BBP CCMP Vulnerability Assessment Report

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EXECUTIVE SUMMARY

The consequences of a changing climate are expected to threaten New Jersey's natural ecosystems and wildlife. The Barnegat Bay Partnership (BBP) has conducted a Climate Vulnerability Assessment, following USEPA guidelines, to engage stakeholders and gain consensus on the range of potential climate impacts to the Bay and its watershed. As part of the revision to their Comprehensive Conservation and Management Plan the BBP developed a list of priority goals, objectives and actions under the categories of Water Quality, Water Supply, Living Resources, and Land Use, and solicited input from regional stakeholders concerning how climate change and its effects would impact those actions.

Sea level rise and increased storminess were identified as the primary climate stressors that will impair our ability to implement priority water quality, water supply and land use actions. Warming temperature trends, drought, sea level rise and increased storminess were identified as the primary stressors that will impair the ability to manage the Bay's living resources and sensitive habitats, including wetlands, floodplains and submerged aquatic vegetation. Among the four focus areas, certain consequences of climate change were identified as "high-priority" and in greatest need of response, through new planning guidelines, management strategies, continued monitoring and infrastructure development. In the future, greater stream flow variability will alter water quality and water supply within the Bay and watershed. Damage to stormwater systems from stream erosion and sea level rise will challenge regulatory requirements for system maintenance. The ability to monitor the Bay's natural resources and implement effective conservation and restoration strategies will be challenged. Sea level rise will gradually render baseline habitat mapping, including tidal marshes and riparian buffers, obsolete. These habitats will become increasingly vulnerable to inundation from more intense coastal storms. Open space planning throughout the Bay should ensure that water-dependent uses are prioritized and promote biodiversity conservation and management among the Bay's municipalities, as well as climate change adaptation and resilience.

INTRODUCTION

The Barnegat Bay Estuary

The Barnegat Bay-Little Egg Harbor (BB-LEH) watershed is approximately 670 square miles in area, encompassing nearly all of Ocean County, as well as small portions of Monmouth and Burlington Counties (Figure 1). It is comprised of a mosaic of different natural habitats and human altered lands (urban, suburban, agricultural). One of the most iconic landscapes within the estuary and watershed are intertidal wetlands. In addition to providing essential food, nursery and refuge habitats for many estuarine-dependent fishes and shellfishes and other wildlife species, intertidal wetlands also provide critical ecosystem services, including flood protection, water quality improvements, nutrient retention/cycling and carbon sequestration (BBP 2016). Another critical component of the Barnegat Bay ecosystem is submerged aquatic vegetation (SAV). SAV provides essential habitat and food for many recreationally and commercially important estuarine and marine species, and fulfils a similar role in providing ecosystem services

in subaquatic habitats. These habitats, and others throughout the watershed, are impacted by a variety of stressors, including high nutrient levels and encroaching human development (shoreline hardening, loss of buffers, failed and/or inadequate stormwater infrastructure, forest loss, etc.).

Climate change is also impacting the health and biological integrity of the Bay, exacerbating the effects of the degradation factors described above. Rising average air and water temperatures, more frequent and extreme weather events, and steadily rising sea levels are already changing baseline conditions and affecting the Bay's aquatic habitats and biota. The magnitude of these ecological changes is expected to increase in the future (BBP 2016).

Climate Change – Global and Regional Patterns

Globally, climate change has resulted in a variety of ecological and socio-economic impacts. The Intergovernmental Panel on Climate Change (IPCC 2014) has documented an average global temperature increase among land and ocean surfaces of 0.85 °C between 1880 and 2012. Additionally, the upper ocean (0 to 75 m) has, on average, warmed by 0.11 °C every decade since the early 1970s. Throughout the mid-Atlantic coastal region, projected air temperature changes by 2050 (in comparison with a 1990 baseline) are anticipated to increase approximately 1.0 to 1.5 °C (Najjar *et al*. 2000). Along with temperature increases, extreme precipitation events over mid-latitude land masses are likely to become more intense and more frequent by the end of the 21st century (IPCC 2014). Heavy rainfall events can cause flooding, streambank erosion, and increases in the rate and amount of nutrients and sediments delivered into estuaries and coastal waters. Surface water warming is the primary trigger for the onset of harmful algal blooms (HABs), which may impair fish survival in coastal waters (Gobler *et al.* 2017). However, once a bloom has commenced, other factors such as nutrients, hydrodynamics, and grazing determine its magnitude and duration (Hallegraeff 2010). The greatest concern for human communities in the coastal zone is HAB species that produce neurotoxins; these can transmit through consumption of shellfish and fish and produce a variety of gastrointestinal and neurological illnesses (O'Neil et al. 2012). Finally, elevated ocean acidity caused by increased atmospheric CO_2 absorbed by ocean surface waters may impair survival of sensitive fish and invertebrate larvae (Wallace et al. 2014) and marine taxa that produce carbonate skeletons (*e.g.*, shellfishes, corals) (Talmage and Gobler 2011, Gazeau *et al.* 2013).

Climate Change in New Jersey

The impacts of climate change have already been observed in New Jersey. Sea levels along the New Jersey shore have risen faster than the global average, in part to due to land subsidence. At Atlantic City, where records extend back to 1912, sea level has risen by an average rate of 3.8 cm per decade over the period of record (Rutgers Climate Institute 2013). In the coming decades, warmer average temperatures are forecasted to occur in all seasons. Precipitation has been and likely will continue to exceed historical averages, primarily resulting from more intense storms. More variable stream flows, with higher peaks during intense storm periods, are predicted. Increased drought frequency will reduce ground water recharge, reducing stream base flows and freshwater inputs to the estuary (Kopp *et al*. 2016).

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. Coastal areas are at risk of submergence due to increases in sea level and alteration of barrier islands, inlets and other coastal landforms from more intense and frequent coastal storms (Strauss *et al*. 2014). The major climate impacts and risks for terrestrial resources, such as forests, include warmer summers and winters, drought and invasive species. The major climate change threats for tidal and non-tidal wetlands are sea level rise and drought. Streams and riparian areas within New Jersey's watersheds are threatened by more frequent, heavier precipitation events, droughts and warmer water temperatures.

The consequences of a changing climate, including sea level rise, 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 of the projected outcomes of climate change in the New Jersey region is a greater degree of climate variability, including more intense precipitation/storm events, during both summer and winter seasons (Rutgers Climate Institute 2013, Kopp *et al*. 2016). More intense precipitation could cause more flooding and erosion in streams and rivers, impacting characteristic assemblages of fish and aquatic invertebrates. More frequent and destructive flooding may induce landowners within riparian areas 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. Some species (*e.g.*, surf clams, lobsters, hake) have responded by shifting their distributions into deeper, cooler waters; many mid-Atlantic and southern species have expanded their native ranges northward, becoming established in southern New England estuaries (Collie *et al*. 2008). 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. For example, oceanic warming 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 (Najjar *et al*. 2000). Warmer waters can increase plankton blooms in an unpredictable fashion 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 physiological impacts on fish and shellfish, including hard clams and scallops (Hallegraeff 2010, Gobler *et al*. 2017), as well as on seagrasses (via light reduction and inhibition of photosynthetic capacity). Higher water temperatures will also affect New Jersey's rivers, streams, and freshwater wetlands, potentially impairing freshwater fish and other aquatic organisms, including turtles, amphibians, and invertebrates, which may not be as adaptable by shifting distributional ranges, in comparison to marine/estuarine fauna (NJDEP 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 base flow, causing changes in the timing and amount of fresh water reaching the estuary, and concentrating nutrient and pollutant loadings, which in turn may alter water quality and habitat for both resident and transient species (Van 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 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). In contrast, shorter and milder winters would potentially increase recharge rates, but this benefit would likely be offset by a longer growing season (increased evapotranspiration). Similarly, higher annual precipitation could potentially increase recharge in natural areas, but more intense storms will increase runoff, especially in developed areas of the Bay's watershed, at the expense of recharge (Van Abs 2016). Finally, 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

Changes in precipitation patterns are projected to bring an increase in the frequency of heavy precipitation storm events (Rutgers Climate Institute 2013, Kopp *et al*. 2016). An increase in overall storm intensity would raise the threat of greater storm surges and more devastating coastal flooding throughout the Bay, along with changes in the pattern of sediment supply and erosion in the bay's coastal and freshwater wetlands. A projected continued increase in sea level rise in future decades will exacerbate these problems (Strauss *et al*. 2014).

Marine/estuarine, freshwater and terrestrial wildlife are likely to experience a wide range of impacts associated with an increase in storminess, including inundation, degradation and alteration of 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 (including smothering/siltation of nesting, rearing, and foraging habitat). 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. Severe storms can also result in extensive tree damage, altering forest structure, which impacts nesting/roosting opportunities for various avian species, including colonial waterbirds in coastal and maritime forests (NJDEP 2017).

Sea level rise

Sea level rise is predicted to be greater in New Jersey than the global average due to coastal subsidence caused by post-glacial rebound (Strauss *et al*. 2014, Kopp *et al*. 2016). 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 the geomorphology of coastal features, including tidal marshes, shallow-open water habitats (including SAV beds) and coastal uplands. Sea level rise will also alter water chemistry (through 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 *et al*. 2015). In addition to the effect of sea level rise alone, the bay will experience higher salinity levels due to reduced stream base flows, though this effect may be mitigated somewhat by higher annual average precipitation (as described previously). However, more frequent droughts and higher summer evapotranspiration rates may offset the advantage of higher average precipitation (Van Abs 2016).

Coastal 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 2016). Under the predicted range of sea level rise rates in coastal New Jersey, inundated and eroded salt marshes would be replaced by intertidal flats, possibly providing a benefit for migratory shorebirds and waterfowl, but at the expense of suitable nesting habitat for marsh-breeding birds (NJDP 2017). 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 (Van 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 *et al*. 2015, NJDEP 2017).

