Chapter 4

CLIMATE, DROUGHT AND WATER SUPPLY

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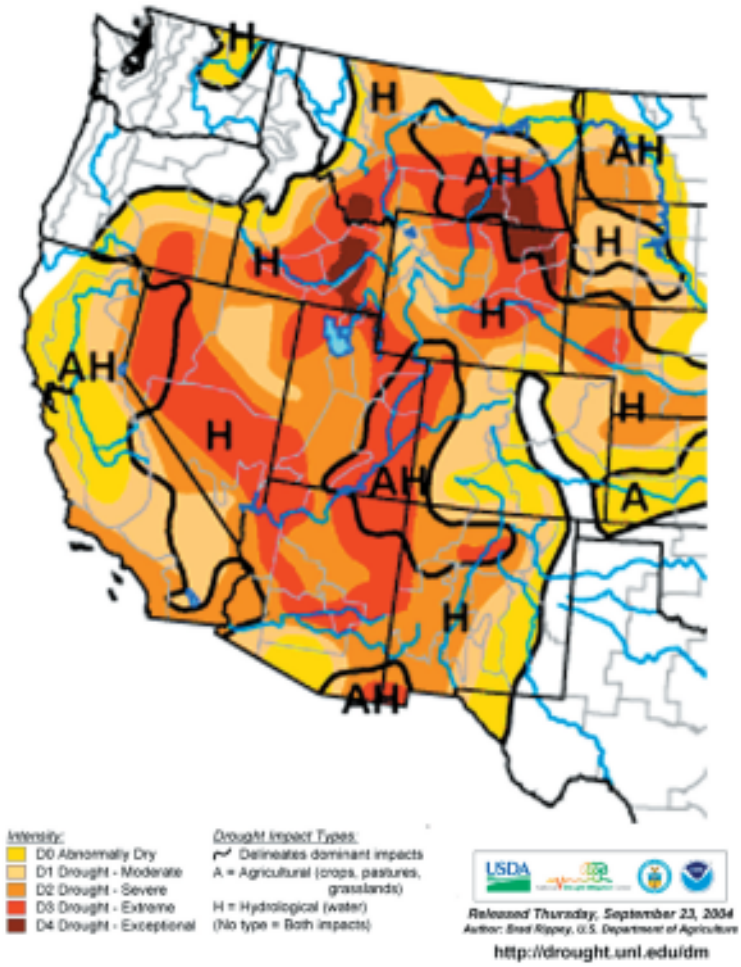
Climate drives Arizona's water supply picture through both the supply and demand sides of the equation. Air temperature has a strong impact on demand, while precipitation is our only truly renewable source of water. Improving our understanding of past conditions and improving our ability to predict likely future climate conditions will improve our adaptive capacity and limit the negative economic impacts currently associated with climate extremes. Temperature and precipitation patterns change on a daily, monthly, seasonal, inter-annual and decadal basis. **Climate conditions, defined as prevailing weather conditions over a long period of time, do not necessarily return to the same average condition, but rather the climate itself changes over time.** The southwestern United States has been unusually hot and dry in recent years, with 2002 being one of the driest years since the weather record began about a century ago. It is unclear whether this is part of a long-term trend or the result of climate variability.

CURRENT DROUGHT CONDITIONS

The National Weather Service's Arizona Drought Data site has a summary of precipitation records for 83 Arizona stations. All stations in the state have developed a precipitation deficit since 1998, the largest being Flagstaff, which has accumulated a 53.45-inch deficit. This is almost three times the total normal annual rainfall of 22.91 inches. Research by the Climate Assessment for the Southwest (CLIMAS) at the University of Arizona indicates that, across Arizona, 1999 through 2003 was one of the driest five-year periods of winter precipitation in the climate record.[1] The National Drought Monitor produces a weekly map of drought conditions

[1] For background on this subject, see http://www.ispe.arizona.edu/climas/research.html.

