BARNEGAT BAY PROSPECTUS:
MONITORING, ASSESSMENT, AND RESEARCH PRIORITIES FOR THE BARNEGAT BAY-LITTLE EGG HARBOR ECOSYSTEM TO SUPPORT SCIENCE-BASED WATERSHED MANAGEMENT

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By: Barnegat Bay Partnership (BBP)

EXECUTIVE SUMMARY

It is widely understood that the health of the Barnegat Bay-Little Egg Harbor ecosystem has continued to decline due to eutrophication and other factors (*e.g.*, habitat loss and alteration). For the past few months, the New Jersey Department of Environmental Protection (NJDEP) has been engaged in a stakeholder process for the Barnegat Bay watershed in response to a commitment made by Governor Christie. The Barnegat Bay Partnership (BBP), known as the Barnegat Bay National Estuary Program (BBNEP) until earlier this year, has been working since 1997 to identify the research and management needs related to the restoration of the bay.

The BBNEP/BBP has produced several guidance documents, most notably the Comprehensive Conservation and Management Plan (CCMP) and the 2008-2011 Strategic Plan, which provide the consensus view of the bay's stakeholders. We encourage the NJDEP to review and consider these documents and communicate and discuss any potential decision-making regarding the Barnegat Bay with the BBP. (Additional information regarding the BBP is provided in the Prospectus.)

Background: the Problem

The Barnegat Bay-Little Egg Harbor system is recognized as suffering from a variety of ailments, with eutrophication being the main driver of degradation to the system. Haphazard planning and permitting throughout the watershed have contributed to or resulted in loss of forests and other open spaces, losses of freshwater and coastal wetlands, losses of buffers adjacent to the bay itself and its contributing streams, and shoreline hardening. Failed and/or inadequate stormwater infrastructure, boating and personal watercraft impacts on submerged aquatic vegetation, and adverse effects of Oyster Creek Nuclear Generating Station (*i.e.*, entrainment, impingement, thermal impacts) are also recognized as problems.

Two documents, the Comprehensive Conservation and Management Plan (May 2002) and the 2008-2011 Strategic Plan, serve as blueprints for research, monitoring and restoration of bay function for the Barnegat Bay-Little Egg Harbor estuary (BB-LEH). The latter document is the most current and identifies key priorities to help restore bay structure and function:

- Improve recognition and understanding of the bay's condition, and address the causes of water quality degradation within the ecosystem, especially eutrophication in the bay and stormwater and non-point source pollution in the watershed;
- Address water supply and flow issues that affect the bay and watershed;
- Prevent habitat loss, especially of submerged aquatic vegetation, and support habitat restoration; and
- Improve understanding of, and address fisheries declines.

Several critical scientific elements are lacking that can help address each of the research priorities stated above. They can be divided into the following categories.

Comprehensive Water Quality and Biotic Monitoring (Water Quality: $450,000 in installation costs, $170,000 in yearly maintenance and operation costs; Biotic Monitoring: $210,000 - $700,000)

This category forms the backbone of the monitoring and assessment skeleton for understanding changes and impacts to the bay. The water quality aspect consists of a comprehensive, multi-instrument network that continuously records water quality parameters at a number of sites throughout the bay, as well as nutrient exchange at the inlets. These data would be available via an open access website and would assist scientists in discerning the links between water quality, biological activity, and stress-induced events. Because the last comprehensive studies of the biota of the bay date back to the late 1970's and early 1980's, the biotic monitoring proposed under this section is critical to evaluate changes in the bay's condition and its biota against a backdrop of increasing development/urbanization and other external drivers of ecosystem change (*e.g.*, sea level rise). This monitoring is critical given the apparent decline in the distribution and abundance of a number of recreationally, commercially, and ecologically important biota, including fishes, crabs, shellfish, and seagrasses in recent years. At the same time, there has been an apparent increase in the abundance of jellyfish and sporadic outbreaks of other noxious and/or nuisance taxa (*e.g.*, brown tide).

Long term, consistently collected data are necessary to identify trends and changes over various time scales; thus, it is important that a stable funding source (*e.g.*, NJ Corporate Business Tax, Tourist or Transportation fees) be identified for funding this monitoring and assessment.

Targeted Watershed Studies ($50,000 - $828,000)

Included in this category are focused research projects that advance our understanding of watershed processes as they relate to nutrient inputs to the bay, which can lead to eutrophic conditions and subsequent adverse impacts. This includes determining the primary sources of nutrients that end up in the bay, how they are transported from throughout the watershed to the bay, the physical processes that distribute water and nutrients throughout the bay itself, and modeling the effects of possible management actions on nutrient loads.

Water Supply/Flow Issues ($100,000)

As the population within the Barnegat Bay watershed continues to increase so does the consumption of freshwater from the local aquifers and surface waters. This consumption leads to a decrease in the amount of freshwater entering the bay, potentially altering temperature and salinity regimes and circulation patterns, which could have far-reaching implications. The major research need in this area involves the effect of the regionalized sewer treatment plants and their ocean outfalls. These plants currently pump 50 million gallons per day of treated effluent offshore; previously, sewage effluents were discharged into the bay.