If tidal wetlands are afforded the opportunity to gradually migrate landward, they can persist – especially if the rates of sea level rise are on the lower end of predicted rates over the next several decades, and sufficient sediment is available to maintain accretion rates on par (or in exceedance of) rates of sea level rise. However, because Barnegat Bay is a lagoon (and therefore lacking a major riverine sediment source), its coastal wetlands are generally sediment-starved (Ganju *et al.* 2014). Additional, interactive factors which determine whether or not coastal wetlands keep pace with sea level rise include plant productivity, nutrient loading, wave energy, and land subsidence (Haaf *et al*. 2015). Finally, even if the average rate of sea level rise was

slow enough to allow tidal wetlands to migrate inland, areas providing this opportunity are extremely limited as a result of human development and infrastructure (Strauss *et al.* 2014).

Ocean acidification

In recent years, ocean acidification, *i.e.*, an ongoing decrease in the pH of oceanic surface waters due to anthropogenic increases in atmospheric CO_2, 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. However, while acidification in the open ocean is driven by external, atmospheric CO_2 loading, the contribution of atmospheric CO_2 in temperate estuaries and coastal zones is thought to be relatively minor compared to internal CO_2 loading processes such as organic matter production (Wallace *et al.* 2014). For example, in portions of Barnegat Bay, expansive nuisance macroalgae blooms occur seasonally and rapidly decompose, releasing nutrients and providing a large CO_2 subsidy, potentially diminishing pH in the Bay, especially in areas with restricted tidal circulation patterns.

BARNEGAT BAY PARTNERSHIP'S CLIMATE CHANGE PLANNING

The Barnegat Bay Partnership
The Barnegat Bay Partnership (BBP), originally established in 1997 as the Barnegat Bay National Estuary Program (BBNEP), 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 mission of the BBP is 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). *Ad hoc* Technical workgroups (*e.g.*, the Eutrophication Workgroup, Shellfish Workgroup, Climate Change Workgroup) provide support on specific issues as needed.

The BBP's original Comprehensive Conservation and Management Plan (CCMP) was completed and approved by its partners in May 2002. The CCMP was supplemented by a 2008-2011 Strategic Plan in which the BBNEP partners identified key priority issues and tasks to accomplish the objectives of the CCMP. A second Strategic Plan was completed for 2012- 2016, focusing the efforts of all partners on those priority challenges facing the ecosystem along with a time frame for tracking progress and performance measures. The BBP is currently in the process of revising their CCMP. As part of this revision, the BBP and its partners recognize that climate change and its effects can potentially have far –reaching impacts on the estuary and watershed, and as such should be included in their planning process. This is being accomplished through a Climate Change Vulnerability Assessment.

Climate Change Vulnerability Assessment

Vulnerability assessment is a means to engage stakeholders and gain consensus on the range of potential impacts to the Barnegat Bay's watershed. Potential impacts are not limited to changes in the ecology, hydrology or water quality of the Bay. They 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. A vulnerability assessment is often a precursor to a coastal resiliency action plan, but it can 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) to obtain funding, resources, buy-in, or regulatory approval. Finally, a vulnerability assessment represents a tool that can help answer questions about risks and mitigating options in the development of a regional climate resilience action plan (EPA 2014).

METHODS

We employed the EPA-recommended procedure[1] for conducting an estuary-wide Climate Vulnerability Assessment described in the U.S. Environmental Protection Agency's (EPA 2014) *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans*. The EPA climate vulnerability assessment process identifies five general steps.

Step 1—Communication and Consultation

The BBP implemented this step in several ways. First, the initial review of CCMP and Strategic Plan goals, objectives, and actions plan by the BBP's CCMP Steering Committee comprised of representatives from all BBP committees and BBP staff. Several staff and partners received CCVA training from EPA and/or others familiar with the EPA process. The BBP staff and some partners discussed climate change in their review and considerations of all actions. After the Steering Committee completed its deliberations, all partners were asked to review the draft goals, objectives, and actions and to consider climate change in their consideration of the appropriateness of all CCMP components.

Step 2—Establishing the Context for the Vulnerability Assessment

Using its review of previous CCMP and Strategic Planning actions, the BBP Steering Committee, including BBP staff (**Appendix 1**), developed a list of priority goals, objectives and actions, including those susceptible to climate change. The BBP also solicited input from the public at more than 35 events regarding citizens' concerns, including climate change and its effects, throughout the watershed. All of the draft goals, objectives, and actions were then pulled together and shared with the BBP's Steering Committee, Advisory Committee, Science and Technical Advisory Committee, and Communication and Education Committee. Where

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[1] See EPA's 2016 National Estuary Program Comprehensive Conservation and Management Plan Revision and Update Guidelines, 5-3-16. EPA, Office of Water, Office of Wetlands, Oceans, and Watersheds. Washington, D.C.

appropriate, climate change was broadly incorporated into this document. That is, it was recognized that climate change potentially impacted many BBP priorities to varying, and in some cases, unknown degrees.

The goals of the CCMP can be divided into four categories as follows:

Water Quality - To protect and improve water quality throughout Barnegat Bay and its watershed by reducing the causes of water quality degradation to achieve swimmable, fishable and drinkable water, and to support aquatic life.

Water Supply - To ensure adequate water supplies and flow in the Barnegat Bay Watershed for ecological and human communities now and in the future.

Living Resources - To protect, restore, and enhance habitats in the Barnegat Bay and its watershed as well as ensuring healthy and sustainable natural communities of plants and animals both now and in the future.

Land Use - To improve and sustain collaborative regional approaches to responsible land use planning and open space protection in the watershed that protect and improve water quality, water supply, living resources, soil function and hydrology.

All of the objectives and actions that fall within each of the overarching goals can be found in **Appendix II**.

Steps 3 and 4—Risk Identification and Analysis

Risk identification and analyses were broken up into several components. A preliminary risk assessment worksheet was shared with all BBP committee partners and outside experts to gauge the risk of all draft CCMP actions to climate change. The worksheet included a listing of each CCMP Action under the Water Quality, Water Supply, Living Resources, and Land Use categories (an individual alpha-numeric designation was assigned for each) and a series of columns for the 7 climate change stressors previously identified (EPA 2014). All participants were asked to categorize the risks of each action attributable to individual stressors as high, medium, low, or none. That is, what is the level of risk that the BBP and its partners would be unable to successfully complete the action given that particular climate change stressor. *An indication of no risk suggests that the action should be able to be completed regardless of the climate stressor, while high risk suggests that there is a strong likelihood the action could not be successfully completed, or would need to be majorly modified, given that climate stressor.* To help ensure that all individuals participating in these preliminary assessments were familiar with potential vulnerabilities and climate stressors and the vulnerability assessment, all participants were provided common background materials (Rutgers Climate Institute 2013, Leichenko *et al.*

2014, NJCAA 2014a, 2014b, 2014c, Strauss *et al*. 2014, Kopp *et al*. 2016, Van Abs 2016, NJDEP 2017), together with the EPA (2014) workbook.

The preliminary climate vulnerability assessments for each action/stressor combination were compiled into one of four categories (high, medium, low, or none; color-coded as red, orange, yellow, and green, respectively) determined by the distributions of responses from all participants (**Appendix III**). Preliminary assessments identified a number of proposed CCMP actions whose successful completion would be relatively unaffected by climate change (*i.e.*, when risks = little to none), especially in the Land Use Priority Area.

Actions that were identified as having some significant risk (low, moderate or high) were then shared with the BBP's STAC and subject matter experts prior to a workshop held on December 13, 2018 at Ocean County College. Participants were asked to populate the spreadsheets in advance of the meeting identifying risk pathways, likelihood and consequence of stressor impacts, the spatial extent within the Bay and/or watershed, specific habitats affected, and anticipated time frame for the consequence to occur (**Appendix IV**).

The individual responses provided the starting point for discussions during the meeting and to provide more detailed information about the risks to those actions in the CCMP vulnerable to climate change stressors. The BBP STAC and local experts compiled these responses into a "CCMP Actions Affected by CC Stressors" summary matrix. Following the meeting, the BBP staff reviewed the outcomes and developed draft vulnerability summary tables for each of the CCMP priorities (*e.g.*, Water Quality, Water Supply, Living Resources, Land Use).

Step 5—Risk Evaluation: Comparing Risks

The information gathered at the STAC workshop was then used to produce a consequence/ probability (C/P) matrix for each focus area to assist with identifying how resilient BBP's proposed actions are to climate change. The purpose of a C/P matrix is to gain "a broad, risk-based assessment of climate change vulnerability in your system," and to find "agreement among management and key stakeholders about how the climate change risks will affect your organization" (EPA 2014). This is accomplished/visualized by charting the intersections of low, medium, and high climate change stressor consequences and likelihoods. Risks were highlighted as "low," "medium," or "high" in yellow, orange, or red according to the format established in the example C/P matrix in the EPA climate workbook EPA (2014). The discussions and products developed at the STAC meeting, including the C/P matrices for each programmatic focus area, were then forwarded to subject area experts for their independent review and assessment. The four C/P matrices and the subject area experts' assessments were then synthesized and integrated into this report, which was then subsequently reviewed by the BBP staff, STAC (including BBP Staff), and subject area experts.

RESULTS

Review and synthesis of the outcome of the STAC workshop by external subject matter experts resulted in the final consequence/probability matrices (**Appendix V**), which identify the subset of CCMP actions within each of the programmatic focus areas that were likely to be impacted by one or more climate stressors. In addition, STAC members and external subject matter experts provided recommendations, within each focus area, for future actions to be undertaken by BBP and its partners, to address potential impact and ensure that future management actions incorporate adaptive management and promote resiliency, to the maximum extent practical.

Water Quality/Water Supply

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

> *WQ 1-1, 1-2: Support development and implementation of a Barnegat Bay nutrient TMDL (Total Maximum Daily Load. Develop/revise and implement Watershed Plans at the sub watershed level;*

> *WQ 1-5, 1-6: 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 1-9, 3-1: Identify sources and reduce pollution inputs from livestock, agriculture and wildlife. Support completion and expansion of source tracking for bacteria, pathogens, and novel and other pollutants;*

> *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, 1-3: Assess watersheds for water supply capability related to streamflow, surface water, shallow groundwater withdrawal capacity, and ecological impact; and*

> *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.*

The STAC identified <u>sea level rise</u> and <u>increased storminess</u> as the primary climate stressors that will impair the ability to implement the recommended water quality/supply actions. To address these, the STAC further recommended that the BBP:

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/salt water intrusion impacts on regional water supplies.