Figure 4.1
U.S. Drought Monitor

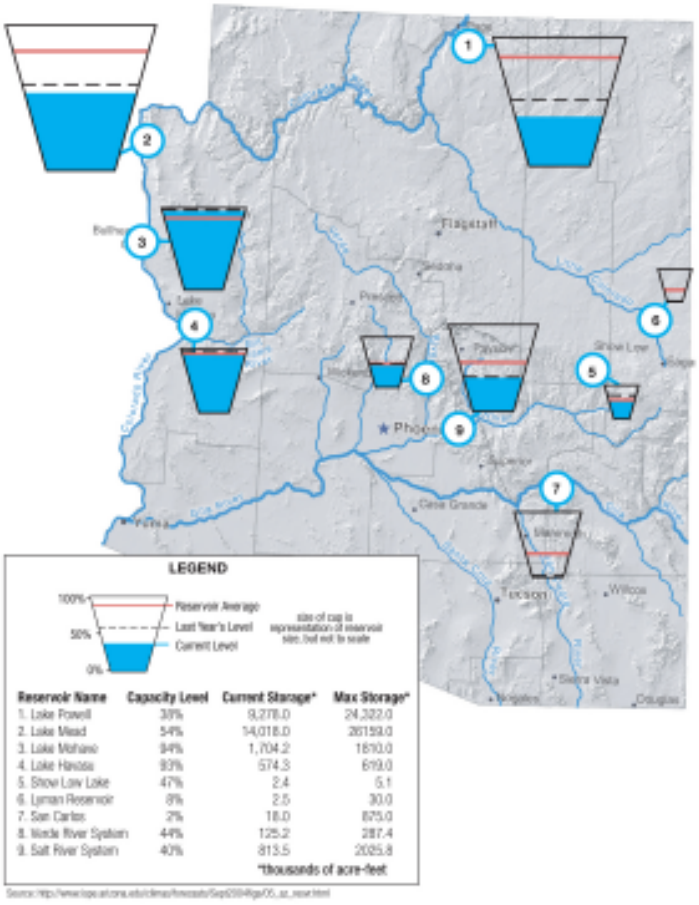


nationwide.[2] Figure 4.1 illustrates that the entire state was in some degree of drought as of September 23, 2004, ranging from abnormally dry to extreme drought.

Among the most visible impacts of the drought have been large-scale forest fires at higher elevations throughout the state, bark beetle infestations due to drought-stressed trees across the northern and eastern portions of the state, significant statewide impacts on cattle ranching due to reduction in forage and changes in habitat quality in key environmental areas. In addition, drought impacts on the water supply system have been substantial, with reservoirs on the Colorado River at below 50 percent of capacity, the lowest level since Lake Powell was first filled, Roosevelt Lake in the Salt River Project system currently at 28 percent (Figure 4.2) and groundwater level declines documented throughout Arizona. Lake Powell is below ten million acre-feet for the first time since May 1970; Lake Mead is at 14 million acre-feet for the first time since June 1964. Most other western states also have experienced critical water supply, wildfire and endangered species issues.

[2] See http://www.drought.unl.edu/dm/monitor.html.

Figure 4.2
Current Reservoir Storage



Both droughts and floods have very significant implications for water managers, because providing for adequate water supplies during droughts and limiting damage from flooding both require long-term investments in infrastructure and planning. Preparing for the extremes of climate variability is much more challenging than managing water supplies for "normal" conditions. Although Arizona currently is focused on drought, it would be incorrect and shortsighted to assume that flooding will not be a major problem in Arizona at some point in the future. Preparing for sustainability means being prepared for both ends of the water supply spectrum.

There are two primary seasons for rainfall in Arizona: the winter season (November through April), which is particularly important to Arizona water supplies, and the summer "monsoon" season (July through September). Winter precipitation is associated with widespread storms, one to several days in duration, which provide rains at lower elevations and snowfall at higher elevations.

CLIMATE "DRIVERS"

Climate conditions in the southwest United States are linked to sea surface temperatures and global circulation patterns. Understanding these climate drivers improves our ability to project

probable future climate conditions. A key factor affecting winter precipitation is the El Niño-Southern Oscillation (ENSO), which results from changes in equatorial Pacific Ocean sea surface temperatures and associated atmospheric circulation. When ENSO is in its El Niño phase due to warm temperatures in the eastern Pacific, Arizona frequently receives above average winter precipitation. In the La Nina (cool) phase of ENSO, drought conditions generally prevail in the southwest, though there are exceptions in both cases.

Summer precipitation currently is not well understood from the perspective of climate "drivers," but it is associated with the North American monsoon and typically is of high intensity and short duration. Precipitation provided by the monsoons may be locally very important from a range, forage and soil moisture perspective, but it varies substantially from place to place and is not as important as winter precipitation for filling Arizona's reservoirs.

