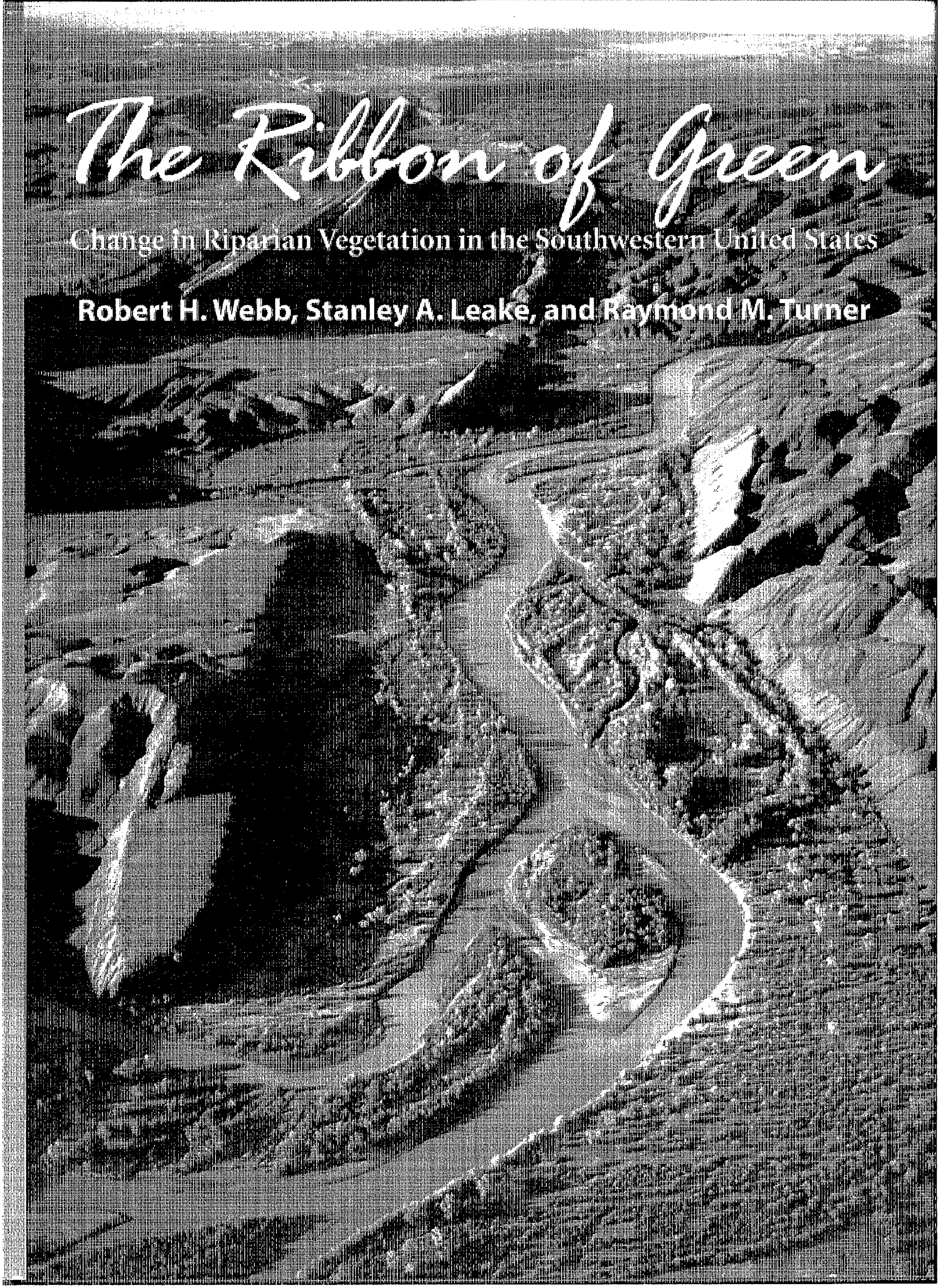
The Ribbon of Green

Change in Riparian Vegetation in the Southwestern United States

Robert H. Webb, Stanley A. Leake, and Raymond M. Turner



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24 The Salt River

Summary. The Salt River is arguably the most important drainage basin wholly within Arizona, providing water supply and hydroelectric power to the Salt River Valley. This river drains much of the highlands of eastern Arizona before flowing through deep bedrock canyons that end about 20 miles upstream from Phoenix. Most of the upper Salt River flows through narrow bedrock canyons, where both native riparian vegetation and nonnative riparian vegetation have increased modestly despite the occurrence of extremely large floods. Downstream from its confluence with the Verde River, the Salt River flows through the Salt River Valley in a meandering pattern over a broad floodplain. Despite full regulation by dams upstream from Phoenix, the combined flows of the Salt and the Verde Rivers produced damaging floods through the Salt River Valley as recently as 1993. Little water is normally released through the deep alluvial valleys of the Phoenix basin, which once supported scattered stands of cottonwood. It is likely that open groves of cottonwood once existed in the Salt River Valley, and they were eliminated by the combination of nearly complete surface-water diversion, except during extreme floods; agricultural clearing; urban development; and channelization of the Salt River.

Arising along the Mogollon Rim in east-central Arizona, the Black and White Rivers merge to form the Salt River, which then flows 200 miles to its confluence with the Gila River (fig. 24.1). The Salt's drainage area of 13,223 square miles includes some of the most rugged mountainous and desert terrain in Arizona. Downstream from the Black-White River confluence, the river is confined in Salt River Canyon before emerging into shallow alluvial basins upstream from Theodore Roosevelt Lake. A series of four dams—three upstream from the confluence with the Verde River (chapter 23)—completely regulates flow from the mountain ranges on the east to the alluvial Phoenix basin. Crossing the Salt River Valley, the river flows ephemerally between soil-cemented banks during rare periods of storm runoff not captured by the upstream reservoirs.

Although this river has had many names, it is called the Salt River owing to the brackish nature of groundwater effluent during low-flow periods.[1] Because it provides most of the water supply for Phoenix, it is arguably Arizona's most important river, having headwaters wholly within the state. The Salt River was a benchmark in water development in the West because it was the first to be affected by the major flow-regulation projects. Granite Reef Dam, completed in 1908, was one of the first concrete structures built to divert surface water for irrigation. More than 1,000 miles of irrigation canals channel surface water through the Salt River Valley,[2] overshadowing Hohokam irrigation projects of the twelfth and thirteenth centuries.[3] In addition to the intensive use of surface water, groundwater resources were developed and used extensively in the twentieth century. By 1922, yearly groundwater withdrawals in the Salt River Valley exceeded combined groundwater use in the rest of Arizona.

Early Observations of the Salt River

The first visitors to the Salt River Valley guessed that the river had perennial flow that was about 200 feet wide with a depth of as much as 4 feet.[4] James Ohio Pattie and his companions arrived at the confluence of the Gila and Salt Rivers on February 1, 1826. They saw the abundant beaver in the Salt River and traveled upstream more than 80 miles, trapping in both the Salt River Canyon and the Verde River Canyon. Pattie described the Salt River near present-day Phoenix as "a most beautiful stream, bounded on each side with high and rich bottoms,"[5] but he did not mention whether cottonwood trees were present through the Salt River Valley. Beaver sign were seen near the Salt-Gila confluence as late as 1885.[6]

Settlement of the Salt River Valley began with the arrival of Mormons to found Mesa, Arizona, in 1877.[7] They immediately began to regulate the Salt River, using an abandoned Hohokam canal to irrigate fields carved into the floodplain. Thus began a thirty-year struggle with this river that ended with construction of Granite Reef Dam and the establishment of the Salt River Project (SRP). Settlers observed abundant bonytail, Colorado River pikeminnow, and other native fishes in the river and irrigation canals before about 1915.[8] The last known Colorado River pikeminnow was caught in the Salt River upstream from Phoenix in 1937; this species, reportedly common in 1906, was the basis of a commercial fishery.[9]

