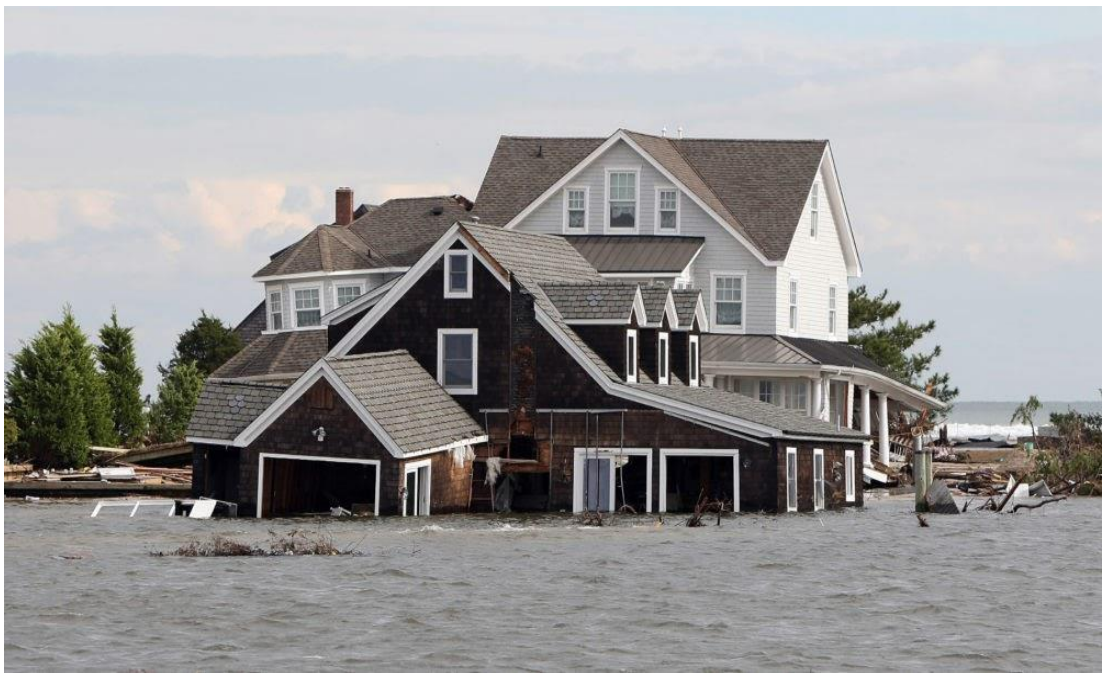
Chapter 8 - Climate Change in the Barnegat Bay

8.1 Climate Change in New Jersey

Climate change and sea level rise have the potential to alter ecosystem processes and life in coastal communities in ways that we are just beginning to recognize and have yet to truly address. Changes in air and water temperatures, precipitation, surface water hydrology and sea/land surface elevation will have significant impacts on New Jersey's marine/estuarine, freshwater and terrestrial ecosystems.

The impacts of climate change have already been observed here in New Jersey. New Jersey coastal areas, including the Barnegat Bay estuary, are experiencing one of the highest rates of sea-level rise in the continental United States. At Atlantic City, where records extend back to 1912, sea level has risen by an average rate of 3.8 cm per decade during this time-period (Rutgers Climate Institute, 2013). Of equally great concern, future rates of sea-level rise in the region are projected to nearly double.

Estuaries and coastal areas are particularly vulnerable to sea-level rise and other aspects of climate change such as higher temperatures, more precipitation, invasive species, and more frequent and intense storms, which makes our collective response to sea-level rise and changing climate a top concern for BBP and our many stakeholders. Recognizing Barnegat Bay's vulnerability to climate change impacts, BBP engaged experts to assess the Revised CCMP Actions to determine the degree to which the implementation of these Actions may be impacted by climate



change (BBP, CCMP Vulnerability Assessment) (Yozzo, 2019). The subsequent sections address the identified climate change risk factors, and which Actions are most impacted by these risk factors.

