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Water/Wastewater Utilities and Extreme Climate and Weather Events

CASE STUDIES ON COMMUNITY RESPONSE, LESSONS LEARNED, ADAPTATION, AND PLANNING NEEDS FOR THE FUTURE

CC7C11

WATER/WASTEWATER UTILITIES AND EXTREME CLIMATE AND WEATHER EVENTS

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A collaboration of:

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For more information, contact:
Water Environment Research Foundation
635 Slaters Lane, Suite G-110
Alexandria, VA 22314-1177
Tel: (571) 384-2100
Fax: (703) 299-0742
www.werf.org
werf@werf.org

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Report Preparation and Research Team:

Nancy Beller-Simms, Ph.D. (NOAA)
Erica Brown (AMWA)
Lauren Fillmore (WERF)
Katy Lackey (WERF)
Karen Metchis (EPA)
Kenan Ozekin, Ph.D. (WRF)
Claudio Ternieden (WEF)

Water Environment Research Foundation Staff

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ABSTRACT AND BENEFITS

Abstract:

Extreme climate and weather events are occurring more frequently and with more intensity across the nation. They often leave communities, and the water utilities that serve them, reeling from costly aftermath. These extreme events have the potential to disrupt water services including drinking water supply, wastewater conveyance and treatment, and stormwater management.

In 2009 President Obama established a national task force charged with better preparing the nation to manage the impacts of climate change. There is global recognition that the water sector remains at the forefront of these impacts, yet water resources and services have reverberating impacts on energy, development, and economic sectors. Utilities' abilities to successfully respond and adapt to increasing trends of extreme events is of the utmost importance for resiliency in all sectors.

This report is intended to facilitate peer-to-peer sharing on how water resource managers are coping with extreme events and building resiliency. Research was conducted at six local workshops, organized to include participants that experienced different types of extreme events throughout a river basin or watershed. The localities included:

- Apalachicola-Chattahoochee-Flint River Basin, Georgia
- Central Texas
- Lower Missouri River Basin, Kansas and Missouri
- National Capital Area
- Russian River Basin, California
- Tidewater Area, Virginia

Several common themes emerged from the workshops. They are summarized in Chapter 3.0 of this report and elaborated upon in each case study.

Benefits:

- Demonstrates how national organizations such as WERF, WRF, and many federal agencies are working to help communities assess and manage risk from a changing climate.
- Looks forward to enhance resiliency to include actions for "rebuilding differently" in the aftermath of extreme events.
- Closes information gaps and increases accessibility to existing information in order to provide a useful first step forward.

Keywords: Climate change, extreme weather, preparedness, resiliency, water services, infrastructure.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACF	Apalachicola-Chattahoochee-Flint River
AF	Acre-feet
AMWA	Association of Metropolitan Water Agencies
ASCE	American Society of Civil Engineers
ASR	Aquifer Storage and Recovery
BAECCC	Bay Area Ecosystem Climate Change Consortium
BCM	Basin Characterization Model
BG	Billion Gallons
BGE	Baltimore Gas and Electric
BMP	Best Management Practice
BS/EACD	Barton Springs/Edwards Aquifer Conservation District
cfs	Cubic Feet per Second
CCMWA	Cobb County-Marietta Water Authority
CCWS	Cobb County Water System
CEQ	White House Council on Environmental Quality
CHP	Combined Heat and Power
CN RFC	California/Nevada River Forecast Center
CRE	Climate Ready Estuaries
CREAT	Climate Resilience Evaluation & Awareness Tool
CSO	Combined Sewer Overflow
CTC	Concurrent Technologies Corporation
CRWU	Climate Read Water Utilities
CWA	Clean Water Act
CWF	California Water Foundation
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DATs	Damage Assessment Teams
DDOE	District Department of the Environment
EMSC	Emergency Management Systems Compact
ENSO	El Niño Southern Oscillation

EOC	Emergency Operations Center
EPA	United States Environmental Protection Agency
EPD	Environmental Protection Department/Division
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency
GCSD	Granton Community Services District
GIS	Geographic Information Systems
GSIP	Global Shore Infrastructure Plan
GWRI	Georgia Water Resources Institute
HMT	Hydrometerological Testbed
HRPDC	Hampton Roads Planning District Commission
HRSD	Hampton Roads Sanitation District
HUD	Department of Housing and Urban Development
ICPRB	Interstate Commission on the Potomac River
ICS	Incident Command System
I/I	Infiltration and Inflow
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
IWRSS	Integrated Water Resource Science and Services
JCW	Johnson County Wastewater
KCMWSD	Kansas City Missouri Water Services Department
KDHE	Kansas Department of Health and Environment
KRWAD	Kansas River Water Assurance District
kW	Kilowatt
KWO	Kansas Water Office
LCRA	Lower Colorado River Authority
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LIDAR	Light Detection and Ranging
LMR	Lower Missouri River
LMRB	Lower Missouri River Basin
MAF	Million acre-feet
MARC	Mid-America Regional Council

MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
MW	Megawatts
MWCOG	Metro Washington Council of Governments
MWRC	Missouri Water Resources Center
NAVFAC	Naval Facilities Engineering Command
NBCAI	North Bay Climate Adaptation Initiative
NCA	National Climate Assessment
NCPC	North Capital Planning Commission
NCR	National Capital Region
NEPA	National Environmental Protection Act
NFESC	Naval Facilities Engineering Service Center
NIDIS	National Integrated Drought Information System
NIMS	National Incident Management System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
O&M	Operations and Maintenance
PET	Potential Evapotranspiration
QDR	Quadrennial Defense Review
RFC	River Forecast Center
RIOP	Revised Interim Operating Plan
RSIP	Regional Shore Infrastructure Plans
SAWS	San Antonio Water System
SCWA	Sonoma County Water Agency
SDWA	Safe Drinking Water Act
SLR	Sea Level Rise
SSO	Sanitary Sewer Overflow
SWRCB	State Water Resources Control Board (California)
TBC3	Terrestrial Biodiversity Climate Change Collaborative
USACE	United States Army Corps of Engineers
USGCRP	United States Global Change Research Program

USGS	United States Geological Survey
VEMA	Virginia Emergency Management Association
VERT	Virginia Emergency Response Team
VIMS	Virginia Institute of Marine Science
VIPER	Virginia Interoperability Picture for Emergency Response
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WRF	Water Research Foundation
WRRF	Water Resource Recovery Facility
WSA	Water and Sewer Authority
WSSC	Washington Suburban Sanitary Commission
WUCA	Water Utility Climate Alliance
WWARN	Water/Wastewater Agency Response Network

EXECUTIVE SUMMARY

Extreme climate and weather events are occurring more frequently and with more intensity across the nation, often leaving communities – and the water utilities that serve them – reeling from costly aftermath. These extreme events have the potential to disrupt water services including drinking water supply, wastewater conveyance and treatment, and stormwater management. Attention to emergency response and vulnerability assessment for all sectors increased in the aftermath of 9/11. This focus has merely strengthened since, as the nation's understanding and acceptance of climate change continues to grow. In 2009 President Obama established a national task force charged with better preparing the nation to manage the impacts of climate change. There is global recognition that the water sector remains at the forefront of these impacts. Water resources and services have reverberating impacts on energy, development, and economic sectors. Utilities' abilities to successfully respond and adapt to increasing trends of extreme events is of the utmost importance for the water sector itself, but equally important for resiliency in all sectors. In 2013, President Obama stressed previous executive orders for federal support in addressing climate change impacts and renamed the interagency climate task force the Council on Climate Preparedness and Resilience. In light of this reiteration and subsequent actions to prepare for climate change, this research is of paramount importance.

This report is intended to facilitate peer-to-peer sharing on how water resource managers are coping with these events and building future resiliency, as well as to identify gaps in the availability of information and information pathways needed to inform local decision making. This examination of current and future risks, and exchange of successful strategies contributes to nationwide efforts to advance extreme event preparation and adaptation to climate change.

This report is based on the results of six local workshops, organized to include participants that experienced different types of extreme events throughout a river basin or watershed:

- Apalachicola-Chattahoochee-Flint River Basin, Georgia
  (May 2012 workshop on floods and droughts)
- Central Texas Region
  (March 2013 workshop on prolonged drought and wildfires)
- Lower Missouri River Basin, Kansas and Missouri
  (February 2013 workshop on floods and droughts)
- National Capital Area
  (December 2012 workshop on hurricanes and derechos)
- Russian River Basin, California
  (March 2012 workshop on atmospheric rivers, droughts, and frosts)
- Tidewater Area, Virginia
  (September 2012 workshop on nor'easters, hurricanes, and sea level rise)

The study discusses how water, wastewater, and stormwater utilities – and other local water resource managers – in these six regions made decisions in response to recent extreme events. The study examines what happened, how information was used to inform decisions, what institutional dynamics helped or hindered, and how water utilities (and their communities) are planning to deal with extreme events in the future.

At the outset of the project, the research team planned to examine a particular event in each locale, but quickly realized that communities were grappling with a series of multiple events, both flood and drought, among other stressors. Communities are pressed to plan for a variety of climate and weather extremes, and water resource managers are juggling many objectives simultaneously.

Despite the unique attributes of each region, several common themes emerged from the workshops.

Managing the Risks of Extreme Events

- **Cascading Nature of Extreme Events** – Localities are dealing with multiple types and occurrences of extreme events, many of which have become more severe and more frequent in recent decades.

- **Integrated Planning for Multiple Risks** – The variety of extremes experienced in communities necessitates managing multiple risks.

Recognizing the Importance of Water Services and Infrastructure

- **Water Services as Critical Infrastructure** – Water services are part of the nation's most critical infrastructure and investments.

- **Emergency Response** – Emergency response is an essential component of preparedness, and ensuring the ability to recover operations following extreme events is among communities' top priorities.

- **Long-term Preparedness** – Utilities are beginning to re-design infrastructure to address particular vulnerabilities or to increase the flexibility of existing systems.

Building Resilient Communities

- **Public Awareness** – The community must understand their risk and define their risk tolerance.

- **Community Decision Making Within a Basin** – The complex array of decisions needed to support resilience within a basin requires coordination across water service areas and jurisdictional boundaries.

- **Leadership and Innovation** – Communities need leadership to help navigate new paths to resilience.

Creating Actionable Information

- **Multi-Disciplinary Collaboration** – Multi-disciplinary collaboration and communication increases access to actionable information for science-based decision making.

- **Active Engagement in Acquiring Information and Tools** – There is no ‘silver bullet’ decision support tool. All tools require effort to customize and apply to local conditions over a variety of adaptation strategies.

The six communities and their water utilities have continued to develop their approaches and capabilities, since the workshops finished in 2013. The communities are all engaged in collaborative efforts to develop locally specific information and tools, raise public awareness and support, and put programs in place to advance sustainable communities with increased resiliency to extreme variability in climate and weather. Meanwhile, national organizations such as WERF, WRF, and many federal agencies are working to help communities assess and manage risk from a changing climate. Looking forward to enhance resiliency includes actions for ‘rebuilding differently’ in the aftermath of extreme events and planning for integrated water resource management through flexible adaptation pathways. Closing information gaps and increasing accessibility to existing information will be a useful first step forward. Water resource managers are essential leaders in this process.

CHAPTER 1.0

INTRODUCTION

Extreme climate and weather events[1] are occurring more frequently and with more intensity across the nation, often leaving communities – and the water utilities that serve them – reeling from costly aftermath. A recent study found a statistically significant increase in billion-dollar climate/weather disasters of about 5% per year since 1980 (Smith and Katz, 2013).[2] This increase parallels a worldwide documentation of increasing intensity and frequency of heat waves, heavy precipitation, and coastal storm events (IPCC, 2014). Climate scientists expect this trend to continue.

There are various ways to define an extreme climate/weather event. For example, the Intergovernmental Panel on Climate Change (IPCC) defines an extreme event as one that ranks in the bottom 10th or top 90th percent of occurrences (IPCC, 2012). As this study focuses on communities of all sizes, the research team defines an ***extreme event*** as one that is highly unusual within local memory and that has significant consequences as defined by that community (in terms of impact, cost, etc.). These events typically involve water – too much, too little, in the wrong place, or at the wrong time. They include more frequent heavy downpours, prolonged higher temperatures, multi-year droughts, earlier snowmelts, and rising sea levels. Events have the potential to disrupt water services including drinking water supply, wastewater conveyance and treatment, and stormwater management.

Based on the results of six local case studies, this report includes information from participants at workshops in the following river basins that experienced different types of extreme events:

- Apalachicola-Chattahoochee-Flint River Basin, Georgia, May 2012 workshop on floods and droughts.
- Central Texas Region, March 2013 workshop on prolonged drought and wildfires.
- Lower Missouri River Basin, Kansas and Missouri, February 2013 workshop on floods and droughts.
- National Capital Area, December 2012 workshop on hurricanes and derechos.
- Russian River Basin, California, March 2012 workshop on atmospheric rivers, droughts, and frosts.
- Tidewater Area, Virginia, September 2012 workshop on nor'easters, hurricanes, and sea level rise.

This study examines how drinking water utilities, water resource recovery facilities,[3] and stormwater utilities – henceforth referred to as ***water utilities*** unless otherwise or individually

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[1] See Appendix A: Glossary of Water, Weather, and Climate Terms for a differentiation between climate and weather events.
[2] Biases suggest these costs are underestimated by approximately 10-15% (Smith and Katz, 2013).
[3] As of 2013, WERF publications use the term 'water resource recovery facility' in place of 'wastewater treatment plant' (except in cases where case study institutions' names include the former), keeping up to date with the sector's

specified – and other local water resource managers in these six river basins made decisions in response to recent extreme events. The study examines what happened, how information was used to inform decisions, what institutional dynamics helped or hindered, and how communities (including water utilities) plan and build resilience for extreme events in the future. It further identifies gaps in the availability of information and information pathways, as well as opportunities to improve access to decision making tools.

Undertaken so that water utility managers could learn from their peers, the results of this study are also meant to stimulate dialogue across jurisdictional boundaries and inform Federal agencies as to how they can better support local communities with needed data, forecasts, tools, and other services.

1.1 Changing Climate and Implications for Water Services

The IPCC is the leading international organization on scientific assessments on climate change. It summarizes the current knowledge about climate change and its potential impacts to the environment and society. The US Global Change Research Program (USGCRP) provides periodic updates to the nation about observed climate changes, makes future projections, and creates information and tools to support adaptation throughout the U.S. The USGCRP's 2014 report includes these messages concerning water resources:

- Climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses.
- Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall comes in heavier events (with longer, hotter dry periods in between).
- Climate change will place additional burdens on already stressed water systems.
- The past century is no longer a reasonable guide to the future for water management.

Air and sea surface temperatures drive the hydrologic cycle. The complex interrelationship between various aspects of water resources and the earth system – seasonal precipitation (or lack of), runoff and stream flow, air and water temperature, wind, evapotranspiration, snow pack, and storm intensity, among other factors – is central to water resource management. The continuous evolution of water resource management science over the past century or more, informs methods to provide society with sanitation, safe drinking water, and quality of life. However, the advent of unexpected variations outside the historical norm challenges the current planning methods honed over decades of experience.

Water resource managers and water service providers look to past observations to guide the design of systems, expecting that future climates will fall within reasonably similar bounds in the future. This concept is known as 'stationarity' and reflects that natural systems – including water cycles – occur within a consistent range of variability. For water resource managers, this variability is typically defined by observations over the past 100 years of precipitation, stream flow, and other hydrologic parameters on various time and space scales (Brekke et al., 2009).

Recent studies show that historic climate and weather patterns may no longer be as reliable for future planning as they once were (Milly et al., 2008). As an increasing number of

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focus on the benefits and products generated from treatment instead of the waste entering facilities prior to treatment.

extreme climate/weather events occur outside the historical range, communities are now re-examining design and operational assumptions about water supplies, system demands, performance requirements, and operational constraints. When the frequency and/or intensity of events exceed the design capacity or disrupt the ability to provide the level of service expected by ratepayers, there are serious implications for water managers and customers.

Water managers and decision makers are working to increase the resiliency of water supplies and services in order to effectively plan for future variability and extremes. **Resilient systems** are those with the ability to maintain critical services under extreme circumstances and return to a fully functional state quickly. Resiliency can be measured in terms of adaptability of functions in short time periods in the face of extreme events, associated decreases or disruptions in service, and the level of effort and costs to maintain or restore services.

1.2 Water Resources, Utilities, and National Regulations

Localities around the nation generally build, operate, and maintain their own water utilities; however, management systems are subject to regional laws and national regulations aimed at protecting the quality and quantity of water resources and supplies. Drinking water utilities, water resource recovery facilities, and stormwater management programs are subject to an intricate network of local expectations, regional practices, and national standards. However, select federal regulations provide the overarching framework that dictates water supply, treatment, discharge, and management. Summarized below, the *Federal Regulations Terminology Explained* section of Appendix A: Glossary of Water, Weather, and Climate Terms offers supplemental information on these and other regulations, amendments, and supporting programs.

1.2.1 Drinking Water Supply Sector

Approximately 155,000 public water systems in the U.S. provide safe drinking water, each of which serves at least 25 people (EPA, 2009). Twenty-three percent of these systems serve 3,300 people or more. All drinking water utilities are required to provide treatment in accordance with the Safe Drinking Water Act (SDWA) for distribution to residential, commercial, and oftentimes, industrial customers. In addition to treatment and distribution, some drinking water utilities also manage their water source, such as from reservoirs or groundwater systems.

Established in 1974, the SDWA protects the quality of drinking water in the U.S. Essentially, it seeks to ensure public health. The law focuses on all actual and potential waters treated for drinking use, regardless of the ground or underground supply origin (EPA, 2012). The SWDA authorizes the U.S. Environmental Protection Agency (EPA) to establish minimum standards to protect tap water. All owners or operators of public water systems are required to comply with the EPA's primary (health-related) standards (EPA, 2012). The EPA can approve state governments to implement these standards; in fact, many states also encourage nuisance-related secondary standards (e.g., for aesthetic considerations such as taste and odor). Under this regulation the EPA also establishes minimum standards for state programs to protect underground sources of drinking water from endangerment by the underground injection of fluids.

Congress passed additional amendments in 1986 and 1996. The 1996 amendments required the EPA to consider a detailed risk and cost assessment and best available peer-reviewed science when developing these SWDA standards (EPA, 2012). Potential amendments regarding the oversight of chemical storage tanks are under current consideration in Congress.

Although water utilities regularly meet the SDWA standards, extreme climate/weather events challenge regular treatment efficiency, as increased pollutants from excess water or increased sediment loads from a lack of water can drive up processes and the cost of treatment to continue achieving sufficient standards (AWWA, 2012).

1.2.2 Wastewater Conveyance and Treatment Sector

According to the EPA, there are approximately 15,000 publicly owned water resource reclamation facilities in the U.S. that treat domestic wastewater from residential and commercial establishments (EPA, 2009). An additional 4,800 service providers collect domestic wastewater through a satellite collection system but maintain agreements with other utilities for treatment (EPA, 2009). In about 770 older cities and major urban areas, combined sewer systems (CSS) collect rainwater in the same pipes as domestic wastewater. These systems pose unusual challenges during rain events and often have special facilities which function only when triggered by large storms. The National Pollutant Discharge Elimination System (NPDES) permit program of the Clean Water Act (CWA) regulates the wastewater sector.

Originally enacted as the Federal Water Pollution Control Act of 1948, the federal government and the EPA expanded, reorganized, and renamed the CWA in 1972 (EPA, "Laws and Regulations," 2014). Authorizing the EPA to implement pollution control programs and discharge permits, the CWA is the basis for regulating surface water quality in the U.S. The EPA regulates surface water quality to maintain the "chemical, physical, and biological integrity of the nation's waters" through the CWA by requiring permits for any point-source pollutant discharge (discrete conveyances, pipes, human-made ditches, etc.) into navigable waters (EPA, "Laws and Regulations," 2014). Individuals, industrial, municipal, and water resource recovery facilities obtain permits through the NPDES program. The CWA does not cover water quantity or groundwater issues.

Extreme events can challenge the ability of water resource recovery facilities to consistently meet their permit limits in several ways. Extreme precipitation can cause wet weather flows to exceed the capacity of collection systems, and even recovery facilities. This results in performance difficulties and occasional overflows or bypasses. Discharge limits are set by NPDES permits, most of which use 7Q10 as the basis for water quality based permit limits and mass-based limits. 7Q10 is a statistical flow metric evaluated based on long-term flow trends, magnitude, frequency, and duration elements. Since water-quality based discharge limits reflect a base flow in the receiving water body, prolonged drought below historic base flows leaves aquatic life unprotected by existing permit limits.

1.2.3 Stormwater Management Sector

Approximately 7,400 jurisdictions manage urban runoff under local stormwater programs (EPA, 2009). Local jurisdictions are also responsible for urban drainage and flood control. Stormwater management varies across the U.S.: some municipalities jointly manage wastewater and runoff, while others have separate stormwater utilities altogether. Stormwater collection systems may include CSS with wastewaters, or fall under Municipal Separate Storm Sewer Systems (MS4s).

As extreme climate/weather events increase in frequency and intensity, municipalities are struggling to manage more persistent storms and heavier amounts of rainfall in shorter periods of time. Stormwater management programs are exploring grey and green infrastructure options, as well as a combination thereof, depending on particular needs for flood control, to reduce the quantity of water flow, and/or to minimize the increased pollutants during a storm.

The NPDES permit structure is the main mechanism for regulating stormwater systems, as the CWA specifically includes stormwater as a point source. Currently, the EPA is implementing regulations for different types of stormwater discharges, updating some, and clarifying others. The NPDES permit program regulates the discharge from stormwater collection systems that, like wastewater discharges, can cause erosion and impair water quality (EPA, "Stormwater Discharges," 2014). Stormwater flowing into CSS may alter cost and treatment times for discharges from water resource recovery facilities, or may result in CSS overflows when systems exceed capacity during heavy precipitation events. Runoff is less likely to receive treatment prior to direct discharge in local water resources if transported through an MS4 system (EPA, "Stormwater Discharges," 2014). EPA thus initiated Phase I (in 1990) and Phase II (in 1999) of the MS4 program to augment the NPDES permit program by requiring specific permits for meeting quality standards for stormwater runoff discharges (EPA, "Stormwater Discharges," 2014).

1.2.4 Water Utility Management

Water utility services fall under several typical management structures. They are often provided by local jurisdictions, but are rarely consolidated into one departmental unit. For example, the stormwater program may be under the local department of natural resources while water or wastewater services are provided by the department of public works. Frequently, quasi-public authorities are formed to provide wastewater treatment or water supply services, while a few authorities provide multiple services. Occasionally, public water services are provided by private or semiprivate organizations.

In many locations, portions of the local water resource are managed or co-managed by federal agencies, often the U.S. Army Corps of Engineers (USACE) or the Bureau of Reclamation. Within a river basin, multiple local, state, and federal agencies manage different aspects of the water resource, some for drinking water supply, flood management, water quality, protection of endangered species, and groundwater management. In some regions, tribal governments also manage water resources and services. As described in these case studies, there is considerable diversity of organization and management structure of water utilities and water resources throughout the U.S.

1.3 Integrated Water Resource Management and Regulatory Frameworks

In an effort to increase future sustainability, water resource managers are working to address the relationships and trade-offs among ecological needs, human welfare, and our desired use of water for irrigation, water supply, transportation, and recreation. The emerging Integrated Water Resource Management (IWRM) framework seeks to accomplish this through an integration of the competing facets of water use, considers how natural systems, and human activities interact, while striving for more sustainable water resources and services from water as a finite yet renewable resource (Thornton, 2006). There is a growing realization within the water resource management realm that the IWRM approach is desirable, as many water utilities historically managed in isolation of other sectors that impact the very resource they administer.

The increasing complexity of managing the impacts of extreme events has begun to move water utility managers in the direction of working outside of their silos. Governance structures of both water utilities and the political jurisdictions with authority over those water utilities affect preparation for and response to extreme climate/weather events. For instance, the USACE retains jurisdiction over water resource management through the Water Supply Act, Flood Control Act, and Rivers and Harbors Act, among other legal frameworks. There are additional considerations in areas with military training lands and bases, such as Tidewater, VA (see Appendix H). Managing water resources in an integrated manner must occur within this context, including the many regulations that address ecosystem services and species that inhabit areas where utilities are located (for example, the National Environmental Policies Act (NEPA) and the Endangered Species Act).[4] As water utilities must comply with these regulations, they are of important consideration for IWRM and planning for extreme climate/weather events.

Presidential executive orders to reduce greenhouse gases, reduce water use, and plan for climate change adaptation further direct interactions between water utilities and federal lands/agencies. In 2009, President Obama directed the White House Council on Environmental Quality (CEQ), the White House Office of Science and Technology Policy, and the National Oceanic and Atmospheric Administration, to form an interagency task force, including representatives from more than 20 federal agencies. He directed the task force to develop recommendations on how the federal government can strengthen policies and programs to better prepare the nation for the impacts of climate change. In 2013, he reiterated this mandate and renamed the task force the Council on Climate Preparedness and Resilience.

Three national adaptation strategies, produced in 2010/2011, are being implemented: a National Action Plan for Managing Freshwater Resources, a National Ocean Policy Implementation Plan, and a National Fish, Wildlife and Plants Climate Adaptation Strategy.[5] In addition, all federal agencies were required to develop, and are now implementing, agency adaptation plans to protect their operations and ensure success of their missions in the face of the changing climates.[6] Similarly, water utilities are being encouraged to integrate adaptation into routine planning in order to build future climate resiliency.

These statutes, regulations, and executive orders cover a broad spectrum of areas intended to provide additional protections to the natural environment. Their jurisdictions spread across different federal agencies and require coordination and consultation among those responsible for various areas of responsibility as they relate to water resources, infrastructure, and governance.

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[4] For more information on contextual regulations affecting water utilities, IWRM, and extreme event preparation and response, visit the *Federal Regulations Terminology Explained* section of Appendix A: Glossary of Water, Weather, and Climate Terms. Acts mentioned in this chapter and in Appendix A are not an exhaustive list of water laws and regulations in the U.S.; rather they represent those most relevant to the scope of this study.

[5] For more information, visit: http://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience.

[6] Annual progress reports can be viewed at: http://archive-sustainability.performance.gov/.

CHAPTER 2.0

WORKSHOP APPROACH TO PREPARING CASE STUDIES

In August 2010, over 80 drinking water, stormwater, and wastewater service practitioners participated in a two-day workshop that focused on their climate/weather-sensitive information needs for making decisions on long-lived and costly investments (Raucher, 2011). Practitioners expressed particular concern about their risk and vulnerability in preparing for and adapting to an increased number and intensity of extreme climate/weather events. In discussions at this conference, participants noted a number of their colleagues whom faced an extreme event and that they could benefit from the knowledge gained and lessons learned from one another's experience to better prepare for and adapt to future events.

An outcome of the 2010 workshop discussions was a joint research endeavor by staff from two federal agencies, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA), and several not-for-profit research organizations which support water resources and the utilities providing water services such as drinking water, wastewater management, and stormwater control. The organizations include the Water Environment Research Foundation (WERF), the Water Research Foundation (WRF), Concurrent Technologies Corporation (CTC), and Noblis. Through this novel collaboration, the researchers convened six local workshops, resulting in the case studies presented here.

The research team held a series of six regional workshops focused on specific river basin areas in the U.S. (Figure 2-1) that had recently experienced one or more extreme events. While there are countless examples of communities dealing with extreme events across the nation and several other locations would have added different benefits and perspectives to this study, it was impossible to include them all. Time and resource constraints demanded a selection of focused studies; the benefit of this is in-depth examinations of six study sites. The research team chose locations because of their geographic diversity, differences in extreme events witnessed, ties with one or more of the sponsoring water foundations, and geographic and program ties to current projects with the federal partners.

The research team planned the first workshop in the Russian River Basin of California to examine a particular flood event, but quickly realized that communities were grappling with a series of multiple events, both flood and drought, among other stressors. Communities are pressed to plan for a variety of weather and climate extremes, and water resource managers are juggling many objectives simultaneously. This proved true in all six workshops and the focus of the workshops reflects that.

For each workshop, the research team assembled a local planning team representing a mixture of water managers in the case study location. The research team probed the local planning team to elicit the issues of importance to them, identify invitees, structure the agenda, and invite local speakers. The result was six unique workshops tailored to their issues and communities. Workshop invitation lists included representatives from the water utilities, water-intensive industries, local environmental groups, and local, tribal, state, and federal staff who played a role within the basin. In some cases an elected official also attended.[1]

Workshops generally lasted a day and a half. Presentations covered a) expert presentations about the basin, past and future climate, including an overview of the extreme event(s) being discussed; b) description of institutional arrangements and constraints under which the specific water utilities operate; c) first-hand accounting of the specific water utilities' and water users' experiences during the event; d) descriptions of the roles that decision makers, information providers, and other relevant officials played during the event and in planning for future extreme events; and e) how the utilities expect to plan for future extreme events and what adaptation strategies they will pursue. In most cases, the workshop provided an opportunity to share available tools and studies. In some cases the research team planned these meetings in conjunction with related local meetings to take advantage of similar attendees and interests.

In facilitated breakout sessions and group discussions, researchers probed participants on lessons learned and information needed to make better decisions to prepare for and respond to extreme events in the future. Overall, those engaged in the workshops benefited from the multi-dimensional view of the same extreme event.

After each workshop, the research team compiled the information and prepared two-page fact sheets summarizing the outcomes. The research team later prepared case studies which are included with this report (Appendices C through H) to more fully document the wealth of information presented at the workshop. Case studies primarily relied upon notes and materials from the workshops, as the goal was not to provide an exhaustive analysis of the climate, the basin, or the communities, but rather to reflect the particular experiences, challenges, and lessons of specific events through the specific speakers and participants at the workshops. However, the research team incorporated additional information and references as needed to ensure the accurate portrayal of the events and the response by the water utilities. The workshop speakers and research team reviewed the draft case studies and provided their comments; these are incorporated herein. Chapter 3.0 reflects overall findings and common lessons learned from the six case studies, while Chapter 4.0 provides a synthesized commentary on looking forward from those findings to building future resiliency.

[1] Visit appendices for local planning 'Regional Teams' (on the cover page) and workshop participant 'Attendees' (at the end) of each case study.

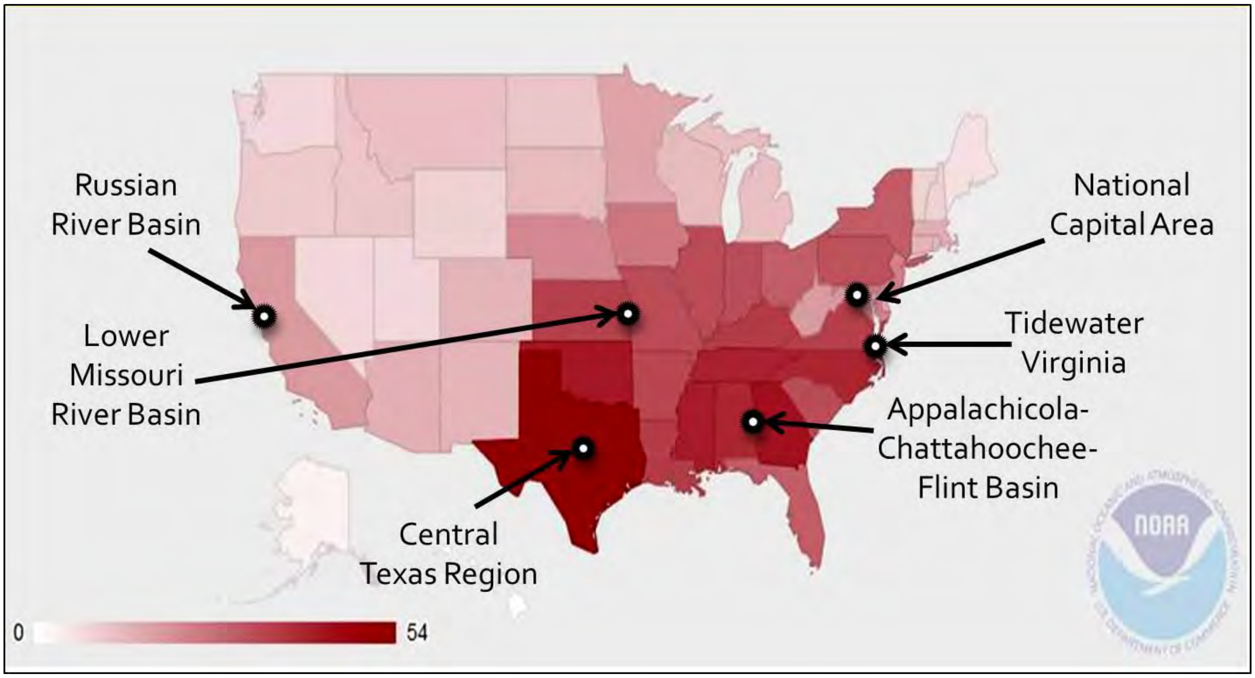

Figure 2-1. Extreme Event Case Study Locations and Number of 1980-2012 Billion-Dollar Climate/Weather Disasters.
Source: NOAA, 2013.

CHAPTER 3.0

FINDINGS

3.1 Overview of Findings

The initial motivation for undertaking this study was a desire among water utility managers to learn from the experiences of their peers. The six case studies presented in this report allow for the observation of the experiences and practical challenges recently faced by water utilities and their communities. Findings from the case studies draw some lessons that may stimulate others to consider emerging practices and new ways of thinking about extreme events. This study reveals a confluence of other factors equally as important as the need for improved forecasts and 'actionable information.' Summarized below (Figure 3-1), Sections 3.2 through 3.5 elaborate upon these points and discuss additional challenges that surfaced during workshops. To add a practical edge, this chapter – and this report – includes examples of strategies adopted by water utilities to build resilience in their particular situations.

Managing the Risks of Extreme Events

- **Cascading Nature of Extreme Events:** Localities are dealing with multiple types and occurrences of extreme events, many of which have become more severe and more frequent in recent decades.
- **Integrated Planning for Multiple Risks:** The variety of extremes experienced in communities necessitates managing multiple risks.

Recognizing the Importance of Water Services and Infrastructure

- **Water Services as Critical Infrastructure:** Water services are part of the nation's most critical infrastructure and investments.
- **Emergency Response:** Emergency response is an essential component of preparedness, and ensuring the ability to recover operations following extreme events is among communities' top priorities.
- **Long-term Preparedness:** Utilities are beginning to re-design infrastructure to address particular vulnerabilities or to increase the flexibility of existing systems.

Building Resilient Communities

- **Public Awareness:** The community must understand their risk and define their risk tolerance.
- **Community Decision Making Within a Basin:** The complex array of decisions needed to support resilience within a basin requires coordination across water service areas and jurisdictional boundaries.
- **Leadership and Innovation:** Communities need leadership to help navigate new paths to resilience.

Creating Actionable Information

- **Multi-Disciplinary Collaboration:** Multi-disciplinary collaboration and communication increases access to actionable information for science-based decision making.
- **Active Engagement in Acquiring Information and Tools:** There is no 'silver- bullet' decision support tool. All tools require effort to customize and apply to local conditions over a variety of adaptation strategies.

Figure 3-1. Lessons Learned from the Six Case Studies.

3.2 Managing the Risks of Extreme Events

The natural variation of extreme climate/weather events throughout the U.S. is significant. Communities stressed that effectively managing the impacts of extreme events depended on several factors, including the type and timing of an event itself, as well as integrating into variable responses into conventional planning methods and risk management.

3.2.1 Cascading Nature of Extreme Events

Localities are dealing with multiple types and occurrences of extreme events, many of which have become more severe and more frequent in recent decades. Workshop participants reiterated time and again that extreme climate/weather events are quickly becoming the 'new normal' in their regions. Rather than one dominant event, communities face consecutive events that affect those in every walk of life – from vineyards in California's Russian River Basin, to microchip industries in Central Texas, and naval facilities in Tidewater, Virginia.

It came as no surprise that workshop participants described record breaking events. Globally, 874 climate and weather related disasters occurred in 2010; studies indicate 2010 was the wettest year on record and tie it for the warmest year (along with 2005) since 1880 (Huber & Gulledge, 2011). This reflects an apparent trend in the increasing number of extreme events in recent decades. The U.S. is no exception; states are continuously breaking records. The Lower Missouri River Basin, for instance, experienced two record floods less than fifteen years apart: the Great Flood of 1993 broke all historical records only to then be surpassed by the 2007 Flood. Two nor'easters hit the Tidewater Area in 2012 alone, both breaching 100-year storm records.

What did come as a surprise, however, was that rarely did an area experience just one type of extreme event, but rather multiple types within relatively short periods of time. Oftentimes, areas are recovering from one event when another one hits. The drought stricken ACF Basin plunged into two consecutive record floods, followed by another persistent drought. Central Texas experienced raging wildfires amidst a three-year drought. Rajendra Bhattarai of Austin Water Utility remarks, "Texas has become a land of extremes. We may be in our worst drought, but we must also prepare for inevitable flooding" (Synthesis Meeting, 2013). Each region visited for these case studies similarly reflected this sentiment.

3.2.2 Integrated Planning for Multiple Risks

The variety of extremes experienced in communities necessitates managing multiple risks. Storms provoke emergency response and result in high initial damage, clean up, and recovery costs. Hurricanes, nor'easters, derechos, and atmospheric rivers commonly cut off water supplies due to loss of power. Excess flooding further compromises water quality and affects communities through property damage and loss of life.

In contrast, unfolding droughts incur long-term costs that affect revenue and impair utilities' abilities to meet regulatory obligations (such as water quality standards and endangered species mandates). Parched landscapes may result in limited of watering days, uprooted pipes, challenged water rights, and increased user costs. Managing the impacts of drought requires a sustained, community-wide effort. Preparations for each type of event require different kinds of data, tools, players, and response actions.

Nevertheless, the increased frequency, severity, and variation of extreme events demand that utilities prepare for many types of events. Communities can increase resilience by incorporating responses to both immediate and long-term impacts directly into risk management planning. Defining the risk associated with a variety of extreme events, understanding the implications these events have for water systems and services, and identifying major assets are the first steps.

3.3 Recognizing the Importance of Resilient Water Services and Infrastructure

Water infrastructure is one of the most significant factors affecting reliable water services during and in the aftermath of an extreme event. Time and again, communities noted a critical need to address emergency preparedness and long-term adaptation strategies in order to prepare for and respond to future extreme climate/weather events.

3.3.1 Water Services as Critical Infrastructure

Water services are part of the nation's most critical infrastructure and investments. The single largest threat to human health is a lack of access to safe water supplies. Economic livelihoods are similarly dependent upon access to water resources of a sufficient quality and quantity. Drinking water, wastewater, stormwater, and urban drainage systems remain the largest financial investments in communities throughout the U.S.

> ✓ **Resiliency Strategy**
>
> Norfolk began using a 10-year rainfall storm level in 2000 for all new and replacement urban drainage infrastructure, an increase from standards previously set at the two-year rainfall level in the **Tidewater Area**.

While communities historically made large investments to build and maintain drinking water, wastewater, stormwater, and urban drainage systems, the vast reliability of service promotes an 'out of sight, out of mind' perception; the public is largely unaware of the cost to maintain water services due to aging and routine wear. When storms damage water and wastewater infrastructure, the impact is even more costly. Atlanta's R.M. Clayton Water Reclamation Center in the ACF Basin, for example, suffered more than $60 million in recovery costs during the September 2009 Flood, on top of annually accrued service and maintenance costs. High water tables due to sea level rise in Virginia's Tidewater Area increase infiltration and inflow (I/I) into sanitary pipes, even during dry weather. Aside from maintenance costs, this further affects water quality as the number of overflows may increase.

> ✓ **Resiliency Strategy**
>
> To safeguard water service operations during emergencies, utilities in the **Lower Missouri River Basin** installed standby computer servers in separate locations for power outages, dual power feeds, automatic switching gears, and generators in case both feeds are down.

Despite ongoing investments, most water infrastructure was built more than half a century ago; the impacts of extreme events exacerbate the ongoing challenges of managing this aging infrastructure. Excluding unplanned costs inflicted by extreme events, some estimates indicate that over the next 25 years, drinking water infrastructure will reach $1 trillion alone

(AWWA, 2012), with upwards of another $298 billion[1] for wastewater and stormwater infrastructure (EPA, 2009). These case studies reveal that successful resilience is contingent upon water utilities and communities embracing both emergency response and long-term preparedness, which often goes hand-in-hand with a utility's asset management program.

3.3.2 Emergency Response

Emergency response is an essential component of preparedness, and ensuring the ability to recover operations following extreme events is among communities' top priorities. Communities struggle to recover from climate/weather-driven disruptions, especially if the event led to a lack of access to safe drinking water and sanitation.

When events damage treatment facilities or compromise operations, water utilities are among the most critical public services to restore. Workshop participants frequently reported that storms caused loss of power at facilities, flooded electrical equipment, or exhausted fuel supplies and interrupted supply routes. In the Tidewater Area, downed power lines and infiltration compromised water quality at some facilities during Hurricane Isabel in 2003. The Virginia Department of Emergency Management delivered water, ice, and generators to meet service priorities in providing safe drinking water and restoring water treatment facilities. Compromised water services further challenge other emergency operations. For instance, without water services firefighters in central Texas could not fight the 2011 Wildfires. Many utilities are thus working to ensure that water utilities are on power companies' emergency priority list.

> ✓ **Resiliency Strategy**
>
> When cell lines were jammed, utilities in **Central Texas** relied on radio communications with multiple frequency options.
>
> In the **National Capital Area**, utilities used walkie talkies and landlines to back up email and cell communications during events.

Workshop participants consistently described sophisticated emergency response planning already in place or those constantly being improved. One successful example is in the Tidewater Area, where response 'action tables' based on storm tide levels and after-action reports evaluate operational performance during events and constantly help refine emergency operations. However, the increasing occurrence of severe events is beginning to force utility managers across the nation to make trade-offs between resources for operations and maintenance versus resources for emergency preparedness and response. In reality, neither should be neglected – and communities need to be made aware of the costs for both.

Workshop participants asserted the critical role water and wastewater managers hold in emergency

> ✓ **Resiliency Strategy**
>
> Water utility employees and firefighters in **Central Texas** worked side-by-side to re-pressurize pumps and repair meters melted during wildfires. Utilities also used GPS to track locations in need of emergency response when landmarks disappeared during fires.

[1] This number includes improvement costs for pipes, correction of combined sewer overflows, wastewater treatment systems, distributing recycled water, and stormwater management (EPA, 2009). Costs are in 2008 dollars, and the report derived data from all states except North Dakota, American Samoa, and the U.S. Virgin Islands.

management systems, as essential 'first responders.' In turn, cultivating both informal and formal ties with members of a variety of community service sectors increases a utility's ability to manage emergencies. Case studies repeatedly demonstrated that support and communication networks throughout the community are critical for building emergency response capabilities as well as enabling long-term resilience. For example, the Aqua Water Supply Corporation in Bastrop County, Texas restored service within one week of severe damage to water lines and meters during raging wildfires in 2011. In this and other cases, workshop participants repeatedly reported the value of regional Incident Management Teams and Mutual Aid Networks – such as the emergency support that ACF Basin utilities received from the Georgia Water/Wastewater Agency Response Network floods in 2009-2010. Other examples of important networks included those related to energy, communications, transportation, industry, supply chain providers, local, state, tribal, regional, and federal governments sectors.

3.3.3 Long-Term Preparedness

Utilities are beginning to re-design infrastructure to address particular vulnerabilities or to increase the flexibility of existing systems. While utilities are highly competent and increasingly skilled at responding to emergencies, there is a growing need to also adopt long-term solutions, especially when rebuilding after incurring significant damage. More and more utilities are conducting critical vulnerability assessments to understand the risks systems encounter with the increasing intensity of precipitation and frequency of storm events and prolonged droughts. Such assessments lend to adaption strategies over time.

Water managers increasingly recognize that building long-term resiliency into systems means reassessing standards. Infrastructure was previously designed to smaller storm standards than storms seen today. This occurred for a number of reasons: cost-effectiveness, feasibility issues of large-scale infrastructure projects, climate/weather data available at the time, and the assumption of stationarity. However, historical flow and precipitation trends do not necessarily apply anymore. Planning based on these historical observations is no longer adequate, as shifts in climate leave an unprecedented impact on water cycles and supplies (Milly et al., 2008).

> ✓ **Resiliency Strategy**
>
> In the **ACF Basin**, Douglas County refurbished their water resource recovery facility after the 2009 Flood by installing overhead structures to lift pumps above flood levels and relocating the control room to a higher floor. Such action protects water quality by decreasing recovery time and allowing facilities to restore operations following a flood event.

Of the communities visited, it was uncommon to hear that utilities were changing the infrastructure design to accommodate the increasing statistical intensity, duration, and frequency of storms.[2] One exception was WaterOne in Johnson County, Kansas. This private utility in the Lower Missouri River Basin designed its system to withstand a 500-year flood. Though 2011

[2] Urban drainage systems are typically designed for 2-10 year storm return periods, whereas water utility facilities are sited for 100-year flood levels (ASCE and WEF, 1992). Infrastructure design for each depends heavily on a community's risk tolerance, land use and development, cost effectiveness, and the return storm analysis at the time of design. Drainage systems comprising conveyance and storage – i.e., routine operations dealing with runoff capacity – are based on the above factors and local policies. As water treatment plants and water resource reclamation facilities cannot tolerate the level of risk that routine operations can, these are typically designed to flood levels, with consideration of FEMA flood insurance rates.

floodwaters temporarily isolated the collector well, the utility itself did not flood and remained in operation. In several other areas, utility managers are conducting risk assessments. The Hampton Roads Sanitation District (HRSD) in Tidewater, Virginia, for example, employs a scenario-planning methodology to examine future exogenous and endogenous factors affecting the utility's long-term operating strategy (Bernas, 2012).

The location of water infrastructure near water resources is also a key element that affects vulnerability. In both the ACF Basin and Tidewater Area, participants noted the vulnerability of water resource recovery facilities located close to rivers or in floodplains. For instance, it took R.M. Clayton Reclamation Center nearly six weeks to reduce coliform levels and restore water quality due to extensive flooding of the facility in 2009. Utilities are realizing that they need to reposition future investments to minimize increasing flood risks. Case studies confirmed the important lesson learned: when possible, do not continue to build important infrastructure near rivers or in low flood plains. This is easier with non-water related infrastructure, as water resource reclamation facilities are often situated closely to rivers for discharge purposes.

Communities are gradually diversifying their strategies to reduce vulnerability. They are adopting innovative approaches such as integrated water resources management (IWRM), combining green and grey infrastructure options, recognizing the ecosystem's role in reducing risk, and valuing natural assets (such as healthy aquifers). Combinations of green and grey infrastructure can help control flooding, reduce the impacts of drought, improve water quality, and protect ecosystems in general. For example, in the National Capital Area, the District Department of the Environment (DDOE) is working to retrofit homes with landscaped rain gardens and rain barrels to capture stormwater prior to it entering waterways and conveyance systems. Meanwhile, DC Water is undertaking a massive tunneling project under the city to construct a pipe to hold excess flows during major storm events. These techniques both seek to meet water quality standards, promote cleaner waterways, and lessen floods in the nation's capital. These cases reflect a larger movement throughout the country to redesign infrastructure and move into a new era of water management.

A number of financial, political, and practical constraints confront utility managers, but as professionals and dedicated public servants, they are working to understand risks, juggle priorities, and meet public expectations for reliable and consistent water service. Water utility managers who participated in the workshops recognize that the provision of their services in light of extreme weather/climate events is closely tied to the function of the local watershed and its communities. The success of utility actions and activities, at least in part, depends on the larger, interrelated system.

3.4 Building Resilient Communities

The integral impact water services have on every individual's life and sector's activities necessitates the inclusion of communities themselves in planning for and responding to extreme climate/weather events. Workshop participants discussed the importance of increasing public awareness and community decision making, These elements help provide the type of leadership needed to spark innovation and build resilience.

> ✓ **Resiliency Strategy**
>
> To promote water conservation during drought, utilities in **Central Texas** issued continuous, real-time water use alerts that informed users of hourly water use or when users exceeded certain amounts of water supply.

3.4.1 Public Awareness

The community must understand their risk and define their risk tolerance. Water utility managers are expected, and expect themselves, to meet public expectations to deliver reliable water and sanitation service. In so doing, utility managers are balancing resources, while budgeting for daily operations, ongoing maintenance, and capital infrastructure planning. Since 9/11, managers have also become skilled at vulnerability assessments and emergency response planning. More recently, the emerging trend of extreme climate/weather events pressures managers to step up efforts to plan and respond to environmental incidents, which often provokes trade-offs. Similarly, communities and town councils are typically reluctant to adopt means of addressing risk – whether through changing public behavior about using water or committing budgets to retrofit facilities and build new infrastructure to more conservative specs.

While extreme events temporarily raise public attention, understanding the long-term implications for a community and the true worth of water requires public education, awareness, and involvement. Local governments currently subsidize water. However, reducing the risk of losing water control, treatment, or supply during extreme events is costly; it may mean communities must pay higher costs for the same amount of water. Individuals must recognize this risk and absorb higher costs as an investment in advance planning and action. To do so requires a change in consumer behavior as communities continue to use water services. Changes may involve actions such as altering daily consumption patterns through landscape practices or other reductions. Workshops revealed the need to entrench extreme event preparation into public perception, much like auto safety has become somewhat habitual in our thought processes.

In discussions about how to shift sentiment, many at the workshops said that they encounter a general lack of public understanding about extreme climate/weather events and the associated impacts on water supplies and services. They agreed that this is partially attributable to the historic success in the U.S. to provide clean water and sanitation at a low cost, leaving the general public unaware of what is involved in collecting, treating, and delivering water services.

Several participants suggested that utilities can counter this by stressing that changes are not merely about saving money – they are about managing risk. Communities need public dialogue about the cost of reducing risk and defining levels of acceptable risk – in other words, establishing a 'willingness to pay.'

> ✓ **Resiliency Strategy**
>
> In the **ACF Basin**, Douglas County adopted two additional water billing tiers to discourage water use over 9,000 gallons during drought, reflecting scarcity value.
>
> Douglasville-Douglas County Water and Sewer Authority increased the public's awareness about their daily water consumption with bill stuffers; letters from the utility directors; TV and radio broadcasts; continuously updated websites; and information displays.

Similarly, changing behavior requires building public acceptance of the benefits of adopting long-term water conservation strategies, altered pricing structures, or other response measures that can delay or even avoid the collision between hydrologic droughts and demand-induced droughts. Utilities are recognizing that designing messages to better address specific audiences and target particular goals helps communities adopt new strategies for preparation and adaptation.

3.4.2 Community Decision Making Within a Basin

The complex array of decisions needed to support resilience within a basin requires coordination across water service areas and jurisdictional boundaries. Water utility managers are competently taking action within their span of control, but also confronting vulnerabilities that require broader action. Workshop participants were most effective in solving problems when they communicated with other service providers within the community, across jurisdictional boundaries throughout the basin, and with various levels of governments. For example, reliable access to power and communications is the most common vulnerability that lies outside of the control of water service providers, especially during emergency response situations. Working with power suppliers and telecommunication providers prior to an event's onset may significantly diminish the amount of time water and wastewater services remain offline in the aftermath.

Perhaps most challenging is the coordination of decision making by different authorities managing overlapping water resources in a basin. Multiple uses of water resources, i.e. for agricultural irrigation, energy generation, ecological functions, industry, and municipal water supply, are often managed or affected by different laws, jurisdictions, levels of government, or simply diversity of users.

Every locale is unique and community context can facilitate or constrain a utility's ability to conduct and implement long-term planning (including for emergency response). Failure to understand interdependencies among the many organizations and constituents that play a role in affecting water utility operations can undermine the success of actions. Responses are ineffective when siloed within service areas or political boundaries. Multi-jurisdictional fragmentation merely creates additional vulnerabilities that are difficult to address.

> ✓ **Resiliency Strategy**
>
> Agencies in the **National Capital Area** worked together to set up food and shelter support locations prior to Sandy's landfall for utility personnel asked to remain working during the event. Collaboration further provided early calls to electric utilities to minimize power loss where possible.

When diverse parties collaborated, workshop participants described improved problem solving during – or as a result of – extreme events when diverse parties collaborated. For example, dam operations upstream significantly affect both water supply and flood management downstream, and can affect utilities' in unintended ways. In the ACF Basin, USACE-authorized reductions in Buford Dam water releases during the 2007-2008 Drought threatened water quality for downstream and Gulf ecosystems. The complex array of decisions needed to support resilience requires coordination across water service areas and jurisdictional boundaries. Engaging key stakeholder sectors in problem solving is one way to address this and to yield more locally viable solutions.

Federal agencies, including DOT, FEMA, EPA, USACE, and others play a key role and can promote community decision making and cross-sector collaboration. Coordinating activities to support local and regional efforts, as well as national programs, increases community resiliency.

Also during the 2007-2008 Drought in the ACF Basin, for instance, re-activating the use of Bear Creek Reservoir for the first time in over 13 years helped supplement withdrawals from the Dog River Reservoir. Coordinating agencies were better able to protect water quality and meet water demands during drought conditions.

Water utility managers are finding themselves in the nexus of understanding community adaptation strategies; they are most effective when their decision making works within the broader watershed context.

3.4.3 Leadership and Innovation

Communities need leadership to help navigate new paths to resilience. While many of the water utility managers in the workshop described how actions taken by others within the basin affect their system operations, and while several examples were presented describing how working across jurisdictional boundaries helped to solve problems, participants provided other examples concerning the ongoing challenges with the broader socio-economic context. Values, economic goals, pre-existing development patterns, and politics all came into play in every community. It is almost too much to expect water utility managers to provide the leadership needed to navigate this complex and ever-shifting maze. Nonetheless, workshop participants noted exemplary leadership that demonstrated the importance of this element in solving long-term problems.

In every workshop, participants acknowledged that they were experiencing unprecedented extremes and that the climate was changing. However, participants' values and beliefs varied – not all agreed that 'climate change' is the cause. In the context of adaptation, this seeming contradiction did not affect community action per se. For example, in Tidewater, Virginia, despite the reluctance of the state legislature to attribute sea level rise to climate change, a joint resolution in 2012 entrained the Virginia Institute of Marine Science (VIMS) to conduct a study of recurring coastal flooding that will inform strategies to protect communities. In Texas, the state legislature adopted legislation requiring all communities to conduct both conservation and drought planning, an action supported by industry, environmentalists, and municipalities alike. But communities still need local leadership to put these practices and strategies into action.

> ✓ **Resiliency Strategy**
>
> By delegating funding authority to Douglasville-Douglas Water and Sewer Authority in the **ACF Basin**, the utility was able to quickly commit emergency funds to recover water services within a week following the September 2009 Flood.

Some participants described cases when economic goals collided with the harsh impacts of extreme events. In the ACF Basin, for example, recreation on Lake Lanier contributes significantly to the local and state economies and the extreme Drought of 2007-2008 took its toll on this. Broader state messaging that did not want to dampen tourist attraction to lakes upriver hampered the ability for local municipalities and other economic interests, such as the downstream agricultural community, to raise public awareness about conserving water. Community leaders stepped up to convene the ACF Stakeholders, a consortium of farmers, environmentalists, commercial interests, and local and state government officials. This group builds common understanding and develops long-term strategies, including leveraging opportunities, such as the under-utilized

State Water Plan. As one ACF workshop participant noted, “We need bold leadership. If we don’t solve these political issues, nature will solve them for us.”

Long-standing development patterns and service obligations pose unavoidable challenges. Pre-existing development patterns mean that extreme events inevitably affect certain communities – and oftentimes marginalized populations – more than others. Every community faces this challenge: tribal communities concerned about exercising their water rights in the Lower Missouri River Basin; the rice growers downstream of Austin, Texas, who have been denied water allocations during droughts in order to preserve supplies for urban users; long-standing communities in the Russian River Basin that now find themselves in areas that increasingly flood, causing erosion and landslides; desirable coastal zones in Tidewater, Virginia that face high-risk from the combined effects of land subsidence and sea level rise; neighborhoods in metropolitan DC and surrounding suburbs with insufficient drainage; economically marginal and underserved communities in the ACF Basin that flood repeatedly.

Water managers are obliged to serve high risk areas despite the known risks and recurring costs. Given the larger socio-economic and political context, changing these patterns is not within water utility managers’ purview. However, some workshop participants indicated that certain strategies can at least inform the larger decision making context or reduce risk. While water utilities cannot alter existing FEMA programs, for example, increasing coordination with local planning departments can help reduce risk. In the ACF Basin, neighborhoods such as Austell and Clarkdale flooded during Hurricane Floyd in 2005 (a 100-year event) as well as the 2009 Flood (a 500-year event). After FEMA granted permission to rebuild the Clarkdale elementary school in the same location, a community forum stepped in to spend $19.2 million to rebuild on higher ground. In Tidewater, Virginia, suspending future emergency services on Sandpoint discouraged further development in the high-risk, flood-prone area of Virginia Beach.

Finally, workshop participants described examples of how the broader political context came into play. In the Russian River Basin, environmental and economic water demands challenged joint USACE and SCWA operated dams during the 2007-2009 Drought and Spring Frost of 2008. Grape growers withdrew allocations in a short time to spray grapes for frost protection, while environmentalists pressed the state legislature to mandate action under the Endangered Species Act to protect water quality and base flow to support fish species. Meanwhile, community members worked to find more locally driven solutions to address the drawdown of water supplies by the municipalities, grape growers, and others. Conflicting water interests, particularly during extreme events, necessitate community decision making, leadership, innovative solutions, and collaboration.

- ✓ **Resiliency Strategy**

While grape growers worked with wine councils in the **Russian River Basin** to construct water storage ponds to reduce diversions during drought, 10 utilities in the Sonoma-Marin Saving Water Partnership adopted a regional strategy between cities to conserve water.

3.5 Creating Actionable Information

Decision making that effectively builds community resilience to extreme climate/weather events demands decisions based on climate science. Workshop participants found that multi-disciplinary collaboration helps create actionable information for this very purpose and can help communities customize support tools and strategies to meet their unique needs.

3.5.1 Multi-Disciplinary Collaboration

Multi-disciplinary collaboration and communication increases access to actionable information for science-based decision making. The desire for access to data and information to inform planning and response actions is universal. Workshops frequently call for improved local forecasts over a variety of near-term and long-term timeframes. Despite this common need, and the many efforts underway to address it, finding information for the multitude of local scale decisions is not as straight-forward as desired.

Workshops demonstrated, however, that certain strategies can fill this need. Multidisciplinary teams of local experts from academia; nonprofit organizations; and local, state, tribal, and federal agencies, including a variety of disciplines (e.g., meteorology, climatology, hydrology, ecology, etc.), can develop information and decision support tools targeted to local decision making needs. This approach further builds community buy-in to adopt strategies informed by locally generated information.

In many areas, water utilities are establishing team approaches to information development. For example, in the Russian River Basin water utility managers joined with a wide variety of stakeholders to actually generate their own information. They have found that it takes time and effort to understand information created within the broader climate change research community – who often do not understand local watershed decision needs – and to make information useable for communities at particular spatial and temporal scales.

3.5.2 Active Engagement in Acquiring Information and Tools

There is no 'silver-bullet' decision support tool. All tools require effort to customize and apply to local conditions over a variety of adaptation strategies. Despite the perception that there is a lack of readily usable information for reconsidering operational and design strategies for improving resilience of water utilities, the workshops revealed that there is more information available than is sometimes realized. The workshops accentuated how each locality's particular experiences during and after extreme climate/weather events have changed their planning strategies, rather than informing managers of national level tools and information available to them. This approach demonstrated what is working, and highlighted areas for improvement.

> ✓ **Resiliency Strategy**
>
> In the **Lower Missouri River Basin**, the City of Overland Park and Johnson County developed **stormwatch.com**, a localized flood warning system. The counties established an MOU with the National Weather Service and worked with the USACE to collect data from weather stations in the Kansas City metropolitan area. The website provides relevant, real-time weather data and customizable dashboards to assess flood risk.

The result demonstrated that water managers and communities actually had a great deal of information they could use, at least until more is available, but also that more information is needed or would be more beneficial if presented in alternative ways. Managers pointed towards how they might obtain additional information in the future, identifying that the keys to success were:

- ♦ Expressing needs in contextually specific ways.
- ♦ Actively engaging in customizing information and developing tools tailored to particular decisions.
- ♦ Having access to training and resources to cover the cost of training.
- ♦ Taking time to be trained on using new information.

Water utilities are increasingly articulating their needs to the research community. When expressed more specifically, the information they are seeking may in fact already be available, or, if not, there may be an untapped capability to develop the needed information. This specificity enables utilities to reach out and engage information providers in making information more understandable and accessible. For example, the agriculture community in the ACF Basin, coming to terms with harsh realities of drought, has asked for decadal projections to inform new cropping patterns. In another instance, NOAA's Hydrometerological Testbed (HMT) tool for coastal atmospheric river monitoring and early-warning system helped Santa Rosa predict localized impacts during the 2012 storms in California.

Water managers are also pointing out when information is too aggregated to be of use or is too difficult to access in a timely way. By engaging information providers, they may find ways to customize tools for their particular, locally scaled decisions. Other workshop participants brought up the idea of water utility-oriented climate dashboards. NOAA responded with a joint effort in this direction, described in Chapter 4.0.

In recent years, managers, and researchers developed many tools to help solve problems. Unfortunately, despite their needs, water managers can be overwhelmed and unable to either keep up with what is new or to make use of potentially valuable tools. Furthermore, workshop participants state that they do not necessarily understand the pros and cons of using one database or tool over another. More work is needed on how to validate and disseminate useful tools; but decision makers still need to take the time to be trained on their use. Useful tools are out there,[3] but they require effort to customize and apply to local conditions over a variety of adaptation strategies. Funding for training and education is often cut when financial resources are tight. This kind of support for local utility managers and decision makers, however, is a key factor in sustainability and building resiliency. In order to effectively understand, plan for, and respond to extreme events, water managers need useful resources and tools, but also support in knowing what is out there and how to use it.

3.6 Conclusion

These case studies demonstrate that water resource managers are grappling with serious and costly impacts from extreme climate/weather events. Managers are juggling normal operations with emergency planning and response, while working with new approaches to build long-term resilience. They are forging working relationships with other water resource managers throughout their watersheds to achieve multiple objectives and avoid unintended consequences.

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[3] Visit Appendix B: Tools and Resources for the general, regional, and national tools localities in this study found most useful. See Chapter 4.0 3.0: Looking Forward for examples of resources pertaining to particular case study locations.

They are exercising community leadership to build agreement and achieve buy-in on new strategies. And they are becoming more knowledgeable about the changing hydro-climatological patterns and engaging with multidisciplinary teams in order to build the tools they need to inform future decision making. Workshops highlighted the unique ways in which communities work to meet their specific challenges. This reinforces that there is no silver-bullet answer, but also that information sharing and innovation are paramount. These case studies illustrate the kind of approaches others might consider as they, too, grapple with the localized risks extreme climate/weather events present in their communities.

CHAPTER 4.0

LOOKING FORWARD

These case studies provide a look, at one point in time, into the experiences six communities had with one or more extreme climate/weather events. While most reports of this type focus on examples of the most innovative leaders in addressing the impacts of climate/weather extremes, the research team selected these six to examine more typical communities. Originally intended as a way to promote peer-to-peer sharing of experiences, this approach fosters solutions both adaptable and applicable to common issues faced by many water utilities, rather than highlighting approaches that, while commendable, are unattainable for most. The research team further designed the project to highlight how national organizations and federal agencies can help communities throughout the U.S. grapple with their emerging realization of the need for new approaches that ensure resiliency in the face of dynamic change.

Since the completion of these workshops in 2013, participating communities and water utilities have continued to develop their approaches and capabilities. A spot-check of the six communities shows that they are all engaged in collaborative efforts to develop locally specific information and tools, raise public awareness and support, and to put in place programs that advance sustainable communities with increased resiliency to extreme variability in weather and climate. Meanwhile, national organizations such as WERF, WRF, and many federal agencies are working to help communities assess and manage risks from a changing climate.

4.1 Collaborating to Build Locally Specific Information, Tools, and Expertise

"There is an upward trend in U.S. billion dollar weather and climate disasters. Though each state experiences different types of extreme events, no state is exempt."

– Wayne Higgins, NOAA Climate Program Office (Synthesis Workshop, 2013)

These six case studies demonstrate that impacts and responses are local. Understanding of hydrological and meteorological phenomena that is useable at the local scale requires local involvement. To this end, all of the communities studied have continued to engage in projects to build locally specific information. In other words, taking local initiative – whether done with or without the involvement of the federal government or other national organizations – and collaborating with locally based institutions is the leading trend as water utilities work to build resilience.

For example:

- In the Russian River Basin, the Sonoma County Water Agency (SCWA) recently completed LIDAR and high-resolution imagery of the Basin, partnered with NOAA on its Hydrometeorological Testbed (HMT), and installed soil moisture probes above Lakes Mendocino and Sonoma. All of this will enable local planners to better understand atmospheric rivers, anticipate deluges and droughts, and assess correlations between rainfall and runoff in the Basin to inform both long-term and emergency planning.

- In the Apalachicola-Chattahoochee-Flint Basin, the ACF stakeholders continue to coalesce as the integrating forum for diverse interests and levels of government. They are building the information they need in order to understand river flows and lake levels and how they vary over time. They have commissioned independent hydrologic modeling and in-stream flow studies that will inform the data-driven analyses necessary to address the demands of the many different stakeholders in the ACF Basin, including the needs of aquatic habitats.
- The National Capital Planning Commission in Washington, D.C. convened a Monumental Core Climate Adaptation working group (http://www.ncpc.gov/climate/) to facilitate collaboration among 24 federal, district, and regional agencies. The group works to identify a common set of baseline climate data, define the short- and long-term climate risks, and formulate a shared set of climate adaptation priorities. Also, in 2013 the Interstate Commission on the Potomac River Basin published a study titled *2010 Washington Metropolitan Area Water Supply Reliability Study Part 2: Potential Impacts of Climate Change*. (http://www.potomacriver.org/publicationspdf/ICPRB13-07.pdf). Planners in the area are using this study to understand water supply vulnerabilities in the coming decades.
- The WRF is working with researchers at Berkeley, Stanford, and the SCWA to manage a study on stormwater capture, treatment, and groundwater recharge. The study will examine a system-based approach and design in order to increase nutrient removal from runoff and help mitigate flood risk. WERF and the EPA are also collaborating through WERF's National Research Center for Resource Recovery and Nutrient Management to fund this study.

Such collaborations – and their continuing work – reinforces the important role networking among water utilities and across sectors and local, regional, and federal jurisdictions has in building resilience. As communities experience multiple events and types of events, these efforts help navigate through the information, resources, and strategies needed to move forward, raise public awareness, and, where necessary, rebuild differently in the aftermath of an extreme event.

4.2 Raising Public Awareness and Support

> *"What we confront now is primarily a communications awareness issue. Things are moving quickly, but the challenge is to get the information into the hands of those making decisions."*
>
> *– Carl Hershner, Virginia Institute of Marine Science (Synthesis Workshop, 2013)*

Water utilities have always understood the importance of communicating with taxpayers and ratepayers to ensure they are informed, educated, and supportive when undertaking new projects. Raising public awareness of the trends and impacts of extreme climate/weather events poses additional challenges in some communities – the polarized discourse about climate change requires a careful framing so as to avoid undercutting the goals of raising awareness and changing behavior.

Nonetheless, productive dialogue is becoming more commonplace, fed by the increasing visibility of extreme events throughout the nation. Indeed, most communities agree with the understanding that the extreme climate/weather events are happening with greater frequency and intensity. Concern over personal safety and property opens the door to engage in conversations for local planning, especially when managers and decision makers present to the public, not just the problem, but practical actions in which they can engage. Communities with a strong sense of place have particular challenges, but also many opportunities.

- In Texas, the City of Austin and the Capital Metropolitan Planning Organization (CAMPO) received a federal grant from the U.S. Department of Transportation's Federal Highway Administration. The project, the *Central Texas Climate Change and Extreme Weather Vulnerability Assessment*, will promote dialogue in Central Texas communities facing extreme drought, heat, and wildfire (http://austintexas.gov/article/how-vulnerable-central-texas-climate-change).
- In the Tidewater Area, Old Dominion University, the Virginia Sea Grant, and the Hampton Roads Planning District Commission are partners in the Hampton Roads Sea Level Rise/Flooding Adaptation Forum. The Forum fosters a regional dialogue among municipalities committed to adopting effective adaptation designs and plans, tailored to meet the needs of communities in the face of rising sea levels. Dr. Poornima Madhavan's work – Assistant Professor of Psychology at Old Dominion University and Director of the Applied Decision Making Laboratory – on local understanding of sea level rise and how it affects decision making and informs conversations in the region (http://science.nasa.gov/earth-science/climate-policy-speaker-series/psychology-climate-change/).
- The Metropolitan Washington Council of Governments (MWCOG) in Washington, D.C., as a member of the Monumental Core Climate Adaptation working group, continues to sponsor webinars and workshops to build local awareness and improve regional coordination (http://www.mwcog.org/environment/climate/resilience.asp).

Despite unanswered questions, uncertainty about local scale impacts, and political barriers, the general public is more aware and accepting of the occurrence of extreme climate/weather events overall. Utility managers and local decision makers continue to engage in public dialogue, while the media's mainstreaming of terms such as *atmospheric river*[1] and *derecho,* mark important steps in promoting climate resiliency. This trend parallels improvements in science and forecasting, allowing utilities to alter emergency response action plans, assess assets, and improve existing operations and maintenance.

[1] For the first time, officials pre-evacuated the hills around Santa Barbara and Los Angeles in February 2014, anticipating floods with the arrival of an atmospheric river in Southern California (http://www.huffingtonpost.com/2014/02/06/atmospheric-river-may-put_n_4738699.html http://www.nbclosangeles.com/news/local/Second-Storm-Arrives-in-Southern-California-Rain-247764801.html).

4.3 Building Resilience: Emergency Response, O&M, and Asset Management

> *"Do you have that right balance [between emergency response and long-term planning]? Are you sustaining, not just reacting?"*
>
> *– Tanya Spano, MWCOG in the National Capital Area (Synthesis Meeting, 2013)*

Most water utilities are already challenged to concurrently maintain aging water infrastructure, accommodate urban growth, and preserve environmental quality. In addition, they must adhere to a multitude of local, state, regional, and national guidelines and regulations. Extreme climate/weather events add another dimension of complexity to this task, underscoring the importance of integrating adaptation and resilience *into*, not merely on top of, planning in the water sector (Synthesis Meeting, 2013). Indeed, a major finding of this study is that resilient communities are actively engaged in learning how to incorporate long-term preparedness and risk reduction to all activities: emergency response planning, operations and maintenance, and asset management. In some cases, this includes a consideration to rebuild differently in the aftermath of an extreme event.

Since 9/11, the nation continues to shore up the security of critical infrastructure and the capacity for emergency response. Increasingly, communities are recognizing that the principles of vulnerability assessment, risk mitigation, and threat reduction apply to natural hazards, including long term shifts in extreme climate/weather as well. Communities are learning from experience and incorporating new scenarios of extreme events, including cascading events, into their strategic planning exercises. For instance:

- The Washington Suburban Sanitary Commission in the National Capital Area realized that the loss of power was a critical vulnerability during Hurricane Sandy; this led to working with the local power company to include water utilities on future priority lists for power restoration during emergencies.
- In the Lower Missouri River Basin, Johnson County's experience during extended droughts has led them to incorporate more heat and drought tolerant pipes in their drinking water distribution system.

> *"There's a difference between planned maintenance and emergency maintenance. Planned maintenance does much more in the long-run than chasing after what's broken during a storm."*
>
> *– Mike Armstrong, WaterOne (Synthesis Meeting, 2013)*

Increasingly, communities are beginning to incorporate long-term planning that contemplates risk from increasingly variable extreme events into their asset management and capital investment planning processes. In very few cases is it likely that whole communities will uproot and move. Nor is it likely that communities will simply abandon a functioning treatment plant to build a new one elsewhere. However, planners may have to adopt long term plans to retrofit – or rebuild – in ways that reduce long-term risks and costs, particularly in vulnerable locations, such in some coastal areas or the location of recovery facilities in flood-prone areas. In addition, all utilities regularly review their operations and conduct maintenance of their infrastructure. Increasingly, they are taking steps to identify 'the weak links' for targeted action. For example:

- Sonoma County planners in the Russian River Basin are considering methods to leverage times of high precipitation to supplement times of low precipitation by proposing groundwater banking and conjunction use strategies.

- In Hampton Roads, 'action table' scenario-based planning is helping planners conduct assessments, develop levels for advance warning of extreme events, and consider future infrastructure upgrades in the Tidewater Area.

In summary, water utilities increasingly recognize that long-term planning for a range of extreme climate/weather events is part and parcel to every day actions: emergency response planning, operations and maintenance, and asset management.

4.4 Managing Risk and Creating Sustainable Communities

> *"We work to prioritize water conservation and recycled water and to balance surface and groundwater though conjunctive programs. It behooves us to bolster and better manage [these] three supplies so we can more reliably react to extreme events."*
>
> *– Jay Jasperse, Sonoma County Water Agency*
> *(Synthesis Meeting, 2013)*

In many communities, local governments are progressively taking additional steps to design and retrofit their urban footprint to manage their risk and increase quality of life by creating 'sustainable communities'. The adoption of innovative methods such as integrated water resource management (IWRM), green infrastructure for stormwater management, purple pipes for reuse of partially treated wastewater, energy and water conservation programs, groundwater banking, recycling and reducing waste, walkable/bikeable/transit-oriented communities, and low impact development (LID) facilitates this effort towards resiliency. Water utilities are conducting more proactive maintenance and installing back-up power to avoid loss of power during storms. They are designing collection systems to hold runoff from larger storms to reduce sewer overflows and flooding, installing drinking water pipes that are more drought-tolerant to avoid breakage, and expanding wetlands and riparian buffer zones to modulate storms impacts and protect water supplies. In some cases, water utilities are rebuilding treatment plants to be less vulnerable. These activities build resilience by improving drainage, preserving watershed functions, improving water quality, assuring adequate water supplies, reducing greenhouse gas emissions, reducing heat island effects, protecting investments, and creating a sense of place. But is it enough to build resilience to trends in extreme heat and precipitation? What else might a community do to reduce vulnerability and manage risk when the exact nature and extent of the threat is unclear?

To this end, one paradigm suggests using 'flexible adaptation pathways' to provide a continuous, dynamic consideration of risk tolerances and corresponding policies (NASA, 2013)

(Figure 4-1). Acceptable risk is defined and set as the target threshold and steps are taken to minimize risk, based on best available information. Even the "best available science changes over time and with a better understanding of likely changes, site-specific adaptation must also evolve" (NASA, 2013). Rather than locking into a long-term strategy based on imperfect understanding, as new information is developed and efficacy of initial steps is assessed, communities can take additional risk management steps. The idea is to keep the level of risk within an acceptable boundary while buying time to develop more actionable information.

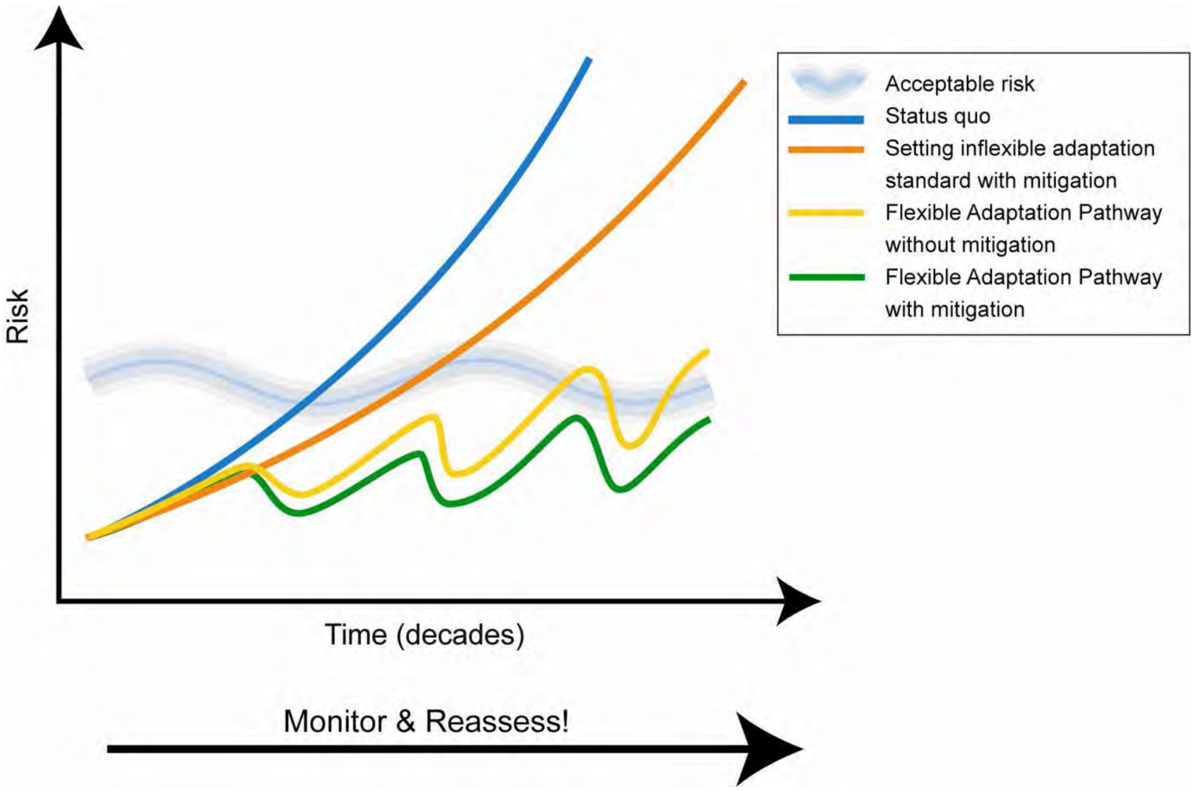


Figure 4-1. Flexible Adaptation Pathways.
Source: New York Panel on Climate Change, 2010.

Many communities have begun working with local universities and research institutions to downscale climate information and incorporate information into hydrology models. Some are simply taking the 'no regrets' steps that are readily available to them and within their budgets. Other communities increasingly find IWRM a successful adaptation pathway by focusing on cross-sector interests in water quality and supplies, ecosystem needs, the water-energy nexus, and stakeholder involvement (Jasperse, 2012). Regardless of the approach, such actions step towards resiliency and it behooves us all to go ahead and take the next step.

4.5 Closing the Information Gap

> *"Wider acceptance of climate forecasts will depend on their being incorporate into existing organizational routines."*
>
> *– Cody Knutson, National Drought Mitigation Center (LMRB Workshop, 2013)*

Extensive research on the impacts of climate change, drought, coastal storms, and hurricanes has been underway for decades and much of this information is publicly available. But, for years, while scientists document continental and global-scale changes with increasing certainty, community decision makers were strictly warned about the reliability and validity of this information for use at the local scale. While that caution remains, models have improved, methods of using information for risk management have evolved, and users have become much more sophisticated in their understanding.

Nonetheless, communities have been calling for more customizable information at a variety of spatial and time scales relevant to informing many different types of decisions: both for long-term risk management planning and for emergency preparedness. The good news is, an increasing number of opportunities for communities to engage in the collaborative translation of information for local use is emerging.

For example, on March 19, 2014, President Obama announced a climate data initiative involving many federal agencies and private sector companies.[2] The initiative will deliver open data platforms, free cloud computing, mapping capabilities, interactive dashboards, innovation challenge grants, simulations and calculators, and geographically targeted partnerships.

Meanwhile, all federal agencies are building capacity to serve their constituencies. The EPA, USGS, Bureau of Reclamation, Army Corps of Engineers, NOAA, DOE, and others maintain websites on their efforts. For example, EPA's Climate Ready Water Utilities program (http://water.epa.gov/infrastructure/watersecurity/climate/index.cfm) and Climate Ready Estuaries program (http://water.epa.gov/type/oceb/cre/index.cfm) provide a variety of user-friendly tools for local water utilities and watershed groups. NOAA provides current maps and data (http://www.climate.gov/maps-data) as well as climate and historical weather data (http://www.ncdc.noaa.gov/). The NIDIS provides tools and resources directly related to current and forecasted droughts (www.drought.gov). Other efforts underway at NOAA include working with decision makers to provide them with the forecasts and information they need and the understanding and ability to apply them at the appropriate temporal and spatial scale. For example, NOAA is currently working with representatives of the water utility and planning field to understand how to better provide usable, easily accessible information for incorporation into

[2] For further information on the initiative, visit: http://www.whitehouse.gov/the-press-office/2014/03/19/fact-sheet-president-s-climate-data-initiative-empowering-america-s-comm.

short and long-term planning efforts. Meanwhile, WERF and WRF continue to conduct research on behalf of their member utilities.

4.6 Next Steps

> *"Responding to climate-related risks involves decision making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation. Iterative risk management is a useful framework for decision making in complex situations characterized by large potential consequences, persistent uncertainties, long timeframes, potential for learning, and multiple climatic and non-climatic influences changing over time."*
>
> *– IPCC, 2014*

While this study sheds light on significant lessons learned and information needs across six communities, the path towards resiliency is continuous and one that reinforces collaboration, promotes community awareness and buy-in, and continues to share experiences and strategies. Several areas for future research are highlighted among the findings in this report. Potential ideas include pilot studies on defining risk thresholds, risk communication and guidance on risk evaluation in the likelihood of extreme events; an examination of decision support systems; customizing information at various spatial and temporal scales; and increasing the accessibility and utility of climate information for the water utility sector, such as the recent information dashboard project initiated by NOAA; among others areas of research.

Water resource managers have always taken their jobs seriously. They know that clean and safe water is fundamental to their communities. However, as this report demonstrates, the service they provide goes beyond providing plenty of water for our taps and keeping our waters clean. They keep us safe from floods, beautify our neighborhoods, and provide the basis for a thriving economy. Their leadership, though often not visible to many, is essential to ensuring our communities remain resilient in the face of the changing climate.

APPENDIX A

GLOSSARY OF WATER, CLIMATE, AND WEATHER TERMS

Water Resource Terminology Explained

Assimilative Capacity is the ability of a waterbody – river, lake, sea, etc. – to receive waste and toxins, naturally cleansing in order to avoid harmful effects on aquatic ecosystems or other users.

Combined Sewer System (CSS) refers to a sewer system in which pipes convey both storm water runoff and sanitary sewage to local treatment plants. CSSs may result in overflows during heavy precipitation events, as the carrying capacity of pipes is often exceeded due to large volumes of combined waters. About 850 communities, primarily in older cities, rely on a combination of CSSs and separated wastewater and stormwater systems (also called Municipal Separate Stormwater Systems or MS4s) to manage domestic wastewater flows. To comply with requirements to reduce or prevent overflows communities are increasingly adopting a variety of practices such as installing storage, decreasing impervious cover with the use of green infrastructure, and other methods that control excess flows.

Evapotranspiration refers to water lost to the atmosphere from the ground, evaporation from the capillary fringe of the groundwater table, and the transpiration of water by plants. Transpiration accounts for roughly 10% of our atmosphere's moisture. The other 90% comes from evaporation directly from oceans, surface water, and a small portion from sublimation.

Green infrastructure refers to a runoff management approach which uses natural processes in vegetation and soil to manage rainwater where it falls. Green infrastructure provides stormwater management, flood mitigation, air quality, and urban heat island benefits. Strategies may include downspout disconnection, rain gardens, rainwater harvesting, bioretention cells, and permeable pavements, among others.

Groundwater banking refers to the practice of recharging specific amounts of water in a groundwater basin that can later be withdrawn and used by the entity that deposited the water. This practice uses aquifers as storage, including water for users who do not overlie groundwater basins. Groundwater banking provides flexibility for water managers during periods of short supply, and is increasingly important in areas facing extreme climate and weather events.

HUC code or the hydrological unit code refers to the four classification codes of that divides and subdivides the U.S. based on watershed boundaries and drainage regions and sub-regions.

