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An online, peer-reviewed journal
published in cooperation with the
Texas Water Resources Institute

TEXAS WATER JOURNAL

Volume 6 Number 1
2015

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Volume 6, Number 1
2015
ISSN 2160-5319

texaswaterjournal.org

THE TEXAS WATER JOURNAL is an online, peer-reviewed journal devoted to the timely consideration of Texas water resources management, research and policy issues. The journal provides in-depth analysis of Texas water resources management and policies from a multidisciplinary perspective that integrates science, engineering, law, planning, and other disciplines. It also provides updates on key state legislation and policy changes by Texas administrative agencies.

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Cover photo: Anzalduas Dam in Hidalgo County. Photo courtesy of the Texas Water Development Board.

Texas Water Resources Institute
Texas Water Journal
Volume 6, Number 1, Pages 121–135

Texas water policy appendix: the weather

Carlos Rubinstein[1,2]

Abstract: The climate of Texas makes our state particularly susceptible to droughts, floods, and hurricanes. Weather events over the past 150 years have resulted in policy changes at the state and federal level that have helped us prepare for, respond to, and prevent weather disasters. Many of these efforts have been successful; however, continuous planning and improvement will be necessary to meet the needs of our growing population. Recent droughts and floods have demonstrated that traditional infrastructure must work in tandem with early forecasting and warning systems, which will require effective policies at both the state and federal level to support them along with citizen engagement.

Keywords: Drought, flood, weather, disaster, planning

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[2]The author wishes to extend special thanks to TWDB staff for their assistance with the article: Kathleen B. Ligon, Senior Policy Analyst; Todd Chenoweth, Senior Advisor; and Dr. Robert Mace, Deputy Executive Administrator.

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Citation: Rubinstein C. 2015. Texas water policy appendix: the weather. Texas Water Journal. 6(1):121-135. Available from: https://doi.org/10.21423/twj.v6i1.7015.

Term used in paper

Short name of acronym	Descriptive name
TWDB	Texas Water Development Board

INTRODUCTION

In 1892, Mark Twain published the novel the *American Claimant*, at the beginning of which he announced: "No weather will be found in this book." It was reportedly the first work of fiction without mention of the weather; all weather was contained in an appendix at the back of the book, which the reader was encouraged to consult from time to time.

Fittingly, the book was published near the beginning of the modern era of weather recordkeeping. As Mark Twain concedes, despite being relegated to an appendix, "…weather is necessary to a narrative of human experience." This observation holds true for the weather in Texas, which has not only informed how we manage our water and our other natural resources, but has also helped shape the course of our history. Knowledge of these events is essential to a thorough understanding of Texas water policy.

In addition to the advent of scientific recordkeeping, a considerable amount of change has occurred since the late 1800s in not just how we manage our water resources but how we live our daily lives. Before 1900, most Texans got their water from private wells, springs, rainfall, or running streams. Plumbing was rare, and there were no sewage treatment plants, little to no treatment of drinking water, and no significant flood control or water supply infrastructure (Freese and Sizemore 1994). Texas saw tremendous population growth in the last 50 years of the 19th century, growing from just over 200,000 to 3 million (Figure 1). This growth set the stage for steady and significant progress in water management during the entire 1900s, and our weather undoubtedly played a role in that progress.

Climate of Texas

The climate of Texas is marked by extremes in temperature, precipitation rates, and the variation and extent of severe weather, making our state particularly susceptible to droughts, floods, and hurricanes (TWDB 1966). Since 1980, Texas has suffered the greatest number of billion-dollar weather and

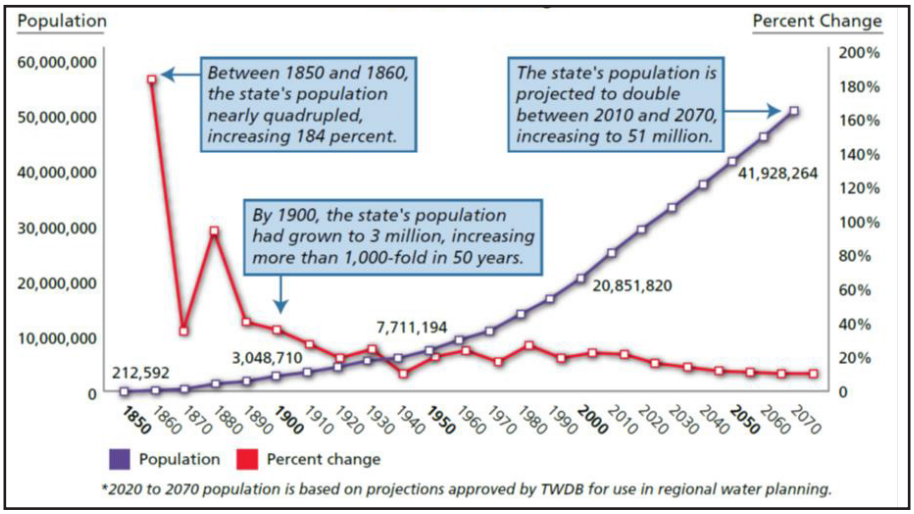


Figure 1. Texas historical and projected population growth* and percent change.

climate disasters of any U.S. state, with 58 such disasters (NOAA 2015a).

Droughts have influenced Texas history since the very beginning of European settlement and before. Though droughts develop slowly, they can ultimately have socio-economic consequences as catastrophic as other weather disasters. Droughts have devastated Texas agriculture, caused hardship in all economic sectors, and early in our history, left communities vulnerable to fire and famine. Modern droughts still cause economic hardship but have helped foster a growing appreciation of water as a scarce resource that should be conserved—even in times of plenty.

As we have witnessed in recent events in 2015, floods can take an especially dramatic toll on our collective conscious, since their sudden force can result in a swift and ruthless taking of human life. Prior to the construction of much of our flood control infrastructure and use of early warning systems, major floods could take hundreds of lives in a single event, often disproportionally affecting economically disadvantaged settlements in low-lying areas. Prior to the construction of dams on the Colorado River, our state capital was bifurcated by major floods on multiple occasions.

Central Texas—often called "Flash Flood Alley"—has a greater risk of deadly flash flooding than most regions of the United States because of its steep terrain, shallow soils, and unusually high rainfall rates. Heavy rains can quickly transform rivers and streams into walls of fast-moving water that can evade even our contemporary warning systems (LCRA 2015a).

The construction of dams not only made much of the state far safer from catastrophic floods but also put people to work during the Depression of the 1930s. These dams provided electricity to the rural Texas Hill Country, which lagged considerably behind most of the country in electrification. Construction of multipurpose reservoirs in the 20th century also provided reliable water supplies in an otherwise arid landscape.

It is difficult to compare droughts because of the variables in measuring them, and floods are just as challenging to compare. Droughts are generally ranked by intensity, duration, and areal extent. Floods are evaluated by comparison of peak flow with known averages, intensity and duration of rainfall rates, and areal extent of flooding. Rain can fall in tremendous amounts and flood relatively small geographic areas, such as the 2015 Memorial Day weekend floods in Blanco and Hays counties. Floods can also occur when considerable amounts of rain fall over a large area of the state, such as the 1957 floods that affected most of the major river basins of Texas. Floods can occur at the beginning, end, or even during a major drought event. Some floods are most notable for the catastrophes that they *did not* cause, because of infrastructure that tempered their effects.

Weather and public policy

It is axiomatic to say that weather drives state water policy. Both droughts and floods have led to the creation of many of our water management entities, such as river authorities, state agencies, and hundreds of local water districts. Weather events have informed how we administer surface water rights, regulate groundwater, and plan for future water supplies and flood mitigation.