Floods

Because the Salt River flowed perennially through an arid region, it attracted civilizations. The Hohokam established major cities fed by a network of canals from the Salt. This culture abandoned the river valley around A.D. 1350, leaving a desolate basin largely uninhabited by humans. The reason for the abandonment might have been large floods combined with sustained droughts. Twenty-seven floods between around A.D. 850 and

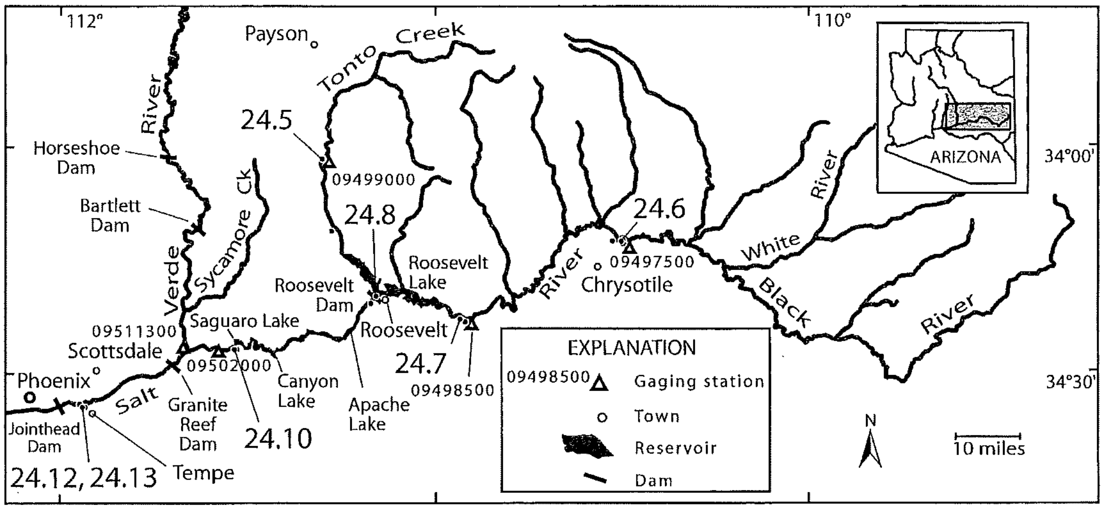


Figure 24.1 Map of the Salt River in central Arizona.

1976 exceeded a bankfull discharge threshold of 175,000 ft^3/s on the Salt River upstream from Tempe.[10] In A.D. 899, the Salt River reportedly yielded 2.5 million acre-feet of runoff, based on tree-ring reconstructions,[11] and a flood with a peak discharge of 420,000 ft^3/s occurred at about this time.[12] The long-term average flow volume of the Salt and Verde Rivers at gaging stations upstream from the Salt River Valley is 1.2 million acre-feet per year,[13] and the largest measured flood, in February 1891, had a peak discharge of about 300,000 ft^3/s (see the next section).

The combined flow of the Salt and Verde Rivers has created some of the most devastating floods in Arizona history. For example, in February 1890, the Salt River rose 17 feet, washing out the bridge at Tempe and damaging floodplain structures all the way to Yuma.[14] In February 1891, the river rose one foot higher than this and flooded a swath of the valley up to 8 miles wide. The 1891 flood on the Salt River, with a peak discharge estimated to be 300,000 ft^3/s,[15] had serious consequences for the fledgling town of Phoenix; the floodwaters reportedly destroyed one-third of the town.[16] Floods that caused inundation or other damage occurred in September 1897, January 1905, March 1905, January 1916, November 1919, and March 1938.[17]

Despite the presence of dams upstream on both the Salt and the Verde Rivers, floods in the last quarter of the twentieth century were severe through Phoenix. Generated mostly upstream in the Salt River (fig. 24.2), these floodwaters combined with waters pouring down the Verde River to create truly awesome floods through the urban area. In March 1978, floodwaters peaked at 125,000 ft^3/s through Phoenix, and on January 8, 1993, the peak discharge was 129,000 ft^3/s (see fig. 24.11). The need to protect floodplain structures, such as bridge abutments, and to increase the area for development next to the river drove channelization of the river and the installation of soil cements on its banks.

Flow Regulation and Groundwater Development

The first diversion of the Salt River for irrigation purposes occurred in 1885.[18] This structure paled in comparison to what came next: Granite Reef Dam (1908), Roosevelt Dam (1911), Mormon Flat Dam (1926), Horse Mesa Dam (1927), and Stewart Mountain Dam (1930). Other dams on the Verde River (see chapter 23) completed the full regulation of the Salt River by 1946. Roosevelt Dam, originally called Tonto Dam because it was built at the mouth of Tonto Creek, impounds Theodore Roosevelt Lake and flooded the town of Roosevelt. In 1959, the dam was renamed for President Theodore Roosevelt. The original dam, 284 feet high, was raised to a height of 357 feet in a project completed in 1996.[19] Downstream from the former town of Roosevelt, the Salt River is completely regulated for the purposes of flood control, irrigation, and domestic water supply for the Salt River Valley.

The SRP, which began in 1903 as part of the Salt River Valley Water Users Association,[20] delivers a little less than one million acre-feet per year of water to central Arizona, primarily to Phoenix and its suburban satellite communities.[21] It also produces hydroelectric power from the dams it manages: potential power production of 36 megawatts (MW) from Roosevelt Dam; 129 MW from Horse Mesa Dam and its pumped storage unit; 60 MW from Mormon Flat Dam and its pumped storage unit; 13 MW from Stewart Mountain Dam;, and a combined output of less than 5 MW from several small structures on canals. The combination of flood control, water storage, and power generation makes this complex of dams on the Salt River extremely important to Arizona's development and economy.

Despite the abundance of surface-water diversion for irrigation, groundwater pumping in Arizona began to

