2009

Drought in the United States: Causes and Issues for Congress

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March 2, 2009

Congressional Research Service
7-5700
www.crs.gov
RL34580

CRS Report for Congress
Prepared for Members and Committees of Congress

Summary

Drought is commonly defined as a deficiency of precipitation over an extended period of time, usually a season or more, relative to some long-term average condition. Droughts have affected the United States, particularly the American West, for centuries. Drought affects societies because of the combination of reduced supply (e.g., less precipitation, reduced reservoir levels, a lower groundwater table) and competing demand (e.g., for irrigation, municipal and industrial supply, energy production, species protection). This report focuses on the physical causes of drought, its history in the United States, and what may be expected in the near future. Although currently drought can be predicted for a particular region for at best a few months in advance, past history suggests that severe and extended droughts are inevitable and part of natural climate cycles, particularly in the West.

Some studies suggest that the American West may be in transition to a more arid climate, raising concerns that the region may become more prone to extreme drought than was the norm during most of the 20th century. While drought is most common in the West, drought can also provoke water resource conflicts in other parts of the country. For example, the 2007-2008 drought in the Southeast has heightened a long-standing dispute over water in the Apalachicola-Chattahoochee-Flint River basin, even though the three states at odds with each other—Georgia, Alabama, and Florida—receive more rainfall in dry years than many western states receive in average years.

The physical conditions causing drought in the United States are increasingly understood to be linked to sea surface temperatures (SSTs) in the tropical Pacific Ocean. Studies indicate that cooler-than-average SSTs have been connected to the recent severe western drought, severe droughts of the late 19th century, and precolonial North American "megadroughts." Some climate model projections suggest that warming temperatures resulting from increased greenhouse gases in the atmosphere could return the western United States within decades to more arid baseline conditions similar to those during earlier times.

The prospect of extended droughts and more arid baseline conditions in parts of the United States could suggest new challenges to federal water projects, the construction of which was based largely on 20th century climate conditions. In responding to competing demands for water, such as deliveries to serve agricultural demands, municipal needs, endangered species, and others, federal water delivery systems may have to be re-tuned to match a drier average climate in the West. As a further complication, federal, state, and local authorities make water resource decisions within the context of multiple and often conflicting laws and objectives, competing legal decisions, and entrenched institutional mechanisms.

The evolving nature of drought, split federal and non-federal responsibilities, and a patchwork of federal programs and congressional committee jurisdictions make development of a comprehensive national drought policy difficult. Although Congress has considered some of the recommendations issued by the National Drought Policy Commission in 2000, comprehensive drought legislation has not been enacted. Congress may move to review how federal agencies such as the U.S. Army Corps of Engineers and the Bureau of Reclamation have responded to recent droughts in the Southeast, West, and Northwest to help assess whether the National Drought Policy Commission's recommendations are still relevant.

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Introduction

Drought has afflicted portions of North America for thousands of years, particularly in the West, although severe drought has also occurred in the more humid Mississippi Valley and southeastern United States. Severe, long-lasting droughts may have been an important factor in the disintegration of Pueblo society in the Southwest during the 13th century, and in the demise of central and lower Mississippi Valley societies in the 14th through 16th centuries.[1] In the 20th century, droughts in the 1930s and 1950s were particularly severe. In 1934, 65% of the contiguous United States was affected by severe to extreme drought.[2]

At any given time, drought of at least moderate intensity covers approximately 10% of the United States.[3] The proportion rises during extended droughts. For example, during early September 2002, as much as 45% of the nation, by area, was gripped by drought of at least moderate intensity.[4] Each year some portion of the country nearly always experiences periods of extreme or exceptional drought. Over an eight-year period starting in 2000, extreme or exceptional drought has affected approximately 7% of the nation on average.[5] During the month of August 2002, extreme or exceptional drought extended over 19% of the country. Severe drought has occurred and will likely continue to occur periodically in the United States.

The likelihood of extended periods of severe drought, similar to conditions experienced centuries ago, and its effects on 21st century society in the United States raise several issues for Congress. Drought often results in significant agricultural losses, which can have widespread effects. It can also impact other industries and services, including power production, navigation, recreation, and natural resources such as fisheries and water quality. Addressing these impacts on an emergency basis is costly—often resulting in hundreds of millions and sometimes billions of dollars in federal assistance. Additionally, drought affects management of federal reservoirs and in many cases exacerbates existing tensions among the beneficiaries of competing uses.

This report discusses how drought is defined (e.g., why drought in one region of the country is different from drought in a different region), and why drought occurs in the United States. How droughts are classified, and what is meant by moderate, severe, and extreme drought classification, are also discussed. The report briefly describes periods of drought in the country's past that equaled or exceeded drought conditions experienced during the 20th century, including periods during earlier centuries where the American West was substantially drier, on average, than it is today. This is followed by a discussion of the prospects for a future climate in the West that

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[1] Cook, Edward R., Richard Seager, Mark A. Crane, and David W. Stahle, "North American drought: reconstructions, causes, and consequences," *Earth-Science Reviews*, vol. 81 (2007): pp. 93-134. Hereafter referred to as Cook et al., 2007.

[2] Donald A. Wilhite, et al., *Managing Drought: A Roadmap for Change in the United States*, (Boulder, CO: The Geological Society of America, 2007), p. 12; at http://www.geosociety.org/meetings/06drought/roadmap.pdf.

[3] According to data collected by the National Drought Mitigation Center (NDMC) since 2000. U.S. Drought Monitor at the NDMC in Lincoln, NE. See http://www.drought.unl.edu/dm/DM_tables.htm?archive.

[4] NDMC reports that during the week of August 26, 2004, 45.9% of the nation faced at least moderate intensity drought. Over the time period between January 2000 and March 2008, at least moderate intensity drought has occurred over roughly 28% of the country on average.

[5] Although in some years no part of the country was under extreme or exceptional drought during certain months. For example, from January 2000 through the first two weeks of April 2000, extreme or exceptional drought did not affect any portion of country, according to the NDMC.

may be drier than the average 20th century climate—perhaps similar to drier periods centuries ago. The report concludes with a description of policy challenges for Congress, such as the existing federal/non-federal split in drought response and management, and the patchwork of drought programs subject to oversight by multiple congressional committees. An exhaustive discussion of each policy challenge facing Congress is beyond the scope of this report.