Living Resources

The BBP STAC 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, 1-2: Compile existing data, identify missing data and map sensitive habitats. 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, 4-2: Restore fish passage and riparian habitats to improve habitat quality and connectivity;

LR 2-5: Monitor, manage, and control invasive and nuisance species (estuarine, freshwater and terrestrial) through ecologically appropriate methods; and

LR 3-2, 3-3: Continue and expand (Mid-Atlantic Coastal Wetlands Assessment (MACWA) related tidal wetland monitoring and mapping of riparian areas to capture changes occurring throughout Barnegat Bay.

The STAC identified warming temperature trends, drought, sea level rise and increased storminess as the primary climate stressors that will impair the ability to implement the recommended actions. To address these, the STAC further recommended that BBP and its partners:

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.

Land Use

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 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); and*

> *LU 4-3: Promote a balanced, collaborative and coordinated approach to dredging and dredged material placement (including beneficial use of dredged materials).*

The BBP STAC identified <u>sea level rise</u> and <u>increased storminess</u> as the primary climate stressors that will impair the ability to implement the recommended actions. To address these, the STAC further recommended that BBP and its partners:

> *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.*

> *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.*

SUMMARY

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, via explicit consideration and incorporation into new planning guidelines, revised management strategies, continued long-term monitoring programs and planned infrastructure development. These consequences and recommended actions are summarized as follows for each of the major programmatic priority areas.

Water Quality/Water Supply

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 and may increase pollution impacts from boating activities and marinas throughout the bay. Increased runoff associated with stronger, more frequent storms will affect the conveyance of pollutants derived 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 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. Lost recharge should be reclaimed wherever possible to increase base flows.

Finally, 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.

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. Stochastic events will require adjustments in the way that the Bay's ecological resources and coastal features are monitored and evaluated. 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.

Many of the identified climate-related constraints identified by BBP staff, STAC members and subject matter experts pertain to anticipated impacts on specific critical habitats throughout the Bay, including SAV beds, coastal wetlands, and riparian/tributary habitats. 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 needs to occur 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 were expressed by BBP staff, STAC members and subject matter experts 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. These stressors degrade critical habitat for fish and wildlife species which depend on the Bay's tidal wetlands, limit the amount of carbon sequestered and stored in wetland soils and peat, and alter patterns of biogeochemical cycling, which can affect primary production and decomposition processes associated with the capacity of tidal wetlands to maintain elevation and keep pace with sea level rise. 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 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.

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. To mitigate for these impacts, coordinated land use strategies

in the Barnegat Bay watershed should include the development of modifications or additions to the infrastructure required to mitigate water supply and water quality risks. Limiting the development of forested lands to support water conservation and recharge areas, as well as habitat for at-risk species, will also help mitigate future climate risks.

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. With warmer summers and increasing heavy precipitation events, increasing green spaces in cities will be important for climate change adaptation in the urban and suburban areas of the watershed.

Successful and effective implementation of current and future open space plans throughout the watershed must ensure that water-dependent uses are prioritized, and that other authorized waterfront uses are compatible to minimize conflicts among development, commercial and recreational activities. Finally, dredged materials can be a suitable resource for enhancing the resilience of communities through wave attenuation, possible reduction of flood risk through increased shore elevation, and creation of resilient coastal habitats for "at-risk" species. Dredged materials management planning in the Barnegat Bay watershed should seek to maximize benefits for flood resilience and ecosystem enhancement. 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.

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Figure 1 – A map of the Barnegat Bay watershed
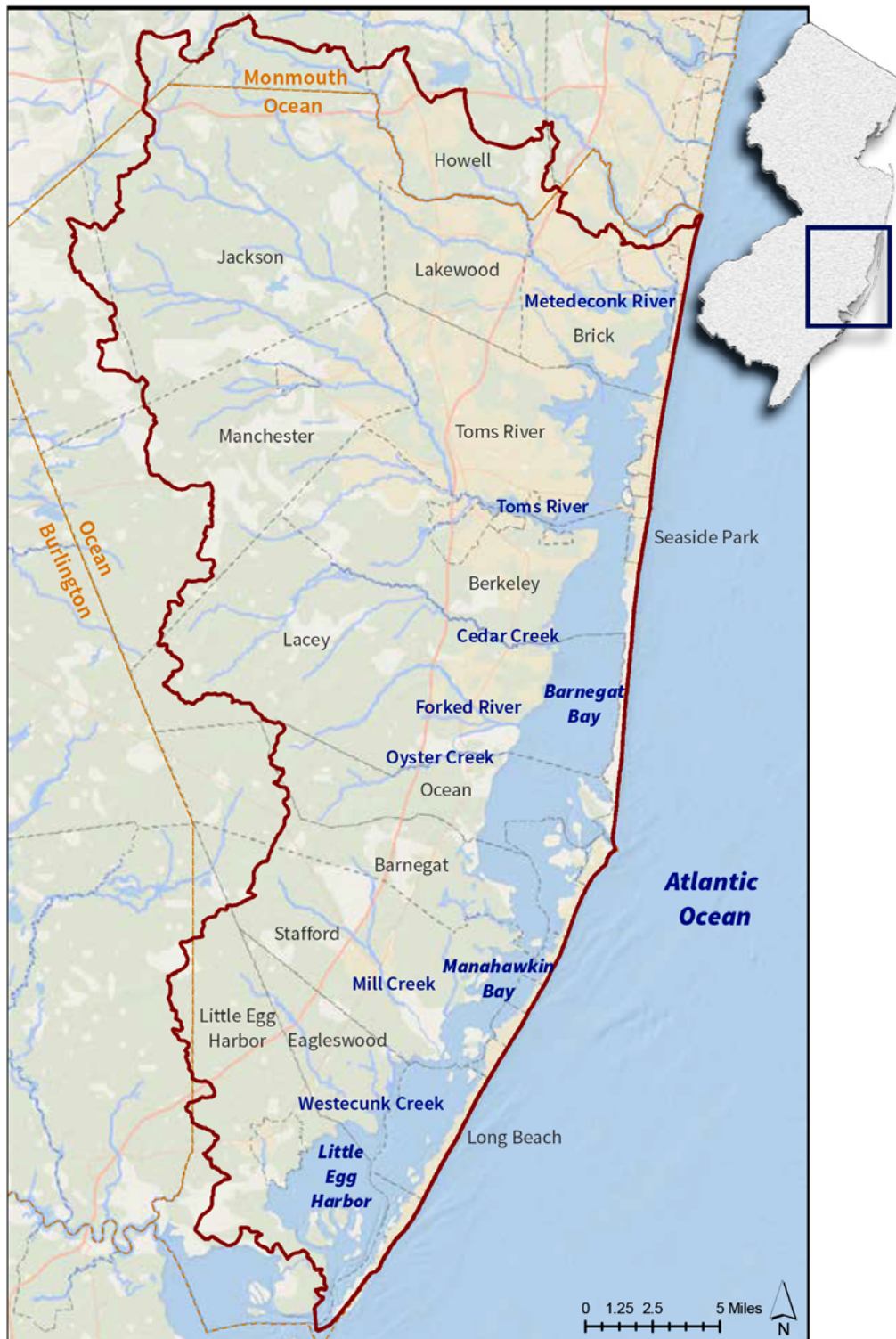
Appendices

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Appendix II – BBP Draft CCMP Objectives and Actions
Assessed for Climate Change Vulnerability

CCMP Objectives and Actions	
CCMP Objectives	**CCMP Action**
<u>**Water Quality 1:**</u> **Reduce sources of nutrients, contaminants, debris and other pollutant loadings.**	WQ 1-1: Support development & implementation of a Barnegat Bay nutrient TMDL (Total Maximum Daily Load).
"	WQ 1-2: Develop/revise and implement Watershed Plans (i.e., WQMP/319 and Watershed Based Plans) at the sub watershed level.
"	WQ 1-3: Implement the Soil Restoration Law & associated comprehensive soil restoration procedures.
"	WQ 1-4: Support implementation & enforcement of stormwater rules and ordinances at state, county and municipal levels.
"	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 mainte-nance (pesticides, herbicides, fertilizer, roadsalts, deicer and automotive waste).
"	WQ 1-7: Map all stormwater BMP facilities within the watershed associated with major development.
"	WQ 1-8: Identify sources and reduce pollution inputs from marinas & boating activities.
"	WQ 1-9: Identify sources and reduce pollution inputs from livestock, agriculture and wildlife.
<u>**Water Quality 2:**</u> **Assess status and trends of water quality throughout the watershed.**	WQ 2-1: Maintain, review, and revise as necessary the existing comprehensive water quality ambient monitoring program throughout the watershed.
"	WQ 2-2: Continue to identify the current status and trends in water quality within the watershed, and identify pollutant sources and loads.
"	WQ 2-3: Support the continuation of the existing beach monitoring program, and evaluate possible monitoring strategies for known public recreational areas of high public use.
<u>**Water Quality 3:**</u> **Conduct studies to improve under-standing of the science, conditions & the dynamics of the bay & watershed.**	WQ 3-1: Support completion and expansion of source tracking for bacteria, pathogens, and novel and other pollutants.
"	WQ 3-2: Continue to identify and address data gaps and water quality issues of emerging concern.
"	WQ 3-3: Continue to support research that identifies and quantifies the sources and fates of nutrients within the watershed and bay.

Water Quality 4: Increase public education, engagement, and stewardship regarding water quality.	WQ 4-1: Assist training and education/outreach programs to help municipalities meet MS4 permit compliance.
"	WQ 4-2: Share Barnegat Bay-friendly ordinances and establish a Jersey-Friendly Yards certification and training program for homeowners, businesses, and/or landscaping professionals.
"	WQ 4-3: Implement components of the BBP Communications Plan related to water quality improvement.
Water Supply 1: Protect, maintain and enhance existing water supply and surface and ground water flow.	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 and shallow groundwater withdrawal capacity, and ecological impact.
"	WS 1-4: Support comprehensive planning that will guide sustainable water supply management, and to the maximum extent possible, maintain natural hydrology.
"	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.
Water Supply 2: Prevent degradation of water supplies.	WS 2-1: Inventory and promote municipal land use regulations that emphasize water supply protection as a primary goal.
"	WS 2-2: Identify and acquire open space to support water supply protection, encourage natural recharge and reduce consumption.
"	WS 2-3: Establish and enforce 300-foot riparian buffers and pursue opportunities for green/blue acres acquisitions in buffer areas and floodplains.
"	WS 2-4: Identify, implement and support voluntary and mandated conservation and infiltration practices and regulation to maintain and restore base stream flows and natural hydrology.

