Chapter 2.
Salt Water Resources

Chapter Summary

Pleasant Bay's 7,000 acres of generally shallow, warm, and uniformly saline water resources serve as critical animal and plant habitats, and support extensive commercial and recreational activities.

Water quality testing and technical studies conducted over the past three decades have indicated that water quality in the Bay is generally high. The small number of isolated water quality problems that have been identified have been precipitated by surrounding land uses, restricted flushing, or both. The on-going health and vitality of the Bay's salt water resources will continue to be influenced by these two factors. The formation of the Chatham breakthrough in 1987 increased the rate of tidal circulation in the Bay and, in some areas, raised the tidal range and strength of wave action. These changes are credited with improving water quality in the Bay. However, the southward migration and potential re-filling of the breakthrough could diminish the rate of flushing, and return the Bay to the near eutrophic conditions experienced prior to the breakthrough. Alternatively, the formation of additional breaches along North Beach could increase the forces of erosion in the Bay, and change water conditions to more closely resemble adjacent ocean waters. Either event could have a profound influence on the Bay's habitats.

The inflow of fresh water into the Bay through groundwater discharges, overland run-off, and tributaries will also continue to influence the Bay's water quality. Fresh water intrusions are increasing as sea level rises, and are helping to dilute water salinity in certain areas of the Bay. Freshwater intrusions may further change water quality in the Bay by increasing the flow of a variety of pollutants. The quality of fresh water intrusions is influenced by land uses within the watershed. The increasing flow of nutrients, bacterial contaminants, and other pollutants from intensifying land and marine uses poses a threat to water quality in the Bay.

2.1 Saltwater Resources

Pleasant Bay's salt water resources, which cover nearly 7,000 acres at mean high tide, serve as critical wildlife habitats, and support a wide variety of commercial and recreational activities including fishing, shellfishing, boating, and swimming.

Despite the variety of terms used to describe the salt water bodies that make up the Pleasant Bay System, they all share the same basic estuarine characteristics of lower salinity and higher temperature relative to surrounding ocean waters. Harbors and bays in the system include "Big" and "Little" Pleasant Bay, Frostfish Cove, the Horseshoe, Round Cove, Ryder's Cove, Bassing Harbor, and many others. With the exception of Big and Little Pleasant Bay, and Chatham Harbor which experience stronger tidal action, the remaining harbors and coves are very much like salt ponds.

Typical of an estuary, the Pleasant Bay System is comprised by numerous sub-embayments that connect with the Bay before entering the ocean. In two notable areas, a number of water bodies are linked together before entering the Bay, and are referred to in the plan as complexes. The River Complex includes The River (sometimes referred to as Meeting House River) , and Namequoit River (commonly referred to as Arey's River). The rivers link Meeting House Pond, Kescayogansett Pond (also known as Lonnie's Pond), and Arey's Pond with Little Pleasant Bay. The Bassing Harbor Complex encompasses the Harbor, Crow's Pond and Ryder's Cove. Other salt ponds and coves outside of either complex , such as Paw Wah Pond, Quanset Pond, and Round Cove, are linked to the Bay by short entrance channels.

While all part of the same estuarine system, each sub-embayment has a different flushing rate, tidal range, water temperature, and salinity, and each experiences different impacts from land and water uses. All of these factors combined influence the water quality of a particular sub-embayment, and the variety of habitats it can support. As discussed below, water quality conditions and characteristics throughout the Bay were altered by the formation of the breakthrough in 1987, and will continue to be influenced by the anticipated southern migration of the breakthrough.

2.2 Barrier Beach and Shoreline Processes

The eastern boundary of Pleasant Bay is known as North Beach in the Nauset-Monomoy Barrier Beach System. The seven miles of barrier beach within the study area protect Pleasant Bay from the open ocean, and temper the strength of tides and currents throughout the estuary. The barrier beach, which serves as an important haven for many species of migratory shore birds, is within the boundary of the Cape Cod National Seashore. However this portion of barrier beach is managed by the towns of Orleans and Chatham, respectively. Both towns are currently working with the National Park Service to develop barrier beach management plans for their respective portions of North Beach. The local management plans will address human use and resource protection issues, much like the Bay's resource management plan. In recognition of these on-going planning efforts, the resource management plan for Pleasant Bay focuses on the Bay's inner shore and the back side of North Beach, and is intended to complement the towns' barrier beach management programs.

