Planning for Drought

Draft

Colorado Water Conservation Board   May 2000

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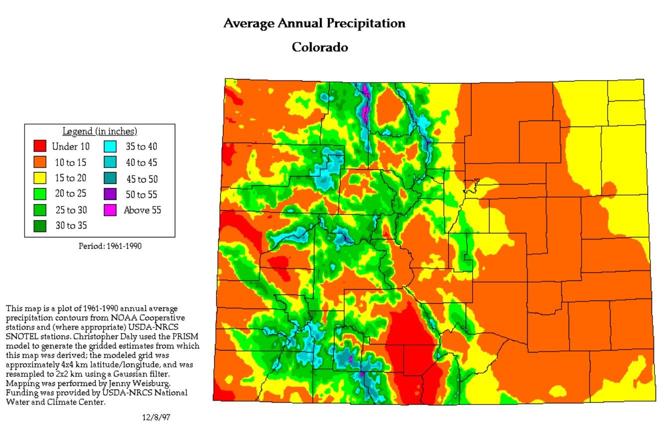
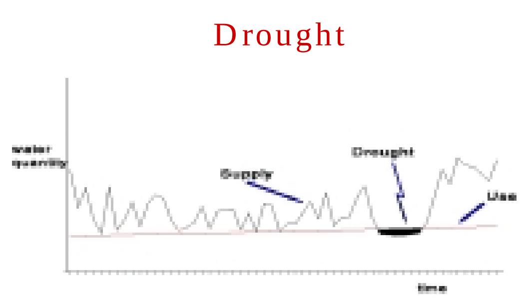
Colorado's climate is relatively dry and extremely variable. Annual precipitation averages only 17 inches statewide. It varies from a high of 55 inches in a few isolated high-mountain locations to a low of 6 inches in some valleys. Compared to the rest of the United States, the level of precipitation in Colorado is meager. A study of historical dry and wet periods in Colorado by the Colorado Climate Center at CSU identified five significantly severe statewide droughts from the instrumental record over the last century. The last significant multi-year drought in Colorado ended in 1978. The last two decades have seen the most reliable precipitation since before the "dust bowl" of the 1930's, but a severe, sustained drought will occur again. It is only a question of how often, how dry, and how long.



Drought is a shortage of water, usually associated with a deficiency of precipitation. Drought occurs when the demand for water exceeds the available supply of water. The severity of drought depends on the magnitude of the deficiencies compared to historic averages, the aerial extent or size of the area impacted, and the duration.

"Drought" is a concept that cannot be easily defined except in the context of a specific region and a set of needs or expectations. Generally, it is a period of time (months, years, decades) during which the availability of water is significantly less than the people, animals and plants in a region are accustomed to enjoy. As Colorado continues to grow, and as we approach the "fully appropriated" situation in every major river basin, survival during drought will require increasingly greater planning and preparation to assure the long-term continuation of our lifestyle and economy. Without such advance planning, some hardships or regrettable trade-offs will occur.



Source: National Study of Water Management During Drought, The Report to the U.S.Congress, 1995.

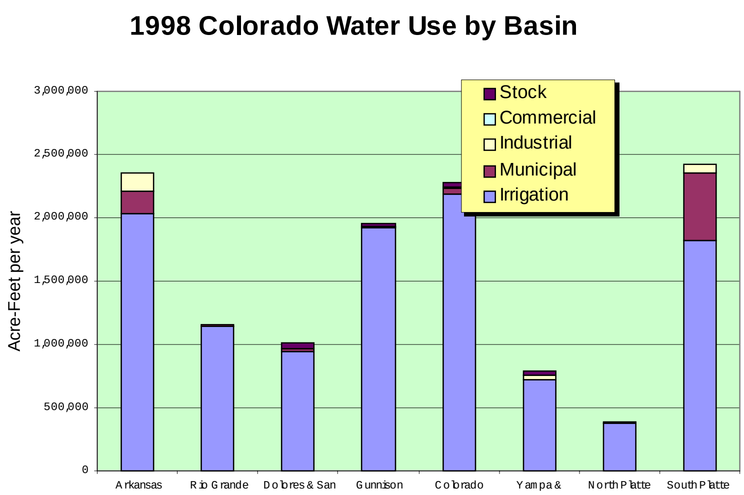
Drought is a unique natural hazard. Drought differs from other natural hazards in that it usually has a slow onset, develops over months or even years, affects a large spatial region, and causes little structural damage. It usually has no clear beginning or end. The impacts of drought span a broad range of economic, environmental, and social sectors. However, like other natural hazards, drought's impacts can be reduced through mitigation and preparedness. It just takes more foresight, advance planning, and discipline than other types of hazards.

