Oklahoma Comprehensive Water Plan
Supplemental Report

Climate
Issues & Recommendations

December 2010

This study was funded through an agreement with the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, the state's long-range water planning strategy. Results from this and other studies have been incorporated where appropriate in the OCWP's technical and policy considerations. The general goal of the 2012 OCWP Update is to ensure reliable water supplies for all Oklahomans through integrated and coordinated water resources planning and to provide information so that water providers, policy-makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

Climate Issues and Recommendations

The following report was developed for the 2012 Update of the Oklahoma Comprehensive Water Plan to address Oklahoma climate issues as they relate to water management. This analysis, conducted by the Oklahoma Climatological Survey, details the anticipated climate-related water management challenges facing the state and offers recommendations for future related research and development.

Oklahoma Climatological Survey

The Oklahoma Climatological Survey (OCS; http://climate.ok.gov) was established by the State Legislature in 1980 to provide climatological services to the people of Oklahoma. The Survey maintains an extensive array of climatological information, operates the Oklahoma Mesonet, and hosts a wide variety of educational outreach and scientific research projects.

Section 1, Chapter 63, O.S.L. 1982 (74 O.S. 2006, Section 245) outlines the powers and duties of the Oklahoma Climatological Survey. Under that act, the Survey is to:

- Acquire, archive, process, and disseminate, in the most cost-effective way possible, all climate and weather information that is or could be of value to policy and decision makers in the state;
- Act as the representative of the state in all climatological and meteorological matters both within and outside of the state when requested by the legislative or executive branches of the state government;
- Prepare, publish, and disseminate periodic regular climate summaries for those individuals, agencies, and organizations whose activities are related to the welfare of the state and are affected by climate and weather;
- Conduct and report on studies of climate and weather phenomena of significant socioeconomic importance to the state;
- Evaluate the significance of natural and man-made, deliberate and inadvertent changes or modifications in important features of the climate and weather affecting the state, and to report this information to those agencies and organizations in the state who are likely to by affected by such changes or modifications; and
- Maintain and operate the Oklahoma Mesonetwork, a statewide environmental monitoring network which is overseen by the Mesonet Steering Committee, comprised of representatives of the University of Oklahoma and Oklahoma State University according to its Memorandum of Agreement.

The Oklahoma Mesonet (http://weather.ok.gov) is a world-class network of environmental monitoring stations operated by the Oklahoma Climatological Survey. The network was designed and implemented by scientists at the University of Oklahoma and at Oklahoma State University. The Mesonet consists of 120 automated stations covering Oklahoma. Mesonet stations report real-time weather and climate information every five minutes from every county in Oklahoma. The Mesonet's infrastructure allows for the OWRB to install groundwater depth sensors at several sites (e.g., El Reno, Fittstown) at no recurring cost and for federal programs, such as the Agriculture Research Service, to fund and collaborate with OCS on watershed monitoring for water resources research.

OCS leads the Southern Climate Impacts Planning Program (SCIPP), a Regional Integrated Sciences and Assessments program funded by the National Oceanic and Atmospheric Administration (NOAA). SCIPP's research goal is to help communities better plan for weather and climate-related disasters in the southern United States, particularly in the face of changing climate. Focusing on the six-state study region of Oklahoma, Texas, Louisiana, Arkansas, Tennessee, and Mississippi, SCIPP concentrates on the high frequency of hazardous climatological events that plague the region including extremes in precipitation (e.g., droughts and floods) as well as other hazards including severe storms and hurricanes.

OCS scientists also led the development and implementation of EarthStorm, a results-based K-12 teacher enhancement program that brought authentic learning about weather and its impacts to classrooms statewide, and OK-First, a weather education program and decision-support system for the state's public safety officials, predominantly emergency managers. OCS climatologists worked with the National Drought Mitigation Center to prototype a materials kit for towns and cities to become a Drought-Ready Community, modeled after the successful Storm-Ready Community program of NOAA's National Weather Service.

OCS serves a dual role as an expert in Oklahoma's current and past climate as well as an active listener to the needs of our state's citizens, state agencies, tribal nations, cities, and other stakeholders. We value our partners throughout the state, combining expertise, key relationships, and resources to address our state's weather and climate challenges. OCS's data, products, and services are used to document the history of Oklahoma's climate and provide context to current weather events; save lives and property through preparation for and response to natural disasters; decrease costs for agricultural producers through livestock- and crop-specific decision tools; provide a competitive advantage for Oklahoma researchers and businesses through high-quality data; and educate schoolchildren and the public about weather, weather safety, and climate.

