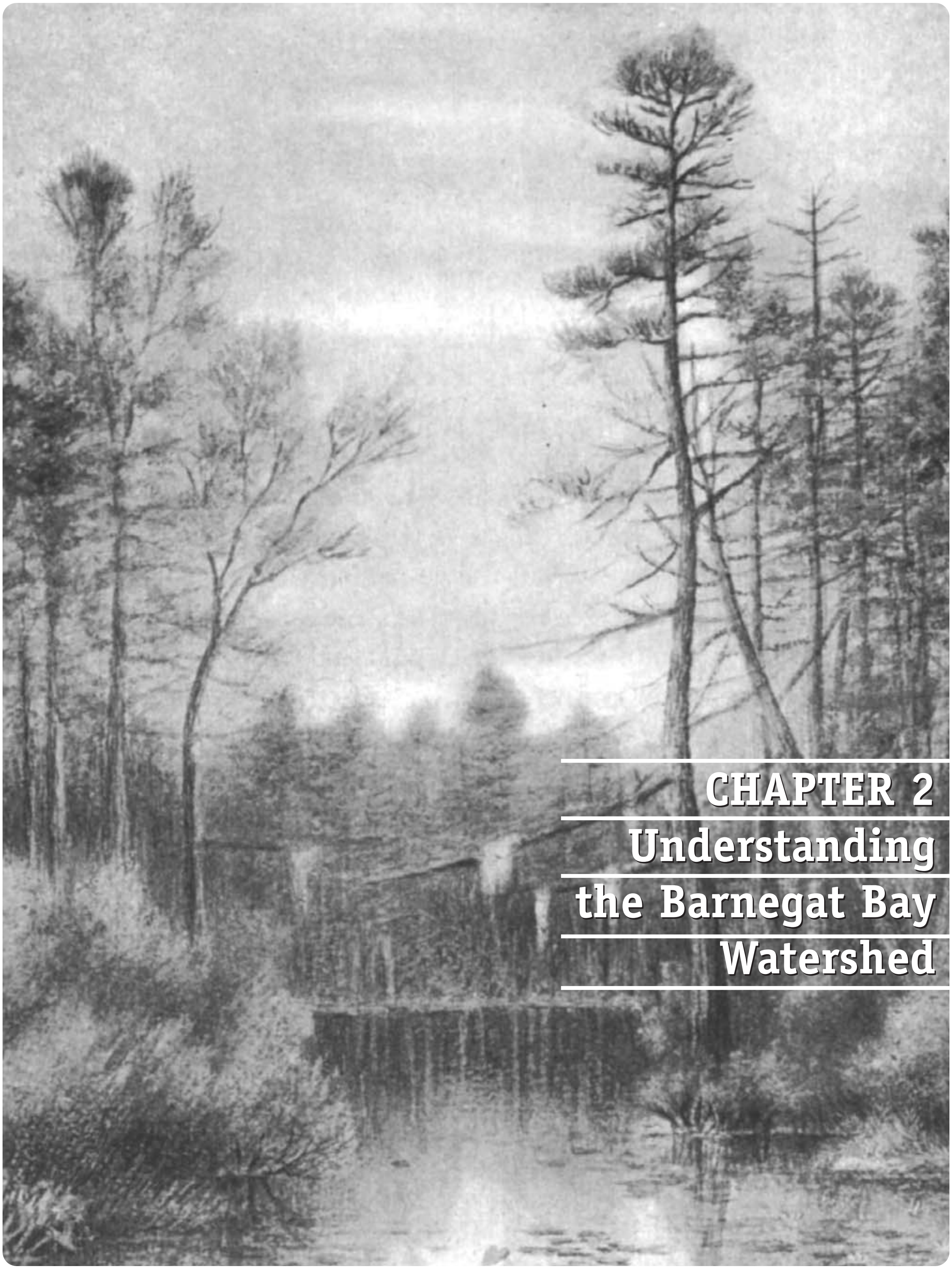
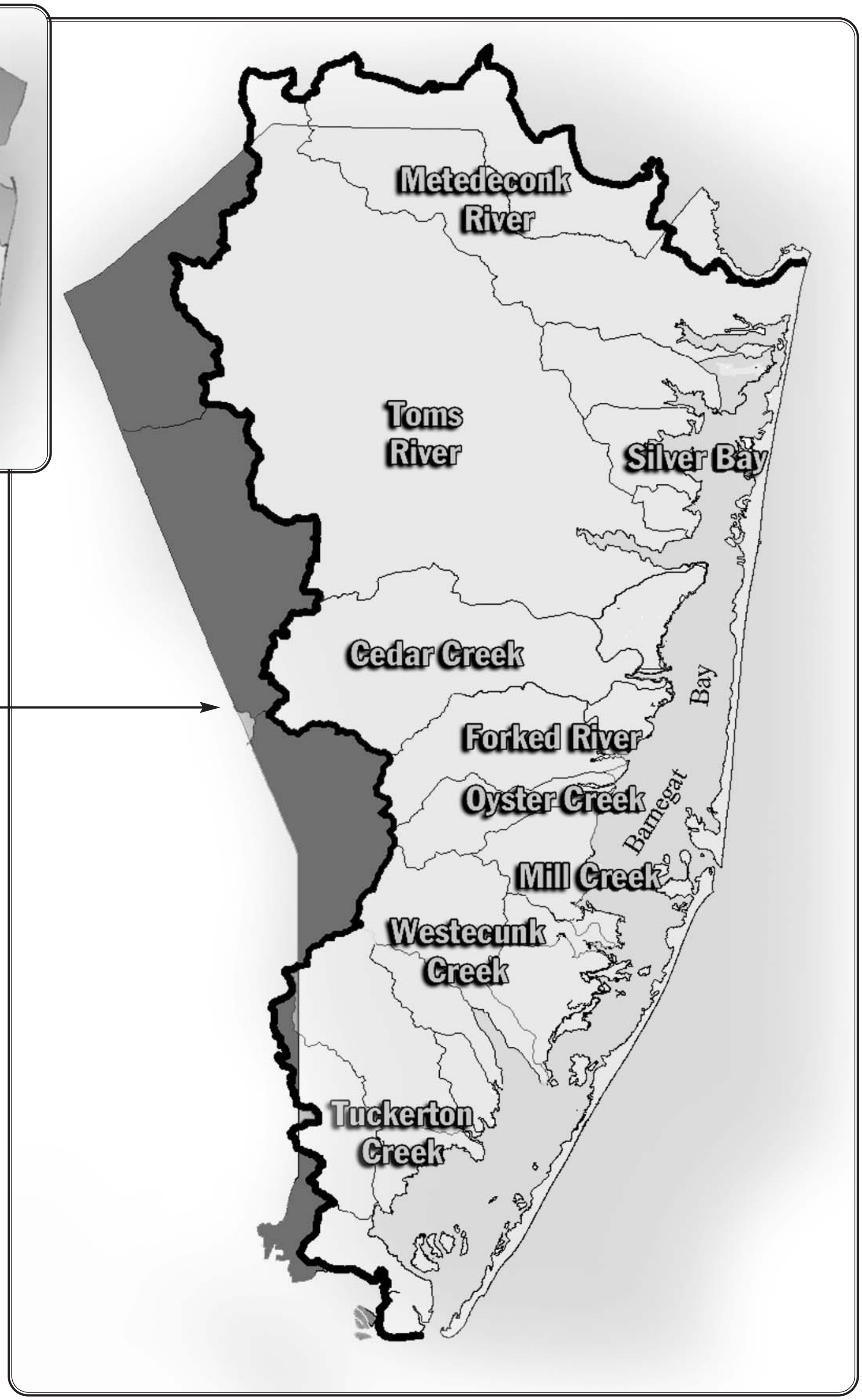


CHAPTER 2
Understanding the Barnegat Bay Watershed

Along the Metedeconk. *FROM THE LITHOGRAPH BY G.R. HARDENBERGH, 1909, COURTESY OF MR. & MRS. CURLES J. HULSE.*

The Barnegat Bay Watershed



2.1 THE ABUNDANCE OF BARNEGAT BAY

The Barnegat Bay Estuary is an ecological treasure. The bay's ecological productivity and broad appeal make this coastal area one of the most valuable "living" resources in the nation. An array of environmentally sensitive habitats exists here, such as sand beaches, bay islands, submerged aquatic vegetation (SAV), finfish nursery areas, shellfish beds, and waterfowl nesting grounds. Its biological resources are rich, and include migratory birds, threatened and endangered species, and commercially and recreationally important species of fish and shellfish.

