases out the use of TBT as an additive to marine paint. As of April 1988, Massachusetts banned the use of TBT-containing paints on all non-aluminum vessels under 25 meters in length. Paints with low TBT release rates (micrograms per day) can be used on larger vessels.

Trace Metals

Trace metals are chemical elements; as such they cannot be destroyed or broken down through treatment or environmental degradation. Certain metals occur naturally at low concentrations in seawater and in marine and estuarine sediments. Additional metals can be added to the marine environment through municipal and industrial wastewater discharges, atmospheric deposition, stormwater runoff, and leaching from boat paints and moorings. Once in the marine environment, metals are generally incorporated into the sediment. Marine invertebrates that live in sediments with high metal contamination may accumulate the metals above natural levels. These toxic metals may then be passed along the marine food web that includes humans.

Evidence shows that the New Bedford Harbor area, especially the Inner Harbor, has received substantial inputs of trace metals such as copper, nickel, zinc, and chromium in the past. High metal concentrations are often found in sediments around docks and mooring areas. Dredging, disposal of dredged materials in the main part of Buzzards Bay, and normal physical processes such as storms are contributing trace metals to the Bay.

Nutrients and Eutrophication in Buzzards Bay

Nitrogen, the primary nutrient of concern in marine waters such as Buzzards Bay, is essential for the proper growth and reproduction of individual organisms and, consequently, for the general productivity of the Bay (Figure 4.4). In nature, nitrogen occurs in many forms (e.g., ammonia, nitrates). The addition of excessive amounts of nitrogen (also called "nutrient enrichment" or "nitrogen loading"), to coastal waters results in eutrophication effects and a general decline in the health of coastal ecosystems.

In general, excessive nutrient inputs can result in increased growth of microalgae (such as phytoplankton) and macroalgae (seaweeds), which in turn changes the distribution and abundance of species present and in food-web relationships. For example, increased turbidity from phytoplankton growth prevents sunlight from reaching submerged vegetation like eelgrass, and beds of eelgrass begin to disappear. Because eelgrass beds are a valuable habitat and nursery for many organisms, the loss of this community can cause shifts in many populations of animals. Excessive algal growth may result in the depletion of oxygen levels when algae die and decompose. Severe oxygen depletion leads to fish kills and death of sensitive benthic organisms.

There is also increasing evidence that the effects of high nutrient loading, such as increased turbidity and the release of dissolved organic matter from algae, contribute to the prolonged survival and possible growth of coliform bacteria in coastal waters. Because coliform levels are used to classify swimming and shellfish areas, nutrient loading may contribute indirectly to the closing of these areas.

Coastal embayments receive nitrogen from a variety of sources including septic systems, sewage facilities, atmospheric inputs, and fertilizers used on lawns, golf courses, and agricultural areas. The nitrogen from these sources is conveyed to the Bay by effluent outfalls, streams and rivers, overland runoff, and groundwater that drains from the land. The relative importance of these sources depends on the specific land use within each drainage sub-basin.

In Buzzards Bay as a whole, sewage treatment facilities, together with CSOs, are the principal source of nitrogen entering the Bay, accounting for 62% of all inputs (Table 4.1). Although these inputs are very significant, the effects of nitrogen from these discharges are largely confined to the vicinity of the outfalls. Even a large nitrogen source like the New Bedford sewage treatment facility are localized and the nitrogen impacts to benthic communities occur mostly within several miles of the outfall, and may contribute to hypoxic conditions. For these reasons, nitrogen inputs from this outfall must be managed. However, studies conducted by the Buzzards Bay Project, have shown that the central portion of most of the Bay is not nutrient enriched,