Hydrological and demand-induced droughts explain droughts which occur either due to periods of precipitation shortfalls (hydrological) or excess consumption (demand-induced), both of which affect available water supplies. The frequency and severity of a hydrological drought usually depends on a basin-wide scale, whereas demand-induced droughts may be more localized.

Hydropeaking refers to the abrupt changes between high and low flows from reservoir hydropower stations in order to generate electric power. This technique is used to quickly meet periods of high energy demand, as opposed to *hydropulsing*, which occurs more gradually. Hydropeaking changes flows downstream, which can have severe impacts at times.

Impervious cover refers to any non-natural cover such as cement and other non-porous materials used in parking lots, sidewalks, roads, roofs, etc. that does not allow water to percolate into the ground during storms. Rainfall washes pollutants from impervious surfaces into city stormwater or combined sewer systems, and is eventually deposited into waterways. Growing urbanization parallels an increase in an area's percentage of impervious cover.

Low Impact Development (LID) refers to small-scale landscape-based development that seeks to imitate natural hydrologic functions and minimize the environmental impacts of developing undeveloped or redeveloped sites.

MAF (million acre feet) is a common way to measure quantities of water. The measurement indicates that water covers one acre of land one foot deep.

National Pollutant Discharge Elimination System (NPDES) was authorized by the Clean Water Act section 402 to control the discharge of pollutants into the nation's waterways by requiring the discharger to obtain a permit. The initial permits issued in the 1970s and early 1980s focused on domestic wastewater treatment utilities and industrial wastewater. Subsequent amendments expanded the permit program to cover stormwater discharges from municipal separate storm sewer systems (MS4) and industrial sources. Non-stormwater permits typically include numeric effluent limitations for specific pollutants. Stormwater permits typically include best management practices.

Neap tide refers to the period when the difference between high and low tide is least; the lowest level of high tide. Neap tide comes twice a month, in the first and third quarters of the moon.

Potential Evapotranspiration (PET) refers to the amount of water that would be removed from an area via evaporation and/or transpiration. PET measures the atmosphere's ability to remove water from a surface, and is an important component of measuring local vegetation and ecosystem health in a given area.

River basin is an area of land where surface water flows to a single waterbody, such as a river. A basin may have any tributaries which drain into the larger river. Rivers act as arteries connecting waterbodies within a basin. Surface and groundwater in the basin's area are interconnected and affect water flow in other areas of a basin. The term basin is used internationally, and is synonymous with the term watershed.

Sanitary Sewer Systems collect and transport all of the sewage that flows into them to a publicly owned treatment works (POTW). Unintentional discharges of raw sewage from municipal sanitary sewers (called sanitary sewer overflows or SSOs) are caused by inadequate design, lack of maintenance of aging infrastructure, power failures, etc. The untreated sewage from overflows can contaminate waterways. Sewage can also back-up into basements, causing property damage and threatening public health.

Soil moisture refers to the water that is held in the spaces between soil particles. Surface soil moisture is the water that is in the upper 10 cm of soil, whereas root zone soil moisture, water that is available to plants, is in the upper 200 cm of soil.

Spring tide refers not to the season, but rather to the point when a tide's range reaches its natural maximum due to increased forces during new and full moon periods.

Stationarity is a hydrological concept often used in water resources management. It is the idea that natural systems fluctuate within a typical unchanging envelope of variability, usually based on historical observations (e.g., the past 100 years or so) and which infrastructure engineers use as a point of reference for designing systems. Non-stationarity refers to the concept that climate change is introducing unexpected variations in the hydrological system that engineers and water managers need to plan for.

Storm surge refers to a sudden rise of water generated during a storm's shoreward winds. These winds force the disruption and circulation of hurricanes or tropical storms near coastal land, pushing water inland. Surges usually occur near coastlines, but may penetrate far inland.

Stormwater systems are conveyances to control stormwater runoff from municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. Most stormwater discharges are considered point sources, and operators of these sources may be required to receive an NPDES permit before they can discharge. This permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters such as streams, rivers, lakes, or coastal waters.

Sublimation, as it relates to the hydrologic cycle, is the process by which ice and snow turn into water vapor. This occurs directly, and does not first melt into water before evaporating.

Turbidity refers to a measure of relative water clarity. Water turbidity increases when there is a large amount of suspended solids present, and too little inflow of freshwater to dissipate these solids. Suspended solids may include clay, silt, sand, plankton, microbes, and algae. Higher water turbidity results in increased water temperatures, decreased dissolved oxygen content, and decreased photosynthesis. Turbidity occurs due to runoff, algae growth, contaminants, soil erosion, and other land disturbances.

Watershed is an area of land where surface water flows to a single waterbody, such as a river, stream, lake, marsh, or groundwater. The term, commonly used in North America, is basically synonymous with the terms 'river basin' or 'drainage basin'. Watersheds are measured by hydrological unit codes (HUCs) and can be small (e.g., an area draining to a small tributary) or large (e.g., an area draining to a large river basin).

Climate/Weather Terminology Explained

Atlantic Multidecadal Oscillation (AMO) occurs in the North Atlantic Ocean. This natural model of climate variability retains a relative pattern of 60-80 years, principally expressed in sea surface temperatures. The natural variation changes temperatures by about 1°F, and affects air temperatures and rainfall in Europe, North America, and other parts of the Northern Hemisphere.

Atmospheric rivers are very long and narrow bands of moisture in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics. On average, about 30-50% of annual precipitation in the west coast states occurs in just a few atmospheric river events. Atmospheric rivers can create extreme rainfall and floods especially when they stall over land.

Climate and weather events differ in that climate is comprised of the atmosphere, hydrosphere, cryosphere, land surface, and the biosphere and describes average conditions over a long time period, typically 30 years. Weather, on the other hand, refers to day-to-day precipitation and temperature, i.e., conditions at a specific place and time.

Derecho refers to a widespread, long-lived wind storm associated with bands of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of a tornado, the damage typically occurs in one direction along a relatively straight path.

El Niño Southern Oscillation, or ENSO, occurs when unusually warm ocean waters migrate across the Pacific Ocean, near the equator. The results are felt initially in Indonesia, Malaysia, and northern Australia, where rainfall is reduced. This is followed by wetter than normal conditions that occur along the west coast of tropical South America, and at subtropical latitudes of North America (Gulf Coast) and South America (southern Brazil to central Argentina). These episodes typically occur every 3-5 years and often last 9-12 months. See also *La Niña.*

Extreme events are climate/weather events that are highly unusual within local memory and that have significant consequences as defined by that community (in terms of impact, cost, etc.).

Flood refers to water that overflows into usually dry land, submerging it. Floods vary drastically in size and can manifest in various levels from flooded streets, saturated fields, or submerged buildings. Floods may occur due to an overflow of a waterbody such as a lake, a river when flow rate exceeds capacity, or when heavy precipitation oversaturates the ground and results in a lack of sufficient infiltration into the soil. Floods are damaging to environmental and human health, such as when excess water overflows sewer systems that threaten water quality and supplies.

Hurricanes/Typhoons are tropical cyclones that form over large bodies of warm water that have strong winds, characterized by low-pressure centers, and are accompanied by strong thunderstorms that produce heavy rain. Sustained wind speed characterizes the strength of a hurricane, which is based on the Saffir-Simpson Hurricane Wind Scale 1 to 5 rating. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. However, impact depends on the cyclone path. For example, Hurricane Sandy (2012) had reduced winds and had been downgraded to a tropical storm when it made landfall in New Jersey and New York. Damage estimates across this area vary, but are believed to exceed $18 billion.

North Atlantic Oscillation (NAO) comprises two pressure systems – the Icelandic low and Azores high – and the fluctuations of their strength affect storms across the North American continent. The NAO contributes to temperature and precipitation distributions in the northern hemisphere, particularly the eastern U.S.

La Niña occurs when cooler ocean waters migrate across the Pacific Ocean resulting in impacts opposite of an El Niño. These impacts include wetter than normal conditions across the Pacific Northwest and dryer and warmer than normal conditions across much of the southern tier of the United States. See also *El Niño***.**

Nor'easter is a type of cyclone forming outside of the tropics in the mid-latitudes (30-60° north latitude). They have cold-core lows, or low pressure systems where most of the air above the center of this system is cold. Mid-latitude cyclones are among the largest weather systems in the world; they are often double, triple, or even quadruple the size of an average hurricane. Their name indicates the direction from which the wind is coming. Often associated with these storms is heavy snow, rain, and giant waves along the Atlantic coastline that cause beach erosion and structural damage. Wind gusts associated with these storms can exceed hurricane force in intensity.

Pacific Decadal Oscillation (PDO) refers to a phenomenon occurring in the Pacific Ocean in which warm and cool ocean temperature anomalies are present. This affects climate along the North American coast and Pacific Basin. These patterns are similar to ENSO, though occur over longer periods of time, such as 20-30 years. Depending on the phase, the PDO may intensify or diminish the impacts of ENSO.

Resilient systems are those with the ability to maintain critical services under extreme circumstances, and return to a fully functional state quickly.

Transition zone or climate cusp refers to areas that sit within more than one typical climate region. For example, the Lower Missouri River Basin sits on the edge of northern and southern climate regions in the U.S., which can make climate predictions difficult.

Geologic Terminology Explained

Karst-Formation Aquifer refers to an aquifer formed by dissolute layers of bedrock (carbonate rock, limestone, dolomite, gypsum). Rainwater and pollutants can easily pass through the rock fractures, eroding and enlarging passages and developing further caves, sinkholes, springs, and sinking streams. Runoff through these features quickly stocks water supplies in karst aquifers, though water is subject to heavy contamination as it bypasses natural filtration processes.

Bollide is a comet or asteroid that collides on Earth's land surface or in oceans creating a crater or depression.

Fall line refers to a geographical feature marking the area where the upland region of the Piedmont province meets the Atlantic Coastal Plain. The fall line is typically a prominent drop in elevation where a river crosses it, characterized by rapids or waterfalls.

Piedmont is the physiographic province bounded on the east by the Fall Line, which separates the province from the Atlantic Coastal Plain, and on the west by the Appalachian Mountain province in the eastern U.S. The province is characterized by gently rolling topography and deeply weathered bedrock, typically without solid rock outcrop.

References to Federal Regulations Explained

Clean Water Act was signed in 1972, as an expansion of the Federal Water Pollution Control Act of 1948. It authorized EPA to implement pollution control programs and discharge permits (EPA, "Laws and Regulations," 2014). This act is the basis for surface water quality regulation in the U.S., and covers wastewater and stormwater permitting.

Coastal Zone Management Act (CZMA) sought to balance environmental conservation with economic development of coastal zones throughout the United States, including the Great Lakes. Signed into effect in 1972, the act outlines the National Coastal Zone Management Program and the National Estuarine Research Reserve System which work to protect, develop, restore, and enhance coastal zones (NOAA, 2012).

Endangered Species Act of 1973 amended Public Law 93-205 and repealed the Endangered Species Conservation Act of 1969, to implement two conventions for ecosystem conservation: The Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (U.S. Fish and Wildlife Service, 2014b). By protecting ecosystems upon which endangered and threatened species depend, the act authorized – among other aspects – the listing of endangered and threatened species, acquiring land for conservation, establishing cooperative agreements for protection, and assessing criminal and civil penalties for violations of the act.

Federal Leadership in Environmental, Energy, and Economic Performance: Executive Order (EO) 13154 is also known as the *Greening of the Government* or *Federal Organization of Water Reductions* Executive Order came into effect in 2009, extending and developing upon environmental performance and energy reduction requirements for federal agencies (U.S. Department of Energy, 2014). The order set accountability, transparency, strategy, sustainability, building, and greenhouse gas management, waste reduction, and water efficiency goals, among others.

Fish and Wildlife Coordination Act of 1958 served as amendments to the original Fish and Wildlife Coordination Act of 1934. The 1934 act provided assistance to federal and state agencies by the Secretaries of Agricultural and Commerce to protect game and fur-bearing animal stocks and study the impacts of pollution, domestic sewage, and trade wastes on wildlife. The 1958 amendments were significant, as they recognized the value of wildlife resources and required equal consideration for conservation within water resource development programs (U.S. Fish and Wildlife Service, 2014a). The amendments further provided public fishing areas authorized by the Secretary of Interior.

Integrated Training Area Management: Army Regulation 350-4 implemented an inventorying and monitoring land management program to help establish optimal and sustainable use of training lands (Hutchinson, 2013)

National Environmental Policy Act (NEPA) was signed in early 1970, establishing national regulations to protect, maintain, and enhance the environment, framing co-existence between humans and the natural world. NEPA further guided federal agencies to implement these regulations and established the President's Council on Environmental Quality (CEQ). NEPA required all federal agencies to prepare environmental impact assessments and alternatives to any government actions with significant effect on the environment (U.S. EPA, 2012). The act developed in response to growing concern for the environment and wildlife, such as with the major oil spill in Santa Barbara in 1969.

NIDIS Act of 2006 (Public Law 109-403) or the National Integrated Drought Information System Act of 2006 was one of the major pieces of legislation, along with the National Drought Policy Act of 1998, that led to the development of the National Integrated Drought Information System program. The NIDIS Act of 2006 defined drought and established the purposes of the NIDIS program operating within NOAA and improving drought monitoring and forecasting (U.S. Drought Portal, 2014). It was recently reauthorized in 2014.

Pick-Sloan Flood Control Act of 1944 authorized extensive dam construction, modification, and levees throughout the United States. Named after General Lewis A. Pick, the head of the USACE, and W. Glenn Sloan, a prominent figure at the Bureau of Reclamation, the act served as a bridge between their two plans each focusing on different aspects of development (National Park Service, 2014). The act transferred land ownership around the Missouri River from several Native American groups to the USACE. Intended to provide more effective flood control of the Missouri River Basin, the act sought to ensure irrigation and municipal water demands were met, as well as promote hydropower generation.

River and Harbors Act was originally enacted in 1824 and provided federal funding for navigation improvement, primarily along the Ohio and Mississippi rivers. The significance of this act lies in that the Supreme Court ruled interstate commerce and navigation fell under federal authority. Several River and Harbors Acts have passed in the past two centuries, addressing various issues related to construction, navigation, infrastructure, and water supply along these waterbodies.

Safe Drinking Water Act was established in 1974 as the basis to protect drinking water quality and protect public health in the U.S. The law covers surface and ground water resources (EPA, 2012). It further authorizes EPA to establish water quality standards to protect tap water, which all water owners and operators are required to follow. Significant amendments to this law include those made in 1986 and 1996, strengthening actions to protect drinking water supplies and its sources (U.S. EPA, 2012).

Water Assurance Program Act of 1996 was passed by the Kansas Legislature and served as the foundation to establish three water assurance districts in the State. This allowed these districts to purchase storage space from the State in federal reservoirs for river water they had rights to (Kansas Department of Agriculture, 2009). This ensures protected water for Assurance Districts, to be released to meet demands.

Water Resources Development Act (WRDA) refers to a broad range of acts beginning in the mid-1970s in which Congress enacts various public laws dealing with water resources. Topics may include navigation, flood protection, environmental, and hydrology issues. The most recent, passed by the Senate in 2013 and in the House at the time of this report's publication, discusses conservation and development and authorizes the construction of improvement projects on rivers and in harbors overseen by the Secretary of the Army (GovTrack, 2013).

Water Supply Act of 1958 was prominent as Congress officially recognized the authority of local and state entities to develop and delegate water supplies for municipal, industrial, domestic, and other purposes. While the federal government retained involvement in developing water resources and infrastructure for flood control, navigation, multipurpose dams, hydropower production, and irrigation, the act constrained the federal role in municipal and industrial water supply (Carter, 2010).

APPENDIX B

EXTREME CLIMATE/WEATHER TOOLS AND RESOURCES

Extreme Climate/Weather Tools and Resources

Workshop participants identified the following tools and resources particularly useful in planning for and responding to extreme climate/weather events. Each case study location noted resources pertaining to the specific contexts and events faced in their region. National level tools are those used by some or all workshop sites as significant information sources during extreme events.

National Level Tools and Resources

Collaborative

Climate Preparedness and Resilience Task Force: http://www.whitehouse.gov/administration/eop/ceq/initiatives/resilience/taskforce

Community Collaborative Rain, Hail, and Snow Network: http://www.cocorahs.org

Emergency Management Assistance Compact: http://www.emacweb.org/

National Integrated Drought Information System (NIDIS): http://www.drought.gov

Sea Level Rise Planning Tool for Hurricane Sandy Recovery: http://globalchange.gov/what-we-do/assessment/coastal-resilience-resources

Third National Climate Assessment: http://nca2014.globalchange.gov

U.S. Drought Monitor: http://droughtmonitor.unl.edu/

U.S. Global Change Research Program: http://globalchange.gov/

Water Utility Climate Alliance: http://www.wucaonline.org

Water/Wastewater Agency Response Network: http://www.awwa.org/resources-tools/water-knowledge/emergency-preparedness/water-wastewater-agency-response-network.aspx

EPA

Climate Ready Estuaries: http://water.epa.gov/type/oceb/cre

Climate Ready Water Utilities: http://water.epa.gov/infrastructure/watersecurity/climate/

Climate Resilience Evaluation and Awareness Tool (CREAT): http://water.epa.gov/infrastructure/watersecurity/climate/creat.cfm

Emergency Response Training: http://water.epa.gov/infrastructure/watersecurity/emerplan/index.cfm

Green Infrastructure: http://water.epa.gov/infrastructure/greeninfrastructure/

WaterSense: http://www.epa.gov/watersense/

FEMA

Map Service Center: https://msc.fema.gov

National Flood Insurance Program: http://www.fema.gov/national-flood-insurance-program

National Incident Management System:

- http://www.fema.gov/national-incident-management-system
- http://www.fema.gov/incident-command-system

National Weather Information Service (NWIS)

http://waterdata.usgs.gov/nwis

NOAA

Advanced Hydrologic Prediction Service: http://water.weather.gov/ahps2/

Climate and Weather Forecasts and Outlooks: http://www.cpc.ncep.noaa.gov/

Climate Data: http://www.climate.gov

Climate Program Office: http://www.cpo.noaa.gov

(continued on reverse)

WERF Water Environment Research Foundation *Collaboration. Innovation. Results.* · Water Research Foundation · NOAA · EPA · CTC *Concurrent Technologies Corporation* · noblis *For the best of reas*

National Level Tools and Resources (Continued)

Coastal Service Center Digital Coast: http://www.csc.noaa.gov/digitalcoast/

Earth System Research Lab: http://esrl.noaa.gov/

NOAA (continued)

Earth System Research Laboratory: http://www.esrl.noaa.gov/psd/atmrivers/

Hydrometeorological Testbeds: http://hmt.noaa.gov

National Climatic Data Center (Historical Information): http://www.ncdc.noaa.gov/

National Weather Service:

- http://www.weather.gov
- Real-Time Precipitation Data by Region: http://www.wrh.noaa.gov/mesowest/gmap.php?map=pqr

Oceanic and Atmospheric Research:

- http://www.oar.noaa.gov/
- http://www.research.noaa.gov/

Sea Lake Overland Surge for Hurricanes (SLOSH) Model – National Weather Service: http://www.nhc.noaa.gov/ssurge/ssurge_slosh.shtml

Sea Level Affecting Marshes Model (SLAMM): http://www.warrenpinnacle.com/prof/SLAMM

Sea Level Rise Data: http://tidesonline.nos.noaa.gov/geographic.html

Shoreline Technical Assistance Toolbox: http://coastalmanagement.noaa.gov/initiatives/shoreline_stabilization.html

U.S. Army Corps of Engineers

http://www.corpsclimate.us/ccaceslcurves.cfm

U.S. Geological Survey

- http://usgs.gov/water
- http://water.usgs.gov/wateralert/
- http://water.usgs.gov/hif/streamail

GSFLOW for Coupled Groundwater and Surface-Water Flow Simulation: http://water.usgs.gov/nrp/gwsoftware/gsflow/gsflow.html

Data on Water Conditions: http://water.usgs.gov/waternow/

National Streamflow Information Program: http://water.usgs.gov/nsip/

Case Study-Specific Tools and Resources

ACF Basin (Georgia)

GA Water/Wastewater Agency Response Network (GA WARN): http://www.gawarn.org/

Georgia Environmental Protection Division River Basin Management Plans: http://www.gaepd.org/Documents/river_basin_management.html

USACE – Apalachicola-Chattahoochee-Flint (ACF) Water Management and River Level Data: http://water.sam.usace.army.mil/acfmain.htm

Central Texas Region

Texas Water/Wastewater Agency Response Network (TX WARN): http://www.txwarn.org/

Lower Missouri River Basin

Kansas Water Assurance District: http://www.ksda.gov/water_management_services/about/

Missouri Basin Experimental Monitoring and Forecasting Portal: http://www.esrl.noaa.gov/psd/csi/monitor/mobasin/index.html

Overland Park Flood Warning System: www.stormwatch.com

U.S. Army Corp Engineers (ACE) Missouri River Basin Water Management Division: http://www.nwd-mr.usace.army.mil/rcc/

National Capital Area

National Capital Region Water/Wastewater Agency Response Network (NCR WARN) http://www.ncrwarn.org/

Russian River Basin (California)

DWR's Real-Time 8-Station Northern Precipitation Index: http://cdec.water.ca.gov/cdecapp/precipapp/get8SIPrecipIndex.action

California Water Science Center: http://www.scwa.ca.gov/srgw-studies

NOAA National Weather Service California/Nevada River Forecast Center: http://www.cnrfc.noaa.gov/

SCWA and USGS Integrated Flood Control/Recharge Studies: http://www.scwa.ca.gov/stormwater-groundwater/

Tidewater Area

Virginia Interoperability Picture for Emergency Response (VIPER): https://cop.vdem.virginia.gov/

Virginia Water and Wastewater Agency Response Network (VA WARN): http://www.vawarn.org/

WebEOC: http://www.vaemergency.gov/search/node/WebEOC

APPENDIX C

APALACHICOLA-CHATTAHOOCHEE-FLINT BASIN

The project's ACF Basin workshop took place May 9-10, 2012 at Gwinnett Center in Duluth, Georgia. The workshop and findings detailed in this study would not have been possible without the regional team listed below. The research team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

Lisa Darby (NOAA/NIDIS)
Bob Howard (U.S. EPA Region 4)
Pam Knox (University of Georgia, Athens)
Chad McNutt (NOAA/NIDIS)
Kathy Nguyen (Cobb County Water System)
Tyler Richards (Gwinnett County/DWR)
Sandy Smith (Gwinnett County/DWR)

The Story in Brief

Communities in the Upper Apalachicola-Chattahoochee-Flint River Basin (ACF Basin) faced four consecutive extreme climate/weather events: the Drought of 2007-2008, the September Flood of 2009, the Winter Floods of 2009-2010 and the Drought of 2011-2012. In Georgia, these events cost taxpayers millions of dollars in damaged infrastructure, homes, and businesses, while simultaneously threatened water supplies for ecological, agricultural, energy, and urban water users. Water utilities faced challenges in providing reliable service during and after these events. Though preparations and response in the City of Atlanta and surrounding suburban counties (Gwinnett, Cobb, and Douglas) rendered an impressive recovery, much work remains for the region as a whole in preparation for future extreme climate/weather events. Current trends and future projections indicate temperature increases coupled with less frequent, more intense precipitation throughout the ACF Basin. Workshop participants identified the importance of collaboration and communication, as well as the integration of science, conservation, resource management, and infrastructure design. Information needs include improved forecasts, modeling, and vulnerability assessments.

Background

Nestled between eastern Alabama, western Georgia, and Florida's panhandle, the Apalachicola-Chattahoochee-Flint (ACF) Basin is an important support for life in the South (Figure C-1). The majority of the Chattahoochee River, the entire Flint River, a portion of the Apalachicola River, several tributaries, Lake Lanier, Lake Seminole, and smaller lakes comprise the ACF system within the state of Georgia. Extending for an area of nearly 19,600 square miles – about 380 miles long by 50 miles wide – (Couch, 2013; Crane, 2012) the Basin eventually drains into the Gulf of Mexico.

Spanning three states, the ACF Basin remains a crucial resource for human health, environmental viability, and economic production. It provides water for 2.6 million people that live within the Basin (excluding water transfers outside the Basin), supports six fossil fuel plants and one nuclear power plant, irrigates 900,000 acres of cropland, provides water for industrial use, and sustains a lush ecosystem for more than 100 fish species and countless other aquatic life forms (Couch, 2013; Georgakakos, 2009). Water provides for healthy poultry, beef, hog, milk, crops, horticultural industry, and orchard and vegetable production. Commercial forestry, hydroelectricity, and recreation uses also rely on Basin flows.

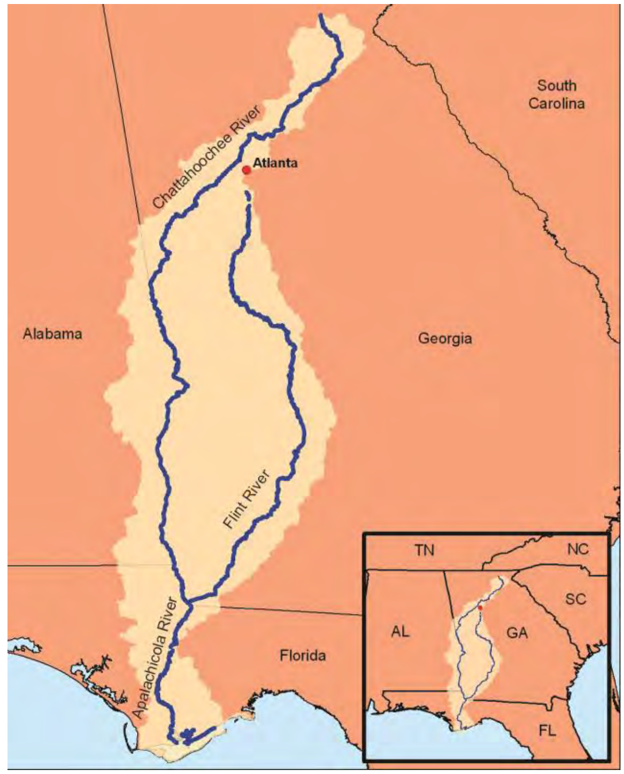


Figure C-1. The ACF River Basin.

Five major aquifers underlie the Basin; these consist of alternating sand, clay, sandstone, dolomite, and limestone units that dip gently and thicken to the southeast. It is common for rivers and streams to deeply incise into these aquifers, receiving substantial amounts of groundwater discharge. Fractured rock is not drought-proof in this Piedmont region. Water evaporates easily and to the west; the rock sits on the surface. Groundwater discharge contributes more significantly to base flow in the Flint River than in the Chattahoochee River: an estimated one-fifth of the amount of aquifer discharge to the Flint River discharges to the Chattahoochee River (USGS, 2013).

Chattahoochee River

The Chattahoochee River originates in the Blue Ridge Mountains, 12 miles from the Tennessee border (USGS, 2013). Approximately 430 miles long, the Chattahoochee has a drainage area of 8,770 square miles (Couch, 2013). This case study's workshop focused on the Chattahoochee, as it is Georgia's most heavily used water resource. Users include household consumption, agricultural irrigation, power generation, production, and surrounding ecosystems. Hydroelectric plants releasing water for hydropower production control the majority of the Chattahoochee's flow (Crane, 2012). Hydro-peaking can result in daily stage fluctuation of four feet or more (USGS, 2013).

Lake Sidney Lanier and Buford Dam

In 1957 the US Army Corps of Engineers (USACE) constructed Lake Lanier in northern Georgia. It is one of five Corps operated federal reservoirs in the ACF Basin: West Point Lake, Lake Walter F. Georgia, Andrews Lock and Dam, and Lake Seminole are the other four. Lake Lanier is approximately 160 feet deep at full pool and fed by the Chestatee and Chattahoochee Rivers.

Located 48 miles upstream of Atlanta, Buford Dam is 192 feet high and 2,360 feet long. Lake Lanier provides 65% of conservation storage, yet drains a mere 5% of the ACF Basin, or 1,040 square miles (Crane, 2012). Lake Lanier is a key economic component of the region. Authorized uses include water supply, navigation, hydroelectricity, flood management, recreation, environmental stewardship, and fish and wildlife management. Lanier receives around 7.6 million annual visitors and is one of the most popular Corps-operated lakes. (Seaman and Bleakly Advisory Group, 2010). Shoreline residential housing and commercial marinas are developing rapidly (Georgia EPD, 2011). As of 2010, there were 216,000 shoreline residents (Seaman and Bleakly Advisory Group, 2010). The Lake is also Georgia's southernmost cold-water fishing body with bass and trout (Seaman and Bleakly Advisory Group, 2010).

Combined, the Chattahoochee River, its tributaries – including the Flint River and Apalachicola River –, and Lake Lanier provide water for most of the Atlanta and Columbus metro populations, including Cobb, DeKalb, Douglas, Forsyth, Fulton, and Gwinnett counties.

Water Laws and Governance

Water utilities fall under city and county jurisdictions. However, some utilities have more autonomy in funding decision making than others. Eleven regional water-planning councils in Georgia work to initiate the State Water Plan and govern these critical water resources. The Governor, Lt. Governor, and Speaker of the House appoint members to these councils (Georgia Water Planning, 2009). The Georgia Emergency Planning Department (Georgia EPD) provides additional support, information, and consultation services these councils and ACF stakeholder groups.

Governing water laws in Georgia that affect the ACF Basin include the following:

- 2004 Comprehensive State-Wide Water Management Planning Act.
- Flint River Drought Protection Act.
- State Drought Management Plan.
- US ACE Master Water Control Manual.
- Water Stewardship Act of 2012.

Climate and Water Trends

Warm, humid, and temperate climates characterize much of the ACF Basin. Average annual temperature ranges from about 60°F in the north to 70°F in the south. Average daily temperatures range from about 40°F to 55°F in January and from 75°F to 80°F in July. Average annual precipitation - primarily rainfall - is about 55 inches, but ranges from a low of 45 inches in the east-central part of the Basin to a high of 60 inches in the Florida panhandle (USGS, 2013).

In the last 50 years (1960-2009), all major Georgia river basins, including the ACF, experienced intensified droughts (Table C-1). Dr. Aris P. Georgakakos, director of the Georgia Water Resources Institute (GWRI) at Georgia Tech, expects these trends to continue.

Georgakakos' climatology and hydrology studies (2012) project wetter and dryer extremes due to an overall reduction in precipitation coupled with greater variation in seasonal rainfall patterns. All ACF watersheds show significant potential evapotranspiration (PET) increases, especially in summer. During most months, and particularly in the summer, an expected decrease in mean runoff and soil moisture has critical implications for agricultural production. Runoff variability severely affects water management.

In dry years these effects are particularly pronounced at Lake Lanier, which falls below the normal 75% distribution values (Georgakakos, 2009). Global climate change models indicate a future with increasing temperatures and more variable precipitation. Though average precipitation at the Lake may not change significantly, a 'stretch' in precipitation distribution resulting in both wetter and drier periods is likely (Georgakakos, 2012). This means a skew in runoff distribution: the 15% wettest years will likely bring higher-than-historical runoff, while other years will see a drier-than-historical runoff.

Major factors influencing climate variability in the Basin are latitude, altitude, and proximity to the Atlantic Ocean and Gulf of Mexico, due to hurricanes and tropical storms. Understandings of regional climate variability support the GWRI's findings in the ACF Basin (Georgakakos, 2009). Shifting El Niño and La Niña patterns would render a significant impact on the ACF region. These cyclical and generally annual events already appear to be pushing the southern 'transition zone'– in which the ACF Basin sits – between drier and wetter than normal winters and springs. This occurs because of a weakening of La Niña and strengthening of El Niño (NOAA, 2009).

Table C-1. Changes in ACF Basin Climate Parameters: 1960-2009.

Precipitation	9-16% decline
Soil Moisture	3-6% decline
Watershed runoff	16-27% decline
PET (potential evapotranspiration)	1-3% increase
Temperature	Fluctuating, but warming trends

Source: Data adapted from Georgakakos, 2009.

Georgakakos asserts that, "future floods and droughts will be more severe than those experienced in the historical past." The ACF Basin region experienced two 500-year floods between 2007 and 2012. Record rainfall immediately following severe drought reveals the potential for more frequent and extreme climate/weather events.

Georgia can expect these trends to continue. Water policies and regulation procedures based on historical stream flows and water levels cannot effectively respond to a changing, more variable climate (Georgakakos, 2009). Frequent extreme climate/weather events necessitate a reconsideration of water management in the increasingly vulnerable ACF Basin.

Demographic Trends

Climate variability is one of several factors affecting water in the ACF region. Projections of reduced rainfall coupled with population growth indicate cities such as "Atlanta will be vulnerable to future water deficits beyond 2060" (Georgakakos, 2012). Population grew by 37% from 1970 to 1990, an additional 15% by 2000 and an expected 30% by 2010 (Couch, 2013). As Georgia's population continues to grow, the state anticipates a doubling in water demand as well (Figures C-2 and C-3).

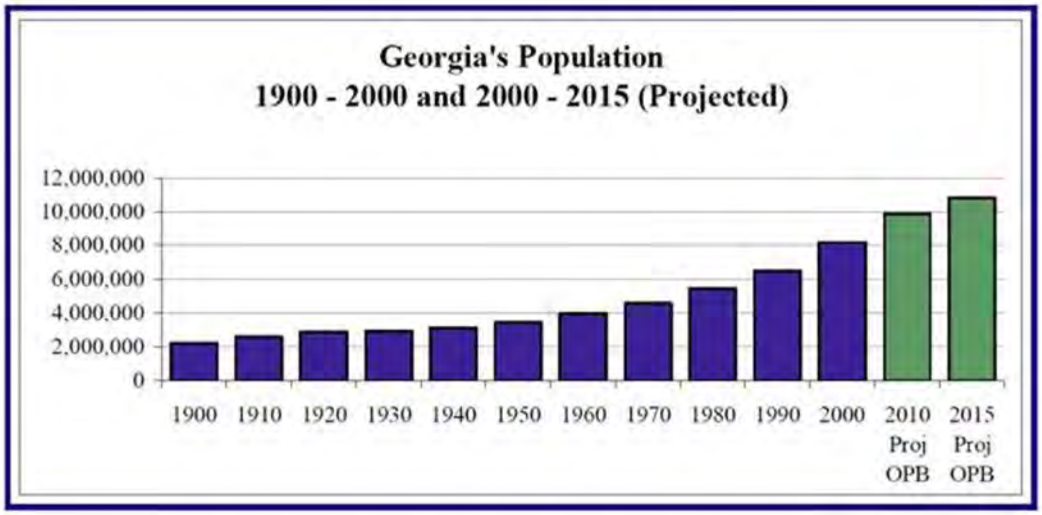


Figure C-2. Population Growth and Projected Population Growth in Georgia.
Source: Georgakakos, 2012.

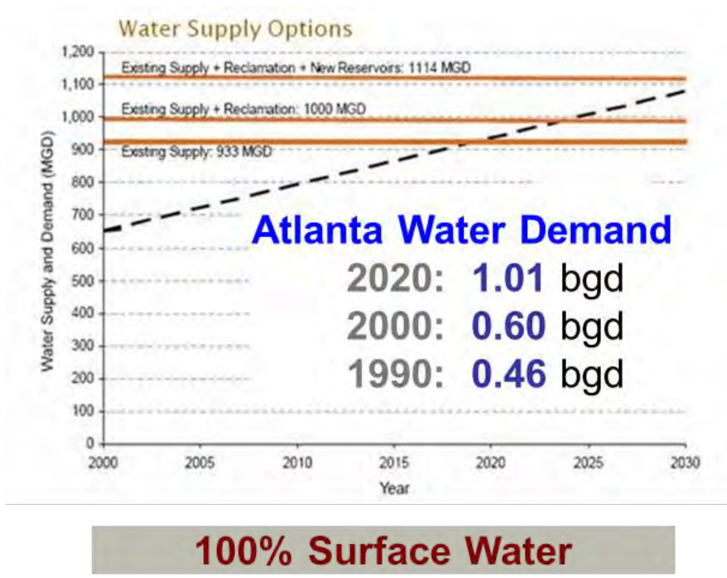


Figure C-3. Projected Water Demands for Atlanta, GA.
Source: Georgakakos, 2012.

Rising irrigation rates further stress water resources. Irrigated acres in 2000 were seven times those in 1970 (Figure C-4). With growing populations and water exports, it is likely that the trend of higher water demands will continue over the next several decades. It is important for future agricultural water demand projections to account for changing climates, though at this time many do not (Georgakakos, 2012). Growing populations and production demand more water, yet water resources in Georgia continue to decline. It is clear that changing climates may "impair the ACF's capacity to meet in-stream flow targets, especially beyond 2060 and under increased demands" (Georgakakos, 2012). While 2060 may seem distant, recent extreme climate/weather events in Georgia offer a glimpse into the potential stress and devastation that lies ahead.

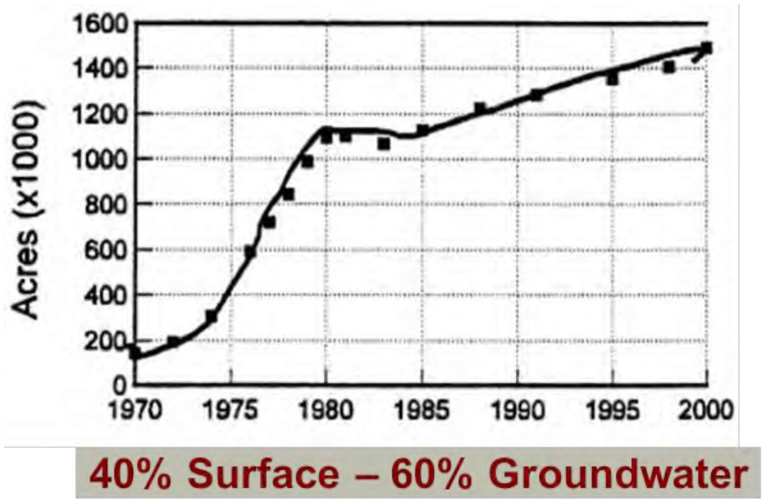


Figure C-4. Irrigated Agricultural Growth, South Georgia.
Source: Georgakakos, 2012.

Extreme Events

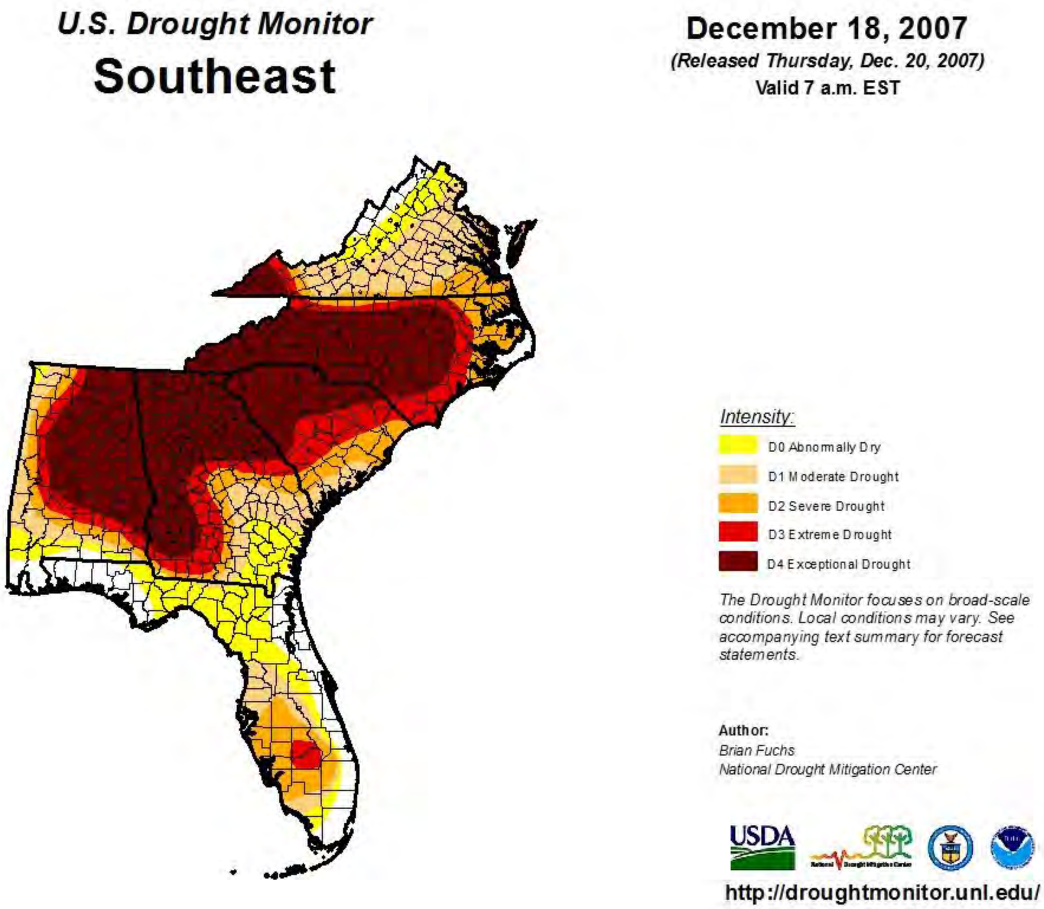
> *"Normals are made up of a series of extremes."*
> *– Jeff Dobur, NOAA's Southeast River Forecast Center*

For the ACF Basin in Georgia, extreme climate/weather events are increasingly normal. Between 2007 and 2013, the state experienced four major events: two droughts and two floods. Fluctuation between these extremes left little space for recovery and marked significant, persistent challenges for communities, water utilities, and local governments. The workshop focused on impacts and responses during the 2007-2008 Drought and the September 2009 Flood. However, it is important to note the cumulative impact of the four events within a six-year period.

Drought 2007-2008

Northern Georgia experienced record-low precipitation in 2007-2008. Annual rainfall averaged 49.7 inches since the 1970s, yet the National Weather Service reported 2007 totals at a mere 31.9 inches, representing a 36% decrease in average precipitation (Dobur, 2012). Rainfall deficits in Athens, Atlanta, Columbus, and Macon ranged from 2.8 to 13.9 inches per year. A subsequent reduction in soil moisture contributed to record-breaking temperatures. State-wide high temperatures resulted in the decreased evaporation cooling and cloud formation needed for rainfall. This cycle plunged Georgia into extreme dry conditions for most of 2007 and 2008, marking 'exceptional' drought (Figure C-5) throughout the entire ACF Basin (Rammo-Kuhs, 2012).

The Drought's impacts were widespread and varied. Most residential and industrial water – including for power generation and cooling- from the upper ACF is returned for use downstream (Rammo-Kuhs, 2012). The Drought challenged utilities to maintain minimum flows and meet competing user needs: human, agricultural, industrial and ecological.



December 18, 2007

Figure C-5. U.S. Drought Monitor, Southeast United States, December 18, 2007.

Source: The U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration.
Map courtesy of NDMC-UNL. Author: Brian Fuchs.

Impacts to the Environment

The lack of rain severely affected water recharge in the ACF Basin. Dry conditions hit Lake Lanier particularly hard due to its dependence on surface water recharge. Reduced flow and dried tributaries caused further ecological damage in a landscape previously succumbed to the negative impacts of urbanization and impervious cover. By late spring 2008, Lake Lanier fell to 50% normal storage capacity and 18 feet below full pool level. This marked a record-low for that time of year.

Rivers and tributaries suffered as well. Water levels in the Dog River - a major tributary to the Chattahoochee – declined in mid-May 2007, instead of the normal mid-summer drop (Patton, 2012). Strained water resources in the Dog River and others produced poor support for aquatic and surrounding ecosystems, as well as an inability to meet water demands for human consumption and production downstream. Environmental groups and some agro- and fishery-based municipalities stressed that the reduction of water releases to preserve water user supply for summer months negatively affected water dependent river ecosystems (ACF Facilitator

Notes, 2012). Downstream users expressed alarm that this would increase water turbidity, mudflats, and erosion downstream, causing harm to trout farms, other aquatic life, and ultimately Gulf ecosystems (ACF Facilitator Notes, 2012).

Impacts to the Community

Diminished water resources greatly impacted communities throughout the ACF Basin. In some sense, drought sensitized community members to the 'worth' of water (Richards, 2012). Having less, readily available water brought people's attention to personal consumptive use. This had positive and negative effects.

Perhaps most apparent were outdoor water bans. Cobb County issued a complete outdoor water ban in September 2007, due to extremely low water levels and water quality issues in Lake Allatoona (Nguyen, 2012). In Gwinnett County, an outdoor water ban led to increased water theft; neighbors reported each other for 'illegal' watering under the ban (Richards, 2012). All local governments in Georgia eventually imposed an outdoor water ban. Landscapers, nurseries, and other major suburban economic sectors, especially, felt the effects of this.

Other impacts included loss of confidence in conducting business in the region and forgone business relocation opportunities. Groundwater users - private well owners - worried about wells drying up and sought tools to measure water levels and quality in these wells. Simultaneously, hydropower energy production, which depends on Buford Dam releases, conflicted with the need to preserve water storage for municipal supplies.

Agricultural Losses

Drought conditions greatly harmed agricultural production downstream. Diminished water availability meant the agricultural sector faced growing difficulty across most major types of production. Counties in southwestern Georgia bore the greatest overall financial loss (Flanders et al., 2009). This likely resulted from significant decreases in water availability as it reached downstream users. It is important to note that different parts of Georgia suffered greater losses for specific crops. Furthermore, these losses did not exist within the ACF Basin vacuum, but were partly impacted by decreased water availability from stressed water basins throughout the state of Georgia. Nevertheless, the findings remain: the 2007-2008 Drought in the ACF Basin severely impacted production and economic benefits among the agricultural community.

Hay and pasture fields lost the most, yet cotton, peanuts, and corn also suffered significant production losses (Table C-2), at least in part due to drought conditions (Flanders et al., 2009). Soybeans, grains, tobacco, vegetables, melons, pecans, and fruits also lost production value during the drought.

Table C-2. Major Agricultural Losses in Georgia, 2008.

Commodity	Monetary Production Loss (millions)	Percent Loss of Expected Production Value
Hay / Pastures	$126.7	53%
Cotton	$44	24%
Corn	$30.3	29%
Peanuts	$28.1	17%
Source: Data adapted from Flanders et al., 2009.		

Production losses further "lead to additional losses, as typical economic multiplier effects are not realized in the Georgia economy" (Flanders et al., 2009, 1). In fact, though the agriculture sector suffered an estimated $256.1 million production value loss, these contributed to a nearly $418.9 million loss in total output (Flanders et al., 2009). Output losses impacted worker incomes, among other things. The Drought affected approximately 4,424 agricultural-related jobs, representing a total income loss of $132.6 million (Flanders et al., 2009).

The 2007-2008 Drought severely impacted agriculture in Georgia, both on state-wide production and individual farmer income levels. Though slow to develop, the overall economic loss during this time was substantial and further exacerbated tension over perceived levels of urban water use.

Recreational Use Losses

As with the agricultural sector, the 2007-2008 Drought significantly impacted recreational water use in the ACF. Though recreational losses were felt throughout the entire Basin, Lake Lanier is a stark example of how deep these losses struck.

Lake Lanier during Non-Drought Conditions.
Source: Rooks, 2012.

Average years bring nearly 7.6 million visitors to Lake Lanier, generating approximately $207 million in recreational spending (Rooks, 2012). Day visits to the Lake account for 47% of these visitors, while the other 53% are those using parks, camps, clubs, islands, and marinas (Rooks, 2012). Lake Lanier's drop to 50% storage capacity had a multiplier effect on recreation in terms of visitation economics and real estate.

Lake Lanier during the 2007-2008 Drought.
Source: Rooks, 2012.

Visits began to drop in 2007 and continued throughout 2008. At the height of the Drought, visitor numbers fell by 889,000 and spending by $44 million (Rooks, 2012). This caused additional losses in sales and lodging. Marina renters and private dock owners spent $4.7 million less on boat trips and boat purchases fell by $35 million (Rooks, 2012). Total spending on recreation dropped an estimated $90.2 million (Rooks, 2012). All of this led to a 23% employment reduction, or 1,244 jobs lost (Rooks, 2012).

The economic impacts associated with the drought-related loss of ACF's recreational value were vast. The drought impacted activities, spending, employment, and real estate. Though residents and businesses hoped these losses are temporary, communities expected to see the long-term impacts of these losses.

Impacts to Water Utilities

The drought had direct, dramatic impacts on local water utilities throughout Georgia. Water utilities faced two major challenges: ensuring an adequate water supply to customers and complying with environmental regulations. Higher temperatures and decreased precipitation meant utilities had less water to allocate among different users, coupled with higher water delivery costs. Gwinnett County, for example, primarily draws water from Lake Lanier. Falling levels in the Lake increased power costs for water utilities to pump withdrawals and treat water

(Richards, 2012). Furthermore, increased turbidity demanded an increase in chemical use, raising the cost of drinking water treatment.

Supply costs rose, while water service provider revenues fell. In Gwinnett County, water consumption dropped around 20% due to state-imposed outdoor water bans (Richards, 2012). Conservation was necessary for environmental flows and regulations. Yet this left Gwinnett's water utility with an expected $41 million revenue gap, resulting in hiring freezes and cut contracts. The impact of water bans continued into the winter months. As people made an effort to conserve water in their homes, the County saw a slight, but discernible, overall reduction in consumption (Richards, 2012).

Simultaneously, customer service demands rose. One of the services Gwinnett County water utility provides is fixing leaks. The cost of sending out a crew solely to fix a small leak is significant under normal circumstances; thus the utility often sends workers out the following day to fix leaks when they are already out for other services. Since water was so precious during the Drought, customers demanded immediate fixes for even the smallest of leaks (Richards, 2012). Sensitized to the new 'value' of water and seeing water run down the street caused homeowners to call in services regardless of whether it was from someone watering or an actual leak, which increased operating costs (Richards, 2012).

The impacts discussed here are not unique to Gwinnett County. Water utilities throughout Georgia experience similar struggles and reductions in revenue. In Douglas County, decreased water utility revenues impacted overall systems operations and deferred capital improvements (Patton, 2012). Douglas County had a 2007 water purchase budget of $50,000, yet spent nearly $1.55 million due to the drought (Patton, 2012).

Droughts provide a particular challenge for water utilities, as the impacts are both slow and long-term. Combined with record-high temperatures, the Drought caused an estimated $1.3 billion in economic losses in the ACF Basin and threatened local water utilities' ability to meet water demand for millions people.

Utility and Community Response

Responding to the extreme 2007-2008 Drought necessitated short and long-term action, as well as water utility, government, and community involvement. Responses centered on natural recharge, water conservation, consumption reduction, and efforts to account for the true cost of water.

Actions Taken – Emergency Response Short-Term Responses

Short-term utility responses included tiered billing structures and strict conservation measures. Gwinnett and Douglass counties adopted a tiered billing structure, increasing the cost of water with increased use. In Douglass County, the pre-drought rate structure had two tiers for increasing usage. During the drought, the County added two more tiers to discourage water use over 9,000 gallons. Tier 4, priced at $7.60/kgal over 12,000 gallons used became a special drought tier (Patton, 2012). The County found that "pricing is an excellent tool for promoting water conservation" (Patton, 2012).

After consulting with counterparts in other states also dealing with dry conditions, Gwinnett County further renegotiated electrical rates, insourced capital project management, treated sewage during off peak electric rates, and closed older facilities (Richards, 2012). These aggressive cost-adaptive initiatives helped the utility decrease their predicted $41 million revenue gap to $15 million (Richards, 2012).

In neighboring Cobb County, dry conditions fostered new levels of coordination and a revamped communication plan (Nguyen, 2012). The Cobb County Water System (CCWS) drew upon frameworks and relationships created during a water efficiency stakeholder meeting in 2005 for the new communication plan (Nguyen, 2012). The plan delineated specific contact personnel and hierarchies for communication. CCWS prioritized conservation communication with the public, as “crisis breeds concern – [so] there is an opportunity for discourse with the public” (Nguyen, 2012). Though better suited for a prolonged crisis, the development of this effective plan allowed for rapid notification and information delivery to the public that became crucial during subsequent flood events. In fact, CCWS later formally incorporated the communications plan into their emergency response plan (Nguyen, 2012).

The Water and Sewer Authority (WSA) in Douglas County similarly recognized the importance of open, public communication in effective drought response. The County’s pre-drought contingency planning led to timely actions that ensured drinking water, public health, and fire protection (Patton, 2012). Regular monitoring of Dog River Reservoir since 1992 immediately notified the County when water levels fell earlier in the season than usual (Patton, 2012).

Looking at local conditions compared to historical records, the County foresaw water shortage problems. Thus, Douglas County issued a total ban on outdoor water use in July 2007. Douglas County ‘Water Police’ enforced restrictions by locking irrigation meters and cutting off service for water ban offenders (Patton, 2012). Though many felt this to be a harsh, ‘knee-jerk’ reaction at the time, WSA was praised for their foresight and planning when state-wide conservation bans fell in late September 2007 (Patton, 2012).

Water Utilities and Institutions Participating in the ACF Basin Workshop

CCMWA – Cobb County-Marietta Water Authority

CCWS – Cobb County Water System

Dekalb County Department of Watershed Management

DDCWSA – Douglasville-Douglas County Water and Sewer Authority

Georgia EPD – Georgia Emergency Planning Department

GWRI – Georgia Water Resources Institute

Gwinnett County Department of Water Resources

Anticipating a draw-down of Dog River Reservoir, the County completed maximum flow testing through meters and prior-established connections with Cobb County-Marietta Water Authority (CCMWA) and CCWS to increase winter purchases leading up to the Drought and thus reduce summer surcharges (Patton, 2012). Douglas County supplemented water withdrawals from Dog River Reservoir by pumping water from Bear Creek Reservoir. The County began this in October 2007; it was the first use of the reservoir in over 13 years (Patton, 2012). Yet, this action demonstrated the value of conservation during non-drought periods; having and maintaining a back-up raw water supply made a significant difference for Douglas County during the drought (Patton, 2012). By late December 2007, Dog River Reservoir returned to its full pool capacity (Patton, 2012).

Thus, short-term adaptation action sought to address consumption. Counties immediately curbed water use by charging higher prices. A statewide outdoor water ban further promoted conservation.

Water Release Compromise

To complicate matters in February 2008, the USACE granted the Georgia Environmental Protection Department (EPD)'s request to reduce water releases from Buford Dam to 550 cubic feet per second (cfs) for a period of three months in order to preserve water supply for the coming summer. This discharge was below Atlanta's 750 cfs discharge permit standard. In order to supply consumption needs during the Drought, the USACE altered operations on Buford Dam and Lake Lanier.

The USACE requested stakeholder and agency comment on the proposed reduction in the flow discharged downstream. Environmental groups expressed alarm that this would harm downstream and Gulf ecosystems. In a February 25, 2008 letter, the Southern Environmental Law Center stated that "the proposed reduction in flow requires major operational change in the usage of Buford Dam and Lake Sidney Lanier, and is a major federal action significantly affecting the quality of the human environment." It stated that conservation measures had not been fully explorer, nor had electric utilities been asked to conserve. In fact, the that the governor eased existing conservation restrictions when the Drought showed signs of worsening and the Chattahoochee River was already stressed due to existing point source discharges.

Georgia Power, for its part, requested that the flows be enough to meet the company's Federal Energy Regulatory Commission license levels of not less than 621.6 cfs. Atlanta and other jurisdictions, however, supported the lower limits to ensure future water supplies.

After reviewing data, modeling, and stakeholder input, on March 3, 2008 the director of the Georgia EPD wrote the USACE that water quality and supply would, in fact, be protected at reduced flows. The USACE chose to limit the reduction in flow to 650 cfs, meeting most objections while conserving some water supplies.

Actions Taken – Long-Term Planning Long-Term Responses

Longer-term drought response measures included heightened awareness of the interrelation between water supply and its stakeholders. Conservation measures employed during drought conditions had a reverberating impact on community awareness of the value and worth of water. In fact, in 2011, metro Atlanta used 14% less water than averages over the past decade (Bush, 2012). Local environmental groups lobbied for increased water quality monitoring in rivers. Further recognizing the need to improve natural recharge of local streams, utilities began promoting green infrastructure and conservation (ACF Facilitator Notes, 2012).

Douglas County's long-standing open communication with both the media and customers was essential. The Executive Director of Douglasville-Douglas County Water and Sewer Authority (DDCWSA) heightened awareness during the drought through their website, bill stuffers, local television and radio (Patton, 2012). Public information displays and letters from the Executive Director educated people about their daily water use and encouraged conservation (Patton, 2012). Presentations to community groups along with workshops on drought-tolerant landscaping and rain barrel use were particularly important during the drought, but also promoted a long-term awareness, public involvement and action plan in adapting to extreme climate/weather events. Due to water quality concerns with low reservoir levels, the County increased monitoring of iron and manganese at lower depths and blended withdrawals from upper and lower intake gates (Patton, 2012). They also increased reuse water applications. As part of their long-term plan to deal with low reservoir levels, Douglas County raised Dog River Reservoir by 10 feet in 2009 (Patton, 2012). This increased total volume by 0.7 BG.

Yet, there was also recognition that understanding and awareness is crucial for successful communication and long-term planning. In December 2009, the National Integrated Drought Information System (NIDIS) piloted a full-basin scoping workshop at Lake Blackshear. The workshop sought to address gaps in understanding and measurements, present drought impact information and educate about drought indicators and forecasting (McNutt, 2012). Subsequent workshops were held in 2010 throughout the basin. The workshops found common concerns among stakeholders in the Upper Chattahoochee, Middle Chattahoochee and Flint and Apalachicola River and Bay areas; this provided a point of collaboration for a potential future regional drought early warning information system (McNutt, 2012). NIDIS held several successful webinars where citizens, utilities and planners could discuss climate outlooks with experts in the field (McNutt, 2012).

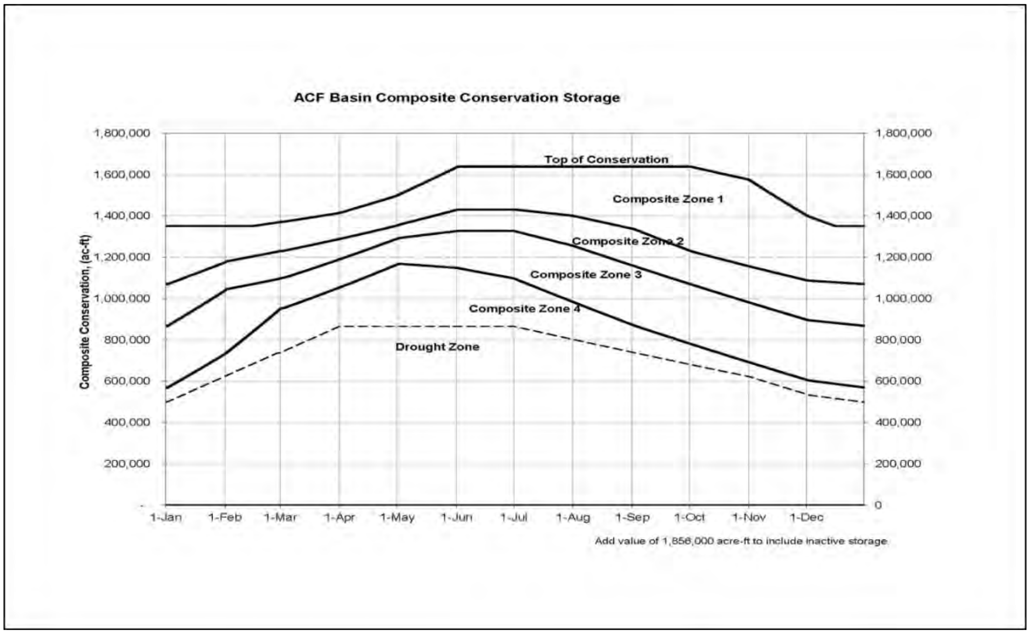


Figure C-6. RIOP Water Storage Zone Levels in the ACF.
Credit: USACE Water Management Section, 2014.
Source: Crane, 2012.

Growing awareness, understanding and acceptance of drought impacts led to USACE's development of a Revised Interim Operating Plan (RIOP), which dictated future drought operations and zones within the ACF system. The RIOP determines operations based on basin inflow and releases from the Jim Woodruff Dam in order to provide storage when water is plentiful (Crane, 2012). The idea is to support flow needs for sturgeon spawning, mussels and host fish (Crane, 2012). Water levels below the Zone 4 marker in Lake Lanier trigger drought operations (Figure C-6): a suspension of ramping rates, a break from meeting basin inflow requirements and a minimum 5,000 cfs release maintained (Crane, 2012). If water levels continue to fall to the 'Drought Zone', dam flow is reduced to 4,500 cfs (Crane, 2012). Year-round operations under the RIOP seek to minimize or avoid low flow operations impacts on listed species or critical habitats (Crane, 2012).

Short- and long-term actions by communities, water utilities and local governments helped ease the devastating and diverse impacts the 2007-2008 Drought had throughout Georgia.

September 2009 Flood

Long-awaited rains in the ACF Basin hit suddenly and without notice. In September 2009, intense, prolonged precipitation in North Georgia caused flooding over several days. Peak flooding occurred September 20-21: in some counties, 11 inches of rain fell in a mere 18 hours, while others experienced 20 inches of rainfall in 24 hours. The USACE reported that water retained in Lake Lanier significantly reduced damages downstream; in the absence of Buford Dam, there would have been an additional seven feet of flooding (Rainey, 2012). Despite this, the drastic impacts to citizens and infrastructure challenged water utilities and local governments to act quickly and effectively.

> *"It was mammoth. It was what you call epic. What you hope never happens, but then somehow does."*
>
> *–Pete Frost, Douglasville-Douglas County Water and Sewer on the September 2009 Flood*

Impacts to the Environment

The Chattahoochee River reached the 500-year flood level. Lake Lanier rose about 4.4 feet in just 10 days (September 19-29th).[1] Buford Dam received 4.5 inches of rain in three days (September 21-23), nearly causing it to overtop (Rainey, 2012). Lanier also had 80% more inflow than outflow during the 2009 water year (October 1, 2008 - September 30, 2009). Though many blamed public water utilities for the floods, land use was a large culprit in the flood severity (Frost, 2013). Previously altered flood plains left land more susceptible to flooding due to erosion. Impervious surface areas in urban areas further disrupted natural infiltration, causing polluted stormwater to flow directly into nearby waterways (Williams, 2010). High percentages road, parking, and roof cover in the Atlanta area significantly altered the intensity of runoff during the storm, and severely impacted ecosystems due to degraded water quality (Williams, 2010).

Impacts to the Community

Of the 159 counties in Georgia, the State declared 69 disaster areas due flooding. Douglas County lost seven lives (Patton, 2012). Communities faced threatened drinking water supplies, collapsed structures and fallen trees, inundated houses and buildings, injuries and some loss of life. Hospitals increased water tests due to compromised drinking water quality (ACF Facilitator Notes, 2012). Unreliable electric power, damage to roads and bridges, and lack of landfill capacity to hold all the debris impeded utility recovery efforts to assist communities.

Marginalized communities already vulnerable to the impacts of environmental disasters or residing in locations at higher risk for flooding were completely inundated. These communities struggled to rebuild and retain access to safe drinking water, as they were some of the last to be reconnected to water services.

Some of the worst flooding occurred in the western and northeastern suburbs of metropolitan Atlanta (Bush, 2012). The evolving, unpredictable events disrupted daily life throughout communities in the ACF Basin. Heavy flooding shut down cities on Sunday, September 20th, while utilities predicted a total water ban due to compromised drinking water. Water continued to flow through streets on Monday, preventing most from returning to work.

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[1] From December 2008 through September 2009, Lake Lanier actually rose.

Impacts to Water Utilities

Water utilities faced devastating infrastructure damages and recovery costs. For instance, Cobb County lost tertiary treatment at the R.L. Sutton Wastewater Treatment Plant and excessive damage to lift stations and underground infrastructure (Nguyen, 2012). Douglas County suffered 94 water line breaks, 21 sewer line breaks, and two water resource recovery facilities washed away (Patton, 2012). Floods compromised road, fencing, and operating components, and at least 44 pump stations (Patton, 2012). Damages to water, wastewater, and stormwater services cost Cobb County nearly $9 million (Patton, 2012).

Flooded Houses on Windsor Drive in Douglas County, GA.
Source: Patton, 2012.

Immediate dangers included the biological and chemical contamination of potable water, with possible wastewater overflows resulting in permit violations. Real-time flood and other water data disappeared: operators could not access flooded areas and floodwaters washed away monitors. Compromised roads inhibited access to infrastructure such as burst pipelines. Loss of power increased service requests and repair delays.

In Gwinnett County, the storm shut down two of the 225 wastewater pumping stations and caused three others to overflow due to water overloads (Richards, 2012). Several other treatment plants flooded, inundating sewers and floodways. Twenty-eight storm culverts under roads collapsed and 21 roads closed due to flooding, making water supply recovery difficult (Richards, 2012). Stormwater service requests – mainly for sinkholes – rose dramatically during September and October 2009. The County received 1,770 requests in two months as opposed to the 1,514 requests during the prior eight months (January to August 2009). Stormwater infrastructure repairs costs Gwinnett County $7.5 million alone (Richards, 2012).

Atlanta's R.M. Clayton Water Reclamation Center was particularly prone to flood impacts, given its location built on top of Whetstone Creek. Waters overtopped the Creek's berm by more than two feet (Bush, 2012). Flooding caused extensive damage to primary clarifiers, the solids thickening building, a mixed liquor pumping station, biological nutrient removal basins, and centrifuge electrical gear and supply. (Bush, 2012). The Turblex Floodwaters completely submerged blowers (Bush, 2012). Power outages further disrupted treatment processes. Despite extensive recovery efforts, damage remained as of mid-2012. Total suspended solids subsequently spiked from 0 mg/L to almost 100mg/L. Fecal coliform counts jumped from near 0/100mL to 1,000,000/100 mL immediately following the floods. Recovery costs exceeded $60 million total (Table C-3).

Utility and Community Response

Flooding presented sudden and urgent challenges, coupled with long-term recovery efforts that imposed large capital costs to repair damaged infrastructure. Utility managers worked to immediately restore critical potable water operations and wastewater treatment services to protect public health, while simultaneously working to remediate long-term damage.

Actions Taken – Emergency Response

Short-Term Responses

Within a few days, Gwinnett County remarkably was back online and running, including pumping stations. County officials reported strong flood preparation: previous experience preparing for Y2K prompted a sense of 'operational resilience,' leading to the institution of basic ordering agreements for potential loss of chemicals or power. Gwinnett County already had generators, supplies, and additional support on hand. Lessons from the 2007-2008 Drought, enabled Gwinnett County's stable staff to utilize the previously identified personnel essential during extreme climate/weather events, enact various communications mechanisms with stakeholders, and maintain a nimble management process that immediately sent resources to needed locations (Richards, 2012).

Table C-3. Costs to R.M. Clayton Water Reclamation Center in Atlanta, GA during the September 2009 Flood Event.

Cost	Purpose
$34 million	Emergency work – debris removal, protective measures.
$19 million	Permanent work – buildings, equipment, utilities.
$5.5 million	Additional wastewater treatment immediately following flood.
$2 million	Engineering and project management.

Source: Adapted from Bush, 2012.

Major initiatives taken prior to the 2009 Flood further served Gwinnett County's response. The National Resource Conservation Service's 1999 Dam Program upgraded 14 dams in the county. When the flood engaged four auxiliary spillways, these upgrades helped avert a more severe disaster (Richards, 2012). Moreover, the FEMA Floodplain Map Modernization Program, the USDA Natural Resources Conservation Services Watershed Dam Rehabilitation Program, and a new stormwater utility established in 2006 that provides funding for county stormwater operations and capital improvements helped in Gwinnett County's preparation. Updated maps identified at-risk bridges and culverts and confirmed that 10 of 14 dams remained within compliance standards.

Damaged Water Pipes on Brown Lee Road in Gwinnett County, GA during the September 2009 Flood.
Source: Richards, 2012.

CCWS's command center was largely responsible for the success of their response. Operators worked in 16, 28, and 30-hour shifts to maintain the infrastructure's integrity at RL Sutton Plant (Nguyen, 2012). Clearly defined roles and responsibilities allowed for quick action. Previously identified key personnel based upon their area of expertise and the particular incident were better able to inform and work with the public (Nguyen, 2012). This headed off confusion and "streamlined the ability to get key information and instructions to the citizens and affected stakeholders in a more timely and accurate process" (Nguyen, 2012). Existing relationships between managers, first responders, and staff at other agencies assisted in response efforts for various crisis needs. The CCWS modified its communication plan established during the 2007-2008 Drought for immediate coordination with water wholesaler CCMWA, ensuring sufficient water quality and supply to citizens (Nguyen, 2012).

The RM Clayton Water Reclamation Center robust and tested emergency response plan in Atlanta unfolded immediately. Staff quickly established a command center in trailers on high ground, so that they could work despite water continuing to flow through the streets. The Deputy Commissioner, RM Clayton staff and operation managers "worked around the clock to address the changing situation" (Bush, 2012). They defined priority areas, and then addressed them through rolling wave planning. This allowed for manually conducted operations and the utilization of alternative processes where necessary (Bush, 2012). As a top priority, the team first addressed disinfection, followed by sand filters, blower restoration, electrical system restoration, and solids removal (Bush, 2012). The team mobilized an engineering firm to prepare emergency contract specifications. The Department of Finance authorized the emergency procurement of contractors, as well as equipment such as portable pumps and generators to remove debris and clean and dry buildings. (Bush, 2012). Staff dewatered other areas with the dry fit pump station. Generators and blowers remained in place for eight days; within 15 days the center was back in service.

Flooded (left) and Recovered (right) BNR Basins and Blower Building, RM Clayton Water Reclamation Center.
Photo Credit: City of Atlanta, Watershed Department. Source: Bush, 2012.

Actions Taken – Long-Term Planning and Responses

Though Gwinnett County, Cobb County, and Atlanta were all quite successful in emergency response, the 2009 Flood was a stark reminder of the increasing intensity and variability of extreme climate/weather events in the ACF Basin. Recognizing the importance of event response evaluation, as well as anticipation of future events, these counties engaged in several long-term planning strategies.

Gwinnett County continued to build operational resiliency, water resource adequacy and work on both internal and external communication plans. The County established stronger partnerships with communities, environmental groups, mutual-aid organizations such as the Georgia Water/Wastewater Agency Response Network (GA WWARN) and other government agencies to foster collaboration prior to extreme climate/weather events (Rammo-Kuhs, 2012; Richards, 2012).

CCWS built upon lessons learned by improving coordination and building stakeholder and county relationships. A continuously updated website contains numerous helpful links, including those to the county emergency management agency, the National Flood Insurance

Program and forecasting sites (Rammo-Kuhs, 2012). Cobb County offered FEMA assistance in updating flood insurance maps for the area; FEMA released new maps in March 2013 (Nguyen, 2012). The County further set goals to improve overall extreme event preparation and response measures. This goals included planning structure and nonstructural capital improvement to the County's stormwater master plan; updating hydrologic and hydraulic basin simulation models; creating and improving planning maps, including stream buffer maps, monitoring station location and rain gage maps; performing studies to evaluate the effect of urbanization on downstream properties; and designing upgrades to the stormwater management infrastructure (Nguyen, 2012).

Physical damage persisted in Atlanta until mid-2012. Thus, the city employed a worst-case scenario planning approach to help prepare for future storm events. The usefulness of emergency response service contracts during the Flood prompted the city to explore more of these options and utilize existing agreements in the future. Awareness programs educated utility staff members about the FEMA public assistance program, as conflicting information from FEMA first-response team members during the event left some distrust in their knowledge and usefulness. Future planning in Atlanta called for floodwalls to meet site-specific requirements.

Winter 2009 – 2010 Flood[2]

Wet weather continued throughout Winter 2009-2010. Heavy rain caused additional flooding due to oversaturation. The normally wet spring season had yet to come. This wet weather period required carefully controlled dam releases.

Impacts and Response

Compared to the September 2009 Flood, there were minimal impacts on communities and water utilities in the ACF Basin. However, following such a heavy storm, the wet winter endangered larger water supplies. Lake Lanier remained at full pool the entire winter; thus it was necessary to reclaim flood storage capacity (Rainey, 2012). Buford Dam threatened overspill at the 1,085-foot flood pool. Looking downstream to determine a feasible release amount, the USACE safely discharged more than 100,000 cfs monthly for five months: November 2009 through March 2010 (Rainey, 2012). These controlled releases limited damages and stored flood water. Although Roswell, a town along the Chattahoochee River, reached flood action stage, controlled releases prevented a full flood stage (Rainey, 2012). Minimal impacts included encroachments in floodplains and a slight alteration of peak release standards (Rainey, 2012).

Drought of 2012-2013

Following the September 2009 Flood and the Winter 2009-2010 Flood, Central and South Georgia once again experienced drought conditions by the early summer months in 2012. By August, drought conditions spread to North Georgia as well.

Impacts and Response

Georgia declared numerous counties declared disaster zones again, though this time for drought. Stream flows in the upper ACF Basin remained low and counties experienced

[2] Note: As previously mentioned, the ACF workshop focused on the 2007-2008 Drought and September 2009 Flood. Therefore, information in this case study is heavily weighted towards those events. However, it is important both to discuss and distinguish the subsequent Winter 2009-2010 Flood and 2012-Present Drought, as they signify the seemingly increasing cyclical nature of extreme climate/weather events in the ACF Basin.

groundwater declines. In fact, Miller County groundwater levels were in the lowest 10% of historic observations. At the time of this case study, some counties were already experiencing other impacts, and more expected to if the drought continued. Potential impacts included decreased water supplies, diminished water quality, threatened aquatic environments, and declines in recreation (Williams, 2012). Sectors such as power generation, navigation, agriculture and forestry are also likely to be affected (Williams, 2012).

Forecasting quickly became an essential tool for water utilities and local governments planning for drought conditions. The Engineering and Atmospheric Sciences Department at the University of Georgia and the Georgia EPD worked with drought monitoring techniques to assess conditions. Current conditions, short-term outlooks (6-10 days), long-term outlooks (1-6 months) and seasonal patterns were essential for drought forecasting (Stooksbury, 2012). The Georgia EPD used these to help determine the intensity of the drought and communicate this information to the public, water utilities and local governments (Williams, 2012). In addition, the Department worked to offer guidance, encourage regional water resources planning, provide technical assistance and regulatory oversight, and communicate with different agencies addressing drought impacts (Williams, 2012).

In May 2012, NOAA's National Integrated Drought Information System (NIDIS) reported that, despite recent rains, 30-day and 180-day rainfall deficits remained large. At the time of this workshop, drought persisted throughout most of the ACF Basin, with significant areas classified as either 'extreme' or 'exceptional.'

Decisions, Challenges, and Gaps

Extreme events in the ACF Basin over the past decade alone reveal key adaptation challenges shaping the decisions communities, water utilities, and governments are making. Responding to extreme climate/weather events is particularly difficult, as different types of events present different challenges (Howard, 2012). Series of events, such as the recent cyclical nature of droughts and floods in Georgia, compound these challenges and mark important information and management gaps.

Climate-Driven

A number of the challenges and gaps are related specifically to climate-driven factors.

- **Increasing and Varied Exceptional Events**

Workshop participants noted that climate outlooks and predictions indicate that exceptional floods and droughts may become a typical cycle in the ACF Basin, or two sides of the same coin. Workshop participants remarked, "variable, extreme, and uncertain weather events are the *new normal*," and that acute flood events demand different management than long-term droughts. Thus usually sudden nature of floods may affect limited areas, but also raises water utilities' emergency response expenses (Richards, 2012). On the other hand, droughts are slower to develop, more persistent, and affect everyone; these deeply impact revenue and require a sustained response and change in customer perception (Richards, 2012). Water utilities discussed the need to improve emergency and long-term actions, while simultaneously adapting to a fluctuation of extremes. As cycles of extreme become the norm throughout the ACF Basin, periods of droughts and flooding begin to determine what decisions are made. Pete Frost of Douglasville-Douglas County Water and Sewer Authority notes that during the September 2009 Flood, "literally, our entire community was about water" (2013).

♦ **Historic Base for Management and Infrastructure**

The challenges associated with an increase in exceptional events are particularly evident in traditional modes of water resource management and infrastructure. Counties base water agreements, reservoirs, and release plans on old climate profile assumptions. Yet research and recent events clearly indicate a shift in climate variability and the extremes that come with that shift. "Reservoirs might get us through a year of drought, but not necessarily a multi-year drought," one workshop participant explained. Though management practices and infrastructure has served the ACF Basin well for decades, workshop participants questioned not only how to adapt to extremes, but rather how to rethink and revamp management plans and new infrastructure to better suit changing climates.

Water Service and Resource-Based

A number of the challenges and gaps are related specifically to resource-based factors.

♦ **Insufficient Infrastructure and Planning**

For water utilities in the ACF Basin, existing infrastructure deteriorates over time, challenging managers to maintain operations and meet future needs. Infrastructure replacement or repair that interrupts travel routes or services often aggravates citizens. As one participant noted, "the USACE has given Georgia's water infrastructure a D-, the lowest grade. Financing for this type of work is hard to come by, putting an extreme burden on communities in addition to extreme events." Deteriorating infrastructure becomes even more pressing when extreme climate/weather events such as floods cause severe damage. Immediate or short-term needs in these cases may conflict with the need to make long-term capital improvements and address the impacts of climate change on water infrastructure.

While infrastructure poses some planning challenges, workshop participants further noted that water planning is a constant gamble overall, especially when it comes to extreme climate/weather events. Storing too much water could contribute to flooding in unexpected rainy years, whereas storing too little water merely worsens drought years. Regardless of climate uncertainty, water utilities are recognizing the need to consider the future; communities cannot rely on short-term planning alone. Yet one ACF workshop participant stressed that: "Our strategy is still to wait for hurricanes or tropical storms to fill up reservoirs. That water comes in so fast it runs straight off. We need to retrofit our infrastructure to retain the water."

Planning for water resources further necessitates the incorporation of planning and collaboration with other sectors. Workshop participants stressed several challenges faced throughout extreme climate/weather events from 2007-2013. Generators need fuel, but if roads are impassable, diesel and gas cannot reach them, workshop participants explained. In addition, large amounts of fuel pose spill potential that must be considered. Other examples requiring more comprehensive plans include the life-threatening risks of sending staff into dangerous areas for recovery operations and determining how many and which emergency supplies to have on hand or what kind of data (such as visual versus computerized observations) are needed for decision making.

- **Meeting Population Demands**

Water utilities further stressed the need to address increasing development and rising populations. Currently 85% of the ACF Basin is developed, without any indication that this trend will cease in the near future. One workshop participant commented: "the thing that's going to swamp utilities is population. Rainfall may decrease by 10%, but population keeps rising." Increased development parallels an increase in water demand, both for household consumption and in terms of production (Georgakakos, 2012). The ACF Basin has already seen an increase in demand; this is only expected to grow. An increase in population and subsequent increase in water demand places severe pressure both on water resources and utility supply and delivery.

- **Decreased Water Leads to Decreased Revenue**

Changing user behavior patterns and conservation awareness are generally important to maintain water in the ACF Basin and particularly important with population growth or during times of drought. People cannot allocate, use, debate or fight over water if there is none. Participants stressed the need to protect water resources and ensure adequate water for ecosystems to promote long-term water availability and sustainability in the region.

Nevertheless, a decrease in water consumption is a direct decrease in revenue for water utilities, as experienced by several water utilities during recent extreme events in the ACF Basin. This is challenging under 'normal' circumstances, but particularly so during extreme climate/weather events when treatment costs or damaged infrastructure repair costs increase dramatically. Workshop participants expressed that decreased revenue feeds directly back into the challenge of funding deteriorating infrastructure repairs or new, more climate-ready infrastructure. Users must realize that conservation is essential, but it does not necessarily mean water will be cheaper. Perhaps tightening the gap between what users pay for water and the true value of water could address this shortfall. Rate structures that account for water scarcity and address the cost of extraction, treatment, supply, delivery, and waste removal may assist in providing water utilities with the funds necessary to maintain operations and deal with extreme climate/weather events.

Political and Intergovernmental

A number of the challenges and gaps are related specifically to political and intergovernmental-based factors.

- **Disbelief or Uncertainty in Climate Science**

Varying community perceptions are not the only ones challenging water utilities. Uncertainty in climate science leads to a complete disbelief in some cases. Some decision makers appear unwilling to consider the science behind climate projections and potential effects on weather events. One participant asserts, "The current [state] administration has been virtually silent. In the middle of a drought, [the governor] fired state climatologists. … We have to have facts, science, and transparency. They are so often missing when it comes to climate change in Georgia. …I have been impressed by how much local governments have done with very little funding or support from state government." On the other hand, the ACF Basin experienced four major weather events in a mere six years. Climate data supports this reality, and given the recent devastation of floods and droughts, it is difficult to ignore future projections that indicate climate trends continuing in this direction. Another participant stated that "Politicians are not trained in hydrology." While water utilities and local governments appear to be working with climatologists, greater regional acceptance and collaboration is necessary. As one workshop participant acknowledge, “we need more science in our policy.”

♦ Conflicting State Goals

Increasing development throughout Georgia complicates water planning and infrastructure. Projections indicate that Atlanta is the fastest growing metropolitan area (Couch, 2013). Rising populations, production, and urbanization drive up water demands. A boost in economic development provides incentive to meet such demands. Yet, changing climates and the increasing pressure extreme events place on communities exacerbate the longstanding tension between development and environment.

Landscaping and landscape messaging reflects one such tension. In Atlanta, there is a lack of covenant restrictions on landscaping; incentives for low impact use depends more on neighborhood peer pressure. When turf is laid out on the ubiquitous red clay, water runoff is high, requiring a great deal of water to re-establish the surface. However, with enough water most turf, such as Bermuda and Zoysia grass, is adaptable. Turf industry ads that promote watering do not help.

Furthermore, workshop participants noted that current residential design requirements do not necessarily appease the adaptation necessary for recent and future events. Many designs are not in accordance with FEMA’s 100-year flood plain mapping. FEMA requirements are somewhat siloed; even with federal incentives, economic pressures often determine local decisions. Land use is tied to property taxes, so housing on water bodies tends to be more expensive.

State laws mandate municipalities to adopt and update three plans each year: basin, wastewater, and water quality plans. Too often, however, workshop participants find that planning commissions approve development without considering utilities or consulting these plans. Georgia EPD evaluates safe yields when evaluating surface water withdrawal permits. But the local commission level does not always consider this.

Water planning for conservation in the ACF Basin affects ecosystems, human health, community development, and the economy. Further collaboration between the state and local governments, as well as community groups and water utilities is essential in order to reconcile conflicting user needs and state goals and ensure an adequate supply and quality of water during cycles of extreme climate/weather events.

♦ Water Rights

One workshop participant commented that, “Every time there is an extended drought, politicians say we need to be more water-independent.” However, water rights remain a question in Georgia. State water laws afford riparian rights, which gives rights to those on the banks of water bodies for ‘reasonable use’ of ‘natural flow’ of water (Dellapena, 2005). These rights conflict with the needs of inland stakeholders, with demands such as those of growing agricultural economies.

Workshop participants identified entrenched water disputes over supplies and water use of reservoirs within the ACF Basin. “Everyone has an opinion on reservoirs, whether they work or not, but they won’t work if there is no rain,” said a workshop participant. Nevertheless, Florida and Alabama are still fighting over water rights of shared resources. There is fear that any resulting laws or ordinances will not provide enough flexibility for communities and counties to address their needs during extreme climate/weather events. In 2011, the Eleventh Circuit of the U.S. Court of Appeals ruled that Lake Lanier is authorized for water supply and gave the USACE one year to determine the extent of its existing authority. Alabama and Florida appealed.

The Basin's recent droughts aggravate tension over water supply, but workshop participants noted this could be an opportunity for collaboration. Without rain, no one will have water. Extreme climate/weather events require additional planning; "even if everybody can agree, it will require joint action by several powerful groups to make any kind of plan work," stated a workshop participant.