A Scientific Characterization, describing existing technical data and other relevant information on the estuary and its watershed (Table 2-1), has been compiled by a diverse group of stakeholders and technical experts. This chapter is a summary of that work. More detailed information beyond this summary can be found in the BBNEP characterization document, which is available upon request.

2.2 HYDROLOGICAL RESOURCES

2.2.1 BARNEGAT BAY AND ESTUARY

The Barnegat Bay-Little Egg Harbor (referred to as "Barnegat Bay" for the remainder of this document) estuarine system is composed of three shallow, microtidal bays: Barnegat Bay, Manahawkin Bay, and Little Egg Harbor (see Figure 2-1).

A nearly continuous barrier island complex runs along the eastern edge of Barnegat Bay, separating it from the Atlantic Ocean. Seawater enters the Barnegat Bay system through the Point Pleasant Canal via the Manasquan Inlet in the north and Barnegat Inlet and Little Egg Inlet in the south. The U.S. Army Corps of Engineers (USACE) recently completed a large-scale reconfiguration of the Barnegat Inlet. The full impact of this project on the circulation and flushing patterns of the estuarine system are beginning to be examined.

The physical nature of the bay makes it vulnerable to degradation. The bay itself is very shallow, with a relatively small amount of freshwater flowing from tributaries and a limited connection to the ocean. These factors cause a slow flushing time and thus a long residence time for pollutants harmful to plant and aquatic life.

2.2.2 FRESHWATER RESOURCES

The freshwater supply in the region derives from four sources:

- Surface water flow;
- Groundwater from the unconfined Kirkwood-Cohansey aquifer system;
- Groundwater from deeper, confined aquifers; and
- Water transferred into the region from adjacent areas.

Freshwater inflow from surface water discharges and direct groundwater input affects salinity and circulation in the estuary. Hence, it is important to determine the relative magnitude of the various freshwater sources.

TABLE 2-1. The Barnegat Bay and Its Watershed

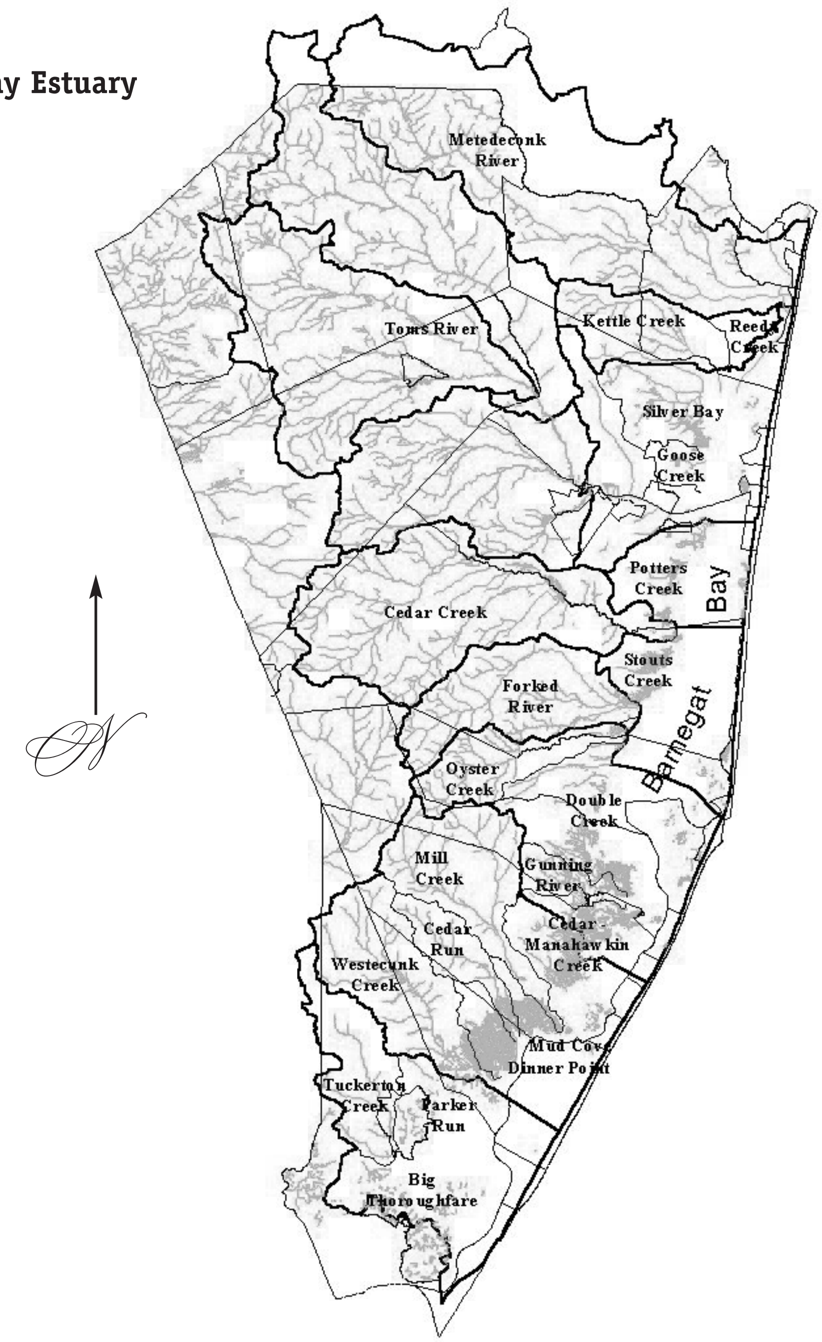
Length (North-South)	43 miles (70 kilometers)
Watershed Area	660 square miles (1,716 square kilometers)
Estuary Width	3 to 9 miles (2 to 6 kilometers)
Estuary Depth	3 to 23 feet (1 to 7 meters)

UNDERSTANDING THE BARNEGAT BAY WATERSHED

To this end, a hydrologic budget has been produced for the region that details the movement of fresh water through the system.

Most freshwater inflow to the estuary is groundwater that either discharges to streams that flow into the bay or that seeps directly into the bay. Stream surface water discharges (763 ft3/s, 22.9 m3/s) exceed direct groundwater seepage (103 ft3/s, 3.1 m3/s) and incident precipitation. Freshwater discharge into the estuary from both surface water and groundwater amounts to 7.5 x 107 ft3/d (2.25 x 106 m3/d). Maximum stream flows occur during the winter and spring.

**Figure 2-1.
The Barnegat Bay Estuary and Watershed.**



The principal sources of surface water flow to the system include the Metedeconk River, Kettle Creek, Toms River, Cedar Creek, Forked River, Mill Creek, West Creek, and Tuckerton Creek. In the northern section of the system, the Manasquan River connects with Barnegat Bay via the Point Pleasant Canal; however, there is not a substantial interchange of fresh and salt water between the bay and river. Portions of the Manasquan River watershed are also included in the study area.

Tributary water quality is altered most greatly in developed areas of the watershed where higher concentrations of nitrogen, phosphorus, sulfate, and other inorganic constituents have been observed. Elevated values of pH and specific conductance have also been observed in these areas. The instream concentrations of the inorganic constituents appear to be related to the intensity of development upstream of the surface water sampling sites. The constituent loads transported by tributary systems to the estuary depend primarily on the size of the drainage basin and the type of land cover existing there. Urban centers and heavily developed residential areas with considerable impervious cover contribute greater constituent loads than rural areas with vegetative cover.