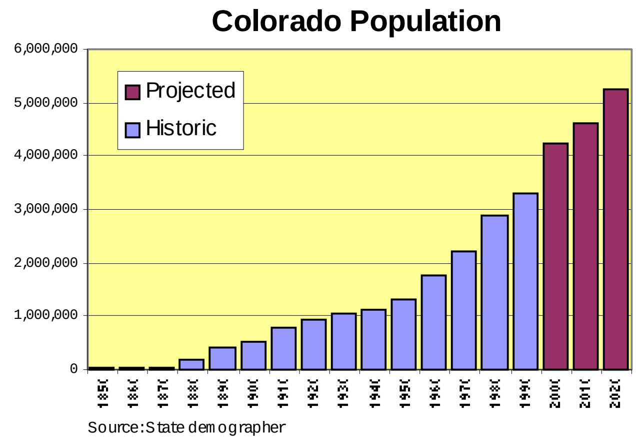
Baca County, Colorado, about 1936

Photo by D. L. Kernodle

Drought can significantly impact Colorado's water dependent economy. Agriculture, tourism, hydropower generation, commercial and domestic use, manufacturing, and mining all depend on a firm supply of water. The potential impact of drought on the economy depends on how much water is demanded by each sector and how much is consumed, when and where it is consumed, and if it can be stored before use. Tourism uses are generally non-consumptive, but snowmaking, rafting, and fishing are also effected by drought.

Water in Colorado is used primarily for agricultural purposes. Of the approximately 12.4 million acre-feet diverted for use statewide each year, irrigation for agriculture accounts for about 11.1 million acre-feet, or about 90%. About half of the diversions for irrigation return to the river and go towards meeting our compact obligations to downstream states. Municipal use is about 800,000 acre-feet (7%), industrial use is about 250,000 acre-feet (2%), stock water use is about 132,000 acre-feet (1%), and commercial use is about 16,000 acre-feet (0%).





The next drought in Colorado will pose a significant water management challenge. Colorado's population is growing at an average rate of 2.9% per year. At this rate, the population will double every 24 years. The unrestrained growth of our population is resulting in the need for more water for municipal and industrial (M&I) purposes. Assuming one acre-foot per four persons per year, the need for M&I water is projected to increase from 1.0 million acre-feet in the year 2000 to 2.2 million acre-feet in 2100. Where precluded from developing new water supplies and reservoirs, municipalities are buying farms and ranches for the water rights, and land previously used for agriculture is being dried up. There is also a growing desire for water based recreational and environmental use. The patterns of water use are changing from a seasonal demand to a year round demand, and new values emphasize in-stream flows as opposed to diversions and consumptive uses. Not only is there competition to change water use patterns, but we are faced with challenges from downstream states and the influence of national laws and changing perspectives. Considering Colorado's growing population, demand management will play a huge role in reducing the future impact of drought.

River Basin Population

Basin	1990	1998	Average Annual Percent Change	Doubling Time, years
South Platte	2,210,700	2,714,000	2.8%	25
Arkansas	662,500	807,600	2.7%	26
Rio Grande	36,600	45,500	3.0%	23
Colorado Mainstem	164,700	214,200	3.8%	19
Dolores & San Juan	72,800	94,600	3.7%	19
Gunnison	58,700	75,900	3.7%	19
Yampa & White	31,900	38,100	2.4%	29
North Platte	1,900	2,100	1.3%	53
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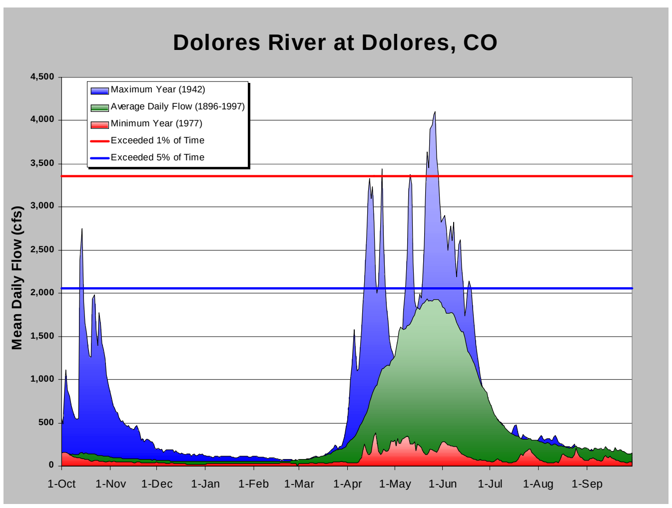
Fact Sheet Totals	3,239,800	3,992,000	2.9%	24

