Understanding Needs for a Drought Early Warning System: Urban Water Systems in North Carolina

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Supported by

National Integrated Drought Information System

National Oceanic and Atmospheric Administration

Climate Program Office

Regional Integrated Sciences and Assessments Program

May 2011

Preferred citation:

Lackstrom, K., Dow, K., Ferguson, S., Kettle, N. 2011. Understanding Needs for a Drought Early Warning System: Urban Water Systems in North Carolina. Research Report: CISA-2011-01. Carolina Integrated Sciences and Assessments. Columbia, SC: University of South Carolina.

Executive Summary

CISA conducted an online survey and meeting with the North Carolina Urban Water Consortium, a member organization representing the state's 12 largest water systems. Research objectives included learning about their current use of drought data and information, exploring drought impacts and concerns of urban water systems, and identifying needs and preferences for new drought-related tools and information. This is among the first-steps to support National Integrated Drought Information System (NIDIS) efforts to develop an early warning system in the Southeast. Such a system will include monitoring and forecasting tools as well as decision support for water managers and other affected sectors, education and outreach, and networks that facilitate sharing and communicating information among different groups. Key findings from this research include:

Use of Data and Information. Because of the local-scale variability of drought severity, water systems primarily rely on localized or system-specific data and information to plan for and manage drought events. Managers use historical water supply-demand and hydrological data and supply models to guide planning. Each system has its own "drought of record" which it uses as a benchmark. Managers reported that they only considered using seasonal forecasts in a qualitative way when water supply deviates from "normal" expectations or patterns.

Impacts on Water Systems. Water system managers reported a diversity of impacts and concerns during the 2007-2008 drought. Impacts to water supply were related to limited access, uncertainty about drought duration, and additional treatment costs incurred. On the demand-side, drought contributed to increased water usage for some systems. For other systems, water use restrictions contributed to revenue losses by reducing both short- and long-term water demand patterns. The actual implementation of drought response plans (e.g. monitoring, administration, enforcement) also created concerns for water managers.

Needs and Preferences for New Tools and Information. Managers reported that they would benefit from data, information, and tools that help them understand when a system moves out of drought and improve their understanding of the processes that affect local water supply availability. Priorities included more monitoring gages, probabilities related to weather and inflows, historical comparisons or analogs to help identify early signals, models that produce a range of expected water supply scenarios, and better understanding of the influence of changing land use on local and regional hydrological processes. Managers also reported that more education and outreach was needed to improve the publics' and decision-makers' understanding of the linkages between drought conditions and risks and local water supply conditions. For example, although overall statewide drought conditions may be classified as "severe", factors such as water supply infrastructure or the amount of capacity relative to demand, may mitigate or exacerbate local water shortages. The existence of fragmented water management jurisdictions, sometimes existing adjacent to each other but having different response plans, also contributes to confusing and difficult public communications.

This document presents details about the various activities conducted as part of this research project and a synthesis of the workshop results. Taken together, these efforts will contribute towards a greater understanding of drought preparedness needs. For more information about this research, please contact cisa@sc.edu.

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Introduction

Drought in the Carolinas

Although the Carolinas normally receive ample annual precipitation, the region is not immune to drought risks. Significant periods of statewide drought occurred in 1925-29, 1930-35, 1950-57, 1965-1971, 1980-82, and 1985-88 (USGS 2002, Weaver 2005). Beginning in 1998, several years of below-normal precipitation contributed to critically low river and reservoir levels in summer 2002. This drought severely impacted water systems and numerous water users across the Carolinas. Many areas experienced record lows for stream flows, ground water levels, and reservoir storage, and at least 60 community water systems were vulnerable to running out of water had the drought continued (NCDENR 2004, Weaver 2005, SCDNR 2003). Many sectors experienced substantial economic losses including agriculture ($357,410,000), forestry ($1,311,533,243), and hydropower generation ($38,000,000) (SCDNR 2003). On the Yadkin-Pee Dee River, rapidly declining water supplies necessitated emergency meetings among dam operators, North Carolina and South Carolina state agencies, and water users to manage the limited water resources throughout the duration of the drought.

In 2007-2008 the Carolinas experienced another “drought of record.” This drought’s rapid and intense onset in summer 2007 was exacerbated by above-average temperatures. North Carolina experienced the driest year on record and a record number of days above 90˚F, and South Carolina experienced its 5th driest year on record in 2007 (NC DMAC 2008). Below-average rainfall persisted throughout 2008, and streamflow, reservoir, and groundwater levels failed to recover as they normally would through the winter and spring months.

These recent droughts have raised awareness of the need to improve planning for such events and understanding impacts. While drought impacts on agriculture and water supplies are relatively well-studied, less is known about how local communities can build capacity to more effectively prepare for, cope with, and manage drought events. Water systems are expected to support local economic development (e.g. industrial, commercial, and residential growth). Historically, North Carolina’s abundant annual rainfall has facilitated development and growth. However, water systems in the state’s urban areas are now facing an increasing variety of stresses, which may exacerbate the vulnerability of communities to drought events. Such stresses include rapid population growth, increasing water use in urban and suburban areas (Vickers 2007), limited opportunities to develop new supplies, and more stringent regulations regarding water quality and allocation (Whisnant et al. 2009). For example, the population of North Carolina increased 18.5% between 2000 and 2010. Regionally, Mecklenburg (Charlotte), Wake (Raleigh, Cary), Pitt (Greenville), and Brunswick (Wilmington) counties recorded population growth rates above 25 percent (U.S. Census 2010).

Research Objectives

In collaboration with the National Integrated Drought Information System (NIDIS), the Carolinas Integrated Sciences and Assessments (CISA) team conducted a research project to improve understanding of the needs for a drought early warning system in North Carolina urban areas. The primary objectives of this research were to:

- Identify and explore drought impacts, concerns, and vulnerabilities of urban areas,
- Learn about needs and preferences for a drought early warning system, and
- Identify potential building blocks for the design of a drought early warning and information system.

To this end, CISA conducted an online survey and focus group discussion with members of the North Carolina Urban Water Consortium. An additional component of this project entailed examining water systems' current drought management practices and use of drought-related data and information. This document reports on insights resulting from the various research activities. Appendices A – D provide additional information on the water systems, survey design and responses, and discussion outline.

The National Integrated Drought Information System (NIDIS)

NIDIS is an interagency program that works to improve drought planning and preparedness on the national level. A major goal of NIDIS is to create a "drought early warning system," a comprehensive approach to drought planning and management that provides accurate information and tools to monitor and forecast drought conditions (NIDIS 2010). The NIDIS drought portal (www.drought.gov) provides further details. The early warning system supports communication networks, stakeholder partnerships, and education and outreach programs to enable information-sharing among different groups. NIDIS also includes interdisciplinary research to understand how to make scientific data useable and accessible to decision-makers and how to incorporate drought information into drought response planning effectively.

NIDIS is currently developing and implementing drought early warning system pilot projects in the Southeast. This report represents one part of CISA efforts to support NIDIS. The broader research includes engagement with a range of decision makers to determine their decision-support needs and possible opportunities and regional activities through which NIDIS can support those needs. CISA works with NIDIS and decision makers to prioritize, develop, and initiate projects to be included in an early warning system pilot and help to develop ways to transfer tools and information to other regions.