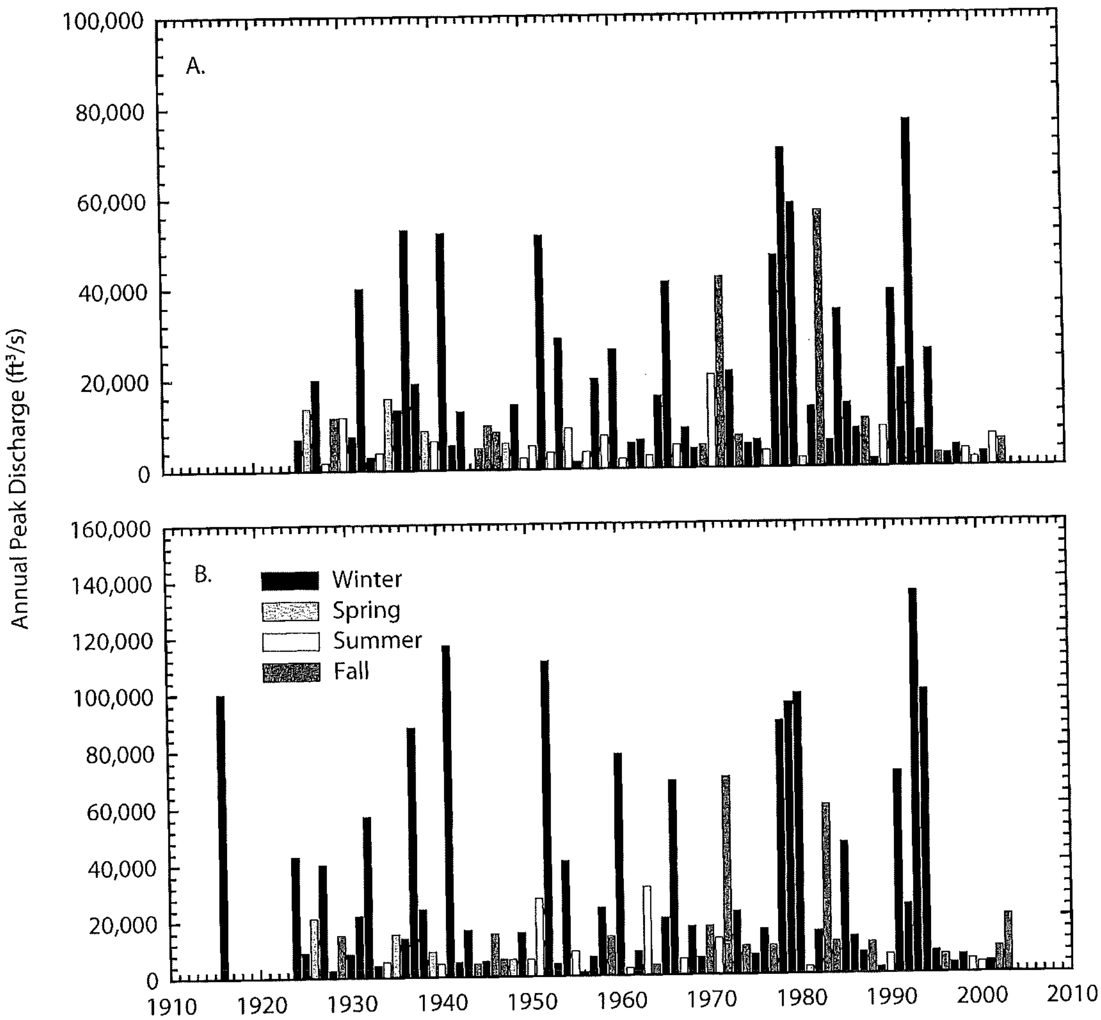


Figure 24.2 Annual flood series for the Salt River.

A. The Salt River near Chrysotile, Arizona (station 09497500; 1925–2003).

B. The Salt River near Roosevelt, Arizona (station 09498500; 1916, 1924–2003).

accelerate in the 1920s following the development of turbine pumps (fig. 24.3).[22] As water levels dropped, some fragile layers in the alluvial aquifer drained and compacted, causing subsidence of the ground surface. In the Salt River Valley, problems attributed to land subsidence, including earth fissures and collapsed well casings, were documented by the early 1960s.[23] Excessive groundwater development in the Salt River Valley led to the creation of the Phoenix Active Management Area in 1980.[24] Water levels in some areas had declined as much as 450 feet between 1923 and 1982. Nearer to the Salt River, water levels that had declined in the 1960s rebounded by the 1980s (fig. 24.3B), responding to the combination of flood releases and use of CAP water imported from the Colorado River.

Changes in Riparian Vegetation

Tonto Creek

Tonto Creek, named for the Tonto Apache who once inhabited this watershed,[25] drains an area of more than 675 square miles below the Mogollon Rim of central Arizona (fig. 24.1). As with many drainages in this region, floods can be extremely large during regional storms. The flood of record, which occurred during the January 1993 floods, had a peak discharge of 72,500 ft^3/s (fig. 24.4). The effect of the early-twenty-first-century drought is shown in the substantial decrease in peak discharges between 1996 and 2002 in this drainage basin. Despite the floods and perhaps because of a sustained drought period, photographs show that riparian vegetation has increased

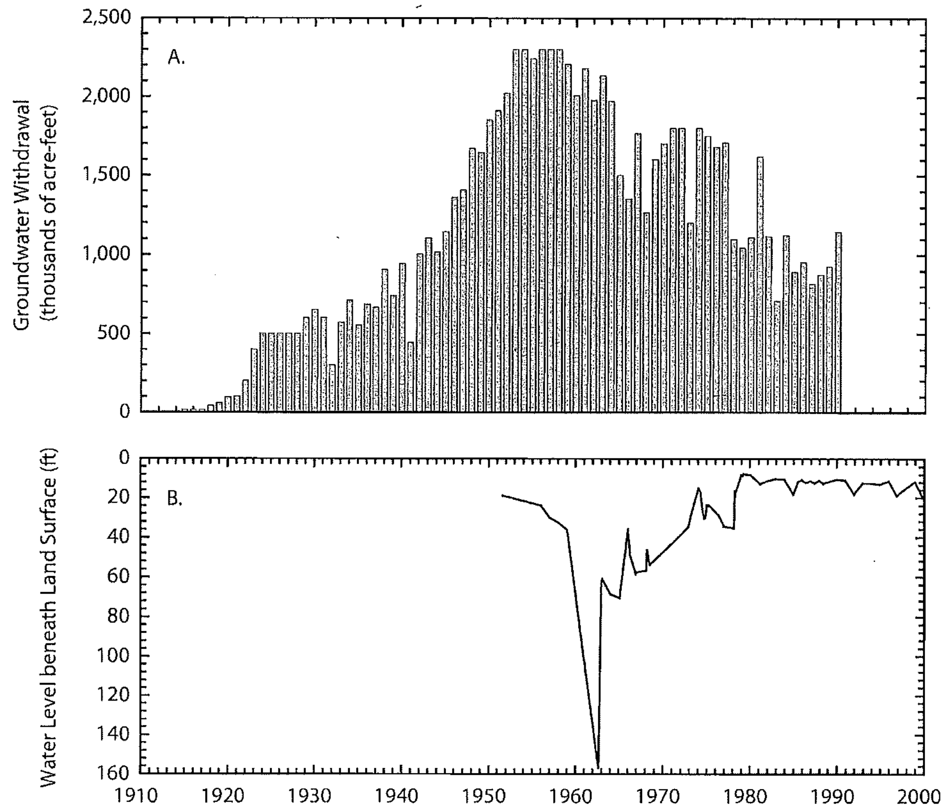


Figure 24.3 Groundwater records for the Salt River Valley near Phoenix.

A. Annual amount of groundwater used in Maricopa County (from Anning and Duet 1994).

B. Groundwater levels for well B-01-02 36BBC near the Salt River in Phoenix, Arizona.

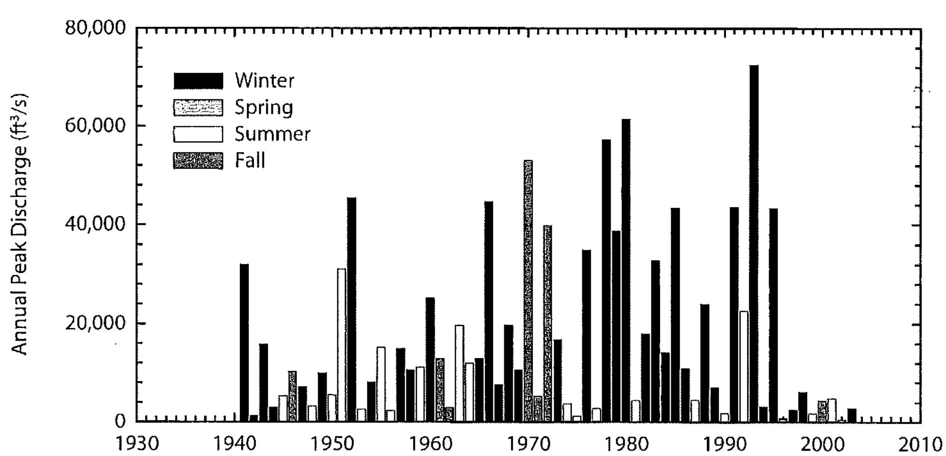


Figure 24.4 Annual flood series for Tonto Creek above Gun Creek, near Roosevelt, Arizona (station 09499000; 1941–2003).

along Tonto Creek, even in relatively narrow channel reaches (fig. 24.5). Other photographs near the delta with Theodore Roosevelt Lake show similar increases, although tamarisk is more abundant.