North Beach acts as a buffer protecting the Bay from harsh ocean conditions. However, the level of protection was drastically altered by the formation of the Chatham breakthrough in 1987. Perhaps no other event in recent history has had as great an influence on conditions in the Bay as the formation of the breakthrough. The breakthrough effectively divided Nauset Beach and created North and South Beaches, resulting in a more direct point of entry for ocean waters into Pleasant Bay. This event increased the flushing rate in the Bay, raised the tidal range and caused higher high tides in the Bay, and increased wave energy in Chatham Harbor. These altered conditions have influenced habitats for marine plant and animal life in the Bay, and have heightened the potential for erosion, particularly along the Bay's southern and western shorelines.

Recent studies of the breakthrough and barrier beach have concluded that South Beach will migrate southward as its northern tip erodes and sediments are transported by wave and tide action to its southern end. Simultaneously, the southern tip of North Beach has experienced a retreat of vegetated dunes. Littoral drift from the eroding southern end of North Beach is causing shoaling in and near the entrance to the breakthrough.[1] Continued southward growth of North Beach is anticipated.[2]

The southward migration, or potential closure, of the breakthrough could return the Bay's water quality and characteristics to pre-1987 conditions. Alternatively, continued storm-induced erosion along low-lying portions of North Beach could result in additional breaches in the barrier beach system. Additional flow of ocean water through a new breach along North Beach could help to sustain current water quality conditions in the Bay or, alternatively, influence conditions to more closely resemble adjacent ocean waters. While the exact timing or extent of either occurrence cannot be predicted, it is certain that the evolution of the barrier beach will continue to be an important factor in the ecology of the Bay.

2.3 Water Quality and Characteristics of Saltwater Resources

The conditions and characteristics of the Bay's extensive salt water resources have been evaluated and recorded in a number of studies and monitoring efforts over the past thirty years. These reports provide historical data on tidal ranges, temperature, salinity, and other water quality characteristics throughout the Bay.[3] A study of tidal flushing in the Bay was recently completed for the resource management plan.[4] The study measured tidal flushing in the Bay under current conditions and under pre-breakthrough conditions. The study confirmed that the direct flow of ocean waters through the breakthrough has altered some characteristics of salt water resources in Pleasant Bay, and generally has improved water quality.

2.3.1 Tidal Range, Water Depth, and Flushing

[1] Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

[2] Giese, Graham, et al. *Development, Characteristics and Effects of the New Chatham Harbor Inlet*. W.H.O.I. 1988.

[3] The studies include:

- In a 1967 study of the Bay's marine resources , the Division of Marine Fisheries conducted an analysis of the Bay's water temperature, salinity, and water quality, and included data from a 1965 survey of water quality from the Department of Public Health.
- In 1976 the DEQE Division of Water Pollution Control conducted a survey of water quality.
- In 1991 a water quality study of the Bay was conducted by Robert Wilhelm II for the Friends of Pleasant Bay. That study was followed by a study of water quality in the Bay's tributaries conducted by IEP, Inc. in 1991.
- In addition to these studies, there is on-going water quality monitoring undertaken by the towns, the Division of Marine Fisheries, and, in Meeting House Pond, a citizen water quality monitoring group.

[4] Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

The flushing rate, or *residence time*, is the average time required for a parcel of water to migrate out of an estuary from fixed points within the system. For the entire Pleasant Bay system, the *system residence time* is the time it takes for water to exchange with the Atlantic ocean. For smaller water bodies within the Bay system (i.e., Ryder's Cove), the *local residence time* is the average time it takes for water to migrate from that water body to another point outside of the water body, but still within the system (i.e., to Bassing Harbor). The application of system and local residence times is discussed below.

The Bay's residence times are influenced by its physical characteristics. Because it is semi-enclosed system, the time that nutrients and pollutants are retained in the Pleasant Bay System before being flushed out to adjacent waters is greater than it would be for a more open system. The Bay's shallow depths both decrease the ability for retained pollutants to be diluted in the water column, and increase the secondary impacts from nutrients and pollutants found in sediments.[5] Three primary elements of the flushing process – tidal range, water depth, and residence time – have been influenced to varying degrees by the formation of the breakthrough.