North Carolina Urban Water Consortium

The North Carolina Urban Water Consortium (UWC) is a partnership between the North Carolina Water Resources Research Institute (WRRI) and urban water systems. Located at North Carolina State University, the North Carolina WRRI is a unit of The University of North Carolina System. It was established in 1964 to provide water resources research and information transfer in partnership with state and local entities. In 1985 WRRI established the UWC. Through funding from state and local sources, the UWC supports independent scientific research and provides a venue for members to share information about water and wastewater issues of particular concern to large urban systems and their customers. Topics of interest include the management of supply and distribution systems, water quality and treatment processes, project financing, and rate setting (Howells 1989). The group meets quarterly, rotating the meeting location among the member organizations. Table 1 lists the 12 water system members of the North Carolina UWC, the populations served by each system, and their water supply source(s). Together, the North Carolina UWC member systems serve a population of over 2.76 million, or approximately 29% of the state's total population. Figure 1 illustrates their distribution across the state.

Table 1. North Carolina Urban Water Consortium

Member Water Systems	**Population Served**[1]	**Primary supply**[2]
Cape Fear Public Utilities Authority (Wilmington)	132,936	Cape Fear River
Charlotte-Mecklenburg Utilities	774,331	Mountain Island Lake (Duke Energy reservoir)
City of Burlington Water Resources Department	52,034	Stoney Creek Reservoir, Lake Cammack, Lake MacKintosh
City of Durham Department of Water Management	232,226	Lake Michie, Little River Lake
City of Greensboro Water Resources Department	250,000	Lake Brandt, Lake Higgins, Lake Townsend
City of High Point Public Services Department	96,867	Oak Hollow Lake, City Lake
City of Raleigh Public Utilities Department	453,384	Falls Lake (U.S. Army Corps of Engineers reservoir)
City of Winston-Salem City/County Utilities Division	286,028	Yadkin River (water supply agreement with U.S. Army Corps of Engineers), Salem Lake
Fayetteville Public Works Commission	179,000	Cape Fear River
Greenville Utilities Commission	85,189	Tar River
Orange County Water and Sewer Authority (Chapel Hill-Carrboro)	75,000	Cane Creek Reservoir, University Lake, Quarry Reservoir
Town of Cary Department of Public Works and Utilities	149,000	Jordan Lake (U.S. Army Corps of Engineers reservoir)

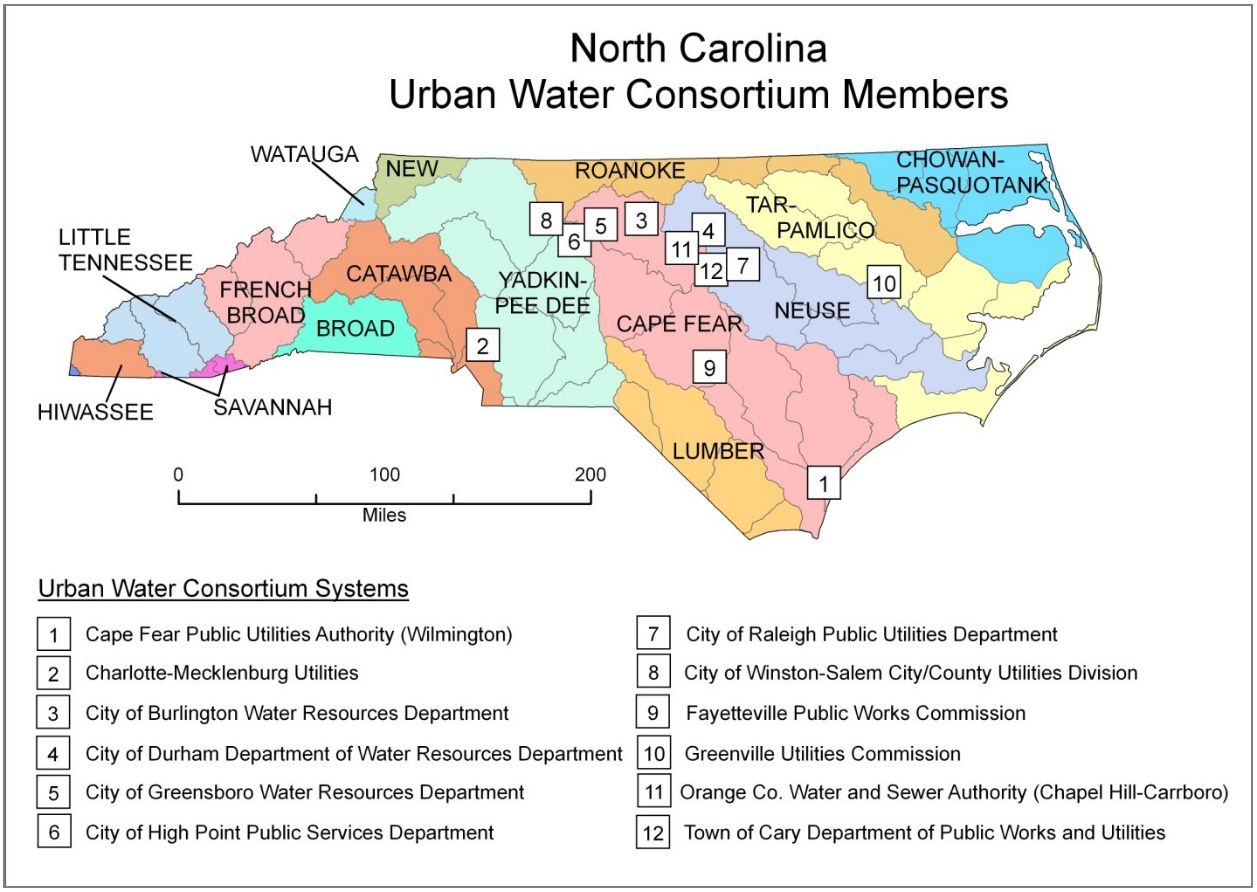
[1] U.S. Environmental Protection Agency 2010

[2] Water supply reservoirs are managed by water systems unless otherwise noted

Project Design

We used a variety of information sources to meet the objectives of this project. Early in this process we worked with staff of the North Carolina WRRI to schedule time with the UWC at one of their quarterly meetings. We expected this opportunity would allow us to use a "focus group" approach as a means to obtain information from the member water systems about their experiences with drought and perspectives on planning issues. In order to prepare for this meeting, we conducted a review of relevant documents and an online survey. Pre-meeting and meeting activities are described below.

Figure 1. North Carolina Urban Water Consortium Members



Pre-Meeting Activities

We conducted several interrelated activities prior to our meeting with the North Carolina UWC. First, we examined the drought management context by investigating the state role in drought planning activities and the drought management practices of the UWC water systems. This background information was obtained through a review of relevant literature, a study of the Water Shortage Response Plans (WSRP) of the North Carolina UWC members, and an online survey. Appendix A discusses the evolution of the state role in drought response and planning. Appendix B provides additional information about the WSRP review process. The intent of the WSRP review was to identify and compare the drought triggers, stages, and information used by the various systems to manage during drought or water shortage conditions. We used the results – and subsequent questions that emerged – from this review to guide the development of online survey questions. The review indicated that most plans use water system-specific triggers and information. We were interested in obtaining more information about how water managers use climate- or drought-specific data and whether WSRP triggers measured drought-induced water shortages effectively.

An online survey was conducted in February 2010 through Survey Monkey to obtain background information from the North Carolina UWC members regarding their water systems, drought experiences, impacts and concerns, drought management process, and data use and needs. Questions required several types of responses, ranging from open-ended to selecting answers from a set list. We received responses from 10 of the 12 UWC members. Survey responses were used to develop follow-up questions and discussion topics for the group meeting with the UWC members. Appendix C presents the survey questions and responses.