Soil Health Assessment and Restoration ($95,000 - $250,000)

With an increase in the population of the watershed comes a concomitant increase in the conversion of natural forest and agricultural areas to urban land cover. This landscape alteration has a significant impact on the function of the native soils and vegetation. Programs and demonstration projects are needed in the following priority areas.

a) Upland Soil Condition/Assessment **(Research, develop, and pilot cost-effective tools and procedures to assess soil conditions.)** How can the soil health (and function) of stormwater basins be assessed simply and effectively, without costly and specialized testing, equipment, and procedures?

b) Upland Soil Restoration **(Develop soil amendment specifications and soil restoration guidelines.)** What is the optimum amount of compost to add, and what is the most appropriate type and application method for local soil conditions? What are the optimal strategies to minimize soil compaction and restore the soil's physical and hydraulic properties to improve infiltration, water quality, and reduce consumption? What are the optimal specifications for soils in the BB-LEH system? Lastly, how can we efficiently transfer the newly-created soil restoration guidelines to agencies, organizations, and businesses for implementation?

Shoreline Stabilization

There is an increasing awareness of marsh edge erosion along the western edge of the bay and the major river systems that feed it. Current practice is to reduce erosion through the construction of hardened shoreline structures, but recent studies have documented declines in many aquatic species abundances adjacent to these structures. As an alternative, a project that develops implementation guidelines and training for an engineered vegetated solution known as "living shorelines" is proposed.

CONCLUSION

Taken together, the research, monitoring, and implementation projects detailed in the following prospectus address the most pressing of the Barnegat Bay Partnership's Strategic Plan Priorities. First and foremost, we strongly encourage the NJDEP to utilize all of the resources of the BBP and its partners; moreover, we recommend that the NJDEP communicate and coordinate with the BBP regarding any planning or other activities regarding the Barnegat Bay watershed. Lastly, we strongly encourage the state of New Jersey to establish a stable funding mechanism for bay monitoring, assessment, and other targeted studies.

The Barnegat Bay is a harbinger of the challenges facing the New Jersey shore; thus, addressing issues in the Barnegat Bay provides an opportunity for ensuring a sustainable future for the New Jersey shore.

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Background: the BBP

The BBP, one of 28 National Estuary Programs, is a partnership of federal, state, and local government agencies, academic institutions, nongovernmental organizations, and businesses working together to restore and protect a nationally significant estuary, the Barnegat Bay. The BBP was established in 1997 pursuant to Section 320 of the Clean Water Act (33 U.S.C. 1330; as amended by P.L. 100-4, *et seq.*) following the nomination of then-Governor Whitman to the U.S. Environmental Protection Agency (USEPA) to provide an inclusive, local stakeholder-based mechanism to protect the Barnegat Bay for its economic, environmental, and cultural resources. The BBP's organizational structure consists of a Policy Committee, Advisory Committee, Science and Technical Advisory Committee (STAC), and Communication and Education Committee (CEC). Technical workgroups (*e.g.*, the Eutrophication Workgroup, Fisheries Workgroup, and Climate Change Workgroup) provide support on specific issues.

The Policy Committee representatives include the NJDEP Commissioner, the USEPA Region 2 Regional Administrator, the President of Ocean County College, an Ocean County Freeholder, the chairperson of the Ocean County Mayors' Association, and a Citizen Representative. The Policy Committee provides these core partners with a forum to share and discuss their concerns regarding the bay and with opportunities to build a broad consensus for actions and commitments to protect and restore the Barnegat Bay.

Comprehensive Water Quality and Biotic Monitoring

1. Bay-wide continuous water quality monitoring.

Central Question: How do water quality parameters (salinity, temperature, dissolved oxygen, turbidity, and freshwater input) in the estuary change in relation to longer temporal and larger spatial scales, as well as in response to discrete events (storms, hypoxia, *etc.*)?

BBP Strategic Plan Action Number: WQ2, WQ4, WS4

Summary: A network of automated water quality sensors, tide gauges, and stream gauges in Barnegat Bay will allow scientists to discern the links between water quality, biological activity, and stress-induced events. The data from this network, when operated over a long time span, will allow scientists to identify trends in the bay's water quality which are not available from discrete, scattered sampling. This "observing system" would be integrated into the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) network, which coordinates and facilitates observations of the ocean and estuaries between Cape Hatteras and Cape Cod as part of the national Integrated Ocean Observing System (IOOS) effort to improve scientific observations of our coastal oceans.

There are currently three automated water quality sensors located in Barnegat Bay, which measure water level, salinity, temperature, turbidity, and dissolved oxygen.

The stations are located primarily in the northern and central portions of the bay, including Mantoloking Yacht Club, Seaside Park Yacht Club, and Bonnet Island. As these stations age and as new technology comes online (nutrient probes, chlorophyll–a sensors), they require sensor replacements and upgrades to provide reliable data. Furthermore, additional nodes are needed at key points throughout the bay (Oyster Creek, Little Egg Inlet, Barnegat Inlet, Point Pleasant Canal) to ensure adequate spatial coverage. Existing stream gauges monitor freshwater inputs from four streams draining to the estuary; however, there are three additional streams draining much of the watershed where monitoring is needed. These streams include South Branch Metedeconk River, Oyster Creek, and Mill Creek. Tide gauges are currently operating at six sites within the estuary, but there are three additional sites where tide gauges are needed: Bay Head, Forked River, and North Beach/Brant Beach.