What Is Drought?

Drought has a number of definitions; the simplest conceptual definition may be a deficiency of precipitation over an extended period of time, usually a season or more. [6] Drought is usually considered relative to some long-term average condition, or balance, between precipitation, evaporation, and transpiration by plants (evaporation and transpiration are typically combined into one term: evapotranspiration).[7] An imbalance could result from a decrease in precipitation, or an increase in evapotranspiration (from drier conditions, higher temperatures, higher winds), or both. It is important to distinguish between drought, which has a beginning and an end, and aridity, which is restricted to low rainfall regions and is a relatively permanent feature of climate (e.g., deserts are regions of relatively permanent aridity).[8]

An increased demand for water from human activities and vegetation in areas of limited water supply increases the severity of drought. For policy purposes, drought becomes an issue when it results in a water supply deficiency: less water is available than the average amount for irrigation, municipal and industrial supply (M&I), energy production, preservation of endangered species, and other needs. At the national level, drought is monitored and reported in an index known as the U.S. Drought Monitor, which synthesizes various drought indices and impacts, and represents a consensus view of on-going drought conditions between academic and federal scientists.

Drought Is Relative

"Normal" conditions can vary considerably from region to region. For example, in late January 2009, extreme drought simultaneously gripped south central Texas and northern California, according to the U.S. Drought Monitor.[9] (See **Figure 1**.) However, extreme drought means something different to the city of Midland, in south central Texas, than it does for Sacramento, in northern California. Midland receives an average total of 1.83 inches of rain for the three-month period from November through January of each year.[10] In contrast, Sacramento receives an average of 8.48 inches over the same time period.[11] From November 2008 through January 2009, Sacramento received 5.32 inches, nearly three times the average precipitation for Midland, but only 62% of what Sacramento normally receives. Both cities faced extreme drought, but what is "normal" for each city is different.

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[6] NDMC, at http://www.drought.unl.edu/whatis/what.htm.

[7] Evapotranspiration may be defined as the loss of water from a land area through transpiration from plants and evaporation from the soil and surface water bodies such as lakes and ponds.

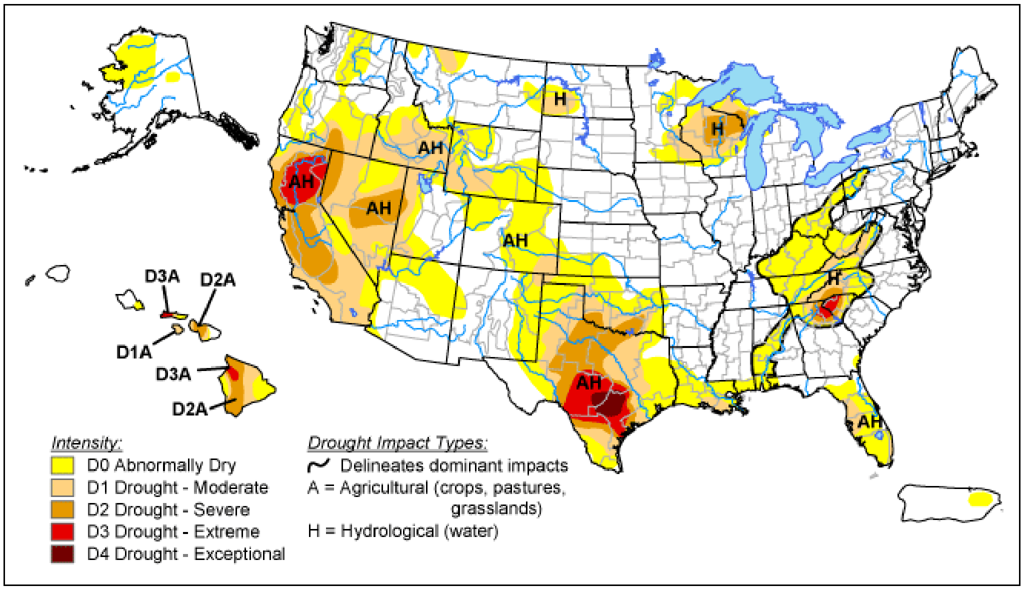
[8] NDMC, at http://www.drought.unl.edu/whatis/concept.htm.

[9] See U.S. Drought Monitor at http://www.drought.unl.edu/dm/monitor.html.

[10] The National Weather Service Forecast Office, Midland/Odessa, Texas, at http://www.weather.gov/climate/index.php?wfo=maf.

[11] The National Weather Service Forecast Office, Sacramento, CA, at http://www.weather.gov/climate/index.php?wfo=sto.

Figure 1. Extent of Drought in the United States on January 27, 2009



Source: Drought Monitor, at http://drought.unl.edu/dm/archive.html, January 27, 2009.

To deal with these differences, meteorologists use the term meteorological drought—usually defined as the degree of dryness relative to some average amount of dryness and relative to the duration of the dry period. Meteorological drought is region-specific because atmospheric conditions creating precipitation deficiencies vary from region to region, as described above for Sacramento and Midland.

Drought Is Multifaceted

The Drought Monitor uses an "A" to indicate that the primary physical effects are agricultural (crops, pastures, and grasslands) and an "H" to indicate that the primary impacts are hydrological (to water supplies such as rivers, groundwater, and reservoirs).[12] When both effects are apparent, the letters are combined, appearing as "AH" for both Sacramento and Midland (see **Figure 1**). The Drought Monitor maps thus indicate the severity of a drought, ranging from abnormally dry (shown as D0 on the maps) to exceptional drought (shown as D4), as well as the primary physical effects that are important to the region affected (A or H). How these conditions are assessed and how drought is classified are discussed below.

Drought Classification

To assess and classify the intensity and type of drought, certain measures, or drought indices, are typically used. Drought intensity, in turn, is the trigger for local, state, and federal responses that can lead to the flow of billions of dollars in relief to drought-stricken regions.[13] The classification

[12] U.S. Drought Monitor, at http://www.drought.unl.edu/dm/classify.htm.

