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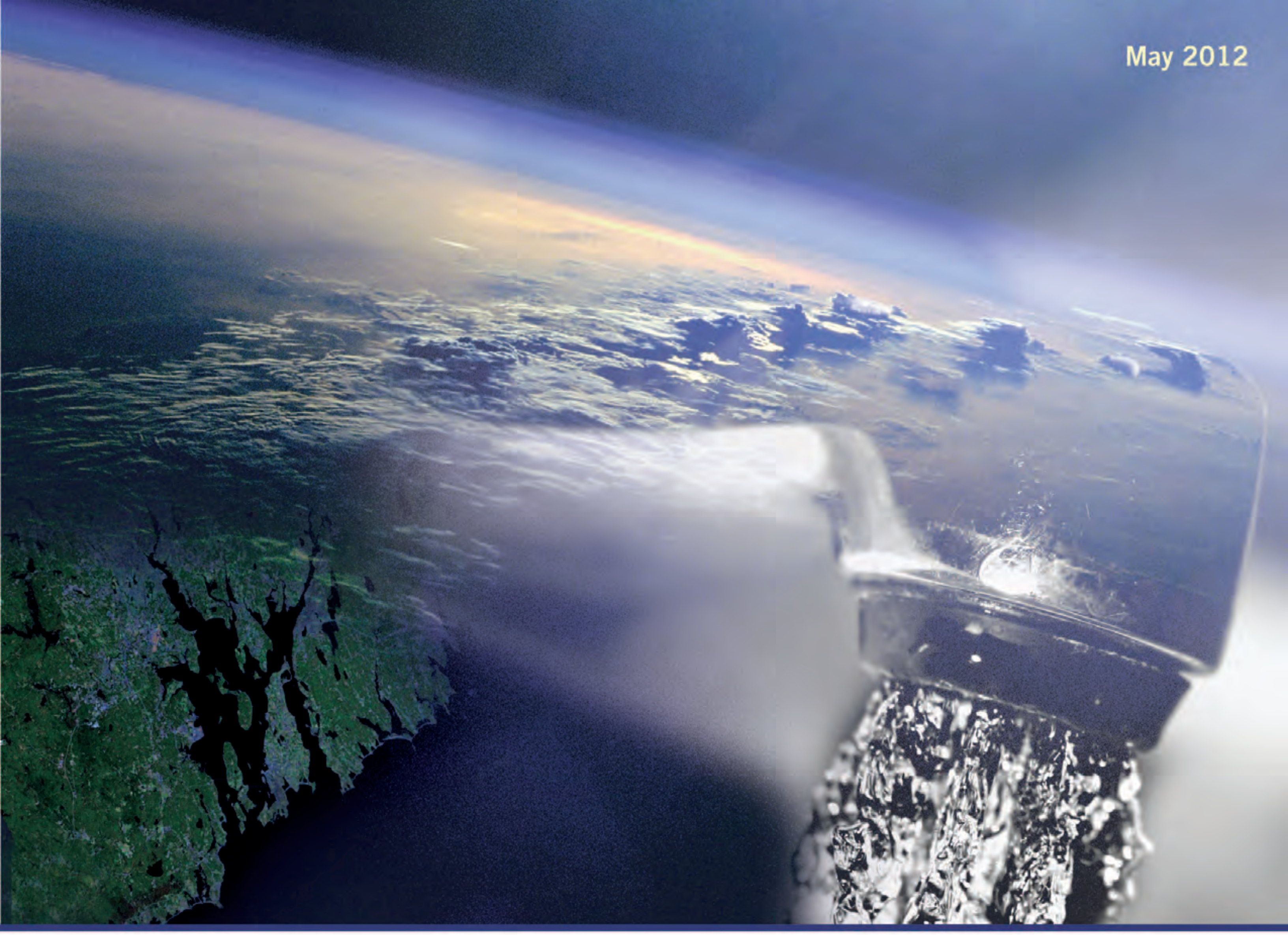

SafeWater RI

Ensuring Safe Water for Rhode Island's Future

Phase 1 Report

Prepared for:

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1.0 BACKGROUND AND OVERVIEW

Drinking water utilities in Rhode Island face numerous challenges such as drought, pollution, competing water uses, and aging infrastructure that must be addressed to ensure that their customers receive safe, dependable drinking water. The impacts from global climate change will exacerbate current challenges and present new risks to Rhode Island water utilities and their service areas.

Altered precipitation patterns could increase flood events, like the recent flooding experienced in 2010, while more extreme weather events will pose storm surge risks to the state's more than 400 miles of coastlines. In addition to physical damage to water infrastructure systems and dams, flooding can also increase turbidity and pollutant loads in source water, requiring more extensive treatment to remove the pollutants. Excessive flooding can also release pathogens from storm sewer systems when their capacity is exceeded to manage wastewater during storm events. Areas that rely heavily on wells, such as the eastern portion of the state, could potentially become contaminated by surface water containing pathogenic protozoa such as *Giardia* and Cryptosporidium. Additionally, the global melting of glaciers and ice sheets will impact coastal areas through sea-level rise. The elevated sea-levels can contaminate aquifers through intrusion of saltwater and damage coastal ecosystems, which will be particularly challenging for Rhode Island since the majority of the population lives along the coastline.

In January 2012 the Rhode Island Department of Health (HEALTH), Office of Drinking Water Quality, launched *Safe***Water** RI*: Ensuring Safe Water for Rhode Island's Future (Safe***Water** RI*)* which is being led by Tetra Tech Inc. The project will help address the implications of climate change to drinking water utilities by providing locally relevant and actionable data for water utility managers to evaluate and plan for future scenarios. The objective of the project is to assess changing environmental conditions (including temperature, precipitation patterns, sea-level rise, and storm surge) and their potential impacts on drinking water utilities in Rhode Island, and develop strategies to address these changing conditions. The *Safe***Water** RI project includes four project components:

- Phase 1: Data Collection
- Phase 2: Assessment of Impacts
- Phase 3: Development of Management Strategies
- Phase 4: Outreach and Education

This report provides a summary of the methodology and findings of the first phase of the *Safe***Water** RI project. Phase 1 data collection activities included both primary data collection and a desktop literature review. The information presented in this report will inform the remaining *Safe***Water** RI project phases and is intended to present HEALTH with a summary of project activities and findings to date.

2.0 PRIMARY DATA COLLECTION

Tetra Tech collected primary data using 1) a survey that was distributed to the principal drinking water utilities and 2) consultation sessions that were held with Rhode Island government partners and drinking water utility representatives.

2.1 Survey

2.1.1 Methodology

A survey was developed to obtain information from water utility representatives and to initiate engagement with the water utilities at the project launch. The survey was designed to collect the following information:

- Current and future concerns of the water utility
- Planning tools and horizons used by the water utility
- Methods the water utility uses to address uncertainty associated with future planning
- Perceptions of the term climate change with various stakeholders

The survey used a mixed-methods approach so that quantitative data could be generated through multiple choice and priority ranking questions, while qualitative data could be obtained through open-ended questions. Survey Monkey was used for survey development and distribution. HEALTH identified a primary point of contact from each of the 25 largest water utilities in the state and distributed the initial survey request via email. The contacts were also encouraged to distribute the survey to others in their water utility that could complete the survey (targeted positions for survey completion included General Manager, Chief Engineer, Operator, Superintendent). The initial survey request was sent in February 2012 and responses were collected through March 2012. Appendix A includes the survey questions as they were presented to the drinking water utility representatives via Survey Monkey.

2.1.2 Key Findings

Survey responses were received from 23 drinking water utilities, with 26 total responses recorded.[1] Appendix B contains a complete listing of individuals that completed the survey.

Tetra Tech presented the initial survey results at the kickoff meeting with drinking water utility representatives (described in Section 2.3). The PowerPoint presentation is included as Appendix C.[2] Graphical and numerical summaries are provided for quantitative question responses, while qualitative question responses have been included in full or grouped where appropriate. Key findings from the survey include the following:

- Primary concerns for drinking water utilities include protection of public health, financial challenges, water quality protection, aging infrastructure, and regulatory restrictions. These concerns are similar for both short- and long-term planning horizons.
- Drinking water utilities use several strategies and techniques to manage their current water quality, water availability, and infrastructure needs. Most drinking water utilities employ a combination of approaches such as aggressive water quality monitoring, demand management, preparation of assessment and planning reports, and maintenance and replacement of aging infrastructure.
- The vast majority of drinking water utilities are encumbered by economic concerns in addressing their priority needs.
- Very few utilities use decision-support tools to assess future risk and demand.
- Most responders noted that they are “somewhat concerned” with the potential impacts of climate change but in many cases “don’t know” how climate change impacts would affect their utilities.

[1] Multiple surveys were received from the following utilities: Portsmouth Water & Fire District (3 responses) and Naval Station Newport (2 responses).

[2] The PowerPoint presentation in Appendix C includes additional survey results that were received after the kickoff meeting.

- In addressing the impacts of weather-related events, respondents noted that water board members are the most proactive stakeholders, and customers and elected officials are generally viewed as reactive stakeholders.

The key findings highlight that although drinking water utilities are somewhat concerned with the potential impacts of climate change, they are not currently factoring climate change into their planning efforts. Responses suggest that water utilities do not have the necessary financial resources, decision-support tools or site-specific data to effectively evaluate how climate change might impact their utility and to plan for future scenarios.

