4.8 Drought

4.8.1 Hazard Profile

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It occurs in virtually all climate zones, but its characteristics vary significantly from one region to another. Oklahoma's State Emergency Management Office defines drought as "a persistent and abnormal moisture deficiency having adverse impacts on vegetation, animals or people." Drought is caused by a deficiency of precipitation, which can be aggravated by high temperatures, high winds, and low relative humidity. Duration and severity are usually measured by deviation from norms of annual precipitation and stream flows.

The "Dust Bowl" of the 1930s, the greatest natural disaster in Oklahoma history, drove over 800,000 people off the land

Drought is an insidious hazard of nature, characterized as a "creeping phenomenon." It is often difficult to recognize the occurrence of drought before being in the middle of one. Drought analysis is more subjective than that for floods, because droughts do not occur discretely. They evolve over time as certain conditions are met and are spread over a large geographical area. Drought severity depends on its duration, intensity, geographic extent, and the regional water supply demands made by human activities and vegetation. This multi-dimensional nature makes it difficult to define a drought and to perform comprehensive risk assessments. This leads to the lack of accurate, reliable, and timely estimates of drought severity and effects, and ultimately slows the development of drought contingency plans.

There are normally considered to be four kinds of drought, which occur at different stages, illustrated by Figure 4-21.

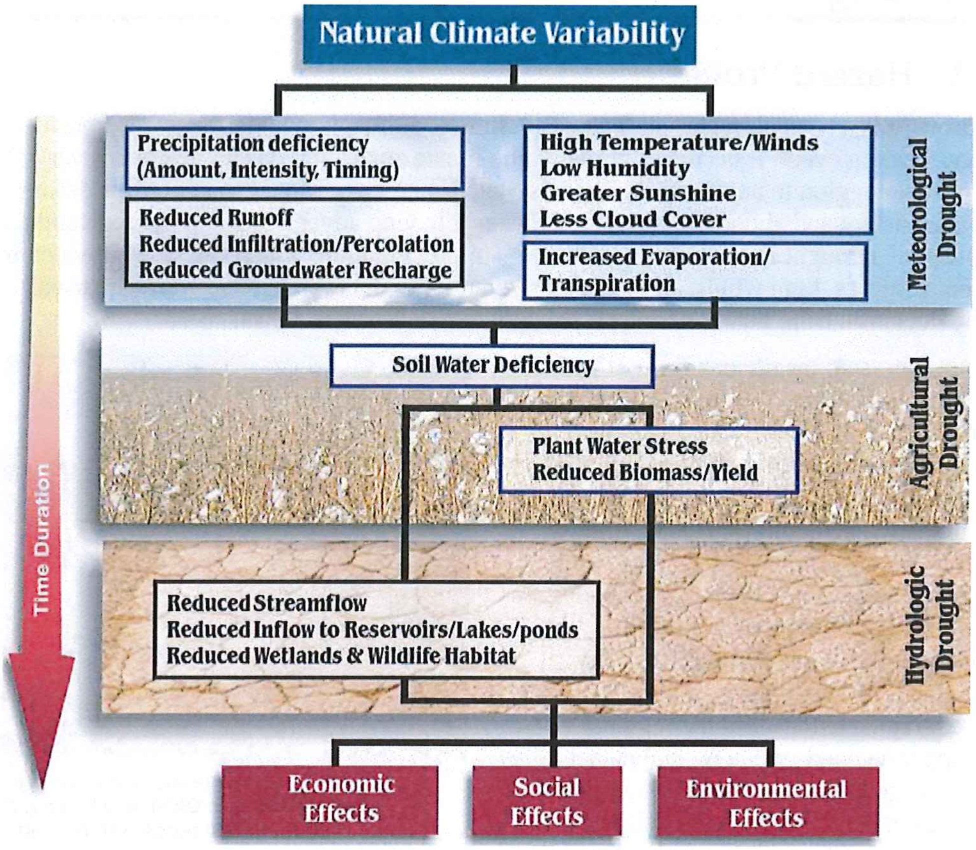
Meteorological drought is usually an expression of precipitation's departure from normal over some period of time. These definitions are usually region-specific, and presumably based on a thorough understanding of regional climatology.

Agricultural drought occurs when there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.

Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as streamflow and as lake, reservoir, and groundwater levels. There is a time lag between lack of rain and less water in streams, rivers, lakes, and reservoirs, so hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

Socioeconomic drought occurs when physical water shortage starts to affect people, individually and collectively. Or, in more abstract terms, most socioeconomic definitions of drought associate it with the supply and demand of an economic good.

Figure 4-21: Kinds of Drought



Location

Drought is a widespread phenomenon that occurs over broad regions encompassing not only multiple communities, but frequently multiple states. Over the last few years, western Oklahoma has been hit harder by water shortages than eastern Oklahoma, but no location in the state is immune. Canadian County is at Moderate to High risk of drought. See Figure 4-22 for a recent drought map of the U.S. showing impacted areas.

Measurement

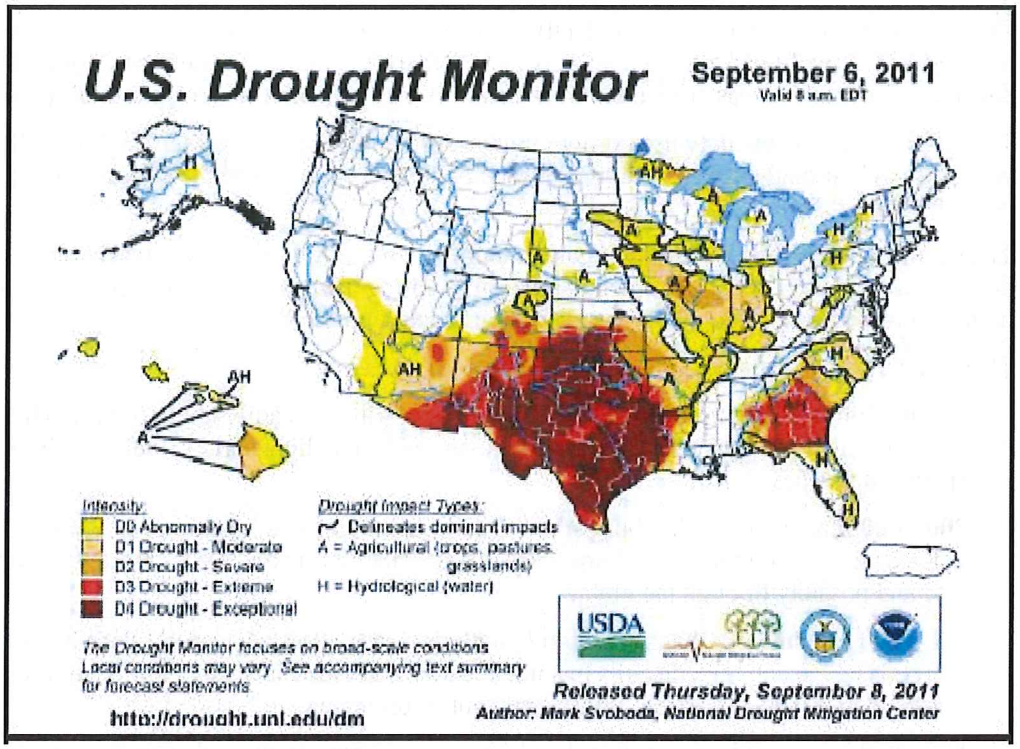
Different methods are used to predict the severity and impact of droughts, but each one measure different aspects or types of drought. Any single index cannot describe everything about the original data, and the indices are only approximations of real-world phenomena.

Palmer Drought Severity Index (PDSI)

The Palmer Index, the most familiar and widely used, measures the departure from normal precipitation. This index uses a range from 4 (extremely wet) to –4 (extremely dry). It incorporates temperature, precipitation, evaporation, runoff, and soil moisture when designating the degree of drought. Hydrologic Indices of drought (such as groundwater levels, reservoir volumes, or water levels) may be used to determine surface water supplies.

In 1965, Palmer developed an index to "measure the departure of the moisture supply". Palmer based his index on the supply-and-demand concept of the water balance equation, taking into account more than only the precipitation deficit at specific locations. The objective of the Palmer

Figure 4–22: US Drought Monitor Map for September 6, 2011



Drought Severity Index (PDSI), as this index is now called, was to provide a measurement of moisture conditions that were "standardized" so that comparisons using the index could be made between locations and between months.