"	WS 2-5: Inventory and evaluate municipal ordinances, rate structures and other available information for opportunities to better ensure judicious water usage and incentivize water conservation at the household and community levels; including metering all water usage.
Water Supply 3: Monitor & assess status and trends of water supplies throughout the watershed.	WS 3-1: Conduct shallow aquifer protection monitoring.
"	WS 3-2: Continue to monitor water use trends.
"	WS 3-3: Continue, and if possible expand, stream flow monitoring throughout the watershed to assess the effects of changing precipitation patterns, water use and development.
"	WS 3-4: Assess water-supply trends and effects of current and projected surface and groundwater withdrawals.
Water Supply 4. Conduct research to improve understan-ding of water con-servation, advanced potable treatment, and reuse.	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.
"	WS 4-2: Conduct research on the effects of sea level rise, salt water intrusion, and deicer/chloride on regional water supply and ecology.
Water Supply 5: Educate consumers regarding water supply issues and indoor/outdoor water conservation and reuse.	WS 5-1: Promote water reuse demonstration projects for stormwater, graywater and wastewater.
"	WS 5-2: Disseminate educational materials related to best practices for water conservation activities.
"	<u>WS 5-3</u> Develop program to educate stakeholders on the source and value of their water.
"	WS 5-4: Implement components of the BBP Communications Plan related to water supply protection.
Living Resources 1: Develop and implement Habitat Protection and Restoration Plans for ecologically sensitive habitats.	LR 1-1: Compile existing data and maps; determine and collect missing data for ecologically sensitive habitats and associated buffers.
"	LR 1-2: Develop & implement conservation and/or restoration plans for ecologically sensitive habitats.
"	LR 1-3: Create a web-accessible database of habitat protection and restoration activities.
"	LR 1-4: Encourage the protection & management of habitats on a sub-watershed basis through coordination across municipal boundaries.
"	LR 1-5: Promote management of ecologically sensitive and other target areas.

Living Resources 2: Restore & maintain sustainable populations of fishes and wildlife.	LR 2-1: Develop a bay-wide multi-use management plan that supports sustainable aquaculture, commercial and recreational harvest, recreation, and restoration.
"	LR 2-2: Restore fish passage and other riparian habitats to improve habitat quality and connectivity.
"	LR 2-3: Participate in the implementation and periodic update of the New Jersey State Wildlife Action Plan.
"	LR 2-4: Create and restore wildlife corridors for habitat quality and connectivity.
"	LR 2-5: Monitor, manage, and control invasive and nuisance species through ecologically appropriate methods.
Living Resources 3: Monitor & assess the status and trends of living resources through-out the watershed.	LR 3-1: Assess distribution and abundance of SAV through coordinated, regular surveys.
"	LR 3-2: Continue the Mid Atlantic Coastal Wetlands Assessment program to evaluate the condition and function of wetlands.
"	LR 3-3: Update and/or complete mapping of riparian and tidal wetlands buffers.
"	LR 3-4: Monitor & assess the status of commercially, recreationally, and ecologically important aquatic species.
"	LR 3-5: Monitor & assess target animal and plant species, including pollinator & migratory species, threa-tened & endangered species, and plant communities of special concern.
"	LR 3-6: Monitor & assess the impact of the closure of the Oyster Creek Nuclear Generating Station on the bay's living resources.
Living Resources 4: Conduct studies to improve scientific understanding of living resources and ecologically sensitive habitats.	LR 4-1: Conduct research to identify appropriate mecha-nisms and strategies to support restoration of ecolo-gically sensitive habitats identified in Obj. 1.
"	LR 4-2: Identify and assess habitat suitability, connectivity, and barriers to fish passage (e.g. North Atlantic Aquatic Connectivity Collaborative approach.)
"	LR 4-3: Conduct studies that identify and document the life history and/or ecology of pertinent living resources.
Living Resources 5: Increase education and public outreach related to habitats and living resources.	LR 5-1: Disseminate information to promote an understanding of science-based decision-making in the management of habitats and living resources.
"	LR 5-2: Develop educational materials, programs, and online resources to promote restoration of habitats and living resources (e.g., living shorelines, shellfish).

"	LR 5-3: Develop materials, programs, and online resources to educate about the functional role of critical bay habitats, such as seagrass beds and wetlands, and the early life stages of estuarine-dependent species.
"	LR 5-4: Produce educational materials, including online resources, about the impacts of climate change on the living resources of the bay.
"	LR 5-5: Promote an improved understanding of the economic and ecological importance of fisheries through fisheries programs and activities.
"	LR 5-6: Promote education and enforcement of regulations and best practices for respons-ible use of ecologically sensitive and target areas (e.g. personal watercraft and boating, off-road vehicles).
Land Use 1: Raise awareness and provide technical support to state, counties and municipalities to reflect and complement the CCMP goals and objectives in plans and land use practices.	LU 1-1: Align and expand existing municipal plans, BMPs, incentive programs and other related planning tools (e.g.,, Ocean County All-Hazards Mitigation Plan, GTR and Sustainable Jersey).
"	LU 1-2: Identify regulatory gaps and overlaps and promote planning tools (such as draft ordinances, policies and model language) that support sustainable land use development practices.
"	LU 1-3: Coordinate with muni-cipal, county, regional & state planning representatives to develop a Land Use Element (including Working Water-fronts, Regional Resilience, Restoration and Enhancement activities/ targets) for inclusion in their planning documents.
"	LU 1-4: Develop a BBP Recognition Award Program (incl. potential for funding availability to award recipients) for municipalities which are implemen CCMP Actions and coordinate in developing Barnegat Bay-wide Land Use Elements.
Land Use 2. Encourage economically and environmentally sustainable land use development and redevelopment techniques and solutions that conserve, restore and enhance bay resources.	LU 2-1: Support and encourage land use practices that incorporate BMPs such as Low Impact Development (LID) and Sustainable Jersey actions; these practices should minimize soil disturbance, minimize forest and wetland loss, protect soil integrity recharge, and promote nature-based infrastructure.
"	LU 2-2: Support the develop-ment of localized and/or regional adaptation plans for vulnerable, low-lying commun-ities (e.g., those with repetitive losses).

"	LU 2-3: Promote innovative zoning and land use management techniques, such as transfer of development rights, rolling easements, acquisition (fee simple and easements), buy-outs, strategic retreat, non-contiguous density transfer, center-based development and septic density.
"	LU 2-4: Provide landowners with existing information and modeling tools that identify hazard vulnerability, adapta-tion and response actions.
"	LU 2-5: Promote land use practices which ensure that water supply reserves are not exceeded and are distributed equitably.
"	LU 2-6: Promote land use practices that ensure water-dependent land uses are recognized and remain a priority and that other authorized waterfront uses are compatible in order to lessen the conflicts between development and commercial and recreational activities.
"	LU 2-7: Conserve and enhance forestry areas with multiple ecosystem benefits.
Land Use 3: Support open space acquisition, planning and management for people and nature.	LU 3-1: Convene intergovernmental working group to review all existing public and private planning documents (such as Green Acres Inventory, County and Municipal Open Space Inventories, TPL 2020 Plan, municipal master plans, CIPs, and All Hazard Mitigation Plans, Conservation Blue Print initiative) and holdings, in order to coordinate future efforts to maximize ecological services of preserved lands.
"	LU 3-2: Compile a compre-hensive inventory of open space and natural lands held in permanent and temporary easements.
"	LU 3-3: Promote acquisition and management of lands towards achieving community and natural resource protection and resilience and a landscape that supports recreation and the cultural heritage of the Barnegat Bay through implementation of current and future watershed-wide open space plans.
"	LU 3-4: Promote the expansion of the NJDEP Environmentally Sensitive Areas Plan.
Land Use 4: Support the conservation, protection, and restoration of wetlands.	LU 4-1: Promote understan-ding of the importance of wetlands and nearshore areas: 1) as habitats for living resources, 2) as providers of ecosystems services important to matural lands and built communities.

"	LU 4-2: Coordinate the conservation, protection, restoration, and creation of wetlands through the use of innovative strategies, tools and funding opportunities (e.g., TDR, Acquisition, Easement, Mitigation, Adaptation, Beneficial Reuse of Dredge Material, Infrastructure Trust).
"	LU 4-3: Promote a coordinated and collaborative bay-wide approach to the dredging, disposal and beneficial re-use of dredge materials.
Land Use 5: Conduct research to improve scientific and societal understanding of the impacts of current and future land use practices on the Barnegat Bay and its watershed.	LU 5-1: Identify the social, economic and environmental impediments and solutions for implementing sustainable land-use practices on existing and future private development, including green and gray infrastructure in relation to SLR and climate change, repetitive losses and 'Willingness to Pay' and contingent valuation studies.
"	LU 5-2: Support the develop-ment of an updated Land Use Land Cover Map with Vdatum, to include analysis of LU/LC Change, analysis of imper-vious surface, and shorelines (land/water interface).
Land Use 6: Increase education and outreach focused on sustain-able land use practices for public & private property.	LU 6-1: Promote comprehensive land use planning and inclusion of CCMP land use goals into local and regional planning documents.
"	LU 6-2: Develop and coordinate workshops for specific audiences on sustainable land-use practices, e.g., low impact development (LID) and soil restoration techniques.
"	LU 6-3: Disseminate information and provide workshops to help communi-ties plan and prepare for climate change & sea level rise.
"	LU 6-4: Maintain and expand the Jersey-Friendly Yards website as a comprehensive source of information about sustainable landscaping practices for watershed property owners.
"	LU 6-5: Promote the understanding of the ecosystem services and economic value of wetlands and other natural habitats.