Salt River Upstream from Roosevelt Dam

About 30 river miles downstream from the confluence of the Black and White Rivers, the Salt River passes under a pair of bridges for the combined U.S. 60 and Arizona Highway 77. Photographs upstream from the older bridge (fig. 24.6) show conditions in the bedrock-controlled channel of the Salt River in the vicinity of the gaging station (near Chrysotile; fig. 24.2A). Riparian vegetation, mostly native species but also with significant amounts of tamarisk, has steadily increased along the channel. Interestingly, one of the species here is fan palm (fig. 24.6C). This tree likely was planted, although the species has been found in natural settings in central Arizona.[26]

Downstream from the bridges, the Salt River flows through a wilderness reach renowned for its whitewater characteristics. Several small tributaries add flow to the river, including Cibecue Creek, Canyon Creek, and Cherry Creek from the north and Pinal Creek from the south. A second gaging station is on the bridge for Highway 288 at the downstream end of this reach and just upstream from the delta of Theodore Roosevelt Lake. As shown in fig. 24.2, the increase in flood magnitude on the Salt River is dramatic owing to contributions by the intervening tributaries.

The valley widens downstream from the bridges, and the river flows through a shallow alluvial valley with considerable room for growth of riparian vegetation. Between 1937 and 2000, the channel width decreased, and riparian vegetation increased despite the spate of severe floods between 1978 and 1995 (fig. 24.7). Although most of the riparian vegetation in this reach is tamarisk, the presence of carrizo grass, seepwillow, and black willow suggests that native species are also increasing here.

Theodore Roosevelt Lake was the first large reservoir in Arizona, and it covers about 10 miles of the once free-flowing Salt River and 8 miles of Tonto Creek in a relatively wide reach. All woody riparian vegetation in these reaches was killed, but replacements occurred on the delta. As shown in figure 24.8, little riparian vegetation was present in 1910 at the confluence of the Salt River and Tonto Creek, just upstream from the present-day location of the dam. Fluctuations in lake level preclude establishment of significant riparian vegetation along the steep shoreline (fig. 24.8B), although tributary deltas can support dense stands of mostly nonnative vegetation.

Salt River Downstream from Stewart Mountain Dam

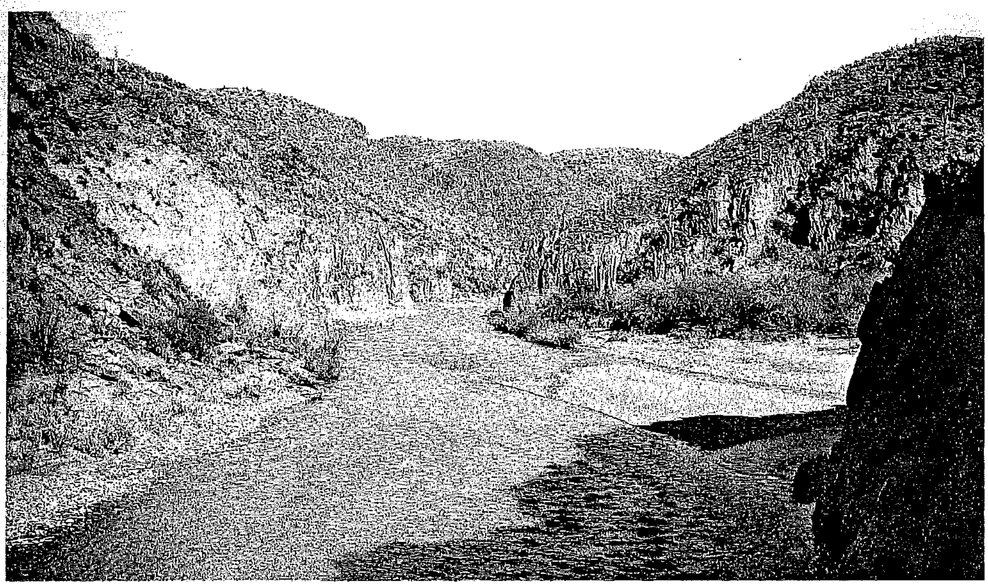
The reservoir system on the Salt River upstream from its confluence with the Verde River (fig. 24.1) controls small- and intermediate-size floods on the main stem. However, large floods have overwhelmed the combined storage capacity of the reservoirs, resulting in damaging releases downstream into the Salt River Valley. Ultimately, floods such as those shown in figure 24.9 prompted raising the height of Roosevelt Dam and the storage capacity of Theodore Roosevelt Lake in 1996.

Because the presence of dams regulated floods after 1911, and because releases were steady to supply irrigation water to the Salt River Valley, the channel along the lower Salt River was stable enough to grow significant amounts of riparian vegetation in the 1930s (fig. 24.10A). Tamarisk, which was introduced into the basin in the late nineteenth century, was well established here in 1938. The clear-water releases of the late 1970s, in particular the January 1979 release that peaked at 54,000 ft^3/s, scoured the channel in this reach and coarsened the substrate on the low floodplain, reducing its ability to sustain riparian vegetation (fig. 24.10B). By 1995, and following the 1980 and 1993 releases of 64,000 and 34,500 ft^3/s, respectively (fig. 24.9), the channel had widened, and floodplain substrate had coarsened even more (fig. 24.10C). Riparian vegetation here consists of tamarisk as well as native shrubs and Frémont cottonwood.

Granite Reef Dam, below the confluence of the Salt and Verde Rivers, diverts most of the surface flow from the channel into an intricate system of canals, and riparian vegetation quickly diminishes downstream in the main channel. The channel of the Salt River has migrated laterally up to a mile across a broad floodplain,[27] which would minimize the ability for riparian vegetation to remain established near the channel. This migration occurred during extremely large floods fed by the combination of the two rivers (fig. 24.11). Before modifications were completed in 1996, the dams upstream from the confluence of the Salt and Verde could not control the largest discharges, so that four floods with peak discharges greater than 100,000 ft^3/s passed through the Salt River Valley between 1978 and 1993.

Long-term changes in the Salt River corridor (1868–1969) have been described where it flows through Tempe.[28] Before channelization, the channel was braided and shifting. Cadastral survey notes from 1868 described the channel as being lined with "timber cottonwood along banks, and mesquite and willow brush." By 1934, the floodplain was devoid of vegetation, although riparian vegetation lined the low-flow channel.[29] By the late 1950s, urban and industrial encroachment had eliminated the original channel of the Salt River, constraining the ill-defined channel within discontinuous dikes.