Oklahoma's climate

Weather is the state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness. Climate is the statistical collection of weather conditions (e.g., averages, extremes) at a place over a period of years. In addition to the composition of gases in the atmosphere, the climate of an area is primarily affected by its latitude, elevation, proximity to a large water body (e.g., Gulf of Mexico), and the prevailing winds. Terrain, vegetation, smaller water bodies, and other more localized physical conditions can affect the climate of any specific location.

The mean annual temperature over the state ranges from 62˚F along the Red River to about 58˚F along the northern border. It then decreases westward to 56˚F in Cimarron County. Temperatures of 90˚F or greater occur, on average, about 60-65 days per year in the western panhandle and the northeast corner of the state. The average is about 115 days in southwest Oklahoma and about 85 days in the southeast. Temperatures of 100˚F or higher occur, frequently during some years, from May through September, and very rarely in April and October. Except for most of the panhandle, the western half of Oklahoma averages 15 days or more with temperatures of 100˚F or higher, ranging from about 35 days in the southwest corner to 25 in the northwest. The eastern half of the state and most of the panhandle average less than 15 days of triple-digit temperatures. Years without 100˚F temperatures are rare, ranging from about one of every seven years in the eastern half of the state to somewhat rarer in the west.

Precipitation provides an estimated 127 million acre-feet of renewable water each year to

Oklahoma, founding the state's water budget. The dominant feature of the spatial distribution of rainfall across Oklahoma (Figure 1) is a sharp increase in rainfall from west (~17 inches) to east (~56 inches), helping to support more ecosystems than all but one other U.S. state. Excessive daily rainfall of 8 inches or more, while rare, has been recorded. Recently, however, several 500-year events have been observed by the Oklahoma Mesonet, including at Oklahoma City on June 14, 2010 (10.0 inches over 12 hours); Burneyville on April 29, 2009 (28.9 inches over 1 day); and Fort Cobb on August 19, 2007 (7.4 inches over 3 hours).

Extreme precipitation events pose a substantial risk to lives and property, especially in areas prone to flash flooding. In fact, since 2000, flooding was involved in 13 Presidential Disaster Declarations in Oklahoma (overseen by FEMA). Overall, Oklahoma has had more Major Disaster Declarations than any other state since 2000. Flash flooding claimed 13 lives in Oklahoma from 2000-2010. Heavy rainfall also is associated with enhanced soil erosion as well as increased leaf and root pathogens in vegetation. Although these high-flow events typically capture the headlines, the other end of the water-availability spectrum –– drought –– is arguably more economically devastating. Drought is associated with agricultural crop and pasture damage (both quality and quantity), increased residential water demand, increased risk of wildfire and smoke-related respiratory diseases, and differential mortality and morbidity in forest species. Low streamflow associated with drought affects water quality as well as quantity. Since 2000, drought was involved in 14 declared disasters by the U.S. Department of Agriculture where one or more Oklahoma counties were listed as "primary natural disaster areas."

Floods of major rivers and tributaries may happen during any season, but they occur with greatest frequency during those spring and autumn months associated with greatest rainfall. Such floods cost many lives and property damage during the first 50 years of statehood, but flood prevention programs have reduced the frequency and severity of such events. Flash flooding of creeks and minor streams remains a serious threat, especially in urban and suburban areas, where urban development and removal of vegetation have increased runoff.