The "appendix" that follows provides a brief summary of many of Texas' major weather events in the past 150 years, the state's population at the time, and policy changes at the state and federal level that resulted from these events. As can be seen in the timeline, some weather events unmistakably precipitated specific policy changes, such as the droughts of the 1880s that made fence cutting a felony and the 1950s drought that brought about mechanisms to both fund water projects and plan for future droughts. Other weather events likely had indirect or cumulative effect on public policy over time.

This timeline is not comprehensive due to time and space constraints: droughts and floods have occurred in Texas in every single decade of the last 100 years. Several other excellent histories and timelines are available, without which this piece would not have been possible. Most notably, these include:

- Texas Water Law Timeline (LRL 2015)
- Timeline of Droughts in Texas (TWRI 2011)
- National Water Summary 1988–89, Hydrologic Events and Floods and Droughts (USGS 1991)
- A Century in the Works, Freese and Nichols Consulting Engineers, 1894–1994 (Freese and Sizemore 1994)
- A Chronology of Major Events Affecting the National Flood Insurance Program (American Institutes for Research 2005)

The primary purpose of this article is to not only provide context to the evolution of state and federal policy related to droughts and floods but to prompt the reader's consideration[1] of our successes, failures, and challenges to come, such as:

- Are our current policies and planning processes sustainable?
- How reliable is our current infrastructure?
- How effective are our early warning systems?
- How viable are our current plans?

[1] Consideration of the vast scope of these issues will not be attempted in this article, but it is hoped that they will be explored further in other venues.

TIMELINE

Prior to 1900

1850 Population: 212,592

1860 Population: 604,215

1870 Population: 818,579

1880 Population: 1,591,749

1890 Population: 2,235,527

Flood of 1869: *After 64 hours of continuous rains in July—and prior to any significant damming of the river—the Colorado River crested at 51 feet in Austin and inundated both Bastrop and La Grange. The flood still stands as the worst on record for the Colorado River (LCRA 2015b).*

1875 Indianola Hurricane: *At the peak of Indianola's prosperity, the storm nearly wiped out the low-lying city and caused considerable loss of life (Malsch 2015).*

Droughts of mid-1800s: *Predating official weather records, the droughts devastated farmers new to the dry climate of Texas, with some suffering up to complete crop losses (TSHA 2002). The drought was a landmark in the history of West Texas, with many old settlers referring to events as taking place, "before the drought" or "after the drought" (TSHA 1928).*

1886 Indianola Hurricane: *After rebuilding from the previous decade's storm, the hurricane and accompanying fire permanently destroyed Indianola.*

Flood of 1899: *In June, average rainfall of almost 9 inches fell over 60,000 square miles, causing the Brazos River to overflow and inundate an estimated 12,000 square miles (Bishop 2010).*

Texas and the American West saw a great deal of change in the later decades of the 19th century. Pioneers from the eastern states that came to Texas to farm were unaccustomed to and unprepared for the harsh and variable weather, particularly droughts. The drought in the mid-1880s led to policy discussions at both the state and federal level. The "fence cutting wars"—a series of disputes in Texas and the American West—were exacerbated by the drought that made it more difficult for those without land of their own to find grass and water necessary for grazing herds of cattle. By the fall of 1883, the conflict between landless cattlemen and those who fenced land with barbed wire, first patented in 1874, had resulted in millions of dollars in damages, discouraged farming, and scared away prospective settlers. Governor John Ireland called a special session of the Texas Legislature to meet January 1884; after heated debates, the Legislature made fence cutting a felony punishable with prison time (Gard 2015). Though this action did not affect water policy per se, it effectively linked Texans' access to water with private property rights.

The drought of the 1880s also resulted in the creation of a state geological survey[2]—to study artesian wells and to propose a state program to build reservoirs—and the introduction of a prior appropriation system of "first in time, first in right" for managing surface water. Inspired by the plight of the farmer and rebelling against the interests of cattlemen, Governor Lawrence Sullivan "Sul" Ross advocated for prior appropriation in Texas. The Legislature passed the First Irrigation Act in 1889, establishing the doctrine of prior appropriation in the arid portion of the state; all unappropriated water was declared to be the state's property but could be acquired through a "certified fining." In 1895, the Second Irrigation Act applied the prior appropriation system statewide (LRL 2015).

At the national level, the drought of the mid-1880s set off a policy debate on how the federal government should respond to disasters. In response to efforts by John Brown, an Albany, Texas minister, and those of Clara Barton, founder of the American Red Cross, Congress passed the Texas Seed Bill of 1887. The bill appropriated $10,000 for the purchase of seed grain for distribution to farmers in Texas counties that had suffered from the drought. The legislation was vetoed by President Grover Cleveland, but the Texas Legislature appropriated $100,000 for drought relief, providing a little over $3 to each needy person. The Red Cross and other donors also sent clothing, household goods, tools, and seed to drought-stricken areas (TSHA 2002).

Despite a number of major floods around the country, no far-reaching state or federal policy actions relating to floods emerged until the beginning of the 20th century, with the exception of the initiation of the U.S. Geological Survey Stream Gaging Network in 1889. The purpose of the initial network was to determine the potential for irrigation development in 8 river basins in the arid West, a vital concern for the economic development of the region. Now known as the National Streamflow Information Program, the network is a cooperative effort between federal, state, and local agencies. Data produced by the program is used for forecasting and operational decisions as well as long-term resource planning, infrastructure design, and flood hazard mitigation (USGS 1998).

1900s

1900 Population: 3,048,710

Galveston Hurricane of 1900: *Although more violent and costlier storms have struck coastal areas of the United States in the years since, the September hurricane is still widely known as the*

[2] A drought in 1856 led to the creation of a first geologic survey to make scientific recommendations on soil utilization and water resources to assist drought-stricken farmers, but the survey was suspended after the start of the Civil War.

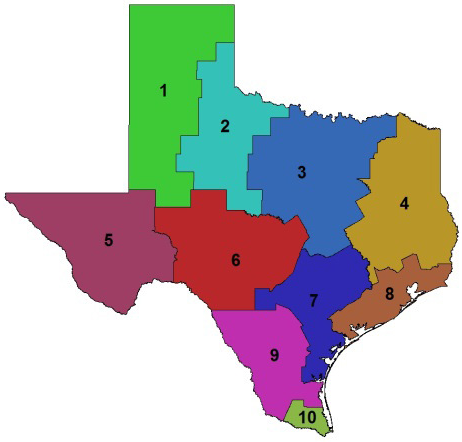
deadliest natural disaster in our country's history. The Category 4 storm submerged the entire island and took an estimated 6,000 to 12,000 lives (NOAA 2015b).

Flood of 1900: *In April, flooding destroyed a 500-foot section of the original Austin Dam, reported at the time to be the largest dam in the world spanning a major river. Shortly after it was reconstructed, the dam suffered damage in 1915 and again in 1935 (Freese and Sizemore 1994). Remains of the old structures can still be seen just downstream of Tom Miller Dam, dedicated in 1940 as the "Third and Final Austin Dam."*

Drought of 1896 to 1902: *Though much of Texas escaped the worst of the turn-of-the-century drought, it was one of the state's longest and most intense, particularly for northeast Texas and the lower Rio Grande Valley (Table 1).*

Flood of 1908: *In May, a 10-inch rainfall in the upper Trinity*

Table 1. Ranking of Palmer Drought Severity Indices based on drought duration and intensity for climate divisions of Texas.