Appendix III – BBP STAC's Preliminary Vulnerability Assessment of CCMP Actions to Climate Change Stressors

BBP STAC
Preliminary Climate Change Vulnerability Assessment

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	CC Stressors						
		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
WQ 1-1	Support development and implementation of a Barnegat Bay nutrient TMDL (Total Maximum Daily Load).	Green	Green	Yellow	Yellow	Green	Yellow	Yellow
WQ 1-2	Develop/revise and implement Watershed Plans (i.e. WQMP/319 and Watershed Based Plans) at the sub watershed level.	Green	Green	Green	Orange	Yellow	Yellow	Green
WQ 1-3	Fully implement the Soil Restoration Law and associated comprehensive soil restoration procedures.	Green	Green	Green	Green	Green	Green	Green
WQ 1-4	Support implementation and enforcement of stormwater rules and ordinances at state, county and municipal levels.	Green	Green	Green	Green	Green	Green	Green
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.	Green	Green	Green	Green	Yellow	Green	Green
WQ 1-6	Identify sources and reduce pollution inputs from roadways and yard maintenance (pesticides, herbicides, fertilizer, roadsalts, deicer and automotive waste).	Green	Yellow	Green	Green	Orange	Green	Green
WQ 1-7	Map all stormwater BMP facilities within the watershed associated with major development.	Green	Green	Green	Green	Green	Green	Green
WQ 1-8	Identify sources and reduce pollution inputs from marinas and boating activities.	Yellow	Green	Green	Green	Green	Green	Green
WQ 1-9	Identify sources and reduce pollution inputs from livestock, agriculture and wildlife.	Yellow	Yellow	Green	Yellow	Orange	Green	Green
WQ 2-1	Maintain, review, and revise as necessary the existing comprehensive water quality ambient monitoring program throughout the watershed.	Green	Green	Green	Green	Yellow	Green	Green
WQ 2-2	Continue to identify the current status and trends in water quality within the watershed, and identify pollutant sources and magnitudes.	Yellow	Green	Yellow	Yellow	Green	Green	Yellow
WQ 2-3	Support the continuation of the existing beach monitoring program, and evaluate possible monitoring strategies for known public recreational areas of high public use.	Yellow	Green	Green	Green	Yellow	Green	Green
WQ 3-1	Support completion and expansion of source tracking for bacteria, pathogens, and novel and other pollutants.	Yellow	Yellow	Yellow	Yellow	Orange	Green	Green
WQ 3-2	Continue to identify and address data gaps and water quality issues of emerging concern.	Green	Green	Yellow	Green	Yellow	Green	Green
WQ 3-3	Continue to support research that identifies and quantifies the sources and fates of nutrients within the watershed and bay.	Green	Green	Green	Green	Green	Green	Green
WQ 4-1	Assist training and education/outreach programs to help municipalities meet MS4 permit compliance.	Green	Green	Green	Green	Green	Green	Green
WQ 4-2	Share Barnegat Bay-friendly ordinances and establish a Jersey-Friendly Yards certification and training program for homeowners, businesses, and/or landscaping professionals.	Green	Green	Green	Green	Green	Green	Green
WQ 4-3	Implement components of the BBP Communications Plan related to water quality improvement.	Green	Green	Green	Green	Green	Green	Green

An indication of little risk suggests that the action should be able to be completed regardless of the climate stressor, while high risk suggests that there is a strong likelihood the action could not be successfully completed.

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	CC Stressors						
		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
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	Yellow	Yellow	Green	Orange	Orange	Yellow	Green
WS 1-2	Determine minimum ecological flow requirements for streams, rivers and wetlands within the watershed.	Orange	Orange	Yellow	Red	Orange	Yellow	Green
WS 1-3	Assess watersheds for water supply capability related to streamflow, surface and shallow groundwater withdrawal capacity, and ecological impact.	Orange	Orange	Yellow	Red	Orange	Yellow	Green
WS 1-4	Support comprehensive planning that will guide sustainable water supply management, and to the maximum extent possible, maintain natural hydrology.	Yellow	Green	Green	Yellow	Green	Green	Green
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	Green	Green	Green	Yellow	Green	Green	Green
WS 2-1	Inventory and promote municipal land use regulations that emphasize water supply protection as a primary goal.	Green	Green	Green	Yellow	Green	Green	Green
WS 2-2	Identify and acquire open space to support water supply protection, encourage natural recharge and reduce consumption.	Green	Green	Green	Green	Yellow	Yellow	Green
WS 2-3	Establish and enforce 300-foot riparian buffers and pursue opportunities for green/blue acres acquisitions in buffer areas and floodplains.	Green	Green	Green	Yellow	Yellow	Green	Green
WS 2-4	Identify, implement and support voluntary and mandated conservation and infiltration practices and regulation to maintain and restore base stream flows and natural hydrology.	Yellow	Yellow	Green	Yellow	Green	Green	Green
WS 2-5	Inventory and evaluate municipal ordinances, rate structures and other available information for opportunities to better ensure judicious water usage and incentivize water conservation at the household and community levels; including metering all water usage.	Green	Green	Green	Green	Green	Green	Green
WS 3-1	Conduct shallow aquifer protection monitoring.	Yellow	Yellow	Green	Yellow	Yellow	Green	Green
WS 3-2	Continue to monitor water use trends.	Green	Green	Green	Green	Green	Green	Green
WS 3-3	Continue, and if possible expand, stream flow monitoring throughout the watershed to assess the effects of changing precipitation patterns, water use and development.	Yellow	Yellow	Green	Yellow	Yellow	Green	Green
WS 3-4	Assess water-supply trends and effects of current and projected surface and groundwater withdrawals	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Green

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BBP STAC
Preliminary Climate Change Vulnerability Assessment

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	CC Stressors						
		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
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.	Green	Green	Green	Yellow	Yellow	Yellow	Green
WS 4-2	Conduct research on the effects of sea level rise, salt water intrusion, and deicer/chloride on regional water supply and ecology.	Green	Yellow	Green	Yellow	Yellow	Yellow	Green
WS 5-1	Promote water reuse demonstration projects for stormwater, graywater and wastewater.	Green	Green	Green	Green	Green	Green	Green
WS 5-2	Disseminate educational materials related to best practices for water conservation activities.	Green	Green	Green	Green	Green	Green	Green
WS 5-3	Develop program to educate stakeholders on the source and value of their water.	Green	Green	Green	Green	Green	Green	Green
WS 5-4	Implement components of the BBP Communications Plan related to water supply protection.	Green	Green	Green	Green	Green	Green	Green

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		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
LR 1-1	Compile existing data and maps; determine and collect missing data for ecologically sensitive habitats and associated buffers.	Green	Green	Green	Green	Green	Yellow	Green
LR 1-2	Develop and implement conservation and/or restoration plans for ecologically sensitive habitats.	Yellow	Yellow	Yellow	Yellow	Yellow	Orange	Yellow
LR 1-3	Create a web-accessible database of habitat protection and restoration activities.	Green	Green	Green	Green	Green	Green	Green
LR 1-4	Encourage the protection and management of habitats on a sub-watershed basis through coordination across municipal boundaries.	Green	Green	Green	Green	Green	Green	Green
LR 1-5	Promote management of ecologically sensitive and other target areas.	Green	Green	Green	Green	Green	Green	Green
LR 2-1	Develop a bay-wide multi-use management plan that supports sustainable aquaculture, commercial and recreational harvest, recreation, and restoration.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
LR 2-2	Restore fish passage and other riparian habitats to improve habitat quality and connectivity.	Yellow	Yellow	Yellow	Orange	Orange	Yellow	Green
LR 2-3	Participate in the implementation and periodic update of the New Jersey State Wildlife Action Plan.	Green	Green	Green	Green	Green	Green	Green
LR 2-4	Create and restore wildlife corridors for habitat quality and connectivity.	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Green
LR 2-5	Monitor, manage, and control invasive and nuisance species through ecologically appropriate methods	Orange	Orange	Orange	Yellow	Yellow	Green	Green
LR 3-1	Assess distribution and abundance of SAV through coordinated, regular surveys.	Green	Green	Green	Green	Green	Green	Green
LR 3-2	Continue the Mid Atlantic Coastal Wetlands Assessment program to evaluate the condition and function of wetlands.	Green	Green	Green	Green	Green	Green	Green
LR 3-3	Update and/or complete mapping of riparian and tidal wetlands buffers.	Green	Green	Green	Green	Green	Yellow	Green
LR 3-4	Monitor and/or assess the status of commercially, recreationally, and ecologically important aquatic species.	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow
LR 3-5	Monitor and assess target animal and plant species, such as pollinator and migratory species, threatened and endangered species, and plant communities of special importance.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green
LR 3-6	Monitor and assess the impact of the closure of the Oyster Creek Nuclear Generating Station on the bay's living resources.	Green	Green	Green	Green	Green	Green	Green
LR 4-1	Conduct studies that identify and document appropriate mechanisms and strategies to support restoration of ecologically sensitive habitats identified in Obj. 1.	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow
LR 4-2	Identify and assess habitat suitability, connectivity, and barriers to fish passage (e.g. North Atlantic Aquatic Connectivity Collaborative approach.)	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow
LR 4-3	Conduct studies that identify and document the life history and/or ecology of pertinent living resources.	Green	Green	Yellow	Green	Green	Yellow	Yellow

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		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
LR 5-1	Disseminate information to promote an understanding of science-based decision-making in the management of habitats and living resources.							
LR 5-2	Develop educational materials, programs, and online resources to promote restoration of habitats and living resources (e.g. living shorelines, shellfish)							
LR 5-3	Develop materials, programs, and online resources to educate about the functional role of critical bay habitats, such as seagrass beds and wetlands, and the early life stages of estuarine-dependent species.							
LR 5-4	Produce educational materials and online resources about the impacts of climate change on the living resources of the bay.							
LR 5-5	Promote an improved understanding of the economic and ecological importance of fisheries through fisheries programs and activities.							
LR 5-6	Promote education and enforcement of regulations and best practices for responsible use of ecologically sensitive and target areas (e.g. personal watercraft and boating, off-road vehicles)							