Weekly Palmer Index values are calculated for the Climate Divisions during every growing season and are on the World Wide Web at the National Drought Mitigation Center.

Table 4–25: Palmer Drought Severity Index (PDSI)

Rating	Condition
4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.50 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.50 to -0.99	Incipient dry spell
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

Source: http://drought.unl.edu/whatis/indices.htm

Keetch-Byram Drought Index, Fire Danger Rating System

The Keetch-Byram Drought Index (KBDI) is a mathematical system for relating current and recent weather conditions to potential or expected fire behavior. This system was originally developed for the southeastern United States and is based primarily on recent rainfall patterns.

The KBDI is the most widely used drought index system by fire managers in the South. It is also one of the only drought index systems specifically developed to equate the effects of drought with potential fire activities.

The result of this system is a drought index number ranging from 0 to 800 that accurately describes the amount of moisture that is missing. A rating of zero defines the point where there is no moisture deficiency and 800 is the maximum drought possible.

These numbers correlate with potential fire behavior as follows:

0 - 200 Soil and fuel moisture are high. Most fuels will not readily ignite or burn. However, with sufficient sunlight and wind, cured grasses and some light surface fuels will burn in spots and patches.

200 - 400 Fires more readily burn and will carry across an area with no gaps. Heavier fuels will still not readily ignite and burn. Also, expect smoldering and the resulting smoke to carry into and possibly through the night.

400 - 600 Fire intensity begins to significantly increase. Fires will readily burn in all directions exposing mineral soils in some locations. Larger fuels may burn or smolder for several days creating possible smoke and control problems.

600 - 800 Fires will burn to mineral soil. Stumps will burn to the end of underground roots and spotting will be a major problem. Fires will burn through the night and heavier fuels will actively burn and contribute to fire intensity. Source: http://www.wfas.us/content/view/32/49/

Extent/Severity

Because of the gradual nature of drought's onset, and its uneven impacts, it is often difficult to determine the beginning, end and extent of a drought event. The complexity of the drought phenomenon also makes it difficult to predict drought probabilities. Drought evolves over time and can spread over a large area, but has widely differing impacts in specific areas, depending upon duration, intensity, water supplies, and the demands made upon water supplies by human activities and vegetation. The impacts of related hazards, such as extreme heat, expansive soils and wildfires, can be intensified during periods of drought. Drought impacts can be both environmental and economic, and include the following:

- reduced crop, rangeland;
- increased livestock and wildlife mortality;
- reduced income for merchants, farmers and agribusiness;
- increased fire hazard;
- reduced water supplies for municipal/industrial, agricultural and power uses;
- damage to fish and wildlife habitat;
- increased food prices;
- reduced tourism and recreational activities;
- unemployment;
- lower tax revenue due to reduced expenditures;
- foreclosures on bank loans to farmers and businesses.

Canadian County has experienced drought four times in the past 15 years, characterized primarily by crop damage, water rationing and wildfire. The impacts of drought can be lessened by early warning and notification systems, backup sources of water supply, cooperative agreements with neighboring jurisdictions, local ordinances for rationing water use, clearing brush and Eastern Red Cedar from structures in the urban/rural interface, and participating in the national Firewise program.

Canadian County considers a minor severity drought to be mild or moderate on the Palmer Index, and a major severity event to be a Severe or Extreme drought on the Index, which results in crop loss or restrictions on water use.

Frequency

Given that six major drought events have occurred in Oklahoma over the past 50 years and that nine notable droughts have taken place nationwide in the last century, one may conclude that Oklahoma can expect a drought every decade and that droughts will occur more frequently than in the nation as a whole. However, long-term forecasts of droughts are difficult and inexact. There is no commonly accepted way of determining a probability that is analogous to the 100-year or 1-percent-annual flood chance.