	Duration Ranking			Peak Intensity Ranking		
Climate Division	**1**	**2**	**3**	**1**	**2**	**3**
1: High Plains	1950 to 1957	2010 to 2014	1961 to 1965	2010 to 2014	1950 to 1957	1932 to 1936
2: Low Rolling Plains	1951 to 1957	2010 to 2014	1962 to 1966	2010 to 2014	1951 to 1957	1915 to 1918
3: Cross Timbers	1950 to 1957	1908 to 2013	2010 to 2014	1950 to 1957	1924 to 1925	1915 to 1918
4: Piney Woods	1908 to 2013	1896 to 1899 & 1962 to 1965		2010 to 2013	1915 to 1918	1924 to 1925
5: Trans-Pecos	1949 to 1957	1998 to 2003	1961 to 1966	2010 to 2014	1949 to 1957	1915 to 1918
6: Edwards Plateau	1949 to 1957	2010 to 2014	1908 to 1912	2010 to 2014	1949 to 1957	1915 to 1918
7: Post Oak Savanna	1949 to 1957	2010 to 2014	1915 to 1918 & 1896 to 1899	1949 to 1957	2007 to 2009	2010 to 2014
8: Gulf Coastal Plains	1961 to 1965	2010 to 2014	1937 to 1940 & 1953 to 1957	1915 to 1918	1953 to 1957	2010 to 2014
9: South Texas Plains	1949 to 1957	1906 to 1911	2010 to 2014	2010 to 2014	1949 to 1957	2008 to 2009
10: Lower Rio Grande Valley	1896 to 1902	1906 to 1911	1949 to 1954	1896 to 1902	2010 to 2014	2004 to 2006
Entire State	**1950 to 1957**	**2010 to 2014**	**1961 to 1965**	**2010 to 2014**	**1950 to 1957**	**1915 to 1918**

*Drought duration is defined as the number of months from when the Palmer Drought Severity Index went negative to when it returned to a positive (or zero) value; drought "intensity" is defined as the lowest (peak) value of the Palmer Drought Severity Index during the drought period.

River Basin caused flooding in Dallas, killing 11 people (TRA 2015). It was immediately followed by the most serious drought and water supply crisis of the city's history (Freese and Sizemore 1994).

Shortly after its first drought, the 20th century was marked with a momentous state water policy shift when the Texas Supreme Court in 1904 adopted the "rule of capture" doctrine in *Houston & T.C. Railway Co. v. East*. Though Texas had historically followed the English common law rule that landowners have the right to remove all of the water that can be captured from beneath their land, the *East* case and later court rulings established that landowners, with few exceptions, may pump as much water as they choose without liability.

That same year also marked the beginning of a new era of water development efforts, with Texas voters approving a constitutional amendment allowing local issues of bonds and lending of credit for irrigation, navigation, flood control, drainage, and other public purposes (TLC 2014).

1910s

1910 Population: 3,896,542

Drought of 1908 to 1913: *The drought was second in duration only to the drought of the 1950s in a large portion of the state, impacting the heart of Texas from the Oklahoma border to the lower Rio Grande Valley. At the worst of the Dallas drought, water mains were used only for fire protection and tank wagons were provided for domestic supply (Freese and Sizemore 1994).*

Flood of 1913 (Figure 2): *In December, the Guadalupe and Trinity rivers left their banks and the Colorado and Brazos rivers were joined by floodwaters below Columbus, resulting in a lake 65 miles wide covering over half a million acres (LCRA 2015b). The flood killed 177 people and caused the Brazos River to change course and enter the Gulf of Mexico at Freeport (USGS 1991).*

Drought of 1915 to 1918: *One of the most significant droughts in Texas history, the drought of the mid-1910s severely impacted the state's economy.*

As bad as the flood of 1913 was in Texas, it was eclipsed by events on the Mississippi and Ohio rivers. A flood the same year in the Ohio River valley killed over 400 people, caused extensive property losses, and spurred great public interest in flood control (American Institutes for Research 2005). In response, Congress approved the Flood Control Act of 1917, the first federal act aimed exclusively at controlling floods. Though the $45 million program was targeted solely at the lower Mississippi and Sacramento rivers, the action set a precedent with the federal government accepting responsibility for flood control (American Institutes for Research 2005).

The decade's weather events also led to policy developments at the state level. As a result of the drought, the 1913 Burges-Glasscock Act created the Texas Board of Water Engineers to regulate appropriations of water and to centralize claims for water rights. After the epic flooding, the Brazos River and Valley Improvement Association was formed with the goal of harnessing the Brazos River, but the association's efforts were hindered by a lack of financing (BRA 2015). The Legislature responded by passing the Conservation Amendment of 1917, enabling the creation of "conservation and reclamation districts" to develop water resources. The conservation amendment was significant because it declared water resources to be public rights and duties. The Legislature used this authorization over the next several decades to create a number of new special purpose districts, later dubbed river authorities, to build and operate public works such as dams and water delivery systems.

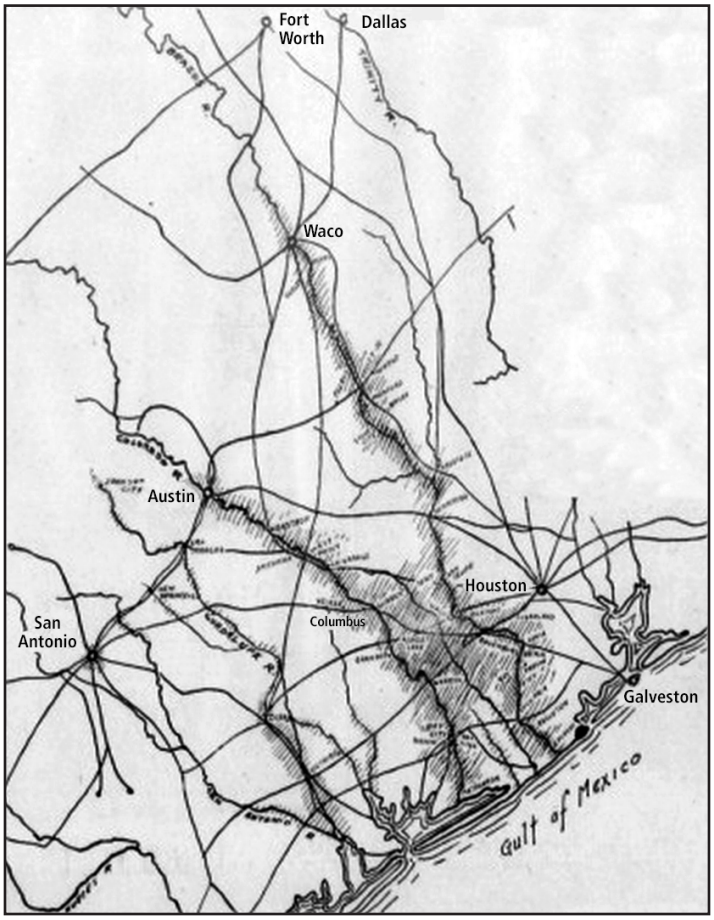


Figure 2. 1913 flood on the Brazos and Colorado Rivers (San Antonio Express News 1913). The Colorado and Brazos rivers were joined by floodwaters below Columbus, resulting in a lake that covered over half a million acres just southwest of Houston.