[13] For example, the Palmer Drought Index has been widely used by the U.S. Department of Agriculture to determine when to grant emergency drought assistance. See NDMC at http://drought.unl.edu/whatis/indices.htm#pdsi.

of drought intensity, such as that shown in **Figure 1** for January 27, 2009, may depend on a single indicator or several indicators, often combined with expert opinion from the academic, public, and private sectors. The U.S. Drought Monitor uses five key indicators,[14] together with expert opinion, with indices to account for conditions in the West where snowpack is relatively important, and with other indices used mainly during the growing season.[15] The Drought Monitor intensity scheme—D0 to D4—is used to depict broad-scale conditions but not necessarily drought circumstances at the local scale. For example, the large regions depicted as red in **Figure 1** faced severe drought conditions in early 2008, but they may contain local areas and individual communities that experienced less (or more) severe drought.

The "A" and "H" terms shown in **Figure 1** give additional information on the nature of the drought in the affected region. Agricultural drought ("A") can be defined as when there is insufficient moisture to meet the needs of a particular crop at a particular time.[16] For example, deficient topsoil moisture during planting might hinder germination and affect the final yield, even if moisture is replenished later in the growing season. However, if enough moisture is available for early growth requirements, although below normal levels, the final yield may not be affected if subsoil moisture is replenished over the length of the growing season.[17]

Hydrological drought ("H") can be defined as deficiencies in water supplies, as measured by stream flows, lake or reservoir levels, or elevation of the ground water surface. Hydrological drought usually lags behind agricultural drought because it takes longer for deficiencies in precipitation to affect the broader hydrologic system. Lack of rainfall during a critical part of the growing season may have an immediate impact on farmers—an agricultural drought—but the deficiency may not affect reservoir or river levels for many months.[18] Because a hydrological drought affects the broader hydrologic system, such as one or several river basins, a severe hydrological drought could exacerbate competition among water uses: irrigation, navigation, recreation, M&I, energy production, preservation of endangered species, and others.

Examples: The Southeast and California Droughts

An example of hydrological drought was the 2007-2008 drought in the southeastern United States. A persistent severe drought in the region, beginning with below-average rainfall in the spring of 2006,[19] exacerbated an ongoing interstate conflict involving Alabama, Florida, and Georgia over water allocation in the Apalachicola-Chattahoochee-Flint (ACF) river system. The decision to draw down Lake Lanier, the uppermost federal reservoir in the ACF basin, in the fall of 2007 to support minimum flows in the lower basin Apalachicola River triggered concerns from Atlanta's municipal and industrial water users over loss of their principal water supply.[20]

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[14] The five key indicators include the Palmer Drought Index, the Climate Prediction Center soil moisture model, U.S. Geological Survey weekly streamflow data, the Standardized Precipitation Index, and short- and long-term drought indicator blends. For a discussion of drought indices, see the NDMC, at http://www.drought.unl.edu/whatis/indices.htm.

[15] U.S. Drought Monitor, at http://www.drought.unl.edu/dm/classify.htm.

[16] NASA Earth Observatory, at http://earthobservatory.nasa.gov/Library/DroughtFacts/.

[17] NDMC, at http://www.drought.unl.edu/whatis/concept.htm.

[18] Ibid.

[19] NOAA, The National Weather Service, Southeast River Forecast Center, *When Did the Drought Begin, a Focus on the North Georgia and Atlanta Areas* (Nov. 16, 2007), at http://www.srh.noaa.gov/alr/drought/Journal111607.pdf.

[20] For more information on the ACF drought conflict, see CRS Report RL34326, *Apalachicola-Chattahoochee-Flint* (continued...)

Conversely, efforts to halt the drawdown drew criticism from downstream interests concerned about species protection and energy production.

California's Drought Worsens in 2009

Drought conditions in 2008 that prompted California Governor Schwarzenegger to declare a statewide drought on June 4, 2008, are continuing into 2009. On January 29, 2009, the California Department of Water Resources (DWR) announced that California average snow water content in the Sierra Nevada was 61% of normal for the state: 49% of normal in the northern Sierra, 63% of normal in the central Sierra, and 68% of normal in the southern Sierra. DWR Director Lester Snow concluded that "California is headed for a third dry year. We may be at the start of the worst California drought in modern history." Rain and snowstorms in February improved the outlook somewhat, but the precipitation was not enough to forestall significant cuts to federal and state water supplies. As of Februrary 23, 2009, DWR's California Data Exchange Center noted that the California average snow water content in the Sierra Nevada was 73% of normal for the state: 70% of normal in the northern Sierra, 72% of normal in the central Sierra, and 79% of normal in the southern Sierra.

The DWR noted in January that Lake Oroville, the principal storage reservoir for the State Water Project (SWP), was at 28% capacity, which is 43% of the storage average for the time of year. Recent projections are for 35% capacity, still well below average. Lake Oroville has a capacity of 3.5 million acre feet, which is approximately 60% of the total capacity of the SWP system of 5.8 million acre feet. Based on the snow survey results, the DWR stated on February 20, 2009, that only 15% of requested SWP water will be delivered to SWP contractors in the Bay Area, San Joaquin Valley, central coast, and southern California. More than 25 million California residents and more than 750 acres of farmland are normally served by SWP water supplies.

Many Californians also rely on federal Central Valley Project (CVP) water deliveries managed by the U.S. Dept. of the Interior's Bureau of Reclamation. On January 23, 2009, Reclamation noted that capacity in five key CVP reservoirs ranged from 22% of normal capacity to 48% of normal, averaging just 35% of normal capacity. This figure is 52% of average for the last 15 years—the time period since the last major, multi-year drought in California. February precipitation did not measurably alter Reclamation's predictions of exceeding low water supply allocations. On February 20, 2009, Reclamation announced the third straight year of critically dry conditions and made the formal announcement that CVP water supply deliveries for now would be 50% of contracted amounts for municipal and industrial water (M&I) contractors (with exceptions for public health and safety); 75% for senior water rights holders north of the Delta and 77% for those south of the Delta; 75% of level II refuge water supplies (30% of "optimum" level IV supplies); and 0% to agricultural water service contractors (generally, those with water rights junior to senior water rights holders noted above) north and south of the Delta. The CVP in a normal year typically supplies water to 2 million M&I users and 3 million acres of farmland.