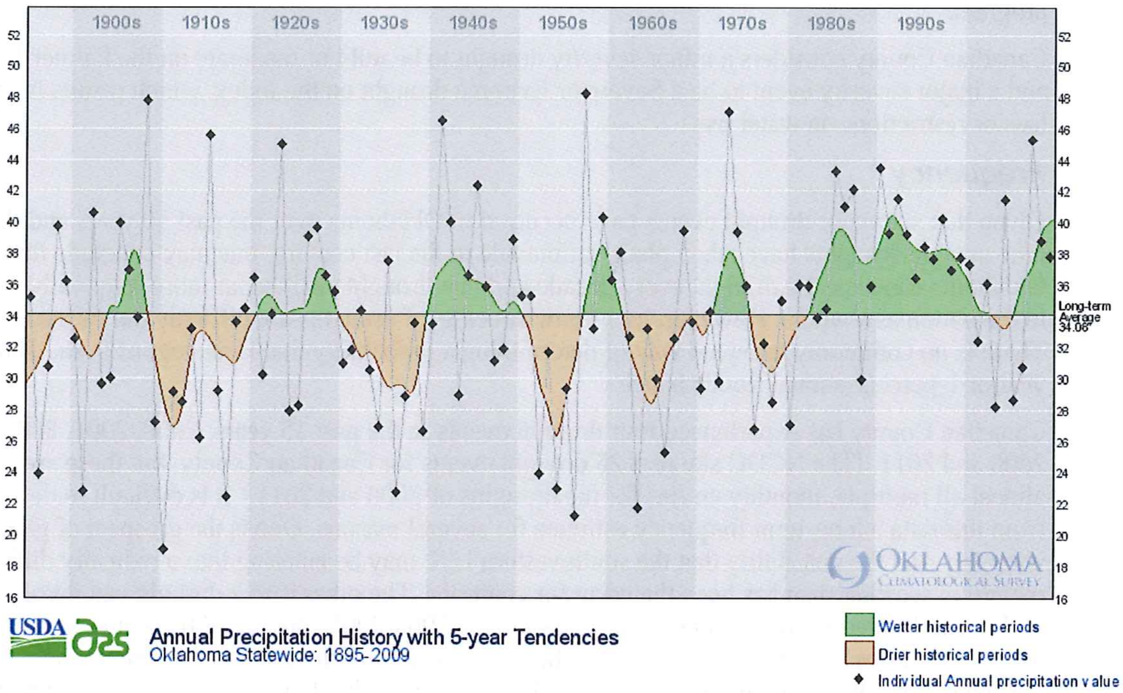
Canadian County has experienced four drought events in the past 15 years: 2000, 2001, 2005-2006 and 2011. (The NCDC site lists 25 drought events for Canadian County, but these are almost all multiple, monthly entries for the droughts of 2006 and 2011.) It is difficult to derive from this data a long-term frequency estimate for several reasons. One is the prospect of global warming, and the possibility that the southwestern U.S. may be entering into a radically different pattern of weather than has been the norm for centuries. The other is that drought can involve both local, limited events lasting a year or two (as in 2005-2006 and 2010-2011), and larger weather cycles whose periodicity can only be determined after the fact. For example, the region has gone through alternating wet and dry cycles since the early 1900s, with the latest being an almost 20-year period of wet weather lasting from about 1983 to 2003 (see Annual Rainfall History Figure 4-23). If these trends continue, and the recent wet cycle is followed by a more or less equal number of dry years, then Canadian County may well be facing a period of prolonged drought in the coming decades. If this cycle is real, and the dire warnings of global warming prove to be valid, a conjunction of wet and dry swings and atmospheric warming could usher in cycles of unprecedented, catastrophic drought.

Impact

The most direct impact of drought is economic rather than loss of life or immediate destruction of property. Drought affects water levels for use by industry, agriculture, and individual consumers. Water levels can have both a direct and indirect effect on hunting, fishing, and other recreational activities that may have a significant place in a community's revenue. During droughts crops do not mature, wildlife and livestock are undernourished, land values decrease, and unemployment rises.

In addition, water shortages affect fire-fighting capabilities through reduced water flows and pressures. Drought can also increase the cost of power production, since electric companies cannot produce enough inexpensive hydropower to meet demand and are forced to purchase power from other, usually more costly sources. Communities that rely on hydroelectric vs. coal/gas-fired generating plants may be financially impacted. The primary threat to Canadian County public school districts from drought is to landscaping, vegetation and playing fields, which could be damaged or require special maintenance during periods of water shortage and low rainfall

Figure 4–23: Annual Rainfall History from 1895-2009



Most droughts dramatically increase the danger of wildland fires. When wildlands are destroyed by fire, the resulting erosion can cause the heavy silting of streams, rivers, and reservoirs. Serious damage to aquatic life, irrigation, and power production then occurs. (See the section, "Wildfires")

4.8.2 History/Previous Occurrences

The National Weather Service's drought monitor map illustrates the pervasive nature and degrees of dryness and prolonged drought in several areas of the country. The current Drought Monitor map for the U.S., which is updated weekly, is shown in Figure 4-22.

