CHAPTER 3: THE AFFECTED ENVIRONMENT

***Chapter Outline*:** **Page**

CHAPTER 3: THE AFFECTED ENVIRONMENT

New Bedford Harbor is an estuary--a place where fresh and salt water mix in a dynamic coastal environment--within a larger estuary, Buzzards Bay. The unique characteristics of New Bedford Harbor and Buzzards Bay are a result of this dynamism: interactions among the waves and tides of the sea, the winds of the atmosphere, the flow of rivers and wetlands. Temperatures and salinities change; sediments are deposited or scoured; creatures in the water, land and air eat and are eaten, transferring energy and materials into, out of, and throughout the ecosystem.

These estuarine environments are home to about 150,000 people as well, living and working in the four communities on the banks of the New Bedford Harbor Estuary. This human environment is at least as complex as the physical environment, and at least as significant an aspect of the affected environment. Particularly relevant to natural resource restoration issues are human uses of the environment, whether commercial, recreational, or simply aesthetic.

In order to assess the potential impacts of natural resource restoration on the New Bedford Harbor Environment, both human and natural aspects of the environment must be considered, as well as interactions between the two: human uses of the environment. An examination of the effects of PCB contamination on the environment and the economy of New Bedford Harbor is an essential component of this assessment.

3.1 Geography

New Bedford Harbor is an urbanized tidal estuary on the western shore of Buzzards Bay, in southeastern Massachusetts. The City of New Bedford and the Town of Dartmouth are situated on the west bank of the Harbor, while the Towns of Fairhaven and Acushnet occupy the east bank. The Acushnet River flows north to south into the New Bedford Harbor Estuary.

For restoration purposes, the New Bedford Harbor Trustee Council (NBHTC) has defined the New Bedford Harbor Environment (the affected environment) as the Acushnet River and its watershed from the New Bedford Reservoir south through New Bedford Harbor, to the outermost fishing closure line **(Figure 1.1).** However, emphasis for restoration will be placed on the part of the site most affected by PCB contamination of New Bedford Harbor: estuarine and marine areas in which fishing closures have been implemented as a result of the Harbor contamination, along with their natural resources and adjacent shorelines. These saltwater portions of the New Bedford Harbor Environment will be referred to as the New Bedford Harbor Estuary, bounded in the North by Wood Street and in the South by the Area III closure line **(Figure 3.2).** The Estuary may be further subdivided into the Upper Acushnet River Estuary, from Wood Street to the Route 195 bridge; Inner New Bedford Harbor, from Route 195 to the Hurricane Barrier; and Outer New Bedford Harbor, from the Barrier to the Area III closure line, including Clarks Cove. The boundaries established by the US Environmental Protection Agency (EPA) for the New Bedford Harbor Superfund Site conform roughly to those of the New Bedford Harbor Estuary.

New Bedford, Fairhaven, Dartmouth and Acushnet, the communities adjoining the New Bedford Harbor Estuary, are those which have been most affected by the contamination of the Harbor. The human environment of the New Bedford area is discussed more fully in Section 3.4, but it is important to note here that the area's economic, cultural, and historical links to the marine environment are strong. In the 19th Century, the New Bedford whaling fleet was the largest in the world; today, New Bedford Harbor is a major East Coast fishing port, a regional center for marine transportation, and a gateway to marine recreation on Buzzards Bay and beyond.

3.2 Physical Environment

3.2.1 Geomorphology

Buzzards Bay was formed as a result of the Pleistocene glaciation; the subsequent retreat of the Laurentide ice sheet, beginning about 16,000 years ago; and the rise in sea level which accompanied the retreat of the glaciers. The bedrock beneath the estuary is granitic gneiss, overlain with 8-9 ft (2.4-2.7 m) of glacial till or 6-9 ft (1.8-2.7 m) of gravelly sediments. Sands and silts also cover these materials; in some areas, such as New Bedford Harbor, marine sediments are 60 ft (18.2 m) thick (VHB 1996; Summerhayes et al., 1977). The Elizabeth Islands, southeast of New Bedford, are remnants of the glacier's terminal moraine--materials deposited at the furthest extent of glaciation.

3.2.1.1 Shorelines

The upper reaches of the New Bedford Harbor Estuary are low-energy areas. Shorelines in these places are composed of fine-grained sediments. Wetlands and tidal flats are the predominant natural shoreline types, although much of the natural shoreline has been altered.

Manufacturing facilities and residential neighborhoods occupy the shores of the Upper Acushnet River Estuary. While most of the western shore of the Upper Estuary has been altered by land-filling, bulkheading, and other shoreline modifications, there are fringing marshes and tide flats in the vicinity of the cove by Coffin Ave. By contrast, the eastern shore of the Upper Estuary is largely natural or semi-natural, with fairly extensive salt marshes.

The shores of Inner New Bedford Harbor are heavily developed. Wharves for the fishing fleet and other commercial uses are the dominant feature of the New Bedford shoreline, while boatyards dominate the Fairhaven shore. Fuel docks, fish processing operations, and other support services for the commercial and recreation fleet are prominent on both sides of the Inner Harbor, as well. Considerable land-filling has taken place, particularly on the New Bedford side, and relatively little unmodified shoreline remains between Route 6 and the Hurricane Barrier.

By contrast with the developed shorelines of the Upper Estuary and Inner Harbor, the shoreline of Outer New Bedford Harbor is largely natural or semi-natural, although modifications such as bulkheads and groins are evident in some areas. Since the shores of the Outer Harbor area are more exposed than those of the Inner Harbor and Upper Estuary, shorelines outside the Hurricane Barrier tend toward ledge or beach rather than wetlands. Exceptions include the large salt marsh in the Pope Beach area of Fairhaven, the salt marshes behind Winsegansett Pond on Sconticut Neck, Fairhaven, and the salt marshes of Padanaram and Nonquitt in Dartmouth.

3.2.1.2 Marine Sediments and Sedimentation Processes

Tidal and wind-driven currents are the primary mechanisms of sediment transport and sorting in Buzzards Bay. Like many estuaries around the world, Buzzards Bay as a whole is a net depositional area -- that is, sediments tend to accumulate there over time. Within Buzzards Bay and within the Harbor Estuary, patterns of sediment transport are more complex. Tidal currents carry silts and clays landward from Buzzards Bay, depositing them in the Upper Estuary and Inner Harbor, while sediments tend to move from the Outer Harbor back out into Buzzards Bay. As a result, the Upper Estuary and Inner Harbor are net depositional areas, accumulating sediment, while the Outer Harbor is not. Fine-textured sediments such as muds accumulate in Harbor Estuary's low-energy environments: the Inner Harbor, Upper Estuary, and deeper parts of the Outer Harbor. Coarser sediments -- sand and gravel -- are present in higher-energy areas: the shoals, channels and beaches of the Outer Harbor (VHB, 1996).

Marine sediments on the seabed of the New Bedford Harbor Estuary are thinnest over the topographic highs and thickest in the drowned channels. The shallower deposits typically consist of 8-9 ft (2.4-2.7 m) of glacial till or 6-9 ft (1.8-2.7 m) of gravelly outwash over bedrock, sometimes with a thin (less than 3 ft (1 m)) layer of marine sands or silts capping the underlying deposits. In the Inner Harbor, unconsolidated sediments are as deep as 60 ft (18 m). Sediment clay to mud (silt + clay) ratios are 0.34 in central Buzzards Bay; 0.28 in the Outer Harbor and 0.18 in New Bedford Harbor (Summerhayes et al., 1985).

The deepest sediments in the Estuary consist of silt and sandy silt, above which are sandy sediments of gravel and silt. The uppermost layer is as much as 10-15 ft (3-5 m) thick and consists of organic enriched silts. While organic carbon content in the upper 4 in (10 cm) of sediment in most of Buzzards Bay is 1-2%, the Inner Harbor contains surface sediments with an organic carbon content of 4-7%, and the area near the Clarks Point sewage treatment plant outfall has sediments with 3.2% organic carbon. These elevated levels of organic carbon have been attributed to urban sewage discharges, organic wastes, and oil residuals from shipping (Summerhayes et al. 1985). The sediment-water interface beneath New Bedford Harbor is dominated by a thin, soupy layer of clay-rich sediments in suspension. This turbid layer is not unusual in estuaries, and is referred to as "fluff" in the scientific literature. Levels of organic materials and metals in the sediments are high, particularly in the Inner Harbor (VHB, 1996; Summerhayes et al., 1977).

Rates of sedimentation in Buzzards Bay are, on average, 0.04-0.12 in (1-3 mm) per year. Sedimentation rates are highest in deeper and more protected waters, and less around shoals and channels. Historically, the rate of sedimentation in the deeper parts of Inner New Bedford Harbor was about 0.08 in (2 mm) per year. However, construction of the Hurricane Barrier across the Harbor mouth in 1966 increased sedimentation rates nearly tenfold, to approximately 0.7 in (17 mm) per year. Sedimentation rates are also high near the Clarks Point waste treatment plant outfall: 1.2 in (30 mm) per year directly beneath the sewer outfall, and 0.12 in (3 mm) per year at a distance of 0.3 miles (0.5 km) from the point of discharge (Summerhayes et al., 1977).

3.2.2 Hydrology and Bathymetry

3.2.2.1 Acushnet River and Watershed

The Acushnet River is a small fresh water stream of approximately 2.5 miles in length, flowing north to south from the New Bedford Reservoir in Acushnet into the New Bedford Harbor Estuary. The River is dammed at three points, all within the Town of Acushnet: at the south end of the New Bedford Reservoir; at the Hamlin Road crossing; and at the Acushnet Sawmill, off Mill Road on the New Bedford/Acushnet town line. Discharges of fresh water from the Acushnet River to the New Bedford Harbor Estuary are small, ranging during the year from a low of 0.55 cubic feet per second (cf/s) (0.02 cubic meters per second (cm/s)) to a high of 26 cf/s (0.73 cm/s) (Malcolm Pirnie Inc., 1982). Estimates of mean annual discharge rate and 100-year storm flow are 30 cf/s (0.85 cm/s) and 1,350 cf/s (38.2 cm/s), respectively (NUS, 1984). The small flow rates of the Acushnet River explain the relatively high salinities of the Upper Estuary and Inner New Bedford Harbor described below.

The watershed of the Acushnet River is about 18.5 square miles (48 sq. km) in extent, including land within the borders of Lakeville, Rochester, Freetown, New Bedford, Acushnet and Fairhaven, MA. Approximately 59% of the Acushnet River watershed is forested, including both upland and wetland forest (VHB, 1996; EPA, 1991). Approximately 21% of the watershed is non-forested wetlands, tidal as well as non-tidal; 12% is pasture or cropland; and approximately 7% is open land and woody perennial. In 1984, residential, commercial, and industrial development comprised 14.3%, 0.1%, and 0.02% of the watershed, respectively. These figures suggest that the Acushnet River watershed remains relatively undeveloped; however, land-use mapping clearly reveals intensive development in the lower watershed, particularly within New Bedford and Fairhaven, and in coastal areas adjoining the Upper Estuary and Inner Harbor. Land use in the New Bedford Environment is discussed in more detail in Section 3.4.

3.2.2.2 New Bedford Harbor Estuary

3.2.2.2.1 Bathymetry

The New Bedford Harbor Estuary is a shallow embayment consisting of approximately 18 sq. mi. (47 sq. km) of open water, rocky shores, beaches, salt marshes, tidal creeks, and other coastal habitats. A well-defined, narrow channel extends from the Upper Acushnet River Estuary, south-southeast to Outer New Bedford Harbor, approximately one and one-quarter mile. The channel has been widened and deepened to 30 ft (9 m) at mean low water (mlw) by occasional dredging activities since 1839, although no dredging has occurred for more than 30 years, and channel depths are now generally less (VHB, 1996).

Depths in the Upper Estuary north of the Coggeshall Street Bridge are generally less than 6 ft (1.8 m) mlw, although there is a natural channel of about 15 ft depth (5 m) beneath the bridge. South of Coggeshall Street, the dredged channel runs along the west side of the Harbor and through the 150 ft (45 m) wide Hurricane Barrier entrance. With the exception of areas along the piers of New Bedford and Fairhaven that have been dredged to accommodate shipping, the Inner Harbor and Upper Acushnet River Estuary are quite shallow; shoals and intertidal flats are present throughout. South of the Hurricane Barrier, Outer New Bedford Harbor is also relatively shallow, with depths ranging to about 40ft along the Area III closure line (VHB, 1996; NOAA, 1995).

3.2.2.2.2 Dynamics

The New Bedford Harbor Estuary is classed as a weakly stratified, low-energy microtidal estuary. Tides are semidiurnal, tidal currents are generally weak, and wave energy is low. The Upper Estuary and Inner Harbor are poorly flushed, and have been made more so by human modification, intensifying problems caused by discharge of pollutants within the Upper Acushnet River Estuary and Inner New Bedford Harbor.

Fresh water flows into the New Bedford Harbor Estuary from the Acushnet River, smaller streams on the east bank of the Upper Estuary, as stormwater runoff, and as wastewater from combined sewer overflows (CSOs). Taken together, these inputs are relatively small and the Harbor Estuary is relatively saline. Salinities in the Upper Estuary have been measured at 7-31 parts per thousand (ppt); at the Coggeshall Street Bridge, salinities range from 10-33 ppt (ACOE, 1990; Bellmer, 1988). Salinity in Buzzards Bay is generally 31-33 ppt (Summerhayes et al. 1977). Vertical salinity gradients vary; gradients up to 18 ppt have been measured at the Coggeshall Street Bridge (Battelle Memorial Institute, 1990) while vertical salinity gradients in the Inner Harbor range from 1-3 ppt (VHB 1996). The average horizontal salinity gradient in the Inner Harbor is approximately 4 ppt over a 3.1 mile (5,000m) distance (Bellmer, 1988).

Water temperatures in New Bedford Harbor range from 33 F (0.5 C) in winter to 66 F (19 C) in summer. Higher temperatures during the summer reduce dissolved oxygen levels while increasing biological activity and biological oxygen demand (BOD) levels; at times, such conditions stress marine organisms, causing fish kills in poorly-flushed areas (VHB, 1996).

Tidal currents are the principal force of circulation in the New Bedford Harbor Estuary. Tidal flushing of the Upper Acushnet River Estuary is estimated to occur every 1.6 tidal cycles (18.2 hours), but appears to vary throughout the year. The Upper Estuary flushes less frequently in summer, suggesting that suspended materials such as pollutants may remain in the Upper Estuary for longer periods during the summer than during other times of the year (VHB, 1996; SES, 1988).

Tidal velocities in the New Bedford Harbor are generally weak. Velocities are higher on the flood tide than on the ebb (Summerhayes et al., 1977), and maximum currents occur approximately 3 hours before the turn of each tide (Battelle Memorial Institute, 1990). Currents in the Upper Estuary are relatively low: 0.3 knots (0.15 m/s) on average, and generally less than 0.6 knots (0.3 m/s) (ACOE, 1988). In the Inner Harbor, current velocities are generally less than 0.4 knots (0.18 m/s); bottom friction results in small-scale eddies that create a vertically well-mixed boundary layer in the deeper waters, thereby causing sediments and other materials to remain suspended in the water column, giving rise to the turbid layer of "fluff" described above (VHB, 1996; Summerhayes et al., 1977). Maximum tidal velocities in the Outer Harbor are generally comparable to those of the Inner Harbor, at

0.4 knots (0.18 m/s) or so, running generally north and south, into and out of the Inner Harbor (Eldridge Tide and Pilot Book, 1994).

The dynamics of the Estuary have been significantly altered by human modification. The Coggeshall Street Bridge and the Hurricane Barrier have constricted tidal flow in the Inner Harbor and Upper Estuary, forcing local accelerations of tidal currents and altering flow patterns. The flood tide enters the Inner Harbor in a jet-like stream, moving through the 150 ft (45 m) wide Hurricane Barrier entrance at 2.4 k (122 cm/sec). This jet, with secondary eddies on either side, dominates Inner Harbor mixing patterns. The Coggeshall Street Bridge is thought to cause similar flow patterns as the tides force water to move between the Inner Harbor and Upper Estuary. (EBASCO, 1990; SES, 1988; Summerhayes et al., 1977). Tidal currents at Coggeshall Street have been measured as high as 3.5 k (1.8 m/s) during the ebb (Battelle Memorial Institute, 1990). Construction of the Hurricane Barrier also appears to have altered tidal range within the Inner Harbor and Upper Estuary--average tidal range in the Inner Harbor is 3.7 ft (1.1 m) with a spring tidal range of 4.6 ft (1.4 m), while outside the Barrier, average tidal range is 4.65 ft (1.42 m) with a spring range of 5.05 ft (1.54 m) (VHB, 1996; ACOE, 1990).

Winds also affect currents within the Outer Harbor. Moderate southwesterly winds in summer and strong northwesterlies in the winter cause distinct seasonal current effects. A fetch of more than 8.7 miles (14 km) is present to the Southwest, and waves at times may reach 6.5 ft (2 m)(Battelle Memorial Institute, 1990). While the Inner Harbor is generally well protected from waves by the Hurricane Barrier, waves as high as 3 ft (0.92 m) have observed north of Coggeshall Street during storms (Battelle Memorial Institute, 1990). In waters less than 20 ft (6 m) deep, wind-driven waves may be the most important factor in generating currents at the bottom, particularly during storms (VHB, 1996).

3.2.2.3 Buzzards Bay

Like New Bedford Harbor, Buzzards Bay is classed as a low-energy microtidal estuary. The Bay is 28 miles (45 km) long with an average width of 8 miles (12 km); total area is 228 square miles (590 square km). It is generally shallow, with an average depth of 36 ft (11 m) and a maximum depth of roughly 75 ft (23 m). The Bay has a drainage area of 425 square miles (1,104 square km), which is small for an estuary of its size. The land:water ratio of Buzzards Bay is less than 2:1, far less than the 14:1 land:water ratio of Chesapeake Bay. Nearly 250,000 people live in the drainage basin, in 17 municipalities (Buzzards Bay Project, 1991).

The Bay’s southwestern shoreline--formed by the terminal moraine--is physically regular, while the northern and northwestern shores are characterized by the irregular topography of drowned river valleys and embayments such as the New Bedford Harbor Estuary. Seven major rivers drain the western shore of the Bay, including the Acushnet; but along the eastern shore, groundwater is the most important source of fresh water to the Bay. At the head of the Bay is the Cape Cod Canal, providing a passage for vessels--and a tidal connection--to Massachusetts Bay. Buzzards Bay has a shoreline of more than 280 miles (470 km), including 11 miles of public beaches and a variety of important coastal habitats: salt marshes; tide creeks; sea grass beds; tidal flats; and barrier beaches (Buzzards Bay Project, 1991).

3.2.3 Climate

Wind, precipitation, and temperature have a significant influence on the flow of the Acushnet River, the circulation of the New Bedford Harbor Estuary, and ecological processes in the New Bedford Harbor Environment. Ocean winds moderate summer and winter temperatures; mean annual air temperature is 50 F (10 C), while average monthly temperatures range from 30 F (-1 C) in January to 72 F (22 C) in July (Battelle Memorial Institute, 1990). Average annual precipitation is 46 in (114 cm), uniformly distributed throughout the year (approximately 4 in (10 cm) per month).

During the winter, strong northwest winds prevail, while gentle southwest winds are more frequent during the summer. Brief but severe thunderstorms with high winds occur in the area, generally from May through August. Hurricanes sometimes pass through during the summer and fall, while northeasters, coastal storms which can also produce severe erosional effects, occur from late fall through spring. Storm winds as high as 78 knots (90 mph, 40.3 m/s) have been recorded; related storm surges may drive tides 1 to 3 ft (0.3 to 0.9 m) above normal (Battelle Memorial Institute, 1990).

3.3 Biological Environment

3.3.1 Habitats

Habitat is the complex of geographic features, hydrologic conditions, and living organisms within an ecosystem that provides food, nesting and resting areas, and shelter for fish and wildlife. Broadly speaking, the habitats of the New Bedford Harbor Environment include fresh water and upland habitats, salt marsh, tidal flat and soft-bottom habitats, beaches and rocky intertidal habitats, sea grass beds, and open water habitats.

In spite of human modification of much of the shoreline, significant coastal habitats of all these types remain in and around the New Bedford Harbor Estuary, supporting a wide range of plants, animals, fish, and shellfish. Moreover, these habitat types function together in the New Bedford Harbor Environment and beyond, since many of the most important organisms in New Bedford Harbor--fish and birds in particular--are dependent on a number of habitat types. Therefore, while it is useful to consider each of these habitat types individually, the New Bedford Harbor Environment should also be seen as a single, multifaceted habitat which is, in turn, part of larger marine and terrestrial systems--Buzzards Bay and the New England coastal plain.

3.3.1.1 Fresh water and Upland Habitats

A range of fresh water and upland habitats is present in the New Bedford Harbor Environment. There are riverine habitats; fresh water wetlands of several types; natural and man-made lakes and ponds; and upland forests and meadows throughout the watershed. Some of these systems are quite extensive and many have significant natural value, though in many cases their ecology has been adversely affected by land clearing, development, ditching or diversion for residential use, roads and utilities, sand and gravel operations, agriculture, industrial purposes, or urbanization.

Upstream of tidal influence, the Acushnet River and other water courses are characterized as riverine habitat. The Acushnet is the largest of these, yet it is relatively small, less than 30 ft

(10 m) in width and less than 18 in (0.45 m) deep during average flow conditions. It originates at the south end of the New Bedford Reservoir and widens in two impoundment locations: above the Hamlin Street Dam in Acushnet, and at the Acushnet Sawmill Dam off Mill Street in Acushnet. Much of the substrate is sand, gravel, and cobble, as high flows in the spring and during storm events create erosive conditions that transport sediments and detritus downstream. Behind the dams and in other areas where flow velocities are low, organic-rich mud and fine sand sediments are deposited. While there are small streams throughout the less developed parts of the Acushnet River watershed, few surficial fresh water flows remain in the more urbanized parts of New Bedford and Fairhaven, having been diverted into the stormwater system. **Table 3.1** provides a list of the fresh water fish inhabiting the Acushnet River.