Conditions and stated delivery allocations may change if the Sierra receives above average amounts of precipitation throughout the remainder of the winter. In January 2008, snow water content for the northern, central, and southern Sierra was higher than normal, but an exceptionally dry spring nullified much of the benefit from the early season snowpack. A worst-case scenario for 2009 would be continued low snow water content in the mountains combined with a dry spring.

Sources: Governor of the State of California, Office of the Governor, press release (June 4, 2008), at http://gov.ca.gov/index.php?/press-release/9796/; California Department of Water Resources, press release (Jan. 29, 2009), at http://www.water.ca.gov/news/; California Department of Water Resources, press release (Jan. 31, 2008), at http://www.water.ca.gov/news/archive/index.cfm?yr=2008; CDEC hydrologic data (Feb. 23, 2009) at http://cdec.water.ca..gov/cgi-progs/reports/EXECSUM; and Reclamation press release (Feb. 20, 2009) at http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=26721.

(...continued)

(ACF) Drought: Federal Water Management Issues, by Nicole T. Carter et al.; and CRS Report RL34440, *Apalachicola-Chattahoochee-Flint Drought: Species and Ecosystem Management*, by M. Lynne Corn, Kristina Alexander, and Eugene H. Buck.

Another example is the ongoing California drought, classified as both "A" and "H" (see **Figure 1**). The California situation is complicated by decades of tension between water supply deliveries for irrigation and M&I uses, and preserving water flows to protect threatened and endangered species. On June 4, 2008, Governor Arnold Schwarzenegger declared a statewide drought, responding to dry conditions and lower than normal snowpack. Dry conditions have continued into the winter of 2009 (see box).

California's dry conditions exacerbated an already tight water supply where federal and state water deliveries had been reduced, in response to a court order, to prevent extinction of the Delta Smelt.[21] The governor's decision to declare drought in 2008 reflected the meteorological constraints on water supply together with the court-imposed restrictions on water supplies in favor of an endangered species. This combination of factors underscores why drought is complex and not simply a result of dry conditions. Long-simmering tensions between supply and demand in California are made worse by drought conditions.

Responding to Drought

When a drought is declared by the U.S. President or by a state governor for a locality or region of the United States, it sets in motion a series of alerts, recommendations, activities and possible restrictions at the local, regional, or state level depending on the drought length and severity. Ultimately, a multiyear severe drought could initiate a federal response and transfer of federal dollars to the affected area. Before drought severity reaches a level requiring a federal response, however, many states take action. As of 2006, 37 states had some form of drought management, mitigation, or response plan, according to the National Drought Mitigation Center.[22] For example, the governor of Alabama issued a drought declaration on March 21, 2008, placing the 10 northernmost counties under an emergency drought declaration level, in accordance with the draft Alabama Drought Management Plan.[23] The emergency drought declaration level for Alabama is its most extreme category of drought. According to Alabama's Plan, declaring drought does not "automatically invoke a required response from the various categories of water users";[24] however, upon confirmation of a drought emergency, the governor's office may issue "public statements that a drought emergency exists, disaster declarations, and the appropriate implementation of water conservation and drought emergency ordinances."[25]

Federal Aid

If the effects of a drought overwhelm state or local resources, the President, at the request of the state governor, is authorized under the Stafford Act (42 U.S.C. 5121 et seq.) to issue major disaster or emergency declarations that result in the distribution of federal aid to affected

[21] Natural Resources Defense Council v. Kempthorne, No. 1:05-cv-1207 OWW GSA (E.D. Cal., Dec. 14, 2007).

[22] Their tally, however, may not reflect plans that are in draft form. For more information, see http://www.drought.unl.edu/plan/stateplans.htm.

[23] For more information, see http://www.adeca.alabama.gov/Office%20of%20Water%20Resources/Document%20Library/20080321%20-%20DroughtAdvisoryMap_Final.pdf.

[24] Alabama Drought Management Plan, p. 7.

[25] Ibid., p. 8.

parties.[26] For example, on October 20, 2007, the governor of Georgia requested a presidential drought disaster declaration because of prolonged exceptional drought conditions existing in the northern third of the state.[27] No such presidential declaration has occurred in response to the request from Georgia. More frequently, a state governor requests drought disaster assistance through the U.S. Secretary of Agriculture, who can declare an agricultural disaster as a result of drought and make available low-interest loans and other emergency assistance through various U.S. Department of Agriculture programs.[28] The U.S. Army Corps of Engineers (Corps) and the U.S. Bureau of Reclamation (Reclamation) also have limited drought emergency authorities and funding (e.g., the Reclamation States Emergency Drought Act, as amended [43 U.S.C. 2211 *et seq*.]).

Under current U.S. farm policy, financial losses caused by drought and other natural disasters are mitigated primarily via the federal crop insurance program (administered by the U.S. Department of Agriculture's Risk Management Agency). Since the severe drought of 1988, Congress has also regularly made supplemental financial assistance available to farmers and ranchers, primarily in the form of crop disaster payments and emergency livestock assistance. Since 2000, the federal contribution to the crop insurance program has averaged about $3.3 billion per year, mostly in the form of a premium subsidy and reimbursements to private insurance companies.[29] Another $1.1 billion in ad-hoc crop disaster payments has been made available on average each year since 2000.

Federal Facilities

Even absent federal drought disaster declarations, sustained hydrological drought can affect operations of federally managed reservoirs, dams, locks, hydroelectric facilities and other components of the nation's water infrastructure. As discussed above, the 2007-2008 Southeast drought directly affected how the Corps manages its facilities in the ACF basin. Similarly, current drought conditions in California coupled with declining fish species have resulted in operational changes to Reclamation facilities, including significantly reduced water deliveries to Central Valley Project contractors, as well as to California's State Water Project (SWP) contractors. Reclamation, whose facilities currently serve over 31 million people and deliver a total of nearly

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[26] For more information about the Stafford Act, see CRS Report RL33053, *Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities, and Funding*, by Keith Bea.