2.3 BIOLOGICAL RESOURCES

Since Barnegat Bay exists in the zone where rivers and streams meet salt water, many plants and animals that are adapted to salt water, fresh water, and brackish water inhabit its ecosystem. This transitional zone, or area where two ecological zones meet, is biologically rich because species tolerant to these zones coexist and form unique ecological communities.

The shallow depth of Barnegat Bay creates an environment in which significant amounts of sunlight can reach submerged aquatic plants, producing thriving benthic (bottom) plant communities. Microscopic organisms, such as phytoplankton and zooplankton, form the basis of the estuarine food chain. Large, diverse populations of aquatic life, which depend on phytoplankton and submerged aquatic vegetation, flourish in the shallow salt marshes of the estuary.

Prominent species found in the system include winter flounder, white perch, inland silverside, northern pipefish, bluefish, weakfish, striped bass, blue crab, and hard shell clams.

Most major biological groups are represented, including approximately 180 species of phytoplankton (single-celled plants), nearly 100 species of benthic flora (algae and vascular plants), more than 200 species of benthic invertebrate fauna, and about 110 species of fish.

2.3.1 FISHERIES

Barnegat Bay and Little Egg Harbor sustain important local and regional fisheries. The estuary and the surrounding wetlands are important nursery areas for a variety of shellfish and finfish, many of which are commercially valuable and/or prized by recreational anglers. In addition, anadromous fish, which migrate from the ocean to freshwater streams to reproduce, use the bay during their migrations.

2.3.2 BIRDS AND WILDLIFE

The Barnegat Bay system is used by an abundance of wildlife. Colonial waterbirds, shorebirds, songbirds, waterfowl, and raptors use the bay and wetlands for a variety of purposes, including breeding, nesting, and foraging. The threatened diamondback terrapin (an estuarine turtle) uses the bays for all of its life stages.

Barnegat Bay serves as the breeding habitat for the gull-billed tern, common tern, least tern, great blue heron, herring gull, great egret, snowy egret, little blue heron, tricolored heron, black-crown night heron, glossy ibis, laughing gull, great black-backed gull, and black skimmer. However, the populations of some of these bird species are in decline. The bay also provides habitat for several endangered and threatened bird species, including the piping plover, least tern, and Ipswich sparrow.

Migratory birds of the Atlantic flyway utilize Island Beach State Park for feeding and resting on their migration. The bay is also an important wintering site for many species of waterfowl, including the Atlantic brant.

Up to 80 percent of the Atlantic brant along the Atlantic flyway winter in the bay.

2.3.3 WETLANDS

Wetland forests cover 25 percent of the total watershed. In the past, coastal wetlands were destroyed in order to open up areas for more shoreline development. However, since the passage of the Wetlands Act of 1970, tidal marsh disturbance for lagoon residential construction has virtually ceased.

In the Barnegat Bay watershed, salt marshes, freshwater marshes, and forested wetlands create natural buffers that minimize the impacts of coastal storms and wind on coastal and inland habitats. Coastal wetlands are able to withstand major storms without suffering lasting damage, while at the same time protecting inland communities. In addition, freshwater wetlands have the capacity to temporarily store large quantities of floodwaters, releasing waters over an extended period of time into groundwater and adjacent water bodies. The wetlands also effectively filter sediments and reduce erosion.

2.3.4 BARRIER ISLAND-COASTAL DUNE SCRUB/SHRUB COMPLEX

Island Beach and Long Beach Island form a nearly continuous barrier island complex that separates the estuary from the Atlantic Ocean. Barrier islands also adjoin the shallower portions of Little Egg Harbor. This system of coastal barriers minimizes the impacts of coastal storms and wind.

The dune scrub/shrub and woodland communities of the barrier islands, with the exception of the eight miles of Island Beach State Park, have been substantially altered and in many cases destroyed.

2.3.5 SUBMERGED AQUATIC VEGETATION

More than 70 percent of New Jersey's total SAV acreage is located in the Barnegat Bay Estuary, where approximately 32 percent of the benthic area has been mapped as potential SAV. Commonly known as eelgrass or seagrass beds, SAV serves several major functions in the estuary:

- It is an important primary producer, helping to oxygenate bay waters;
- Some animals, such as fish, ducks, and muskrats, graze on SAV; and
- SAV provides critical habitat for numerous organisms in the estuary.

There is some indication of the loss of SAV beds in the estuary in recent years, although differences in mapping methods make it difficult to unequivocally establish the occurrence of a major dieback and loss of eelgrass area. One study, which compared a number of SAV surveys, suggests that there has been loss of eelgrass in the deeper waters of the estuary resulting in the restriction of the beds to shallower subtidal flats, less than 6.5 feet (2 meters) deep. The loss appears to have been most severe in Barnegat Bay north of Toms River but is also evident in southern Little Egg Harbor. Because of the uncertainty regarding the conclusions of this analysis, however, more investigations of SAV distribution in the estuary are recommended.

2.3.6 UPLAND WATERSHED

Upland forests cover 37 percent of the Barnegat Bay watershed. A portion of this consists of critically important Pinelands habitats that are protected by regulations and local, state, and federal management programs. The Pinelands habitats support unique fish, amphibian, reptilian, mammalian, and avian populations. Largely unprotected tracts of interior contiguous pine/oak forests include the Forked River Mountains, Berkeley Triangle, Heritage Minerals tract, and Maple Root Branch/Long Brook tract in Jackson Township.

2.3.7 WILDLIFE HABITAT MAP

A list of animal and plant species of special emphasis has been developed for the Barnegat Bay estuarine system as a general indicator of biodiversity. Species that are either commercially or recreationally important, threatened or endangered, or otherwise ecologically significant, have been compiled and cross-referenced with their respective habitats. This list may be found in the publication, "Scientific Characterization of the Barnegat Bay-Little Egg Harbor Estuary and Watershed

Report" (September 2001) which can be found on the www.bbep.org website or a copy can be obtained on CD-ROM from the Barnegat Bay National Estuary Program Office.

2.4 ECONOMIC VALUE

2.4.1 TOURISM/RECREATION

The Barnegat Bay Estuary supports a thriving tourism industry, with thousands of people visiting Ocean County each year. In 1995, tourists expended $1.71 billion in Ocean County. At that time, roughly 45,000 tourist industry jobs were registered in the county, accounting for more than $631 million in annual payroll. A more detailed study by Longwoods International found that in 1998 tourists spent more than $1.67 billion in the county (Table 2-2).

Table 2-2. 1998 Tourism Input to the Ocean County Economy (Longwoods International, 1998).

Total Expenditure by Tourists	$1.67 billion
Restaurants	$520 million
Retail Sales	$501 million
Lodging	$274 million
Auto & Travel Expenses	$240 million
Recreational Expenses	$132 Million
Jobs Created	51,300
Annual Payroll	$726.5 million
State Taxes Generated	$220.3 million
Local Taxes Generated	$89 million

In 1991, recreational fishing in New Jersey generated approximately $1.3 billion in economic output and employed approximately 17,000 people. Ocean County makes up a significant percent of the statewide total.

Recreational activities such as fishing and boating lure many visitors to this portion of the New Jersey coast. Recreational boating, including motorboats, sailboats, yachts, canoes, kayaks, and personal watercraft, supports a total of 182 marinas situated within the watershed (Ocean County Planning Dept., 1999). Many more private slips are located in lagoon developments.

Both Little Egg Harbor and Barnegat Bay are important to the state's recreational fishing industry as actual fishing grounds and as important habitat for juvenile fish that may be caught in other areas of the state. Recreational fishing is a popular summer activity and helps to support many small businesses.

Between 40 and 50 percent of all commercial inshore hard clam landings in New Jersey occur in Ocean County waters.