Table 3.1: Fish using fresh water habitats in the Acushnet River (Hurley, 1996).

common name	scientific name
American eel	*Anguilla rostrata*
Blueback herring	*Alosa aestivalis*
Alewife	*Alosa pseudoharengus*
Brook trout	*Salvelinus fontinalis*
Rainbow smelt	*Osmerus mordax*
Redfin pickerel	*Esox americanus*
Chain pickerel	*Esox niger*
Golden shiner	*Notemigonus crysoleucas*
Bridled shiner	*Notropis bifrenatus*
White sucker	*Catostomus commersoni*
Creek chubsucker	*Erimyzon oblongus*
Brown bullhead	*Ameiurus nebulosus*
White Perch	*Morone americana*
Striped Bass	*Morone saxatilis*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropteruis salmoides*
Tasselated darter	*Etheostoma olmstedi*
Yellow perch	*Perca flavescens*

There are forested wetlands throughout less developed parts of the Acushnet River watershed; these systems may be dominated by either deciduous (broad-leaved) or coniferous (evergreen) trees. Red maple (*Acer rubrum*) and green ash (*Fraxinus pennsylvanica*) are dominant tree species in many of the broad-leaved deciduous wetlands, which may be seasonally-flooded or saturated. A detailed ecological description of these wetlands is provided by Golet et al. (1993). White pine (*Pinus strobus*) and Atlantic white cedar (*Chamaecyparis thyoides*) are coniferous tree species that are common in the forested wetlands in the watershed. Often, white pine is a sub-dominant or co-dominant canopy species in red maple swamps in the Acushnet River watershed. Atlantic white cedar sometimes occurs as a dominant species, particularly in semi-permanently flooded and permanently saturated sites underlain by thick organic mucks. Laderman (1989) presents a detailed overview of the Atlantic white cedar wetlands found in southeastern New England.

A large forested swamp along the southwestern shore of Long Pond (east of Route 140), dominated by red maple and white pine along its perimeter and Atlantic white cedar in the interior, is a classic example of the forested wetlands found in the watershed. Other, similar wetlands include the Fall Brook drainage in the western portion of the Acushnet watershed; an 1,100 acre (445 ha) floodplain swamp along the Acushnet River south of New Bedford Reservoir; the 600 acre (245 ha) Bolton Swamp (between Route 140 and Country Road in Freetown); and the 350 acre (140 ha) Hathaway Swamp, southeast of the Peckham Road-Acushnet Avenue intersection in Acushnet. The Acushnet Swamp, which is actually in the Paskamanset River watershed to the west of the Acushnet River watershed, is an expansive Atlantic white cedar-dominated wetland.

Scrub-shrub wetlands are prevalent in areas where the forest canopy has been cleared, and in semi-permanently and shallow permanently flooded areas where the hydrology inhibits tree establishment or growth. Scrub-shrub wetlands in the Acushnet River watershed are generally dominated by alders (*Alnus* spp.), highbush blueberry (*Vaccinium corymbosum*), buttonbush (*Cephalanthus occidentalis*), red maple saplings, and willows (*Salix* spp.). Examples of scrub-shrub wetlands in the watershed include a large buttonbush and willow-dominated swamp at the north end of Long Pond adjacent to Assawompset Pond in Lakeville, and a red maple sapling swamp near the impoundment above Hamlin Street in Acushnet.

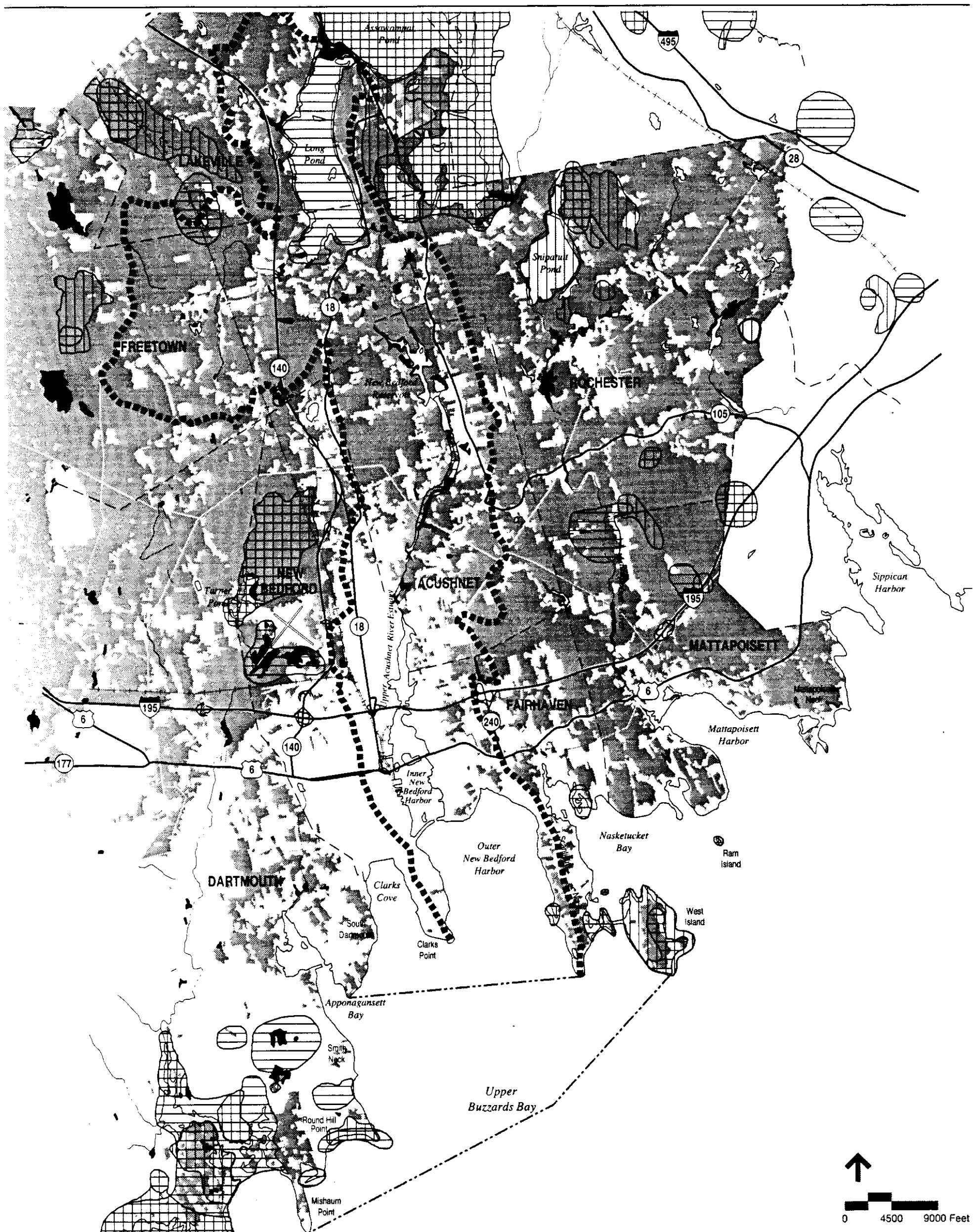
Palustrine emergent wetlands are fresh water marshes dominated by non-woody plants, and include seasonally saturated meadows, the fringes of ponds and lakes, and semi-permanently flooded areas lacking woody species cover. Cattail (*Typha* spp.) and wetland grasses commonly dominate the emergent wetlands within the Acushnet River watershed; duck potato (*Sagittaria* spp.) and pickerelweed (*Pontederia cordata*) are typical non-persistent species. Examples of emergent wetlands occur as fringes along the impoundments off Mill Street and Hamlin Street in Acushnet.

Small, shallow bodies of open fresh water lacking significant emergent vegetative cover are classified as palustrine open water. This habitat type is present throughout the Acushnet River watershed, and includes small natural ponds with mud or mucky substrates, as well as man-made basins created for cranberry production, stormwater management, or resulting from sand and gravel mining. Examples of this habitat type include the small impoundment north of the Hamlin Street Dam in Acushnet and the numerous cranberry production and quarry ponds off Braley Road and Route 18 in the northern portion of Acushnet.

Larger, deeper bodies of open water are classified as lacustrine habitat. Long Pond and New Bedford Reservoir are examples of lacustrine wetlands in the watershed.

Figure 3.1 shows upland and fresh water habitats of the New Bedford Harbor Environment.

Figure 3-1



Vanasse Hangen Brustlin, Inc.

- Watershed Boundary
- Non-Forested, Non-Tidal Wetlands
- Upland and Wetland Forests
- High Priority Rare Habitats and Exemplary Natural Communities (Source: MNHP, 1995)
- Habitats of Rare Wetlands, Wildlife, and Certified Vernal Pools (Source: MNHP, 1995)
- X Known Fish Blockages
- Area Closure Boundaries

Acushnet River Watershed Habitats and Resources

New Bedford Harbor Trustee Council RP/EIS

70602AHR

3.3.1.2 Salt marsh

From an ecological perspective, salt marshes are among the most important shoreline types in Buzzards Bay. There are nearly 400 acres (160 ha) of salt marsh along New Bedford Harbor, mostly along the east bank of the Upper Acushnet River Estuary and by Pope Beach, on the Outer Harbor in Fairhaven. Elsewhere in the New Bedford Harbor Estuary there are fairly large salt marshes in Nonquitt, Dartmouth (60 acre (24 ha)); in Padanaram, Dartmouth, on Apponagansett Bay (6.5 acres (2.6 ha)); and in the Winsegansett Pond area of Sconticut Neck, Fairhaven. These wetland areas are rich in the flora and fauna that typifies New England salt marsh.

The ecology and composition of salt marsh plant and animal communities depends on their elevation and corresponding frequency of tidal inundation. The high marsh is the area between mean high water and the highest spring tides; because of its elevation it is irregularly flooded by the tide. Dominant plant cover in the high marshes of the New Bedford Harbor Estuary is salt hay *(Spartina patens)*, but dozens of other plant species are present. Spikegrass *(Distichlis spicata)* and blackgrass *(Juncus gerardi)* are sometimes co-dominants with the salt hay. Common forbs include sea lavender *(Limonium carolinianum)*, sea orach (*Atriplex patula)*, seaside goldenrod (*Solidago sempervirens*), and slender-leaved aster (*Aster tenuifolius*)*.* Stunted salt-marsh cordgrass *(Spartina alterniflora)* and glasswort *(Salicornia spp.)* are present in areas where soil salinity is exceptionally high, such as in depressions on the marsh surface (VHB, 1996; SES, 1988).

Toward the inland edges of the marsh and on high spots, marsh elder *(Iva frutescens)* is common. At their landward edges, or where human alteration has reduced the frequency of tidal inundation, the salt marshes of the New Bedford Harbor Estuary often show a transition from salt-tolerant vegetation to vegetation more characteristic of fresh- or brackish-water wetlands, such as red maple *(Acer rubrum)* , cattail *(Typha angustifolia)*, and common reed *(Phragmites australis)* (VHB, 1996; Lloyd Center, 1989; SES, 1988). The reed, in particular, is an invasive species which tends to quickly colonize recently-disturbed wetland soils of moderate salinity to form dense, monotypical stands of limited wildlife habitat value (VHB, 1996; Odum et al. 1984). **Table 3.4** provides a complete list of plants observed on the salt marshes of the New Bedford Harbor Estuary.

A 1988 study of the marshes of the Upper Acushnet River Estuary and Pope Beach area found several invertebrates to be "ubiquitous" throughout these areas: the coffee bean snail *(Melampus bidentatus)* and two groups of small crustaceans: amphipods *(Orchestia spp.)* and isopods (Isopoda) (SES, 1988). Reptiles that have been observed on the Nonquitt marsh are the black racer snake (*Coluber constrictor)* and snapping turtle *(Chelydra serpentina)*, while a variety of amphibians, such as the spring peeper *(Hyla crucifer)* are present in less-saline wetland areas at the inland edges of the marsh (Lloyd Center, 1989).

Small mammals observed on the high marshes of the Upper Estuary include the white-footed mouse *(Peromyscus leucopus)*; eastern chipmunk *(Tamias striatus)*; gray squirrel *(Sciurus carolinensis)*; oppossum *(Didelphis virginiana)*; rabbit *(Sylvilagus floridanus)* and skunk *(Mephitis mephitis)* (SES, 1988). White-tailed deer

(Odocoileus virginianus) and raccoon (*Procyon lotor)* have been observed in the Nonquitt marsh (Lloyd Center, 1989). Muskrat *(Ondatra zibethica)* are common generally in Southern New England high marsh and may live in some of the New Bedford Harbor Estuary salt marshes, but their presence has not been documented.

A variety of insects is present in the marshes of the Harbor Estuary, including katydids (Tettigoniidae), casebearers *(Coleophora spp.)*, mantids *(Tenodera aridifolia)* and mirids (Miridae). (SES, 1988). Mosquitos *(Aedes spp.)* are also present. The insects of the salt marshes and their larvae are important sources of food for birds and, in some cases, fish as well.

Low marsh is the regularly-flooded portion of the salt marsh, lying between mean high water and mean low water and inundated by the tides twice daily. In the New Bedford Harbor Estuary, low marsh is dominated by the tall form of smooth cordgrass *(Spartina alterniflora*). While plant diversity is low in this part of the marsh, primary productivity--the production of plant material--is high, as is faunal diversity (SES, 1988; Teal, 1984). The faunal community present in this habitat is, generally, that characteristic of low marshes in Southern New England. Some of the more common invertebrates are fiddler crabs *(Uca spp.)*, ribbed mussel *(Geukensia demissus)*, and periwinkle *(Littorina spp.).* Large numbers of silversides *(Menidia spp.)*, mummichogs, and killifish *(Fundulus spp.)* move into the low marsh with the tide, using the cordgrass zone as habitat; these small fish are a major food source for larger fishes of direct importance to humans as well as the wading birds of the Estuary.

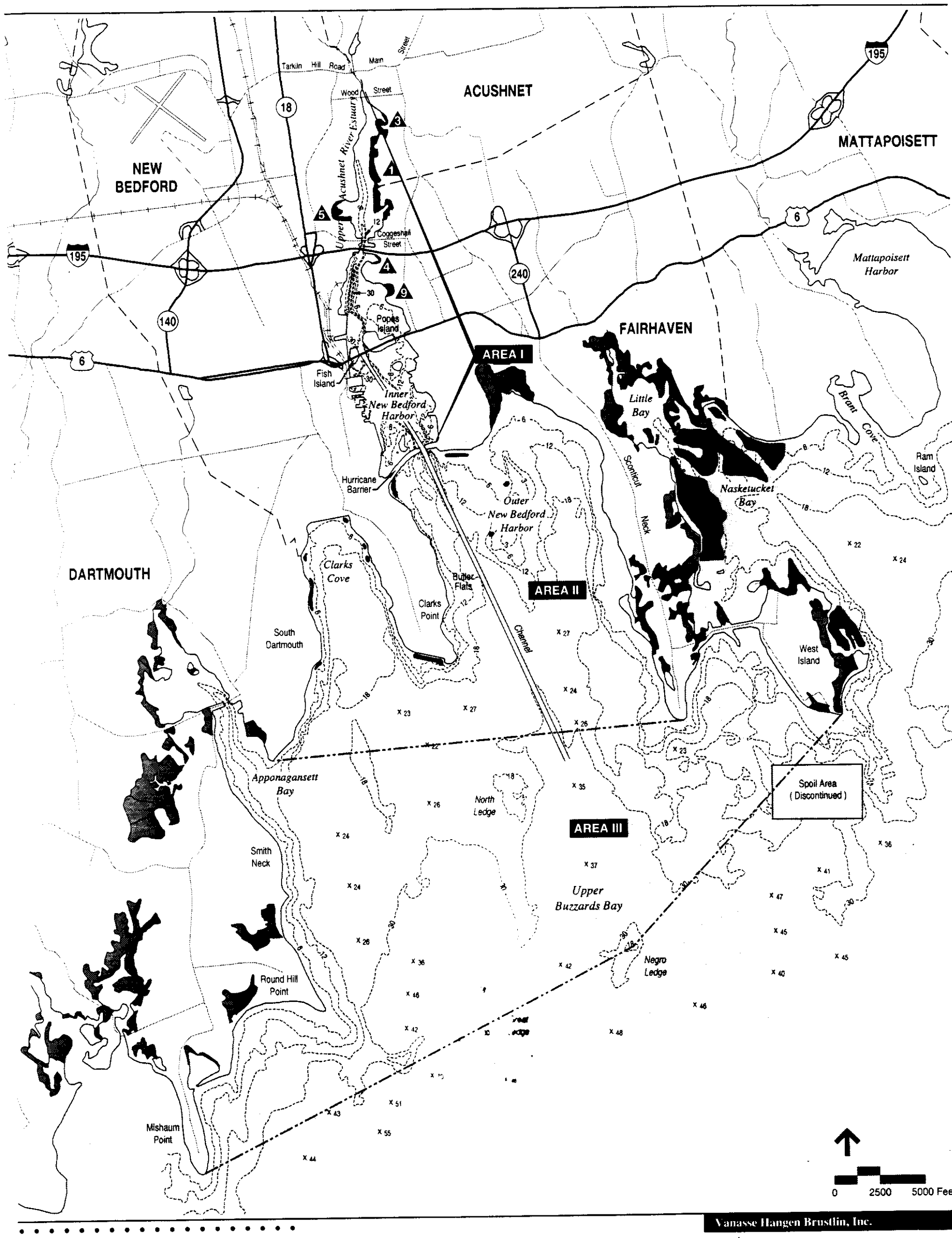
Tables 3.5 and 3.6 list vertebrate and invertebrate marine species in the New Bedford Harbor Estuary, including those which use salt marsh habitat. Some of the estuarine fish and shellfish most closely associated with the salt marshes of the Estuary are winter flounder *(Pleuronectes americanus)*; bluefish *(Pomatomus saltatrix)*; menhaden *(Brevoortia tyrannus)*; American eel *(Anguilla rostrata)*; and Eastern oyster *(Crassostrea virginica)*.

Both high and low salt marsh in the New Bedford Harbor Estuary are important bird habitat. The 1988 study of the marshes of the Upper Estuary and Pope Beach documented roughly eighty species of birds using the marshes and their upland edges (SES, 1988) while over seventy species have been observed in the Nonquitt marsh (Lloyd Center, 1989). Bird species that regularly use the marshes of the Estuary include large and small wading birds, such as herons, egrets, and bitterns; hawks, ospreys, vultures and other birds of prey; a variety of ducks, geese, and other waterfowl; and a wide range of songbirds. **Table 3.8** lists bird species associated with the estuarine environments of the New Bedford Harbor area, but does not include songbirds and other primarily terrestrial species which use the marsh occasionally.

The importance of salt marshes to the ecosystem of the New Bedford Harbor Estuary cannot be underestimated. Salt marshes are among the most biologically productive of ecosystems, providing habitat to hundreds of organisms and of particular importance to the lower trophic levels, that is, the base of the estuarine food pyramid which supports such top predators as sportfish, birds of prey, and humans. In addition, salt marshes play critical physical and chemical roles within the estuarine environment, trapping sediments, filtering pollutants, and buffering the effect of floods.

Figure 3.2 shows the salt marshes of the New Bedford Harbor Environment.

Figure 3-2



Vanasse Hangen Brustlin, Inc.

Historical Submerged Aquatic Vegetation Beds (Costa, 1988)

Tidal Wetlands (MassGIS; 1994 NGS Aerial Photographs)

Wetland Number (Corresponds to Text Discussion)

Fishery Resource Closure Area (Areas I, II, III) Boundaries (MADPH)

New Bedford Harbor and Upper Buzzards Bay Habitats and Resources

New Bedford Harbor Trustee Council RP/EIS

70602NHR

3.3.1.3 Tidal flats and Soft Bottoms

Soft (unconsolidated) sediments underlay most of the New Bedford Harbor Estuary. In low-energy areas such as the Upper Estuary and Inner Harbor, these are organic-rich silts, fine-textured muds, and sandy muds. Sands and gravelly sands are prevalent on shoals and where current velocities are greater, while sands, gravels, and muds are present in deeper areas of the Outer Harbor, interspersed with rocky reefs.

Tidal flats--intertidal areas of soft sediments, irregularly exposed by the tide--form the transition between salt marsh and subtidal habitats in much of the New Bedford Harbor Estuary. In unaltered salt marshes, tidal flats may lie seaward of the marsh or may take the form of shallow creeks running into the marsh and periodically emptied by the tide. In some marshes, drainage ditches dug for mosquito control may function as tidal flats; in other areas, the shoreline has been bulkheaded or filled, but the tidal flat remains seaward of the bulkhead. There are about 50 acres (20 ha) of tidal flats in the Upper Estuary and New Bedford Harbor (VHB, 1996).

Tidal flats and soft bottoms are habitat to dozens of species and of great ecological importance to the Estuary. They also have the highest concentrations of PCBs and metals in New Bedford Harbor and, particularly in the Upper Estuary, are probably the habitat type most affected by the contamination of the Harbor.

Bottom composition in these shallow-water and intertidal habitats is silt, clay, and peat; common plant species include sea lettuce *(Ulva lactuca)*, filamentous algae, and rockweed *(Fucus spp.)* (SES, 1988). Perhaps the most important infauna--animals which live within the soft sediments--of the New Bedford Harbor Estuary are two species of clams: quahogs *(Mercenaria mercenaria)* and soft-shelled clams *(Mya arenaria)*. But the tidal flats and soft bottoms of the Harbor Estuary are characterized by diverse invertebrate communities which are important sources of food for fish and shorebirds. Benthic worms (polychaetes and oligochaetes) are common in the tidal flats and soft bottoms of the Harbor Estuary, as are amphipods (small crustaceans), at least ten species of molluscs, and 13 other shellfish species (VHB, 1996). These invertebrate communities support populations of bottom-feeding fish such as flounder, scup and tautog, as well as diverse shorebirds, like oystercatchers, sandpipers, plovers, herons, egrets, and some waterfowl (Whitlatch, 1982). **Table 3.2** lists the dominant organisms in the soft-bottom intertidal habitats of Buzzards Bay. The fish, shellfish, and birds of the New Bedford Harbor Estuary, including those which live on or in tidal flats and soft bottoms, are discussed more fully in subsequent sections of this chapter.