Water Quality Sensors Cost: approximately $300,000 for installation of four new sondes, $25,000 for upgrades to three existing sondes, and $80,000-100,000 in recurring maintenance and operation costs (spare parts, technician/data maintenance) for all sondes per year.

Stream Gauges Cost: Installation costs are approximately $23,000 per station, or $69,000 total. Operation and maintenance costs are approximately $16,000 annually, or $48,000 per year for the three-station network.

Tide Gauges Cost: Installation costs are approximately $20,000 per station, or $60,000 total. Operation and maintenance costs are approximately $13,000 annually, or $39,000 per year for the three-station network.

2. Assessment of Fishes and Crabs Responses to Human Alteration of the BB-LEH System.

Central question: What is the influence of urbanization/development (as reflected in human population density, nutrients, *etc.*) on the distribution and abundance of fishes and crabs in Barnegat Bay habitats?

BBP Strategic Plan Action Number: F1

Summary: Fishes and crabs make up a large component of the biomass in the BB-LEH system, components that people harvest either in recreational or commercial fisheries, and components they seek to maintain in order to conserve the basic ecological functions of this important ecosystem. At the same time, the fisheries for many species are declining. Since the last comprehensive studies of the bay in the late 1970's and early 1980's, human population density and urbanization of the bay has increased primarily along the north (upper bay) to south (Little Egg Harbor) gradient. Thus, we ask, "What is the influence of urbanization/development (as reflected in human population density, nutrients, *etc.*) on the distribution and abundance of fishes and crabs in Barnegat Bay habitats?" To evaluate the response, a three-year study is proposed to extend an ongoing trawl survey (since 1988) in the lower bay (Little Egg Harbor) to the entire bay with an emphasis on sampling the distribution and abundance of submerged aquatic vegetation (eelgrass, widgeon grass, macro algae) and unvegetated areas along the urban gradient (as derived from remote sensing maps). Prior use of this approach, albeit at a smaller scale, has demonstrated its value in interpreting habitat quality in pristine and altered estuaries. These, together with an improved understanding of the circulation and nutrient loading along the urban gradient will enable a better understanding of the status of the BB-LEH system and how it responds to human impacts. Analysis will include the annual and seasonal variation between years, seasons, and habitat types relative to the urban gradient and environmental variables. Observed patterns may be related to the nutrient gradient, but examination of circulation patterns will inform and perhaps alter that expectation. Regardless, the approach will provide an enhanced capability to detect and predict the human impacts on this economically important ecosystem.

Cost: $700,000 for three-year program.

3. Assessment of the Distribution and Abundance of Jellyfishes in the BB-LEH System.

Central Question: What is the distribution and abundance of jellyfishes in the BB-LEH system, and how does that vary with changing water quality conditions?

BBP Strategic Plan Action Number: F1

Summary: While the populations of many species of fish and shellfish appear to be on the decline in Barnegat Bay, there appears to be an increase in the abundance and distribution of jellyfishes in the bay, stinging sea nettle (*Chrysaora quinquecirrha*) in particular. While this species appears in the historical record of the bay, very little is known about it in this system. As such, a research program focusing on two of the life history stages is proposed. Placement of settlement plates throughout the estuary will identify the distribution and abundance of polyps across a number of gradients (salinity, temperature, development). This will be paired with twice monthly (April to November) plankton trawls to quantify the abundance and distribution of the medusa stage. The abundance and distribution data will then be examined with the environmental data in an attempt to tease out any correlative factors, with long-range goals of: (1) understanding jellyfish causal factors, (2) predicting jellyfish distribution and abundance, and (3) assessing the feasibility of control.

Cost: $250,000 for a three-year program.

4. Benthic Invertebrate Community Monitoring in the BB-LEH System

Central Question: What is the status of benthic invertebrate assemblages as an indicator of ecosystem health in the BB-LEH system?