Following heavy usage in the middle of the twentieth century, groundwater levels rebounded and remained high near the Salt River (fig. 24.3B). The declines were in part in response to the midcentury drought, and the rebound occurred at least in part because of importation of CAP water to the Phoenix basin in 1985.[30] In the latter half of the twentieth century, the Salt River alternated between extreme floods and drought (fig. 24.11), hardly conditions that would sustain growth of significant amounts of riparian vegetation. However, a time series of aerial photographs[31] shows the midcentury establishment and destruction of considerable riparian vegetation—possibly dominated by tamarisk—along the Salt River upstream from the Mill Avenue Bridge in Tempe. The destruction was largely complete at the time of a devastating flood in late December 1965.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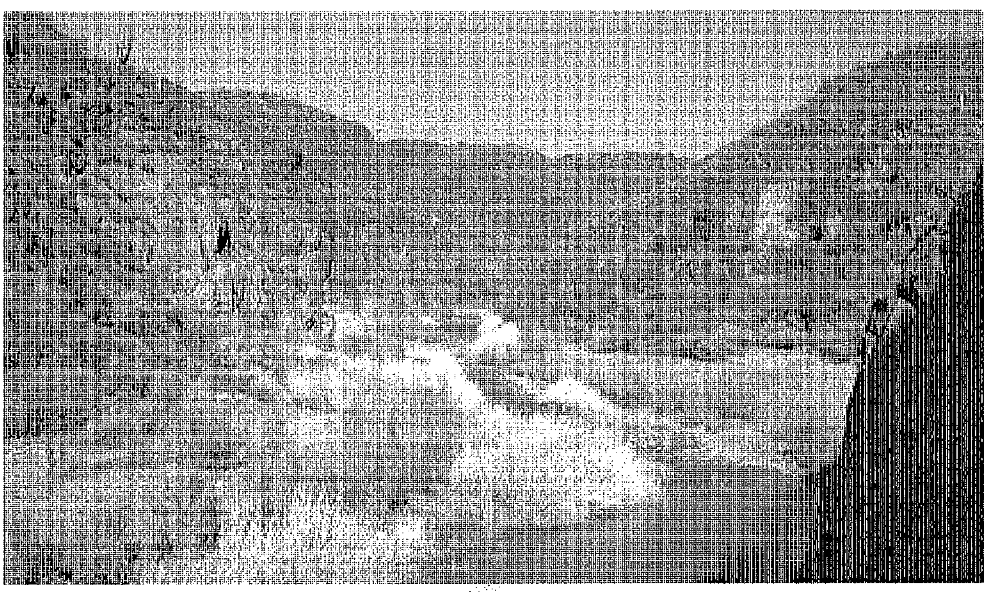
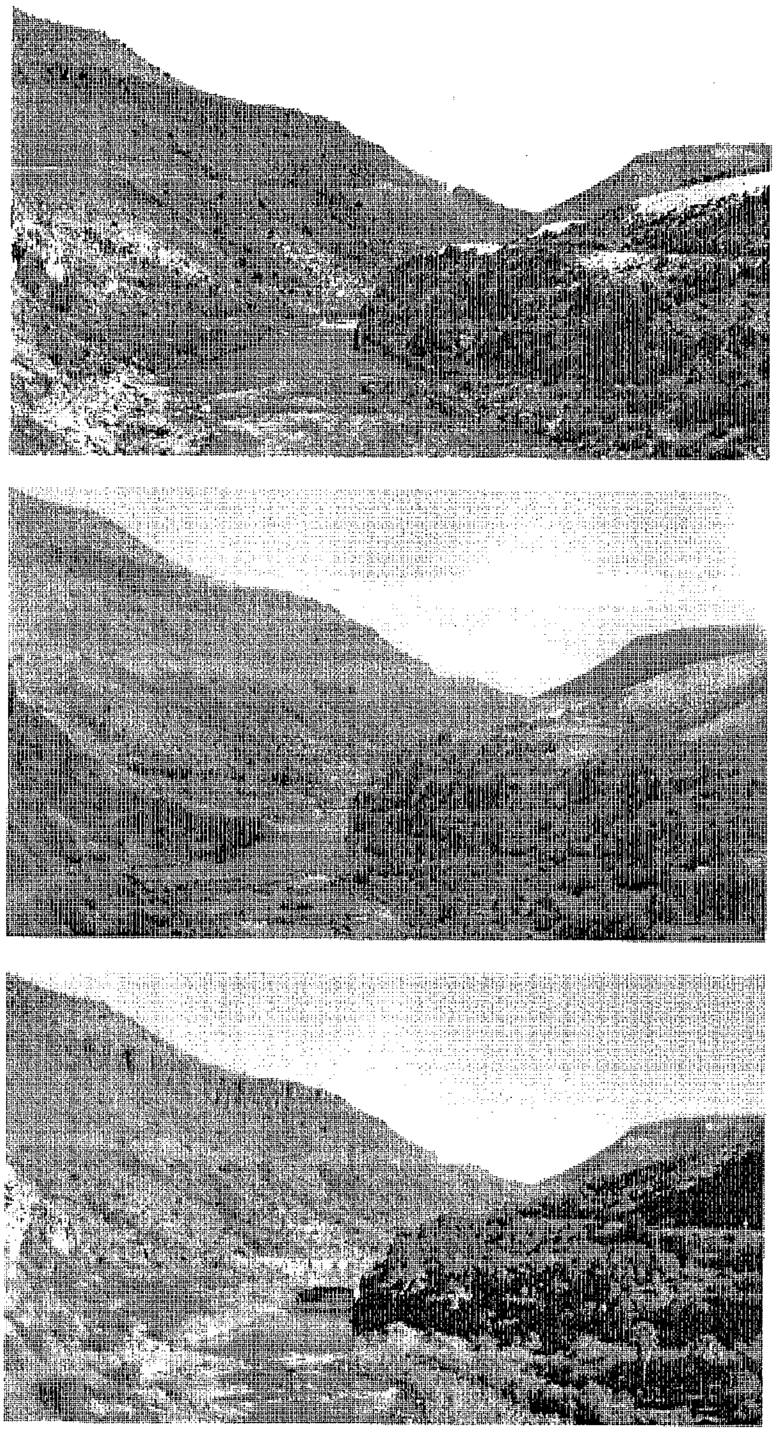

B

Figure 24.5 Photographs of Tonto Creek.

A. (February 1, 1941.) This upstream view of Tonto Creek shows the approach to the gaging station within a bedrock canyon with a flow of 456 ft^3/s. Riparian vegetation covers the few alluvial terraces, notably the one on river left *(photo right)*. The vegetation appears to be mostly mesquite with scattered willows. (J. A. Baumgartner 3403, courtesy of the U.S. Geological Survey.)

B. (November 10, 2002.) Flow at this time is low (less than 0.5 ft^3/s) into a pool upstream of Gun Creek. The vegetation present is diverse and includes carrizo grass, tamarisk, seepwillow, and lesser amounts of mesquite, netleaf hackberry, and black willow. (T. Brownold, Stake 4427.)

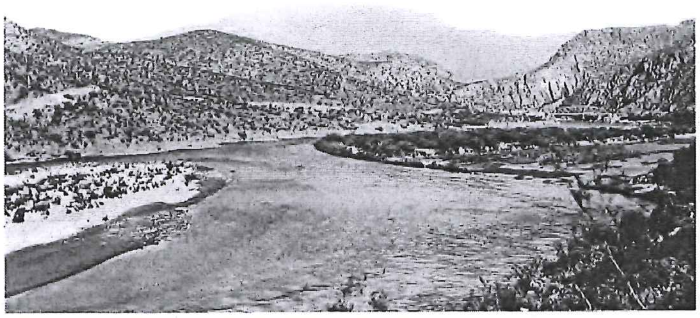


A. (November 26, 1935.) This upstream view from the old, two-lane bridge that crosses the Salt River in Salt River Canyon shows a relatively small discharge of 277 ft^3/s. Scattered native shrubs, including willows and brickellbush, appear to occupy the floodplain at right center. The road leading to Show Low (the combined U.S. Highway 60 and Arizona Highway 77) appears as a one-lane cut through the hillslope at center. (R. E. Cook 2280, courtesy of the U.S. Geological Survey.)

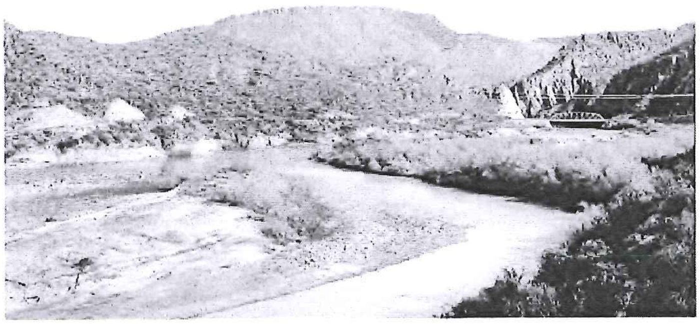
B. (June 25, 1964.) The water is low (about 97 ft^3/s), exposing the bedrock that forms the channel bed and the low-water control downstream from the gaging station. In the intervening twenty-nine years, three floods with peaks of greater than 50,000 ft^3/s passed through this reach. At this time, tamarisk is interspersed with the native shrubs on the floodplain and lines river left, which was mostly devoid of woody vegetation in 1935. Fan palms *(lower right)*, which are not native to this area, were planted as part of a roadside park well before this photograph was taken. The roadcut on the skyline has been widened. (R. M. Turner.)