[27] The last presidential drought disaster declaration in the continental United States was for New Jersey in 1980. More recent drought declarations have been issued for U.S. territories in the Pacific. See http://www.fema.gov/news/disasters.fema.

[28] The Secretary of Agriculture declared a disaster for every county in Georgia in 2007 because of the ongoing drought and severe April 2007 freeze. For more information on this program, see CRS Report RS21212, *Agricultural Disaster Assistance*, by Ralph M. Chite. See also CRS Report RL34207, *Crop Insurance and Disaster Assistance in the 2008 Farm Bill*, by Ralph M. Chite.

[29] The causes of crop loss can vary dramatically from year to year, although drought is one of the most common, if not the most common, cause of crop loss. See CRS Report RS21212, *Agricultural Disaster Assistance*, by Ralph M. Chite, and CRS Report RL31095, *Emergency Funding for Agriculture: A Brief History of Supplemental Appropriations, FY1989-FY2009*, by Ralph M. Chite for more information.

30 million acre-feet[30] of water annually, faces operational challenges because of conflicts among its water users during drought in states it serves.[31]

Severe drought conditions in 2001 exacerbated competition for scarce water resources in the Klamath River Basin, on the Oregon-California border, among farmers, Indian tribes, commercial and sport fishermen, other recreationists, federal wildlife refuge managers, environmental groups, and state, local, and tribal governments. Reclamation's decision in April 2001 to withhold water from farmers for instream flows for three fish species listed as endangered or threatened under the Endangered Species Act sparked congressional debate that continues today.

The droughts in California, the Southeast, and the Klamath River Basin underscore an underlying difficulty of managing federal reservoirs to meet multipurpose water needs. In the future, the United States may face severe and sustained periods of drought not experienced in the 20th century. If so, disputes over water management like those in California, the ACF basin, and Klamath River Basins may increasingly determine short-term actions by Reclamation and the Corps, and result in long-term consequences for congressional oversight and funding.[32]

What Causes Drought in the United States

The immediate cause of drought is:

> the predominant sinking motion of air (subsidence) that results in compressional warming or high pressure, which inhibits cloud formation and results in lower relative humidity and less precipitation. Regions under the influence of semipermanent high pressure during all or a major portion of the year are usually deserts, such as the Sahara and Kalahari deserts of Africa and the Gobi Desert of Asia.[33]

Desert regions that experience semipermanent high pressure are arid regions of the globe, reflecting persistent dry climate conditions, as distinguished from drought, which is a shorter-term departure from wetter average conditions.

Prolonged droughts occur when atmospheric conditions leading to the predominant sinking motion of air over a certain geographic area, as a result of large-scale anomalies in atmospheric circulation patterns, persist for months or years.[34] Predicting drought, however, is difficult because the ability to forecast surface temperature and precipitation depends on a number of key variables, such as air-sea interactions, topography, soil moisture, land surface processes, and how

[30] One acre-foot is enough water to cover one acre of land one foot deep. An acre-foot is equivalent to 325,851 gallons. For more information about federal water supply programs, see CRS Report RL30478, *Federally Supported Water Supply and Wastewater Treatment Programs*, coordinated by Claudia Copeland and others.

[31] Reclamation is a central player in water resource management in the West, and a devastating drought at the end of the 19th century was probably one of the many factors that led to the 1902 Reclamation Act that launched the federal reclamation effort and Reclamation itself. (See Marc Reisner, *Cadillac Desert*, (New York, New York, Penguin Books, 1986), pp. 108-109. Other research suggests that the failures of some late 19th century private irrigation projects, undertaken following passage of the Carey Act [see footnote 47], may have occurred in part due to drought conditions.)

[32] For a discussion of some of these policy issues, see CRS Report R40180, *Water Resources Issues in the 111th Congress*, coordinated by Betsy A. Cody.

[33] See NDMC, at http://www.drought.unl.edu/whatis/predict.htm.

[34] Ibid.

other aspects of the dynamics of weather systems influence each other.[35] Scientists seek to understand how all these variables interact and to further the ability to predict sustained and severe droughts beyond a season or two in advance.

In the tropics, a major portion of the atmospheric variability over months or years seems to be associated with variations in sea surface temperatures (SSTs). Since the mid-to late-1990s, scientists have increasingly linked drought in the United States to SSTs in the tropical Pacific Ocean. Cooler-than-average SSTs in the eastern tropical Pacific region—"la Niña-like" conditions—have been shown to be correlated with persistently strong drought conditions over parts of the country, particularly the West.[36] A number of recent studies have made the connection between cooler SSTs in the eastern Pacific and the 1998-2004 western drought,[37] three widespread and persistent droughts of the late 19th century,[38] and past North American "megadroughts" that occurred between approximately 900 and 1300 A.D.[39] The precolonial megadroughts apparently lasted longer and were more extreme than any U.S. droughts since 1850 when instrumental records began. Some modeling studies suggest that within a few decades the western United States may again face higher base levels of dryness, or aridity, akin to the 900-1300 A.D. period.[40]

El Niño-Southern Oscillation (ENSO)

Under normal conditions, the trade winds blow towards the west in the tropical Pacific Ocean, piling up the warm surface waters so that the ocean surface off Indonesia is one-half meter higher than the ocean off Ecuador. As a result, deep and cold water flows up to the surface (upwelling) off the west coast of South America. The upwelling waters are 8 degrees Celsius (14.4 degrees Fahrenheit) cooler than waters in the western Pacific. During El Niño, the trade winds relax, upwelling off South America weakens, and sea surface temperatures rise. The El Niño events occur irregularly at intervals of 2-7 years, and typically last 12-18 months. These events often occur with changes in the Southern Oscillation, a see-saw of atmospheric pressure measured at sea level between the western Pacific and Indian Ocean, and the eastern Pacific. Under normal conditions, atmospheric pressure at sea level is high in the eastern Pacific, and low in the western Pacific and Indian Oceans. As implied by its name, the atmospheric pressure oscillates, or see-saws between east and west; and during El Niño the atmospheric pressure builds up to abnormally high levels in the western tropical Pacific and Indian Oceans—the El Niño-Southern Oscillation, or ENSO. During a La Niña, the situation is reversed: abnormally high pressure builds up over the eastern Pacific, the trade winds are abnormally strong, and cooler-than-normal sea surface temperatures occur off tropical South America. Scientists use the terms ENSO or ENSO cycle to include the full range of variability observed, including both El Niño and La Niña events.