BBP Strategic Plan Action Number: WQ2, F1, F2

Summary: Multiple human and natural stressors affect the Barnegat Bay-Little Egg Harbor estuary. To effectively assess the structure and function of the estuary and the ongoing ecosystem changes occurring in response to these stressors, a three- to five-year study of the benthic invertebrate community is proposed. At present, the benthic invertebrate community in the estuary is poorly characterized because the last extensive seasonal structured study of this biotic component was conducted four decades ago (1968 to 1974) by Rutgers University. From 2000 through 2006, the USEPA conducted the National Coastal Assessment, which measured the benthic community during the summer season at approximately six stations per year. This data was generated for a national analysis and not to develop a local index. As part of a USEPA REMAP grant administered by the NJDEP, Rutgers University will make recommendations for sample measures, as well as sample designs for a benthic invertebrate community index for shallow coastal bays in December 2010 that will have relevance to the benthic component of the prospectus. As in the case of the finfish and nekton study proposed above, the benthic invertebrate project will examine annual and seasonal variation of the community between years, as well as within seasons and habitat types relative to the urban gradient and environmental variables. Benthic indices employing species abundance, dominance, biomass, diversity, and other parameters are useful measures of community composition and function, and they serve as excellent indicators of estuarine condition. Because of their sensitivity to stress-induced changes in benthic communities, benthic indices also have utility in assessing anthropogenic impacts. Metrics obtained on benthic invertebrate assemblages are often used as indicators of environmental health because these organisms are relatively sedentary, and they usually respond predictably to natural and anthropogenic stressors, such as along nutrient and organic carbon gradients. Therefore, carefully designed investigations utilizing appropriate measures of benthic condition (metrics) are essential for accurately assessing estuarine environmental status and trends. While the state's current determination of estuarine ecological health is based solely on dissolved oxygen measurements, it is also important to investigate benthic biotic indicators for ecosystem-based assessment of condition. A benthic invertebrate study will also yield vital data for accurately determining where impairments exist in the estuary and for delineating where environmental remediation must be focused. Finally, the study will improve understanding of benthic-pelagic coupling, *i.e.*, linkages between the bottom and water column environments, which determines in large part the production and biotic structure of the system.

Cost: $175,000 -- year one, $175,000 -- year two, $175,000 -- year three.

5. Assessment of Hard Clam Populations in the BB-LEH System.

Central Question: What is the current population level of hard clams in the BB-LEH system?

BBP Strategic Plan Action Number: WQ2, F1

Summary: The hard clam, *Mercenaria mercenaria*, is a recreationally important bivalve species in the Barnegat Bay-Little Egg Harbor estuary. It is also an important indicator of estuarine ecosystem and eutrophic condition. It was recognized as an economically important species in decline in the CCMP, and identified as a key species for stock assessment in the Strategic Plan for Barnegat Bay.

The hard clam was once the most commercially important shellfish species in the estuary, but it has declined appreciably in abundance over the past three decades. Since the mid-1970's, the total harvest of clam meats in the estuary decreased by more than 99%. However, despite its dramatic decrease in harvest statistics, surveys of the hard clam stock have not been conducted in Barnegat Bay since 1986 and in Little Egg Harbor since 2001. Studies in Little Egg Harbor indicate that the hard clam stock decreased by approximately two-thirds over the period from 1986 to 2001. An update of hard clam stock assessment is therefore critically needed.

A comprehensive survey of hard clams is proposed for both Barnegat Bay and Little Egg Harbor to determine current stock levels. A matrix of sampling stations will be established throughout the estuary, with each sampling point separated by 300 m. Sampling will be conducted by trawl with a clam dredge consistent with state standards.

Cost: $250,000 for the hard clam surveys in the estuary, with sampling conducted in successive years at $125,000 each year (Barnegat Bay – year one and Little Egg Harbor – year two).

6. Monitoring of Submerged Aquatic Vegetation's Response to Human Stressors in the BB-LEH System.

Central Question: What is the condition of seagrass beds in the BB-LEH system and the extent to which eutrophication impacts this critical habitat?

BBP Strategic Plan Action Number: WQ2, F1

Summary: Submerged aquatic vegetation (SAV) is a term used to describe a variety of estuarine and marine plants, including seagrasses and macro algae. Due to their important ecological role in the BB-LEH ecosystems, as well as their sensitivity to degraded water quality, SAV has been adopted as a primary indicator of estuarine ecosystem health (BBEP, 2003). The spatial distribution, abundance and health of SAV are important environmental indicators of the overall status of the BB-LEH system. Of special concern are the bay's two principal species of seagrass, eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). The bay's seagrasses are an important element of the bay ecosystem, because they harness energy and nutrients that are consumed by other organisms. The seagrass beds also provide a critical structural component in an otherwise barren sandy bottom, serving as essential habitat for a host of organisms from shellfish and crabs to fish and waterfowl. BB-LEH seagrass habitats are important not just locally but regionally, with the BB-LEH system containing ~75 % of the known seagrass habitat along the entire New Jersey coast.

We propose to use high-resolution digital satellite and/or airborne imagery complemented with *in situ* sampling to map the spatial extent and condition of the seagrass beds. The proposed SAV survey is needed to assess the status of seagrass habitats and to more comprehensively assess the extent to which eutrophication continues to impact the ecology of the BB-LEH system.

Cost: $70,000 -- year one, $70,000 -- year two, $70,000 -- year three.

7. Equipment Support.

Central Question: This tool is essential to support many of the questions/tasks throughout this document, especially those related to water quality, habitat restoration, and fish stock assessment.

BBP Strategic Plan Action Number: WQ2, WQ3, F1, F2

Summary: An autonomous underwater vehicle (AUV) will be extremely useful to support many of the research priorities identified in this prospectus, and will provide a long-term monitoring capability for the BB-LEH system. AUVs as a whole are capable of supporting a broad range of sampling schemes, including those with vertical (water column profiling), 2-dimensional (area coverage) at the fine- to meso-scale (meters to 10s of km), or both, and time series (repetitious sampling of a single transect, from hours to repeated day scale). AUVs are capable of being launched from small boats or shore and can work in adverse conditions, including under ice and during storms. Specific to the proposed project, an AUV would be applied to 1) mapping water quality, especially as a complement to hydrography, bathymetry, and surface conditions owing to its multiple sensors, 2) benthic habitat mapping (using side scan sonar and an underwater camera), and 3) defining circulation patterns relevant to larval fish and crab supply, retention, and survival. Data may be used directly for analysis of these questions but also to inform development of a robust, accurate, and precise BB-LEH circulation model.

