A Summary of Climate Change Impacts and Preparedness Opportunities for the Water Resources Sector in New Jersey

This report is one of a series of working briefs prepared by the New Jersey Climate Adaptation Alliance to provide background information on projected climate impacts for six major sectors in New Jersey, including agriculture, built infrastructure (utilities and transportation), coastal communities, natural resources, public health, and water resources. These working briefs present information to be used throughout the Alliance's deliberations to develop recommendations for state and local public policy that will enhance climate change preparedness and resilience in New Jersey. These briefs are living documents that are periodically updated. This document updates a prior version from April 2013. For more information about the Alliance and its activities, visit *http://njadapt.rutgers.edu*.

This report provides an assessment of water resources-based perspectives on the topic of adaptation planning for climate change in New Jersey, including strategies related to (1) the availability and delivery of fresh water and (2) the management of waste water and storm water. The analysis will not include the effects of climate change on habitat or fisheries, as these topics will be covered under the natural resources and agriculture scoping papers, respectively. Any current New Jersey efforts as well as current and planned adaptation practices and strategies in other states are presented as the basis for a series of recommendations to address additional needs as a starting point for discussion and prioritization of comprehensive adaptation planning for New Jersey.

Water Resources in New Jersey

New Jersey is just over 5 million acres in size and is approximately 166 miles long and 65 miles wide. Five major drainage basins occur in the state: Delaware River, Atlantic Coastal, Passaic/Hackensack River, Raritan River and Wallkill River. Groundwater supplies 50% of the state's potable water supplies. Moreover, about 25% of the state's residents rely on private wells. Eighty percent of the state's area, the highest percentage of any state in the country, is located within federally designated sole source aquifers, which supply at least 50% of the drinking water consumed in the area overlying the aquifer.[1] These areas can have no alternative drinking water source(s), which could physically, legally, and economically supply all those who depend upon the aquifer for drinking water.[2]

Estimates of New Jersey's available water show 850 million gallons per day for surface water and 900 million gallons per day for groundwater. The 1990 statewide water demand was 1,500 million gallons per day. According to the State Water Supply Master Plan, last updated in 1996, the 2040 demand was projected to be 1,790 million gallons per day based on a prediction that the state's population would reach 8.25 million in 2010.[3] However, the state's population has surpassed that estimate, reaching approximately 8.8 million in 2010.[4]

The delivery of freshwater to residential and industrial customers in New Jersey is managed and regulated through a number of different entities. The Board of Public Utilities (BPU) regulates rates of a small number of mostly investor-owned utilities (31) that serve over 40% of state residents and businesses. Of New Jersey's 620 public community water supply systems, three-quarters serve less than 3,000 customer accounts. More than 300 public community water systems (nearly two-thirds of which serve less than 3,000 customer

[1] USDA Natural Resources Conservation Service (2006)
[2] US EPA (2010)
[3] USDA Natural Resources Conservation Service (2006
[4] U.S. Census Bureau (2012)

accounts) are municipal utilities and utility authorities, whose budgets are regulated under the New Jersey Department of Community Affairs. The remainders of the public community water supply systems include large commercial facilities, mobile homes, community associations, and other users. The Department of Environmental Protection (NJDEP) regulates the quality of potable water received by customers, the quantity of water that may be withdrawn from natural resources, system water losses, and physical modifications regardless of the type of system that may be providing the water to customers.[5]

Sanitary wastewater utilities are largely public sector entities rather than private sector, with municipal and regional utilities serving areas ranging from intra-municipal to county or even multi-county scale. Of more than 260 community wastewater systems, roughly 60% are publicly-owned. Nearly 60% of the community wastewater systems are also very small, processing average daily flows of less than 1 million gallons per day. DCA also regulates budgets of the publicly-owned utilities, while NJDEP authorizes and regulates the quality and quantity of effluents discharged from wastewater treatment plants through the NJPDES permit program.[6]

Public storm water infrastructure is managed by municipal and county public works departments or their equivalent using taxpayer-funded operating budgets, not as utility operations with user fees. DCA oversight (through the Division of Local Government Services and the Local Finance Board) occurs only through the review of general government budgets. NJDEP regulates municipal and public institutional storm water systems regarding limited issues, not including maintenance, through NJPDES storm water permits.[7]

Although potable water resources in New Jersey are heavily protected through sole source aquifer designation, demand for water in New Jersey is far surpassing predicted needs. In addition, the supply and management of water resources in New Jersey occurs through a number of different state and local agencies, some of which only oversee portions of different water resources. As such, it is important to focus on coordination of strategies and dissemination of information among various stakeholder groups, include watershed management bodies (such as the Delaware River Basin Commission), utility authorities, private well users, and others who must work together to fully implement adaptation strategies and provide input into any planning processes.