Meeting with the North Carolina UWC

CISA met with North Carolina UWC members on March 18, 2010, at the Charlotte-Mecklenburg Utilities Lee S. Dukes Water Treatment Plant in Huntersville, North Carolina. The meeting agenda is provided in Appendix D. Two staff members of the North Carolina WRRI attended the meeting. The CISA team included researchers from the University of South Carolina, the Southeast Regional Climate Center (based at The University of North Carolina-Chapel Hill), and the North Carolina State Climate Office.

To start the meeting, CISA provided a brief introduction to NIDIS and national efforts to support drought planning and response. We discussed the role of the Southeast Regional Climate Center, the North Carolina State Climate Office, and CISA in providing climate services to the region and the expected contributions of this research project to NIDIS.

The primary goal of the meeting was to follow-up with the UWC members about their survey responses and to obtain more in-depth information about the top priorities for a "drought early warning system." Discussion questions focused on the following topics:

- Impacts and stresses of greatest concern for urban water systems during the 2007-2008 drought,
- Key concerns related to drought preparedness and decision-making processes, including any gaps or shortcomings in the drought-related data and information used by water systems,
- Preferences and priorities for new resources, research, data, information, tools, or techniques to address drought planning, management, and monitoring needs, and
- Existing activities or partners that would serve as a useful foundation for the development of drought early warning system.

Project Results

Drought Decision-Making

The North Carolina Context

Drought planning in North Carolina traditionally occurs at the local level, by individual water systems and the various entities involved in water provision (e.g., municipalities, county governments, local government partnerships, special purpose water and sewer districts, private water companies). Drought events are generally considered a short-term risk, a temporary supply-demand imbalance. As such, the principal approach to reduce drought risks has been to secure supply through infrastructure projects. Storage and distribution systems, as well as treatment and pumping capacity, have been constructed to ensure that operations can accommodate periods of peak demand and unrestricted water use, even during drought periods. In our meeting with the UWC, managers indicated that they refer to specific historical drought periods as benchmarks for future supply-demand planning. In this case, each individual system has a benchmark drought that is unique to the system in terms of spatial scale, local hydrology, and impacts on water supply. Drought planning is thus embedded within water supply planning and may be shaped by a range of interacting and system-specific factors that affect water supply conditions and system operations. Such factors include: water source (reservoir or river), topography and size of the service area, system location (upstream or downstream), types of customers (residential or industrial), local water use patterns, and water quality requirements.

Until recently, the State has had a minimal role in drought planning and response. Experiences with the 1998-2002 and 2007-2008 droughts demonstrated the limitations of local- and state capacity to cope with and manage extreme events. State-level organizations and agencies have gradually increased their engagement with drought management through efforts to improve preparedness, monitoring, and communications. Changes include the formalization of drought response through legislation and requirements for local WSRPs, authorization of the North Carolina Drought Management Advisory Council (NC DMAC), and expanding role of state agencies (particularly the Division of Water Resources) in providing technical and planning assistance to water systems. See Appendix A for a summary of the significant steps in this process.

Practices of the UWC Members: Data and Information Use

Themes related to data and information use center on the type and level of information used by water system managers and the timing and nature of that use.

Because of the local-scale variability of drought severity, water systems primarily rely on localized or system-specific data and information to plan for and manage drought events. Managers use historical water supply-demand and hydrological data (stream flows, levels), as well as water system reservoir and supply models, to guide planning. Each system has its own "drought of record" which it uses as a benchmark. One manager noted that the most recent drought events (1998-2002, 2007-2008) provided useful benchmarks for future water supply and drought planning.

The system-specific nature of drought planning (and response) is demonstrated in the review of WSRPs. The plans exhibit commonalities in terms of how they monitor water supply conditions (most systems use water supply indicators from lake levels, daily stream flows, demand indicators that trigger water shortage stages, or both. On the other hand, systems vary in terms of number of stages and the specific criteria used to determine those stages. This diversity makes it difficult to compare not only the response plans, but also drought severity and duration across communities. In addition, some WSRPs indicate that climate- and drought-related information is used when assessing water shortage conditions, but not necessarily in declaring water shortage stages. This information includes weather conditions, drought forecasts, and North Carolina DMAC declarations. (See Appendix B for more information about WSRPs.) Systems that draw from or depend on large reservoir systems, such as those from U.S. Army Corps of Engineers projects, report using regional- and basin-level information. The Charlotte-Mecklenburg Utilities Department is a member of the Catawba-Wateree Management Group, a status which requires that their water shortage response plan follow a common, basin wide set of drought triggers, stages, and actions.

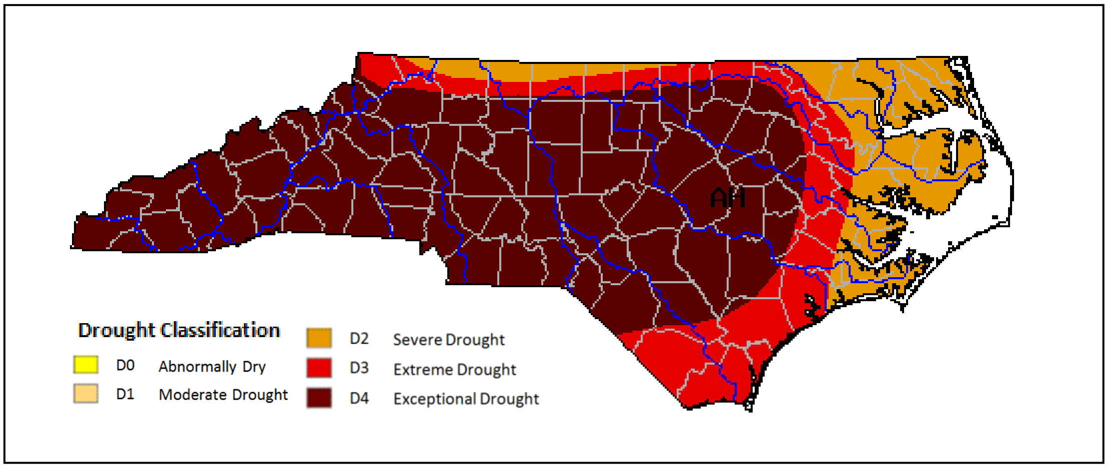
Participants report that they primarily rely on daily to shorter-term (<6 months) data for day to day management operations. Participants consider seasonal forecasts in a qualitative way when water supply deviates from "normal" expectations or patterns. While North Carolina receives abundant annual rainfall (45 inches/year), precipitation and evaporation rates experience notable seasonal and interannual variability (Moreau 2006). Surface water resources typically decline in the summer and fall and depend on rain and groundwater to sustain flows. Winter and spring rainfall is critical to the recharge of reservoirs and ground water systems. The decision to consult seasonal forecasts depends upon water levels in local water system sources in the spring. If reservoirs are full in the spring, then managers will not look at seasonal forecasts. If reservoirs are not full, or if minimal rain has fallen within a 6-month period, then seasonal forecasts will be used to examine expected precipitation and demand conditions through the summer months and the potential for winter recharge. While seasonal forecasts are often used monitor conditions and information, they are not used to trigger specific management or operational decisions.

Urban Water Systems and Drought: Impacts, Concerns, and Vulnerabilities

From the state perspective, the 2007-2008 drought was the worst experienced in North Carolina history. From August 2007 to February 2008, the entire state was under some level of drought designation. Figure 2 shows the NC drought map for December 25, 2007, when 78 of North Carolina's 100 counties were classified at the D4 ("exceptional drought") level. Although conditions generally began to improve during spring 2008, in some areas drought conditions lingered and reoccurred throughout 2008-2009. It was not until December 20, 2009 that the North Carolina drought monitor indicated that no county was experiencing drought or abnormally dry conditions, the first time since January 30, 2007 (NC DMAC 2009).