- **Lack of Funding for a Unified Approach**

Even if there were a regional-state-local unified approach to water management, many fear a severe lack of funding exists. A workshop participant noted, "the state has created a state-wide water plan. Every jurisdiction in this state had stakeholders [in the process]. A lack of money is preventing the Water Planning Council from doing its work. We need to get behind an organization; we can't have 50 splintered organizations. Between EPD and EPA, they've made decisions that drive how everybody uses water. We need a push to have statewide water planning councils to give money to do the work to do the plans." The water utilities in various counties had successful responses during the 2007-2008 Drought and September 2009 Flood events. What is evident was that communication, planning and collaboration were essential in those successes. To transfer this success on a larger scale, adequate funding must support plans that are unified and benefit all stakeholders.

Socioeconomic

A number of the challenges and gaps are related specifically to socioeconomic factors.

- **Communication is Key**

Valuing water, understanding the true cost of water, and supporting water conservation challenge communication between users, sectors, and utilities in different ways. Workshop participants noted the seeming 'invisible' nature of water services and infrastructure in the ACF Basin and across the nation. Most users do not have to think about where their water comes from, how it reaches their tap, or where their waste goes. Extreme climate/weather events are changing this. The 2007-2008 Drought affected industries and agricultural production, but the outdoor water ban hit people at the household level. Similarly, in September 2009, floods inundated houses, prevented people from moving around the city and resulted in boiling contaminated water in some counties. Education and awareness is equally important prior to and during events.

Establishing trust between utilities or decision makers and their users, as well as between utilities themselves is also important. Communication during events such as floods is challenging, given the need for quick decisions and immediate action. As one workshop participant commented, "with floods you have the undivided attention of the public. All of a sudden, they're all about water. You have to be ready with a message." However, in some cases, normal protocols suffered during the 2009 Flood, as decisions were 'on-the fly' (Nguyen, 2012). Another participant noted: "you have to throw out the window consistent equitable treatment of customers to focus on priority risk areas."

Many questions about how water utilities can effectively communicate remain: How do you get the word out? What is the right message? How do you coordinate it in a crisis? How do you address inconsistencies among different utilities in messaging? How do you make the technical understandable? (Nguyen, 2012).

- **Environmental Justice**

Other questions that arose during the workshop are those regarding the capability of marginalized populations to confront water challenges and recover from disaster. Poorer communities often suffer the most during droughts and floods and commonly reside in areas most prone to environmental disasters. Workshop participants noted the EPA's priority for economic environmental justice, yet saw discrepancies within their communities during event aftermath in 2007-2009.

In Cobb County, for instance, the September 2009 Flood completely inundated Clarkdale Elementary School, in large part because of its floodplain location. Once waters resided, FEMA authorized the school to be rebuilt within the floodplain, which would have reinforced future vulnerability (ACF Facilitator Notes, 2012). A community forum stepped in, however, to spend $19.2 million to rebuild on higher ground. Furthermore, three years later, hundreds of homes in Austell and Sweetwater cities remained abandoned. These cities were among the hardest hit, yet as low income areas, many property owners were unable to restore their homes (Frampton, 2012). At the time of the September 2009 Flood, many homes in Austell resided outside the 100-year floodplain (Nguyen, 2012). In contrast, more affluent communities, such as Vinings, rebounded from the damage quite quickly, returning to 'normal' life. This was in part due to the fact that many homeowners in Vinings had flood insurance (Nguyen, 2012).

- **Varying Perceptions**

Individual perceptions of extreme climate/weather events and the ensuing damages differ greatly among the general population. Upper basin users do not necessarily experience the same water threats as downstream users. Urban, suburban, and rural areas differ in their water needs and understandings.

Convincing citizens of the connection between the state of water resources and human health, as well as how their actions impact other users, is an ongoing task for workshop participants. Part of this comes from what one participant terms the 'hydro-illogical cycle:' drought raises awareness of water needs, concern causes responses such as conservation, panic that water will run out arises, rains break the drought and relieves public concern and the resulting absence of further crisis causes the public to become apathetic – until the next event (Williams, 2012). Reluctance to accept climate science furthers this. Thus continuous extreme climate/weather events challenge utilities to encourage customers to conserve water in 'normal' rain years, rather than only during emergencies.

Information Needs

Workshop participants identified the following as the most important, though not an exhaustive compilation, information needs for water utilities to deal with future extreme climate/weather events in the ACF Basin:

- Improved forecasts for short-term storms and longer-term droughts, especially at a local level.
- Targeted vulnerability assessments of water utilities.

- Climate modeling for South Georgia that includes Florida.
- Water demand and use estimates.
- Updated floodplain maps.
- Updated engineering design manuals to improve infrastructure capacity.

This information will help fill current gaps and address challenges mentioned above. As seen earlier in this case study, water utilities in different counties employed varied response plans when hit by floods and droughts. Though impacts of such extreme climate/weather events were substantial to both communities and water utilities, their remarkable work perhaps prevented further devastation. Additional information and a more solid understanding of how to access and integrate this information exists will further enable water utilities, decision makers, and communities in their adaptation efforts.

Partnerships and Collaboration

The lakes, major rivers, and tributaries within the ACF Basin serve countless purposes and support life and economic growth, each with an array of stakeholders with specific interests. Interest in water resources from the ACF Basin vary. Competing interests and diverse impacts during extreme events highlights the importance of collaboration as communities, businesses, water utilities, and governments adapt to changing climates.

Several partnerships formed or were forming in response to floods and droughts in the ACF Basin detailed in this case study. These seek to integrate water resource management throughout the Basin and in Georgia. Partnerships include community groups, environmental groups and several government agencies.

A notable example is the ACF Stakeholders, established in 2008 as part of long-term actions following the Drought. Comprised of 70 members from Georgia, Alabama, and Florida, the group includes agricultural users, community members, environmental groups, water utilities, power companies, and local government agencies.

Charles Stripling, Chair of ACF Stakeholders, noted during the workshop, “we want to do something that is not a knee-jerk reaction. We’ve got a problem, lets us do something right away. We won’t solve the problem alone; there is nothing simple, nothing one sub-basin can do to solve the problem. The more we talk, the more we study, the more we find out how interrelated and complicated everything is.” ACF Stakeholders thus initiated bilateral and multilateral discussions and meetings. In 2011 it approved a five-year plan aimed at reaching consensus on ecological protection and safeguards for businesses that rely on the basin. “We’ve already raised $800K and are going for $1M, but we need $1.2 for a plan – and that is just a start,” Stripling reported.

The broad scope of climate/weather events and the emerging interconnectedness communities witness in the impacts events have, continues to build trust among stakeholders in the ACF Basin. Groups, like ACF Stakeholders, increasingly recognize that they cannot address the regional needs for water, research, data, communication, prevention, mitigation, preparedness, and response that affect them on an individual level without the help and support of others.

Refer to Water Utility Profiles and Stakeholder charts at the end of this case study for more information on those whose involvement was of great importance during in the workshop.

Lessons Learned

Lesson Learned: ***Integrated solutions through collaboration*** **ensure effective response to extreme events.**				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Collaboration with other organizations and governing bodies responsible for water management helps foster IWRM. • Engagement with existing regional planning structures, such as water planning councils and state initiatives, is challenging but helps promote long-term planning for multiple objectives.	• ACF Stakeholders is an unprecedented and promising stakeholder engagement organization. • In some jurisdictions, consensus among water use industries and regulated entities like landscapers, homeowner's associations, utilities, and real estate developers have allowed for conservation and land use regulations. • Following this workshop, water utility managers met for the first time to discuss extreme event experiences, specifically. • One workshop participant noted, *"After looking at everything we heard, there was some good news, common concerns. When this started, some people would not sit next to each other."*	• Workshop participants agree that weather events are getting less predictable and more extreme. Regardless of the reasons, this requires more appropriate responses. • Greater protections against less-than-epic events are also needed, as impacts tend to accumulate.	• Separate meters for indoor and outdoor water use and automatic cut-offs when outdoor water limits are reached, required soil or amendments under turf layers, and other water-saving measures.	• Better recognition and balance of multiple competing water needs and work to balance them. • Ensure that the State Water Plan is a sustained process; it's a very good start, but must not be a one-time plan.

Lesson Learned: ***Staffing, experience, and practices*** **at utilities greatly impacts the outcome events have on communities.**				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Emergency response training programs for staff are essential. • "What if" planning for worst-case scenarios can help identify vulnerabilities for advanced preparedness. • Responses must be proportionate to the crisis.	• Experienced staff was critical in getting services back on-line as quickly as possible and managing chaos during events. • Existing relationships among water utilities and between utilities and other sectors allowed for quicker response times. One utility received immediate emergency help from police based on a phone call to someone he knew well.	• Greater familiarity with how FEMA operates as needed, as this helps with restoration efforts. • Technical response plans and communication plans must both be in place and flexible to adapt to different events.	• 'Monday-morning quarterbacking' as valuable for better future preparation following extreme climate/weather events. • Build relationships among utilities and between sectors in advance. Coordinate at the commissioner or similar levels. • Establish financial contracts for response and consultation services in advance.	• Further staff trainings under the National Incident Management System (NIMS) ahead of time and establish the Extension Disaster Emergency Network (EDEN) and ensuring staff know how to use it.

Lesson Learned: *Communication* is essential to any successful extreme events response plan.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Effective communication is challenging – weather disrupts power and so many decisions must be made so quickly there appears to be little time to communicate. • Communication between staff at utilities, sectors and between service providers and their constituents enhances emergency responses during flooding and promotes conservation and awareness during droughts.	• Cobb County's revised communication plan and delegated responsibilities incorporated lessons learned from previous extreme climate/weather events and helped them prepare for the floods and droughts in the past decade. • Ongoing communication and collaboration in some counties promoted education among the public, encouraged conservation during drought and built trust during emergency response for floods.	• Functioning sirens, cell phones and radios that receive the same notifications and emergency information.	• Establish effective and various emergency notification procedures prior to events; emergencies can change things in an instance and back-up plans may be needed.	• Teach neighbors how to talk to each other during droughts to ensure all users' water needs are met, while people conserve and encourage each other to conserve where possible.

Lesson Learned: *Decision tools* enhance adaptive responses to extreme events.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Modern decision support tools can back up IWRM. • Decision tools can support designs to best-practices vs. "good-enough-for-now" options.	• Tools such as GA WWARN that help participants understand and use data during extreme climate/weather events.	• Some institutions are not willing to embrace modern decision support tools.	• Bring in decision analysts into conversations on decision tools for water planning. • Plan! As one workshop participant commented, *"As you plan new infrastructure, usually the materials are the cheap part of that. Designing to best standards costs virtually nothing more. For 100 year events – cost is minimal when designing upfront. Think ahead."*	• Increase understanding regarding how elected officials or regulators make decisions. This will help utilities and other agencies that need funding and other support to plan and prepare for the future know how to obtain resources.

Lesson Learned: *Education* is a long-term adaptive action and can promote better solutions.				
Outcomes / Findings	**Success**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Extreme climate/weather events happen to the entire community. Interconnections are priceless. • Ongoing education is crucial to promote sustained awareness.	• NIDIS workshops and webinars throughout the ACF Basin increased understanding about drought indicators and forecasting. Citizens and utilities engaged with experts to increase their awareness on climate outlooks and how these could be used in future planning. • Ongoing stakeholder involvement in some counties helped with conservation when drought hit.	• Residents too often believe flooding is the "fault" of utilities when, in fact, it is made worse by detrimental land use decisions they may be part of. • Persuading decision makers to expend scarce funds for long-term solutions can depend on their knowledge of the problem.	• Use extreme climate/weather events as opportunities to connect with the public and promote education. As one participant mentioned, *"We need another good drought to encourage reuse. We only heard one discussion so far on using reclaimed water."* • Network and collaborate with community groups, environmental groups and nation-wide institutions (such as the EPA, NIDIS, NOAA, etc.) to effectively reach and educate citizens.	• Continue and further promote education programs.

Looking Forward

Extreme climate/weather events in recent years left devastating impacts throughout the ACF Basin, yet water utilities and communities continue to demonstrate remarkable recovery efforts, as they build towards climate resiliency. In many cases, counties successfully adapted response preparation and plans through the incorporation of lessons learned from one event to another. A broad array of concerned citizens, stakeholders, and government officials are understanding that managing water resources for multiple objectives in a context of changing climate requires foresight, communication, understanding, collaboration, and flexibility.

While water utilities can only act within their realm of control, it is evident that they are also working to leverage their approach toward integrated water resource management and adaptive preparedness to better ensure reliable service. Water utilities are identifying information gaps and resource needs and actively pursuing ways to bridge these into more effective water planning. Actions underway to build support and inform decisions include monthly conference calls with NIDIS to help regional planners understand unfolding events and use of the USGS tools, such as StreaMail, to provide real-time alerts.

Community engagement and various sector involvement is blossoming throughout the Basin. The growing ACF Stakeholders group enables constructive dialogue. Atlanta is promoting green infrastructure and adopting water conservation practices. The landscaping industry is reorganizing around water-efficient landscaping. The Lake Lanier Association is educating school children and the public about this threatened resource.

In 2012, intense dialogue about ways (some controversial) to ensure adequate water supply against a backdrop of significant population growth and changing precipitation and watershed characteristics fully emerged. Local governments, utilities, and stakeholders debated ideas such as new or expanded reservoirs, inter-basin transfers, aquifer recharge systems, restoring natural hydrology, and expanding water conservation. This dialogue marks an important step in the pending actions necessary to redefine water management in the ACF Basin. It further exhibits a significant effort to ensure that attention to water resources and awareness of extreme climate/weather events remains at the forefront of conversations and planning in Georgia.

As one workshop participant noted, "the human response is to forget a tragedy or disaster. This is a societal issue – the tragedy of the commons. We believe we have minimal impact." The ACF Basin can no longer afford this luxury. Floods and droughts over the past six years merely signify the likelihood that this series of extreme climate/weather events will continue in future years. Continued awareness, collaboration, flexibility, and innovation are essential to build resiliency and ensure future water supplies throughout the Basin. Participants marked the importance of this workshop and other activities, which encourage dialogue and offer opportunities to return to their communities with lessons learned and adaptation strategies.

Cobb County-Marietta Water Authority (CCMWA)	
Overview	CCMWA draws from the Chattahoochee River and Lake Allatoona to treat and distribute water to wholesale customers in and around Cobb County. The institution does not sell water directly to consumers, but treats drinking water for other jurisdictions to then distribute. CCWMA built and manages two water treatment plants: the Quarles Water Treatment Plant and the Wyckoff Water Treatment Plant. The first combined source Authority in Georgia, CCWMA is in the process of upgrading both of the Treatment Facilities as part of a $120 million updating initiative. It also operates Simmons Microbiological Laboratory, which regularly tests ~500 water samples/month. Samples include water from the Chattahoochee, Lake Allatoona, CCMWA's system, and wholesale distribution systems.
Location	Headquarters: 1170 Atlanta Industrial Drive Marietta, GA 30066 http://www.ccmwa.org/
Operations conducted	Fire protection Water treatment Water distribution Wholesale of treated water
Size	• Service Area: 13 wholesale customers (no residential customers) in Cobb County, Paulding County, Austell, Marietta, Powder Springs, Smyrna, Mountain Park, Woodstock, Cherokee County Water & Sewerage Authority, and Douglasville/Douglas County Water & Sewer Authority. • Employees: 75+ at all facilities combined • Pipelines: 200+ miles of mains, ranging from 16-64 inches • Water Produced: 158 MGD permitted: 72 MGD at Wyckoff WTP; 86 MGD at Quarles WTP • Storage Facilities: 9 tanks across Cobb County • Storage Capacity: ~40 million gallons
Administrative structure	Named in 1951 a political subdivision of the State of Georgia, CCWMA has a seven member Board that helps to direct its growth and sustainability through monthly board meetings. CCWMA is currently working under five year action plan created in 2009.
Cobb County Water System (CCWS)	
Overview	CCWS is a water distribution and wastewater utility that partners with CCMWA. It operates through four major divisions: Engineering & Records, Business Services, Operations, and Stormwater Management. The Stormwater Management Division is responsible for maintaining stormwater infrastructure in unincorporated Cobb County. CCWS maintains a water quality laboratory and four water reclamation centers: Noonday, Northwest, South Cobb, and RL Sutton.

Location	Headquarters: 660 South Cobb Drive, Marietta, GA 30060 http://water.cobbcountyga.gov/index.html
Operations conducted	Solids treatment /reuse (composting, landfill, incineration) Stormwater management Wastewater collection Wastewater treatment/reuse Water distribution
Size	• Service Area: over 170,000 customers throughout Cobb, North and South Marietta, Mableton, Acworth, West and East Kennesaw, portions of Fulton, Cherokee, and Bartow Counties. • Employees: ~450 • Pipelines: 3000+ miles of distribution mains • Treatment Capacity: 128 MGD: 20 MGD at Noonday; 8 MGD at Northwest; 40 MGD at South Cobb); 60 MGD at RL Sutton
Administrative structure	Cobb voters elect a five-member Board of Commissioners, who then appoint the County Manager and Water System Agency Director. CCWS currently operates under a five year, \$640 million dollar Capital Investment Plan and over 100 projects.
DeKalb County Department of Watershed Management	
Overview	Established in 1942, the DeKalb County Department of Watershed Management became a division within the Public Works Department in 1985. It operates through five internal divisions: Administrative Services, Construction & Maintenance, Water Treatment, GIS/GPS Mapping & System Inventory, and Technical & Production Services. The authority draws water from the Chattahoochee River to treat and distribute drinking water. The utility maintains distribution and collection systems, as well as the Scott Chandler Filter Plant, Pole Bridge Advanced Wastewater Treatment Plant, Snapfinger Advanced Wastewater Treatment Plant, and DeKalb County Raw Water Pumping Station.
Location	Headquarters: 1580 Roadhaven Dr., Stone Mountain, GA30083 http://dekalbwatershed.com/
Operations conducted	Solids treatment/reuse (biosolids land application) Stormwater management Water distribution Water treatment Wastewater collection/sewerage Wastewater treatment
Size	• Service Area: • Employees: 670 • Storage Facilities: • Pipelines: ~5,000 miles of distribution mains • Pumping Stations: • Water Withdrawals: maximum of 140 MGD for DeKalb County Raw Water Pumping Station

	• Treatment Capacity: 184 MGD total: 128 MGD at Scott Candler Filter Plant; 20 MGD at Pole Bridge Advanced Wastewater Treatment Facility; 36 MGD at Snapfinger Creek Advanced Wastewater Treatment Facility
Administrative structure	DeKalb County elects the Board of Commissioners for seven districts, A Chief Executive Officer is elected by the entire county, who then appoints the DWM director.
Douglasville-Douglas County Water and Sewer Authority (DDCWSA)	
Overview	Formed in 1985 by combining city and county water and sewer systems, the Douglasville-Douglas County Water and Sewer Authority responsibilities were expanded in 2003-4 to include city and county stormwater. DDCWSA also charges customers a stormwater management fee to help offset costs. This fee is based on impervious surface area that contributes to stormwater runoff.
Location	Headquarters: 8762 Hospital Drive, Douglasville, GA. 30134 http://www.ddcwsa.com/
Operations conducted	Stormwater management Wastewater collection/sewerage Wastewater treatment Water distribution Water treatment
Size	• Service Area: ~40,000 customers in Douglas County • Storage Facilities: two 3-million gallon clearwells; six water towers • Storage Capacity: 2 billion gallons of raw water at Dog River Reservoir • Treatment Capacity: 23 MGD at Bear Creek Water Treatment Plant; 12 MGD at South Central Wastewater Treatment Plant • Reused Wastewater: 3.5 million gallons/month
Administrative structure	A seven member Board of Directors made of up of the Mayor of Douglasville, the Chairman of the Board of Commissioners, and five local community members to direct policies.
Gwinnett County Department of Water Resources	
Overview	Gwinnett County Department of Water Resources oversees water management, distribution, and treatment for this second most populous county in Georgia. The Department authorizes water withdrawals from portions of three major watersheds (Chattahoochee, Ocmulgee, and Oconee) in the area. With an operating budget of $1.3 billion in 2012, the Department has recently directed investments towards streamlining and collapsing facilities into fewer, more modern and efficient ones, rather than increasing total capacity at sites.
Location	Headquarters: 684 Winder Highway, Lawrenceville, GA 30045 www.gwinnettcounty.com/portal/gwinnett/Departments/PublicUtilities
Operations conducted	Stormwater management Wastewater collection/sewerage Wastewater treatment/reuse (effluent, gray water, etc.)

	Water distribution Water treatment
Size	• Service Area: 437 square miles in Gwinnett County • Pipelines: 3400+ miles of distribution mains • Sewer System: 2800+ miles of water collection mains • Treatment Capacity: 22 MGD at Yellow River Water Reclamation Facility; 16 MGD at Crooked Creek Water Reclamation Facility; 60 MGD at F. Wayne Hill Water Reclamation Center
Administrative structure	Gwinnett Department of Water Resources is an agency of Gwinnett County Government and the Board of Commissioners oversees the Department of Water Resources. The Department currently operates under a 50-year Master Plan for the county which called for the upgrading and consolidation found in the Yellow River and Crooked Creek WRF plants.
R.M. Clayton Water Reclamation Center (WRC), Department of Watershed Management, City of Atlanta	
Overview	One of four reclamation centers in the City of Atlanta, the R.M Clayton WRC was established in 1935. The Center is responsible for collecting and treatment wastewater for customers in and around the Atlanta service area.
Location	Headquarters: 2440 Bolton Road Atlanta, GA http://www.atlantawatershed.org/inside-dwm/offices/water-treatment-and-reclamation/facilities/water-reclamation/rm-clayton-wrc/
Operations conducted	Solids treatment /reuse (land application, composting, landfill etc.) Wastewater collection/sewerage Wastewater treatment/reuse (effluent, graywater, etc.)
Size	• Service Area: the City of Atlanta, mostly north of I-20, a portion of north Fulton County, and the majority of north Dekalb County • Treatment Capacity: 122 MGD for discharge to Chattahoochee River
Administrative structure	The R.M. Clayton WRC falls under the authority of the City of Atlanta Department of Watershed Management: http://www.atlantawatershed.org/
U.S. Army Corps of Engineers Mobile District	
Overview	In 1815 the Mobile Works District was established and today it administers a wide range of projects in the American South-East. The Mobile District has massive authority with its ability to work in four states, six major river systems, four major inland waterways, seven deepwater ports, and eight hydropower facilities along with an expansive recreation initiative. Employing a range of professionals and some military personnel, the District has more than twelve hundred people in their workforce. USACE contracts with the Atlanta Regional Commission to guarantee maximum daily flows in rivers within the ACF Basin system.

Location	Headquarters: 109 St. Joseph Street, Mobile, AL 36602 http://www.sam.usace.army.mil/Home.aspx
Operations conducted	Hydroelectric power generation Site restoration Storm water management Recreation site management Other military and civilian projects
Projects in Georgia	Allatoona Lake Project Carters Lake Lake Lanier Lake Seminole Walter F. George Lake and Lake George W. Andrews West Point Project
Administrative structure	Headed by four main officers, the different sections of the program are then directed by nine district leaders whose operations range from real estate to regulations to construction.

STAKEHOLDERS: ACF BASIN WORKSHOP PARTICIPANTS

Organization/ Institution	Description	For More Information
ACFS Stakeholders	Group of various stakeholders that meet to discuss water resources in the ACF and work to develop a sustainable water management plan.	http://acfstakeholders.org/
American Rivers	Works to protect and restore the nation's rivers and streams. Engages at the state level with surrounding states and is working in Georgia to implement no-regret solutions focusing on green infrastructure, water efficiency and source protection.	http://www.americanrivers.org/
City of Austell	Provides information on extreme events and the hazard mitigation grant program, as well as an approved contractor's list for Austell's Flood Response Group.	http://www.austellga.gov/
Georgia Association of Floodplain Management	Open to professionals, public and private entities, students and citizens interested in or involved in floodplain, watershed, storm water, wetlands and hazard mitigation management within the state of Georgia. Holds conferences and provides training.	http://www.gafloods.org/
Georgia Environmental Protection Division	The Environmental regulatory agency in the state. Determines the event intensity, communicates drought information, provides guidance, encourages regional water resources planning, provides technical assistance, offers regulatory oversight and communicates with other agencies.	http://www.gaepd.org/
Georgia Green Industry Association	Promotes and advances the economic lifestyle and environmental benefits of the Georgia horticulture for its members.	http://www.ggia.org/
Georgia Water Resources Institute (GWRI) at Georgia Tech	Uses education, research, information, and technology/knowledge transfer to improve the science and practice of water resources planning and management.	http://www.gwri.gatech.edu/
Georgia Water/ Wastewater Agency Response Network (W/WARN)	Network of utilities that help through mutual assistance agreements to share emergency resources among members statewide. Open to all utilities, does not require a disaster declaration for aid. Essential during 2009 Flood, as facilities exhausted their resources.	http://www.gawarn.org/

Lake Lanier Association	Works with regulators to manage the various uses of the reservoir and advocate for its recreational, environmental and economic value.	http://lakelanier.org/
Nicholas School of the Environment, Duke University	Research contributions in environmental science and policy, earth and ocean sciences and conservation.	http://www.nicholas.duke.edu/divisions/
NOAA's National Integrated Drought Information System (NIDIS)	Provides drought-related technical expertise, support and services to states and stakeholders. Works to meet data and event prediction needs for stakeholders. On April 29-30, 2008, it held its first southeast drought pilot workshop in Peachtree City, GA.	http://www.drought.gov/portal/server.pt/community/drought_gov/202
NOAA's National Weather Service	Generates extreme event forecast maps, tracks rainfall and air quality, issues active alerts.	http://www.weather.gov/
NOAA Southeast River Forecast Center, National Weather Service	Provides routine daily forecasts of river conditions and precipitation, as well as water resources outlook informational summaries.	http://www.srh.noaa.gov/serfc/
State Climatologist	Collects, disseminates and interprets climate data.	http://www.gaepd.org/Documents/stateclimatology.html
University of Georgia, College of Agricultural and Environmental Sciences	Located in Athens, Georgia. Works on regional research projects in three laboratories. Contributes to research on water conservation in agricultural production and ensuring safe food supplies.	http://www.caes.uga.edu/research/
Chattahoochee Riverkeeper	Established in 1994, its mission is to advocate and secure the protection and stewardship of the Chattahoochee River, its tributaries and watershed, to restore and preserve their ecological health for the people and wildlife that depend on the	http://www.ucriverkeeper.org/riversystem
U.S. EPA Region 4	Located in Atlanta, Georgia. Serves regional environmental needs for Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and 6 Tribes. Addresses issues such as severe weather recovery, ecosystem restoration and environmental justice.	http://www2.epa.gov/aboutepa/about-epa-region-4-southeast

ATTENDEES: ACF BASIN WORKSHOP PARTICIPANTS

Cliff Arnett	Columbus Water Works
Lorrie Backer	National Center for Environmental Health
Nancy Beller-Simms	NOAA
Sally Bethea	Upper Chattahoochee Riverkeeper
Rob Bush	Atlanta Department of Watershed Management
Chris Butts	Georgia Green Industry Association
Lowell Chambers	Atlanta Department of Watershed Management
Bailey Crane	USACE
Jeff Dobur	Southeast River Forecast Center
Ernet Earn	Cobb County Water System
John Feldt	NOAA/NWS/SERFC
Lauren Fillmore	WERF
Kent Frantz	National Weather Service
Aris Georgrakakos	Georgia Water Resource Institute / Georgia Tech
Marilyn Hall	Athens-Clarke County Public Utilities
Laura Hartt	Upper Chattahoochee Riverkeeper
Miriam Heller	MHITech Systems
Caroline Hemenway	Hemenway Inc.
Jenny Hoffner	American Rivers
Robert Howard	U.S. EPA Region 4
Srinivas Jalla	CH2M HILL
Bruce Knighton	Sinclair Water Authority
Pamela Knox	University of Georgia
Charles Lambert	DeKalb County Watershed
Michelle Lawrence	Fulton County Government
Kim Linton	WRF
Stephen Maurano	U.S. EPA Region 4
Brian McCallum	USGS
Chad McNutt	NOAA-NIDIS
Karen Metchis	U.S. EPA Office of Water

Kenneth Mitchell	U.S. EPA Region 4
Kathy Nguyen	Cobb County Water System
Kenan Ozekin	WRF
Michael Patton	Douglasville-Douglas County Water and Sewer Authority
Tim Rainey	USACE
Neela Ram	Atlanta Regional Commission
Amy-Rammo-Kuhs	Georgia Environmental Protection Division
Kenneth Reckhow	Cardno ENTRIX
Jill Reisdorf	UCAR
Tyler Richards	Gwinnett County Department of Water Resources
Mark Risse	University of Georgia
Sean Roche	Michael Baker Jr., Inc.
Wilton Rooks	Lake Lanier Association
Lans Rothfusz	NOAA/NWS
James Scarbrough	Gwinnett Water Resources
Sarah Simmons	Metro Water District
David Stooksbury	University of Georgia
Charles Stripling	ACF Stakeholders
Katie Sullivan	U.S. EPA ORD/NERL/ERD
Lara Thurn	AECOM
Nancy Tosta	Ross & Associates
Amy Warnock	Cobb County Water System
Charles Williams	Georgia Environmental Protection Division
Joseph Witcher	Sinclair Water Authority
Max Zarate-Bermudez	Center for Disease Control

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APPENDIX D

CENTRAL TEXAS REGION

The project's Central Texas Region workshop took place March 19-20, 2013 in the Commons Learning Center at the University of Texas at Austin. The workshop and findings detailed in this study would not have been possible without the Regional Team listed below. The Research Team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

Rajendra Bhattarai (Austin Water)
Jim Brown (U.S. EPA Region 6)
Tina Bui (Austin Water)
Christina Cooper (Delaware Nation of Oklahoma)
David Greene (Austin Water)
Mike Howe (Texas AWWA)
Bridget Scanlon (University of Texas)
Bob Rose (LCRA)

The Story in Brief

Central Texas entered its third consecutive year of drought in 2013. Drought began in 2011, when the state endured its worst single-year drought and hottest summer in recorded history. That year, communities in Central Texas faced 90 days of triple-digit heat, during which extensive wildfires burned hundreds of homes. The reservoir system on the Lower Colorado River entered the 2013 summer season at lower levels than at that same time in 2011. For the second year in a row the Lower Colorado River Authority (LCRA) restricted water releases for downstream agricultural uses that had 'interruptible' standing under water rights provisions, which allowed for the curtailment. Urban users purchased primacy rights to available water during times of drought, resulting in the perception by urban water users that there was plenty of water, thereby creating tension with downstream agricultural users. The Drought of 2011-2013 brought challenges both in advancing an ethic of water conservation, and in finding the means to fund utility operations despite reduced water sales.

Background

The Central Region spans a significant portion of water resources and diverse populations in Texas. This case study focuses on extreme climate/weather events and water supplies in the area that includes Austin, San Antonio, Waco, and nearby communities (Figure D-1).[1] Surface water from the Lower Colorado River and groundwater from a network of aquifers, including the Edwards Aquifer, provide a range of services to this region. Power generation, agricultural production, ecosystems, and domestic water use are all dependent on these vital water resources (Walker, 2013).

Figure D-1. The Central Texas Region and Lower Colorado River Basin.

Lower Colorado River Basin and the Highland Lakes

The Lower Colorado River Basin is the major source of surface water supply in Central Texas.

Irrigation remains among the most important water uses of the Lower Colorado River. Irrigation began in the late 1800s, primarily by rice farmers, and three of the four major irrigation districts were in place by 1915 (Gerston, 2013). Over time, irrigation district owners deemed the Lower Colorado River Authority (LCRA) the "legal guardian of the river with a legal mandate for providing irrigation water [to] better manage, preserve, and provide for the growing needs of irrigation operations" (Gerston, 2013).

Buchanan Dam.
Source: Walker, 2013.

A network of dams on the Lower Colorado created the Highlands Lakes: this system of lakes includes Lake Buchanan, Inks Lake, Lake LBJ, Lake Marble Falls, Lake Travis, and Lake Austin.

Formed by the construction of Buchanan and Mansfield Dams, Lake Travis and Lake Buchanan supply domestic water for more than a million people in Central Texas including the City of Austin, (Texas Drought, 2013). Buchanan Dam is one of the largest dams on the Lower Colorado River. Built in 1938, the 876,000 acre-foot reservoir has 37 floodgates (Walker, 2013). Larger still is the 1,135 acre-foot, 24 floodgate Mansfield Dam, established in 1941 (Walker, 2013). Water released from these dams "meet the needs of the City of Austin, downstream customers, and state-mandated environmental requirements for the amount of water flowing in the Colorado River

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[1] While exact boundaries of what constitutes the 'Central Texas Region,' may vary, this case study focuses on cities and communities that participated in the workshop. It does not attempt to, nor intend to, cover the extensive events, impacts, and response strategies of every water utility or community present in Central Texas.

and into Matagorda Bay" (Lower Colorado River Authority, 2013). Water levels in Lakes Buchanan and Travis are reliant on inflows from upstream precipitation; withdrawals, releases for downstream users, and high evaporation rates due to hot, dry weather further affect water levels.

Located entirely within the city limits of Waco, Texas, and north Austin, the U.S. Army Corps of Engineers (USACE) operates Lake Waco. Created in 1929 and expanded in 1966 with the construction of a new dam, Lake Waco lies on the Bosque River. Topography predisposes the Lake to low water levels during dry months, even in years that receive average precipitation. During July and August a severe drop in water levels is common, due to evaporation loss that outpaces Waco's entire municipal usage (Garrett, 2013).

Underground Aquifers

Rainfall draining into fractures and ground faults recharges an extensive network of karst-formed[2] aquifers that underlie and serve communities throughout Central Texas (Edwards Aquifer Authority, 2013). The Edwards Aquifer alone is about 180 miles long, nearly 40 miles wide in some places, and is the primary resource of water for two million people, including much of San Antonio, (Eckhardt, 2013; Edwards Aquifer Authority, 2013). The prized Barton Springs segment of the Edwards Aquifer underlies south Austin and is home to 50 endangered animals and plant species, including the Barton Springs salamander (Center for Biological Diversity, 2013).

Continually increasing water demand and reduced recharge due to drought challenge the capacity of aquifers to simultaneously meet user needs and sustain endangered species in the area (Eckhardt, 2013). For example, eight of the 40 known species to which the Edwards Aquifer is home are on threatened or endangered species lists (Edwards Aquifer Authority, 2013), prompting lawsuits over precipitous drawdowns.

Though the Lower Colorado River, Highlands Lakes, Lake Waco, and the Edwards Aquifer are not an exhaustive list of water resources that comprise Texas' Central Region, they reflect the importance of water resources in sustaining human activities, economic growth, and ecosystem services throughout the state.

Water Laws and Governance

Cities in Central Texas manage their own water, wastewater, and stormwater services. However, other governance structures manage surface water flow and the state's overall water resources.

As one of the most prominent water governance structures in Central Texas, the LCRA is an important driver of water management decisions. Established by the Texas Legislature in 1934, the LCRA is a conservation and reclamation district that relies solely on revenues generated from supplying energy, water, and community services. The LCRA monitors the Colorado River's natural flow and coordinates activities among downstream users (Walker, 2013).

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[2] Karst aquifers are those formed from the "dissolution of limestone, dolomite and gypsum" (Edwards Aquifer Authority, 2013).

Six dams and reservoirs comprise the LCRA system and form the Highland Lakes (Figure D-2): Buchanan, Inks, LBJ, Marble Falls, Travis and Austin (Walker, 2013). The LCRA operates the reservoirs for water supply to cities in Central Texas, power plants and industries, agricultural production, and environmental and fishery needs; flood control to reduce damages and replenish supplies; and recreational benefits (Walker, 2013). The LCRA's adaptive Water Management Plan for the reservoirs determines firm yield, firm demands, and excess firm capacity "on an interruptible basis for non-firm purposes" (Walker, 2013). Firm stored water use means water supply that is "reliable through a repeat of the drought of record" (Gerston, 2013). The structure of this plan ensures lower water rates for irrigators than for firm water customers "due to the unreliable nature of interruptible water," and requires stakeholder involvement and input for monitoring and planning (Gerston, 2013). A downside for irrigators, however, is that increased firm water usage decreases the reliability of water supplies for irrigation. Evident in 2013, the LCRA cut water supplies for irrigators for the second year in a row.

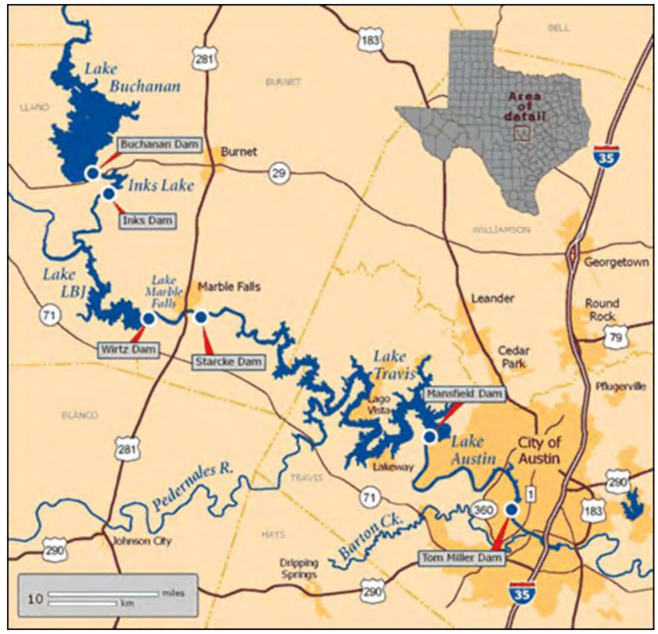

Figure D-2. Reservoirs and Dams Governed by the Lower Colorado River Authority, Central Texas Region.
Source: Walker, 2013.

Groundwater Conservation Districts (GCDs) authorized by the State of Texas manage groundwater supplies in the Central Region. These conservation districts delegate local control; decentralized management systems retain the statutory authority to space and construct wells, register permit pumping, and study aquifers (Holland, 2013). About 98 GCDs manage 90% of Texas' groundwater withdrawals (Holland, 2013).

In Texas' Central Region, four zones – contributing zone, recharge zone, confined zone, and saline water zone – comprise the Barton Springs/Edwards Aquifer Conservation District (BSEACD); these zones direct groundwater use decisions (Holland, 2013).

During emergency situations, Texas' Government Code (Section 418.018) grants the governor authority to recommend evacuation; control disaster areas; prescribe routes, transportation, and destinations for evacuations; and "allow state agencies to waive or amend business activities" (Bewley, 2013). The same code informs local decision making as well; county judges and majors can declare local areas disaster zones, order mandatory evacuations, and restrict occupancy in disaster areas. Annex V of the State Plan permits up to 21 days of commodity distribution in cases of temporary water outages due to mechanical failure or natural/human-made disasters (Bewley, 2013). Emergency precautions vary among many strategies: moving intakes, establishing connections with nearby water systems, drilling new wells or re-establishing previously used wells, inter-basin transfers, desalination via temporary lines, and hauling treated and untreated water, among other strategies (Bewley, 2013).

While cities manage their own water services within their jurisdictions and the LCRA and GCDs manage surface water and groundwater supplies, regulations exist that may override these authorities when facing extreme climate/weather events and disasters.

Governing water laws in the Central Texas Region include the following:

- 1999 and 2007 LCRA Agreements.
- 2007 Supplemental Water Supply Agreement.
- Government Code (Section 418.018) for Emergency Management.
- Regional Water Plan.
- State Water Plan.
- Texas Common Law "Rule of Capture".
- Texas Water Code, Chapter 36, Subsection 36.101 for GCDs.

For more information on these, visit: http://www.tceq.texas.gov/drinkingwater/pdw_rules.html

Climate and Water Trends

Weather patterns off the Atlantic Ocean and Gulf of Mexico interact with the region's western Rocky Mountain barrier; this largely determines climate in Central Texas (Nielsen-Gammon, 2013). Many characterize Texas as a hot and dry state, subject to frequent droughts. Recent shifts in climate trends, however, further indicate a rise in temperature, continued low precipitation, depleted groundwater supplies, and increased threats of drought and wildfires (Nielsen-Gammon, 2013).

Shifting Precipitation and Temperature

Central Texas lies in a zone between the hot and dry western portion of the state to the wetter, eastern portion. Moving from west to east increases annual precipitation from about 16-20 inches to as much as 50-60 inches. Recent trends and projections indicate shifts in this east/west boundary, resulting in a hotter, drier climate throughout the Central Texas Region than evidenced in the past.

Variations in sea surface temperatures and multi-decadal variations in ocean circulation patterns[3] affect rainfall in Central Texas (Nielsen-Gammon, 2013). Precipitation patterns generally demonstrate greater variation during the periods of December-March and August-November; however, the El Niño Southern Oscillation (ENSO) can bring a drought-inflicting La Niña phase (Nielsen-Gammon, 2013).

As climatologists expect an increase in global temperatures, projections also indicate hotter temperatures for longer periods of the year throughout Central Texas (Nielsen-Gammon, 2013). Coupled with increasingly regular low annual precipitation levels, these hot, long periods challenge the region to continuously meet water demands.

[3] These patterns include the Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO). Refer to the Appendix A: Glossary of Water, Climate, and Weather Terms.

Water Supplies

Observed and projected trends of increased temperature, low reservoir and aquifer recharge, and population growth render this region even more susceptible to drought.

Central Texas depends heavily on the Highland Lakes on the Lower Colorado River for the region's water supply, especially the Lake Travis and Lake Buchanan reservoirs. Inflows over the past five years were the lowest of any five-year period in recorded history, eclipsing the long-standing record drought in the 1950s (Holland, 2013).

Communities south of Austin, including the city of San Antonio, rely on small karst aquifers that are susceptible to multi-year drought cycles (Holland, 2013). Though the Edwards Aquifer "began forming 100 million years ago…[it] is still changing due to rainfall and other weathering processes" (Edwards Aquifer Authority, 2013). Soil moisture is likely to decrease drastically by 2045-2055 for most of Texas, threatening groundwater supplies and leaving the state's Central Region more dependent on winter rain moving in from the Atlantic (Nielsen-Gammon, 2013).

Demographic Trends

Population trends in the southwestern U.S. drive water demand that often equals, or even exceeds, water supplies in the region (Nielsen-Gammon, 2013). "Public water supply is [the] principal groundwater use, in burgeoning growth area;" in fact, the Barton Springs/Edwards Aquifer Conservation District[4] already use this major aquifer "beyond its sustainable yield" (Holland, 2013).

Projections indicate an 82% increase in the state's population by 2060 (Gerston, 2013). From 2000 to 2010, population grew more than 10% in Waco alone (Garrett, 2013). The City of San Antonio estimates recent growth rates at about 20,000 people per year (Guz, 2013).

Agriculture remains one of the largest water uses in Texas, both for local consumption and exports.[5] As populations grow, so does agricultural production and the demand for irrigation water. About 57% of the state's water use goes towards irrigation; nearly 10% of all irrigated acres in the U.S. are in Texas (Gerston, 2013). The majority of irrigation water comes from groundwater resources (Gerston, 2013).

Impacts of Population Growth

Population growth and increased agricultural production constantly drive up water demands in Central Texas. The City of Waco's 2003 study on projected water needs revealed that the demand for water already reached capacity (Garrett, 2013). The study uses historical usage data and growth trends prior to 2001 to point to the pressure imposed on water resources by increasing populations and water use throughout Texas. Barton Springs currently pumps an annual 572,000 AF from the Edwards Aquifer, while San Antonio pumps around 7,500 AF (Holland, 2013)

[4] This conservation district includes communities in Bastrop, Caldwell, Hays, and Travis Counties.

[5] Worldwide, food production consumes approximately 1,000 times the amount of water per individual than the WHO's assertion of a necessary 4-5 liters of water per person to fulfill daily water needs (Gerston, 2013).

Currently, there are 3.1 MAF of unmet irrigation during drought period; by 2060 these shortages will reach 3.8 MAF or represent 44% of water demands (Gerston, 2013). Nevertheless, the State Water Plan of Texas “projects a 17% decline in irrigation demands by 2060” due to improved irrigation efficiency and other factors (Gerston, 2013). Many argue the decrease in irrigation demand is a gross underestimation given population growth and the need to sustain agricultural industry in Texas (Gerston, 2013). Larger populations are likely to mean less land and water for production, along with decreased yield improvement rates.

Thus, even in average or ‘normal’ weather years, tension between water supplies and demands persists throughout Central Texas. The region’s struggle to consistently meet a growing population’s needs becomes increasingly difficult during times of drought.

Extreme Events

Extreme climate/weather events are nothing new to Central Texas. Floods and droughts occurred in the early 1900s, the early 1950s, and again in 2007 (Walker, 2013). In fact, continued drought monitoring and seasonal outlooks for La Niña predicted the onset of drought in 2011 for the Southern Plains of the U.S., including Central Texas (Brown, D. 2013).

The extreme lack of precipitation over a several year period not only led to the prolonged Drought of 2011-2013, but perhaps marked a shift in the frequency and duration of extreme climate/weather events for Texas’ Central Region. Though droughts are common in Central Texas, consecutive drought years are “relatively rare” (Guz, 2013). Whereas severe droughts previously seemed to occur every 50 years or so, the 2011-2013 Drought arrived a mere four years after another significant drought in 2007. Furthermore, the “rapid intensification and extreme magnitude” of the 2011-2013 Drought surprised water managers and decision makers in the region (Brown, D. 2013).

In 2007 and from 2009-2010, cities such as San Antonio also experienced some of the wettest months on record, serving as bookends to the driest 24 months on record from September 2007-August 2009 (Guz, 2013). Yet again, 2011 broke these records. The year marked the least rain recorded in San Antonio since precipitation monitoring began in 1871; the city received a mere 7.6 inches (Guz, 2013).

Drought of 2011- 2013

Low winter rain and high summer temperatures caused extreme drought in Central Texas in 2011. On July 5, 2011, Governor Rick Perry issued an Emergency Disaster Proclamation, certifying ‘exceptional drought,’ potential disaster for Texas, high temperatures, prolonged dry conditions, threatened water supplies and services, and high wildfire dangers (Perry, 2013). The Governor declared that “drought conditions have reached historic levels and continue to pose an imminent threat to public health, property, and the economy” (Perry, 2013).

By March 2013, the region was on track for not only a third consecutive year of drought, but a summer season threatening even drier conditions than in 2011, and nearly matching the 1950s record-setting drought. Water supply reservoirs in Central Texas were a mere 44% full at the 2011-2013 Drought’s onset compared to 75% at the same time in prior years. On October 3, 2013 the Governor renewed the Drought’s emergency proclamation (Perry, 2013). The “aggressive and intense nature of the Drought left many struggling to prepare and respond,” resulting in numerous impacts throughout 2011-2013 (Brown, D., 2013).

Impacts to the Environment

Nearly 39,000 acres of protected wildlands around Austin serve to ensure water quality and endangered species habitats (Slusher, 2013). Yet, dry conditions led to widespread, severe vegetation loss throughout Central Texas, even by mid-2011 (Figure D-3) (Bewley, 2013).

Figure D-3. Changes in Vegetation Cover, August 2010 (below left) and August 2011 (below right).
Credit: Gordon L. Wells, Center for Space Research, University of Texas at Austin.
Source: Bewley, 2013.

Dry conditions severely depleted the area's main water supplies at Lakes Travis and Buchanan, as well as area aquifers. Inflow into Central Texas' Highland Lakes was only 10% of the yearly average (Table D-1) by 2011, which continued to drop (Texas Drought, 2013). Furthermore, 60-month inflows for the Highlands Lakes were the lowest of all historical droughts (Walker, 2013). Inflows in 2012 were the fifth lowest on record, at 32% of annual average (Slusher, 2013). Total combined storage of Lakes Buchanan and Travis had a historical low of 621,000 AF in 1951; levels approached this at a mere 736,000 AF in 2011 (Slusher, 2013). By 2013, the highly prized Barton Springs portion of the Edwards Aquifer, just south of Austin, reached critically low levels.[6] Although a federally protected habitat area, low precipitation and infiltration levels threatened the aquifer's ability to support the endangered salamander in Barton Creek (Holland, 2013).

Table D-1. Lakes Travis and Buchanan Inflows.

2011	10% of average, lowest in history
2012	32% of average, 5th lowest in history
2013	13% of average (measured in September, indicates 2nd lowest in history)

Source: Data adapted from Texas Drought, 2013.

It is unclear whether drought and heat triggered the increased algae blooms in surface water sources during this time (Slusher, 2013). Nevertheless, three years of drought conditions severely affected water quality and species habitats in these areas, and limited the ability to manage the wildland-urban interface through prescribed burns.

6 Groundwater droughts do not always equate to other types of drought, such as meteorological or agricultural droughts; multi-stage triggers determine groundwater drought, based on the conditions of the aquifer itself (Holland, 2013).

Low environmental flow releases from Lakes Buchanan and Travis left Matagorda Bay, Texas' second largest estuary, severely threatened. Low flow caused high salinity levels that endangered fish, shrimp, and shellfish species, particularly the growth of juvenile organisms (Texas Drought, 2013).

The prolonged, dry conditions rendered an environment more susceptible to other extreme climate/weather events, such as wildfires. The fact that surface water resources, aquifers, soil moisture, and precipitation levels all reached historical lows demonstrates the remarkable severity of the 2011-2013 Drought.

Figure D-4. Onion Creek (tributary to the Colorado River) in 2007 (left) and during Drought in 2011 (right).
Source: Slusher, 2013

Impacts to the Community

Impacts throughout the Central Texas Region varied from 2011-2013. Communities in Austin endured 90 days of triple digit temperatures (Bhattarai, 2013) versus the average 13 such days annually[7] (Buchele, 2012). The third consecutive year of drought in 2013 hit economic sectors throughout Central Texas particularly hard, agriculture, microchip manufacturing, and energy production.

Agriculture

Rice farmers endured a second year of LCRA-authorized reductions in water releases. Water curtailments and cutoffs were more extensive and frequent throughout 2012, as "total stored water supply [was] limited under all conditions, even when the lakes [were] full and overflowing" (Gerston, 2013). Such curtailments threatened Texas' main crop: rice. Other pressing issues included water supplies to livestock, forest fires, and salinity content that affected the ability of crops to uptake water (Brown, B., 2013).

> *"It's been devastating. It's hit the farmers the hardest. The people who are closer to the earth, they feel the impact of the drought immediately."*
>
> *– Rajendra Bhattarai, Austin Water Utility*

7 Since 2007, the number of triple digit temperature days in Austin has broken this annual average (Buchele, 2012).

Industry

Changes in water supply have significant impacts on the industrial sector, one of the largest water consumers in Central Texas. Main factors affecting industrial water use are the quality, availability, and cost of water (Wilcox, 2013). For instance, droughts alter water quality by increasing the concentration of contaminants, which “can lead to defects and lost revenues” (Wilcox, 2013). During the 2011-2013 Drought, low reservoir levels concentrated inorganic compounds such as ions and metals, which, in the absence of removal, some industries considered “killer defects” (Wilcox, 2013).[8] Thus, dry conditions threatened industries such as micro-chip manufacturing with potential defects in production and lost revenues.

At the University of Texas in Austin, nearly 90% of electricity relies on thermoelectric power generation, another heavy water consumer (Scanlon, 2012). Water for electricity demand decreased by 60%, while reliance on storage increased by 120% during the 2011-2013 Drought (Scanlon, 2012).

> *“Like most water utilities, we’re at the mercy of Mother Nature. In dry weather, we have drought management policies that help lower consumption during droughts, but our water supplies are still reduced, either physically or by a regulator.”*
>
> *– Karen, Guz, San Antonio Water System*

Impacts to Water Utilities

Lower reservoir levels depleted groundwater supplies and challenged water utilities to sustain services throughout in Central Texas (Brown, B., 2013). In Austin alone, water use restrictions caused an estimated $35 million in revenue loss for the city’s main water utility from 2011 through March 2013.

The Aqua Water Supply Corporation (Aqua WSC) reported that the six counties the utility serves in Central Texas reached peak demand earlier in 2011 than in a typical year; this peak demand also lasted longer than usual. Whereas typical summer peak demand lasts three months (early June through early September), peak demand lasted for six months in 2011, from late April to early October (McMurray et al., 2013). Average daily demand was also three MGD higher than usual during this time (McMurray et al., 2013). Aqua WSC pump run times hit 85%, compared with an average 65% during typical summers (McMurray et al., 2013). Line leaks increased by 20%, due at least in part to soils shifting in dry conditions; Aqua WSC considered all these leaks ‘emergencies,’ due to a potential shortage of chlorine supplies (McMurray et al., 2013).

Austin Water Utilities (AWU) also experienced a variety of heat and drought impacts. This included increased pipeline breaks, hot temperatures affecting blowers, and the need to change staff scheduling to minimize heat exposure (Slusher, 2013).

Meanwhile, the San Antonio Water System (SAWS) estimated a 20-44% loss of water supply during the 2011-2013 Drought (Guz, 2013). As locating new water supplies is both

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8 Organic contaminants from low water levels are more difficult to remove if derived from synthetic or chemical sources, rather than natural or biological sources (Wilcox, 2013).

expensive and challenging, the utility had to re-strategize how to supply water during all kinds of weather conditions (Guz, 2013).

Water utilities struggled to meet demands by users competing for increasingly diminished supplies throughout the 2011-2013 Drought. This necessitated emergency response, but also demanded the revision of long-term water management planning.

Utility and Community Response

Effective drought management involves two elements: long-range supply and demand planning, and short term response. In fact, the State of Texas requires communities to adopt both long-range water conservation plans and short term drought management plans. Historically, however, utilities in Texas typically implemented drought plans only once amidst drought. Unlike many extreme climate/weather events that primarily require immediate action – floods or wildfires – followed by long-term future mitigation and adaptation measures, the 2011-2013 Droughts demanded quick response actions to control immediate water demand, as well as sustained demand management to replenish water supplies.

Actions Taken – Emergency Response / Short-Term Responses

Annex A of the Texas' State Plan includes an Emergency Drinking Water Plan and State Drought Plan (Bewley, 2013). Thus, immediate response to the 2011-2013 Drought sought to control demand by prioritizing and balancing user needs throughout Central Texas. Water utilities essentially worked to maintain diminishing water supplies. Strategies centered on voluntary conservation, demand reduction, release restrictions, and altering water fees.

Aqua WSC implemented voluntary conservation beginning in Summer 2011, re-implemented a metering program previously used in 2008, minimized redundancy, and adjusted both construction schedules and storage set points to meet peak flows early (McMurray et al., 2013). Aqua WSC to continuously reassessed management plans and successfully maintained a constant and reliable supply service from groundwater supplies by closely monitoring aquifer levels throughout the Drought (McMurray et al., 2013).

The SAWS's short-term response to the Drought focused on demand reduction management. San Antonio relies largely on groundwater from the Edwards Aquifer for its municipal supply. Other supplies include: the Carrizo Aquifer, the Trinity Aquifer, Canyon Lake, Lake Dunlap, and an Aquifer Storage and Recovery (ASR) facility.

Water Utilities and Institutions Participating in the Central Texas Region Workshop

Aqua WSC – Aqua Water Supply Corporation

AWU - Austin Water Utilities

BS/EADC - Baton Springs / Edwards Aquifer Conservation District

GCDs - Groundwater Conservation Districts

LCRA - Lower Colorado River Authority

SAWS – San Antonio Water System

TCEQ - Texas Commission on Environmental Quality

Water supplies pumped from the Edwards Aquifer are curtailed at certain drought triggers (Figure D-5) (Guz, 2013). In the absence of rain (and natural recharge for the Edwards Aquifer), water levels drop due to continued withdraw from cities – including San Antonio –, irrigation, and industries. When measuring wells indicate aquifer water levels drop below certain mean sea levels ("Edwards Stage," Figure D-5), pumpers must reduce their withdrawals by a certain percent ("Edwards Supply," Figure D-5). Depending on other factors and the utility's ability to meet demand with other supplies, this may result in customer water use restrictions ("City Restrictions," Figure D-5).[9] During the 2011-2013 Drought, most customers supported and complied with these drought restrictions (Guz, 2013).

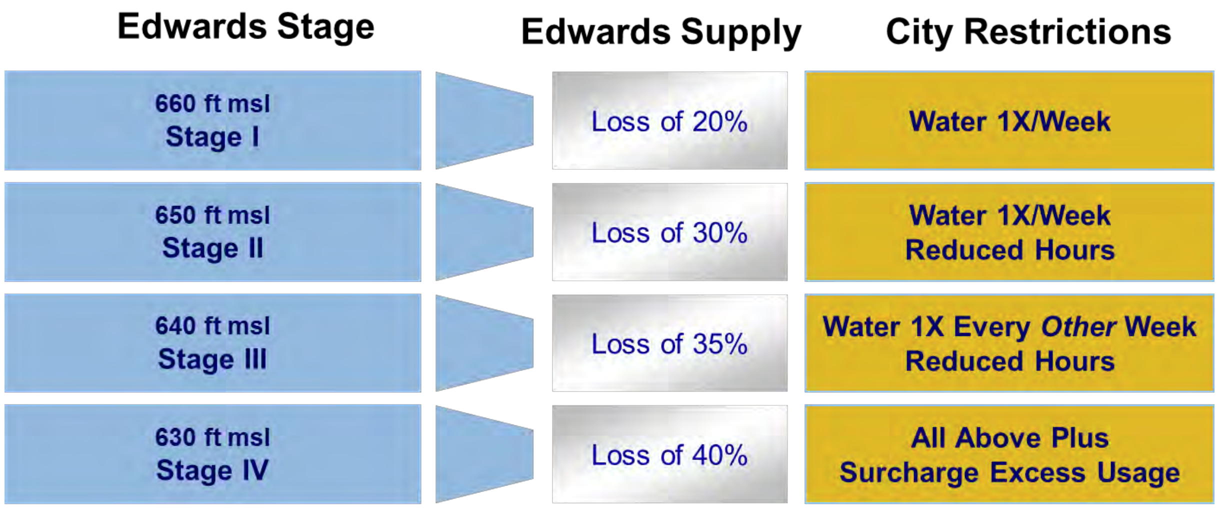

Figure D-5. SAWS Demand Management Strategy to Reduce Demand During Reduced Supply Periods.
Credit: San Antonio Water System
Source: Guz, 2013.

The SAWS's Drought Management Team further convened weekly meetings between nine separate departments, allowing for information sharing and strategy development to ensure a rapid response to changing conditions and provide operational and policy recommendations to the Executive Management Team (Guz, 2013). Continued planning and supply scheduling helped reduce consumption during the summers of 2011 and 2012. This demand reduction slowed declines in aquifer water levels and resulted in water savings at a cost of approximately $100/AF for the utility (Guz, 2013).

The LCRA, altered its 2010 Water Management Plan (WMP), the strategy that guides operations and water releases from the Highland Lakes. Adjustments curtailed releases in 2012 and 2013 to those agricultural customers deemed interruptible (Slusher, 2013). The City of

[9] Figure D-5 represents a framework, rather than set rules, for the relationship between water levels, the SAWS's pumpage permits, and user restrictions. City restrictions do not necessarily correspond to the stage and supply loss levels. For instance, water levels in the Edwards Aquifer may be at Stage III and the utility under a 35% reduction in the supply of water they are allowed to pump, but customers may still be allowed to water once a week depending on weather patterns, and the SAWS's flexibility to meet demand through other supplies (Guz, 2013. Regulations guiding this framework changed during the 2011-2013 Drought; triggers are now determined from a 10-day rolling average of water levels in the Edwards Aquifer (Guz, 2013).

Austin supported these efforts and worked with the LCRA and other stakeholders to address water user needs, while also reaching conservation targets (Slusher, 2013).

In Austin, a community known for its innovation and conservation ethic, Austin Water Utility (AWU) responded to the prolonged dry conditions through a revision of revenue structure and water restrictions. In 2011, AWU added a revenue-stability fee to customers' bills to fund fixed utility costs, such as debt services, contractual services, transfers, and personal costs (Slusher, 2013). AWU subsequently eliminated this fee in 2012 with the adoption of a residential-tiered minimum charge based on monthly water usage. This resulted in a lower charge for low water users and a higher charge for high water users (Slusher, 2013). It further redefined the pricing blocks that categorize water use. Though up to 9,000 gallons of water use previously fell under Block 2 rates, anything above 6,000 gallons became a Block 3 category, accruing higher charges (Figure D-6) (Slusher, 2013).

Volume Rates: ($ / 1,000 gals.)	Existing	Proposed	2012 Rates	2013 Rates
Block 1:	0 - 2,000	0 - 2,000	$1.17	$1.25
Block 2:	2,001 - 9,000	2,001 - 6,000	3.08	2.80
Block 3:	9,001 - 15,000	6,001 - 11,000	7.92	5.60
Block 4:	15,001 - 25,000	11,001 - 20,000	10.95	9.40
Block 5:	25,001 and over	20,001 and over	12.19	12.25

Figure D-6. Austin Water Utility's Water Rate Structure: Adjusted Residential Volumetric Blocks.
Source: Slusher, 2013.

The Barton Springs / Edwards Aquifer Conservation District (BS/EACD) also imposed pumping restrictions. Through their Drought Management Program, BS/EACD utilized data analysis to tailor strategies for managing the Edwards Aquifer based on changing local conditions (Holland, 2013). Different drought stages indicated varying requirements for residential water use (e.g., number of outdoor watering days allowed per week). By early March 2013 the BS/EACD hit Drought Alarm Stage II, which required permittees to curtail monthly pumpage by an additional 20% (Figure D-6). This dropped non-essential water uses to 1,000 gallons/month below the Alarm Stage I permit of 2,000 gallons/month (Holland, 2013).

Urban users purchased primacy rights, or water available during times of drought. Because users could purchase this additional water, this resulted in a false perception of sufficient water availability, eventually resulting in tension between urban purchases and downstream agricultural users.

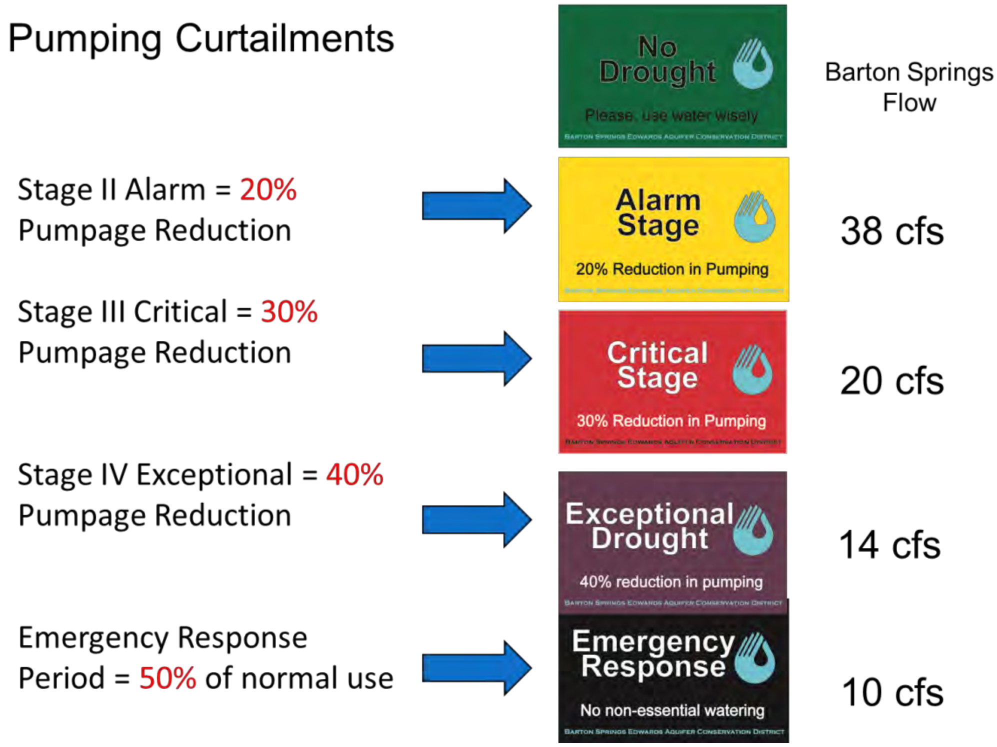

Figure D-7. BS/EACD Drought Alarm Stages and Pumping Curtailments.
Credit: Barton Springs / Edwards Aquifer Conservation District.
Source: Holland, 2013.

The LCRA authorized the Texas Commission on Environmental Quality (TCEQ) to diverge from regular water management plans, resulting in a 4,000 AF deficit in irrigation releases (Gerston, 2013). In early 2013, another state-wide drought emergency order curtailed 22,000 AF of irrigation (Gerston, 2013). The State of Texas deemed such orders necessary because the irrigation releases, coupled with climatic and hydrologic conditions, would cause lake storage to fall below record drought levels (Gerston, 2013). This meant that irrigators at all crop stages were cut off completely, while 'firm water' customers cut usage by 20% (Gerston, 2013). The agriculture community long-standing work to reduce water losses by updating irrigation equipment and adopting practices such as laser leveling fields assisted in water conservation during this time.

Conflict between user demand and environmental flow requirements resulted in a state-mandated release of 8,684 AF from Lakes Buchanan and Travis to ensure the health of Matagorda Bay in September 2013 (Texas Drought, 2013). The LCRA Board then petitioned TCEQ for emergency relief from future release requirements during drought (Texas Drought, 2013).

The State responded by instigating a long-term drought emergency. Governor Rick Perry invoked portions of Texas Government Code Section 418 to "renew the disaster proclamation and direct that all necessary measures, both public and private as authorized under Section

418.017 of the code, be implemented to meet that threat. As provided in Section 418.016 of the code, all rules and regulations that may inhibit or prevent prompt response to this threat are suspended for the duration of the state of disaster" (Perry, 2013). Once immediate demand control measures were in place, communities, utilities, and local governments turned to more long-term actions to manage demand over time. In many cases this meant a constant re-evaluation of management techniques, with several shifts in action.

The LCRA maintained an updated, active website throughout the 2011-2013 Drought (Walker, 2013). The website sought to inform farmers of water release restrictions, as well as the overall intensity of the Drought and the institution's response (Walker, 2013). The LCRA also began projects to drill wells and construct a new reservoir downstream of Austin in an effort to obtain new water supplies and prevent future drought impacts (Texas Drought, 2013).

> *"We prepared and were sometimes ahead of the game. That helped immensely, but events still forced us to make adjustments."*
>
> *– Daryl Slusher, Austin Water Utility*

Actions Taken – Long-Term Planning and Long-Term Responses

Building supply resiliency over time contributed to Austin's success in responding to the Drought (Slusher, 2013). Supply resiliency strategies included signed agreements with the LCRA in 1999 and 2007 regarding river rights and return flows, as well as an official partnership with the LCRA to help manage future water supplies in a cooperative manner (Slusher, 2013). The agreements established new watering restrictions in 2007-2008: yearly permanent restrictions and Stage 1 drought restrictions. The city successfully utilized these pre-established restrictions during the 2011-2013 Drought, such as limiting the number of days per week and times people watered their lawns (Slusher, 2013).

AWU began the development of a third water resource recovery facility to directly engage in highly treated wastewater reuse actions (Slusher, 2013). The 51st Street Storage Tank currently uses more than one billion gallons of reclaimed water annually, serving the University of Texas and other institutions (Slusher, 2013). Reclaimed water provides supplies for irrigation, cooling, and manufacturing. The utility paints reclaimed water pipes purple, distinguishing them from the City's potable water system and encouraging public awareness and support. AWU plans to extend reclaimed wastewater services through 130+ miles of pipelines, seven tanks, and treatment for 5.5 billion gallons of water per year (Slusher, 2013). This will protect water resources and supplement water supplies during future droughts. Since 2009, Austin further conserved water by curtailing use to around half the city's annual water rights dictated by LCRA agreements (Slusher, 2013).

The BS/EACD worked to strengthen plans for recurrent droughts, aligning regulatory requirements according to groundwater action levels (Holland, 2013). Important considerations in such planning were well permits that included a water balance, conservation/compliance credits and rebates, and fines for breaking permits. The institution sent monthly notices to non-compliant permittees and held targeted compliance meetings (Holland, 2013). Other long-term drought response strategies included increasing water bills through conservation tiers, *Reductions in water use not only saved Spansion money in the absence of high water bills, but also eased some of the pressure on Austin Water Utility to meet high demand in a time of scarcity.*

establishing flow restrictors, temporarily disconnecting services, and issuing citations for wasting water (Holland, 2013).

Large Water Users Adopt Conservation Practices

Prior to the onset of the Drought in 2011, the private sector realized the need to protect itself from the rising cost of scarce water supplies. One microchip company, Spansion, evaluated its water use and adopted a cutting-edge suite of practices, the FAB25. The FAB25 system increased energy and water efficiency, recovered contaminants from process wastewater for resale, and enabled water reuse (Wilcox, 2013). Though not a direct response to the 2011-2013 Drought, Spansion's practices reflect a long-term strategy industries can take in areas increasingly susceptible to prolonged dry conditions that threaten water production supplies, such as Central Texas.

Such a forward-looking approach placed the company at an advantage during the 2011-2013 Drought: Spansion successfully continued to meet production needs while using less water. Reductions in water use not only saved Spansion money in the absence of typically high water bills, but also eased some of the pressure on AWU to meet high demand in a time of great scarcity. Spansion reuses 1.3 million gallons of water per day. Since 2008, this project has decreased its purchase of city water by 22% (Wilcox, 2013). In 2012, about 60% of water use – or 561 million gallons of reclaimed and reused wastewater – saved Spansion nearly $6.4 million (Wilcox, 2013). This was the first time the company used more reclaimed and reused water than water purchased from the Austin (Wilcox, 2013).

Despite innovative short and long-term response measures among utilities and cities throughout Central Texas, the 2011-2013 Drought resulted in several primary and secondary impacts.

2011 Wildfires

Wildfires occurred primarily due to severely low field moisture, and were one of the most destructive consequences of the 2011-2013 Drought. Prolonged dry conditions and low water supplies left counties throughout Central Texas "extremely susceptible" to wildfire threats; 2011 was a particularly devastating year (McMurray et al., 2013).

Impacts to the Environment

Wildfires in several counties ravaged ecosystems and damaged more than 1.5 million trees. Loss of root structure and vegetation resulted in erosion, increased sedimentation in rivers, altered organic matter, and compacted water-repellent soils (Voytko, 2012). Such effects have a ripple effect on the quality and quantity of source water in previously forested areas (Voytko, 2012).

Impacts to the Community

In April 2011, wildfires in Oak Hill destroyed 100 acres and 10 homes (Slusher, 2013). On Labor Day 2011, fires blazed through Steiner Ranch and Bastrop County. Steiner Ranch lost about 160 acres and 23 homes, while Bastrop County fires killed two people and destroyed 35,000 acres and more than 1700 homes (Slusher, 2013). Fires in Bastrop County had a 16-mile front line and moved at five miles per hour (Jervis, 2012). The three converged fires in Bastrop County were the "costliest and most destructive blaze in Texas history and the third most destructive in the U.S.," breaking the state's previous record in an April 2011 fire west of Dallas (Jervis, 2012). Property damage totaled $360 million.

Impacts to Water Utility

As fires moved through communities, some utilities lost power. Water meters melted and pipes burst due to increased pressure (McMurray et al., 2013). Utilities issued a boil water notice for immediate safety precautions due to degraded water quality and the need for increased treatment.

Figure D-8. The National Guard Dumps Water Buckets on Wildfires Burning Near Homes in Bastrop County, 2011.
Credit: Staff Sgt. Malcolm McClendon.
Source: The National Guard, 2011.

Utility and Community Response

During the 2011 Bastrop County wildfire, a well-prepared emergency response team evacuated 5,000 people in less than three hours. The Bastrop County Office of Emergency Management requested essential personal by the afternoon of September 4th, and completed initial response and planning recovery plans by midnight (McMurray et al., 2013).

Aqua WSC personnel reported to work early on Labor Day. The utility paired together employees and required check-ins three times a day to ensure safety (McMurray et al., 2013).

Firefighters assisted water utility personnel and vice-versa. Firefighters reported melted meters and pipes spewing water; utility personnel protected by firefighters restored water pressure (McMurray et al., 2013). Personnel successfully recovered the full water system within a week. The utility accomplished this by using generators, repairing and re-pressurizing the system, and using Bac-T (McMurray et al., 2013). Aqua WSC then lifted the boil water notice

Wildfires in 2011 demonstrated the importance of established relationships and shared knowledge between emergency responders and water managers. Collaboration among TexasWARN, the City of Austin, AWU, Travis County, the City of Bryan, and Bluebonnet Electric allowed for rapid response. Coordination between firefighters, law enforcement, and private contractors yielded the generators, radios, and extra personnel necessary to identify leaks and inoperable hydrants (McMurray et al., 2013). The fires left utilities and cities working towards even further collaboration by establishing pre-event terms of response and agreements.

Plans were made to plant one million seedlings over the next four years in order to restore the forests to previous conditions. Nevertheless, trees near homes that could threaten future fires were removed in Bastrop County (Jervis, 2012). Seven months after the fire, neighborhoods began reconstructing homes and removing cars still abandoned along roadsides (Jervis, 2012).

Decisions, Challenges, and Gaps

The 2011-2013 Drought and 2011 Wildfires bore light on the increasing severity of extreme events in the Central Texas Region, and subsequent challenges and gaps in decision-making processes.

Climate-Driven

A number of the challenges and gaps are related specifically to climate-driven factors.

Extreme Events and Water Measurements

Knowing how much water is available, when it is available, and what makes that supply vulnerable are key pieces of information when balancing conflicting interests and user demands. Real-time measures of surface water flows assist in this process. For groundwater, two types of measures are particularly important: metered measurements of actual groundwater use for non-exempt wells, as well as period estimates of non-metered exempt use (Holland, 2013). Combined results from surface and groundwater measurements determine the amount of water available and influences decisions on how to distribute that water.

Water Service and Resource-Based

A number of the challenges and gaps are related specifically to resource-based factors.

Environmental Needs and Ecosystem Services

Water releases regulations for Matagorda Bay on the state’s eastern coast is one of the most significant factors that affect water levels in Lakes Buchanan and Travis. The Texas Commission on Environmental Quality (TCEQ) regulates these important environmental flow requirements; the Bay is one of the nation’s largest, and supports a diverse aquatic ecosystem. Thus, even amongst user demands and tensions during the 2011-2013 Drought, TCEQ mandated releases to protect the health of Matagorda Bay (Texas Drought, 2013). Among other such mandates, the decision demonstrates the State’s recognition of and reliance on important ecosystem services. Ecosystem protection throughout the Lower Colorado River and extending to the coast therefore remains a crucial decision-driver in the region.

Maintaining Utility Revenues During Shortages

Though the 2011-2013 Drought demonstrated a need for increased, more efficient water conservation throughout Central Texas, such measures did not evolve without cost. In this case, water utilities bore the brunt of such cost. The severity of water scarcity in Austin required conservation among users. The need for water conservation inspired research into water distribution systems as well as water reuse strategies (Breakout Sessions, 2013). However, when users conserved and purchased less water, utilities lost revenue and struggled to maintain operations (Breakout Sessions, 2013). A major challenge thus emerged: how to fund utilities while selling less water to users.

This issue is likely to deepen in the event of more frequent, prolonged droughts throughout Central Texas. While utilities managed during shortages in 2011-2013, meeting operating costs with decreased funding over time requires additional consideration in the state's future water conservation planning efforts.

> *"You can't manage what you don't measure"*
>
> *– Kirk Holland,*
> *Barton Springs/Edwards Aquifer Conservation District*

Meeting Agricultural Needs While Conserving Water

Water restrictions challenged governments to balance competing interests and meet user needs. Water shortages and the need to limit access inevitably means some users 'lose out;' this was the rice farmers in 2012-2013. Irrigation curtailments, authorized by the LCRA, while deemed necessary, severely impacted agricultural production in those years. Many asserted that, given the likelihood of future droughts in the Central Texas Region, the State must take "active measures to preserve sustainable agricultural water supplies or face potentially dire food and fiber shortages in the future" (Gerston, 2013). Regulatory supply cutbacks and decreased water quality further threatens the complexity of such supply sustainability (Guz, 2013).

Political and Intergovernmental

A number of the challenges and gaps are related specifically to political and intergovernmental-based factors.

Focus on Shortage Preventions

The long duration of the 2011-2013 Drought sparked a shift in thinking from merely immediate drought management to more long-term planning and water shortage prevention in cities throughout the region (Bewley, 2013). This presents a new challenge for the Central Texas Region. Though in many ways, the 2011-2013 Drought helped make the case for conservation measures, balancing water demands while managing drought remains difficult. Political pressure and the desire to meet user needs "can drive water management decisions in ways that contradict sound science" (Gerston, 2013). While state agencies are working to adapt to crisis needs, federal agencies continue to grapple with prevention problems (Bewley, 2013).

‘Real-Time’ Coordination and Response

Coordinated response based on information sharing proved a difficult issue during the 2011-2013 Drought. There is a historical “lack of coordination in ‘real-time’ response to [the] evolving impacts of drought” in the Central Texas Region (Brown, D., 2013). Though several service-providing entities such as NOAA, state climatologists, USDA, DOI, NGOs, local government, and private institutional agencies have a strong presence in the region, these institutions do not always work together to share information and alter management plans. The 2011-2013 Drought, however, “created an opportunity to coordinate a multi-faceted, regional response among multiple partners” (Brown, D., 2013).

Socioeconomic

A number of the challenges and gaps are related specifically to socioeconomic factors.

Perception of ‘Plenty of Water’

Utilities in the Central Texas Region are working to establish a strong water conservation ethic. Despite dire drought conditions, consumers tended to retain the perception that ‘plenty of water’ exists. This was largely due to the fact that most users retained a sustained, sufficient supply of water during the three-year drought. Communities curtailed outdoor water use; however no taps went completely dry (Bhattarai, 2013). A combination of factors led to this, including the ability of urban users to purchase primacy rights and utilities conserving water through reclaimed water use.

Workshop participants noted the difficulty and importance of building a new ethic of water conservation. Utilities cited various potentially useful approaches to change individual behavior and alter the public’s perception on water availability: fees, prices, and learned conservation behaviors through tools such as real-time water use alerts (Breakout Sessions, 2013). Participants noted the necessity of research into understanding individual motivations is to better assess which approaches are most applicable in different communities (Breakout Sessions, 2013). They further asserted that utilities and cities must work together to develop a base public understanding of where their water comes from, how much water is available, and what water risks currently exist (Breakout Sessions, 2013).

Awareness programs that stress three things – the shared nature of groundwater and surface water resources, that resources are already strained, and that these affect everyone – will be most effective in creating this new water conservation ethic (Holland, 2013). Other strategies included in discussions were facilitated workshops, discussions, and information portals; these help promote accurate perceptions of water issues (Breakout Sessions, 2013). Workshop participants stressed that for the Central Texas Region, conservation must become a way of life, rather than a temporary management strategy during drought.

Information Needs

Workshop participants in Central Texas brainstormed the following information needs as some of the most important for improved resiliency to extreme climate/weather events:

- Studies that evaluate the socioeconomic impacts of drought.
- Formal analysis of reservoirs.

- Guidance for structuring water rates to provide adequate revenue while incentivizing conservation.
- Improved precipitation monitoring to support adaptive management.
- Local (vs. regional) monthly projections, seasonal, and long-term forecasts of drought parameters.
- Translating data from models and gauges into useful reports to bridge the gap between researchers and stakeholders.
- Literature that promotes awareness, adaptation, and mitigation strategies.
- Strategies to increase the American public's awareness on where their water comes from.
- Increasing the understanding of the water sector among the emergency management sector.
- Promoting a more integrated dialogue across key energy and water providers.
- Federal government recognition of drought as an emergency situation.

Partnerships and Collaboration

Texas' Central Region is home to the diversity of stakeholders reliant on water resources from the Lower Colorado River Basin. As demonstrated during events from 2011-2013, extreme climate/weather affects the water quality and water supply of industries, communities, and ecosystems. Such impacts create the potential for conflict during times of shortage, but also present opportunities for collaborative water management. The variety of stakeholders and water demands in Texas' Central region render participation in regional planning essential to the protection and sustainable use of water resources (Holland, 2013).

Collaboration through partnerships allowed the Central Region to effectively respond to the 2011-2013 Drought and look towards more sustainable water resource management in the future (Holland, 2013). Best management practices began to emerge with a consideration of cross-jurisdictional differences and by "calibrating local risks and regional benefits" (Holland, 2013).

The 2011-2013 Drought and 2011 Wildfires particularly demonstrated the value such collaboration. Firefighters and water utility employees worked side by side to restore pipe pressure and water meters. The Barton Springs / Edwards Aquifer Conservation District (BS/EACD) worked with water suppliers throughout the district to conserve water, while simultaneously meeting end user needs (Holland, 2013). Partnering with the San Antonio Police Department and municipal courts allowed the SAWS to implement drought management plans, providing backbone for regulation and enforcement in an efficient and fair manner (Guz, 2013).

Long-term awareness and regulatory initiatives were equally crucial in response efforts. For instance, the Southern Climate Impacts Planning Program (SCIPP) – a six-state research program that increases resilience within the southern region of the U.S. – held numerous web seminars on topics related to La Niña, droughts, water resources, wildfires, seasonal forecasts, and others (Brown, D., 2013).

The City of Austin and the LCRA established an official partnership in 2007. This joint-planning arrangement allows the City of Austin and the LCRA to "cooperatively manage future water supplies while being mindful of other needs in the basin, including environmental needs" (Slusher, 2013). This partnership helped to settle disputes over return flows for water resource recovery facilities in Austin. It further laid groundwork for the 2007 Supplemental Water Supply

Agreement which included planning for additional water supplies for Austin until 2100 (Slusher, 2013).

Such partnerships allow for more natural collaboration during events, but also ensure more sustainable water resource management over time.

> *"Expect the unexpected. Build partnerships and establish communication procedures ahead of time. So that when the time comes and you have to call an institution at 2am in the morning, they will actually pick up that phone and deliver that badly needed generator."*
>
> *– Rajendra Bhattarai,*
> *Austin Water Utility*

Lessons Learned

Lesson Learned: Develop Drought Management Plans before drought strikes and *implement plans according to drought stage triggers.*				
Outcomes / Findings	**Successes**	**Weaknesses / Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Reporting frequency depends on what effective management response requires (Holland, 2013). • It is important to "differentiate groundwater drought from other types of drought" for effective public communication and drought management (Holland, 2013). • Well permitting is essential for aligning regulatory requirements and groundwater droughts (Holland, 2013).	• San Antonio held weekly meetings for information sharing and strategy development. • High frequency reporting for sustained droughts increased monitoring accuracy. (Holland, 2013). • Partnered with police departments and municipal courts for drought restriction enforcement and efficiency (Guz, 2013).	• Water conservation is often confused with drought management. • Lack of quantification of drought impacts on system's water supply sources" (Guz, 2013).	• Establish regulatory programs for drought management that are responsive, fair, enforced, and require measurements and actual drought-time use reporting (Holland, 2013). • "Consider response times (to changes in pumping) as well as the amount of inputs/ outputs, relative to triggers" (Holland, 2013). • Use real data to examine aquifers as systems and respond to aquifer drought in a dynamic manner (Holland, 2013).	• Pre-establish a Drought Management Team for rapid response during changing conditions. • Tailor strategies to aquifers and regions, when possible (Holland, 2013). • Aquifer storage and recovery offers potential to bank water in plentiful times for use during drought periods. • Integrate drought management into the regulatory program and bottom-up regional planning (Holland, 2013).