Table 3.2
DOMINANT SOFT-BOTTOM, HARD-BOTTOM AND ROCKY INTERTIDAL COMMUNITIES IN BUZZARDS BAY[1]

Substrate Type	Scientific Name	Common Name	Class or Phylum[2]
Soft Bottom	*Nucula proxima*	Nut clam	Bivalvia
	Nephthys incisa	Red-lined worm	Polychaeta
	Ninoe nigripes	Lumbrinerid worm	Polychaeta
	Cylichna orzya	Minute bubbleshell	Gastropoda
	Callocardia morrhuana		Crustacea
	Hutchinsoniella macracantha	Cephalocarid	Crustacea
	Lumbrineris tenuis	Lumbrinerid thread worm	Polychaeta
	Turbonilla sp.	Turbonillid pyramid shell	Gastropoda
	Spio filicornis	Spionid mud worm	Polychaeta
	Retusa canaliculata	Channeled bubbleshell	Gastropoda
	Stauronereis caecus	Burrowing worm	Polychaeta
Hard Bottom	*Ampelisca spinipes*	Four-eyed amphipod	Crustacea
	Byblis serrata	Four-eyed amphipod	Crustacea
	Cerastoderma nulatum[3]	Little cockle	Bivalvia
	Ampelisca macrocephala	Four-eyed amphipod	Crustacea
	Glycera americana	Bloodworm	Polychaeta
	Nephthys bucera	Red-lined worm sp.	Polychaeta
	Tellina agilis	Fragile wedge clam	Bivalvia
	Ninoe nigripes	Lumbrinerid tread worm	Polychaeta
	Lumbrineris tenuis	Lumbrinerid tread worm	Polychaeta
	Nephys incisa	Red-lined worm	Polychaeta
	Molgula complanata	Sea grape	Tunicata
	Unicola irrorata	Tube-dwelling amphiod	Crustacea
Rocky Intertidal	*Semibalanus balanoides*	Acorn barnacle	Crustacea
	Balanus balanus	Large rock barnacle	Crustacea
	Carcinus maenas	Little green crab	Crustacea
	Cancer irroratus	Rock crab	Crustacea
	Pagurus longicarpus	Long-clawed hermit	Crustacea
	Littorina littorea	Common periwinkle	Gastropoda
	Littorina obtusata	Round (Obtuse) periwinkle	Gastropoda
	Littorina saxatilis	Rough periwinkle	Gastropoda
	Mytilus edulis	Blue mussel	Bivalvia
	Modiolus modiolus	Horse mussel	Bivalvia
	Crepidula fornicata	Slipper shell	Gastropoda
	Nereis virens	Clam worm	Polychaeta
	Ascophyllum nodosum	Knotted wrack	Phaeophyta
	Fucus vesiculosus	Rockweed	Phaeophyta
	Chondrus crispus	Irish moss	Rhodophyta

[1] Adapted from Howes and Geohringer (In Press).
[2] Phyla are listed for seaweeds, classes for other species.
[3] Because *Cerastoderma* populations are highly seasonal, it is not considered to be a good characterizing species for this community.

The most complete published study of tidal flat and soft bottom habitats in the New Bedford Harbor Estuary is the 1988 study of the salt marshes of the Upper Acushnet River Estuary and the Pope Beach area (Bellmer, 1988; SES, 1988). This work documented a variety of invertebrates living in the tidal creeks of New Bedford Harbor's salt marshes, but found markedly higher biodiversity and higher abundance of benthic invertebrates in the tidal creeks of the Pope Beach marsh, probably because of the high levels of contaminants present in the Upper Estuary as well as other factors. Thirty benthic species were observed in the mud banks of the Upper Estuary wetlands, while over sixty were found at Pope Beach (SES, 1988); the most common of these are listed in **Table 3.3.** Section 3.5 discusses the reduction of benthic biodiversity caused by the contamination of New Bedford Harbor.

TABLE 3.3.

DOMINANT BENTHIC MACROIVERTEBRATES SAMPLED FROM NEW BEDFORD HARBOR IN DECREASING ORDER OF ABUNDANCE[1]

Scientific Name	Common Name
Streblospio benedicti	Bar-gilled mud worm
Eteone heteropoda	Freckled paddle worm
Nassarius obsoletus	Eroded basketshell snail
Podarke obscura	Swift-footed worm
Tharyx acutus	Cerratulid worm
Polydora ligni	Whip mud worm
Mercenaria mercenaria	Hard clam or quahog
Mulinia lateralis	Dwarf surf clam
Mediomastus ambiseta	Thread worm
Tubificoides sp.	Annelid worms
Weteromastus filiformis	
Pectimaria gouldii	Trumpet worm
Lumbrinerus tenis	Lumbrinarid thread worm
Nereis succinea	Common clamworm
Odostomia seminuda	Odostone pyramid shell
Tellina agiluis	Fragile wedgeclam
Brania welfleectensis	Sylid worm
Capitella capitata	Capitellid thread worm
Eobrolgus spinosus	

[1] Adapted from Bellmer, 1988

3.3.1.4 Beaches and Rocky Shores

Habitat aspects of the beaches and rocky shores of the New Bedford Harbor Estuary are not particularly well documented. Beaches of major recreational value within the New Bedford Harbor Environment are discussed in Sections 3.4 and 3.5; however, there are several smaller, more natural barrier beach systems, notably at Nonquitt in Dartmouth and at Winsegansett Pond, on Sconticut Neck in Fairhaven. Barrier beaches are naturally mobile coastal systems; plant species common to this shoreline type include beach grass *(Ammophila breviligulata)*, beach pea *(Lathyrus maritimus)* and beach rose *(Rosa rugosa).* Rocky intertidal areas are inhabited by several species of barnacle, crabs, and a variety of molluscs. **Table 3.2** lists the dominant organisms along rocky intertidal shores in Buzzards Bay, generally; however, the mussel species listed here are uncommon in the New Bedford Harbor Estuary.

3.3.1.5 Sea Grass Beds

Eelgrass *(Zostera marina)* is the dominant species of submerged aquatic vegetation in Buzzards Bay, found in shallow water at various salinities and on different types of substrate. It is an important source of food for herbivores, such as canada geese, and detritivores, such as polychaete worms. Eelgrass beds also serve as important cover and nursery habitat for shellfish, particularly bay scallops, and finfish such as winter flounder (Thayer et al., 1985).

During the 1930s, eelgrass virtually disappeared from Buzzards Bay due to "wasting disease," caused by a parasitic protozoan (*Labarynthula* spp.). Aerial photographs from the 1940s show few eelgrass beds in the New Bedford Harbor Estuary, attributable to the wasting disease as well as urbanization of the Harbor, which inhibited recovery of the beds following the disease (Buzzards Bay Project, 1991; Costa 1988).

Eelgrass subsequently recovered in some areas of Buzzards Bay, including parts of Outer New Bedford Harbor, although not in the Inner Harbor. This is probably the result of poor water quality and clarity in the Inner Harbor, caused by PCBs, heavy metals, sewage and other pollutants from industrial and urban sources, ship traffic, and the effects of the Hurricane Barrier (Costello, PC, 1996; Costa, 1988).

Currently, eelgrass beds are scattered along nearshore areas of New Bedford Outer Harbor, particularly on the west shore of Clarks Point and the west shore of Sconticut Neck. **Figure 3.2** shows the sea grass beds of the New Bedford Harbor Environment based on a 1988 study; more current information will be available in 1997, when the Massachusetts Wetlands Conservancy Program completes an inventory of sea grass beds in State waters.

3.3.1.6 Open Water Habitats

The habitats of Outer New Bedford Harbor are somewhat different from those in the upper reaches of the New Bedford Harbor Estuary, though both are estuarine environments and many of the same species are present. The Outer Harbor is the deepest part of the New Bedford Harbor Estuary, generally 10-30 ft, so water temperatures tend to be more moderate. Wind and wave energy are higher, so the waters of the Outer Harbor have more dissolved oxygen; shoreline and bottom sediments are sandier; and salt marshes exist only in locally sheltered areas--behind barrier beaches, for example. Since the Outer Harbor is open to Buzzards Bay, it is well-flushed in comparison to the Inner Harbor and Upper Acushnet River Estuary, and therefore its waters tend to be cleaner and more saline, and the species present tend to be those representative of Buzzards Bay, generally. **Table 3.7** lists more nearly 50 species of finfish that have been observed in Buzzards Bay, most of which undoubtedly make use of Outer New Bedford Harbor at least seasonally. There are several important shellfish species in the Outer Harbor as well. More complete information on the fish and shellfish of the New Bedford Harbor Estuary is provided in subsequent sections of this chapter.

3.3.1.7 Interaction Among Habitats

The biology of the New Bedford Harbor Estuary is not easily separable from the fresh water and upland habitats of the New Bedford Harbor Environment, nor from the waters of Buzzards Bay. Indeed, an estuarine ecosystem is defined by physical and biological interactions between fresh water and saltwater, waters and wetlands, wetlands and uplands (NOAA, 1990).

As noted above, habitat types in the watershed include woodlands, lakes, streams, pasture land, and inland wetlands. Important, if fragmented, habitats are also tucked in among mixed-used residential areas, urban and industrial areas. The salt marshes, tidal flats, and subtidal areas of the New Bedford Harbor Estuary are a continuum of nearshore environments, distinguished from one another by elevation and frequency of tidal inundation. And the Harbor Estuary itself is home to a range of habitats, from open water to rocky reef.

Ecologically, there is a great deal of interaction between all these habitats. Tidal creeks, for example, are used by estuarine fish, like winter flounder, at high tide and by marsh invertebrates, such as fiddler crabs, when the tide is out. Songbirds and mammals often nest in upland forests, but feed on the salt marsh. Herring and alewives run up the Acushnet river to spawn, while eels move into saltwater for the same purpose. Mummichogs feed on the salt marsh and are in turn fed on by striped bass, bluefish and other estuarine species. Indeed, there are few species that do not depend on a variety of habitats; like any ecosystem, the New Bedford Harbor Environment is not defined by any single habitat type, but rather by the basin-wide interaction among species and habitats.

The New Bedford Harbor Environment is, in turn, part of the larger environments of the Massachusetts coastal plain, Buzzards Bay, and beyond. New Bedford's terns and herons winter on the Gulf of Mexico, while winter waterfowl summer in Canada or Alaska. Winter flounder move offshore toward Georges Bank in summer, and bluefish and striped bass migrate south toward Florida in winter.

3.3.2 Plankton

Plankton are microscopic or nearly microscopic marine plants (phytoplankton) and animals (zooplankton) that form the basis of marine food chains. Phytoplankton are primary producers, converting sunlight to plant material usable as food by other species, such as menhaden. Phytoplankton are also eaten by zooplankton, which are eaten in turn by macroinvertebrates, larval fishes, and planktivores such as bay anchovy. There are over 100 species of plankton in the New Bedford Harbor Estuary. Dominant phytoplankton species include *Cyclotella michiganiana*, *Skeltonema costatum, Chaetocerus* spp., *Leptocylindrum minimus*, *Rhizosolenia* spp., and flagellates. Zooplankton is dominated by copepods (*Acartia* spp.), followed by *Paracalanus crassirostris*.

“Blooms”--periods of rapid growth of phytoplankton--occur naturally in the early spring and fall in temperate estuaries. However, anthropogenic pollutants, particularly nutrients from sewage, can further stimulate plankton growth, causing reduced water clarity and low-oxygen conditions when the bloom decomposes. These factors, in turn, can result in loss of sea grass beds, fish kills, changes in species composition, and other impacts on coastal ecosystems. In the 1980s, discharges from the New Bedford wastewater treatment facility were linked to seasonal phytoplankton blooms; however, the improvements to the City’s treatment system discussed in Section 3.4 are expected to mitigate these effects.

3.3.3 Coastal Plants

A description of all the upland and fresh water plants of the New Bedford Harbor Environment would be outside the scope of this document. However, as discussed in the sections on habitats, above, coastal wetland plants function as an important part of the estuarine ecosystem. Therefore, **Table 3.4** lists coastal plants of the affected environment--salt marsh species as well as fresh water or upland species which grow on the upland edge of the marsh, and are therefore associated with salt marsh communities in the New Bedford Harbor Estuary. The information is based on studies of the wetlands of the Upper Acushnet River Estuary and the Nonquitt Salt Marsh.

Table 3.4
Coastal Plants of the New Bedford Harbor Estuary
(from Lloyd Center, 1989; SES, 1988).

common name	scientific name
Red Maple	*Acer rubrum*
Seaside Gerardia	*Agalinus maritima*
Bent Grass	*Agrostis spp.*
Little Blue Stem	*Andropogon scoparius*
Slender-leaved Aster	*Aster tenuifolius*
Sea Orach	*Astriplex patula*
Sedge	*Carex spp.*
Twig Rush	*Cladium mariscoides*
Sweet Pepperbush	*Clethra alnifolia*
Umbrella Sedge	*Cyperus spp.*
Spatulate-leaved Sundew	*Drosera intermedia*
Massachusetts Fern	*Dryopteris simulata*
Marsh Fern	*Dryopteris thelypteris*
Spike Grass	*Distichlis spicata*
Dwarf Spike-Rush	*Eleocharis parvula*
Beaked Spike-Rush	*Eleocharis rostellata*
Dye Bedstraw	*Galium tinctorium*
Grass spp.	*Gramineae spp.*
Marsh St. John's-wort	*Hypericum virginicum*
Rose mallow	*Hibiscus palustris*
Jewelweed	*Impatiens capensis*
Marsh Elder	*Iva frutescens*
Canadian Rush	*Juncus canadensis*
Blackgrass	*Juncus gerardi*
Red Cedar	*Juniperus Virginiana*
Sea Lavender	*Limonium spp.*
Water Horehound	*Lycopus virginicus*
Purple Loosestrife	*Lythrum salicaria*
Sweet Gale	*Myrica gale*
Bayberry	*Myrica pensylvanica*

Sensitive Fern	*Onoclea sensibilis*
Switch Grass	*Panicum virgatum*
Common Reed	*Phragmites communis*
Salt Marsh Fleabane	*Pluchea purpurascens*
Black Cherry	*Prunus serotina*
Mock Bishop's Weed	*Ptilimnium capillaceum*
Oaks	*Quercus spp.*
Winged Sumac	*Rhus copallina*
Swamp rose	*Rosa palustris*
Annual Glasswort	*Salicornia europaea*
Perennial Glasswort	*Salicornia virginica*
Chairmaker's Rush	*Scirpus americanus*
Bayonet Grass	*Scirpus paludosus*
Salt Marsh Bulrush	*Scirpus robustus*
Greenbriar	*Smilax rotundifolia*
Sea-side Goldenrod	*Solidago sempervirens*
Slender-leaved Goldenrod	*Solidago tenuifolia*
Sow Thistle	*Sonchus arvensis*
Salt Marsh Cordgrass	*Spartina alterniflora*
Salt Hay	*Spartina patens*
Fresh Water Cordgrass	*Spartina pectinada*
Sand-Spurrey	*Spergularia marina*
Sphagnum Moss	*Sphagnum spp.*
Sea-Blite	*Suaeda spp.*
Poison Ivy	*Toxicodendron radicans*
Arrow Grass	*Triglochin maritima*
Cattail	*Typha angustifolia*
Large Cranberry	*Vaccinium macrocarpon*
Arrow-wood	*Viburnum recognitum*
Grape	*Vitis spp.*

3.3.4 Marine Invertebrates

The salt marshes, tide flats, and waters of the Upper Estuary are home to a wide variety of marine invertebrates. Several species of polychaete worms are present in the tide flats; these organisms are an important source of food for inshore fish such as winter flounder, as well as for many shorebirds. Mollusks that live in the marshes and tide flats include soft-shell clam, quahog, oyster, and ribbed mussel. Bay scallop have also been observed in some numbers in the Inner Harbor and Upper Estuary. Numerous crustacean species use the salt marshes, including fiddler, mud, and marsh crabs; these are an important source of food for wading birds such as herons. Lobster and blue crab are also common in the Inner Harbor and Upper Estuary, at least in winter (SES, 1988; Hoff et al., 1973).

A number of commercially important species of shellfish are present in Outer New Bedford Harbor, although because of contamination or lack of abundance, only a few presently support fisheries in the Harbor Estuary. Lobster are abundant; the Outer Harbor supported a commercial fishery for this species until the 1979 fishing closure was enacted due to the discovery of elevated levels of PCBs in lobsters (McConnell and Morrison, 1986). Quahogs support both commercial and recreational fisheries in Clarks Cove and other areas of the Outer Harbor. Bay scallop, soft-shell clam, whelk, and limpet are present; of these, only whelk supports a commercial fishery, while limpets are taken in an informal, unregulated fishery. Blue mussel are present in the Outer Harbor, but are not abundant enough to support a fishery (Whittaker, PC, 1996). **Table 3.5** lists invertebrates known to be present in the New Bedford Harbor Estuary.

Table 3.5
Marine invertebrates of the New Bedford Harbor Estuary
(from Whittaker, PC, 1996; SES, 1988; Hoff et al., 1973)

common name	scientific name
Crustaceans	
American Lobster	*Homarus americanus*
Blue Crab	*Callinectes sapidus*
Fiddler Crab	*Uca pugnax*
Mud Crab	*Neopanope texana*
Marsh Crab	*Sesarma reticulatum*
Green Crab	*Carcinus maenas*
Rock Crab	*Cancer irroratus*
Spider Crab	*Libinia emarginata*
Lady Crab	*Ovalipes ocellatus*
Hermit Crab	*Pagurus longicarpus*
Horseshoe Crab	*Limulus Polyphemus*
Sand Shrimp	*Crangon septemspinosa*
Grass Shrimp	*Palaemonetes vulgaris*
Mantis Shrimp	*Squilla empusa*
Barnacles	*Balanus spp.*
Isopods	*Isopoda spp.*
Mollusks	
Quahog	*Mercenaria mercenaria*
Soft-shell Clam	*Mya arenaria*
Macoma Clam	*Macoma balthica*
Eastern Oyster	*Crassostrea virginica*
Bay Scallop	*Argopecten irradians*
Blue Mussel	*Mytulis edulis*
Ribbed Mussel	*Geukensia demissus*
Channeled Whelk	*Busycon caniliculatum*
Knobbed Whelk	*Busycon carica*

Mudsnail	*Ilyanassa obsoleta*
Common Periwinkle	*Littorina littorea*
Coffee Bean Snail	*Melampus bidentatus*
Arks	*Anadara spp.*
Limpet	*Crepidula fornicata*
Jingle	*Anomia simplex*
Minute hydrobid	*Hydrobia totenti*
	Cepea hortensis
	Discus spp.
Other Invertebrates	
Common Starfish	*Asterias forbesi*
Sea Anemone	*Metridium dianthus*
Shipworm	*Toredo navalis*
Nereid Polychaete	*Nereis succinea*
Trumpet Worm	*Pectinaria gouldii*
Serpulid Tube Worm	*Filograna implexa*
Serpulid Tube Worm	*Spirobus spirillum*
Boring Piddock	*Zirfaea crispata*

3.3.5 Fish

The finfish of the New Bedford Harbor Estuary have not been adequately studied. Nevertheless, it is clear that a number of important species spend part or all of their lives in the Upper Acushnet River Estuary and Inner New Bedford Harbor. A trawl survey conducted in 1972-1973 found 14 fish species in the vicinity of the Hurricane Barrier, including striped bass, bluefish, winter and windowpane flounder, and tautog. Other species known to frequent the Inner Harbor and Upper Acushnet River Estuary include scup and summer flounder. Many more marine species are probably present in larval or juvenile stages. The salt marshes and waters of the Upper Acushnet support significant populations of important baitfish, such as mummichog, Atlantic silverside, menhaden, and eel. Anadromous fish that run up the Acushnet River to spawn include blueback herring and alewife (VHB, 1996; SES, 1988; Kolek & Ceurvals, 1981; Hoff et al., 1973).

Information is also lacking on fish species in the waters of Outer New Bedford Harbor. In addition to the fish listed above, black sea bass, butterfish, fourspot flounder, tomcod, silver and red hake, and cunner have been sampled in these waters (VHB, 1996; Kolek & Ceurvals, 1981; Hoff et al., 1973). However, this list is surely incomplete. Nearly 50 species of finfish are known to use the waters of Buzzards Bay (NOAA 1994), many or most of which are undoubtedly present in Outer New Bedford Harbor for at least part of the year. **Table 3.6** lists finfish species known to use the New Bedford Harbor Estuary, while **Table 3.7** lists commercially important species in Buzzards Bay.

Table 3.6
Finfish in the New Bedford Harbor Estuary
(from VHB, 1996; Kolek & Ceurvals, 1981; Hoff et al., 1973).

common name	scientific name
Striped Bass	*Morone saxatilis*
Bluefish	*Pomatomus saltatrix*
Tautog	*Tautoga onitis*
Scup	*Stenotomus chrysops*
Black Sea Bass	*Centropristis striata*
Atlantic Tomcod	*Microgadus tomcod*
Butterfish	*Peprilus triacanthus*
White Perch	*Morone americanus*
Winter Flounder	*Pleuronectes americanus*
Summer Flounder	*Paralichthys dentatus*
Fourspot Flounder	*Paralichthys oblongus*
Windowpane Flounder	*Scopthalmus aquosa*
Alewife	*Alosa pseudoharengus*
Blueback Herring	*Alosa aestivalis*
Menhaden	*Brevoortia tyrannus*
American Eel	*Anguilla rostrata*
Smelt	*Osmerus mordax*
Atlantic Silverside	*Menidia menidia*
Silver hake	*Merluccius bilinearis*
Red hake	*Urophycis chuss*
Cunner	*Tautogolabrus adspersus*
Goby	*Gobiosoma Ginsburgi*

Table 3.7
DOMINANT COMMERCIALLY VALUABLE FISH SPECIES IN BUZZARDS BAY IN ORDER OF ABUNDANCE AND PREFERRED PREY ITEMS[1]

Common Name	Scientific Name	Preferred Prey Items
Scup (porgy)	*Stenotomus chrysops*	Assorted benthos, occasionally small fish
Butterfish	*Peprilus triacanthus*	Copepods, small fish, jellyfish, worms
Winter flounder	*Pleuronectes americanus*	Worms, gastropods, bivalves
Alewife	*Alosa pseudoharengus*	Copepods, shrimp, eggs, and larvae
Blueback herring	*Alosa aestivalis*	Copepods, shrimp, eggs, and larvae
Atlantic menhaden	*Brevoortia tyrannus*	Phytoplankton
Black sea bass	*Centropristis striata*	Mysids and other benthic organisms
Tautog (blackfish)	*Tautoga onitis*	Mollusks, crabs, worms, lobster
Bluefish	*Pomatomus saltatrix*	Fish, worms, shrimp, lobster, squid, crab
Striped bass	*Morone saxatilis*	Fish, worms, shrimp, lobster, squid, crab

[1] Adopted from Howes and Geohringer (In Press)

Anadromous Fish

In the past, significant anadromous fish populations utilized the Acushnet River as spawning and nursery habitat, as evidenced by the 1790 establishment of the Herring Committee mentioned in Section 3.4. More recently, anadromous species have been severely reduced by overfishing, pollution, and loss of spawning habitat caused by dam construction. Alewives and blueback herring are known to spawn in the river; adults enter the river during April or May and young-of-the-year migrate from the river during the following fall. Population levels of alewives and herring are unknown; it is also unknown whether American shad *(Alosa sapidissima)* still spawn in the Acushnet.