One objective of the online survey was to obtain information from the UWC members about how drought affected their water systems and their key concerns associated with the 2007-2008 drought. Survey responses demonstrated a diverse set of experiences and impacts (see Appendix C). For example, the most severe drought stage, and length of time in that stage, varied from system to system. Likewise, the drought affected individual water system supplies differently. Available supply at the most extreme point of the drought ranged from 10 to 87% of water systems' full pool capacity or water supply allocation. Supply-related concerns were related to the maintenance of storage and access to supplies, uncertainty about drought duration, and water quality changes (e.g., deteriorated or poor source water quality, increased flushing and treatment costs).

Figure 2. Drought Conditions in North Carolina. December 25, 2007[1].



[1] North Carolina Drought Management Advisory Council 2011.

Managers reported a variety of demand-related impacts. Drought contributed to increased demand for some systems. Other systems reported that, although water use restrictions helped to reduce demand (and hence, conserve supplies), less water use adversely affected water system revenues and impacted "targeted" uses and businesses related to lawn care, pools, and car washing. Some managers also noted that they experienced more media coverage and increased public awareness about drought and improving water efficiency.

One way UWC members responded to drought was by implementing measures to conserve water supply and reduce demand. Survey responses indicated that methods such as public education, requests for voluntary or mandatory restrictions, and leak detection and repair resulted in "some" to "significant" savings. A few of the respondents also used tools such as rate increases, excess use fees or penalties, and programs to promote water saving technologies. Survey responses indicated that implementing the logistics of drought response plans – monitoring, administration, and enforcement – created challenges for water managers. Other concerns pertained to the lack of coordination and inconsistent messaging and communications that occurs across agencies, communities, and the media. The severity of drought conditions does not affect water systems equally because due to differences in design, demand, and source, but those differences in sensitivity and associated actions are difficult to convey, particularly where the systems serve adjacent communities.

The face-to-face meeting with the UWC members provided an opportunity to learn in more detail, and from the water systems' perspective, about the factors that either facilitated or challenged the drought response and management process. They discussed two factors that constrain local-level drought decision-making. First, managers noted the lack of understanding about drought risks and water system operations by the public and elected officials. For example, local water supply conditions may be more or less severe than overall state conditions. Managers expressed frustration that the media portrayed *all* water system conditions as *severe* based on the overall state conditions, rather than acknowledging local differences. Similarly, local- and state officials often recommended or required mitigation actions that were not clearly feasible or implementable due to a systems' technical design (e.g., 50% water use reductions, interconnections across neighboring water systems). A second key concern involved the existence of fragmented water management jurisdictions and the lack of a structured communication network across those jurisdictions. Because each community has a different water supply situation, their WSRPs frequently contain different drought triggers, stages, and response actions. Public communications were confusing and difficult particularly in situations where one media market encompassed several different water systems which did not have consistent plans, triggers, recommended actions, or messages.

Needs and Preferences for a Drought Early Warning System

Water system managers discussed several tools and techniques that would help them address their drought-related concerns and improve their capacity to prepare for and respond to future droughts.

- **Improved information about the processes that affect local water supply availability**. During this most recent drought, UWC members experienced uncertainty concerning the appropriate timing and combinations of triggers, especially with regards to groundwater. Priorities include more monitoring gages (surface- and groundwater), better understanding of the indicators which show when a system is moving out of drought, and probabilities related to future weather and water supply conditions.
- **Historical comparisons or analogs**. Members expressed a need for historical comparisons or analogs to help identify early signals of drought. Such information may also help managers to assess water system performance and future management scenarios.
- **Models to understand risks and vulnerability**. While water system managers typically have and use historical records, they expressed interest in using climate- and hydrological models to improve understanding the likelihoods of future inflows and scenarios. Topics of interest pertain to models that produce a range of expected water supply scenarios (e.g., demonstrate future variability of reservoir capacity as well as demand), improve understanding of the influence of changing land uses on hydrology and processes which contribute to local spatial variability, and improve understanding of how and why "droughts of record" vary across and within natural and social systems.
- **Spatial scales of drought**. With system interconnections recommended as a tool to reduce vulnerability to future droughts, managers indicated a need to examine how local precipitation and water supply variability may influence the effectiveness of interconnect strategies. Water sources and the systems they serve may experience different levels of stress due to distances between them.
- **Education and communication**. Managers also reported that more education and outreach was needed to improve the public's and decision-makers' understanding of the linkages between drought conditions, risks and local water supply conditions. As noted above, although state or regional conditions may be severe, due to technical design characteristics of localized water supply

capacities and specifics of local demand may be capable of managing the stress without undertaking drought response actions. Measures to facilitate improved coordination and public communications among neighboring water systems may help reduce public confusion about differences between drought designations and a water system's capacity to meet demand.

Potential building blocks for the design of a drought early warning and information system

UWC members identified several existing activities that may serve as starting points or examples for a drought early warning system.

- Local water systems have developed and implemented projects that may be applicable to other systems across the state. For example, after 2008, utilities in the Triangle region developed consistent conservation practices and frameworks for their WSRPs. Although plans retained separate trigger points and responses are implemented independently, consistency in announcements of required actions (no car washing, alternate day watering or no watering) simplified the message and reduced confusion in public and media communications. Another system offered precipitation and longer-term climate data to monitor water supply conditions.
- Many state and federal agencies are currently engaged in activities related to drought preparedness and management. For example, the Division of Water Resources and Army Corps of Engineers are creating an inflow dataset for the Cape Fear basin hydrologic model. This dataset will incorporate local inflows as well as regional climate conditions. The Army Corps of Engineers conducts weekly calls to discuss water and drought management with basin stakeholders. The Catawba-Wateree Water Management and Drought Management Advisory Groups are additional examples of basin-level organizational structures that may provide lessons about ways to facilitate communications across diverse water management organizations.
- Organizations, such as university departments and water utility associations, have programs and individuals already conducting research related to the needs and issues identified by the UWC members. For example, faculty members in the Department of Geography, University of North Carolina-Chapel Hill, have ongoing research related to land use and hydrology.

Summary

This project has identified several areas of concern for the managers of urban water systems and potential building blocks and priorities for the design of a drought management support system in the Carolinas. While large water utilities are actively pursuing improvements in drought preparedness and response at an individual level, managers' reflections on recent drought response activities offered additional insights relevant to the design of a drought early warning system. First, they recommend research to improve understanding of the many different processes that affect local water supply availability. Second, they identify a need for new tools and processes to improve drought communications and the public's understanding of drought risks. The development of a Southeast early warning system requires a regional approach to understanding drought monitoring and impact assessment needs, gaps in scientific understanding of drought processes, and development of communication strategies useful to a variety of groups involved in drought preparedness and response. Managers cited several existing activities that are contributing to new drought monitoring and response networks. Emerging, cooperative and collective efforts among water utilities may provide invaluable opportunities and forums to expand regional drought preparedness efforts.

About CISA

Carolinas Integrated Sciences and Assessments (CISA) integrates climate science into decision-making by developing information, tools, and processes to support water and coastal management and planning processes. CISA is one of 11 Regional Integrated Sciences and Assessments (RISA), a NOAA-sponsored program that seeks to advance scientific understanding of climate variability and change and improve society's ability to respond to climatic events and stresses. A hallmark of the RISA program is the focus on partnerships between scientists and decision-makers to produce usable, useful, and accessible climate information. CISA engages with water and coastal stakeholders to ensure that our activities continually address management and decision-making needs. Current CISA projects encompass drought monitoring and assessment, watershed modeling, and working with communities to identify coastal climate vulnerabilities and adaptation options.