2.4.2 COMMERCIAL FISHERIES/SEAFOOD

Barnegat Bay contributes valuable fishery resources to the Mid-Atlantic region. In 1994, the combined value of the Mid-Atlantic commercial finfish and shellfish landings totaled approximately $149 million. In that same year New Jersey's commercial finfish and shellfish landings totaled approximately 202 million pounds, valued at approximately $100 million. In 1997, Ocean County vessels landed more than 21 million pounds (961,000 kilograms) of finfish and nearly 20 million pounds (888,000 kilograms) of shellfish.

The most valuable commercially caught species in the area is the inshore hard clam. In some years revenues derived from hard clam represent as much as 80 percent of the total value of commercial fisheries in Ocean County. Another important shellfish species found in Barnegat Bay is the blue crab. Blue crab landings from this area comprise about 10 to 15 percent of the state's total blue crab landings.

2.5 LAND USE

2.5.1 POPULATION GROWTH

The Barnegat Bay watershed lies almost entirely in Ocean County, one of the most rapidly growing counties in the northeastern United States. Since 1950, Ocean County's population has increased by more than 775 percent.

Municipalities on the barrier islands may experience a 10-fold increase in population during the summer.

The watershed area's population is now approximately 500,000 (Table 2-3), a figure that more than doubles during the summer season. During the 1990s, year-round population in the municipalities surrounding the bay on average increased 20 percent.

The population is concentrated in the northeastern and central portions of the watershed, as well as along the barrier island system.

Table 2-3. U.S. Census Data for the Barnegat Bay Watershed.

Year	Watershed Population	Year	Watershed Population
1940	40,000	1980	346,000
1960	108,000	1990	433,000
1970	208,000	2000	>500,000 (estimated)

2.5.2 LAND-USE TRENDS

A strong gradient of decreasing human development and subsequent habitat loss and alteration is evident when proceeding from northern to southern sections of the watershed and estuary. There are four distinct land use areas:

- The northeastern mainland area, which is heavily developed with very little dedicated public open space;
- The barrier islands, which are heavily developed with the exception of Island Beach State Park;
- The less densely developed southeastern mainland area with protected environmentally sensitive areas such as the Forsythe National Wildlife Refuge and the State Manahawkin Fish and Wildlife Management Area; and
- The western side (upland) of the watershed, which has very low density development and is partially protected by the Pinelands Comprehensive Management Plan.

Residential development is the primary land use in the watershed (Table 2-4). As new people arrive to this area, they require housing, services, and roads. The area of the watershed under residential, commercial, industrial, or institutional development increased from 18 percent to 21 percent to 28 percent from 1972 to 1984 to 1995, respectively.

More than 70 percent of the Barnegat Bay estuarine shoreline buffer zone is developed or altered, leaving only 29 percent in natural land covers. Approximately 45 percent of the estuarine shoreline is bulkheaded.

Table 2-4. Land Use in the Watershed, 1994-1995.

Land Use	Percent of Watershed
Forested	45.9
Wetlands (tidal & freshwater)	25.2
Urban/Residential	19.5
Agricultural/Grasslands	6.6
Barren Lands	1.9
Water Bodies	0.9

2.6 PRIORITY PROBLEMS

The Barnegat Bay National Estuary Program CCMP was developed to identify and control priority problems in the watershed. The Barnegat Bay watershed is highly susceptible to environmental degradation. Historically, these waters have served as repositories for raw sewage, sewage effluent, toxins, and garbage. Estuarine wetlands and shorelines and inland areas have been destroyed or modified to accommodate development.

Water quality degradation has led to the loss of commercial and recreational fishing opportunities, closed shellfish harvesting waters and swimming areas, and contributed to oxygen-depleting algae blooms and subsequent fish kills. Suburban growth has contributed to the magnitude of coastal storm damage resulting from loss of wetlands and other natural lands. Misuse and abuse of Barnegat Bay and its watershed are threatening the viability of its ecologically and economically valuable resources.

The characterization study of the Barnegat Bay Estuary and its watershed indicate that the most significant threats to the watershed are:

- Water quality and water supply, including the issues of stormwater and nonpoint source pollution, nutrient loading, and pathogen contamination;
- Habitat loss and alteration;
- Human activities and competing uses; and
- Fisheries decline.

Population growth and accompanying development within the watershed contributed to each of these environmental problems.

There are several areas within the watershed that suffer from known water quality impairment. Table 2-5 lists water bodies that have, or are expected to have, the following violations:

- Exceedance of chemical/physical criteria (minus metals and ammonia);
- Exceedance of chemical/physical criteria obtained from the BBNEP (minus metals);
- Fish and shellfish consumption advisories;
- Shellfish harvesting restrictions; and
- Public lakes having undergone detailed assessments under the Clean Lakes Program.

Table 2-5. Water Bodies with Known Water Quality Impairment.

Water Body Name	Reach #/ Location	Pollution/Impact: Water Quality Violation	Pollutant/Impact: Biological	Use Impairment
Metedeconk River Estuary		Fecal coliform		Shellfish consumption
Lake Carasaljo	Lakewood, Ocean County		Mercury in fish tissue	Fish consumption
Pohatcong/ Tuckerton Lake	Ocean County	Elevated bacteria, phosphorous, sedimentation. Current source: nonpoint sources including suspended solids from surrounding urban areas, bacteria and phosphorus from surrounding septic systems.	Heavy macrophyte growth	Boating and fishing
Manahawkin Lake		Elevated bacteria, phosphorus. Current source: resident goose and gull population. Former source, surrounding septic systems, most have been eliminated through sewering.	Localized heavy macrophyte growth	Primary contact recreation, some boating and fishing impairment
Toms River Estuary	02040301-018-022	fecal coliform		Shellfish consumption
Toms River	02040301-018-080/ nr Toms River	pH, fecal coliform		Primary Contact, Aquatic Life Support
Barnegat Bay	Portion adjacent to Toms River	fecal coliform		Shellfish consumption

Table 2-6 lists water bodies in the Barnegat Bay Estuary that meet the following criteria:

- Moderately impaired AMNET sites;
- 304(l) listings;
- Metals and ammonia violations recorded through ambient monitoring;
- Heavy metal violations obtained through the Harbor Estuary Program; and
- Public lakes having undergone cursory assessments under the Clean Lakes Program.

Table 2-6. Water Bodies Where Use Impairment is Not Known, Confirmation Needed.

Water Body Name	Reach#/Location	Pollution/Impact: Water Quality Violation	Pollutant/Impact: Biological	Use Impairment
Metedeconk River N. Brook	Aldrich Rd., Howell Twp.		moderately impaired	Aquatic Life Support
Metedeconk River N. Brook	Rt. 9, Lakewood		moderately impaired	Aquatic Life Support
Haystack Brook	Southard Rd. Howell Twp.		moderately impaired	Aquatic Life Support
Metedeconk River N. Brook	Rt. 88, Lakewood		moderately impaired	Aquatic Life Support
Cabinfield Brook	Lanes Mill Rd., Lakewood		moderately impaired	Aquatic Life Support
Metedeconk R S Brook	Jackson Mills Rd., Jackson		moderately impaired	Aquatic Life Support
Metedeconk R S Brook	Cedar Bridge Rd., Lakewood		moderately impaired	Aquatic Life Support
Metedeconk R S Brook	Chambers Bridge Rd., Brick Twp.		moderately impaired	Aquatic Life Support
Beaver Dam Creek	Rt. 88, Brick Twp.		moderately impaired	Aquatic Life Support
Forked R N Brook	@ powerlines, Lacey Twp.		moderately impaired	Aquatic Life Support
Mill Creek	Rt. 72, Manahawkin		moderately impaired	Aquatic Life Support
Mill Brook	Nugentown Rd., Nugentown		moderately impaired	Aquatic Life Support
Toms River	02040301-018	arsenic, cadmium, chromium, copper, iron, lead, mercury, zinc		Aquatic Life Support
Toms River	02040301-017	zinc, iron		Aquatic Life Support
Toms River	02040301-014	arsenic, copper, lead, nickel		Aquatic Life Support
Toms River	Paint Island Rd., Millstone Twp.		moderately impaired	Aquatic Life Support
Toms River	Rt. 571, Holmson		moderately impaired	Aquatic Life Support