Sector Risks and Impacts

The EPA has developed a guide for climate ready utilities that outlines a series of challenge groups for utilities to understand when addressing climate change.[8] These groups provide a useful framework for discussion when applied to the Alliance and more generally across other industries in order to understand the direct and indirect effects of climate change, and include: (1) Heat and drought, (2) Water quality degradation, (3) Sea level rise and flooding, and (4) Increased demand.[9]

Heat and drought[10]

Drought risks can be classified through the reduction of groundwater recharge, lower lake and reservoir levels and changes in the seasonal runoff and snowpack in a given region. More specifically, decreases in surface water supplies and groundwater recharge, and overall lower levels available in reservoirs, coupled with the potential to have higher peaks and troughs for varying infrastructure present significant concerns for water utilities throughout the country.

The increasing variability of water levels may result in difficulty collecting water from abnormally high flows, and may also render infrastructure, such as intakes useless based on their current levels. Lower stream flow in many locations may lead to diminished water quality, which could lead to more stringent requirements for

[5] Clean Water Council of New Jersey (2010)
[6] Clean Water Council of New Jersey (2010)
[7] Clean Water Council of New Jersey (2010)
[8] US EPA (2012)
[9] US EPA (2012)
[10] US EPA (2012)

wastewater discharges and higher treatment costs and the need for capital improvements. Drought may also lead to increased risks of wildfire. Fires present a direct risk to property and infrastructure, in addition to potential degradation of water supply from contaminated runoff or increased sedimentation from the erosion of burned areas.

Water quality degradation [11]

Water quality degradation may occur because of increases in salinity from saltwater intrusion from flooding events or a more gradual intrusion of saltwater. Higher temperatures can lead to algal bloom, which compromises source water quality and may require treatment that is more advanced. Compounding the degradation of water quality, turbidity and pollution inputs may increase due to extreme storm and high flow events and altered or reduced vegetation cover in watersheds. Finally, biological wastewater treatment processes may be impaired due to changes in the efficacy of microbial populations due to higher plant and influent temperatures on hot days.

Diminished water quality may lead to more stringent requirements for wastewater discharges; subsequently leading to higher treatment costs and the need for capital improvements. Saltwater intrusion could increase treatment costs for water treatment facilities drawing from coastal aquifers or from surface intakes in tidal estuaries near the saltwater line. Desalination plants may have to treat water with higher salt content, which would also increase costs. These water quality impacts will drive the need for additional drinking water treatment processes, potentially leading to higher energy demand and capital and operating costs.

Sea level rise and flooding [12]

Intense precipitation events may challenge infrastructure for water management and flood control. Episodic peak flows into reservoirs will strain the capacity of these systems, and inflow will be of lesser quality due to erosion and contaminants from overland flows, leading to treatment challenges and degraded conditions in reservoirs. Coastal storm surges may increase in extent where sea-level rise is combined with projected increases in storm intensity.

Inundation may damage infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems, and cause disruption of service. Aside from water infrastructure, transportation infrastructure and utility infrastructure may also be affected by inundation, hampering access and relief efforts for emergency responders. In addition, overflows in combined systems could reduce the capacity of sewer systems already impacted by inflow and infiltration. Wastewater facilities are often located at low points in the watershed, and wastewater infrastructure is particularly at risk to flooding when these extreme events occur. Desalination plants in coastal areas could also be vulnerable to sea-level rise and storm surges based on their typical location in coastal areas. Drinking water treatment plants are typically not as vulnerable as wastewater plants to flooding, as they are often located at higher elevations.

Increased demand [13]

Climate change may lead to a growing imbalance in the demand for service and the ability of drinking water and wastewater utilities to meet it. Drought may increase in frequency and severity in some areas and in areas dependent on snowpack, higher temperatures will reduce snowpack and can decrease water storage. These factors result in decreased stream flow, reservoir safe yield, and groundwater recharge. These impacts will reduce the available supplies for water systems dependent on surface water as well as groundwater, and potentially lead to service disruption.

Changing water needs of agricultural practices due to climate change could significantly impact the ability of drinking water utilities to provide sufficient supply. Competition could lead to shortfalls in water supply in the summer growing period, in particular. However,

11 US EPA (2012)
12 US EPA (2012)
13 US EPA (2012)

Table 1: New Jersey Impacts and Risk for Water Resources as a result of climate change

Climate Impacts	New Jersey Risks
Heat and Drought	• Degraded infrastructure • Obsolete and aging infrastructure • Decreases in surface water supplies and groundwater recharge • Overall lower water levels in reservoirs • Greater variability in water levels
Water Quality Degradation	• Saltwater intrusion • Contamination from flooding due to erosion and contaminants from runoff or failure of low-lying treatment infrastructure
Extreme Weather Events and Flooding	• Damage to infrastructure from intense precipitation events or storm surge • Contamination of water resources from infrastructure failure • Physical damages and losses to public and private property from flooding
Resource Demand	• Limited capacity to meet demand • Potential contamination of protected aquifers limits available resources • Failure of aging infrastructure

collaboration between the water and agricultural sectors can assist in meeting the water needs of both of these sectors.