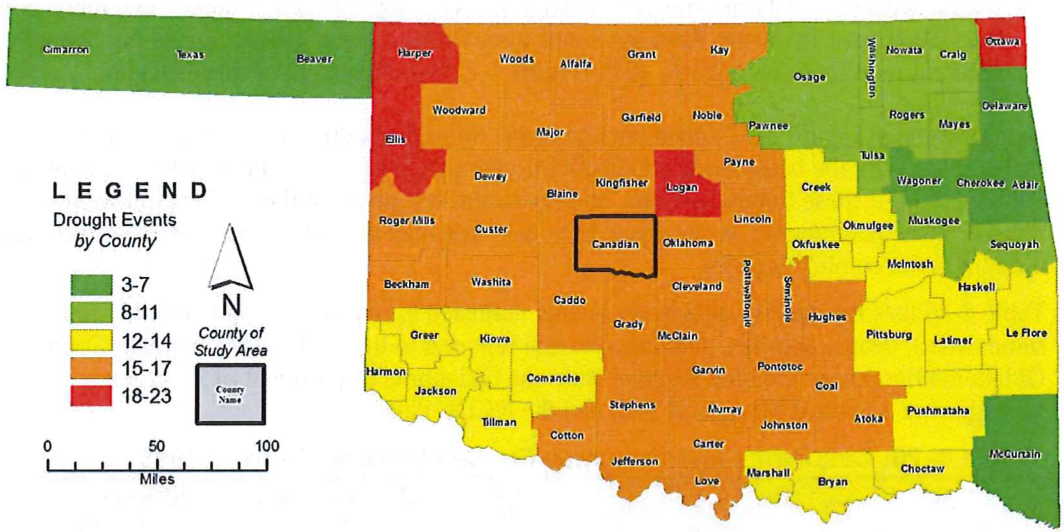
There have been nine notable droughts in the United States during the Twentieth Century. Damage estimates are not available for most; however it is thought that the 1976-1977 droughts in the Great Plains, Upper Midwest, and far Western States caused direct losses of $10-$15 billion. The 1987-1989 droughts cost $39 billion, including agricultural losses, river transportation disruption, economic impacts, water supply problems, and wildfires. The droughts and high temperatures of 2005-2007 and 2011 have been among the most severe in Oklahoma history. In 2007, large portions of the southeastern U.S. were in the worst drought in more than a century, sparking water wars among Georgia, Alabama and Florida.

In Oklahoma, six major drought events were reported over the past 50 years resulting in damage to crops estimated at $900 million. These droughts, as determined from stream flow records collected since the early 1920s, have predominately occurred during four periods: 1929-1941, 1951-1957, 1961-1972, and 1975-1982. A map showing drought events by county from 1989-

2009 is shown in Figure 4-24. As stated above, although it is too soon to tell, Oklahoma may have entered another drought cycle in 2010.

One of the greatest natural disasters in U.S. history and the most severe and devastating to Oklahoma was the decade-long drought in the 1930s that became known as the Dust Bowl. Reaching its peak from 1935 through 1938, high temperatures and low rainfall combined to destroy crops and livestock. High winds literally blew the land away, causing massive soil erosion. Hundreds of small rural communities were ruined and about 800,000 people were displaced. The total expenditure by the American Red Cross for drought relief in Oklahoma in 1930-1931 was the third largest in its history. Although the Dust Bowl years have become a hallmark of the Depression era, captured in photographs, fiction and family chronicles, the driest five years in Oklahoma history were 1952-1956.