2.2 Consultation with Rhode Island Government Partners

Consultative sessions were held with the Water Resource Board and Department of Environmental Management Office of Water Resources representatives. Separate consultative sessions were organized with each of the agencies by HEALTH and held on February 28, 2012. The objectives of the consultations were to: 1) introduce the project and objectives to the agencies; 2) solicit useful data or other resources that could inform the project; and 3) encourage the continued collaboration of these agencies throughout the life of the project. Several relevant resources were identified through these consultations and are included in Appendix D (listed under Rhode Island Government Resources).

2.3 Consultation with Rhode Island Drinking Water Utilities

A project kickoff meeting was held with representatives of the major drinking water utilities on February 29, 2012. Nine utilities participated: Bristol County Water Authority, East Smithfield Water District, Harrisville Fire District Water Department, Jamestown Water Department, Johnston Water Control Facility, Naval Station Newport (2 representatives), Portsmouth Water & Fire District (2 representatives), Town of North Kingstown, and the University of Rhode Island. A complete listing of individuals that attended the kick-off meeting is included in Appendix B.

2.3.1 Meeting Objectives and Design

The overall objective of the consultation was to solicit input from the drinking water utilities at the beginning of the project and to ensure that the project design and scope is optimal in addressing the drinking water utility needs. Early and continued engagement with the drinking water utilities will facilitate the implementation of adaptation options and stakeholder communication strategies to be developed later in the project.

The primary components of the consultation included: 1) outlining the objectives and process of the *Safe* **Water** RI project; 2) presentation of the survey results; and 3) a facilitated discussion with the utility representatives.

2.3.2 Key Findings

The purpose of the facilitated discussion was to solicit input from drinking water utilities to inform the scope and priorities of the *Safe***Water** RI project. The questions that were posed to participants include the following:

- Are there additional concerns that your drinking water utility faces that were not captured in the survey results?
- Are there current policies or regulations that would help your utility in meeting critical needs and priorities?
- Are there current policies or regulations that hinder your utility in meeting needs and priorities?
- What planning horizons do your utility use?

- What are the types of obstacles that your utility faces in operating your facility?
- What type of outreach do you currently conduct with your stakeholders? What additional outreach would you like to conduct with your stakeholders?
- How concerned are you about the impacts of climate change to your utility? How is the term climate change perceived by your stakeholders?

Primary Concerns

It was noted that consideration of both the geographic location of the utility and the water source is important in understanding the different concerns of each utility. Much of the drinking water in the central and southern parts of the state is drawn from groundwater aquifers. Surface water sources supplies the needs of the rest of the state, particularly in the northwest section.

Many of the participants identified drought as a concern. However, several of the utilities purchase their water from other utilities, such as from the Pawtucket and Providence Water Supply Board, and are not subjected to withdrawal/purchase limitations. Thus, potential water scarcity from drought is not a primary concern for those utilities. It was noted that the state is currently studying safe and sustainable withdrawal rates. If withdrawal restrictions are determined as a result of this study, then utilities would be forced to address the issue more aggressively. It was also noted by several participants that identifying an effective means of selling or shipping water from the northern to southern parts of the state could assist in meeting emergency water needs. The Portsmouth Water and Fire District cited their agreement to buy water on an emergency basis as a potential model for other utilities. Participants also identified regionalization[3] as an applicable issue for several areas and utilities in the state, and one that should be explored in more detail to assist with water sharing.

The majority of Rhode Island's population and several of the principal drinking water utilities are located in proximity to the coastal zone. While sea-level rise was identified as a potential concern, participants cited a lack of definitive data to indicate the extent of encroachment of future sea-levels on coastal resources. The lack of data makes it impossible to plan for sea-level rise in any meaningful way.

Water quality was identified as an area that is becoming more of a priority issue due to SEA-LEVELEPA water quality mandates and the inclusion of additional contaminants. Utilities are investing in water infrastructure that may not be able to handle the treatment necessary for new contaminants. Detecting additional contaminants could also increase the overall cost of service.

Many water utilities are struggling with changing water demand and the resultant revenue fluxes. For example, East Smithfield operates a small system in a town with a large elderly population, many of which live on a fixed income. Over the past two decades the mills that were once the economic engine of the town left—leaving an aging and outdated water supply infrastructure. East Smithfield now sells only half of the amount of water that was once sold in the 1980s and 90s, and has been forced to raise water rates significantly over the past five years. Conversely, Johnston Water Control Facility is seeing an increase in water demand as industry moves into their town over the next few years.

Useful Regulations or Policies

Water supply plans are now required to include a drought component. These plans are due for each utility in the July/August timeframe, which should help the utilities in planning for drought events.

The Water Resource Board developed a grass water policy with the landscapers association as a demand-side strategy to reduce water consumption, which was in general cited as a positive policy. However,

[3] For the purposes of this Report, regionalization is defined as the combination of services and cooperation among neighboring water systems to improve service and efficiencies, and to lower costs.

participants said that the policy has seen only limited response to date. North Kingstown noted that during a drought in the 1970's they instituted a watering policy using odd/even day allocations. An increase in water usage was actually recorded during that time-period. There was the sense from the public that "it's my day and so I need to water my lawn". Participants expressed that as Rhode Island shifts from primarily an industrial state to a residential state, water demand becomes less predictable. For example, there is a typical seasonal demand shift from winter to summer; however, the economic downturn has impacted the amount of water used as people struggle to pay their bills.

Challenging Regulations or Policies

The participants identified demand-side water reduction strategies as a "double-edged sword". If customers conserve water, then the utility sells less water, and is thus less able to meet financial obligations and sufficiently maintain infrastructure.

The requirement of the 2009 Water Use and Efficiency Act for utilities to establish revenue stabilization accounts and debt service reserves was identified as a challenge. Several participants said that they are not in a position to create the fund. They felt that their customers have been experiencing rate increases over the years and that obtaining approval to raise rates in the future will be difficult.

Johnston Water Control Facility noted that they are under a local government mandate to create a sewer utility, however the utility will not be funded at the amount it will take to develop and operate system.

Planning Horizons

Participants noted that they develop a 20-year comprehensive planning document that is updated every 5 years. The 20- and 5-year planning horizons are the most commonly used planning horizons for Rhode Island drinking water utilities.

Obstacles to Planning and Implementation

The participants underscored the survey results, in that economic constraints are the primary obstacles faced by drinking water utilities. One participant described the issue of rate increases for their utility as "trying to get blood from a turnip"—their utilities have raised rates all they can in trying to maintain aging infrastructure with decreased demand.

Many participants also noted that their utilities are small with limited staff, thus, there are technical and administrative barriers to implementing current and planned projects. For example, utilities don't always have the needed expertise to perform tasks in-house and there are staffing shortages if staff are sick or on vacation. East Smithfield Water District, Johnston Water Control Facility, and Harrisville Fire District Water Department each acknowledged that they had approached other utilities to share technical skills, and potentially merge and form larger utilities.

Outreach

Several utilities identified existing outreach efforts to their customers. The Portsmouth Water & Fire District televises all board meetings, and the Harrisville Fire District Water Department informs customers with changes and news via mailings. The Providence Water Board was cited as more proactively engaging with their customers and having resources for public outreach. Participants suggested that the utilities did not have the time/resources to develop and implement public outreach efforts but acknowledged these materials would be useful.

Several participants noted that water is severely underpriced and that a united message in pricing water, perhaps coming from the Rhode Island Water Works Association, would assist to stress how undervalued water is compared to other services. Participants also commented that public outreach and education efforts on the issue of aging infrastructure and increased maintenance costs, as well as seasonal demand issues (i.e., summertime water usage rates) could be beneficial.

Climate Change

There was a general agreement that climate change is a 'charged' term. There is a perception among drinking water utility stakeholders that the science is unsettled on whether climate change is actually occurring and whether man-made greenhouse gas emissions are causing climate change. Use of the terms 'extreme weather events' or 'severe weather' was recognized as potential substitute terms, particularly with water board members.

Participants also agreed that there are many immediate, pressing needs that water utilities are struggling with so that climate change is not viewed as a priority issue.

3.0 DESKTOP LITERATURE REVIEW

Tetra Tech conducted a desktop literature review to research the following issues: 1) the state of knowledge regarding climate change trends for the Northeast and specifically Rhode Island; 2) potential climate change impacts on drinking water utilities; and 3) best practices used in adaptation strategies for drinking water utilities. Resources were compiled through desktop research and consultations as part of the *Safe***Water** RI project and are listed in Appendix D.[4] The list is not intended to be exhaustive or complete, but the resources included are considered the most relevant/illustrative secondary information sources.

The literature review resources in Appendix D are organized into five sections:

- **Climate Trends.** Resources that include pertinent information on observed and/or projected climate trends.
- **Rhode Island Government Resources**. Relevant government resources and authorities for the *Safe***Water** RI project. These resources will be used to ensure regulatory compliance with proposed adaptation options and identify planning synergies associated with the *Safe***Water** RI project.[5]
- **Rhode Island: Additional Climate Resources**. A listing of climate resources that have been developed by coalitions and associations for the state.
- **Understanding and Managing Climate Risk.** Representative information on how municipalities and communities have approached climate risk management, including the role of state and local government action.
- **Water Utilities: Climate Change Vulnerability Assessment and Adaptation Planning.** A listing of resources that specifically address climate vulnerability assessment and best practices in adaptation for drinking water utilities.

