Division of Science, Research and Technology

Research Project Summary

NJDEP

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Hydrographic Study of Barnegat Bay

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Abstract

The Barnegat Bay in Ocean County, New Jersey, is an important ecosystem for natural resource species and recreational uses. Similar to other coastal ecosystems, the Bay receives elevated inputs of pollutants from various sources. The transport of pollutants is determined by the ambient circulation pattern of the Bay. The primary objective of this study was to gather a complete set of hydrographic field data (including water surface elevation, current velocity, salinity and temperature) to calibrate and verify an appropriate model that would provide detailed information on the circulation patterns and dispersal of pollutants in the Bay. In addition, several bay-wide circulation parameters were quantified based on the data collected. The calculation results indicated that a large fraction of the water that exited the Bay on the previous ebb tide re-entered the Bay on the following flood tide because it was not quickly dispersed away from the vicinity of the Barnegat Inlet. The calculation results also indicated that the average flushing time (= average time it takes a pollutant to be moved through the bay), or residence time, in Barnegat Bay was very long at about 49 days with seasonal variation. Normalizing the flushing time by the Bay volume and drainage area indicated that Barnegat Bay is much more susceptible to point sources of pollution and similarly susceptible to non-point sources of pollution in comparison to the Chesapeake Bay. Moreover, the amount of direct groundwater seepage to the Barnegat Bay was quantified to be small relative to the total amount of surface water input to the Bay.

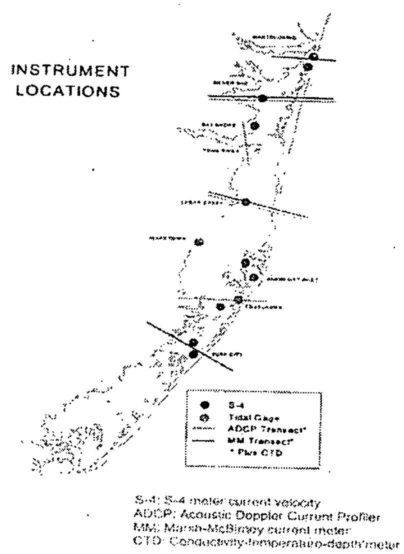
Introduction

The Barnegat Bay in Ocean County, New Jersey, is an important ecosystem for natural resource species and recreational uses. Barnegat Bay has been designated as one of three National Estuary Programs in New Jersey; the other programs include the NY-NJ Harbor Estuary Program and the Delaware Estuary Program. Barnegat Bay is a shallow bay with an average depth of 4.6 feet and extends for 30 miles parallel to the mainland with a total drainage area of 286,659 acres (Rogers et al. 1990; Kennish 2001). The Toms River is the largest river in the Barnegat Bay drainage area. Other significant rivers include the Metedeconk River, Cedar Creek and Forked River (Figure 1). The tidal inflow of salt water occurs though Barnegat and Manasquan Inlets. Similar to other coastal ecosystems, the Bay receives elevated inputs of pollutants (e.g., nutrients and pathogens) from various sources (especially development on land and recreational uses and boating) (NJDEPE 1993). The transport and dispersal of pollutants is determined by the ambient circulation pattern that is critical to maintaining the water quality of the Bay. Therefore, the primary objective of this study was to gather a complete set of hydrographic field data (including water surface elevation, current velocity, salinity and temperature) to calibrate and verify a circulation model. The circulation model, in conjunction with a water quality model, can then be used by environmental managers, scientists and engineers to predict spatial and temporal variations of water quality parameters, and to identify the critical combination of natural and anthropogenic conditions that will lead to the most severe environmental and ecological problems.

Project Design & Methods: Data Collection & Analysis

Data were collected at sites at the boundaries and within the Bay (Figure 1) and included continuous long-term data and short-term data (e.g., water surface elevation, current velocity, conductivity and temperature, and salinity). Measuring instruments were deployed during three long-term time periods (one month) during December 1994-January 1995, May-June 1995 and June-July 1995 to provide information about temporal

Figure 1. Distribution of Data Collection Points and Transects in Barnegat Bay



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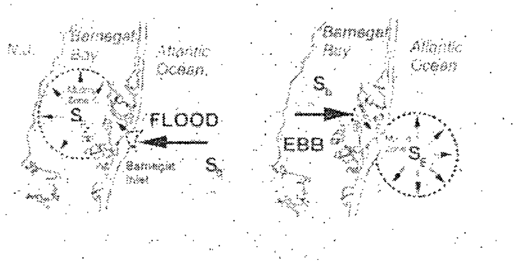
variation. Short-term data (one tidal cycle) at certain transects provided information about spatial variation. Several bay-wide factors were calculated based on the data collected before the data were used for calibration and verification of a detailed circulation model. The flushing time (= residence time) determines the time it takes a pollutant to move through the bay (by action of freshwater discharge and tidal exchange). This factor is strongly influenced by ocean water and bay water interactions (Figure 2). For example, water that exits the bay (with a pollutant loading) on the previous ebb tide may re-enter the bay on the following flood tide because of incomplete mixing outside the bay. This returned bay water might add to the pollutant loading in the bay. The data collected were used to calculate the residence time. The freshwater input was also calculated because it is the primary carrier of pollutants entering the Bay. The total (net) freshwater input to the bay includes:

- freshwater inflow from surface streams;
- direct groundwater seepage;
- direct runoff from land surface; and
- direct precipitation onto the water surface.

Direct water evaporation from the bay water surface is excluded.