1920s

1920 Population: 4,663,228

Flood of September 1921: *A tropical storm produced widespread flooding in Central Texas that caused a 12-foot flood wave to rush through downtown San Antonio. Statewide, 215 deaths were reported and rainfall totals at Thrall—over 38 inches in 24 hours—set a Hill Country record (USGS 1991).*

Flood of 1922: *A cloudburst in April inundated low-lying sections of Fort Worth, drowning 16 people and driving hundreds from their homes. The flood shut down the city's water system and washed out rail lines and nearly a mile of the city's levee system (Freese and Sizemore 1994).*

After the extensive damage to the San Antonio business district from the 1921 flood, the next year San Antonio began construction of Olmos Dam, the first Texas dam specifically for flood control (TWC 1964).

Despite its local impacts, the 1922 Fort Worth flood proved to have ripple effects far beyond the city. Local groups quickly began to investigate how to prevent such a disaster from happening again, culminating in the creation of the Tarrant County Water Improvement District in 1924. It soon became clear though that Texas law was inadequate to allow the district to effectively and economically address the city's dual problems of water supply and flood control. After local interests proposed legislation, the Texas Legislature passed the Water Control and Improvement District Act of 1925. The first such district in Texas, Tarrant County Water Control and Improvement District Number One, was approved in 1926. The next year Tarrant County voters approved the construction of Bridgeport and Eagle Mountain reservoirs, the first large reservoirs in the country to provide separate capacities for flood control and water supply (Freese and Sizemore 1994).

In 1923, the Legislature appropriated funds for a survey of all rivers in the state and an analysis of flood and water problems (BRA 2015). The study clearly established the need for a state agency with sufficient powers to tame the Brazos River (BRA 2015). In 1929, 12 years after the passage of the Conservation Amendment, the Legislature authorized the creation of the first river authority—the Brazos River Conservation and Reclamation District[3]. A milestone event in the history of water management, the law was the first in the country to assign the management of a river and its watershed to a single public entity (Freese and Sizemore 1994).

[3]The name of the district was officially changed to the Brazos River Authority in 1955.

1930s

1930 Population: 5,824,715

"The Dust Bowl" of 1930s: *Caused by drought, high temperatures, strong winds, and a failure to prevent wind erosion, the Dust Bowl affected millions of acres across the Great Plains. The worst year for storms was 1935, when 1 complete blackout lasted for 11 hours in Amarillo (Worster 2015).*

Floods of 1930s: *Heavy rainfall in West Texas in 1935, 1936, and 1938 resulted in massive downstream flooding on the Colorado, making the river impassable and splitting the city of Austin in two (LCRA 2015b). San Angelo was hit the worst with rains exceeding 30 inches over a large part of the Concho River Basin during September 1936 (Slade 2003).*

The 1930s were eventful for water policy at both the state and federal level. It began with the passage of the state Wagstaff Act of 1931, which provided protection to upstream municipal water suppliers from downstream senior appropriations for hydroelectric and irrigation purposes. The act declared that it was the public policy of the state that in the allotment and appropriation of water and issuance of permits after the date of the act, preference and priority were to be given to uses in the order listed in statute. Domestic and municipal were first priority, followed by agricultural and industrial uses, followed by mining, hydropower, and other beneficial uses. The Wagstaff Act also recognized the prior appropriation doctrine but further provided that new appropriations of water would be granted subject to the right of municipalities to make additional appropriations without the necessity of condemnation or paying for that water[4].

Like the floods of 1913, those of the mid-1930s were not unique to Texas: disastrous events on a number of the nation's rivers galvanized Congress behind the cause of flood control (Arnold 1988). The resulting Flood Control Act of 1936 represented an initial step toward the development of a national flood control program by providing for studies, surveys, and the construction of around 250 projects using work relief funds (American Institutes for Research 2005).

After the Legislature created the Lower Colorado River Authority in 1934, the state's third river authority[5] received a $20 million federal allotment to complete the Highland Lake dams and reservoirs above Austin; the federal appropriation was third only to federal funds provided for Hoover and Grand Coulee dams (Freese and Sizemore 1994). Combining flood control, water supply, and power, the Highland Lakes

[4]This provision was controversial but never used and therefore never tested in court. It was finally repealed in 1997.

[5]The Guadalupe-Blanco River Authority, created in 1933, was the state's second river authority.

were one of the most important national river developments of the decade. Federal New Deal programs also funded the Red Bluff Dam on the Pecos River and a number of smaller water projects around the state.

The Dust Bowl of the 1930s prompted a considerable amount of debate regarding groundwater management. In 1936, President Roosevelt created the Great Plains Committee, which noted that the Great Plains states, with the exception of New Mexico, had inadequate or non-existent groundwater statutes. State legislation to regulate groundwater failed in 1937, but the following year the Texas Board of Water Engineers called for state ownership of groundwater, echoing previous recommendations.

In 1935, Texas Governor James Allred created the Texas Planning Board to seek federal emergency Depression relief funds and to make recommendations for a number of other issues, including development of the state's natural resources (Freese and Sizemore 1994). In 1938, the Board published, *Development of Texas Rivers, A Water Plan for Texas* (Figure 3).

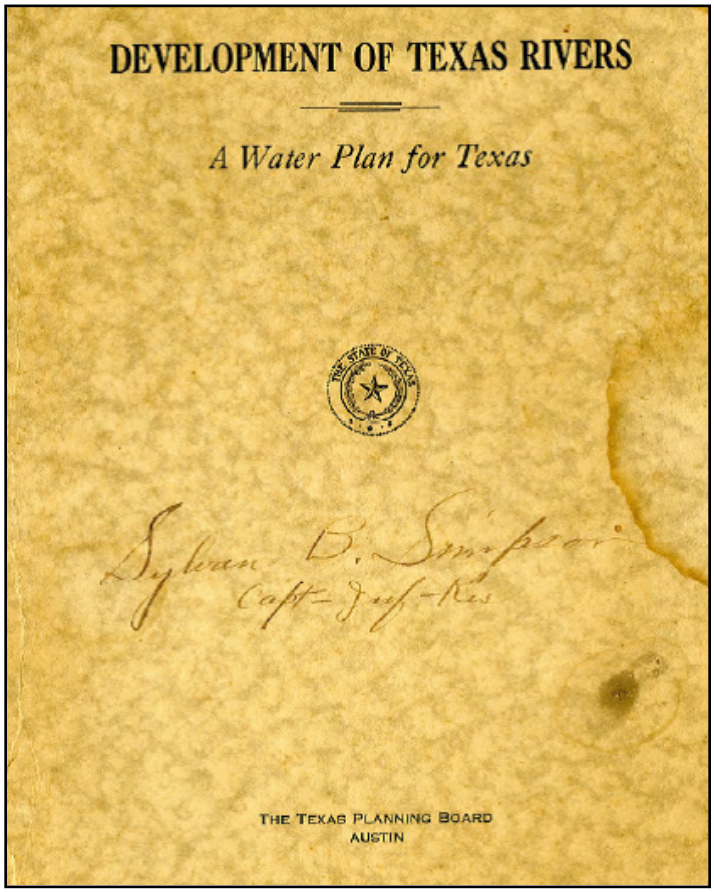


Figure 3. The Texas Planning Board's 1938 water plan. Effectively Texas' first comprehensive state water plan, the plan advocated that flood protection, hydroelectric power, and water supply development should not be treated as separate issues.