Changes in climate will impact both the energy sector directly and the energy needs of water utilities. The need for water used in energy generation is significant: thermoelectric power generation accounted for 49% of total water withdrawals in 2005. The energy required by the water sector for providing services is significant as well. Electricity accounts for about 75% of the cost of municipal water processing and transport and consumes about 4% of the nation's electricity.[14] Without consideration of increased water and energy demands, future impacts from climate change may include higher operating costs, frequent loss of power, and water shortages.

Vulnerable Groups

Given the potential effects of climate change on water resources, certain disadvantaged groups have been identified through a variety of different studies. The NYSERDA ClimAid Team (2010) identified a number of different groups that could be at risk due to a changing climate.[15] These groups included:

- Smaller water systems, which can be more vulnerable to drought and other types of water supply disruptions as a result of a lack of resources for management
- Elderly and disabled persons that are vulnerable to flood hazards due to limited mobility
- Rapidly developing, higher-income exurban communities as a result of limited water supply to those regions
- Lower-income or low English proficiency populations that may be less aware of government programs and warnings and have less access to health care

The communities above, and others, may experience disproportionate direct and indirect effects from changes to the availability of water resources. These communities

[14] USGCRP (2009)
[15] NYSERDA ClimAID Team (2010)

are worth specific focus and efforts for identification and outreach in order to mitigate detrimental effects on the population

New Jersey Specific Risks and Impacts

Of the aforementioned risks to water resources, there are a number that are of particular concern to areas in New Jersey. Specific impacts on the supply of water resources are discussed below.

Heat and Drought

Decreases in surface water supplies and groundwater recharge, overall lower water levels in reservoirs, and the potential for greater variability in water levels present significant concerns for utilities and other industries dependent on a stable and predictable supply of water. Increasingly unpredictable water supply may render infrastructure inadequate for appropriate collection and storage, specifically affecting positioning of intakes, creation and design of reservoirs and other infrastructure.[16] Delaware River Basin reservoirs are of particular concern as the supply to New Jersey in addition to the need to supply water resources to New York City. The droughts of 2002 brought particular concern to New Jersey, when reservoirs ran dry and state officials realized that greater interconnectivity should be developed between each of the available reservoir sources in order to get water to the places most in need.[17]

Water Quality Degradation

As sea level rises, saltwater migrates and can infiltrate coastal aquifers, and more frequent flooding is likely to increase the salt content of surface and groundwater. Saltwater intrusion can cause the salinity of water supplies to rise above acceptable drinking standards. The southern portion of the state is particularly susceptible; studies show that areas supported by water utilities along the Delaware River basin are at risk of increased salinity as sea level rises.[18] This is a particular issue for areas near Camden, NJ where a decrease in the level of the Delaware River is cause for concern. It is suggested that a number of power and industrial intakes could be damaged, in addition to endangering the water supply of southern NJ and Philadelphia.[19] During a drought from 1961-1966, the Potomac-Raritan-Magothy aquifer was recharged by saltwater, resulting in elevated chloride levels that endured for more than 10 years.[20] After Cape May had to abandon multiple wells as a result of saltwater intrusion, the city installed a desalination plant. Today, the plant provides 2 million gallons of potable water a day.[21]

The quality of water supply is further endangered by the vulnerability of wastewater infrastructure, which is particularly at risk to flooding due to the typically low elevation of facilities in the watershed. The Passaic Valley Sewerage Commission's main treatment facility in Newark, which serves 1.4 million customers in Bergen, Passaic and three other counties, was inundated with over 200 million gallons of tidal surge[22] and dumped roughly 240 million gallons of raw or partially treated sewage per day into Newark Bay and Upper New York Bay during Hurricane Sandy.[23] Water quality may also be diminished because of lower stream flows, increased temperature, and other climatic changes. Changes to water quality could lead to more stringent requirements for wastewater discharges and higher treatment costs and the need for capital improvements for both the water utilities and their industrial customers.[24]

Extreme Weather Events and Flooding

Intense precipitation events will challenge infrastructure for water management and flood control. Extreme events, be they hurricanes or floods, have the capability to damage infrastructure such as treatment plants,