Improved climate predictions can have great importance from an economic perspective because drought causes severe hardship for some sectors, and there are many adaptive actions that can be taken to limit impacts (Christensen *et al.*, 2004). Very significant contributions to understanding the history of climate conditions and drought over the past 1,000 years have been made by the Laboratory of Tree Ring Research at the University of Arizona and others studying a variety of proxy records such as ice, sediment and coral reef cores (Figure 4.3). For example, although the amount of water allocated among the Colorado River basin states and Mexico is 16.5 million acre-feet and the measured flow at the time of the Colorado Compact in 1922 was 15.8 million acre-feet, long-term tree ring records show an average flow of only 13.5 million acre-feet. Other evidence indicates that the average long-term flow may be even lower. Thus,

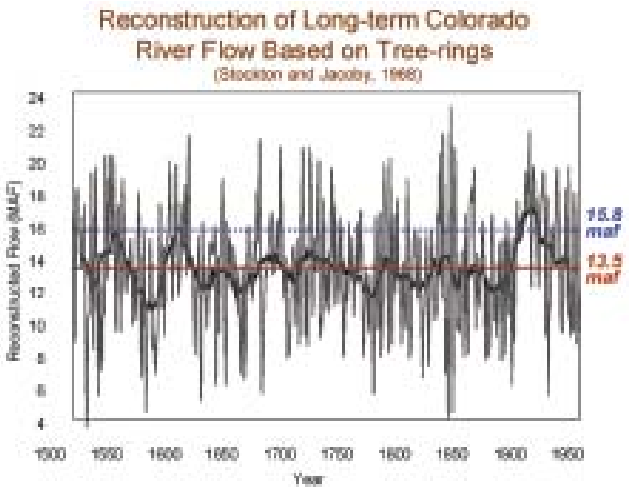


Figure 4.3 Colorado River Flow, 1500-1950.

the Colorado River is over-allocated, potentially leading to additional conflict between the states. The combination of a long-term record of climate conditions, which provides evidence of more severe, sustained droughts in the past than those experienced in this century, and new understanding of multi-decade climate variability patterns both lead to concerns about the reliability of future water supplies to serve Arizona's growing population (Jacobs and Garfin, in press).

An understanding of long-term trends in climate conditions is needed in order to give context to Arizona's water supply planning. For example, when compared to the tree-ring records of the last 1,000 years, it appears that the last quarter of the twentieth century was abnormally wet. Yet, the 30-year period from 1970 to 2000 is the time frame most commonly used to calculate the "average" climate conditions for Arizona. If this time period was anomalously wet, as most experts believe, water supply planning in the coming decades could be very problematic because our assumptions about supply availability will have been overly optimistic. The previous 30-year period of 1940 to 1970 contained the noted drought of the 1950s, which would have provided a very different view of the "average" conditions.

Rapid "step" changes from one climate regime to another, such as the recent transition from a multi-decade wet period to serious drought, may be associated with major ecological change, especially wildfires. High levels of precipitation result in a buildup of forest fuels. Drought following this buildup is likely to result in massive fire damage, such as has recently been experienced in Colorado and Arizona (Swetnam and Betancourt, 1998). Thus, climate factors need to be considered in addition to fire suppression in explaining current forest conditions.

Enhanced ability to predict probable future climate trends may be a significant tool for resource managers in the future. For example, information about the likelihood of a wet winter could allow reservoir managers to release more water to ensure that there is adequate flood flow protection. Conversely, a projection of dry conditions might result in curtailing reservoir releases. For this reason, recent increases in understanding the implications of multi-decade phases in the sea surface temperatures of both the Pacific and Atlantic Ocean basins may become very important. In the Pacific Ocean, a feature called the Pacific Decadal Oscillation (PDO) has been

associated with winter precipitation variations in the western United States (Mantua *et al.*, 1997; McCabe and Dettinger, 1999; and Sheppard *et al.*, 2002). The PDO appears to have a 20 to 30 year cycle that may be related to long-term climatic conditions in Arizona. Sea surface temperatures and western United States drought patterns since 1999 indicate the possibility that the PDO might have shifted to a phase favoring dry conditions in Arizona for the next ~20 years. Multi-decadal temperature changes in the Atlantic Ocean (the Atlantic Multi-decadal Oscillation) also have recently been found to be associated with dry conditions in Arizona (McCabe *et al.*, 2004). If this is true, Arizona may not be well prepared for the implications, due to the high likelihood of impacts on the Central Arizona Project (CAP) system in the relatively short term. Shortage sharing discussions, now ongoing between the seven Colorado River basin states and within Arizona, are of great importance in preparing for this possibility.