Effectively the first comprehensive state water plan, it acknowledged that flood protection, hydroelectric power, and water supply development should not be treated separately from one another (TPB 1938a). The plan inventoried water problems in each major Texas river basin and included recommendations for each basin that addressed an impressive range of issues: salt water intrusion, waste disposal, water supplies, malaria control, flood control, drainage, hydroelectric power, navigation, land use and conservation, streamflow measurement, groundwater surveys, topographic mapping, and climate data. Notably, the plan included a prioritized list of projects for each basin, a concept not truly utilized again in Texas water planning until the Legislature and voters approved creation of the State Water Implementation Fund for Texas in 2013.

The Texas Planning Board also weighed in on the groundwater debate. The Board sent a second report to Governor Allred in 1938 calling for "administrative control of ground water," in the form of legislation consistent with existing surface water law (TPB 1938b).

1940s

1940 Population: 6,414,824

Veritably the calm before the storm, Texas experienced only a few notable floods during the decade of the 1940s and no significant droughts, with the exception of the beginnings of the drought of the 1950s that got an early start in the western and south central portions of the state (Table 1).

Continuing the groundwater debate from the previous decade, state legislation to regulate groundwater failed again in 1941. In 1946, both Lubbock and Big Spring passed resolutions calling for the regulation of groundwater, but irrigation interests from the High Plains formed a group called the High Plains Water Conservation and Users Association to fight legislation to regulate groundwater.

Groundwater legislation died once more in 1947, and concern over water level declines continued to grow with more calls for regulation by industry and municipal groups. Finally in 1949, the Texas Legislature authorized the creation of groundwater conservation districts for the local management of groundwater. The weather of the 1940s may have been uneventful, but the Texas Groundwater Act represented a landmark event in the evolution of Texas water policy. The first district created was the Martin County Underground Water Control District Number 1 in September 1951[6], followed by 5 more in the Texas Panhandle in the 1950s.

[6]Martin County Underground Water Control District No. 1 was later reorganized with Howard County to form the Permian Basin Underground Water Control District in 1985.

1950s

1950 Population: 7,711,194

Drought of the 1950s (Figures 4a, 4b, and 4c): *For most of Texas, the drought of the 1950s is still the longest drought in recorded history. In 1953, 28 municipalities were forced to use emergency sources of water supply, 77 were rationing water, and 8 resorted to hauling in water from neighboring towns or rural wells (TBWE 1959). In 1956, President Dwight Eisenhower declared most of Texas' counties as drought disasters.*

Flood of 1952: *In the middle of the state's worst drought on record, September rains caused Lake Travis to rise 57 feet in about 14 hours (LCRA 2015b). It was later estimated that without the capacity of Lake Travis to store floodwaters, peak flow would have been over 803,000 cubic feet per second at the Colorado River at Austin, instead of 3,720 cubic feet per second as recorded (USGS 1991).*

1954 Hurricane Alice: *In June, the storm moved directly up the Rio Grande Valley and stalled between the Devils and Pecos river drainages, flooding much of Eagle Pass and Laredo. Falcon Dam, just completed in October 1953, captured the floodwaters and in doing so went from nearly empty to close to conservation storage in only 3 days (Slade 2003).*

Floods of 1957: *Ending the historic drought, May rains flooded much of the state, recharging groundwater and sending many reservoirs over their spillways (Freese and Sizemore 1994).*

The entire 1950s proved to be a watershed year in Texas, with some activity also at the federal level. Proving opportune and timely for Texas later in the decade, Congress passed the Disaster Relief Act of 1950 to assist states and local governments in responding to major disasters without the need for congressional action. State governments had to formally request the president declare a major disaster, and if granted, the federal government could then provide disaster assistance to supplement state and local resources (American Institutes for Research 2005).

Following massive flooding in Kansas and Missouri in 1951, President Harry Truman recommended the creation of a national system of flood disaster insurance; however, no law providing a federal source of flood insurance was enacted until the Federal Flood Insurance Act of 1956. Despite extensive discussions among various federal agencies, state and local governments, and the insurance industry, no program was ultimately developed to implement the act, and Congress refused to grant appropriations.

After World War II, Texas and the nation saw a great spike in water consumption due to increased use per person, rapid population growth, urbanization, and industrialization. These factors, combined with an unprecedented drought, made for a busy water policy decade. While cities did what they could to survive the drought, many interests continued to persist for a comprehensive, long-term solution to the state's water problems (Freese and Sizemore 1994). In 1953, the Legislature created the Texas Water Resources Committee to make a detailed inventory of both surface water and groundwater in the state and to develop a long-range water policy and conservation program. By 1957, the committee had drafted 16 bills, including 1 that would authorize state support of local water development projects (Freese and Sizemore 1994).

Following the May 1957 rains, the Legislature passed a resolution in August that authorized $200 million in bonds to help construct water supply projects and created the Texas Water Development Board (TWDB) to administer the funds from the bond sale. In November, voters approved the constitutional amendment—by a greater than 2 to 1 margin—authorizing the TWDB to administer the $200 million water development fund. Then in December of that year, the Legislature passed the Water Planning Act of 1957 during a special session called by Governor Price Daniel. The act created the Water Resources Planning Division of the already existing Board of Water Engineers, which was assigned the responsibility of water resources planning on a statewide basis[7].

In addition to new planning and financing mechanisms, the historic drought brought about other significant changes in Texas water law. In the 1950s, Texas still recognized stream-side landowner or "riparian" water rights based on English common law, along with the western prior appropriation system. This dichotomy continued to lead to conflicts, especially in the lower Rio Grande Valley where some water right holders claimed rights under Spanish law as well. These conflicts were particularly fierce during the drought, leading to the *State vs. Hidalgo County Water Control and Improvement District no. 18*, also known as the "*Valley Water*" case[8], which effectively settled the various claims for water from Falcon Reservoir to the mouth of the Rio Grande. To govern all water rights in the Rio Grande from Amistad Reservoir and below, the case established a priority of use system—with municipal, domestic, and industrial use first, reservoir system operations second, and agriculture last—with a "watermaster" appointed to administer the court's decision.

[7]In 1962, the Texas Board of Water Engineers became the Texas Water Commission, with additional responsibilities for water conservation and pollution control.

[8]The *Valley Water* case involved roughly 3,000 parties, cost an estimated $10 million in court costs and attorney's fees, and took more than 30 years to decide (Jarvis 2014).

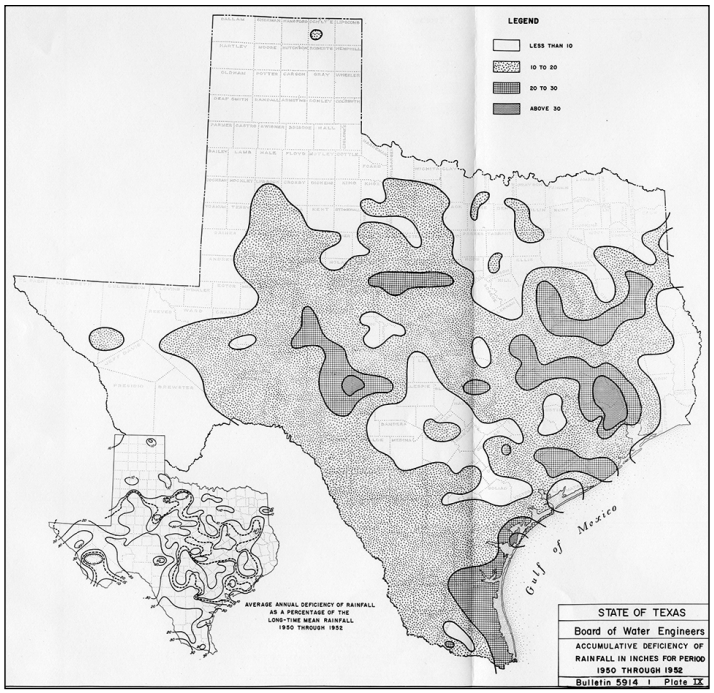


Figure 4a. Accumulative deficiency of rainfall in inches for period 1950 through 1952 (TBWE 1959). The early years of the 1950s drought were particularly severe, with some parts of the state more than 30 inches deficient in rainfall.