Acknowledgements

The authors thank the members of the North Carolina Urban Water Consortium for their participation in this project. The authors also acknowledge the following individuals for their assistance:

- Ryan Boyles, State Climatologist, North Carolina State Climate Office
- David Genereaux, Associate Director for Research, Water Resources Research Institute of The University of North Carolina
- Chip Konrad, Director, Southeast Regional Climate Center
- Kelly Porter, Environmental Education & Communications Coordinator, Water Resources Research Institute of The University of North Carolina

This research was supported by the National Integrated Drought information System (NIDIS) and the NOAA Climate Program Office.

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Appendix A: The State Role in Drought Planning

State-level involvement in water supply management in the southeastern United States has been typified by a “traditional hands-off approach to water allocation” and is based upon a riparian water rights system (Moreau and Hatch 2008, p. 2). Historically, there have been few statutes, rules, or regulations to govern water supply, allocation, and efficient use in North Carolina. State oversight of water systems has focused on operational and water quality parameters, not necessarily the amount of water they withdraw or use. Two limited exceptions are programs that regulate interbasin transfers and capacity use in coastal aquifers. Similarly, the state has had limited involvement in drought planning and response activities. This brief summary, and accompanying table (Table 2), describe how state involvement in drought planning and response has gradually evolved since the late 1980s.

The State began to engage with drought and drought-related issues after 1985-1988. Legislation established the North Carolina Drought Management Council and the Local Water Supply Planning (LWSP) program. The 1998-2002 drought, however, exposed the limitations of the drought management strategies in place at the time. The changes made after 1988 provided only a skeletal structure for state-level response and included no incentives or requirements for local drought response plans. There was limited authority and no precedents to guide the monitoring and communication of water supply conditions and impacts. Consequently, state-level response to the 1998-2002 event was reactive as water supplies reached critically low levels and water shortage crises required emergency actions. Such crises necessitated state involvement in planning and improved coordination among the various realms of water management. In order to bolster state and local capacity, House Bill 1215 (North Carolina General Assembly 2002) was subsequently passed. This legislation required that water systems develop WSRPs, although administrative rules for developing these plans were not approved and issued until 2007 (NC DENR 2007), and the Division of Water Resources (DWR) lacked authority to enforce the adoption and implementation of WSRPs. The legislation also gave the Drought Management Advisory Council (DMAC) a more formal role in overseeing drought monitoring response. The Technical Drought Advisory Team, a sub-group of the DMAC, meets weekly to discuss local drought conditions and update the North Carolina drought map. This group is responsible for submitting information and providing guidance about North Carolina conditions to the U.S. Drought Monitor.

During the 2007-2008 drought, state-level response was more structured as the changes made since 2002 were implemented. The state agencies with responsibility for drought response (namely the DWR) engaged with other state- and local entities to monitor drought conditions and communicate that information to the public. Despite improvements to state-level response, many individual water systems were affected by the extreme conditions. Up to 30 North Carolina communities were designated at Tier 1 during the drought, meaning their water systems were within 100 days of running out of water. In October 2007, the DMAC (2007) reported that of 236 water systems had implemented some level of water restrictions (1 emergency, 110 mandatory, 125 voluntary). In October 2008, 350 of 656 reporting systems indicated that they had water restrictions in place (0 emergency, 149 mandatory, 201 voluntary, 306 no restrictions) (NC DMAC 2008). Ultimately, the 2007-2008 drought triggered additional efforts at the state level to encourage a more proactive approach to drought planning, including the passage of the 2008 “drought bill” (General Assembly of North Carolina 2008), establishing more stringent requirements for local response. . The drought of 2007-2008 also focused attention on the need for the State to take a more active role in water quantity and allocation issues. To that end, the General Assembly commissioned a Water Allocation Study (Whisnant et al. 2009) to examine measures to secure water supplies and reduce the risks of future water shortages.

Table 2: Drought Planning in North Carolina

Drought Years	State-level Actions Related to Drought Planning and Response
1985-1988	1989: Local Water Supply Planning (LWSP) program authorized • requires water supply systems submit plans to the Division of Water Resources, update plans every five years • program intended to be an education experience for the water systems, an opportunity to review and anticipate long- and short-term supply needs
	1992: Drought Management Council (DMC) established • purpose is to facilitate interagency cooperation and information-sharing during drought events
	1994: State drought response plan finalized, incorporated into the State Emergency Operations Plan
1998-2002	2002: House Bill 1215 (Session Law 2002-167) • requires all water systems to develop a Water Shortage Response Plan (WSRP) as part of their LWSP • renames DMC, new Drought Management Advisory Council (DMAC) provided with statutory authority to make drought declarations • establishes a more formalized process for the DMAC to monitor and communicate drought conditions
	2003: DWR develops a WSRP Handbook to aid water systems as they develop response plans
	2007: “Drought Rules” approved • administrative rules set official guidelines and minimum standards for response plans, water conservation, and other activities to be implemented during drought and water supply emergencies
2007-2008	2008: “2008 Drought Bill” (Session Law 2008-143, House Bill 2499) • gives state agencies more authority to oversee drought response • further strengthens WSRP requirements; water systems must submit plans to DWR for approval, otherwise they must follow default triggers and responses or face monetary fines • requires that local systems report weekly water use if their county is designated as Extreme (D3) or (D4)
	2008: Water Allocation Study • Recommends measures to reduce the risk of future water shortages: a state water withdrawal permitting and allocation system; improved understanding of water supply and use by integrating data collection, adoption of river basin modeling and planning processes across the state; investigation of ways to improve water supplies (e.g. create more storage, support water efficiency and the development of reuse systems)

Appendix A: References

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Whisnant, R, B Holman, et al. 2009. 2008 Report of the Water Allocation Study of the NC Environmental Review Commission. 64 pages. Accessed 16 December 2010. http://www.ncleg.net/gascripts/DocumentSites/browseDocSite.asp?nID=12&sFolderName=%5CWater%20Allocation%20Study%5CReports

Appendix B: Review of the Water Shortage Response Plans of the NC Urban Water Consortium

Water Shortage Response Plans (WSRPs) plans are designed to guide response to water shortage, regardless of the cause of the water shortage (drought or other natural disasters, infrastructure or pressure problems, water quality problems, upstream or downstream conditions). A water shortage is generally defined as any event or condition that affects a system's ability to supply, treat and/or distribute water. This appendix provides a summary of the North Carolina UWC members' WSRPs.[1]

For each WSRP, we recorded the water system's primary water supply source, the factors used to evaluate and monitor drought (or water shortage) conditions, the number of drought stages and triggers specified in the plan, and if hydro-climatic information is referenced (Table 3). We then examined the information within Table 3 in order to obtain insights about drought decision-making. As drought is considered a water supply-demand imbalance, the specific triggers to move in and out of water shortage stages generally reflect water supply conditions and/or demand trends rather than hydrologic and/or climatological factors. Only 3 systems specify drought data as a trigger (Cape Fear, CMUD, Winston-Salem). Supply-related triggers include reservoir levels, remaining water supply storage (in terms of days, to accommodate a particular amount of water use), and treatment capacity. Supply triggers are linked to the primary water supply source (e.g., reservoir or river). Demand-related triggers include demand relationship to supply/treatment capacity, daily usage, current and/or projected consumption, and the effectiveness of conservation measures in reducing demand.