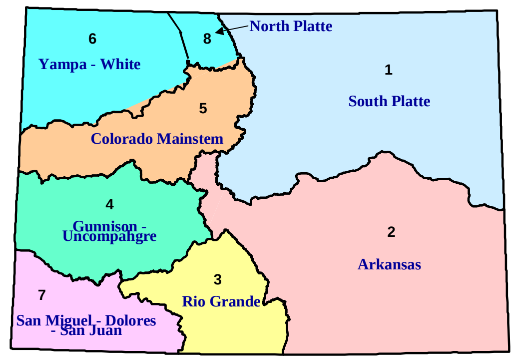
Reservoir storage has been a critical element of western drought management strategy. It has been estimated that approximately 80% of the surface water supply in Colorado is naturally available during the four-month snowmelt runoff period in April, May, June, and July.



Reservoir storage grew tremendously after droughts in the 1930's and 1950's. By about 1970, active reservoir storage per capita in Colorado peaked at about 1.5 acre-feet per person and has been steadily declining ever since. By about 1990, total statewide active reservoir storage capacity exceeded 4 million acre-feet, but the population is growing faster than new surface water supplies and reservoirs are being developed.

Each of Colorado's eight major river basins has a unique history of drought. The following is a brief summary of historic droughts for each river basin. The information comes from precipitation records, available from 1880 in some basins, and tree-ring studies going back to year 481 in at least one basin. Several researchers have used tree-ring data to reconstruct various climatic parameters such as precipitation, the Palmer Drought Severity Index, and stream flow in the case of the Colorado River. The Palmer Index is based on soil moisture and is used by the Department of Agriculture to determine when to provide federal drought assistance.

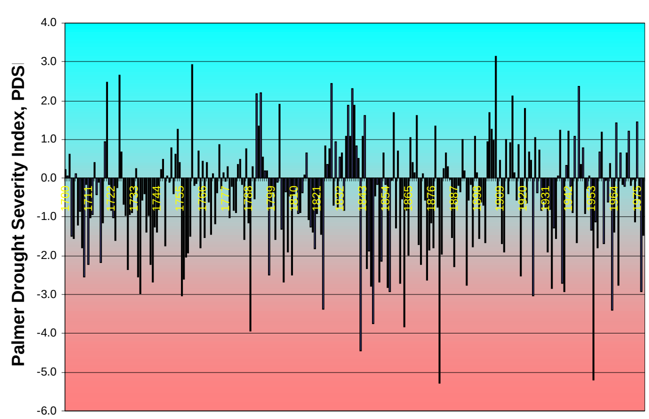
CWCB River Basins



<u>South Platte River Basin</u>

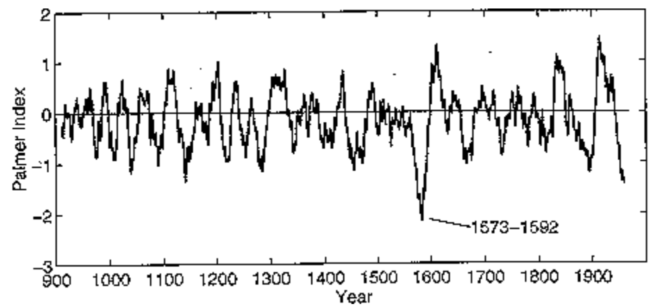
Sufficient precipitation records are available from 1891 in the lower South Platte River Basin and from 1880 in the upper basin. Recent droughts in the lower South Platte River Basin occurred in 1891-1892, 1895-1898 (extreme), 1911-1912, 1931-1941, 1953-1957, and 1974-1979. Recent droughts in the upper South Platte River Basin occurred in 1880-1881, 1893-1895 (extreme), 1903, 1912-1913, 1931-1937, 1940-1941, 1954-1956, 1963-1965, and 1977-1979.