The Ecomapper AUV (Yellow Springs Instruments, Yellow Springs, Ohio) has been identified as a particularly promising tool for use specific to the BB-LEH system for several reasons. Of numerous commercially available AUVs, the Ecomapper size, weight, battery capacity, and operating specifications are appropriate to the scale of study in this system. The Ecomapper is sufficiently small for tight turns in restricted embayments and can be launched and recovered by a single person from beach or small boat. It can be driven from the surface using Wi-Fi, which is also appropriate to inland waters. Importantly, the sensors are made by YSI and utilize the same calibrations and technologies currently approved and applied in moored and vessel-deployed arrangements within the state of New Jersey's and the National Estuarine Research Reserve's water quality monitoring programs.

Ecomapper instruments include height (altimeter), water speed sensor, depth (pressure), conductivity, temperature, chlorophyll, turbidity, and dissolved oxygen.

Cost: $195,000 (includes complete operating system, key spare parts, annual maintenance and support plan, and onsite training).

Targeted Watershed Studies

8. Identify nutrient sources.

Central question: What are the primary sources of nutrient loads, and what is the relative importance of each source?

BBP Strategic Plan Action Number: WQ3

Summary: A project is presently underway to evaluate sources of nutrients in samples collected from a limited number of streams and groundwater wells using stable isotopes of oxygen and nitrogen. At least one second-phase project of similar magnitude will be needed to confirm major nutrient sources, resolve ambiguous results, and identify specific human activities contributing to excessive nutrient loads. A second-phase effort would include sampling five additional streams and five wells. The second phase would have a narrower focus, and tributaries of a single major stream, such as the Toms or Metedeconk River, with varying watershed land uses would be targeted. The suite of analytes would include at least one additional isotope, most likely boron.

Additional research should also be done to look at atmospheric deposition in the watershed (*i.e.*, a fixed station in the northern part of the watershed) together with additional studies on a finer scale (on different landscape types at different distances from roadways) and for different sources (*e.g.*, fossil-fuel burning power plants, automobile, and outboard exhaust).

Cost: approximately $185,000 for radioisotope study; $150,000 for atmospheric deposition, fixed station, and fine-scale study.

9. Evaluate distribution of nitrate in groundwater.

Central question: What are the primary sources of nutrient loads, and what is the relative importance of each source?

BBP Strategic Plan Action Number: WQ3

Summary: Previous studies have demonstrated that much of the nitrogen load in streams discharging to the estuary is transported via groundwater flowing from recharge areas to streams. Additionally, nitrate-N in direct groundwater discharge to the estuary is estimated to account for 12% of the total nitrogen load to the estuary. The distribution of nitrate in groundwater needs to be characterized so that past, present, and future nitrogen loads delivered to the estuary through groundwater transport can be better estimated. The number of wells in the watershed that have been sampled as part of recent subsurface investigations is limited. However, a large amount of untapped information on nitrate in groundwater has been generated through the Private Well Testing Act and previous county-wide regulations. This source of valuable data needs to be mined and processed to help characterize the distribution of nitrate in groundwater in the Barnegat Bay watershed and the delivery of nutrients to the bay through groundwater transport. The project would include data screening and quality-assuring, compilation of well-construction information, field-checking site locations, GIS processing, geo-database creation, and preparation of maps of subsurface nitrate distribution.

Cost: Approximately $50,000.

10. Quantification of Ocean/Estuary Nutrient Exchange.

Central question: What is the magnitude and timing of nutrient exchange between the estuary and the ocean, and to what extent do nutrient inputs from the ocean contribute to the nutrient load?

BBP Strategic Plan Action Number: WQ3

Summary: A major gap in the nutrient budget for the bay is the magnitude of mass exchange of nutrients between the bay and the ocean. Previous short-term monitoring of nitrate in Barnegat Inlet suggests that variability in this exchange may be substantial (Guo and Psuty, 2000). Exchange of water and chemical loads between the ocean and the bay occurs primarily at three locations: Barnegat Inlet, Point Pleasant-Bay Head Canal, and Little Egg Inlet at Holgate. Monitoring nitrate concentration and flow at these sites on a continuous basis for at least 12 months can provide the information needed to understand the importance of this potential nutrient transport process. This project will utilize nitrate probes and acoustic-doppler current profilers (ADCPs) associated with the water quality network to collect information at Barnegat Inlet and the Point Pleasant-Bay Head Canal. Fixed ADCP installation is problematic at Little Egg Inlet, and so at this site, flow would need to be measured periodically using a boat-towed ADCP, and measured flows would be correlated with tide elevation and phase, as measured at the continuous tide gauge operating nearby at the Rutgers University Marine Field Station.

Cost: Approximately $485,000 for installation, maintenance, and operation for 12 months.