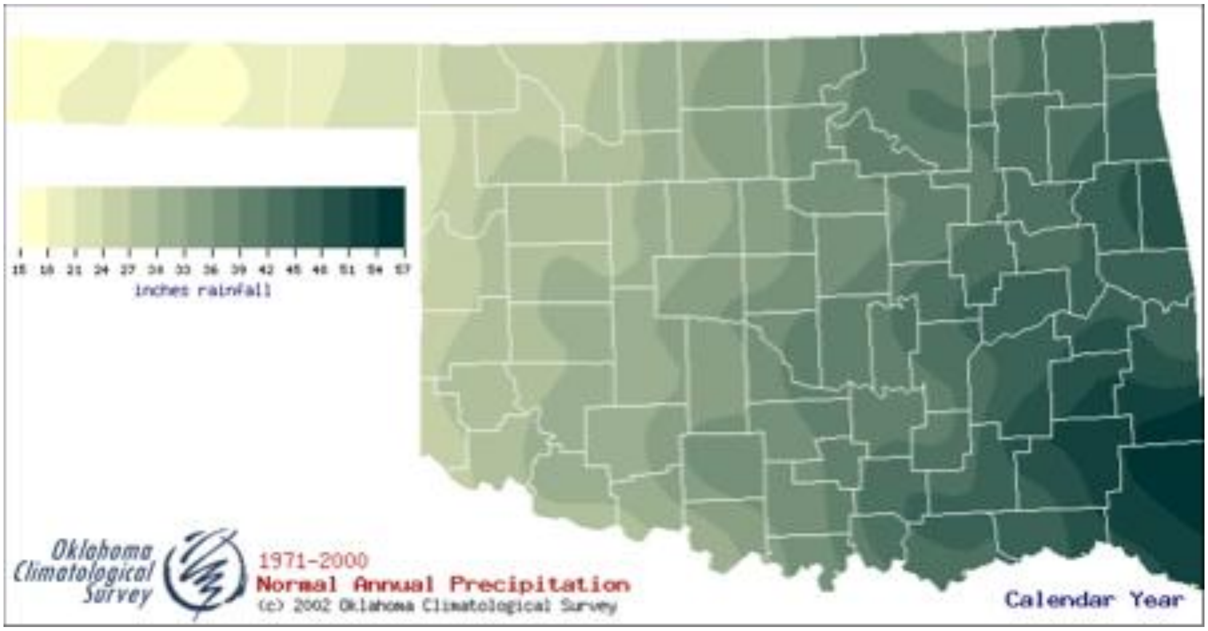

Figure 1. Map of the normal annual precipitation (in inches) for Oklahoma using data from 1971 to 2000.

Drought is a recurring part of Oklahoma's climate cycle, as it is in all the Plains states. Almost all of Oklahoma's usable surface water comes from precipitation that falls within the state's borders. Therefore, drought in Oklahoma is tied almost entirely to local rainfall patterns (i.e., the influence of upstream events on drought is very small). Western Oklahoma is slightly more susceptible to drought because precipitation there tends to be more variable (percentage-wise) and marginal for dryland farm applications.

Drought episodes can last from a few months to several years. Those that last a few months can elevate wildfire danger and impact municipal water use. Seasonal droughts can occur at any time of the year, and those that coincide with crop production cycles can cause billions of dollars of damage to the farm economy. Multi-season and multi-year episodes can severely impact large reservoirs, streamflow and groundwater.

Annual average relative humidity ranges from about 60 percent in the panhandle to just over 70 percent in the east and southeast. On average, cloudiness increases from west to east across Oklahoma. Average annual lake evaporation varies from 48 inches in the extreme east to 65 inches in the southwest, numbers that far exceed the average yearly rainfall in those areas. Evaporation and percolation into the soil expend about 80 percent of Oklahoma's precipitation.

Prevailing winds are from the south to southeast throughout most of the state from the spring through autumn months. These prevailing winds typically are from the south to southwest in far western Oklahoma, including the panhandle. The winter wind regime is roughly equal split between northerly and southerly winds.

On average, thunderstorms occur about 55 days per year in eastern Oklahoma, decreasing to about 45 days per year in the southwest. The annual rate increases to near 60 days annually in the extreme western panhandle. Late spring and early summer are the peak seasons for thunderstorms. December and January, on average, feature the fewest thunderstorms.

Tornadoes are a particular hazard in Oklahoma. Since 1950, an average of 54 tornadoes have been observed annually within the state's borders. Tornadoes can occur at any time of year, but are most frequent during springtime. Three-fourths of Oklahoma's tornadoes have occurred during April, May, and June. May's average of 20 tornado observations per month is the greatest. The winter months each average less than one tornado per month.

Climate-related water challenges in Oklahoma's future

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." – the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC)

That statement reflects the essence of a vast amount of observational data and climate research: the earth's climate has warmed on average during the last 100 years and will very likely continue to warm through the 21st century. Further, ample evidence from observational data and climate modeling studies indicates that this global-scale warming is not attributable to natural variability.

OCS has conducted a review of the current assessments of climate change research and concludes the following to be true:

- The earth's climate has warmed during the last 100 years;
- The earth's climate will very likely continue to warm for the foreseeable future;
- Much of the global average temperature increases over the last 50 years can be attributed to human activities, particularly increasing greenhouse gases in the atmosphere; and
- Oklahoma will be impacted.