Tree-ring Record for Northeastern Colorado (Point 58), 1700-1978



Paleoclimatic records of the Great Plains, including the South Platte River Basin and the Arkansas River basin, indicate that widespread prolonged drought (3-10 years) equaled or surpassed the 1930's drought in intensity and duration in the late 1750s, early 1820s, and early 1860s. Major droughts that likely exceeded twentieth century droughts occurred on the Great Plains in the second part of the 16th century (possibly the periods 1539 to1564 and from 1587 to 1605) and the last quarter of the 13th century (possibly from1276 to1313). The evidence further suggests at least four periods of widespread multi-decadal drought occurred on the Great Plains between A. D. 1 and 1200 (roughly in the periods 250-300, 750-800, 940-990, and 1130-1180).

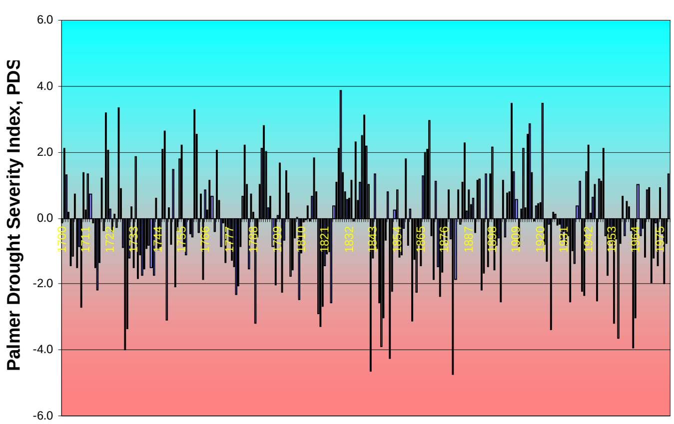
The most severe sustained drought in the tree-ring record for the Rio Grande Basin occurred in 1573-1592.



Arkansas River Basin

Sufficient precipitation records are available from 1891 in the lower Arkansas River Basin and from 1880 in the upper basin. Recent droughts in the lower Arkansas River Basin occurred in 1894-1898, 1911-1913, 1934-1941 (extreme), 1952-1957, 1964-1966, 1974-1977, and 1981-1982. Recent droughts in the upper Arkansas River Basin occurred in 1880-1881 (extreme), 1888-1894, 1907-1909, 1932-1940, 1950-1956, 1963-1965, and 1975-1977.

Tree-ring Record for Southeastern Colorado (Point 60), 1700-1979

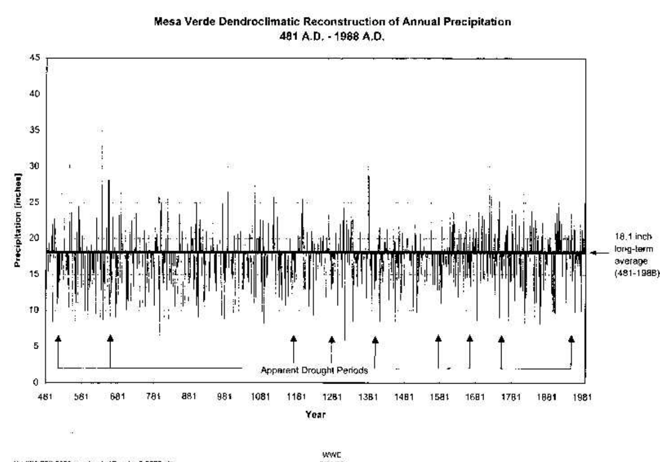


Rio Grande Basin

Sufficient precipitation records in the Rio Grande Basin are available from 1897. Recent droughts in the Rio Grande Basin occurred in 1897, 1900-1906, 1923, 1939-1940, 1943-1947, 1950-1952 (extreme), 1955-1956, 1963-1964, 1972-1973, and 1996-1997.