11. BB-LEH Circulation Model.

Central Questions: How does the residence time and circulation of the BB-LEH system vary seasonally, annually, and in response to storm events? What are the spatial and temporal dynamics of nutrients once they have entered the BB-LEH system?

BBP Strategic Plan Action Number: WQ2, WQ3, F2

Summary: To understand more fully the spatial and temporal dynamics of nutrients once they have entered the BB-LEH system, the nutrient loading model must be coupled with information on water residence time and circulation which has been shown to vary greatly seasonally and annually. A coupled watershed-bay circulation modeling framework is required to achieve a greater understanding of the dispersal of nutrients within the system, as well as possible flushing from the system, particularly their variability due to seasonal and extreme weather conditions. This is a priority need for resource managers to improve water and habitat quality in the BB-LEH system through science-based restoration and mitigation strategies.

Barnegat Bay partners propose to develop a coupled watershed/estuarine/coastal ocean model to support physical and ecological studies of the BB-LEH system, and consequent restoration programs. An extensive field program is required to collect hydrographic, optical, and chemical data for the bay, develop a quantitative description of circulation in the bay, and to facilitate development of the circulation model of the bay. The estuarine circulation model will utilize the three-dimensional Regional Ocean Modeling System (ROMS) that has been developed at Rutgers University and is now used by thousands of researchers worldwide. The model will be coupled to an existing coastal ocean model on the seaward side and an existing watershed model on the landward side to provide appropriate forcing from the ocean and loadings from land. The circulation model will provide a detailed characterization of circulation and mixing in the bay and provide the backbone for future system-wide ecological studies and restoration programs related to eutrophication, water clarity, and primary production. In addition, the model can be used to assess the physical, chemical, and biological response of the bay to human impacts, such as increased urbanization of the watershed and global climate change.

Cost: \$494,000 -- year one, \$253,000 -- year two, \$81,000 -- year three.

12. Develop and Apply a Capability to Predict Changes in Nutrient Loading and Freshwater Inputs

Central question: What are the likely effects of possible management actions on nutrient loads and freshwater inputs?

BBP Strategic Plan Action Number: WQ3

Summary: Ongoing monitoring and research is providing insight to important nutrient transport processes and the delivery of freshwater to the bay under current conditions. The capacity to predict potential future changes in inputs of nutrients and freshwater is proposed through further development and use of existing hydrologic models to evaluate the potential outcome of various management actions. Linkage of these models with the proposed estuarine circulation model will facilitate evaluation of the estuary response to human impacts. The three predictive modeling components are listed below:

12a. Groundwater nutrient inputs: Groundwater has been shown to be an important transport pathway for nutrients, and the capacity to predict potential nutrient loads transported through groundwater in the future is needed in order to evaluate management alternatives and understand the likely timeframe for changes in delivered loads. An ongoing project is using a detailed groundwater-flow model (developed using the MODFLOW code in cooperation with the NJDEP Division of Water Supply) with a newly developed particle-tracking capability using the MODPATH code to estimate nitrogen concentrations in groundwater discharge to surface water, based on relations between land use and the concentration of nitrogen in aquifer recharge. A new modeling phase using this technique is needed to identify groundwater "hot spots" with elevated nitrogen concentrations and to simulate changes over time in groundwater transport of nitrate to streams. These results and results of prior investigations will be used to: 1) assist in identifying areas for groundwater and stream baseflow sampling for isotopic analysis and source identification; and 2) determine the capability of the model to hindcast observed trends in nitrogen load in stream base flow in the Toms River. The model will then be used to 3) predict nitrogen inputs through groundwater transport under alternative land-use planning and management strategies in the watershed (such as build-out conditions, BMP application, fertilizer ordinances, *etc*.)

12b. Surface water nutrient inputs: An existing PLOAD model of the Barnegat Bay watershed has been developed that is capable of evaluating changes in surface-water nutrient loads to the estuary in response to changes in land use and water-supply development. The PLOAD model simulates surface-water nutrient loads based on event-mean concentrations derived from field data and land-use characteristics. This model will be used to simulate changes in nutrient loads delivered by surface water that can be expected to occur under different land use planning and management strategies. The PLOAD model results, together with results from the groundwater MODFLOW/ MODPATH model described above, will be used to evaluate the relative contribution of loads transported slowly through groundwater and the loads transported relatively rapidly through surface-water runoff, providing an understanding of the timeframe for the system response to management actions.

12c. Freshwater inputs: The MODFLOW groundwater-flow model described earlier simulates groundwater conditions in the Barnegat Bay-Little Egg Harbor watershed and includes critical hydrologic processes such as spatially and seasonally variable recharge patterns, groundwater withdrawals, discharge to streams and discharge to the estuary. The model can be used to simulate changes in groundwater discharge to streams and the estuary in response to changes in human stresses, such as groundwater withdrawals and land alterations (such as impervious surfaces and stormwater-management facilities) that affect groundwater recharge and runoff patterns. Application of the model to predict potential future changes in freshwater inputs to the bay in response to these stresses is proposed.

Cost: Approximately $150,000 -- year one; $70,000 -- year two.