Source: Tropical Ocean Atmosphere Project, Pacific Marine Environmental Laboratory, at http://www.pmel.noaa.gov/tao/proj_over/ensodefs.html.

[35] Ibid.

[36] Cook et al., 2007.

[37] Hoerling, Martin and Arun Kumar, "The perfect ocean for drought," *Science*, vol. 299 (Jan. 31, 2003), pp. 691-694. Hereafter referred to as Hoerling and Kumar, 2003.

[38] Herweiger, Celine, Richard Seager, and Edward Cook, "North American droughts of the mid to late nineteenth century: a history, simulation and implication for Mediaeval drought," *The Holocene*, vol. 15, no. 2 (Jan. 31, 2006), pp. 159-171. Hereafter referred to as Herweiger et al., 2006.

[39] Cook et al., 2007.

[40] Richard Seager et al., "Model projections of an imminent transition to a more arid climate in southwestern North America," *Science*, vol. 316 (May 25, 2007): pp. 1181-1184.

Although the relationship between cooler-than-normal eastern tropical Pacific SSTs (La Niña-like conditions) and drought is becoming more firmly established, meteorological drought is probably never the result of a single cause. Climate is inherently variable, and accurately predicting drought for one region in the United States for more than a few months or seasons in advance is not yet possible because so many factors influence regional drought. What is emerging from the scientific study of drought is an improved understanding of global linkages—called teleconnections by scientists—between interacting weather systems, such as the El Niño-Southern Oscillation, or ENSO. (See box for a description of ENSO.) For example, some scientists link La Niña conditions between 1998 and 2002 with the occurrence of near-simultaneous drought in the southern United States, southern Europe, and Southwest Asia.[41]

Prehistorical and Historical Droughts in the United States

Some scientists refer to severe drought as " ... the greatest recurring natural disaster to strike North America."[42] That claim stems from a reconstruction of drought conditions that extends back over 1,000 years, based on observations, historical and instrumental records where available, and on tree-ring records or other proxies[43] in the absence of direct measurements. What these reconstructions illustrate is that the coterminous United States have experienced periods of severe and long-lasting drought in the western states and also in the more humid East and Mississippi Valley. The drought reconstructions from tree rings apparently confirm that severe multidecadal drought occurred in the American Southwest during the 13th century, which anthropologists and archeologists suspect profoundly affected Pueblo society. Tree ring drought reconstructions also document severe drought during the 14th, 15th, and 16th centuries in the central and lower Mississippi Valley possibly contributing to the disintegration of societies in that region.[44]

More recently, a combination of tree ring reconstructions and other proxy data, historical accounts, and some early instrumental records identify three periods of severe drought in the 19th century: 1856-1865 (the "Civil War drought"), 1870-1877, and 1890-1896.[45] The 1856-1865 drought, centered on the Great Plains and Southwest, was the most severe drought to strike the region over the last two centuries, according to one study.[46] The 1890-1896 drought coincided with a period in U.S. history of federal encouragement of large-scale efforts to irrigate the relatively arid western states via the Carey Act,[47] and with congressional debate over a much larger federal role in western states irrigation which led to the Reclamation Act of 1902.

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[41] Hoerling and Kumar, 2003.

[42] Cook et al., 2007.

[43] Proxies are indirect measurements typically used where direct measurements are unavailable. Tree rings can be used as a proxy for measuring dryness and drought. Similarly, ice cores from glaciers and polar caps can be used as proxies for measuring atmospheric temperatures and carbon dioxide concentrations from thousands of years ago.

[44] Cook et al., 2007.

[45] Herweiger et al., 2006.

[46] Ibid.

[47] The Carey Act, signed into law on Aug. 18, 1894 (Chapter 301, Section 4, 28 Stat. 422), initially made available up to 1 million acres of federal land in each state provided that the state met several requirements for the eventual development of water resources for reclamation. Some observers have suggested that the failure of the Carey Act to foster irrigation projects in all the land made available, compounded in part by the 1890-1896 drought, led to the Reclamation Act of 1902 and the emergence of the Bureau of Reclamation in the 20th century. (See Marc Reisner, *Cadillac Desert*, (New York, New York, Penguin Books, 1986)).

In the 20th century, the 1930s "Dust Bowl" drought and the 1950s Southwest drought are commonly cited as the two most severe multiyear droughts in the United States.[48] (The 1987-1989 drought was also widespread and severe, mainly affecting the Great Plains but also instigating extensive western forest fires, including the widespread Yellowstone fire of 1988.) According to several studies, however, the 19th and 20th century severe droughts occurred during a regime of relatively less arid conditions compared to the average aridity in the American West during the 900 to 1300 A.D. megadroughts. One study indicates that the drought record from 900 to 1300 A.D. shows similar variability—drought periods followed by wetter periods—compared to today, but the average climate conditions were much drier and led to more severe droughts.[49]

Drought Forecasts for the United States

Predicting the severity and duration of severe drought over a specific region of the country is not yet possible more than a few months in advance because of the many factors that influence drought. Nevertheless, some modeling studies suggest that a transition to a more arid average climate in the American West, perhaps similar to conditions in precolonial North America, may be underway.[50] Some studies have suggested that human influences on climate, caused by emissions of greenhouse gases, may be responsible for a drying trend.[51] Whether future greenhouse gas-driven warming can be linked to La Niña-like conditions, discussed above as a possible mechanism for causing drought conditions in the United States, is unclear.[52]