Figure 2. Illustrative Tidal Exchange at Barnegat Inlet, New Jersey: Ocean Water and Bay Water Interaction.



Results and Discussion

While this study generated a great deal of data on hydrography (e.g., salinity, temperature, etc.), an analysis of the data clearly indicated some potential problems in Barnegat Bay with respect to pollutant dispersal and removal. The annually averaged flushing time (residence time) in Barnegat Bay was estimated to be long at approximately 49 days (Guo et al. 1998; Guo and Lordi 2000). The residence/flushing time is the time it takes a pollutant to be moved through the bay averaged over the entire bay and over one year. However, the flushing time in Barnegat Bay varied greatly with season, it was 24 days for January 1995 but was 74 days for June/July 1995. In contrast, the residence time in the Chesapeake Bay is much longer at 7 months (ca. 210 days) (Paerl et al. 2002). However, Chesapeake Bay has a much larger volume (holding 18 trillion gallons of water) than Barnegat Bay (holding 60 billion gallons of water)(Table 1). Table 1 summarizes the residence and flushing times and drainage areas in several estuaries. Normalizing the flushing time by the bay volume indicates that Barnegat Bay is much more susceptible to pollutant loading from point sources (loading in pounds per year). In addition, Chesapeake Bay has a much larger drainage area (40,960,959 acres); this leads to Chesapeake Bay's ratio of bay volume over drainage area to be about twice that of Barnegat Bay (1.35 vs. 0.68 cubic feet per squared foot). Normalizing the flushing time by the bay volume-drainage area ratio indicates that Barnegat Bay and Chesapeake Bay are

Table 1. Summary of residence/flushing times and total drainage area in several estuaries.

Site Characteristics	[1]Barnaget Bay, NJ	[2]Plum Island, NC	[3]Chesapeake Bay, NC & VA	[4]Neuse-Pamlico, SC	[5]North Inlet, NC
Residence/ Flushing Time (days)	49	0.5-40	~210 days	Days-1yr.	2-10
Total Drainage Area (km^2)	1730	585	165,769	16,038	~75
Tidal Range (m)	1.4 -1.5	>3	1	<0.1	2
Percent Residence Time to Total Drainage Area	2.8	0.08-6.8	0.1	Up to 2.2	2.6 - 13%

[1]Guo et al. 1996; Kennish 2001; Seabergh et al. 1998
[2]Paerl et al. 2002; http://ecosystems.mgl.edu/PIE/site.htm
[3]Paerl et al. 2002; http://www.chesapeakebay.net/info/factoids.cfm
[4]Paerl et al. 2002
[5]Paerl et al. 2002; http://ecosystems.mgl.edu/PIE/site.htm

similarly susceptible to pollutant loading from non-point sources (loading in pounds per acre of drainage area per year). Another characteristic of the Barnegat Bay, which may influence the time that pollutants remain in the Bay, as well as their dilution and dispersion, is the poor mixing of ocean water and bay water at the Barnegat Inlet area (Figure 2). New ocean water can dilute pollutants in the Bay whereas returned Bay water, which already has a pollutant load, cannot. Bay water that exits from the Bay and is discharged to the nearshore coastal waters on the previous ebb tide, is not quickly dispersed away from the shoreline by the longshore ocean current. Therefore, a large fraction (83%) of the exited Barnegat Bay water (from the previous ebb tide) returns to the Bay on the subsequent flood tide (the fraction derived from the refined results in Guo et al. 1998; Guo and Lordi 2000). This returned Bay water is not available to dilute pollutants. Effluents from various sources (e.g., wastewater treatment plants, outfalls and nearshore sources) discharging into the coastal waters outside Barnegat Inlet may not be quickly removed and dispersed from the shoreline and may enter the Bay through the Barnegat Inlet on the flood tide. Finally, the direct groundwater input to the Bay was relatively small in comparison to the input from surface streams (Guo et al. 1998; Guo and Lordi 2000). This is consistent with previous studies in the New Jersey Coastal Plain (Martin 1989) and the results from three-dimensional groundwater modeling of the Barnegat Bay watershed (Nicholson and Watt 1997). Because the direct ground water inputs are estimated to be insignificant, watershed (landside) contributions to water quality in the Bay are mostly derived from the streams in the watershed, making it possible to sample watershed outputs and determine the efficacy of water quality programs.

Conclusion and Recommendations

Field data collected through this study are sufficient to calibrate and verify a recommended depth-averaged two-dimensional numerical circulation model. Data analysis indicated that while the average flushing time (residence time) in Barnegat Bay was very long at approximately 49 days, it varied with season. Direct ground water sources entering Barnegat Bay are limited, the landward contributions to water quality in the Bay are mostly derived from the streams in the watershed, making it possible to sample watershed outputs and determine the efficacy of water quality programs. The development of a numerical circulation model that is coupled with a water quality model could potentially help understandings of the impacts of various past and future watershed land uses and coastal zone management practices and may help characterize the potential pollutant sources in the nearshore coastal waters that may enter Barnegat Bay through Barnegat Inlet.

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Prepared By

[1] *This is an updated research project summary of the following final report available in the Division of Science, Research and Technology.*

Guo, Q., N. P. Psuty, G.P. Lordi, S. Glenn, and M.R. Mund. 1995. Hydrographic Study of Barnegat Bay, Year 1: Volume 1 and 2. Prepared by the Rutgers the State University of New Jersey, New Brunswick, NJ, for the New Jersey Department of Environmental Protection, Division of Science and Research.

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RESEARCH PROJECT SUMMARY