Lesson Learned: Extreme climate/weather can have *secondary and tertiary impacts* (e.g., droughts produce wildfires), requiring more coordination and collaboration to improve resiliency.				
Outcomes / Findings	**Successes**	**Weaknesses / Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Integrated planning between water, agriculture, energy, health, and emergency services improves resiliency. • Radios are more reliable and effective than cell phones; these can coordinate frequencies with emergency management teams, lines remain unjammed, and batteries last longer.	• Facilitated workshops helped to share strategies among different stakeholders (Breakout Sessions, 2013). • Web seminars discussed and taught approaches to adaptation – smaller jurisdictions can learn from other jurisdictions that are farther along (Breakout Sessions, 2013). • Used games such as "Drought Tournament" in which participants assume different roles to understand varying perspectives and increase collaborative approaches (Breakout Sessions, 2013).	• Reporting field issue locations is difficult when mailboxes, houses, and other landmarks were burned during wildfires. (McMurray et al., 2013). • Need good planning guides that identify goals and key strategies water industries and programs use to mitigate and adapt to changing climates (Breakout Sessions, 2013).	• Have 96-hour survival plans, work w/local emergency management operators, "form an ad hoc cross functional team" and know contractor's plan if you have one (Bewley, 2013) • Instigate Incident Command System training, get to know local emergency management personal and establish plan to "immediately assimilate into IC system" (McMurray et al., 2013). • When in doubt, use LIPS strategies: promoting life safety, incident stabilization, property protection, societal restoration (McMurray et al., 2013).	• Use GPS devices instead of landmarks to verify and report field service locations. • Establish an information portal that provides good planning guides and strategies on adaptation measures (Breakout Sessions, 2013).

Lesson Learned: *Public awareness* of drought, as well as *support and reception of conservation measures* improves water management plans and ensures sustainability of water resources.				
Outcomes / Findings	**Successes**	**Weaknesses / Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Conveying information through trusted sources improves public reception of drought. Trusted sources vary by community. • Rate structures can incentivize conservation, while maintaining adequate revenues for utility operations. • It is vital to understand the roles of and build relationships among community service providers.	• Georgetown's real-time water use alerts notify users when they exceed certain limits. Round Rock's real-time water use alerts users of their hourly water use. • Media-specific web seminars in April and May 2011, press conferences and outlook forum advisories, participation in NOAA's winter outlook teleconference increased public awareness (Brown, D., 2013)	• Public acceptance of conservation as a way of life. • Urban areas lack understanding of agriculture, exacerbating drought problems. • How do we more effectively communicate the uncertainty of water? (Breakout Sessions, 2013).	• Use the news media as an important partner in raising public awareness. • Study base understanding of public regarding water knowledge – supplies, access, risks, etc. (Breakout Sessions, 2013).	• Work with public to build a new water conservation ethic. • Year-round water conservation that addresses season to season shortages, not just management during drought events.

Looking Forward

During the 1952 drought, fewer than 10 million people lived in Texas. Drought onset in 2011 occurred with a population of 25 million that is projected to grow to 46 million by 2060. The increasing frequency of drought in the Central Texas Region, coupled with a growing urban population, necessitates a strategy in which water conservation is standard operating procedure. The prolonged 2011-2013 Drought and subsequent Wildfires of 2011 demonstrated the need for long-term conservation.

Water utilities and cities worked to balance conflicting user demands, prioritize water needs, adjust rate structures to reflect the true value of scarce water, and combat the ‘plenty of water’ perception throughout the Central Texas. While such short and long-term response measures were both impressive and successful adaptation strategies, the severity and length of the Drought marked the need for a more sustainable shift in water management. Climate projections indicate decreased precipitation and increased heat in the Central Texas Region. Short-term event management is no longer sufficient; Central Texas must prepare for the reality that extreme climate/weather events are likely to increase in frequency and duration throughout the region.

Conservation must be viewed as a drought management strategy, but perhaps more importantly as a way of life to support a vibrant economy and the beautiful natural resources that sustain it. Area water managers recognize this – building public acceptance is the challenge that lies ahead.

Finally, while utilities reported many lessons learned from the 2011-2013 Drought and 2011 Wildfires, they also express the need for Central Texas to move towards adaptation for all kinds of extreme climate/weather events. The 2011-2013 Drought represents major challenges currently facing the region; however the state must also prepare for inevitable flooding (Bhattarai, 2013).

WATER UTILITY PROFILES: CENTRAL TEXAS WORKSHOP PARTICIPANTS

Aqua Water Supply Corporation (Aqua WSC)	
Overview	Aqua WSC is a non-profit water supply company working with local governments, regional water utilities, civic groups, schools, and police to ensure safe, reliable drinking water and wastewater services. The corporation works to practice and promote conservation through Texas' 'Water Wise' conservation program. Established in the 1970s, Aqua WSC was part of the U.S. Farm and Home Administration's effort to bring safe, affordable water to rural areas.
Location	Headquarters: 415 Old Austin Hwy, Drawer P, Bastrop, TX 78602 http://www.aquawsc.com/
Operations Conducted	Conservation Drinking water distribution Wastewater management
Size	• Service Area: 953 square miles covering parts of six counties: Bastrop, Travis, Lee, Caldwell, Fayette, Williamson • Connections: 18,079 connections serving over 50,000 residents • Pump Stations: 24 • Storage Tanks: 44 (22 ground, 22 elevated) • Storage Capacity: 14, 285,800 • Pipelines: 1,711 miles of mains • Wells: 29
Administrative Structure	Elected by cooperative members, Aqua WSC's eight-person board is comprised of members from each of the utility's service zones. This Board of Directors has managed Aqua WSC's over $85 million in system investment.
Austin Water Utility	
Overview	Previously served by a private water company, the City of Austin bought out this institution following a 1900 flood, establishing Austin Water Utility. Today, Austin Water Utility provides retail and wholesale water services, as well as wastewater permits and water reclamation options for residents and commercial customers throughout Austin and neighboring areas. Austin Water promotes conservation through many tactics, such as the Water Conservation Task Force, offering customers Drought Survival Moisture Meters, and awareness programs in service area communities. Austin Water also manages the Hornsby Bend Biosolids Facility, which takes a portion of the effluent sludge out of the regular wastewater facilities to create a recycled compost for land use and public sale.
Location	Headquarters: 625 E 10th St Austin, TX 78701 http://austintexas.gov/department/water
Operations conducted	Biosolids redistribution and reuse Conservation awareness Drinking water treatment and distribution Wastewater management Water reclamation and recycling

Size	• Service Area: 538 square miles, including much of Austin and surrounding communities, such as Rollingwood, Sunset Valley, five water supply corporations, seven municipal utility districts, and three private utilities. • Connections: 200,000 serving ~890,000 customers • Storage Capacity: 167 million gallons • Pipelines: 3,714 miles of mains (652 miles of transmission, 3,062 miles of distribution • Sewer Pipelines: 2,693 miles of mains (2,614 miles of gravity, 78 miles of force) • Treatment Plants: 5 (Four currently, fifth in progress) • Treatment Capacity: 150 MGD at South Austin Regional, Walnut Creek, Ullrich, and Davis wastewater treatment plants, soon to increase with the completion of Wastewater Treatment Plant 4
Administrative structure	The City of Austin owns and operates Austin Water Utility. Nine divisions covering areas such as customer service, utility development, wildland conservation, and others handle the daily tasks of the utility.
Barton Springs/Edwards Aquifer Conservation District (BS/EACD)	
Overview	BS/EACD formed in 1987 as a Texas Groundwater Conservation District (GCD) under Senate Bill 988. Directed to protect and conserve groundwater resources within its jurisdiction, the BS/EACD covers the unconfined, recharge and confined zones of the Barton Springs segment of the Edwards Aquifer. This also includes all wells, natural outlets, and smaller springs, but does not include the contributing zone.
Location	Headquarters: 1124 Regal Row, Austin, TX 78748 http://www.bseacd.org/
Operations conducted	Monitors and collects data on the Edwards Aquifer Conducts reduction, conservation, and recharge programs Promotes community awareness and education on groundwater resources and drought Manages a regulatory program that handles drought, tracks pumpage and ensures compliance, makes rules, provides inspections, permitting, and enforcement, as well as drilling oversight.
Size	• Service Area: 247 square miles, serving Bastrop, Caldwell, Hays, and Travis Counties. • Employees: ~11
Administrative structure	A five-member Board of Directors oversees the BS/EACD. Serving staggered four-year terms, board members are elected by registered voters in the district's five precincts. Five staff teams – General Management, Administrative and General Services, Aquifer Science, Education and Community Outreach, and Regulatory Compliance – conduct daily operations, reporting directly to the General manager.
City of Bastrop's Water and Wastewater Department	
Overview	Bastrop's Water and Wastewater Department withdraws groundwater from an alluvium of the Colorado Rive3r to supply drinking water to customers. The Department focuses on drought management and conservation through regularly updated water management plans.

Location	Headquarters: 300 Water Street, Bastrop, TX 78602 http://www.cityofbastrop.org/default.aspx?name=water.home
Operations conducted	Drinking water Wastewater management
Size	• Service Area: ~10 square miles, serving • Connections: 2,867 serving 8,700 residents in the City of Bastrop • Pipelines: 68 miles of transmission and distribution mains • Groundwater Wells: 7 • Sewer Pipelines: ~54 miles of mains (46 miles of gravity lines, 7.78 miles of force lines) • Wastewater Treatment Plants: 2
Administrative structure	Acting under the authorization of the City Council, the Director and Superintendent oversee this department.
City of Waco Water Utility	
Overview	The City of Waco Water Utility withdraws water from Lake Waco to provide drinking water for residents in Waco and surrounding populations. The utility focuses on water conservation, drought management, lake operations, and wetland protection and restoration.
Location	Headquarters: 425 Franklin Avenue, Waco, TX 76701 http://www.wacowater.com/
Operations conducted	Drinking water treatment and distribution Stormwater management Wastewater management Water quality testing Watershed protection
Size	Water Quality Laboratory Riverside Treatment Plant- (24 mgd)- from Lake Waco Mount Carmel Treatment Plant- (42 mgd) Drinking Water Pipeline System- 900+ miles Waste Water Pipeline System- 800+ miles WMARSS Wastewater Treatment Plant • Service Area: Waco and surrounding areas • Pipelines: 900+ miles of mains • Treatment Plants: Mount Carmel, home to the Water Quality Laboratory • Sewer Pipelines: 800+ miles of mains • Wastewater Treatment Plants: 1, jointly operated by Waco and surrounding communities
Administrative structure	A team of 18 managers, supervisors, and administrators manage the day-to-day operations of the Waco Water Utility's programs.
Lower Colorado River Authority	
Overview	Providing energy, public space, and wholesale water to various groups as a state created conservation and reclamation district, the LCRA provides power and water up and down a six hundred mile stretch of this historic water supply. Specific to water, it operates six dams and many pipelines to allow both for flood control but proper water distribution and management to

	a variety of agricultural, industrial, and municipal stakeholders.
Location	Headquarters: 3700 Lake Austin Blvd., Austin, Texas 78703 Online: http://www.lcra.org/
Operations Conducted	Water Level Control Lake Management Wholesale Water Sale
Administrative structure	A 15-member board of directors shapes the long-term objectives of the organization while a general manager oversees the general operations. These board members also tend to serve on affiliated organizations that heavily use the LCRA's recourses.
San Antonio Water System (SAWS)	
Overview	Founded in 1992 by the City of San Antonio, SAWS is a consolidation of the City Water Board, City Wastewater Department, and Alamo Water Conservation and Reuse District. Through a large-scale reorganization process that saw the drinking water, wastewater, and water reuse boards at the time all shuffled into one major office, SAWS has grown tremendously. A true leader in the "trifecta" of wastewater recycling practices, the San Antonio Water System not only has the largest recycled water system and infrastructure in the nation but also in agricultural composting efforts and in renewable energy biogas usage.
Location	Headquarters: 2800 U.S. Hwy 281 North, San Antonio, TX 78212 http://www.saws.org/
Operations conducted	Conservation and drought management Drinking water treatment and distribution Stormwater management Wastewater management Wastewater reuse
Size	Pulling Water from: Edwards Aquifer, Trinity Aquifer, Twin Oaks Aquifer Storage, Canyon Lake, and other sites. • Service Area (Water Supply): 560 square miles serving 460,000+ customers, covering most of Bexar County, as well as Medina and Atascosa Counties. • Service Area (Wastewater Collection): 411,000 customers in the regular water supply service area plus military bases, suburban cities, some contracted developments outside regular service area. • Pipelines: 9000+ miles of mains
Administrative structure	Owned and operated by the City of San Antonio, a seven-member Board of Trustees manages policies and oversees operations. In addition, five citizens groups learning about water issues in San Antonio advise the Board of Trustees and staff.
Texas Water Development Board	
Overview	Established in 1957, the Texas Water Development Board serves as the state wide management, coordination, and financing of water planning, groundwater and surface water monitoring, flood control, and conservation efforts.

Location	Headquarters: 1700 North Congress Avenue, Austin, TX 78701 http://www.twdb.state.tx.us/index.asp
Operations conducted	Loan and Grant Provider Technical Support to Different Regions Administrates the Texas Water Bank Maintains Various Central Databases Distributes DW & CW State Revolving Funds
Administrative structure	A six-member Board of Directors appointed by the Texas governor oversees the Development Board in the creation of various state initiatives, directs information gathering efforts, allocates funding and financial aid, and works to educate the public.

STAKEHOLDERS: CENTRAL TEXAS WORKSHOP PARTICIPANTS

Organization/ Institution	Description	For More Information
Central Texas Water Efficiency Network	Part of the non-profit Texas Water Foundation, this network is a collaborative effort seeking to increase public awareness of Texas' water issues and works to promote conservation and efficient water use.	http://www.texaswater.org/ctwen/
Lone Star Chapter of the Sierra Club	A local advocacy group working under the national organization of the Sierra Club, Lone Star works on local environmental issues in Texas, including water rights management.	http://www.texas.sierraclub.org/
Office of the Texas State Climatologist	Housed in the Department of Sciences at Texas A&M University, this office provides information on climate impacts in Texas through monthly reports, data, and various resources available to the public.	http://climatexas.tamu.edu
Spansion	Spansion is a micro-chip industry that primarily produces the flash-memory that powers many electronics systems. This industry is a high water user in the production and manufacturing of such technology. Despite locations all other the world, Spansion's manufacturing facility in Austin is one of the largest.	http://www.spansion.com/Pages/Default.aspx
Southern Climate Impacts Planning Program (SCIPP)	A 6-state research program – Oklahoma, Texas, Arkansas, Louisiana, Tennessee, and Mississippi – SCIPP is dedicated to increasing resilience and preparedness for extreme events within the region. SCIPP works to increase awareness among various stakeholder groups and provide decision makers with important climate hazard data.	http://www.southernclimate.org
Texas Commission of Environmental Quality (TCEQ)	As the state's environmental agency, TCEQ protects public health and natural resources – primary issues of importance include, air quality, water quality, and waste management. TCEQ further works to implement environmental laws and enforce regulations.	http://www.tceq.texas.gov/about
Texas Department of Public Safety (DPS)	Serving the state in a variety of capacities, the Texas DPS oversees highway management and supervises various criminal management systems.	http://www.txdps.state.tx.us/

Texas Nature Conservancy	A national organization full of local participation, the Texas branch of the Nature Conservancy works in all of the state's ecoregions to provide conservation, advocacy, and public education. With over 37 nature preserves and over 100 private partnerships, the Conservancy looks after over 800,000 acres in the state alone.	http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/texas/index.htm
Texas Rice Producers	A sub-branch of the U.S. Rice Producers Association, the Rice Producers of Texas are well organized through a variety of mechanisms including the Rice Council, a legislative group, a research foundation, and various coalitions and lobbying groups. Representing a water-intensive and climate impacted agricultural field, rice producers are heavily involved in maintaining their water security.	http://www.usriceproducers.com/stateassociations/51-texas
UT Austin Jackson School of Geosciences	A national leader in the geosciences field, the Jackson School provides innovative methods to water resources while educating future professionals. With the impacts of climate change unknown, schools like this create a more water-secure tomorrow.	http://www.jsg.utexas.edu

ATTENDEES: CENTRAL TEXAS WORKSHOP PARTICIPANTS

Zach Baumer	City of Austin, Climate Program
Nancy Beller-Simms	NOAA
Mike Bewley	Texas Division of Emergency Management
Rajendra Bhattarai	Austin Water Utility
Brenner Brown	Texas Water Development Board
David Brown	NOAA
Jim Brown	U.S. EPA Region 6
Roger Brown	Austin Water Utility
Tina Bui	Austin Water Utility
Susan Butler	CH2M HILL
Marc Coudert	City of Austin, Office of Sustainability
James D'Souza	Aqua Water Supply Corporation
James Dwyer	CH2M HILL
Vanessa Escobar	Texas Water Development Board
Lauren Fillmore	WERF
Mike Fisher	Bastrop County Emergency Management Department
Tom Fitzpatrick	Texas Engineering Experiment Station
Trey Fletcher	City of Pflugerville
Jeff Fox	Austin Water Utility
Ricky Garrett	City of Waco
Ronald Gerston	Colorado Water Issues Committee, Texas Rice Producers Legislative Group
Jack Goodman	Retired
David Greene	Austin Water Utility
Karen Guz	San Antonio Water System
Maureen Hodgins	WRF
Kirk Holland	Barton Springs/Edwards Aquifer Conservation District
Laura Huffman	The Nature Conservancy
Ken Kramer	Sierra Club – Lone Star Chapter
Teresa Lutes	The Nature Conservancy
Robert Mace	Texas Water Development Board

Charles Maddox	Austin Water Utility
Danielle Martin	COA Water Utility
Dave McMurry	Aqua Water Supply Corporation
Karen Metchis	U.S. EPA Office of Water
Whitney Milberger	City of Cedar Park
John Nielsen-Gammon	Texas A&M
Kenan Ozekin	WRF
Patricia Rinehart	City of Pflugerville
Bob Rose	Lower Colorado River Authority
Amrith Sagar	NOAA
Bridget Scanlon	Bureau of Economic Geology; University of Texas, Austin
Jody Slagle	City of Austin
Daryl Slusher	Austin Water Utility
Nancy Tosta	Ross Strategic
Arthur Talley	Texas Commission on Environmental Quality
David Walker	Lower Colorado River Authority
Daniel Wilcox	Spansion FAB 25
Cara Wilson	CDM Smith
Darrell Winslett	City of Pflugerville
Jessica Woods	City of Round Rock
Kate Zerrenner	Environmental Defense Fund
Jad Ziolkowska	University of Texas, Austin
Sandra Zuniga	Austin Water Utility

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APPENDIX E

LOWER MISSOURI RIVER BASIN

The project's Lower Missouri River Basin workshop took place February 19-20, 2013 in the Johnson County Administration Building in Olathe, Kansas. The workshop and findings detailed in this study would not have been possible without the Regional Team listed below. The Research Team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

John Albert (WaterRF)
Mike Armstrong (WaterOne)
Tom Jacobs (Mid-America Regional Council)
Doug Kluck (NOAA Central Region)
Chad McNutt (NOAA/NIDIS)
Vikram Mehta (CCRES)
Mary A. T. Mindrup (U.S. EPA Region 7)
Susan D. Pekarek (Johnson County Wastewater)

The Story in Brief

Extreme climate/weather events are an historical experience in the Lower Missouri River Basin (LMRB). The last 20 years, however, witnessed an increasing frequency and severity of floods and droughts in the Basin. Communities endured new record floods in 1993 and again in 2011. Recent droughts, including the Drought of 2012-2013, ignited tension over water supplies and river flows in a region that traditionally perceives itself as having plenty of water. For water utilities on the Missouri River, the issue was low water levels due to riverbed degradation, not the availability of water itself. Water utilities also are concerned about congressionally mandated operating rules that require the U.S. Army Corps of Engineers to use Kansas River Reservoir storage to support navigation at the expense of water supply needs in a drought. Managing the Lower Missouri River (LMR) to control flash flooding, protect water quality and habitat for endangered species, and support the agriculture and barge-based economy provide a critically challenging context. Changes in the intensity of extreme climate/weather add pressure to the future of these water management challenges.

Background

The Lower Missouri River Basin (LMRB) is an important sub-basin of the much larger Missouri River Basin (Figure E-1). Home to urban, rural, and tribal populations, the LMRB supports aquatic ecosystems, domestic and industrial water uses, and agricultural production. The Basin resides below the High Plains region of the western United States. Water resources and the hydrologic cycle in this larger region influence water quantity and quality in the LMRB (Shulski, 2013).

The Lower Missouri River (LMR) stretches from Gavin's Point Dam to its confluence with the Mississippi River. The LMRB includes a corner of Wyoming, and parts of Colorado, North Dakota, South Dakota Nebraska, Kansas, Minnesota, Iowa, and Missouri.[1] Snowmelt originating in the Rocky Mountains of the High Plains region makes up 75% of the LMRB's recharge from March to July (Farhat, 2013). There exists a history of floods and droughts, as well as tension among varying state water laws and stakeholder needs, in the area.

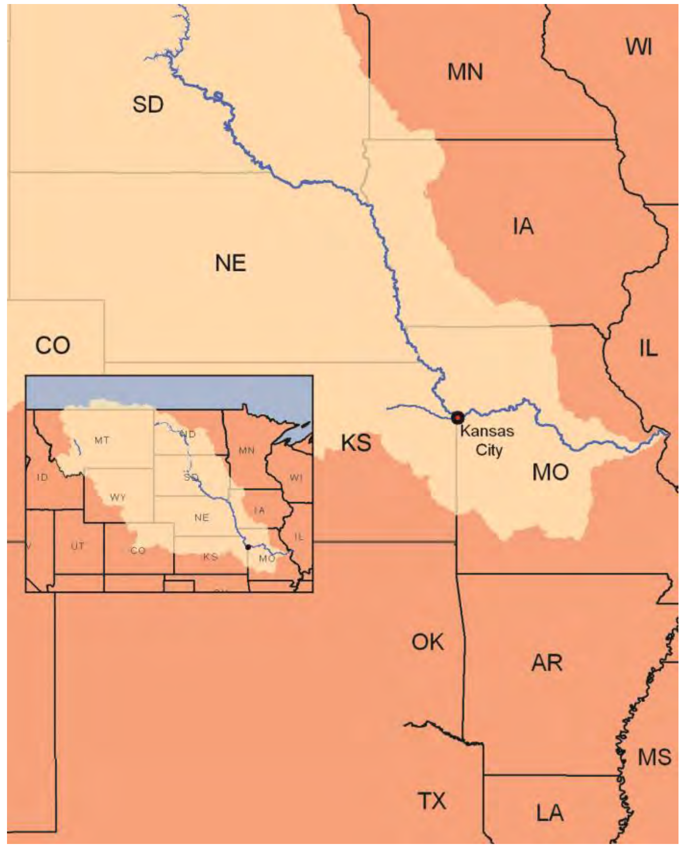

Figure E-1. The Lower Missouri River Basin.

Gavin's Point Dam

Authorized by the Flood and Control Act of 1944 – also known as the Pick-Sloan Plan – and managed by the U.S. Army Corps of Engineers (USACE), Gavin's Point Dam signifies the beginning of the LMRB. Just north of this, Lewis and Clark Lake is among the most popular recreational spots in the High Plains (Gavins Point Dam, 2013). Though construction in 1952 cost $50 million, Gavin's Point brings in an estimated $35 million annually in social and economic benefits (Gavins Point Dam, 2013). Gavin's Point has three turbines with a maximum capability of 132,300 kW power generation, as well as 14 gates that support a 1,180-foot spillway (Gavins Point Project, 2013). The Missouri River is the major water supplier for Gavin's Point and Lewis and Clark Lake.

Missouri River

As the longest river in the U.S., the Missouri River's 2,540 miles represent a significant waterway for the central part of the country (USGS, 2013). The river flows through Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri before joining with the

[1] Although the LMRB includes all these areas, this case study focuses on impacts and adaptation strategies in Kansas, Missouri and Omaha, Nebraska, as represented by workshop participants. It is important to note, however, the 'water knows no-political boundaries' nature of this resource. What happens in the Missouri Basin as a whole – in terms of climate trends and water management – affects the LMRB and visa-versa.

Mississippi River at St. Louis. The Missouri River consists of two political basins – the Upper and Lower Missouri River Basins – as well as eight sub-basins (Missouri River, 2013).

Kansas River

The Kansas River is a major tributary to the Missouri River, joining the LMR portion at Kansas City. Fed a watershed extending into Colorado and Nebraska, it supplies water for consumption, industry, flood control, and endangered species habitats. Several USACE-controlled dams and reservoirs on the Kansas River affect downstream water quality and quantity. Located on Kansas River tributaries, water releases from Tuttle, Milford, and Perry reservoirs increase the flow at the confluence point of the Kansas and Missouri Rivers, near Kansas City.

Tuttle Reservoir

Located on the Big Blue River – a major tributary to the Kansas River – Tuttle Creek Lake sits five miles north of Manhattan, Kansas (Tuttle Creek, 2012). Constructed in 1952 and filled in 1963, Tuttle Creek had an original storage capacity of 425,312 AF. Last surveyed in 2009, the reservoir had an estimated capacity of 249,830 AF (Tuttle Creek, 2012). Tuttle Reservoir serves many purposes, including aquatic ecosystem sustenance, recreation, food procurement, industrial and domestic water supplies, navigation, and flood control (Tuttle Creek, 2012).

Milford Reservoir

Milford Lake is a reservoir that sits on the Republican River, another important tributary to Kansas River. Construction began in 1962; the USACE filled the multi-purpose pool five years later in 1967 (Milford Lake, 2012). Milford had an original storage capacity of 415,403 AF; the estimated capacity in 2009 was 370,133 AF (Milford Lake, 2012). Kansas utilizes the reservoir for domestic and industrial water supplies, recreation, food procurement, aquatic life support, navigation, and flood control (Milford Lake, 2012).

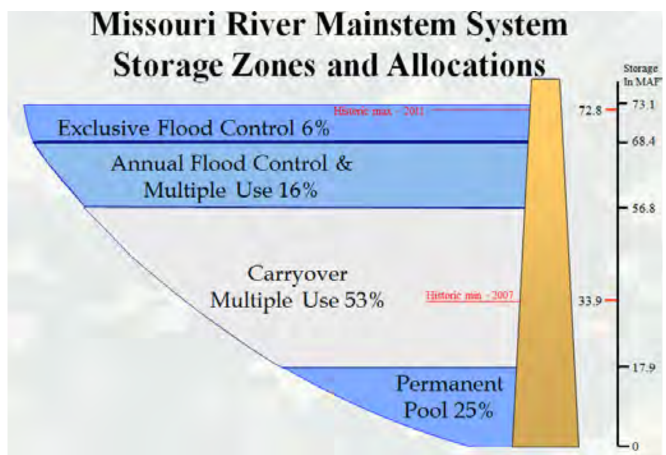

Figure E-2. USACE Storage Zones and Allocations on the Mainstem Missouri River System.
Source: Farhat, 2013.

Perry Reservoir

Perry Lake sits a few miles northwest of Perry, Kansas, along another tributary to the Kansas River, the Delaware River. With a smaller storage capacity than Milford and Tuttle, in 2009 Perry had an estimated 197,843 AF capacity of the original 243,220 AF (Perry Lake, 2012). Established in 1964 and filled in 1970, the reservoir serves for domestic water supply, flood control, navigation, aquatic life support, food procurement, and contact recreation purposes (Perry Lake, 2012).

Water Laws and Governance

The USACE operates six major dams on the Missouri River for flood control, navigation and bank stabilization, irrigation, hydropower, water supply, water quality, recreation, and to support fish and wildlife. The main-stem reservoirs on the Missouri River support 73.1 MAF of water; the USACE dictates particular allocation percentages from this supply (Figure E-2) (Farhat, 2013). As one of the largest reservoir management systems in the country, the USACE is an influential water manager in the region (LMRB Facilitator Notes, 2013).

The Missouri Water Resources Center manages the quantity and quality of the state's water resources, under advisement of the State Water Plan Inter-Agency Task Force. The Kansas Department of Agriculture's Division of Water Resources regulates water through the Water Appropriation Act, while the Kansas Water Office oversees reservoir storage contracts.

The Water Services Department operates water utilities, providing drinking water and managing stormwater and wastewater for Kansas City, Missouri. Johnson County, a Kansas City suburb, operates its own stormwater and wastewater departments. A quasi-municipal government, WaterOne, supplies drinking water to 16 cities in Johnson County. Some smaller cities and communities in the Kansas City metropolitan area, such as Olathe and Leavenworth, also provide many water services, including stormwater management.

There are 28 Indian tribes that live in the Missouri River Basin. To date, the tribes have not fully exercised their water rights.

Governing water laws in Kansas and Missouri that affect preparation for and response to extreme climate/events include the following:

- Missouri Major Water Users Law.
- Missouri Soil Conservation Law, Section 278.
- Water Appropriations Act.
- Water Assurance Program Act of 1996.

These acts serve to balance user needs with environmental flow requirements, while simultaneously mitigating the effects of the common occurrence of floods and droughts in the LMRB region.

Climate and Water Trends

Approximately 25% of runoff in the larger Missouri River Basin arrives March-April through snowpack and rainfall in the High Plains. (Farhat, 2013). Mountain snowpack and rainfall during May, June and July, and some rainfall from April-October comprises an additional 50% of the Basin's annual runoff (Farhat, 2013).

However, the LMRB region is known for extreme climate/weather variability. The northern areas of the High Plains are likely to get wetter while the south and west are likely to become drier due to reduced rainfall and higher temperatures.

On the Cusp of Climate Change

Climatologists project increased precipitation in the northern half of the United States and decreased in the precipitation in the southern half of the United States from 2090-2099, relative to 1980-1999 trends (IPCC, 2007). The LMRB lies at the intersection of these two climate regions, where only 66% of models agree on whether precipitation will increase or decrease (Lucas, 2013). This makes future water projections at the local level more difficult, due to disagreements among models. Past trends support uncertainty in this region. Climate reports indicate that the cusp of both positive and negative historical precipitation changes for the past fifty years lies right around the LMRB (USGCRP, 2009).

Decreased Summer and Fall Precipitation

What scientists know is that changes at this cusp were small, or around zero (USGCRP, 2009), meaning that "on average, the LMRB has not [yet] experienced long-term major precipitation changes" (Lucas, 2013). Nevertheless, future changes indicate more significant seasonal changes in the amount and timing of precipitation. Specifically, the LMRB can expect generally drier summers and falls than in the past, but similar winters and springs (USGCRP, 2009).

Understanding Climate Regions

Defining a 'climate region' is complex task that varies depending on the particular area. Scientists may define regions in terms of *physical changes and/or impacts within the context of climate* (Lucas, 2013). For instance, the Arctic is classified as a climate region based on temperature changes, as this region experiences larger changes than any other (Lucas, 2013). Other regions are classified in terms of physical variables or precipitation, as they may experience large changes in precipitation, but little change in temperature (Lucas, 2013).

Defining climate regions based on impacts to existing climates is more difficult. In the central United States, for example, "small changes in precipitation or in maximum daytime temperature can either make or break an agriculture crop year," though opinions differ on whether this should classify an area as a climate region or not (Lucas, 2013).

As climates change, the Rockies are likely to experience earlier spring snowmelt. The second half of the 20^{th} century demonstrates this (Figure E-3), and is a trend likely to continue. Earlier snowmelt in the Rockies will affect water flows and supplies in the LMRB (Shulski, 2013).

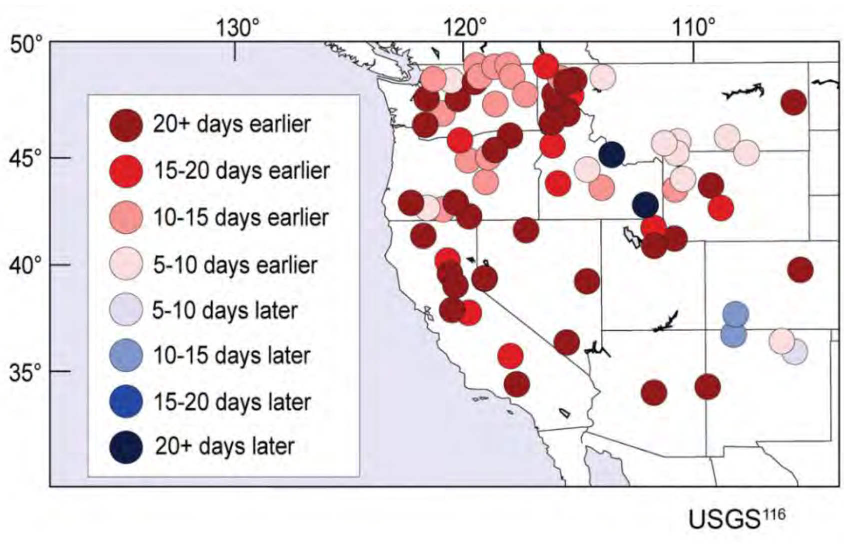

Figure E-3. Onset of Earlier Snowmelt in the Western United States from 1948-2000.
Source: USGCRP, 2009.

Increased Variability and Flooding Potential

With regards to precipitation, the increase in variation over the past 40 years is of particular importance. A USACE-funded study by NOAA found that "year-to-year variability of annual runoff has increased dramatically" and is largely due to more frequent high flow events (Webb and Hoerling, 2013). Events such as the 2011 Flood may be a rare occurrence, yet the study confirms that "annual flow in the Upper Missouri Basin has been more volatile in recent decades compared to prior decades dating to 1989" (Webb and Hoerling, 2013). Flooding corresponds with basin runoff. However, despite five years of high than average annual runoff, the Missouri Basin experienced below normal runoff in 2012. Meteorological events thus greatly affect overall runoff, and can "contrasting impacts" from year to year (Webb and Hoerling, 2013). Variability changes that favor more runoff correspond to a greater potential for future flooding (Kluck, 2013).

Increased Temperatures

Models project future increases in temperatures above 95°F, as well as the number of consecutive days above 95°F throughout the High Plains. These projections hover around 40-80 days above 95°F annually and 10-40 consecutive days of high temperatures annually by 2041 in the eastern and southern parts of North Dakota, South Dakota, Nebraska and Kansas (Figure E-4) (Shulski, 2013). Overall, models predict year-round increases in temperatures, but particularly hot temperatures during summer months in these areas (Shulski, 2013).

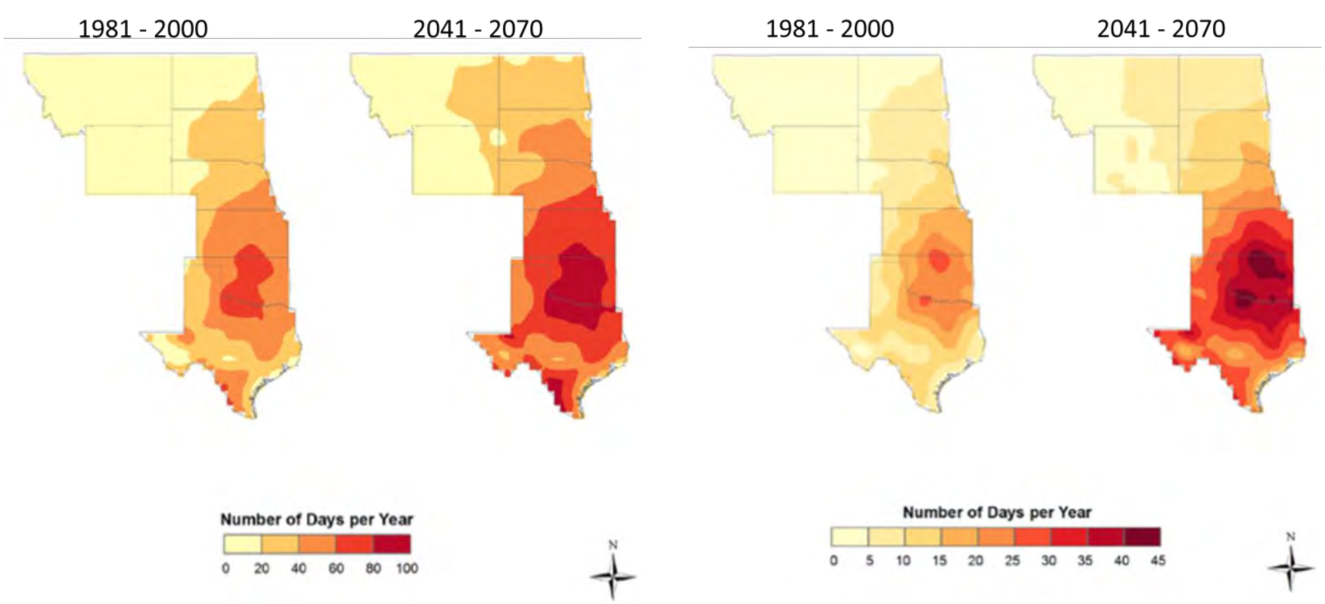

Figure E-4. Changes in the Number of Days Above 95°F and Number of Consecutive Hot Days by 2041.
Source: Kunkel et al., 2013.

Demographic Trends

The LMRB is home to rural and urban populations in five states, as well as a large number of Native American tribes. Demographic trends vary in all these areas; trends are difficult to assess, as the LMRB is a sub-basin of the Missouri Basin, which covers more populations. Statistics often include trends for an entire state in the Missouri Basin, of which only part belongs to the LMRB. However, since 2000, reports of decreasing rural populations and increases in urban populations are evident throughout the Basin (Missouri River Basin, 2009). This affects land use and development, in turn changing the anthropogenic impact on water resources (Missouri River Basin, 2009). Agricultural production remains a major economic activity throughout the LMRB, and as populations increase overall, so does the demand for water (Missouri River Basin, 2009).

Extreme Events

> *"You can never sit back and relax – there is always some event that needs to be planned for."*
>
> *– LMRB Workshop Participant*

The LMRB has a long history of floods and droughts. However, the increasing frequency of extremes in recent decades continues to break historical records and demonstrate unpredictability. Droughts, large rainfall events, and ice storms persistently hit the LMRB region, causing wet weather issues, as well as power, communication, and technology failures (Witt, 2013). Though "variability has always existed and droughts and floods will continue," seasonal variability is worsening (Kluck, 2013).

Great Flood of 1993

The Great Flood of 1993 led to widespread flooding in the Midwest and is still referred to as one of the worst floods in U.S. history. The Flood topped previous records by 20%, as "previous wet fall, normal to above-normal snow accumulation, rapid spring snowmelt accompanied by heavy spring rainfall, and heavy rains in June and July" created a series of events that led to the flooding (Historic Flood Events, 2010). Deemed by the National Disaster Report as an "unprecedented hydrometerological event," river stages reached record levels, as did the number of displaced persons, property damage, and crop loss (Historic Flood Events, 2010).

Sewer System Overflow in Johnson County. Credit: Johnson County Wastewater
Source: Witt, 2013

Impacts to the Environment

The Great Flood of 1993 resulted from a series of stationary weather events that lasted through the spring and summer, causing flooding until October. Nearly 150 rivers and tributaries flooded (Bucco, 2013). This event "inundated an area twice the size of New Jersey" (Ayres, 1993), or 400,000 square miles in portions of the LMRB and the Upper Mississippi Basin (Bucco, 2013). Ecosystems sustained continuous overflows, rather than a single event or short-flood duration. The Missouri River hit record crests in several areas, flooding the lowlands and damaging nearby land and ecosystems. Lands lost upwards of 600 billion tons of top soil, depositing sand and silt into waterways and farm land, and adversely affecting surface water and infiltrated groundwater quality (Bucco, 2013). Coupled with subsequent flooding, this event contributed to severe riverbed degradation in the LMRB.

Impacts to the Community

The Great Flood impacted 75 cities and towns, claimed the lives of 50 people, damaged 50,000 homes, and left nearly 70,000 people homeless (Bucco, 2013). Transportation halted and houses flooded. Flooding was worse in small towns, as levees offered some degree of protection in many larger cities (Ayres, 1993). The thousands of evacuations during the event lasted months. Nebraska was among the hardest hit areas in the LMRB; the combination of sustained flooding, tornadoes, and ice storms resulted in 52 counties federal disaster areas (Bucco, 2013).

Floodwaters breached eight levees throughout the Midwestern United States (Ayres, 1993). Damages were costly: approximately $4 billion worth in property, $8 billion in agricultural losses, and $200 million in railways and bridges (Ayres, 1993). Total damages for both the Upper Mississippi Basin and LMRB reached $20 billion (Bucco, 2013).

WaterOne's Isolated Intake during Floods in 1993.
Source: Schrempp, 2013.

Impacts to Water Utilities

The Flood damaged some 200 municipal water and 388 wastewater systems, many in the LMRB. Overall, water utility damages totaled $85 million. Heavy rains primarily damaged infrastructure and recovery efforts. The accumulation of 6 inches of rain in Johnson County caused about 175 SSOs (sanitary sewer overflows) and basement backups (Witt, 2013). The Flood isolated WaterOne's intake; water levels were so high that access to the intake required a boat (Schrempp, 2013).

Utility and Community Response

Communities immediately responded by piling millions of sandbags to mitigate damage where possible. Waters were so heavy, however, that the event "stirred a new debate over the nation's flood-control system and its policies" (Ayres, 1993).

Johnson County Wastewater (JCW) reinvested in the utility's commitment to improve system maintenance (Witt, 2013). Projects from the mid-1980s supplemented this reinvestment.[2] In 2001 JCW established the Pump Station Standby Power Project to evaluate standby power for treatment plants and pump stations. The project selected 11 sites for further evaluation of "physical site constraints, residential sound attenuation, second power feed availability, portable or stationary generator requirements, and flow diversion" (Witt, 2013). The project outcome included "stationary generators at five sites, second power feeds at two sites, system storage at one site," portable generators for the remaining sites and, finally, removed one site from service in order to divert flow to gravity flow directly to the water resource recovery facility (Witt, 2013).

Water utilities and communities in the LMRB substantially increased planning and collaboration efforts following the Flood of 1993 (LMRB Facilitator Notes, 2013). In addition, the USACE worked with states in the LMRB to increase observations of the Missouri River and tributaries (Bucco, 2013). This effort compiled peak ice formation and breakup period data in order to better predict early flood warnings.

Record Flood of 2011

Though remembered as one of the worst in history, the Great Flood of 1993 was surpassed in 2011 in the LMRB. Above average and late arriving snowpack combined with record rainfall in the Upper Missouri Basin, exceeding 1993 runoff by another 20% and flooding the LMRB (Farhat, 2013). Rainfall from May-July reached 102 inches, compared to the annual average of 14 inches (Galat et al., 2005). Runoff during these months topped 34.3 MAF; this was more runoff than annual totals for 102 of the 113 years on record (Farhat, 2013). June was "the single wettest month on record with 14.8 MAF of runoff, surpassing the old record of 13.2 MAF set in April 1952" (Farhat, 2013). Cumulative runoff for 2011 was 61.0 MAF or 247% more than 'normal' and the "highest runoff in 114 years" (Farhat, 2013).

Impacts to the Environment

Despite some successful flood mitigation due to dam control, the Flood of 2011 is "still the highest flow on record since the construction of dams…[and the impacts] will be felt for a long time" (Cowman, 2012). Prior to the event repeated flooding caused erosion of the Missouri riverbed degradation.[3] Conditions from the 2011 Flood "drastically rearranged bed sediments," left behind large sand deposits, and altered the natural formation of the Missouri riverbed (Cowman, 2012). This

Nebraska City Rail Underwater during the 2011 Flood.
Source: Snook, 2013.

[2] Due to the more than 300 annual 'wet weather backups' – or "30 per 100 miles of sewer" in the early 1980s – JCW initiated a $56 million removal and system improvements project that reduced inflow and infiltration by 50% (Witt 2013). The project began in the mid-1980s.

[3] Refer to the Decisions, Challenges, and Gaps section of this case study for further information on riverbed degradation.

led to wetland loss, changed in backwaters along the LMR, redistributed of seeds from the invasive purple loosestrife plant species, and damaged cottonwood trees that had previously adapted to low water level tables (Cowman, 2012).

Impacts to the Community

Through June, river levels hung around a steady 920.5 feet at the Omaha Public Power District's nuclear Nebraska City Station just a few miles outside Nebraska City (Snook, 2013). Located 19 miles from Omaha, the Omaha Public Power District's nuclear Fort Calhoun Station Reactor shut down on April 9th due to high river levels and anticipated flooding (Snook, 2013). This relocated nearly 350 employees at the Fort Calhoun Station (Snook, 2013).

Impacts to Water Utilities

The 2011 Flood tested reservoir systems throughout the Lower Missouri. At a record 72.8 MAF, system storage peaked by July 1st, with mainstream reservoirs holding nearly 16 MAF of flood waters (Farhat, 2013). In Missouri, Kansas City's only water plant experienced high flows, creating turbidity and depositing debris in storage tanks.

In Kansas, the 2011 Flood isolated WaterOne's Wolcott Collector Well, requiring boat access and special permission to cross the closed river to reach the well (Schrempp, 2013). Remarkably, operation "continued throughout the Flood" (Schrempp, 2013).

Remarkably, JCW did not experience power failures or backups despite the massive 2011 Flood. Following floods in June, 2010, improvements to the utility's Backup Prevention Program and Sewer Overflow Response Plan, in conjunction with standby power,[4] protected operations during the event (Witt, 2013).

Water Utilities and Institutions Participating in the LMRB Workshop

JCW – Johnson County Wastewater

KCMWSD – Kansas City Missouri Water Services Department

KWO – Kansas Water Office

KRWAD – Kansas River Water Assurance District

MWRC – Missouri Water Resources Center

MARC – Mid America Regional Council

WaterOne – Johnson County Water One Utility

Utility and Community Response

Local entities coordinated with the Kansas State Department of Emergency Management, the Kansas City Emergency Operations Center, and the Missouri River Joint Operations Center throughout the 2011 Flood (Schrempp, 2013). Missouri Basin Climate Outlook efforts monitored precipitation levels and offered monthly webinars (Schrempp, 2013).

Actions Taken – Emergency Response / Short-Term Responses

The USACE's system of seven levees and pre-designed flood plans protected much of the Kansas City metro area. The USACE opened two spillways on this dam system, Garrison and Big Bed, for the first time under wet conditions. This operation reduced water levels by seven

[4] The State of Kansas, Department of Health and Environment (KDHE)'s Minimum Standards for Design of Water Pollution Control Facilities, dictates that "electrical power should be available from at least two independent sources, or emergency power equipment should be provided" (Witt, 2013).

feet in order to accommodate the deluge (Farhat, 2013). In addition, four mainstream reservoirs utilized exclusive flood control zones, while two utilized surcharge storage (Table E-1) (Farhat, 2013).[5] Releases from all mainstem reservoirs set records (Farhat 2013).

In early June, the USACE further increased releases at Gavin's Point Dam in order to minimize flooding at nuclear facilities (Snook, 2013). Though previous record flows hit 72,000 cfs, heavy precipitation releases between 85,000 and 150,000 cfs/day during the Flood (Snook, 2013).

The Omaha Public Power District used over 350 pumps, a mile of hoses, 11,000 tons of sand and one million sandbags, 1.3 million square feet of plastic sheeting, 4,000 feet of fabric wall and sand barriers, and 6,000 feet of aqua-berm to protect the Fort Calhoun and Nebraska City nuclear stations from flooding (Snook, 2013).

Table E-1. Reservoir Operations During Flood Response, Summer 2011.

During Flood	Reservoirs Involved
Flood Control Zone utilized	Fort Peck, Garrison, Oahe, Fort Randall
Surcharge Storage utilized	Fort Peck, Garrison
Record Pool Levels set	Fort Peck, Oahe, Fort Randall
Spillways operated	Garrison, Big Ben

Source: Data adapted from Farhat, 2013.

Having previously planned for 500-year floods, Johnson County's main drinking water supplier, WaterOne, reported minimal impacts. Floodwater isolated its Missouri River intake collector well, however, this continued to operate during the event.

The City of Overland Park's flood warning system includes a five route interactive flood barricade plan (Miller, 2013). Highlighting several evacuation routes, this plan includes multiple types of barricades (Figure E-5). The City made and supported decisions through a pre-established communication system employing real-time and site-specific information: this included collecting and transmitting data, disseminating data, processing precipitation information, conducting a watershed runoff model, rating functions through a channel and floodplain hydraulics model, and then utilizing a visualization tool to assess flood impacts (Miller, 2013). Overland Park worked with Johnson County, the National Weather Service, and the USACE to build a localized flood warning system called Stormwatch. The online database (www.stormwatch.com), offers communities more accurate predictions during storm, as it reports real-time rainfall, temperature, stream levels, wind, humidity, and other weather-related data. An MOU amongst the partners dictated rights to collect weather station data from around the Kanasa City metropolitan area. Stormwatch is customizable for different utilities and communities, and provides relevant, real-time data to help assess flood risk.

[5] For details on storage zones, refer to Figure C-2 under the **Water Laws and Governance** section of this study.

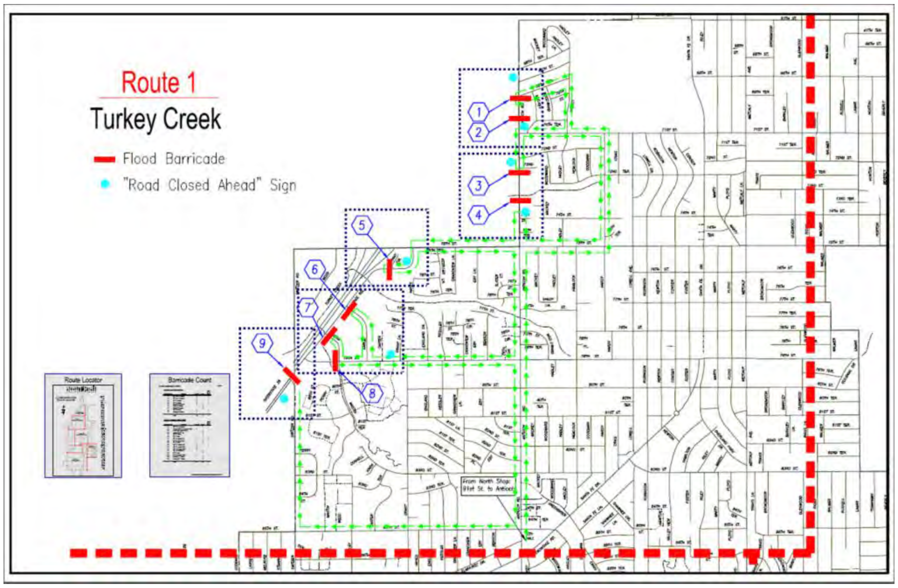

Figure E-5. Example Map of Barricades, City of Overland Park.
Source: Miller, 2013.

Actions Taken – Long-Term Planning – Long-Term Responses

Localities collaborated to find regional solutions to flooding and river quality issues. The Mid-America Regional Council (MARC), the planning organization for the bi-state Kansas City region, began working on solutions to prevent riverbed degradation, improve bank stabilization, and accelerate sustainable ecosystem restoration projects.

Fort Calhoun Station during 2011 Flood.
Source: Snook, 2013.

More than 25 years ago, JCW accelerated its program to prevent rainwater infiltration and inflow (I/I) into sewer lines by implementing a program to remove private sector sources of I/I and to improve system maintenance (Witt, 2013). The program was successful, reducing dry weather backups and wet weather backups from 273 and 210 in 1985, respectively, down to 10 and 0 in 2011 (Witt, 2013). This occurred, despite adding 1,174 miles of new sewer during this timeframe. This was largely due to improved "I/I reduction, capacity enhancement, system maintenance and a Backup Prevention Program" (Witt, 2013). Current efforts include an ongoing evaluation of cost-effective inflow/infiltration removal "including private service laterals" (Witt, 2013).

After the 2011 Flood, managers incorporated data backups, real-time monitoring at standby locations and redundant communication systems into Johnson County's disaster recovery plan. JCW completed a combined heat and power project – the Solids Improvements and Cogeneration Project – with the capability to run one plant independently in 'island' mode (Witt 2013). The project put dual power sources in place by adding generators that use biogas to generate electrical power onsite. This results in operational abilities even when disconnected from the power grid (Witt, 2013). This project upsized power feeds, installed gears for automatic switching and protection of the grid from utility surges and increased the "ability to run the plant from the generators only while disconnected from the grid, if both feeds were down" (Witt, 2013).

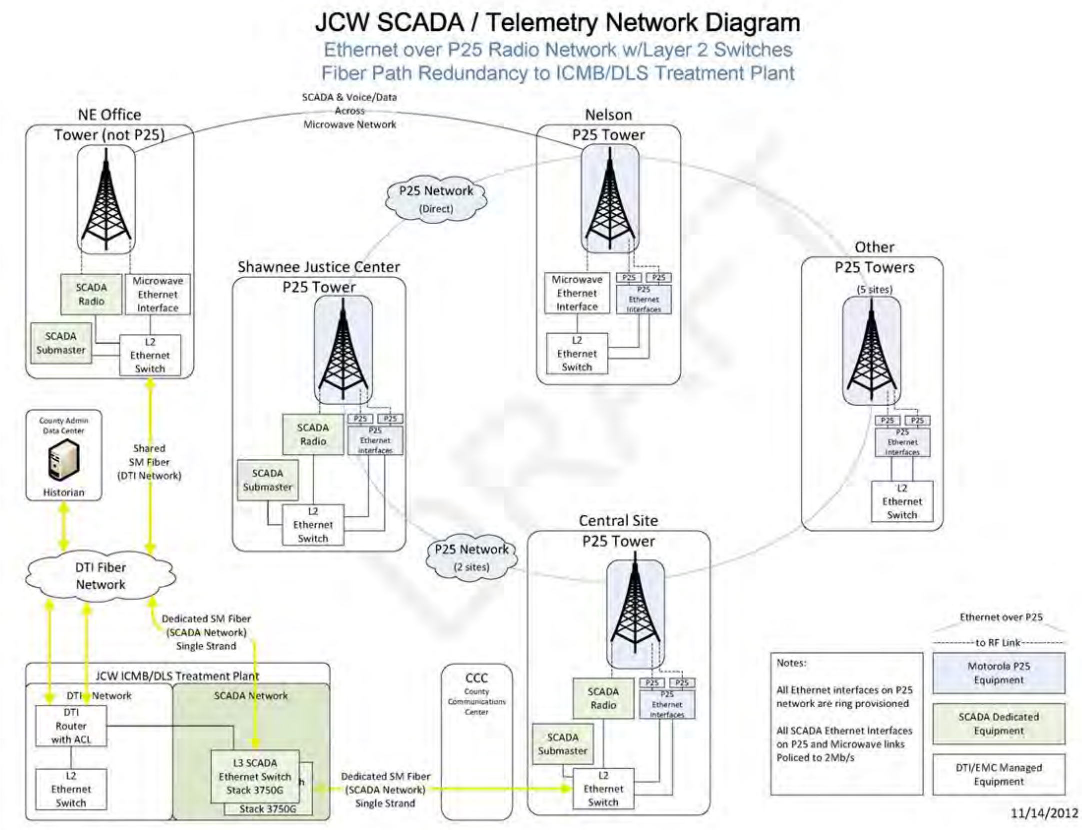

Figure E-6. Johnson County Water's Communication Network Plan.
Credit: Galen Bergthold and Johnson County Wastewater.
Source: Witt, 2013.

JCW's continued dedication to communication and technology achieved remarkable improvements during previous events and the 2011 Flood. JCW's SCADA Telemetry system provides pump stations and treatment plants with essential monitoring and alarming actions (Witt, 2013). Communications run on a redundant system (Figure E-6) that pages personnel if power or equipment fails, redirecting information through the three towers if one is taken out by weather (Witt, 2013). As an added precaution, JCW provides redundant radios at critical sites to ensure communication if these technologies fail (Witt, 2013).

After the flood, utilities recognized the valuable role for Missouri and Kansas Water and Wastewater Agency Response Network (WWARN). Data and information from WWARN helped utilities in the area monitor water levels, flood risk, and impacts.

Drought of 2012-2013

Periodic droughts are a customary experience in the LMRB. WaterOne was aware of river intake shut downs at other utilities due to low river levels in 1990-1991 and 2000-2001 cost several million dollars (Schrempp, 2013). Low winter flows and degraded rivers during these droughts prompted first the construction of rock structures and later a concrete weir to sustain channel flow lines at the WaterOne Kansas River Intakes (Schrempp, 2013). Despite such noteworthy adaptation, the increasing frequency and intensity of droughts is a recent concern in the LMRB. Drought conditions expanded dramatically from late January 2012 through the time of this case study's workshop in February 2013, with a forecast to intensify through the Spring of 2013 (Figure E-7) (Farhat, 2013).

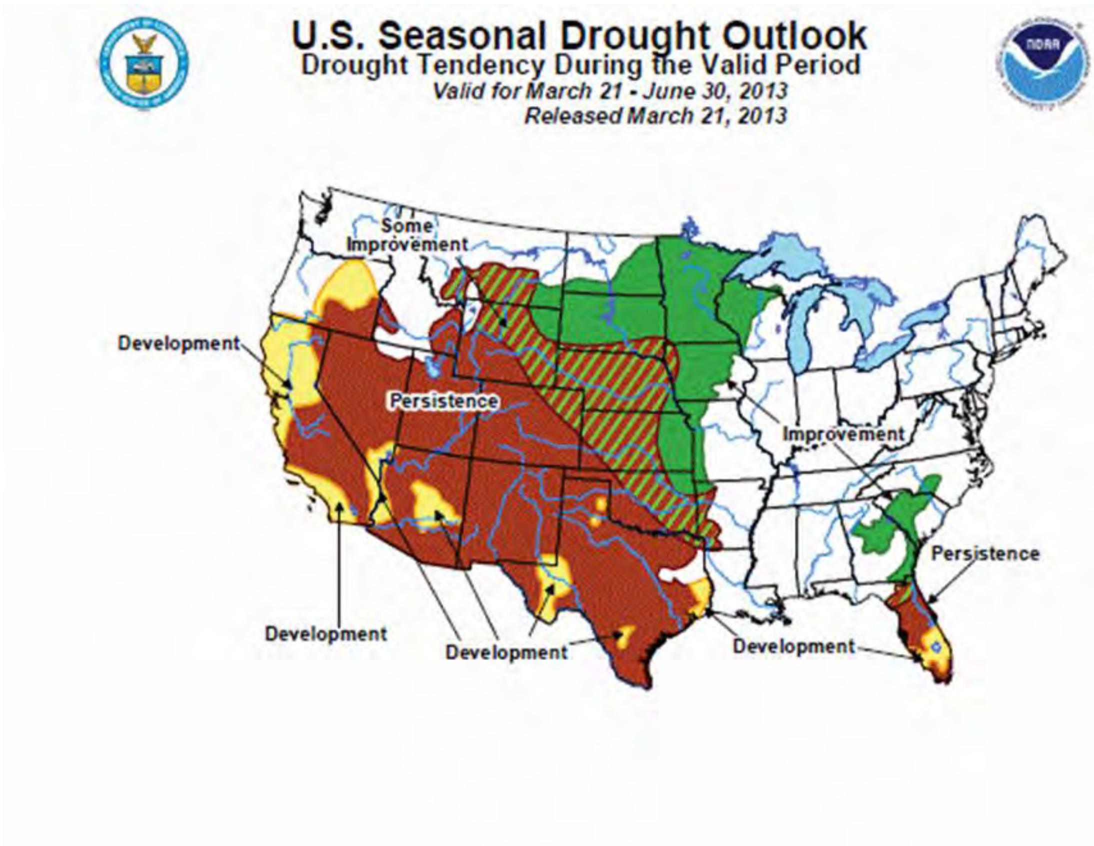

Figure E-7. Drought Outlook for Summer 2013.
NOAA's s National Weather Service predicted drought conditions would continue or persist with little improvement in much of the LMRB.
Source: National Weather Service, 2013.

Impacts to the Environment

The 2012-2013 Drought combined with channel degradation over the years resulted in record low river elevations (Schrempp, 2013). Low reservoir levels affected water quality, which further threatened aquatic ecosystems and increased treatment costs at municipal intakes (Farhat, 2013).

Impacts to the Community

The Drought affected community factions in different ways and to varying degrees throughout the LMRB. The Missouri River channel dropped from 9 by 300 feet to 8 by 200 feet (Farhat, 2013). A reduced support for navigation and shortened navigation seasons emerged;

rivers flowed at minimum service levels due to dry conditions. Shortened seasons and low flows further led to "severe taste and odor problems" (Schrempp, 2013).

Other issues included limited access to waterways at marinas and boat ramps (Farhat, 2013). Utilities estimated that "if drought persisted, 16 domestic water intakes, including seven tribal intakes on Garrison and Oahe reservoirs, would be threatened by declining reservoir levels" (Farhat, 2013). This threatened current consumption patterns throughout many communities. Though dry conditions reduced flood risk substantially, this risk was not eliminated (Farhat, 2013).

Agriculture

The particularly hot, dry summer of 2012 severely impacted agriculture, including "reduced crop yields, record crop prices [and] huge crop insurance payments, record feed costs, fewer livestock and poultry, and less post-farm-gate business" in the LMRB (Plain, 2013). Both corn and pasture conditions dropped significantly compared to the year before (Plain, 2013). Though dry conditions swept most of the U.S., agricultural production suffered particularly in Missouri (Figure E-8).

Higher crop prices and crop insurance payments moderated the economic impact crop farmers faced during the Drought (Plain, 2013). Higher feed costs hit livestock and poultry producers in particular, though all producers endured heavy losses (Table E-2). In 2012, crop insurance payouts in Missouri hovered around $1 billion, $740 million for corn alone (Plain, 2013). Due to crop insurance in the LMRB, however, production losses were less than anticipated (LMRB Facilitator Notes, 2013).

Table E-2. Production Costs to Missouri Livestock and Poultry During 2012 Drought.

Production Type	Cost
Broilers	$204 million
Beef Cattle	$183 million
Hogs	$62 million
Turkeys	$52 million
Dairy Cattle	$45 million
Sheep/Goats	$1 million
Total	**$548 million**

Source: Data adapted from Plain, 2013.

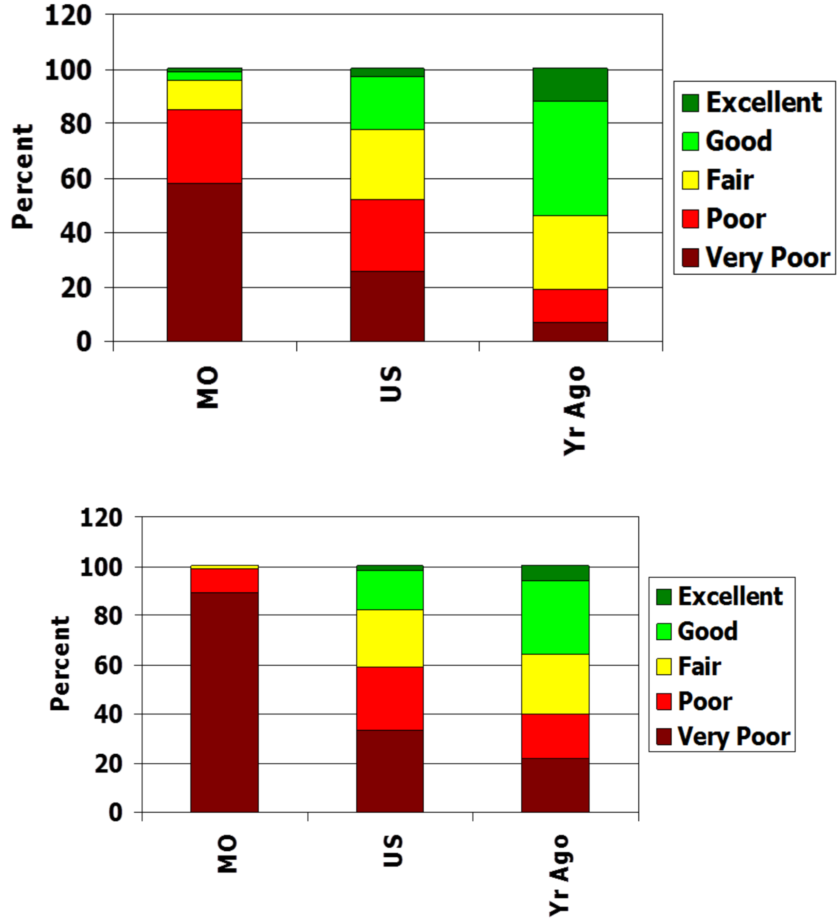

Figure E-8. Corn Conditions (below left) and Pasture Conditions (below right) in Missouri and the United States, August 2012.
Source: Plain, 2013 (using data from USDA National Agriculture Statistics Service).

Impacts to Water Utilities

The ongoing Drought persistently lowers water levels at intakes throughout the LMRB. In fact, this exacerbates the existing "degradation of the Missouri River[6] [that] has resulted in problems withdrawing water at these intakes" (Schrempp, 2013). This increases pumping costs at irrigators due to adjustments to reach declined levels (Farhat, 2013). Operational costs for utilities overall are higher during persistent droughts. WaterOne estimates higher energy usage at $20,000/year and taste and odor treatment at $750,000/year due to drought conditions (Schrempp, 2013). A survey of river take owners obtained further estimates of the need to invest more than $286 million in low water infrastructure in the future (Schrempp, 2013).

Already, utilities are experiencing water flows that dropped well below targets (Schrempp, 2013). In fact, colder water and minimum river levels at WaterOne's Wolcott Collector Well lowered capacity to under 25MGD of the intake's 31.5MGD capacity (Schrempp,

[6] Though the "exact cause [of degradation] has not been determined…chief suspects are reservoirs, which trap sediments, dredging and channelization" (Schrempp, 2013).

2013). As temperatures drop, water "increases in density and viscosity…making it more difficult for the groundwater to flow into the well" (Schrempp, 2013). Groundwater levels lowered due to lower river levels during the Drought. This reduced pressure that pushes water into the well, resulting in an overall capacity reduction (Schrempp, 2013). Mainstem dams in the LMRB have a reduced hydropower generation (Farhat, 2013). Continuing drops will decrease winter releases. Low releases during those months "create access problems for municipal and industrial water intakes along the lower Missouri River, particularly during icing conditions" (Farhat, 2013).

Utility and Community Response

Reponses to the ongoing Drought in the LMRB continue to blend emergency response short-term actions with long-term actions.

WaterOne previously designed facilities to accommodate winter demands for water due to previous periods of lower water levels (Schrempp, 2013). Completed in 2004, the $2 million low water level pumping facility allowed for successful pumping during record low river levels that dropped below main intake pumps in January 2007. In addition, WaterOne continues to implement conservation measures and monitors the USGS, the USACE, and Accuweather sites for updated information (Schrempp, 2013). The USACE Northwest division held semi-annual meetings where utilities can learn about trends in declining water levels at the KCMO gage (Figure E-9) (Schrempp, 2013).

The Kansas River Water Assurance District (KRWAD), of which WaterOne is a member, has had an Operations Agreement with the Kansas Water Office (KWO) since 1991. This Operations Agreement sets minimum target flows in the Kansas River (Schrempp, 2013). KRWAD updated the 2010 safety factor in storage and evaluated climate sensitivity study to include current drought conditions (Schrempp, 2013). This aided in the utility's response to the current Drought. The Operations Agreement allocated Milford, Tuttle Creek, and Perry Reservoir storage for use by KRWAD members during the Drought (Schrempp, 2013).

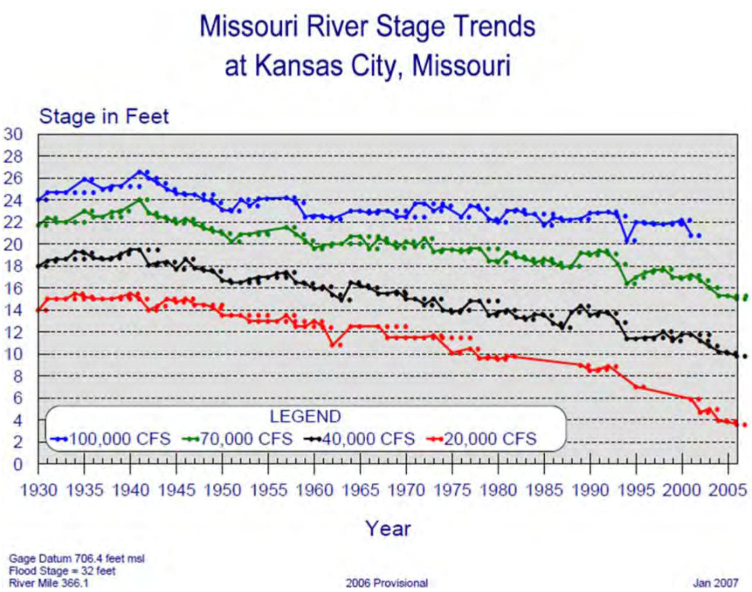

Figure E-9. KCMO Gage River Stage Trends.
Source: Schrempp, 2013.

Decisions, Challenges, and Gaps

Utilities, agencies and communities in the LMRB continue to display a remarkable sense of good working relationships among many parties, strong overall planning much of the time, and a resourceful use of what data is available. Yet the larger political and geographical context of the LMRB, amongst increasing climate/weather impacts on the region, render a complicated terrain in which to navigate sound water management. The identification of challenges and gaps is the first step towards improved adaptation decisions in the Basin.

Climate-Driven

A number of the challenges and gaps are related specifically to climate-driven factors.

Increasing Exceptional Events

Though droughts and floods are common occurrences in the LMRB, recent years demonstrate a heightened "potential to spend more time on both ends of the hydrologic spectrum" (Farhat, 2013). The management of expectations, attitudes, and data is a key facet of adequate preparation. Monitoring changing climates is thus paramount, both to understanding and predicting future extreme climate/weather events in the LMRB, including the frequent monitoring of weather, water, drought, and basin biology (Shulski, 2013). These measures provide timely data that can drastically alter emergency planning and response. This proves difficult, however, when budgets are on a constant ebb and flow basis tied up by politics, legal processes and economic downturns (Shulski, 2013).

Seasonal to Decadal Gaps in Data

To adequately plan for extreme climate/weather events, seasonal and decadal data is essential. There is great annual, spatial, and seasonal variation in temperatures and precipitation patterns in the LMRB; these shifts cause "significant implications for the environment, economy, and society" (LMRB Facilitator Notes, 2013). Yet, there is a major data gap, and thus climate projection gap, from seasonal to decadal events (LMRB Facilitator Notes, 2013). The uncertainty with regards to wet and dry periods challenges effective management of reservoir releases and flows (LMRB Facilitator Notes, 2013). This makes it difficult to decide what level of risk to plan for and respond to (LMRB Facilitator Notes, 2013). Utilities wonder just how far to take the expenditure of resources and, for example, whether to plan for a 10 versus 20-year drought (LMRB Facilitator Notes, 2013).

New information for seasonal and decadal forecasts can help LMRB stakeholders better facilitate changes in water management (Knutson, 2013). Monitoring of the LMRB and the larger basin context is essential to bridge this gap. Information on soil, snow, and extreme climate/weather event warning and watches, are among the most-needed data (Kluck, 2013). However, relevant data must be easily accessible, aggregated, and consolidated on websites in order to truly be useful (Knutson, 2013). Data access and use varies greatly; "many jurisdictions and agencies want and need more locally focused, integrated, and easily accessibly data" (LMRB Facilitator Notes, 2013).

This will require a great deal of funding, collaboration, and education of both politicians and constituents (Knutson, 2013). In fact, issues with reliability, temporal and spatial scales, and regulatory constraints feed the climatic information gap. Thus, "wider acceptance of climate forecasts will depend on their being incorporated into existing organizational routines" (Rayner et al 2008 in Knutson 2013).

Water Service and Resource-Based

A number of the challenges and gaps are related specifically to resource-based factors.

Riverbed Degradation

Riverbed degradation along the Missouri River is a dramatically increasing problem. The specific cause is unknown; however, many speculate that scouring is one significant factor. While "some stretches of the river are degrading…others are aggrading or relatively stable" (Schrempp 2013). Nevertheless, the impacts of degradation extend to tributaries, such as the Kansas River. This can result in many other problems, including a "loss of submergence of water intakes, decline in water table for groundwater wells affecting their capacity, undermining flood control structures such as levees and floodwalls, the exposure of buried pipelines crossing the tributaries, a loss of wetlands and critical habitats, unstable stream banks caving in, [and the] exposure of bridge piers" (Schrempp, 2013). Riverbed degradation further pronounces the drought impacts on water infrastructure. When riverbed degradation occurs, low water levels from dry weather conditions will sink even lower, necessitating additional pumps to draw water up to the regular basement level (Figure E-10).

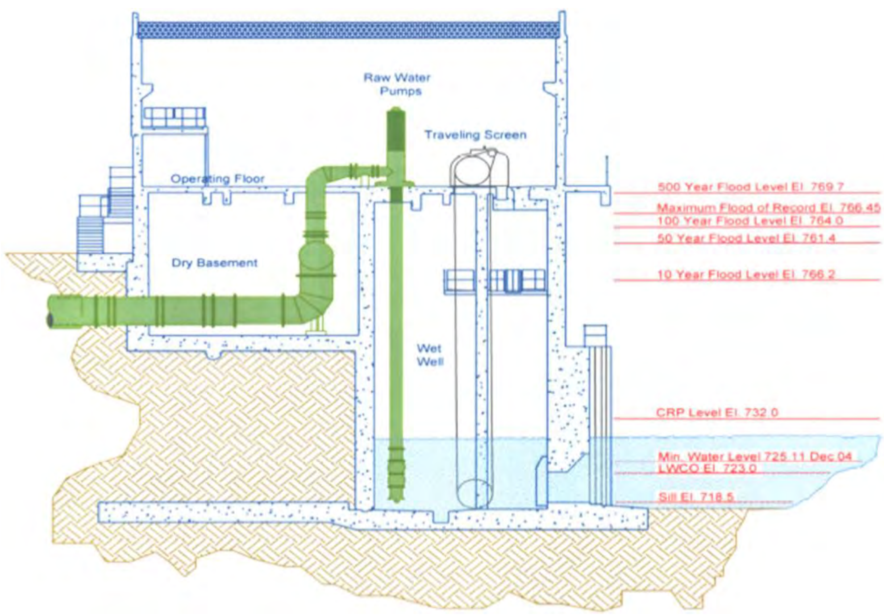

Figure E-10. Missouri River Intake Cross-Section.
Source: Schremmp, 2013.

Utilities cite the USACE as a potential institution to study this issue, the cause and possible solutions (Schrempp, 2013). This information could lead to restoration of the Missouri Riverbed. If river conditions were restored to those in 1990, benefits could include: lowered winter releases by 10,000 cfs, the availability of additional water left in upstream reservoirs for navigation, reduced habitat erosion for endangered species, increased water for irrigation, water stored for water quality protection, and the release of water during valuable hydropower opportunities in the summer months (Schrempp, 2013). Fewer degraded channels would no longer undermine USACE-operated flood control structures or storm and sewer discharge structures (Schrempp, 2013).

Infrastructure and Service Constraints

Workshop participants noted a feeling of constraint challenging sound water management in the LMRB. Addressing more extreme climate/weather events and climate change was cited as "just one more thing on our plate, and we have lots of other things we need to do" (LMRB Facilitator Notes, 2013). Resources and services require prioritization and adaptation to extreme climate/weather is not always a priority when it needs to be (LMRB Facilitator Notes, 2013).

Flexibility was built into the Mainstem Reservoir System of the LMRB; the USACE designed the system to handle extreme floods and prolonged droughts (Farhat, 2013). Nevertheless, new regulations over the years mean operations constantly adjust to comply, such as the Endangered Species Act and Clean Water Act (Farhat, 2013). Constrained by a naturally runoff driven system, at times, water infrastructure and utility services struggle to meet varying demands (Farhat, 2013). Despite drought conditions, many utilities prioritize water supply for customers (LMRB Facilitator Notes, 2013). Though WaterOne previously steered away from curtailments, the utility issued voluntary curtailments in 2013 ("Water conservation urged," 2013).

Extreme events damage already aging infrastructure, challenging constraint demands further. Comparative analysis of different piping type life cycles is a potential source of mitigation to this issue (LMRB Facilitator Notes, 2013).

Political and Intergovernmental

A number of the challenges and gaps are related specifically to political and intergovernmental-based factors.

Government Support, Information, and Funding

Uncertainty in climate change is not only a concern among citizens in the LMRB, but, at times, heavily challenged by critical government officials at times. Though data gaps persist and climate/weather events may not always be directly attributable to climate change itself, the increased frequency of extreme climate/weather events in the LMRB is certain. Those officials with a strong stance on climate uncertainty represent a significant barrier to preparedness. Congressional regulations mandate certain operating rules for the USACE, regardless of dry conditions (LMRB Facilitator Notes, 2013). Under these regulations, reservoir storage used to support navigation, threatens water supplies for other users during drought.

In particular, utilities expressed a need for relevant data from the federal government. Short-term needs such as local flood response, as well as long-term needs, such as preparing for record events would benefit immensely from federal information and support. Yet, utilities in the LMRB do not believe this to be a federal priority. The lack of federal funding for preparation remains a barrier to adaptation.

Tension in Variable Water Laws

While regulations should respect local differences and needs, navigating these is difficult in the LMRB (LMRB Facilitator Notes, 2013). Several states and kinds of users span the Basin, all within a context where traditional western allocation and eastern riparian rights water laws collide.

The variation in western and eastern water laws and perceptions ignites tension among federal, state, local, community, and NGO parties. Parties hold different motivations and interests; at times these deliberately exclude certain groups of stakeholders. For example, "where you are a user in Missouri has a bigger impact on what you can get than it does in Kansas" (LMRB Facilitator Notes, 2013). Thus, differences in institutional structures of both utilities and governments impact the Basin's overall capabilities to plan for and react to extreme climate/weather events (LMRB Facilitator Notes, 2013).

Socioeconomic

A number of the challenges and gaps are related specifically to socioeconomic factors.

Tribal Engagement and Water Rights

Additionally, tribal water rights and needs challenges risk management and the ability of water managers to meet resource demands throughout the Basin. Native American tribes represent a significant portion of LMRB stakeholders, both in the sense of who affects water resources and those impacted by water resources and extreme events. Further engagement among these tribes is essential. Areas for improvement include listening to tribal needs, training on water rights and management, assessing vulnerabilities and identifying adaptations, and building partnerships (Kluck, 2013).

Understanding Residual Risk and Combating 'Plenty of Water' Notion

Changing conditions on the ground reveal altered river channels and encroachment into flood plains, which demands developments in infrastructure (Farhat, 2013). Yet many believe there is still a sufficient water supply, even in times of drought. Although intakes dropped below normal water levels in 2012-2013, many people seem unconcerned about drought in the LMRB (LMRB Facilitator Notes, 2013). Many do not understand the growing residual risk in the area, even though water quantity affects navigation, conservation, and agricultural production (LMRB Facilitator Notes, 2013).

As more data becomes available, there is a greater perception of risk. Water managers increasingly realize "the need to more effectively communicate and educate people in the LMRB about residual risk" (LMRB Facilitator Notes, 2013). Given the state's broad range of responsibilities in providing water to different users, the KWO recognizes the potential shortage of water and asserts the essentiality of storage and conservation in successful adaptation (LMRB Facilitator Notes, 2013). Convincing citizens of this can be difficult, considering a long-standing perception that plenty of water exists.

If the public understands risk, however, they are more likely to support and fund initiatives to protect and conserve water resources. The more funding and resources derived from communities, the more likely solutions will be focused and relevant rather than a 'one-size fits all' solution from the federal government (LMRB Facilitator Notes, 2013).

Dealing with Uncertainty in Climate Science

Part of understanding residual risk in the LMRB is the understanding and acceptance of climate trends. Aside from the actual uncertainty that exists in climate models, dealing with this uncertainty on a social level remains a pressing challenge in the LMRB. Uncertainty on the science end often disproportionately transfers to uncertainty on the stakeholder end, despite the increase in extreme climate/weather throughout the Basin (Shulski, 2013). How scientists and decision makers communicate uncertainty and what level of communication are difficult questions (Shulski, 2013). On the one hand, it is difficult to communicate what is unknown. Yet, stakeholders need to understand climate trends in order to better prepare for future extremes.

One solution to this issue is to work on "filling the gap between research and the stakeholder, by understanding [their] needs from the beginning" (Shulski, 2013). Information is more usable when science and technology blend together in a way that stakeholders can understand (Shulski, 2013). Several state, regional, and federal institutions work to address such needs. Some particularly relevant LMRB institutions include the High Plains Regional Climate Center, national Drought Mitigation Center, NOAA's NIDIS, DOI Climate Science Centers, Extension at the University of Nebraska and the Missouri Basin Climate Collaboration (Shulski, 2013).

Information Needs

Participants in the Lower Missouri River Basin workshop noted several information needs, including the following:

- Information at decadal time scales.
- Level-of-service design standards for community infrastructure by location.
- Relevant, practical science and technology translated into useful tools
- A dashboard to navigate among many federal data websites and to customize needed data that can be manipulated for daily, weekly and monthly views.
- Large spatial and temporal-scale determinations converted for support of shorter-scale decision making.
- Real-time data and monitoring in key locations for soil moisture, precipitation, snow pack and water levels.
- Accurate and localized flood data.
- Regional information exchanges.

Such information would help address some of the major challenges and gaps noted above, allowing utilities throughout the LMRB to capitalize off of existing infrastructure, plans, partnerships, and opportunities in order to better adapt for future extreme climate/weather events.

Partnerships and Collaboration

The large and diverse area within the LMRB is privy to a challenging water management context: five states, western and eastern water laws and Native American territories. "Differences in approaches, alliances and attitudes toward water between those utilities drawing water from the MO and KS Rivers" are vast (LMRB Facilitator Notes, 2013). Thus, partnerships, agreements, and collaboration are of the utmost importance in the LMRB.

Partnerships offer opportunities for critical information sharing, such as Stormwatch (see Extreme Events section above), provide support during extreme climate/weather events, and strengthen the LMRB region's ability to adapt to changing climates. Although federal partnerships between the LMRB and institutions such as the USACE, FEMA, the USGS, the EPA, the NOAA, the USFWS, the USDA and the BOR are key, partnerships between states and local institutions are equally important (Kluck, 2013). Mutual-aid agreements help identify and direct regional network systems and operations (LMRB Facilitator Notes, 2013).

Among the partnerships active in the Basin are several Missouri Basin climate collaborations: the High Plains Regional Climate Center, National Drought Mitigation Center, Regional Integrated Sciences Assessment, State Climatologists, Climate Science Centers and the Landscape Conservation Cooperatives (Kluck, 2013). The work of these institutions is critical, as the LMRB is a sub-basin of the Missouri Basin. Changing weather, land policy, and other events in the larger context of the region's watershed has an effect on the LMRB.

Partnerships involving Native Americans help bridge the gap between state and tribal water laws to address water issues in a more comprehensive manner The American Indian and Alaska Native Climate Change Working Group works to connect different tribes, federal agencies, and NGOs as they address changing climates together (Kluck, 2013). The regional interstate organization, MoRast – the Missouri River Association of States and Tribes – aims as an information exchange and management facilitating organization between states and tribes in the Missouri Basin (Kluck, 2013).

Federal, state, local, and intertribal partnerships successfully organize webinars on extreme climate/weather events and emergency response. Information from these webinars help "determine the need for pre-planning for specific large-scale, transportations system involving, weather events," as well as correct some misinformation and information gaps (Kluck, 2013). Furthermore, partnerships launched an analysis of stakeholder needs in the Missouri Basin, as well as the 2011 Flood Attribution and 2012 Drought Assessments to better understand causes, frequency, impacts, and areas for improvement regarding adaptation to extreme climate/weather events (Kluck, 2013).

In addition to partnerships already mentioned here, workshop participants highlighted the importance assurance districts and pilot projects such as Fort Riley.The KRWAD and other assurance districts in the LMRB area play "an important role in ensuring water allocations and long term planning take place" (LMRB Facilitator Notes, 2013).

In April 2011, Fort Riley was one of eight installations in the United States selected by the Office of the Assistant Secretary of the Army for Installations, Energy and the Environment to be a Net Zero Water Pilot Installation (Hutchinson, 2013). The idea behind this pilot project was to "limit the consumption of freshwater resources and return water back to the same watershed so not to deplete groundwater and surface water resources of that region in quantity and quality over the course of a year" (Hutchinson, 2013). Located in northeastern Kansas, Fort Riley covers 101,733 acres in the LMRB (Hutchinson, 2013).