8.2 Identification of Risk Factors and Consequences

The consequences of a changing climate are forecast to pose significant threats to New Jersey's natural ecosystems and wildlife. Recognized climate stressors include the following:

- ***More variable summer/winter weather*** - One projected outcome of climate change is a greater degree of climate variability, including more intense precipitation/storm events, during both summer and winter seasons (Kopp R. A., 2016). More intense precipitation could cause more flooding and erosion in streams and rivers, impacting fish and aquatic invertebrate populations. More frequent and destructive flooding may result in riparian landowners to reinforce or "harden" river and stream banks to protect property and infrastructure, further altering important habitats and natural areas. A projected trend towards warmer winter temperatures will allow species which are intolerant of colder weather, including problematic invasive plants, insects and pathogens, to expand their ranges into New Jersey, impacting native wildlife and their habitats. For avian species, shifts in nesting times or egg incubation durations can limit breeding success and recruitment. Changes in the seasonal cycles of plants and animals can lead to increased competition for resources and hybridization among species, as north-south distribution patterns change (NJDEP, 2017).

- ***Increases in oceanic, estuarine and freshwater temperatures*** - Increases in water temperature due to climate change are already occurring in marine and estuarine systems along the Atlantic coast. Most estuarine and aquatic species are adapted to living within an optimal temperature range, and departures from that range can cause stress, leading to reduced feeding, impaired reproductive cycles, altered metabolic rates, and in some cases, direct mortality. Warming of ocean waters reduces the total amount of dissolved oxygen (DO) that can be held in water and increases the demand for oxygen in cold-blooded aquatic animals, directly affecting fish survival and health (Najar, 2000). Warmer waters can increase plankton blooms which decreases water clarity. Additionally, warmer waters have significant negative impacts on SAV (especially eelgrass) growth and survival through warmer summer months. Harmful algal blooms (HABs), triggered by elevated water temperatures, can discolor coastal waters (typically red, yellow or brown) and may cause negative impacts on fish and shellfish, including hard clams and scallops (Hallegraeff, 2010), as well as on seagrasses. Higher water temperatures will also affect New Jersey's rivers, streams, and freshwater wetlands, potentially impacting freshwater fish, turtles, amphibians, and invertebrates, which may not be as adaptable as marine/estuarine species (NJDEP, 2017) (Gobler, 2017).

- ***Increased/prolonged drought conditions*** - As the population in the Bay's watershed has grown, the amount of water withdrawn from rivers, streams, and aquifers for human uses has increased. Greater withdrawals can result in reductions in stream base flow, causing

changes in the timing and amount of fresh water reaching the estuary. This also concentrates nutrient and pollutant loadings, which in turn may alter water quality and habitat for both resident and transient species (Abs, 2016). Anticipated higher summer temperatures may result in more frequent short-term summer droughts and lower stream and river flows in summer, exacerbating this problem. Higher evaporation (and evapotranspiration) rates, throughout the growing season but especially in the summer, will further reduce groundwater recharge and increase soil moisture losses, reducing stream flows. In addition, lower water levels in rivers and streams could impede fish access to spawning and overwintering areas. Drought conditions may impair and isolate important wildlife habitats in the upper watershed, such as vernal pools (NJDEP, 2017). And extended drought conditions, combined with warmer winters/summers, will encourage insect pest outbreaks and invasions by non-native plant species, which will affect survivability of native tree species in riparian and forested habitats (NJDEP, 2017).

- ***Increased frequency and magnitude of storms*** - The Union of Concerned Scientists project that the seasonal average temperatures across most of New Jersey will rise 7°F to 12°F above historic levels in winter and 6°F to 14°F in summer by late century (Union of Concered Scientists, 2006). Under these scenarios, New Jersey can expect a dramatic increase in the number of days over 100°F. As temperatures have risen, temperate zones like New Jersey have seen an earlier onset of spring. This can have severe consequences for our native flora and fauna, which rely on these temperature changes as a cue for important life history events.

  Likewise, changes in precipitation patterns are projected to bring an increase in the frequency of heavy precipitation storm events (Kopp R. A., 2016). An increase in overall storm intensity would raise the threat of greater storm surges and more devastating coastal flooding throughout the Bay. A projected continued increase in sea level rise in future decades will exacerbate these problems (Strauss , 2014). Marine/estuarine, freshwater and terrestrial wildlife are likely to experience a wide range of impacts associated with an increase in storminess, including: impacts on critical breeding, nesting and foraging areas for seabirds, shorebirds, terrapins and horseshoe crabs; changes to offshore or back-bay benthic environments; increased water column turbidity; and damage to SAV beds (NJDEP, 2017). In the upper reaches of the watershed, more intense precipitation will induce more flooding and erosion in streams and rivers, with a variety of potential impacts on fish, freshwater mussels, and other aquatic invertebrates. Furthermore, increased flooding may motivate landowners within coastal and riparian areas to reinforce or "harden" shorelines to protect properties and infrastructure, further impacting critical wildlife habitat.