C. (October 25, 2000.) The water level is only slightly higher in 2000 than it was in 1964. In the intervening thirty-six years, two floods have exceeded 70,000 ft^3/s, and four have exceeded 50,000 ft^3/s. Despite these floods, riparian vegetation along the banks has increased, in particular nonnative tamarisk. The palms have grown considerably. (D. Oldershaw, Stake 363.)

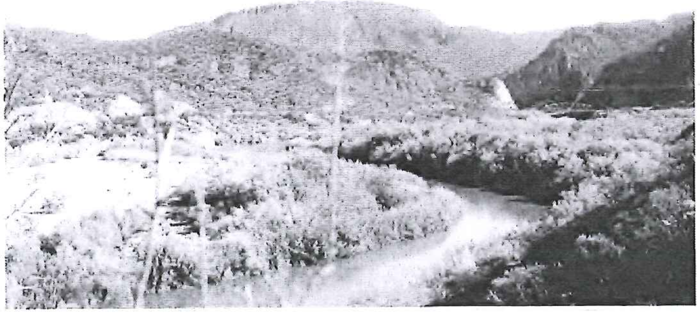
Figure 24.6 Photographs of the Salt River near Chrysotile, Arizona.



A. (April 22, 1937.) In this upstream view, the Salt River is flowing at 4,000 ft^3/s. The long-term gaging station in this reach is associated with the bridge in the distance, and a diversion dam is present just downstream from the camera station. Two months before this photograph was taken, the brush-covered island at right center was submerged during a February flood; most floods on the Salt River occur during the winter months. This camera station is several miles upstream from the top of Roosevelt Lake, the first of the major flood-control and water-supply structures on the Salt River upstream from Phoenix. (W. E. Dickinson 2166, courtesy of the U.S. Geological Survey.)



B. (February 3, 1979.) The brush-covered island is now densely covered with mostly nonnative tamarisk, although many native species also occur in this reach, including cottonwood, coyote willow, black willow, and various species of brickellbush. The bar in the left foreground was scoured during large floods in both 1978 and 1979. (R. M. Turner.)



C. (November 25, 2000.) Flood frequency on the Salt River did not change significantly in the twentieth century, as it did on other rivers in the region, although four one-hundred-year floods did occur in a fifteen-year period. The 1993 flood, which had a peak discharge of 143,000 ft^3/s at the gaging station on the bridge visible in the distance, did little to slow the advance of riparian vegetation—in particular tamarisk—at this site. Native species, notably carrizo grass, have also increased, although they are difficult to distinguish from the tamarisk in this view. (D. Oldershaw, Stake 955.)

Figure 24.7 Photographs of the Salt River near Roosevelt, Arizona.

A

B

Figure 24.8 Photographs of the Salt River at Roosevelt, Arizona.

A. (Ca. 1910.) This view and several others taken immediately before completion of Roosevelt Dam show the crossing of the Salt River at the town of Roosevelt. Tonto Creek enters the Salt River from the left. The channel is wide and mostly barren of riparian vegetation, although discontinuous patches of what likely is mesquite appear on the floodplain in the midground. (G. W. James P4539, courtesy of the Southwest Museum.)

B. (April 8, 2004.) Theodore Roosevelt Lake now covers the former town of Roosevelt, which was moved several miles toward Globe, Arizona, after construction of Roosevelt Dam was completed. As this view shows, lake level fluctuates, minimizing establishment of riparian vegetation on coarse talus slopes. (D. Oldershaw, Stake 4770.)

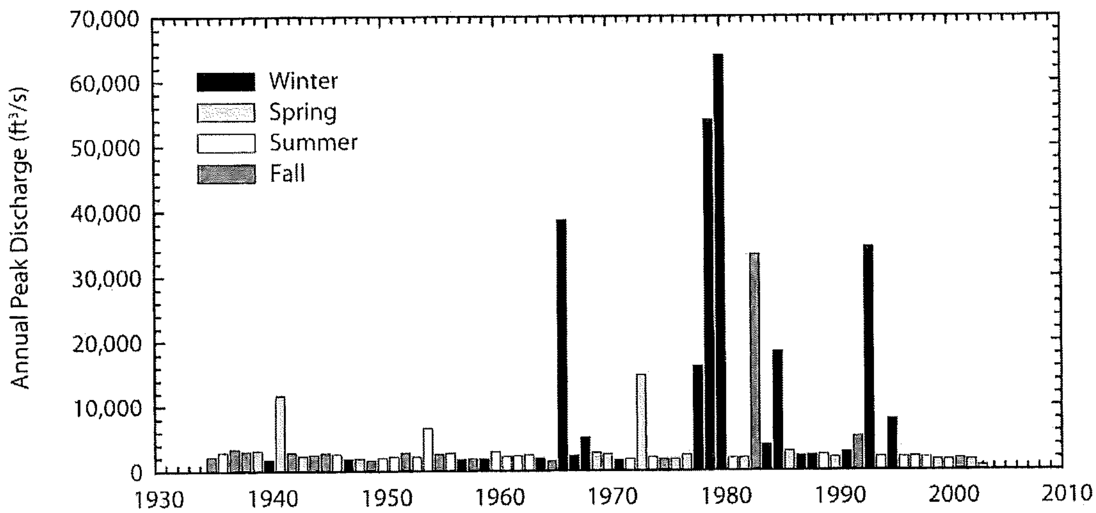
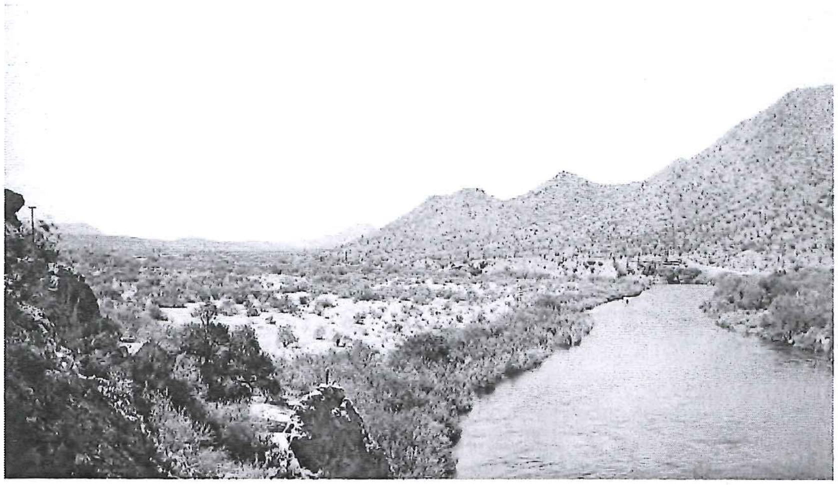


Figure 24.9 Annual flood series for the Salt River below Stewart Mountain Dam, Arizona (station 09502000; 1935–2003).

Nonetheless, it is difficult to assess the change in woody riparian vegetation in the roughly 35 miles of channel between Granite Reef Dam and the Salt's confluence with the Gila River. Most old photographs taken in this reach either cannot be replicated owing to blockage by structures (e.g., Sun Devil Stadium in Tempe), elimination of camera stations owing to extensive urbanization, or difficulty in determining the location of the original camera station. Moreover, although riparian vegetation quickly established, it persisted for only short periods before destruction from urban encroachment or floods.

Some photographs taken from prominent overlooks can be matched, yielding some information on the amount of change that has occurred in this reach (figs. 24.12 and 24.13). Many early photographs show an open gallery forest of cottonwood with low shrubs that may be coyote willow. Significantly, some of these stands of riparian vegetation appear to form a narrow band on a low floodplain beneath higher terraces, reminiscent of the condition present in arroyos. During the first third of the twentieth century, riparian vegetation was becoming reestablished within the eroded channel margin, as occurred along the Santa Cruz River at Tucson (chapter 21). Other photographs from the middle of the twentieth century (fig. 24.12A) show mostly herbaceous vegetation along the channel.