POLICY IMPLICATIONS OF GLOBAL WARMING FOR WATER SUPPLY PLANNING

In addition to natural variability in climate, long-term human-induced climate change also is altering the hydrologic cycle in important ways. There is evidence that the Colorado and other western rivers are already being affected by changes in snowpack that are likely to be related to global warming. Increases in temperature affect the rate of evaporation and water use by plants, lowering soil moisture and increasing stress on water supplies. The key challenge for water managers, who traditionally have looked at past climate conditions as an indicator of the future, is anticipating the ways in which climate change may lead to new extremes or possibly even abrupt changes in the climate system.

The earth's surface has warmed over one degree Fahrenheit over the last century, leading to melting glaciers and ice caps, sea level rise, extended growing seasons and changes in the geographical distributions of plant and animal species documented by, among others, the National Research Council and the Intergovernmental Panel on Climate Change (Figure 4.4). Although the average temperature change seems small in comparison to daily temperature fluctuations, the warming is not spread evenly over the globe. It is concentrated most heavily at higher

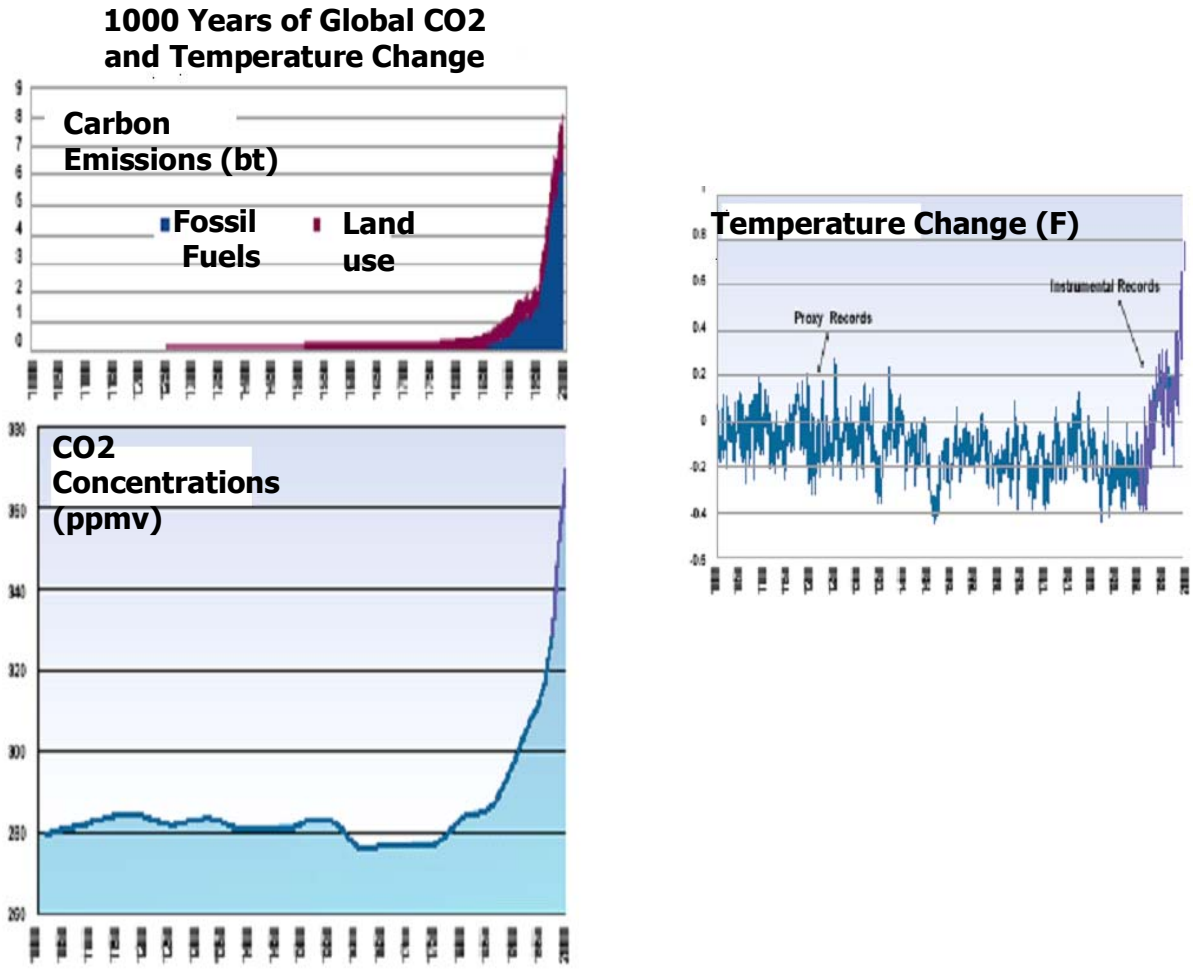


Figure 4.4 Global warming phenomenon.

latitudes, and the impacts are most visible near the poles.