Highlights from the literature review are presented in the sections below.

[4] All resources listed in the literature review are available for download and review on the *Safe***Water** RI ftp site: ftp://rhode_island/array1/RICC/. (Note: Copy and paste into windows explorer to open the link.)
[5] Note that resources that directly or indirectly inform climate change and water resources are included and is in no way exhaustive of relevant Rhode Island Government resources.

3.1 Climate Change Trends in the Northeast United States and Rhode Island

The following publications were found to have the most comprehensive and informative summaries of historic and projected future climate trends relevant to Rhode Island and New England:

- (Rhode Island) Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007b. *Rhode Island Report*, in Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Cambridge, MA, Union of Concerned Scientists (UCS).
- (Rhode Island) Heffner, L., R. Williams, V. Lee, P. Rubinoff, C. Lord. 2012. *Climate Change and Rhode Island's Coasts: Past, Present, and Future*. URI Coastal Resources Center and Rhode Island Sea Grant, Providence, Rhode Island.
- (Rhode Island) Roberts, T., Birky, K., Damm, K., Fisher, N., Hojagyedliyev, D., Knee, J., Marciante, L., Marshall, C., Mattison, C., McCracken, C., Mersha, S., Pagan, J., and Poyar, K. 2010. *Summary: Preliminary assessment of Rhode Island's vulnerability to climate change and its options for adaptation action*. Brown University Center for Environmental Studies, Graduate Seminar on Special Topics in Environmental Studies: Urban Adaptation to Climate Change. Available online at: http://envstudies.brown.edu/Summary-RIClimateChangeAdaptation.pdf.
- (Northeast) Union of Concerned Scientists (UCS). 2006. *Climate Change in the U.S. Northeast - A Report of the Northeast Climate Impacts Assessment*. Available online at: http://www.ucsusa.org/assets/documents/global_warming/necia_climate_report_final.pdf.
- (Northeast/United States) U.S. Global Change Research Program. 2009. *Global Climate Change Impacts in the United States*. Cambridge University Press, Cambridge, MA.
- (Global) Intergovernmental Panel on Climate Change (IPCC). 2007: Climate Change 2007: Synthesis Report. Available online at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

There is a growing body of scientific research that is documenting the impacts of climate change in the region. In Rhode Island, research shows that spring is arriving earlier, summers are growing hotter, and winters are producing less snowfall. Table 1 summarizes recorded trends in air temperature, precipitation, ocean temperature, sea-level rise, and storminess for Rhode Island (adapted from Heffner et al. 2012).

Table 1. Climate change trends for the United States, the Northeast, and Rhode Island

Climate Change Variable	Geographic Scale	Observations of Recent Change
Air Temperature	Global	Global mean temperature has increased 1.33°F over the last 100 years
	Northeast	Since 1900, the annual mean temperature has risen 1.5°F
	Rhode Island	Average annual temperature rose 1.7°F from 1905 to 2006
Precipitation	Global	Rainfall has decreased in the Northern Hemisphere subtropics and increased in mid-latitudes over the last 50 years
	Northeast	Studies have found a 5 to 17 percent increase in regional precipitation during roughly the last 100 years
	Rhode Island	Over the past 100 years, Rhode Island precipitation has increased by 3 mm (0.12 in) per year. Annual mean wind speed at T.F. Green Airport has significantly declined since at least the 1960s
Ocean Temperature	Global	The ocean has been warming consistently over the past 50 years, with 2007 as the warmest on record
	Northeast	Annual average temperatures in the waters off the southern New England coast have increased by about 2.2°F since the 1970s

Table 1. (Continued)

Climate Change Variable	Geographic Scale	Observations of Recent Change
	Rhode Island	In Narragansett Bay, winter sea-surface temperatures have risen 4°F since the 1960s
Sea Level Rise	Global	Globally, sea-level rose in the 20th century at an average rate of 1.8 mm (0.07 in) per year, a rate greater than that of the preceding eight centuries. Between 1993 and 2003 this rate almost doubled to 3.4 mm (0.13 in) per year.
	Rhode Island	In Newport, sea-level has risen an average of 2.6 mm (0.1 in) per year since 1930
Storminess	Global	The severity of hurricanes has increased since the 1970s
	Northeast	The severity of hurricanes in the North Atlantic has increased

A comprehensive modeling effort on the projected impacts of climate change has not yet been undertaken for Rhode Island. However, Frumhoff et al. (2007b) identified the primary climate trends that could impact Rhode Island under a high emissions scenario[6] based on research conducted for the northeast region by the Union of Concerned Scientists (UCS). These primary climate trends include the following:

- Temperature: Seasonal average temperatures across Rhode Island are projected to rise 7°F to 13°F above historic levels in winter and 6°F to 14°F in summer by late-century. Figure 1 illustrates changes in the average summer heat index for Rhode Island under the high and low emission scenarios.
- Winter snow: Rhode Island could see its snow season reduced to just a few days per winter month by mid-century, and virtually eliminated by late-century.
- Drought: Rising summer temperatures, coupled with little change in summer rainfall, are projected to increase the frequency of short-term (one- to three month) droughts.
- Sea-level rise: Global sea-level is projected to rise between 10 inches and two feet by the end of the century.

These findings provide an overview of the state of knowledge regarding climate change trends and impacts as it relates to New England and Rhode Island.

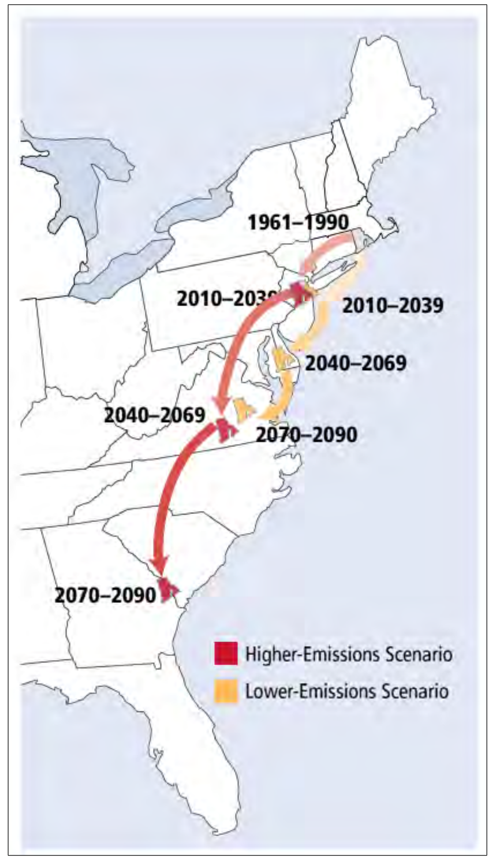


Figure 1: Migrating state climate under predicted high and low emissions scenarios

3.2 Climate Change Implications for Drinking Water Utilities

The most direct climate-change related impacts to Rhode Island water utilities are likely to be caused by changes in water availability (e.g. drought), sea-level rise, and storm intensity and frequency. Several

[6] Climate models are run against greenhouse gas emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). There are 40 different scenarios, each making different assumptions for future greenhouse gas pollution, land-use and other driving forces. The higher-emissions scenarios represent a world that experiences rapid economic growth and reliance on fossil fuels; whereas the lower-emissions represent a more ecologically friendly world.

resources describe the potential impacts of climate change on drinking water utilities in general terms, which are summarized below.

Cromwell et al. (2007) provides an overview of how drinking water utilities in various regions of the country might be impacted by climate change. Impacts on drinking water utilities relevant to Rhode Island are included in Figure 2.

Potential Climate Change Impacts on Drinking Water Utilities

Rising sea levels:

- Increased saline intrusion into groundwater aquifers
  - Water treatment challenges: increased bromide; need for desalination
- Increased salinity of brackish surface water sources
  - Water treatment challenges: increased bromide; need for desalination
- Increased risk of direct storm and flood damage to water utility facilities

Warmer overall:

- Changes in discharge characteristics of major rivers due to upstream changes
- Changes in recharge characteristics of major groundwater aquifers due to upstream changes
- Increased water temperature
  - Increased evaporation and eutrophication in surface sources
  - Water treatment and distribution challenges (disinfection, byproducts, regrowth)
- Possible increased water demand
  - Increased irrigation demand
  - Increased urban demand with more heat waves and dry spells
  - Increased drawdown of local groundwater resources to meet the above

More intense rainfall events:

- Increased turbidity and sedimentation
  - Shallower, warmer water; increased evaporation and eutrophication
  - Potential conflicts with flood control objectives
- Increased risk of direct flood damage to water utility facilities

Figure 2. Potential Climate Change Impacts on Drinking Water Utilities

Based on the findings of several climate change studies, the AWWA Research Foundation (2007) broadly categorizes potential climate change impacts on water utilities as water quality impacts, water quantity impacts, operational reliability impacts, and financial and institutional impacts. Water quality could be impacted by extreme weather (increasing sediment, pathogen loads, and urban stormwater runoff), as well as from gradual processes such as more widespread algal blooms, changes in watershed vegetation, and increased water temperature (increasing eutrophication and disinfectant demand). Water quantity will be impacted due to increasing temperature and precipitation variability—which will not be uniform across the country, and could include reduced in-stream flows, decreased snowpack, earlier and more intense snowmelt, and reduced aquifer recharge. Climate change could impact the operational reliability of drinking water utilities in a variety of ways: flood damage and pipe breaks could impact utility infrastructure, coastal facilities could be threatened by sea-level rise and increased corrosion, warmer temperatures could increase the range of invasive species such as zebra mussels; and reservoir management could be complicated by changes in runoff timing and intensity. AWWA recognized financial and institutional implications from climate change as potentially the most significant, yet least understood, issue for drinking water utilities. For example, utilities may need to design new rate structures to better reflect the increasing value of water and increasing conflict with competing water users. Climate change could also lead to population shifts that may increase or decrease a utility's customer base.