16 US EPA (2012)
17 NJDEP (2004)
18 Cooper, Beevers and Oppenheimer (2005)
19 Cooper, Beevers and Oppenheimer (2005)
20 Cooper, Beevers and Oppenheimer (2005)
21 Lacombe and Carlton (2002)
22 Passaic Valley Sewerage Commission (2014)
23 O'Neill (2012)
24 US EPA (2012)

intake facilities and water conveyance and distribution systems, and cause disruption of service. Such events can also deteriorate water quality due to erosion and contaminants from runoff, subsequently leading to treatment challenges and degradation of reservoir conditions. Hurricane Irene resulted in an estimated $15 billion in economic losses and $3.7 billion in insured losses, with $755 million in insured losses in New Jersey alone.[25] Impacts from Sandy were even greater, with an estimated cost of $29.5 billion to repair damage caused by the storm in New Jersey, including $6.3 billion in insured losses.[26] Public hearings after Hurricane Irene noted that New Jersey utilities must do more to inform well-dependent customers about power reliance, and recommended that well water-dependent customers be identified and provided restoration information on a regular basis.[27] Following Sandy, stakeholders indicated that there is inadequate public notification and education regarding impacts such as storm discharges from combined sewer overflows (CSOs), stormwater systems, and wastewater treatment plants (WWTPs).[28]

Resource Demand

As previously discussed the population and demand of the state have already passed 2040 state water supply master plan projections. In a recent study, a New Jersey-based workgroup estimated that at least $36.6 billion and possibly as much as $40 billion was needed in 2008 to fund New Jersey's water systems infrastructure needs. Development patterns and a lack of investment may continue to strain water resources if conservation efforts are not implemented.[29] Without consideration of increased water and energy demands, future impacts from climate change may include higher operating costs, frequent loss of power, and water shortages.[30] Changes in agricultural practices in response to climate change could also significantly impact the ability of drinking water utilities to provide sufficient supply for their ratepayers. Source water quality can be impacted by temperature, runoff, wastewater, and a host of other environmental variables. Impacts are seen through algal blooms, increases in turbidity and pollution inputs and altered or reduced vegetation cover in watersheds. Such vulnerabilities suggest the need to not only review the strategies of water utilities to meet customer demands, but also to manage the demands of other interdependent systems to ensure resilience in meeting growing customer needs.

Benchmark Adaptation Practices

A number of risks associated with climate change have been discussed or addressed at the federal, state, and local level in the state of New Jersey; however, much remains to be completed. Efforts cited include the recommendations by the New Jersey Department of Environmental Protection to include climate change variables into water resource planning, though no water plan has been released at this point.[31] New Jersey climate adaptation planning for water resources has largely come as a result of EPA planning agency activities or potential activities from private industry. Individual agencies and organizations responsible for watershed management have also begun to develop strategies related to climate change planning in addition to meeting the challenges of a rapidly growing and shifting population in the state. Recent events, including storms and other infrastructure breakdowns, have created a stronger focus on better asset management for water providers and managers in the public and private sectors. If climate change impacts create more intense storms, precipitation impacts, drought, or other issues, resources will continue to be strained. There are a number of adaptation strategies that have been undertaken by nearby states to address some of the challenges associated with climate change. These strategies can range anywhere from policy recommendations to planning requirements and other mechanisms that directly or indirectly incorporate adaptation and resilience for climate change into projects and policies.

25 Linkin (2012)
26 ESA (2013)
27 Emergency Preparedness Partnerships (2012)
28 NJCAA (2013)
29 Facing Our Future (2013)
30 US EPA (2012)
31 NJDEP (2009)

The New York State Department of Environmental Conservation (NYDEC) and New York City Department of Environmental Protection (NYCDEP) have enacted a number of climate change initiatives focused on dealing with adaptation practices to help manage water resources. NYCDEP has identified a number of strategies related to the protection of the water supply in New York City. Demand management strategies include recommendations for providing rebates for the installation of water efficient home appliances and potentially extending similar strategies to industrial uses. Management of shared water resources will also play a critical role in the City of New York, as they work toward providing shared infrastructure. For water quality, NYCDEP has focused on maintaining the avoidance of filtration on certain watersheds through protection initiatives. Such strategies defer what would otherwise be costly installations of infrastructure required to maintain the drinking water supplies. It should be noted that some of these shared resources would come from New Jersey, and, as such, should be integrated and coordinated with any planning done at the state level.[32] New York City's "A Stronger, More Resilient New York" report, written to address the need for additional resiliency planning following Hurricane Sandy, includes localized climate change projections and a risk assessment of how these changes will impact the city's infrastructure. The report identifies strategies to make the city's water resources more resilient, including protecting wastewater treatment facilities from storm surge, improving drainage infrastructure, and promoting redundancy in the water supply delivery system.[33]