Figure 4–24: Drought Events in Oklahoma 1989-2009



Source: National Climatic Data Center U.S. Storm Events Database

Flanagan & Associates, LLC

Canadian County Drought Events

- **August-September 2000.** In early August an extended period of unusually dry weather began that lasted for 2 months. Many parts of the state did not receive rain in August, and portions of southern and south central Oklahoma remained dry for almost 90 days, starting in June. Total agricultural losses were estimated between $600 million and $1 billion statewide. Reservoir levels across southwest and south central Oklahoma averaged 50 percent of normal. Seven counties near the Texas border were declared federal disaster areas.
- **July 2001** – A month of excessive heat and little rainfall brought drought to western and north central Oklahoma that lasted into 2002. It was to become the fifth driest June-May period on record for west central Oklahoma. Eight people died from heat-related illnesses in July, six in the Oklahoma City Metro Area. A Presidential Disaster Declaration for the drought of 2001-2002 included all the western counties of Oklahoma, including Canadian County.
- **December 2005-January 2007** – A sustained period of dry weather and high temperatures spread drought across much of Oklahoma, especially the east central and southeast portions of the state. The winter of 2005-2006 was the second driest since records began being kept in

1895. High winds, combined with dry soil conditions, helped spread the worst series of wildfire outbreaks in Oklahoma history. (See *4.11- Wildfire*) By April 2006, the severe drought had become "extreme drought" in most of the state. The drought and high temperatures led to the loss of half of the wheat crop and fish kills on the Deep Fork River. Lakes were low and recreation revenues down. Farmers were forced to sell off cattle when hay crops failed and ponds dried up. Wildfires burned over 400,000 acres and resulted in $7.5 million property damage, and agricultural losses of $158 million.

- **January 2011-October 2011** – A dry winter in 2010 led to a drought declaration in January 2011 and warnings that the winter wheat crop was likely to be poor. The bulk of the crop did fail and by July Oklahoma and Canadian County were experiencing the hottest month since the beginning of records in the 1890s. In Lawton, temperatures in July rose above 100° every day of July, and in El Reno every day but four. Farmers had to sell of much of their herds, Lake Heffner almost dried up, and there were many fish kills in overheated streams and rivers. Most of Oklahoma and Texas had months of "exceptional drought," and most cities in the Oklahoma City Metro Area instituted some form of water rationing. See the Drought Monitor map for September 6, 2011 (Figure 4-22) for the extent of this drought.

As illustrated in Figure 4-23, Oklahoma has gone through six drought cycles, statewide, since the early 1900s, with the latest being an almost 20-year period of wet weather lasting from about 1983 to 2003. If these trends continue, and the recent wet phase of the cycle is followed by a more or less equal number of dry years, then the State may well be facing a period of prolonged drought in the coming decades.

Table 4-26 lists the number of drought events (adjusted to remove multiple monthly reports of the same event), deaths, injuries, and crop damage reported to the NCDC for Canadian County. The Oklahoma figures are cobbled together from the Oklahoma Department of Emergency Management's Hazard Mitigation Plan and the NCDC data.

Table 4–26: Casualties and Damages Caused by Drought from 1995 - 2009

Location	Events	Deaths	Injuries	Damage Events	Property/Crop Damages
Canadian County	4	0	4	4	$561,590,000
Oklahoma	6	0	4	6	$1,129,669,000

From NOAA National Climatic Data Center http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

Probability/Future Events

As drought is a direct by-product of normal climatological activity, it is accepted that Canadian County will continue to be hit by droughts of varying severity.

Based on history and previous occurrences, Canadian County can expect limited drought conditions every 4 years and larger drought cycles every 15 years. The region has gone through alternating wet and dry cycles since the early 1900s, and the region is just coming out of a 20-year period of wet weather, which lasted from about 1983 to 2003.

Drought, generally, will have a more devastating effect on the County's rural areas and agricultural and ranching communities than on its urban residents. Although Canadian County's water supplies are, for the present, adequate to meet all but the most severe drought conditions, the jurisdiction will remain vulnerable to drought over the long term.

Canadian County, its Communities and Public School systems have a moderate probability of experiencing a future drought event.

4.8.3 Vulnerability

This section summarizes information about Canadian County's vulnerability to drought, including the impact on people, structures and buildings, critical facilities, and infrastructure. This information, as well as information provided by the County, Incorporated Communities and Public Schools, was used to determine the Vulnerability Criteria identified in Tables 4-2 and 4-3. Canadian County was determined to be at Moderate to High risk concerning the drought hazard. (See Table 4-2 Hazard Risk Analysis, and Table 4-3, Summary of Hazard risk Analysis Ranking Criteria for an explanation of how the rankings were derived.) Appendices F and G identify where the Incorporated Communities and Public School Systems differ from Canadian County.