A likely consequence of higher temperatures in the West would be higher evapotranspiration, reduced precipitation, and decreased spring runoff. A recent, controversial study asserts that water storage in Lake Mead on the Colorado River has a 50% probability by 2021 to "run dry" and a 10% chance by 2014 to drop below levels needed to provide hydroelectric power under current climate conditions and without changes to water allocation in the basin.[53] This study raised awareness of the vulnerability of western water systems, but drew criticism that global climate models are insufficient to forecast climate change effects at the regional scale.[54] Some western water officials were especially critical of the report's assertions. One explained that Reclamation and other agencies recently developed new criteria for the allocation of Colorado River water in times of shortages (shortage criteria), including drought, and commented that the likelihood that Lake Mead would run dry was "absurd."[55] The study was based on predictions of future warming

[48] Fye, F., D.W. Stahle, and E.R. Cook, "Paleoclimate analogs to twentieth century moisture regimes across the United States," *Bulletin of the American Meteorological Society*, vol. 84, pp. 901-909.

[49] For example, one report showed that 41% of the area studied in the American West was affected by drought during the years 900 to 1300, versus 30% between 1900 and 2003, a 29% difference. See Cook et al., 2007.

[50] Richard Seager, et al., "Model projections of an imminent transition to a more arid climate in southwestern North America," *Science*, vol. 316 (May 25, 2007): pp. 1181-1184.

[51] Tim P. Barnett, et al., "Human-induced changes in the hydrology of the western United States," *Science*, vol. 319 (Feb. 22, 2008), pp. 1080-1082.

[52] Cook et al., 2007.

[53] Tim P. Barnett and David W. Pierce, "When will Lake Mead go dry?" *Water Resources Research*, vol. 44 (March 29, 2008), p. W03201, DOI:10.1029/2007WR006704.

[54] Felicity Barringer, "Lake Mead could be within a few years of going dry, study finds," *New York Times* (Feb. 13, 2008); at http://www.nytimes.com/2008/02/13/us/13mead.html.

[55] Jenny Dennis, "Stunned Scientists: 'When Will Lake Mead go Dry?'" *Rim Country Gazette* (February 28, 2008), quoting Larry Dozier, Central Arizona Project deputy general manager, at http://ahacreativeink.com/newspapers/featurepage02-28-08GAZETTE.pdf.

in the West without increased precipitation. If reduced runoff predictions are borne out, then water allocation policies for regions like the Colorado River basin may need to be revisited.[56]

Policy Challenges

Severe drought can exacerbate water competition in nearly all regions of the United States at some time; in other words, no area of the country is immune to drought. However, several key factors have made it difficult to address drought policy in a systematic fashion at the national level. Some key policy challenges include:

- the "creeping" nature of drought;
- split federal and non-federal drought response and management responsibilities;
- a patchwork of federal programs and program oversight, and little coordination at the federal level.

Drought conditions often develop slowly and are not easily identified. Consequently, drought declarations are made well after the onset of drought conditions—typically once impacts are felt. This situation makes it difficult to mitigate or prevent drought impacts. Further, even though drought is certain to occur, the unpredictability of its timing, location, and severity makes it difficult to address systematically.

When severe meteorological drought affects a region, the supply of available water often shrinks before demand is reduced. Adjusting the demand for water as supplies shrink during droughts is difficult. Federal, state, and local authorities make water resource decisions within the context of multiple and often conflicting laws and objectives, competing legal decisions, and entrenched institutional mechanisms, including century-old water rights and long-standing contractual obligations (i.e., long-term water delivery and power contracts). The ongoing dispute over water resources in the ACF basin between Georgia, Alabama, and Florida exemplifies the challenge of reducing demand for water when drought reduces the supply.

A mismatch between supply and demand during droughts underscores the responsibility of local, state, and federal authorities, as well as the private sector, to anticipate the influence of drought and plan accordingly. The federal government has several drought monitoring and response programs, the latter of which are primarily aimed at easing the economic impacts of drought. Drought planning and mitigation responsibilities lie largely at the non-federal level (i.e., at the state and local levels), but the federal government also provides some drought planning assistance. Additionally, the federal government often provides emergency funding for drought relief. The National Drought Commission and others have noted, however, that federal relief programs and emergency funding provide little incentive for state and local planning and drought mitigation.

A further challenge is that there is no cohesive national drought policy at the federal level, nor is there a lead agency that coordinates federal programs. Rather, several federal programs have been developed over the years, often in response to specific droughts. Additionally, occasional

[56] CRS has not determined to what degree scenarios considered in the Barnett/Pierce study overlapped with those considered in studies supporting the new shortage criteria for Colorado River water allocations under the Colorado River Compact.

widespread economic effects have prompted creation of several federal relief programs, These programs in turn are overseen by several different congressional committees.

Legislative Action

Congress has long recognized the lack of coordinated drought planning and mitigation activities among federal agencies and the predominance of a crisis management approach to dealing with drought. Over the last decade, legislative action has focused on the question of whether there is a need for a national drought policy. For example, in 1998, Congress passed the National Drought Policy Act (P.L. 105-199), which created a National Drought Policy Commission. Congress also considered, but did not enact, legislation creating a National Drought Council during deliberations on the 2008 farm bill. Congress has considered recommendations from the commission's 2000 report; to date, it has enacted one part of the recommendations. Both the commission findings and the proposed council are discussed below.

The National Drought Policy Act of 1998

In passing the National Drought Policy Act of 1998, Congress found that "at the Federal level, even though historically there have been frequent, significant droughts of national consequences, drought is addressed mainly through special legislation and ad hoc action rather than through a systematic and permanent process as occurs with other natural disasters."[57] Further, Congress found an increasing need at the federal level to emphasize preparedness, mitigation, and risk management. Those findings are consistent with a recognition of the inevitability, albeit unpredictability, of severe drought occurring.

The act created the National Drought Policy Commission, and required the commission to conduct a study and submit a report to Congress on:

- what is needed to respond to drought emergencies;
- what federal laws and programs address drought;
- what are the pertinent state, tribal, and local laws; and
- how various needs, laws, and programs can be better integrated while recognizing the primacy of States to control water through state law.