Pennsylvania has worked to integrate climate change into existing planning frameworks and processes. The 2009 State Water Plan specifically called for integrating climate change impacts into water resource planning decisions. In order to address the issues that climate change, population growth, and other factors may pose in the future to water resources, the plan recommended that water conservation and efficiency measures be improved through incentives, metering, and pricing changes; that water use registration and reporting regulations be reformed; and that the flooding sections of the state's hazard mitigation plan be revised and updated. The plan also identified alternative water sources such as water reuse and storm water capture, for decreasing potable water demand, recommended regionalization of water systems to improve reliability and flexibility, and promoting improving groundwater recharge through natural or artificial methods. Because the demand for new energy generation facilities is expected to grow in the future and considering the water-intensive nature of power generation, the Pennsylvania Department of Environmental Protection also recommended that all new and existing facilities recycle their process water to meet future cooling water demands.[34]

Maryland has taken a number of steps related to managing water resources for the potential impacts of climate change through legislative and planning requirements at the state level. The Stormwater Act of 2007 requires new development and redevelopment to incorporate Environmental Site Design or low-impact development (LID) techniques wherever possible to promote natural recharge and reduce the volume of runoff and water pollution. In addition, the Water Resources Element (WRE) Law requires that the adequacy of water resources for existing and future development be evaluated as part of local comprehensive plans.[35] Though the WRE currently does not require climate change to be considered, the state is working to develop tools to guide the integration of climate science and adaptation strategies into the WRE, making special area designation categories to include areas subject to climate change impacts such as sea level rise or extreme weather events.[36]

Massachusetts has also created a number of different planning and policy requirements that indirectly help to create more of a focus on climate change impacts of water resources. The State's Water Management Act requires users that withdraw an average of 100,000 gallons per day from surface or groundwater sources to apply for a permit, conditional on adherence to specific values for water use per capita and water loss as well

32 NYSERDA ClimAID Team (2010), US EPA (2010)
33 PlaNYC (2013)
34 PDEP (2009)
35 Maryland Department of Planning (2007)
36 Maryland Department of Planning (2011)

as to implement landscape water use restrictions in stressed basins. Water suppliers are required to conduct water audits annually, ensure 100 percent metering of all uses, and implement a comprehensive residential water conservation program.[37] To prepare infrastructure for climate change impacts, an Adaptation Advisory Committee recommended conducting mapping and surveys to identify and prioritize at-risk facilities; implementing no-regrets strategies such as water conservation and improving storm water management; exploring amendments to planning and zoning regulations and building permitting that account for climate impacts; and enhancing natural systems through wetlands restoration to provide flood protection. With regard to water resources infrastructure, the committee recommended the use of low-impact development (LID) to maintain storm water on-site and improve groundwater recharge, and the expansion of water conservation and reuse measures. The committee also recommended that governments improve planning and land use by ensuring that state investments in infrastructure and development projects consider future climate risks, create flood storage whenever possible by providing incentives for the adoption of LID strategies, and consider floodplain expansion in land use planning as a means of directing development away from vulnerable areas.[38]

In addition to state level management practices and policies, there are also examples of federally-funded or guided local planning agencies and private initiatives underway to help communities adapt to the impacts of climate change. National Oceanic and Atmospheric Administration (NOAA) funding for Climate Resilient Communities allowed the Hampton Roads Planning District Commission in Virginia to complete a three year project to understand the effects of climate change on the region. In particular, climate change impacts to water resources are accounted for in both the water supply plan and the larger regional planning study. Federal initiatives underway also include support in developing adaptation practices for water resources. The US Army Corps of Engineers and NOAA in particular have provided a number of federal guidance documents and supported studies through grants programs to account for adaptation to climate change. Diversifying water sources addresses some challenges associated with increased temperature, such as increased treatment costs associated with declining surface water quality. Groundwater often requires less treatment than surface water, and water recycling reduces the total amount of water that needs to be treated.[39]

There are a number of common approaches to adaptation among the initiatives in each state:

1. Develop a stakeholder group to organize and coordinate state-level adaptation planning and implementation
2. Foster partnerships to stay current on climate science and sector-specific developments
3. Conduct vulnerability assessments to determine potential climate change impacts
4. Use comprehensive planning, current management strategies and legislation, and other existing platforms to begin to address climate risks in relevant sectors.

The NJCAA is employing these approaches in facilitating the development of strategies, ensuring identification of adaptation responses in New Jersey that are consistent with leading practices in other areas.