Table 2-6. (continued)

Water Body Name	Reach#/Location	Pollution/Impact: Water Quality Violation	Pollutant/Impact: Biological	Use Impairment
Maple Root Brook	Bowman Rd., Jackson Twp.		moderately impaired	Aquatic Life Support
Blacks Brook	Rt. 70, Lakehurst		moderately impaired	Aquatic Life Support
Union Brook	Colonial Dr., Manchester Twp.		moderately impaired	Aquatic Life Support
Sunken Brook	Mule Rd., Berkeley Twp.		moderately impaired	Aquatic Life Support
Jakes Brook	Dover Rd., Berkeley Twp.		moderately impaired	Aquatic Life Support
Jakes Brook	Double Trouble Rd., So. Toms River		moderately impaired	Aquatic Life Support
Toms River Tributary	Rt. 37, Dover Twp.		moderately impaired	Aquatic Life Support
Kettle Creek	New Hampshire Ave., Lakewood Twp.		moderately impaired	Aquatic Life Support
Kettle Creek	Moore Rd. Brick Twp.		moderately impaired	Aquatic Life Support
Cedar Creek	Double Trouble South. Park, Lacey Twp		moderately impaired	Aquatic Life Support
Webbs Mill Brook	Rt. 539, Lacey Twp.		moderately impaired	Aquatic Life Support

2.6.1 KIRKWOOD–COHANSEY AQUIFER

Groundwater from the unconfined Kirkwood–Cohansey aquifer system is critical to surface water quality in the watershed. It is regarded as the largest source of fresh water for the estuary because most of the flow in local streams consists of base flow, which is discharge entering stream channels from groundwater. For example, 63 to 73 percent of the total stream flow in the Metedeconk River between 1973 and 1989 was calculated as base flow. Similarly, 80 to 89 percent of the total stream flow in the Toms River between 1929 and 1989 was calculated as base flow. Virtually all of the flow in streams during periods of little or no rainfall consists of base flow. The ratio of surface runoff to base flow increases during periods of precipitation.

Because of the significant volume of groundwater inputs to tributary systems, the quality of groundwater in the Kirkwood–Cohansey aquifer is critical to the quality of freshwater inflow to the estuary.

Groundwater in this aquifer system is generally acidic with low ionic strength and alkalinity. Its pH ranges from 4.4 to 6.7, and the total dissolved solids concentration is less than 100 mg/l. Nitrogen and phosphorus levels are generally low.

2.6.2 WATER QUALITY: STORMWATER/NONPOINT SOURCE POLLUTION

PROBLEM

Development in the watershed increases the probability of water quality degradation in bay tributaries. Nutrients and chemical contaminants enter these influent systems from point source discharges and nonpoint sources, such as stormwater runoff, groundwater influx, and atmospheric deposition. Nonpoint sources can extend throughout the watershed, and can include pollutants originating from agricultural, residential, and commercial properties, and rights-of-ways (e.g., highway and railway borders).

UNDERSTANDING THE BARNEGAT BAY WATERSHED

POTENTIAL CAUSES

To support the rapidly growing population in the region, Ocean County in particular, land use within the watershed has become increasingly more developed and urbanized. As a result of this development, wetlands, forests, and other natural areas have been replaced with impervious surfaces, such as roofs and pavement. The increase in impervious surface area affects the water quality of Barnegat Bay and its tributaries. Without natural land to absorb excess rain and to filter contaminants, greater concentrations of contaminants in more significant flows reach the estuary.

stormwater and other forms of runoff, particularly from older developments and municipal streets where no detention is required, contribute to water quality problems in the following ways:

- Impervious surfaces as a result of development lead to an increase in runoff and sedimentation;
- Groundwater transports pollutants to Barnegat Bay and tributaries;
- Marina activities contribute oil and grease;
- Gas stations/auto repair shops contribute petroleum products and other automotive contaminants;
- Spills and illegal discharges of acute and persistent toxicants;
- Household and agricultural waste contribute bacteria and nutrients;
- Agriculture contributes bacteria and nutrients.

IMPACTS

- Impaired water quality and water clarity;
- Impaired habitat;
- Loss of drinking water supply;
- Adverse impacts to waters supporting water recreation, including beach and shellfish closures;
- Toxic contaminants can accumulate in tissue of fish and shellfish, rendering them unsafe to eat.

TRENDS AND STUDY RESULTS

Due to the land-use patterns of the bay system, polluted runoff is a greater concern in the northern portion of the system. There is a significant need for a Natural Resources Inventory (NRI) to provide a more detailed analysis regarding the impact human land-based activities has on the water quality of the estuary.

Essentially, the NRI is a statistical, intensive watershed-based survey which has been designed and implemented to assess conditions and trends of soil, water and related natural resources. The NRI is conducted by the Natural Resource Conservation Service (NRCS), in cooperation with the Iowa State University and the local soil conservation district. It is important to note that it acts to enhance local understanding of natural resources and their conditions. (This could be significant to connect residents on the land to the bay.) Data are collected at the field level by technical personnel who have been trained in soil and water conservation.

Toxic chemical contaminants may be locally important in the Barnegat Bay Estuary (e.g., near marinas). Comprehensive monitoring of shallow groundwater in the watershed reveals widely scattered occurrences of volatile organic compounds, mercury, and radium isotopes. When found, these contaminants generally exhibit low concentrations. However, there are some areas where the levels of these contaminants in groundwater exceed the maximum permissible levels for public drinking water. The number of volatile organic compounds and the concentration of methyl tert butyl ether (MTBE) in streams tend to increase with residential and industrial land use.

The most extensive database on chemical contaminants in the estuary exists on trace metals and radionuclides. Other toxic chemical contaminants (e.g., halogenated hydrocarbons and polycyclic aromatic hydrocarbons) are not sufficiently characterized. Because of their potential carcinogenic, mutagenic, or teratogenic effects on estuarine organisms, additional study of these contaminants is warranted.

2.6.3 WATER QUALITY: NUTRIENT LOADING

PROBLEM

Nutrient loading, primarily nitrogen and phosphorus, is one of the primary problems confronting the nation's estuaries. Excessive levels of these nutrients stimulate the growth of algae in Barnegat Bay. As the algae grow, they block sunlight needed by the submerged aquatic vegetation of the bay; when the algae die and decay, they reduce the level of oxygen in the water, which can result in large fish kills. Some species of algae are toxic to aquatic organisms and humans.

POTENTIAL CAUSES

Excess inputs of nutrient constituents, nitrogen and phosphorus can be caused by the following:

- Urban runoff;
- Leaking or failing septic systems;
- Animal waste;
- Fertilizer use (household landscaping and agriculture).

IMPACTS

Excess nutrient inputs can result in widespread negative ecological and health effects:

- Reduced oxygen can kill fish and make the water unsuitable as nursery habitat;
- Impaired habitat in creeks for fish and possibly wildlife;
- Reduced light levels result in loss of submerged aquatic vegetation (eelgrass);
- High nutrient levels can make water unsafe to drink;
- Atmospheric deposition;
- Boater discharges.

TRENDS AND STUDY RESULTS

Nutrient inputs to the Barnegat Bay Estuary originate essentially from nonpoint sources, mainly stream and river discharges, atmospheric deposition, and groundwater influx. Table 2-7 lists some of the nutrient inputs to the Barnegat Bay Estuary. The estimated total nitrogen load to the system amounts to ~1.74 x 106 lb/yr (7.9 x 105 kg/yr). This value is considered to be an underestimate because it does not account for:

- Nitrogen in storm runoff that discharges directly to the estuary;
- Nitrogen released from bottom sediments of the estuary; and
- Nitrogen in ocean water entering the system on flood tides.