In May 2000 the commission submitted its report,[58] which included 29 specific recommendations to achieve the goals of national drought policy, including the establishment of a National Drought Council. (The Appendix of this report lists the five goals in the commission's report.) As background for its recommendations, the commission noted the patchwork nature of drought programs, and that despite a major federal role in responding to drought, no single federal agency leads or coordinates drought programs—instead, the federal role is more of "crisis management."[59] Most of the specific recommendations were targeted at the President and federal agencies, coupled with calls for Congress to fund drought-related activities in support of the

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[57] The National Drought Policy Act of 1998, P.L. 105-199 (42 U.S.C. 5121 note).

[58] The report is available via the National Drought Mitigation Center, at http://www.ndmc.unl.edu/pubs/pfd21main.html.

[59] See full report, p. 1, at http://www.ndmc.unl.edu/pubs/pfd21main.html.

recommendations. An overarching recommendation was for Congress to pass a National Drought Preparedness Act to implement the commission's recommendations.

National Drought Preparedness Legislation and the 2008 Farm Bill

National Drought Preparedness Act bills were introduced in 2002 (107th Congress), 2003 (108th Congress), and 2005 (109th Congress), but were not enacted. Similar stand-alone legislation was introduced in the 110th Congress; however, the House-passed version of H.R. 2419, the Farm, Nutrition, and Bioenergy Act of 2008 (also known as the 2008 farm bill), contained a section creating a National Drought Council. This section of the 2008 farm bill would have charged the council with creating a national drought policy action plan that would incorporate many of the components recommended in the commission's report; however, it was not included in the conference agreement. The Senate version of H.R. 2419 did not contain a similar section, although the Senate bill authorized permanent disaster payments in hopes of precluding the need for ad hoc disaster payments. The conference agreement on the 2008 farm bill (P.L. 110-246, enacted June 18, 2008) included a new $3.8 billion trust fund to cover the cost of making agricultural disaster assistance available on an ongoing basis over the next four years.

National Integrated Drought Information System

Although Congress has not enacted comprehensive national drought preparedness legislation, it acted on the second of five commission goals by passing the National Integrated Drought Information System (NIDIS) Act of 2006 (P.L. 109-430). That goal called for enhanced observation networks, monitoring, prediction, and information delivery of drought information. P.L. 109-430 established NIDIS within the National Oceanic and Atmospheric Administration (NOAA) to improve drought monitoring and forecasting abilities.[60]

Conclusion

While many water allocation and other water management responsibilities largely lie at the state or local level, localities and individuals often look to the federal government for relief when disasters occur. Over time, Congress has created various drought programs, often in response to specific droughts and authored by different committees. Crafting a systematic or broad drought policy that might encompass the jurisdiction of many different congressional committees is often difficult. This is similar to the situation for flood policy, and water policy in general, at the national level. The National Drought Policy Commission recognized these patterns, and they underlie many of the commission's recommendations.[61] The currently fragmented approach can be costly to national taxpayers; however, it is not certain that increased federal investment in drought preparation, mitigation, and improved coordination would produce more economically efficient outcomes.

The overall costs to the federal government as a result of extreme drought, apart from relief to the agricultural sector, are more difficult to assess. As discussed above, the operation of the nation's complex federal water infrastructure is affected by drought. Thus, Congress may move to

[60] More information about NIDIS is available at http://www.drought.gov.

[61] *Infra,* note 52.

examine how the two major federal water management agencies, the Corps and Reclamation, plan for and respond to severe drought and account for its impacts. For example, Congress may move to explore how a national drought policy may or may not address the complex factors that have led to the current stalemate over a tri-state water allocation agreement in the ACF basin. How a national drought policy would apply to, and potentially assist in alleviating conflicts over water use in other complex river basins managed by Reclamation and the Corps, such as the Colorado River, Klamath River, Missouri River, Sacramento and San Joaquin Rivers, is also at issue.

In its report accompanying the NIDIS Act of 2006, the House Committee on Science wrote: "Experts in drought mitigation argue that substantial losses from drought are not inevitable. With adequate forecasting and monitoring capabilities, government and business can adjust their activities and substantially mitigate the extent and severity of many impacts of drought."[62] The National Drought Policy Commission identified forecasting and monitoring activities as one important aspect of the nation's overall drought management policy, as well as numerous other facets of federal drought management. Congress may opt to revisit the commission's recommendations and reevaluate whether current federal practices could be supplemented with actions to coordinate, prepare for, and respond to the unpredictable but inevitable occurrence of drought. Given the daunting task of managing drought, Congress may also consider proposals to manage drought impacts, such as assisting localities with water supply augmentation via water conservation and reuse projects. Other proposals may include those that develop demand management techniques, such as facilitating water transfers, water markets, and variable water pricing.

[62] U.S. House, Committee on Science, National Integrated Drought Information System Act of 2006 (June 15, 2006), http://www.congress.gov/cgi-lis/cpquery/R?cp109:FLD010:@1(hr503):p. 3.

Appendix.

The following is an excerpt from the 2000 National Drought Policy Commission Report: *Preparing for Drought in the 21st Century—A Report of the National Drought Policy Commission.*

Policy Statement

- Favor preparedness over insurance, insurance over relief, and incentives over regulation.
- Set research priorities based on the potential of the research results to reduce drought impacts.
- Coordinate the delivery of federal services through cooperation and collaboration with nonfederal entities.

Goals

Goal 1. Incorporate planning, implementation of plans and proactive mitigation measures, risk management, resource stewardship, environmental considerations, and public education as the key elements of effective national drought policy.

Goal 2. Improve collaboration among scientists and managers to enhance the effectiveness of observation networks, monitoring, prediction, information delivery, and applied research and to foster public understanding of and preparedness for drought.

Goal 3. Develop and incorporate comprehensive insurance and financial strategies into drought preparedness plans.

Goal 4. Maintain a safety net of emergency relief that emphasizes sound stewardship of natural resources and self-help.

Goal 5. Coordinate drought programs and response effectively, efficiently, and in a customer-oriented manner.

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