In all droughts, agriculture feels the impact, especially in non-irrigated areas such as dry land farms and rangelands. Other heavy water users, such as landscapers, are also negatively impacted. Water-related activities of residential users might be restricted. Droughts may exacerbate the impacts of expansive soils (see Section 4.9). Tourism and recreation also suffer as lakes and streams dry up and heated surface water causes fish kills. Droughts also cause power shortages in Oklahoma, because much of the state's power comes from hydroelectric plants. Heavy power users can be negatively affected by the results of electricity shortages due to drought, such as brownouts, blackouts, and spiking prices.

Population

Generally, in times of severe drought, states rely on the Federal Government to provide relief to drought victims when water shortages reach near-disaster proportions. Forty separate drought relief programs administered by 16 Federal agencies provided nearly $8 billion in relief during the drought years of the 1970s. Federal assistance efforts totaled more than $5 billion in response to the 1987–1989 droughts. However, since the mid-1970s, most states have taken more active roles in overseeing water issues and drought contingency plans are now in place in at least 27 states, including Oklahoma. In Canadian County, farmers and ranchers would be impacted by drought. Drought is a concern and Moderate risk for Canadian County and its communities, but of less risk to public school systems as schools are typically not in session during the hottest days of the summer.

Structures/Buildings

The primary threat to structures, including schools, in Canadian County from drought is from the secondary impacts of drought on Expansive Soils and Wildfire. See Sections 4.9 and 4.11 for more information on these hazards.

Critical Facilities

The critical facilities most impacted by drought are those that rely upon water to fulfill their primary functions, or to operate at all, such as fire departments, rural water districts, medical and health care facilities, water and wastewater treatment plants, and daycare centers.

Infrastructure

The effect on infrastructure is, for the most part, similar to the effect on structures, in that the primary danger is drought's effect on expansive soils and wildfire. In many communities, drought can have impacts on the community's ability to fight both wildland and structure fires.

Water Treatment – Drought increases the demand for water and at the same time may impact the availability of raw water. Water treatment plants can be highly vulnerable to extended periods of drought. The greatest vulnerability of water plants and delivery systems is aging pipelines put under stress by shrinking and swelling soils. This is a growing problem throughout the country, particularly in communities with iron pipelines dating from the early 1900s.

Wastewater Treatment – Water shortages during periods of drought can reduce the capacity of wastewater systems in the County. Shrinking soils can cause wastewater pipeline breaks and groundwater contamination.

Utilities- No vulnerabilities exist except that of the secondary impact of wildfire, which can burn distribution poles and the smoke from which can cause flashovers to ground.

Transportation Systems (Highways, Public Transportation, Railway, Airports) – Roadways and railways can be damaged by expansive soils, a secondary effect of drought.

Emergency Services- Fire services could potentially be affected if a severe drought reduces availability of water for fire suppression. Police and medical services would not face any vulnerability other than those experienced by other county services/facilities.

4.8.4 Drought Scenario

Almost all of western Canadian County's water is drawn from groundwater wells, drilled into alluvial aquifers or terrace deposits of the North Canadian and Canadian Rivers. These groundwater resources have proven remarkably stable. However, in recent years there have been significant declines in water flows in the upper North Canadian, largely due to irrigation, stock ponds, reservoirs and municipal use. It is too early to say what the long-term impact of this decline will mean for Canadian County communities like Calumet, El Reno, Union City and Okarche. It has been determined by earlier studies that the aquifers that supply water for the western half of the county, including El Reno, can ride through up to three years of severe drought, given current levels of demand. Several cities in the county have formed a Central Oklahoma Water Resource Authority whose task it is to find long-term solutions to the area's water needs. El Reno, Piedmont, Mustang, Calumet, Union City and Okarche are all members. The major cities in eastern Canadian County, including El Reno, Union City, Piedmont and Mustang have all connected their water systems to the Oklahoma City system, which provides them with a reserve to draw upon in water emergencies. However, as shown by the drought of 2011, the near emptying of Lake Hefner, and the imposition of moderate rationing, this backup is itself vulnerable to extended drought and low flows on the Canadian and North Canadian rivers. The Oklahoma Water Resources Board's *Oklahoma Comprehensive Water Plan* has determined that the Central Planning Region's Basin 51, which includes both the Canadian and North Canadian rivers and alluvial aquifers, will face significant water supply limitations in coming years.