As mentioned in Section 3.2., three structures on the Acushnet River interfere with upstream migration by anadromous species. The first is the Acushnet Sawmill Dam off Mill Street in Acushnet, where a fishway built in 1970 is impassable during low water periods. A second blockage is a dam at the Hamlin Street crossing, also known as the White's Dairy impoundment. This dam was reconstructed in 1920 and consists of two stone culverts, each with a flash board system. Local residents have been known to adjust these flashboards to facilitate passage by the migrating alewives. Further upstream, a 10 ft (3 m) high dam forming the New Bedford Reservoir also serves as an impediment to migrating fish.

3.3.6 Birds

The waters, shores and wetlands of the New Bedford Harbor Environment support many species of waterfowl, shorebirds, and other avifauna, including several species which are endangered or of special concern. Many of these avian species are associated with salt marshes and other wetland environments in the New Bedford Harbor Estuary; as mentioned above, a 1988 study counted about 80 species of birds in the marshes of the Upper Estuary and Pope Beach (SES, 1988) while over 70 species are known to use the Nonquitt marsh (Lloyd Center, 1989). **Table 3.8** lists bird species known to use estuarine environments of the New Bedford Harbor area, but does not include songbirds and other primarily terrestrial species which use the marsh occasionally.

Common avian species using open-water areas near the Upper Estuary and Pope Beach salt marshes include herring gull *(Larus argentatus)*, double-crested cormorant *(Phalacrocorax auritus)*, mallard duck *(Anas platyrhynchos)*, great black-backed gull *(Larus marinus)*, and rock dove *(Columbia livia)*. The gulls commonly feed on fish and shellfish, while the mallards frequently feed on macroinvertebrates, such as amphipods and polychaetes, found in shallow intertidal habitats. Through these feeding patterns, contaminants such as PCBs can be transferred from the Harbor sediments to higher organisms, including humans.

Other bird species which utilize open-water areas near these marshes are least tern *(Sterna albifrons)*, designated by the Commonwealth as a "Species of Special Concern," which feeds on Atlantic silversides *(Menidia menidia)* in the Upper Acushnet River Estuary. Osprey *(Pandion haliaetus)* and common tern *(Sterna hirundo)*, also state-listed Species of Special Concern, have been observed using open-water habitat by the Pope Beach marsh. Peregrine falcon *(Falco peregrinus)*, which is on the federal Endangered Species List, has been observed by the marshes of the Upper Acushnet River Estuary, though it is rare in the New Bedford Harbor Environment. The nearest known nesting site of this bird is the Braga Bridge in Fall River, about 11 miles west of New Bedford Harbor.

Waterfowl use the salt marshes of the Upper Estuary and Pope Beach as breeding habitat: mallard at Pope Beach and black duck *(Anas rubripes)* in the northernmost salt marsh in the Upper Estuary, just south of Wood Street. Many more avian species undoubtedly use the open water habitat of the Upper Estuary and Pope Beach area during the fall migration, feeding on macroinvertebrates in the shallow intertidal waters.

Shorebirds and wading birds observed in the marshes of the Upper Estuary and Pope Beach include killdeer *(Charadrius vociferus)* and spotted sandpiper *(Actitus macularia)*. At the time of the 1988 study, snowy egret *(Egretta thula)* was the most common wading species throughout these wetlands, while least bittern *(Ixobrychus exilis)*, a state-listed "Threatened Species," was observed foraging along a common reed stand at the north end of the Upper Estuary.

Other bird species using this area are mourning dove *(Zenaida macroura)* and insectivores such as chimney swift *(Chaetura pelagica)*, barn swallow *(Hirundo rustica)*, tree swallow *(Tachycineta bicolor)* and sharp-tailed sparrow *(Ammodramus candacutus)*, which nests in salt marsh. Diversity of species is particularly high at the upland edges of the marsh, where common species include red-winged blackbird *(Agelaius phoeniceaus)*, European starling *(Sturnus vulgaris)*, northern mockingbird *(Mimus polyglottos)*, song sparrow *(Melospiza melodia)*, American robin *(Turdus migratorius)*, and common yellowthroat *(Geothlypis trichas)*.

Roseate tern *(Sterna dougalli)*, another species on the federal Endangered Species List, are known to feed in New Bedford Harbor. Bird Island, located approximately 11 miles (18 km) east/northeast of New Bedford Harbor in the town of Marion, MA, is the largest known nesting colony of roseate tern in the Western Hemisphere, consisting of approximately 1,500 breeding pairs of roseate tern as well as a greater number of breeding pairs of common tern. Ram Island, 3 miles (4.9 km) northeast of New Bedford Harbor in Mattapoisett, also is inhabited by a nesting colony of approximately 300 pairs of roseate tern and 1,000 pairs of common tern. Roseate tern inhabiting these nesting islands feed primarily on sand lance, while common tern in the area feed on sand lance, menhaden, and alewives.

The ingestion and biomagnification of contaminants by bird species in the New Bedford Harbor Environment is a function of diet, feeding habits, and the amount of time spent in the affected environment. The avian species found in the New Bedford Harbor Estuary represent seven feeding guilds: molluscivores, piscivores, carnivores, granivores, omnivores, herbivores, and insectivores. Diving ducks and oystercatchers are molluscivores; molluscs comprise more than 60 percent of the food volume of winter sea ducks (Terres, 1980). Loons, grebes, and cormorants are piscivores, feeding on Atlantic silverside, sand lance, bay anchovy and other small fishes. Osprey are both piscivorous and carnivorous, feeding on larger fish such as menhaden, dabbling ducks such as black duck, and small mammals such as muskrat. Dabbling ducks, pigeons, and doves are granivores, while gulls and crows are omnivores. Canada geese are primarily herbivorous; their diet may include marsh grasses, eelgrass, and other coastal plants. Many of the other species using the intertidal habitats are insectivores; for example, tree swallows feed on mosquitoes. The diversity of feeding patterns of birds in the New Bedford Harbor Environment, and the exceptional mobility of these animals, provide a myriad of potential pathways of ingestion, biomagnification, and transport--within and beyond the Harbor Environment--of contaminants present in the marine sediments of the New Bedford Harbor Estuary.

Table 3.8
BIRD OBSERVATIONS IN NEW BEDFORD HARBOR AND UPPER BUZZARDS BAY, 1986-1995

SPECIES NAME		AREA					
COMMON NAME	SCIENTIFIC NAME	A	B	C	D	SEASON**	ABUNDANCE ***
Red-throated Loon	*Gavia stellata*				X	W	U
Common Loon	*Gavia immer*			X	X	W	C
Horned Grebe	*Podiceps auritus*	X	X	X	X	W	C
Red-necked Grebe	*Podiceps grisegena*	X				W	U
Great Cormorant	*Phalacrocorax carbo*	X	X	X	X	W	A
Double-crested Cormorant	*Phalacrocorax auritus*	X	X	X	X	S	A
Great Blue Heron	*Ardea herodias*	X	X	X	X	W, S	C
Great Egret	*Casmerodius albus*	X	X	X	X	S	C
Snowy Egret	*Egretta thula*	X	X	X	X	S	C
Green-backed Heron	*Butorides striatus*	X				S	C
Black-crowned Night-Heron	*Nycticorax nycticorax*	X		X	X	S	C
Mute Swan	*Cygnus olor*	X	X	X	X	W, S	A
Great White-fronted Goose	*Anser albifrons*	X				W	R
Snow Goose	*Chen caerulescens*	X				W	R
Brant	*Branta bernicla*			X	X	W	C
Canada Goose	*Branta canadensis*	X	X	X	X	W, S	A
Wood Duck	*Aix sponsa*	X				S	R
Green-winged Teal	*Anas crecca*	X				W, S	U
American Black Duck	*Anas rubripes*	X	X	X	X	W, S	A
Mallard	*Anas platyrhynchos*	X	X	X	X	W, S	A
Northern Pintail	*Anas acuta*	X				W	U
Blue-winged Teal	*Anas discors*	X				S	U
Northern Shoveler	*Anas clypeata*	X				W	U
Gadwall	*Anas strepera*	X				W, S	U
Eurasian Wigeon	*Anas penelope*	X				W	R
American Wigeon	*Anas americana*	X	X			W	C
Canvasback	*Aythya valisineria*	X				W	U
Redhead	*Aythya americana*	X				W	R
Ring-necked Duck	*Aythya collaris*	X				W	U
Greater Scaup	*Aythya marila*	X	X	X	X	W	C
Lesser Scaup	*Aythya affinis*	X	X	X	X	W	C
Common Eider	*Somateria mollissima*				X	W	C
Oldsquaw	*Clangula hyemalis*			X	X	W	C
Black Scoter	*Melanitta nigra*				X	W	U
Surf Scoter	*Melanitta perspicillata*				X	W	C
White-winged Scoter	*Melanitta deglandi*				X	W	C
Common Goldeneye	*Bucephala clangula*	X	X	X	X	W	C
Barrow's Goldeneye	*Bucephala islandica*	X			X	W	R
Bufflehead	*Bucephala albeola*	X	X	X	X	W	C
Hooded Merganser	*Lophodytes cucullatus*	X			X	W	U
Common Merganser	*Mergus merganser*	X				W	U
Red-breasted Merganser	*Mergus serrator*	X	X	X	X	W	C
Turkey Vulture	*Cathartes aura*	X				S	U
Osprey	*Pandion haliaetus*	X			X	S	C

Table 3.8
BIRD OBSERVATIONS IN NEW BEDFORD HARBOR AND UPPER BUZZARDS BAY, 1986-1995

SPECIES NAME		AREA*					
COMMON NAME	SCIENTIFIC NAME	A	B	C	D	SEASON**	ABUNDANCE ***
Bald Eagle	Haliaeetus leucocephalus	X	X			W	R
Northern Harrier	*Circus cyaneus*				X	W	U
Sharp-shinned Hawk	*Accipiter striatus*	X				W	U
Cooper's Hawk	*Accipiter cooperii*	X				W	U
Red-tailed Hawk	*Buteo jamaicensis*	X	X			W, S	C
American Kestrel	*Falco sparverius*	X				W, S	U
Peregrine Falcon	*Falco peregrinus*	X		X		W	R
Clapper Rail	*Rallus longirostris*	X				S	U
Virginia Rail	*Rallus limicola*				X	S	U
American Coot	*Fulica americana*	X		X		W	C
Black-bellied Plover	*Pluvialis squatarola*				X	S	C
Semipalmated Plover	*Charadrius semipalmatu*s				X	S	C
Killdeer	*Charadruis vociferus*	X			X	S	C
American Oystercatcher	*Haemotopus palliatus*			X	X	S	C
Greater Yellowlegs	*Tringa melanoleuca*				X	W, S	C
Lesser Yellowlegs	*Tringa flavipes*				X	S	C
Willet	*Catoptrophorus* semipal*matus*				X	S	C
Spotted Sandpiper	*Actitis macularia*				X	S	C
Ruddy Turnstone	*Arenaria interpres*				X	S	C
Sanderling	*Calidris alba*				X	W	U
Semipalmated Sandpiper	*Calidris pusilla*				X	S	C
Least Sandpiper	*Calidris minutilla*				X	S	C
Purple Sandpiper	*Calidris maritima*				X	W	U
Dunlin	*Calidris alpina*				X	W, S	C/U
Laughing Gull	*Larus atricilla*	X	X	X	X	W, S	C
Common Black-headed Gull	*Larus ridibundus*	X				W	R
Bonaparte's Gull	*Larus philadelphia*	X	X	X	X	W	C
Ring-billed Gull	*Larus delawarensis*	X	X	X	X	W, S	A
Herring Gull	*Larus argentatus*	X	X	X	X	W, S	A
Iceland Gull	*Larus glaucoides*	X		X		W	R
Lesser Black-backed Gull	*Larus fuscus*	X				W	R
Glaucous Gull	*Larus hyperboreus*	X				W	R
Great Black-backed Gull	*Larus marinus*	X	X	X	X	W, S	A
Roseate Tern	*Sterna dougalli*				X	S	C
Common Tern	*Sterna hirundo*	X	X	X	X	S	C
Forster's Tern	*Sterna forsteri*				X	S	U
Least Tern	*Sterna albifrons*	X	X	X	X	S	C
Black Tern	*Chlidonias nigra*				X	S	R
Snowy Owl	*Nyctea scandiaca*	X			X	W	U
Belted Kingfisher	*Megaceryle alcyon*	X			X	W, S	C

Source: National Audubon Society (Christmas Count Data), M. Boucher, D. Zimmberlind (Unpublished Data)
Note: Data not collected during Spring and Autumn

* **Area A** = Wood Street Bridge to I-195 Bridge
Area B = I-195 Bridge to Route 6 Bridge
Area C = Route 6 Bridge to Hurricane Barrier
Area D = Hurricane Barrier South; all shorebird sitings in this area were from Fort Phoenix State Beach and Pope Beach

** **W** = Winter **S** = Summer
*** **A** = Abundance **C** = Common **U** = Uncommon **R** = Rare

3.3.7 Mammals--Terrestrial and Marine

As noted above, the salt marshes of the New Bedford Harbor Estuary are home to a variety of small mammals, as well as deer. Marine mammals are not believed to use the affected environment to a significant extent, but are common in Buzzards Bay, and may make occasional use of Outer New Bedford Harbor.

Harbor seals (*Phoca vitulina*) are present in Buzzards Bay and the Elizabeth Islands from mid-October to May; during the winter and early spring, 300 to 400 of them are present in the Bay. The largest colony is at Gull Island, where 280 seals were recorded in 1988.

Gray seal (*Halichoerus grypus*) are occasionally seen in the Bay in very small numbers. Other marine mammals using the Gulf of Maine and Cape Cod Bay that may occasionally be found in Buzzards Bay are Atlantic bottlenose dolphin (*Tursiops truncatus*), harbor porpoise (*Phocoena phocoena*), long-finned pilot whale (*Globicephala melas*), humpback whale (*Megaptera novaeangliae*), and finback whale (*Balaenoptera physalus*).

3.3.8 Endangered Species

According to the Massachusetts Natural Heritage and Endangered Species Program (NHESP), there are a number of rare species and high-priority habitats within the New Bedford Harbor Environment. The largest of these are Round Hill Point and the Nonquitt Marsh area in Dartmouth, the Winsegansett Pond area of Sconticut Neck in Fairhaven, and a 2-mile stretch of the Acushnet River south of the New Bedford Reservoir. Endangered, threatened or rare species known to inhabit or use the affected environment are the piping plover *(Charadrius melodus)*, roseate tern *(Sterna dougalli)*, least tern *(Sterna antillarum)*, common tern *(Sterna hirundo)*, diamondback terrapin *(Malaclemys terrapin)*, eastern box turtle *(Terrapene carolina)*, water-willow borer moth *(Papaipema sulphurata)*, eastern pondmussel *(Ligumia nasuta)*, and American burying beetle (*Nicrophus americanus*) (MNHESP, 1996 and USFWS, 1997).

As discussed in Section 3.3.6, other rare species which occasionally use the New Bedford Harbor Environment include the perigrine falcon *(Falco perigrinus)* and bald eagle *(Haliaeetus leucocephalus)*. Leatherback turtle *(Dermochelys coriacea)*, Atlantic ridley turtle *(Lepidochelys kempii)*, and loggerhead turtle *(Carietta caretta)* are transient species occasionally found in Buzzards Bay and possibly in the vicinity of New Bedford Harbor.

3.4 Human Environment

3.4.1 Population

The New Bedford Superfund Site crosses the boundaries of four municipalities: New Bedford, Fairhaven, Acushnet, and Dartmouth. Of these four affected communities, the City of New Bedford is by far the largest and most intensely urbanized, serving as the economic center of the area. **Table 3.9** summarizes the population of the four municipalities of the New Bedford Harbor Environment.

Table 3.9
Population of the New Bedford Harbor Environment
(from DOC 1992a)

New Bedford	99,922
Fairhaven	16,132
Acushnet	9,554
Dartmouth	27,244
Total	152,852

As discussed in the following sections, industry in the New Bedford area has declined somewhat since the Second World War, and with it, to some extent, the economy of New Bedford. The 1990 US Census reported median household income in New Bedford at $22,647, or just 61% of the median for Massachusetts, while the portion of the City's residents living below the official poverty level was nearly double the state average. Unemployment in New Bedford in 1990 was over 12%, and less than half the City's adult residents had finished high school. Higher rates of income were reported for Fairhaven, Acushnet and Dartmouth; indices of prosperity in these municipalities are comparable to statewide figures. **Table 3.10** summarizes economic statistics for the four municipalities of the New Bedford Harbor Environment.

Table 3.10
1990 Economic statistics for the New Bedford Harbor Environment
(DHCD, 1996; DOC, 1996)

	Median household income	Per Capita Income	Unemployment rate	Poverty Rate
Massachusetts	$36,952	$17,224	6.7%	8.9%
New Bedford	$22,647	$10,923	12.2%	16.8%
Fairhaven	$30,097	$13,114	7.6%	6.5%
Acushnet	$35,734	$14,040	5.3%	4.8%
Dartmouth	$35,138	$15,389	7.9%	5.7%

The demographics of the area reflect the legacy of immigration, spurred initially by the availability of work in the mills and fishing fleet, but continuing today. The population of the area is largely ethnic; according to the 1990 Census, nearly 30% of New Bedford residents speak Portuguese at home (DOC, 1992b).

3.4.2 Historic Patterns of Natural Resource Use and Impacts

3.4.2.1. Settlement Period

Before European contact, approximately 21,000 to 24,000 Wampanoags lived in what is now southeastern Massachusetts and Eastern Rhode Island (Russel, 1980; Weinstein-Farson, 1988). With European settlement in the late 17th and early 18th Centuries, human impacts on the watershed and estuarine waters of the New Bedford Harbor Environment increased. Land was cleared for farming and timber; agriculture and grazing became widespread. The settlers used the high salt marsh for cattle grazing, harvested salt meadow hay and cordgrass, and cut ditches to drain the marsh surface (Teal and Teal, 1969). These actions probably caused significant increases in sediment and nutrient loadings to the Harbor Estuary and began the pattern of coastal habitat alteration that continues today.

During the late 18th Century the New Bedford offshore whale fishery was developed, leading to the rapid growth of settlements and infrastructure in the Area. By 1774, New Bedford was home port to more than 50 whaling vessels and a number of merchant ships, Fairhaven had become a shipbuilding center, and blacksmith shops, rope works, cooperages, sail lofts, and candle factories had been established. Between 1775 and 1795, New Bedford’s population doubled, to 1,000 residents; increasing populations on the Acushnet River probably resulted in discharge of relatively minor quantities of sewage and debris to Inner New Bedford Harbor.

Construction of wharves and shoreline structures also began during the 18th Century, affecting localized intertidal and subtidal habitats in the New Bedford Harbor Estuary. In 1760, the Old South Wharf was built in Fairhaven, at the site of the present Kelley Wharf (MHC, 1981b). By 1771, New Bedford had more than 30,000 feet of wharfage. The construction of the first Fairhaven-New Bedford Bridge linked New Bedford with Fairhaven and resulted in the loss or alteration of about 3.7 acres (1.5 hectares) of subtidal habitat and restricted circulation and flushing in the Inner Harbor.

Acushnet became an early center of milling and manufacturing, taking advantage of the Acushnet River as a source of water power (MHC, 1981c). Sawmills and an iron forge were developed in Acushnet along the northern portion of the Acushnet River and its tributaries during the 1700s; cotton mills and factories were constructed on the river in the early 1800s. Besides altering river flow, the dams served as barriers to anadromous fish, and in 1790 a Herring Committee was established to ensure that passageways were provided around these obstructions (Belding, 1912). The Herring Committee was also responsible for setting gear and time restrictions in the Acushnet River.

An example of coastal habitat loss in the New Bedford Harbor Estuary during the 18th Century is provided by the history of Mill Pond in Fairhaven. This was a 5 acre (2 ha) tidal embayment at the mouth of the Herring River, southeast of the intersection of present-day Route 6 and Main Street in Fairhaven. During the 1700s, Mill Pond served as a sheltered anchorage for ships, but in the late 1700s, Main Street was constructed over the creek, ending the use of the Pond as a mooring area. Due to the bridge construction, tidal circulation decreased and Mill Pond began to fill in. In

1792, tide gates were installed under the bridge to power a mill, and in 1871, a dam was constructed across the Pond's mouth, converting it to a non-tidal waterbody. By 1906, the Pond had become a wetland of about 13 acres (5.3 ha), which was filled to create Cushman Park (McCabe, 1988). Incremental modifications to the Mill Pond had altered it over time from habitat for fish, shellfish, and birds, to an upland recreational area with little or no habitat value.

3.4.2.2 19th Century

During the first half of the 19th Century, the New Bedford whaling industry continued to grow, and with it, the population, commerce and infrastructure of the New Bedford Harbor Environment. In 1800, the population of the New Bedford Harbor area was approximately 4,000; by 1850, it was 20,000 (Boss and Thomas, 1983; McCabe, 1988). As the area continued to develop, impacts on coastal resources intensified. An 1834 map shows more than 30 wharves along the western shore of New Bedford Harbor, representing an estimated 9 acres (3.6 hectares) of intertidal and subtidal habitats destroyed (VHB, 1996). During the same period, seven saltworks were developed along the Apponagansett River near Padanaram, probably by diking coastal marshes or salt ponds.