- ***Sea Level Rise*** - Sea level rise is predicted to be greater in New Jersey than the global average due to coastal subsidence (Strauss , 2014). Since the land is sinking while sea level is also rising, this creates a higher local "relative rate of sea level rise." The effects of predicted rates of sea level rise in the coming decades along the New Jersey's Atlantic coast will result in substantial changes in coastal features, including tidal marshes, shallow-open water habitats (including SAV beds) and coastal uplands. Sea level rise will

also result in an increase in salinity throughout the Bay, and affect the distribution, abundance and life history patterns of plants and animals which are dependent on these imperiled coastal habitats (Haaf e. a., 2015). In addition to the effect of sea level rise alone, the bay will experience higher salinity levels due to reduced stream base flows.

Tidal wetlands (salt, brackish and freshwater tidal marshes) provide essential ecosystem services to the coastal communities of Barnegat Bay, including essential habitat for estuarine-dependent fish and wildlife species, flood protection, water quality improvements, nutrient retention/cycling and carbon sequestration cycling. These services benefit the surrounding natural and human communities of the bay and its watershed (BBP, State of the Bay Report, 2016). Sea level rise will also increase saltwater intrusion into inland freshwater systems, including tributary streams which provide spawning habitat for anadromous fish, and will contribute to the salinization of coastal aquifers that residents of the Barnegat Bay watershed rely on (Abs, 2016). Areas of high salt marsh will eventually convert to low salt marsh, threatening wildlife species that depend on high marsh habitat. Sea level rise will also eventually promote the transition of some upland habitats to tidal wetlands, potentially displacing resident terrestrial species (Haaf e. , 2015) (NJDEP, 2017).

- ***Ocean Acidification*** - In recent years, ocean acidification (a decrease in the pH of ocean waters) has raised concern among climatologists, marine ecologists and coastal resource managers. The primary consequence of increased acidification is the potential inhibition of marine invertebrates' (including many commercially important species such as clams and oysters) ability to incorporate calcium in the formation of shells and exoskeletons.

8.3 Impacts on BBP CCMP Priorities and CCMP Action Implementation

A vulnerability assessment is a means to gain consensus on the range of potential impacts to the Barnegat Bay's watershed. Potential impacts range from threats to coastal infrastructure (such as public access and recreational facilities, water-dependent businesses, and public water supply and sewer pipelines) to impacts on the effectiveness of natural resource and water supply planning, mapping, and public education programs. The goals of conducting a vulnerability assessment are to:

- Provide essential context for communication, coordination and decision support among regional partners and stakeholders (*e.g.*, municipalities, public utilities, educational institutions, and public advocacy groups), and
- Obtain funding, resources, buy-in or regulatory approval.
- Serve as a tool that can help answer questions about risks and mitigating options in the development of a regional climate resilience action plan (USEPA, Planning for Climate Change Adaptation, 2014).

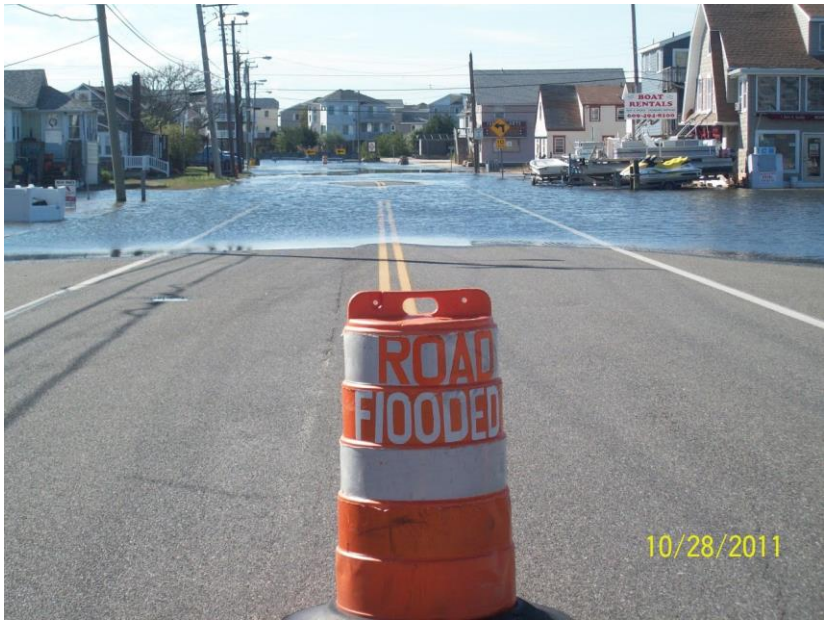


Figure 8.2. – Flooded Road in Coastal Community

Among the four BBP programmatic focus areas, certain consequences of climate change and strategies for adaptation to, and mitigation for, impacts were identified as "high-priority" and in greatest need of response. These Barnegat Bay specific consequences and recommended actions are summarized as follows for each of the major programmatic priority areas.