As Table 3 demonstrates, plans vary in terms of the number of stages and the specific criteria used to indicate a system's water shortage stages. Upon further examination of the WSRPs text, it was noted that some plans also identify additional factors that, while not listed as specific triggers, are considered when water supply and shortage conditions are assessed. According to the WSRPs, these factors include weather conditions, drought forecasts, hydrological conditions (reservoir levels, stream levels) compared to seasonal norms, North Carolina DMAC or governor declarations, conservation actions of neighboring water systems or communities, reservoir management protocols and actions (if the water system draws from or relies on a reservoir operated by the Army Corps of Engineers or a FERC-licensed operator), and the availability of supplies from other systems (if interconnected).

One shortcoming of this evaluation is that it is not easily discernible from the formal plans how water managers use the various types of information (including hydro-climatological data) indicated in the WSRP, how that use influences water management- and drought decisions, and whether the specified triggers were an accurate measure of drought-induced water shortage. Based on the WSRP review and overarching objectives of the research project, additional questions for urban water system managers emerged: What are the key gaps in information? What are your climate and water resource data, information, and forecast needs? What are the priorities? These questions guided the development of online survey questions and meeting discussion topics.

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[1] WSRPs were downloaded from the North Carolina Division of Water Resources (DWR) website on October 26, 2009. (http://www.ncwater.org/Water_Supply_Planning/Water_Shortage_Response_Plans/plan).

Table 3. Summary Information from NC Urban Water Consortium Water Shortage Response Plans

Water System • **Primary Supply**	**Factors Considered**	**Stages and Specified Triggers**				
Cape Fear • Cape Fear River	demand, drought declaration	1	"…if water use under the normal conditions and voluntary water conservation best management practices have not resulted in sufficient reduction of the average day customer water demand from the water distribution systems…" or D1			
		2	3 consecutive days where demand >80% of capacity or D2			
		3	2 consecutive days when water demand >90% of capacity or D3			
		4	1 day when demand exceeds 100% of capacity or D4			
Charlotte-Mecklenburg Utilities • Mountain Island Lake (Duke Energy)	multiple • Storage Index/Target Storage Index (SI/TSI) • U. S. Drought Monitor, 3-month average • USGS streamflow gages (6-month average v. historical 6-month average)	1	SI/TSI <90% and USDM 0 or USGS 85% of average			
		2	SI/TSI 75%<90% and USDM 1 or USGS 78% of average			
		3	SI/TSI 57%<75% and USDM 2 or USGS 65% of average			
		4	SI/TSI 42%<57% and USDM 3 or USGS 55% of average			
		5	SI = 42% TSI and USDM 4 or USGS 40% of average			
City of Burlington • System reservoirs	multiple	1	75% reservoir capacity remaining			
		2	60% reservoir capacity remaining			
		3	45% reservoir capacity remaining			
		4	30% reservoir capacity remaining			
		5	15% reservoir capacity remaining			
City of Durham • System reservoirs	multiple, depends on season, whether additional sources are available/not available	Triggers are based on the percent of lake storage available				
			May - October		November - April	
			Additional sources available	No additional sources available	Additional sources available	No additional sources available
		1	75%	80%	40%	45%
		2	55%	60%	35%	40%
		3	40%	45%	30%	35%
		4	30%	35%	20%	25%
City of Greensboro • System reservoirs	multiple	1	below seasonal norms, daily water demand approaches 95% of system capacity			
		2	<150 days water supply available			
		3	<125 days water supply available			
		4	<100 days water supply available			
		5	<75 days water supply available			
		6	<50 days water supply available			
City of High Point • System reservoirs	reservoir level, demand, remaining reservoir capacity	1	<80% reservoir full capacity			
		2	<60% reservoir full capacity			
		3	<50% reservoir full capacity			
		4	<40% reservoir full capacity			

City of Raleigh • Falls Lake (Army Corps of Engineers)	reservoir level, demand	1	<70% available water supply capacity
		2	<50% available water supply capacity
City of Winston-Salem • Yadkin River (releases from Army Corps of Engineers), system reservoir	multiple	1	demand exceeds 85% of capacity for 3 consecutive days, USDM severe, reservoir level <1027, river flow <554 cfs
		2	demand exceeds 90% of available capacity, USDM extreme, reservoir level <1023 feet, river flow <200 cfs for more than 5 consecutive days
		3	demand exceeds 90% of capacity for 3 consecutive days, USDM extreme, reservoir level <1019 feet, river flow <175 for more than 3 consecutive days
		4	Demand exceeds 95% available capacity, USDM extreme, reservoir level <1015 feet, river flow < 125 for more than 2 consecutive days
Fayetteville Public Works Commission • Cape Fear River	multiple (streamflow, levels at 3 different wells, demand)	1	streamflow below seasonal norms, 3 consecutive days of demand exceeding 85% of capacity
		2	<250 cfs, 3 consecutive days of demand exceeding 90% of available capacity
		3	daily demand exceeds 50% of available flow, 5 consecutive days of demand exceeding 90% of capacity
		4	daily demand exceeds 75% of available flow, 1 day of demand exceeding 100% of capacity
Greenville Utilities Commission • Tar River	demand, river level, saltwater interface	1	3 consecutive days when demand is 80% of capacity, river levels <-1.0 feet mean sea level, saltwater interface is <10 miles from raw water pump station
		2	2 consecutive days when demand exceeds 90% of capacity, river level <-1.5 feet mean sea level, location of salt water interface is 7 miles from raw water pump station
		3	1 day when demand exceeds 100% of capacity, river level is <-2.0 feet mean sea level, location of saltwater interface is <4 miles from the raw water pump station
Orange County Water and Sewer Authority • System reservoirs	multiple	4	Specific triggers are not designated. Water shortage declarations are "…guided primarily by the risk that OWASA's water supplies will decline to 20 percent or less of total storage capacity within the next 12-month period. . A Stage One Water Shortage declaration will generally correspond to a two percent (or greater) risk that reservoir levels will decline to 20 percent or less of total storage capacity within the next 12 months…."
Town of Cary • Jordan Lake (Army Corps of Engineers)	multiple	1	<120 days of supply remaining
		2	<90 days of supply remaining
		3	<60 days of supply remaining
		4	<30 days of supply remaining

Appendix C: Online Survey Summary

(n= 10/12 Urban Water Consortium members)

SECTION 1: DROUGHT EXPERIENCES, IMPACTS, AND CONCERNS

Question 1: Based on your water shortage response plan, what was the most severe drought stage your system reached in the 2007-2009 drought? Please indicate the dates when your system was in this stage.

Stage 4 [of 6], mandatory restrictions	12/3/07-4/1/08
Phase 1, Water Shortage Alert	
Voluntary Conservation	7/29/08-3/12/10 (ongoing conservation due to WTP renovations)
Stage 2B, Level II, Mandatory Restrictions	10/9/07-3/11/08
Stage 2, elimination of all outdoor use, including irrigation	2/15/08-4/6/08
Stage 2, Water Shortage Warning	10/07-3/08
Stage 3 restrictions	3/1/08-4/11/08
Stage 2	10/18/07-4/5/08
No water shortage, banned irrigation due to governor's request	11/1/07-4/1/08
Stage 2, moderate mandatory conservation	7/07-10/07

Question 2: Please check the description that best matches your utility's experience with drought at its most severe stage:

No impacts, no changes in utility operation required to prevent service disruption	3
Moderate impacts, voluntary use restrictions required to prevent service disruption	3
Severe impacts, mandatory use restrictions required to prevent service disruption	4
Extreme impacts, service disruption	0

Question 3: During the recent drought event, please compare water supply conditions at the most extreme point of the drought with what you would expect during normal conditions.