By the 1850s, the combined New Bedford and Fairhaven fleets totalled 426 vessels, employing more than 10,000 seamen, and New Bedford ranked third among U.S. ports for the tonnage of goods shipped. Dredging of the Harbor appears to have begun in 1839, when about 2 ft of sediments were dredged to create a 30 ft wide, 12.5 ft deep channel, affecting no more than 5 or 10 acres of subtidal habitat. A dredged channel to Fairhaven Village was completed in 1840, leading to the development of additional wharves, marine railways, and shipyards, many of which remain in place today (VHB, 1996).

Ship repair and construction during this period probably contributed some contaminants to the Harbor Environment. Copper and lead-based compounds, as well as creosote, were used for antifouling and other purposes, and may have caused locally elevated levels of toxics in the waters and sediments of the Harbor.

In the mid-19th Century, during the heyday of the New Bedford whale fishery, several events occurred that would eventually lead to the decline of the whaling industry. Whale stocks were being depleted, requiring ever longer voyages to fill a vessel with oil. In 1859, petroleum was discovered in Pennsylvania, and by 1860, two companies in New Bedford were refining and distilling petroleum (Boss and Thomas, 1983). During the 1860s, New Bedford businesses were devastated by a tremendous waterfront fire. After the Civil War, the industry declined steadily. Insurance costs rose as whalers ventured into the Arctic for whales; in 1871, 29 New Bedford whaling ships were abandoned in Arctic ice. By 1897, the whaling fleet was reduced to 32 vessels (Boss and Thomas, 1983); and by 1905, the era of New Bedford whaling had ended.

While the New Bedford whale fishery was waning, the Industrial Revolution was getting underway, and New Bedford, with its well-developed port infrastructure and ready supply of capital, was well-positioned to take advantage of it. Beginning in the mid-19th Century, New Bedford became a major industrial center. The first major textile mill was built in 1849; over the next several decades, many others were built. Telephone, electric, and trolley service were established. Housing, retail establishments, schools and churches sprang up in the new factory neighborhoods as the population burgeoned with immigrants from Ireland, French Canada, the Azores, Portugal, and the Cape Verde Islands. New Bedford's population grew from 15,000 to 27,000 (56 %) between 1870 and 1880; doubled by 1900; and doubled again to 118,000 by 1918 (Boss and Thomas, 1983; McMullin, 1976).

In the 1860s and 1870s, Steamship Wharf was constructed. The railroad was extended to the Wharf, providing a direct shipping link for the factories as well as transportation for tourists taking advantage of ferry service to Nantucket and Marthas Vineyard. The steamers that had carried whale oil to New York City now carried fine textiles to the New York City market. In addition to manufacturing, New Bedford became a major center of coal transshipment, supplying manufacturers throughout the newly industrialized Northeast (Boss and Thomas, 1983). Harbor dredging was increased to accommodate deeper vessels. In the late 1800s, a 200 ft wide, 18 ft deep channel was dredged from the Inner Harbor to Butlers Flat in Buzzards Bay, along with an anchorage in the Inner Harbor, south of Popes Island.

During the late 19th and early 20th centuries, a few mills were developed in Fairhaven, Acushnet, and Dartmouth. Fairhaven's waterfront became a center of boat building and repair, with several marine railways. Fairhaven and Acushnet became residential communities for New Bedford factory workers, while Dartmouth and the northern part of Acushnet remained fairly rural. Padanaram Village in South Dartmouth and other areas along the coast of Buzzards Bay became vacation communities (VHB, 1996).

The rapid economic growth of 19th Century caused increased losses of coastal habitat in the Harbor Estuary. Between 1844 and 1919, dozens of mill buildings were constructed in the North and South Ends of New Bedford and at the head of Clarks Cove, mostly on filled salt marshes (Nelson, et al. 1996). North of Crow Island, on the eastern shore of the Inner Harbor, there was a marsh of about 145 acres (59 hectares (ha)), while on the western shore of the Harbor, south of the present-day I-195 bridge crossing, there was a marsh of 35 acres (14 ha). Other large salt marshes and sandflats were located in New Bedford, directly west and southwest of Palmer Island (57 acres (23 ha)). At least half of the area of Popes and Fish Islands appears to have been salt marsh (4.8 acres (2 ha)). Around 1900, a 50-acre marsh at the head of Clarks Cove was filled. In all, at least 250 acres (100 ha) of tidal and intertidal habitat in Inner New Bedford Harbor and the Upper Acushnet River Estuary were filled during the 19th and early 20th centuries (VHB, 1996).

Tidal exchange in the Inner Harbor and Upper Estuary was reduced by bridges across the Acushnet, while damming continued upriver. The Coggeshall Street bridge was completed in 1893, resulting in the loss of approximately 2 acres (0.8 ha) of salt marsh and subtidal habitats and constricting tidal flow into the Upper Estuary. The Wood Street bridge, constructed in 1900, filled habitats and further reduced flow. In 1869 the New Bedford Reservoir was created, affecting fish migration and altering fresh water inflows to New Bedford Harbor, although the reservoir was used as New Bedford's primary water supply for only 30 years (VHB, 1996).

Wharves continued to be built during this period, primarily in New Bedford, resulting in more lost or altered nearshore habitats. In 1860, a 700' stone jetty was constructed (1.2 acre (0.5 ha) fill) on the east side of Clarks Point. A new bridge from Fish Island to Fairhaven was completed in 1898 (U.S. House of Representatives, 1898), resulting in subtidal habitat loss. By the early 1900s, wharves extended from Howland Street to Maxfield Street in New Bedford. The State Pier was built after World War I, while the development of coal terminals and oil refineries resulted in the filling of salt marsh and other intertidal and subtidal habitats on Popes, Fish and Palmer Islands.

With the increase in industry and population during this period, significant pollutant loadings began to be discharged to the New Bedford Harbor Estuary, including sewage, household, and industrial waste. Tryworks, candle manufacturers, brass foundries, sawmills,cotton mills, and a paper mill established during this period released large quantities of debris, oils, metals, organic wastes, dyes, nutrients, and other pollutants into the Harbor Estuary. Discharges were most significant near the central business districts of New Bedford and Fairhaven, and from industries along the Upper Estuary. The installation of an underground sewer system in the New Bedford area began in 1850, resulting in the piping and filling of smaller streams. This, in turn, altered patterns of water flow, sedimentation, and pollutant runoff along the edges of the Harbor Estuary, concentrating pollutant discharges at "point sources"--the outlets of pipes.

In spite of the growth of anthropogenic impacts during the 19th Century, fish and shellfish were still readily available from the Harbor. Fish and crabs were trapped at the head of the Upper Estuary in the mid to late 1800s; scallop and quahogs were caught along the Fairhaven shore north of the Fairhaven-New Bedford Bridge in the 1880s; quahogs were harvested in the late 1800s from the Coggeshall Street Bridge for depuration and sale; and soft-shelled clams were dug along the Fairhaven shore in 1900 (McCabe, 1988; Boss and Thomas 1983). Commercial scalloping began in the New Bedford Harbor area about 1870. In 1880, New Bedford and Fairhaven inshore lobster landings were 50,000 and 44,000 pounds, respectively (Howes and Goehringer, in press). In 1860, a local newspaper article reported large catches of Atlantic menhaden in the Acushnet River. However, the effects of pollution became evident during this period, with the closure of shellfish grounds due to outbreaks of typhoid fever during the 1850s (VHB, 1996).

3.4.2.3 Early 20th Century

The early 1900s were the height of the textile industry in New Bedford, which at its peak employed more than 35,000 people (Wolfbein, 1968). From 1900 to 1910, 17 new textile corporations were founded, accompanied by the construction of housing, schools, churches, and businesses (Boss and Thomas, 1983).

Rapid population growth during this period generated large loadings of nutrients and raw sewage to the Harbor Environment. In 1904, most of Inner New Bedford Harbor and the northern part of Clarks Cove were closed to shellfishing due to an outbreak of typhoid fever. Around 1920, a main north-south sewer line was installed in New Bedford, carrying sewage and stormwater to waters off Clarks Point via a 3,300-ft

(1,000-m) pipe, but many combined sewer overflow units (CSOs) continued to discharge into the Inner Harbor (CDM, 1990). In 1925, the Inner Harbor was again closed to shellfishing because of typhoid fever (VHB, 1996).

In addition to the habitat impacts of mill development noted in the preceding section, the textile industry contributed significant wastes to the Harbor Environment. Acids, nutrients, metals and toxics were discharged, first by cotton mills, later by manufacturers of synthetic fabrics. VHB (1996) estimates that in 1920, at the height of production, the mills discharged 100,000 tons of biological oxygen demand (BOD) generating materials and 69,000 tons of sodium hydroxide into New Bedford Harbor. During the late 19th century, wastes were mostly discharged along the western shore of the Harbor, but after 1920, the bulk of the discharge shifted to the Outer Harbor, off Clarks Point. The release of great quantities of BOD-generating materials probably resulted in abnormally low levels of dissolved oxygen in some parts of the Harbor, which in turn may have caused fish kills, migration of fish from the area, or other harmful effects on marine resources.

Other industries were sources of pollutants to the Harbor. The New Bedford Copper Works (later Revere Copper and Brass) was a significant source of copper, lead, and other metals. Atlas Tack Company in Fairhaven (now a separate Superfund Site) was a source of heavy metals to the Outer Harbor, discharging near Pope Beach. Coal houses and bins along the waterfront and on Fish and Pope Islands were a source of coal dust, while the oil refineries on the islands were a source of hydrocarbons and other wastes. Tanneries were likely a source of suspended solids, high BOD, chromium, and sulfides (Nemerow, 1978). Boatbuilding and repair facilities along the Fairhaven waterfront were a source of metals, organic solvents, and hydrocarbons. The Acushnet Processing Company, a rubber manufacturer founded in 1910 near the head of the estuary, was a probable source of suspended solids, oils, organic solvents, and high BOD (Sittig, 1975).

Like the whale fishery, the textile industry brought a period of prosperity to New Bedford which turned out to be relatively brief. The New Bedford textiles industry peaked in 1923, then declined rapidly due to a variety of factors: a prolonged strike in 1928, the Great Depression, and competition from the South. From 1917 to 1937, New Bedford lost 21,000 jobs as mills were closed. Some of the remaining mills switched to the production of rayon and silk. The Hurricane of 1938 damaged machinery and stock, placing approximately 10,000 workers temporarily out of work. World War II again brought brief prosperity, but many mills closed after the War (Boss and Thomas, 1983).

During the 1920s, the introduction of diesel power allowed New Bedford fishermen to compete with Gloucester for the Georges Banks harvest and New Bedford’s offshore fishing fleet grew. By 1925, the City had 14 large fishing vessels (valued at more than $25,000 each) and numerous smaller vessels; in 1936, the fleet earned over $1 million.

In spite of the effects of industrialization, the New Bedford Harbor Estuary and surrounding waters had harvestable quantities of fish and shellfish during the first half of the 20th Century. Belding (1909, 1912) described the Inner Harbor, Clarks Cove, and Priests Cove as “good” quahog production areas and other parts of the Outer

Harbor as “fair.” Waters along the west shore of Sconticut Neck were described as “full of eel grass and scallops” during the 1930s. Quahogs were harvested from as far upriver as the Coggeshall Street Bridge and transplanted to waters west of Sconticut Neck during the 1930s. Data collected by the Massachusetts Division of Marine Fisheries on quahogs relayed from the Inner Harbor, Outer Harbor, and Clarks Cove to depuration waters suggest that significant densities of hard clams were present in these waters in the late 1930s and early 1940s. Boss (1983) describes swordfishing in nearshore waters using sailboats during the early 1900s, and later using motorized vessels. Cod reportedly caught from local waters were brought in daily to Kelley Wharf in Fairhaven during the 1930s (VHB, 1996).

Table 3.11 summarizes historic and current patterns of natural resource use and impacts in the New Bedford Harbor Environment.

Table 3.11
Summary of Land Use Activities and Impacts, and Ecological Effects on New Bedford Harbor Resources

Selected Time Period	Land Use Activity	Impact Type	Ecological Effects
1200s - 1650	agricultural development by Native Americans	localized erosion and sedimentation; minor changes in watershed hydrology	potentially minor releases of sediments to the Acushnet River and estuary; possible localized smothering of shellfish
1650 - 1750	deforestation and agricultural development by Early Europeans	increases in upland and marsh erosion; minor changes in watershed hydrology; cattle grazing, cutting, ditching in marshes	salt marsh loss,degradation, and hydrologic alteration; small-scale releases of sediments and smothering of shellfish
	scattered residential and commercial development in villages of New Bedford, Acushnet, Oxford and Fairhaven	relatively minor releases of sewage to local streams and New Bedford Harbor	localized increases in nutrients, Biological Oxygen Demand (BOD), resulting in loss of sensitive stream and/or harbor biota
	wharf development in New Bedford and Fairhaven villages	pier construction, minor fills	shading or loss of intertidal and subtidal habitats, potentially affecting submerged aquatic vegetation; loss of nearshore shellfish beds
	grist and sawmills, iron forge, fulling on upper Acushnet River and tributaries	dam construction	blockages to anadromous fish migration and access to spawning habitat
1750 - 1860	small-scale shipbuilding at the head of river	minor fills, pollutant discharges	minor loss of salt marsh and subtidal habitat for fish, shellfish, waterfowl, and wading birds; increased water column turbidity
	harbor development 1839, 1840	dredging of bottom sediments, increasing water depths in central part of harbor	alteration of benthic community; short-term increases in water turbidity; possible changes in tidal flushing patterns

Table 3.11
Summary of Land Use Activities and Impacts, and Ecological Effects on New Bedford Harbor Resources

Selected Time Period	Land Use Activity	Impact Type	Ecological Effects
1750-1860	shipbuilding and repair in Fairhaven and New Bedford	wharf construction; debris discharges; localized release of metals, hydrocarbons	loss or degradation of intertidal and nearshore subtidal habitats; minor changes in tidal flushing particularly along shorelines of mid portion of harbor where wharves concentrated; possible bioaccumulation of metals (Cu, Pb, Zn) in local shellfish
	tryworks and other whaling-related industries	organic waste discharges	increases in BOD in harbor; possible localized harbor areas experiencing hypoxia
	Wamsutta Textile Mill	organic waste and chemical discharges	increases in BOD in harbor in vicinity of N. Front Street-Wamsutta Street; possible localized hypoxia
	saw mills, grist mills, foundry	dam construction	conversion of riverine habitat to pond habitat in upper Acushnet River and tributaries (Acushnet) and Herring River (Fairhaven)
1860 - 1930	port development	dredging of channel, ship turn-around	alteration of 50-80 acres (20-33 hectares) of subtidal habitats; effects on tidal flushing; temporary increases in water column turbidity
	industrial, residential, and commercial development in New Bedford and Fairhaven	wharf and bridge construction	loss of salt marsh and intertidal flats along western harbor shore (40+ acres (16 hectares)), eastern shore (20+ acres (8 hectares), and Clarks Cove (40+ acres (16 hectares)); loss of intertidal and subtidal habitats (2+ acres (0.8 hectares)) for Coggeshall Street bridge, and 0.5 acres (0.2 hectares) for Wood Street

Table 3.11
Summary of Land Use Activities and Impacts,
and Ecological Effects on New Bedford Harbor Resources

Selected Time Period	Land Use Activity	Impact Type	Ecological Effects
1860-1930	industrial, residential, and commercial development in New Bedford and Fairhaven	wharf and bridge construction	Bridge; alteration of tidal flushing in upper Acushnet River estuary and Inner New Bedford Harbor; new fill (4+ acres (1.6 hectares)) associated with Fairhaven-New Bedford bridge reconstruction
	water supply	dam construction and water withdrawals	alteration of habitat in upstream portion of Acushnet River; loss of flows to Acushnet River estuary
	coal terminals, oil refineries, and other industries	wharf construction, expansion, and infilling	loss of degraded intertidal and subtidal habitats, primarily along the western shore (10+ acres (4 hectares))
	textile mills and residential areas	exponential increase in organic wastes and chemical discharges	extensive water quality degradation in Inner and Outer New Bedford Harbor, algal blooms, hypoxic and/or anoxic conditions in poorly flushed areas; increased water column turbidity and loss of submerged aquatic vegetation; loss of shellfish and sensitive fish species; bioaccumulation of contaminants in fish, shellfish, and other fauna
	metal industries	waste discharges	bioaccumulation of metals (Cu, Pb, Zn, Cd, Cr); loss of sensitive species due to acute or chronic toxic effects
	boat building and repair industries	metal and chemical discharges	bioaccumulation of metals (Cu, Zn, Pb); toxic effects due to hydrocarbons and solvents

Table 3.11
Summary of Land Use Activities and Impacts,
and Ecological Effects on New Bedford Harbor Resources

Selected Time Period	Land Use Activity	Impact Type	Ecological Effects
1930 - present	port access and shipping maintenance	maintenance dredging of channel and maneuvering area	alteration of 30 ± acres (12 ± hectares) of severely degraded benthic substrates
	port protection	hurricane barrier and seawalls	loss of 34.5 ± acres of intertidal and subtidal habitats; severe reduction in tidal flushing in Inner Harbor
	port development	large fills, bulkheading	loss of 51± acres of subtidal and intertidal habitats
	roadway development (I-195, Route 18)	fills, pollutant discharges	loss of 4.7 acres of intertidal habitats; severe reduction in tidal flushing in upper estuary
	industrial development	PCB, metals	bioaccumulation of contaminants in sediments/food web; toxic effects to marine organisms
	residential, commercial and industrial development	bacteria, BOD materials, nutrients	increase in hypoxic and/or anoxic conditions; loss of shellfish and finfish

3.4.3 Current Patterns of Natural Resource Use and Impacts

As New Bedford's textile industry declined, so did the City's population, from 130,000 in 1924 to 105,000 in 1955. It has remained relatively stable since, at just under 100,000 residents. While New Bedford's population was declining, the population of the suburban towns doubled, but the City of New Bedford still accounts for the majority of the area's population, as shown in **Table 3.9,** above. As the textile business waned, the New Bedford area diversified, remaining a regional center for industry, retail trade, and other business. Currently, New Bedford Harbor is characterized by working urban waterfronts in New Bedford and Fairhaven, supporting commercial fishing, shipping, and marina operations.

3.4.3.1 Manufacturing

Since the late 1930s, New Bedford has attracted a variety of manufacturers and other industrial concerns, although these new employers generally have employed fewer people than the textile mills. A variety of industries has recolonized the old mill buildings, while elsewhere, mills have been razed for housing or commercial development. In 1960, the New Bedford Redevelopment Authority was formed to implement four major urban revitalization projects, including the North and South Terminal projects. The terminal projects created new highways along the waterfront, including the John F. Kennedy Memorial Highway, and created new waterfront property and bulkheads for industry and fishing. The 1300 acre New Bedford Industrial Park was opened in 1961 in the northern part of the City; in 1982 it was fully occupied with 18 companies employing 2500 people. The Air Industrial Park was developed during the 1980s immediately east of the New Bedford Airport (Boss and Thomas, 1983).

Manufacturing has decline further since 1984, when it represented 8,000 jobs or 45% of employment; at least five major manufacturers have discontinued operations in the New Bedford area since 1980. However, some types of manufacturing increased during the mid-1980s, including instruments, primary metals, chemical and allied industries, and transportation equipment.   Even today New Bedford’s largest employers are manufacturers: the Acushnet Company; Cliftex Corporation; Aerovox, Inc.; Calish Clothing Corp.; and Polaroid Corp. (DHCD, 1996; City of New Bedford, 1993).

3.4.3.2 Tourism and Recreation

During recent decades, tourism has grown in importance in the New Bedford Harbor Environment. The New Bedford Whaling Museum has been an important tourist attraction since the 1960s. Passenger ferries run from New Bedford to Marthas Vineyard and the Elizabeth Islands. In 1962, the Waterfront Historic Area LeaguE (WHALE) initiated an effort to preserve historic sections of New Bedford, and in 1984, the Bedford Landing Waterfront Historic District was established. Other efforts to encourage waterfront tourism include walking tours, visitor centers, and the berthing of historic vessels along the downtown waterfront. Annual events such as the Sea Fair, Feast of the Blessed Sacrament, and the Whaling City Festival bring thousands to the City. In 1988, downtown New Bedford was designated a “Main Street” district by the Commonwealth, and in 1996, the waterfront historic district was designated a National Park by act of Congress to commemorate the City's whaling heritage.

There are two public beaches in New Bedford. East Town Beach, a quarter of a mile long, is on the east side of Clarks Point, while West Town Beach, a half mile long, is on the northwest shore of Clarks Point. Fort Phoenix, a state-owned beach in Fairhaven, runs along a half mile of shoreline southeast of the Hurricane Barrier. Public access to the shore is also available at the Town of Fairhaven’s West Beach, a three-quarter mile beach on the west side of Sconticut Neck. Several other small beaches and numerous jetties along the west side of Sconticut Neck offer public access for swimming, fishing, and other recreational activities (McConnell and IEc, 1986). The public may also access the shore along Hurricane Barrier, at Palmer Island, and at Tonnessen Park.   Section 3.5.3 discusses some of the effects of PCB contamination on public access in the New Bedford Harbor Environment.

3.4.3.3 Offshore Fishing and Maritime Industries

New Bedford Harbor's offshore fishing industry grew rapidly following World War II. The fishing fleet was severely damaged by both the Hurricane of 1938 and Hurricane Carol in 1954 (VHB, 1996). To protect the working waterfront, built the Hurricane Barrier across the entrance to the Inner Harbor between 1962 and 1965. Terminal improvements and fish packing facilities were upgraded; together, these developments made New Bedford the premier fishing port on the East Coast.

Today nearly 300 commercial fishing vessels work out of New Bedford, mostly scallopers and trawlers fishing on Georges Bank, Nantucket Shoals, and the Great South Channel for sea scallops, Atlantic cod, haddock, winter flounder, mackerel, and other species (Doeringer et al., 1986). Fish landings in 1993 were valued at more than $100 million, making New Bedford the second-largest fishing port in the nation in terms of value of catch. During the late 1980s the City was home to 23 seafood product and fishing-related businesses, employing more than 1,500 people (City of New Bedford, 1993). Recently, however, landings have declined, primarily because of overfishing in New England waters (DOC, 1995), and many large trawlers are now idle.