The issue of variability is stressed throughout the literature; climate change will cause increased variability for water supply planning, including changes in the capability to store water and changed water demands (Cromwell 2007; Water Utility Climate Alliance 2009; Bloetscher et al. 2010; Dorfman and Mehta 2011; Interdepartmental Climate Change Group 2009; USEPA 2009).

Strzepek et al. (2011) and USEPA (2009) describe the importance of conducting climate change assessments at the watershed level to fully identify the risks to water supply and infrastructure systems, as well as to effectively develop water resource management strategies.

The literature also states that the most useful climate change assessments are those that are tailored to the site-specific considerations and information needs of the water utility (Yates and Miller 2011; Water Utility Climate Alliance 2009; California Department of Water Resources 2008).

Recognizing the common challenges that drinking water utilities face related to climate change is useful to this project in that it assists in identifying best practices in conducting vulnerability assessments and identifying priority vulnerabilities.

3.3 Adaptation Options for Drinking Water Utilities

The most comprehensive resource for drinking water utility adaptation strategies is the *Adaptation Strategies Guide for Water Utilities* (USEPA 2012). The Guide provides adaptation options for drinking water, wastewater, and stormwater utilities based on region and projected climate impacts. Adaptation options are grouped according to impact (drought, water quality degradation, flooding, ecosystem changes, and service demand and use) and indicate relative costs are also provided for each option. Appendix E lists the adaptation options identified in the Guide for each of the climate hazards. The three categories of adaptation options included are:

- **Planning strategies:** which include use of models, research, training, supply and demand planning, natural resource management, land use planning, and collaboration at watershed and community scales;
- **Operational strategies:** which include efficiency improvements, monitoring, inspections, conservation, demand management, flexible operations, and sustainable strategies; and
- **Capital / infrastructure strategies:** which include construction, water resource diversification, repairs and retrofits, upgrades, phased construction, new technology adoption, and green infrastructure.

The literature review also identified several beneficial case studies, as these evaluate adaptation options that have been or are being applied in a specific context (Ewert 2011; Interdepartmental Climate Change Group 2009; Ofwat 2008; USEPA 2011; WSAA 2011; Yates and Miller 2011). The case study of New York City is considered particularly relevant, as the city is one of the few in the country that has conducted a climate vulnerability assessment and adaptation planning inclusive of drinking water utilities. The City is also located in the Northeast, in close proximity to the Atlantic Ocean, and will experience similar climate hazards to Rhode Island.

As identified in Dorfman and Mehta (2011), the New York City Department of Environmental Protection (NYC DEP), the agency responsible for managing the city's water supply, sewer, and wastewater treatment; implemented the following ongoing adaptation efforts, primarily due to concern for the city's aging infrastructure and vulnerability to sea-level rise, drought, and increased flood events:

- increased water conservation through rebate programs;
- implementation of low-impact development strategies;
- maximization of water supplies from existing facilities;
- conversion of combined sewers into high-level storm sewers (HLSS) that capture and transport rainfall directly to waterways, thereby reducing the volume of stormwater flowing into the sewer system; and
- infrastructure improvements to enhance reliability of water distribution systems.

NYC DEP is also working on actions that will address climate change over the long term, such as:

- development of a methodology for including climate change impacts in the City Environmental Quality Review process;
- consideration of future sea and tide levels in sewer design and siting of outfalls;
- inclusion of climate change as a risk when prioritizing projects; and
- identification of vulnerable infrastructure and inclusion of flood protection measures in capital improvement funding cycles.

Loftus (2011b) notes that New York City is following an integrated planning approach, whereby adaptation planning is driven by a multi-stakeholder involvement process which has placed special importance on the role of scientific research, particularly in the steps linked to forecasting climate change impacts and assessing vulnerability. Rosenzweig (2007) further describes the adaptation framework being used by NYC DEP, which details the 9-step adaptation assessment procedure, consisting of the following steps:

- Conduct adaptation assessment
- Identify risk
- Identify main climate change impacts to that project
- Apply future climate change scenarios
- Characterize adaptation options
- Conduct initial feasibility screening
- Link to capital cycles
- Evaluate options: e.g., benefit and cost analysis
- Develop implementation plans, including timeframe for implementation
- Monitor and reassess

Within the assessment procedure, climate change adaptations are divided into management, infrastructure, and policy categories, and are assessed by their relevance in terms of climate change time-frame (immediate, medium, and long term), the capital cycle, costs, and other impacts.

A case study by Bloetscher et al. (2010) of the City of Pompano Beach Water Utility provides a useful summary of adaptation options associated with water conservation programs. The case study notes that to be effective, water conservation programs should be an ongoing effort since it can take years to achieve significant results, and that they are most appropriate where there is no driver for immediate reduced demand. The study also presents issues associated with utility economics and capacity under-utilization, where reduced demand decreases revenues that cannot be offset without cost increases. Thus, effective conservation programs may require the utility to increase rates or impose surcharges on the public to meet bond covenants and legal requirements. Capacity underutilization can also cause operating problems requiring increased maintenance (i.e., line flushing). The study notes that these problems are generally offset in those cases where population growth increases demand, capacity utilization, and revenues.

Non-emergency water conservation program tools that are commonly employed by utilities include:

- Meter reading/water billing
- Inverted block water rates (pay more for higher use)
- Leak detection and repair of faucets, toilets, pipes, etc.
- Pressure reduction to the distribution system to reduce water use
- Regional-imposed irrigation restrictions and daytime watering bans (to reduce evaporation loss)
- Educational outreach programs, billing inserts, etc. with tips for how to conserve water
- Seasonal water rates
- Distribution system leak detection programs

Programs that require the support of local government include:

- Building Code changes that require high efficiency water fixtures and rain sensors with automatic shut-off in new construction and major renovations
- High-efficiency clothes washer rebates
- Grants for water conservation (i.e., grants for migrating away from potable water use and changing plumbing fixtures)
- Ultra low flush (ULF) toilet rebates

The adaptation options identified in the literature review will be evaluated for applicability to Rhode Island drinking water utilities in Phase 3: Development of Management Strategies.

4.0 DATA COLLECTION FOR MODELING EFFORTS

Tetra Tech collected data sets under Phase 1 which will be used for modeling efforts in the next phase of the project. Table 2 summarizes the type of data, source, and anticipated use for climate vulnerability modeling and assessment.

Table 2. Data sets collected under Phase 1 for Phase 2 modeling efforts

Data Type	Source	Model
Digital Elevation Model (3m resolution)	U.S. Geological Survey (USGS)	SWAT (setup)
Land Use Land Cover (NLCD 2006)	Multi-Resolution Land Characteristics Consortium	SWAT (setup)
Soils (SSURGO)	Natural Resource Conservation Service	SWAT (setup)
Point Sources	Department of Environmental Management (Deb Merill)	SWAT (setup)
Weather (Daily precipitation and temperature)	EPA BASINS	SWAT (setup)
Scituate reservoir operation data	Providence Water	SWAT (setup)
Flat River reservoir operation (limited information)	Quidnick Reservoir Company	SWAT (setup)
Daily flow	USGS National Water Information System	SWAT (calibration)
Erosion Rates	Coastal Resources Management Council	HAZUS (Coastal Flood, SLR, and Surge)

Table 2. (Continued)

Data Type	Source	Phase 2 Model
Digital Elevation Model (3m resolution)	USGS	HAZUS (Flood, SLR, Surge)
Flood Maps and Flood Insurance Studies	Federal Emergency Management Agency	Stillwater Elevations and HAZUS Calibration/Validation
Infrastructure Data	Water Utilities	HAZUS
Infrastructure Data	Water Resources Board	HAZUS
Tide Measurements	National Oceanic and Atmospheric Administration	Sea-Level Rise Analysis

5.0 NEXT STEPS

The *Safe***Water** RI project is iterative, with each phase building on the previous phase(s). The primary data collection efforts have established a baseline of understanding of the viewpoints and activities of water utility partners which will be used to inform the remaining *Safe***Water** RI project phases. For example, the identification of priority issues and key challenges of the water utilities will assist in developing appropriate adaptation options (Phase 3: Development of Management Strategies), while understanding the utility stakeholder perceptions of climate change and extreme weather will assist in the development of education and outreach strategies (Phase 4: Outreach and Education). Developing and maintaining relationships with the water utility partners will also assist in facilitating the ultimate “buy-in” of the project recommendations.

The results of the desktop literature review provide data on the state of knowledge of climate trends and impacts of the Northeast and Rhode Island. Phase 2 of the *Safe***Water** RI project (Assessment of Impacts) will use the data collected in Phase 1 and identified in Section 4 above. The literature review also identified the most relevant and comprehensive sources of information related to adaptation options for drinking water utilities. Adaptation options will be assessed in Phase 3 of this project (Development of Management Strategies).