Uncertainties remain about the magnitude and effects of future climate change, but almost all global climate models show that even very conservative assumptions about continued increases in temperature in the two degree Centigrade range over the next 100 years lead to key impacts from a water supply perspective. The most important consequence for the western United States, other than increasing evaporation and plant water use, is a reduction in snowpack and changes in runoff patterns (US Global Change Research Program, 2000). These changes may require new investments in storage and water delivery facilities as well as changes in water demand patterns to ensure sufficient water supply availability in critical areas. The primary policy

implication of climate change is that it is likely to increase competition for water by increasing demand while simultaneously reducing supplies that are dependent on snowpack. Water-dependent habitats, such as riparian corridors in the southwest, have been identified as being among the natural ecosystems most vulnerable to climate change and, therefore, natural resource managers may have additional challenges ahead.

DROUGHT PLANNING AND ADAPTATION OPTIONS IN ARIZONA

Virtually all parts of Arizona currently have a cumulative water supply deficit due to lower than average precipitation over multiple years. However, Arizona's major urban areas, Phoenix and Tucson, were until recently thought to be somewhat insulated from the impacts of drought because of past federal and state investments in water supply sources such as the Salt River Project and the CAP. In addition, Arizona's efforts to manage the groundwater supplies in the Active Management Areas of the state have made substantial contributions to reducing drought impacts in those areas. However, recent drought conditions have raised awareness of the need for a comprehensive state drought plan, including ways to address the possibility of long-term, sustained drought conditions as well as short-term emergencies.

The most urgent need for drought planning is in the growing cities, towns and communities in the rural parts of the state, especially in the Central Highlands, the southeastern parts of the state and the Colorado Plateau where alternative water supplies generally are very limited and the economy, particularly the grazing, recreation and forestry-related sectors, is strongly affected by drought. The environmental impacts of drought generally are more difficult to manage than the societal impacts, and there are limited ways to limit the impacts on wildlife and vegetation.

DROUGHT TASK FORCE

In response to the current drought and in recognition of the need for better planning, Governor Janet Napolitano established the Governor's Drought Task Force by executive order on March 20, 2003, requiring three major products:

- A short-term drought plan for the summer of 2003 that was adopted on July 10, 2003

and amended on June 10, 2004 for use in 2004;

- A long-term drought mitigation and coordination plan to address various specified areas of concern, *i.e.*, the Arizona Drought Preparedness Plan itself; and

- Development and implementation of a statewide water conservation strategy.

The Drought Task Force is composed of various state agencies and elected officials. Workgroups were established to solicit input from the municipal and industrial sectors, irrigated agriculture, environmental and resource management interests, tribal governments and the commerce, recreation and tourism sectors. In addition, public and private sector volunteers who supply much-needed expertise directly supported the planning process. The Task Force also was aided by experts from the National Drought Mitigation Center and supported financially by the United States Department of the Interior, Bureau of Reclamation. Current expectations are that the drought plan will be adopted in October 2004.

Drought is cumulative and does not affect all economic sectors in the same ways. The proposed Arizona Drought Preparedness Plan[3] is designed to respond to the differences in water supply availability and drought vulnerability for each sector and geographic area. The plan contains a separate section called the "Operational Drought Plan," which addresses the recommended adaptation, mitigation and response activities.

APPROACH AND OBJECTIVES OF THE DROUGHT PLAN

The adopted mission statement for the Governor's Drought Task Force is to develop a sustainable drought planning process for Arizona that includes:

- Timely and reliable monitoring of drought and water supply conditions in the state and an assessment of potential impacts;

- An assessment of the vulnerability of key sectors, regions, and population groups in the state and potential actions to mitigate those impacts; and

[3] http://www.water.az.gov/gdtf/.

- Assisting stakeholders in preparing for and responding to drought impacts, including development of a statewide water conservation strategy and public awareness program.