We had 10.8% available of our easily accessible water storage volume on 12/24/07
We had 30 percent reduction in our available water supply compared to normal
87% of the conservation pool capacity
We had a 47% reduction in water supply for 2007 as compared to normal year averages.
Water supply pool was reduced by 74% compared to full pool; I would estimate that the 2007-2008 drought represented approximately a 50% reduction compared to "normal" summer/fall seasons [due to tremendous variability in lake levels from year to year].
We are a run of river intake, At the height of the drought the water quality pool at XX Lake was 40% depleted. So I guess you could interpret that to say the lowest our water supply got was 60% of normal.
Water supply reservoirs were 39% full (1.38 BG)
Basically stable through flow releases from XX Lake
Water supply allocation was 78% full
The city had an estimated 152 days of storage remaining

Question 4: Please indicate how water demand was affected by the recent drought event.

With Stage 3 restrictions, demand decreased between 15% & 20%. With Stage 4 restrictions which were imposed during winter months, there was a 12 - 15% reduction as compared to the same months in previous year.
Demand increased by about 50% and after the Phase 1 we saw a slight reduction by about 15%
Due to the drought daily demand for the 2008 calendar year increased approximately 3%. It should be noted that this increased, although seemingly small occurred the same year our system lost a significant industrial consumer which alone accounted for approximately 4% of our daily average consumption. In the month following our declaration of Voluntary Conservation measures we actually saw an increase in consumption. The month after this our area started getting significant rain so the true extent of the Voluntary Conservation measure couldn't be truly measured.
5% - 9% reduction in demand depending on level of mandatory restrictions implemented. XX has 5 levels of mandatory.
Difficult question to answer. Daily demand was not unusual for an extremely hot and dry summer, but it was certainly high. The City did not formally notify the public that drought restrictions may be implemented, but it was covered in the media ad nauseum. After implementation of drought restrictions (i.e. one day per week irrigation), we saw approximately a 19% reduction in demand compared to the months prior to Stage 1. After full elimination of irrigation, the reduction was 25% compared to the months prior to drought restrictions. Elimination of minor water uses such as pool filling and power washing did not any meaningful further reductions.
This is difficult to quantify. We are unable to accurately state how much affect the drought had on water use prior to and after implementation of restrictions.
Demand decreased ~5% before mandatory restrictions. Additional reduction of ~10%-15% with Stage 3 restrictions in place.
Daily demand increased by approximately 50% and was reduced by 4-5% once restrictions were implemented.
Average annual demand was about 5% higher than normally expected due to hot, dry weather. We did not ban irrigation until Nov 1 and irrigation demand had already decreased due to lower temps and media attention on drought.
During the drought of 2009, the demand for water increased as XX provided an additional 3 MGD to the neighboring City of ZZ in an effort to prolong their water supply. This began in July of 2009 and lasted until November 2009 - after ZZ's reservoirs returned to stable levels.

Question 5: What are some specific examples of drought impacts your system experienced?

Examples	# of Responses
Water line breaks	1
Developed temporary supply source	1
Increased public awareness, increased reporting of breaks and illegal usage, interest in household efficiency	2
High/increased demand	2
Reduced demand, reduced revenue, higher rate increases than expected	3
Heavy media coverage	1
Deteriorated/poor source water quality, increased flushing and treatment costs; high water age within some parts of the system	2
Impacts of restrictions on "targeted" users (lawn care, pools, car washes, pressure washing)	2
Uncertainty about when will drought end	1

Question 6: Did the 2007-2009 drought affect the budget of the water system?

Yes	3
No, but we did reallocate some funds	3
No	4

Question 7: If yes to Question 6, please specify the level of cost and whether additional funds were necessary.

	Level of cost			Additional funds required	
	minor	moderate	significant	yes	no
Administrative (e.g. additional personnel)	4	1	0	0	5
Monitoring	1	3	0	0	4
Maintenance and repair	2	2	0	2	2
Supply augmentation	2	1	1	1	3
Treatment (related to water quality)	3	1	0	0	4
Revenue loss because of water conservation measures	2	2	1	3	2
Public education awareness and outreach	1	3	1	3	2
Other	0	0	0	0	0
Additional Comment:	No additional budget funds were needed, reallocated from contingency.				

SECTION 2: DROUGHT MANAGEMENT PROCESS

Question 8: WSRPs list many different indicators to assess drought conditions. Which factors, conditions, or indicators were most important for your system in determining the stages of drought?

Time of year	1
Climate, drought info; weather patterns	2
Availability from alternative sources, including reclaimed water	1
Operational changes	1
Reservoir levels, supply indicators, including safe-yield analyses	9
Daily usage	2
River flows, source conditions	4

Question 9: Did your WSRP triggers accurately depict the drought-induced water supply/demand conditions in 2007-2009?

Yes	7
No	3
If no, please explain:	4
WRSP on file at the time didn't actually list specific triggers. Computer model used did accurately indicate when to enact specific stages of the existing ordinance.	

This question really does not make sense. However, we do feel that the trigger activation guidelines were set too high (i.e. they would initiate drought restrictions too early if implemented as "hard triggers"). But, after the addition of another water supply source, these trigger guidelines now appear to be relatively appropriate (according to recent OASIS modeling).
The WSRP would never have been triggered.
We implemented water restrictions in 2007 based on pressure from the state to implement conservation measures - not based on a concern over our water supply. While our lake levels were as low as they had been in recent history, we believed that our remaining capacity combined with our demand did not warrant implementing water restrictions at the time. Our reservoir analysis, completed in 2008, confirmed our belief.

Question 10: Did your system take measures to reduce water use?

Yes	10
No	0

Question 11: If yes to Question #10, what measures did you use to reduce water use and how effective were they?

	Not worth the trouble	Some savings	Significant savings	Not applicable
Public notices and education	0	6	3	0
Request for voluntary restrictions	2	8	0	0
Request for mandatory restrictions	0	4	4	1
Leak detection and repair	3	5	0	2
Water rate increase	0	2	2	5
Excess use fees or penalties	0	1	2	6
Rebates or incentive programs for water saving technologies	2	0	0	7
Other	0	0	0	3
Additional comments or explanation:				
Rebate program was initiated as we came out of the drought. Tiered rates were implemented on the tail end of the drought (7/1/08) but were discussed publicly and supported by council at the height of the drought.				
Plant Operational changes were made which realized additional savings that could be categorized as "Some Savings".				
Went to Increasing Block Rates in 2002 Water Rate increases were not for the purpose of conservation but to cover operating expenses. However, rate increases and block rates appear to cause people to reduce consumption.				
Our drought response plan includes water rate surcharges during declared "water supply shortage" conditions; i.e., when mandatory use restrictions are imposed.				
I interpret question to mean "during the drought". We have an ongoing leak detection and repair program. We started some new incentive programs in 2008 that will be ongoing as long as they appear cost-effective as a way to meet long-term water demands and avoid water supply expansion and/or water treatment plant expansion.				

Question 12: What are your system's top 3 concerns about drought management?

	Concern #1	Concern #2	Concern #3	Total
Inconsistent messaging, communication, media	2	1	2	5
Reservoir management, maintaining storage, intake	2	1	0	3
State constraints on local decision-making, what is appropriate level	2	0	1	3
Equity of impacts among users	1	0	0	1
Local logistics, enforcement, organizational adherence to plan, monitoring	1	2	3	6
Understanding drought risks, prediction	2	0	0	2
Revenue, from short-term water restrictions and longer-term demand changes due to drought	0	3	2	5
Economic impacts	0	1	0	1
Coordination: working with regulatory agencies on emergency projects, neighboring utilities	0	1	1	2
Purpose of reclaimed water, reuse or consumption	0	1	0	1
Loss of confidence in local water supplier to provide daily needs	0	0	1	1

Question 13: What resources, tools, or techniques are necessary to address your top concern?