Despite an approximate increase in building inventory by 45% square footage since 2006, Fort Riley remarkably "decreased water consumption on a square footage basis" as part of the net zero initiative (Hutchinson, 2013). Fort Riley accomplished this through 29 LEED-certified buildings[7] that reduced water consumption 30-40%, as well as a water efficient golf course that saves 12 million gallons of water per year, an industrial wastewater closed loop system and a new wastewater treatment plant at Camp Funston (Hutchinson, 2013).

EPA's Office of Research and Development partnered with the Army in November of 2011 to further promote these efforts at the Fort Riley installation. Areas of focus include water

[7] LEED or Leadership in Energy and Environmental Design building standards certify newly constructed buildings according to several sustainability measures.

quality and treatment, leak detection, water reuse, sewer mining, site stability, safety and mobility, land management vegetation condition, education, and outreach (Hutchinson, 2013).

Fort Riley is a successful example of collaboration and innovation in order to combat the LMRB's tendency to abstain from water conservation, given the Basin's history of adequate water supplies.

Lessons Learned

Lesson Learned: The *array of decisions* within a basin requires *coordination beyond jurisdictional boundaries*.				
Outcomes / Findings	**Success**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• State water laws differ between Missouri and Kansas, impacting the perceptions and opinions of water users in each state. • Community decision making is an important aspect in assessing stakeholder needs.	• Mutual-aid agreements help facilitate collaborative regional networks. • Educational and awareness programs increase stakeholder participation and promote collaboration between jurisdictions, as well as between states and their constituents.	• The path to resolve conflicts in state legislation is not always clear. • People do not understand residual flood risk and relationship-to-return (e.g., 100-year) floods.	• Share information with different municipalities in own state and other states in the basin. • Work with local and national government agencies, as well as relevant organizations to establish mutual-aid agreements and emergency plans prior to events.	• Increase stakeholder awareness of issues within the LMRB. • Promote cross-state collaborative efforts for water management on a basin-scale development.

Lesson Learned: ***Access to and interpretation of data*** **is an issue for operations and emergency response.**				
Outcomes / Findings	**Success**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Utilities and emergency agencies need additional, more accurate, and trusted data to improve response operations. • Data is not very useful if utilities and employees cannot easily and quickly interpret and aggregate information. • Informal communication prevails in instances of distrust or lack of awareness.	• Federal tools and webinars are useful in promoting awareness of issues and improving data access and usability (LMRB Facilitator Notes, 2013). • Data backup and recovery plans for critical data and applications. • Designating priority levels, including “hot swappable servers in alternate, secure locations, so they would be ready to connect if a tornado took out the primary server” and “hot standby” servers in other locations, all to ensure continuing operations during different kinds of events (Witt, 2013). • SCADA monitoring and alarming (Witt, 2013).	• Many distrust information sources; this critically affects where utilities and communities get their information and can inhibit adequate planning and response. • There is a need for “better dissemination to stakeholders who want local data from trusted sources – e.g., NOAA tweets to corn growers” (LMRB Facilitator Notes, 2013). • People have concern whether forecasts are accurate or not.	• Fill in gaps with data reliability issues, “e.g. during icing this year – reliable data points in winter and low flow conditions” can be taken from USGS gauging data. (LMRB Facilitator Notes, 2013). • Cross-sector and agency training sessions on data access, interpretation and use.	• Better identify stakeholder needs and help them know where to access trusted data. • Create “easier access and ability to display data from multiple federal sites [and] aggregation of data into subsets” (LMRB Facilitator Notes, 2013). • Reach politicians and educate constituents; “tell stories that Board members will understand and develop asset management plans” (LMRB Facilitator Notes, 2013).

Lesson Learned: *Asset management* is a key tactic for extreme event preparation.				
Outcomes / Findings	**Successes**	**Weaknesses / Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Asset and infrastructure management are the most pressing concerns of both water utilities and water resource recovery facilities (LMRB Facilitator Notes, 2013). • Ideally, asset management includes preventative maintenance.	• The utilization of mutual-aid agreements, existing partnerships, and research studies in the LMRB. Building upon experiences such as the Great Flood of 1993 to assess damages and prepare for future flooding events.	• Operational efficiency and better operational decisions (Knutson, 2013). • Improved emergency response with a better knowledge of critical utility assets, and a greater ability to plan and pay for future repairs and replacements (Knutson, 2013).	• Utilize pre-planning for the logistics of emergency response amidst inevitable flooding. • Work with the USACE to review the eight 'uses' of water and prioritize these during extreme climate/weather events (LMRB Facilitator Notes, 2013).	• Insurance policies that discourage building in flood plains. • Address aging infrastructure, payment for the true cost of water, and inefficient water use through asset management.

Looking Forward

The long history of efforts to control the Missouri River yields disparate authorities, differing legal frameworks, and water rights that confound a ready resolution to these complex issues. Planning and infrastructure continues to improve among water utilities in the LMRB. Utilities and other agencies build upon collaborations and seek innovative solutions. This is particularly important considering the vast and diverse stakeholder groups dependent upon the LMRB for daily use, livelihoods, agricultural production, and ecosystem needs. Conflicting interests heighten when droughts and floods hit the region, challenging water supplies and access.

Such extreme events are increasingly common and pose several water management challenges for utilities. The variable nature of weather in the region can cause dramatic shifts in runoff from year to year. Thus, there is a need additional and localized data to better assess such changes. At times, however, a mistrust of data sources inhibits this process. Utilities assert the future benefits of federal agencies providing better access to useful forecasting and data in a simple, aggregated form. However, water utilities worry that a proposed Missouri River Compact could create multiple lawsuits, which delay solutions.

Many believe that the USACE, emerging stakeholder alliances, and top-rate data sets remain the most likely mechanisms for balancing intertwined and entrenched water management needs. Demonstrated success with partnerships and collaborative initiatives offers insight into future opportunities to direct water resource management in the LMRB.

WATER UTILITY PROFILES: LMRB WORKSHOP PARTICIPANTS

City of Independence Water Department	
Overview	The City of Independence established the Water Department in 1883. The first private water utility on the Missouri River, the Water Department has grown to not only serve the city itself, but also offer wholesale water to eleven area water district distributers. Wells supply water that the Department then treats at the Courtney Bend Water Treatment Plant.
Location	Headquarters: 11610 East Truman Road, Independence, MO 64050 http://www.ci.independence.mo.us/Water/Default.aspx
Operations conducted	Drinking water treatment and distribution Stormwater Services Wastewater management Wholesale water provider
Size	• Service Area: 250,000 people in the City of Independence and among wholesale customers. • Wells: 38 • Treatment Plants: 2 (Courtney Bend and Rock Creek)
Administrative structure	The Water Department is one of 20 departments within the City of Independence government. Water resource protection plans direct the Department, which also works closely with the Water Pollution Control Department.
City of Olathe Public Works Department	
Overview	Divisions within the Public Works Department manage water quality protection efforts and stormwater runoff in Olathe. Formed under the Infrastructure Management Division of Public Works in 2011, the Stormwater Section maintains curb inlets, boxes, pipes, streams, lakes, and ponds. Flood control projects work to protect water quality, development, and the environment. The Department monitors for illicit discharges and works to meet NPDES standards set by EPA.
Location	Headquarters: 100 E. Santa Fe St., Olathe, KS 66061 http://www.olatheks.org/PublicWorks/Stormwater
Operations conducted	Monitoring and enforcement Stormwater management Water quality protection
Administrative structure	The Stormwater Section operates under the umbrella of the Public Works Department, collaborating with several divisions and sectors.
City of Olathe Utility Services Department	
Overview	Various divisions within the Public Works Department regulate and manage water and wastewater in the City of Olathe. The Water Protection Division runs daily water quality tests, city crews manage pressure leaks, issues connection permits, tests for backflow, and promotes drought management.

Location	Headquarters: 1385 S. Robinson, Olathe, KS 66061 http://www.olatheks.org/OMS/Water
Operations conducted	Conservation and drought management. Water supply management Wastewater services
Administrative structure	Water services and management within the Utility Services Department operate under the Water Conservation Plan.
City of Shawnee Stormwater Management Division	
Overview	Shawnee's stormwater runoff falls under the management of the Stormwater Management Division of the Public Works Department. The Division operates Stormwater Treatment Facilities to control and treat runoff prior to it entering the conveyance system. They also monitor land disturbance permits, and work with FEMA for floodplain mapping and flood insurance services. Finally, the Division offers rebates for stormwater controls.
Location	Headquarters: 11110 Johnson Drive, Shawnee, KS 66203 http://www.cityofshawnee.org/WEB/ShawneeCMS.nsf/vwContent/StormwaterManagement?OpenDocument
Operations conducted	Stormwater management
Administrative structure	The Division is operated under the Stormwater Manager, who is overseen by the Department of Public Works.
Johnson County Wastewater (JCW)	
Overview	Johnson County created the County's first sewer district in 1945 JCW's first wastewater treatment plant opened operations in 1949. JCW provides wastewater collection, transport, and treatment for residential, industrial, and commercial customers. The utility's regularly tests water quality at their laboratory.
Location	Headquarters: 11811 S. Sunset Dr. , Olathe, KS 66061 http://www.jcw.org/
Operations conducted	Education and outreach Wastewater management Water quality testing
Size	• Service Area: 200+ districts • Connections: 135,500, serving more than a half million people of commercial, industrial, multi-family, and single-family accounts • Employees: 200+ • Sewer Pipelines: ~2,200 miles of mains • Wastewater Treatment Plants: 6 • Treatment Capacity: 64MGD total • Sewer Pump Stations: 30

Administrative structure	The County Board of Commissioners oversees JCW operations, along with the County manager and Deputy County Manager. Five divisions - Asset Management, Planning, and Public Project; Business Operations and Planning, Customer Relations; Operations and Maintenance; and the Water Quality Laboratory – organize daily operations.
Kansas City Board of Public Utilities (BPU)	
Overview	Kansas City's BPU, a not-for-profit public utility, was established over a hundred years ago. This occurred when Kansas City bought the previously privately-owned water system in 1909. The BPU manages services for the city's electric and water customers, including both residences and businesses. It is currently involved in an array of green initiatives ranging from energy audits to weatherization programs. It is one of only seven water systems nationally to be ranked "gold" by the American Water Works Association.
Location	Headquarters: 540 Minnesota Avenue, Kansas City, KS 66101 http://www.bpu.com/
Operations conducted	Drinking water distribution Hydroelectric authorization
Size	• Service Area: 130 square miles in Wyandotte and Johnson Counties, serving over 50,000 customers • Collector Wells: 2 • Pipelines: 1000+ miles of mains • Treatment Facility: 1; Nearman Water Treatment Facility • Treatment Capacity: 84 MGD • Storage Capacity: 31 MGD
Administrative structure	A six member Board of Directors oversees the BPU, along with a general manager. The BPU is self-governed, and part of the administrative arm of the Unified Government of Wyandotte County.
Kansas Department of Health and Environment	
Overview	The Kansas Department of Health and the Environment is a state wide agency which deals with oversight, regulation, and assistance in a wide variety of human and ecological issues. The Bureau of Water (BOW) represents one of several divisions within the Department, assisting with public water supply and watershed management.
Operations Conducted	Data assessment and management Education and outreach Monitoring and enforcement Pollution control Stormwater management Watershed protection
Location	Headquarters: 1000 SW Jackson, Suite 420, Topeka, KS 66612 http://www.kdheks.gov/

Administrative structure	The Director leads the BOW's operations, and is overseen by the Department of Health and Environment.
Kansas City Water Services Department	
Overview	The Kansas City Water Services Department was established in 1874. The Department manages water, wastewater, and stormwater services for Kansas City and nearby areas.
Location	Headquarters: 4800 E. 63rd Street, Kansas City, MO 64130 https://www.kcwaterservices.org/
Operations conducted	Drinking water treatment and distribution Stormwater management Wastewater management and treatment
Size	• Service Area: Kansas City and surrounding regions • Customers: 170,000 residential and business and 33 wholesale customers • Treatment Capacity: 240 MGD • Pumped Water: • Pipelines: 2800+ miles of mains • Wastewater Treatment Plants: 6
Administrative structure	Customer use and impacts fees fund Kansas City Water Services operations. A five-year capital improvement plan provides guidance for the utility.
Leavenworth Water Department	
Overview	The Leavenworth Water Department provides direct sale services to the people of the city (through direct sale), as well as to wholesale customers in Lansing (Lan-Del District) and six other water districts. The City of Leavenworth bought out the private water supplier in the 1880s, establishing the Leavenworth Water Department.
Location	Headquarters: 601 Cherokee, Leavenworth, KS 66048-0576 http://www.lvnwater.com/index.html
Operations conducted	Drinking water treatment and distribution
Size	North Plant – from intake facility on west back of Missouri River South Plant – from 9 intake wells on west bank of Missouri River Pilot Knob Reservoir- receives water from both plants • Service Area: 10,000 connections, serving about 50,000 people in Leavenworth, Lansing, and six water districts • Employees: 34 • Pump Stations: 1 (booster pump station) • Pipelines: 180 miles of raw water, treated water, and distribution mains • Wells: 9 along the west bank of the Missouri River • Treatment Facilities: 2 (South Plant and North Plant) • Treatment Capacity: 12 MGD total

Administrative structure	Independent from the local government, a five-member Governing Board oversees the broad direction of the Department and helps manage an annual $3.5 million budget and the 2012 Capital Investment Improvement Plan.
Metropolitan Utilities District-Omaha (MUD)	
Overview	The Metropolitan Water District was established in 1913 Nebraska Legislature. By 1918, it was renamed the Metropolitan Utilities District, as it acquired responsibilities for managing the gas system as well. As a political subdivision of the State, MUD provides water and natural gas for metropolitan Omaha. MUD is 'consumer owned' and one the fifth largest gas utility in the U.S.
Location	Headquarters: 1723 Harney St., Omaha, NE 68102-1960 http://www.mudomaha.com/water
Operations conducted	Conservation awareness and actions Drinking water treatment and distribution Water supply management
Size	Drinking Water Pipeline System: 2750+ Miles • Service Area: 203,230 customers in the Omaha area • Employees: 828 (for entire utility, including water division) • Pumped Water: ~90 MGD • Pipelines: 2,722 miles of mains
Administrative structure	A seven person Board of Directors oversees management and helps to establish long term planning initiatives ranging from water emergency plan to conservation education systems and area events. The Board is elected by customers and holds monthly meetings.
Raytown Water Company (RWC)	
Overview	Established in 1925, this public utility is governed by the Missouri Public Service Commission. RWC supplies water to residential, commercial, and industrial users. The utility withdraws water from the Missouri River, authorized by the Kansas City Water Department, for customer services.
Location	Headquarters: 9820 E. 63$^{Rd.}$ Street, Raytown, MO 64133 http://raytownwater.net/
Operations conducted	Community engagement and awareness projects Drinking water distribution
Size	• Service Area: 6,700 customers in Raytown, Independence, and Kansas City • Storage Towers: 4 (3 operating currently) • Storage Capacity: 2.5 MG at Hydropillar (2 MG), Gregory (.25 MG), and Chapel (.25 MG) Towers. • Pumped Water: 1.3 MGD • Pipelines: 65+ miles of mains

Administrative structure	A seven-member Board of Directors oversees the appointment of officers and policy direction. The Board President also serves as the General Manager of the business, participating in the daily activities and operations.
WaterOne	
Overview	A quasi-municipal agency, WaterOne provides Since its founding in 1957 when Johnson County bought out the older private utility, WaterOne has gradually increased its services and capacity to reflect changes within Johnson County. WaterOne is the largest water utility in Kansas, and draws water from the Kansas and Missouri Rivers.
Location	Headquarters: 10747 Renner Boulevard, Lenexa, KS http://www.waterone.org/home
Operations conducted	Drinking water treatment and distribution Water quality testing
Size	• Service Area: 272 square miles, including 16 cities and serving 140,000+ accounts or 400,000+ individuals. • Employees: 350+ • Wells: 21 • Pipelines: 3000+ miles of mains • Treatment Capacity: 200 MGD
Administrative structure	A seven-member Board of Directors oversees the policy and direction of the organization, while the General Manager supervises its seven-member Executive Team. With a budget just under a $100 million, WaterOne follows an expansive Master Plan program that will continue for years to come.

STAKEHOLDERS: LMRB WORKSHOP PARTICIPANTS

Organization / Institution	Description	For More Information
AgriServices – Brunswick	A full-service agricultural retail and fertilizer wholesale company on the Missouri River. Apart from its line of fertilizer components, it provides a full line of farm goods, animal feed, and nutrition products. Heavily relies on the Missouri for transportation needs, AgriServices is an example of a company highly vulnerable to climatic changes.	http://www.agriservices.com/
Friends of the Kaw-Kansas City (FOK)	A grassroots environmental advocacy group looking after the largest prairie river, the Kansas River (known as the Kaw). FOK promotes sustainable and recreational use of the river. They sponsor the Kansas River Keepers, an advocate of many stakeholder groups working to benefit the 'Kaw.'	http://kansasriver.org/
Intertribal Council on Utility Policy (COUP) – Rosebud	The Intertribal Council on Utility Policy is an advocacy, coordination, and outreach group that focuses on increasing utility resources and effectiveness across their states and tribes. With wind and solar projects in areas most impacted by drought and poverty, COUP helps to address tribal issues and build sustainable economies among tribal communities.	http://www.intertribalcoup.org/index.html
Kansas River Water Assurance District – Topeka	Created by the 1996 Water Assurance Program Act by the Kansas Legislature, these three river districts work to provide storage to additional needed waters across the state. The Kansas River District stretches from Kansas City to Junction City and has three water storage locations/reservoirs that allow for citizens or groups holding valid rights to certain water amounts, even during drought.	http://www.ksda.gov/water_management_services/content/210
Kiksapa Consulting, LLC – Mandan	With broad reaching solutions in management consulting, climate change adaptation, geospatial technologies, environmental research, and science education, Kiksapa Consulting works on public, private, and tribal water and environmental projects.	http://www.kiksapa.com/web/guest/home

Larkin Lamp Rynearson – Kansas City	Recently combined, the engineering firms of Larkin Associates (Kansas City) and Lamp Rynearson (Omaha) work in 12 core service areas, including the specialty area of 'Larkin Aquatics.'	http://www.lra-inc.com/
Layne Christensen Co – Kansas City	Layne manages water, construction, and drilling through various and new technologies. The company works through an integrated approach to water, mineral, and energy-based challenges.	http://www.layne.com/en/solutions/water-management/
Mid America Regional Council	Serves as a major coordination and organization body for the greater Kansas City area, encompassing nine counties and over 100 cities. Major program areas include: enhanced response, caring communities, efficient transportation, healthy environment, and effective government. The healthy environment program covers regional forecasting, green governance building, land use planning, and regional waste initiatives.	http://marc.org/
National Drought Mitigation Center (NDMC)	The NDMC focuses on long-term mitigation, risk management, and societal vulnerability reduction. It further acts as a decision-making assistant and toolmaker, conducting research and outreach and coordinating between industry and government.	http://drought.unl.edu/
Omaha Public Power District – Omaha	One of the largest publicly-owned electric utilities in the U.S., the Omaha Public Power District provides electricity to 13 southeast Nebraska counties containing over 350,000 households. Powering this grid are three main plants – two coal, one nuclear – as well as a smaller variety of renewable sources. The majority of these plants are on the Missouri River.	http://www.oppd.com/index.htm
University of Missouri – Columbia	With programs in environmental leadership, management, science, health, safety, and soil, the environmental programs of this Columbia based university help to underpin the green efforts of the whole state.	http://missouri.edu/
Urban Water Institute-KSU – Manhattan	The Kansas State University's Urban Water Institute uses its two laboratories, students, staff, and community partnerships with both industry and faculty to assist in the planning and implementation of water based research and projects across four states.	http://www.k-state.edu/urbanwaterinstitute/index.html

Water Systems Engineering, Inc. – Ottawa	Water Systems Engineering uses an in-house laboratory to research water treatment and transport applications.	http://www.h2osystems.com/index.html

ATTENDEES: LMRB WORKSHOP PARTICIPANTS

John Albert	WRF
Mike Armstrong	WaterOne
Nancy Beller-Simms	NOAA
David Bries	City of Olathe
Carl Brooks	City of Peculiar
T.M. Bull Bennett	Kiksapa Consulting, LLC
Chris Burns	Delich, Roth, and Goodwillie
Terry Chism	Raytown Water
Rex Cox	Kansas Department of Health and Environment
K. Deason	U.S. EPA Region 7
Rodney Geisler	Kansas Department of Health and Environment
Bob Gough	Intertribal Council On Utility Policy
Michael Gregory	City of Shawnee, Public Works Department
Patrick Ertz	PWSD#2 of Jackson County
Lester Estelle	Water One
Jody Farhat	USACE
Lauren Fillmore	WERF
Steve Fitzgerald	Layne Christensen Co.
Karen Flournoy	U.S. EPA Region 7
Joe Foster	City of Olathe
John Harrington	Kansas State University
Miriam Heller	MHITech Systems
Caroline Hemenway	Hemenway Inc.
Stacy Hutchinson	Kansas State University
Tom Jacobs	Mid-America Regional Council
Bill Jackson	AgriServices
Durward Johnson	Board of Public Utilities
John Kaufman	Leavenworth Water Department
Lee Kellenberger	Johnson County Stormwater Management Program
Jeanette Klamm	City of Lawrence
Michael Klender	Kansas City Missouri Water Services Department

Doug Kluck	NOAA
Mary Knapp	State Climatologist, Kansas State University
Jane Knecht	WERF
Cody Knutson	National Drought Mitigation Center
Chad McNutt	National Integrated Drought Information System
Matthew McLaughlin	Missouri Water, City of Independence
Vikram Mehta	Center for Research on the Changing Earth System
Karen Metchis	U.S. EPA Office of Water
Dan Miller	City of Overland Park
Mary Mindrup	U.S. EPA Region 7
Kent Newport	HDR Engineering
Tanya Nix	U.S. EPA
Randy Norden	Missouri Rural Water Association
Anthony O'Malley	Larkin Lamp Rynearson
Kenan Ozekin	WRF
Susan Pekarek	Johnson County Wastewater
Bethany Perry	NOAA
Kip Peterson	Kansas City Water Services
Rob Plain	University of Missouri
Dong Quach	KC BPU
Mike Rawitch	Friends of the Kaw
Lesley Regney	Mid-Atlantic Regional Council
Thomas Schrempp	WaterOne
William Schumacher	Intertribal Council On Utility Policy
Larry Shepard	U.S. EPA Region 7
Martha Shulski	High Plains Regional Climate Center
David Shrout	City of Peculiar
Gene Siadek	Metropolitan Utilities District
Martha Silks	Leggette, Brashears, and Graham
Sarah Smith	GBA
Dennis Snook	Omaha Public Power District
Tracy Streeter	Kansas Water Office
Claudio Ternieden	WEF

Chiki Thompson	Raytown Water
Nancy Tosta	Ross Strategic
Kent Weatherby	Kansas River Water Assurance District
Daniel Wildcat	Haskell Indian Nations University
Kyle Wilkens	Congressman Emanuel Cleaver, II
Michelle Wirth	City of Olathe
Kathleen Wiseman	Water Systems Engineering, Inc.
Aaron Witt	Johnson County Wastewater

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APPENDIX F

NATIONAL CAPITAL AREA

The project's National Capital Area workshop took place on December 17, 2013 at the Metropolitan Washington Council of Governments in Washington, D.C. The workshop and findings detailed in this study would not have been possible without the Regional Team listed below. The Research Team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

Caroline Hemenway (Hemenway, Inc.)
Kim Linton (WRF)
Jonathan Reeves (DC Water)
Tanya Spano (Metro Washington Council of Governments)

The Story in Brief

In 2012, two extreme events struck the National Capital Area that provide insight into the value and cost of water utility and community preparedness. With little warning, a rare derecho windstorm left a swath of damage across its path. Four months later and after a week of tracking and preparation, 'Superstorm' Sandy devastated much of the East Coast. These two events affected water utilities in very different ways: short-term power outages resulted from the 2012 Derecho, while long-term preparation for Sandy stretched resources. The National Capital Area was largely spared from Sandy, but many lessons emerged from full-scale preparation for the storm. These two events highlight critical interdependencies among power, transportation, and water infrastructures, as well as the persistent need for more coordinated resiliency planning.

Background

The National Capital Area (Figure F-1) sits along the Potomac River and encompasses the District of Columbia (District); Frederick, Montgomery, Prince George's, and Charles counties in Maryland; Arlington, Fairfax, Loudoun, and Prince William counties in Virginia; plus several small nearby cities in both states, including Alexandria and Falls Church. Though other cities and counties reside within the Washington metropolitan area, this case study focuses on those represented at the Extreme Events Workshop in December 2012.[1] It is for this purpose that we refer to this area as the National Capital Area, rather than the Washington metropolitan area. We use the latter term only in cases including cities and counties not represented at the workshop (for instance, when referring to some demographic data).

Figure F-1. The National Capital Area.

Topography in the National Capital Area ranges from close to sea level along the Anacostia and Potomac Rivers – including the U.S. Capitol Mall and Tidal Basin – to about 400 feet above sea level. The Atlantic seaboard fall line, or the area where coastal plain abuts the geologic boundary of the upland hard rock Piedmont zone, crosses through the National Capital Area. Like many older east coast cities, Washington, D.C. and Alexandria, VA take advantage of power from the rapidly moving rivers as they cross this fall line. The relationship between urban areas and rivers places certain neighborhoods within the National Capital Area at high risk for frequent flooding.

Chesapeake Bay Watershed

The Chesapeake Bay is the largest estuary in the United States. Though bordered primarily by Virginia and Maryland, this watershed originates with the Susquehanna River in the states of Pennsylvania and New York, as well as the Shenandoah-Potomac Rivers in West Virginia; it also includes portions of Delaware. Water in the lower Chesapeake Bay is saline, while freshwater comprises the upper stretches. The Chesapeake Bay and its tributaries are the major water resource system for the National Capital Area.

Approximately 17 million people live in the Bay's watershed, of which approximately 30% reside in the metropolitan Washington region. As a result of population density and agricultural operations in the upper watershed, water quality suffers from excess nutrients and the presence of chemical contaminants. Formed in 1983 in response, the Chesapeake Bay Program leads and directs Chesapeake Bay restoration and protection. Partners include the states of Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia; the District; the

[1] Refer to Water Utility Profiles and Stakeholders charts at the end of this case study for further information about workshop participants.

Chesapeake Bay Commission (a tri-state legislative body); the US Environmental Protection Agency (EPA); and participating advisory groups representing citizens, local governments, and the scientific community. This regional partnership signifies both the importance of the Bay, as well as the many challenges it faces.

Potomac River

The Potomac River, a major tributary for the Chesapeake Bay watershed, begins in the mountains of Virginia and West Virginia. The Potomac River Basin crosses four states in addition to the District, flowing 383 miles before entering the Chesapeake Bay. In the National Capital Area, the Potomac River is tidally influenced up to the fall line. Temperature fluxes and circulation patterns affect the dissolved oxygen levels in the Bay, which is a major fish and shell fishery. The average river flow through the District is seven billion gallons per day. Municipalities withdraw 486 million gallons per day; this provides some 90% of the region's drinking water supply (ICPRB, 2012).

Anacostia River

The Anacostia River is a major tributary of the Potomac River. It flows 8.5 miles through Prince George's County, MD and the District before joining the Potomac just south of the city. As with many areas in the metropolitan Washington region, heightened urbanization trends throughout the Anacostia watershed result in a degraded river with significant loss of natural wetlands due to dredging and other urban activities. Local community efforts and regional efforts[2] by states, local, and federal agencies to reduce pollution, clean up the river, and restore hundreds of acres of wetlands, are slowly recovering the Anacostia (Tucker, 2011).

Water Laws and Governance

A number of laws are governing bodies influence policies in this area.

Water Supply Reservoirs: Georgetown, McMillan, and Dalecarlia

Three major water supply agencies treat about 95% of the region's drinking water: the Washington Aqueduct Division of the U.S. Army Corps of Engineers, the Fairfax County Water Authority, and the Washington Suburban Sanitary Commission (WSSC).

The Washington Aqueduct spans 147 square miles and serves one million people through three wholesale customers in the District, Arlington County, VA, and Falls Church, VA (Gamby, 2012). Agencies withdraw water from the Potomac River at Great Falls; it then flows by gravity to the Dalecarlia Reservoir. The Dalecarlia Reservoir allows sediment to settle out before flowing water into the Dalecarlia water treatment plant or diverting water to the Georgetown Reservoir for subsequent treatment (Figure F-2). The Dalecarlia plant treats 100-160 million gallons per day (Gamby, 2012).

The McMillian Reservoir, built by the U.S. Army Corps of Engineers (USACE) in 1902, was the District's major source of drinking water until the Dalecarlia Reservoir was built 50 years later. About 75% of the water treated by the Washington Aqueduct today – and thus 75% of operating costs – serves DC Water, the District's main water supply utility (DC Water, 2013).

Wastewater and Stormwater Management

The area has 19 major wastewater plants managed by 15 local governments or authorities. DC Water runs the Blue Plains Advanced Wastewater Treatment Plant, the largest advanced treatment plant in the world, and holds agreements to collect and manage wastewater

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[2] For more information, visit the Anacostia Watershed Restoration Plan: http://www.anacostia.net/plan.html.

from parts of Maryland and Virginia suburbs. The WSSC provides wastewater collection and treatment services for Montgomery and Prince George's counties in Maryland. Alexandria Renew Enterprises, Arlington County, Fairfax County, Prince William County Service Authority, Loudoun Water, and the Upper Occoquan Service Authority also provide wastewater treatment and collection services to various jurisdictions in Virginia.

More than 22 county or city governments manage stormwater in the National Capital Area. In the District, the District Department of the Environment (DDOE) Stormwater Management Division is largely responsible for managing stormwater that discharges directly into waterways, while the management of stormwater runoff that enters the combined sewer system is the responsibility of DC Water. Combined wastewater and stormwater systems cover one-third of the city. In order to effectively manage the volume of combined flows that occur in the system, DC Water is undertaking several major projects to construct 12.8 miles of underground tunnels as holding tanks during rainstorms (Shaver, 2013). The \$2.6 billion project goal is to mitigate around 96% of combined sewer system overflows by 2025 (Shaver, 2013).[3] In the District, DDOE's approach to stormwater management focuses more heavily on green infrastructure options – rain barrels, rain gardens, impermeable surfaces, and various retrofitting options for homes – to reduce future runoff before it enters the conveyance system (DDOE, 2013).

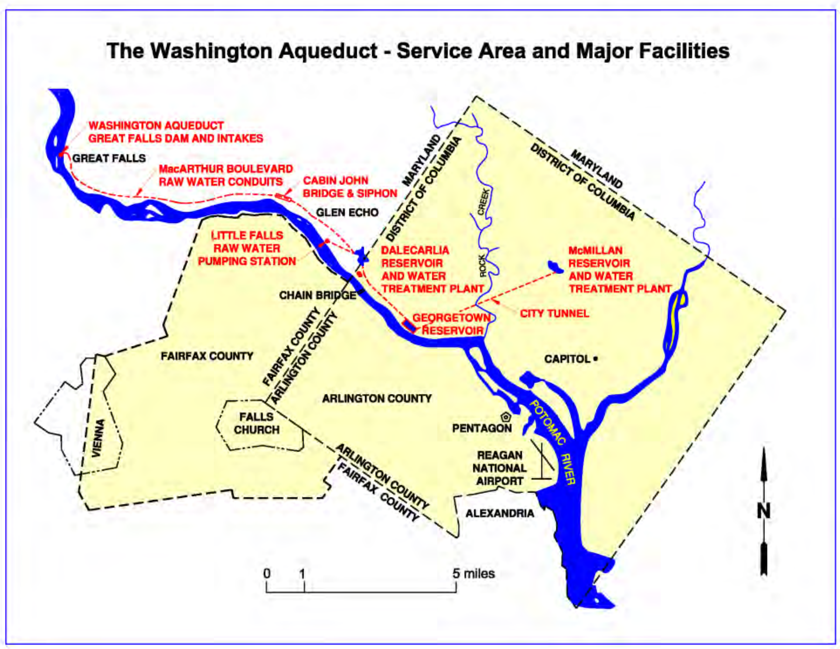

Figure F-2. Washington Aqueduct Division Service Area, Raw Water Supply and Major Facilities.
Source: Gamby, 2012.

[3] DC Water recently proposed an initiative that would potentially incorporate significant green infrastructure elements into its future Long-term Control Plan. See http://www.dcwater.com/news/listings/press_release630.cfm for more information.

Climate and Water Trends

Research at the National Center for Environmental Prediction (NCEP)[4] indicates an increase in storm frequency and variation for the National Capital Area. Though it is not always possible to attribute individual weather events directly to climate change, it is certain that "changes in the number and intensity of some events (for example, more intense rainfall and warmer winter nights) have strong links to climate change" (Higgins, 2012). Climate trends over time indicate that individual events have linkages to certain extreme climate/weather events (Higgins, 2012). Climate research is an ongoing process for the National Capital Area, yet some trends are evident.

NOAA climate models show that sea level rise will impact the District. The Metropolitan Washington Council of Governments (MWCOG) further confirms that the metropolitan Washington region "is experiencing the effects of climate change with rising sea levels and a warmer Chesapeake Bay – more than 2°C (3.6°F) in the past 70 years. Consistent with observed increases in atmospheric water vapor," these events result in intensified precipitation patterns (Higgins, 2012). Exposure to an increasing number of tropical storms and nor'easters, heat waves, snowmelt, and heavy rain combinations in the National Capital Area cause localized flooding. Models show that the frequency and severity of extreme climate/weather events is likely to increase.

As observation methods have changed dramatically over time (pre- and post-satellite era), it is difficult to establish hurricane patterns and trends. Furthermore, hurricanes vary greatly from year to year. Despite some spikes in the number of hurricanes in past years such as 1951 and 1970 (Figure F-3), data suggests a general increase in overall hurricane numbers since 1995 (Figures F-3 and F-4) (Higgins, 2012).

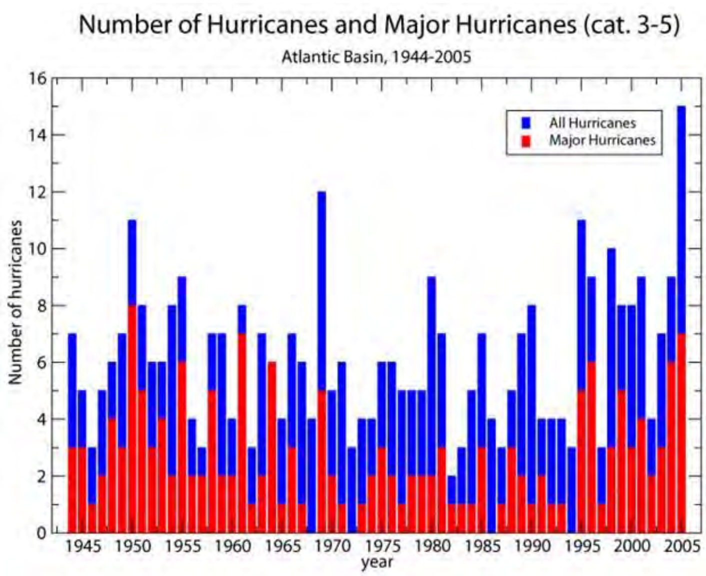

Figure F-3. Number of Hurricanes and Major Hurricanes by Year in the Atlantic Basin.
Credit: NOAA. Source: Higgins, 2012.

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[4] The NCEP is a central component of NOAA's National Weather Service that provides forecasts for climate seasons, El Nino/La Nina, weather up to seven days, extreme climate/weather events, aviation warnings and high seas workings (Higgins, 2012). Solar monitoring, various modeling, and data assimilation assist NCEP in forecasting abilities and international partnerships (Higgins, 2012). See Appendix B for further information.

Demographic Trends

Due to abundant flows in the Potomac River, the National Capital Area's primary drinking water supply, drought that impacts the potable water systems is far less severe for the majority of the region than elsewhere in the U.S. At the same time, the potential for drought impacts can in fact be acute for several smaller and outlying jurisdictions that rely primarily or exclusively on groundwater supplies. In addition, the forecasted increase in populations throughout the National Capital Area by 2040 indicates additional stress on infrastructure and water resources. Populations within the Potomac Basin boundaries increased 5% from 2005-2010 (ICPRB, 2012). A study by the ICPRB estimates that the region could experience water shortages by 2040 under certain scenarios, as water demand will reach around 611 million gallons/day (Ahmed et al., 2013). Unrestricted demands will increase as temperatures increase (Ahmed et al., 2013).

Extreme Events

Recent years revealed shifts in weather patterns throughout the National Capital Area, as well as some uncommon, but significant, climate/weather events. Hotter summer temperatures, hurricanes, earthquakes, and the striking 'Snowmageddon' storm of 2010 characterized an increasing commonality of the region's formerly rare events. Such events varied in their predictability and in the actions necessary to effectively respond to their aftermath. Among these events, were the notable 2012 Derecho and Superstorm Sandy of 2012. The workshop focused on these events, given their recent occurrence and the many lessons learned from differences in the storms' forecasts, paths, impacts, and emergency preparation and response.

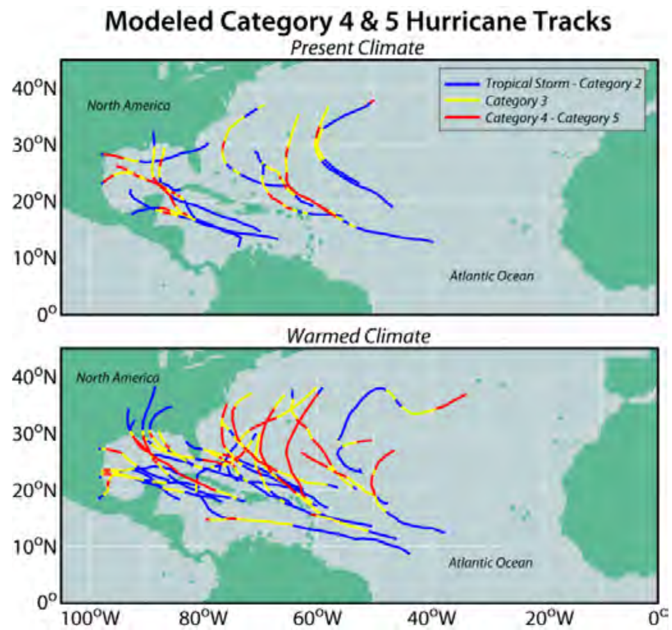


Figure F-4. Category 4 and 5 Hurricane Tracks Modeled for Current and Warming Climate in North America.
Credit: NOAA.
Source: Higgins, 2012.

2012 Derecho

On June 29, 2012, a fast-moving, large, and violent thunderstorm called a *derecho* slammed into the National Capital Area. This derecho hit amidst record high summer temperatures; in the days before, Prince George's and Montgomery Counties' temperatures soared to a high 103°F. Peak level water and power usage throughout residential areas was also at record highs, due to hot temperatures.

Though forecasts predicted thunderstorms during this time, the day quickly transformed into one of unexpected winds up to 85 mph. The derecho hit with such surprise and fury that utilities and localities had little time to prepare. In fact, the DC Department of Homeland Security and the Department of Homeland Security Emergency Management Agency (HSEMA) was in the process of responding to the heat wave when wind storms reached the National Capital Area. The derecho also brought unexpected and abnormal precipitation (Quarrelles, 2012).

> *Whereas the derecho had a unique footprint (high winds and rain), the forecast for Sandy was clear and somewhat predictable"*
>
> *– Jamie Quarrelles*
> *District of Columbia Homeland Security and Emergency Management Agency*

Impacts to the Community

The derecho killed five people (Harish, 2012) and high precipitation levels associated with the derecho caused low-lying areas to flood, mainly in traditionally vulnerable areas such as Bloomingdale in the Northwest portion of the District (Quarrelles, 2012). Flooding disrupted transportation in some areas of the District, Virginia, and Maryland; this inhibited regular business activities. Businesses outside of flood-prone areas suffered minimal damage (Quarrelles, 2012).

Perhaps the most immediately felt effect was heat, as the derecho caused widespread power outages during an already record-hot summer. Nearly 1.2 million homes in the District lost power (Harish, 2012). Record temperatures put stress on cooling systems, and loss of power put vulnerable populations at risk. Power outages completely shut down phone lines and internet services for many customers in the National Capital Area, including critical 911 services in some areas.

Impacts to Water Utilities

Emergency managers faced many challenges in responding to the derecho, particularly related to power outages. Emergency staff shortages further hindered response efforts. In anticipation of record-high temperatures, utilities sent staff home early for the Fourth of July weekend. Area governments were shut down to relieve congestion during the heat. A lack of public transportation left many emergency responders unable to commute to work.

Downed Trees in Montgomery County during the 2012 Derecho Windstorm.
Source: Montgomery County, MD, OEMHS.

Issues arose with the Potomac Electric Power Company (Pepco), the power utility which serves Maryland and Washington, D.C. Extensive wind and flood damage resulted in a time-consuming process to restore power to water treatment and distribution facilities. Over 3,700 organizations were on Pepco's priority list; the sheer number of services needing restoration, combined with a lack of coordination in response efforts caused problems for some area water utilities. PJM Interconnection LLC (a Mid-Atlantic region power company) also curtailed electrical usage (Grey, 2012).

The Potomac and Patuxent Water Filtration Plants went offline around midnight on June 29th (Grey, 2012). Additionally, 50 other facilities in Prince George's and Montgomery Counties, including some raw water pumping stations, temporarily lost power. Downed trees blocked off streets, hampering the movement and fueling of mobile generators.

As utilities typically fill water storage tanks during low power-load periods overnight, tanks were below maximum capacity when the derecho arrived. Most were at 65% capacity when the storm hit, lower than usual because high temperatures had increased demands for water. The storm struck when storage at WSSC was at the lowest point of the day, a mere 114 MG of a total 174 MG capacity (Grey, 2012). WSSC produced 206 MG of water to try and meet needs, yet power outages limited how much water WSSC could treat and distribute (Grey, 2012). On June 30th, WSSC released a water restriction notice.

Utilities Work to Restore Power in Montgomery County Following the 2012 Derecho Windstorm.
Source: Montgomery County, MD, OEMHS.

Despite the storm's fury, WSSC successfully maintained uninterrupted water services. Nevertheless, the derecho cost WSSC $75,000 in repairs (Grey, 2012).[5] WSSC's total accumulated costs from the 2012 Derecho were minor compared with the considerable cost of debris removal. City officials trimmed trees after the storm, which helped forestall similar power outage and repair issues when Sandy arrived four months later.

Water runoff through sewer systems and into wastewater treatment plants increased significantly. Largely due to the derecho's heavy rains, existing development further contributed to the accumulation of runoff. Increasing rates of commercial and residential development in the National Capital Area leaves large areas of impervious surface, which had little capacity to naturally absorb and control runoff during the storm (Quarrelles, 2012).

Utility and Community Response

Actions Taken – Emergency Response Short-Term Responses

The unexpected thunderstorms that transformed into the 2012 Derecho primarily instigated reactive responses from utilities and communities in the National Capital Area. Utilities called in emergency response personnel and addressed issues as they arose. This proved difficult, as many personnel had already left town for the holiday (Quarrelles, 2012). Those staff able to return to work used small portable generators to obtain water level and water quality parameter readings at several sites where batteries ran low (Grey, 2012).

Water utilities contacted electric utilities to collaborate on energy service restoration. WSSC benefited from the facility prioritization work previously completed with local power companies Pepco and Baltimore Gas and Electric Co. (BGE) following a 2010 storm.[6] Frequent

[5] This figure does not account for the costs of power outages; it only relates to specific water services.

[6] Following an electrical outage in July 2010 due to a major storm, WSSC "met with Pepco to inform staff of the importance of water supply to the region and the vitally important role…water filtration plants play" (Grey, 2012).

exchanges with Pepco's Control Center, Montgomery County's Emergency Operations Center, and fire departments in both Montgomery and Prince George's counties facilitated the exchange of important power and water storage information during the event (Grey, 2012).

Power restoration remained a priority. Montgomery County prioritized the area's five hospitals, followed by the 911 center and Emergency Operations Center backup, two water treatment plants, 34 county nursing homes, 27 assisted living facilities, and the county's two correctional facilities (Voss, 2012). Utilities restored power at the Potomac Water Filtration Plant by the morning of June 30th,[7] while plants in Wheaton remained offline until later that night (Grey, 2012). After system verification response and approval by the fire department, utilities lifted water restrictions in all areas by mid-day on July 1st (Grey, 2012).

Water Utilities and Institutions Participating in the National Capital Area Workshop

DC Water – District of Columbia Water and Sewer Authority

DDOE – District Department of the Environment

MWCOG – Metropolitan Washington Council of Governments

Pepco – Potomac Electric Power Company

PJM Interconnection LLC – Pennsylvania, New Jersey, Maryland

Washington Aqueduct – Division of USACE

WSSC – Washington Suburban Sanitary Commission

Actions Taken – Long-Term Planning Long-Term Responses

WSSC finished an electrical reliability study with local power companies Pepco and BGE; this study was underway prior to the derecho. As part of ongoing regional calls and coordination efforts, the utilities all agreed to place water and water-related facilities as a first priority restoration during future storms (Grey, 2012). Construction for a 10 MW generator began at the Potomac Water Filtration Plant, with a buffer for sound attenuation, at an estimated cost of $30-40 million. While the generator will be useful during power outages and extreme climate/weather events, it also requires a massive amount of fuel of approximately 1,000 gallons/hour. Thus, the need for improvements to fuel delivery and storage infrastructure remains significant, along with associated emergency management. WSSC planned to purchase three mobile generators (in addition to its existing six), ranging from 450 KW to 40 KW in size to provide power for smaller facilities (Grey, 2012). Pepco also trimmed trees along electrical supply routes to the Potomac Water Filtration Plant (Grey, 2012).

Prior to the storm, DC Water's Blue Plains Advanced Wastewater Treatment Plant was in the process of constructing onsite anaerobic biosolids digesters with combined heat and power, part of a larger initiative to reduce its reliance on the electrical grid and curb carbon emissions. These efforts continued, with particular attention to the potential benefits of this during storms.

In response to a lack of preparation, WSSC and the Montgomery County Emergency Operations Center committed to participate in an annual Multi-Jurisdictional Hazard Mitigation Planning meetings starting in 2014 (Montgomery County, 2013). After-action planning and an

[7] The 10-hour, 49-minute power loss at the Potomac Water Filtration Plant was the facility's longest power outage since 2008 (Grey, 2012).

improved response planning process by the DC Department of Homeland Security clarified roles and responsibilities already in place. It also began using an online emergency operations center database (WebEOC) to track resources and manage logistics.

As with immediate response, long-term response plans for the derecho were somewhat reactive overall. However, as of mid-2013, water and wastewater utilities continued to work toward energy independence and increased water storage capacities, due to the likelihood that events such as the 2012 Derecho will occur with more frequency in the future.

Superstorm Sandy – October 2012

On October 22, 2012, NOAA's National Hurricane Center issued an advisory for the 18th named tropical depression of the season. By October 24th, the advisories turned into warnings for 'Hurricane Sandy.' This tropical storm eventually became the largest and second-costliest Atlantic hurricane in history. Mid-Atlantic communities were on high alert. Hurricane Sandy made landfall as a post-tropical (mid-latitude) cyclone along southern New Jersey on the evening of October 29th, continuing on a path of destruction up the Eastern coast.

Flooding of the Potomac River Along Washington, D.C.'s Georgetown Waterfront during Superstorm Sandy.
Credit: DC Water Employee
Source: Office of Emergency Management, DC Water.

While Sandy devastated much of the East coast, killing more than 250 people and causing an estimated $65 billion in damage in New York and New Jersey alone, the storm's impact in the National Capital Area was far less than anticipated. Nevertheless, the Superstorm surpassed the region's 50-year storm record (Bartlett, 2012).

Hurricane forecasts gave adequate warning time for the National Capital Area; communities and utilities made full-scale preparations for hurricane-force winds, coastal and inland flooding, and even blizzards.

Impacts to the Community

Community impacts were minimal, as Sandy did not directly hit the National Capital Area. Heavy rains, however, threatened flooding in the National Gallery of Art and American History Museum due to the low lying topography in the Federal Triangle area of the District. In fact, most of the Smithsonian Institution buildings on the National Mall are a mere foot or so above sea level. Longstanding concerns regarding the potential loss of historical data and cultural assets resurfaced. Floods severely threatened archives in the basements of these buildings in June 2006. The need to waterproof underground spaces grew urgent and the Smithsonian allocated hundreds of millions of dollars to do so (Greeley and Hansen, 2011). A direct hit by Sandy would have caused an estimated $500M in damage to the Smithsonian's archives. After Sandy, Smithsonian emergency management staff called for renewed attention to risk management associated with such disasters.

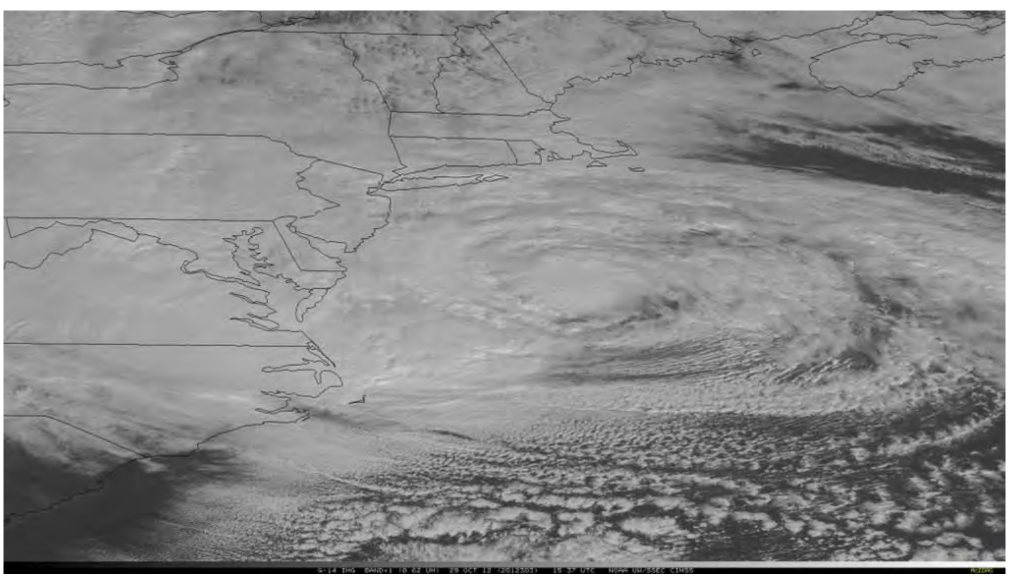
Impacts to Water Utilities

Because Sandy skirted the service area almost entirely, there were fairly minimal effects on area water utilities. Most utilities provided uninterrupted service throughout the event. WSSC reported that there were normal temperatures, water consumption, electric usage, and full water storage in Montgomery and Prince George's Counties leading up to Sandy's arrival (Grey, 2012).

Other water utilities in the area experienced short power outages and a few sewer overflows, which, along with heavy rain, caused flooding. Fairfax County suffered flooding in low-lying communities along the Occoquan River. Unlike during the derecho, the Potomac and Patuxent Water Filtration Plants retained full power (Grey, 2012).

Sandy's greatest impact on the National Capital Area resulted from the length of preparation time and sustained nature of being 'on call' for the potential disaster. Superstorm preparations acted as a valuable 'drill' event and revealed several areas for improvement.

Costs incurred mostly related to overtime pay for planning and maintaining alert status, plus the high cost of deploying backup generators. This preparation totaled about $500,000 at WSSC. Grey (2012) reported that utilities found that, "although essential for mitigating the effects of the storms, these preparations are costly. Just letting the derecho happen, and then dealing with the aftermath was far less expensive." Utility managers stated that in terms of physical costs, advance and sustained preparations for an event like Sandy can be more expensive than recovery costs – if the event and its impacts are not as severe as they might have been – and that not all costs can be quantified. However, the hassle, emotional impact of various losses, and indirect impact costs with a storm are not always accounted for in aftermath expense records. Though costly, the short and long-term responses taken by communities and utilities potentially prevented a great deal of damage and loss had Sandy directly hit the area. Furthermore, valuable lessons about response efforts emerged from these full-scale preparation measures.



Satellite Image of Hurricane Sandy approaching the United States.
Credit: NOAA. Source: Higgins, 2012.

Utility and Community Response

Actions Taken – Emergency Response Short-Term Responses

Coordinated forecasts[8] were the essential first step in effective emergency response actions during Superstorm Sandy. Forecasting collaboration by the NOAA, National Centers for Environmental Prediction (NCEP), Ocean Prediction Center (OPC), National Hurricane Center (NHC), and local weather forecast offices (WFOs) provided information on Sandy's projected path, possible changes in the path as the hurricane interacted with jet streams, wind intensity, and speed probabilities (Higgins, 2012). It also allowed NOAA to work closely with the Department of Homeland Security's Federal Emergency Management Agency (FEMA). Weather monitoring several days out allowed Homeland Security and Emergency Management Agency (HSEMA) to advise emergency support function (ESF) agencies (Quarrelles, 2012).

This forecasting was an integral aspect of the extreme climate/weather event response and largely responsible for the impressive preparation that took place in the National Capital Area. It not only allowed for preparation prior to Sandy's landfall, but in some cases led to advanced notification of potentially life-threatening situations. In the NYC area, this forecasting similarly allowed emergency operators to initiate evacuations and shut down transportation a few days before the storm hit (Higgins, 2012). Consistent forecast messages of Sandy's westward track, large size, the destructive surge potential at historic levels, heavy precipitation, and record-setting blizzard conditions all contributed to full-scale preparation in the National Capital Area (Higgins, 2012).

WFOs issued specific information for their areas, while all special storm-response messages between agencies linked to local emergency centers (Higgins, 2012). A general communication strategy that focused the message on impact-based decision support services emphasized the unique tropical to extratropical transitional nature of the storm and "worse-case-scenario" plans (Higgins, 2012).

Fairfax County, one of the most sophisticated emergency management programs in the country, began using its multi-media citizen alert network well in advance, and opened area shelters. Emergency water facility personnel were already at work in Prince George's and Montgomery Counties when Sandy arrived (Grey, 2012). The response team established contact with electric utilities early-on, working to minimize power loss to water utilities. Coordination between Pepco and the Montgomery County Emergency Operations Center had improved since the derecho (Grey, 2012). Logistics related to chemical inventory and biosolids hauling were put in place. Agencies adjusted truck schedules to avoid spreading biosolids, as well as stockpiled landfill polymers and limes.

About 10 days before Sandy's predicted landfall in the National Capital Area, DC Water activated its emergency management plan, which included daily calls with its trained response teams, and ESFs like Metropolitan Washington Council of Governments (MWCOG). MWCOG regularly coordinates emergency preparedness calls during events such as Sandy. DC Water also previously held mandatory training for managers, supervisors, and all other senior staff members in preparation for natural and man-made disasters of many types (Reeves, 2012). Once Sandy's track was apparent, managers activated incident command system protocols, including regular and planned conference calls that started a week before Sandy's expected arrival (Reeves, 2012). These calls covered updated weather information and constantly reassessed preparation actions.

[8] "Forecast success [is] heavily dependent on the linkage of global observing systems to numerical prediction models" (Higgins, 2012).

DC Water distributed documents regarding pre-storm planning, response, and incident command system details. The enterprise activated the Incident Management Team and followed the emergency planning ‘P’ process depicted in Figure F-5 (Reeves, 2012). Specifically, DC Water collected weather information to accurately plan the institution’s response, discuss who would take on what roles during the storm, and review the capability of the current response plan to handle leaks, pipe breaks, excess water, and customer service requests (Reeves, 2012).

DC Water’s public information website was updated. The utility’s department of external affairs allowed it to communicate directly with its stakeholders and to upload a great deal of information on its website as early as ten days out (Reeves, 2012). Updates included tips for flood prevention at home, as well as notifications of DC Water’s response plan (Reeves, 2012).

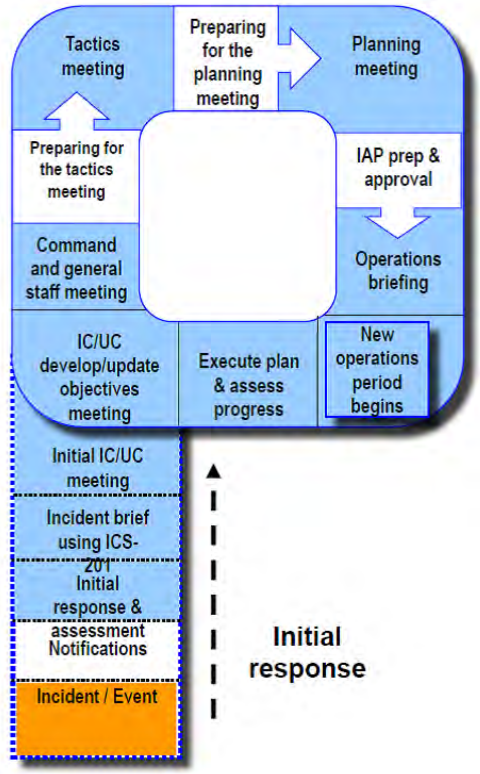


Figure F-5. DC Water’s Emergency Planning ‘P’ Strategy.
Source: Reeves, 2012.

As with other utilities, DC Water activated automated flood maps. However, flood data were not localized enough for targeted block-by-block response (evacuating communities too frequently can cause citizens to ignore warnings).To minimize flooding impacts, the utility sandbagged perimeters not previously hardscaped and moved at-risk equipment. Jonathan Reeves, Emergency Response and Planning Coordinator for DC Water, noted that the process would have been improved with a better ability to reach out to utility partners in New York and New Jersey, and local food and shelter support for personnel asked to work or stand by during the emergency (Reeves, 2012).

Actions Taken – Long-Term Planning Long-Term Responses

Most area water utilities conducted post-Sandy debriefs to improve emergency operations, institute improved plans and mechanisms, and identify training needs.

In Montgomery County, regular training and exercises occurred for Emergency Management Group members (Voss, 2012). Topics focused on response and recovery from severe storms in terms of leadership, preparedness, storm tracking, legal support, damage assessments, and more (Voss, 2012).

Many counties took advantage of their involvement in mutual aid agreements for emergency response and long-term recovery. One of the most robust is the National Capital Region Water/Wastewater Agency Response Network (NCR WWARN), a process for sharing emergency resources. This includes a mutual assistance program consistent with other national mutual aid and assistance programs and the National Incident Management System. It ensures that agencies have the resources to respond and recover more quickly from natural or human-caused disasters, and provides a forum for developing and maintaining emergency contacts and relationships. During Sandy, utilities used this to track useful resources and available equipment, working to ensure access to these throughout the region.

The web-based emergency operations center system, WebEOC, further centralized emergency information. The region's agencies and responders also took advantage of other alert systems that involved mass-emails and text messages to archived numbers. These communications systems allowed agencies to identify or manage the deployment of mass care equipment, outer gear for responders, communications equipment, and expand hospital surge capacity, license plate readers, information sharing [and] situational awareness (Voss, 2012).

DC Water's extensive pre-planning for Superstorm Sandy left the institution with a strong basis for response, had the storm hit DC directly. Reeves (2013) asserted that this kind of planning involved three major considerations that should be mainstreamed into future extreme climate/weather event preparation: 1) planning for *what you think* will happen, 2) for *what may* happen, and 3) for what will happen in the *worst case scenario*. The adoption of this mentality moved DC Water from a level 0 to a level 3 on FEMA's emergency response preparedness rating scale. At the time of this workshop, DC Water was undertaking additional measures to move the institution to a level 5 emergency preparedness (Reeves, 2013).

> *"The least we can do is use the 'no regret' option."*
>
> *– Tanya Spano, Metropolitan Washington*

After Sandy, agency representatives met to share experiences and lessons. They acknowledged that the area may not be so fortunate during future extreme climate/weather events. In assessing no-regret preparation options, Reeves (2012) insists both the examination of existing weaknesses in response efforts and the identification of specific improvements are necessary. The long lead-time that kept the response community on alert for days before Sandy's arrival proved exhausting, he noted. It revealed a weakness in water utilities' planning for staffing, including housing, provisions, and transportation; deployment, relief, and stand down schedules; and unscheduled pay. Conveying central planning decisions to field staff was another challenge. Utilities reported that no amount of planning could stop power outages and flooding, making the management of customer expectations, as well as of their own, critical during emergencies.

To prepare for extreme climate/weather events over time, the Fairfax County government continues to activate many plans. These include dam safety and flood mitigation regarding stormwater; addressing wastewater overloading, power outages, and infrastructure damage; hazardous tree inspections; solid waste debris removal; building inspections; flood response for high-risk flood areas and breach zones; drills; staffing plans; and the monitoring of rain gages and stream flows (Bartlett, 2012).

As of mid-2013, long-term efforts for storm preparation and flood mitigation in the National Capital Area were addressing the waterproofing of museum facilities and archives. DC Water was ensuring that regular water sewer system monitoring and clearance took place.

Questions remain of how best to reduce the region's vulnerability to flood-inducing storms and power outages. In the post-Sandy climate, area planners – including the National Capital Planning Commission (NCPC), MWCOG, the Interstate Commission on the Potomac River Basin (ICPRB), a consortium of federal facilities managers, and HSEMA – continued to engage in active dialogue regarding these issues. Such dialogues highlight challenges and gaps in extreme climate/weather event response actions throughout the National Capital Area, but also present opportunities for collaborative solutions.

Decisions, Challenges, and Gaps

While many cited Superstorm Sandy as an 'emergency planning success,' the National Capital Area's 2012 extreme events revealed a wide range of areas for improvement in preparation and response actions. Rapid shifts in weather patterns and forecasts during the derecho highlighted some of the more climate-related challenges. Preparation processes of both events, as well as their impacts, identified gaps in event predictions, water services, resource allocation, collaboration with other sectors, communications, and supporting policies.

Climate-Driven

The National Capital Area experienced multiple 50- and 100-year storms between 2000 and 2012. This leaves water and wastewater utilities with a "reality that emergency management planning and response should be less something to put on a shelf and something we should use more on a daily basis" (Reeves, 2012). Yet, as extreme climate/weather events become increasingly common in the National Capital Area, there are times when gaps in climate modeling and foreseen impacts inhibit adequate emergency response planning.

- **Predicting and Modeling More Frequent Exceptional Events**

A sustained climate record could provide important decadal modeling for future infrastructure design considerations, yet the "credible extrapolation of trends in extremes depends on future model improvements" (Higgins, 2012).

While climate modeling provided seasonal outlooks in the region, hurricane centers provided five-day forecasts. Modeling that closes the gap between these two in the future, however, would offer predictions with higher rates of confidence and assist utilities in adaptation planning beyond emergency response actions (Higgins, 2012). Improved predictions require additional data that could, for example, identify a storm's landfall with greater precision (Higgins, 2012). Despite these gaps, many utility managers expressed more confidence in modeling than in the past, which was largely responsible for the National Capital Area's successful storm preparation during Sandy (Reeves, 2012).

While utilities and emergency responders in the National Capital Area identified the need for additional climatic models, many also said they felt bombarded with information that was difficult to prioritize. Thus, there is a need for greater collaboration between the area's numerous data centers, as well as an information filter for users, depending on intended uses. Collaboration must also include political leaders, as jurisdictions cross geographical and governance lines throughout the National Capital Area (Higgins, 2012).

- **Weather Information Versus System Risks**

The workshop noted a significant gap in how climate modeling information related to impacts. Utilities found that weather data was not necessarily helpful in understanding the full potential impact of an event on specific areas. For example, increased knowledge of rainfall patterns did not cover the behavior of stormwater systems relative to flood risks. Weather information and modeling alone were not enough to adequately prepare for event impacts. Utility managers and stakeholders identified the need to consider real storms versus hypothetical storms, the multitude of factors involved, and their impacts on localized areas.

Water Service and Resource-Based

The vast number of water utilities and jurisdictions in the National Capital Area renders, at times, challenges in collaborative water governance. Nevertheless, the region has a history of well-organized regional coordination with the help of MWCOG and other organizations. MWCOG coordinates with local governments and utilities on a broad range of water resource issues, such as water quality, wastewater management, stormwater management, collaboration within the Chesapeake Bay, as well as regional water infrastructure protection. The ICPRB coordinates with the states and local utilities regarding water supply and source water protection in the region, while MWCOG coordinates regional drought and water supply emergency planning. Within these efforts, challenges regarding water infrastructure, funding for water services, and competing water issues arise, particularly during extreme events.

♦ Infrastructure

The workshop revealed an increasing necessity for improvements to existing water infrastructure. Due to aging infrastructure, systems must be altered to increase resiliency in the face of more frequent and intense storms. Proper maintenance of infrastructure requires sufficient funds, staff, and training. During a storm, failing infrastructure requires additional staff to maintain operations.

Utility managers noted that acknowledging the extent of aging or failing infrastructure is important in order to focus attention on these critical resources. Local governments could then identify the most vulnerable infrastructure and target improvements. The public, too, must be aware of this need because areas prone to flooding are the ones most affected by extreme climate/weather events. Public support for costly improvements is important in order to adequately fund infrastructure projects and reduce risks in flood-prone areas.

♦ Sufficient Funding and Support for Staff

Managing water infrastructure and staff support services, especially during extreme events, is a challenging balance. One emergency manager reminded the workshop that "there is a human price to all these events" (Spano, 2013b). Staff training and support is crucial, as many utilities focus on sustaining daily activities. Promoting longer-term sustainability in response efforts oftentimes places an unexpected burden on staff (Reeves, 2012). Heightened customer expectations during extreme climate/weather events place further importance on sufficient staff, funding, and support.

DC Water Personnel Work Together to Prepare for Superstorm Sandy's Landfall.
Credit: DC Water Employee.
Source: Office of Emergency Management, DC Water.

Extreme events often require significant preparation and sustained response stand-by, which can wear people out (Reeves, 2012). Staff on duty may suffer exhaustion from long, stressful hours. Though valuable lead time for Superstorm Sandy allowed utilities to spur into immediate action, maintaining an alert status over a long period when little was actually happening proved difficult. Sustained responses require extensive support operations for staff, an area for improvement Sandy highlighted. Utilities struggled to meet personnel management needs, such as providing food and shelter. Grey (2012) affirmed that to close this gap, emergency team leaders "should be permanently authorized to purchase food, hotel rooms, etc.," equipping staff to better handle unexpected challenges and prolonged response efforts.

Furthermore, transportation disruption during events can prevent key staff from traveling to work. Such staff shortages, in addition to those on vacations or other absences exacerbated personnel issues during the 2012 events. In some cases there was insufficient staff planning to identify who were 'essential personnel' and needed to stay, versus those who volunteered or otherwise remained onsite because they were already there. Emergency Operations Center staff was not always available to work entire shifts, nor were they always clear on responsibilities, roles, and expectations during emergencies (Quarrelles, 2012). Staff often assumed additional responsibilities they were not necessarily prepared to handle (Quarrelles, 2012). Small utilities with minimal staff or those who have specialized staff ran the risk of a shortage of the skills and knowledge needed during the event. Even for a large utility, such as DC Water, balancing a range of the available staff capabilities during emergency response can be difficult. While neither the derecho nor Sandy posed post-response issues that were too significant, they revealed that most utilities do not have the personnel to maintain months-long responses in the aftermath (Reeves, 2013).

The 2012 events also demonstrated gaps in training and staff familiarity with new response technologies. Though useful, utilities did not fully exercise the capabilities of the crucial WebEOC application[9] during the derecho. Many emergency liaison officers were unfamiliar with how to use it (Quarrelles, 2012). Cross-training can make up for a lack of skills or knowledge when a utility's staff is unable to respond during an event. All staff would need to be informed on notification protocols to DC agencies and on effective use of checklists during no-notice and planned emergency events (Quarrelles, 2012). For example, educating both emergency and off-hours staff on how to reset computer access following power outages and use information technology emergency hotlines emerged as an important lesson learned during 2012 (Grey, 2012).

"Severe weather is now the new normal," was an expressed sentiment among water and wastewater utility managers witnessing four or five extreme climate/weather events each year in the National Capital Area. The challenge is thus to figure out how to support regional utilities and maintain emergency management, in addition to sustaining core services (Reeves, 2013). This is progressively difficult as climate change impacts the region, in that "the issue we're having now is that everybody is in the same boat" (Reeves, 2013). This pointed to the need for further collaboration and utility standards regarding preparation and response.

- **Cross-Issue Collaboration**

Prior to Sandy, collaboration was slow in the National Capital Area, as it was difficult to establish buy-in for change among the numerous agencies in a region sometimes divided among federal and local needs. To break down silos, interpersonal relationships and face-to-face efforts

[9] Refer the e-book's appendices for Tools and Resources.

proved effective, but there a need to leverage the resources among agencies remains a significant challenge for the area. Potential benefits, however, include collaboration on hardscaping, collective risk management, reducing redundancies, avoiding unintended consequences, and ensuring one agency's work does not negatively impact another's. Additional challenges include addressing competing interests and limited resources among stakeholders, as well as establishing regulatory mandates for updated priorities. Agency liaisons must better collaborate on solutions and re-evaluate design and system performance of the region's water and wastewater system as a whole.

In particular, the close relationship between stormwater and flooding demands greater attention to cross-issue collaborative efforts. In programmatic terms, flood management is not the same as stormwater management, which is largely structured by the requirements of the Clean Water Act Stormwater Rule. Stormwater managers generally do not have the authority or funds to address all flood-related impacts, as in many cases those responsibilities belong to other program managers (Spano, 2013b). Community investment into stormwater infrastructure and best management practices (BMPs) is generally designed to meet water quality objectives – although stormwater flow management is essential for flood control – and to a limited extent for managing wet weather inflows into wastewater systems.[10] In the National Capital Area, stormwater runoff passes through multiple jurisdictions like national parks; systems managed by one agency can feed into another. It is therefore important that government agencies coordinate both preparation and response efforts together.

Some progress is underway in this arena. In order to better address stormwater management and continue restoration along the Anacostia River, along with other environmental concerns, former DC Mayor Adrian Fenty launched a plan in 2009 to increase sustainability in the city. Included in this plan were a green infrastructure program and the enhancement of parks and natural areas. Mayor Vincent Gray continued the effort with the Sustainable DC Plan, promoting landscaping to capture stormwater and prevent runoff. While these efforts will not reduce stormwater runoff entirely, they attract residents who care about sustainability. The hope is that the population will be more willing to pay taxes to support needed changes, such as infrastructure improvements for day-to-day stormwater mitigation and grey water infrastructure to handle overflows, thereby bridging sustainability and emergency planning.

Political and Intergovernmental

Political and intergovernmental support during extreme climate/weather events like Sandy and the derecho remain a challenge in itself. Even with the significant amount of ongoing coordination in the region, given that there are more than two dozen local governments and utilities responsible for managing various water resource issues in the National Capital Area, it is inevitable that events command a working through of political and legal issues (Spano, 2013b).

♦ Climate as a Political Agenda

One challenge during the 2012 events was getting all 22 local governments representing more than 19 water and wastewater utilities and millions of residents to fully understand and acknowledge the impacts of climate change on extreme events and thus, on water resources. Though less of an issue in the National Capital Area than elsewhere in the nation, some jurisdictions are just beginning to really dig into climate adaptation planning efforts (Reeves, 2013). Yet there are gaps in actively and specifically linking these to water resource needs during

[10] Only two utilities in the National Capital Area have a portion of their systems combined.

extreme climate/weather events. Perhaps more challenging, is the dissonance between local efforts and federal regulations that could be more supportive.

During the 2012 events, water and wastewater utilities in the National Capital Area addressed this challenge with the message that, regardless of one's view of climate science or uncertainty, we must plan for extreme climate/weather events. Shifting weather patterns do occur, and ensuring sustainability and resiliency are a necessary response regardless of the cause (Spano, 2013b). Utility and other agency managers stressed the need to phrase conversations to involve everyone in response and adaptation discussions. Prior to Sandy, there were too few of these discussions.

- **Conflicting State and Organizational Goals**

The National Capital Area poses a unique, ongoing jurisdictional challenge in addressing extreme weather/climate events. First, two states govern the area (Maryland and Virginia), as well as the District (DC) and the federal government (along with military installations and parks). In addition, inter-governmental organizations like MWCOG and ICPRB help to coordinate regional water issues. Elected officials serving in Congress often live where they work and carry unusual federal weight on a local level. A multitude of national agencies and organizations with keen interest in the subject and a half dozen universities, each claiming expertise in the field of climate change also exist. Every entity has its own goals, at times conflicting, at other times very aspirational. One way around this, utilities found, is to create a checklist for senior officials to use during the first hour of an event to provide regular updates and reassessments across jurisdictions and build executive and legislative support for response efforts (Quarrelles, 2012).

> *"As far as collaboration is concerned, you just have to do it….You cannot understate or underestimate the importance of collaboration."*
>
> *– Jonathan Reeves, Emergency Response Coordinator, DC Water, 2013*

Conflicting goals may also arise within a water utility; this is a nationwide issue, not an internal shortcoming within utilities in the National Capital Area. Nevertheless, water managers at the workshop noted particular examples. For instance, although water services remain the utility's primary responsibility and area of expertise, they must prioritize the maintenance of pressurized fire suppression within potable water systems followed by data storage protection. This is due to the potential immediate and catastrophic risks unstable systems pose to those outside the utility. While drinking water is essential, even low-pressure potable water could serve the public during the time needed to protect fire and data control centers. Should such events be prolonged, conflicts could emerge (Reeves, 2013).

- **Making Water Service a Priority**

The notion of improved, adaptive water infrastructure was seen as very important and needing adequate support by local, state, and federal governments. For years, water services in many areas have been underfunded; the effects of which were becoming increasingly evident with more frequent extreme climate/weather events (Spano 2013b). One workshop participant argued that the "experience in this region [is] that no one thinks about water, wastewater or stormwater until something, some extreme event, happens" (Reeves, 2013). If water supplies for the federal government were shut off, then the entire government essentially would be disabled. But too few are concerned about water when things go well (Reeves, 2013).

Water infrastructure must be seen as a priority and considered in critical related sectors, especially energy and transportation (Spano, 2013b). It is a question of balance; efforts must be both responsive and sustainable (Spano, 2013b). This is challenging, as such a prioritization requires ratepayers/taxpayers and governments to agree on what cost they are willing to pay to minimize or mitigate the effects of extreme events (Spano, 2013b).

Extreme Events Are Becoming More Frequent in the National Capital Area.
Credit: DC Water Employee
Source: Office of Emergency Management, DC Water

Socioeconomic

A multitude of socioeconomic challenges in emergency response arise with increased knowledge and experience of extreme climate/weather events. Flooding is a relatively new issue in the District due to significant development, increases in single-family homes and infrastructure stressed by population growth (Quarrelles, 2012). Finished basements and more developed land raise property values, augmenting existing weather-related damage concerns (Bartlett, 2012). While climate modeling and predictions are beneficial, advanced warning of extreme climate/weather events raises both anxieties and expectations, leading to many challenges in event response plans and efforts (Bartlett, 2012).

♦ Communication

As extreme climate/weather events increase in frequency and intensity, utilities and localities encountered a pressing need to communicate to the public the challenges associated with the dynamic and sometimes erratic nature of water. Many stakeholders did not understand why flooding occurred during some events but not others. Stunning improvements in materials and technology in their daily lives gave residents the expectation that nothing should fail. Utilities needed to convey the reality that infrastructure does fail, especially if it is not properly serviced and maintained, and that emergency response may not always reach every area in need right away.

Clear, concise, adequate communication during events themselves was seen as a need. Contacts during events remained a planning challenge. Localities anticipated a high volume of calls, but when 200 or more people placed emergency and service calls, and called requesting updated information, lines jammed (Grey, 2012). It was also difficult to track who was calling and from where. Various agencies needed to be 'on board' to help establish a rolling call system during emergencies. Some counties provided six-hour updates, yet received calls every 90 minutes, tying up phone lines and inhibiting response work. Agency managers identified the need for more specialization to handle calls to give citizens enough detailed information to keep them from jamming lines. Insufficient communication prior to events otherwise leads to severe time pressure to put measures in place once an event begins.

Agencies also faced challenges disseminating information during events to people in neighborhoods experiencing power outages (Quarrelles, 2012). Utilities and emergency responders used the internet and social media sites such as Facebook and Twitter. These were not options in neighborhoods off the grid entirely, or with power outages, as some communities experienced during the derecho (Quarrelles, 2012). Even when these were options, many older people did not have knowledge about or access to them. Some learned about such resources for the first time during the 2012 events. The need to bridge information and skills across generations to aid in more effective community preparation is an existing challenge in the National Capital Area, and around the country.

- **Meeting Expectations and Encouraging Community Buy-In**

According to one utility manager, the diversity and size of the National Capital Area meant that "one of the largest challenges for our region is meeting everyone's expectations" (Reeves, 2013). Individuals, counties, and utilities have varying interests and needs, and it is difficult to manage these during extreme climate/weather events when resources and capabilities are limited.

Traditionally, water utilities had made efforts to be invisible; providing a high quality of service meant that satisfied customers did not have to think about water needs like access, treatment, or wastewater disposal. This has become a detriment over time, in that utilities are now the 'victims of their own success.' In the face of extreme climate/weather events, we must remove this veil. Utilities need to impress on communities the importance of this critical service so as to increase the public's willingness to pay for system maintenance and improvements, as well as to take greater personal responsibility for their own safety and sustainability during extreme climate/weather events.

Greater public dialogue and awareness further helps utilities identify and prioritize community needs, while moving individual expectations to a level that they are willing to support and fund. Several workshop participants suggested that efforts should also be made to empower citizens and businesses to take additional actions to sustain themselves during these types of extreme events. Not only would this help address needs during times of limited resources, but it would also avoid always portraying citizens as 'victims' of these events.

The challenge for utilities is in assessing acceptable outcomes given a particular storm event. This requires both utilities and their customers to accept uncomfortable truths, such as they may inevitably be without services for a period of time. For example, during a crisis, questions arise such as: can communities function for a week without water? Without communication services? Without power? If not, for how long, and what tradeoffs would they accept? (Reeves, 2013).

For instance, in the District of Columbia, alleviating a single point source of contamination from overflows during a storm event can cost $50-70 million (Reeves, 2013). Such projects are important to lessen contamination during storm overflows, but utilities cannot complete such projects on their own. Utilities need buy-in, support, and finances from the communities that benefit from their services (Reeves, 2013). Communities also must also have political support for water utility response and adaptation.

Partnerships and Stakeholders

Relationships established before the derecho among HSEMA and external partners such as NWS, Red Cross, Hotel Association, and local water utilities proved useful in securing support for emergency response staff and communities during that event and Sandy (Quarrelles, 2012). However, the events also revealed some weaknesses.

Though utility providers demonstrated strong information sharing among themselves there was a lack of collaboration among residents, utilities, NGOs, and DC response agencies, resulting in inconsistent or insufficient information at times (Quarrelles, 2012). For instance, "coordination issues prevented the District from accepting supplies donated from a major retailer" during the derecho (Quarrelles, 2012). Better coordination among partners would have led to a better response during the derecho.

Better partnerships may also better address financial needs and gaps. Estimates determined that it would cost about $1 million to evacuate one mile of coastline during an event, and it cost nearly half a billion dollars to move people out of Hurricane Isabel's path (Higgins, 2012). Had Sandy hit land in the National Capital Area, the extent of such costs or the impact of doing nothing would have been severe, highlighting the need for collaboration through partnerships. For example, water utilities have difficulty meeting threshold requirements for federal reimbursements of response efforts, or often need further information to file claims with FEMA (Quarrelles, 2012). Even in cases when FEMA has come in with an assistance check, it is often too late after an area hit by an extreme climate/weather event (Reeves, 2013).[11] Strong partnerships could expedite this process or fill in financial gaps in relief efforts in situations that do not qualify for federal reimbursement.

Though operational and financial decisions may differ during notice and no-notice events, partnerships could help augment staff, provide mutual aid, prepare and test equipment, improve situational awareness, and stage or pre-deploy equipment (Voss, 2012). Effective partnerships need to identify each stakeholder's priorities and realistic potential points of future collaboration (Reeves, 2013).

Information Needs

Utilities and emergency mangers in the National Capital Area identified the following important information needs to better address extreme climate/weather events:

- Updated FEMA maps with more accurate and localized flood data.
- Improved modeling projections for the frequency and intensity of extreme climate/weather events at a local scale.
- Five-day or shorter forecasting, as well as forecasting between seven-day and seasonal windows.
- Downscaled climate data that pertains to more localized areas.
- Real-time data and monitoring, such as soil moisture, rain gages, and water level monitoring stations in key locations.
- Translating what river elevation data means to water utilities, including photos to show what a river stage means for localized flood potential.
- Methods for determining long-term costs and benefits of different climate-adaptation investments.

[11] At the time of the workshop, the District was still waiting for FEMA money from Hurricane Irene (Reeves, 2013).

Lessons Learned

Lesson Learned: Planning for *personnel scheduling, communications, transportation and provisions* is critical, especially for events with long durations.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• People often wait too long for personnel planning because there is so much concern over operations. When this happens, emergency response action suffers. • People have physical limits – a strong emergency response relies on staff whose needs are taken care of.	• Using old communications systems such as walkie-talkies and landlines backs up email communication and moves towards a closer 'real time' information exchange; this is crucial for emergency response staff turnover during long events. • Demonstrated improvement in planning for staff by DC Water and Federal Triangle Group.	• Accommodations, food, and transportation for staff are often overlooked in emergency planning. • No amount of after-action planning or reporting can make up for direct experience.	• Use pre-event planning class to identify relief crews for staff (Reeves, 2012).	• Incorporate minor non-operations related details directly into emergency management plans, such as who will supply food to responders in the field (Reeves, 2012), securing hotel rooms close to work for employees (Grey, 2012; Gamby, 2012) and child care for emergency response staff during school closures.

Lesson Learned: *Formal and informal partnerships are invaluable* during emergency response.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Reliable processes through formal relations and the ability for flexibility through informal relations better equips utilities and communities to handle extreme climate/weather event impacts. • Partnerships between utilities and among sectors fills gaps where federal, state and local jurisdictions overlap or are not clearly defined. • Individual leaders drive the response and adaptation processes when there is an authority vacuum to address emerging issues.	• Formal partnerships provide clearly defined roles and a reliable process. • Informal partnerships provide flexibility and agility to respond to needs and often move faster. • Identifying roles ahead of time – what roles are for each person in a response team and each agency – is immensely helpful (Reeves, 2012). • ESF/ICS training improves knowledge of roles and better equipped partners for emergency response through cross-training efforts (Quarrelles, 2012). • Strong relationships with FEMA allowed the District to move through the emergency declaration process quickly (Quarrelles, 2012).	• Informal structures sometimes lack clearly defined roles and responsibilities necessary to prevent overlap. • FEMA provides money for response and recovery efforts, while DC Water funds mitigation and preparedness. While preventing overlaps, this can create a fragmented approach to overall extreme climate/ weather event management.	• Include supporting departments of different agencies early on in the emergency response planning process (Reeves, 2012). • Establish relationships ahead of time, so that connections are made and during emergencies responders know who they can count on. • Repair partnerships that were stressed or broken during an emergency immediately after. Extremes are likely to continue and those relationships matter. • Increase communication and coordination efforts between public and private agencies (Quarrelles, 2012).	• Streamline the way in which various District agencies share situational information with each other and the public (Quarrelles, 2012). • Establish protocol on how to obtain information across utilities and sectors (Quarrelles, 2012). • Promote additional training exercises with partners to establish personal relationships and increase communication during events. • Work with organizations, e.g., WMATA, to provide services across sectors (Quarrelles, 2012).