In addition to the fishing fleet, New Bedford Harbor is home to a variety of port facilities and maritime industries. Merchant vessels call at New Bedford to deliver produce for distribution throughout the Northeast. There is a Coast Guard facility with two 270 ft vessels, two passenger ferries, and at least 1,200 slips and moorings for recreational boats in the New Bedford Harbor Estuary. As of 1965, there were five public boat launches in New Bedford and another three in Fairhaven. Fishing vessels and yachts from throughout the region take advantage of extensive storage and repair facilities at commercial marinas in Fairhaven, New Bedford, and Dartmouth. Fairhaven Shipyard, for example, has the largest travelift in the U.S., a 330-ton hoist capable of hauling 120 ft vessels for maintenance and repair.

3.4.3.4 Inshore Fishing

3.4.3.4.1 Commercial Fishing

More than 100 years ago Buzzards Bay, including New Bedford Harbor, was closed to commercial finfishing with nets, seines, and fish traps because of recognition of the importance of the Bay as a spawning area (Cardin et al., 1995). Therefore, with the exception of the occasional harvesting of anadromous fish such as alewives for bait or other purposes, commercial fishing in the New Bedford Harbor Estuary centers on the Estuary's shellfisheries.

In 1971, harvesting of quahogs, scallops, and oysters in the Inner and Outer Harbor and Clarks Cove was restricted because of high bacterial counts caused by sewage releases. In 1979, the Commonwealth closed 18 square miles of the New Bedford Harbor Estuary to the taking of bottom-feeding fish and lobsters due to discovery of PCB contamination. This closure, and some of its economic effects, are discussed in Section 3.5.3.

Commercial shellfishing continues in the New Bedford Harbor Estuary outside of the closed areas. At present, the most important species taken is the quahog or hard clam *(Mercenaria mercenaria)*, which is highly abundant in the upper reaches of the Harbor Estuary, particularly in the Inner and Outer Harbor and in Clarks Cove. Soft-shelled clam *(Mya arenaria)* and bay scallop *(Argopecten irradians)* support small commercial fisheries as well. Limpets *(Crepidula fornicata)* are also taken, but the fishery is unregulated, so no data are available. **TABLE 3.12** provides the most recent available landings figures for commercial shellfisheries in the New Bedford Harbor Estuary.

TABLE 3.12
Commercial landings of shellfish in the New Bedford Harbor Estuary, in bushels (Whittaker, 1996).

Quahog			
	1993	1994	1995
New Bedford	9,035	8,710	n/a
Fairhaven	14,700	14,000	n/a
Dartmouth	25,653	21,544	15,418 (?)
Total	49,388	44,254	n/a
Soft-shelled Clam			
	1993	1994	1995
New Bedford	0	0	n/a
Fairhaven	1100	1300	n/a
Dartmouth	59	99	82
Total	1159	1399	n/a
Bay Scallop			
	1993	1994	1995
New Bedford	0	0	n/a
Fairhaven	5	10	n/a
Dartmouth	0	0	85
Total	5	10	n/a

At $41 per bushel landed value for quahogs of mixed size, a rough estimate of the annual value of the New Bedford Harbor Estuary quahog catch is about $1.8 million dockside. Using an economic multiplier of 4.5, the value of this fishery to the regional economy may be estimated at about $8 million.

The shellfish catch in the Estuary might be larger if pollution were better controlled. As many as 500,000 bushels of quahogs, worth over $24 million, may be present in closed or restricted waters (CLF, 1988). Some of these shellfish are relayed to cleaner waters for depuration.

Shellfish species of potential commercial importance that are present in the Harbor Estuary, but not taken because either because of inadequate abundance or contamination, are lobster (Homarus americanus), oyster (Crassostrea virginica) and whelk (Busycon spp.)

While lobsters may not be taken from the New Bedford Harbor Estuary because of the PCB contamination, the lobster fishery in Buzzards Bay and offshore is of economic importance to New Bedford Harbor. Buzzards Bay is a major lobster spawning ground, and landings from the Bay have averaged more than 250,000 lbs annually during recent years. Nearly 200 lobster fishermen work out of New Bedford; about 50 work from Fairhaven; and roughly 10 from Dartmouth (MDMF, 1993-1995), fishing inshore as well as offshore waters. **Table 3.13** provides lobster landings statistics for Buzzards Bay, while **Table 3.14** presents landings for the ports of New Bedford and Fairhaven.

Table 3.13
COMMERCIAL LOBSTER LANDINGS FOR BUZZARDS BAY FROM 1981 TO 1991[1]

Year	Landings (pounds)	Landings (kg)
1981	214,079	97,088
1982	273,775	124,161
1983	317,593	144,033
1984	276,073	125,203
1985	237,374	107,653
1986	238,777	108,289
1987	249,822	113,298
1988	296,956	134,674
1989	316,199	143,401
1990	326,565	148,102
1991	290,769	131,868
1992	193,956	87,978
1993	268,719	121,891

1 Adapted from Holmes and Geohringer (In Press) and MDMF (1994, 1995)

TABLE 3-14
LOBSTER HARVEST BY NEW BEDFORD AND FAIRHAVEN FISHERMEN
1991 - 1993[1]

	1991		**1992**			
Homeport	**Territorial Waters**	**Non-Territorial Waters**	**Territorial Waters**	**Non-Territorial Waters**	**Territorial Waters**	**Non-Territorial Waters**
New Bedford	152,367 (69,258)	541,266 (246,030)	103,067 (46,849)	583,344 (265,156)	102,647 (46,658)	655,683 (298,038)
Fairhaven	81,769 (37,168)	718,585 (326,630)	110,197 (50,090)	643,693 (292,588)	133,617 (60,735)	599,121 (272,328)
Total	234,136 (106,425)	1,259,581 (572,537)	213,254 (96,934)	1,227,037 (557,744)	236,264 (107,393)	1,254,804 (570,366)
Combined	1,493,717 (678,962)		1,440,291 (654,678)		1,491,068 (677,759)	

[1] Data from MDMF 1993, 1994, 1995; Values are in pounds and (kilograms)

Annual commercial landings for these ports during this period averaged 1.47 million lbs, while the catch landed in Dartmouth ranged from roughly 10,000-30,000 lbs.

3.4.3.4.2. Recreational Fishing

Recreational finfishing and shellfishing in Inner New Bedford Harbor and the Upper Acushnet River Estuary have been limited by the Harbor's chronic contamination problems, resulting from sewage discharges as well as PCB releases. Sportfishing remains popular, however, in the Outer Harbor and Buzzards Bay. Rod-and-reel fishermen fish for "schoolie" striped bass near the Route 6 Bridge; striped bass, bluefish, tautog, and scup are caught from shore along the Hurricane Barrier, jetties along Clarks Point, Fort Phoenix, and other areas both in the Inner Harbor and Outer Harbor (D. Kolek, PC, 1996). Recreational fishermen in boats catch striped bass, bluefish, tautog and other species in the waters around Little and Big Egg Islands, the Butler Flats Lighthouse, and elsewhere in the Outer Harbor.

Anadromous fish including alewife, blueback herring, and American shad were once abundant in the Acushnet River. Although no catch statistics are available, there is a small alewife fishery on the River, managed by the MDMF (P. Brady, PC, 1996). The alewife harvested in this fishery are probably used primarily as bait for lobster, bluefish, and striped bass.

Quahogs, soft-shelled clams, and bay scallops are taken by recreational fishermen in the New Bedford Harbor Estuary, although recreational landing statistics are unavailable. In 1993, roughly 270,000 pounds of lobster were caught by recreational fishermen in Buzzards Bay, but the amount caught by recreational fishermen from the four affected communities in the New Bedford Harbor Environment is unknown (VHB, 1996).

3.4.4. Impacts of Current Uses on Coastal Resources

In 1952, ACOE dredged the New Bedford ship channel and turning basin to 30 ft depth, affecting about 15 acres (6 ha) of subtidal habitats. 107,000 cubic yards of dredged materials were disposed of in a designated offshore disposal area south of West Island (Malcolm Pirnie Inc., 1982). Since 1952, two large anchorages have been dredged near the Fairhaven waterfront, along with some smaller navigational projects (ACOE, 1971).

Between 1962 and 1965, the ACOE constructed the Hurricane Barrier to control storm-related flooding and help protect the New Bedford and Fairhaven fleets. The main section of the Barrier is a 3,500 ft (1,070 m) long riprap wall across the entrance to Inner New Bedford Harbor; the channel passes through a 150 ft (45 m) wide opening, with floodgates. A 3,800 ft (1,170 m) seawall, also with floodgates, runs along the northern shore of Clarks Cove; a 3,400 ft (1,035 m) seawall runs along the Outer Harbor on the northeast shore of Clarks Point (by East French Boulevard); and a 3000 ft (920 m) seawall crosses the Pope Beach marsh in Fairhaven.

Construction of the Hurricane Barrier resulted in the loss of an estimated 11.4 acres (4.6 ha) of subtidal and intertidal habitats, while the seawalls in the Clarks Point area resulted in the loss of approximately 23.1 acres (9.3 ha) of primarily intertidal habitats. Moreover, construction of the Barrier significantly reduced tidal action in the Harbor. As described in Section 3.2.3, the Barrier reduced the tidal range within the Inner Harbor and Upper Estuary; reduced flushing, causing retention of pollutants; drastically altered patterns of current flow and wave action; and probably caused a seasonal reduction in dissolved oxygen, and therefore habitat suitability, in the Inner Harbor and Upper Estuary. The dike across the Pope Beach marsh reduced tidal flushing in the northern part of the marsh, causing it to begin to revert to upland habitat (SES, 1988).

Coastal construction and redevelopment projects in the City of New Bedford during this period caused further loss or alteration of the Harbor Estuary's nearshore habitats. Shoreline was bulkheaded and backfilled near Wamsutta Mills, the Coggeshall Street bridge, and along the shorelines of Fish and Popes Islands. In Fairhaven, shoreline was bulkheaded or filled on the south side of Marsh Island (south of I-195) and along the shore by Fort and Middle Streets.

The State Pier was constructed off Commercial Street by filling 7.3 acres (3.0 ha) of subtidal habitats. The North Terminal and extension, located northwest of Fish Island, was completed in 1970 and resulted in the filling of 25 acres (10 ha) of subtidal habitat (City of New Bedford, 1976). In 1968, construction of the South Terminal Project, off Hassey Street, created a 19 acre (7.7 ha) area, principally for fish processing, gear manufacturing, and ancillary services for the fleet. The project also created a 1,600 ft (485-m) deep-water docking facility behind the Hurricane Barrier, where the majority of the fleet unloads its catch. Wharves in the vicinity of the South Terminal provide berthing for fishing vessels.

During this period, a number of small groins or jetties were built along East and West French Boulevards on Clarks Point to control beach erosion, resulting in a minor loss of intertidal and subtidal habitat (2 acres (0.8 ha)). By 1977, at least five such structures had been built along the east shore of the Point, and six along the west side.

The construction of I-95 across the Harbor Estuary in 1970, just south of the Coggeshall Street Bridge, reduced the effective width of the Estuary at this point by 90% (from 1,150 ft (350 m) to 100 ft (30 m)) and destroyed 4.7 acres (1.9 ha) of intertidal and subtidal habitats. Although tidal flow in this area had already been reduced by the Coggeshall Street Bridge, construction of the I-195 crossing probably further constricted tidal flushing of the Upper Estuary.

The discharge of large quantities of sewage, industrial waste, household debris, and other pollutants has continued to adversely affect Harbor resources in the late 20th Century. Nutrients and pathogens are discharged to the Harbor Estuary by the wastewater treatment systems of New Bedford and Fairhaven, as well as by combined sewer overflow units (CSOs), of which there are at least 35 along the Harbor shoreline. In the Inner Harbor, where tides and waves are impeded by the Hurricane Barrier and Coggeshall Street Bridge, levels of nutrients and coliform bacteria are high, and dissolved oxygen is periodically low (VHB, 1996; SES, 1988; Summerhayes et al., 1977).

High levels of fecal coliform bacteria led to shellfishing closures in 1971 (in Clarks Cove and the Outer Harbor), and additional closures in 1979. In 1983, Clarks Cove was again closed to shellfishing due to sewage contaminants (CLF, 1988). By 1987, 3,478 acres of New Bedford shellfish beds, 2,256 acres of Fairhaven shellfish beds, and 1,593 acres of Dartmouth shellfish beds were closed due to sewage contamination (Germano, 1987).

In the Outer Harbor, recent improvements to New Bedford's wastewater treatment system are expected to mitigate wastewater-related nutrient problems. The City's new treatment plant, which began operating in 1996, is designed to impart secondary treatment to 30 million gallons per day (mgd) with a peak capacity of 75 mgd for wet-weather processing (VHB, 1996).

Electrical parts manufacturing plants used large amounts of polychlorinated biphenyls (PCBs) from the 1940s through 1977, and discharged wastes containing PCBs and other contaminants directly to the Harbor, or indirectly through New Bedford's wastewater treatment system. Between 1958 and 1977, an estimated 145 tons of PCBs were discharged to the Harbor area (Howes and Goehringer, in press), while an estimated 200 to 700 pounds of PCBs were being discharged annually during the late 1970s and early 1980s. Residual amounts of PCBs from the City's sewage lines have continued to flow into the Harbor long after their use by manufacturers ceased (Weaver, 1982).

Other industrial facilities (metals finishing, glass and rubber manufacturers, welding, iron foundries, plastics, fish processing, food packaging, and the few remaining textile mills) have also generated discharges. Summerhayes et al. (1985) suggest that metal enrichment in New Bedford Harbor has been occurring for approximately 100 years; in recent years, two firms alone have discharged as much as 200 pounds of copper per day into the Upper Estuary. Section 3.5 details distributions of PCBs and metals in the New Bedford Harbor Estuary.

The growth of the commercial fishing industry during the 20th Century led to the development of seafood processing plants that discharged large quantities of fish waste to the New Bedford Harbor Estuary. These organic wastes greatly increased the BOD in the Harbor Estuary, and probably caused hypoxic conditions and fishkills within the Harbor. One estimate suggests that fish processing operations may result in the annual generation of nearly 3,000 tons of BOD, although, due to treatment of some of the wastes at the New Bedford facility, not all of this is released to the Harbor (VHB, 1996).

Completion of I-195 in 1970 and the JFK Memorial Highway in 1975 also resulted in water quality impacts to the New Bedford Harbor Estuary. The construction of these roads provided opportunity for new industrial development along New Bedford Harbor and increased motor vehicle use, generating hydrocarbons, salts, metals, and other contaminants which are released to the Harbor Estuary as non-point source pollutants (road runoff).

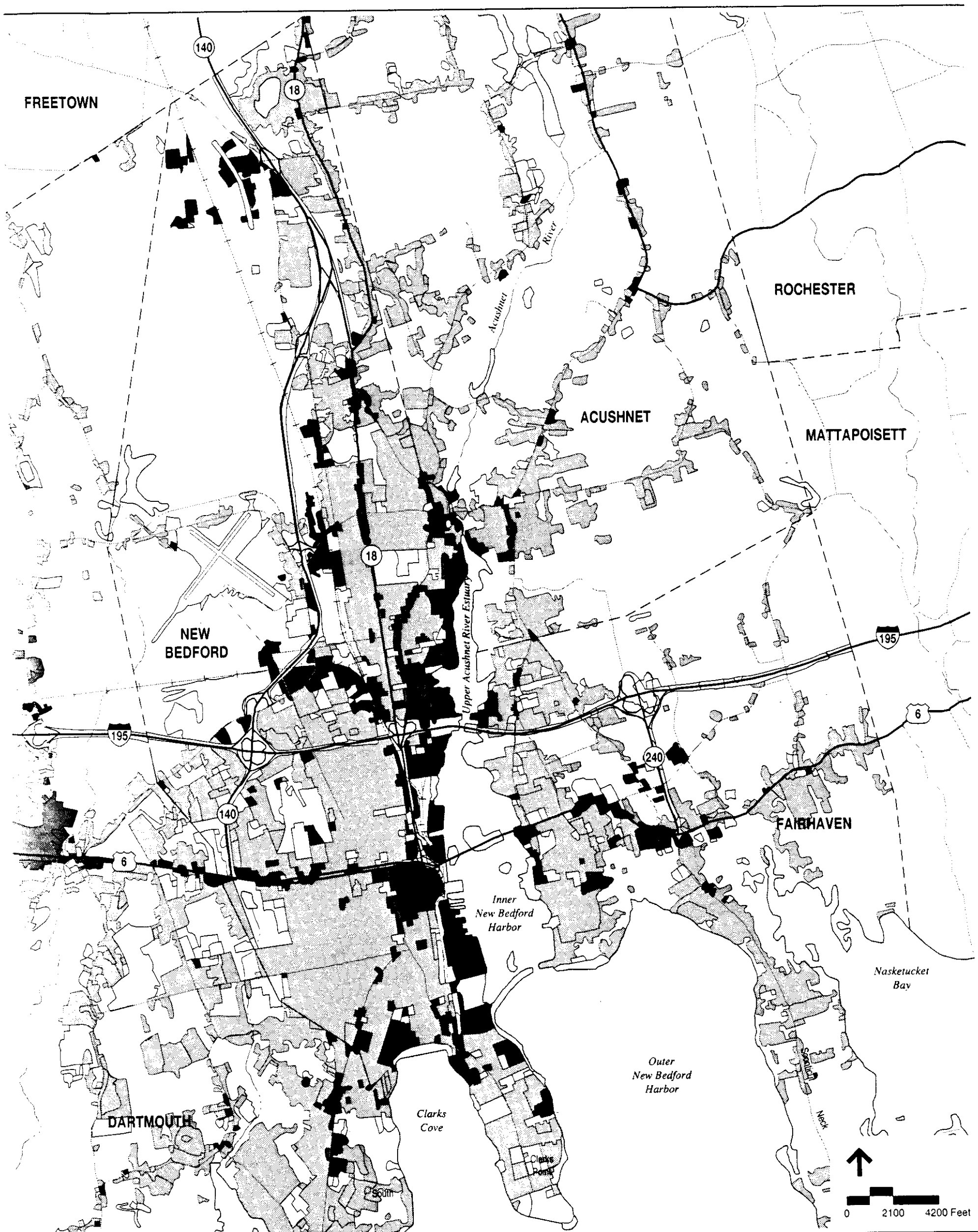
3.4.5 Current Land Use

In spite of the decline of the mills, land use in New Bedford -- and to a lesser extent in Fairhaven, Acushnet, and Dartmouth -- remains dominated by the nodal development patterns of the Mill Era. Vast brick mills -- many now vacant, or partially so -- stand surrounded by residential and retail neighborhoods of two- and three-story wood-frame tenements.

The most intense development is along the western shore of the Harbor and along Route 140. Industrial uses are centered in the old mills along the Acushnet River and Clarks Cove, and in newer industrial parks near the New Bedford Airport and in northern New Bedford. High-density residential uses are concentrated in the central portion of New Bedford and along the Fairhaven and Acushnet waterfronts. Commercial development is located along Routes 6 and 18. The New Bedford and Fairhaven downtown areas are mixed commercial and residential areas, with small industries and public offices. Rural and suburban residential development and undeveloped lands (primarily wetlands) extend east and west of the developed corridor which surrounds the Upper Estuary and parts of the Acushnet River.

Figure 3.3 describes current patterns of land use in the New Bedford Harbor Environment.

Figure 3-3



Vanasse Hangen Brustlin, Inc.

Residential
Commercial, General Urban
Industrial
Transportation, Recreation, Public and Institutional Open Space

Source: Mass GIS

Existing Land Uses
New Bedford Harbor and Vicinity

New Bedford Harbor Trustee Council
RP/EIS

70602ELU

3.4.6 Baseline for Restoration: Mid-20th Century

In order to provide a blueprint for restoring the natural resources of New Bedford Harbor to their pre-contamination condition, the RP/EIS must attempt to establish a baseline--a measure of the condition that would have existed within the Harbor Environment had the release or discharge of PCBs to New Bedford Harbor not occurred. Because of the complexity and range of cumulative human impacts on the Harbor Environment--before, as well as since, the injury--and the lack of quantitative data on water quality, fish populations, and other measures of environmental quality, a precise, quantitative baseline cannot be established for New Bedford Harbor. Nevertheless, by examining the history of resource uses and impacts discussed in the previous sections, we can develop a qualitative sense of the environmental status of the Harbor in the 1930s and '40s--the period when PCB releases to New Bedford Harbor began--and attempt to isolate, in a general way, the effects of PCBs on the Harbor Environment.

As discussed in the preceeding section, the downtown shorelines of New Bedford and Fairhaven were more or less completely wharved by the mid-19th Century. Navigational channels to New Bedford and Acushnet had been dredged along with turning basins. Around the turn of the the 20th Century, at least 250 acres of salt marsh along the western shores of the Upper Estuary and Inner Harbor and at the head of Clarks Cove were filled for industrial and residential development. Once-forested or agricultural areas near the Harbor had become completely urbanized. Eelgrass beds had entirely disappeared from the Inner Harbor. By the 1940s, therefore, a good deal of the Harbor's original estuarine habitat had already been lost or degraded--perhaps half of the original coastal and nearshore habitat of the Upper Estuary and Inner Harbor had been adversely affected.

As shown also in the preceeding section, the circulation and dynamics of the Harbor Estuary had been significantly modified by the mid-20th Century, though not nearly as much so as today. Tidal circulation in the Upper Estuary and in the upper half of the Inner Harbor, between Coggeshall Street and Route 6, had been reduced and modified by the construction of bridges. Before the construction of the Hurricane Barrier in the 1960s, however, the waters of the lower half of the Inner Harbor communicated more freely with the waters of the Outer Harbor. Tidal amplitude in this part of the Inner Harbor was greater; tidal flushing was more frequent; and some pollutant effects, such as problems caused by low levels of dissolved oxygen in the water column, were probably less severe. Since fish and shellfish could move more easily between the Inner and Outer Harbors before construction of the Barrier, a wider effective range of estuarine habitat was available to these animals, and they were likewise more available for harvest to the urban residents of New Bedford, Fairhaven, and Acushnet.