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		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
LU 1-1	Align and expand existing municipal plans, BMPs, incentive programs and other related planning tools (e.g.,, Ocean County All-Hazards Mitigation Plan, GTR and Sustainable Jersey).							
LU 1-2	Identify regulatory gaps and overlaps and promote planning tools (such as draft ordinances, policies and model language) that support sustainable land use development practices							
LU 1-3	Coordinate with municipal, county, regional) and state planning representatives to develop a Land Use Element (including Working Waterfronts, Regional Resilience, Restoration and Enhancement activities/targets) for inclusion in their planning documents.							
LU 1-4	Develop a BBP Recognition Award Program (including potential for funding availability-to award recipients) for municipalities who are implementing CCMP Actions and coordinating in the development of the Barnegat Bay -wide *Land Use Element.*							
LU 2-1	Support and encourage land use practices that incorporate BMPs such as Low Impact Development (LID) and Sustainable Jersey actions; these practices should minimize soil disturbance, minimize forest and wetland loss, protect soil integrity recharge, and promote nature-based infrastructure.							
LU 2-2	Support the development of localized and/or regional adaptation plans for vulnerable, low-lying communities (e.g., communities experiencing repetitive losses).					Yellow	Yellow	
LU 2-3	Promote innovative zoning and land use management techniques, such as transfer of development rights (TDR), rolling easements, acquisition (fee simple and easements), buy-outs, strategic retreat, non- contiguous density transfer, center-based development and septic density.							
LU 2-4	Provide landowners with existing information and modeling tools that identify hazard vulnerability, adaptation and response actions.							
LU 2-5	Promote land use practices that ensure that water supply reserves are not exceeded and are distributed equitably.							
LU 2-6	Promote land use practices that ensure water- dependent uses are recognized and remain a priority and that other authorized waterfront uses are compatible in order to lessen the conflicts between development and commercial and recreational activities.							
LU 2-7	Conserve and enhance forestry areas with multiple ecosystem benefits.				Yellow			

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		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
LU 3-1	Convene intergovernmental working group to review all existing public and private planning documents (such as Green Acres Inventory, County and Municipal Open Space Inventories, TPL 2020 Plan, municipal master plans, CIPs, and All Hazard Mitigation Plans, Conservation Blue Print initiative) and holdings, in order to coordinate future efforts to maximize ecological services of preserved lands.	Green	Green	Green	Green	Green	Green	Green
LU 3-2	Compile a comprehensive inventory of open space and lands held in permanent and temporary easements.	Green	Green	Green	Green	Green	Green	Green
LU 3-3	Promote acquisition and management of lands towards achieving community and natural resource protection and resilience and a landscape that supports recreation and the cultural heritage of the Barnegat Bay through implementation of current and future watershed-wide open space plans.	Green	Green	Green	Green	Green	Yellow	Green
LU 3-4	Promote the expansion of the NJDEP Environmentally Sensitive Areas Plan.	Green	Green	Green	Green	Green	Green	Green
LU 4-1	Promote the understanding of the balance of wetlands and nearshore areas as natural habitats and the functions they provide to the ecosystem and development.	Green	Green	Green	Green	Green	Green	Green
LU 4-2	Coordinate opportunities to conserve, protect restore and create wetlands through the use of innovative strategies, tools and funding opportunities (such as: TDR, Acquisition, Easement, Mitigation, Adaptation, Beneficial Reuse of Dredge Material, Infrastructure Trust, Jersey-Friendly Yards Program).	Green	Green	Green	Green	Green	Green	Green
LU 4-3	Promote a balanced, collaborative and coordinated approach to the dredging of the Barnegat Bay, disposal and beneficial re-use of dredge materials	Green	Green	Green	Green	Green	Yellow	Green
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 strategies in relation to SLR and climate change, repetitive losses and 'Willingness to Pay' and contingent valuation studies.	Green	Green	Green	Green	Yellow	Yellow	Green
LU 5-2	Support the development of an updated Land Use Land Cover Map including analysis of LU/LC Change, analysis of impervious surface; shoreline (land/water interface); V Datum.	Green	Green	Green	Green	Green	Green	Green
LU 6-1	Promote comprehensive land use planning and inclusion of CCMP land use goals into local and regional planning documents.	Green	Green	Green	Green	Green	Green	Green
LU 6-2	Develop and coordinate workshops for specific audiences on sustainable land use practices, e.g., low impact development (LID) and soil restoration techniques.	Green	Green	Green	Green	Green	Green	Green

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		Summer Weather	Winter Weather	Warmer Waters	More Drought	More/Big Storms	SLR	Coastal Acidification
LU 6-3	Disseminate information and provide workshops that help watershed communities plan and prepare for climate change/sea-level rise.							
LU 6-4	Maintain and expand the Jersey-Friendly Yards website as a comprehensive source of information about sustainable landscaping practices for watershed property owners.							
LU 6-5	Promote the understanding of the ecosystem services and economic value of wetlands and other natural habitats.							

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Appendix IV –STAC Workshop CCMP Vulnerability Assessment

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	Stressor	Pathway (how)	Likeli-hood: High, medium, low	Conse-quence: High, medium, low	Spatial Extent: Site, Sub-watershed, Region	Specific Habitat?	Time: Immediate, 10-20 yrs, 20+
WQ 1-1	Support development and implementation of a Barnegat Bay nutrient TMDL (Total Maximum Daily Load).	Warmer water	Lower DO	High	High	Subwatershed/Region	No	Immed
WQ 1-1		Drought	Higher salt, lower DO	High	High	Subwatershed/Region	No	Immed
WQ 1-1		SLR	Higher Pollutants	Low	Medium	Subwatershed/Region	No	Immed
WQ 1-2	Develop/revise and implement Watershed Plans (i.e. WQMP/319 and Watershed Based Plans) at the sub watershed level.	Drought	OK to plan but more difficult to implement	Medium	Low/High	Subwatershed/Region	No	Immed
WQ 1-2		Storms	OK to plan but more difficult to implement	Medium	Low/High	Subwatershed/Region	No	Immed
WQ 1-2		SLR	OK to plan but more difficult to implement	Medium	Low	Subwatershed/Region	No	Immed
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.	Storms	System damaged or over-whelmed	Medium	High	Subwatershed/Region	No	Immed
WQ 1-6	Identify sources and reduce pollution inputs from roadways and yard maintenance (pesticides, herbicides, fertilizer, roadsalts, deicer and automotive waste).	Winter Weather	Human activities, enforcement, education	Medium	Medium	Subwatershed/Region	No	Immed
WQ 1-6		Storms	Human activities, enforcement, education	Medium	Medium	Subwatershed/Region	No	Immed
WQ 1-8	Identify sources and reduce pollution inputs from marinas and boating activities.	Summer Weather	Human activities, enforcement, education	Medium	Medium	Subwatershed/Region	No	Immed
WQ 1-8		Storms	Human activities, enforcement, education	Medium	Medium	Subwatershed/Region	No	Immed
WQ 2-1	Maintain, review, and revise as necessary the existing comprehensive water quality ambient monitoring program throughout the watershed.	Storms	Change in pollutant loadings	Medium	Medium	Subwatershed/Region	No	Immed
WQ 2-2		Winter Weather	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed
WQ 2-2		Summer Weather	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed
WQ 2-2	Continue to identify the current status and trends in water quality within the watershed, and identify pollutant sources and magnitudes.	Warmer water	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed
WQ 2-2		Drought	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed
WQ 2-2		Storms	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed
WQ 2-2		Coastal Acidification	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/Region	No	Immed

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WQ 2-3	Support the continuation of the existing beach monitoring program, and evaluate possible monitoring strategies for known public recreational areas of high public use.	Summer Weather	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/ Region	No	Immed
WQ 2-3		Storms	Dynamic conditions affect people, equipment	Low	Low	Subwatershed/ Region	No	Immed
WQ 3-1	Support completion and expansion of source tracking for bacteria, pathogens, and novel and other pollutants.	Storms	Dynamic conditions affect people, equipment	Medium	Medium	Subwatershed/ Region	No	Immed
WQ 3-2	Continue to identify and address data gaps and water quality issues of emerging concern.	Warmer Waters	Recogizing dynamic env. conditions	Low	Low	Subwatershed/ Region	No	Immed
WQ 3-2		Storms	Recogizing dynamic env. conditions	Low	Low	Subwatershed/ Region	No	Immed

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WS 1-1	Assess and implement existing shallow ground-water protection programs including wellhead protection, rainwater and treated wastewater recharge. Evaluate & implement new septic designs that may better address the release of nutrients and anthropogenic compounds to groundwater	Summer weather	seasonal pop change; irrigation	Medium	Medium	Regional	Wetland and surface water	Immediate
WS 1-1		Winter weather	seasonal pop change; irrigation	Low	Low	Regional	Wetland and surface water	Immediate
WS 1-1		Drought	seasonal pop change; irrigation	High	High	Regional	Wetland and surface water	Immediate
WS 1-1		Storms	seasonal pop change; irrigation	High	High	Regional	Wetland and surface water	Immediate
WS 1-1		SLR	discharge to GW			Site (coast)	Wetland and surface water	10-20 yrs
WS 1-2	Determine minimum ecological flow requirements for streams, rivers and wetlands within the watershed.	Summer weather	streamflow and water usage	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-2		Winter weather	streamflow and water usage	Med	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-2		Warmer Water	Evap rates	High	High	Regional	Rivers, streams & wetlands	10-20 yrs
WS 1-2		Drought	streamflow and water usage	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-2		Storms	runoff	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-2		SLR	none	Low	Low	Regional	Tidal areas	10-20 yrs
WS 1-3	Assess watersheds for water supply capability related to streamflow, surface & shallow ground-water withdrawal capacity & ecological impact.	Summer weather	streamflow and water usage	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-3		Winter weather	streamflow and water usage	Medium	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-3		Warmer Water	Evap rates	High	High	Regional	Rivers, streams & wetlands	10-20 yrs
WS 1-3		Drought	streamflow and water usage	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-3		Storms	runoff	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-3		SLR	none	Low	Low	Regional	Tidal areas	10-20 yrs
WS 1-4	Support comprehensive planning that will guide sustainable water supply management, and to the maximum extent possible, maintain natural hydrology.	Summer weather	water usage & availability	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-4		Winter weather	water usage & availability	Medium	High	Regional	Rivers, streams & wetlands	Immediate
WS 1-4		Drought	water usage & availability	High	High	Regional	Rivers, streams & wetlands	Immediate