Lesson Learned: *Manage public expectations* regarding potential governmental responses and *encourage individual self-sufficiency*.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Everybody has different priorities during extreme climate/weather events and varying expectations of what utilities and governments can do. • An unclear understanding of what can and cannot be done during emergencies, as well as the potential timeframe for responses, can lead to outrage by the public or faulty preparation on the individual's part.	• Community response and preparedness workshops help teach individuals to be self-sufficient during emergencies. • Trainings programs in immediate emergency response and 72-hour survival during events is helpful, as it is more likely neighbors will reach one another before a first responder is on the scene to help.	• It is not always possible to plan for everything or meet everyone's expectations. • Good planning cannot be too event-specific, as it must be robust enough to respond to likely events, yet flexible enough to deal with the reality that no event unfolds exactly as predicted.	• Establish levels of acceptable risk and costs – internally as well as with local governments, stakeholders, ratepayers, and citizens. • In order to keep the public aware of the situation and what is being done about it, "communicate up, down, in and out" (Reeves, 2012). • Leverage social media to get messages out to residents (Quarrelles, 2012). • 'De-victimize and empower the public' (i.e., identify and communicate ways that citizens/communities can be more self-reliant.).	• Continue community preparedness education outreach efforts (Quarrelles, 2012). • Promote new iPhone applications and others that provide information and increase personal preparedness (Quarrelles, 2012).

Lesson Learned: *Integrated planning at a regional level leads to better decisions* for adaptation to extreme events.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Given the state and federal presence in the region, multi-jurisdictional organizations are well suited to facilitate regional integrated planning. • There is a 'snow-balling' relationship of decisions during extreme event response. Thus, integrated planning within water utilities and across sectors is warranted. • Dependence on power is a major vulnerability, including electricity for equipment operations, automated monitoring and communications systems and fuel for generators and vehicles. This necessitates a more holistic planning approach for extreme climate/weather events.	• A shift in the 'decision space,' is bringing in more social and economic considerations into planning for extreme climate/weather events, such as whether or not to build in basements, develop in vulnerable areas, urban density and infrastructure age considerations. • Consolidating multiple objectives and authorities prevents overlap and promotes collaboration. • Systems are losing institutional knowledge and intellectual infrastructure through retirements and downsizing, but integrated regional planning helps mitigate this.	• Four year election cycles make progress with long-term planning difficult, as changes in political staff often redirect response policies. • Limited budgets and financial constraints often force tradeoffs between short- and long-term actions. • Geographically, it is often difficult to know which predictions apply to a specific area (Spano, 2013b). • A dashboard information tool could facilitate regional planning. However, this must have greater convergence, as current information planning tools offer an overload of information and it is "like dealing with four organizations/agencies at once (Reeves, 2013).	• Plan for the number of days it takes to reach 'criticality,' for example to ensure that regional plans include the entire supply chain and fuel, energy, and drinking water for 10 days. • Use follow-up training and exercise programs to "focus on specific improvements…and emphasize decision making processes, responding to an undeclared emergency, public information sharing, procurement and transportation needs" (Quarrelles, 2012).	• Having ongoing/regular conversations with the 20-30 water/wastewater entities in the area for a regional discussion of infrastructure problems and potential solutions (Quarrelles, 2012). • Move to a 500-year flood plan (rather than a 100-year flood plan) for the region as a whole (currently being assessed by the Federal Triangle Group).

Lesson Learned: Extreme event preparation must *recognize and balance the need for emergency management, sustainability and climate resiliency.*				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• As climate adaptation evolves, the focus on water shifts to discussions regarding availability, quality and flooding controls. • Discrepancies between management to address flood control and those aimed at stormwater control to affect water quality need better integration. • While sustained day to day stormwater management is important, stormwater managers must integrate effective long-term investments to also address the risks associated with large flooding.	• NASA is helping the National Capital Area with risk analysis and providing regional climate data at a high level. • Predictive and modeling data shows the correlation between freshwater flows and river inundation. This kind of information is useful in preparing for events, such as Sandy. • MWCOG's regional climate change program's policy committee focuses on GHGs, encouraging climate resiliency throughout the region.	• Limited budgets force trade-offs between short and long-term actions. • While updating FEMA maps is useful for emergency response, many are hesitant to do this, as it will place more people in the flood plains and impact property values.	• Encourage planners to consider changing hydrology as a factor when making land-use decisions. • Assess what the risks versus investments are when addressing sustainability and emergency management issues.	• Procure and track resources and use in a systematic way (Quarrelles, 2012). • Use NASA's adaptation for their own buildings in DC as a pilot project for all federal facilities. • Explore LID options and determine whether such options that provide quality control sacrifice quantity control (i.e., flooding).

Looking Forward

As the National Capital Area recovered from the 2012 Derecho and Superstorm Sandy and integrate lessons learned further into the region's overall planning for extreme climate/ weather events, tensions among stakeholders, as well as short and long-term needs were apparent. Water utilities found that the pressure of short-term budget realities conflicted with the need to understand and address long-term risks. Thus, resilience was a priority and many utilities were increasing investments in strategies to accomplish this.

While ongoing improvements were evident in the way local jurisdictions and utilities communicated, planned, and trained for emergency response, water professionals throughout the metropolitan Washington region were recognizing the need for more integrated planning and coordination among the various jurisdictions and water service entities. Infrastructure needs replacement and improvement; this must also be incorporated into the long-term planning and impacts under climate change. Funding and implementing of such plans would benefit from a public conversation to expand understanding of the various causes of flooding and other problems. Utilities and localities would need to enable communities to make choices that met near-term needs while building long-term adaptive preparedness.

A less centralized and more cross-functional approach would be beneficial. Moving from a compartmentalized method to a more coordinated one would allow offices to share labor and resources during emergency situations (Reeves, 2012). Essentially, what the National Capital Area is working towards is to "change the 'water utilities paradigm,' not just adapt to a new model" (Reeves, 2013). A paradigm that educated the public, built partnerships along local and federal levels, and sought to bridge emergency planning with sustainability would better equip the region to address the increasing frequency and diversity of extreme climate/weather events and prepare for the unexpected.

WATER UTILITY PROFILES: NATIONAL CAPITAL AREA WORKSHOP PARTICIPANTS

Alexandria Renew Enterprises (AlexRenew or Alexandria Sanitation Authority)	
Overview	The Virginia Water and Sewer Authority Act established AlexRenew in 1952 in order to manage sewage in the City of Alexandria. The utility is responsible for the construction, operation, and maintenance of the sewage system that serves Alexandria, as well as portions of Fairfax County. The utility's first wastewater treatment plant (operating since 1956) underwent upgrades in the late 1970s to include tertiary treatment. More recent changes include the incorporation of biological nitrogen removal to meet limits set by EPA and Virginia DEQ. AlexRenew serves approximately 350,000 people.
Location	Headquarters: 1500 Eisenhower Ave. Alexandria, VA 22314 http://alexrenew.com/
Operations Conducted	Wastewater collection and treatment Biosolid/nutrient repurposing Water reclamation/reuse
Size	• Treatment Capacity: 54 MGD • Biosolids: 90% nitrogen and ~100% phosphorus removal • Reused Water: 1.3 BG treated (2011) and used for cleaning/maintenance at AlexRenew plants, saving nearly $3 million in purchased water.
Administrative Structure	Appointed by the Alexandria City Council, five members serving four-year terms comprise the Board of Directors. The Board oversees the Engineer-Director, who oversees six departments within the institution: engineering, communications, finance, human resources, process, and quality services.
Arlington County Department of Environmental Services	
Overview	Water and wastewater for Arlington County is managed within the Department of Environmental Services, along with several other environmental resource management projects. The Department uses automated meter readers to track and bill customers. It is also responsible for maintaining pipe systems by continuous monitoring and repairs of the County's water infrastructure. The Dalecarlia Water Treatment Plant (operated by the Washington Aqueduct) treats water that the Department then distributes to most of the County; 2,000 Arlington citizens receive water from the Willston Water Distribution System. The Water Control Center controls and operates pumps and valves for distribution to 37,200 service connections.
Location	Headquarters: 2100 Clarendon Blvd. Arlington, VA 22201 http://departments.arlingtonva.us/des/
Operations Conducted	Drinking water distribution Wastewater collection and treatment Stormwater management
Size	• Service Area: Arlington County • Storage Facilities: three • Pipelines: ~ 500 miles of mains

	• Wastewater Pumping Stations: 14 • Wastewater treatment – 40 MGD capacity • Drinking Water Storage: 32 MG
Administrative Structure	Water distribution and management is run as part of the overall Department of Environmental Services, a government entity. The Environment and Energy Conservation Commission, which provides a citizen's voice for a range of environmental topics, in part oversees the Department's management decisions.
DC Water (District of Columbia Water and Sewer Authority)	
Overview	DC Water is the primary water utility for the Nation's Capital, as well as many customers in Montgomery and Prince George's Counties in MD and Fairfax and Loudoun Counties in VA. DC Water was first established in 1938. The utility runs the largest advance wastewater treatment plant in the world (i.e., Blue Plains) and distributes drinking water treated by Washington Aqueduct. **Drinking and Wastewater services:** DC Water serves more than 600,000 residents, 17.8 million annual visitors, and 700,000 people who employed in the District of Columbia. **Wastewater services:** DC Water treats wastewater from jurisdictions in Maryland and Virginia for an additional 1.6 million people.
Location	Headquarters: 5000 Overlook Ave. SW. Washington, D.C. 20032 http://www.dcwater.com/
Operations Conducted	Drinking water distribution Wastewater collection and treatment Stormwater management (from combined sewer systems)
Size	• Service Area: 725 square miles • Employees: ~1,100 **Water System** • Water Pipelines: 1,300 miles • Water Pumping Stations: four • Reservoirs: five • Water Pumped: 106 MGD average for FY 2011 • Drinking Water Storage: 61 MG at eight facilities (additional 49MG is stored by Washington Aqueduct) **Wastewater System** • Sewer System (combined and sanitary): ~1800 miles with 22 flow-metering stations and nine off-site pumping stations • Treatment Capacity (Blue Plains): 370 MGD average and more than 1 BGD peak capacity.

Administrative Structure	A 22-member Board of Directors (11 principle members + 11 alternate members) oversees DC Water. Members represent the District (6), Prince George's County (2), Montgomery County (2), and Fairfax County (1). Policy actions may occur 6+ Board votes. All Board members participate in decisions directly affecting the management of joint-use facilities. The District of Columbia members participate in those matters that affect District ratepayers and in setting fees for various services. The Board oversees the General manager, Chief of Staff, Secretary to the Board, and an outsourced Internal Auditor.
District Department of the Environment (DDOE)	
Overview	As the leading environmental and energy authority in the District, DDOE works to issue permits, monitor conditions, provide technical and financial assistance, assess risks, complete inspections, and enforce environmental regulations. Water-specific divisions within DDOE help to monitor and regulate water resources and stormwater runoff in the District. DDOE assumed responsibility for managing stormwater flows (outside the CSS, which flows to DC Water's Blue Plains) in 2007.
Location	1200 First Street NE. Washington, D.C. 20002 http://green.dc.gov/service/water-district
Operations Conducted	Watershed protection Stormwater management Policy-making Permit-issuing Monitoring Enforcement
Size	• Service Area: The District of Columbia • Employees: ~300
Administrative Structure	Overseen by the Director, DDOE is comprised of four administrations, including the Natural Resources Administration, which is primarily responsible for water management. This administration includes four sub-divisions: Fisheries and Wildlife, Water Quality, Watershed Protection, and Stormwater management.
Fairfax County Department of Public Works and Environmental Services	
Overview	Serving the City of Fairfax and smaller communities throughout Fairfax County, the Department of Public Works and Environmental Services oversees a wide range of environmental issues, including stormwater and wastewater in the area. The Department works to provide the public with basic information, monitor and maintain environmental systems, enforce regulations, and help prepare for and mitigate emergency hazards. Wastewater is treated at six different treatment facilities (i.e., Blue Plains, Noman Cole, AlexRenew, HL Mooney, UOSA, and Arlington).
Location	Headquarters: 12000 Government Center Parkway, Fairfax, VA 22035 http://www.fairfaxcounty.gov/living/environment/

Operations Conducted	Wastewater collection and treatment Stormwater management
Size	**Wastewater** • Service Area: 200+ square miles • Wastewater Treatment Capacity: 67 MGD (at Noman Cole plant only – the only facility which Fairfax operates) • Residential/Business Connections: 340,000+
Administrative Structure	The Department is overseen by the Fairfax County government.
Fairfax Water (previously Fairfax County Water Authority)	
Overview	Fairfax Water serves ~2 million people in northern Virginia through the operation of two water treatment plants. The utility was created in 1957, in an effort to standardize the service of many small, privately owned water systems in the area. Fairfax Water establishes water rates and revenue bonds under the authority of the Virginia Water and Waste Authority Act.
Location	Headquarters: 8570 Executive Park Avenue, Fairfax, VA 22031 http://www.fcwa.org
Operations Conducted	Drinking water treatment and distribution
Size	• Service Area: Fairfax, Loudoun, Prince William, and Alexandria • Pipelines: ~3,380 miles of mains • Water Produced: ~150 MGD • Treatment Capacity: 345 MGD (combined at Corbalis and Griffith Treatment Plants)
Administrative Structure	A ten-member Board of Directors oversees Fairfax Water. Fairfax County's Board of Supervisors elects these members, who support the utility's General Manager and senior staff that manage day-to-day operations. Four departments running five divisions manage these operations.
Howard County Department of Public Works Bureau of Environmental Services – Bureau of Utilities	
Overview	The Bureau of Utilities works to maintain the County's public water system. The Stormwater Management Division of the Bureau of Environmental Services helps to manage watershed and restoration studies, interpret flood plain and insurance maps, and conducts stormwater inspections.
Location	Headquarters: various offices in Columbia, MD 21045
Operations Conducted	Drinking water distribution Wastewater collection and treatment Stormwater management Resource protection and water quality programs
Size	• Service Area: More than 85% of Howard County's population • Water Provided: 22+ MGD

Administrative Structure	The Bureau of Utilities works through four major divisions, while the Bureau of Environmental Services
Loudoun County Stormwater Management Program	
Overview	A small municipal separated storm sewer system, the Loudoun County Stormwater Management Program works on the design, operation, monitoring, maintenance, and improvement of stormwater management throughout the county.
Location	Headquarters: P.O. Box 7000, Leesburg, VA 20177 http://www.loudoun.gov/index.aspx?NID=686
Operations Conducted	Stormwater management
Size	• N/A
Administrative Structure	The Program is part of the Department of General Service's Public Works Division in Virginia.
Loudoun Water	
Overview	Created by the Loudoun County Board of Supervisors in 1959, Loudoun Water operates under the Water and Waste Authorities Act. The utility provides unincorporated areas of Loudoun County with water and wastewater services. Loudoun Water, a political subdivision of the State of Virginia, manages user fees for operating expenses.
Location	Headquarters: 44865 Loudoun Water Way, Ashburn, VA 20146 http://www.loudounwater.org
Operations Conducted	Drinking Water treatment and distribution Wastewater collection and treatment Water reuse
Size	• Wastewater Service Area: east of Route 15 and south of Route 50 to the County line, plus many community systems • Treatment Capacity: 11 MGD at Broad Run Water Reclamation Facility
Administrative Structure	Appointed by the Loudoun County Board of Supervisors, a nine-member Board of Directors oversees the utility and appoints the General Manager of operations. Loudoun Water holds an agreement with DC Water to treat the majority of wastewater collected.
Montgomery County Department of Environmental Protection	
Overview	The Department of Environmental Protection manages stormwater runoff. The County's Ten-Year Comprehensive Water Supply and Sewerage Systems Plan, guides policies related to coordinating land development with water and wastewater services which are provided by WSSC, City of Rockville, and Town of Poolesville, among smaller providers.
Location	Headquarters: 255 Rockville Pike, Rockville, MD 20850 http://www.montgomerycountymd.gov/dep/
Operations Conducted	Stormwater management

Size	• N/A – See corresponding water utilities mentioned in the Overview.
Administrative Structure	The Department requires an update on the Water and Sewer Plan every three years; the County Executive prepares these. Amendments are approved by the County Council.
Prince George's County Department of Environmental Resources	
Overview	The Department of Environmental Resources Stormwater Management division manages the Rain Check Rebates program and oversees the County's Clean Water Act Fee; these programs finance stormwater management projects throughout Prince George's County. Several other programs help establish long-term objectives for water resource management in the County.
Location	Headquarters: 9400 Peppercorn Place, Largo, MD 20774 http://www.princegeorgescountymd.gov/sites/environmentalresources
Operations Conducted	Stormwater management
Size	• N/A – See treatment plants serving these areas.
Administrative Structure	Four divisions comprise the Department, which are overseen by the Director and County government.
Prince William County Service Authority (PWCSA)	
Overview	Created in 1983 by the Prince William Board of County Supervisors, the Prince William County Service Authority operates as an independent, public water utility that serves nearly ¼ million customers in Prince William County. Water is drawn primarily from the Occoquan Reservoir, Potomac River, and Lake Manassas. Several treatment plants in the area, including Fairfax Water, treat water for PWCSA.
Location	Headquarters: 4 County Complex Court, Woodbridge, VA 22192 http://www.pwcsa.org/
Operations Conducted	Drinking water distribution Water reclamation Wastewater collection and treatment
Size	• Service Area: 33 square miles, 85,000 customers • PWCSA has 1,200 miles of water main and 1,100 miles of sewer • Water storage tanks = 22 tanks (total capacity = 26.2 MG) • Storage tanks at the H.L. Mooney AWRF = 3 equalization basins (total capacity = 8 MG) • Wastewater treatment capacity = 43.8 MGD (24 MGD @ the H.L. Mooney AWRF and 19.8 MGD @ UOSA)
Administrative Structure	The General Manager oversees day-to-day operations; she/he is appointed by an eight-member Board of Directors.

Upper Occoquan Service Authority (UOSA)	
Overview	A joint-resolution between Fairfax and Prince William Counties and the Virginia Water and Waste Authorities Act established the Upper Occoquan Service Authority in 1971. UOSA acts to fill the Occoquan Policy mandate (1971) to replace 11 treatment plants with the construction of a regional water reclamation facility. The UOSA Regional Water Reclamation Plant began operations in 1978.
Location	Headquarters: 14631 Compton Road, Centreville, VA 20121 http://www.uosa.org/
Operations Conducted	Water reclamation Wastewater collection and treatment
Size	• Service Area: 4 jurisdictions – Fairfax County, Prince William County, City of Manassas, City of Manassas Park • Treatment Capacity: 54 MGD wastewater
Administrative Structure	UOSA's Financing and Purchasing Departments work to support the institutions partnerships and agreements within the four jurisdiction service areas. UOSA is also a charter member of the National Institute of Governmental Purchasing (NIGP).
Washington Aqueduct (U.S. Army Corps of Engineers Baltimore District)	
Overview	Federally owned, the Washington Aqueduct is a public water supply agency. Designed and operated by the USACE, it has been treating water for drinking since 1859. The Washington Aqueduct serves one million citizens in three jurisdictions.
Location	Headquarters: 10 South Howard Street, Baltimore, MD. 21201 http://www.nab.usace.army.mil/Missions/WashingtonAqueduct.aspx
Operations Conducted	Drinking water treatment Biosolids disposal Water security
Size	• Service Area: the District of Columbia, Arlington County, and the City of Falls Church. • Two Water Treatment Plants, McMillan and Dalecarlia, treat up to 390 MGD capacity
Administrative Structure	The Washington Aqueduct is operated and maintained by the Army Corps of Engineers, though a 1997 memorandum placed capital improvements under the control of DC Water.
Washington Suburban Sanitary Commission (WSSC)	
Overview	The Washington Suburban Sanitary Commission is a large water and wastewater utility in the National Capital Area, serving 1.8 million people with clean water and wastewater treatment. Established in 1918, WSSC was the product of many efforts and public health activists to join counties in providing and protecting water resources following down to the nation's capital.

Location	Headquarters: 14501 Sweitzer Lane, Laurel, MD 20707 http://www.wsscwater.com/home/jsp/home.faces
Operations Conducted	Drinking water treatment and distribution Wastewater collection and treatment
Size	• Service Area: 1,000 square miles in Prince George's and Montgomery Counties; • Serves 1.8 million residents through approx. 460,000 customer accounts • WSSC operates and maintains two drinking water plants: Patuxent and Potomac Water Filtration Plants • Drinking Water Pipelines: 5,600 miles of mains • WSSC operates and maintains six wastewater treatment plants. The Western Branch, Piscataway, Parkway, Seneca, Damascus and Hyattstown treatment plants have a total capacity to handle 74.1 million gallons of wastewater per day. The remainder of the wastewater from our service area is treated at the Blue Plains wastewater treatment plant in the District of Columbia. Sewer System Pipelines: 5,400 miles
Administrative Structure	Six commissioners (three from each county) are appointed by County Executives, serve four year terms, and oversee the General Manager and Corporate Secretary.

STAKEHOLDERS: NATIONAL CAPITAL AREA WORKSHOP PARTICIPANTS

Organization / Institution	Description	For More Information
Center for Naval Analyses	Established in 1942, the Center for Naval Analyses is a federally funding R&D center for the Navy and Marine Corps. The center seeks to provide data and information related to national security for government decision makers. One major research focus area includes water management, demands, climate change, and energy production.	http://www.cna.org/
DC Department of Homeland Security and Emergency Management Agency (HSEMA)	HSEMA works to promote and coordinate emergency operations in the District. This includes 24-hour operations, planning and response procedures, training, and outreach programs. HSEMA works closely with several local and federal agencies and volunteer organizations.	http://hsema.dc.gov/
EPA/Chesapeake Bay Program Office	The Chesapeake Bay Program is a unique regional partnership that has coordinated the restoration of the Chesapeake Bay and its watershed since 1983. Bay Program partners include the states of Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia; the District of Columbia; the Chesapeake Bay Commission, a tri-state legislative body; the U.S. Environmental Protection Agency, representing the federal government; and participating advisory groups representing citizens, local governments and the scientific community.	http://www.epa.gov/region3/chesapeake/, http://www.chesapeakebay.net/
Federal Emergency Management Agency (FEMA)	FEMA supports first responders during disasters and emergencies and operates the National Flood Insurance Program. The institution partners with tribal and local leaders, states, federal agencies, private sector institutions, non-profits, and faith-based groups to help communities protect against and recover from various natural hazards.	http://www.fema.gov/

Department of Homeland Security	The Department of Homeland Security has several divisions and works to achieve many missions that ensure the well-being and protection of U.S. citizens. This includes disaster response and recovery. The Department works closely with FEMA during disasters to help communities prepare for and respond to disasters.	http://www.dhs.gov
Georgetown University Climate Center	Housed under the Georgetown Law School, the Center conducts research, analyzes regulations, shares best practices, and connects states and federal policymakers to advance climate adaptation and energy efficiency.	http://www.georgetownclimate.org/
Interstate Commission on the Potomac River Basin (ICPRB)	Established by an interstate compact in 1940, ICPRB represents several jurisdictions along the Potomac. The commission works to protect river water quality, ensure sustainability in the Potomac watershed, and promote collaboration.	http://www.potomacriver.org
Maryland Department of Natural Resources	Among many other areas, the Department of Natural Resources helps manage streams, the Chesapeake Bay, and coastal bays in Maryland.	http://www.dnr.state.md.us/
Maryland Emergency Management Agency (MEMA)	MEMA provides emergency updates, weather information, preparedness tips, and support for communities during disaster preparation and recovery.	http://mema.maryland.gov
Maryland-National Capital Park and Planning Commission	As a bi-county agency, the Maryland-National Capital Park and Planning System owns, manages, and improves parks in Montgomery and Prince George's Counties. This includes considerations for land use planning and recreation.	http://www.mncppc.org/Commission_Home.html
Metropolitan Washington Council of Governments (MWCOG)	MWCOG is a coalition of 22 local governments in the National Capital Area, and works on issues ranging from transportation to homeland security. The Department of Environmental Programs at the Metropolitan Washington Council of Governments focuses on a variety of environmental issues in the region. The key program areas are environmental resources programs (air quality, climate change, waste management and recycling, and energy) and water resources programs (watershed planning and restoration, nonpoint source	http://www.mwcog.org/

	pollution assessment and control, urban best management practices, forestry, wastewater management, water quality monitoring, database management, GIS, drinking water, and modeling).	
National Capital Planning Commission (NCPC)	Comprised of urban planners, architects, urban designers, and general professionals, the National Capital Planning Commission is a federal government planning agency. The Commission helps create, update, and review development projects in the District of Columbia and throughout the region.	http://www.ncpc.gov/
National Centers for Environmental Prediction	A central component of NOAA's National Weather Service, the National Centers for Environmental Protection conduct climate predictions and modeling, hydrometrics, and ocean monitoring in the National Capital Area.	http://www.ncep.noaa.gov
National Park Service Chesapeake & Ohio Canal National Historical Park	A nationally protected park, Chesapeake and Ohio Canal Park serves as an important buffer and protection for the Potomac River and surrounding waterways. The 175 miles of park area also serve as a recreation area and historical attraction for the region.	http://www.nps.gov/choh/index.htm
Northern Virginia Region Planning District Commission (NVRC)	NVRC is a regional council comprised of fourteen northern Virginia governments. Among many projects, the council works on programs supporting the Chesapeake Bay, living shorelines, and green infrastructure.	http://www.novaregion.org/
Smithsonian Institution	Founded in 1846, the Smithsonian Institution brings public awareness and scientific research to several key environmental issues, such as climate change, marine science, and conservation biology.	http://smithsonianscience.org/
U.S. General Services Administration	U.S. GSA supports federal government workplaces, acquisitions, and technology service. It has an active sustainability program.	http://www.gsa.gov
VA Department Environmental Quality	The VA DEQ helps in the protection and use of the natural resources through the administration of state and federal regulations. Supporting programs work to improve technical and financial assistance for environmental protection.	http://www.deq.virginia.gov/TheVirginiaDepartmentofEnvironmentalQuality.aspx

Water Environment Federation (WEF)	Since 1982, WEF has served as a technical and educational institution of water professionals. Focused on water quality issues, the institution works on point and non-point source pollution issues, through various programs and research.	http://www.wef.org/
Washington Metro Area Transit Authority (WMATA)	WMATA operates and maintains Metrorail, Metrobus, and paratransit service in the District's metro area.	http://www.wmata.com/?forcedesktop=1

ATTENDEES: NATIONAL CAPITAL AREA WORKSHOP PARTICIPANTS

Catherine Allen	U.S. EPA
Wesley Andrews	FEMA
Michael Arceneaux	WaterISAC
Muminu Badmus	DC Water
Randy Bartlett	Fairfax County
Lisa Barton	DC Water
Cody Beckman	FEMA
Nancy Beller-Simms	NOAA
Karin Bencala	Interstate Commission on the Potomac River Basin
Scott Biernat	Association of Metropolitan Water Agencies
Cuthbert Braveboy	DC Water
Erica Brown	Association of Metropolitan Water Agencies
Malia Butler	
Amanda Campbell	
Autumn Campbell	National Association of Regional Councils
Aldo Davila	Fairfax County
Robert Dyer	Office of the Inspector General, NRPC
Julie Espina	G&H International Services, Inc.
Adrienne Fancher	Alexandria Renew Enterprises
Darlene Finch	NOAA Coastal Services Center
Bonnie Gilton	Office of Water
Ronnie Gill	Prince George County, Office of Emergency Management
Gary Grey	Washington Suburban Sanitary Commission
Steven Harrison	WEF
Miriam Heller	MHITech Systems
Wayne Higgins	NOAA
Rick Howlett	NJ Water Association
Katharine Jacobs	Office of Science and Technology
Liz Jackson	FEMA
Tim Karikari	District Department of the Environment
Salil Kharkar	DC Water

Ann Kosmal	U.S. General Services Administration
Evelyn Mahieu	Prince William County Service Authority
Vikram Mehta	Center for Research on the Changing Earth System
Karen Metchis	U.S. EPA Office of Water
Erik Meyers	The Conservation Fund
Katie Miller	U.S. General Services Administration
Gregoor Passchier	FEMA
Phetmano Phannavong	District Department of the Environment
Kara Reeve	National Wildlife Federation
Jonathan Reeves	DC Water
Dunbar Regis	DC Water
Alan Roberson	American Water Works Association
Emily Seyller	U.S. Global Change Research Program
Laurel Shultzaberger	Fairfax County Public Works and Environmental Services
Kate Skaggs	Maryland DNR / UMCES
Tanya Spano	Metropolitan Washington Council of Governments
Robin Snyder	GSA / National Capital Region
Suzanna Sterling-Dyer	Washington Metropolitan Area Transit Authority
Tanya Stern	DC Office of Planning
Hiram Tanner	DC Water
Amy Tarce	National Capital Planning Commission
Claudio Ternieden	WEF
Nancy Tosta	Ross Strategic
Brianne Walsh	University of Maryland Center for Environmental Science
Tyrone Wells	Prince George County, Office of Emergency Management
John Whitler	
Taylor Wilkerson	FEMA
Ning Zhou	Chesapeake Bay Program Office

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APPENDIX G

RUSSIAN RIVER BASIN

The project's Russian River Basin workshop took place March 13-14, 2012 at the Finley Community Center in Santa Rosa, California. The workshop and findings detailed in this study would not have been possible without the Regional Team listed below. The Research Team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

Shonnie Cline (WRF)
Lisa Darby (NOAA/NIDIS)
Ann DuBay (SCWA)
Jay Jasperse (SCWA)
Lorraine Flint (USGS/NIDIS)
Suzanne Marr (U.S. EPA Region 9)
Chad McNutt (NOAA/NIDIS)
Robin Webb (NOAA/NIDIS)

The Story in Brief

California's Russian River Basin has a history of variable weather, yet recent events reveal an emerging pattern even more erratic and unpredictable than previously experienced. The 2006 New Year's Day Flood, the 2007-2009 Drought, and an unusually intense period of frost in Spring 2008 are examples of this pattern. Those discussed in this case study are not an exclusive list of extreme climate/weather events to hit the region in recent years. They merely provide striking instances of increasingly common occurrences in the Russian River Basin. The cascading impact of such climate/weather-driven events requires a more holistic kind of management that addresses flood risk and water supply in balance with environmental needs. These events further illuminate the interdependent challenges water resource managers face.

Background

Covering 1,485 square miles in the northern range of California's coast, the Russian River Basin (Basin) lies at an average elevation of 2,000 feet, though ranges from sea level to over 4,000 feet (Anderson, 2012). Bounded by the coastal mountain range to the west and the Mayacama Mountains to the east, the Basin primarily spans Mendocino and Sonoma counties.

Headwaters begin in Redwood and Potter valleys, north of the City of Ukiah. The Basin then drains into the Pacific Ocean about 60 miles north of San Francisco and just west of Jenner (Figure G-1).

Figure G-1. The Russian River Basin.

The Russian River and Tributaries

The Russian River – the Basin's principal river – extends for 110 miles and maintains an average flow volume of 1.6 MAF (with a range of 0.17-4.9 MAF) (Anderson, 2012). Other major tributaries to the Basin and corresponding sub-basins include the East Fork of the Russian River, Austin Creek, Dry Creek, Big Sulphur Creek, Maacama Creek, Santa Rosa Creek, Laguna de Santa Rosa, Mark West Creek and Green Valley Creek.

Groundwater / Aquifers

Groundwater is an important source of water in California, particularly during dry years or dry spells (Snow, 2012). Groundwater withdrawals now occur to varying degrees in all sub-basins of the Russian River Basin. Utilities such as the Sonoma County Water Agency (SCWA) transport a significant amount of water from the Russian River to urban areas in nearby communities. The infrastructure used to accomplish this has an impact on groundwater conditions and basins that underlie populated areas, such as the Petaluma Valley, Santa Rosa Plain, and Sonoma Valley basins (Jasperse, 2012). In addition, nearly 14 MAF or an average of one-third of urban and agricultural water supplies derives from aquifers (Snow, 2012). In 2000, groundwater satisfied more than half the water demand in parts of Sonoma County. During wet years, about 25% of water supply comes from groundwater, compared to 40% during dry years, resulting in an average overdraft of 2-4 MAF during dry years (Snow, 2012). Consequences from pumping include localized declining groundwater and potential groundwater quality problems from seawater intrusion and geothermal upwelling (Farrar et al., 2006).

The Value of Water Resources

The significant value water resources hold throughout the state reflects the importance of the Russian River Basin. In fact, "California's health and prosperity are fundamentally tied to water" (Snow, 2012); water is a major source of sustenance for the state's economic dependence on agricultural production. While two-thirds of California's precipitation falls in the northern part of the state, the south consumes and uses two-thirds of California's water, primarily for irrigation and human consumption (Snow, 2012). Thus, even communities that fall outside the boundaries of the Russian River Basin depend largely upon its resources.

Water Laws and Governance

Water governance at the utility, basin, and state levels drives how institutions prepare for and respond to extreme events. Structures already in place work with one another, and at times are in conflict with one another, during events such as the 2006 New Year's Day Flood and 2007-2009 Drought. Emergency responders often rely on existing mechanisms and partnerships for direction and resources when disaster strikes. For instance, authorization to release water from dams during floods falls to the USACE in California. The California EPA serves as an information resource center for laws and regulations regarding water rights, permits, and emergency response for both decision makers and other stakeholders in the Russian River Basin.

The Sonoma County Water Agency (SCWA) provides naturally filtered drinking water to 600,000 people, as well as flood protection and wastewater services. The USACE and the SCWA operate Coyote Valley and Warm Springs Dams in the Russian River Basin, where the USACE is responsible for flood control operations, while the SCWA is responsible for water supply operations. Local communities such as the City of Santa Rosa manage their own stormwater and wastewater systems. Many water utilities generally act independently.[1] However, there is increasing collaboration between counties and among utilities and other institutions, as common needs and interests emerge during extreme events. Governing water laws of particular importance in the Russian River Basin include the following:

- California Water Code.
- California Health & Safety Code.
- Statutory Water Rights Laws.
- Porter-Cologne Water Quality Control Act.
- Water Right Law for the Western United States.
- Water Resources Development Act.

These regulations specify water rights, uses, permits, quality, and quantity control for the various challenges associated with water resources in the Russian River Basin and the State of California as a whole. They serve as guidelines for utilities and local governments to effectively manage water, balancing competing user needs. For more information on these, visit: http://www.waterboards.ca.gov/laws_regulations/.

Climate and Water Trends

Warm, dry summers and cool, wet winters characterize the typical climate of the Russian River Basin. A fog-moderated coastal climate lengthens the agricultural summer growing season. Maximizing storage for yearlong water supply is a priority, as rainfall and subsequent runoff concentrates during winter months. Historically, more than 93% of rainfall occurs from November to April; 80% of the Basin's annual discharge into the Pacific also occurs around this time (Anderson, 2012).

[1] There are hundreds of water utilities throughout the Russian River Basin. This case study focuses on those represented at the workshop.

Climate models and projections indicate an overall future increase in sea levels, temperatures, and shifts in extreme climate/weather patterns (Anderson, 2012). Scientists recently downscaled four projected climate scenarios in the region to create monthly and daily averages over a hundred-year period, from 2000 to 2100 (Flint, 2012). Such studies allow for the evaluation of future stream flow conditions, seasonal shifts in runoff, and natural water resource recharge. Scientists expect both runoff and recharge to decrease significantly, while overall climate variability increases (Flint, 2012).

More extreme shifts in weather patterns – such as droughts and floods – in addition to rising sea levels and higher air and water temperatures, continue to threaten current water supplies and consumption patterns throughout California (Snow, 2012).

Increasing Temperatures

Changing temperatures in the Bay Area alter weather patterns moving from the coast further inland. Increased average temperatures lead to more extreme heat days and fewer cold nights. Although this has already changed traditional climates in the Russian River Basin, it is unclear whether it will also create novel ecosystems (Micheli, 2012). The emergence of novel ecosystems is certainly a possibility, however, especially if temperatures continue to shift dramatically.

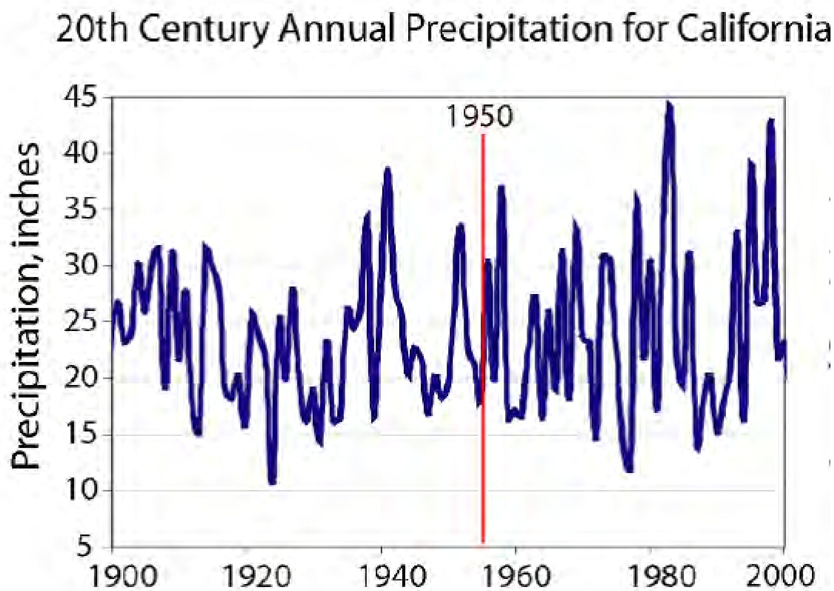
Future projections indicate a sustained and significant increase in temperatures throughout the Basin. Regional models for northwestern California, which include the Russian River Basin, suggest increases for both mean maximum and minimum temperatures, with an expected decrease in diurnal temperature variation. Climatologists expect average temperatures to rise more than 2ºF between 2005 and 2034, regardless of the emissions scenario taken into account (Anderson, 2012). From 2035 to 2099, they predict average annual temperatures to increase from an estimated average of 2.5ºF to 11ºF (Anderson, 2012). Climatologists expect temperatures to increase more during the summer than the winter, as well as year-round at inland locations and higher elevations, rather than along the California coast (Franco et al., 2011).

The expected increase in frequency of extreme heat days, heat waves, and hot spells parallels an expected decrease in extreme cold days and cold spells. Of particular relevance to the Russian River region is the projected lengthening impact this will have on the frost-free growing season (PRBO, 2011). Some of the region's most valuable crops – including wine grapes and fruit – require minimum daily temperature variations and dormancy periods. Under the projected change in conditions, yields from these crops will decline, resulting in the need to seek alternative cultivars or crops (Moser and Ekstrom, 2012). In this scenario, the remainder of the year then corresponds to an extended, dry summer season with an increased potential for drought. Increased temperatures will also increase crop evapotranspiration, decrease soil moisture, increase irrigation demand, and pose additional stress to water infrastructure, most of which already suffers from aging deterioration and leaking.

Increasing Precipitation

Future precipitation is difficult to predict due to current downscaling model and method limitations. Nevertheless, annual precipitation maximums, averages, and minimums have all increased in the Russian River Basin since 1950 (Figure G-2) (Anderson, 2012). This suggests a future trend towards more variability and extremes. Precipitation may concentrate into shorter periods, prolonging droughts, and increasing flood risk. Climatologists expect cool, wet winters in northern California to compress into fewer midwinter months (Flint and Flint, 2012).

This is consistent with recent observations for the Russian River Basin, in which wet seasons now appear to occur from January through March, rather than November through April. Studies indicate that variability will continue to characterize the regional climate, with high potential for increases in the number and intensity of extreme rainfall events (Cayan et al., 2008). Recent decreases in snowpack throughout northern California alter the timing and flow volume in rivers that charge the Russian River, such as the Eel River. By 2050, California's northern mountain snowpack will diminish between 25 and 40% (Snow, 2012). A continued trend in this may demand changes in water resource system operations, as the state traditionally relied on the gradual snow melt for water needs during drier months.



Annual Precipitation, in

	Max	Average	Min
Pre-1950	38.5	23.1	10.7
Post-1950	43.8	24.4	12.1

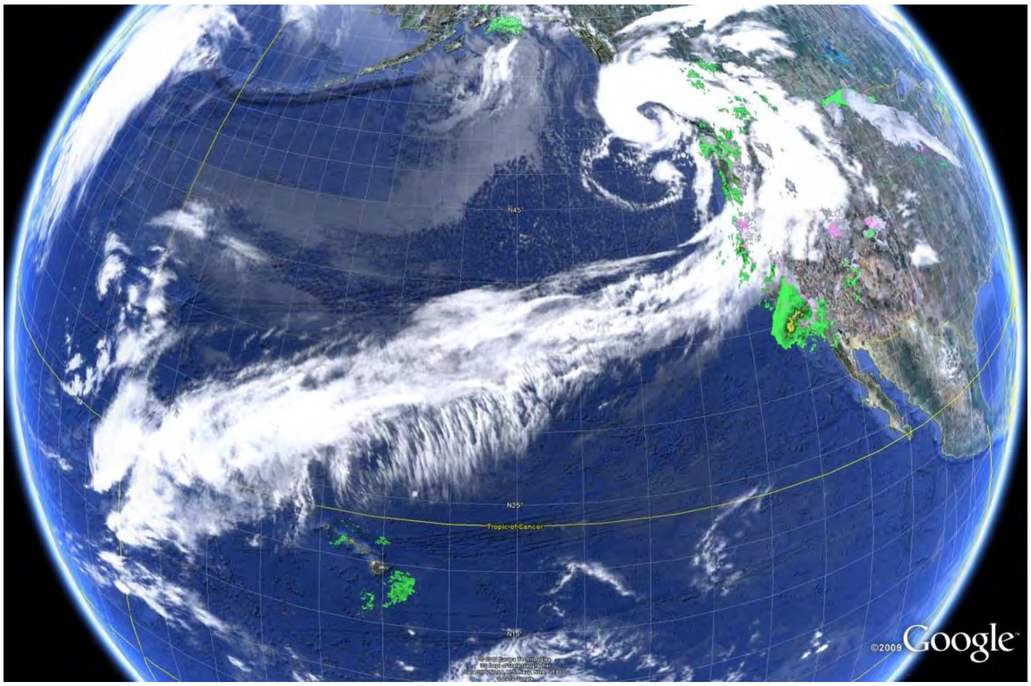
Figure G-2. Changes in Precipitation throughout California.
Source: Anderson, 2012.

Atmospheric Rivers

The Russian River Basin faces a unique climatic challenge that largely shapes precipitation patterns in the region: atmospheric rivers. These narrow, horizontal bands of concentrated water vapor travel from the tropics towards the poles (NOAA, 2012). Atmospheric rivers are generally a couple hundred miles wide and at least a thousand miles long, though their size and shape vary significantly (NOAA, 2012).

Atmospheric rivers occur regularly in several parts of the world, including the northern California coast. They are characterized by a 'dry intrusion' from upper atmosphere levels, mainly from the upper troposphere and lower stratosphere and a 'warm conveyor belt' from the lower level in the atmosphere (Dettinger, 2012). Recent studies indicate that around 95% of the pole-ward water vapor flux outside the tropics comes from atmospheric rivers (Dettinger, 2012).

Atmospheric rivers are a “primary feature in the entire global water cycle and are tied closely to both water supply and flood risks, particularly in the Western U.S.” (NOAA, 2012). Known historically as the ‘pineapple express,’ atmospheric river storm events that hit California’s coast commonly arrive from Hawaii. Peak atmospheric river seasons typically occur in the fall and winter (Dettinger, 2012).



An Atmospheric River Moves Over the Northern Pacific Ocean, Hitting the Western United States.
Credit: Courtesy NASA/JPL-Caltech.
Source: Dettinger and Ingram, 2013.

Rain and snow brought by atmospheric rivers are crucial to water supply in this region. Atmospheric rivers account for nearly 25-50% of California’s precipitation; Sonoma County attributes about 45% of their precipitation to these events (Dettinger, 2012). Often known as ‘drought busters’ along the western coast of the United States, atmospheric rivers are largely responsible for groundwater recharge in the Mojave River and other tributaries (Dettinger, 2012). However, atmospheric rivers that carry large amounts of moisture and are accompanied by strong winds may become dangerous if they stall over basins, as land areas below may receive extreme amounts of rainfall that result in life-threatening floods (NOAA, 2012). This is a common occurrence in the Russian River Basin, making the area prone to flooding from atmospheric river storms (Figure G-3). Other impacts of the Basin’s atmospheric river phenomenon include changes in precipitation, the quantity of river outflow, and sustaining or altering aquatic life. With heavy atmospheric river storms, outflows increase in several locations and flood-risk is high. Much of this depends upon the time of year an atmospheric river arrives in a given year.

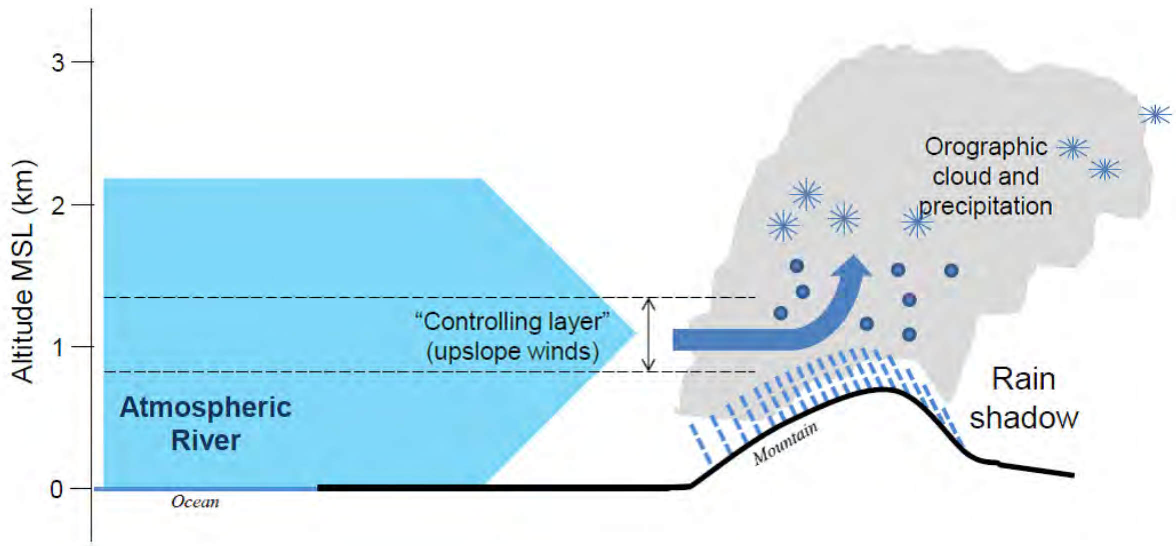


Figure G-3. Movement of a Landfalling Atmospheric River.
Source: Dettinger, 2012. Figure modified by Ralph et al., 2004.

Fluctuations in atmospheric rivers hitting the Russian River Basin may include "more atmospheric vapor content, but weakening westerly winds, a net increase in 'intensity' of extreme atmospheric river storms, warmer atmospheric rivers (+1.8 C), a snowline raised by about 1000 feet on average, [a potential] lengthening of atmospheric river season… [and] a projected 10% increase in levee breaks" (Dettinger, 2012).

Floods, Droughts, and Wildfires

Projected changes in precipitation and intensified atmospheric rivers are likely to heighten the number of floods and droughts in the Russian River Basin. The area's steep, narrow alluvial valleys naturally concentrate runoff from heavy winter rains into a few vulnerable areas. This contributes to the Basin's signature rapid, brief, and dramatic hydrological response. Increased annual precipitation during fewer winter months coupled with the Basin's geography thus raises the potential for flash flooding.

Since 1997, seven major floods caused by atmospheric rivers hit the Russian River Basin (Ralph et al., GLR, 2006 in Dettinger, 2012). However, the impact of atmospheric rivers on flooding in the area is even greater than this. Of the 39 floods occurring between 1948 and 2011, atmospheric rivers caused 34 or 87% of them (Dettinger, 2012).

On the other side, only 7% of annual rainfall in the Russian River Basin falls between May and October; as a result, management of these intense, winter rain events is even more crucial. Water storage and release during the winter must account for water supply requirements during long, dry summers. The Russian River Basin has been privy to several extended dry periods and persistent droughts for at least 250 years (SCWA).

Drier, longer summers and more frequent droughts impact the number of wildfires throughout California. Studies project that wildfires will increase between 11% and 55% after 2070, depending on a lower-wetter or medium-drier increase in projected temperature ranges

(Anderson, 2012). Wildfires may threaten flooding, while increased sediments and dissolved organic carbon impair water quality. Increased fire risk will likely stress the region's water supply as fire suppression increasingly competes with other water needs. Wildfires also threaten electricity outages and water supply failures.

Climatic Water Deficit and Environmental Changes

A climatic water deficit, by definition, occurs when the "annual evaporative demand exceeds available water" (Flint, 2012). Climate modeling examines potential versus actual evapotranspiration by integrating climate information with energy loading, drainage, available soil moisture storage, vegetation indicators, and energy demand (Flint, 2012). Such studies in the Russian River Basin show a general increase in climatic water deficit under all future climate scenarios (Flint, 2012). Specifically, all future climate scenarios suggest increases in late summer aridity, which could contribute to water deficits during summer seasons (Micheli, 2012). There is a potential for fog to mitigate this effect (Micheli, 2012), but it is unclear how much or where this would happen. It is uncertain whether the predicted decline in coastal fog relates to climate change or whether a decline in fog will affect coastal ecosystems (Micheli, 2012).

The most certain impact of climate change in the Bay Area – sea level rise – already measures in as an increase of 4.6 inches since 1950 (Anderson, 2012). Future projections vary; though, researchers and planners near the San Francisco Bay-Delta area estimate an additional 20 to 55 inches in sea level rise by the end of the century (Mount, 2007). Saline intrusion already threatens some coastal aquifers, such as the Sonoma Valley aquifer. Erosion, landslides, and infrastructure damage are possible future impacts.

Modeling further suggests climates that favor shrub and grassland in the Bay Area, at the expense of forest cover (Micheli, 2012). This new vegetation is more arid and fire-prone than forest cover. As habitats adapt, an expected loss of those habitats requiring high soil moisture for sensitive species means that vegetation in protected headwaters will become more important (Micheli, 2012).

Another problem facing environmentalists is the influx of invasive species. These species are not as protective of the landscape as native plants. Vegetation transitions will occur in the Russian River Basin, but the degree of existing protection could determine whether transitions are to native (neo-natives or novel ecosystems) vegetation versus full-scale alien invasions (Micheli, 2012). This also depends on two other factors: the "mortality of existing mature plants and propagule [reproductive] sources for new species" in the region (Micheli, 2012).

Green infrastructure, such as diverse ecosystems and 'working landscapes,' is essential to building communities resilient to disaster; mitigating various hazards; and providing food, water and health services (Gaffney, 2012). Studies demonstrate a 7:1 cost effectiveness ratio among natural buffers to response mechanisms in the prevention of detrimental impacts during natural and extreme climate/weather events (Gaffney, 2012).

Demographic Trends

A number of demographic trends are influencing California's water system.

Population

Demographic trends are a significant factor intensifying California's water system crisis, particularly as temperatures, precipitation, and the frequency of atmospheric rivers increase in the Russian River Basin (Snow, 2012). The state's growing population and aging infrastructure continues to result in groundwater overdrafts and degraded ecosystems (Snow, 2012). The full circle effect increases conflict over water resources and supplies, which is merely exacerbated by climate change (Snow, 2012).

The Russian River Basin is home to approximately 360,000 people. The Russian River alone supplies water to nearly 840,000 residents in Mendocino, Sonoma, and Marin counties (US Census, 2012). Population swelled from the late 19th century on, once the construction of railways made the region highly accessible from the San Francisco Bay Area and vacationers flocked for the once mild summer climate and to build second homes. Many of these homes were built in what is today considered floodplain. The Sonoma County Water Agency (SCWA) expects the urban population in its service area to increase by another 15% between 2010 and 2025 (Sonoma County Water Agency, 2011).

Impacts of Population Growth

This kind of growth results in greater water demand and stressed water supplies, increased percentage of impervious surfaces, heavier stormwater runoff, and degraded water quality. Authorized under the Clean Water Act, the State of California classifies the entire Russian River Basin an impaired water body due to sedimentation; siltation; and temperature associated with historic grazing, agriculture, logging, road construction, and habitat modification, all of which increase as populations grow (North Coast Region, 2012). Indicator bacteria, dissolved oxygen, specific conductivity, nitrogen, phosphorus, and mercury show significant impairments along specific segments of the Russian River (North Coast Region, 2012). Stormwater runoff further poses a serious threat to water quality and triggers conflicting objectives for urban stormwater management and habitat protection. Elevated concentrations of contaminants due to a lack of dilution during drought and increased stormwater runoff during floods result in higher water treatment costs (North Coast Region, 2012).

The region's strong economic base in agriculture and recreational tourism ties directly to the quantity and quality of water resources. Agricultural production varies dramatically as a function of the local microclimate, overall weather trends, and soil type. In Sonoma County, wine grape production dominates. Fruits and nuts yielded 72% of Sonoma County's 2012 production, of which wine grapes represented the vast majority or nearly $583 million (Agricultural Commissioner, 2013).

Demographic and climatic trends produce a triple threat to water challenges in the Russian River Basin (Hartman, 2012). High water demand and vulnerability due to increases in population and economic development is exacerbated by climate change and variability: these factors escalate the socio-economic risks associated with both floods and droughts (Hartman, 2012). Water imports or reuse link several communities outside the Basin, particularly those in southern Sonoma County and Marin County.

Extreme Events

Various emergencies and disasters arise as serious consequences of extreme climate/weather events in the Russian River Basin. The Sonoma County OES (emergency management division) distinguishes between the two. Emergencies involve multiple dangers: injuries, fatalities, property damage, and a disruption in normal operations (Helgren, 2012). Disasters, on the other hand, are more dynamic. They usually involve more than one incident, resulting in a greater need for resources than those available and demanding the clear establishment of priorities (Helgren, 2012). The 2006 New Year's Day Flood, 2007-2009 Drought, 2008 Spring Frost, and other events represent disasters and emergencies that demonstrate the devastating impacts of changing climates in the Russian River Basin.

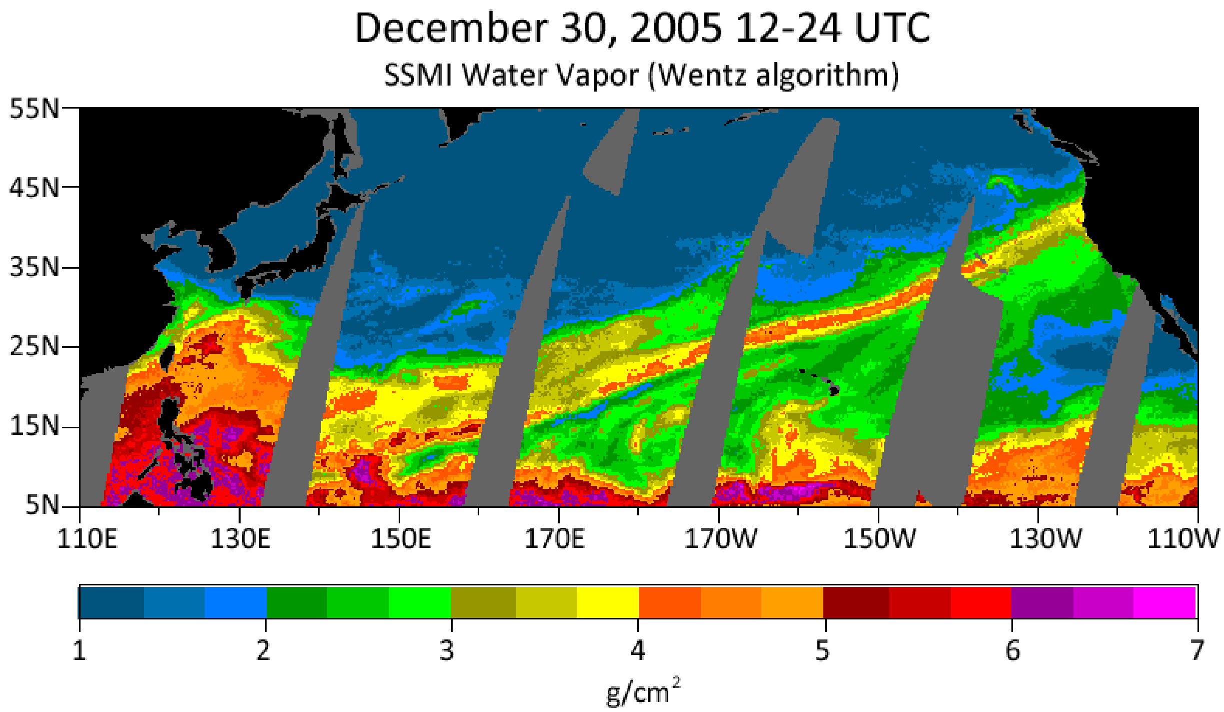


Figure G-4. Atmospheric River Hitting the Russian River and Napa River Basins and Causing Flooding in January, 2006.
Source: NOAA Earth Systems, 2006.

2006 New Year's Day Flood

On December 24th, 2005 a series of storms descended upon California's northern coast, just west of the Russian River Basin. Heavier rainfall from the second storm system that hit on the 28th left fully saturated soil in the Basin. The next and most extreme of the storm series moved in by way of an atmospheric river on December 30th, 2005, stalled, and then pummeled the region over the next couple of days (Figure G-4). Counties in the Basin witnessed intense and sustained rainfall through New Year's Day. This primarily originated from dense, tropical moisture from the western Pacific Ocean a week earlier.

Exceptional rains broke several records and prompted forecast points above flood stage in the North Coast, Russian, Petaluma, and Napa Rivers. Sonoma Creek in the Sonoma Valley was also hit particularly hard by the storm, causing extensive damage (Jasperse, 2012). The City of Santa Rosa saw 17.6 inches of rainfall during the month of December, with over 4 inches on New Year's Eve alone (Permit and Resource Management Department, 2011). In comparison, average rainfall for Santa Rosa from 1931-2005 hovers around 5.8 inches in December or 30.5 inches annually (Western Regional Climate Center).

In the early morning on New Year's Eve, the Russian River topped flood stage at three points: Hopland, Healdsburg, and Guerneville. Later that day at Guerneville, the river crested to nearly 41.9 feet, or 10 feet above flood stage, flowing at 73,754 cfs. This quantity corresponded to an average 10 to 25-year flood level (Parrett and Hunrichs, 2006). Flood stage persisted until rains ceased on January 3rd (Takamoto, 2008).

Impacts to the Environment

Extreme climate/weather events have severe implications for ecosystem services (Micheli, 2012). Floods – such as the 2006 New Year's Day Flood – as well as droughts, fires, and other extreme events are "disturbances that stress and/or renew systems [and] force transitions or extirpations" (Micheli, 2012). There is a great need to better understand these processes. For instance, increasingly apparent during the New Year's Day Flood, was the need to examine the impact on the sedimentation and storage capacity of floodplains in the Santa Rosa Lagoon (Flint, 2012). Ecosystem services help human communities buffer against climate change through water filtration, groundwater recharge, stormwater control, air purification, nutrient recycling, crop pollination and soil enrichment" (Micheli, 2012). Thus, how extreme events impact ecosystem services has serious impacts for humans.

Impacts to the Community

The 2006 New Year's Day Flood impacted communities in the Russian River Basin in several direct, indirect, short, and long-term ways. The storms had severe impacts on infrastructure, residential and commercial buildings, businesses, electric power, transportation, and mobility throughout the region. Heavy rains resulted in significant crop loss, devastating economic sectors.

Flooding in Santa Rosa during the New Year's Day Flood 2006.
Credit: Sonoma County Fire and Emergency Services.
Source: Helgren, 2014.

Infrastructure and Building Losses

Sonoma County was hit especially hard. The event inundated some 2,100 business and residential properties, leaving 50,000 residents without power (Permit and Resource Management Department, 2011). Losses reached an all-time high for flood damage in the County: $104 million (Permit and Resource Management Department, 2011).

Flooding in the City of Petaluma damaged 53 structures, including an outlet mall, an auto mall, other commercial structures, and three mobile home parks (City of Petaluma, 2010). Excluding the mobile home parks, estimated damage was $56 million, twice the city's previous damage record during floods in 1982 (City of Petaluma, 2010).

Flooding, mudslides, and fallen rocks blocked more than 100 roadways throughout the Russian River Basin. More than 100 Hacienda residents and many others in Guerneville, Rio Nido, and surrounding counties voluntarily evacuated prior to the New Year's Day Flood (Doyle et al., 2006). Yet, heavy rains isolated these communities, stranding others.

River flows estimated at 52,600 cfs buckled a pier at Geyserville,[2] causing the bridge deck to drop nearly a foot (US Department of Transportation, 2006). In the absence of this direct bridge connection, the resulting 25-minute detour hindered emergency response and had long-term effects on town income. The Geyserville Fire Protection District spent an additional $32,000 per month to add staff to the town's eastern fire station to maintain adequate fire, medical and rescue response over an expanded 200 square mile coverage area due to this detour (Norberg, 2006). This increased gas consumption by about $10,000 per month for mandatory trips among citizens, such as attending school, while simultaneously hurting commercial business on the west side of town (Norberg, 2006).

Floodplains Near Laguna de Santa Rosa during the 2006 New Year's Day Flood.
Credit: Alan Flint, USGS. Source: Flint, 2012.
Source: Flint, 2012.

The detour also decreased sales for Geyserville's businesses until full access was restored in August 2006. Geyserville's River Rock Casino experienced a decline in first and second quarter financial results, attributable to diminished traffic from the bridge closure (Norberg, 2006). This was particularly devastating to the Dry Creek Rancheria Band of Pomo Indians Tribal government, who own and operate the casino (Norberg, 2006).

Agricultural Losses

The heavy rains of the New Year's Day Flood caused an approximate 17% decline in field crop production (Agricultural Commissioner, 2007). This included hay and silage, and resulted in about $1.2 million in economic loss (Agricultural Commissioner, 2007).

Wine grapes, Sonoma County's dominant crop,[3] appeared unscathed by the extreme event, despite many flooded vineyards, which remain dormant during the winter months when the Flood occurred (Agricultural Commissioner, 2007). Vine trellises suffered minimal damage (Agricultural Commissioner, 2007).

Impacts to Water Utilities

The New Year's Day Flood impacted water utility facilities and operations in various ways: water and wastewater utilities in the Russian River Basin differ in size, age, types of processes, and discharge and reuse practices. Nevertheless, water quality due to uncontrolled

[2] Geyserville is an unincorporated community of fewer than 1,000 residents that was divided into east-west sections when the Russian River Bridge experienced structural damage in 1932.

[3] Wine grapes account for about $430 million or 73% total crop production in the area (Agricultural Commissioner).

discharges of untreated and partially treated wastewater was a widespread impact throughout the Basin. Costs associated with these discharges were likely high; however, utilities did not gather specific information on incremental costs of water quality violations or treating discharge and stormwater runoff (i.e., event information separate from regular utility costs).

On December 31, 2005 and January 1, 2006, heavy rainfall in Santa Rosa inundated an estimated 3.4 thousand acres of the Laguna de Santa Rosa (Potter, 2013). This Laguna lies in a 100-year floodplain, along with vineyards, pastures, beef cattle farms, dairy farms, and poultry farms (Potter, 2013). As the largest tributary of the Russian River, the Laguna is a high-risk flood area. Nearby, the Laguna Wastewater Reclamation Plant discharges reclaimed effluent during winter months into the Laguna (Potter, 2013). The 2006 Flood event submerged much of the Santa Rosa sub-regional treatment plant (Guhin, 2012). In the earliest hours of New Year's Day, over a quarter of the plant was flooded with sediment-laden water from the Laguna de Santa Rosa. Floodwaters disrupted some of the treatment processes and mixed with spillage, then moved into the effluent channel and the pump station (Potter, 2013). Operations shut down one pump to prevent partially reclaimed effluent flowing to the geysers. The other pump discharged partially treated effluent to storage ponds. No irrigation operations were underway in winter. Remarkably, none of the plant's five electricity load centers went down; the plant also had emergency backup power (Potter, 2013).

Recent changes made to the collection systems and treatment operations at the Guerneville treatment plant helped avert disasters experienced in the past. Though in February 1999 more than a million gallons of partially treated wastewater discharged into the Russian River after three days of flooding, water operations remained intact during the New Year's Day Flood.

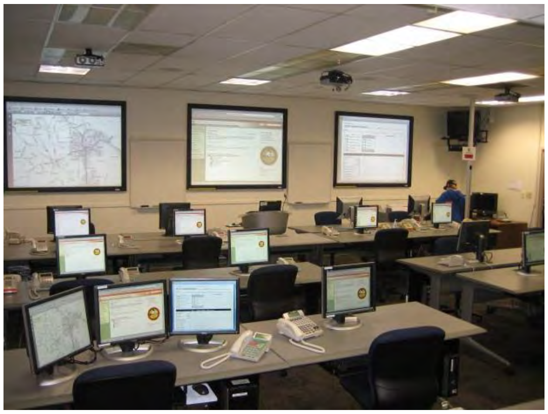
Santa Rosa Subregional Treatment Plant Normal Conditions (left) and during Flood 2006 (right).
Source: Guhin, 2012.

Impacts to small, unincorporated towns, such as Graton, demanded longer-term, more costly action. A pre-event deteriorated Graton Community Services District's (GCSD) Wastewater Treatment Plant flood mitigation wall, as it lacked sufficient height to prevent flooding (Abbott, 2010). Over three decades without proper maintenance meant storage ponds for tertiary-treated water nearly four feet of sediment containing copper and other metals accumulated during the 2006 Flood (Abbott, 2010). Treatment services ceased for 18 days.

Utility and Community Response

Actions Taken – Emergency Response / Short-Term Responses

The U.S. Army Corps of Engineers (USACE) and the Sonoma County Water Agency (SCWA) used information provided by NOAA's California/Nevada River Forecast Center (CN RFC) to implement a pre-release program for reservoir operations. Under this program, USACE and SCWA estimated pre-release flows with the goal of controlling releases during the event in order to maintain particular water levels downstream. The joint management[4] of Warm Springs Dam on Lake Sonoma and Coyote Valley Dam on Lake Mendocino made this possible. When sufficient capacity was available at these dams, the USACE and the SCWA held water in order to avoid contributing to flood peak; they later released water at a slower rate and with fewer consequences.



Santa Rosa Emergency Operations Center.
Credit: Sonoma County Fire and Emergency Services.
Source: Helgren, 2014.

USACE officials speculate that without the dams and controlled releases, the New Year's Day Flood would have exceeded crest levels. Though pre-releases did not completely mitigate flood waters during the event, it is likely flooding would have been much worse in their absence. The pre-release operating strategy was a good option, as it proved successful in past floods throughout the Russian River Basin. For example, the record 1986 February Flood crest level hovered at 48.6 feet instead of the predicted 55-58 feet due to controlled pre-releases of floodwaters near Guerneville.

Water Utilities and Institutions Participating in the Russian River Basin Workshop

CWF – California Water Foundation

CN RFC – California/Nevada River Forecast Center

EOC – Emergency Operations Center, Santa Rosa

SCWA – Sonoma County Water Agency

Despite this, significant flooding impacts demanded emergency response during the event. In fact, the Federal Emergency Management Agency (FEMA) declared the event a major disaster for communities within the Russian River Basin.[5] By 6:00 a.m. on New Year's Day, the City of Santa Rosa opened its Emergency Operations Center (EOC) to ensure a coordinated emergency response to imminent and actual emergency situations. Four different EOC sections – legal, operations, assessment and logistics – managed all aspects of the emergency: public information, legal support, police, fire, public works, utilities operations, damage assessments, situation

4 USACE manages for flood control while SCWA manages for water supply.

5 Extreme flood events such as the 2006 Flood are Sonoma County's most frequent weather-related hazard and the most costly. The Federal Emergency Management Agency estimated declared flood damage and losses from 1995 to 2005 in Sonoma County at more than $200 million (Sonoma County Hazard, 2011). Sonoma County has the highest Flood Insurance Program, with repetitive losses among all California communities. Moreover, Sonoma County payments are higher than the next nine highest communities combined and account for 34% of total state dollar outlays (California State, 2010).

status, supplies coordination, shelter, communications, and transportation. During the 18-day closure of the GCSD Wastewater Treatment Plant, operators and volunteers pumped out 1.5 million gallons of contaminated floodwater (Abbott, 2010). Though this did not rectify pre-existing aging infrastructure problems, operators worked to restore treatment plant functions as quickly as possible (Abbott, 2010).

Emergency erosion control measures stabilized the Geyserville Bridge once floodwater receded. At a cost of $30,000, the town also built a temporary one-lane bridge exclusively for emergency vehicles. Construction on the new Geyserville Russian River Bridge began less than five months after the old bridge closed. Also within this time, CalTrans and the U.S. Department of Transportation received a Biological Opinion approval from NOAA in order to ensure compliance regarding threatened species for two post-event construction mitigation projects. Largely due to this Biological Opinion, as well as the expeditious design and construction plans, the new bridge opened in mid-August 2006 (Norberg, 2006). The new bridge cost an estimated $11.8 million, with another $10 million allotted to the demolition of the failed bridge (Norberg, 2006).

Actions Taken – Long-Term Planning and Long-Term Responses

Continued work by the USGS to develop flood inundation maps and model sedimentation was a key long-term planning response following the 2006 New Year's Day Flood. A more developed "conceptual model of floodplain processes, along with general sediment budgets and rates," better prepares communities in the Russian River Basin for extreme events (Flint, 2012). By quantifying spatially distributed sedimentation, it is possible to develop a 2-D flow model to better understand flooding and impacts (Flint, 2012). A work in progress, this information will permit water utilities and managers to effectively evaluate and initiate controlled pre-flood releases and prepare for the impacts of future events (Flint, 2012).

Pre-existing work by the Sonoma County Flood Elevation Mitigation Program – a community development grant partnership between the Federal Emergency Management Agency (FEMA), the Department of Housing and Urban Development (HUD), Sonoma County, and local agencies – helped prevent some damage, while also easing long-term recovery action times. With 25% matching local funds (such as HUD's block grants), the program provided 75% of the cost of raising a flood-prone residential structure above the 100-year flood level (Sonoma County Flood, 2013). Since established by FEMA in response to the winter floods of 1995 and 1997, the program spent over $10,000 to elevate more than 230 homes, primarily in and around Guerneville (Sonoma County Flood, 2013). Sonoma County's EOC revised and republished the Sonoma County / Operational Area Operations Plan later that year (Helgren, 2012).

More than three years after the New Year's Day Flood, FEMA awarded the GCSD $1.8 million to build a flood mitigation wall. Intended to bring the overall height of the facility to 101 feet, the new wall will be slightly higher than the 99.7 foot flood stage during the 2006 Flood (Kritz, 2012). In 2007 the North Coast Regional Water Quality Control Board ordered the GCSD to "cease and desist" environmental discharges following the plant's neglect to report discharges and violations of state and federal effluent limits from October 6, 2004 through October 30, 2006 (Kritz, 2012). Following the $56,000 fine for these penalties, the GCSD devised a collection system inspection, maintenance, and repair program to prevent future infiltration (Kritz, 2012).

Although the Laguna Wastewater Treatment plant did not experience any power outages, the 2006 New Year's storm and flooding impacts contributed to the decision to install a combined heat and power (CHP) system. This CHP will supplement the plant's regular energy needs, complementing its existing emergency stand-by power generation capacity in the event that flows into the plant are exceptionally high and power is lost (Schwall, 2013).

For planners throughout the Russian River Basin, the New Year's Day Flood encouraged the use of low impact development (LID) options and awareness. Using small scale landscape-based features to imitate the natural hydrologic function of an undeveloped site (or semi-undeveloped or redeveloped) by capturing, treating, and infiltrating storm water as close to the source as possible, LID offers an alternative way to mitigate the impacts of floods such as the 2006 event (Russian River Watershed Association, 2013). LID options may also contribute to groundwater recharge, further protecting resources during other events, such as droughts (Sonoma County Water Agency, 2013). Though many criticize the uncertainty in LID's science or engineering base, as well as the lack of current LID standards, emerging best management practices prove the success of this approach in many areas.

A high correlation exists between atmospheric rivers and the intense wet weather events that supply water and, at times, severely flood California's northern coast. Flood events, such as the 2006 New Year's Day Flood, are largely responsible for the advancement of flood forecasts and water resource management. Initiatives apply and use tools in the Russian River Basin such as Basin Characterization Models, the Hydrometerological Testbed (HMT), the Hydrologic Index, and the Atmospheric River Observatories. These tools aim to provide timely information of the highest scientifically possible confidence in order to support operational flood management decisions during time-sensitive responses to extreme events.

Figure G-5. Example of a Low Impact Development Option Currently Utilized in Sonoma County, CA.
Source: Sonoma County Water Agency, 2013.

One of these major initiatives, the HMT, focuses on research pertaining to precipitation and weather conditions that can lead to flooding. The program advances new hydrometeorological observation instruments, methods, models, and the understanding of underlying physical processes. Demonstration projects of these tools will help accelerate their use into operations at the National Weather Service and will be used by various other programs, such as the NOAA Climate Program Office, for improved forecasting. SCWA has provided over a million dollars to date in support of the implementation of HMT, data collection, and improving regional forecasting skills (Jasperse, 2012).

The yielding of a water vapor flux prototype tool for coastal atmospheric river monitoring and early warning is a recent success of the HMT. This tool is one of many that provide foundational capabilities at Atmospheric River Observatories. Specifically, this flux tool system will provide decision support by integrating observations and meso-scale model data to identify atmospheric river conditions and predict flooding.

Data collected from this and other tools could mean additional water supplies during dry summer months. To this end, several accelerated long-term data-collection, modeling, and forecasting projects by NOAA, the USGS, Scripps, and others promise improved decision making in areas of emergency planning, preparedness, emergency operations, evacuation procedures, and coordinated reservoir operations.

Drought of 2007-2009 and Spring Frost of 2008

California was affected by two other events which occurred in the following years.

Drought of 2007-2009

The following year, another, more prolonged event arrived in the Russian River Basin. On the heels of the 2006 Flood, the 2007-2009 Drought brought three years of below-average precipitation that significantly reduced available runoff and groundwater recharge. Water years 2007 and 2008 had 53% and 58% of the average annual runoff, while statewide projections anticipated a slightly higher average of 71% runoff for water year 2009.

Lake Mendocino sunk as low as 30,000 AF during dry seasons from 2007-2009, compared with a lowest average of 55,000 AF during the prior four decades (Jones, 2010). Interestingly enough, local and state water levels during the Drought were less severe than record-breaking droughts in California's history. For instance, Lake Mendocino storage dropped to 12,081 AF in 1976-1977. (Jasperse, 2012).

Nevertheless, for the first time in California's history, the governor proclaimed a statewide drought emergency in February 2009. Both Sonoma and Mendocino Counties issued city-specific emergency proclamations as well. Though primarily affecting Sonoma County, drought impacts on the environment, economy, and water supply resonated throughout the Russian River Basin. In many ways the impacts of and responses to the 2007-2009 Drought in the Russian River Basin mirrored the macro-scale impacts and responses at the state-level.[6]

Spring Frost of 2008

In the Spring of 2008, unusually intense frosts occurred during the Drought. River flows, typically 500-1000 cfs or more, were already extremely low due to dry conditions during the 2007-2009 Drought. The 2008 Frost intensified these low levels, as grape growers withdrew additional water to spray vineyards and prevent damage. Generally a low-water use crop, spraying vines with additional water coats the grapes in a protective ice shield. These frost

Sonoma County Vineyards.
Credit: Caitlyn Kennedy. Source: NOAA Climate.gov, 2014.

[6] For instance, since 2006, Lake Mendocino's ability to provide reliable water supplies decreased due to reduced diversions through PG&E's Potter Valley hydroelectric project of Eel River water to the East Fork of the Russian River (Jasperse, 2012).

protection practices prevent crop loss, but also result in intensive use of water over a short period of time. This was necessary, as the region's world-renowned vineyards and winemaking industry dominate the local economy. Yet, when grape growers sprayed vineyards to prevent damage, river flows dropped to below 180 cfs, resulting in immediate high water demands (Agricultural Commissioner, 2007). This impacted other downstream users as well.

Impacts to the Environment

The 2007-2009 Drought and water withdrawals during the 2008 Frost left very little flow to sustain aquatic environments throughout the Russian River Basin. Low levels threatened various fish species in the region. One of the largest affected species was the Central California coho salmon, which suffered a 72% decline in returning adults in 2007-2008, compared to the same cohort in 2004-2005 (Butler, 2012). NOAA's National Marine Fisheries Service (NMFS) discovered dead juvenile coho and steelhead fish in the Russian River and one of its tributaries. By 2011, populations had significantly declined (Figure G-6).

Impacts to the Community

Salmon fishermen endured canceled and shortened seasons between 2008 and 2010 due to low water flows and adult return levels. Crop losses due to drought and the frost were significant. In 2008 the USDA Crop Insurance Program paid Sonoma County $11,112 per producer for losses attributable to the conditions of these events (CDWR, 2010). The State Water Resources Control Board (SWRCB) responded to the 2008 Spring Frost with regulations to restrict and govern water use, amidst already growing water conservation efforts. Tensions between conservationists and the grape industry flared, as the agricultural community challenged the legality of these regulations. In September 2012, the trial court ruled in favor of the grape growers and set aside the frost regulations.

Impacts to Water Utilities

The 2007-2009 Drought significantly decreased surface water and groundwater recharge. Lake Mendocino storage was dangerously close to drying up. Water utilities had to adjust and balanced allocation plans, working to meet competing water demands.

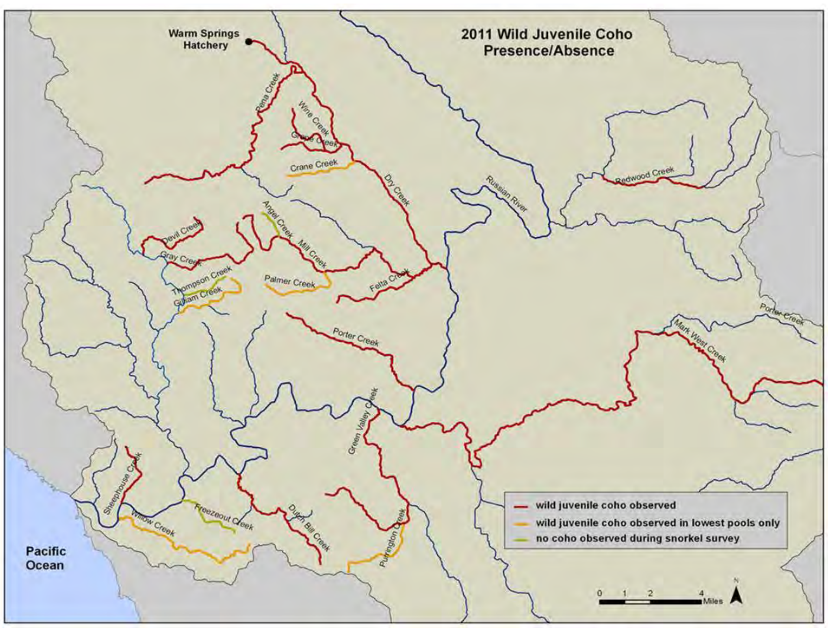


Figure G-6. Presence and Absence of Wild Juvenile Coho Salmon in 2011.

Source: Butler, 2012.

WERF

Utility and Community Response

Actions Taken – Emergency Response / Short-Term Responses

Drought conditions challenged water resource recovery facilities to achieve multiple objectives by discharging in a way that supplemented water supply, protected water quality, and generated energy. To preserve water supplies, California's State Water Resources Control Board (SWRCB) permitted reduced releases from Lake Medocino; water levels fell below minimum in-stream flow requirements. In 2007 and 2009, the SWRCB ordered Russian River water users to curtail diversions between 25-50% (Jasperse, 2012).[7] The Laguna Wastewater Treatment Plant conveyed about two-thirds of its treated wastewater to the Geyser Project, using recharged water in the geyser steam-field to generate 100 MW of thermal energy daily.

Statewide priorities to protect listed fish species resulted in water delivery reductions and other conservation measures. The state further imposed unprecedented restrictions in State Water Project and federal Central Valley Project diversions from the Sacramento-San Joaquin Delta to protect listed fish species.

Actions Taken – Long-Term Planning and Long-Term Responses

The resounding, long-duration of impacts from the 2007-2009 Drought and Spring Frost of 2008 prompted several long-term adaptation planning measures throughout the Russian River Basin and the state of California. After 16 months of outreach, the SCWA prepared and released a new Water Supply Strategies Action Plan in 2010, updating it in subsequent years. The plan "provided the framework for regional integrated water resource planning by focusing on implementing nine key strategies to improve overall resiliency of water resources" (Jasperse, 2012). Action strategies taken by the SCWA included developing coordinated forecasts for reservoir operations, improving conjunctive management of surface and groundwater supplies, recycling water to offset water use, and increasing water conservation methods (Jasperse, 2012).

Other long-term efforts focused on increasing the capacity to monitor and predict factors leading to droughts in the Russian River Basin. Investigations by the SCWA, the NMFS, and others regarding the consequences of frost protection revealed limited prediction capabilities and the lack of coordination between grape growers. As a result, NOAA and the SCWA partnered to improve frost event forecasting, supporting the SCWA's efforts to coordinate with grape growers. The SCWA also worked with the USGS to increase the number of stream gauges on the Russian River in an effort to expand the monitoring network and support reservoir operations. In Mendocino County, the Russian River Flood Control and Water Conservation Improvement District led efforts with grape growers to construct storage ponds for frost protection, thus significantly reducing water diversion from the Russian River during frosts.

Ongoing efforts improved the use of forecasting tools, coordination procedures, and water management projects; since 2008 frost impacts have proved less severe. In addition, NOAA's forecasting tools are expected to improve summer heat wave predictions, thus helping growers coordinate irrigation schedules up to 72 hours in advance. Use of indicators, as well as

[7] The SWRCB 2012 ruling in favor of grape growers to set aside frost regulations is currently under appeal.

soil moisture measuring and monitoring techniques strengthened forecasting for early warning among agriculture and grape growers.[8]

Managing for multiple objectives lies at the heart of integrated water resource management in the Russian River Basin, and the Drought and Frost stressed the need for partnerships. No single utility or institution can respond effectively to such extremes alone. Following these events, SCWA engaged in a variety of partnerships and innovative approaches for water supply management. This includes the Sonoma-Marin Saving Water Partnership; to date, ten utilities have committed to provide a sustained level of funding to implement best management practices for water conservation while focusing on programs that benefit the region as a whole. Initiatives include the exploration of groundwater banking and aquifer storage systems during times of heightened precipitation. By stemming freshwater withdraws and reusing treated wastewater for agriculture and urban landscaping, the partnership maximizes water supplies.

Other partnerships,[9] such as the non-profit Pepperwood Preserve, explore science-based conservation to protect biodiversity, linking functioning ecological landscapes through conservation easements and protected basin areas. Scientific collaborations participate in a regional integrated monitoring strategy to advance understanding of the impacts of climate change on terrestrial and aquatic ecosystems. In early 2012, the SCWA's Board of Directors established the Independent Science Review Panel to promote science-based management and policies. SCWA is also a leading collaborative stakeholder-driven groundwater management programs.

Other Extreme Events

While monumental, the 2006 New Year's Day Flood, 2007-2009 Drought, and Frost of Spring 2008 are mere examples of the series of events to hit the Russian River Basin in the past decade. More than rare instances of extreme climate /weather, these events represent a larger shift towards polarizing extremity in the region. While this report focuses on these particular events, it is important to note that weather in the area has been anything but static or 'normal' since 2009. Following the two-year Drought, floods once again pummeled the Russian River Basin in September 2009 and through the Winter of 2009-2010 (Flint, 2012). Utilities and institutions in the Basin are therefore continually re-evaluating existing response mechanisms and plans. For instance, the Sonoma County OES updated and approved the Hazard Mitigation Plan in November 2011. The Plan identified eleven specific mitigations for flooding, ten specific mitigations for wildland fires, and "discussed climate change as a contributory role to hazard vulnerability" (Helgren, 2012).