2.3.1.1 Tidal Range

Tidal range in the Bay, defined as the difference between mean low and mean high tides, increased one and one-half feet following the breakthrough, to approximately four feet. Prior to breakthrough, the tidal range observed at Meeting House Pond was 2.6 feet, as compared to 4.4 feet at the entrance to the Atlantic Ocean. The difference in tidal range between the two ends of the Bay at that time was attributed to shoaling which blocked tidal flow. [6] Following the breakthrough, the tidal range at Meeting House Pond had increased to 4.1 feet, and remained 4.4 feet at the Fish Pier near the entrance to the Atlantic Ocean.[7] The increase in tidal range has raised high tides in the Bay, rather than lower the low tides.

2.3.1.2 Residence Time or Flushing

Prior to the breakthrough the Pleasant Bay System had a system residence time of 1.1 days, compared to .98 days after the breakthrough. [8] Thus, the formation of the breakthrough has reduced the system residence time for water in the Bay by approximately twelve percent.

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[5] Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

[6] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

[7] Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts*. The Friends of Pleasant Bay, Inc.. July, 1989.

[8] Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

Since Pleasant Bay exchanges its two billion cubic feet of water with the open ocean approximately once a day, its water quality is considered high.[9] In situations where the water quality of the estuary is high, flushing for the sub-embayments is more meaningful when expressed in terms of *local residence time*. The breakthrough reduced local residence times by thirteen percent for the Bassing Harbor Complex, and The River Complex, respectively. In Muddy Creek, where an undersized culvert restricts flushing, local residence time was reduced twenty-nine percent.

2.3.1.3 Bathymetry or Water Depth

While the formation of the breakthrough has increased the tidal range and flushing rate in the Pleasant Bay System, it has had surprisingly little apparent influence on water depth. Bathymetric conditions remained relatively stable in most of the Bay following the Breakthrough.[10] Recent water depth measurements undertaken for the flushing study matched conditions recorded prior to the breakthrough, where sixty-five per cent of the Bay was less than six feet deep, and only fifteen per cent was greater than twelve feet deep, at mean low water.[11]

2.3.1.4 Summary of Impact of the Breakthrough on Water Quality

By increasing the rate of flushing in the Pleasant Bay System, the breakthrough is credited with generally improving water quality throughout the Bay. However, the extent of improvement varies within the system, with more enclosed water bodies still experiencing considerable tidal restrictions. Water quality conditions in enclosed water bodies within the system may be affected if higher tidal ranges help to increase the flow of nutrient-rich groundwater into those areas. Thus, the beneficial effects of flushing may not, in and of themselves, lead to high water quality in the long term if the flow of pollutants into the Bay increases at a fast enough rate. In addition, the anticipated migration and possible closure of the breakthrough may elongate residence times throughout the Bay, unless an alternative breakthrough forms elsewhere along North Beach.

2.3.2 Temperature and Salinity

Typically an estuary is considered to be an arm of the sea that becomes diluted by fresh water intrusions. Pleasant Bay is sometimes considered to be more like a tidal

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[9]Note: A short residence time is usually an indicator of high water quality. However, if the rate of pollutants flowing in is high, or if the quality of water flushing in is poor, then a short residence time may not indicate high water quality. See: Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

[10] Ramsey, John. *Hydrodynamic and Tidal Flushing Study of Pleasant Bay Estuary, MA. Final Report for the Pleasant Bay Steering Committee*. Aubrey Consulting, Inc. August, 1997.

[11] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

lagoon because it experiences relatively little variation in temperature or salinity from its headwaters to its opening to the ocean as compared to most other marine estuaries.[12]

Temperature measurements taken before and after the breakthrough indicated relatively little variation in temperature among areas within the Bay. As measured during 1965, water temperatures at various locations in the Bay ranged from a low of 29 degrees (F) in February to 78 degrees (F) in July. [13] As measured in 1988, after the breakthrough was formed, temperatures ranged from a low of 34 degrees (F) in December, to a high of 81 degrees (F) in July. As would be expected, water temperatures in the Bay overall are generally warmer than temperatures in adjacent ocean waters. The Bay's relative warmth is attributed to its shallowness, since water is able to warm earlier in the Spring and retain high temperatures longer into the Fall. Warm water temperatures overall help to elongate the reproduction and growth period for some shellfish species. However in isolated shallow areas, high temperatures may actually inhibit some types of marine organisms.[14] Conversely, cold temperatures are sustained long enough during some winters for ice to form in the upper reaches of the Bay .[15]