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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	Drought	water usage, availability, recharge & runoff	High	High	Regional (per NJWSP)	Rivers, streams & wetlands	Immediate
WS 2-1	Inventory and promote municipal land use regulations that emphasize water supply protection as a primary goal.	Drought	water usage & availability	High	High	Regional	N/A (nothing specific)	Immediate
WS 2-2	Identify and acquire open space to support water supply protection, encourage natural recharge and reduce consumption.	Storms	flooding and land conservation programs	High	Medium	Regional & floodplains	Floodplains & connected open land	Immediate
WS 2-2		SLR	inundation	High	High	Regional (coast)	Tidal uplands and wetlands	Immediate
WS 2-3	Establish and enforce 300-foot riparian buffers and pursue opportunities for green/blue acres acquisitions in buffer areas and floodplains.	Drought	none	Low	Low	Regional	Floodplain	Immediate
WS 2-3		Storms	flooding	High	High	Regional	Floodplain	Immediate
WS 2-3		SLR	flooding & inundation	High	High	Regional	Floodplain	Immediate
WS 2-4	Identify, implement and support voluntary and mandated conservation and infiltration practices and regulation to maintain and restore base stream flows and natural hydrology.	Summer weather	water use and availability; land use	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 2-4		Winter weather	water use and availability; land use	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 2-4		Drought	water use and availability; land use	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 2-4		Storms	water use and availability; land use	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 3-1	Conduct shallow aquifer protection monitoring.	Summer weather	GW recharge & wastewater discharge	Med	Med	Regional	All habitats	Immediate
WS 3-1		Winter weather	GW recharge & wastewater discharge	Med	Low	Regional	All habitats	Immediate
WS 3-1		Drought	GW recharge & wastewater discharge	High	Medium	Regional	All habitats	Immediate
WS 3-1		Storms	GW recharge & wastewater discharge	High	Medium	Regional	All habitats	Immediate
WS 3-3	Continue, and if possible expand, stream flow monitoring throughout the watershed to assess the effects of changing precipitation patterns, water use and development.	Summer weather	Runoff & baseflow	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 3-3		Winter weather	Runoff & baseflow	High	Medium	Regional	Rivers, streams & wetlands	Immediate
WS 3-3		Storms	Runoff & baseflow	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 3-4	Assess water-supply trends and effects of current & projected surface & groundwater withdrawals	Summer weather	N/A	N/A	N/A	N/A	N/A	N/A
WS 3-4		Winter weather	N/A	N/A	N/A	N/A	N/A	N/A
WS 3-4		Drought	N/A	N/A	N/A	N/A	N/A	N/A
WS 3-4		Storms	N/A	N/A	N/A	N/A	N/A	N/A
WS 3-4		SLR	N/A	N/A	N/A	N/A	N/A	N/A

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WS 4-1	Identify infrastructure, research & piloting op-tions for the use of advanced treatment at waste-water treatment plants and water reuse, incl. wastewater & gray water, within the watershed.	Drought	streamflow and inflow to bay; infrastructure condition	High	Medium	Regional	Rivers, streams, wetlands & bay	10-20 yrs
WS 4-1		Storms	streamflow and inflow to bay; infrastructure condition	High	Low	Regional	Rivers, streams, wetlands & bay	10-20 yrs
WS 4-1		SLR	streamflow and inflow to bay; infrastructure condition	Medium	Medium	Regional	Bay	10-20 yrs
WS 4-2	Conduct research on the effects of sea level rise, salt water intrusion, and deicer/chloride on regional water supply and ecology.	Winter weather	surface water & groundwater	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 4-2		Drought	surface water & groundwater	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 4-2		Storms	surface water & groundwater	High	High	Regional	Rivers, streams & wetlands	Immediate
WS 4-2		SLR	surface water & groundwater	High	High	Regional	Rivers, streams & wetlands	Immediate

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LR 1-1	Compile existing data and maps; determine and collect missing data for ecologically sensitive habitats and associated buffers.	SLR	SLR renders existing maps obsolete; missing data	High	Med	Region	Tidal and non-tidal wetlands, SAV, Riparian habitat, Shellfish, Uplands, Shallow subtidal, Intertidal flats, Tributaries	Immediate
LR 1-2	Develop and implement conservation and/or restoration plans for ecologically sensitive habitats.	summer weather	Uncertainty; resiliency regarding weather events	High	Short Term - Low; Long Term - High	Region	Tidal and non-tidal wetlands, SAV, Riparian habitat, Shellfish, Uplands, Shallow subtidal, Intertidal flats, Tributaries	Immediate
LR 1-2		winter weather						
LR 1-2		warmer water	Uncertainty regarding degree of warming/trend		Med			
LR 1-2		drought	Uncertainty, resiliency regarding frequency/magnitude		Med			
LR 1-2		storms	SLR renders existing maps obsolete; missing data		Med			
LR 1-2		SLR	SLR renders existing maps obsolete; missing data		High			
LR 1-2		acidifcation	Uncertainty regarding degree of acidification/ internal vs. external loading		Short Term - Low; Long Term - High			
LR 2-1	Develop a bay-wide multi-use management plan that supports sustainable aquaculture, commercial and recreational harvest, recreation, and restoration.	summer weather	Data needs; increasing complexity of planning process to account for stressors	High	High	Region	Tidal marsh, SAV, Shellfish, Intertidal flats, Shallow subtidal	Immediate
LR 2-1		winter weather		High	High			
LR 2-1		warmer water		High	Med			
LR 2-1		drought		High	High			
LR 2-1	Develop a bay-wide multi-use management plan that supports sustainable aquaculture, commercial and recreational harvest, recreation, and restoration.	storms	Data needs; increasing complexity of planning process to account for stressors	High	High	Region	Tidal marsh, SAV, Shellfish, Intertidal flats, Shallow subtidal	Immediate
LR 2-1		SLR		High	High			
LR 2-1		acidifcation		High	Short Term - Low; Long Term - High			

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	Stressor	Pathway (how)	Likeli-hood: High, medium, low	Conse-quence: High, medium, low	Spatial Extent: Site, Sub-watershed, Region	Specific Habitat	Time: Immediate, 10-20 yrs, 20+
LR 2-2		summer weather		Low	Low			
LR 2-2		winter weather	Design for resilience and account for stressors	Low	Low	Sub-watershed	Tributaries, Riparian Habitat	10-20 yrs
LR 2-2		warmer water		Low/Med	Med			
LR 2-2	Restore fish passage and other riparian habitats to improve habitat quality and connectivity.	drought	Design for resilience and account for stressors, especially variability in base flow	High	High	Sub-watershed	Tributaries, Riparian Habitat	Immediate
LR 2-2		storms	Design for resilience and account for stressors	High	High			
LR 2-2		SLR	Design for resilience and account for stressors; movement of salt front up tributaries	Low	Low	Sub-watershed	Tributaries, Riparian Habitat	20+
LR 2-4		summer weather		Low	Low			
LR 2-4	Create and restore wildlife corridors for habitat quality and connectivity.	winter weather	Data needs; increasing complexity of planning process to account for stressors	Low	Low	Site	Tidal and non-tidal wetlands; Riparian habitat, tributaries, Uplands	20+
LR 2-4		drought		Low	Low			
LR 2-4		storms		Low	Low			
LR 2-4		SLR		Low	Low			
LR 2-5		summer weather		High	High			Immediate
LR 2-5	Monitor, manage, and control invasive and nuisance species through ecologically appropriate methods	winter weather	Species response; adaptability to stressors	High	High	Region	Tidal wetlands, Shallow subtidal, Intertidal flats, Tributaries, SAV, Riparian Habitat, Uplands	
LR 2-5		warmer water		High	High			
LR 2-5		drought		Low	Low			10-20 yrs
LR 2-5		storms		Low	Low			
LR 2-5		SLR		Med	Med			
LR 3-3	Update and/or complete mapping of riparian and tidal wetlands buffers.	SLR	SLR gradually renders baseline obsolete; data needs	High	High	Region	Tidal and non-tidal wetlands; Riparian habitat, tributaries, Uplands	Immediate
LR 3-4		summer weather	Sampling/ monitoring logistics, safety, scheduling; data gaps	Low/Med	Low-Med			
LR 3-4		winter weather		Low/Med	Low-Med			
LR 3-4		warmer water		Med	Med			
LR 3-4		storms		Med	Med			
LR 3-4	Monitor and/or assess the status of commercially, recreationally, and ecologically important aquatic species.	SLR	Data needs; movement of salt front up tributaries	Med	Med	Region	Tidal marsh, Shallow subtidal, Intertidal flats, Tributaries, SAV	Immediate
LR 3-4		acidification	Data needs; uncertainty regarding degree of acidification/ internal vs. external loading	Med	Short Term - Low; Long Term - High			

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	Stressor	Pathway (how)	Likeli-hood: High, medium, low	Conse-quence: High, medium, low	Spatial Extent: Site, Sub-watershed, Region	Specific Habitat	Time: Immediate, 10-20 yrs, 20+
LR 3-5	Monitor and assess target animal and plant species, such as pollinator and migratory species, threatened and endangered species, and plant communities of special importance.	summer weather	Sampling/ monitoring logistics, safety, scheduling; data gaps	Low/Med	Low-Med	Region	Uplands, Riparian habitat, Tidal and non-tidal wetlands	10-20 yrs
LR 3-5		winter weather		Low/Med	Low-Med			
LR 3-5		warmer water		Low	Low			
LR 3-5		storms		Med	Med			
LR 3-5		SLR	Data needs; movement of salt front up tributaries	Low	Low			
LR 3-5		acidification	Data needs; uncertainty regarding degree of acidification/ internal vs. external loading	Low	Low			
LR 4-1	Conduct studies that identify and document appropriate mechanisms and strategies to support restoration of ecologically sensitive habitats identified in Obj. 1.	summer weather	Sampling/monitoring logistics, safety, scheduling; adaptive manament; data gaps	Low/Med	Low-Med	Region	Tidal and non-tidal wetlands, SAV, Riparian habitat, Shellfish, Uplands, Shallow subtidal, Intertidal flats, Tributaries	Immediate
LR 4-1		winter weather		Low/Med	Low-Med			
LR 4-1		storms		Low/Med	Low-Med			
LR 4-1		SLR	Data needs; movement of salt front up tributaries Sustainability/ longevity of built projects	Low/Med	Low			
LR 4-2	Identify and assess habitat suitability, connectivity, and barriers to fish passage (e.g. North Atlantic Aquatic Connectivity Collaborative approach.)	summer weather	Hydrologic variability; sampling/ monitoring logistics, safety, scheduling; data gaps	Med	Med	Sub-watershed	Tributaries, Riparian Habitat	10-20 yrs
LR 4-2		warmer water		Low	Low			
LR 4-2		drought		Med	Med			
LR 4-2		storms		Med	Med			
LR 4-2		SLR	Data needs; movement of salt front up tributaries	Low	Low			
LR 4-3	Conduct studies that identify and document the life history and/or ecology of pertinent living resources.	drought	Hydrologic variability; sampling/ monitoring logistics, safety, scheduling; data gaps	Low	Low	Region	Tidal and non-tidal wetlands, SAV, Riparian habitat, Shellfish, Uplands, Shallow subtidal, Intertidal flats, Tributaries	Immediate