From historical accounts, we know a little about inshore fisheries in the New Bedford Harbor area during the first half of the 20th Century, and can say that inshore shellfisheries were well developed, barring periods of closure due to bacterial contamination. From anecdotal evidence, we know too that urban residents of

Acushnet and the North End of New Bedford regularly fished and swam in the waters of the Upper Estuary during this period.

As the preceeding sections pointed out, New Bedford Harbor was no stranger to water pollution before PCB releases to the Harbor began in the 1940s. Nutrients and pathogens from sewage were a particular problem through most of the 20th Century, leading to closure of shellfish beds in the Upper Estuary, Inner Harbor, Clarks Cove, and off Clarks Point (EPA 1996). Metals, hydrocarbons, and other toxic compounds were also being released into the Harbor, varying in scale and location as a function of changing patterns of industrial production and resource use.

These pollutant patterns were fundamentally different from the discharge of PCBs that began in the 1940s. Though the effects of sewage-related pollutants can be locally severe, they are generally short-lived. Sewage-related pollutants are not generally toxic compounds; they do not biomagnify; they cannot be transferred intergenerationally; and they do not usually have reproductive impacts *per se*. Large inputs of sewage-related pollutants can disrupt an estuarine ecosystem by altering its biochemistry--for example, when nutrient discharges cause plankton blooms, which in turn lead to low dissolved oxygen and fish kills, or reduced water clarity affecting eelgrass beds or other habitats. But although moderate amounts of these pollutants render shellfish unsafe for humans to eat, they are not necessarily harmful to marine organisms themselves, and many species, such as winter flounder, quahog, and oysters seem undisturbed by moderate levels of sewage-related pollutants. Generally, an estuarine ecosystem degraded by sewage discharges is capable of recovering naturally within a few years once the releases are reduced, treated, or controlled. Likewise, shellfish taken from waters contaminated by pathogens can be “depurated” or cleansed by placing them, temporarily, in uncontaminated waters.

By contrast, PCBs are among the most persistant of marine pollutants; they are long-lived in the environment and are retained in the tissues of animals, from polychaetes to humans. As a result, PCBs tend to biomagnify through the foodchain, becoming concentrated in higher organisms, and being transferred through the food web and throughout ecosystems. PCB contamination renders not just shellfish, but finfish as well, inedible by humans; and organisms contaminated by PCBs cannot be depurated. As discussed in subsequent sections of this chapter, the toxicity of PCBs to marine organisms, in New Bedford Harbor and elsewhere, is well documented. PCBs are also known to have harmful effects on reproduction and to be mutagenic (causing mutations), and are thought to be carcinogenic (causing cancer) to humans, as well.

Before dredging of the Hot Spot commenced, approximately 700 tons of PCBs resided in the sediments of the New Bedford Harbor Superfund Site, suggesting that hundreds, if not thousands of tons of PCBs were discharged to the waters of New Bedford Harbor during from the 1940s to the 1970s. While the range of effects of these releases on the biota of New Bedford Harbor and Buzzards Bay will probably never be fully known, there is no question that PCBs were dispersed throughout the biotic and abiotic environment of the New Bedford Harbor Environment and, to a lesser extent, Buzzards Bay. As discussed more fully in Section 3.5, the contamination has caused direct mortality of estuarine organisms ranging from benthic worms to common terns, and has altered the structure of biotic communities of New Bedford Harbor.

From these data, as well as from historical information on the presence and use of fish and shellfish in the Harbor, it can be deduced that PCB releases to New Bedford Harbor have reduced the abundance and quality of a wide range of estuarine species of ecological and economic value. In many cases, populations and communities affected by PCBs have been injured by multiple anthropogenic impacts. In particular, it seems clear that PCB contamination and habitat loss have been the major sources of impacts on living resources in New Bedford Harbor. Furthermore, lack of high-quality habitat may prevent populations or communities injured by PCBs from fully recovering from the effects of the contamination once the Harbor sediments are remediated.

Equally important, public and private use of natural resources in the New Bedford Harbor Estuary, from the flounder of the Upper Estuary to the lobster of the Outer Harbor, has been significantly curtailed as a result of PCB releases to the Harbor, particularly since enactment of the 1977 fishing closures described in Section 3.5. An urban estuary which not long ago provided food, sport and recreation to urban residents within the affected environment has become a liability, a hazardous waste site of severely limited use. A more complete discussion of the ecological and economic injury caused by PCB releases to the New Bedford Harbor Environment is provided in Section 3.5.

3.4.7 Future Directions - New Bedford’s Waterfront

New Bedford's stakeholders seem to agree that the City's economic future depends upon its waterfront. The City’s Economic Development Plan suggests that New Bedford capitalize on multi-modal transportation facilities, Free Trade Zone status, excess industrial capacity, and maritime assets wherever possible by focusing on marine-related industrial activities (City of New Bedford, 1993). Specific actions recommended are:

- Expansion of bulkheads at the North and South Terminals. Needed fill may be available from dredging of PCB-contaminated sediments as well as navigational dredged material.
- Addition of docking facilities at the south side of Fish Island.
- Development of a containerized feeder service into the Harbor to encourage foreign trade.

A number of processes are underway to improve maritime transportation and development on both sides of New Bedford Harbor. As discussed in Chapter 2, Massachusetts Coastal Zone Management is in the process of assessing navigational dredging needs for New Bedford Harbor. The New Bedford/Fairhaven Harbor Master Plan, discussed in Chapters 2 and 4, will undertake a comprehensive port development study. Finally, EPA, working with the Commonwealth and ACOE, is considering an “enhanced remedy” for the Harbor Superfund Site, which would address some of the sediment disposal issues related to navigational dredging in New Bedford Harbor.

In October, 1995, the New Bedford Waterfront Historic Area League (WHALE) and the American Institute of Architects sponsored “HarborVisions!,” a “charrette” or exercise in envisioning the future of the Harbor waterfront. The charrette’s major recommendations were:

•Redevelop the State Pier as an international marketplace and open-air seafood and produce markets
•Develop an aquarium, conference center, and ferry terminal at the site of the vacant Commonwealth Electric generating facility
•Redevelop North Terminal for continued industrial use
•Redevelop the old New Bedford rail station as a transportation hub, with rail link to the New Bedford Municipal Airport
•Develop Palmers Island and the Standard-Times field as public recreational areas
•Redevelop Route 18 (WHALE, 1996).

The proposed development of a gambling casino by the Wampanoags could bring tourists to the outskirts of the City who, with careful planning, might be directed to the historic and waterfront districts.

3.5 Injury to the Environment

As described in Chapter 2, the first step toward natural resource restoration at a Superfund site is assessment of the injury to natural resources and the resulting losses to the public caused by the release of hazardous substances. The government, representing the public trust as natural resource trustee, evaluates injury to the resource and determines the cost of restoring the resources to baseline levels and compensating the public for interim losses. Natural resource damage assessments (NRDAs) are expensive and difficult to do, so trustees cannot always quantify all the effects of a contamination incident. Moreover, New Bedford Harbor was one of the first NRDA cases under CERCLA and the case was settled before the NRDA was completed, so the full measure of damages to the environment stemming from PCBs in New Bedford Harbor may never be known. The broad nature of the injury is, however, suggested by the available information.

The following section summarizes the distribution of contaminants in the New Bedford Harbor Estuary, describes injuries to the environment due to PCB releases to the New Bedford Harbor Environment and provides a partial estimate of the losses experienced by the public as a result.

3.5.1 Contaminant Distributions

3.5.1.1 Pre-cleanup

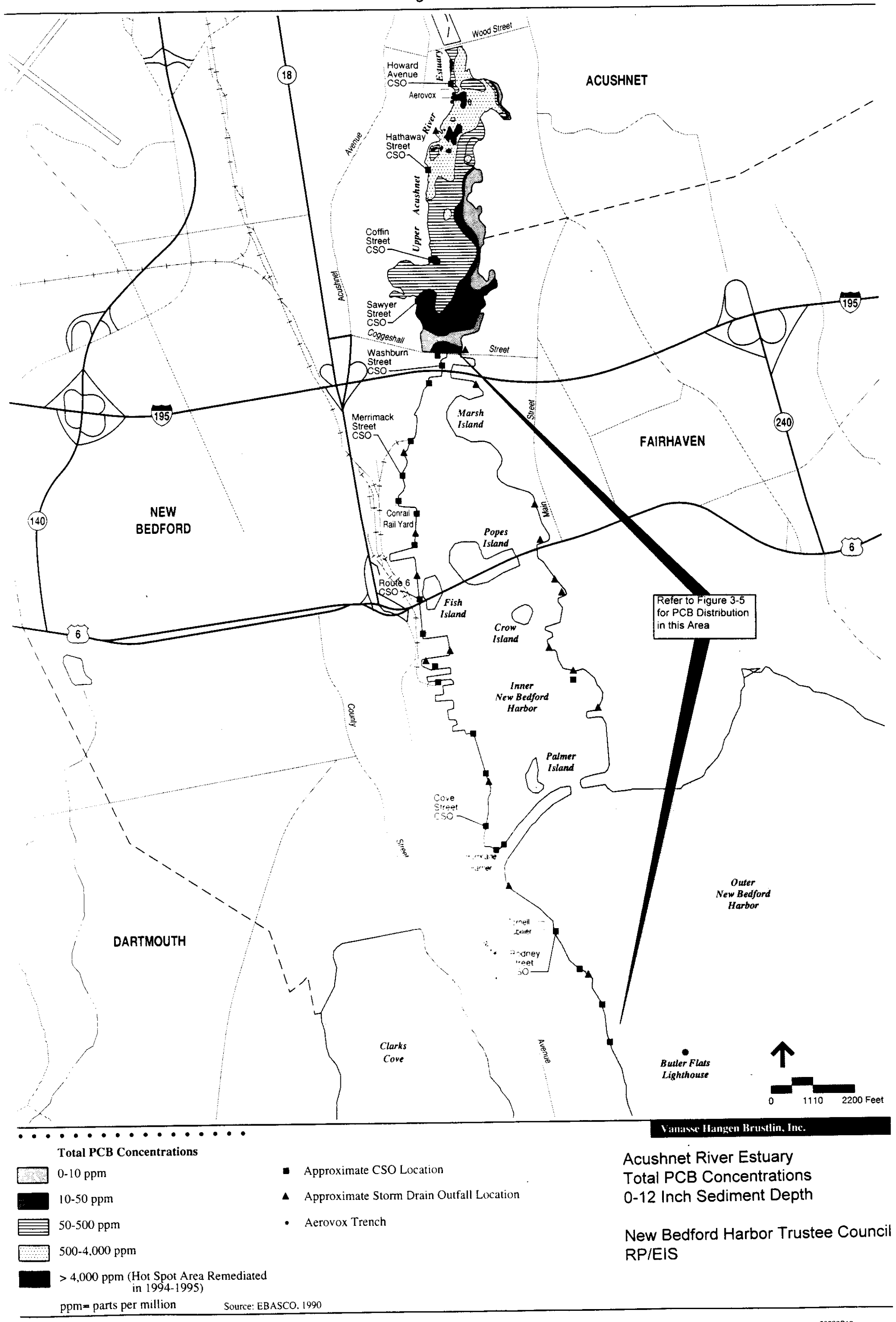
Before EPA and ACOE completed dredging of the Hot Spot, PCB levels in the tide flats and subtidal sediments of the Acushnet River above the Coggeshall Street Bridge ranged as high as 200,000 parts per million (ppm), among the highest levels of PCBs in marine sediments ever recorded (EPA, 1992; Pruell et al., 1990). PCB levels in the peat of the salt marshes of the Upper Acushnet range above 500 ppm. Between Coggeshall Street and the Hurricane Barrier in the Inner Harbor, concentrations of PCBs in estuarine sediments range above 100 ppm in limited areas, while levels in excess of 10 ppm are more widespread. Concentrations of toxic metals are also high in the sediments of the Inner Harbor, exceeding 1000 ppm in some spots (VHB, 1996).

South of the Hurricane Barrier, along the west shore of Outer New Bedford Harbor, PCB concentrations in sediments range above 50 ppm, though concentrations of 1-50 ppm are more widespread. Measurable levels of PCBs have been found in the sediments of Buzzards Bay throughout the Outer Harbor and in Buzzards Bay beyond the Area III closure line, but these are generally low, with the exception of an area roughly half a mile off Clarks Point, by the City's sewer outfall, where PCB sediment concentrations are in the neighborhood of 50 ppm (VHB, 1996).

PCBs have been detected in the water column throughout the New Bedford Harbor Estuary. Measured concentrations have ranged from over 7500 ng/l in the Hot Spot area to 5 ng/l at the outer edge of Area III. The entire New Bedford Harbor Estuary, therefore, exhibits water column concentrations exceeding the level considered by EPA to cause chronic impacts to living marine resources of 0.03 ng/l (EBASCO, 1990; EPA, 1990b).

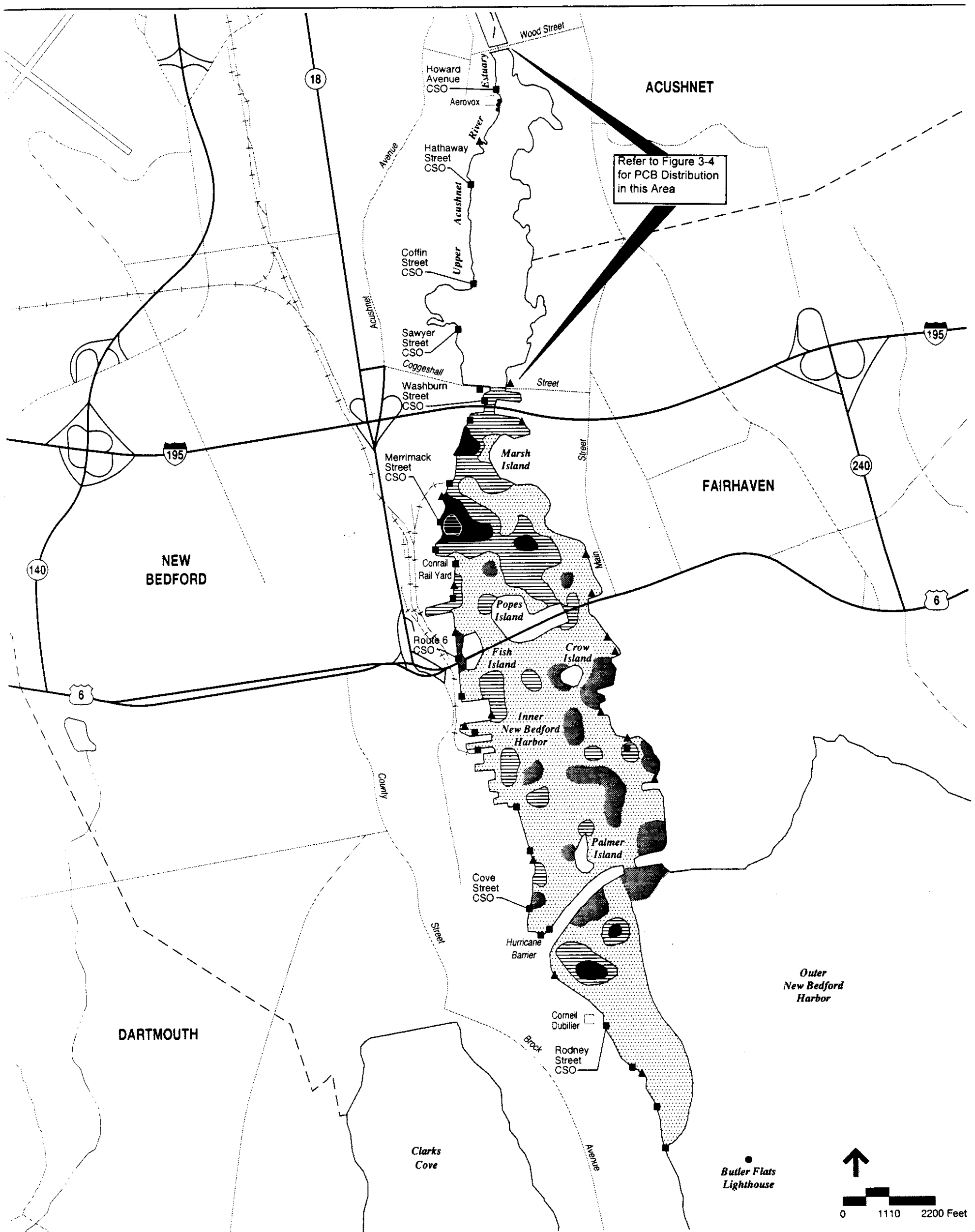
Figures 3.4 through 3.7 describe the distribution of toxic metals and PCBs in the New Bedford Harbor Estuary.

Figure 3-4



Wood Street
Howard Avenue CSO
Aerovox
Upper Acushnet River Estuary
Hathaway Street CSO
Coffin Street CSO
Sawyer Street CSO
Coggeshall Street
Washburn Street CSO
ACUSHNET
FAIRHAVEN
NEW BEDFORD
DARTMOUTH
Merrimack Street CSO
Marsh Island
Conrail Rail Yard
Popes Island
Route 6 CSO
Fish Island
Crow Island
Inner New Bedford Harbor
Palmer Island
Cove Street CSO
Outer New Bedford Harbor
Clarks Cove
Butler Flats Lighthouse
Refer to Figure 3-5 for PCB Distribution in this Area
Acushnet
Avenue
Main Street
County Street
18
195
240
140
6
0 1110 2200 Feet
Vanasse Hangen Brustlin, Inc.
Total PCB Concentrations
0-10 ppm
10-50 ppm
50-500 ppm
500-4,000 ppm
> 4,000 ppm (Hot Spot Area Remediated in 1994-1995)
ppm= parts per million
Source: EBASCO, 1990
Approximate CSO Location
Approximate Storm Drain Outfall Location
Aerovox Trench
Acushnet River Estuary
Total PCB Concentrations
0-12 Inch Sediment Depth
New Bedford Harbor Trustee Council
RP/EIS
70602P12

Figure 3-5



Total PCB Concentrations

- < 1 ppm
- 1-10 ppm
- 10-50 ppm
- 50-100 ppm
- > 100 ppm

ppm= parts per million

- ■ Approximate CSO Location
- ▲ Approximate Storm Drain Outfall Location
- • Aerovox Trench

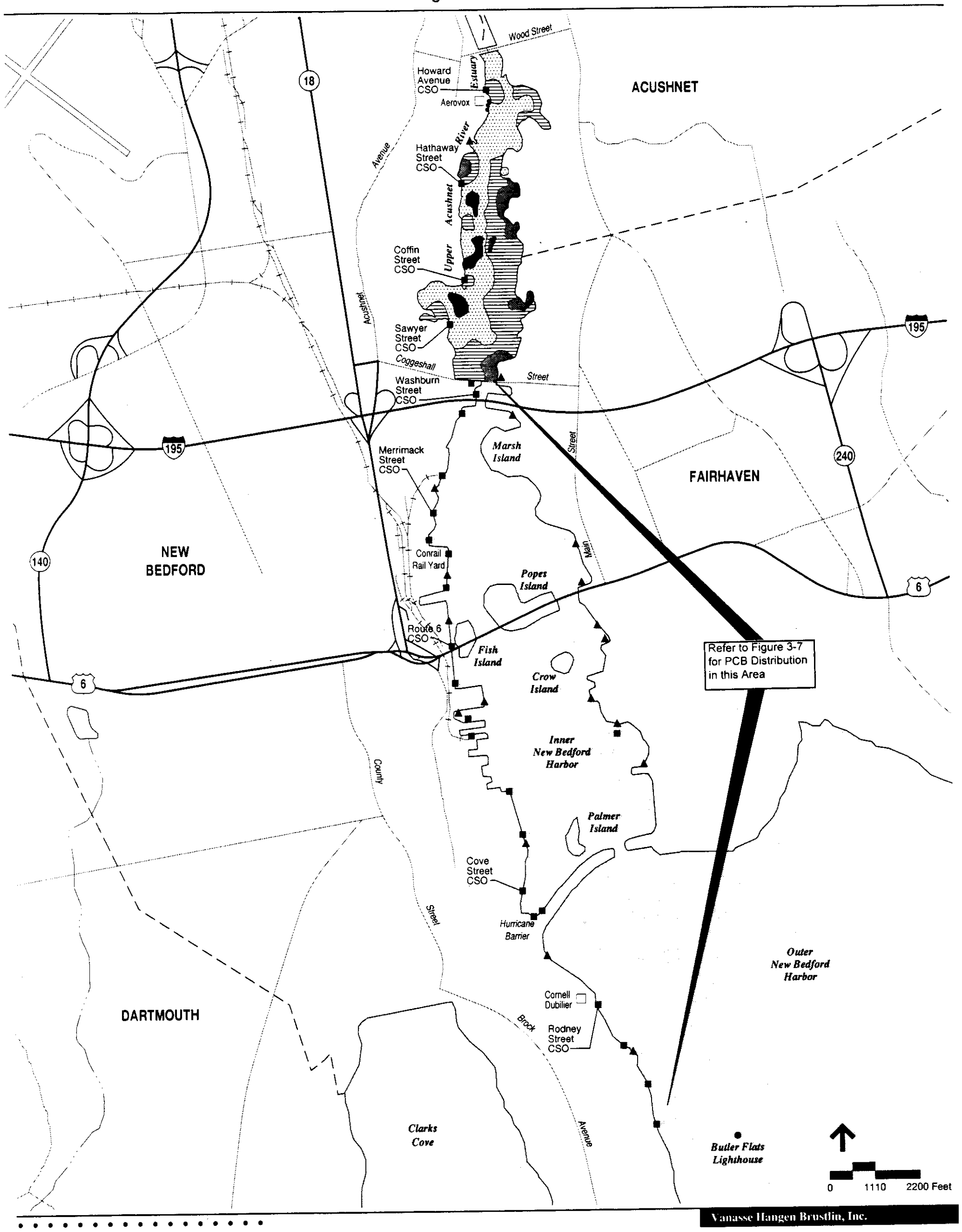
Source: EBASCO. 1990

Acushnet River Estuary
Total PCB Concentrations
0-6 Inch Sediment Depth

New Bedford Harbor Trustee Council
RP/EIS

70602P6

Figure 3-6



Total Metal(Cadmium, Chromium, Copper, Lead) Concentrations

- 0-100 ppm
- 100-1,000 ppm
- 1,000-5,000 ppm
- > 5,000 ppm

- ■ Approximate CSO Location
- ▲ Approximate Storm Drain Outfall Location
- • Aerovox Trench