San Miguel-Dolores-San Juan River Basins

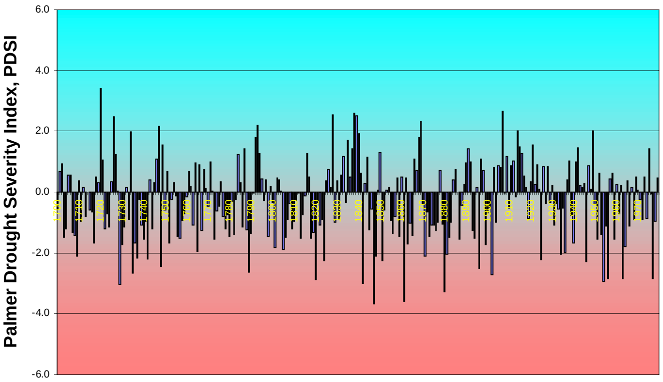
Sufficient precipitation records are available from 1898. Recent droughts in the San Miguel-Dolores-San Juan River Basins occurred in 1899-1905 (extreme), 1918-1919, 1931-1936, 1945-1947, 1951-1952, 1954-1957, 1976-1978, and 1989-1991. The most sustained drought in the tree-ring record for the San Miguel-Dolores-San Juan River Basins occurred in 1273-1289. Many archaeologists believe this period of severe sustained drought coincided with the abandonment of Mesa Verde by the Anasazi. Several shorter, but more severe droughts, were identified between AD 512 and 1673.



Gunnison-Uncompahgre River Basins

Sufficient precipitation records are available in the Gunnison-Uncompahgre River Basins from 1888. Recent droughts in the Gunnison-Uncompahgre River Basins occurred in 1889-1890, 1894, 1899-1905, 1950-1957, and 1975-1978.

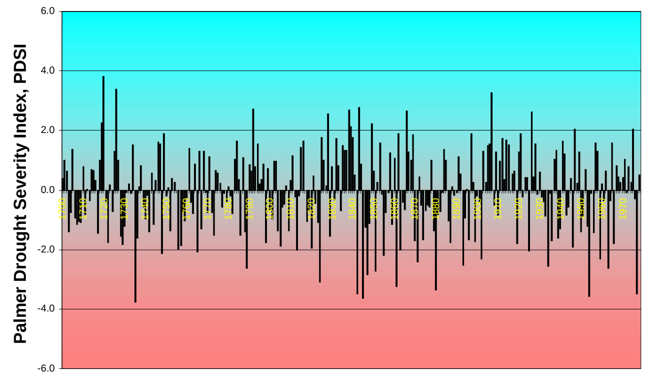
Tree-ring Record for Central Western Colorado (Point 49), 1700-1979



Yampa-White River Basins

Sufficient precipitation records in the Yampa-White River Basins are available from 1894. Recent droughts in the Yampa-White River Basins occurred in 1894-1895, 1901-1904, 1911-1912, 1919-1920, 1934-1937, 1963-1964, 1972-1973, and 1976-1978 (extreme).

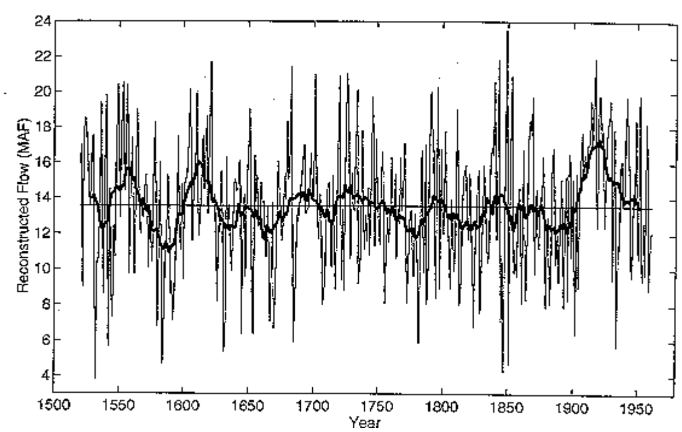
Tree-ring Record for Northwestern Colorado (Point 48), 1700-1978



Colorado River Mainstem Basin

Sufficient precipitation records in the Colorado River Mainstem Basin are available from 1895. Recent droughts in the Colorado River Mainstem Basin occurred in 1899-1905, 1950-1952, 1954, 1956-57, 1963-1964, 1972-1973, and 1976-1978. The most severe sustained drought in the tree-ring record for the Colorado River Mainstem Basin occurred in 1579-1598.