Total nitrogen concentrations in the estuary range from 20 to 80 µM. Organic nitrogen is the dominant form of nitrogen in the bay, with a concentration approximately 10 times greater than the concentration of dissolved inorganic nitrogen. Highest concentrations of organic nitrogen (approximately 40 µM) have been reported during the summer.

Sampling between 1989 and 1996 indicates that mean seasonal ammonium and nitrate levels amount to 2.5 µM and less than 4 µM, respectively. While the highest concentrations of ammonium occur in the summer, nitrate levels peak during the winter. Dissolved inorganic nitrogen levels are higher in the northern part of the estuary due to greater nitrogen loading to the rivers in this region. Phosphate concentrations, in contrast, do not exhibit any obvious spatial patterns.

Mean annual phosphate concentrations are less than 1 µM; highest phosphate levels arise during the summer, a seasonal pattern typical of other Mid-Atlantic estuaries.

Fertilizers used on domestic lawns are considered to be major contributors to Barnegat Bay's high nitrogen levels. Highest phytoplankton biomass values occur in the northern estuary during the summer months in response to greater nutrient inputs from more developed areas of the watershed. During the late spring and summer period in recent years, the southern estuary has been the site of intense blooms of phytoplankton. For example, large blooms of Aureococcus anophagefferens, a species of brown algae, were documented in Little Egg Harbor during 1995, 1997, and 1999. The NJ Department of Environmental Protection (NJDEP) found biologically stressed conditions (dissolved oxygen concentrations less than 5.0 mg/l) at five stations in the central part of the estuary between

Table 2-7. Nutrient Inputs to the Barnegat Bay Estuary

Nutrient Input	Predominant Form	Source	Contribution	Percent Total	Notes
Nitrogen	Nitrate	Surface Water Discharge	8.7×10^5 lb/yr (3.9×10^5 kg/yr)	50	• Much is derived from base flow • Highest total nitrogen loads from Wrangle Brook, Toms River, Mill Creek Basins • Lowest total nitrogen loads from Long Swamp Creek Basis
Nitrogen		Direct Atmospheric Deposition	6.7×10^5 lb/yr (3.0×10^5 kg/yr)	39	• Originates principally from nitrous oxide emissions from fossil fuel combustion
Nitrogen	Nitrate, Nitrite	Direct Groundwater Discharges	2.0×10^5 lb/yr (9.1×10^4 kg/yr)	11	• Concentration of nitrogen species in shallow ground-water exceed 10 mg/l in some areas of watershed • Median concentrations of nitrogen species are less than 0.2 mg/l • Total concentration of nitrogen in shallow groundwater appears to represent a potentially significant reservoir of this nutrient to the estuary
Nitrogen	Total Nitrate Plus Nitrite Load	Surface Water Discharges	3.6×10^5 lb/yr (1.6×10^4 kg/yr)	NA	• Highest in watershed areas characterized by moderate to high urban land cover • Highest yields in Wrangle Brook and Toms River Basins • Much smaller yields from less-impacted Westecunk and Cedar Creek Basins
Nitrogen	Ammonia	Surface Water Discharges	1.1×10^5 lb/yr (5.0×10^4 kg/yr)	NA	• Median Value, 0.05 mg/l • Highest yields from Mill Creek, Toms River, Oyster Creek Basins • Lowest yield from Wrangle Brook Basin
Nitrogen	Total Ammonia Plus Organic Nitrogen	Surface Water Discharges	4.6×10^5 lb/yr (2.1×10^4 kg/yr)	NA	• Storm water appears to be important source of total ammonia plus organic nitrogen • Highest yield from Mill Creek, Oyster Creek, Toms River Basins • Lowest yield from Long Swamp Creek Basin
Phosphorus		Surface Water Discharges	2.3×10^5 lb/yr (1.0×10^4 kg/yr)	NA	• Highest yield from Toms River, Wrangle Brook, Oyster Creek Basins • Lowest yield from Jakes Branch Basin

Toms River and Dipper Point during the 1990s.
High phytoplankton biomass and production during the warmer months of the year contribute to elevated turbidity readings. Phytoplankton, together with suspended sediments, detritus and colored dissolved organic molecules, reduce water clarity and limit light penetration in the water column. This shading effect is detrimental to benthic flora. For example, benthic algal production is reduced by high summer turbidity, and SAV distribution may be restricted by this effect as well, especially in the northern estuary. One way to measure turbidity is with a secchi disk. A secchi disk model formulated for the Barnegat Bay system strongly suggests that light penetration is a major factor controlling the distribution of seagrasses, which appears to be more restricted today than during the past several decades.

2.6.4 WATER QUALITY: PATHOGENS

PROBLEM

Disease-causing microorganisms called pathogens are found in human and animal wastes. Pathogens in coastal waters pose health risks to humans who eat contaminated shellfish or who recreate in beach waters. Gastroenteritis, hepatitis, and other diseases can result from ingestion of pathogen-contaminated seafood or water.

Fecal coliform and total coliform are indicators of pathogens. For this reason, beaches and shellfish beds are closed or restricted when standards for fecal coliform bacteria or total coliform are exceeded. New Jersey has an extensive recreational beach-monitoring program that includes mandatory closure requirements when water quality standards for swimmer safety are exceeded. Though Barnegat Bay no longer has any major point sources of coliform pollution, nonpoint source runoff during wet weather can cause some beaches along the Barnegat Bay shore to close for short periods of time.

POTENTIAL CAUSES

The causes of pathogenic contamination are largely of human or human-related origins:

- Urban and stormwater runoff;
- Faulty septic systems;
- Domestic animal wastes;
- Overboard discharges from boats;
- Waterfowl;
- Agricultural runoff.

IMPACTS

Human health can be significantly affected by pathogenic contamination:

- Gastroenteritis, hepatitis, and other diseases can result from ingestion of pathogen-contaminated seafood or water;
- Closure of shellfish areas with its attendant loss of commercial and recreational activity;
- Closure of recreational beaches.

TRENDS AND STUDY RESULTS

Highest concentrations of fecal coliform bacteria in the Barnegat Bay Estuary are recorded under rain conditions. From 1988 to 1998, 834 beach closings were registered in the estuary as a result of elevated fecal coliform counts in water samples, with the highest numbers reported in 1989 (175), 1990 (186), and 1994 (127). Beachwood Beach in Beachwood, Windward in Brick, and Money Island in Dover had the greatest frequency of beach closings.

In general, areas north of Barnegat Inlet exhibited the most degraded water quality conditions based on beach closings data (e.g., Lavellette, Seaside Heights, Seaside Park, Island Beach, Brick, Point Pleasant, Dover, Island Heights, Beachwood, Pine Beach, and Ocean Gate). However, water quality has improved in these areas in recent years. Since 1995, for example, there have been fewer than 50 beach closings reported each year throughout the estuary.

With regard to shellfish harvesting, the general trend in the estuary has been toward less restrictive shellfish growing classifications. For example, more than 5,000 acres of shellfish waters were upgraded by the State in Barnegat Bay in 2000 alone.

However, local areas of water quality degradation persist. The largest areas of shellfish harvesting restriction are found in Barnegat Bay tributaries from Toms River northward as well as in backbay locations along Island Beach. Shellfish harvesting is also prohibited from marinas and manmade lagoons.

The most dramatic improvement in water quality of the estuary occurred during the 1970s when the Ocean County Utilities Authority commenced operation of a state-of-the-art wastewater treatment system. Prior to operation of this system, wastewaters were discharged to the estuary and fecal coliform levels were elevated. Pipeline outfalls now discharge wastewaters one mile (1.6 kilometers) offshore in the Atlantic Ocean, thus bypassing the estuary.