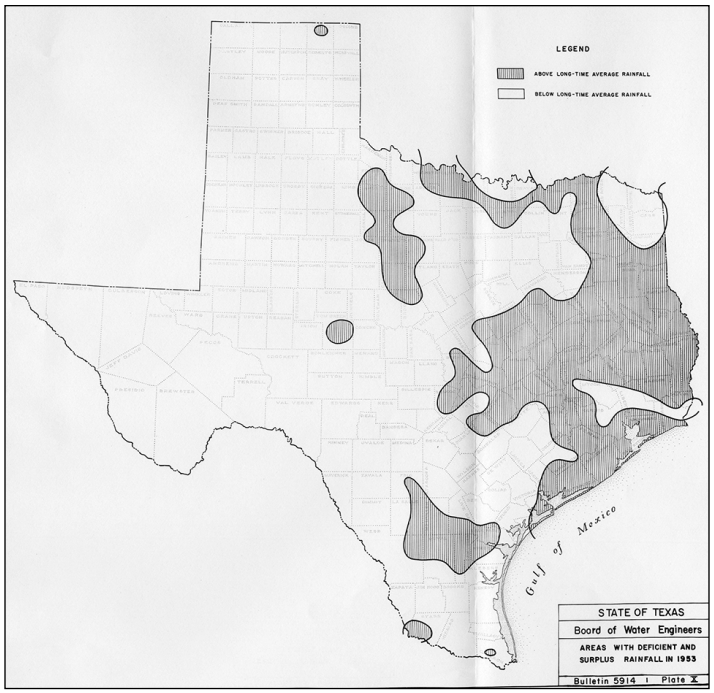


Figure 4b. Areas with deficient and surplus rainfall in 1953 (TBWE 1959). Despite 1953 being one of the worst years of the state's drought of record—with many communities forced to haul in water—some areas received above average annual rainfall.

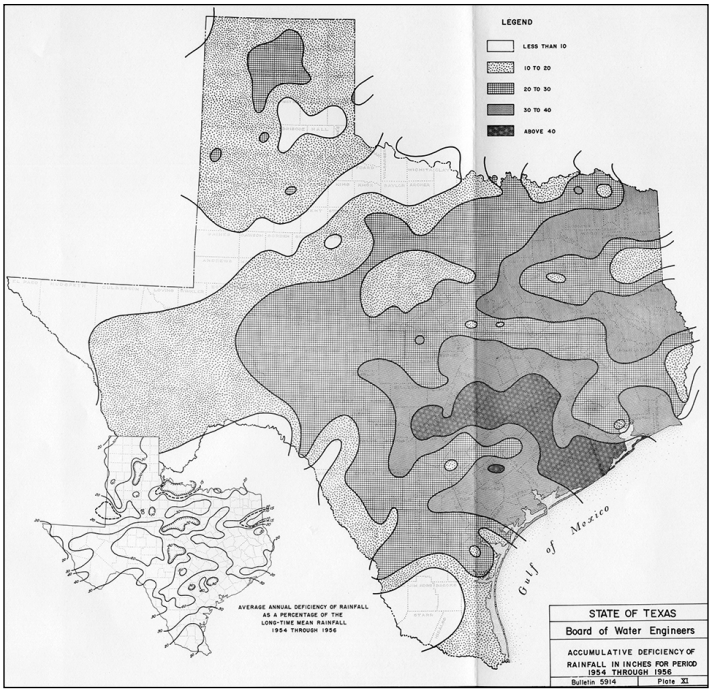


Figure 4c. Accumulative deficiency of rainfall in inches for period 1954 through 1956 (TBWE 1959). By 1956, most of the state had faced years of devastating drought.

1960s

1960 Population: 9,579,677

Three deadly hurricanes struck Texas during the 1960s: Cindy, Carla, and Beulah.

Drought of 1961 to 1966: *Though not one of the most intense droughts, the duration of the 1960s drought ranks third for Texas as a whole (Table 1).*

In response to severe flooding following a series of hurricanes in the 1960s, Congress established the National Flood Insurance Program. Despite the failure of the 1956 Federal Flood Insurance Act, the federal government had continued to study insurance and other financial assistance programs to aid victims of floods and related disasters. Finally in 1968, Congress passed the National Flood Insurance Act, which created the National Flood Insurance Program with 3 key objectives: to reduce the nation's flood risk through floodplain management, to improve flood hazard data and risk assessment by mapping the nation's floodplains, and to make affordable flood insurance widely available in communities that adopt and enforce flood control measures.

Water planning efforts that were kicked off by the drought of the 1950s continued through the 1960s, with the Texas Board of Water Engineers developing a state water plan in 1961, and the TWDB releasing a subsequent plan in 1968[9]. The 1968 plan included an ambitious proposal of 67 dams and reservoirs, redistribution of surplus East Texas water, and importation of water from an out-of-state source such as the Mississippi River (Freese and Sizemore 1994). The next year, Texas voters refused to adopt constitutional changes to enable implementation of the 1968 State Water Plan, including a $3.5 billion water bond authorization and authorization for the TWDB to enter into contracts with other states, the federal government, and other parties for acquisition and development of water resources and facilities (TLC 2014).

After the initiation of the *Valley Water* case during the drought of the 1950s, it was clear that Texas would need a state-administered adjudication process to organize and sort out competing water rights claims. This realization led to the Legislature passing the Water Rights Adjudication Act of 1967 to consolidate all surface water rights into a unified system, transforming previously held Spanish and Mexican grants, riparian rights, and other claims into "certificates of adjudication" (LRL 2015). It took the state a full 40 years to adjudicate all water rights claims, with the final adjudication of the Upper Rio Grande segment above Fort Quitman in 2007 (Jarvis 2014).

The *Valley Water* case also demonstrated that a system of watermasters would be necessary where water was especially in short supply relative to the number and amounts of water rights recognized. Today the Texas Commission on Environmental Quality administers the Rio Grande, South Texas, Concho, and Brazos river watermaster programs.

1970s to 1990s

1970 Population: 11,196,730
1980 Population: 14,229,191
1990 Population: 16,986,510

Despite a relative lull in hurricane activity, Texas was struck by a series of tropical storms in the 1970s, 1980s, and 1990s. In July 1979, Tropical Storm Claudette deluged Alvin with 43 inches of rain in 24 hours, setting the all-time greatest 24-hour precipitation record for the United States (NOAA 2015c).

Shoal Creek Flood of 1981: *Ten inches of rain fell in a span of 4 hours in central Austin, damming Shoal Creek with more than 500 cars from local dealerships and killing 13 people (LCRA 2015b; Slade 2003).*

Christmas Flood of 1991: *Lake Travis rose to an all-time high of 710 feet above mean sea level, just shy of the Mansfield Dam spillway (LCRA 2015b).*

Drought of 1996: *A short drought in the middle of the decade caused Texas agricultural losses estimated at $2.1 billion.*

Flood of 1998: *Canyon Reservoir filled to capacity and water rushed over the spillway for the first time ever, carving a new gorge in its path.*

Flooding experienced at the national level in the 1970s led to the National Weather Service's development of the first early warning systems designed to reduce loss of life, property damage, and disruption of commerce and human activities from flash floods.