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	Stressor	Pathway (how)	Likeli-hood: High, medium, low	Conse-quence: High, medium, low	Spatial Extent: Site, Sub-watershed, Region	Specific Habitat	Time: Immediate, 10-20 yrs, 20+
LU 2-2	Support the development of localized and/or regional adaptation plans for vulnerable, low-lying communities (e.g., communities experiencing repetitive losses).	Storms	Will require community and political will and consensus, local changing condition expertiseand assessments and funding support. Political will; rapidly changing data and access; jurisdiction - local, state, federal; local zoning; education and outreach; identification of most vulnerable; Public perception of severity of Climate Impacts forcing local government to develop resilience and adaptation plans and address impediments to action; - Local economic impacts (tax base, insurance, bonding capability, available fed. funds) of storms and slr will require assessment of impediments and solutions and development of adaptation plans - will become higher priority for BBP implementation as knowledgeable source.	High	Medium High, Medium for plans	Region (watershed-wide)	All	Immediate, increase with time
LU 2-2		SLR		High (local zoning, education and outreach, identify most vulnerable)	High, Medium for plans	Coastal Communities Region (watershed-wide)		
LU 2-5	Promote land use practices that ensure that water supply reserves are not exceeded and are distributed equitably.	Drought	Droughts will impact water reserves	Medium	High	Region (watershed-wide)	All	Immediate
LU 2-6	Promote land use practices that ensure water-dependent uses are recognized and remain a priority and that other authorized waterfront uses are compatible in order to lessen the conflicts between development and commercial and recreational activities.	SLR	Will impact water dependent uses first and there is a need in planning for the future to consider if these uses will be able to moved back	Medium	Medium	Waterfront	Coastal	10-20 years
LU 2-7	Conserve and enhance forestry areas with multiple ecosystem benefits.	Drought	Limit development of forested lands, water conservation, recharge areas	Low	High as buffer for water quality,	Region (watershed-wide)	Forest, forested wetlands	10-20 years
LU 3-3	Promote acquisition and management of lands towards achieving community and natural resource protection and resilience and a landscape that supports recreation and the cultural heritage of the	SLR	Support blue and green acres, explore managed relocation, rolling easements	High	Medium	Region (watershed-wide)	All	Immediate, increase with time
LU 4-3	Promote a balanced, collaborative and coordinated approach to the dredging of the Barnegat Bay, disposal and beneficial re-use of dredge materials	SLR	Encourage regional dredge management plan for watershed	Medium	Medium	Region (watershed-wide)	Tidal and subtidal	Immediate, increase with time

WQ Action ID	CCMP Actions Affected by CC Stressors: Green = little risk, Yellow = low risk, Orange = low-moderate risk, Red= Moderate+ risk	Stressor	Pathway (how)	Likeli-hood: High, medium, low	Conse-quence: High, medium, low	Spatial Extent: Site, Sub-watershed, Region	Specific Habitat	Time: Immediate, 10-20 yrs, 20+
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 strategies in relation to SLR and climate change, repetitive losses and 'Willingness to Pay' and contingent valuation studies.	Storms	Severity and intesity of storms will directly impact sustainable LU practices. Identify more CDF locations, working water-fronts, adaptations plans, education and outreach, ordinances and master plans; Public perception of severity of Climate Impacts forcing local government to develop resilience and adaptation plans and address impediments to action; local economic impacts (tax base, insurance, bonding capability, available fed. funds) of storms and slr will require assessment of impediments and solutions and development of adaptation plans - will become higher priority for BBP implementation as knowledgeable source.	Medium	High	Region (watershed-wide)	All	Immediate, increase with time (already impact and will change over time)
LU 5-1		SLR		High	High			

Appendix V – Final Consequence/Probability Matrices for CCMP Actions Vulnerable to Climate Change Stressors

Water Quality

Consequence of Impact

	Low	Medium	High
High			**WQ 1-5**: Increasingly frequent and sever storms, possibly in combination with other climate stressors, is likely to result in increasing damage to and operational incapacitation of stormwater (and water utility) infrastructure and contribute to water quality degradation in different municipalities, subwatersheds, and possibly the entire estuarine ecosystem.
Medium	**WQ 1-8**: Changing weather and storms, especially, are likely to increase pollution impacts from boating activities and marinas and contribute to water quality degradation. **WQ 2-2**: All climate stressors are likely to change the bay's conditions and living resources and thus significantly but variably impact our collective monitoring and assessment activities. **WQ 2-3**: Summer weather and storms and possibly other climate stressors are likely to affect water quality, human use and monitoring programs at public recreation beaches. **WQ 3-1**: Changing climate, storms, and possibly other climate factors are likely to affect certain pollutants (e.g., bacteria, pathogens) and their identification and tracking, with potential consequences for human health.	**WQ 1-2**: Drought, storms, and sea level rise have considerable and variable likelihood to have significant impacts on features of individual sites and possibly even some characteristics throughout the watershed; thus, these stressors potentially could lead to modifications in the development of site-specific and subwatershed-wide components of watershed management plans. **WQ 1-6**: Changing weather and storms, especially, are likely to affect human behavior and increase pollution inputs from roadways (deicers), automobiles (hydrocarbons), and yard maintenance (pesticides, insecticides, and fertilizers) throughout subwatersheds and possibly the entire watershed.	**WQ 1-1**: Warmer water, drought, storms, sea level rise and other climate stressors have considerable and variable likelihood to increase decrease oxygen concentrations and increase pollutants in regions and/or throughout the bay and may impact TMDL implementation in the Barnegat Bay. **WQ 2-1**: Storms and other other climate stressors are likely to change pollutant sources and loadings to the bay, and thus have considerable potential to alter the details of monitoring programs.
Low			

Likelihood of occurrence

Water Supply

Consequence of Impact

	Low	Medium	High
High		**WS1-2**: Climate change stressors will introduce increased variability to streamflow and water usage, making it more difficult to calculate minimum ecological flows. **WS1-4**: Variability in water usage and availability associated with climate change stressors will add complexity to sustainable water supply planning. **WS2-4**: Warmer summer and winter weather, along with increased drought and storminess will increase variability in water use and availability, impacting the ability to implement conservation practices.	
Medium	**WS3-1 and 3-3**: Climate change stressors may impact the logisitics associated with water monitoring.	**WS1-1**: Increases in water usage associated with seasonal population changes and increased irrigation due to climate change stressors will make it difficult to implement shallow groundwater protection programs. **WS4-1**: Climate change stressors may limit opportunities and options to advance water reuse pilot projects.	**WS1-2**:Warmer winter weather impacts streamflow and water usage, making it more difficult to calculate minimum ecological flows. **WS1-4**: Warmer winter weather leads to increased water usage and decreased availability, impacting the ability to plan for sustainable water supply management.
Low		**WS4-2**: Climate change stressors may impact how research is conducted and on what topics.	

Likelihood of occurrence

Living Resources

Consequence of Impact

		Low	Medium	High
Likelihood of occurrence	**High**	**LR1-2**: Variability in summer and winter weather, drought, and storminess, along with warming and acidifying waters, will introduce uncertainty in habitat conservation and restoration planning. **LR2-1**: Climate change stressors will increase the complexity of the planning process and require additional data to ensure appropriate actions within a bay wide multiuse management plan.	**LR1-1**: Sea level rise will render existing maps of sensitive habitats obsolete. **LR3-3**: Sea level rise will gradualy render baseline mapping of riparian and tidal wetland buffers obsolete, requiring recurring updates.	**LR1-2**: Sea level rise may substantially modify or eliminate some sensitive habitats.
	Medium	**LR3-4 and 3-5**: Climate change will impact the logisitics of how we monitor target species (i.e. storms impacting fieldwork schedules), requiring potential changes to established schemes. **LR4-1**: Climate change will impact the logisitics of how we research effective restoration strategies.	**LR2-5**: Climate stressors may alter conditions in favor of invasive species, requiring additional effort to manage and control them. **LR3-4 and 3-5**: Climate change will impact the logisitics of how we monitor target species, requiring potential changes to established schemes. **LR4-2**: Hydrologic variability associated with climate change may impact our ability to accurately asses habitat suitability and connectivity for aquatic species.	
	Low	**LR2-2**: Severe weather events may have temporary impacts on fish passage and riparian habitats due to extremely low/high flows. **LR2-4**: Climate change factors will increase the complexity of planning for restoration of wildlife corridors.		

Land Use

Consequence of Impact

	Low	Medium	High
High		**LU 2-2**: Sea level rise and increased storminess will make adaptation planning more complex. **LU 5-1:** Severity and intensity of storms will directly impact sustainable LU practices	
Medium		**LU 4-3**: Sea level rise may impact how and where we utilize and dispose of dredge material.	**LU 3-3**: Sea level rise may limit our ability to acquire and manage lands for open space purposes. **LU 5-1**: Rate of SLR coupled with storm intensification will directly impact sustainable LU practices.
Low			**LU 2-7**: Drought will directly impact the survivability of forest areas within the watershed.

Likelihood of occurrence