A worst-case scenario would be a drought as severe as that of 2011 extended over a three-year or longer period, combined with low flows on the Canadian and North Canadian rivers and declines in aquifer levels and recharge rates. A drought event of such magnitude, equaling or surpassing the droughts of the 1930s and 1950s, would force the drilling of new supply wells, or a much greater linking of water systems, both to each other and to more robust sources of supply, perhaps in southeastern Oklahoma, which as a region could begin to serve as a retail water provider to drier parts of the state.

4.8.5 Future Trends

For information on future development areas in Canadian County, see Section 1.2.8.

Population

As drought is primarily an agricultural threat in nature, and, as the eastern portion of Canadian County is largely urban, the populations most vulnerable to drought are the ranching and farming communities in the west. It should not be forgotten, however, that agriculture is a major enterprise in undeveloped parts of Piedmont and Union City. Reduced income in the agricultural community would impact the economy of the County as a whole, and result in a drop in tax revenues for communities and County alike.

Structures/Buildings

The primary threat to structures lies in the effect of drought on expansive soils. Any future development/renovations undertaken by the County for structures/buildings should consider expansive soils, as well as the increased likelihood of wildfire during long-term drought. More information on these hazards is available in Sections 4.9 and 4.11.

Critical Facilities

The most severe threat to future critical facilities lies in the effects of drought on expansive soils. Critical facilities located on highly expansive soils should be monitored. In addition, critical facilities should plan for the possibility of water shortages during drought events, as these could impact daycare centers, nursing homes and other medical/health care facilities.

Infrastructure

The vulnerability of future infrastructure is primarily to drought's impacts on expansive soils. As development continues within the county, the capacity, age and condition of water delivery systems should be reviewed to ensure these can meet the demands of expected population growth. The location and composition of roadways should also be reviewed to ensure appropriate techniques and materials are used in areas of expansive soils. The County should encourage communities to upgrade aging or inadequate water and sewer lines where these pass through areas of highly expansive soils.

4.8.6 Conclusion

There are signs that drought is becoming an increasing problem in the United States, including Oklahoma. However, it is difficult to predict drought probabilities for the near future due to the nature and complexity of the hazard. Nevertheless, there are signs that the region may be entering a period of sustained low rainfall and drought, similar to that of the 1930s and 1950s. In addition, the Oklahoma Climatological Society has cautioned that the global warming trend is real and will have impacts on the state over the long term, resulting in higher summer temperatures and more frequent and severe droughts.

The devastating drought of the 1930s led to the construction of Oklahoma's numerous hydroelectric dams and reservoirs, as well as to the implementation of new farming practices and conservation policies. However, more recent drought response and recovery activities in Oklahoma have not been as ambitious or successful. Planning for the state's critical and emergency water resource needs should not be carried on only during and immediately after drought crises. "There is clearly a need to focus more on long-term water management and planning issues; to integrate the activities of numerous agencies with drought-related missions into a coherent national approach; and to achieve better coordination of mitigation, response, and planning efforts between State and Federal officials."

One step in this direction would be the creation of a water distribution equivalent of the nation's regional electrical transmission grids—that is, an interconnected pipeline system which would allow the southeastern region of Oklahoma to market its precious water resources at reasonable rates to other parts of the state that are experiencing shortfalls. Advances in metering technologies and SCADA systems have made such a network quite feasible.

Canadian County is at Moderate risk from the impacts of drought, due to the vulnerability of the various water supplies and exposure to secondary impacts, such as expansive soils and wildfire. Wells and aquifers are as vulnerable as above ground water sources.

Update Changes

Identified significant changes made from previous Multi-Hazard Mitigation Plans from Canadian County, Calumet, El Reno, Mustang, Piedmont, Union City are outlined in Appendix E. Changes are based on criteria outlined for Plan Updates in the Local Multi-Hazard Mitigation Planning Guidance document of July 1, 2008.

4.8.7 Sources

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