While Texas remained relatively drought free for most of the 1970, 1980s, and 1990s, water supply planning efforts initiated at the end of the state's drought of record continued[10]. And despite defeat of the constitutional amendment to implement the 1968 water plan, studies on transporting water from the Mississippi River continued, but costs were found to be largely prohibitive.

The brief drought of 1996 again galvanized state leadership and led to the passage of Senate Bill 1 the next year, which

[9]In 1965, the Texas Water Commission became the Texas Water Rights Commission, a precursor agency to the Texas Commission on Environmental Quality; functions not related to water rights were transferred to the Texas Water Development Board.

[10]TWDB failed to adopt a revised state water plan that was anticipated in 1977 (TWDB 1976) but adopted subsequent state-level plans in 1984, 1990, 1992, and 1997.

provided for a new regional water planning process[11], a state Drought Preparedness Council, and water conservation and drought contingency plans. Senate Bill 1 explicitly reiterated that groundwater districts were the state's preferred method for managing groundwater resources and brought enhanced scrutiny of interbasin transfers in an attempt to balance the interests of the basin of origin and the receiving basin. Senate Bill 1 also repealed the provision of the 1931 Wagstaff Act that could make water available for municipal use on a watercourse that is otherwise fully appropriated. And to address municipal shortages in times of drought, the bill amended emergency authorizations for water rights.

The 1996 drought was not isolated to Texas: at its peak in May, portions of California, Nevada, Utah, Oklahoma, Kansas, Arkansas, and Louisiana were experiencing severe drought, and most of Arizona and New Mexico were experiencing extreme drought conditions. In response, the Western Governors' Association set an aggressive goal to change the way our nation prepares for and responds to droughts, which ultimately led to the National Drought Policy Act of 1998 and the National Integrated Drought Information System Act of 2006 (Western Governors' Association 2004). These acts began new efforts to implement drought monitoring and forecasting at federal, state, and local levels, including development of early warning systems.

2000s to Present

2000 Population: 20,851,820
2010 Population: 25,388,505

Drought of 1999 to 2002: *During an intense drought in the Lower Rio Grande Valley, low flows—combined with sedimentation and more than 10 years of lack of compliance by Mexico with the 1944 treaty[12]—caused the Rio Grande to cease flowing into the Gulf of Mexico for several months during 2001 (MWH 2003).*

Flood of 2007: *In June, a 19-inch "rain bomb" near Marble Falls resulted in massive runoff into Lake Travis that was contained by Mansfield Dam, minimizing flooding downstream (LCRA 2015b).*

Drought of 2010 to 2014: *2011 was the worst 1-year drought since statewide weather records began. It resulted in record agricultural losses of $7.6 billion (Texas AgriLife Extension Service 2012) and loss of several million urban trees, and contributed to thousands of wildfires across the state, including the Bastrop County Complex fire, the most destructive wildfire in Texas history. Despite its severity, only 1 community had to haul in water during the 4-year drought[13].*

Memorial Day Weekend Floods of 2015: *A brutal storm system ravaged communities in Central Texas and Houston over the Memorial Day weekend, leaving dozens of people dead, missing, injured, or displaced. The Blanco River at Wimberley rose from 5 to near 41 feet in only 4 hours, surpassing the 500-year floodplain and washing away federal stream gages (NWS 2015).*

Only barely through the first 2 decades of the new century, Texas has already experienced the most intense 1-year drought in Texas' recorded history, along with historic flooding on an otherwise tranquil river. The drought, which began suddenly in 2010, again led to significant changes in not only water supply planning but in the financing of water development projects. In 2013, the 83rd Texas Legislature passed legislation providing for the creation of the State Water Implementation Fund for Texas (SWIFT) and the State Water Implementation Revenue Fund for Texas. In addition, it authorized a 1-time, $2 billion supplemental appropriation from the state's Economic Stabilization Fund (also known as the Rainy Day Fund) to SWIFT, contingent on voter approval. Proposition 6 passed on November 5, 2013, with more than 70% in favor. The investment in the SWIFT is designed to support billions of dollars in state financial assistance for water supply projects over the next 50 years. As part of the planning effort, regional water planning groups and the TWDB were directed by the Legislature to prioritize projects based a number of criteria.

The historic flood on the Blanco River in 2015 exposed weaknesses in both local and federal early warning systems, beginning a dialogue that may continue into the next legislative session. The discussion may well include the need for greater support of the National Streamflow Information Network, which has steadily lost both state and federal funding since 2000 (Table 2).

CONCLUSION

Both floods and droughts have had a significant impact on generations of Texans. Lessons have been learned after every event, and the timeline is largely a story of our successful efforts to prepare for, respond to, and prevent disasters. Our flood control infrastructure has time and again prevented the types of catastrophes that predated modern flood control, more than repaying the cost of the original investment. Despite the severity of our most recent drought, only 1 community had to haul

[11]Three state water plans have been developed though the regional water planning process: 2002, 2007, and 2011.

[12]Since the early 1990s, Mexico has repeatedly failed to meet its obligations to a treaty signed in 1944 that allocates waters in the lower reach of the Rio Grande.

[13]The community of Spicewood Beach on Lake Travis had to haul in water for over 2 years beginning in January 2012.

Table 2. Streamgage joint state-federal funding agreement.

Fiscal Year	TWDB	USGS	Total Contract	Percent of Cost		Lake Gages	Stream Gages
				TWDB	USGS		
2000	$773,795	$618,502	$1,392,297	55.6%	44.4%	58	105
2001	$873,282	$616,046	$1,489,328	58.6%	41.4%	58	104
2002	$1,021,161	$643,726	$1,664,887	61.3%	38.7%	58	104
2003	$1,022,000	$643,800	$1,665,800	61.4%	38.6%	60	120
2004	$1,027,746	$643,800	$1,671,546	61.5%	38.5%	57	110
2005	$1,085,980	$669,860	$1,755,840	61.8%	38.2%	57	109
2006	$977,315	$669,860	$1,647,175	59.3%	40.7%	57	109
2007	$963,421	$721,205	$1,684,626	57.2%	42.8%	56	104
2008	$971,120	$785,580	$1,756,700	55.3%	44.7%	57	108
2009	$965,717	$739,500	$1,705,217	56.6%	43.4%	57	101
2010	$917,085	$608,910	$1,525,995	60.1%	39.9%	57	92
2011	$926,565	$601,800	$1,528,365	60.6%	39.4%	57	86
2012	$709,250	$456,095	$1,165,345	60.9%	39.1%	43	59
2013	$687,495	$400,600	$1,088,095	63.2%	36.8%	43	56
2014	$690,545	$372,200	$1,062,745	65.0%	35.0%	40	56
2015	$635,261	$372,200	$1,007,461	63.1%	36.9%	35	53

in water, a testament to our water supply planning efforts.

However, no plans are perfect. The timeline also reinforces the need for continuous planning and improvement. Drought and floods will visit Texas again, and our projected population growth will, if we do not plan accordingly, place more Texans in harm's way. Recent droughts and floods have demonstrated that traditional infrastructure is not the only solution: infrastructure must now work in tandem with early forecasting and warning systems for both floods and droughts. These systems need effective policies at both the state and federal level to support them, and more than ever before, engagement by all citizens. Texans need to know where their water comes from, how they can do their part to mitigate water challenges, and what their responsibilities are when severe weather hits. Only then will our future plans be truly viable.