A. Survey Questions

Ensuring Safe Water for Rhode Island’s Future

Welcome

Thank you for taking the time to participate in the Rhode Island Department of Health (HEALTH), Office of Drinking Water Quality’s project Ensuring Safe Water for Rhode Island’s Future. The objective of this project is to assess Rhode Island’s changing environmental conditions (including temperature, precipitation patterns, sea level rise, and storm surge) and the potential impacts faced by drinking water utilities to develop effective management strategies. This project is in response to several extreme weather events that have occurred in Rhode Island, such as the 1999 drought and the 2010 flood. This project will evaluate current water quality, water availability, and infrastructure conditions; assess how those conditions could change in the future; and recommend adaptation strategies.

1. What is your first and last name? Please note: All personal details are kept private and confidential. Survey participants will remain anonymous in all presentations of the survey results.

2. What is your current position?

3. What is the name of the water utility where you are employed?

4. What is the length of time that you have been employed at the water utility?

- 0-1 year
- 2-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- Over 20 years

5. Please indicate how many years of experience you have in the industry.

- 0-1 year
- 2-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- Over 20 years

The next two questions refer to concerns that you may face under two different planning horizons (0 to 5-year planning horizon and 5 to 30-year planning horizon).

6. Please rank the following concerns as they relate to the viability of your water utility for the <u>0 to 5-year planning horizon</u>. Please rank each item as very important, important, not important, or don't know.

	Very Important	Important	Not Important	Don't Know
Drought (i.e., safe water yields)	◯	◯	◯	◯
Population growth	◯	◯	◯	◯
Aging infrastructure	◯	◯	◯	◯
Extreme weather events (i.e., flood, storm surge, wind damage)	◯	◯	◯	◯
Sea level rise	◯	◯	◯	◯
Groundwater aquifer depletion	◯	◯	◯	◯
Competing water demands (i.e., purchased water, agriculture versus urban demands)	◯	◯	◯	◯
Storage capacity	◯	◯	◯	◯
Water quality (i.e., contaminants, nutrients, sedimentation)	◯	◯	◯	◯
Regulatory restrictions/mandates	◯	◯	◯	◯
Public health	◯	◯	◯	◯
Financial	◯	◯	◯	◯

Other concern(s) not identified above.

7. Please rank these same concerns from Question 6 as they relate to your water utility's viability in the 5 to 30-year planning horizon. Please rank each item as very important, important, not important, or don't know.

	Very Important	Important	Not Important	Don't Know
Drought	◯	◯	◯	◯
Population growth	◯	◯	◯	◯
Aging infrastructure	◯	◯	◯	◯
Extreme weather event (i.e., flood, storm surge, wind damage)	◯	◯	◯	◯
Sea level rise	◯	◯	◯	◯
Groundwater aquifer depletion	◯	◯	◯	◯
Competing water demands (i.e., purchased water, agriculture versus urban demands)	◯	◯	◯	◯
Storage capacity	◯	◯	◯	◯
Water quality (i.e., contaminants, sedimentation)	◯	◯	◯	◯
Regulatory restrictions/mandates	◯	◯	◯	◯
Financial	◯	◯	◯	◯
Public health	◯	◯	◯	◯

Other concern(s) not identified above.

8. What strategies and techniques (e.g., capital improvement plans, water conservation programs, technological improvements) do you use to manage the current water quality, water availability, and infrastructure needs that your utility faces? Please describe briefly below.

9. What obstacles (if any) have hindered or prevented implementation of the strategy(ies) identified in Question 8. Please check all that apply.

- [ ] Economic
- [ ] Social
- [ ] Technical
- [ ] Administrative
- [ ] Political
- [ ] Legal
- [ ] Environmental

Other obstacle(s) not identified above.

10. Please indicate the current planning horizons that your utility uses for capital planning and water management strategies. Check all that are appropriate.

- [ ] 0-1 year
- [ ] 2-3 years
- [ ] 4-5 years
- [ ] 6-10 years
- [ ] 11-15 years
- [ ] 16-20 years
- [ ] Greater than 20 years

Other planning horizons (please specify).

11. Does your utility use specific decision support tools or techniques (e.g, modeling software tools such as EPANET and InfoWorks; techniques such as the IWA/AWWA Water Audit Method; or datasets from the USGS National Water-Quality Assessment Program) for assessing future risk and demand? If yes, please list below.

12. Are you concerned about the potential impacts of climate change on your water utility?

- ◯ Yes, Very Concerned
- ◯ Somewhat Concerned
- ◯ Not Concerned
- ◯ Don't Know

13. Would you consider your stakeholders (e.g., elected officials, water board members, customers) more open to proactive or reactive measures when it comes to addressing the impacts of weather-related events?

	Proactive	Reactive	Don't Know
Elected Officials	◯	◯	◯
Water Board Members	◯	◯	◯
Customers	◯	◯	◯

Thank You!

Thank you for taking the time to participate in this survey. The results of the survey will be collected and presented at an upcoming water utility partner meeting, tentatively scheduled for February 29 at 1:30 PM in Providence. An invitation to the meeting will be sent to each of the utilities shortly. We look forward to working with you throughout this project.

B. Phase 1 Participation Summary

Appendix B
Phase I Participation Summary

Organization	Name	Title	Phase 1 Participation	
			Survey	Kick-off Meeting
Block Island Water Company	Simmons, David	Superintendent	X	
Bristol County Water Authority	Marchand, Pamela	Executive Director	X	X
City of East Providence	Marvel, Jim	Interim Superintendent	X	
City of Newport	Forgue, Julia	Director of Utilities	X	
City of Woonsocket	McGauvran, Sheila	Director of Public Works	X	
East Smithfield Water District	DiSanto, Raymond (Ray)	General Manager	X	X
Harrisville Fire District Water Dept	Bisson, Paul	Superintendent	X	X
Jamestown Water Department	Gray, Michael	Public Works Director	X	X
Johnston Water Control Facility – West End	Caruso, Lori	Johnston Town Engineer	X	X
Kingston Water District	Meyer, Henry	Manager	X	
Lincoln Water Commission	Faile, John	Superintendent	X	
Naval Station Newport	Abraham, Scott	Utilities Work Leader	X	X
Naval Station Newport	Ward, Darlene	Environmental Work Leader		X
North Tiverton Fire District	Perry, Jason	Superintendent	X	
Pascoag Utility District	Kirkwood, Michael	General Manager	X	
Pawtucket Water Supply Board	DeCelles, James	Chief Engineer & General Manager	X	
Portsmouth Water & Fire District	Driscoll, Phil	Water Board Member		X
Portsmouth Water & Fire District	Lister, Nathan	Operator		X
Portsmouth Water & Fire District	McGlinn, William (Bill)	General Manager and Chief Engineer	X	
Providence Water Supply Board	Thompson, Jeff	Technical Advisor to General Manager	X	
RI Department of Environmental Management, Office of Water Resources	Patenaude, Bill	Principal Engineer		X
RI Department of Health, Office of Water	Swallow, June	Chief		X
RI Department of Health, Office of Water	Boudreau, Steven	Program Manager		X
Stone Bridge Fire District	Destremps, Carl	Superintendent	X	
Town of Cumberland	Champi, Chris	Superintendent	X	
Town of North Kingstown	Licardi, Susan	n/a		X
Town of South Kingstown	Schock, Jon	Public Services Director	X	
U of Rhode Island	Bozikowski, Robert (Bob)	Water System Manager	X	X
Westerly Water Dept.	Corina, Paul	Superintendent	X	

C. *Safe*Water RI Kick-off Meeting and Survey Results

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

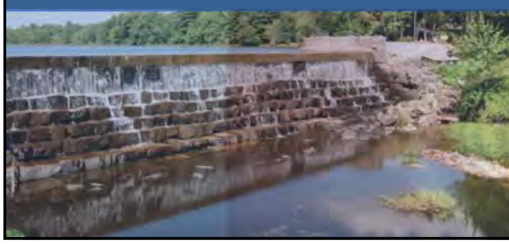
RHODE ISLAND DEPARTMENT OF HEALTH

TETRA TECH

Ensuring Safe Water for Rhode Island's Future

Kickoff Meeting

February 29, 2012



Agenda

- Introductions and overview of *Safe*Water RI project
- Presentation of survey results
- Facilitated discussion with utility representatives
- Identification of additional data needs
- Action items and next steps

TETRA TECH

RHODE ISLAND DEPARTMENT OF HEALTH

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

*Safe*Water RI

Objectives

- Assess changing environmental conditions and potential impacts on RI drinking water utilities
- Develop strategies to address these changing conditions

Guiding Principles

- Broad engagement with RI drinking water utilities
- Innovative modeling to provide accurate and scalable results

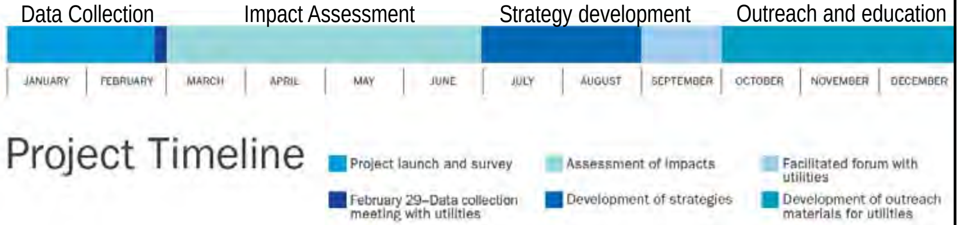
TETRA TECH

*Safe*Water RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Phases of Project

Phase 1 Data Collection | Phase 2 Impact Assessment | Phase 3 Strategy development | Phase 4 Outreach and education



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*Safe*Water RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Phase 1: Data Collection

- Survey to utilities
- Datasets for impact assessment (meteorological, water quality, infrastructure assets,
- Review of policies and regulations

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RHODE ISLAND DEPARTMENT OF HEALTH

Phase 2: Assessment of Impacts

- Identify which assets need to be protected and from what hazards
- Help justify any action which requires funding and
- Help determine the physical characteristics of some management strategies.