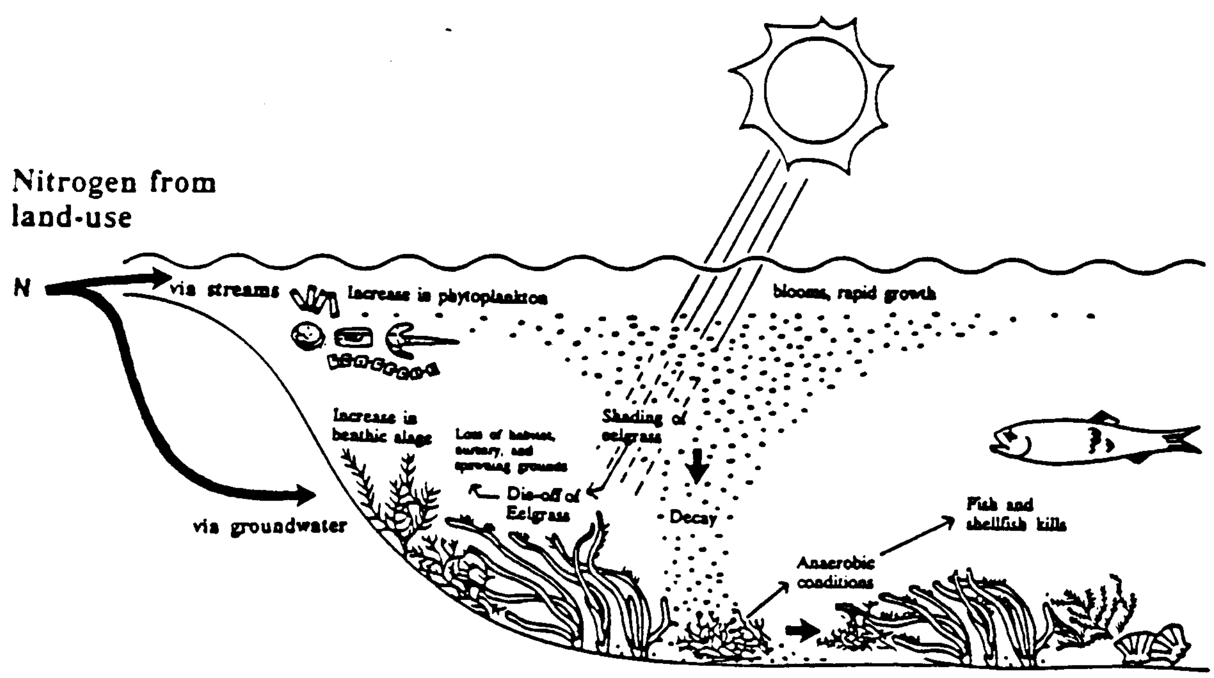


Figure 4.4. Generalized response of shallow coastal embayments to nitrogen loading

Source : Modified from U.S. Fish and Wildlife circular , Restore Chesapeake Bay (2/90).

(Rhoads, BBP in press; Hampson, BBP in press; CDM, 1989). Except in surrounding waters, the New Bedford outfall is not the cause of eutrophication effects observed in embayments in the Bay.

In general, most of the more serious effects of nitrogen loading that are observed in Buzzards Bay are localized in the network of shallow embayments that border the Bay, and are the result of inputs from land in the surrounding drainage basin. In many of these embayments, septic systems are the primary source of nitrogen. For example, in Buttermilk Bay, septic systems now account for more than 74% of the nitrogen entering this system. Septic systems release large amounts of nitrogen as ammonia, which is rapidly transformed to nitrate in the presence of oxygen in the groundwater. In general, nitrate in groundwater flows great distances without attenuation (or dilution) and with little chance of uptake by plants. In rural agricultural areas like Westport, more nitrogen may be contributed to embayments by fertilizers and animal wastes than by septic systems.

Table 4.1. Relative contribution[1] of anthropogenic nitrogen inputs to Buzzards Bay and Buttermilk Bay drainage basins from various sources

	Percent Contributions	
Source	Buzzards Bay[2]	Buttermilk Bay
Precipitation		
- runoff from developed land	2	2
- directly on Bay	12	1
Sewage Treatment Facilities (including CSOs)	62	0
Septic Systems	15	74
Fertilizer		
- on lawns	4	18
- agricultural use	5	5

[1]Sources: Based on Valiela and Costa (1989), SAIC 1991, Horsley Witten Hegeman, Inc., 1991.
[2]Total annual loading is 2246 metric tons.