In particular, climate change is projected to continue to alter the water cycle across the U.S., including the total amount of annual precipitation, timing of the precipitation, precipitation intensity and frequency, and location of precipitation. Nationwide, most locations *already have experienced* increases in both precipitation and streamflow and decreases in drought during the second half of the 20th Century.

The U.S. Global Climate Research Program (USGCRP) projects that more frequent heavy rainfall events and droughts will affect much of the Great Plains as climate changes. The USGCRP notes, "Projections of increasing temperatures, faster evaporation rates, and more sustained droughts brought on by climate change will only add more stress to overtaxed water sources."

A variable precipitation history (Figure 2) and an uncertain future under climate change combine to challenge even the most forward-thinking and resourceful managers of resources and infrastructure. With precipitation intensity projected to increase across much of the United States, recent statements that "stationarity is dead" verbalize concerns that the added uncertainty of climate change, as well as questions about the ability of global climate models to produce realistic precipitation extremes, will confound the already uncertain results from extreme value statistics for long return periods (e.g., 100 years and longer).

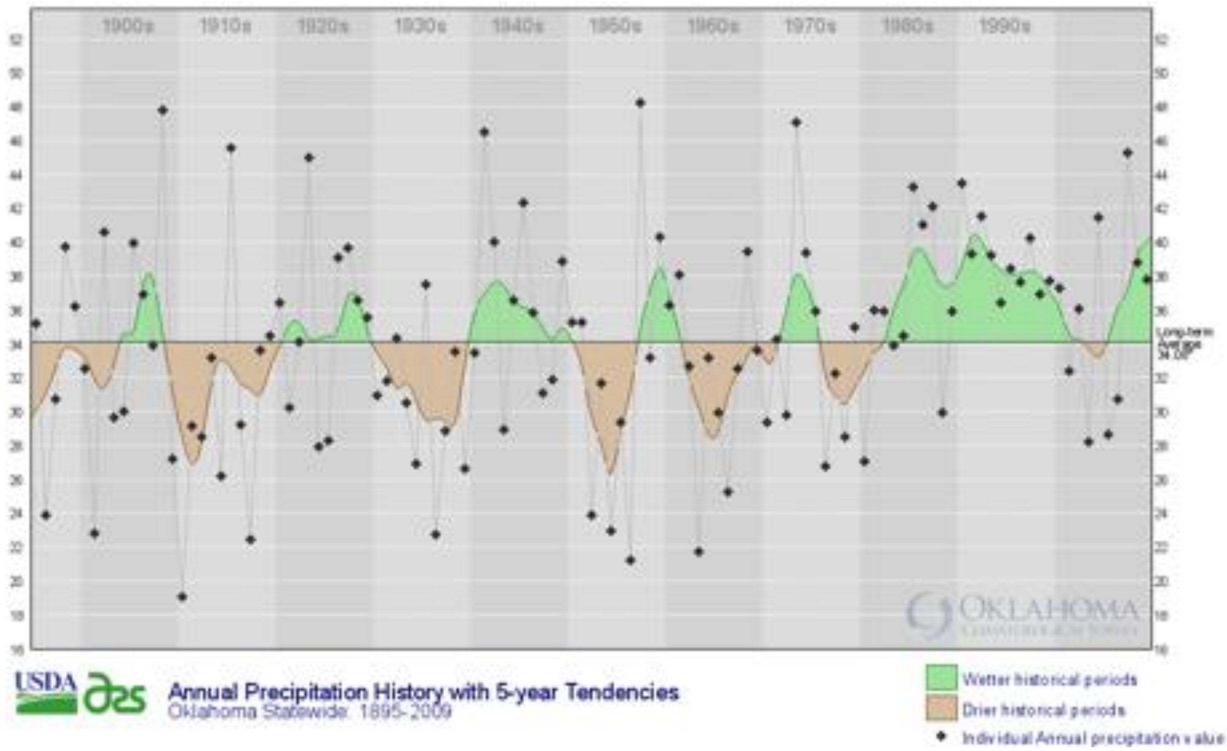

Figure 2. Annual precipitation history for Oklahoma. Dots denote each year's statewide average precipitation (in inches). Five-year running averages highlight drier (brown shading) and wetter (green shading) historical periods.