13. Nutrient Inputs from the BB-LEH Watershed.

Central Question: What is the estuarine response and eutrophic condition of the BB-LEH estuary associated with nutrients from watershed sources?

BBP Strategic Plan Action Number: WQ3

Summary: Most of the nitrogen load enters the estuary from watershed surface-water inflow. While nitrogen loading has been modeled in several watersheds dominated by agriculture, the proposed project will use novel methods of modeling nitrogen flow to characterize the effects of rapid urbanization and altered land use in the Barnegat Bay watershed. Interdisciplinary research already underway will integrate models of the coupled watershed-estuary system to estimate levels of nitrogen loading and will employ a suite of water quality, biotic, and habitat indicators for quantifying and characterizing estuarine responses and eutrophic condition associated with these environmental stressors at local and estuary-wide scales. A spatially explicit (*i.e.*, GIS-based) model will be developed to quantify nutrient export from watershed sources to the BB-LEH system.

Cost: Approximately $480,500 was made available by USEPA Region 2 to the New England Interstate Water Pollution Control Commission to complete this project by Rutgers University, partnering with the Jacques Cousteau National Estuarine Research Reserve, and the US Geological Survey.

14. Subaqueous Soil Mapping of Barnegat Bay.

Central Question: What types of soils underlie Barnegat Bay?

BBP Strategic Plan Action Number: H3

Summary: The purpose of the project is to provide soils information following the National Soil Survey Standards based, in this case, on depths, position, and physical and chemical properties of the sediments. The soil survey can provide information for planning, recreation, aquatic vegetation restoration, alternative shoreline protection techniques, benthic species understanding, and disposal and management of dredge material.

Cost: Approximately $200,000 for fieldwork, mapping, and education/outreach.

Water Supply

15. Assessment of the Benefits of Tertiary Treatment at the Regional Sewage Treatment Plants.

Central Question: What would be the effect of upgrading the three regional sewage treatment plants to tertiary treatment and discharging treated effluent to the bay?

BBP Strategic Plan Action Number: WS4

Summary: The three regional treatment plants operated by the Ocean County Municipal Utility Authority currently pump approximately 50 million gallons of treated wastewater per day into the coastal ocean. This activity, while helping to remove the direct discharge of pollutants into the bay, has also substantially reduced freshwater inputs into the bay. Since the construction of the regional plants, additional technologies have been developed that reduce pollutant loadings to near ambient levels, allowing for discharge into the bay. The feasibility of installing this technology, and its potential effects on the bay's water quality, will be assessed.

Cost: $100,000.

Soil Health Assessment

Upland Soil Condition/Assessment

16. Research, Develop, and Pilot Cost-Effective Tools and Procedures to Assess Soil Conditions.

Central Question: How can the soil health (and function) of stormwater basins be assessed simply and effectively, without costly and specialized testing, equipment, and procedures?

BBP Strategic Plan Action Number: WQ6A, WQ6B

Summary: A. There have been numerous projects and an ongoing commitment to restore and retrofit county-owned stormwater basins throughout the watershed (OCSCD, OCPD, NJDEP) and a current initiative by RU/CRSSA/JCNERR to develop a GIS database and web portal (WQ6D.) The data to identify (and eventually prioritize) the basins that are not functioning, and therefore would benefit most from restoration is not currently available. With an estimated cost of $100,000/basin restoration, it is both economically and strategically practical to focus on the basins that are exhibiting symptoms of poor soil health. Stormwater basins can only be considered a Best Management Practice if they are properly functioning as such.

Cost : $240,000.

B. The existing Ocean County Soil Survey published by the National Cooperative Soil Survey (NCSS) is an Order 2 Survey utilizing a scale between 1:12,000 and 1:24,000. It is not intended to apply to provide detailed and/or use-dependent information. Mapping soils information at a smaller scale less than 1:12,000 would provide site-specific information along with a use-dependent assessment of soil conditions for disturbed lands, including stormwater management basins. As noted in Summary A, basin restoration is very costly. It is paramount that the proper assessment techniques are utilized in developing recommendations for restoring disturbed turf lands/basins. With nearly 3,000 stormwater basins in the watershed, a site-specific soil survey would be very helpful in assessing and in prioritizing basins for potential restoration. This proposal would develop an urban soil series to recognize the presence or absence of compacted layers and massive soil structure with specific criteria related to soil depth and soil bulk density. It would establish interpretations for soil restorations to rebuild pore space in compacted and/or disturbed lands and basins. Conventional soil taxonomy would be applied as related to soil classifications and anthropogenic influences on soil. This would be a pilot project to demonstrate how urban soil interpretations could be used in determining basins for potential restoration techniques.

Cost: $250,000.

Upland Soil Restoration

17. Develop Soil Amendment Specifications and Soil Restoration Guidelines.

Central Question: What is the optimum amount of compost to add, and what are the most appropriate types and application methods for local soil conditions?

BBP Strategic Plan Action Number: WQ10

Summary: Research has shown that phosphorous and nitrogen loadings can be reduced through filtration and adsorption, and through sustaining healthy soils, microbial processes are effectively enhanced to reduce nutrient loadings. There is no definitive research on the sandy coastal soils to indicate optimum organic content to improve soil function and infiltration. The Ocean County Parks Department has experienced increasing difficulty managing turf areas, and some athletic fields have continual soggy turf, restricting use. Moreover, turf often succumbs to drought more quickly since less rainwater is absorbed by compacted soil.