2.6.5 WATER SUPPLY

PROBLEM

The increase of impervious surfaces resulting from development within the watershed results in a reduction in the amount of water that would otherwise recharge the groundwater that serves as drinking water supply and sustains stream base flow. Excessive water withdrawals from area aquifers are also a concern because they can cause saltwater intrusion problems and reductions in stream flow.

POTENTIAL CAUSES

Problems with available water supply can be caused by the following:

- Development within the watershed, increasing contaminant loads in the groundwater and reducing recharge;
- Excessive water withdrawals.

IMPACTS

The impacts of a degraded water supply include the following:

- Decreased drinking water supply;
- Decreased supply of water for irrigation/agricultural purposes;
- Degraded flow regimes in freshwater tributaries;
- Disturbance to salinity gradients in the bay that sustain estuarine biota.

TRENDS AND STUDY RESULTS

In 1990, estimated average groundwater withdrawals from private wells for residential use totaled 8.2 x 106 gal/d (3.16 x 107 l/d), and average groundwater withdrawals from wells for public supply, as well as for commercial, industrial, and irrigation uses, totaled 4.4 x 107 gal/d (1.71 x 108 l/d). Groundwater supplies have been lost in some areas of the watershed due to saltwater intrusion and streamflow reduction related to excessive withdrawal of well water. The regional threat of saltwater intrusion has led to state mandated reductions on withdrawals from affected aquifers. In an extreme case, drought conditions during the summer of 1999 culminated in statewide restrictions on nonessential groundwater use.

There are two areas in the region where saltwater intrusion has affected wells drawing water from the Kirkwood-Cohansey aquifer system. Salt water has adversely affected public-supply wells in Seaside Heights and Point Pleasant Beach. There are numerous other public and private wells that are located near brackish water along the coast.

Although saltwater intrusion into the major confined aquifers is not known to be a problem for supply wells in the Ocean County area, there are wells in several areas that are potentially threatened by saltwater intrusion. These areas include:

- Long Beach Island (Atlantic City 800-ft. sand aquifer);
- Barnegat Light, Seaside Heights, and Seaside Park (Piney Point aquifer);
- Point Pleasant, Lavalette (Englishtown aquifer system);
- Point Pleasant, Chadwick and Lavalette (upper aquifer of the Potomac-Raritan-Magothy aquifer system); and
- Lavallette, Toms River, and other locations in Northern Ocean County (middle aquifer of the Potomac-Raritan-Magothy aquifer system).

2.6.6 HABITAT LOSS AND ALTERATION

PROBLEM

Human activities–both in watershed areas and on open bay waters –have impacted habitats and living resources of the system. Habitat fragmentation and human disturbance in the watershed adversely affect many plant and animal species. The construction of residential, commercial, and industrial structures, as well as the building of roadways not only destroy natural habitat in the watershed but also can create pollution problems in receiving waters. These impervious surfaces facilitate surface runoff, which promote the transport of pollutants (e.g., fertilizers, herbicides, pesticides, oil, metals, etc.) to waterways.

POTENTIAL CAUSES

The causes of habitat loss and alteration include various human development activities:

- Dredging operations in marinas and the Intracoastal Waterway;
- Development of coastal wetlands, barrier islands, and other natural areas in the watershed;
- Bulkheading, diking, or other modifications to wetlands;
- Construction of buildings and roadways.

IMPACTS

The impacts of habitat degradation include the following:

- Increased coastal storm damage and flooding due to loss of wetlands;
- Adverse impacts on endangered or threatened species populations;
- Loss of SAV and other aquatic nursery habitats;
- Loss and fragmentation of upland and coastal habitat adversely affects fish and wildlife resources;
- Loss of coastal beaches.

TRENDS AND STUDY RESULTS

Where development is most extensive, in the northern mainland watershed area and on the barrier island complex, nonpoint source pollution can degrade water quality and the health of living resources in the estuary. New residential construction is subject to peak rate runoff reductions that were designed to control nonpoint source pollution. There are laws that mandate control of stormwater runoff from commercial and other development.

Along the estuarine perimeter, marsh filling and bulkheading, diking and ditching, and dredging and lagoon construction have disrupted salt marsh and shallow water habitats and altered biotic communities. The use of personal watercraft (PWC) and boats has also disturbed some parts of the estuarine shoreline. Increased nutrient inputs and human activities such as dredging and boating, have affected eelgrass in the estuary. These two activities alone have physically altered the habitat and have reduced the sunlight penetration needed to sustain submerged aquatic life.

A strong gradient of decreasing human development and subsequent habitat loss and alteration is evident when proceeding from the northern to southern sections of the watershed and estuary. Development in the watershed has resulted in the following habitat losses:

- 33,916 acres (13,731 hectares) or 20 percent of upland forest between 1972 and 1995;
- 4,631 acres (1,875 hectares) or 6 percent of fresh water wetlands during the same period; and about 33 percent of tidal wetlands, or upwards of 10,000 acres, during the past 100 years.

As of 1988, freshwater wetlands were jointly regulated by the USACE and the NJDEP. In March 1994, New Jersey assumed jurisdiction of the federal 404 program of the Clean Water Act. Between March 2, 1994 and June 30, 1998, 510 acres (207 hectares) of freshwater wetlands were impacted by statewide development activities and granted Statewide General Permits under the permit program of the NJDEP Freshwater Wetlands Protection Act Rules. The filling of isolated wetlands totaled 173 acres (70.1 hectares) during that same time period, and minor road crossings totaled 65 acres (26 hectares) (NJDEP, 1999). Between 1990 and 1998, filling of wetlands for development declined, leaving a total of approximately 300,000 acres (121,500 hectares) of freshwater wetlands that remain in the state (New Jersey Future, 1999).

Apart from dredging and infilling, mosquito control measures (parallel grid ditching) have significantly altered salt marsh habitat. Approximately 14,548 acres (5,890 hectares) of Barnegat Bay salt marshes have been ditched to reduce mosquito-breeding habitat. This represents about two-thirds of the existing tidal salt marsh area. However, parallel grid ditching is no longer a desirable management technique of mosquito control in this system and is being replaced by alternative open marsh water management techniques.

More than 70 percent (10,433 acres, 4,224 hectares) of the Barnegat Bay estuarine shoreline buffer zone is developed/altered, leaving only 29 percent (4,283 acres, 1,734 hectares) in natural land covers. Approximately 45 percent of the estuarine shoreline is now bulkheaded (36 percent when tidal creeks are included). Bulkheading eliminates shoreline beach habitat important for shorebirds and terrapin turtles. It also deepens adjacent nearshore estuarine waters.

2.6.7 HUMAN ACTIVITIES AND COMPETING USES

PROBLEM

Rapid population growth within the Barnegat Bay watershed during the 20th century has led to intense competition for resource use. The areas of conflict can be placed in three general categories: land-use activities; competition between recreational and commercial fisheries; and conflicts between boats and PWC.

LAND-USE ACTIVITIES

POTENTIAL CAUSES

The causes of conflicting uses are activities that place a high demand on limited space:

- Real estate development (residential, industrial, commercial);
- Tourism.

IMPACTS

- Habitat loss and alteration, i.e., bulkheads, sea walls, docks, dredging, suburban development, resulting in reduced carrying capacity for the bay's biological resources;
- Restricted shore access for public.

TRENDS AND STUDY RESULTS

Growth and development in the watershed raise several important issues. Accelerated population growth during the last half of the 20th century has led to changes in land use for homes and businesses. Since the most populated areas are located in the north-central portion of the county, in Dover, Brick, Lakewood, Manchester, Jackson and Berkeley Townships (Ocean County Planning Board, 1998), these areas have experienced the most commonly recognized effects of land-use changes.