Although it is likely that at least some cottonwood groves were eliminated through the Salt River Valley, it is impossible to assess just how much change has occurred in this reach. The extensive channelization using concrete and rock, combined with the complete diversion of base flow, virtually guarantees that significant amounts of woody riparian vegetation are unlikely to become reestablished along this part of the Salt River despite high groundwater levels (fig. 24.3B). Downstream, wastewater effluent is discharged into the Salt River, and woody riparian vegetation has become established in that reach, but we have no photography to evaluate the amount of change.



A. (September 9, 1938.) This downstream view of the Salt River below Stewart Mountain Dam shows low, woody riparian vegetation encroaching to water level on both banks. Flow at the time of this photograph is 2,390 ft^3/s and is completely regulated by the four dams upstream. The vegetation consists of seepwillow and brickellbush, with scattered tamarisk trees on river right. (J. A. Baumgartner 2391, courtesy of the U.S. Geological Survey.)

B. (March 7, 1979.) This view, taken after the 1978 and 1979 floods (highest peak discharge was 54,000 ft^3/s, fig. 24.9), shows a wide, scoured floodplain with a low flow of 13 ft^3/s. Other photographs taken in this reach indicate that although the bars remain composed mainly of cobbles, the average particle size has coarsened, indicating further degradation of habitat within the low floodplains. Despite the floods, tamarisk remains on river right. (R. M. Turner.)

C. (January 31, 1995.) This view, taken after the 1993 peak discharge of 34,500 ft^3/s, shows an even coarser particle size on the floodplain. The flow is 470 ft^3/s. The channel position has shifted in response to rearrangement of the coarse sediment within the channel. One tree that survived the floods of the late 1970s and early 1980s is dead in the center of the view. Low shrubs, tamarisk, and cottonwood appear to be established. (D. Oldershaw, Stake 962.)

Figure 24.10 Photographs of the Salt River below Stewart Mountain Dam.

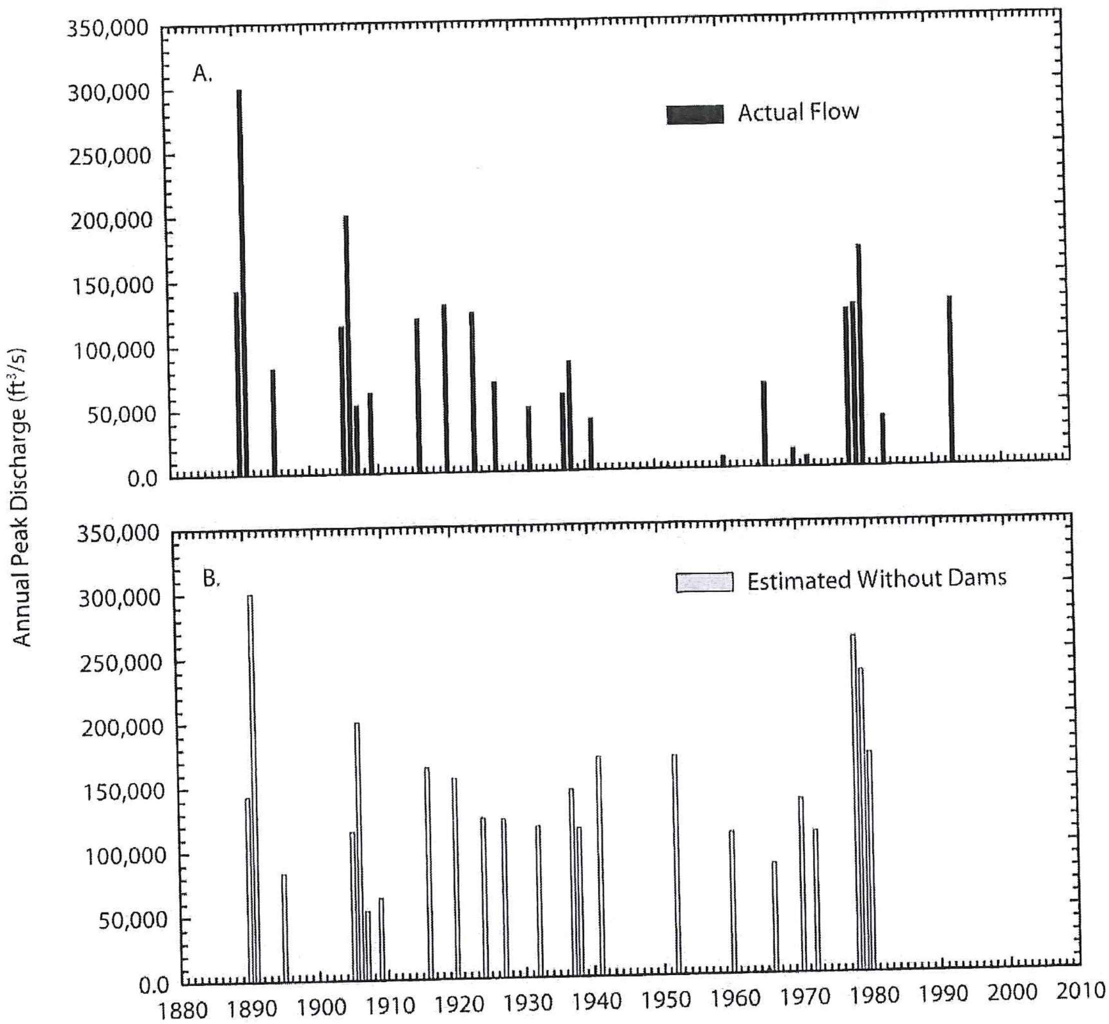


Figure 24.11

A. Annual flood series for the Salt River at Jointhead Dam near Phoenix, Arizona (station 09512060; various years). During many years, the Salt River does not flow here.

B. Annual flood series that would have occurred if the upstream dams were not in place (from Aldridge and Eychaner 1984). The data in series B represent only 1890–1980; clearly, floods would have occurred in other years if dams had not been completed upstream.