There is relatively little intrusion of fresh water to dilute the salinity of Pleasant Bay, however this condition appears to be changing. In general, the salinity of the Bay's waters is only slightly below normal sea water, and varies little from the upper areas to the entrance. Prior to the breakthrough, some dilution was noted at Frost Fish Creek, but little elsewhere.[16] Localized dilution was reported more frequently following the breakthrough, at Arey's Pond, Pah Wah Pond, Quanset Pond, Round Cove and Muddy Creek. Dilution at all of these testing sites was attributed to streams, ground water inflows, or overland runoff. The increased incidence of dilution supports the notion that the increased tidal range from the breakthrough acted to increase ground water infiltration in some areas. [17]

The Bay's relatively high salinity, even in its upper areas, makes it a more hospitable environment to salt water species. Species that are salinity-tolerant (stenohaline) such as quahogs and hake, and as well as species that can tolerate extreme salinity changes (euryhaline), tend to flourish in the Bay. The Bay's warmth, coupled with

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[12] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

[13] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

[14] Converted from Celsius measurements contained in the *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts* by Robert Wilhelm. Wilhelm note that the U.S. EPA has determined that 82 degrees (F) is the maximum temperature waters in the region should reach to protect aquatic life from harmful thermal effects.

[15] Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts.* The Friends of Pleasant Bay, Inc.. July, 1989.

[16] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

[17] Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts.* The Friends of Pleasant Bay, Inc.. July, 1989.

its relatively high and uniform salinity, enhances its value as a nursery for these and other species. [18]

2.3.4 Water Quality Indicators

Studies and testing undertaken over the past thirty years indicate that, overall, the quality of the Bay's salt water resources is quite good. A small number of problem areas exist, primarily where flushing and circulation is restricted by culverts or natural features, or where intensive adjacent land uses generate pollution through groundwater discharges or run-off. The studies also suggest that nitrogen loading from land uses within the Bay's watershed, and on-going uses of the Bay such as boating, pose threats to existing water quality. As discussed below, coliform, dissolved oxygen, pH, phosphorous, and nutrients are among the water quality indicators for the Bay that have been monitored in numerous studies.

2.3.4.1 Bacterial Contamination

Coliform is an indicator of disease carrying bacteria that is associated with soil and the feces of warm blooded animals. Testing for bacterial contamination over the years indicates that coliform contamination in the Bay is generally isolated and variable, and that overall the estuary is suitable for swimming, fishing, and shellfishing.

Measurements conducted at forty-five testing locations during June and July of 1965 found moderate levels of coliform contamination at nine locations , and gross levels of coliform contamination at nine locations. The sources of contamination were believed to be drainage from a duck farm, cesspools, and storm drainage. The fact that test sites included previously clean areas as well as previously contaminated areas led researches to conclude that the coliform problem in the Bay was increasing. At the time of the report, two locations were closed to shellfishing. Tests conducted throughout the Bay by the state Division of Water Pollution Control in 1976 found that the waters of the Bay were generally in a condition suitable for shellfishing, swimming and fishing.[19] By 1988, approximately fifty acres of shellfish beds had been closed due to elevated fecal coliform counts: sections of Meeting House Pond, Muddy Creek, and Paw Wah Pond. A 1988 study included measures of total coliform and fecal coliform at testing sites around the Bay. Measurements varied based on testing conditions, where elevated levels were often attributed to warm weather, run-off from rain , decreased tidal circulation , or adjacent land uses. Fecal coliform, a member of the coliform group more closely linked with

[18] To protect marine life, the U.S. EPA has established a guideline that changes in hydrography or stream flow should not alter naturally occurring changes in isohaline patterns by more than 10 per cent. Source: the *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts* by Robert Wilhelm

[19] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967.

human disease, was found to be extremely elevated near a storm drainage pipe in Meeting House Pond.[20]

On-going testing for bacterial contamination is conducted by the state Division of Marine Fisheries and the towns for the purposes of designating the status of shellfish beds. Currently fifty-one acres or one per cent of the total potential area for shellfishing in the Bay is closed due to contamination. Efforts are underway to determine the potential sources of bacterial contamination and develop strategies for remediation. An additional fifteen acres is closed on a seasonal basis, typically in the warm weather months.