Discussion and Recommendations

Climate change will adversely affect the availability of water resources through both the availability of water and the capability of organizations to deliver it in a clean, safe, and cost effective manner to consumers. Research predicts that demand for water resources will grow as water resource supplies become more variable, quality of those resources degrades, and infrastructure used to manage water continues to degrade or becomes unsuitable for handling increases in extreme weather events. Further complicating matters is the management of those resources by a number of different agencies in

[37] EEA and Water Resources Commission (2006)
[38] EEEA and the Adaptation Advisory Committee (2011)
[39] Miller and Yates (2005), USDA Natural Resources Conservation Service (2006)

New Jersey and elsewhere in the United States.

New Jersey should continue to support science and research in areas that will greatly affect decision making capability to support given policies. There are certain areas where New Jersey has experience with understanding the risks and benefits of loss to systems. An example would be efforts to understand and mitigate the effects of saltwater intrusion. Other areas require more scientific research or understanding, either via creating more certainty or developing priorities. New Jersey should move forward by focusing on the following groups of initiatives:

Understand water resource vulnerability and resilience: Throughout the Northeast, states are working with federal and local agencies and the private sector to continue to understand the vulnerability of various natural and man-made systems to climate change risk. New York and Pennsylvania in particular have created strategic plans for major cities that focus on understanding climate resilience and how those urban areas could use New Jersey resources to foster resilience in their communities. Such strategies should be a focus of understanding in New Jersey to determine whether or not those strategies would dovetail with any currently planned intrastate climate change vulnerability needs.

Integrate climate adaptation with existing planning and regulatory processes: Some states and regions have been successful at incorporating climate change into official planning processes, where others have not. Planning processes can vary from comprehensive plans to transportation planning exercises undertaken by MPOs to host of other planning exercises. Many states are seeking to develop capital planning and strategic planning strategies that will help to account for climate change under current planning processes and project prioritization. Such a process is occurring in Maryland, and recommendations have been made by various New Jersey stakeholders to take a similar approach.[40] The comprehensive planning process appears to be the preferred method for incorporating climate change into a number of different areas. As New Jersey moves forward, climate change adaptation should be added to planning requirements either for particular elements, or for the plan as a whole.

Prioritize and invest in infrastructure: It appears that leading practices revolve around detailed approaches to capital planning and asset management that prioritize maintenance and upgrades to critical infrastructure and technologies. Such strategies can work to support the resilience of the storage and supply mechanisms (e.g. reservoirs) and the delivery of those water supplies to customers. Such investments might take the form of additional hard infrastructure, developing natural resilience capacity in floodplains or around reservoirs, or investing in integrated water resource management. These processes are underway in some areas, but are often expensive to implement as they require new construction or improvements to the current infrastructure. Watershed protection is used by many nearby states in order to protect the availability of resources, in addition to deferring or eliminating the need to build additional infrastructure for filtration, desalination, and other treatment processes. Investing in supply management technology and innovative landscape design can be used to help manage storm water on-site and restore the natural hydrology of the land in order to protect drinking water supplies and mitigate expensive infrastructure upgrades.

Educate and invest to manage demand: In coordination with planning processes, many states have put forth recommendations to increase efforts to educate residents on issues regarding the impacts of climate change as an integral part of implementing adaptation strategies.[41] Such efforts are important not only to garner support for investment, but also to communicate, where appropriate demand management strategies that will be implemented by the public if needed.

[40] Clean Water Council of New Jersey (2010)
[41] NJDEP (2009); NYSERDA ClimAID Team (2010); EEEA and the Adaptation Advisory Committee (2011)

Table 2 : Specific areas for investigation based on leading practices and recommendations

New Jersey Adaptation Need	*Potential Initiatives for Investigation and Projects*
Understand Water Resource Vulnerability and Resilience	• Work with local and regional researchers, businesses, and government officials to improve data collection and analysis of data related to climate change adaptation planning and performance measurement • Quantify the vulnerability of the system to potential climate impacts of demonstrated risks such as saltwater intrusion, storm surge and inland flooding • Understand and promote resilience of critical facilities through partnerships with businesses • Review current regulation with a focus on climate adaptation including: o Floodplain definitions o Permitting o Design and construction standards
Integrate Climate Adaptation with Planning and Regulation Processes	• Develop a stakeholder group to organize and coordinate state-level adaptation planning and implementation • Similar to Maryland, investigate methods to account for climate change and adaptation planning as a required element of master plans • Review zoning and land use in the context of potential climate adaptation, including floodplain management, water and waste water service provision, and other impacted services • Review supply management and permitting processes • Deliver infrastructure for users of secondary sources of water to promote broader use of these supplies
Prioritize and invest in critical infrastructure	• Study interdependencies between sectors to ensure that capital planning and asset management strategies are coordinated to support overall resilience • Identify and address vulnerabilities at critical facilities o Harden infrastructure o Create system redundancy • Develop memorandums of understanding for emergency management • Review approaches to acquisition of watershed properties to protect reservoir water quality • Review protocols for inspection and maintenance of existing systems to account for long term climate impacts • Investigate incentives and financing programs for infrastructure improvements and maintenance • Identify and analyze techniques for conservation, reuse and purification • Promote appropriate residential landscape practices and plants to reduce water use
Educate and invest to manage demand	• Develop education and awareness information for engaging different levels of stakeholders from politicians to elementary school students • Promote water conservation practices and technologies with the general public • Identify key areas for institutionalization of adaptation planning at Municipal and State government levels • Hazard awareness and education • Effective risk communication on cumulative impacts of climate change • Effective communication on citizen action