REFERENCES

American Institutes for Research, The Pacific Institute for Research and Evaluation, Deloitte & Touche LLP. 2005. A chronology of major events affecting the National Flood Insurance Program. Completed for the Federal Emergency Management Agency. Washington D.C. Contract Number 282-98-0029. Available from: http://www.fema.gov/media-library-data/20130726-1602-20490-7283/nfip_eval_chronology.pdf

Arnold JL. 1988. The evolution of the 1936 Flood Control Act. Fort Belvoir (Virginia): United States Army Corps of Engineers. Available from: http://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_870-1-29.pdf

Bishop C. 2010. Brazos flood of 1899. Handbook of Texas Online. Austin (Texas): Texas State Historical Association. Available from: https://tshaonline.org/handbook/online/articles/ydb01

[BRA] Brazos River Authority. 2015. Timeline of the Brazos River Basin. Waco (Texas): Brazos River Authority. Available from: https://www.brazos.org/About-Us/About-the-BRA/About-the-Brazos-River/Basin-History

Freese SW, Sizemore DL. 1994. A century in the works, Freese and Nichols Consulting Engineers, 1894–1994. First edition. College Station (Texas): Texas A&M University Press. 435 p.

Gard W. 2015. Fence cutting. Handbook of Texas Online. Austin (Texas): Texas State Historical Association. Available from: https://tshaonline.org/handbook/online/articles/auf01

Jarvis G. 2014. Historical development of Texas surface water law: background of the appropriation and permitting system and management of surface water resources McAllen (Texas). Available from: http://glennjarvis.com/water-rights-adjudication/3_Hist_Devlpmnt_TX_Surf_Wtr_Law.pdf

[LRL] Legislative Reference Library. 2015. Texas water law timeline. Austin (Texas): Legislative Reference Library. Available from: http://www.lrl.state.tx.us/legis/waterTimeLine.cfm

[LCRA] Lower Colorado River Authority. 2015a. Managing floods in Flash Flood Alley. Austin (Texas): Lower Colorado River Authority. Available from: http://www.lcra.org/water/floods/pages/default.aspx

[LCRA] Lower Colorado River Authority. 2015b. Major floods on the Colorado River. Austin (Texas): Lower Colorado River Authority. Available from: http://www.lcra.org/water/floods/Documents/Major-Floods-on-the-Colorado-River.pdf

Malsch B. 2015. Indianola, Texas. Handbook of Texas Online. Austin (Texas): Texas State Historical Association. Available from: https://tshaonline.org/handbook/online/articles/hvi11

[MWH] Montgomery Watson Harza. 2003. Rio Grande mouth closure study. Prepared for International Boundary and Water Commission, United States Section. El Paso (Texas). Contract number IBM02D0001 Task Order Number IBM02T0002.

[NOAA] National Oceanic and Atmospheric Administration. 2015a. Billion-dollar weather and climate disasters: mapping. Available from: https://www.ncdc.noaa.gov/billions/mapping

[NOAA] National Oceanic and Atmospheric Administration. 2015b. The Galveston Hurricane of 1900. Available from: http://oceanservice.noaa.gov/news/features/sep13/galveston.html

[NOAA] National Oceanic and Atmospheric Administration. 2015c. State Climate Extremes Committee. Available from: http://www.ncdc.noaa.gov/extremes/scec/records

[NWS] National Weather Service. 2015. Memorial Weekend flooding–May 2015. Austin/San Antonio (Texas): National Weather Service Forecast Office. Available from: http://www.srh.noaa.gov/ewx/?n=memorial_weekend_floods_2015

San Antonio Express News. 1913 December 11. Flood waters of Texas rivers take costly toll in life and property in sweep over wide area. Vol. 48, No. 345, Ed. 1. Available from: http://texashistory.unt.edu/ark:/67531/metapth432670/m1/8/?q=%22colorado

Slade RM, Patton J. 2003. Major and catastrophic storms and floods in Texas. United States Geological Survey Open-File Report 03-193. Available from: http://pubs.usgs.gov/of/2003/ofr03-193/cd_files/USGS_Storms/patton.htm

Texas AgriLife Extension Service. 2012. Updated 2011 Texas agricultural drought losses total $7.62 billion. AgriLife TODAY. College Station (Texas). Available from: http://today.agrilife.org/2012/03/21/updated-2011-texas-agricultural-drought-losses-total-7-62-billion/

[TBWE] Texas Board of Water Engineers. 1959. A study of droughts in Texas. Bulletin 5914. Austin (Texas): Texas Board of Water Engineers. Available from: http://www.twdb.texas.gov/publications/reports/bulletins/doc/Bull.htm/B5914.asp

[TLC] Texas Legislative Council. 2014. Amendments to the Texas Constitution since 1876. Austin (Texas): Texas Legislative Council. Available from: http://www.tlc.state.tx.us/pubsconamend/Constamend1876.pdf

[TPB] Texas Planning Board. 1938a. Development of Texas rivers, a water plan for Texas. Austin (Texas): The Texas Planning Board. Available from: http://www.twdb.texas.gov/publications/reports/other_reports/doc/1938WaterPlanforTexas.pdf

[TPB] Texas Planning Board. 1938b. The need for administrative control of ground water. Austin (Texas): The Texas Planning Board.

[TRA] Trinity River Authority. Our History. Dallas (Texas): Trinity River Authority. Available from: http://www.trinityra.org/ourhistory

[TSHA] Texas State Historical Association. 1928. West Texas drouths. The Southwestern Historical Quarterly. 32(2).

[TSHA] Texas State Historical Association. 2002. "God help them all and so must we:" Clara Barton, Reverend John Brown, and drought relief efforts, 1886–1887. The Southwestern Historical Quarterly. 106(4).

[TWC] Texas Water Commission. 1964. Fifty years of water development in Texas. Bulletin 6403. Austin (Texas): Texas Water Commission. Available from: https://www.twdb.texas.gov/publications/reports/bulletins/doc/B6403.pdf

[TWDB] Texas Water Development Board. 1966. Technical papers on selected aspects of the preliminary Texas Water Plan, Report 31. Austin (Texas): Texas Water Development Board. Available from: https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R31/R31.pdf

[TWDB] Texas Water Development Board. 1976. An assessment of surface water supplies of Arkansas with computations of surplus supplies and a conceptual plan for import to Texas. Austin (Texas): Texas Water Development Board. Available from: https://www.twdb.texas.gov/publications/reports/historic_groundwater_reports/doc/SurfaceWaterSupplies_Arkansas.pdf

[TWRI] Texas Water Resources Institute. 2011. Texas drought: now and then. txH2O. College Station (Texas): Texas Water Resources Institute. Available from: http://twri.tamu.edu/publications/txh2o/fall-2011/

[USGS] United States Geological Survey. 1991. National water summary 1988–89—hydrologic events and floods and droughts. USGS Water-Supply Paper 2375. Denver (Colorado): United States United State Geological Survey. Available from: http://pubs.usgs.gov/wsp/2375/report.pdf

[USGS] United States Geological Survey.1998. A new evaluation of the USGS Streamgaging Network. Washington D.C.: U.S. Geological Survey. Available from: http://water.usgs.gov/streamgaging/report.pdf

Western Governors' Association. 2004. Creating a drought early warning system for the 21st century. Denver (Colorado): Western Governors' Association. Available from: https://www.drought.gov/media/pgfiles/nidis.pdf

Worster D. 2012. Dust Bowl. Handbook of Texas Online. Austin (Texas): Texas State Historical Association. Available from: https://tshaonline.org/handbook/online/articles/ydd01