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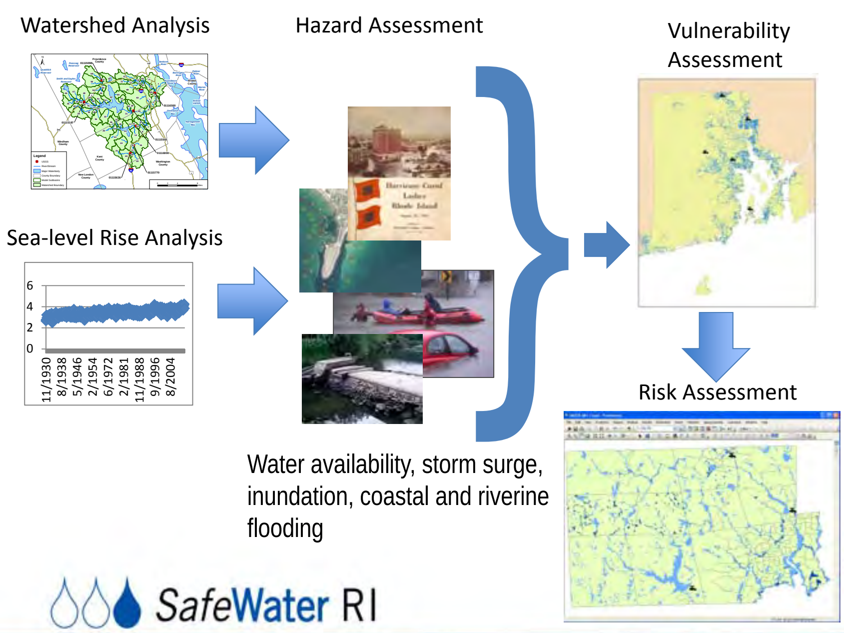
RHODE ISLAND DEPARTMENT OF HEALTH



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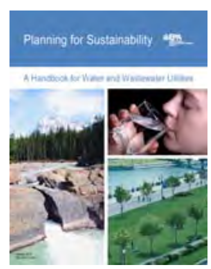
Phase 3: Development of Management Strategies

- Evaluate management options using STAPLEE (Social, Technical, Administrative, Political, Legal, Environmental, and Economic) criteria
- Conduct cost-benefit analysis of options
- Identify short-term and long-term management strategies



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Phase 4: Outreach and Education

- Follow-up forum with utilities on recommended strategies
- Development of outreach and education strategy for utilities to work with customers
- Preparation of outreach materials

Survey Results

SafeWater RI
Ensuring Safe Water for Rhode Island's Future
Tetra Tech

Q3. What is the name of the water utility where you are employed?

- Block Island Water Company
- Bristol County Water Authority
- City of East Providence
- City of Newport
- City of Woonsocket
- East Smithfield Water District
- Harrisville Fire District Water Dept
- Jamestown Water Department
- Johnston Water Control Facility – West End
- Kingston Water District
- Lincoln Water Commission
- Naval Station Newport
- North Tiverton Fire District
- Pascoag Utility District
- Pawtucket Water Supply Board
- Portsmouth Water & Fire District
- Providence Water Supply Board
- Stone Bridge Fire District
- Town of Cumberland
- Town of South Kingstown
- U of Rhode Island
- Westerly Water Dept.

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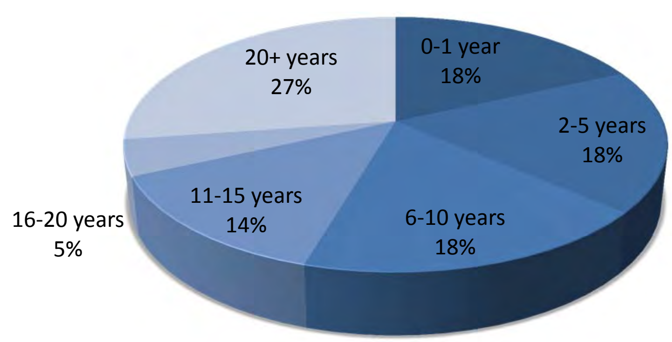
Q4: What is the length of time you have been employed at the water utility?



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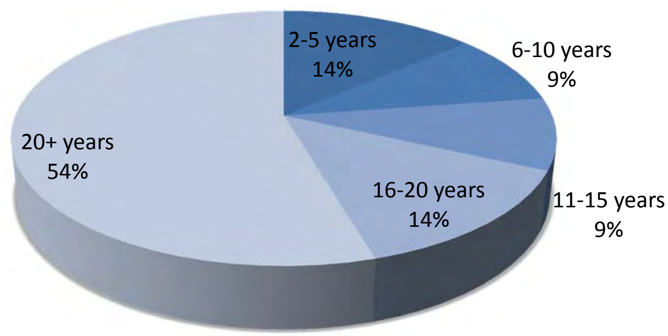
Q5. Please indicate how many years of experience you have in the industry.



Note: "0-1 Years" = 0%

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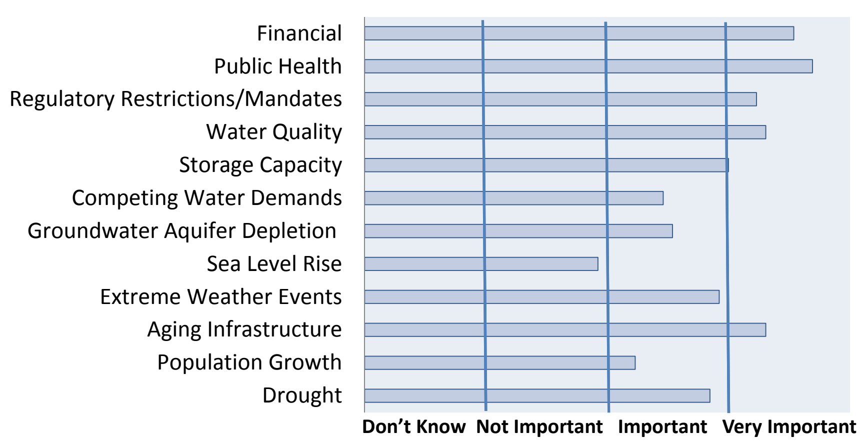
ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q6. Rank the following concerns as they relate to the viability of your water utility for the 0 to 5-year planning horizon.



Note: Results are based on the weighted average of responses

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ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Top five concerns about the viability of the water utility for the next five years:

1. Public Health
2. Financial
3. Water Quality
4. Aging Infrastructure
5. Regulatory Restrictions

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TETRA TECH

Q6. Rank the following concerns as they relate to the viability of your water utility for the 0 to 5-year planning horizon.

- Additional responses:
  - Diminishing ability to find new water sources
  - Emergency Interconnections
  - Lack of qualified operators
  - Too many "small" water districts with insufficient backup and redundancy
  - Water quality issues from deteriorating infrastructure

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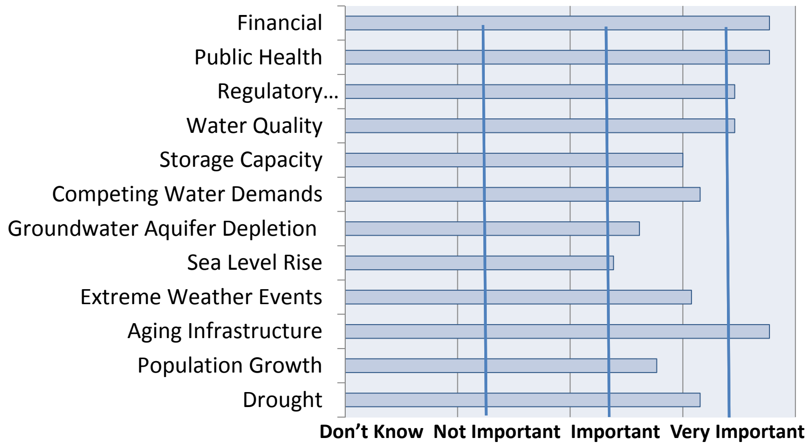
ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE
TETRA TECH

Q7. Please rank these same concerns from Question 6 as they relate to your water utility's viability in the 5 to 30-year planning horizon.



Note: Results are based on the weighted average of responses

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ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Top five concerns about the viability of the water utility for the 5 to 30 year time frame:

1. Aging Infrastructure
2. Public Health
3. Financial
4. Water Quality
5. Regulatory Restrictions

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ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q8: What strategies and techniques do you use to manage the current water quality, water availability, and infrastructure needs that your utility faces?