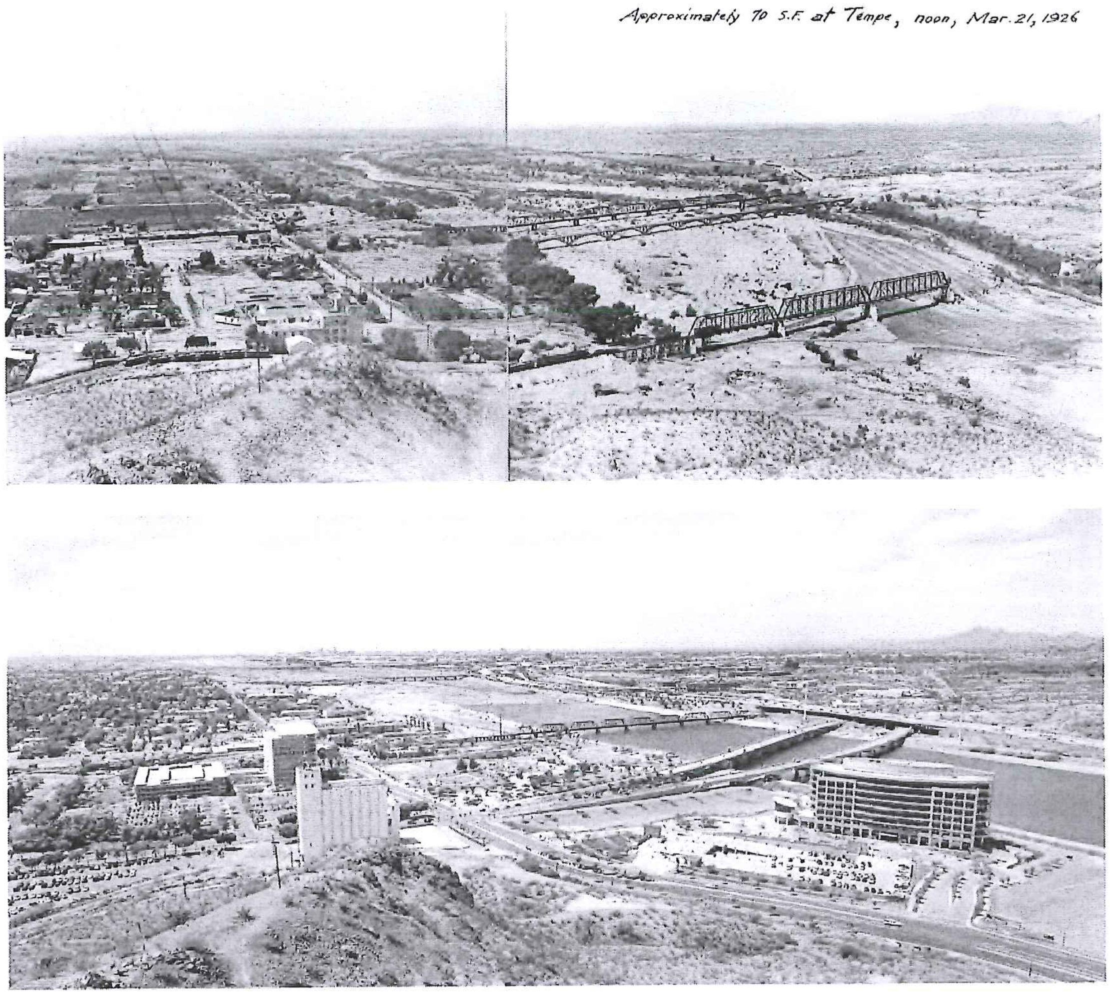
A

B

Figure 24.12 Upstream photographs of the Salt River in Tempe, Arizona.

A. (Just after December 11, 1959.) This upstream view from Tempe Butte shows the Salt River through Tempe after a relatively minor flood of less than 200 ft^3/s released from dams on the Salt and Verde Rivers on December 11. The dike across the right midground likely provided minimal flood protection for part of Tempe. Older photographs of this reach suggest that the combination of high groundwater conditions and the wide channel allowed sparse, mainly nonwoody riparian vegetation to exist here. Scattered groves of cottonwood trees were once present. (J. A. Baumgartner 4624, courtesy of the U.S. Geological Survey.)

B. (December 4, 2002.) The city of Tempe has grown considerably, requiring bank protection along the Salt River to allow floodplain development. The Rio Salado Project, a river-restoration effort for the Salt River through Tempe, consists of a lake confined within the soil-cemented banks of the Salt River. The once wide and shallow channel is now lower into the floodplain and anchored in space, minimizing the potential for meander migration. (T. Brownold, Stake 4442.)



A

B

Figure 24.13 Photographs of the Salt River from Tempe Butte.

A. (March 21, 1926.) This set of photographs makes a panorama of the Salt River Valley west of Tempe Butte. The closest bridge was destroyed by a flood many years before this photograph was taken. A discontinuous row of Frémont cottonwood trees appears along low flow in the channel, which the photographer estimated to be 70 ft^3/s. What appear to be more extensive stands of woody riparian vegetation appear in the background. From this distance, it is uncertain whether these stands are mesquite, cottonwood, or black willow. (Unknown photographer, courtesy of the Salt River Project, Phoenix, Arizona.)

B. (April 7, 2004.) Most of the channel of the Salt River in this view is part of Tempe Lake, impounded by an inflatable dam and part of the Rio Salado Project. Of the three bridges visible in 1926, only one remains the same, and three new highway bridges have been built. The river is channelized through the Salt River Valley, and development occurs up to the edge of the channel in many places. (D. Oldershaw, Stake 4764.)

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7. Roeske, Cooley, and Aldridge (1978).
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10. Granger (1960), p. 361; Byrkit (1978).
11. Pattie (2001).
12. Mearns (1907), pp. 353–59.
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15. Lopez and Springer (2003), p. 5.
16. Whittlesey (1997b), p. 35.
17. McClintock (1985), p. 234.
18. Davis and Turner (1986).
19. Nicholson (1974), p. 88.
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28. Whittlesey (1997b), p. 32.
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31. Tellman, Yarde, and Wallace (1997), p. 48.
32. Rogge and others (1995), p. 11.
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2. From http://reference.allrefer.com/gazetteer/S/S02294-salt-river-valley.html, accessed November 4, 2005.
3. Masse (1976); Fuller (1987).
4. Hodge (1877), cited in Rea (1997).
5. Pattie (2001), 119.
6. Mearns (1907), p. 356.
7. McClintock (1985), pp. 211–14.
8. Minckley (1973), p. 121.
9. Minckley (1973), p. 121.
10. Fuller (1987).
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13. This figure is obtained by adding the long-term averages for the Salt River at Roosevelt, Arizona (09498500), Tonto Creek above Gun Creek, near Roosevelt, Arizona (09499000), and the Verde River below Tangle Creek, above Horseshoe Dam, Arizona (09508500), and assuming that losses downstream from these stations are negligible.
14. Durrenberger and Ingram (1978).
15. Aldridge and Eychaner (1984). The reported discharge is for Salt River at Alma School Road near Mesa, Arizona (09512060); see figure 24.11.
16. Corle (1951), p. 269.
17. Durrenberger and Ingram (1978).
18. Rogge and others (1995), p. 11.
19. From http://www.srpnet.com/water/dams/roosevelt.aspx, accessed November 4, 2005.
20. Kupel (2003), p. 79.
21. From http://www.srpnet.com/, accessed November 4, 2005.
22. Kupel (2003), p. 92. Wolcott (1952) also discusses groundwater use in the first half of the twentieth century.
23. Robinson and Peterson (1962); Stulik and Twenter (1964); Schumann (1974); Kupel (2003), p. 211.
24. Reeter and Remick (1986); Kupel (2003).
25. Granger (1960), p. 119.
26. D. Brown and others (1976).
27. W. Graf (1983).
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29. Ruff (1971), p. 9.
30. Kupel (2003), p. 187.
31. Ruff (1971).

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11. Nicholson (1974), p. 116.
12. C. Ross (1923), p. 67.
13. Couts, quoted in D. Martin (1954), p. 129.
14. Mearns (1907), p. 124.
15. C. Ross (1923).
16. McNamee (1994), pp. 125–26.
17. Burkham (1972).
18. Rea (1997), p. 38.
19. Lee (1904), p. 10, (1905), p. 135.
20. C. Ross (1923), pp. 15, 36, 65.
21. Haase (1973).
22. Office of Arid Lands Studies (1970).
23. Rea (1983), pp. 34–35.
24. Minckley (1973), pp. 120–21.
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26. Mearns (1907), p. 359.
27. Office of Arid Lands Studies (1970).
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29. Huckleberry (1996a, 1996b).
30. McNamee (1994); Blake and Steinhart (1994).
31. Emory (1848), p. 125.
32. Ricketts (1996), pp. 107–8.
33. C. Ross (1923), p. 66; D. Martin (1954), pp. 133–35.
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35. Huckleberry (1995).
36. It is unclear from the information whether two large floods occurred in 1868 and 1869 or only one occurred within one of these years.
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40. Huckleberry (1994). This report gives misleading data on the relative sizes of the 1983 and 1993 floods; the 1993 flood was 19 percent larger than the 1993 flood at the Laveen gaging station. Attenuation of flood peaks in the regulated Gila River makes it essential to state precisely where discharges are estimated.
41. Dobyns (1981), p. 72.
42. Tellman, Yarde, and Wallace (1997), p. 101.