8.3.1 Water Quality

In the future, increased variability and unpredictability in stream flow will alter water quality and water supply within Barnegat Bay and its tributary watersheds. Various climate change stressors will change the loads and pathways of nutrients and other pollutants (including pathogens), potentially decrease dissolved oxygen concentrations in surface waters, and potentially affect monitoring programs and implementation of the nutrient TMDL now under development. More variable summer weather, including more frequent/intense storms, is likely to affect water quality, human use and monitoring programs at public recreation beaches. This may also increase pollution impacts from boating activities and marinas throughout the bay.

Increased runoff associated with stronger, more frequent storms will affect the conveyance of polluted runoff from roadways (deicers), automobiles (hydrocarbons), and yard maintenance (pesticides, insecticides, and fertilizers) throughout the Barnegat Bay watershed.

Future damage to existing stormwater systems from anticipated increases in stream erosion and sea level rise will challenge efforts to satisfy existing regulatory requirements for system maintenance. Saltwater intrusion will increase corrosion of concrete and steel water supply and wastewater system pipelines, necessitating more frequent replacement and/or upgrades. Damage to municipal water or sewer systems from stream erosion and inundation of outfalls from sea level rise can result in uncontrolled release of pollutants to streams and the estuary, increasing the existing challenges of meeting TMDLs as well as the development and implementation of watershed plans.

The BBP STAC identified the following priority actions pertaining to water quality that could be impacted by one or more climate stressors, potentially inhibiting implementation.

WQ 1-1	*Support development and implementation of a Barnegat Bay nutrient TMDL (Total Maximum Daily Load.*
WQ 1-2	*Develop/revise and implement Watershed Plans at the sub watershed level*
WQ 1-5	*Identify and map all stormwater facilities and outfalls; develop tools, assess, prioritize, and implement basin retrofits to reduce nutrient and sediment loadings to the bay.*
WQ 1-6	*Identify sources and reduce pollution inputs from roadways and yard maintenance*
WQ 1-9	*Identify sources and reduce pollution inputs from livestock, agriculture and wildlife.*
WQ 3-1	*Support completion and expansion of source tracking for bacteria, pathogens, and novel and other pollutants*

8.3.2 Water Supply

The most important actions for water supply involve additional monitoring/assessment, to improve forecasting of potential impacts on stream base flow and maximizing the extent to which base flow is maintained and enhanced, including the minimization of consumptive and depletive ground water withdrawals from surficial aquifers. Reduced base flows from recharge losses and increased water demands will change the estuary's salinity profiles, which will also require enhanced monitoring to track changes and responses. Increased runoff will concentrate pollutants in waterways, and monitoring programs should be designed to capture major storm events and detect elevated pollutant concentrations associated with extreme weather. Additional research and monitoring is needed to better understand the extent to which increased storm intensity will change flood frequency, and floodplain/riparian zone delineation and mapping. These changes will, in turn, affect how water supplies throughout the Barnegat Bay watershed can be protected through the protection and restoration of tributaries and riparian areas.

The BBP STAC identified the following priority actions pertaining to water supply that could be impacted by one or more climate stressors, potentially inhibiting implementation.

WS 1-1	*Assess and implement existing shallow groundwater protection programs including wellhead protection and rainwater and treated wastewater recharge. Evaluate and implement new septic designs that may better address the release of nutrients and anthropogenic compounds to groundwater*
WS 1-2	*Determine minimum ecological flow requirements for streams, rivers and wetlands within the watershed*
WS 1-3	*Assess watersheds for water supply capability related to streamflow, surface water, shallow groundwater withdrawal capacity, and ecological impact*
WS 4-1	*Identify infrastructure, research and piloting options for the use of advanced treatment at wastewater treatment plants and water reuse, including wastewater and gray water, within the watershed.*

Sea level rise and increased storminess have been identified as the primary climate stressors that will impair the ability to implement the recommended water supply actions. To address this, BBP and its partners can implement the following Actions:

- *WS 1-4, 2-4: Support comprehensive planning (including open space acquisition/ conservation) that will guide sustainable water supply management. Identify, implement and support voluntary and mandated conservation and infiltration practices and regulation to maintain and restore base stream flows and natural hydrology to the maximum extent possible;*
- *WS 1-5: Promote and support land use activities that enhance water supply protection and minimize water withdrawals and usage, especially in the most stressed water supply planning areas as identified in the State Water Supply Master Plan; and*
- *WS 3-4, 4-2: Assess effects of current and projected surface water and groundwater withdrawals and conduct research on sea level rise/saltwater intrusion impacts on regional water supplies.*

8.3.3 Living Resources

The ability of coastal scientists, resource managers and restoration practitioners to monitor the Bay's natural resources and landforms, and to implement effective conservation and restoration strategies, will be challenged in the future. Sea level rise will gradually render baseline mapping of sensitive habitats obsolete, requiring regular updates of current mapping resources and databases to keep pace with the Bay's changing environment. The direct and indirect effects of sea level rise will gradually render baseline mapping of the Bay's wetlands, including tidal marshes and riparian buffers, obsolete, requiring recurring updates. Ongoing tidal wetland monitoring programs (*e.g.,* MACWA) will require continuation and expansion to capture changes occurring throughout the Bay, with regular updates commensurate with the rate of change being experienced by the system. Wetland restoration and enhancement (including the use of "thin-layer" dredged material placement) should be prioritized and tied into a bay-wide sediment management plan.

With an anticipated increase in the frequency and magnitude of coastal storms, and the increased potential for ecosystem and infrastructure damage or disruption, the nature and frequency of post-disturbance monitoring may change, requiring more frequent monitoring events (and more rapid mobilization of monitoring staff and resources throughout the Bay). Concerns regarding the safety of monitoring personnel, from agencies, research institutions, and NGOs will likely increase, especially for those staff involved in projects which involve operation of vessels and/or accessing remote coastal locations, under conditions of increased storm frequency and magnitude.

Potential challenges associated with designing and implementing effective natural resource mapping and monitoring programs were identified. For example, sea level rise may eliminate SAV in areas where it presently occurs, while providing opportunities for new areas to be colonized in the future. SAV mapping for the Bay requires periodic updates and monitoring frequently enough to detect system-wide declines at a point when management interventions can be effective and/or not too costly. Additionally, with increased frequency and intensity of storm events due to climate change, it will become imperative to monitor SAV beds within the Bay

after large storms in order to track ecosystem recovery. Although impacts to the Bay's SAV resources are anticipated in the future, consequences can be mitigated through a more comprehensive mapping effort, with periodic updates commensurate with the rate of change being experienced by the system.

Similar concerns exist regarding the ability to track impacts on the Bay's remaining tidal wetlands, already considered moderately to severely stressed and at substantial risk from erosion, changes in sediment and nutrient availability, and prolonged inundation. The Bay's freshwater wetlands are also at risk of direct loss and/or alteration from sea level rise and more variable/intense weather. Saltwater intrusion into freshwater areas can occur in short bursts during storms or over longer time periods from a gradual increase in sea level rise. In either case, increasing salinity in the Bay's tributaries will alter the composition of freshwater wetlands (*e.g.*, loss of Atlantic White Cedar forest).

The BBP identified the following priority actions pertaining to living resources that could be impacted by one or more climate stressors, potentially inhibiting implementation.

LR 1-1	*Compile existing data, identify missing data and map sensitive habitats*
LR *1-2*	*Use this information to support the development and implementation of conservation and/or restoration plans for ecologically sensitive habitats and associated buffers*
LR 2-2	*Restore fish passage and other riparian habitats to improve habitat quality and connectivity*
LR 2-4	*Create and restore wildlife corridors for habitat quality and connectivity*
LR 2-5	*Monitor, manage, and control invasive and nuisance species (estuarine, freshwater and terrestrial) through ecologically appropriate methods;*
LR 3-2	*Continue the ongoing Mid Atlantic Coastal Wetlands Assessment program (MACWA) to evaluate the condition and function of wetlands*
LR 3-3	*Update and/or complete mapping of riparian and tidal wetlands buffers to evaluate and monitor status and health*

Warming temperature trends, drought, sea level rise and increased storminess have been identified as the primary climate stressors that will impair the ability to implement the recommended actions. To address these, BBP and its partners can implement the following Actions:

- *LR 3-4 and 3-5: Monitor and assess target "at-risk" animal and plant species, such as pollinators and migratory species, threatened and endangered species, and plant communities of interest; and*
- *LR4-1: Conduct studies that identify and document the life history and/or ecology of pertinent living resources and develop appropriate mechanisms and strategies (including experiments and pilot studies) to support conservation and restoration of sensitive habitats and critical ecosystem services.*

8.3.4 Land Use

As climate changes, communities in the Barnegat Bay watershed will become increasingly vulnerable to permanent inundation from rising sea levels, more frequent nuisance flood events, and more intense coastal storms and precipitation. Areas in the watershed are already experiencing nuisance flood events with increasing frequency. It is anticipated that increasing frequency and duration of droughts will impact water reserves, and saltwater intrusion may contaminate groundwater aquifers.

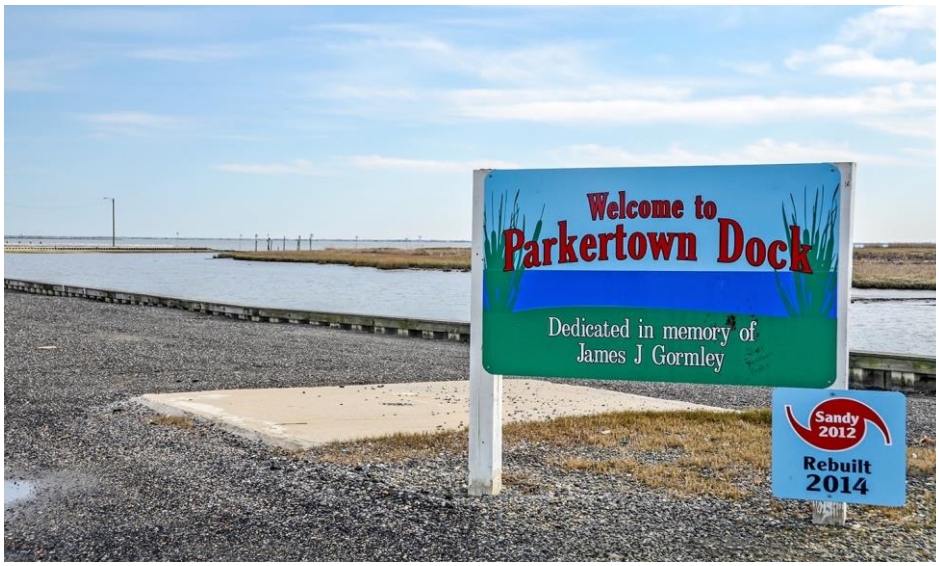
Successful and effective implementation of current and future open space plans throughout the watershed must ensure that water-dependent uses are prioritized. With warmer summers and increasing heavy precipitation events, increasing green spaces in developed areas will be important for climate change adaptation. Because the watershed encompasses many municipalities, promoting and encouraging conservation and management across municipalities is critical for biodiversity conservation as well as climate change adaptation and resilience. Limiting the development of forested lands to support water conservation and recharge areas, as well as habitat for at-risk species, will also be necessary. The BBP and its partners should promote natural area conservation and green infrastructure in urban/ suburban areas of the watershed. Natural areas and green infrastructure (bioswales, green roofs, green walls, *etc.*) in urban and suburban areas are important to mitigate high temperatures, intercept stormwater and increase water quality.

The BBP STAC identified the following priority actions pertaining to land use that could be impacted by one of more climate stressors, potentially inhibiting implementation.

LU 4-3	*Promote a balanced, collaborative and coordinated approach to dredging and dredged material placement (including beneficial use of dredged materials)*
LU 5-1	*Identify the social, economic and environmental impediments and solutions for implementing sustainable land use practices on existing and future private developments (including "green" and "gray" infrastructure)*

The BBP STAC identified sea level rise and increased storminess as the primary climate stressors that will impair the ability to implement the recommended actions. To address these, BBP and its partners can implement the following Actions:

- *LU 2-7: Present and future land conservation and management decisions should 1) consider upland areas that allow for marsh migration, habitat for species-at-risk, and continued long-term public access to the Bay; 2) conserve and enhance forestry areas with multiple ecosystem benefits.*
- *LU 3-3: Promote acquisition and management of lands towards achieving community and natural resource protection and resilience, including recreation and the cultural heritage of the Barnegat Bay through implementation of current and future watershed-wide open space plans.*


Welcome to
Parkertown Dock
Dedicated in memory of
James J Gormley
Sandy
2012
Rebuilt
2014