Colorado River at Lee's Ferry

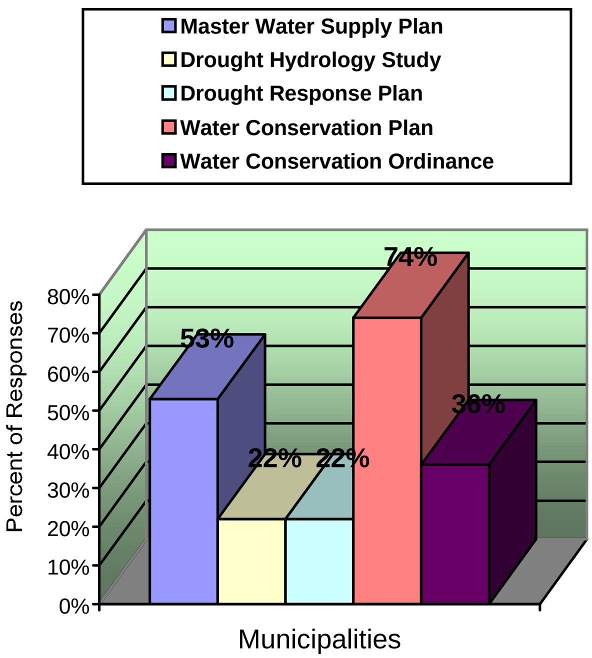


North Platte River Basin

No long-term precipitation data exists for the North Platte River Basin. However a review of stream gage records shows dry periods occurred in 1917-1918, 1920-1923, 1926, 1928-1929, 1943, 1948-1949, 1957-1958, 1961, 1968, 1984, 1986, and 1996-1997.

Colorado first developed a statewide plan to respond to drought in 1981. The purpose of the state's plan is to *"provide an effective and systematic means for the State of Colorado to deal with emergency drought problems which may occur over the short or long term."* The plan is intended to better coordinate the assessment of emerging drought and its impacts, the dissemination of information about drought and alternate response options available to local governments, and the decision when the state would request federal disaster assistance. While Colorado's plan is nationally recognized as a model for state government to assess and respond to drought, it was never intended to address local water supply and demand management issues. Water resource development and drought planning are clearly the responsibility of individual, local water providers.

Few communities have done any serious drought planning. The CWCB recently contacted water providers that produce 2,000 acre-feet or more of treated water per year to determine the extent and level of drought planning in Colorado. We asked if they had a master water supply plan, a hydrology study that considered the risk of drought, a drought response plan, a water conservation plan, and if they had adopted an ordinance that prescribes water conservation in times of drought. The results from 67 municipalities showed that less than half (49%) had done some form of drought planning. 53% had a master water supply plan, 22% had a hydrology study considering drought, 22% had a drought response plan, 74% had a water conservation plan, and 36% had a water conservation ordinance. In reviewing the hydrology studies, only about 4% included a robust, risk based drought analysis. Many water utilities appear to have designed their water systems assuming an average year supply.



The CWCB is developing new design drought parameters based on risk analysis. What is needed are estimates of drought characteristics, such as duration and percent of average precipitation or stream flow, by major river basin or climatic region. With such information, planners would have a better idea about what is needed to survive a drought, and current attitudes disputing the need for reservoir storage might change.

Water Management Tools

Master Water Supply Plan - a projection of future demand for water in a specific service area under various development scenarios and an analysis of the technical, financial, and economic feasibility of various alternative options to develop a reliable supply of water to meet the long-term demand.

Hydrology Study - an analysis of the firm supply of water to a system that considers the physical availability of water, including the risk of severe, sustained drought, and the relative priority of the legal water rights to divert water for beneficial use.