- Aggressive water quality monitoring, communication, demand management and maintenance
  - Leak detection
  - Block rate pricing
  - Outside water use restrictions
  - Unidirectional flushing program
  - Leak detection and notification programs
- Assessment and Planning Reports:
  - Source protection plans
  - GIS
  - USGA groundwater reports and models
  - Hydraulic models
  - Rate Studies
- Maintenance, repair & replacement of aging infrastructure
  - Focus on financial planning, capital improvements
  - Aggressively identify potential problem areas
  - Meter upgrades
  - Replacement/upgrades of storage tanks, water mains, wells and facilities
  - Cleaning and lining of pipes
- Gradual rate increases tend to result in conservation measures and generally yield no increase in revenue

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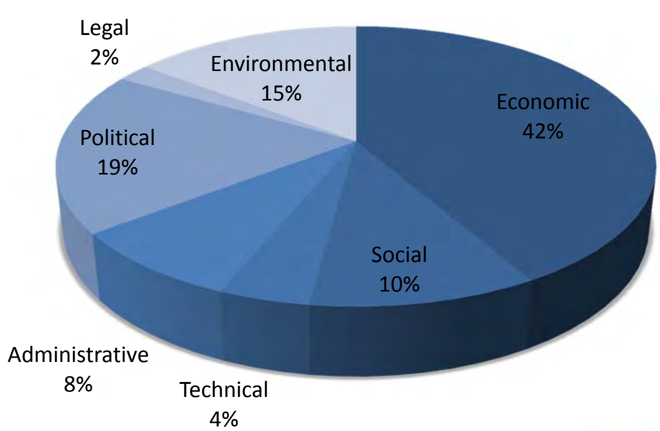
ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q9: What obstacles (if any) have hindered or prevented implementation of the strategies identified in Question 8.



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ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q9: What obstacles (if any) have hindered or prevented implementation of the strategies identified in Question 8.

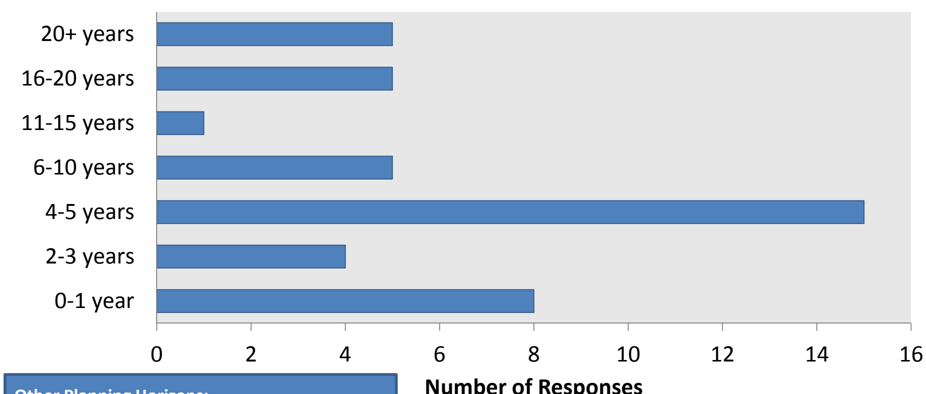
Additional responses:

- Not having a system owned water supply
- Regulatory
- Lack of qualified water system operators
- Watershed limitations for supply

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q10: Please indicate the current planning horizons that your utility uses for capital planning & water management strategies.



Other Planning Horizons:

- Will be initiating 5, 10, 20 year planning
- Working on longer term, 20 year plan

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

Q11: Does your utility use specific decision support tools or techniques (e.g, modeling software tools such as EPANET and InfoWorks; techniques such as the IWA/AWWA Water Audit Method; or datasets from the USGS National Water-Quality Assessment Program) for assessing future risk and demand?

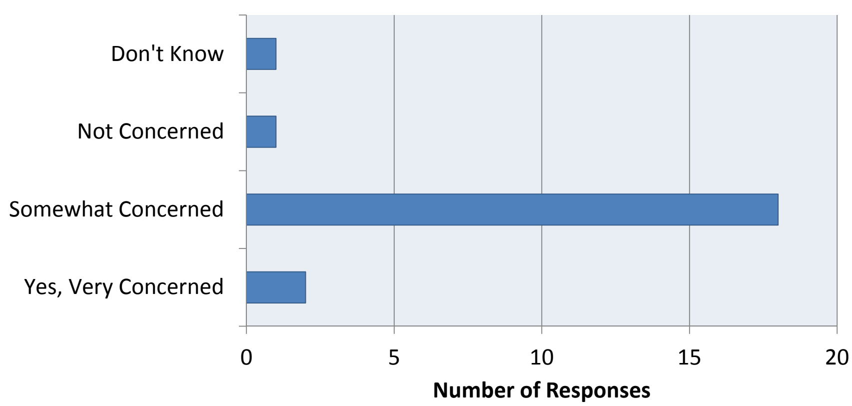
- EPANET
- Modified AWWA Water Audit Method
- For demand: US Census, State Population projections, historical connection rate and water demand trends
- Vulnerability assessments, emergency response planning

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

TETRA TECH

Q12: Are you concerned about the potential impacts of climate change on your water utility?

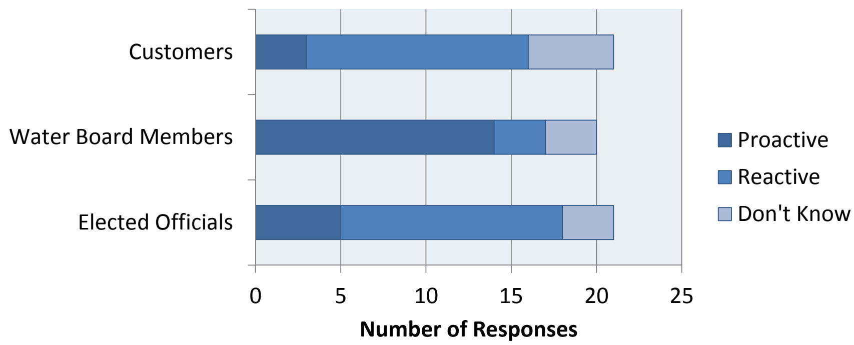


SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

TETRA TECH

Q13. Would you consider your stakeholders more open to proactive or reactive measures when it comes to addressing the impacts of weather-related events?



SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

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RHODE ISLAND DEPARTMENT OF HEALTH

SafeWater RI

ENSURING SAFE WATER FOR RHODE ISLAND'S FUTURE

RHODE ISLAND DEPARTMENT OF HEALTH

TETRA TECH

Ensuring Safe Water for Rhode Island's Future

Kickoff Meeting

February 29, 2012

D. Literature Review Resources

Appendix D
Literature Review Resources

The following resources were compiled through desktop research and consultations as part of the *Safe***Water** RI project. The list is not intended to be exhaustive or complete, but the resources included are considered the most relevant/illustrative secondary information sources to research the following issues: 1) the state of knowledge regarding climate change trends for the Northeast and specifically Rhode Island; 2) potential climate change impacts on drinking water utilities; and 3) best practices used in adaptation strategies for drinking water utilities.

The literature review resources are organized into five sections:

1. **Climate Trends.** Resources that include pertinent information on observed and/or projected climate trends.
2. **Rhode Island Government Resources**. Relevant government resources and authorities for the *Safe***Water** RI project. These resources will be used to ensure regulatory compliance with proposed adaptation options and identify planning synergies associated with the *Safe***Water** RI project.[1]
3. **Rhode Island: Additional Climate Resources**. A listing of climate resources that have been developed by coalitions and associations for the state.
4. **Understanding and Managing Climate Risk.** Representative information on how municipalities and communities have approached climate risk management, including the role of state and local government action.
5. **Water Utilities: Climate Change Vulnerability Assessment and Adaptation Planning.** A listing of resources that specifically address climate vulnerability assessment and best practices in adaptation for drinking water utilities.

All publications referenced in this literature review can be accessed and downloaded through the *Safe***Water** RI ftp site (access information included below). Publications on the ftp site have been saved in the format “Author(s), Year” and in the respective section folder.

*Safe***Water** *RI FTP Site*: ftp://rhode_island/array1/RICC/

Note: Please copy and paste the link into Windows explorer to access it.

[1] Note that resources that directly or indirectly inform climate change with respect to water resources are included and is in no way exhaustive of all relevant Rhode Island Government resources.

1. Climate Trends

Ashton, A., J. Donnelly, and R. Evans. 2007. *A Discussion of the Potential Impacts of Climate Change on the Shorelines of the Northeastern USA.* Northeast Climate Impacts Assessment, Union of Concerned Scientists, Available online at: http://www.whoi.edu/science/GG/coastal/publications/pdfs/AshtonDonnellyEvans_MITI2007.pdf.

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds. 2008. *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

Christensen, J. H., B. Hewitson, et al. 2007. Regional Climate Projections. *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. New York, NY, Cambridge University Press.

Covich, A. 2009. *Emerging Climate Change Impacts on Freshwater Resources: A Perspective on Transformed Watersheds*. Report, Resources for the Future, Washington, D.C.

Frumhoff, P. C., J. J. McCarthy, et al. 2007a. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions*. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA, Union of Concerned Scientists (UCS).

Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007b. *Rhode Island Report*, in Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Cambridge, MA, Union of Concerned Scientists (UCS).

Hapke, C.J., Himmelstoss, E.A., Kratzmann, M., List, J.H., and Thieler, E.R. 2010. *National assessment of shoreline change; historical shoreline change along the New England and Mid-Atlantic coasts.* U.S. Geological Survey Open-File Report 2010-1118. Available online at: http://pubs.usgs.gov/of/2010/1118/.