The main objective is to systematically evaluate the effectiveness of adding measured amounts of various organic materials (readily available) on improving and sustaining soil health (as measured by infiltration), by establishing test plots on selected disturbed sites on Ocean County properties. These test plots will be tested for soil organic matter and infiltration rate (hydrologic conductivity) and bulk density on a quarterly basis for 18 months. Data will be collected, evaluated, and summarized. This will lead to an acceptable amount and type of organic material/compost to be added to disturbed Barnegat Bay/Ocean County soils and is a critical component of any Soil Health Restoration/Post-Construction Guidelines.

Cost: $120,000.

18. Develop and Pilot Cost-Effective Soil Restoration Techniques and Low-Cost Tools to Restore Soil Health.

Central Question: What are the optimal strategies to minimize soil compaction and restore the soil's physical and hydraulic properties to improve infiltration, water quality, and reduce consumption?

BBP Strategic Plan Action Number: WQ8, WQ8D, WQ10A

Summary: Land development projects disturb vegetation, soil, and often increase impervious surface cover, thus altering the hydrologic response of local watersheds. If inadequately or improperly managed, stormwater runoff can deplete groundwater resources and increase flooding, stream channel erosion, and sediment transport and deposition.

Partners propose to pilot soil health guidelines and soil restoration specifications on county projects to minimize soil compaction and restore the soil's physical and hydraulic properties to improve infiltration, water quality and reduce consumption. Partners will evaluate the pilot guidelines for a recommended period and then revise the techniques as needed. In cooperation with the BBP and its partners, the Ocean County Soil Conservation District will develop and adapt a model soil restoration ordinance for Ocean County. This ordinance would be applicable to all land disturbances greater than 5,000 sq. ft.

Cost: $95,000 (plus $30,000 annually for implementation).

19. Develop Post-Construction Soil Health Inspection Guidelines.

Central Question: What are the optimal specifications for soils in the BB-LEH system?

BBP Strategic Plan Action Number: WQ10B, WQ10C

Summary: The amount and type of organic material needed to optimize soil health and thereby improve soil function, is site-specific and dependent on a number of factors and soil properties. To improve soil health throughout the Barnegat Bay watershed, methods and protocols must be developed. Once determined, specifications can be developed to assist in soil restoration. A long-term goal of this project is to help transfer restoration technology to local communities, to build natural resource stewardship capacity and help empower municipalities to implement local guidelines that sustain soil health. The primary product of this component is to develop guidelines for soil health restoration for the Barnegat Bay watershed.

Cost: $180,000.

20. Implement a Pilot Program in Ocean County for Soil Health Restoration.

Central Question: How can we efficiently transfer the soil restoration guidelines to the on-the-ground agencies, organizations, and businesses that will actually implement these practices?

BBP Strategic Plan Action Number: WQ8, WQ10A, WQ10B, WQ10C, P9

Summary: Develop and implement a Soil Health Certification Program for contractors, landscapers, and engineers to ensure that BMPs and stormwater practices are properly constructed to sustain the soil's physical, chemical and biological functions. Prepare inspection procedures and inspections forms as a basis for uniform inspections to evaluate soil conditions. The most effective method is to provide training opportunities that include site visits, demonstrations, and hands-on experiences for the trainees. This is a continuation and further advancement of the "Blue Card for the Blue Crab Program," the Barnegat Bay Soil Health Card (NJDEP/DWM/CBT project), and additional regional training initiatives for Soil Health Restoration. Soil health training would include workshops and field trips to demonstrate soil restoration guidelines to township engineers, public works officials, athletic field managers, and the public.

Cost: $150,000 + (additional funds for annual workshops and training).

Wetlands/Shorelines

21. Shoreline Stabilization

Central Question: What techniques are most effective in stabilizing high energy shorelines along the western edge of Barnegat Bay?

BBP Strategic Plan Action Number: H1,H3, H4, H5

Summary: A natural approach to shoreline stabilization should incorporate marsh vegetation in the project design to enhance the habitat value of an area. This conservation practice can reduce the loss of valuable waterfront land, protect property, and decrease the amount of sediment entering the bay's waters. In many cases, the vegetated marsh fringe serves as a buffer strip that works as a filter for runoff and pollutants. By trapping this sediment, the vegetative beach will grow wider and actually push the high tide away from the base of the bank. This "natural approach" for shoreline erosion works on a variety of shorelines, but each case should be evaluated separately.

Implementing shoreline erosion control projects with natural components has definite benefits for the health of Barnegat Bay's economic and ecological value (*e.g.*, restore marine habitat and spawning areas, maintain water quality, prevent bank erosion and property loss, provide protection from storm surges and sea level rise). This project would be modeled after a similar initiative in Maryland sponsored by NOAA, NRCS, and the Maryland Department of Natural Resources. It would include the development of a guidebook, the implementation of several demonstration sites throughout the watershed, and a series of workshops and training sessions.

Costs: $250,000 over a three-year period.

References

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