The focus on a sustainable drought planning process, one that continues over time regardless of current drought status, has been a key objective from the beginning of this effort. However, sustaining the drought planning process over time will be resource intensive and the source of resources is not yet clear.

The Drought Task Force adopted for the summers of 2003 and 2004 an *emergency Potable Water Plan* that focused on communities that have had drought-related supply problems in the past. Response activities such as trucking of water are coordinated through the Arizona Division of Emergency Management (ADEM). However, the longer-term Operational Drought Plan will include a network of monitoring and response agencies and committees to address most drought planning and response. While there is no funding for implementation of the Drought Plan at this time, it does makes recommendations regarding funding and staffing.

The Drought Task Force developed a planning process that encourages the use of the latest scientific information, particularly the use of climate forecasts and monitoring data at the regional scale to enhance the utility of drought-related information for decision-makers. It is hoped that providing longer-term climate projections, even those that are relatively uncertain, can provide valuable information about the possible range and intensity of drought. Such projections allow a broader assessment of potential drought impacts and identification of early steps to reduce vulnerability and enhance adaptive capacity.

Key vulnerabilities have been identified within the rural portions of the state, related primarily to whether the supply source is drought prone and whether alternative water supplies are available. The Arizona Short-Term Potable Water Plan, updated in June of 2004, noted that several providers had been put into an emergency situation by the recent drought, with some requiring trucked water. Others were identified as at risk. Based on information from the ADEM, Arizona Department of Environmental Quality, Arizona Corporation Commission and Arizona

Department of Water Resources (ADWR) Rural Watershed Initiative Program, systems with historic drought related problems have been identified in or near the communities of Sonoita, Nicksville, Pine, Strawberry, Payson, Chloride, Dolan Springs, Bellemont, Mayer, Summerhaven, Ashfork, Black Canyon City, Cottonwood, Eager, Seligman, Tusayan, Kirkland and Williams.

ARIZONA DROUGHT PREPAREDNESS PLAN

The Arizona Drought Preparedness Plan acknowledges that drought affects multiple sectors in the same location differently and establishes trigger mechanisms[4] or thresholds that are related to the vulnerability of each sector and region rather than establishing statewide drought stages. This approach is imperative in a state that is so dependent on imported surface water supplies from the Colorado River, with reservoirs that hold a multi-year water supply and large groundwater reserves. In the portions of the state that do not have these long-term, generally reliable water supplies, sectors such as grazing and recreation are likely to be in serious drought status more commonly than the major urban areas. The Plan is intended to be compatible with existing institutions and water management activities and to focus on local government adaptation and response options. The current draft indicates that communities may be required to develop their own drought plans.

General recommendations in the Plan include:

- Fund a Drought Coordinator and two half-time staff persons to be located at the ADWR, in addition to adequately funding the State Climatologist, who will share responsibilities (1) to improve the state's preparedness through implementation, assessment and improvements to the Drought Preparedness Plan, including database development, monitoring enhancements and meeting coordination, and (2) to ensure that the drought planning process is maintained.

- Facilitate and encourage coordinated water planning between counties, cities and water providers.

- Require all potable water systems to develop a Drought Contingency Plan. This Plan

[4] Crossing identified threshold conditions results in a change in drought status and may "trigger" particular responses in the affected area.

could be part of an overall Water Plan for each system. Including a drought component and a water conservation component.

- Explore the need for and make recommendations on having potable water systems provide consistent and coordinated water supply information in order to identify the water uses within the system and ensure reductions during times of critical need.

- Initiate immediately the Local Area Impact Assessment Groups to identify a structure and contacts and to facilitate the implementation of the Arizona Drought Preparedness Plan.

Proposed membership in Local Area Impact Assessment Groups consist of the following:

- County Government (Co-Chair)–County Emergency Manager
- County Extension Agent (Co-Chair)
- Rural Watershed Alliance Chair (Co-Chair)
- ADWR (Monitoring Committee Liaison)
- Local Governments
- Potable Water Providers
- Other Local Water suppliers
- Tribal Government
- Local Non-Governmental Organizations
- Arizona Game and Fish
- Irrigation Districts
- Watershed Groups
- Natural Resource Conservation Districts

Tables found in Appendix I of the Operational Drought Plan[5] list sources of drought vulnerability as well as adaptation and mitigation options for municipal and industrial, agricultural, commerce, recreation and tourism, Indian nations and wildlife and watershed health.

[5] http://www.water.az.gov/gdtf/.