Heffner, L., R. Williams, V. Lee, P. Rubinoff, C. Lord. 2012. *Climate Change and Rhode Island's Coasts: Past, Present, and Future*. URI Coastal Resources Center and Rhode Island Sea Grant, Providence, Rhode Island.

Hodgkins, G. A., and R. W. Dudley. 2011. Historical summer base flow and stormflow trends for New England Rivers, *Water Resources Research*, 47.

Kirshen, P., C. Watson, E. Douglas, A. Gontz, J. Lee, and Y. Tian. 2007. Coastal Flooding in the Northeastern United States due to Climate Change. In press for the journal *Mitigation and Adaptation Strategies for Global Change*, as part of the special issue: "Northeast United States Climate Impact Assessment".

Mendelsohn, R., K. Emanuel, and S. Chonabayashi. 2011. *The Impact of Climate Change on Hurricane Damages in the United States*. Available online: http://www.gfdrr.org/gfdrr/sites/gfdrr.org/files/New%20Folder/The%20Impact%20of%20Climate%20Change%20on%20Global%20Tropical%20Storm%20Damages.pdf.

Roy, S., L. Chen, E. Girvetz, E. Maurer, W. Mills, and T. Grieb. 2010. *Evaluating Sustainability of Projected Water Demands Under Future Climate Change Scenarios*. National Resources Defense Council, New York, New York.

Union of Concerned Scientists (UCS). 2006. *Climate Change in the U.S. Northeast - A Report of the Northeast Climate Impacts Assessment*. Available online at: http://www.ucsusa.org/assets/documents/global_warming/necia_climate_report_final.pdf.

2. Rhode Island Government Resources

Rhode Island Division of Planning. 2012. *Rhode Island Water 2030*. State Guide Plan Element 721, Report, Available online: http://www.planning.ri.gov/.

Rhode Island Emergency Management Agency. 2012. *Rhode Island State Hazard Mitigation Plan*. April 2011, Providence, Rhode Island.

Rhode Island General Assembly. 2011. An Act Relating to Health and Safety – Energy Independence, Introduced March 23, 2011, Senate 0724.

Rhode Island General Assembly. 2010. An Act Relating to Health and Safety – Climate Risk Reduction Act, Introduced February 11, 2010, Senate 2439.

Rhode Island Water Resources Board. 2002. *Drought Management Plan*. Drought Steering Committee, Providence, Rhode Island. Available online at: http://www.planning.ri.gov/landuse/dmp.htm.

Rhode Island Water Resources Board. 2008. Statewide Supplemental Water Supply Feasibility Assessment. Phase II: Executive Summary. Providence, Rhode Island.

Rhode Island Water Resources Board. 2012. *Strategic Plan Working Document.* Report from the Rhode Island Water Resources Board Meeting No. 517. Friday, February 17, 2012.

3. Additional Rhode Island Resources

Environment Council of Rhode Island. 2012. *Global Warming in Rhode Island: Warning Signs, Winning Solutions*. Rhode Island Department of Environmental Management, Available online at: http://www.dem.ri.gov/climate/pdf/rigw.pdf.

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E. Adaptation Options for Drinking Water Utilities

Appendix E
Adaptation Options for Drinking Water Utilities

The U.S. Environmental Protection Agency's *Adaptation Strategies Guide for Water Utilities* was identified in the literature review as the most comprehensive resource for drinking water utility adaptation strategies (2012). The Guide provides adaptation options for drinking water, wastewater, and stormwater utilities based on region and projected climate impacts. The three categories of adaptation options included are:

- **Planning strategies:** which include use of models, research, training, supply and demand planning, natural resource management, land use planning, and collaboration at watershed and community scales;
- **Operational strategies:** which include efficiency improvements, monitoring, inspections, conservation, demand management, flexible operations, and sustainable strategies; and
- **Capital / infrastructure strategies:** which include construction, water resource diversification, repairs and retrofits, upgrades, phased construction, new technology adoption, and green infrastructure.

Adaptation options are grouped according to impact (drought, water quality degradation, flooding, ecosystem changes, and service demand and use) and indicate relative costs are also provided for each option. The table below lists the key adaptation options identified in the Guide for each of the climate hazards.

Drought	
Planning Strategies	
Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
Conduct training for personnel in climate change impacts and adaptation strategies.	$
Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
Operational Strategies	
Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
Practice demand management through communication to public on water conservation actions.	$
Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$
Capital / Infrastructure Strategies	
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
Retrofit intakes to accommodate decreased flow in source waters.	$$-$$$
Build or expand infrastructure to support conjunctive use.	$$$

Water Quality Degradation	
Planning Strategies	
Develop models to understand potential changes (e.g., increased turbidity, sea level rise, saltwater intrusion) and costs of impacts.	$
Conduct training for personnel in climate change impacts and adaptation strategies.	$
Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
Develop emergency response plans to deal with the relevant natural disasters and include stakeholder engagement and communication.	$
Operational Strategies	
Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
Monitor vegetation changes in watersheds.	$
Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
Manage reservoir water quality by investing in practices such as lake aeration to minimize algal blooms due to higher temperatures.	$$
Monitor current weather conditions, including precipitation and temperature.	$
Finance and facilitate systems to recycle water to decrease discharges to receiving waters.	$$-$$$
Monitor surface water conditions, including water quality in receiving bodies.	$
Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$
Capital / Infrastructure Strategies	
Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
Increase treatment capabilities and capacities to address decreased water quality due to saltwater	$$$
Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
Install low-head dams to separate saltwater wedge from intakes upstream in the freshwater pool.	$$$
Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Implement watershed management practices to limit pollutant runoff to reservoirs.$$	
Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$

Flooding	
Planning Strategies	
Integrate flood management and modeling into land use planning.	$
Implement policies and procedures for post-flood repairs.	$
Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
Integrate climate-related risks into capital improvement plans, including flood-proofing options to build facility resilience against current and potential future risks.	$
Identify and protect vulnerable facilities, including developing operational strategies that isolate these facilities and re-route flows.	$-$$
Establish mutual aid agreements with neighboring utilities.	$
Ensure that emergency response plans deal with flooding contingencies and include stakeholder engagement and communication.	$
Conduct training for personnel in climate change impacts and adaptation.	$
Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
Plan for alternative power supplies to support operations in case of loss of power.	$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
Operational Strategies	
Monitor and inspect the integrity of existing infrastructure.	$-$$
Monitor surface water conditions, including streamflow and water quality.	$
Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
Capital / Infrastructure Strategies	
Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
Increase treatment capabilities to address water quality changes (e.g., increased turbidity)	$$$
Relocate facilities (e.g., treatment plants) to higher ground.	$$$
Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	$$-$$$
Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$

Ecosystem Changes	
Planning Strategies	
Study response of nearby wetlands to storm surge events.	$
Implement policies and procedures for post-flood and/or post-fire repairs.	$
Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
Integrate climate-related risks into capital improvement plans, including options that provide resilience against current and potential future sea-level and storm surge risks.	$
Ensure that emergency response plans deal with flooding and wildfire and include stakeholder engagement and communication.	$
Develop coastal restoration plans, including consideration of barrier islands, coastal wetlands, and dune ecosystems.	$-$$
Conduct climate change impacts and adaptation training for personnel.	$
Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
Plan for alternative power supplies to support operations in case of loss of power.	$
Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and frequency estimates into land use and facility planning.	$
Update fire models and fire management plans to incorporate any changes in fire frequency, magnitude and extent due to projected future climate conditions.	$-$$
Operational Strategies	
Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
Monitor vegetation changes in watersheds.	$
Monitor surface water conditions, including streamflow and water quality.	$
Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff, storm intensity, sea level).	$
Monitor current weather conditions, including precipitation and temperature.	$
Monitor and inspect the integrity of existing infrastructure.	$-$$
Capital / Infrastructure Strategies	
Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	$$$
Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
Relocate facilities (e.g., treatment plants) to higher ground.	$$$
Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	$$-$$$
Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$

Service Demand and Use	
Planning Strategies	
Update drought contingency plans.	$
Model or understand existing models of regional electricity demand under future scenarios of climate change and regional growth.	$
Model agricultural water demand under future scenarios of climate change and projections of cropping types. Consider evaluating the use of recycled water for irrigation.	$-$$
Work with power companies to evaluate feasibility of using recycled water or alternative cooling	$
Establish a relationship with the local power utility and work jointly on strategies to reduce seasonal or peak water and energy demands (e.g., water reclamation for use in power generation).	$
Operational Strategies	
Monitor current weather conditions, including precipitation and temperature.	$
Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$
Practice demand management through communication to public on water conservation actions.	$
Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
Practice conjunctive use (i.e., optimal use of surface and groundwater).	$$-$$$
Optimize operations by restricting some energy-intensive activities during the summer to times of reduced electricity demand (i.e., nighttime) and work with energy utility on off-peak pricing.	$$-$$$
Improve energy efficiency of operations (e.g., installing more energy efficient pumps).	$$-$$$
Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
Monitor surface water conditions, including streamflow and water quality.	$
Monitor surface water conditions, including water quality in receiving bodies.	$
Capital / Infrastructure Strategies	
Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
Build systems to reclaim wastewater for energy, industrial, agricultural, or household use.	$$$
Build or expand infrastructure to support conjunctive use.	$$$
Retrofit intakes to accommodate decreased source water flows or reservior levels.	$$-$$$
Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$
Establish alternative power supply via on-site power sources.	$-$$
Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
Diversify options to complement current water supply to include those that require less energy for treatment, conveyance, and distribution.	$$$
Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$