Sources:

Clean Water Council of New Jersey. 2010. Draft Recommendations for Water Infrastructure Management and Financing: White Paper for Public Hearing and Comment, October 12, 2010. Available at: *http://www.nj.gov/dep/cleanwatercouncil/hearing2010.htm*

Cooper, M. J.P., M. D. Beevers, and M. Oppenheimer. 2005. Future of Sea Level Rise and New Jersey Coast: Assessing Potential Impacts and Opportunities. Available at: *http://www.princeton.edu/step/people/faculty/michael-oppenheimer/recent-publications/Future-Sea-Level-Rise-and-the-New-Jersey-Coast-Assessing-Potential-Impacts-and-Opportunities.pdf*

Economics and Statistics Administration (ESA). (2013). Economic Impact of Hurricane Sandy Potential Economic Activity Lost and Gained in New Jersey and New York. Retrieved from *http://esa.gov/sites/default/files/reports/documents/ sandyfinal101713.pdf*

Emergency Preparedness Partnerships. 2012. Performance Review of Electric Distribution Companies in 2011 Major Storms. Available at: *http://www.nj.gov/bpu/pdf/announcements/2012/stormreport2011.pdf*

Executive Office of Energy and Environmental Affairs (EEEA) and the Adaptation Advisory Committee. 2011. Massachusetts Climate Change Adaptation Report. September 2011. Available at: *http://www.mass.gov/eea/air-water-climatechange/climate-change/climate-change-adaptation-report.html*

Executive Office of Environmental Affairs (EEA) and Water Resources Commission. 2006. Water Conservation *Standards. Available at: http://www.mass.gov/eea/docs/eea/water/water-conservation-standards.pdf*

Facing Our Future. 2013. Infrastructure Investments Necessary for Economic Success. Retrieved from the council of New Jersey Grantmakers Website at *http://www.cnjg.org/s_cnjg/bin.asp?CID=10859&DID=61695&DOC=FILE.DOC*

Lacombe, P.J., and Carleton, G.B., 2002, Hydrogeologic framework, availability of water supplies, and saltwater intrusion, Cape May County, New Jersey: U.S. Geological Survey Water-Resources Investigations Report 01-4246/

Linkin, M. E. 2011. Catastrophic Risk in New Jersey: Past, Present and Future. Presented at Preparing New Jersey for Climate Change: A Workshop for Decision Makers November 29, 2011. Available at: *http://climatechange.rutgers.edu/njadaptpdfs/linkin_presentation.pdf*

Maryland Department of Planning. 2007. Models and Guidelines #26: The Water Resources Element. Available at: *http://www.mdp.state.md.us/pdf/OurWork/mg26.pdf*

Maryland Department of Planning. 2011. PlanMaryland Revised Draft Plan. Available at: *http://www.plan.maryland.gov/PDF/draftPlan/PM_revisedDraft.pdf*

Miller, K. and D. Yates. 2005. Climate Change and Water Resources: a Primer for Municipal Water Providers. Available at: *http://www.isse.ucar.edu/water_conference/*

New Jersey Climate Adaptation Alliance (NJCAA). 2013. Stakeholder Engagement Report: Water Resources. Climate Change Preparedness in New Jersey. Edited by Daniel J. Van Abs. New Brunswick, New Jersey: Rutgers University. Available at: *http://njadapt.rutgers.edu/resources/njcaa-reports*

New Jersey Department of Environmental Protection (NJDEP). 2004. Water Supply Action Plan 2003-04: DRAFT, New Jersey Statewide Water Supply Planning Process. Available at: *http://www.state.nj.us/dep/watershedmgt/DOCS/pdfs/WaterSupplyActionPlan03-04.pdf*

New Jersey Department of Environmental Protection (NJDEP). 2009. Meeting New Jersey's 2020 Greenhouse Gas Limit: New Jersey's Global Warming Response Act Recommendations Report. Available at: *http://www.nj.gov/globalwarming/home/documents/pdf/njgwra_final_report_dec2009.pdf*