Also noteworthy, was the massive storm that hit the Russian River Basin March 13-14, 2012. An atmospheric river stalled over the region, bringing coastal areas between 4-6 inches of rain within 24 hours with a "sharp southern edge of heavy Sierra precipitation," leaving more

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[8] The relationship between evapotranspiration and soil moisture storage has a significant impact on grower capabilities and climate change. Climatic water deficit models "integrat[e] the effects of increasing temperature and varying precipitation on basin conditions," which, at a fine-scale, provides an analysis of which landscapes are the most "resilient or vulnerable to projected changes" in climate (Flint and Flint, 2012). Knowing where climatic water deficits are likely to increase indicates areas where water demand will likely increase in order to maintain current agricultural and growing practices.

[9] See 'Partnerships' under the Stakeholders and Collaboration section of this case study for further information on these and other initiatives in the Russian River Basin.

than 15 inches in some areas (Ralph, 2012). From March 13-18th, the Northern Sierra received nearly 22% of average annual precipitation, boosting "water supplies by more than 60% from the event" (Ralph, 2012).

During the workshop, an extreme event struck the region, producing heavy rain and runoff. Satellite images and NOAA's HMT indicated the atmospheric river's presence on March 13th, heading straight for Santa Rosa (Figure G-7). The data revealed that atmospheric river conditions were present in the north at Bodega Bay observatory, while absent in the south at Piedras Blancas Observatory: this seems to suggest that atmospheric rivers contribute to wet conditions in the north, while the absence of these conditions in the south may account for the dry conditions (Ralph, 2012). The atmospheric river "transported large amounts of water vapor into the region during this storm" in Sonoma County, while heavy rain did not occur south of Monterey (Ralph, 2012). In fact, the "total amount of water vapor transported up the mountain slopes during atmospheric river conditions explained 75% of the storm-to-storm variability in rainfall and 61% of the variation in stream flow on Austin Creek, a tributary of the Russian River" (Ralph, 2012).

By the morning of March 14, Santa Rosa Creek was already 1500 cfs; in a mere 24 hours during the storm, the Creek rose from 20 cfs to nearly 3000 cfs (USGS, 2013). Measurements peaked on the 14th and then dropped again as the storm passed.

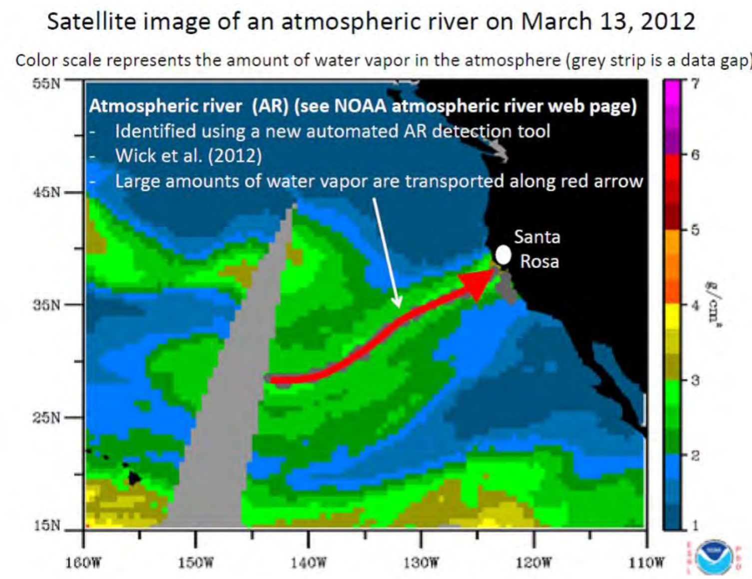

Figure G-7. Atmospheric River Moving in on California Coast During the 2012 Storms.
Courtesy of: Marty Ralph using methods determined in Wick et al., 2013 and Ralph et al.; 2004.

Later in 2012 and throughout 2013 extremes oscillated again, this time resulting in the worst drought in 120 years, since 1984. During 2013, rainfall hovered at 7.8 inches in Ukiah sub-basin and 5.7 inches in the Santa Rosa sub-basin, juxtaposed with 33 inch and 32.5 inch averages (Sonoma County Water Agency, 2014). Several counties imposed restrictions or adopted voluntary restrictions by early 2014 (Sonoma County Water Agency, 2014).

These events demonstrate the nature of extreme climate and weather in the Russian River Basin. Heavily influenced by the atmospheric river phenomenon, these events are striking with increasing regularity and bouncing between extreme floods and droughts as climates change in the Basin. Extremes threaten water supplies – water quality, quantity, or both at a given time – presenting many challenges for ecology, economic production, and communities throughout the region.

Decisions, Challenges, and Gaps

This section describes the decisions, challenges, and gaps faced in the Russian River Basin.

Climate-Driven

Climate-driven factors persist as some of the most considerable information needs for decision making in the Russian River Basin. As extreme events become more common, problems arise with uncertainty, impacts, modeling, and data.

- **Climate Changes, Uncertainty, and Impacts**

The unprecedented nature of climate change inevitably renders a great deal of uncertainty; changes in the Russian River Basin leave questions regarding the exact impacts that will emerge. Shifts in historical precipitation patterns bring periods of more frequent and 'larger' peaks; yet it is difficult to know with complete certainty when these dry or wet peaks will occur (Russian River Facilitator Notes, 2012). The New Year's Day Flood of 2006 followed by three years of drought, and then additional flood and drought cycles demonstrates this. These uncertainties challenge water supplies and management systems to handle various and repeated periods of too little or too much water, reassess water rights and agreements, decision support systems, and adaptation decisions (Hartman, 2012). Some degree of water forecast model inaccuracy further inhibits this uncertainty; there must be greater "quantification of [this] uncertainty" to effectively manage risk in the future (Hartman, 2012).

> *"Our response to fires, floods and disease will determine the difference" for vegetation transitions in changing climates.*
>
> *– Lisa Michelli, Pepperwood Foundation*

It is nearly impossible to predict whether runoff will occur in flash floods prior to a storm's arrival. Increasingly, tools and models are monitoring weather more accurately. However, momentary shifts may stall atmospheric rivers, increasing the length of time precipitation falls in one area, while postponing expected weather in another area for some time (Russian River Facilitator Notes, 2012). Unprecedented shifts in weather and subsequent impacts generate uncertainties about potential whole-scale ecosystem changes (Russian River Facilitator Notes, 2012). While scientists can anticipate certain impacts, until these changes occur, there is no absolute way to know the overall impact of shifting climates on ecosystems.

- **Climate Modeling and Forecasts**

Regardless of the model, climatic predictions for the Russian River Basin all indicate some degree of sea level rise, higher temperatures, more concentrated periods of precipitation, and an increase in the frequency of atmospheric rivers. Yet, 'fuzzy' forecasts remain a constant challenge cited by water utilities, associations, and institutions throughout the Basin (Russian River Facilitator Notes, 2012).

Recently developed tools and information centers such as the Basin Characterization Models, the HMT, the Hydrologic Index and the Atmospheric River Observatories aim to improve climatic modeling and weather forecasts. These have greatly increased the capacity of institutions to predict and monitor weather patterns and extremes in the Russian River Basin and throughout California; as utilities learn more about these processes, decision makers gain the capacity to plan based on available data.

For instance, institutions in Santa Rosa used HMT S-Prof radar during the March 13-14, 2012 storm to monitor precipitation and predict impacts. There was, however, much difficulty in accurate rainfall estimation over Sonoma County. Scans from NWS NEXRAD radar in the tool were “too high to detect the shallow clouds causing about 40% of the rain at Santa Rosa in this storm,” meaning that it was difficult to predict where the rain came from or how much would fall (Ralph, 2012). Nonetheless, the tool allowed the KPIX TV station radar succeeded in monitoring much of the storm’s precipitation (Ralph, 2012).

- **Lack of Integrated Data**

The integration of data arises as a challenge, alongside these issues in climate modeling and hydrologic tools. Though institutions successfully utilize tools for particular locations or events, changing climates affect the Russian River Basin as a whole. Workshop participants asserted the importance of collecting data, modeling, and working to understand what changes are happening in the wider region, as well as the impacts events in certain areas have on other locations.

In 2004 the Western Governors Association remarked that there is “no systematic collection and analysis of social, environmental and economic data focused on the impacts of drought within the U.S.” (Flint, 2012). As extremes become more common throughout the nation, efforts to move towards integrated climate data, modeling, and decision-making are underway. The National Integrated Drought Information System (NIDIS) is one such major effort. Part of the NIDIS pilot design for California examines the North Bay Counties and the Russian River Valley. In fact, Russian River workshop participants spent the afternoon of the second day with NIDIS coordinators. Following this, many of the workshop participants, and a few other community leaders, began outlining work and direction for a NIDIS pilot project for early warning drought in this area. It focuses on “hydrologic extremes with droughts draining reservoirs and extreme precipitation events filling reservoirs” (Flint, 2012). Other aspects of the project include monitoring and measuring activities in the Klamath River Basin, Central Valley, and urban Southern California. The challenge is to implement this design into “meaningful monitoring and prediction products that effectively characterize and communicate regional drought information” (Flint, 2012).

Integrated drought information and other types of climate data (for example, atmospheric rivers), will greatly increase the understanding of shifting weather patterns, thus decreasing uncertainty on a larger scale. This could allow for more localized preparation and the adaptation of infrastructure, economies, and water resource management approaches.

Water Service- and Resource-Based

Extreme climate/weather events challenge water resource management within the Russian River Basin, but California’s water crisis as a whole further exacerbates these issues. This is important to note, as no single strategy will solve water issues in the Russian River Basin (Snow, 2012). Northern California supplies the majority of water used by the southern part of the state. Events that impact water management in the Russian River Basin retain a trickling effect to downstream users, deepening the need for effective, sustainable water management.

- **California’s Prolonged Water Crisis**

Managing water as a natural resource, rather than a mere commodity, remains a significant challenge in the Russian River Basin (Snow, 2012). Swelling populations and agricultural production in California demand larger quantities of water each year. Depleted surface water and groundwater resources coupled with recurrent drought periods are shifting attention towards the need to increase efficiency, decrease consumption, and protect water resources. The California Water Foundation (CWF) plays an integral role in such synthesis and coordination to both address the state's current water crisis and adequately prepare for extreme climate/weather events. CWF maintains four principles to address the impending water crisis throughout the state, while simultaneously enacting mitigation measures for extreme events such as flooding. Essentially, these principles establish the area's focus on Integrated Resource Management (Snow, 2012) and include efficiency, groundwater, rivers, and management aspects. Because of the uncertainty that comes with changing climates and the recent increase of extreme climate/weather events in the Russian River Basin, CWF asserts the importance of these principles and the managing challenges that accompany them:

- **Principle 1: Efficiency** In order to "make every drop of water count," water use efficiency must increase among agricultural users, urban areas must surpass conservation targets, and there is a need for an overall expansion of water recycling and stormwater capturing (Snow, 2012).

- **Principle 2: Groundwater** The sustainable management of groundwater will "reduce overdraft and increase recharge," ensuring adequate water reserves during times of crisis (CWF, 2012). However, this necessitates a major increase in the existing data collection and monitoring of groundwater (Snow, 2012).

- **Principle 3: Rivers** Floodplain destruction decreases flood protection and high quality water supplies during extreme events. Therefore, the protection of floodplains is crucial, as is the "advancement of State policies for integrated flood management, [and] integrated regional land use planning and reservoir re-operation" (Snow, 2012).

- **Principle 4: Management** To strengthen structures of fragmented water management in the past (CWF, 2012), states must "build broad-based coalitions with vibrant leadership, support changes to laws [and] funding mechanisms, institutions need to maximize statewide strategies" (Snow, 2012).

CWF's principles not only identify many of the water-resource based and management challenges within the Russian River Basin, but also the need for integrated, diverse strategies that will lead to more sustainable solutions. For example, CWF and SCWA are working to provide grant funding for projects that improve data interoperability and modeling in the Basin (Jasperse, 2012).

- **Ecosystem Services and Sustainability**

California's water crisis and amplified instances of extreme events demand sustainable policies and management throughout the Basin. Sustainable water management requires "resilient ecosystems, and diverse, adaptable water supply [that can] meet current and future economic and ecosystem water needs" (Snow, 2012).

Ecosystem services are an essential decision driver in the Russian River Basin. Though research and policies heeded greater attention towards water allocation for environmental needs in recent decades, changing climates augment the importance of such allocation in decision-making and climate change adaptation. The 2007-2009 Drought was a harsh reminder that bouts of extreme climate/weather are quickly becoming the norm in the Basin. Such events devastate crops, fish, ecosystems, and human water supplies. Given uncertainty regarding when these events will occur or precisely how extreme their impacts will be, workshop participants noted that protecting and preserving aquatic environments is no longer just a necessity to maintain an ecosystem, but a requirement to sustain the very environments that provide essential services for human water use and consumption.

This is challenging in a state that relies on agricultural production, and where the north produces most of the water while the south consumes it. Economic and ecosystem needs often compete with one another, particularly during dry years. Supply reliability, demand management, ecosystem stewardship, and adaptive management factors must be considered (Snow, 2012). Water utilities at the workshop stressed the need for regional solutions and to fully foster existing collaborations (Figure G-8).

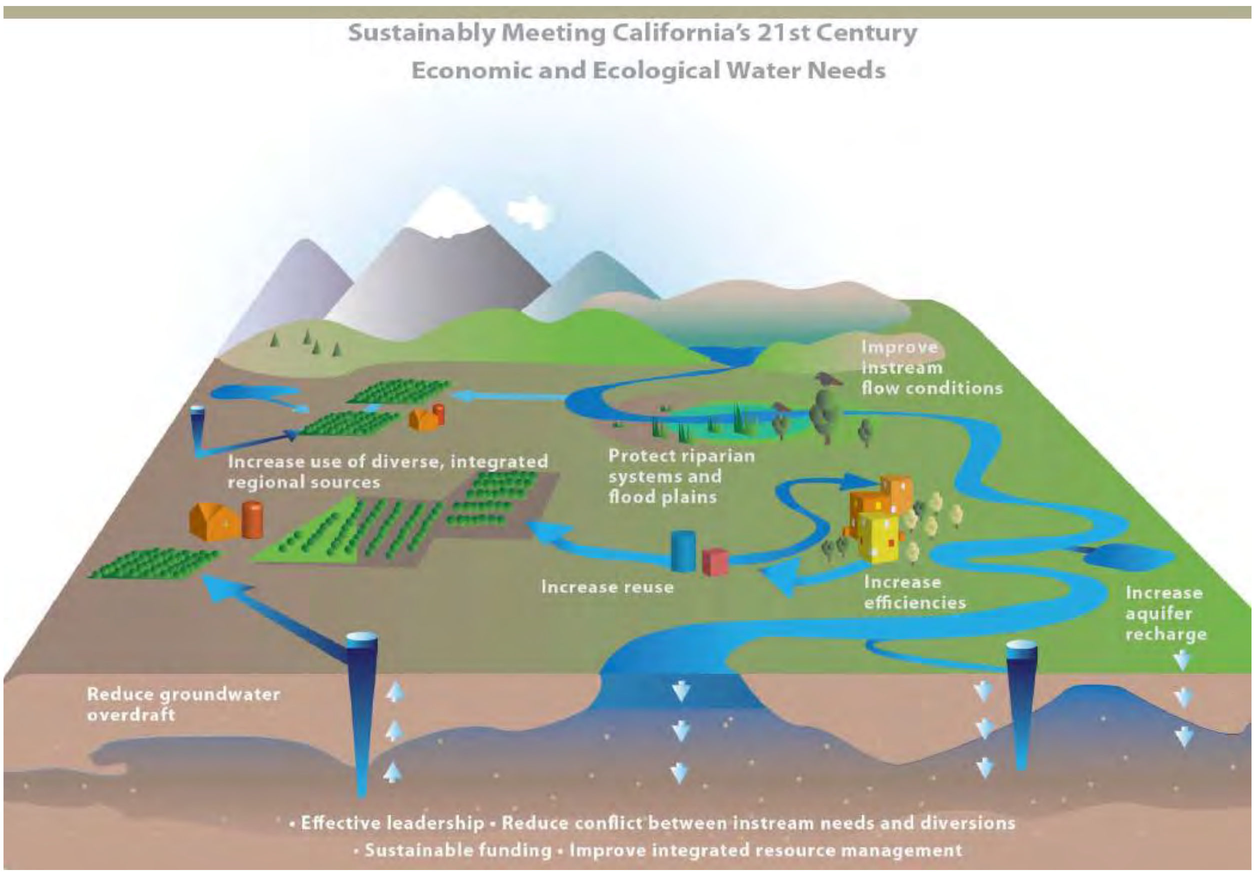

Figure G-8. Regional Sustainability Profile for California Water Resources.
Source: Snow, 2012.

♦ Water Infrastructure and Management

Infrastructure-related decisions significantly affect such regional sustainability, as storage capacity helps ensure sufficient water quantity and quality when floods and droughts threaten water supplies. Water utilities and managers at the workshop discussed how existing infrastructure and funding for maintenance and new infrastructure largely determine what water and how much water they have to meet user demands during events. Monitoring existing resources, they affirmed, is therefore of the utmost importance. When reservoirs experience ‘high pools’ during heavy rainfall, the USACE follows standardized dam inspection and analysis procedures. These consist of reading instrumentation three times a week, daily walking inspections on the face of the dam, measuring water volume three times a week, and conducting past performance engineering analyses (DiCiro and Dillabough, 2012). Such careful monitoring of existing water levels during rainfall assist water managers in timely decision-making regarding dam releases prior to heavy flooding. This can result in several feet of flooding difference during an event. This is a challenge in itself, as decision-makers can change a dam’s water control manual, but only with a high level of review (DiCiro and Dillabough, 2012).

Political and Intergovernmental

Sustainability issues, as well as the underlying drivers of changing climates, a statewide impending water crisis, and competing users leave water managers and governments with a plethora of challenges at the political level.

♦ Conflicting State Goals and Leadership

Competing water uses – household use for a growing population, irrigation requirements for increased agricultural production, recreation and tourism, and ecosystem needs to support aquatic life and overall sustainability – lead to constantly divided perspectives on where to allocate water and how best to manage the threatened resource (Russian River Facilitator Notes, 2012). Workshop participants noted that in a state strapped for water supplies, particularly dry years or prolonged droughts, heighten these tensions and drive incentives for water management decisions within the Basin. Conflict between in-stream needs and diversions for other needs is common throughout the Russian River Basin and between the Basin and other parts of the state (Snow, 2012).

Effective leadership is absolutely essential to manage, and where possible prevent, such conflicts (Snow, 2012). The need for improved and integrated water management is increasingly paramount in the Russian River Basin (Snow, 2012). As extreme events continue to hit the region, competing users must begin to work together to protect shared water resources and deal with floods and droughts in a more holistic manner. Yet in times of scarcity, high water demands pressure institutions and political leaders to carefully balance user needs with sustainability issues and ecosystem needs (Russian River Facilitator Notes, 2012).

♦ Entrenched Bureaucracies and Silos

Institutional and political silos, as well as entrenched bureaucracies are a significant challenge to the need for, recognition of, and push towards sustainability in the Basin (Russian River Facilitator Notes, 2012). Because users and areas differ in their water demands, local governments and bureaucracies often focus on the immediate needs or the needs of the area, without enough foresight towards the future or other users. Organizational fragmentation arises, as the “numerous entities involved in various aspects if water management each have their own jurisdictional authorities and boundaries. This leads to gaps and redundancies” (Jasperse, 2012). Bureaucracies and institutions must work past these silos, instead emphasizing integrated planning and collaboration (Gaffney, 2012). Partnerships may help promote integrated water resource management by coordinating and leveraging resources to minimize fragmentation and silos (Jasperse, 2012).

♦ Sustained Funding

Money for regular water utility operations, extreme event preparation and response, climate and water resource research, and sustainability management is a constant need and challenge (Russian River Facilitator Notes, 2012). In fact, sustainability is not only an issue in terms of water resource management, but also in terms of sustainable funding (Snow, 2012). The nation's economic downturn left many institutions and governments struggling financially at a time when water management demands were both high and costly. Prolonged droughts or flooding in the Basin heavily increase water utility operation costs. Climate data and information is one of the major challenges associated with planning for extreme events in the Basin. These costly endeavors are extremely important to water management. Thus, "sustainable sources of funding for long term data development and analyses," rather than one-time grants are essential (Gaffney, 2012).

Information Needs

Related to the many challenges noted above, workshop participants identified several important information needs. The following needs are essential for water utilities to deal with future extreme events in the Russian River Basin (Gaffney, 2012; Hartman, 2012; Jasperse, 2012; Russian River Facilitator Notes, 2012).

- More integrated information and simplified access to such information.
- Better regional weather forecasting and decision support tools to support operational and emergency planning decisions.
- New and expanded high-resolution time and space water information to better inform decision-making processes.
- Updated and detailed flood forecast maps to enhance communication of flood risk.
- Additional flow monitoring data and use of new technologies.
- Better characterization of surface water and groundwater resources.
- LIDAR and high-resolution imagery.
- Research on assumptions made with green infrastructure, framework experiments, the implementation of long-term economic and ecological analyses, the evaluation of economic value and return investment, and the evaluation of conservation's role in extreme event mitigation.
- Potential funding partnerships for both data development and data analysis.
- Capacity building tools at the local, institutional, and governmental levels.

Partnerships and Collaboration

The Russian River Basin is home to a complicated network of stakeholders, as the Basin is an essential supply of water for much of California. Spanning hundreds of miles and multiple counties, freshwaters and groundwater provide for a diverse set of water needs from ecological benefits to agricultural production. These diverse interests often compete with one another, and suffer varied impacts during extreme events. The increasing demand for water throughout the Basin parallels the increasing depletion of resources and challenge of future changes in climate. In turn, this demands a more holistic and collaborative approach to promoting resiliency. Though stakeholders vary in their interest and needs of the Russian River's resources, they share a common stake in the need to preserve and ensure future water supplies.

For specific information and complete lists of water utility profiles and non-utility stakeholders that participated in the workshop, refer to Appendix E-1 and Appendix E-2, respectively. The involvement of these utilities and stakeholders was of great importance during the workshop, and further reflects the complicated, yet crucial collaboration necessary to adapt to extreme events in the Russian River Basin.

Despite competing needs and interests among Russian River stakeholders, there are an increasing number of partnerships and collaborative efforts throughout the Basin. Occurring on the local, basin, state and national levels and signifying the growing recognition of the common threats faced and interests in managing water resources in a holistic, sustainable manner. Current partnerships and some recent successes include those discussed below.

Sonoma Valley Groundwater Management Program

Comprised of several environmental organizations, water purveyors, residential groundwater users, and agricultural alliances, the Sonoma Valley Groundwater Management Program convened a stakeholder group in June 2006 (Jasperse, 2012). Out of this meeting, a new Groundwater Management Plan emerged for the area, based on a non-regulatory, collaborative process, which sought to balance groundwater needs for the environment, irrigation, and household consumption (Jasperse, 2012). Stakeholders emphasized local control and management. SCWA, the City of Sonoma and the Valley of the Moon Water District adopted the plan in 2007. Operating for about five years now, this collaborative effort continues to reassess needs and groundwater resources, making strides towards holistic water management.

Santa Rosa Plain Groundwater Management Planning Process

Joint funding from the SCWA, local cooperators, and an IRWM grant helped the City of Santa Rosa form a Basin Advisory Panel. The Advisory Panel first met in December 2011, with monthly meetings beginning in 2012. Meeting activities include groundwater briefings, informal presentations, and discussions regarding groundwater management planning options. Currently, there are 23 organizations, cities, and water agencies that are members of the Advisory Panel (Jasperse, 2012).

Integrated Flood Control and Groundwater Recharge Studies

The SCWA further partners with various institutions to conduct several flood control and groundwater recharge studies. Examples include the Laguna Mark West, Sonoma Valley, and Petaluma River area water studies. These studies utilize a multi-benefits approach that seeks to incorporate human consumption, recreation, and ecological needs (Jasperse, 2012). By reducing flood hazards and recharging groundwater, these studies provide information that addresses issues related to water quality, water supply, system sustainability, ecosystem needs, agricultural land, open space, and community benefits (Jasperse, 2012).

Groundwater Banking Study

The SCWA also works with local researchers to study groundwater banking from both local and regional aspects (Figure G-9) (Jasperse, 2012). This research area evaluates opportunities, constraints, hydrogeologic conditions, water availability, and water quality on a regional scale. It further evaluates existing groundwater quality data, well conditions, and potential recharge methods. Recognizing the importance of collaboration in this area, the SCWA encourages stakeholders to participate at key stages, developing conceptual project alternatives and evaluating regulatory and permitting needs (Jasperse, 2012). Localized potential pilot-scale testing projects are then identified. Once demonstration pilot studies are selected, the SCWA prepares work plans, monitors, and reports on the projects. Projects begin small with evaluations as they go, continuously making recommendations for next steps based on the results at each stage (Jasperse, 2012).

Sonoma-Marin Saving Water Partnership

Ten water utilities comprise the Sonoma-Marin Saving Water Partnership, which coordinates and implements water use efficiency programs. Each partner meets a minimum flooding obligation, commits to the implementation of Best Management Practices (BMPs), and seeks to maximize cost-effective projects (Jasperse, 2012). The partnership focuses on programs that provide regional benefit, including the Qualified Water Efficient Landscaper Training initiative, the Water Education Program, the Green Business Program, and the Public Information Program (Jasperse, 2012).

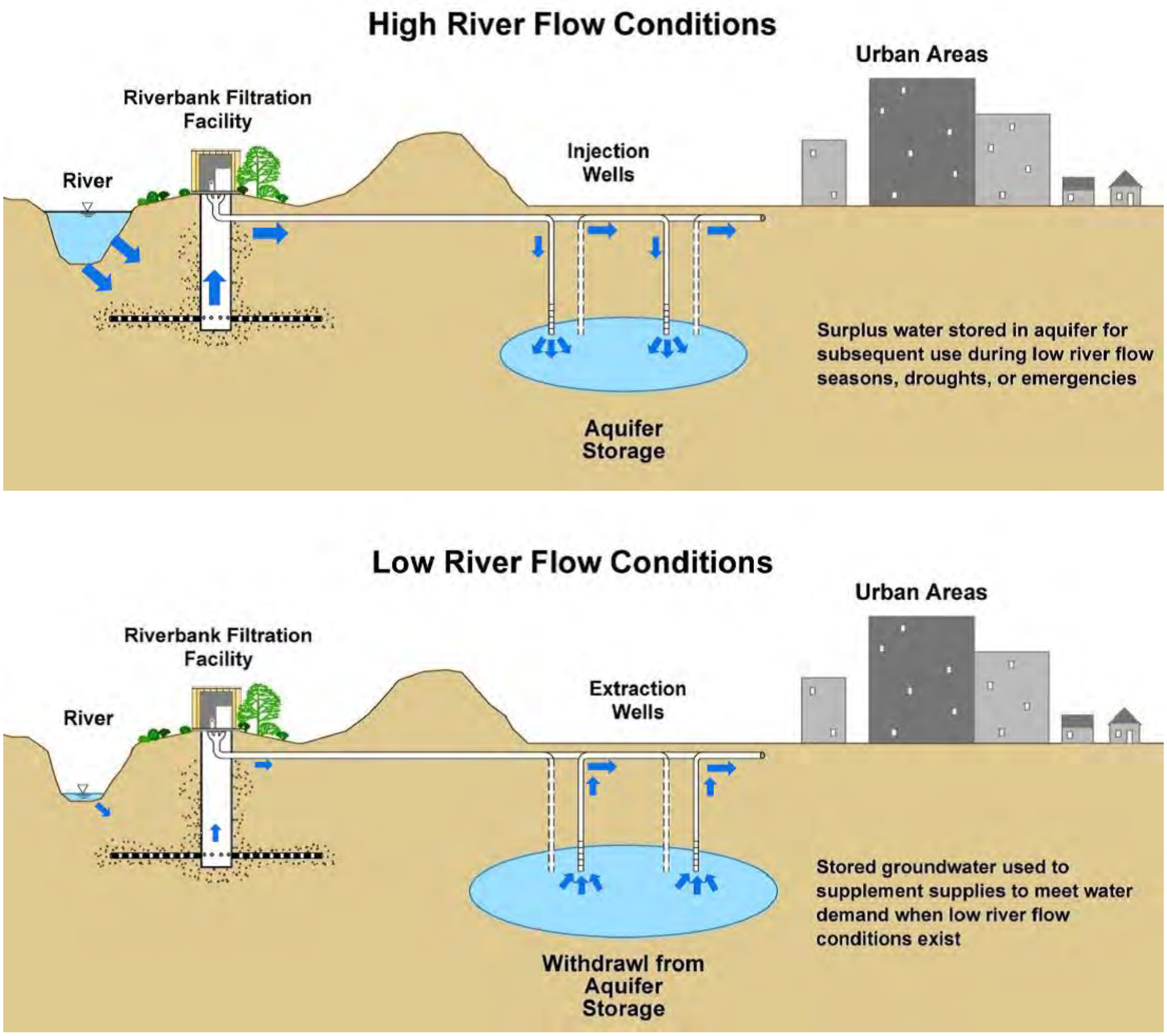

Figure G-9. SCWA Groundwater Banking for High (top) and Low (bottom) River Conditions.
Source: Jasperse, 2012.

Terrestrial Biodiversity Climate Change Collaborative (TBC3)

Perhaps one of the largest collaborative efforts in the Russian River Basin is the Terrestrial Biodiversity Climate Change Collaborative (TBC3). TBC3 examines climate and topography, with an agenda to create basin hydrology and topo-climate data, vegetation cover and habitat structure, and species distribution databases (Micheli, 2012). Specifically, the TBC3 research agenda seeks to create a 270m fine-scaled 13-model ensemble for temperature and precipitation of the Bay Area (Micheli, 2012). Statistical analysis will allow for the team to compare and contrast outputs, helping to create better guidance for basin managers as they select models and applications for use (Micheli, 2012). TBC3 also works to compile Bay Area empirical fog data sets and standardize them for analysis.

On the basin hydrology and topo-climate front, TBC3 pursues a downscaling of future climate scenarios. Basin-scale climate scenarios will offer more accurate projections for the Russian River area (Micheli, 2012). The team's Basin Characterization Model (BCM) addresses water availability for people and ecosystems in the area by looking at the "physical water and energy balance based on topography, soils, rainfall, and temperature for every pixel in the model's domain, in order to estimate flows, recharge, and soil moisture" (Micheli, 2012).

In examining vegetation and habitat structure, the TBC3 research team works to develop and implement field-based protocol for synchronized monitoring of topo-climate and vegetation, including protocol design to detect vegetation in transition and ways of scaling up to multiple reserves across the Bay Area to detect regional changes (Micheli, 2012).

In regards to species distributions, TBC3 faces the question of whether forecasts can predict the location and persistence of various species, how species distributions will shift under different climate scenarios, and whether monthly time steps can develop into projections that evaluate the full impact of extreme events on the area (Micheli, 2012).

TBC3 Partnerships

TBC3's collaborative efforts extend beyond these research agendas to additional partnerships within the Russian River Basin. For instance, the recent integration of TBC3 with the Bay Area Ecosystem Climate Change Consortium (BAECCC) serves a dual purpose: TBC3 acts as the terrestrial technical team, defining estuarine and coastal interfaces, while also helping to develop long-term research strategies for BAECCC (Micheli, 2012).

Several other climate change adaptation-planning opportunities exist within this and other such partnerships. The Pepperwood Reserve and TBC3 team hope to expand their approaches to include aquatic and riparian systems and models to assess daily stream flow and temperature (Micheli, 2012). One such opportunity is the North Bay Climate Adaptation Initiative (NBCAI), which seeks to bring together technical experts, policy makers, land managers, and water managers into dialogue, promoting adaptations strategies and ecosystem preservation and increasing the North Bay's resiliency for ecosystem functions and services (Micheli, 2012).

Integrated Water Resources Science and Services (IWRSS) Framework

The Russian River Basin is a current demonstration area for Integrated Water Resources Science and Services (IWRSS) Framework. The IWRSS framework is a business model, using a multi-agency framework to initiate a five-point strategy to better integrate services, service delivery, standardize data, collaborate on tools, forecast, and provide geospatial water resource information. Strategy steps include federal consortiums, stakeholder participation in the region, the incorporation of digital information products, the creation of a single portal for water information, and the establishment of a national water center (Hartman, 2012). This kind of interagency collaboration leads to higher levels of efficiency, budget effectiveness, aligned program directions. Furthermore, regional pilot studies will "engage key stakeholders; test and refine IWRSS systems, products and services" (Hartman, 2012). Though originally comprised of

NOAA, the USGS and the USACE in 2011, the model is expanding to include other members (Hartman, 2012). In the Russian River Basin, planning activities are identifying opportunities for these federal agencies to work more closely and with local stakeholders to promote innovative management programs and water resource initiatives (Jasperse, 2012).

Sonoma County Agricultural Preservation and Open Space District

Currently partnering with SCWA, regional and state parks, the USACE, the Sonoma Land Trust, Pepperwood/LandPaths, and private landowners, the Sonoma County Agricultural Preservation and Open Space District takes a collaborative conservation-based approach to climate change adaptation (Gaffney, 2012). The multiple benefits derived from such a strategy help serve the institution's district area of 85,000 acres. The institution uses these partnerships to effectively evaluate investments in an ecosystem services context in order to promote biodiversity, connect habitats, increase public access, and link working landscapes (Gaffney, 2012).

For example, the 19,000-acre easement of the Cooley Ranch conservation zone is one of the institution's conservation successes (Figure G-10). Previously, 17,000 acres of this zone suffered from overgrazing, while 1,000 acres belonged to a vineyard (Gaffney, 2012). This zone not only protects a quarter of the water supply in Lake Sonoma now, but further allows for species movement and habitat connectivity. The sensitive riparian zone within this conservation area stretches for 40 miles and is completely protected from cattle grazing and human impacts. Since the establishment of the conservation area, there have been improvements in water supply, flood control, carbon sequestration, food security, agricultural viability, and biodiversity (Gaffney, 2012).

Furthermore, basin protection, agricultural preservation, and habitat restoration at the Mark West River conservation zone led to healthier fish population and functioning green infrastructure in recent years (Gaffney, 2012). Such infrastructure provided land for recreation and learning, while sustaining water supply and mitigating the effects of changing climates.

A Note on Partnerships

Partnerships discussed here are not an exclusive list of those working effectively within the Russian River Basin. Many more noteworthy efforts exist. Those mentioned in this report simply stood out during our workshop. Such partnerships are instrumental in the development of cost-effective means for climate modeling, ecosystem monitoring, and combating the challenges noted above.

The Russian River Basin community is unique in the extent that the area embraces integrated water resource planning and sustainability on a basin basis. The partnerships transcend jurisdictional boundaries with federal agencies (e.g., the USACE, NOAA, and the USGS) and commercial agents (wine growers), working together with local water service agencies. Efforts to adapt to changing conditions and enforce sustainable operations in sectors competing for limited resources continue to emerge through these partnerships. Particularly remarkable is that these partners extend beyond water services for human use and consumption to also restore and preserve ecological basin functions and endangered species habitats.

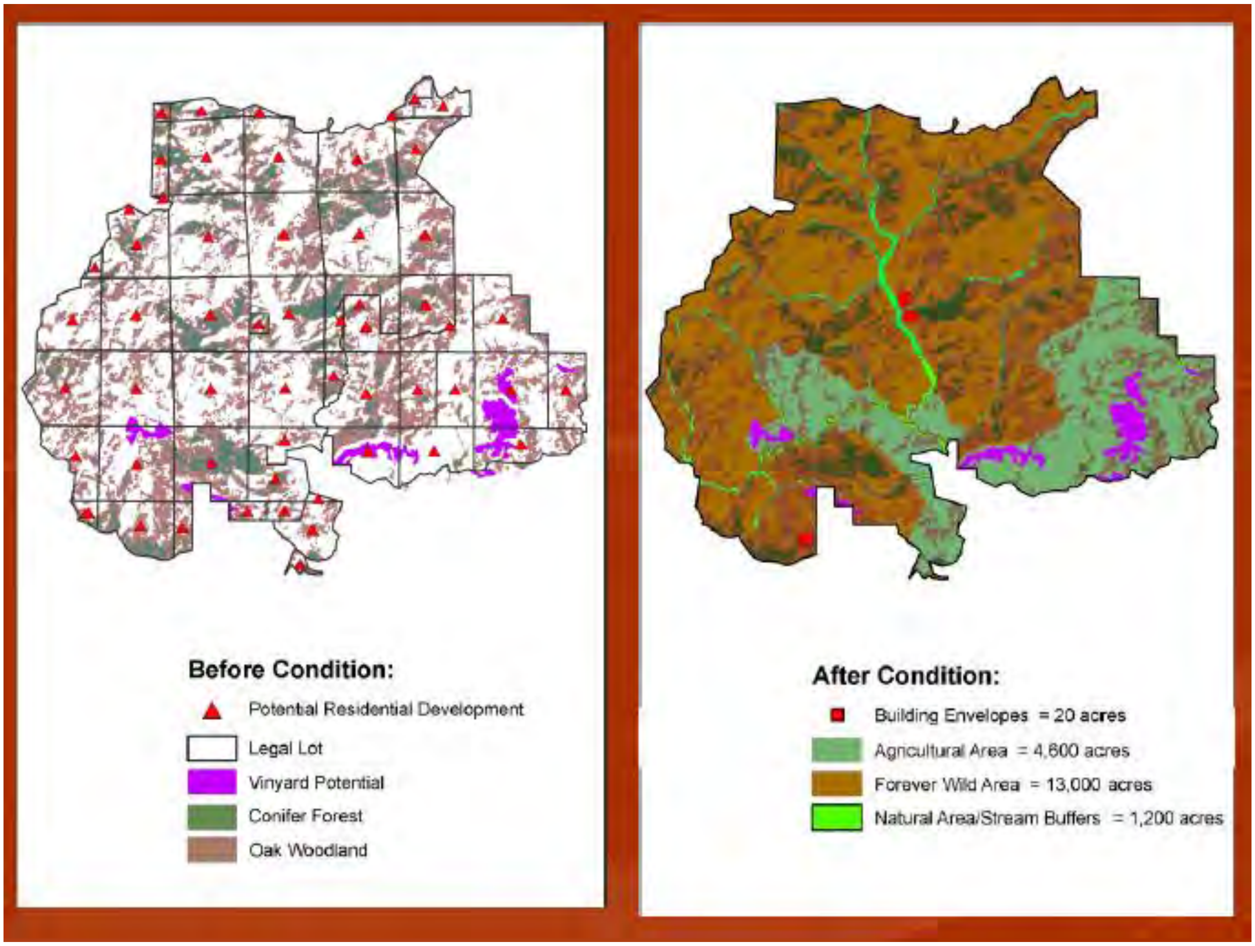

Figure G-10. Cooley Ranch Conservation Area Before and After.
Source: Gaffney, 2012.

Lessons Learned

Lesson Learned: ***Climatic modeling and predictions*** **provide crucial information for extreme event preparation, response, and overall water management in a region.**				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Research into and monitoring of changing climates produces necessary information. • Conducting scenario-based impact analyses for projected average and extreme climate/weather events allows for better preparation and response during events.	• Initial mapping / analysis of carbon sequestration potential (Gaffney, 2012). • Developing partnerships and the use of new climate modeling technologies such as LIDAR radar, collaborative monitoring and CoCORaHs (Gaffney, 2012; Russian River Facilitator Notes, 2012). • Increased knowledge of atmospheric rivers and their contribution to water supplies and threats in the Basin. • The SCWA-NOAA MOA to fund HMT in order to improve monitoring and modeling/analysis capabilities.	• Lack of fine scale vegetation and habitat maps (Gaffney, 2012). • Inevitable uncertainty related to climate science, those that challenge the impact of changing climates, and unpredictable last minute changes in weather patterns.	• Utilize information provided by new technologies, precipitation mapping by CocoRahs, NOAA's HMTs, and sea level rise data to work with governing institutions and store/release water as needed before flooding or droughts hit a county.	• Climate analysis with "unimpaired flows for water management modeling of Russian River basin, climatic boundary conditions for GSFLOW surface water/groundwater model of Santa Rosa Plain" (Flint, 2012). • Develop implications of scenarios, including low-probability events. • Improve modeling / forecasting approaches, and data collection through new technologies (Russian River Facilitator Notes, 2012). • Increase understanding of possible future impacts of changing climates in the area. • Forecast coordinated reservoir operations.

Lesson Learned: *Employing a holistic management view* better ensures sustainability of water resources, balances competing users during extreme events, and *improves communication and information access*.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Looking at the management of an entire basin helps identify the greatest benefits for the lowest cost. • Maximizing basin or regional-scale solutions decreases the impacts of extreme events. • Accounting for all users and needs improves information and moves towards better communication and access among all stakeholders (Russian River Facilitator Notes, 2012).	• Growing recognition that the past is not the prologue for the future. The unusual is now the usual and planning must act accordingly (Russian River Facilitator Notes, 2012). • Increased attention to ecosystem services both to support aquatic environments and human needs. • The establishment of NOAA's National Water Center in Alabama (Hartman, 2012).	• A complete valuation of conservation goals and how this fits in with local and state water plans (Gaffney 2012). • Clear, comprehensive access to information before and during an extreme event, including: Internet, portals, metadata, tags, and searches on water-related issues (Russian River Facilitator Notes, 2012).	• Employ whole / regional systems thinking processes and engage with stakeholders, local governments and other institutions in the area to balance needs and prepare for extreme events (Russian River Facilitator Notes, 2012). • Map and analyze adaptation opportunities for a water utility's service area and how this connects to the Basin as a whole (Gaffney, 2012). • Develop Water Supply Strategies Action Plan that provides the framework for regional integrated water resource management (Jasperse, 2012).	• Further integrate diverse programs and strategies. • Identify opportunities to address multiple challenges through such programs and strategies that contribute to the overall resilience and sustainability of the Basin.

Lesson Learned: ***Partnerships and collaboration*** **between institutions and stakeholders** ***accelerate water management progress and collective learning opportunities.***				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Forming partnerships with other stakeholders, including regulatory agencies, allows institutions to work on problems ahead of regulation instead of waiting for a 'one-size-fits-all' solution (Russian River Facilitator Notes, 2012).	• NWS outreach projects that "objectively define, validate and prioritize stakeholder needs" (Hartman, 2012). • Partnership between Claes Fornell International Group and David Ford Consulting Engineers to survey NOAA hydrologic information users, emergency managers private sector media, and water resource managers (Hartman, 2012.) • The USACE conducted National Needs Assessment for all states, including California, which provided important adaptation information for the Russian River Basin (Hartman, 2012). • Establishing pilot areas for study, including the NIDIS Pilot Area, IWRSS Demonstration Area, and the Russian River as NOAA's pilot for Habitat Blueprint Watershed.	• Clear direction to leverage resources, coordinate activities, and innovate approaches that result in faster progress. • Lack of resources and funding to engage in additional partnerships and collaborative efforts. • Competing interests and needs can incentivize the direction a partnership takes or success of a partnership. • Multi-jurisdictional fragmentation creates additional vulnerabilities that are difficult to address, including conflicting incentives and unintended repercussions from actions, competition for limited funds, and conflicting regulatory priorities (Jasperse, 2012).	• Coordinate information sharing and meetings with other utilities to exchange information on successes and failures during emergency response to better adapt for future events. • Increase communication with institutions related to and that support water services and utility operations. This may include NGOs, advocacy groups, and local governments. • Stakeholder based groundwater management planning that provides a mechanism to implement integrated water resource management on a basin scale (Jasperse, 2012).	• Engage stakeholders for proactive, customized problem-solving and decision-making processes. • Continue supporting existing partnerships and work to increase effectiveness through regular meetings, monitoring, reports, and information sharing opportunities.

Lesson Learned: ***Seizing opportunities for new approaches*** **to water management and extreme event preparation / response** ***promotes adaptation to changing environments.***				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Identification of new research and management opportunities helps address the multiple challenges of extreme events. • Innovative programs and diverse strategies contribute to sustainability.	• Groundwater banking studies and implementation to ensure water during drought (Russian River Facilitator Notes, 2012). • Exploration of green infrastructure to mitigate stormwater runoff and protect ecosystems during extreme events (Russian River Facilitator Notes, 2012). • The USACE-established Dam Safety Program provides better monitoring and information for decision-making during extreme events (DiCiro and Dillabough 2012).	• Lack of time, funding, staff and resources to explore and implement potential management approaches, technologies, and adaptation opportunities. • Lack of research on the impacts of green infrastructure, costs of groundwater banking, etc.	• Information-sharing with other utilities and institutions to learn about new approaches and successes. • Utilize existing partnerships and collaborative efforts when resources are scarce, yet new approaches needed. • Conduct vulnerability assessments of infrastructure and operations and develop adaptation strategies to improve resiliency of water resources (Jasperse, 2012).	• Direct policies towards support for innovation and new technologies and approaches. • Adequately assess new opportunities, such as green infrastructure, and explore implementation costs and needs.

Looking Forward

Forecasts of changing climates in the Russian River Basin reveals a striking demonstration of collaborative innovation, interposed with pressing challenges in water resource management and preparation for extreme events.

The California Adaptation Strategy of 2009 calls on the California Emergency Management Agency and the California Natural Resources Agency to produce a Climate Adaptation Planning Guide. Published in July 2012,[10] this effort reflects the awareness of California legislators, officials, and scientists of the inextricable linkage between effective emergency management and climate resiliency.

In the first decade of the 21st century, extreme climate/weather events emerged as an increasingly common occurrence in northern California. Yet events such as the 2006 New Year's Day Flood, 2007-2009 Drought, Spring Frost of 2008, and the recent 2013 Drought serve as reminders that, though perhaps no longer rare, such events arrive without much warning and can have devastating, long-term impacts on communities and their surrounding environments. Impacts hardly hit a community in isolation. For instance, water shortages from withdrawals for protective coating on grape vines during the 2008 Frost were further exacerbated by a three-year drought. What is certain is that the increasing nature of extreme climate/weather events and cumulative impacts of these events present numerous challenges for the Russian River Basin.

Communities in the area have a remarkable history of collaborative approaches to solve complex problems. In the face of extreme events, institutions nurtured these partnerships. The result is an increasingly sophisticated understanding of extreme weather and changing climates, as well as highly innovative and useful tools such as NOAA's HMTs, integrated flood control studies, and groundwater banking potential.

All this enables a more integrated resource management approach within the Basin. Water and natural resource managers, scientists, and elected officials work together to overcome uncertainty in climate projections by investing in the monitoring, research, tools, and dialogue needed to build resilient responses to the impacts of a changing climates.

Such resilience is increasingly important, not merely because of continued bouts of extreme climate/weather hitting the region, but also because of the mounting challenges that arise with such events. Underlying silos, organizational fragmentation, and competition between users threaten advancements made by collaboration and partnerships. In the face of more extreme and frequent floods, droughts and frosts, institutions, governments, users, communities, NGOs, and research centers will all have to move towards an approach that examines the needs of the Russian River Basin as a whole. The challenge to protect ecosystem services while preserving a balance among competing user needs persists. It is a grave challenge constantly tested by extreme climate/weather events, yet one that the region seems ready to take on.

10 For more information, refer to: http://resources.ca.gov/climate_adaptation/local_government/adaptation_policy_guide.html.

WATER UTILITY PROFILES: RUSSIAN RIVER BASIN WORKSHOP PARTICIPANTS

City of Santa Rosa Utilities Department	
Overview	The City of Santa Rosa Utilities Department is responsible for providing a safe and economical water supply for municipal, industrial, and fire suppression use in Santa Rosa and surrounding areas. As the managing partner for the Subregional Wastewater Treatment Plant it also provides wastewater collection and treatment, disposal, reclamation, industrial waste inspection and laboratory services to Santa Rosa, Rohnert Park, Sebastopol, Cotati and the South Park County Sanitation District. The Department helps set and maintain water connections and user billing. In addition to water and wastewater services, the Utilities Department is home to the City's Water Conservation, Storm Water and Creeks, Materials Engineering, and Environmental Projects divisions.
Location	Headquarters: 69 Stony Circle, Santa Rosa, CA. 95401 http://srcity.org/departments/utilities/Pages/default.aspx
Operations Conducted	Biosolids treatment, reuse, land application Groundwater management Stormwater collection Water treatment Water distribution Wastewater collection/sewerage Wastewater treatment
Size	• Service Area: ~50,000 residents and commercial locations in Santa Rosa, Rohnert Park, Sebastopol, Cotati, and South Park County • Pipelines: 31 miles of mains added in 2007 • Sewer System: 22 miles of sewer mains and 42 miles of reclaimed water pipes added in 2007
Administrative Structure	The Department operates on $94 million/year. Administration includes Current Development Engineering, Planning/Technology Engineering, Project Development, Resources Management, Safety and Training departments.
Marin Municipal Water District (MMWD)	
Overview	Although MMWD lies outside the Russian River Basin, this public agency derives some of its water from the Russian River. MMWD purchases approximately 25% of its supply to serve around 45,000 citizens in Marin County Rainwater collected and stored in five reservoirs supplies the remaining MMWD customers.
Location	Headquarters: 220 Nellen Ave., Corte Madera, CA. 94925 http://www.marinwater.org/
Operations Conducted	Emergency Preparedness Water collection Water conservation initiatives and rebates Water distribution Water recycling Water storage Water treatment

Size	• Service Area: 147 square miles that serve 186,000 people in 10 towns and cities, in addition to unincorporated Marin areas (25% of which receive water from the Russian River). Includes 21,250 acres of watershed lands. • Storage: 7 reservoirs have a total storage capacity of 79,566 AF. 125 tanks can store 82 MG of drinking water. • Imports: ~ 7,700 AF of water from the Russian River annually. • Pipelines: 888 miles of mains • Pumping Stations: 90 • Treatment Capacity: 3 potable water treatment plants have a maximum daily treatment capacity of 59 million gallons (but average of 25 million gallons). • Recycled Water: 24 miles of pipeline, 3 storage tanks with a total of 1.9 MG storage capacity, 5 pump stations, and 1 recycled water treatment plant with a maximum daily treatment capacity of 2 million gallons.
Administrative Structure	Five Board of Directors members represent geographic areas within the water district and govern MMWD. This Board appoints a General Manager who supervises all MMWD operations.
Russian River Utility (RRU)	
Overview	Incorporated into the State of California in April 1983, RRU is a small water utility in Sonoma County. RRU originally operated the County's deteriorated private system only, however, has since expanded service. RRU manages County Service Areas, Public, Mutual, Private and Commercial water systems. RRU maintains, monitors, and prepares reports on water services for the County and State. RRU is a member of the American Water Works Association, California Water Agencies, Wine Country Water Works Association, and California Rural Water Association.
Location	Headquarters: 7131 Mirabel Road, Forestville, CA. 95436 http://www.rruwater.com/
Operations conducted	Meter reading maintenance Water reclamation Water sampling and testing Water treatment Wastewater treatment
Size	• Water Systems: 16, including two wastewater treatment systems • Meters: 3,400
Administrative structure	Boards oversee each of the water systems, which are managed by an overarching Board of Directors.
Santa Rosa's Laguna Wastewater Treatment and Reclamation Plant	
Overview	The Laguna Plant ranks within the world's top 5% for primary, secondary, and tertiary treatment and disinfection treatment technologies for wastewater. These processes treat wastewater from residential, commercial, and industrial users from cities of Santa Rosa, Rohnert Park, Sebastopol, Cotati, South Park Sanitation District, and some unincorporated parts of Sonoma County. The plant includes the Santa Rosa Subregional Water Reuse System and Geysers Recharge Project, which pumps recycled water into underground steam fields to generate electricity.

Location	Headquarters: 4300 Llano Road, Santa Rosa, CA. 95407 http://ci.santa-rosa.ca.us/departments/utilities/treatment/treatment/Pages/default.aspx
Operations Conducted	Energy generation Primary, secondary, and tertiary treatment and disinfection Solids treatment /reuse (composting, landfill, incineration) Stormwater collection Wastewater collection and treatment Wastewater recycling and reuse
Size	• Sewage: 500 miles of mains • Reclaimed Water: 21 MGD • Electricity Generation: 1000 MW capacity for up to 100,000 users
Administrative Structure	Collection systems are operated and maintained by the individual entities.
Sonoma County Water Agency (SCWA)	
Overview	SCWA naturally filters water from the Russian River to nine cities and districts in the Russian River Basin. Since 1995, SCWA has also managed the County of Sonoma's sanitation zones and districts through wastewater collection and treatment, as well as recycled water distribution. SCWA is also responsible for maintaining over 75 miles of streams and numerous facilities throughout Sonoma County to help reduce the risk of flooding.
Location	Headquarters: 204 Concourse Blvd, Santa Rosa, CA. 95403 (operations) http://www.scwa.ca.gov/
Operations Conducted	Drinking water filtration Flood protection Hydroelectric power Recreational opportunities Recycled water distribution River flow management Wastewater treatment Water conservation and environmental resource protection Water resource management
Size	• Service Area: supplies 600,000 residents with drinking water and collects 22,000 residents' and businesses' wastewater including users in the Cities of Santa Rosa, Petaluma, Rohnert Park, Cotati Sonoma, Town of Windsor, Valley of the Moon Water District, North Marin Water District, Marin Municipal Water District • Peak day capacity ~ 110 MGD • Wells: 6 radial collector wells, 10 conventional wells • Pipelines: 79 miles of transmission pipelines, ranging 16-54 inches in diameter each
Administrative Structure	The five member Board of Directors meets weekly to address institution issues. Meetings are open to public participants.

U.S. Army Corps of Engineers, San Francisco District	
Overview	USACE, San Francisco District regulates water quality and water levels at Lakes Mendocino and Sonoma.
Location	Headquarters: San Francisco, with locations at the Bay Model Visitor Center, Lake Sonoma, Lake Mendocino, and the Eureka Field Office http://www.spn.usace.army.mil/
Operations conducted	Navigation Reservoir releases Wetland restoration Water quality testing
Size	N/A
Administrative structure	The majority of USACE's San Francisco District is run by civilian personal divided into several management, services, and regulatory divisions.

STAKEHOLDERS: RUSSIAN RIVER BASIN WORKSHOP PARTICIPANTS

Organization / Institution	Description	For More Information
Bay Area Ecosystems Climate Change Consortium (BAECCC)	Works with resource managers, scientists, and other organizations to support and protect Bay Area ecosystem services. Facilitates meetings and collaborative efforts among stakeholders to reduce climate change impacts.	http://www.baeccc.org/
California Land Stewardship Institute	Works with public and private landowners to promote ecosystem protection and best land use management practices.	http://www.fishfriendlyfarming.org/
California Water Foundation (CWF)	A Resources Legacy Fund initiative founded in 2011, the California Water Foundation works to promote water efficiency practices among leaders and decision makers, and interest groups. Long-term sustainability focuses on the advancement of integrated water resource management, increased water use efficiency, improved groundwater management, and key river restoration.	http://www.californiawaterfoundation.org/
Congressman Mike Thompson	Congressman Thompson is an influential advocate for land use and conservation acts, oceans, waterways, and aquatic species in Northern California.	http://mikethompson.house.gov/issues/issue/?IssueID=14749
Cotati Creek Critters	Works with local communities on environmental stewardship and ecosystem restoration in the Laguna de Santa Rosa.	http://www.cotaticreekcritters.info/
Department of Water Resources (DWR), California	Works with several agencies to manage and protect water resources in California. Oversees the State Water Project, and other projects, that provide water for residential, agricultural, and commercial use.	http://www.water.ca.gov/
E&J Gallo Winery Inc.	A family-run winery and one of California's largest wine exporters, E&J Gallo contributes to the state economy and relies on water from the Russian River Basin to conduct operations.	http://gallo.com/
ESA PWA	Works to provide environmental engineering services, regulatory permitting, compliance monitoring, restoration, and climate change mitigation services for the Bay Area and other locations in the United States.	http://www.esassoc.com/locations/region/esa-pwa
Laguna de Santa Rosa Foundation	Works with communities and institutions to restore and protect Sonoma County's Laguna.	http://www.lagunadesantarosa.org/

Mendocino County Russian River Flood Control and Water Conservation Improvement District	Works to "proactively manage the water resources of the upper Russian River for the benefit of the people and environment of Mendocino County."	http://rrfc.net/
Pepperwood Preserve	A 3,200 acre reserve in eastern Sonoma County, the Pepperwood Preserve directs initiatives and advances science-based conservation, biodiversity, how to localize climate information to help communities cope, the relationship between extreme events, and ecosystem services.	http://app.pepperwoodpreserve.org/pls/apex/f?p=514:1:0
Point Blue Conservation Science	Works with scientists and communities to protect birds, wildlife, and ecosystems by conserving habitats and addressing climate change impacts.	http://www.pointblue.org/
Russian River Watershed Protection Committee	Primarily works on water resource issues and public interests in the lower Russian River and tributaries.	http://www.rrwpc.org/
Sonoma County Agricultural Preservation & Open Space District	Preserves open space in agricultural lands in Sonoma County, as well as beaches and estuaries.	http://www.sonomaopenspace.org/
Sonoma Ecology Center	Works with communities to protect biodiversity, promote restoration, collect data, map water resources, and offer educational programs and science camps.	http://www.sonomaecologycenter.org/
Sonoma County Fire and Emergency Services Department, Emergency Management Division (OES)	OES is one of three divisions (the others are fire prevention and hazardous materials) in Sonoma County's Emergency Services Department. This institution helps information flow between federal, state, and local levels. OES promotes homeland security, offers expert information on subject matters and lead emergency management, and maintains and provides EOC support as needed.	http://www.sonoma-county.org/fire/
Sonoma-Marin Saving Water Partnership	Members of this partnership are California Urban Water Conservation Council (CUWCC) signatories, working to promote water conservation in urban areas and helping to calculate estimates for future savings.	http://www.savingwaterpartnership.org/
Sonoma State University (SSU) Preserves	This is a cross-disciplinary project regarding natural soundscapes that work to increase awareness and collect data.	http://www.sonoma.edu/preserves/info-hub/cross-preserve-projects/soundscape.html
United Winegrowers for Sonoma County	Brings together winegrowers in Sonoma County to share information and protect vineyards.	http://www.sonomawinegrape.org/united-winegrowers-for-sonoma-county-1

ATTENDEES: RUSSIAN RIVER BASIN WORKSHOP PARTICIPANTS

Brenda Adelman	Russian River Watershed Protection
Bob Anderson	United Winegrowers for Sonoma County
Michael Anderson	State Climatologist, Department of Water Resources
David Banister	Laguna Foundation
Nancy Beller-Simms	NOAA
Jenny Blaker	Cotati Creek Critters
Blasser, Brentt	County of Sonoma
Amy Bolten	Sonoma County Water Agency
Valerie Brown	Sonoma County Water Agency, Board of Directors
Jennifer Burke	City of Santa Rosa
Richard Butler	National Marine Fisheries Service
Efren Carillo	Sonoma County Water Agency, Board of Directors
Shonnie Cline	Water Research Foundation
Ellie Cohen	PRBO Conservation Science
Caitlin Cornwall	Sonoma Ecology
Grant Davis	Sonoma County Water Agency
Chris DeGabriel	North Marin Water District
Chris Delaney	Sonoma County Water Agency
Michael Dettinger	USGS
Cheryl Diehm	Congressman Mike Thompson
Mike Dillabough	USACE
Ann DuBay	Sonoma County Water Agency
Mark Duncan	Consultant
Lauren Fillmore	Water Environment Research Foundation
Lorraine Flint	USGS
Alan Flint	USGS
Nick Frey	Sonoma County Winegrape Commission
Karen Gaffney	Sonoma County Agricultural Preservation & Open Space D
Susan Gorin	City of Santa Rosa Council
James Gregory	ESA PWA
David Guhin	City of Santa Rosa

Andrew Gunther	Bay Area Ecosystems Climate Change Consortium
Neil Hancock	Cotati Creek Critters
Rob Hartman	NOAA/NWS/CNRFC
Christopher Helgren	Sonoma County Fire & Emergency Services
Miriam Heller	MHITech Systems
Paul Helliker	Marin Municipal Water District
Caroline Hemenway	Hemenway Inc.
Jay Jasperse	Sonoma County Water Agency
Pamela Jeane	Sonoma County Water Agency
Darrin Jenkins	City of Rohnert Park Water Cycle Branch
Lynn Johnson	Earth System Research Laboratory
Chester Koblinsky	NOAA
Krishna Kumar	Valley of the Moon Water District
Mark Landman	City of Cotati
Jennifer Larocque	Sonoma County Water Agency
Marcelo Lippman	Lawrence Berkeley Laboratory
Daniel Logan	National Marine Fisheries Service (NOAA)
Claudia Luke	SSU Preserves
Steve Mack	Sweetwater Springs Water District
Jake Mackenzie	City of Rohnert Park
David Manning	Sonoma County Water Agency
Laurel Marcus	California Land Stewardship Institute
Suzanne Marr	U.S. EPA Region 9, Watersheds Office
Jessica Lamb	Sonoma County Water Agency
Mike McGuire	Sonoma County Water Agency, Board of Directors
Karen Metchis	U.S. EPA Office of Water
Lisa Micheli	Pepperwood Foundation
John Nagle	E&J Gallo Winery, Inc.
Tracy Nishikaw	USGS
Kenan Ozekin	Water Research Foundation
Connie Perkins	City of Sacramento
David Rabbit	Sonoma County Water Agency, Board of Directors
Marty Ralph	USCD/SCRIPPS (formally NOAA)

Jill Reisdorf	UCAR/JOSS
Patrick Rutten	NOAA Restoration Center
Todd Schram	Sonoma County Water Agency
Don Seymour	Sonoma County Water Agency
Lester Snow	Resources law Group
Anne Steinemann	UW/Scripps
Cordel Stillman	Sonoma County Water Agency
Claudio Ternieden	Water Environment Federation
Michael Thompson	Sonoma County Water Agency
Nancy Tosta	Ross & Associates
Ted Vinson	American Society of Civil Engineers
Robert Webb	NOAA/ESRL
Renee Webber	Sonoma County Water Agency
Mike Webster	USGS
Sean White	MCRRFC/WCID
Allen White	NOAA/ESRL
Robert Wilkinson	UC Santa Barbara
Glen Wright	City of Santa Rosa
Shirlee Zane	Sonoma County Water Agency, Board of Directors

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APPENDIX H

TIDEWATER AREA

The project's Tidewater Area workshop took place September 19-20, 2012 at the Virginia Institute of Marine Science in Williamsburg, Virginia. The workshop and findings detailed in this study would not have been possible without the Regional Team listed below. The Research Team thanks these members for their immense support, direction, and guidance in convening stakeholders, participating in the workshop, and preparing this case study.

Regional Team

Jennifer Faught (NOAA)
Ravi Jefferson-George (WERF)
Lewis Linker (U.S. EPA Bay Program)
Kim Linton (WRF)
Pamela Mason (VIMS)
Jaime Mitchell (HRSD)

The Story in Brief

'Extreme' events and their impacts take on a whole new meaning in the Tidewater Area of Virginia. Numerous hurricanes and nor'easters struck in recent years; yet, the increasing frequency and cumulative impact of smaller 'non-newsworthy' storms poses equally difficult challenges for water resources and utilities. The Tidewater Area is Virginia's eastern coastal plain where the James, Rappahannock, and York Rivers join the Chesapeake Bay. Four major cities – Hampton, Newport News, Norfolk, and Virginia Beach – reside within the Tidewater Area, in addition to rural and small communities, military installations, Norfolk Naval Base, and a large state-owned cargo port. Three metropolitan drinking water utilities and one sanitation district serve 1.7 million people. The region has many wildlife refuges and recreational beaches, alongside areas of dense development. At an average of 33 feet above sea level, continuous storms and floods threaten water services and the delicate estuarine balance between fresh and saltwaters.

Background

The Tidewater Area is the largest freshwater harbor in the U.S. (Hershner, 2012), and an important water resource support for human and environmental needs. The Tidewater Area includes Hampton, Newport News, Norfolk, and Virginia Beach cities, as well as several military bases (Figure H-1).

Geology: Land Subsidence

The majority of land and development in Tidewater resides around 33 feet above sea level; however, the Navy's Norfolk Pier elevation is a mere nine feet above sea level (Senate Joint Resolution, 2012). This low elevation and geology largely shape the region's extreme vulnerability to sea level rise and flooding.

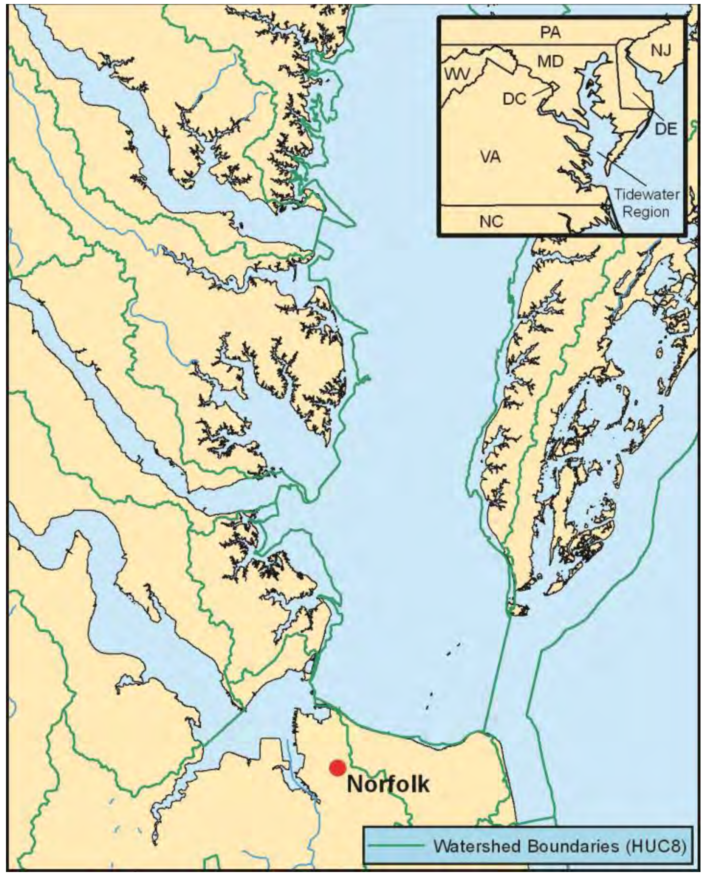

Figure H-1. The Tidewater Area.

Sediment in the Tidewater Area consists of clay, sand, and gravel (W&M Geology, 2011). Nearly 35 million years ago a 3-5 kilometer bolide, resulting in the Chesapeake Bay Crater (Figure H-2), disrupted the landscape and created the area's unique geology today (Hershner, 2013; USGS, 2013). Approximately 90 kilometers wide, the crater rests in the shallow sea beneath 1.2 kilometers of sediment (W&M Geology, 2011). Among other effects to the region, this crater shifted the rate of vertical land surface movement, or 'land subsidence.' (Hershner, 2013; USGS). Following the bolide's impact, an isostatic glacial rebound effect further augmented this acceleration in land subsidence. The rebound effect emerges when land originally elevated by glaciers recedes, or as glaciers melted over the past 12,000 years, land area extending beyond the glaciers bent downward and adjusted the area's elevation (Hershner, 2013; Boon et al., 2010).

Groundwater withdrawals in the Tidewater Area exacerbate this natural land subsidence, contributing to the relative rising in sea levels (Hershner, 2013). In fact, land subsidence "represents at least 50% of the sea level change from 1900 to 2010" (Sammler, 2012). This geological phenomenon affects water resources and the ability of utilities to respond to extreme climate/weather events.

Citizens, Economy, and National Security

Most residential and commercial development in the Tidewater Area resides along the coast (Figure H-3). The coast is also home to large military operations, including most of the mid-Atlantic fleet naval bases as well as multiple government agencies and protection shipyards

(Hershner, 2013). Half of the U.S. Navy Atlantic Fleet is in Hampton Roads alone. On the Elizabeth River, Sewell's Point houses a major naval station and largest sea level gage along the Eastern Seaboard.

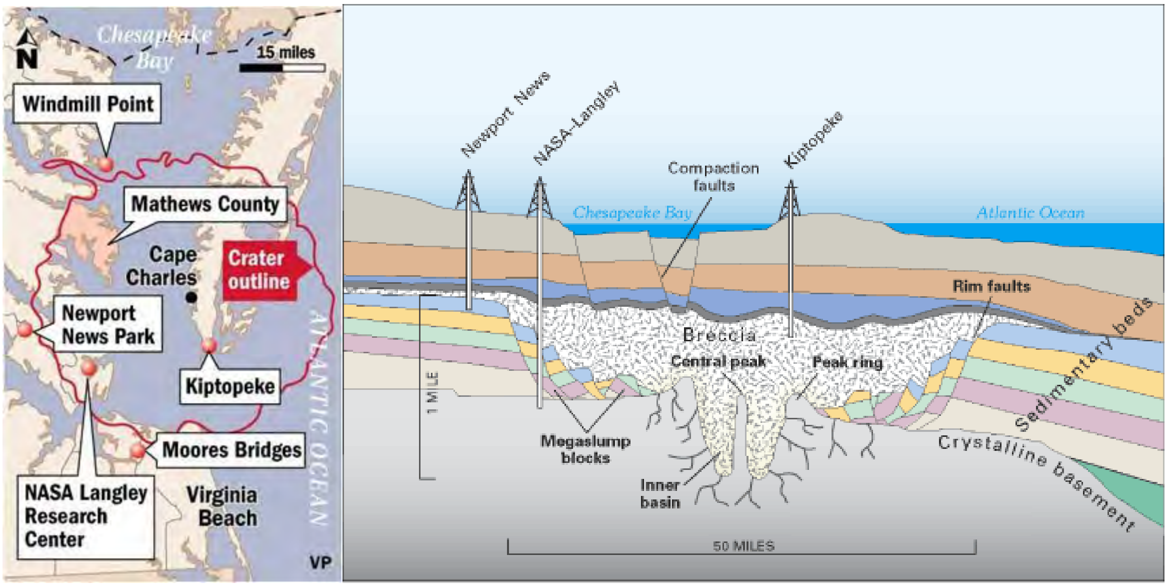

Figure H-2. The Chesapeake Bay Crater.
Credit: The Virginian Pilot and USGS.
Source: Hershner, 2012.

Estuaries and Coastal Habitats

Virginia's thousands of shoreline miles and extensive shallow tidal water areas – including the Tidewater Area – support estuarine flora and fauna in wetlands (Figure F-3). These "shallow water environments are vital to the coastal community, providing an enormous mix of ecological services." (Bilkovic et al., 2012). Key habitats along the coast include sea grass beds, tidal marshes, and beaches. These habitats provide protection, nesting and nursing areas; and foraging for crabs, economically valuable fish species, migratory waterfowl, shorebirds, and diamond back terrapins (Bilkovic et al., 2012). Beaches also protect upland areas from winds and waves, sea grass beds increase water clarity and reduce nutrients, and tidal marshes filter pollutants and sediments (Bilkovic et al., 2012).

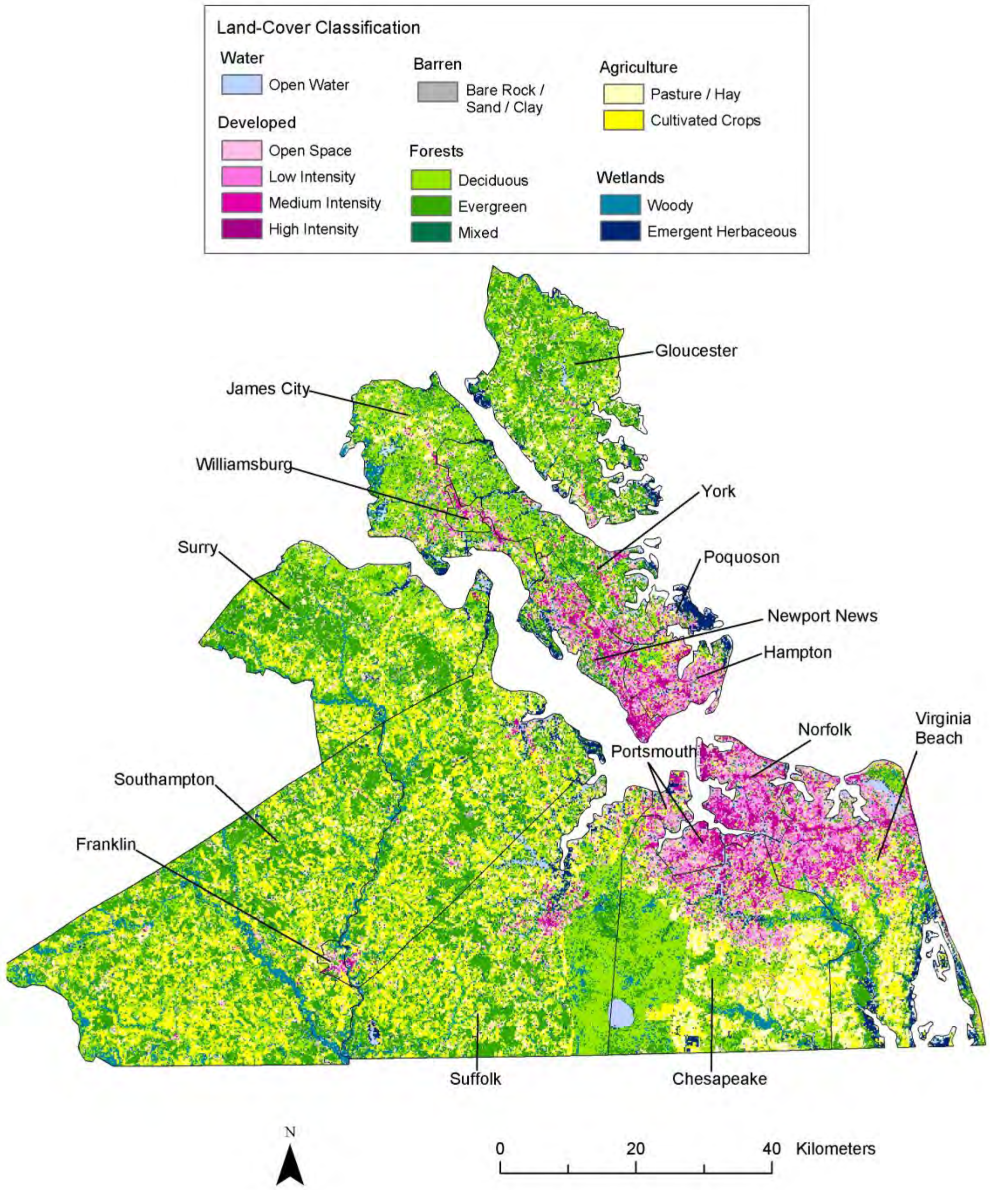

Figure H-3. Land Cover in the Hampton Roads Area.
Source: Kleinosky et al., 2007.

Water Laws and Governance

Water governance is two-fold: The State of Virginia as well as federal naval base reserves manage water resources. Local water utilities serve Hampton, Norfolk, Newport News, Virginia Beach, James City and York counties plus rural areas in the Tidewater Area. While municipalities collect wastewaters, the Hampton Roads Sanitation District (HRSD) is the only major treatment provider in the Tidewater Area, operating 13 water resource recovery facilities. While naval bases are responsible for all services, including water at their facilities, bases often contract wastewater collection or drinking water services through local utility operations. Much collaboration further exists between the Virginia State government and the Navy regarding regular water utility operations and extreme climate/weather event response actions. Furthermore, the area is subject to state and regional water laws including, but not limited to, the following:

- Chesapeake Bay and Virginia Waters Clean-Up and Oversight Act.
- Groundwater Act of 1973.
- Impoundment of Surface Waters.
- Potomac River Riparian Rights Act.
- State Policy as to Waters.
- State Water Control Law.
- State Water Resources Law.
- Waters of the State, Ports, and Harbors (Virginia Code, Title 62.1).

These laws apply to the Tidewater Area, as well as the rest of Virginia; though they address various types of water sources and issues, together such regulations help inform the area's comprehensive water governance plan.

Climate and Water Trends

The interaction between surface and coastal waters – and the effect climate has on this interaction – defines water trends in the Tidewater Area. The Atlantic Meridional Overturning Circulation determines weather patterns; ocean circulation dictates coastal sea levels (Hershner, 2012). Changing ocean climates and weather alter the supply of coastal waters, which in turn shifts the balance between fresh and saltwaters (Ramaley, 2012). These factors render water utilities in the Tidewater Area increasingly vulnerable to extreme climate/weather events, as well as the cumulative impacts of more frequent and smaller storms.

Warming Temperatures

The Tidewater Area experienced more than a 1°C rise in the mean and maximum annual surface water temperatures over the past 50-60 years and expects an additional 2-6°C increase by 2100 (Bilkovic et al., 2012). This has already resulted in an earlier occurrence of seasonal warming by about three weeks (Bilkovic et al., 2012). This upward trend is extremely dangerous for water resources throughout Tidewater.

Temperature increases diminish sea grass beds, stress plant growth, reduce light availability, and promote non-native species growth, (Bilkovic et al., 2012). A general increase in the mean temperature of Atlantic coastal waters could create a 'boom or bust' scenario for several species, as species production becomes "increasingly synchronized at larger spatial scales (e.g. regional), rather than typically smaller spatial scales (e.g., single estuary) (O'Brien, 2012)." Warmer temperatures in the Tidewater Area already threaten the very existence of economically important species such as the winter flounder, soft-shelled clams, menhaden, croakers, blue crabs, and striped bass. These species rely upon particular coastal conditions for early life stage cycles (Bilkovic et al., 2012). Warmer waters also increase biological activities; this decreases overall water quality, resulting in heavier treatment costs (Bilkovic et al., 2012).

Changing Precipitation Levels and Patterns

Annual precipitation is also on the rise in the Tidewater Area. Overall, the region currently receives more rainfall than in the past, though precipitations patters are erratic (Bilkovic et al., 2012). The area primarily shifts between frequent smaller storms to intensified big storms, but also the occasional drought. "Irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents" causes this inter-annual variation (Hershner, 2012).

Tidewater has had 10 significant hurricane and storm surge events since 1970, nine of which occurred after 1978. Tropical storms and hurricane rainfall generally occurs in an 18-30 hour period. This presents a 'one and done' scenario in which storm impacts occur after one tide cycle, then quickly returning the region to normal.

Intensified rainfall patterns and frequent storm events escalate turbidity and shoreline erosion due to increased runoff. This alters nutrient levels in tidal marshes (Bilkovic et al., 2012). Heavy rains pressure spillways to pass more water, threaten sewer overflows, and heighten the risk of storm damage to facilities.

Tidewater, Virginia.
Credit: NASA, 1987. Source: Bilkovic et al., 2012.

Rising Sea Levels

In the Tidewater Area, rising sea levels commonly result in saltwater intrusion and the breach of tidal barriers. Increased precipitation, accelerated land subsidence, and changes in ocean circulation and temperatures[1] leave the Tidewater Area extremely vulnerable to sea level rise. While 85% of the Atlantic Coastline is at a high-moderate risk for rising sea levels (Bilkovic et al., 2012; Ezer and Corlett, 2012), Norfolk is the second most vulnerable city to sea level rise in the U.S., just after New Orleans (Karl et al., 2009; Boone et al., 2010 in Madhavan, 2012).

Saltwater intrusions into freshwater are a serious consequence of sea level rise, as is threatened coastal ecosystems. The Chesapeake Bay faces a potential loss of 50-70% of the area's wetlands due to increases in water depth (Figure H-4) (Kelly, 2012). Saltwater intrusion reduces habitat availability for many of the fish and crab species in Virginia's tidal marshes (Bilkovic et al., 2012). Rising sea levels further threaten water supplies for human use and consumption. Water services areas in Tidewater are at risk for inundation, while saltwater intrusion threatens surface and groundwater supplies (Figure H-5) (Madhavan, 2012). Furthermore, sea level rise causes an overall increase in water tables; this results in infiltration/inflow (I/I) into sanitary pipes near coastal areas. Overflows are thus becoming an issue even during dry weather, simply because water tables are higher.

[1] Nearly "two-thirds of the [global] sea level rise over the 20th Century is from thermal expansion of sea water, although contributions from changes in land ice are accelerating and expected to dominate future sea level rise scenarios" (O'Brien, 2012).

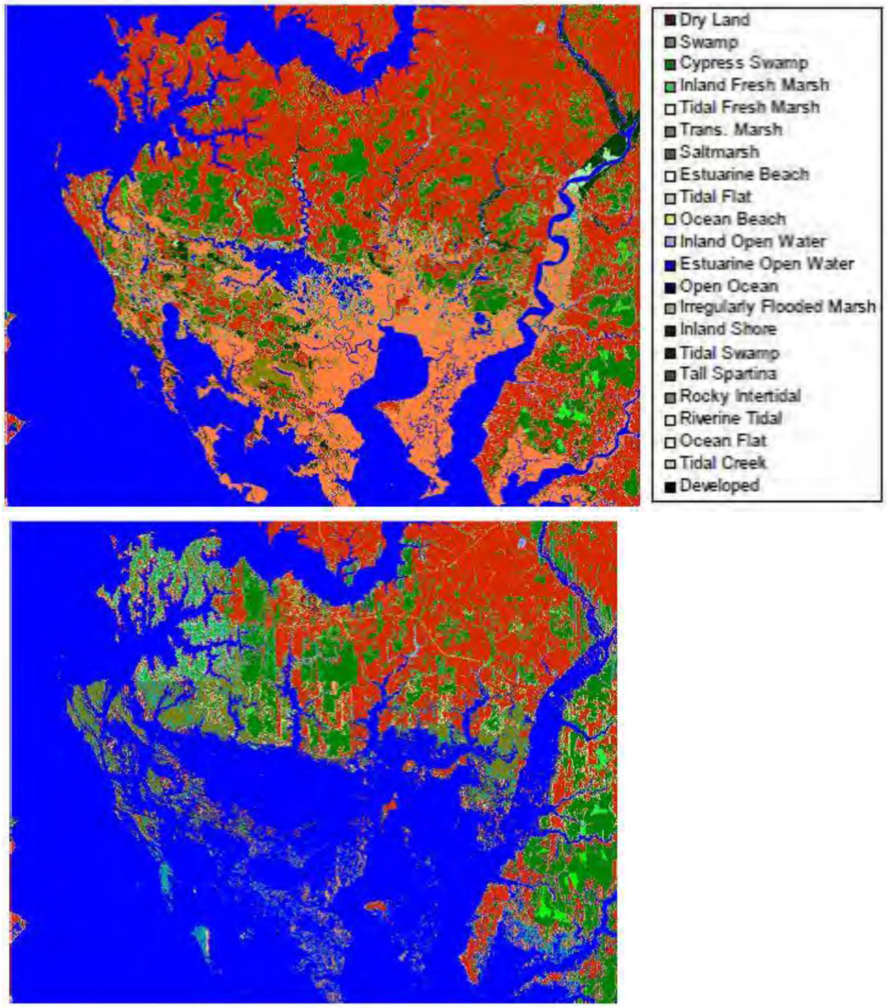

Figure H-4. Impact of Sea Level Rise on Chesapeake Bay Wetlands, 1996 to 2100.
Projections of 1m global sea level rise indicate that some areas in the Chesapeake Bay, such as Cambridge MD and the surrounding peninsula, face a significant loss of wetlands from 1996 (left) to 2100 (right). These wetlands will likely be replaced by open water and salt marshes.
Source: Glick et al., 2008.