Recommendations for Future Research and Development

Funding for the following recommendations can be developed through a combination of permanent state funding for the Oklahoma Climatological Survey, project-based funding via research grants and contracts from external agencies (e.g., National Science Foundation; U.S. Departments of Agriculture, Energy, and Interior; National Oceanic and Atmospheric Administration), and stable funding provided by water or energy users via a small increase in water permit fees or monthly surcharge on electrical bills.

1. Oklahoma should assess the characteristics of, variability of, and trends in moisture and temperature over a range of spatial and temporal scales and use this information to enhance and validate regional climate projections from seasonal to decadal time scales

The complexity of Oklahoma's water environment results, in part, from the type of precipitation that occurs across our state. Much of Oklahoma's precipitation is convective in nature, resulting in isolated thunderstorms, lines or complexes of multiple thunderstorms, and embedded thunderstorms in winter low-pressure systems. These convective events result in river floods, flash floods, significant ice storms, and the occasional blizzard. On the other end of the water-supply spectrum are seasonal to multi-year droughts. Better physical understanding of these events (e.g., how are precipitation conditions related to El Niño and La Niña?, what conditions led to more devastating ice storms in the decade of the 2000s than any previous decade since statehood?) is critical to knowing how our water environment will change in the future. Additional research is needed on the characteristics of, variability of, and trends in moisture and temperature over a range of spatial and temporal scales. This information can be used to enhance the physical mechanisms depicted in regional climate models and to validate the results of both high-resolution and "downscaled" global climate models for the goal of providing decision makers the best projections possible for resource management and infrastructure decisions. In addition, the water demands for each watershed, whether from ecosystem services, residential usage, agriculture, energy development, or other need, needs to be assessed at a variety of temporal scales to determine the resiliency of the system to sudden or slow changes in "normal" precipitation. This knowledge results from learning how individuals, organizations, and communities prioritize water usage and what conditions trigger them to conserve water.

2. Oklahoma should develop and improve predictive water management tools

Even without the population growth, climate change, and land use changes that are projected in the future, Oklahoma water resource managers are plagued by too few tools that display current supply and demand, near-term and long-term projections in precipitation, and comparison with past water years. It is difficult to manage risk without sufficient information and tools.

Water resources management is governed by the interrelationships between the weather and climate system, natural and engineered water systems, and water use decisions. Understanding the variability and trends of our past water budget (e.g., precipitation, evaporation, soil moisture fluxes, groundwater recharge, runoff) and the use of global climate models is only a first step. A similar effort is needed to assess trends and variability in water demand at local and regional scales. What are the primary drivers behind increasing water use or conservation? How do economics (i.e., the cost of providing water) affect individual judgments on conservation? How can other factors, such as aesthetic qualities (e.g., lakes, green vegetation), be valued and how do they affect our water use decisions? How are changes in the natural ecosystems affecting water demand, such as expansive spread of eastern redcedars? How does new technology affect water use (e.g., expanded use of dishwashers)?

Once identified, these factors can be coupled into a decision-support model that allows community planners and water district managers to alter one or more of the inputs to see how the system responds. This tool will give local planners an ability to determine options that preserve local supplies at the lowest possible cost and maintain community quality that residents deem important. Tools such as WaterSim, developed by Arizona State University, are a start in this direction, allowing water managers to adjust factors such as climate change, drought, population growth, technological innovation, land use, and policy decisions. But these are designed for large urban areas on highly managed water systems like the Colorado River. Oklahoma could become a leader in developing a tool that works for small, rural communities that rely primarily upon local lakes, streams, and reservoirs.

3. Oklahoma should measure and account for its water

Currently, Oklahoma is the most comprehensively observed state in the U.S. with respect to water in both the atmosphere and near-surface soil layer. Our observing capabilities provide us high potential to conduct a comprehensive, statewide "water census" on the monthly, seasonal, and annual time scales. Maintaining a strong infrastructure of the Oklahoma Mesonet, in combination with federal resources such as the Doppler radar network, is critical for accounting for water supply, especially through extremes in our climate. Some water elements, especially on the watershed level, need to be better measured or estimated and others that may be measured well by remote sensing technologies may require further validation of algorithms. Many of these additional elements can be funded through research grants, but funding for the Oklahoma Mesonet necessitates the permanent base funding by the Oklahoma Legislature (through the Oklahoma State Regents for Higher Education), with annual cost-of-living adjustments. Without this stable funding, the Oklahoma Mesonet cannot provide the water resource management, operations, education, and research communities with the observations needed to conduct business efficiently and effectively.