AREAS CLOSED OR SEASONALLY APPROVED FOR SHELLFISHING

Prohibited Areas:	**Acres**
Frost Fish Creek	12.8
Muddy Creek	29
Pochet Creek	5.3
Namequoit River	2.0
Pah Wah Pond	.25
Total Prohibited	49.3
Conditionally Approved Areas (Seasonal):	
Muddy Creek	1.5
Ryders Cove	1.84
Round Cove	13.04
Total Conditionally Approved	16.4

Source: Information as of January, 1998, MA Division of Marine Fisheries

2.3.4.2 Dissolved Oxygen

Dissolved Oxygen (DO) measures the oxygen in the water that is available to support plant and animal life. The level of DO decreases as the temperature and salinity of the water increase. Biological Oxygen Demand (BOD) is the measure of demand for DO in the water. BOD can increase due to introduction of nutrients from boats, septic systems or run-off and quickly deplete DO needed by organisms. The increase in BOD in the water from boating or other human activity often coincides with warmer temperatures, exacerbating the depletion of DO. BOD levels measured across the Bay in 1967 and 1988 indicated acceptable conditions with respect to oxygen demand, overall.[21] The lowest levels of DO measured in the 1988 study were detected near the

[20] Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts*. The Friends of Pleasant Bay, Inc.. July, 1989.

[21] Samples for the 1988 study were taken at up to eighteen sampling stations located from Meeting House Pond in the upper reaches of the bay, southward to Aunt Lydia's Cove . Eleven stations were sampled from shore, and the remaining seven by boat at marked offshore locations.

bottom of Meeting House Pond during May 1987, indicating that stagnant or anoxic conditions may exist periodically in Meeting House Pond.[22]

2.3.4.3 Hydrogen Ion (pH)

Hydrogen ion or pH indicates the levels of salts, acids and bases in the water. Measurements of pH taken in 1967 and again in 1988 found levels to be in the normal range for sea water, and within state and federal guidelines for the health of aquatic life.[23]

2.3.4.4 Phosphorus

Phosphorous is a by-product of natural decomposition processes as well as an indicator of the presence of sewage or detergents in the water. Naturally, phosphorous occurs in small amounts in salt waters, and relatively greater amounts in fresh water. Phosphorous levels in the Bay were slightly elevated in the 1967 study, and during the warm weather and wet months during the 1988 testing period, particularly in shallow ponds fed by fresh water sources. [24]

2.3.4.5 Nutrients

Nutrients from the decomposition of organic matter provide a vital food source for plants and phytoplankton. In excessive quantities, nutrients cause excessive plant growth which depletes dissolved oxygen and blocks sun light needed for photosynthesis. Eutrophic ("nutrient rich") conditions, characterized by algae blooms and excessive plant growth, were observed in many areas of the Bay in 1986 but appeared to have receded by 1988.[25] The dramatic change in conditions is largely attributed to the increased flow of ocean water into the Bay from the breakthrough. However, a study of nutrients in Round Cove conducted well after the 1987 breakthrough indicated high nutrient levels due to groundwater inflows from nearby land uses, and restricted tidal flushing due to the enclosed nature of the Cove. This study suggests that, although the breakthrough has increased flushing, nutrient concentrations will continue to be a threat in enclosed areas.

The Cape Cod Commission has completed a nitrogen loading study for Pleasant Bay and its watershed. This study documents the current level of nitrogen loading to the Bay as a whole as well as by sub-embayments. The study also projects future nitrogen loading conditions when all potential land development within the watershed, based on current zoning, occurs, and as the configuration of the Chatham breakthrough changes.

[22] Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts.* The Friends of Pleasant Bay, Inc.. July, 1989.
[23] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967. Also, Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts.* The Friends of Pleasant Bay, Inc.. July, 1989.
[24] Fiske,et al, *A Study of the Marine Resources of Pleasant Bay*. Massachusetts Department of Natural Resources, Division of Marine Fisheries. May, 1967. Also, Wilhelm, Robert W., II. *Report on the Pleasant Bay Water Quality Study Cape Cod, Massachusetts.* The Friends of Pleasant Bay, Inc.. July, 1989.
[25] Specific locations of eutrophic conditions were not indicated in the 1988 study.

The nitrogen loading study has identified three sub-embayments with excess nitrogen loads coming from existing land uses within their sub-watersheds: Muddy Creek, Arey's Pond, and Round Cove. Two other sub-embayments (Pah Wah Pond and Ryder's Cove) are identified as having the potential to exceed their nitrogen loading limits once all land is developed in their watersheds.