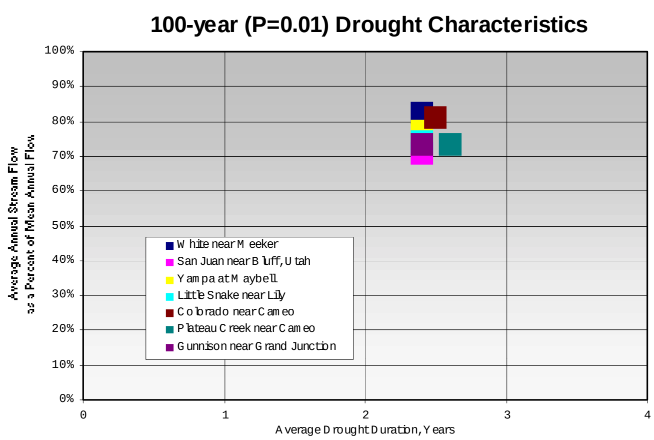
Drought Response Plan – a document that describes an agreed upon process to assess periodically water supply conditions and the options for responding to emerging drought based on pre-defined deficiencies or triggers.

Water Conservation Plan - a formal plan to encourage all customers to use water more efficiently by systematically considering a wide range of specific water-saving measures.

Water Conservation Ordinance - a regulatory measure adopted by local governments designed to encourage water use efficiency.

A true risk based drought analysis of surface water supplies requires the use of sophisticated mathematical techniques to define stream flow characteristics during low-flow periods. This analysis is possible now due to recent advances in computers. Drought severity is a function of duration (in months or years) and the magnitude of the deficits. A deficit is the difference or shortage in volume between the demand and total available supply, including storage, for a given increment of time (typically a month). The design drought is a planning tool to describe a monthly or annual series of low flows. It can be based on the recorded historic drought experienced in the region, but it is difficult to determine the level of risk due to the limited length of recorded data. A better technique is to estimate drought characteristics from a statistical analysis of available stream flow or precipitation records with long term "synthetic" stream flow histories using stochastic models. The synthetic stream flow histories maintain the monthly, seasonal, and annual characteristics of the historic records (such as mean and standard deviation), and also provide a much greater combination of above and below-normal stream flows. The synthetic record allows the water supply system to be tested against a wide range of conditions that may not have been observed in the historic record but are nevertheless possible in the future. This provides a more reliable estimate of system yields than can be obtained from evaluation of the historic data alone, and a more extensive number of drought events against which the design drought can be compared and its severity more accurately determined.

In the design of the Colorado River Decision Support System (CRDSS), one hundred data sets of 100 years each characterizing drought for seven key stream gage locations on the west slope were developed. A preliminary analysis of the results show, for the west slope river basins, that the 100-year drought sequence has an average yield between 71- and 83-percent of the long-term mean annual flow and an average duration that lasts between 2.4 and 2.6 years. The average maximum 100-year drought sequence has an average yield between 68- and 80-percent of the long-term mean annual flow and an average duration that lasts between 7.4 and 8.3 years. This task is still in progress, but the preliminary results based on synthetic stream flows provide a reasonable standard for local water providers to examine their water supply systems.



The CWCB recommends water providers, especially those that are experiencing strong population growth, start by determining how their systems would perform (calculate the magnitude of any monthly deficits) under stream flows reduced to at least 75% of average for a minimum of three years. Using the CRDSS, it will soon be possible to facilitate development of site-specific stream flow sequences for west slope streams for design droughts expected to recur on a 25-, 50-, and 100-year cycle. This capability will be expanded to include other river basins as additional river decision support systems are developed.

The CWCB is working with the Colorado Climate Center at CSU and Henz Meteorological Services to determine regional drought characteristics from existing climate records based on research for the Climate Center's recent report on "Historical Dry and Wet Periods in Colorado."

Water management in the west is constantly evolving to sustain the needs of people living in an arid region. Colorado has adapted to this dry climate through experience, creativity, planning, and diligence. Over the past decade, we have enjoyed the benefit of being in a wet period. But the threat of severe, sustained drought looms over Colorado and its vibrant economy. Growing population increases our vulnerability to the impacts of drought. We may suddenly find ourselves back in the days of fighting for our own survival and a subsistence economy if we take these water-plentiful years for granted.

Frederick Remington's 1903 painting *"Fight for the Water Hole"* reproduced with permission from the Houston Museum of Fine Arts.

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