New York State Energy and Research Development Authority (NYSERDA) ClimAID Team. 2010. Responding to Climate Change in New York State, the Synthesis Report of the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State. Available at: *http://www.nyserda.ny.gov/Publications/Research-and-Development/Environmental/EMEP-Publications/Response-to-Climate-Change-in-New-York.aspx*

O'Neill, James M. 2012. Officials Warn of Contamination Levels in Newark Bay, Lower Passaic and Hackensack Rivers. The Record. November 14, 2012. Available at: *http://www.northjersey.com/news/Officials_warn_of_contamination_levels_in_Newark_Bay_lower_Passaic_and_Hackensack_rivers.html*

Passaic Valley Sewerage Commission. 2014. Recovering From Superstorm Sandy. Available at: *http://www.nj.gov/pvsc/home/forms/pdf/Superstorm_Sandy_Update_2014a.pdf*

Pennsylvania Department of Environmental Protection. 2009. Pennsylvania State Water Plan. Available at: *http://www.pawaterplan.dep.state.pa.us/docs/Publications/3010-BK-DEP4222.pdf*

PlaNYC. 2013. A Stronger, More Resilient New York. Available at: *http://nytelecom.vo.llnwd.net/o15/agencies/sirr/SIRR_spreads_Hi_Res.pdf*

U.S. Census Bureau. 2012. State and County QuickFacts. Available at: *http://quickfacts.census.gov/qfd/states/34000.html*

U.S.Department of Agriculture (USDA) Natural Resources Conservation Service. 2006. New Jersey Water and Related Land Resource Long-Range Plan. Available at: *http://www.nj.nrcs.usda.gov/programs/Water_Long_Range_Plan.html*

U.S. Environmental Protection Agency. 2010. Region 2 Water: Sole Source Aquifers. Available at: *http://www.epa.gov/region2/water/aquifer/*

U.S. Environmental Protection Agency. 2012. Adaptation Strategies Guide for Water Utilities. Available at: *http://water.epa.gov/infrastructure/watersecurity/climate/*

U.S. Global Climate Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). New York: Cambridge University Press. Available at: *http://globalchange.gov/publications/reports/scientific-assessments/us-impacts*

New Jersey Department of Environmental Protection (NJDEP). 2004. Water Supply Action Plan 2003-04: DRAFT, New Jersey Statewide Water Supply Planning Process. Available at: *http://www.state.nj.us/dep/watershedmgt/DOCS/pdfs/WaterSupplyActionPlan03-04.pdf*

New Jersey Department of Environmental Protection (NJDEP). 2009. Meeting New Jersey's 2020 Greenhouse Gas Limit: New Jersey's Global Warming Response Act Recommendations Report. Available at: *http://www.nj.gov/globalwarming/home/documents/pdf/njgwra_final_report_dec2009.pdf*

New York State Energy and Research Development Authority (NYSERDA ClimAID Team). 2010. Responding to Climate

Change in New York State, the Synthesis Report of the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State. Available at: *http://www.nyserda.ny.gov/Publications/Research-and-Development/Environmental/EMEP-Publications/Response-to-Climate-Change-in-New-York.aspx*

O'Neill, James M. 2012. Officials Warn of Contamination Levels in Newark Bay, Lower Passaic and Hackensack Rivers. The Record. November 14, 2012. Available at:
http://www.northjersey.com/news/Officials_warn_of_contamination_levels_in_Newark_Bay_lower_Passaic_and_Hackensack_rivers.html

Pennsylvania Department of Environmental Protection. 2009. Pennsylvania State Water Plan. Available at:
http://www.pawaterplan.dep.state.pa.us/docs/Publications/3010-BK-DEP4222.pdf

U.S. Census Bureau. 2012. State and County QuickFacts. Available at:
http://quickfacts.census.gov/qfd/states/34000.html

U.S.Department of Agriculture (USDA) Natural Resources Conservation Service. 2006. New Jersey Water and Related Land Resource Long-Range Plan. Available at: *http://www.nj.nrcs.usda.gov/programs/Water_Long_Range_Plan.html*

U.S. Environmental Protection Agency. 2010. Region 2 Water: Sole Source Aquifers. Available at:
http://www.epa.gov/region2/water/aquifer/

U.S. Environmental Protection Agency. 2012. Adaptation Strategies Guide for Water Utilities. Available at:
http://water.epa.gov/infrastructure/watersecurity/climate/

U.S. Global Climate Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). New York: Cambridge University Press. Available at:
http://globalchange.gov/publications/reports/scientific-assessments/us-impacts