There has been a dramatic rise in the amount of impervious surfaces in the northern part of the watershed. Current development practices may be severely compacting the soil underlying new residential developments, thereby restricting soil permeability and groundwater recharge capabilities. Soil erosion, sedimentation, and compaction also accelerate nonpoint source problems throughout the watershed. Impervious surfaces that do not drain into detention basins are of particular concern. Beyond soil compaction, direct riparian construction is a cause for concern. The dredging of navigation channels also has an adverse impact on the bay.

Tourism has been a focus of business development over the past 10 years. The coastal waters of Barnegat Bay are the final destination for many visitors. Losing access to the water due to lack of public access has presented problems.

These are among the most common impacts created by modern land-use changes in the watershed. Some of the categories mentioned are controlled by state environmental regulations (e.g., wetland impacts, soil erosion, and sediment control), whereas others are not. The dredging and filling of wetlands in tidal waters are also regulated by federal agencies. Some of the causes of pollution listed above are not being addressed because of the lack of clean-up funds or reduced enforcement budgets. A number of these impacts can be attenuated by more effective planning and development, but some problems may have no immediate solution and will require an intense public outreach effort aimed at education and personal behavioral modification.

FISHERIES CONFLICTS

POTENTIAL CAUSES

- Resource decline;
- Lack of natural stock restoration;
- Commercial and recreational overharvesting of fish and shellfish.

IMPACTS

- Distrust between/among user groups;
- Economic losses.

TRENDS AND STUDY RESULTS

There are few written sources of information on the problems or conflicts between commercial fishermen and recreational anglers in the Barnegat Bay Estuary. According to the NJDEP, conflicts between commercial and recreational clammers in the estuary are so minor that they are not perceived to be an issue requiring regulatory action. Clamming conflicts are related to the minimal stocks in the estuary (Flimlin, 1999).

In recent years, the blue crab fishery has become a limited entry system. There are currently only 312 commercial crabbing licenses for the State of New Jersey, and each license holder in the Barnegat Bay Estuary is limited to no more than 400 crab pots for each license (Halgren, 1999). Since the crabs are a limited resource, there have been complaints to the NJDEP from recreational crabbers, who feel that the commercial crabbers take an unfair proportion of available crabs, and that there are not enough crabs left in the bay for them. That perception has caused recreational crabbers to blame commercial crabbers for a perceived lack of crabs. However, placing blame on the commercial crabbers may not be justified. Local baymen with personal knowledge of the bay have stated that the location chosen for crabbing has more to do with the size of the catch than the number of crabs taken by commercial crabbers (Hook, 1999).

BOATS AND PERSONAL WATERCRAFT

POTENTIAL CAUSES

- High-intensity vs. low-intensity recreational pursuits;
- Lack of boater education.

IMPACTS

- Destruction of seagrass beds;
- Shoreline erosion;
- Destruction of fish larval habitat;
- Disruption of colonial nesting birds, nest abandonment;
- Distress to waterfowl (reproductive problems, behavioral changes);
- Habitat loss/increased water turbidity;
- Disturbance to other recreational water users;
- Interference with fishermen.

TRENDS AND STUDY RESULTS

Recreational boating has experienced tremendous growth within the last decade. Many marinas are located on both the east and west sides of Barnegat Bay and Little Egg Harbor, and along the major inland tributaries. The tidal portions of the Manasquan River also provide boating facilities that are connected to Barnegat Bay by the Point Pleasant Canal.

Conflicts exist between recreational clammers and boaters when boats speed past people treading for clams. The boaters are not sensitive to the safety issues of overboard treaders in the congested bay. Recreational clammers have complained that the boat traffic is so intense around Swan Point that they cannot work the clam beds (Flimlin, 1999). Commercial clammers complain about the improper use of personal watercraft and inconsiderate boaters (Hook, 1999).

Weekend boaters will attest to the crowded conditions that can be found in many areas of Barnegat Bay; however, actual use patterns by time and location have not been quantified.

According to the NJDEP, Bureau of Shellfisheries, boaters complain that commercial crab pots interfere with boat navigation in shallow bay areas (Joseph, 1999). Boaters complain that they cannot navigate in areas where there are many crab pots (Bochenek, 1999).

PWC are classified as boats in New Jersey, but there are several major differences between boats and personal watercraft, the major one being the depth of water in which the PWC can operate. The PWC can maneuver in shallow waters that often contain SAV. These are also important habitats for fish and wildlife.

Although no studies have been performed to assess PWC impact on the larvae in Barnegat Bay, the U.S. Fish and Wildlife Service (USFWS) estimates that approximately two-thirds of commercial and recreational species of fish and shellfish rely on estuarine marshes for spawning and as nursery habitat (Chin, 1998). SAV beds have also been designated as a habitat area of particular concern for summer flounder by the Mid-Atlantic Fisheries Management Council.

Crabbers, anglers, public officials, and members of the public have expressed concerns about the use of PWCs on Barnegat Bay (Burger, et al., 1996; Barnegat Bay Watershed Association, 1998). Given the popularity of this type of watercraft, more research is needed to identify all the specific problems with their use in the Barnegat Bay area. Conflicts between PWC users, the public, and other boaters will continue to exist until environmental restrictions are developed to protect the estuarine resources.

2.6.8 FISHERIES DECLINE

PROBLEM

Historical accounts of fishing in the Barnegat Bay Estuary are replete with descriptions of the vast amounts of fish available to recreational and commercial fishermen. Based on these descriptions, it is almost inconceivable to think that such vast numbers of fish could be depleted and that human use could outstrip the resource's ability to replenish itself. Human exploitation and habitat loss, however, are affecting the abundance of fish and impacting the commercial fishing industry, as well as the recreational angler.

POTENTIAL CAUSES

- Increased and unsustainable fishing effort;
- Excess bycatch;
- Habitat loss/lowered carrying capacity;
- Impaired water quality.

IMPACTS

- Fisheries conflicts;
- Economic losses to commercial and recreational interests.

TRENDS AND STUDY RESULTS

Fishery resource quality is highly dependent on water quality, which can affect the health and bioaccumulation of toxins in fish and shellfish and in organisms that serve as food sources for important fishery species. Other than the condemnation of shellfish beds, there is little information available to determine the effect that water quality has had on fishery resources or the organisms on which they feed.

With regard to fishery resource quantity, there is no information available on the size or sustainable yield of Barnegat Bay populations. Nor is there information on the total harvest of fishery resources from the bay.

The Mid-Atlantic Fishery Management Council, created under the Magnuson-Stevens Act, has a Scientific and Statistical Committee and Advisory Panel to provide expertise for development of Fishery Management Plans

(FMPs). A number of FMPs have been developed for species in the Barnegat Bay-Little Egg Harbor region. These plans can require size limits, bag limits, quotas, limits on the number of vessels, restriction on net mesh size, closed areas and seasons, or any other measure to control fishing activity. They can affect both commercial and recreational fishermen.

Contemporary clam stocks are much lower than the level of historical resource stocks. There is an effort on the recreational side to have Sunday clamming approved in New Jersey, but the restriction on Sunday clamming may never be lifted due to the limited resources available and the fear by regulators that lifting the limit would further deplete the clam stocks.

The blue crab (*Callinectes sapidus*) commercial crabbing industry is a "limited entry fishery," with the goal to reduce the number of crab pot fishermen over time. There are currently 312 commercial crabbing licenses for the State of New Jersey, and each license holder in the Barnegat Bay Estuary is limited to no more than 400 crab pots for each license (Halgren, 1999).

A more detailed scientific and technical description of the Barnegat Bay Watershed can be found in the report, "The Scientific Characterization of the Barnegat Bay-Little Egg Harbor Estuary and Watershed" (2001).

Hard Clams in Barnegat Bay sneakboxes and harvested in Barnegat, February 20, 1930. PHOTO COURTESY OCEAN COUNTY HISTORICAL SOCIETY

Give a man a fish and he will eat for a day.
Teach a man to fish and he will eat for the rest of his life.

-- *Chinese proverb*