Acushnet River Estuary
Total Metal Concentrations
0-12 Inch Sediment Depth

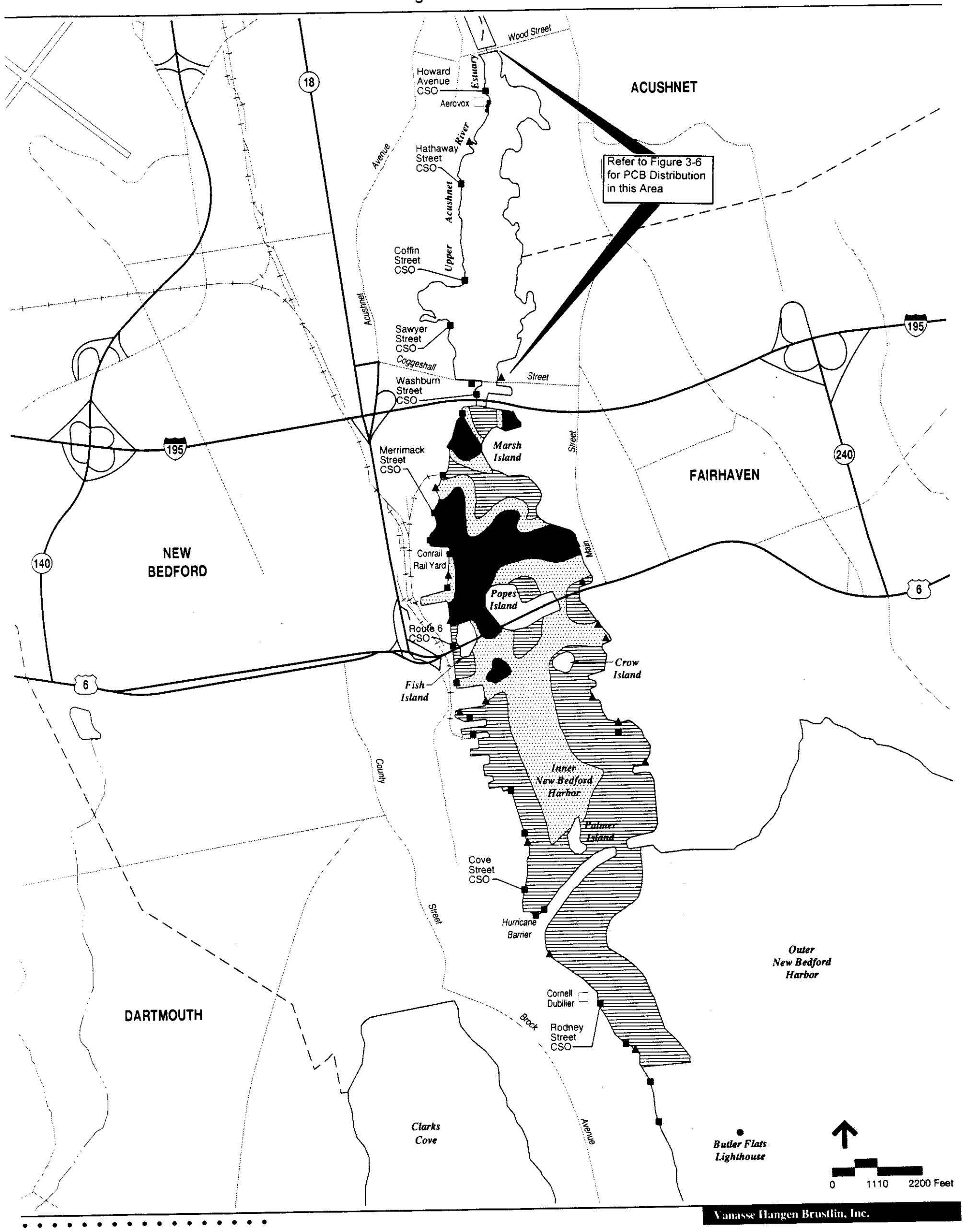
New Bedford Harbor Trustee Council
RP/EIS

ppm= parts per million

Source: EBASCO, 1990

70602M12

Figure 3-7



Total Metal (Cadmium, Chromium, Copper, Lead) Concentrations

- 0-500 ppm
- 500-1,000 ppm
- > 1,000 ppm
- ■ Approximate CSO Location
- ▲ Approximate Storm Drain Outfall Location
- • Aerovox Trench

New Bedford Harbor
Total Metal Concentrations
0-6 Inch Sediment Depth

New Bedford Harbor Trustee Council
RP/EIS

ppm= parts per million

Source: EBASCO, 1990

70602M6

3.5.1.2 Post-cleanup

Since nearly all the sediments in the Upper Acushnet River Estuary were above the action level of 10 ppm, most of the area between Wood and Coggeshall Streets will be dredged. After cleanup, residual levels of PCBs in most of the sediments of the Upper Estuary will be in the 2-10 ppm range (Dickerson, PC, 1996). An exception is a cable crossing area, which must be capped with clean sediments because it cannot be safely dredged. Also, within the salt marshes of the Upper Estuary, only areas exceeding 50 ppm will be dredged and replaced, leaving wetland areas with PCB levels as high as 50 ppm in place after cleanup (Craffey, PC, 1996; Dickerson, 1995).

Below Coggeshall Street, EPA's action level is 50 ppm. Most of the sediments in Inner New Bedford Harbor, between Coggeshall Street and the Hurricane Barrier, have PCB concentrations of 1-50 ppm (VHB, 1996). Since these concentrations will not be dredged, significant PCB concentrations will remain in this part of the Harbor Estuary. In the Outer Harbor, EPA's current cleanup plans call for dredging only the most contaminated spots, leaving residual levels of up to 50 ppm (Dickerson, 1995).

The distribution of toxic metals in New Bedford Harbor does not necessarily coincide with that of PCBs, particularly in the Inner Harbor where total metals concentrations in excess of 1000 ppm are widespread outside of the areas slated for dredging. Therefore, significant concentrations of toxic metals (cadmium, chromium, copper, and lead) can also be expected to persist in the Inner Harbor's benthic habitats once the cleanup is complete (Dickerson, 1995).

EPA has informally estimated that it may take ten years after completion of the cleanup for the Harbor's water quality to meet EPA's target levels for PCBs, placing that portion of recovery squarely into the next century, around 2015 (Dickerson, PC, 1996). Given that contaminant concentrations are certain to persist in portions of the Harbor sediments, it is probable that the ecosystem will not have fully recovered by that date.

3.5.2 Ecological injury

PCBs have been shown to have a variety of harmful effects on fish, birds, and mammals, including toxicity, mutagenicity, and reduction of reproductive success. Information on the extent of ecological injury to the New Bedford Harbor Environment from releases of PCBs is incomplete, but it appears that PCB contamination in waters, sediments, and living resources has reduced the biodiversity of the Harbor ecosystem, reduced species' reproductive capabilities, and increased mortality in resident species of finfish and shellfish. PCBs have also accumulated or biomagnified across trophic levels, with impacts to birds and other predators (NBHTC, 1993; Weaver, 1982).

3.5.2.1 Species

Large numbers of fish, shellfish, and birds in the Harbor have been contaminated by exposure to PCBs. Eight of fifteen species of finfish sampled from 1976-1980 in the New Bedford Harbor area showed mean PCB concentrations above the current FDA limit for edible seafood of 2 parts per million. The maximum observed concentrations in ten of these species exceeded the FDA limit, while the minimum observed concentrations in only three of the species did so (Weaver, 1982; Kolek and Ceurvels, 1981).

The species for which mean PCB levels exceeded the FDA limit were American eel, cunner, three species of flounder (summer, winter, and windowpane), scup, and bluefish. In addition to these species, tautog and striped bass showed maximum observed PCB levels exceeding the 2 ppm limit (Weaver, 1982; Kolek and Ceurvels, 1981).

Among shellfish sampled in New Bedford Harbor during the same period, oysters, soft-shelled clams, blue crabs, and lobsters showed mean PCB levels exceeding the FDA limit; minimum PCB levels observed in soft-shell clams were seven times the limit (Kolek and Ceurvels, 1981). Mean PCB concentration in edible tissues of lobsters sampled was 8.7 ppm; individual samples ranged from 0.1 ppm to 84 ppm (Weaver, 1984).

The one edible marine species for which these early studies found PCB levels to be uniformly low was quahog. Quahogs sampled within the New Bedford Harbor environment showed average PCB concentrations of 0.8 ppm; of 20 samples, only one individual was found to exceed the FDA level with a PCB concentration of 3.3 ppm (Kolek and Ceurvels, 1981).

Herring sampled in Hamlin Pond and the New Bedford Reservoir in 1993 and 1995 showed mean whole-body PCB concentrations below the FDA limit, but mean concentrations in roe and maximum whole-body concentrations exceeded the limit (DMF, 1995).

The toxic effects of New Bedford Harbor PCBs have been documented at both ends of the marine food chain. Amphipods (small benthic crustaceans) exposed to sediments from the more highly contaminated parts of the Upper Estuary, Inner Harbor, and Outer Harbor have low rates of survival (Nelson et al., 1996). Common terns have been lethally poisoned by PCBs as a result of feeding on baitfish in New Bedford Harbor, such as Atlantic silversides, that have high levels of PCBs in their tissues (Nisbet, 1990).

While high levels of PCBs have been documented in species throughout the Harbor Environment, much remains unknown about the ecological effects of the contamination. As discussed in Section 3.3, species within an estuary like New Bedford Harbor are largely interconnected. A great blue heron may be only two steps in the foodchain from a Hot Spot polychaete. It is highly probable, therefore, that the ecological effects of PCB contamination in New Bedford Harbor are not limited to the species in which the injury has been measured, but extends also to species dependent, directly or indirectly, on organisms exposed to high concentrations of PCBs in the waters and sediments the Harbor.

3.5.2.2 Habitats and Communities

Elevated levels of PCBs and other toxic substances have been documented in all the habitats of the New Bedford Harbor Estuary: waters, wetlands, and subtidal and intertidal sediments. Even after clean-up of the Harbor sediments has been completed, elevated levels are expected to persist for some time in the waters and biota of the Harbor Environment.

As discussed in Section 3.3, these estuarine habitats form a complex ecosystem that, even in its currently degraded state, supports a wide range of species. The salt marshes support diverse communities of plants, fish, shellfish, birds, and mammals; provide spawning habitat and forage for marine and avian species; and perform essential biochemical functions within the Harbor ecosystem. The bottom sediments and tide flats are home to dozens of invertebrate species. Some, like quahogs and lobster, are of direct value to humans, while others, like polychaete worms, are of forage value to fish such as tautog and flounder. The waters of the New Bedford Harbor Estuary support a rich assemblage of flora and fauna, ranging from phytoplankton and zooplankton to bluefish and striped bass.

Some of the effects of PCB contamination on the habitats and communities of New Bedford Harbor are suggested by a recent study by EPA on the condition of the Harbor's benthic communities. More highly contaminated areas of the Harbor showed low benthic ecosystem health according to several ecological measures (biodiversity, benthic community condition, and community structure). The study found extremely low benthic biodiversity in the Upper Estuary, which exhibited a degraded benthic community symptomatic of a stressed ecosystem. The Inner Harbor was also found to be "significantly impacted," although less so than the Upper Estuary, with higher biodiversity and less degraded community structure. The Outer Harbor was found to be generally healthy, with normal biodiversity and community structure, although specific areas within the Outer Harbor with higher levels of contaminants exhibited poorer ecological health (Nelson et al., 1996). These findings agreed with an earlier study which showed a correlation between high levels of PCBs and metals in the Harbor sediments and reduced populations of benthic invertebrates (Bellmer, 1988).

The benthic invertebrate communities that these studies examined are a critical food source for a wide variety of estuarine fish and larger crustaceans such as lobsters and crabs. It is probable that the reduced biodiversity and ecological health of benthic communities stemming from the Harbor contamination resulted, in turn, in reduced diversity and abundance of bottom-feeding fish and other predatory species that depend on these communities.

Since PCBs have been shown to impair the reproductive success of birds and other animals, the contamination of New Bedford Harbor may have also reduced the biodiversity and abundance of avian species in the New Bedford Harbor Environment, particularly as regards fish-eating birds such as osprey, terns, and herons (Nisbet, 1990).

While the clean-up of the Harbor can be expected to provide a major improvement overall to the New Bedford Harbor Environment, the dredging itself is not without impacts on habitats and biological communities. Depths will be altered and benthic communities removed. While dredged salt marshes will be replaced, it may be many years before the created marshes replicate the full range of ecosystem functions provided by the natural marshes, depriving the New Bedford Harbor Estuary of some of the special physical and biological functions that only salt marshes can provide.

In summary, PCB contamination has reduced the diversity, health and abundance of biological communities and habitats of the New Bedford Harbor Environment, with particularly severe effects on the fish, shellfish, birds and habitats of the Harbor Estuary. Moreover, the effects of PCB contamination on the natural resources of the Harbor are likely to endure for some time. Natural recovery is expected to proceed slowly following initiation of the Harbor remediation.

3.5.2.3 Wider Buzzards Bay ecosystem

Injuries to natural resources from PCB releases into New Bedford are not limited to resident species. As discussed in Section 3.3, many species move in and out of the Estuary to feed or spawn; in so doing, they may transport contaminants in their tissues. Eels, for example, which exhibited the highest levels of PCBs found among finfish, move out of the Estuary to spawn, while herring move up the watershed; both are important sources of food for birds, sportfish, and other species. The environmental effects of PCB releases in New Bedford Harbor, therefore, extend ecosystem-wide, throughout the New Bedford Harbor Environment, Buzzards Bay, and beyond.

A study of organochlorine residue concentrations in common terns and other species along the Massachusetts coast was conducted from 1971-1981. Study goals were to identify geographic patterns of contamination levels, relate those levels to the patterns of use of the contaminants, and determine the rate of decline of contaminant residue levels using biological monitors. A secondary goal was to determine if contaminant levels were high enough to cause adverse effects.   Included in the study were sampling stations in New Bedford Harbor and Buzzards Bay (Bird Island, Wing's Cove, Wareham River, Widow's Cove and Ram Island). Common terns, Atlantic silversides, juvenile sand lance, and mussels were collected and analyzed for PCBs and other organochlorines. Using common tern eggs, the study determined that contaminant concentrations (including PCBs) were highest at Boston Harbor and Buzzards Bay (Bird and Ram Island) sampling stations.   Similar results were seen for juvenile Atlantic silversides, mussels and sand lance with PCB concentrations increasing as the distance to New Bedford Harbor decreased. The contaminant concentration ratio between fish and tern eggs varied very little between sampling stations which provided further evidence of the geographic pattern. (Nisbet and Reynolds, 1984)

A 1988 study found that levels of PCBs in the tissues of lobsters and flounder throughout Buzzards Bay were higher than the average for coastal Massachusetts, concluding that "high concentrations of PCBs...in New Bedford Harbor provide a continuous source of PCBs to fishery resources in Buzzards Bay" (Schwartz, 1988).

A 1990 paper documented lethal poisoning of common and roseate terns at Bird and Ram Islands in upper Buzzards Bay, caused by eating fish containing high levels of PCBs from New Bedford Harbor. The same study found high levels of PCBs in the eggs of terns at these two sites, concluding that the contamination of New Bedford Harbor threatened the recovery of the tern population of Buzzards Bay. Moreover, this study stated that PCBs from New Bedford Harbor posed a threat to the survival of a number of other species of fish-eating birds in Buzzards Bay, including the double-crested cormorant, snowy egret, great egret, herring gull, great black-backed gull, ring-billed gull, laughing gull, and least tern (Nisbet, 1990). As mentioned in Section 3.3, the roseate tern is on the federal Endangered Species List, while the least tern has been designated a Species Of Special Concern by the Commonwealth of Massachusetts.

In short, PCB contamination in New Bedford Harbor has had ecological consequences for species, communities, and habitats throughout the Harbor Estuary. Moreover, the effects of the contamination have extended throughout much of Buzzards Bay and beyond and, due to the extraordinary environmental persistence of PCBs, have been not just widespread, but long-lived as well.

3.5.3 Losses to the Public

Three main categories of losses to the public were quantified in the New Bedford Harbor NRDA: (1) losses to commercial and recreational fisheries; (2) losses associated with decreased environmental quality; and (3) losses resulting from beach closures.

3.5.3.1 Fisheries

As a result of PCB contamination in the New Bedford Harbor Estuary, the Commonwealth of Massachusetts enacted three commercial and recreational fishing closures in September, 1979. These closures continue in effect through today and are expected to remain in effect until some years after harbor cleanup is completed. Area 1 (Inner New Bedford Harbor and the Upper Acushnet River Estuary) is closed to the taking of all finfish, shellfish, and lobsters. Area 2 (Outer New Bedford Harbor, from the Hurricane Barrier south to a line from Ricketson to Wilbur Points) is closed to the taking of lobsters and bottom-feeding fish (eel, scup, flounder, and tautog). Area 3 (from Area 2 south to a line from Mishaum to Rock Points, running through Negro Ledge) is closed only to the taking of lobsters (105 CMR 260.000 *et seq.*) (**Figure 1.1**).

A 1986 study examined direct damages to the New Bedford area commercial lobster fishery, finding that fishermen incurred increased costs from the closures of more than $50,000 per year, representing a total loss through time of approximately $2.9 million (as recalculated by the trustees in 1996 dollars[1]) (McConnell and Morrison, 1986). A

---

[1] Net present value of the injury was estimated at $2.0 million in 1986. Throughout this section, 1986 dollars have be converted to 1996 dollars using a multiplier of 1.4288. The multiplier was obtained by dividing 156.6 (Consumer Price Index (CPI) fo May, 1996) by 109.6

second study measured economic damages to recreational angling as a result of the PCB contamination, concluding that direct damages could be conservatively estimated at more than $60,000 per year, representing a total loss through time of over $4.4 million in 1996 dollars[2] (McConnell and IEc, 1986).

Together, these two studies suggest that losses to marine fisheries of the New Bedford Harbor Estuary as a result of PCB contamination were over $7 million. However, this estimate is clearly conservative. First, the full range of potentially affected fisheries was not considered. For example, there is a commercial rod-and-reel fishery for flounder in Narragansett Bay; no study has examined whether such a fishery may have existed in the Outer Harbor before the fishing closures were enacted. Nor has any study examined economic effects on real or potential shellfisheries caused by the Harbor contamination.

3.5.3.2 Environmental quality

Another 1986 study, subsequently published in 1992, used changes in residential property values in New Bedford, Dartmouth, and Fairhaven to estimate the lost value experienced by single family home owners due to the impaired environmental quality stemming from the Harbor contamination. The study found that the contamination and resulting prohibitions on swimming, fishing and lobstering had reduced the value of local environmental amenities to residents near the Harbor, as captured in households' willingness to pay for residential property. Lost value of single family homeowners was estimated at approximately $45 million.[3] These estimates are conservative because they do not include renters and homeowners in rental neighborhoods despite the large numbers of these people near polluted waters. (Mendelsohn 1992)

3.5.3.3 Lost Recreational Use of Beaches

The aforementioned 1986 McConnell and IEc study measured reduced demand for beach recreation as a result of the Harbor contamination, estimating economic losses to users of area beaches at $12-16.3 million.[4]

3.5.3.4 Total Quantified Losses to the Public

The damages estimated by the three studies described above cannot be summed. The economic losses estimated by each study overlap to some extent, and since the case was settled before the NRDA was completed, the studies were never

---

(annual average CPI for 1986). The CPI figures, as well as the conversion method, were provided by Richard Bahr of the Bureau of Labor Statistics, U.S. Department of Commerce.

[2] Estimated 1986 NPV $3.1 million, converted to 1996 dolars as per Footnote 1.

[3] Estimated 1989 NPV $35.9 million, converted to 1996 dollars using the adjustment factor of 156.6/125.0 = 1.2525, where 156.6 is the CPI index for 1996 and 125.0 is the CPI index for 1989.

[4] Estimated 1986 NPV $8.3-11.4 million, converted as per Footnote 1.

synthesized. As a result, a truly complete picture of the economic effects of PCB contamination in New Bedford Harbor does not exist.

However, since the studies did not consider the universe of potential damages, the true value of the losses suffered by the public as a result of PCB contamination in New Bedford Harbor was probably greater than indicated by these figures. As noted above, constraints on the NRDA meant that a number of areas of potential injury were not assessed. Contamination may have affected fisheries other than the lobster fishery in Buzzards Bay. Because of the difficulties associated with disposal of contaminated sediments, ship channel dredging has been delayed over the years, the channel depth has decrease, and larger vessels are now unabel to safely enter the port. As a result, navigation, and consequently, harbor front development in New Bedford Harbor have been impeded although these effects cannot be quantified.

In short, while it is impossible to place an exact figure on the losses to the public resulting from PCB contamination in the New Bedford Harbor Environment, the injury to the natural resources of the region is real and has had a considerable impact on many aspects of the economic life of the New Bedford region.

All those who use or would use the natural resources of New Bedford Harbor have been affected by the contamination. This includes resident resource users as well as visitors to the area, and active as well as passive users. Active use of the Estuary has been restricted by the impacts of the contamination on fishing and shellfishing, boating, beachgoing, and other recreational activities.

As noted in Section 3.5.3.1, above, commercial and recreational fishermen have also been affected. In addition to the lobster fishery, for which impacts are well documented, the Inner Harbor and Upper Estuary are closed to fishing for flounder, tautog, eels, scup, quahogs, oysters and other estuarine species. As a result, the in-shore commercial and recreational fisheries common in other New England estuaries are absent from New Bedford Harbor north of the Hurricane Barrier.

There are indications that owners and users of coastal commercial property (for example, marina operators) have been affected by the contamination, through increased development costs, reduced property values, and lost business resulting from delays to navigational dredging. Their customer base--commercial and recreational boat users, shippers, and other end users of marine transportation--have undoubtedly borne some of the added costs of doing business on New Bedford Harbor.

Finally, but perhaps most importantly, all citizens and businesses in the New Bedford area have been affected to some extent by PCB releases to New Bedford Harbor, since the contamination has degraded environmental quality, and reduced the quantity, value and uses of natural resources in the area.