	High Importance	Medium Importance	Low Importance	Not Important
More data or basic research about drought, hydrology, climatology, or impacts	3	4	3	0
Monitoring tools	2	5	3	0
Science-based models, e.g. hydrology, risk vulnerability, supply-demand projections, social-environmental carrying capacity	4	4	1	1
Decision-support and/or online tools to improve access to information	1	6	3	0
Coordination or partnerships with other agencies, organizations	4	4	1	1
Technical training	1	4	2	3
Public education and outreach	4	2	1	2
Financial resources	4	3	2	1
Other	1	0	0	1
Please specify: We do many of these things locally at own expense. High Importance on purchase water interconnects. Methods to measure effectiveness of drought restrictions				

SECTION 3: DATA USE AND NEEDS

Question 14: Please list the data you monitor on a regular basis to track variations in water supply and demand. Does your system archive this data?

Daily demand, raw water withdrawals, distribution of treated water	4
Daily lake levels	9
Daily stream flows, inflows	7
Rainfall, weather patterns, temperature [daily, weekly, monthly, annually]	6
Usage compared to previous years	1
Billed consumption by customer class [monthly]	2
Flood control releases, lake releases	3
Lake management data	1

Question 15: Please list the data you monitor on a regular basis to track variations in raw water quality. Does your system archive this data?

TOC collected and analyzed weekly on raw water. Temperature recorded daily
Water temp(2 hrs) turbidity(2 hrs), ph (2 hrs), Alkalinity (every 6 hrs) data archived
We monitor several parameters for raw water quality which include the following: 1. Temperature 2. Turbidity 3. Nutrient Levels: Phosphorus, nitrate, nitrite, ammonia 4. Dissolved oxygen 5. Microscopy for algae 6. Sechii disk measurements These parameters are monitored at our intakes on the Yadkin River twice per week and are archived for future use/trending.
All WQPs required of a full scale SWTP. Greensboro also maintains a lake water quality monitoring program for pH, DO, Algae, TOC, DOC, SOC, VOC, Crytosporidum, Humic and Fulvic Acids.
pH, Chl a, TOC, turbidity, temp, DO.
Turbidity, pH, alkalinity, specific conductance, color, total coliform, and temperature.
DAILY: Turbidity, Tot Coliform, e Coli, Tot Color, pH, alkalinity, hardness, Fe, Mn TOC (2x/wk) Tot P (1x/wk) O-P (2-3x/wk) ALL DATA ARCHIVED
Daily flows, raw water pH, temp, turbidity, color, alkalinity, TOC, and archived
WTP monitors iron, manganese during low reservoir periods. I'm not familiar with other data.
Too numerous to list, but we conduct extensive raw water quality testing

Question 16: In reference to questions 14 and 15 above, how does your organization use the monitored and archived data for decision-making? (Select all that apply)

To compare present conditions with past conditions	10
To trigger staged response measures, such as water conservation	10
To plan responses to future droughts	7
To review the success of water conservation or drought mitigation measures	8
Other	0
Please explain:	3
For water quality, we create a WQ Index for Treatment plant operations. Also for algae control strategies.	
Data is used to adjust treatment at plant and to assist with expected treatment needs	
Our water conservation program is long-term, designed to reduce normal water consumption patterns. Our water shortage response plan requires specific water use reduction measures - over and above the year-round water conservation program - based on triggers (days in water supply).	

Question 17: What drought-related information do you use?

	I am very familiar with this and use it regularly.	I am familiar with this and have used it.	I am aware of this but have not used it.	I am not aware of this.	I would like to learn more about this.
USGS NC Water Science Center (streamflow, groundwater, water quality data)	7	3	0	0	0
U.S. Drought Portal (drought.gov)	5	2	0	3	0
NC DMAC	5	2	1	2	0
NC State Climate Office	3	5	1	1	0
U.S. Drought Monitor	8	2	0	0	0
Army Corps of Engineers	6	1	1	2	0
National Weather Service	6	2	2	0	0
SE River Forecast Center	0	3	2	5	0
U.S. Seasonal Drought Outlook (NOAA Climate Prediction Center [CPC])	2	5	3	0	0
ENSO forecasts (aka, NOAA CPC Long-lead forecasts)	0	5	1	4	0
Drought Indices	5	1	1	3	1
If you use a drought index (above), please specify which index: Hydrologic index NC Drought Monitor Palmer Drought Index					

Question 18: Is the current set of drought-related data and information sufficient for your needs?

Yes	8
Not entirely	2
If not entirely, what drought-related data and information is most needed?	3
Unfortunately, as demonstrated in 2007, unusual weather patterns can really impact rain events. July and August of 07 were extended dry periods with 95 + degrees. The extent of this pattern, with tropical storms and hurricanes all around (flooding elsewhere) could not be predicted accurately.	
We are probably at the limit of climatological forecasting for long range accuracy.	
risk of drought or low streamflow for specific period in the future, on a site-specific basis.	

Question 19: Are you interested in learning about other drought indicators or blends of drought indicators?

Yes	9
No	1

Appendix D: Meeting Agenda

Meeting with the NC Urban Water Consortium
1:00 – 2:30 p.m., 18 March 2010, Huntersville, NC
Drought Early Warning Discussion Topics

1:00 Meeting Overview and Objectives

- Identify and explore drought impacts, concerns, and vulnerabilities of urban areas
- Learn about needs and preferences for a drought early warning system
- Identify potential building blocks for the design of a drought early warning and information system

1:15 Introductions

- Round the room introductions
- Brief introduction to US National Integrated Drought Information System (NIDIS), what is meant by a "drought early warning system"
- Brief introductions to the Southeast Regional Climate Center, the NC State Climate Office, and the Carolinas Regional Integrated Sciences and Assessments groups – our roles in providing climate services to the region and our relationship with NIDIS

1:30 Discussion

Drought preparedness issues and areas for improvement

- **Data and Models**: Which aspect worked best during the last drought - monitoring, modeling impacts, established triggers?
  - Which needed the most improvement? What were the gaps and shortcomings – how could you have managed better?
  - Do you feel that the monitoring thresholds are well understood and well defined in plans? Or, what types of research and information could improve these? To what extent did water quality considerations influence decision making?
  - Do you use models to anticipate supply and demand? Do you use models to consider future flow and demand conditions? Which models? How far into the future?
  - What types of input data could you use to reduce uncertainty in decision making? At what timescales? Are there specific needs related to anticipating demand?
  - How should drought triggers balance regional and local drought conditions?

- **Management**: Which aspect worked best during the last drought - mitigating impacts, implementing management plans, or planning and preparedness?
  - Which needed the most improvement? What were the gaps and shortcomings – how could you have managed better?
  - To what extent is drought response integrated/coordinated with the actions of other stakeholders and decision makers (e.g. agencies or other systems)? Where does this work best and what are the challenges?
  - How do drought managers engage with the media?

Preferences and Priorities

- Are there specific elements of an “early warning system” which would help address drought planning and management needs?
- Identify top priorities if possible: which additional research, resources, tools or techniques are necessary to address drought management and/or monitoring concerns?
- Which elements would you most like to see improved?

Directions

- What current activities (e.g. climate, hydrology, impacts data; management triggers, drought response plans and practices) would serve as a useful foundation for future efforts in drought early warning and management support?
- Are there other partners or networks who should be involved in designing an early warning system?