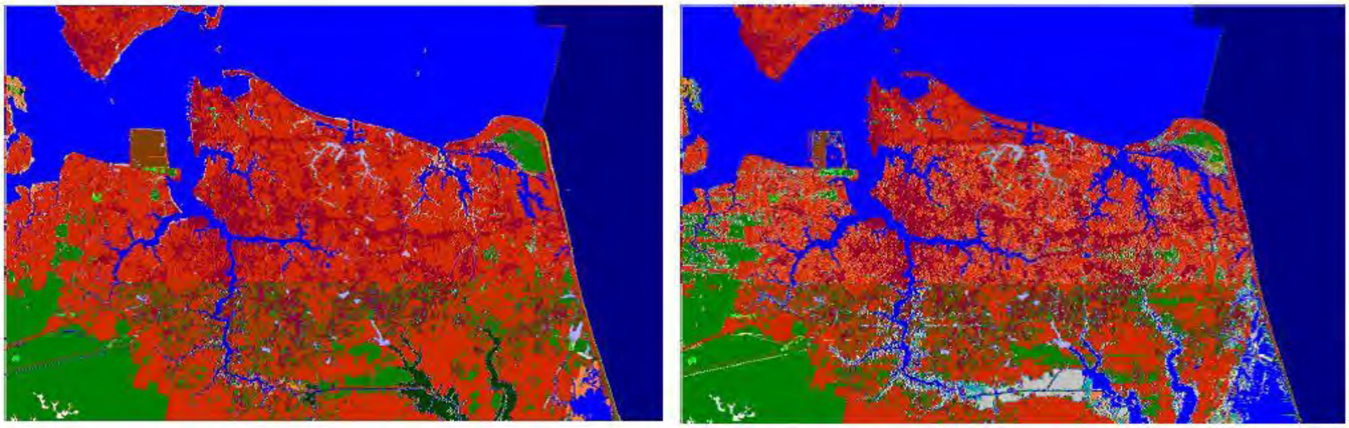

Figure H-5. Impact of Sea Level Rise on Development in Virginia Beach, Norfolk, 1996 to 2100.
Projections of 1m global sea level rise from 1996 (left) to 2100 (right) threaten land development in and around the Norfolk area, even under protected development scenarios.
Source: Glick et al., 2008.

Sewell's Point has the longest tide record of any gage in the Chesapeake Bay. Gages show that sea levels at Sewell's Point rose 0.12 inches per year until 1950; since 2010, this rate has doubled with sea levels continuing to rise at nearly 0.24 inches per year (Hershner, 2012). Sea levels in the Chesapeake Bay currently rise an average of 1.7 inches per year[2], compared to an estimated 8 inches total over a 50-year regional period (Farmer, 2012). Accelerating rates will leave the Bay with at least a 1.5-foot increase in sea level by 2100 (Bilkovic et al., 2012).[3] Such anticipated sea level rises have an impact, even in typical years that are not particularly dry or wet (Table H-1).

Table H-1. Sea Level Rise and Tidal Barriers in the Tidewater Area, Virginia.

Projected Sea Level Rise (SLR)	# of Days High Tide Will Overtop Current Tidal Barrier in a Typical Year
No SLR	17 days
30 cm SLR	120 days
50 cm SLR	195 days
100 cm SLR	214 days
Source: Data adapted from Ramaley, 2012.	

2 Measurements taken at Sewell's Point, this level varies at different points throughout the Chesapeake Bay.

3 The 2014 National Climate Assessment (USCGRP) estimates a global sea level rise between 1-4 feet in the next century.

Demographic Trends

Growth in the general population and military bases is of concern in the Tidewater Area, as more people and livelihoods are vulnerable to extreme weather-related impacts, such as shifting storm patterns and sea level rise. A cyclical effect persists, as human pressures further aggravate the environmental impacts of changing climates in the Tidewater Area. For instance, accelerated land subsidence due to groundwater withdrawal exacerbates rising sea levels, thus contributing to the region's overall vulnerability (Kelly, 2012).

Population throughout the Chesapeake Bay increased drastically in the past several decades. From 2000-2005, Virginia had the greatest population growth in the Bay, placing extreme pressure on water quality by increasing nutrient and sediment loads (Blakenship, 2006). The Tidewater Area is no exception. Three of the four major cities grew 3% or more from 2000 to 2010 (Table H-2). Despite a decrease in Hampton's population growth, the Tidewater Area still retained an overall rise in population. Coupled with growing populations in rural and small communities, as well as on military bases,[4] the increase in human pressure on water resources is significant.

Table H-2. Population Growth in Major Cities, Tidewater Area, VA.

City	2000 Population	2010 Population	Population Growth 2000-2010	2011 Population	2020 Population Projection
Hampton	146,437	137,436	-6.5%	136,401	144,655
Newport News	N/A	180,719	N/A	179,611	182,415
Norfolk	234,403	242,803	3.58%	242,628	237,448
Virginia Beach	425,257	437,994	3%	442,707	470,288
Source: Data adapted from Census Viewer and VIMS, 2013.					

Development adjacent to tidal marshes has already placed 119 square miles or 38% of Virginia's tidal marshes at a moderate-high vulnerability to sea level rise (Bilkovic et al., 2012). Rising sea levels and increased development further affect shoreline hardening. In fact, around 11% or 491 miles of Virginia's tidal shoreline is hardened, with an additional 18 miles hardening each year (Bilkovic et al 2012). This renders inland migration to coastal habitats difficult, while property owners in coastal zones face shoreline hardening and erosion issues, as well as increased flood threats during storms.

Building retirement and summer homes in these zones is expensive, yet waterfront development is expanding throughout the Tidewater Area. Developers commonly install structural barriers to protect land investments and home assets in the face of rising sea levels and erosion (Virginia CZM Program). Such protection primarily includes shoreline stabilization, usually through rock, wood, or vinyl seawalls. Between 1993 and 2004, for example, Virginia

[4] While naval populations are the largest and fastest growing military bases in the Tidewater Area, the growing presence of air force and army bases is also significant.

authorized 230 miles of structural stabilization along the coastline (Virginia CZM Program). This development severely "destroy[s] important wetland, beach and dune habitats and disrupt[s] important natural physical, geological and biological processes" (Virginia CZM Program).[5]

Extreme Events

The Tidewater Area is subject to storm surges, tidal flooding, hurricanes, and nor'easters. Currently ranking as the second highest risk area in the continental U.S. (Kelly, 2012), significant weather and climate events are likely to increase. Tropical storms occurred frequently in the past 15 years; half of all flooding events in the Tidewater Area ensued during this time.

The 'Non-Extreme' Extreme Events

Particularly noteworthy is the varying extremes in which events and impacts hit the Tidewater Area. The low-lying coastal areas leave Tidewater prone to large weather and climate events. Yet each discussion of a hurricane or nor'easter inevitably bears light on the cumulative impacts caused by persistent smaller storms.

> *"We're sort of in the worst-case of the worst-case scenario right now…we're not even on the historical trend anymore"*
>
> *– Carl Hershner, Virginia Institute of Marine Science*

Changing climates impact the Tidewater Area, and workshop participants noted the profound effect of the more frequent, smaller storms on military facilities, water utilities, and daily life. Ezer and Corlett (2012) comment that "Norfolk has experienced storm surge flooding in the past, but today the frequency of flooding increases, and even weak storms or high tide can cause flooding" (Figure H-6). A few inches of rain cause tides to rise several feet (White, 2012). Such storms are rarely newsworthy, but their unprecedented cumulative impact leaves greater effects than a single major event, and in some cases do more damage (Hershner, 2013; Ramaley, 2012). This poses a major challenge for the Tidewater Area and redefines what 'extreme' weather adaptation entails for water service providers.

[5] For further information on efforts to address the tension between the need to protect waterfront properties as well as water resources and surrounding environments, refer to the *Political and Intergovernmental* section under Decisions, Challenges, and Gaps in this report.

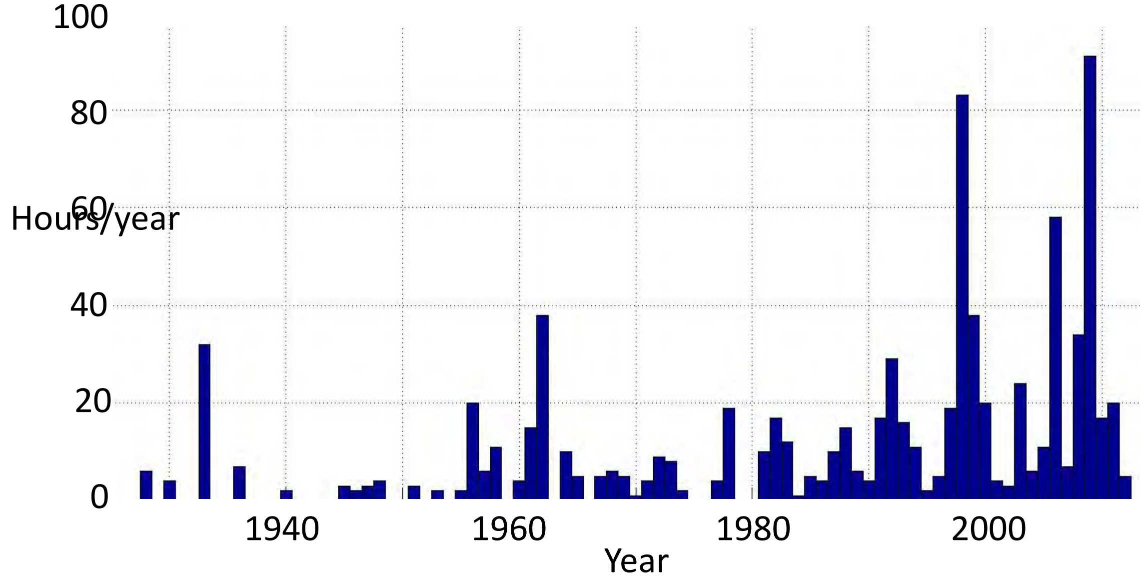

Figure H-6. Number of Hours/Year that Hampton Roads Flooded.
Source: Atkinson et al., 2013.

Flooding in the region has two major origins: heavy rainfall and spring tidal periods. Though these origins may be attributed to events such as Hurricanes Floyd, Irene and Isabel or the 2009 nor'easters (Sammler, 2012), flooding from short-lived thunderstorms and slightly elevated tides is a common occurrence in the Tidewater Area. While high tide events are a typical source of flooding, floods are increasingly more common during spring tides, which recur semi-monthly and likely to increase with rising sea levels (VIMS, 2013). Higher waters during these tides leave coastal areas more prone to flooding.

Heavy rainfall usually occurs within an 18-30 hour time period, which places massive pressure on water resources and water management systems (Sammler, 2012). Urban areas flood more rapidly due to their dependence on drainage systems. Land subsidence and rising sea levels further exacerbate these flooding challenges for cities within the Tidewater Area (Lentz and Tucker, 2012).

In fact, Ramaley (2010) asserts that smaller storms actually have the equivalent destruction potential that larger storms before sea level rise did; the impacts will affect human activities, as well as coastal environments and ecosystems. Piers, military installations, roadways, and utilities are all at high-flood risk during heavy rains. Floods may also cause power outages, structural damage, water main breaks, sanitary sewer overflows, dam failures, and saltwater intrusion (Lentz and Tucker, 2012). Cumulative impacts also affect infrastructure. The Naval Facilities Engineering Command (NAVFAC) manages several Naval and Marine Corps installations in the Tidewater Area. NAVFAC anticipates future flooding impacts to include flooded bases and roadways, over-topped piers, utility disruptions, shoreline erosion, pier and bulkhead scour, increased water levels, ground saturation, increased loading, and uplift (Farmer, 2012). Norfolk Utilities offers several pre-planning and maintenance measures to mitigate such threats (Table H-3).

Table H-3. Pre-Planning the 'What-Ifs' of Storm Events: Strategies from Norfolk Utilities.

Risk	Planning and Implementation Strategies
Power Outage	● Become power independent, especially at critical pump stations! ● Install fixed generators with off-grid capability before storm occurs. ● Rent portable bypass pumps and pre-position at critical stations for wastewater treatment. ● Install fixed bypass pumps, generator plugs. ● Establish a cellular backup Scada system.
Structural Damage (from wind or water)	● Harden facilities, activate hurricane shutters. ● Bury aerial crossings, cut trees. ● Design up to category 2 hurricane force winds. ● Eliminate as many aerial crossings as possible
Water Main Breaks (trees pull up water lines, high pressure in weak sections)	● Identify trees near water lines and remove. ● Lower main pressures. ● Replace aging mains and pipes.
Sanitary Sewer System Overflows	● Replace ageing pipes. ● Install manhole inserts to prevent infiltration. ● Target oldest and most problematic inflows first.
Dam Failures (more common during hurricanes)	● Inspect trees and rodent growths that damage dams. ● Improve overflow structures to relieve pressure. ● Dam inspection programs.
Flooding	● Protect infrastructure from repetitive flooding. ● Raise control panels, install watertight doors and hatches. ● Move portable equipment to higher ground during storms. ● Install manhole inserts. ● Monitor saltwater intrusion.
Source: Information adapted from Lentz and Tucker, 2012.	

'Extreme' events take on a dual meaning in Tidewater: extreme in the sense of consistent and frequent, as well as the larger climate/weather events. Adaptation extends beyond emergency response and long-term planning to incorporate consistent and regular preparation and action.

Hurricane Isabel 2003

Hurricane Isabel struck the Tidewater Area on September 18, 2003. Rain fell for nearly 24 hours, and the highest intensity recorded at 0.25 inches/hour (White, 2012). Though this may not seem like significant rainfall, the combined impact of rain and tidal surges was massive in this coastal area. The slow-moving storm stalled over the York River during high tide. Storm surges reached a record high of eight feet (Bernas, 2012); in Hampton Roads tide levels were five to six feet above normal (Beven and Cobb, 2004).

Impacts to the Environment

Waters flooded tidal habitats, threatening local ecology and ecosystem services. Isabel caused devastating erosion to coastal areas already vulnerable due to previous shoreline hardening and rising sea levels, particularly in Hampton and Newport News cities (NOAA). Eroded areas left habitats with poor water quality and minimal protection from future storms.

Impacts to the Community

While impacts within the Tidewater Area alone are difficult to extract, Virginia state data revealed the severity of the event. Isabel killed 32 people in Virginia – of these 10 deaths were direct impacts and 22 indirect (Beven and Cobb, 2004). Tidal surges, excess water, and infrastructure damage threatened public health (Bernas, 2012). Virginia residents made nearly 6,000 assistance calls to the Virginia Public Inquiry Center, while 93,000 people registered for assistance with FEMA (Hurricane History, 2012).

The Commonwealth of Virginia declared more than 100 localities major disaster areas, including many in the Tidewater Area (Hurricane History, 2012). Furthermore, 1,124 homes destroyed and another 9,027 damaged, 77 businesses destroyed and another 1,400 damaged (Hurricane History, 2012). Isabel left 200,000 football fields of debris throughout Virginia (20 million cubic yards) that required more than 660,000 dump trucks to haul away (Hurricane History, 2012).

Like many cities, hundreds of sidewalks required repairs after Isabel swept through Norfolk (Applegate, 2011). Most of Norfolk lost power; the hurricane cut off electricity for more than 1.8 million customers throughout the Tidewater Area. (Lentz and Tucker, 2012). Moreover, massive damage occurred at fishing piers in Virginia Beach (NOAA). This had longer-term impacts on the area's fishing economy.

Overall, Isabel exceeded $1.9 billion in damage for the Commonwealth of Virginia, excluding economic losses and including both recovery and public assistance in the form of (Hurricane History, 2012):

- $36 million for water control, utilities, parks, road systems and public buildings.
- $179 million in debris removal ($50 million for VDOT).
- $25 million to state agencies.
- $30 million to federal highways.
- $33 million for home repair and rental assistance.
- $79 million for small business administration loans.
- $15 million for mitigation efforts.
- $22 million for recovery needs assistance such as personal property, medical and transportation.

Flooded Roads during Isabel.
Credit: U.S. Navy photo.
Source: Farmer, 2012.

Impacts to Water Utilities

Trees pulled up water lines and high pressures hit the weak sections of distribution mains, leaving major water main breaks at many water and wastewater utilities in the Tidewater Area (Lentz and Tucker, 2012). Isabel caused approximately 92% of the Virginia Beach's 395 sanitary sewer pump stations to lose power, resulting in widespread overflows (City of Virginia Beach, 2011). Infiltration due to flooding put pressure on wastewater conveyance system capacity causing additional overflows (Lentz and Tucker, 2012). Isabel further threatened the "integrity of dams at reservoirs" (Lentz and Tucker, 2012).

Utilities faced challenges in flood mitigation efforts to minimize public health risks and restore drinking water quality as quickly as possible. The Virginia Department of Emergency Management provided 150 generators to localities as well as 6 million pounds of ice (Hurricane History, 2012). Compromised drinking water quality necessitated 1.5 million gallons of water be delivered to localities throughout the Tidewater Area and the rest of Virginia (Hurricane History, 2012).

Utility and Community Response

Cities supported water utilities in hurricane response efforts. Prior experience with storms and pre-readiness plans enabled utilities to act quickly with short-term mitigation strategies, despite the massive structural and economic damage caused by Isabel. The event's stark reminder of just how common storms have become in the Tidewater Area, response efforts also focused on several long-term response strategies.

Actions Taken – Emergency Response Short-Term Responses

Anticipating Isabel, Norfolk's Department of Utilities instigated a Pre-Event Plan to reinstate services quickly and minimize structural damage when the Hurricane reached shore. The City of Norfolk fed power to water treatment plants through two separate feeds, rented generators for raw water facilities and kept a fuel storage truck on site for power outages (Lentz and Tucker, 2012). Also under this Pre-Event Plan, Norfolk rented and positioned portable bypass pumps at critical wastewater pump stations. The "proximity of the wastewater pump station to drinking water reservoirs or state waters, the size of the sewer shed that it serves, whether or not the pump station re-pumped sewage from another pump station [and] the storage time of the pump station wet well" determined critical stations (Lentz and Tucker, 2012).

Norfolk further prepared for structural damage caused by wind and water. The city removed trees in danger of falling on buildings and infrastructure and "harden[ed] facilities against wind and flooding," while simultaneously activating existing hurricane shutters (Lentz and Tucker, 2012).

Actions Taken – Long-Term Planning Long-Term Responses

Many of Norfolk's long-term response actions included previously defined strategies (Table H-3). Since 2000, the City designed new and replacement facilities for 10-year storm levels (Kelly, 2012). Following Isabel, Norfolk dedicated $10 million a year to replacing aging water mains and prevent breaks during storms and worked with the City Forester to remove problematic trees (Lentz and Tucker, 2012). Norfolk designated an additional $17 million a year to replace aging sewer infrastructure and install manhole inserts in flood prone areas, beginning with the oldest and most problematic areas containing significant infiltration and SSO inflows (Lentz and Tucker, 2012).

Lentz and Tucker (2012) further note that, following the City's experience with Isabel, several specific preparation measures took place, including the installment of seven generators to run water treatment plants, fuel storage tanks to back-up the generators, fixed bypass pumps for critical wastewater pump stations, and requiring these pumps in any new station designs. The success of these efforts enabled utilities in Norfolk to continue and maintain operations during major storm events, thunderstorms, and blackouts (Lentz and Tucker, 2012).

Norfolk began construction on a second tube to the midtown tunnel with a max elevation bowl of eight feet in order to mitigate the tide gate failure experienced during Isabel. This exceeded the current standard by two feet for better protection during future hurricanes (White, 2012).

Water Utilities and Institutions Participating in the Tidewater Area Workshop

HRPDC – Hampton Roads Planning District Commission

HRSD – Hampton Roads Sanitation District

NAVFAC – Naval Facilities Engineering Command

VERT – Virginia Emergency Response Team

VIMS – Virginia Institute of Marine Science

As a long-term response approach, the Hampton Roads Sanitation District (HRSD) utilized and revised their Hurricane Response Plan in Isabel's aftermath. Updated annually prior to 2003, this plan is part of HRSD's Planning and Analysis Division.[6] It details prioritized flood damage mitigation actions based on the projected tidal height (Table H-4) (Bernas, 2012). Each treatment plant instigates a customized chart and annual unannounced drills to practice emergency response and identify gaps. Following Isabel, the division made changes to foster the continual improvement of disaster response. Some of these changes included a renewed focus on employees and greater collaboration with FEMA. Specifically, HRSD updated personnel policies and pushed each employee to develop a hurricane plan for their families (Bernas, 2012). They improved disaster recovery to ensure alignment with FEMA. HRSD accomplished this by hiring a consultant to perform a gap analysis on the division's existing plan and update best practices (Bernas, 2012). HRSD management personnel earned certifications in FEMA's Incident Command System (ICS) response (Bernas, 2012). HRSD also developed plans for satellite phone rentals and business continuity to ensure better future communication during events (Bernas, 2012). The division stocked plants with at least seven days of generator fuel storage and analyzed ride-out areas for existing vulnerabilities (Bernas, 2012).

[6] The division was not created in response to particular extreme event, but rather evolved over time as HRSD learned to deal with varying weather patterns.

Table H-4. HRSD Hurricane Readiness and Recovery Plan Response Chart.

Projected Storm Tide In ft. Above MSL	Prioritized Flood Damage Mitigation Actions Based upon projected height of Storm Surge in feet above MSL	Actions based on Actual height of Storm Surge in feet above MSL
>5	Contact the GM to see if plant is to be abandoned; if so, start abandonment procedures and go to designated off-site shelter; if not continue below	
7	Move plant truck to higher ground off plant site Flood proof main switchgear building and electrical substation Flood proof administration building Flood proof IPS Flood proof generator building Secure portable pumps, compressors, generators and important power hand tools in maintenance areas Store tools and equipment at least three feet above floor level Fill empty chemical or fuel storage tanks Work centers may leave as many computers running as they feel necessary. Any computers that are not going to be used during the storm should be shut down and covered with plastic. All computers should be off the floor and away from any windows.	Access road floods Ground floods
8.5	Move files, electrical office equipment and analytical equipment from offices and lab areas to protected rooms and store all items as high above the floor as possible	Finished floor of switchgear and electrical substations flood
9	Remotely Shutdown all power to the plant.	Switchgear and electrical substations flood proofing fails
10		Ground floor of most buildings on plant site flood
11	***Abandon plant; go to designated off-site shelter (Plant must be abandoned prior to storm surge reaching 8.5 feet)	All flood proofing fails Severe flood damage occurs Plant not safe for personnel

Source: Bernas, 2012.

HRSD's Data Analysis Section, a sub-sector of the Planning and Analysis Division also proved useful during Isabel's aftermath. Originally developed in response to the EPA Consent Decree for Sanitary Sewer Overflows (SSOs),[7] the section monitors "hundreds of interceptor system (flow and pressure), rainfall and groundwater meters that help [HRSD] understand the system's response to wet weather events" (Bernas, 2012). Ensuring correct data and working meters helps minimize infrastructure overflows. Coupled with GIS spatial analysis of the SSOs, this plays a crucial role in understanding and responding to extreme events (Bernas, 2012).

[7] Discussions for the Consent Decree between EPA and HRSD began in 2006 and the Decree was officially recorded in early 2010. Prior to this, HRSD was in a Consent Order with the state's DEQ. As part of that, the HRSD planned to install a large number of meters throughout the system. With these policies in place, the Data Analysis Section was established and reviewed data from newly installed meters. This Section became "an integral part of the final Consent Decree to ensure data integrity" (Bernas, 2012) EPA's Consent Decree does not specify how HRSD should respond to extreme climate/weather events; however it does have an indirect impact. The level of service to which infrastructure is designed determines, in part, how well the system can handle extreme climate/weather events.

In the fall of 2008, HRSD established a Post Storm Report to provide a historical record of significant events and system performance. Significant events are deemed those with a greater than one inch rainfall (Bernas 2012). Each Post Storm Report details “flow and pressure, sanitary sewer overflows, groundwater levels, rainfall recurrence intervals, storm surges, spatial rainfall analysis”

Nor’easter Ida: 2009 November

The non-tropical storm Nor’easter Ida hit the Tidewater Area in late 2009. Though Ida’s peak sea level was identical to Hurricane Isabel, the impact was dramatically different, due to the differences in how the extreme climate/weather events evolve (Table H-5). Ida lasted six tide cycles with water levels at or above 4.5-foot floods. This resulted in surges over 6.7 feet. Coastal areas in the area received 3 to 12 inches of rain (Sammler, 2012). Nearly 7.5 inches of rain fell on November 12th and into the next day (White, 2012). After 72 hours of rain, the storm ended. Nor’easter Ida caused some of the worst damage ever experienced in the Tidewater Area.

Table H-5. Hurricane and Nor’easter Characteristics in the Northeastern United States.

Characteristics	Hurricanes	Nor’easters
Point of Origin	0-30° north latitude (in tropics)	30-60° north latitude (outside tropics)
Direction	Counter-clockwise	Counter-clockwise
Pressure Areas	Low	Low
Energy Generation	Warm-core lows (energy from ocean heat)	Cold-core lows (energy from temperature clashes)
Strength	Strong surface winds, decrease with height	Strong aloft winds, decrease at surface
Size	~300 mile diameter	Diameter can be thousands of miles
Duration	Usually passes in a day	Can last for days in one area
Frequency	Once every five years	20-40 times a year

Impacts to the Environment

Ida caused 60% of Virginia Beach’s stormwater outfalls to fill with silt and rising sea levels during the storm (White, 2012). This caused the increased salinity of inland water sources and heightened health risks from disease vectors like mosquitoes (White, 2012).

Impacts to the Community

Ida caused neighborhood evacuations in some areas of Norfolk and Virginia Beach due to the flooding of homes or heightened flood risks (The Virginia Pilot, 2009). Some shelters opened for evacuees.

Streets throughout Hampton Roads flooded even though most interstates were clear, and cities temporarily suspended bus services (The Virginia Pilot, 2009). Many schools shut down during the storm, while some remained closed for repairs in the immediate aftermath (The Virginia Pilot, 2009). Businesses faced significant structural damage; many closed temporarily during extensive and necessary repairs. Expenses related to broken decks and windows, as well as furniture and floors damaged by flood waters, left owners with less funds for regular community program contributions and events (Roth, 2009).

Impacts to Water Utilities

Ida caused a partial dam failure on the Chickahominy River. Water and wastewater facilities built on shorelines were particularly vulnerable. Coastal erosion affected infrastructure. Higher levels of saltwater at intakes inhibited the ability of utilities to drain water at plants.

Utility and Community Response

Actions Taken – Emergency Response Short-Term Responses

President Obama's declared the Commonwealth of Virginia a disaster zone on December 9, 2009. The declaration provided public assistance to local governments for emergency response and repairs. This included countywide per capita impacts of $3.61 for Hampton, $3.69 for Newport News, $15.98 for Norfolk and $6.87 for Virginia Beach, some of the highest costs throughout the state (FEMA, 2009).

Short-term actions focused on mitigating floods and separating contaminated water. For instance, Newport News raised its reservoir water level one foot to keep freshwater upstream and brackish tidal water downstream.

Actions Taken – Long-Term Planning Long-Term Responses

Several response actions in the Tidewater Area addressed more long-term structural issues. Assessments addressed the maximum probable events and consequences. In other words, cities evaluated how bad events could be and what would happen during these, then planned to that level (White 2012). This was particularly important for low-lying areas, as once a storm reaches flood wall levels and ocean water overtops barriers, consequences become more severe. Developers forewarned people residing in these areas of the potential future destruction that could not be averted in these low-lying areas (White, 2012).

Virginia Beach elevated Goodspeed Road to protect wetland areas. Lynnhaven Colony developed Shore Drive with approaches that considered rainfall, surges and ecosystem service needs such as wetland restoration (White, 2012).

HRSD signed EPA's Consent Decree on SSOs in February 2010, months after Ida hit the Tidewater Area (EPA Wet Weather, 2011). Under this consent, thirteen localities developed regional wet weather management plans, establishing a higher level of service and resulting in the construction of $2-3 billion of new infrastructure (Bernas, 2012).

Norfolk developed a more "comprehensive approach to address precipitation and tidal flooding across the entire city…Realizing the magnitude by which [the city] must address this issue, our work…evolved into a four-pronged strategy" (Kelly, 2012), which specified revised planning, communication, preparation, and mitigation efforts.

Norfolk City planning involved modeling and simulation studies. Weekly meetings of the City Flood Prevention Committee collaborated with several departments to analyze long-term tidal and precipitation flooding and, in conjunction with USACE, shoreline protection (Kelly, 2012). These analyses led to the revision of city codes, helped create information partnerships, and further pushed legislative initiatives at the state and federal levels (Kelly, 2012).

In terms of communication, Norfolk furthered citizen outreach and online resource information. A citizen focus group with CMC (Commandment of the Marine Corps) league participation included experts from an Advisory Committee comprised of USACE, US Navy, VPA, HRSD, HRPDC, VIMS, ODU, NOAA, and NASA (Kelly, 2012). Community outreach expanded through inserts, brochures, flooding websites, Facebook, Twitter and the Norfolk Alert System.

Emergency preparedness and response efforts rooted in increased education and training initiatives. The City worked with FEMA to certify staff in the National Incident Management System (NIMS) approved the national weather service Storm Ready Community, increased risk and hazard training for the Community Emergency Response Team, and worked on evacuation strategies and transportation alternatives (Kelly, 2012). The City also increased participation in the National Flood Insurance Program. Norfolk currently rates a Class 9 in the Community Rating System, which translates to an average annual savings of $46 per policy in flood hazard areas (Kelly, 2012).

Mitigation efforts following Ida addressed flood remediation and infrastructure development. This included shoreline protection and stabilization, property acquisition, tidal flooding mitigation projects, and an elevation of many homes through FEMA's Hazard Mitigation Grant Program (Kelly, 2012).

In Ida's wake, Norfolk and other cities within the Tidewater Area worked to utilize and improve upon existing response plans. Long-term responses were especially appropriate considering the region's upward trend in major storms and the persistent challenge of cumulative impacts from smaller storms.

Hurricane Irene – August 2011

Nor'easter Ida was, in many ways, a precursor to another series of extreme climate/weather events. In 2011, one such event, Hurricane Irene, stalled over the Tidewater Area. Though Irene crossed land near Cape Lookout, NC, the Hurricane remained east of the Tidewater Area. Eventually making landfall in New Jersey, the majority of several rainfall and flood damage was inland (NOAA, 2012). Nevertheless, Irene impacted the Tidewater Area. By high tide, Sewell's Point recorded storm surges over 7.5 feet. Three inches of rain fell overnight on August 27th-28th.

Impacts and Response

In the Hampton Roads area, flooding from this storm surge was comparable to that from Hurricane Isabel of 2003. (NOAA, 2012). Particularly heavy rainfall in the Susquehanna River, the Chesapeake Bay's single largest tributary, caused large sediment loads to enter the Bay during Irene's aftermath. The sediment load from the upper Bay tributaries impacted water quality and potentially underwater grasses in the Tidewater Area and the rest of the lower Chesapeake Bay (VIMS, 2011).

Though Irene caused significant damage in the Tidewater Area, many cite Isabel as the more devastating hurricane. For instance, fewer deaths occurred and hospitals reported minimal numbers of injuries in Hampton Roads during Irene (The Virginia Pilot 2011). Many attribute this to greater awareness and better preparation throughout localities. However, the Tidewater Area was not unscathed during the 2011 event.

Half of residents in the City of Hampton experienced power outages, while 63,000 were left without power in Virginia Beach. Traffic intersections lost lights and downed power lines left significant debris on roadways in Hampton (Wavy, 2011). Traffic signals lost power at 22 major intersections in Virginia Beach (Wavy, 2011). Warwick and Bland Boulevards, as well as several other roads in Newport News were impassable; flooding, downed trees and broken power lines inhibited transportation (Wavy, 2011). More than 600 residents in Norfolk evacuated homes, residing in shelters across the city (Wavy, 2011).

Water Main Break in Norfolk, VA During Hurricane Irene, 2011.
Credit: City of Norfolk, Department of Utilities, 2011. Source: Tucker, 2014.

Cities throughout the Tidewater Area reported millions of dollars in damage. Localities in South Hampton Roads estimated $30 million, $9.2 million in Norfolk and $2.6 million damage to 86 private property houses and 16 businesses in Virginia Beach (Applegate, 2011).

Water utilities in the Tidewater Area also suffered infrastructural and costly damage. Water mains broke, pipelines failed, and facilities lost power. The HRSD's main pipeline that crosses the Lafayette River between the Virginia Zoo and HRSD's Pump Station suffered a failure that resulted in a sanitary sewer overflow of approximately 440,000 gallons to the Lafayette River (HRSD, 2012).

Given both the Tidewater Area's history of events and the overall large number of extreme climate/weather events in 2011, Virginia's governor declared a state of emergency prior to Irene's predicted arrival at Hampton Roads. The U.S. Navy sent dozens of ships to sea, universities closed, ferries ceased, cities issued mandatory and voluntary evacuations, and water/wastewater utilities activated emergency response plans.

'Short-Fuse' Nor'easters – August 2012

Two short-fuse nor'easters hit the Tidewater Area on August 25 and 28, 2012, nearly a year-to-date following Hurricane Irene. Rain exceeded 5.21 inches in a 3-hour period and 6.37 inches in a 6-hour period; the events thus surpassed the Tidewater Area's 100-year flood (Sammler, 2012). The dual-polarization storms were almost impossible to forecast ahead of time, due to the small size of affected areas. Highly localized, the two Nor'easters hit the same 20-30 square mile area in Tidewater, VA (Sammler, 2012).

Impacts and Response

The unusual strike in the same locale prevented the drying of soil between the storms. This meant that even though the second Nor'easter brought less precipitation, the cumulative impact was greater (Sammler, 2012). Widespread flooding and power failures reverberated throughout communities in the Tidewater Area. At the Norfolk Naval Base, the storms caused base and roadway flooding, over-topped piers, disrupted utilities, eroded the shore line, caused pier and bulkhead scour, destabilized the ground, and increased loads on structures.

Uprooted trees triggered water line breaks requiring expensive repairs at water and water resource recovery facilities throughout the Tidewater Area. For some utilities this stemmed not only from the heavy rain, but also from sewer system designs.

In Hampton Roads, for instance, sewer systems were designed only to handle sewage flows. Therefore, extreme climate/weather events cause portions of this system to flood through cracked pipes, holes, clean outs, "allowing a mixture of untreated sewage and rain water to get out of the system" (EPA Wet Weather, 2011). While the number of overflows during rain events varies dramatically, the 2012 Nor'easters contributed to a record overall overflow quantity of 22,847,623 gallons of sewage flowing into the streets (EPA Wet Weather, 2011). The red box in Table H-6 indicates this; blue boxes indicate other extreme climate/weather events covered during this workshop.

Table H-6. SSOs in the Hampton Roads Area.

Year	Number of Overflows	Total Quantity (gal) *
2003	70	1,088,990
2004	44	1,955,570
2005	30	362,592
2006	64	808,212
2007	23	834,435
2008	15	22,330
2009	95	2,744,936
2010	59	3,378,912
2011	35	1,870,491
2012	40	22,847,623

Source: Data adapted from EPA Wet Weather, 2011.

Though 2009 brought a record 95 SSOs, the quantity of sewage was greater during overflows in 2012. Thus, the greatest number of overflows does not necessarily equate the greatest impacts.

HRSD's Planning and Analysis Division once again updated their Hurricane Readiness and Recovery Plan, this time with a more in-depth focus on recovery aspects (Bernas, 2012). As part of HRSD's condition assessment program requirement under EPA's Consent Decree,[8] the institution released a 'Pump Station Flooding Analysis.' The analysis identified deficiencies, which HRSD subsequently directed funds to address these through their capital improvement program (Bernas, 2012).

The City of Norfolk updated their city flooding website – a local emergency alert system – in April 2012. Working on several preliminary mitigation designs previously recommended by Fugro Atlantic,[9] Norfolk assessed floodwalls, pumping stations and completed a city wide review analysis of progress regarding tidal and rainfall flooding (Kelly, 2012). Preliminary designs incorporated considerations for Hague floodwall and Pretty lake Floodwalls (estimated at $60 and $50 million each), Masons Creek pumping station (a $30 million project with an expected completion date 2015) and a complimentary water quality analysis and recommendations at Ohio Creek. Norfolk further coordinated with USACE and the Congressional Delegation to include the results of the Fugro Study into federal studies on flooding. In addition, Norfolk publicized project reports, reviewed environmental requirements, and conducted a city-wide watershed analysis (Kelly, 2012).

At the state level, the Virginia General Assembly "approved a joint resolution requesting the Virginia Institute of Marine Science to study strategies for adaptation to prevent recurrent flooding in Tidewater and the Eastern Shore Virginia localities" (Kelly, 2012). This resolution sought to develop a list of strategies used in similar settings, a stakeholder advisory panel, specific recommendations for preferred adaptation techniques, and inform state mitigation funding requests (Kelly, 2012).

As a result of this resolution (SJR 76, 2012), VIMS released the *Recurrent Flooding Study for Tidewater Virginia* in early 2013. The study used Light Detection and Ranging (LIDAR) mapping techniques to collect more detailed topographical information for coastal areas such as the Tidewater Area. Future plans intend to extend accurate elevation data from at least 1.2 feet vertical resolution to four feet (Bernas, 2012; VIMS, 2013). Such efforts are crucial to assess future flood risk and estimate impacts.

Decisions, Challenges, and Gaps

The hurricanes and nor'easters discussed during the Tidewater Area workshop, as well as the cumulative impacts of smaller storms demonstrate an array of challenges facing the region. Better preparation for future events necessitates a close look at these challenges and the drivers

[8] HRSD's and EPA's Consent Decree on SSOs does not directly impact the institution's response to extreme climate/weather events; it merely dictates infrastructure design "up to a level of service" (Bernas, 2012). This has an indirect effect on the effects of extreme climate/weather events, as pump stations and pipelines are designed for the probability of certain events occurring. Such improvements can be a very costly endeavor (Bernas, 2012).

[9] Fugro Atlantic is a Dutch-based engineering firm that worked with Norfolk to assess the city's flooding vulnerability and possible mitigation techniques. The study was released in 2012. For more information or specific results, visit http://www.norfolk.gov/DocumentCenter/View/3977.

behind current decision-making processes, as well as a great deal of collaboration to fill gaps identified by workshop participants.

Climate-Driven

A number of the challenges and gaps are related specifically to climate-driven factors.

- **Forecasting and Adapting to What Has vs. What Could Happen**

Adaptation in the Tidewater Area poses a unique challenge in terms of planning for major storms, smaller more frequent storms, and being prepared for what has versus what could happen. Workshop participants noted that many planners have minimal interest in incorporating less extreme climate/weather events into model validation and capabilities, instead focusing on modeling larger events and their impacts. However, the cumulative impact of recurrent smaller storms is often greater than one large event. Though community response actions are substantial, some workshop participants expressed the seemingly ‘patchwork’ nature of efforts. There is a clear increase in understanding and willingness to act based on the series of events over the past 10 years. For instance, many planners moved from using 2-year storm guidelines to 10-year storm guidelines for urban drainage systems to accommodate the increasing frequency of smaller, significant events. However, uncertainties about timing, rates, endpoints, and impacts create fundamental challenges in knowing exactly what to plan for. Understanding storm surges and the delineation of floodplain risks also remain uncertain.

Forecasting variability coupled with an unprecedented shift in weather patterns produces a gap in the knowledge of recent trends versus future projections. This challenges water utilities to constantly remain prepared, particularly for non-hurricane or smaller events. In the context of long-lived, capital-intensive investments, considering such questions moves immediately into the realm of climate change politics. Heated debates may divert attention from the specific needs of water service providers in order to improve overall adaptation strategies.

Water infrastructure and management traditionally developed under the assumption of stationarity; that “natural systems fluctuate within an unchanging envelope of variability…that any variable (e.g. annual stream flow or annual flood peak) has a time-invariant…whose properties can be estimated from the instrument record” (Milly et al., 2008). Climate change, alters this, leading Milly et al. (2008) to coin the phrase ‘stationarity is dead,’ referring to the fact that climate shifts have an unprecedented impact on the hydrologic cycle and water supply. Water engineers cannot as easily plan for future supplies based on past flow observations and precipitation trends.

In the Tidewater Area, workshop participants noted this concept and expressed concern that even a recognition of and planning for new climate and water trends does not necessarily ensure systems will adequately address extreme climate/weather events. Though recent trends suggest more frequent hurricanes and nor’easters, in reality, much uncertainty exists because of the non-stationary nature of changing climates and the subsequent impact on water resources. The complex geography of the Tidewater area reflects this sentiment; a slight change in a storm’s direction can carry vastly different consequences for the region.

Planners and water managers make development and adaptation decisions within this uncertainty, at times having to make choices despite information gaps. Though it is impossible to know everything the future holds, attention to specific areas and current events demonstrate a certain sense of action urgency. Effective adaptation must therefore “strike a balance between projection uncertainties, risk reduction, and adaptation cost" (Yang, 2010). Workshop participants stressed the need to focus on local water trends and climate indicators, as this is where adaptation can and must occur. By addressing the non-stationarity of climate in future designs, utilities can build better resiliency into water management and water services planning.

Water Service and Resource-Based

A number of the challenges and gaps are related specifically to resource-based factors.

- **Meeting Long-Term Environmental Needs**

Resilient water systems are healthy water systems, yet excess water and polluted floodwaters threaten ecosystem needs in the Tidewater Area. Numerous extreme climate/weather events coupled with smaller storms frequently overflow urban stormwater systems, due to exceeded system capacity and changing climates. Simultaneously, with the arrival of each event, banks that offer a natural protection for water resources erode further. Workshop participants noted the pressing need for flood mitigation efforts to protect water resources that supply drinking water for millions of people in the Tidewater Area, as well as minimizing contaminated flows into the Chesapeake and Atlantic. Water management and extreme event adaptation decisions are beginning to more adequately address the water quantity and quality issues during storms, as sea level rise and intensifying streams threaten water supplies and ecosystem services.

- **Infrastructure that Serves Current Needs and Future Uncertainty**

Infrastructure that meets both quantity and quality needs builds resiliency and helps meet long-term water resource needs. Workshop participants, however, noted that deteriorating infrastructure impacts the ability of water managers to mitigate damage during climate/weather events, while also planning for future intensification of extremes. This is primarily due to the inherent breakdown of infrastructure as well as the need for infrastructure to support multiple services during varying types of weather. Jay Bernas, Chief of Planning and Analysis at the HRSD, states that, "a level of service also provides a level of expectations. So, if we get an extreme event (i.e. something beyond a 10-year peak flow recurrence interval), we would expect (by design) to have sanitary sewer overflows because we purposely did not design the pipes, pump stations, and storage tanks for these events." Aging processes further weaken infrastructure already vulnerable due to coastal locations (Bernas, 2012). Some infrastructure needs repair, while in other cases the best adaptive strategy may involve relocation, necessitating decisions that account for the system as a whole.

While strategies seek to elevate buildings and land to mitigate flooding at water treatment plants and water resource recovery facilities, effective adaptation is impossible in the absence of a consideration for water infrastructure, roads, military base access, and on/off base utilities (Farmer, 2012). Infrastructure maintenance and improvements must serve current needs, but also balance future uncertainty. By setting facility elevation limitations – such as for dry-dock and crane rails – to projected sea level rises, planners and managers can better protect assets and minimize the risks associate with extreme climate/weather events (Farmer, 2012).

- **Inconclusive Planning, Competing Funding Priorities, and Implementation Costs**

Effective, adaptive planning requires the involvement of a wide range of stakeholders. In the Tidewater Area, silos among drinking water, wastewater, and stormwater management personnel and facilities can, at times, inhibit this. At times, smaller systems lack access to participate in planning activities with larger systems; this can limit or fracture response approaches when a big storm hits. The lack of a comprehensive approach, combined with forecasting uncertainty, means various utilities and military installations remain inconclusive in what to plan for. While services in the Tidewater Area demonstrate strong planning and short-term responses, many participants felt it is necessary to extend planning several years out. Knowing how many years out to plan, however, remains a challenge. Studies reviewed by water managers in the Tidewater Area project that planning infrastructure and adaptation for a 1.5-foot sea level rise in the next 20-40 years is a 'best-guess' in terms of reconciling climate uncertainty with cost-effective strategies (Bernas, 2012).

Planning for storm levels is one such area. Though both 2012 Nor'easters broke 100-year flood levels, planning infrastructure for the 100-year flood is extremely expensive (Bernas, 2012). In conjunction with the EPA, the HRSD is currently evaluating for 2, 5, and 10-year recurrence intervals. Bernas (2012) notes that the HRSD has not yet developed a plan for flows at greater intervals yet, as the cost analyses for these are "very preliminary because they are based on conceptual infrastructure. The cost increases are definitely not linear" (Bernas, 2012).

Farmer (2012) identifies four main adaptation strategies for military installations that demonstrate this cost dilemma: accommodation, retreat, elevation protection, and armor protection. Historically, the life span of a naval facility is at least 50 years. Facilities can slowly adapt to extreme events over time, by accommodate parts of a facilities as it becomes necessary. However, this strategy ignores the cumulative effects of sea level rise, potentially putting a facility at much higher risk as the eastern seaboard faces increasing storm surges (Farmer, 2012). Alternatively, abandoning bases and retreating facilities to higher ground provides a greater likelihood of building resiliency for sea level rise. Though this may provide greater reassurance in minimizing flood impacts, this costly strategy may result in functional and operation impacts, as well as a need to realign forces (Farmer, 2012).

Finally, two protection options exist. Elevation techniques involve raising buildings and land to avoid increasing tidewaters. Though a historically solid flood mitigation solution for naval facilities, it is important to consider the associated costs of supporting infrastructure (Farmer, 2012). In contrast, some facilities utilize an armor strategy, essentially protecting assets rather than moving assets. The hardening of shorelines, for example, creates protection floodwalls. Though supporting infrastructure costs may be less than elevating entire facilities, this strategy runs the risk of 'creating a bathtub effect' if tides surge up above the floodwalls (Farmer, 2012).

Home to some of the largest military bases in the U.S. decisions regarding water management and extreme event preparation and response in the Tidewater Area must account for the needs of these facilities. Yet, participants from these facilities stressed the need to balance protection with economic feasibility.

Given limited resources, economic factors drive adaptation decisions in multiple ways. The need to protect important economic centers and infrastructure influences decisions. The Tidewater Area is subject to several regulations, including (but not limited to) EPA's Consent Decree for SSO, compliance with the Chesapeake Bay's TMDL (total maximum daily load of pollutant discharges), and the Clean Air Act. Different water utilities have varying difficulty in meeting standards set by these regulations. Priorities to meet regulations can differ; not all utilities agree on funding allocation decisions. Gaps in information regarding various costs, as well as the risks associated with planning to various levels of adaptation further exacerbate this.

Political and Intergovernmental

On the political side, though the acceptance of rising sea levels is recent, in some cases, it is being written into policy (Hershner, 2013). Nevertheless, further information is needed to inform sound adaptation policy strategies. There is still much work to be done to bridge the political gaps in extreme climate/weather event responses (Hershner, 2013).

♦ **Dillon State Constraint**

Workshop participants expressed existing tension between the need for a regional solution and the need to meet localized needs. On the one hand, a greater understanding of storm surges, sea level rise, and extreme event impacts enables more collaborative solutions and eases financial constraints. Yet, many are uncomfortable with the idea of a statewide, 'one size fits all' mandate regarding adaptation action. Autonomy and attendant flexibility remains desirable, so that different issues may be adequately addressed in different areas. At the same time, however, a lack of granted authority in statewide efforts already constrains some localities in their ability to implement adaptive efforts in their jurisdictions.

This is in part due to the Dillon Rule,[10] which "narrowly defines the power of local governments. It also states that if there is any reasonable doubt whether a power has been conferred on a local government, then the power has NOT been conferred" (County of Fairfax, 2013). This can inhibit adaptive responses to sea level rise, such as changing tidal shore inundations. The Dillon Rule may pose a problem "at the regulatory end…as localities attempt to change development and redevelopment patterns through zoning and building codes, their actions may be subject to a constitutional challenge" (VIMS, 2013, p. 49). Though actions to ensure citizen health and welfare concerns are protected under general local authority, restricting private property development is not (VIMS, 2013).

The City of Norfolk works around this tension through local action coupled with an intergovernmental approach that seeks assistance and collaboration. Working with Congress and federal agencies, local governments and the General Assembly, State Agencies, institutions, and universities within the Commonwealth of Virginia, Norfolk can better drive flooding mitigation decisions that fit within a regional plan (Kelly, 2012). Specific initiatives include the following: seeking federal assistance through the USACE and Congressional Delegation, touring flood prone areas with federal representatives, holding community meetings with government representatives, and collaborating with the USACE to propose that $100,000 of Section 205 funding be re-programed for a Reconnaissance Study (Kelly, 2012). Future plans include seeking Congressional authorization and funding to complete the Reconnaissance study (FY13), conducting a feasibility study (FY14), issuing an environmental impact statement, and coordinating construction with the National Environmental Policy Act (NEPA) (Kelly, 2012). Working on local emergency response planning within state and federal initiatives helps Norfolk navigate local management through the constraint of the Dillon Rule.

[10] Many argue that the effect the Dillon Rule has on local authorities exists in various forms everywhere in the U.S. The specific legislation in Virginia merely formalizes the restrictions. What is evident, however, is that utilities respond to extreme climate/weather events as needed, in spite of what happens at the state level. It is also important to note that there have been cases in which municipalities do not want to take on costly endeavors and invoke the Dillon Rule to delay processes or development.

- **State and Federal Emergency Management Operations**

Tidewater's storm frequency amplifies the significant role Virginia state emergency departments play in preparation policies. The Virginia Department of Emergency Management engages in emergency-related operations that include aircraft incidents, daily operations logs, dam incidents, hazmat incidents, medevac mission dispatch, local situation reports, monthly warning test replies, SDO reports, siren polls, and establishing state shelters during emergencies (Slauter, 2012). Water utilities asserted during the workshop that collaborating with these departments is essential during extreme events, both in terms of response actions and funding adequate response efforts. The politics of responding to disasters in large part centers on funding availability and procedures.

> *"Local governments are faced with the realities of sea level rise and coastal storm impacts and they are in need of solutions and assistance to deal with these challenges."*
>
> *– Carl Hershner, Virginia Institute for Marine Science*

When local first responders exceed resources during an event, they can request additional aid and/or money for disaster response in a couple of ways: requesting help from city or county emergency managers or by requesting a presidential declaration of emergency. To receive city or county assistance, responders first submit a request to the Virginia Emergency Operations Center who works closely with the Department of Emergency Management to then delegate aid to local governments and the Virginia Emergency Response Team (VERT) to provide recovery assistance (Slauter, 2012). Alternatively, if the Department of Emergency Management declares a state of emergency, the Commonwealth can then request for a presidential declaration of emergency (Slauter, 2012). In this case, the requests go to the Secretary, following which FEMA and other federal agencies provide aid to local governments dealing with disaster impacts. In both cases, state and federal stipulations dictate where funding will go and what it may be used for, at times limiting local direction in recovery efforts.

- **Naval Facilities Engineering Command (NAVFAC)**

Military bases regard climate change and sea level rise as national security issues. Coupled with the budgetary impacts associated with infrastructure damage due to erosion and flooding, as well as operational impacts during fleet operations, rapid recovery and base access, military facilities are a driving force behind water and emergency management decisions in the Tidewater Area, both in terms of meeting facilities' adaptation and protection needs, as well as their capabilities to mitigate risks and respond to emergencies (Farmer, 2012).

The Department of Defense's 2010 Quadrennial Defense Review (QDR) acknowledges the link between climate change, energy security, and economic security, pressuring the institution to "foster efforts to assess, adapt to, and mitigate the impacts of climate change" (Farmer, 2012). Military bases are under Federal Executive Order 13514 to "reduce, monitor, track, and report GHG emissions" (Farmer, 2012). The Navy Maritime Strategy's thus called for the Task Force Climate Change, established by Chief of Naval Operations on May 15, 2009. The Navy orders this Task Force in the Tidewater Area to observe, predict, and adapt to sea level rise. The Task Force works with a core team from the Navy, NOAA, and the USGS for sea level rise impact modeling and water resource management, but also receives interagency and international support for adaptation efforts (Farmer, 2012).

Specific water management responsibilities for NAVAFAC include "all types of facilities and infrastructure (waterfront, airfield, admin, training, housing recreation, storage, utilities); facility lifecycle (planning, design, construction, sustainment, demolition); and the sustainability focus (strategic plan, reducing facility costs, lessening environmental impact and sea level rise concerns" (Farmer, 2012). However, because NAVFAC receives its water and wastewater services from municipal systems (as do the other military installations in the region), governing structures and collaboration between local, state, and federal levels have an impact on adaptation strategies and water management throughout the Tidewater Area.

♦ **Development Patterns Inconsistent with Extreme Event Resilience**

Reconciling land use patterns for development versus environmental protection remains a difficult challenge, and driving force behind extreme event response and planning for future climate uncertainty in the Tidewater Area. Many land use and development patterns remain inconsistent with extreme climate/weather event resilience. Local governments make all land use decisions, and development patterns continually grow in vulnerable areas. Expensive residences on Sandpoint in Virginia Beach, for example, are well-sought after, despite their inconsistency with efforts to build resiliency. Furthermore, there are several implications when zoning areas change. Workshop participants noted that depressed property values may constrain action. There is a lack of disclosure at the time of property transfers and the difficulty of buyers conducting due diligence in advance of a transaction. The resulting shoreline hardening places undue pressure on ecological adaptation.

The Virginia Coastal Zone Management (CZM) Program's[11] Climate Change Program works to combat this challenge and related adaptation issues. Preparation for sea level rise is one of the program's main focal efforts, addressed through three of Virginia's Planning District Commissions (PDC), including the HRPDC[12] (Virginia DEQ). Originally divided in 1968 according to interests in towns, cities, and counties; the Commonwealth is comprised of 21 such commissions (VAPDC). Local governments appoint citizens and officials to each PDC, and commissions work to bridge cooperation across local governments within the planning district as well as to the state (VAPDC). Thus, while land use decisions fall under local jurisdiction, PDCs help provide strategies for the entire district and coordinate efforts to reach regional goals.

Socioeconomic

A number of the challenges and gaps are related specifically to socioeconomic factors.

♦ **Communication**

"What we confront now is primarily a communications issue," Hershner (2013) remarks. Formal and informal communication is an underlying issue for many of the challenges faced by water utilities, as well as conflicting policies and adaptation responses. Communication issues occur on multiple levels. Many of the federal people planning adaptation strategies are not the same people that sit down to make, let alone implement, regulations in the Tidewater Area

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[11] Originally part of Virginia's Department of Environmental Quality (DEQ), the Virginia CZM Program now resides under the Department of Conservation and Recreation. Nevertheless, the program worked on climate change efforts in both locations (Virginia DEQ).

[12] The HRPDC includes the following counties: Gloucester, Isle of Wight, James City, Southampton, Surry and York, as well as the cities of Chesapeake, Franklin, Hampton, Newport News, Norfolk, Poquoson, Portsmouth, Suffolk, Virginia Beach and Williamsburg.

(Hershner, 2013). While the increasing regularity of extreme climate/weather events motivates people, a lack of communication about lasting impacts and improved information regarding future vulnerability further drives the gap between planning and implementation. Storms hit, yet when some time passes the region sees "a tail off in the motivation to do something" (Hershner, 2013). Even during events, communication gaps persist. Many facilities and customers depend on private enterprise infrastructure, particularly when it comes to primary communications devices, such as the phone and internet. Thus, the infrastructure challenges already faced by water utilities are further exacerbated by these same infrastructure challenges for power, energy and private enterprises that supply communication devices.

In fact, "building a consensus is a true challenge…this is the microcosm of our nation," that the diversity in the type or amount of impact leaves people conflicted on what to do (Hershner, 2013). Water managers and local leaders are working to address these levels of communication through pre and post event assessments, building action table strategies, and better disseminating plans and regulations to the public.

- **Education, Awareness, and Acceptance**

What citizens are aware of and how they understand events and actions to fit together can change the kinds of impacts a community experiences during an extreme climate/weather event. Part of the communication challenge, then, is public acceptance of extreme climate/weather events and support for response actions play a significant factor in the effectiveness of adaptation strategies (Hershner, 2013).

A study[13] at Old Dominion University revealed that 81.3% of local Norfolk respondents believe "increased flooding will have a strong negative impact on human health conditions" (Madhavan, 2012). Only 1.1% of respondents have flood insurance. Though many citizens have not yet experienced the health impacts of increasing storms, they are aware of the risks and have already experienced other impacts. Over a third of respondents in Storm Surge Zone 1 and almost a fourth of respondents in Storm Surge Zones 2-4 have suffered damage to parked vehicles, while many have been forced to move valuables to prevent flood damage during flood events (Figure H-7) (Madhavan, 2012). Acceptance of rising sea levels and storm surges, as well as the impacts of these events, is increasing in the Tidewater Area.

However, there is little awareness of current efforts that address these impacts, as well as how communities can contribute to them. Around 2/3 of survey respondents felt that the "local government should provide more public information on flooding issues" and 43.3% of respondents were willing to "get involved in local government planning and land use decisions" that could affect sea level rise and flood risk. (Madhavan, 2012).

A gap exists between what community members know and what the government is doing. The Old Dominion University study asserts the need for community intervention through a mix of education marketing techniques in order to combat some of the varying perceptions of risks regarding rising sea levels in the Tidewater Area (Madhavan, 2012). Suggested techniques include seminars, listening sessions, recreational education, and mock adaptation exercises tailored toward needs in specific storm surge zones and based on people's experiences and perceptions (Madhavan, 2012).

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[13] This internally funded study by Old Dominion University completed a 60-question telephone survey about perceptions of flooding and sea level rise. 614 people completed the survey and were a representative sample of Norfolk's population (Madhavan, 2012).

There is also a greater need to develop a more thorough understanding of sea level rise, impacts and adaptation techniques among citizens and organizations that can collaborate for a regional solution. These might include stakeholders from the Naval Facilities Engineering Service Center (NFESC), the Army Society of Civil Engineers (ASCE), the USACE, universities, municipalities, and private engineering firms among others (Farmer, 2012).

Despite challenges in education on rising sea levels, workshop participants noted that "even as it remains imperfect…[the] heightened awareness and acceptance" after each event sparks change. In many ways there is a local door-to-door street level awareness and "things are moving quickly" in regards to public acceptance of climatic shifts and adaptation needs (Hershner, 2013). Yet, some find that the real challenge is to get information into the hands of those making the decisions (Hershner, 2013).

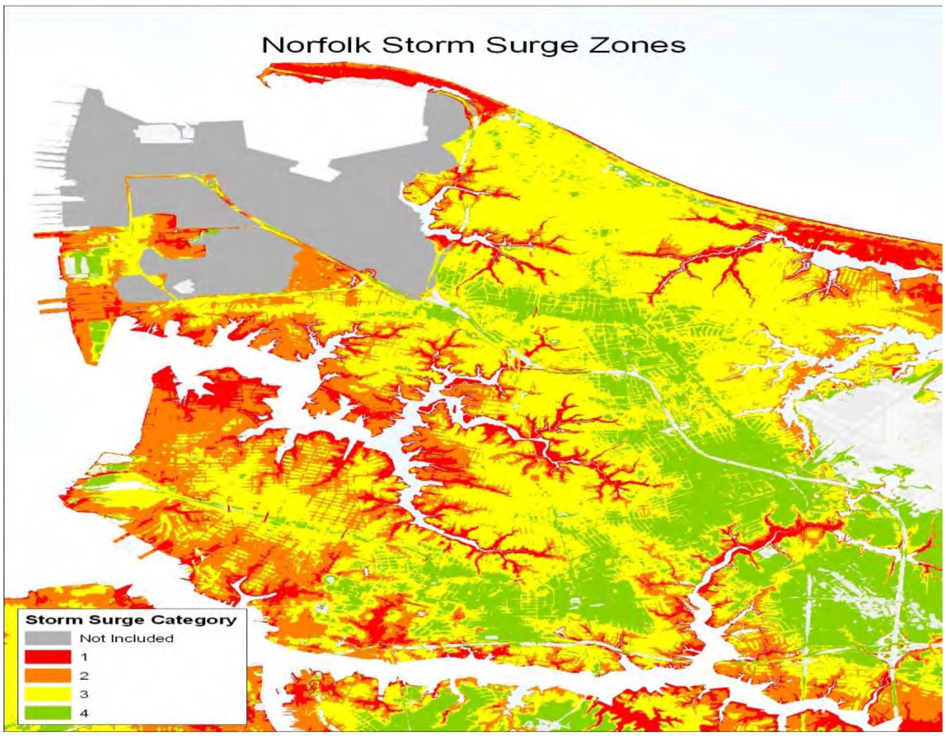

Figure H-7. Flood Zones in Norfolk, VA.
Zone 1 – risk of flooding from Category 1 storm as defined by the VA DEM
Source: Madhavan, 2012

- **Private Sector Involvement and Multi-Objective Strategies**

There is lack of information regarding private sector involvement in the economic sustainability of resources in the Tidewater Area. Gaps persist in understanding how businesses perceive risks imposed by sea level rise, the economic impacts of sea level rise, and coping and adaptation strategies (Madhavan, 2012). The private sector has a large impact on both resource use and economic stability in the region. Workshop participants noted that research in these areas will not only help inform the unfolding impacts of sea level rise, but foster collaboration in overcoming the economic barriers that limit sea level rise mitigation efforts (Madhavan, 2012).

Economic barriers also extend beyond the private sector. There are many critical investment priorities whose high costs pose a challenge to communities with a constrained capacity to pay for them. Multi-objective strategies for resource use and protection could result in greater collaboration in planning efforts among different utilities. Water utilities noted this as a key point of the workshop, as many of the adaptation investments necessary to adequately address rising sea levels and frequent storms in Tidewater Area magnify operating costs.

Information Needs

Participants in the Tidewater Area workshop identified several information needs to help address the challenges they face and some of the conflicting decision drivers of extreme event preparation and adaptation efforts. Some of the most important of these needs include:

- Improved forecasts for short-term and less-intense storms, especially at a local level.
- LIDAR maps of low tidal levels and sea level maps for Hampton Roads to improve predictive flood capabilities.[14]
- Socioeconomic impact studies.
- More sophisticated models that include different elevations and levels of inundation and that incorporate sea level rise, precipitation, bathymetry, storm surges, high tides, hurricanes, and nor'easters.
- Public education on risks and the differences between flooding and storm surges
- Information and incentives to help land- and home-buyers make educated decisions about their investments.
- Guidance to water and wastewater facilities on how to incorporate new information on sea level rise estimates in their planning approaches and on understanding what has happened versus what could happen
- Grants to help smaller communities.

Partnerships and Collaboration

Tidewater stakeholders include everyone from local community members up through those invested in national security measures. Tidewater's low-lying elevation and the area's unique importance regarding national safety and economy reveal both its vulnerability and assets (Figure F-9). Efforts to protect diverse interests center on flood mitigation and erosion control, demanding collaboration at individual, local, state, regional, and national levels.

Among the many collaborative efforts in communities and utilities throughout the Tidewater Area, workshop participants noted the commendable efforts of the HRPDC's partnership with the Virginia CZM's Climate Change Program. This partnership works to combat tensions between the need to provide ecological protection against sea level rise and the drive to develop expensive waterfront properties. Awarded grants in 2008, 2009, and 2010 to conduct studies on climate change adaptation and sustainable communities, the HRPDC issued several reports that continue to influence land use decisions on the local level and adaptation efforts at the state level (Virginia DEQ).

Furthermore, the Virginia CZM Program's *Living Shorelines* initiative offers as an alternative approach to shoreline protection in developed areas. Working closely with the Chesapeake Bay National Estuarine Research Reserve, this initiative promotes the development

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[14] HRSD currently invests over $100,000 for LIDAR aerial mapping of low tidal levels. While all municipalities already have GIS (Geographic Information Systems) programs, these layers will be helpful in sea level rise adaptation strategizing.

of natural protection barriers over traditional hardening techniques (Virginia CZM Program, 2012). The approach uses materials such as low profile sills, marsh plantings, shrubs and other organic materials to “recreate the natural functions of a shoreline ecosystem” and provide erosion and flood protection for homeowners while simultaneously offering wildlife habitat and water quality benefits (Virginia CZM Program, 2012). This can result in “less bank erosion and property loss, especially during storms,” while also saving erosion control construction costs (Virginia CZM Program, 2012).

Refer to Water Utility Profiles and Stakeholders charts at the end of this case study for further information about those represented at the workshop.

Lessons Learned

Lesson Learned: ***'What-if' and 'worst-case' scenario planning*** **prioritizes budgets and future response actions.**				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Pre-planning what-if scenarios is absolutely key to successful adaptation (Lentz and Tucker, 2012). • Too many unexpected events have occurred in the recent past not to plan for the unexpected now (Lentz and Tucker, 2012). • Tabletop exercises help consider asset and operational vulnerability. •	• Utility managers share information and seek common funding sources and methods. • Naval bases incorporate sea level rise into their Master Plans, Region Shore Infrastructure Plans (RSIP) and Global Shore Infrastructure Plans (GSIP) so that criteria and project scopes work as part of a regional solution (Farmer, 2012). • Reaching into the what-ifs that reside outside conventional analysis, typically based on relatively contemporary trend analysis.	• Weather-related information and climate modeling.	• Pre-plan what-ifs on a regional level, but also approach adaptation on a case-by-case basis to address local needs. • Expanding the scope and depth of infrastructure planning and alternatives analysis decision criteria in response to extreme events. • Structured, post event analysis sessions can inform future decision making.	• HRSD seeks to expand its Long Term Operating Strategy to include scenario planning methodologies to account for 50-year time periods (Bernas, 2012).

Lesson Learned: Successful solutions require a certain degree of *sensitivity for people's and institutions values and concerns.*				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Regional solutions to address sea level rise along the eastern seaboard are necessary, but must also incorporate individual needs and concerns (Farmer, 2012). • Local communities need flexibility to implement local solutions. For an organization's work to be relevant, it must be local (Hershner, 2013).	• Utilities working together to mitigate the impacts of flooding. • Designing engineering standards based on reasonable levels of expected services, sensitivity of facilities, criticality of assets and budgets.	• While tools are useful, there are too many sources and often local emergency relief information and operations are overlooked (Hershner, 2013).	• Multi-objective planning approaches address a mixture of priorities and constrained financial capacities. • Provide backup power for critical systems and communications. • Account for flooding risks and response conditions at varying levels; use tide gates, sand bag plans, flood walls, utility trench flooding and utility shutoff accordingly on a case-by-case basis (Farmer, 2012).	• Focus on safety first for employees during emergency response and back with a strong message that utilities are 'behind' their employees. • Incorporate LID into city planning to reduce stormwater runoff and mitigate flooding (Bernas, 2012).

Lesson Learned: *Account for sea level rise* in future design and maintenance practices.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• The continuous and significant impact of rising sea levels necessitates that planners and decision makers incorporate these factors into all water planning, infrastructure and adaptation practices.	• Moving site facilities out of areas that sea level rise could potentially impact (Farmer, 2012). • Evaluating facility elevations based on projected sea level rises and raise pier elevations accordingly (Farmer, 2012).	• Existing coastal habitat datasets need updating to refine predictions. • Ecosystem-based evaluation of ecological consequences of climate change (e.g. effects of tidal marsh loss on fish productivity) (Bilkovic et al., 2012).	• Target landscapes where shallow-water habitat complexes are most likely to be sustainable and protect these. • Use wave analyses for shoreline protection processes (Farmer, 2012). • Establish flood walls and dry docks around existing infrastructure (Farmer, 2012).	• Promote alternative approaches to erosion control and restrict riparian development to enhance ecosystem resilience. • Continue Southeast VA LIDAR mapping for sea level rise by flying around during low tide to map intertidal zones and work towards mapping with a higher vertical resolution (Bernas, 2012).

Lesson Learned: The development of an *overall flood strategy ensures acute event preparation and long-term resilience*.				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Long-term analysis and cross-department coordination improves preparation, mitigation actions and enhances a focus on communication during storms. • Move hard assets and operational 'brain centers' from at-risk locations.	• Improved response and evacuation planning and procedures, including gates on the I-64 entrance ramp and elevated parking garages. • Establishing the Emergency Operations Center (EOC) and Damage Assessment Teams (DATs) to assess high-risk areas and offer suggestions for adaptation measures (Farmer, 2012). • Norfolk's current plans to redesign its 60-year old drainage system, inserting manhole covers to reduce infiltration into sewer lines, monitoring water systems for saltwater intrusion, removing trees that can take down power lines.	• A more proactive implementation of arranging the safety and support of operations staff's families during floods.	• Draw out explicit, detailed storm plans that include specified actions for different levels of storm surges. • Adopt 'action tables' for each wastewater facility on how to respond based on various storm tide levels. • After-action reports help managers refine emergency operations, review water levels and flows and evaluate operational performance to improve flood strategies.	• Install watertight doors and hatches and move portable equipment to higher ground to prevent damage from repetitive flooding. • Improve overflow on dam structures to relieve pressure and instigate an active inspection program to prevent damage from trees and rodents.

Lesson Learned: ***Continual maintenance and testing of emergency equipment and procedures, coupled with increased education and awareness*** **is essential for timely response during extreme events.**				
Outcomes / Findings	**Successes**	**Weaknesses or Gaps**	**Water Utility Adaptation Strategies**	**Future Goals**
• Real-time data and alerts that can be shared among fusion centers and emergency operations centers must be accessible. • Tools for rapid communication are essential for controlling messages and ensuring quick and appropriate emergency responses.	• Water utilities 'borrowing' experience from other sectors and incorporating different methods into their own procedures (Hershner, 2013). • The "existence and use of multiple communications pathways [such as] cell phones, internet, twitter and conventional media" such as Norfolk's Flooding Website are useful mechanisms to disseminate information to the public. • Navy participation in workshops and discussions on the impact sea level rise has on infrastructure and unique requirements associated with this (Farmer, 2012).	• "Water utilities are, in a sense, enablers…[and] should become a voice of reason," they should be taken seriously regarding land use decisions and development that only causes harm (Hershner, 2013). • Greater communication of issues associated with sea level rise is needed for planners and designers at NAVFAC and CNRMA (Farmer, 2012).	• Consequence-based planning in which testing and procedures are employed to a standard high enough to account for life, health and safety risks (White, 2012). • Regularly test and utilize system backups for operations dependent on electricity, such as cell phones. Work to align plans with private sectors to ensure the reliability of different operation systems.	• Update FEMA maps and use them in planning strategy sessions.

Looking Forward

The Tidewater Area is privy to a rapidly changing climate that results in a heightened occurrence of smaller storms, as well as the severity of storms such as hurricanes and nor'easters. In the midst of this, water utilities grapple with environmental challenges, aging infrastructure, and a struggling economy that must continually adapt to more frequent and intense floods. Critical high-cost investment priorities cause utilities to reach limits set by EPA's Affordability Guidelines and stretch communities' ability to pay.

Nonetheless, there is a growing awareness of the need to manage risk and to take a proactive approach in protecting current assets and preserving ecosystem functions. Planners and water managers are deploying new and more sophisticated technologies. For example, the undertaking of a comprehensive LIDAR airborne laser mapping scheme combined with ground topography and elevation mapping will help citizens identify their risks and improve floodplain management.

Water managers at the workshop expressed a need to raise the public's understanding of the difference between hurricanes and nor'easters, as well as the resulting impacts of flooding versus storm surges to increase the effectiveness of public and private solutions. The public also needs access to accurate and timely information for decision making.

Localities in Virginia promote regional collaboration and intergovernmental relationships through active regional planning commissions and citizen boards, such as the Hampton Roads Sanitation Division and the Hampton Roads Planning District Commission. Engaging area utilities, including those in rural areas, has the potential to increase the effectiveness of a coordinated regional approach to building resilience. The Navy is also an important actor and its installations are an integral part of the regional planning process. VIMS and the Virginia Emergency Management Association are important partners in understanding and responding to risk from extreme climate/weather events. The work of VIMS and the Virginia Department of Environmental Quality in promoting living shorelines to control ecosystem erosion is another vital aspect of adaptive planning in the Tidewater Area.

The constant tension between increasingly common small storms ('non-extreme' events) and extreme hurricane and nor'easter events is unique in the tidewaters of Virginia. An equally unique balanced adaptation approach is necessary to handle the cumulative impact of small storms, while also responding effectively to large disasters.

Although limits exist on what individual water utilities can do given their resources, understanding, and authority, water utilities increasingly integrate their resources and strengthen their relationships with other water managers, private service providers, federal, and other agencies. This boosts resilience, increases capacity to effectively respond during crises, and minimizes future risks.

WATER UTILITY PROFILES: TIDEWATER AREA WORKSHOP PARTICIPANTS

City of Norfolk Department of Utilities	
Overview	The City of Norfolk Department of Utilities is the Commonwealth's largest waterworks system, serving customers in Norfolk, Virginia Beach, Chesapeake cities, and U.S. naval facilities. The City owns eight reservoirs, which primarily supply water to Norfolk residents. The Department of Utilities oversees the operation of two water treatment plants – Moores Bridge and 37th Street – as well as wastewater treatment plants.
Location	Headquarters: 400 Granby St. Norfolk, VA 23510 http://www.norfolk.gov/Index.aspx?NID=512
Operations conducted	Drinking water treatment and distribution Wastewater management
Size	• Service Area: 850,000 people in Norfolk, Virginia Beach, Chesapeake, and at US naval facilities or ~65,000 water service accounts, and serves 240,000 wastewater collection connections • Employees: ~397 • Pump Stations: 7 • Storage Tanks: 8 (4 ground, 2 elevated, 2 underground clear wells) • Pumped Water: ~67 MGD • Pipelines: 827 miles of distribution mains and 124 miles of raw water mains, ranging in diameter from 2-60 inches. • Sewer: 817 miles of gravity mains, 62 miles of force mains, 951 miles of water mains • Sewer Pump Stations: 129
Administrative structure	Eight divisions within the Department manage operations. Annual funds include: Water Fund of over $75 million, a Wastewater fund of $25 million, and a Capital Improvement Program of over $60 million.
City of Norfolk Public Works Department	
Overview	The Department of Public Works manages Norfolk's 60-year old conveyance sewer system, for wastewater and stormwater. Currently, the system is designed to a 2-year rainfall storm standard.
Location	810 Union Street, Suite 700, Norfolk, VA 23510 http://www.norfolk.gov/index.aspx?NID=190
Operations conducted	Stormwater management Waste management and recycling
Size	• Pipelines: 18 million linear feet • Stormwater Ponds: 13 • Ditches: 260,832 linear feet • Pumping Facilities: 9 • Downtown Floodwall/Floodgate: 1644 ft long
Administrative structure	Ten departments within the City of Norfolk Public Works coordinate to fulfill the institution's mission; these fall under the Director's authority and management.

City of Virginia Beach Department of Public Utilities	
Overview	The Department of Public Utilities manages water and sanitary sewer services for Virginia Beach. Water is primarily supplied through the Lake Gaston Water Supply Pipeline, which can transfer up to 60 MGD. Virginia Beach partners with Chesapeake on this supply project, transferring 10 MGD in return. Wastewater is collected via the sanitary sewer system through gravity mains, transferred to force mains, and sent to HRSD for treatment prior to discharge.
Location	2405 Courthouse Drive, Building 2, Virginia Beach, VA 23456 http://www.vbgov.com/government/departments/public-utilities/about-pu/Pages/default.aspx
Operations conducted	Drinking water treatment and distribution Wastewater collection
Size	• Service Area: Virginia Beach • Connections: 130,000+ • Water Delivered: 35 MGD • Pipelines: 1,500 miles of mains • Water Tanks: 12 • Pumping Stations: 8 • Wastewater Treated: 35 MGD • Wastewater Treatment Plants: 2, operated by HRSD • Sewer Pipelines: 1,500 miles of mains • Sewer Pumping Stations: 400+
Administrative structure	The Director's Office oversees the Business, Engineering, and Operations Divisions.
City of Virginia Beach Department of Public Works	
Overview	The Department of Public Works manages public infrastructure and services for Virginia Beach. The Department has a $150 million annual budget and nearly 900 employees. Stormwater management represents some of the largest operations within the Department. The Department also participates in FEMA's National Flood Insurance program to help residents obtain coverage.
Location	3024 Holland Rd. Virginia Beach, VA 23456 http://www.vbgov.com/government/departments/public-works/Pages/default.aspx
Operations conducted	Coastal development – navigable waterways and beaches Flood insurance Sandbridge restoration Stormwater Waste management, roads, energy management
Size	• Current Wastewater Projects: 35+ • Recently redesigned 61st Street Pump Station
Administrative structure	Water-related operations fall under 45 different projects with several years of committed funds.

Hampton Road Sanitation District (HRSD)	
Overview	Established in 1940 as the regional wastewater authority, HRSD is a political subdivision of the Commonwealth of Virginia. This quasi-state agency is governed by several Governor-appointed Commissioners. HRSD owns and operates all interceptors and treatment plants; localities own and operate the collection systems themselves.
Location	1434 Air Rail Avenue, Virginia Beach, VA 23455 http://www.hrsd.com/
Operations conducted	Wastewater treatment
Size	• Service Area: serves over 1.6 million people in 17 counties and cities (including Virginia Beach, Norfolk Chesapeake and Newport News). • Wastewater Treatment Plants: 13 (9 major, 4 smaller) • Sewer Pipelines: 500+ miles of mains (90% pressurized; 10% gravity-fed) • Pumping Stations: 111 • Treatment Capacity: 249 MGD
Administrative structure	HRSD established the Planning and Analysis Division within the institution more than 30 years ago. This division houses four sections crucial for responding to extreme events in the area: Hydraulics and Capacity, Data Analysis, GIS/Record Drawings, and Planning.
Newport News Waterworks	
Overview	Newport News Waterworks is a municipal-owned, regional water provider serving drinking water to three cities, two counties, and many military bases. With its mid-Atlantic location at the mouth of the Chesapeake Bay, the system rests at an average elevation of less than 10 meters along the coastal plain. Newport News Waterworks is a system of interconnected pumped storage reservoirs with one river intake: the Chickahominy River.
Location	700 Town Center Drive, Newport News, VA 23606 http://www.nngov.com/waterworks#portlet-navigation-tree
Operations conducted	Drinking water treatment Groundwater desalination
Size	• Service Area: serves over 400,000 people in Hampton, Newport News, Poquoson, and parts of York and James City Counties • Treatment Plants: 2 • Surface Water Availability: 57 MGD safe yield • Treatment Capacity: 50 MGD at Harwood's Mill and Lee Hall Treatment Plants • Remote Sites: 17 storage tanks and pumping stations • Pipeline: 1,700+ miles of mains
Administrative structure	The City of Newport News owns and operates the utility. An eight member City Council, three member team of Waterworks Management, and the City Manager oversee Newport News Waterworks.

STAKEHOLDERS: TIDEWATER AREA WORKSHOP PARTICIPANTS

Organization / Institution	Description	For More Information
Accomack-Northampton Planning District Commission	Works primarily to oversee projects that involve changes in groundwater and coastal areas. A 13-member panel of elected and non-elected officials govern these projects.	http://a-npdc.org/
Hampton Roads Planning District Commission	Focusing on water resource planning, several committees address drinking, wastewater, and stormwater projects throughout Hampton Roads.	http://www.hrpdcva.gov/departments/water-resources
James City Service Authority	Partners with Newport News to help provide municipal water and wastewater treatment services to 20,000 water customers.	http://www.jamescitycountyva.gov/jcsa/index.html
NAVFAC Mid-Atlantic	Though headquarters are in Norfolk, this institute influences naval operations all along the east coast. One area of focus in the Tidewater Area is working along environmental services on different issues facing the area.	https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_NAVFACMIDLANT_pp
NOAA	Works closely with several VA state agencies to support local fisheries. Part of the state/federal Chesapeake Bay Program.	http://www.legislative.noaa.gov/NIYS/
USACE, Norfolk District	Works on environmental and civil engineering projects in the Tidewater Area, networks with NACFAC, promotes river protection, and collaborates with other agencies to provide disaster response.	http://www.nao.usace.army.mil/Home.aspx
US EPA Mid-Atlantic, Office of Water	Serves six states, including Virginia, overseeing landscaping, TMDL, water quality, and other permits.	http://www2.epa.gov/aboutepa/epa-region-3-mid-atlantic
Virginia Association of Planning District Commissions (VAPDC)	Coordinates 21 different Planning Districts and Regional Councils in Virginia. Manages annual conferences and the annual summit of state agency heads.	http://www.vapdc.org/#
Virginia Coastal Zone Management Program	Located within the Virginia Department of Environmental Quality, created under the Coastal Zone Management Act and funded through NOAA, Virginia's CZMP represents a consensus effort on behalf of federal and state agencies to support coastal infrastructure. Eight Coastal Planning Districts implement the Coastal Policy Team's and DEQ's goals.	http://www.deq.state.va.us/Programs/CoastalZoneManagement.aspx

Virginia Department of Environmental Quality (VDEQ)	The Virginia Department of Environmental Quality regulates, permits, and enforces environmental laws while coordinating efforts between local, other state, and federal agencies. Its Tidewater Regional Office oversees this region.	http://www.deq.state.va.us/TheVirginiaDepartmentofEnvironmentalQuality.aspx
Virginia Emergency Management Association (VEMA)	For 50 years, through their seven regions using ten oversight boards, VEMA has coordinated a wide range of emergency response and oversight processes. In the tidewater region, flooding and hurricanes present the main challenge to public safety. VEMA's primary efforts include group recognition, providing a best practices forum, a yearly symposium, and personnel certification.	http://www.vemaweb.org/
Virginia Institute of Marine Science (VIMS)	Located within the College of William & Mary, the Institute conducts interdisciplinary research, citizenry education, and serves in a public policy advisory function. Working with funds split evenly between VA and other grant programs from NGO's and the Federal government, VIMS's 500 staff members provide a range of informational and practical guides, projects, and data for their scientific and policy partners.	http://www.vims.edu/
Wetlands Watch	Started in 1999 by a group of citizens of Norfolk concerned about water channel and resource management, this NGO has grown to be a statewide group that still operates on the grassroots level and focuses on wetland protection. Promotes the importance of wetlands at local, state, and federal governmental forums and to promote changes at all three levels to provide greater resources and awareness to their threatened sites.	http://www.wetlandswatch.org/

ATTENDEES: TIDEWATER AREA WORKSHOP PARTICIPANTS

Larry Atkinson	Old Dominion University
Donna Marie Bilkovic	Virginia Institute of Marine Science
Nancy Beller-Simms	NOAA
Erica Brown	Association for Metropolitan Water Agencies
Marcia Berman	Virginia Institute of Marine Science
Arthur Butt	Virginia Department of Environmental Quality
Jay Bernas	Hampton Roads Sanitation District
Emily Egginton	Virginia Institute of Marine Science
Anthony Farmer	NACFAC Mid-Atlantic
Larry Foster	James City Service Authority
Jennifer Faught	NOAA
Ravi George	WERF
Katherine Filippino	Old Dominion University
Michelle Hamor	USACE
Lauren Fillmore	WERF
Miriam Heller	MHITech Systems
Caroline Hemenway	Hemenway Inc.
Whitney Katchmark	Hampton Roads Planning District Commission
Carl Hershner	Virginia Institute for Marine Science
John Keifer	City of Norfolk, Public Works
Gayle Hicks	City of Hampton, VA
Alice Kelly	City of Norfolk, Public Works
Susan Julius	U.S. EPA
Ann Kosmal	U.S. General Services Administration
Lewie Lawrence	Middle Peninsula Planning District Commission
Poornima Madhavan	Old Dominion University
Thomas Leahy	Virginia Beach, Department of Public Utilities
Pam Mason	Virginia Institute of Marine Science
Kristen Lentz	City of Norfolk, Utilities
Benjamin McFarlane	Hampton Roads Planning District Commission
Lewis Linker	U.S. EPA/Chesapeake Bay Program Office

Kim Linton	WRF
Karen Metchis	U.S. EPA Office of Water
Molly Mitchell	Virginia Institute of Marine Science
Kenan Ozekin	WRF
Jamie Mitchell	Hampton Roads Sanitation District
Beth Polak	Virginia Coastal Zone Management Program
Shep Moon Coastal	Virginia Department of Environmental Quality
Elizabeth Powell	Concurrent Technologies Corporation
David O'Brien	NOAA Fisheries Service
Brian Ramaley	Newport News Waterworks
Ellen Roberts	City of Poquoson
William Sammler	National Weather Service
Elizabeth Smith	Old Dominion University
David Sample	Virginia Tech
William Stiles	Wetlands Watch
Mark Slauter	Virginia Department of Emergency Management
Curt Smith	Accomack-Northampton Planning District Commission
Claudio Ternieden	WEF
Lewis White	Parsons Brinckerhoff, Inc.
Ben Wright	Hazen and Sawyer

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